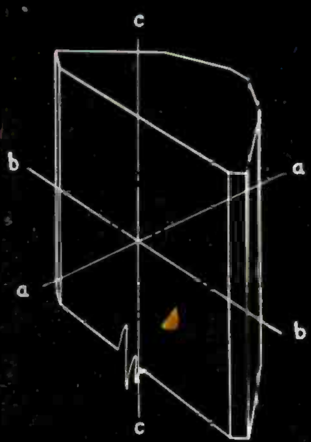
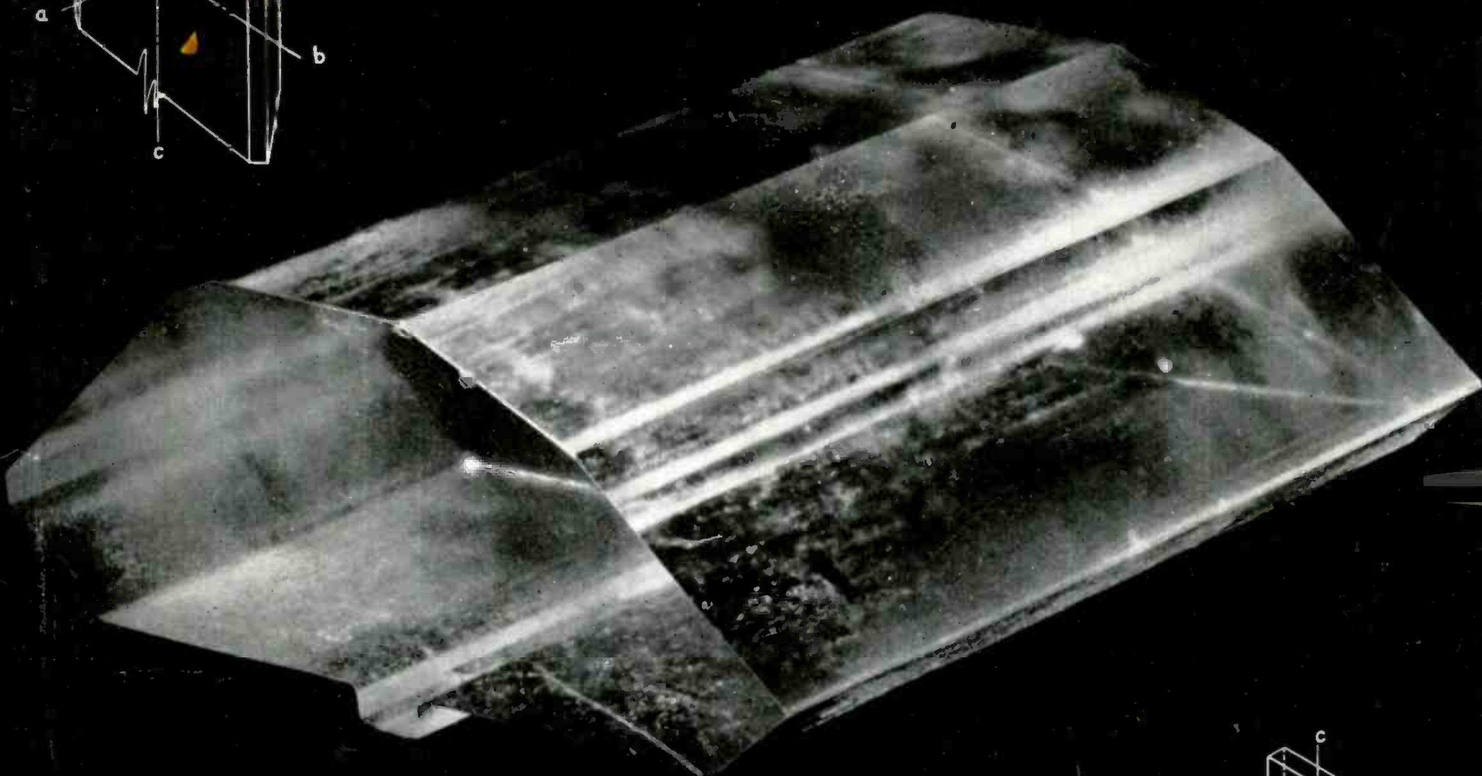
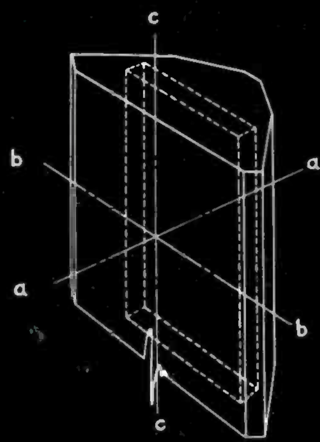
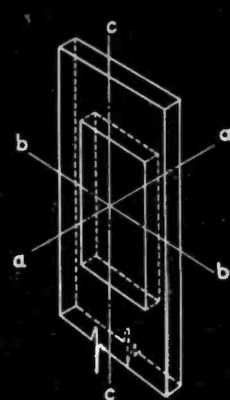
RADIO

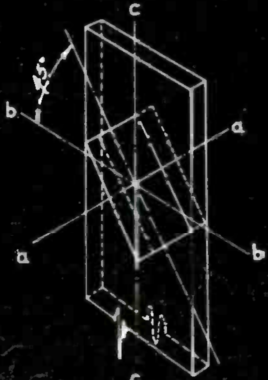
ESTABLISHED 1917











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SEPTEMBER, 1943

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RADIO

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SEPTEMBER 1943 No. 284

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COVER

Large homogeneous bar of Rochelle salt crystal, and the methods of cutting crystal plates from such a bar. See article on page 23.

ARTICLES

MISCELLANEOUS

RADIO (title registered U. S. Pat. Off.) is published monthly at 34 N. Crystal Street, East Stroudsburg, Pa., by Radio Magazines, Inc., Executive and Editorial Offices at 132 West 43d Street, New York 18, N. Y. Subscription rates—United States and Possessions, $3.00 for 1 year, $5.00 for 2 years; elsewhere $4.00 per year. Single copies 35c. Printed in U.S.A. Entered as Second Class Matter October 31, 1942, at the Post Office at East Stroudsburg, Pa., under the Act of March 3, 1879.

EDITORIAL

BUTTON UP

★ For obvious reasons the Government has found it necessary to place restrictions on the publication of any information pertaining to radar and military electronic equipment. This fact is not as yet fully appreciated. To point up the importance of this matter, we quote the following note from Byron Price, Director of the Office of Censorship:

"The extent of current public discussion of radar is causing increasing concern to the Government.

"The principle of radar is generally understood here and abroad, and some limited disclosures have been made officially. New methods of applying the principle are being developed, however, and there is much the enemy does not know.

"The fact of prior publication should not be used to cover added description, discussion, and deduction, or to support a theory or draw a conclusion.

"Radar is a secret weapon within the meaning of the Code. Editors and broadcasters are especially requested to be alert to every mention of radar and military electronic devices; to establish beyond all question that there is appropriate authority for every statement made; and to submit all material on the subject—other than that released by appropriate Government authority—to the Office of Censorship for review in advance of publication or broadcast.

"So inclusive a request would not be made if the highest considerations of national security were not directly involved."

As an addition to the foregoing, we wish to point out that there has been a tendency among some engineers to speak openly on these subjects in their own circles. This is a liberty that should no longer be exercised under any circumstances. An enemy agent is invariably a person you'd never suspect. Or he (or she) may turn out to be a close friend of that close friend of yours.

EARLY BIRTH CATCHES NO WORM

★ A well-known engineer said that, should he have a hand in the development of post-war radio-electronic products, he would set a group of men to digging in the dust of the past in search of new ideas.

What he means, of course, is that many ideas have been born much before their time, and are therefore worth reviewing in the light of more recent developments. A scheme that proved a washout in its time may now prove to be the answer to a trying riddle.

A case in point is the original RCA loop-operated receiver employing the type 199 tubes. In a sense this receiver represented brilliant engineering, but the use of a loop antenna at a time when gain was both expensive and difficult to obtain was definitely a technical *faux pas*. But some years later, when gain became cheap and relatively easy to obtain, the loop was resurrected, and to very good advantage. Yet, not until someone put two and two together to make a very profitable four for the entire radio field.

It is also interesting to observe that a condenser phonograph pickup was developed—and a few manufactured—around 1924 or so. It was designed for use in conjunction with an r-f oscillator and some form of detector, and had no advantages over other types of pickups that we can recall. But there are indications now that the capacity pickup, used in conjunction with a small f-m unit, may find widespread use in the post-war period.

Loudspeakers are another case in point. Small speakers with rather good efficiency and frequency response can be developed if the cone has sufficient rigidity and at the same time a rather large excursion. The answer to this problem may well rest in the use of a single-turn voice coil. If that is the case, it will be found that a single-turn voice coil was first used in a dynamic speaker about 1924.

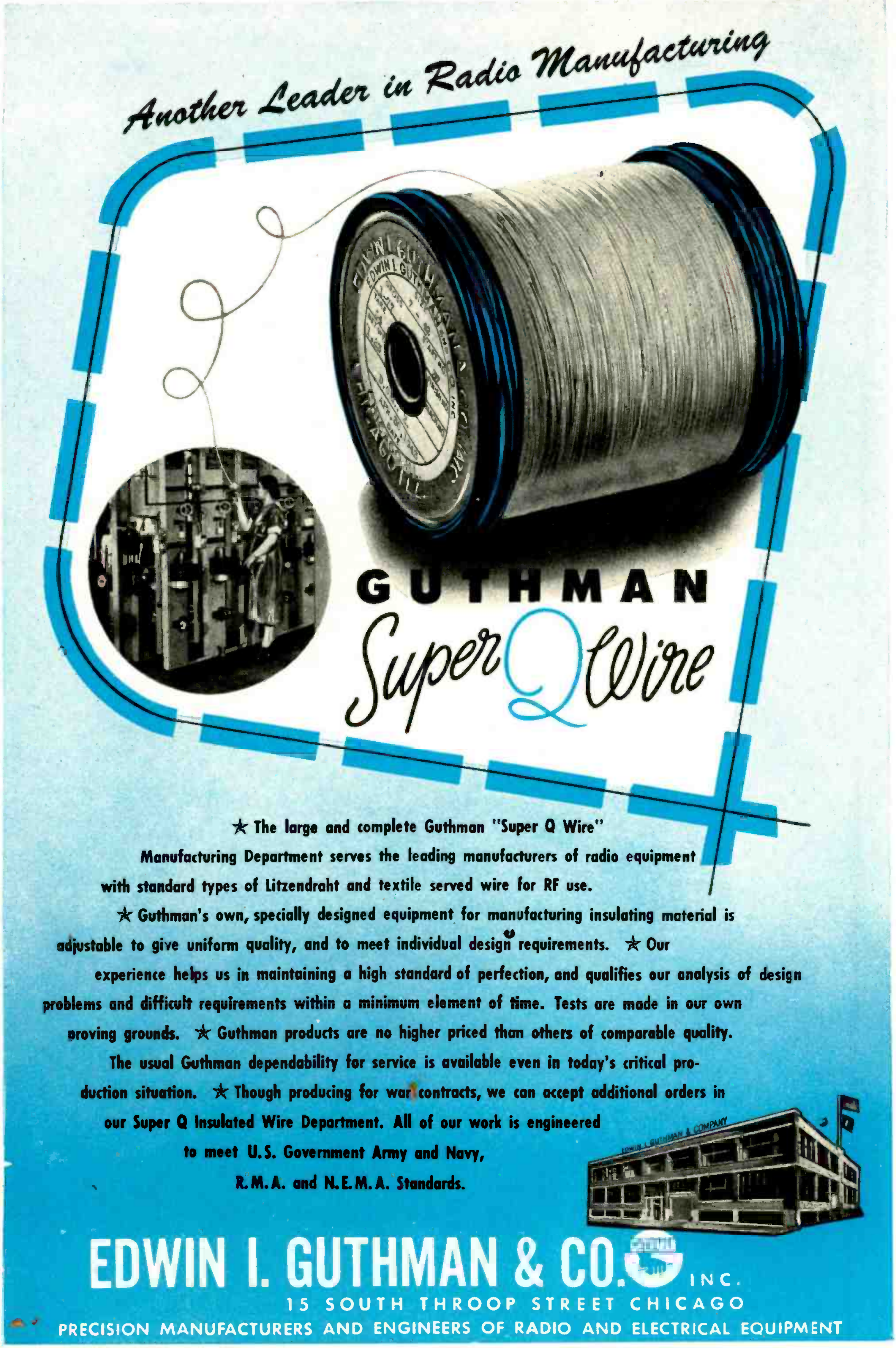
The future is always indebted to the past in some manner, and it is good engineering practice to constantly revalue old ideas in the light of new developments. The Radio Bibliography, published in RADIO each month, is a definite aid in this respect.

MASS PRODUCTION

★ We do not profess to know to what extent the radio-electronic industry in wartime has managed to duplicate the production setup characteristic of the auto industry in prewar days. In this method raw materials and parts suppliers are geared tight to the assembling plants, and stock piles have a life span of little more than two weeks. Flow is continuous and at the same time flexible, and the system has numerous advantages.

We venture the opinion that this system will find widespread use after the war. It is a system that calls for continuous and precise product inspection so that the flow of production can be slowed down or halted when tolerances start creeping.

In the past, product inspection has been almost entirely manual, and therefore subject to error. Radio-electronic equipment would reduce this error to a minimum and make the entire process automatic, just as it has in the sorting of beans and the manufacture of paper. The possibilities are enormous.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TECHNICANA

MEASURING SMALL DC VOLTAGES

THE DIFFICULTY of designing sensitive amplifiers for dc is well known. One of the ways this is overcome is to convert the small dc voltage to be measured into an ac voltage. Various schemes have been developed, but a new one is covered by T. A. Ledward in an article entitled "DC/AC Converter," appearing in *Wireless World* for August 1943. His instrument uses a magnetic core which is polarized by the signal and thereby causes second harmonics in an ac circuit.

"A simple circuit arrangement is shown in *Fig. 1*. Two valves, *V1* and *V2* are used on the input side, as the current through the two sections of the winding *B* on the dc/ac converter must normally be balanced in order to avoid initial polarization. A variable tap on the resistance *R* serves to adjust this balance.

"Upon applying dc to the input terminals, this balance is upset and more current flows through one half of the winding *B* than through the other half. The cores *X1, X2* become polarized and this polarization produces even harmonics in the alternating flux which is produced by the ac exciting windings *A1, A2*. The latter windings are connected in opposition so that the fluxes in *X1, X2* due to normal exciting current are balanced and no voltage is induced in winding *C*. But the polariza-

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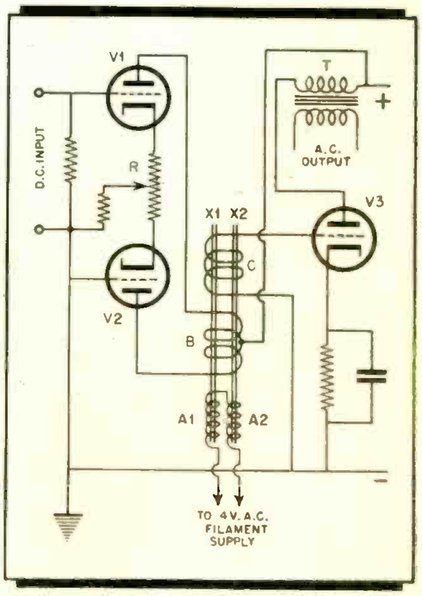
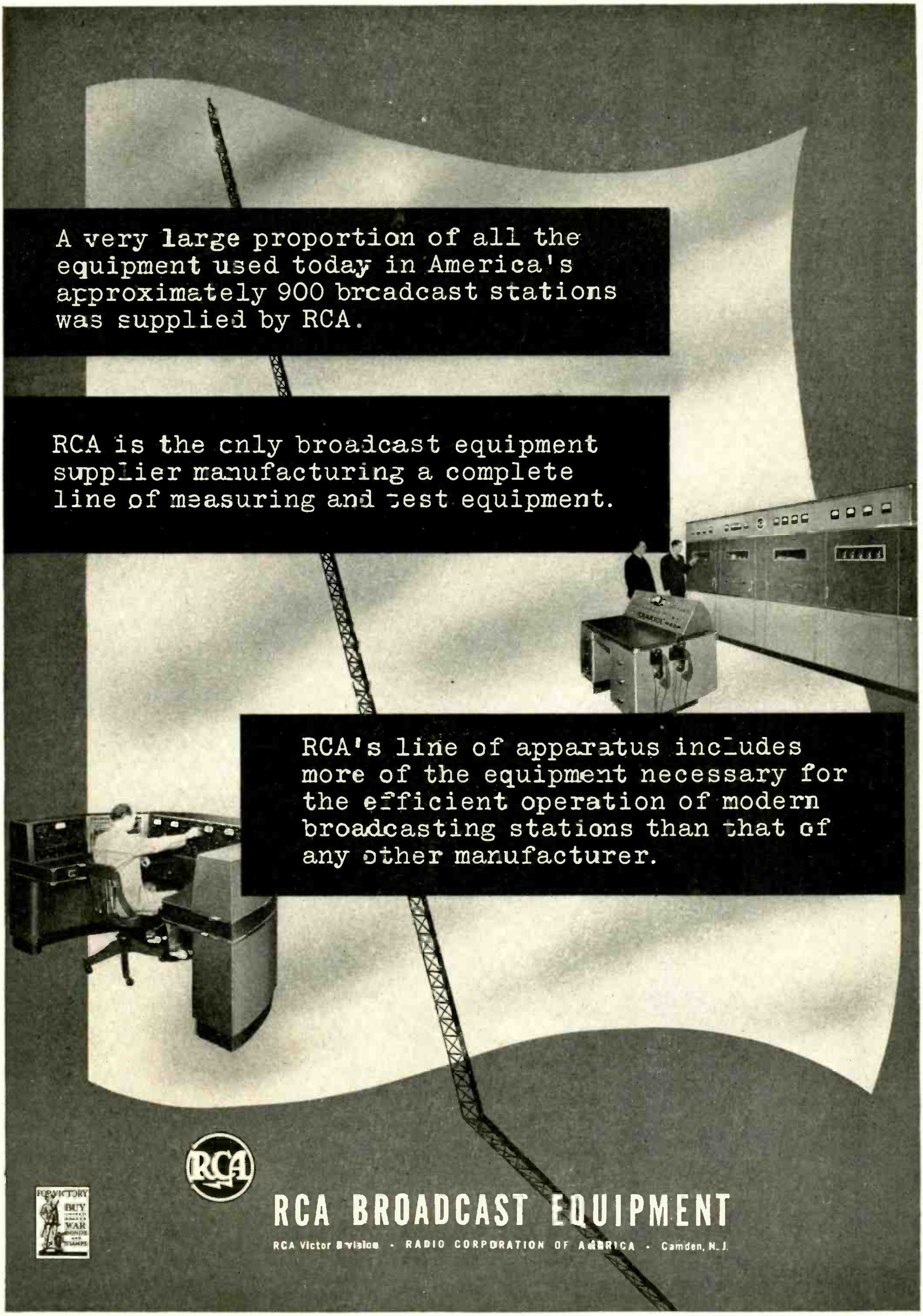


Fig. 1. Circuit of dc/ac converter



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tion due to the winding *B* is in the same direction in both cores, so that the even harmonic components are additive and an even harmonic voltage is induced in *C*. This is applied to the valve *V3*, in the anode circuit of which an output transformer *T* is connected."

The author further suggests a system of feedback (regeneration) by rectifying the output and applying the dc to another winding on the core so as to aid the initial polarizing current. The sensitivity thus obtained is such as to give an output of 2.3 watts with 10-mv input and about .4 watt with 4-mv input.

FREQUENCY COMPARISON

THAT A "MAGIC EYE" can be used for audio-frequency measurement by the beat method is perhaps known to most radio engineers, but some practical pointers on the subject are given in an article by G. D. Brittain entitled "Visual Frequency Comparison" appearing in *Wireless World* for August 1943.

The circuit is shown in *Fig. 2;* the triode section of the tube is operated as a detector and the two input signals are added by a resistance network. Thus additive mixing takes place and the shadow angle will vary with the beat frequency. When the frequency ratio of the two signals is 1:1 the greatest variation in the shadow angle will take place when the two signals are equal in magnitude. Due to persistence of the glow, the beat frequency becomes visi-

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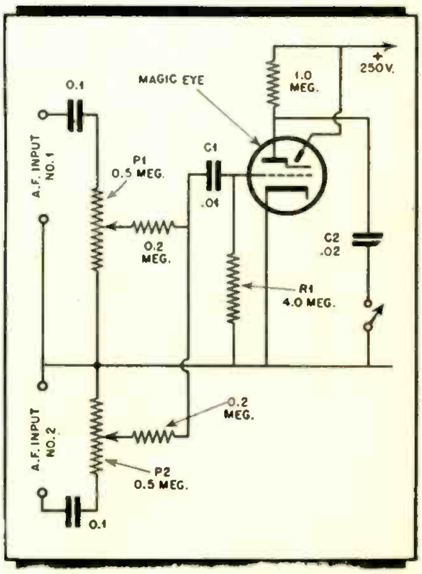
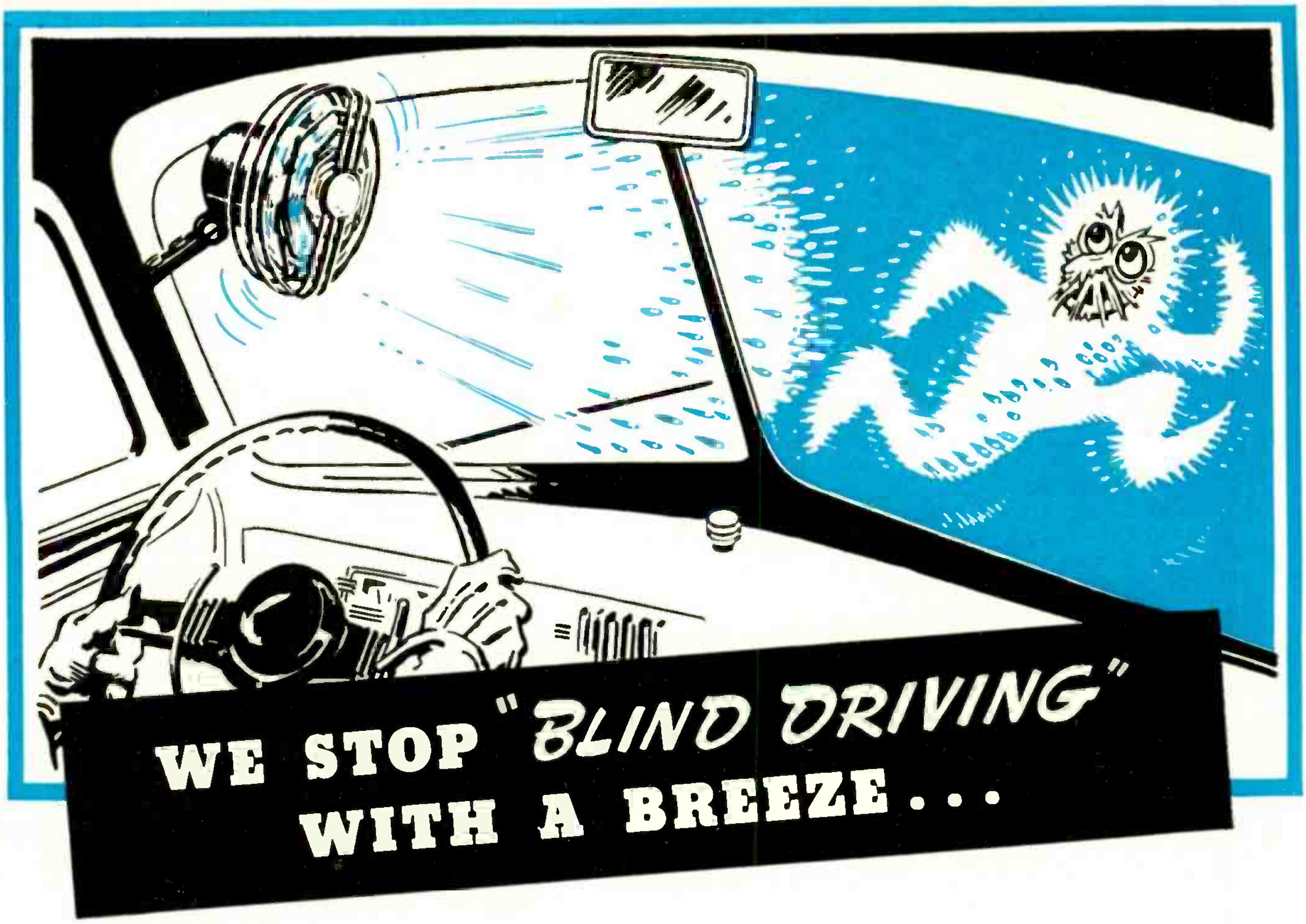


Fig. 2. Frequency-comparison circuit



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ble only when it is less than about 20 cycles.

It is also possible to use the tube to compare two frequencies which are different and to obtain a beat when one signal frequency is equal to a harmonic of the other signal. Ratios up to 12 become possible but a special precaution must be taken; we quote:

"Due to the fact that the amplitude of the nth harmonic of f_2 is small compared to f_2, for this harmonic to be comparable with the other input f_1, it follows that the amplitude of f_2 will have to be very much greater than that of f_1. Hence there will be a comparatively large component of the anode current of frequency f_2 and the shadow will be rapidly deflected to and fro at this frequency, causing blurring of the shadow edge and difficulty in observing the slow movement of the shadow.

"It is thus desirable to eliminate this component of frequency f_2. Since the ratio of maximum perceptible beat frequency to the lowest frequency likely to be compared is of the order of 1:5 the frequency f_2 can be eliminated by differential bypassing. The choice of the capacitor *C2* is a compromise and 0.02 μf is suggested where the lower frequency limit is about 150 c/s."

When comparing equal frequencies, the bypass capacitor *C2* is not needed and can be cut out by means of the switch. This will then indicate that the beat obtained is the beat of the fundamentals because any other beat will appear fuzzy in the absence of *C2*.

MEASURING TUBE NOISE

IN HIGH-GAIN AMPLIFIERS the noise contributed by the first tube is of prime importance since it determines the ultimate signal-to-noise ratio. A method of tube-noise measurement is described in the August 1943 issue of the *Bell Laboratory Record* in an article by J. J. De Buske titled "Noise Measurement in Vacuum Tubes."

The input of the tube is connected to the type of circuit with which it is to be used. In this case it consists of a transformer with an impedance ratio of 135:30,000 and terminating impedances.

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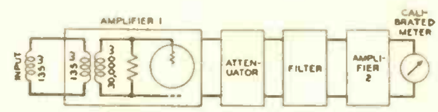
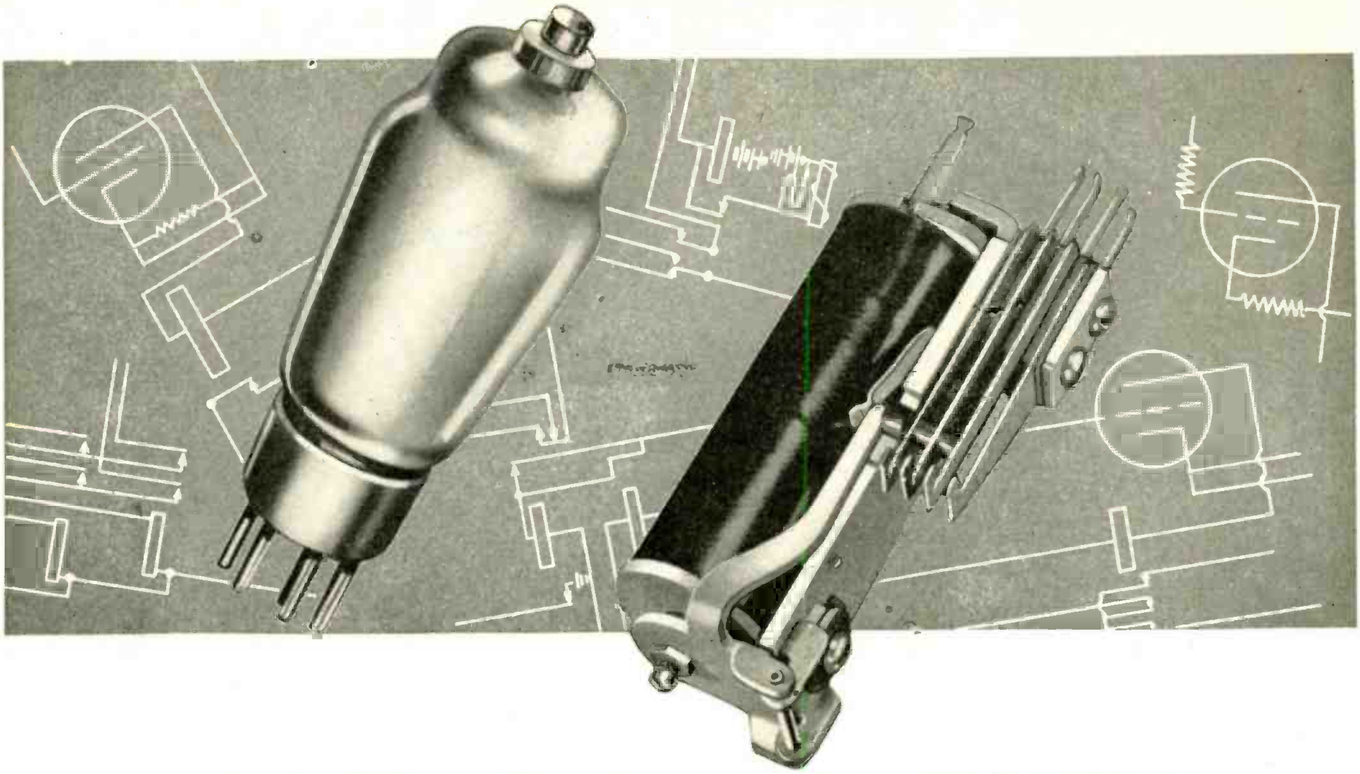


Fig. 3. Tube noise measuring set-up



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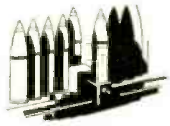
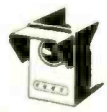
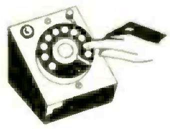


Quality control—automatic inspection and sorting operations



Detecting and Indicating—checking operations and revealing unstandard conditions



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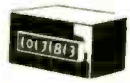

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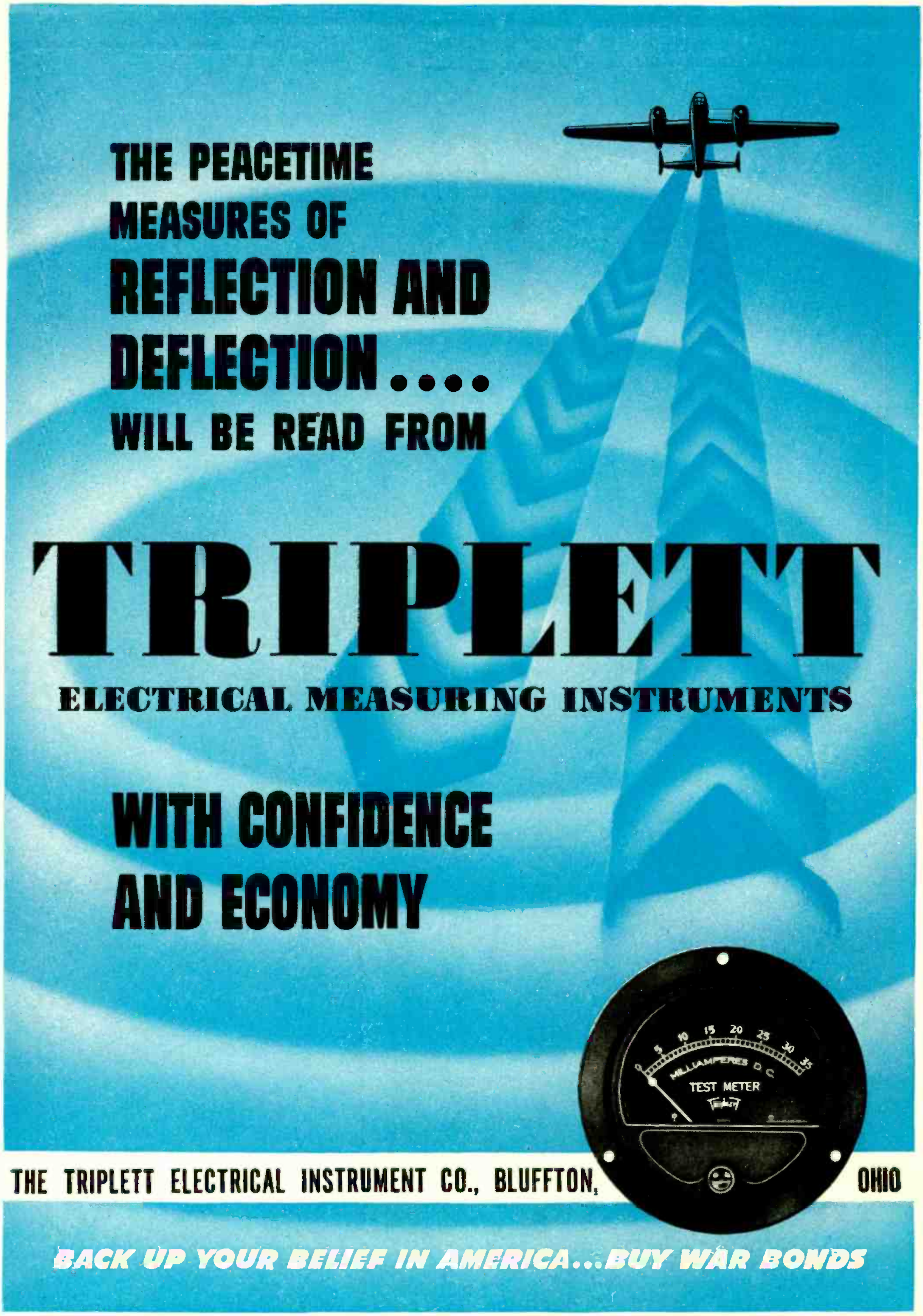
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[*Continued from page 12*]

The remainder of the set-up, as shown in *Fig. 3*, consists of an attenuator, a filter, an amplifier and a meter.

The thermal noise-power of the input circuit can be calculated from the equation given by Nyquist; this gives 134.7 db below 1 milliwatt. Since the input is terminated by a matched impedance only half the noise-power, which is 3 db less, is delivered to the amplifier.

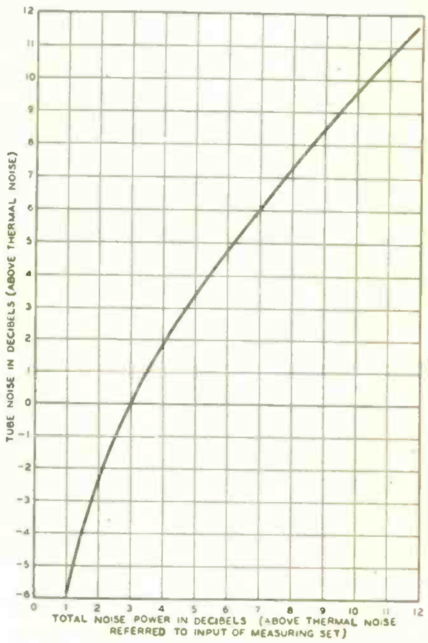

Fig. 4. Conversion Chart

"If an ideally quiet tube could be inserted in the first stage of Amplifier No. 1, the thermal noise would produce a reading of one milliwatt on the calibrated thermocouple meter when the overall gain of the measuring set had been adjusted to 137.7 db. Any actual tube in this position will give a larger reading due to its tube noise. The db change in attenuator setting required to bring the meter reading back to one milliwatt indicates in db the total noise-power above thermal noise referred to the input of the measuring set. The tube noise-power is the difference between the thermal noise-power and the total noise-power. It is shown in *Fig. 4* plotted against total noise-power. Since the input transformer is not ideal, corrections must be made for its effect on the input termination."

THE REFLECTOMETER

THE "REFLECTOMETER" is an instrument for measuring the ratio between the

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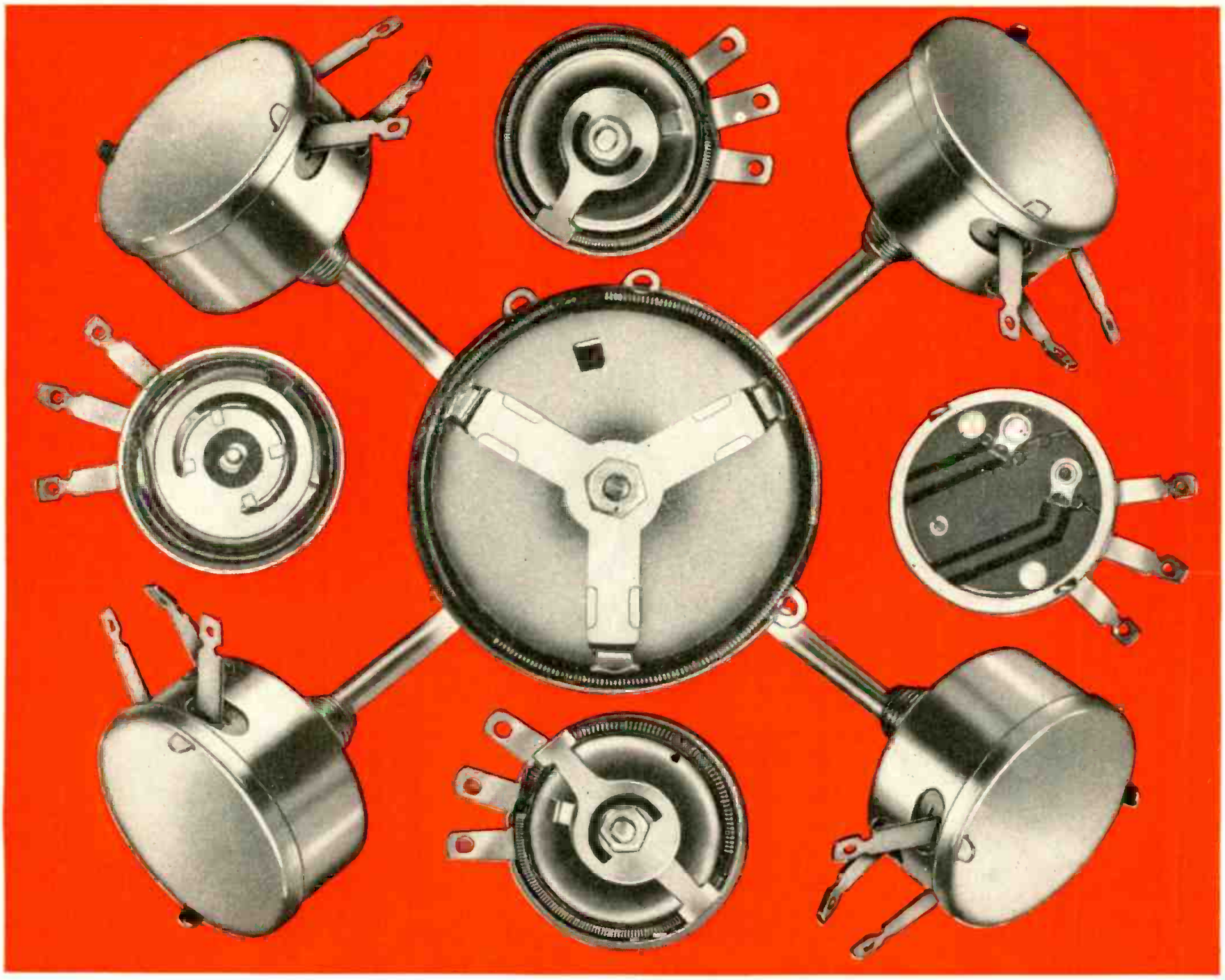

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amplitude of a travelling wave along a transmission line and its reflected wave travelling in the opposite direction. Hence, it is a device for testing whether or not a feeder has been properly terminated.

A description of this instrument appears in an editorial in the *Wireless Engineer* for August 1943, which is again a review of the original article in the Russian journal, *Elektrosvyaz,* No. 4, Vol. IX, April 1941. When a feeder is incorrectly matched, a backward travelling wave is superimposed on the forward travelling wave and there will then be nodes and antinodes. The ratio of the minimum to the maximum amplitude on the feeder is called k and it is this factor which is determined by the reflectometer. We quote:

"Two wires are arranged parallel to the feeder and joined at each end through loads $Z1$ and $Z2$, as shown in *Fig. 5.* This constitutes a secondary transmission line of length l and width w. The electromagnetic wave travelling from left to right along the feeder will induce electromotive forces in the end connections of length w as it sweeps past them. Neglecting any loss in the feeder, the electromotive forces will be equal but will differ in phase by βl where $\beta = 2\pi/\lambda$. Any reflected wave on the feeder will also induce electromotive forces having the same phase difference but in the opposite direction. The magnitude of the electromotive forces will be proportional to the magnitudes of the respective waves on the feeder."

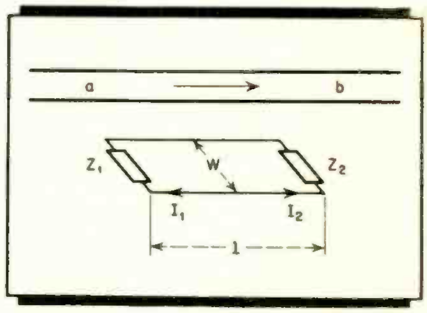

Fig. 5. Measuring Set-up

It is shown mathemtaically that when the secondary line is terminated at both ends in the characteristic impedance of the line, ... "a wave travelling from left to right produces no current I_2 in the right-hand end of the secondary line and a similar wave travelling from right to left; that is, a reflected wave

[*Continued on page 19*]

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Wherever electric current must be changed in voltage, frequency or type, *E·L* Vibrator Power Supplies and Converters offer many definite advantages, for peace, as well as for war.

For Operating High-Powered Radio Receivers and Transmitters, Coin-Operated Phonographs, Public Address Systems and the Like—Standard E·L Model 261 Power Supply. Input Voltage, 115 V DC; Output Voltage, 115 V AC; Output Current, 5 amperes; Output Power, 500 Volt-Amperes; Output Frequency, 60 cycles; Dimensions, 16″ x 9¾″ x 6½″; Weight, 44 lbs.

E·L Standard Vibrator Power Supplies are designed with a wide range of output wattage ratings for input voltages including 6, 12, 32, 115, and 220 volts. Custom-designed and built power supplies can be provided to meet any particular needs.

Electronic
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***E·L* ELECTRICAL PRODUCTS** — Vibrator Power Supplies for Communications . . . Lighting . . . Electric Motor Operation . . . Electric, Electronic and other Equipment . . . on Land, Sea or in the Air.

TECHNICANA

[*Continued from page 18*]

in the feeder produces no current I_1 at the left-hand end of the secondary line.

The reason for this can be easily seen by considering a pulse travelling from left to right along the feeder. As it passes the left-hand end it will produce a pulse of current which will travel with it along the line and arrive at the right-hand end just as the feeder pulse produces an equal and opposite current at the right-hand end, thus giving zero resultant current.

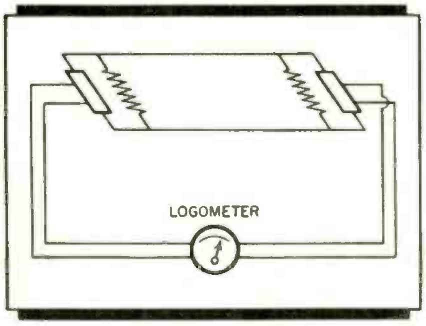

Fig. 6. Circuit with "Logometer"

"The currents or potential differences at the two ends operate thermocouples, detectors or rectifiers, and the resultant direct currents are conveyed as shown in *Fig. 6* to an instrument called a 'logometer' which indicates the ratio of the currents."

The instrument can be located anywhere; and can be calibrated directly in terms of the coefficient k. The readings are independent of frequency and independent of the absolute values of the induced potential differences.

SUPER X-RAY

THE RESEARCH LABORATORY of the General Electric Company announces that on Saturday, August 21st., 100,000,000-volt x-rays were produced for the first time in the history of science.

They were obtained from the large induction electron accelerator recently completed. The characteristics of this new type of radiation will be published as fast as they can be determined. The first few observations suffice to show that these characteristics differ radically from those with which physicists are familiar.

REACTANCE TUBE

SOME INTERESTING DATA on the reactance tube, its design and possible improvements is contained in an article "Reactance Valve Modulator" by E. Williams in the *Wireless Engineer* for

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[*Continued from page 19*]

August 1943. The author first discusses the typical circuit, employing a phase-splitting network to provide the grid-voltage. Expressions are derived for the input impedance and the Q. In a particular application, due to a necessary compromise, the Q becomes equal to $\mu^{1/2}$, where μ is the amplification factor of the tube.

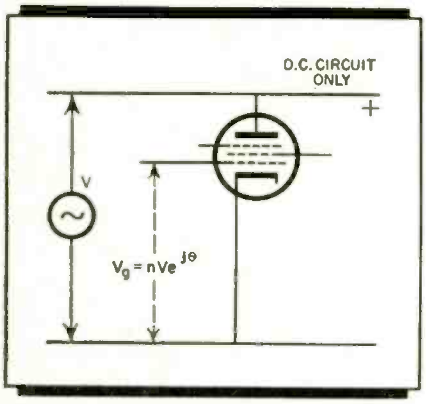


Fig. 7. Grid and plate voltage relation

It is then shown that in order to improve the Q and to make the phase angle of the input impedance equal to 90°, the phase difference between the grid voltage and plate voltage should be

$$\theta = \cos^{-1}\left(-\frac{1}{\mu n}\right)$$

where n is the ratio between the magnitudes of grid voltage and plate voltage, as indicated in *Fig. 7*.

This value of θ is greater than 90 degrees and therefore cannot be obtained by a simple phase-shifting network but would require an inverter tube.

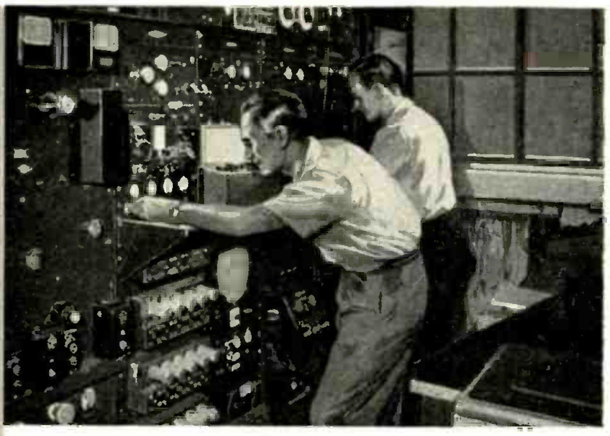
It is also possible to obtain an infinite Q by adding a reactance X in series with the anode circuit. The proper value of X is a function of g_m and therefore this modification is of academic interest only.

"RADIO NAILS"

THE "TACKING" of plywood, plastics, and other industrial materials with "radio nails"—an almost instantaneous method of spot joining thin sections of material—is made possible by one of the newest electronic developments of the Radio Corporation of America.

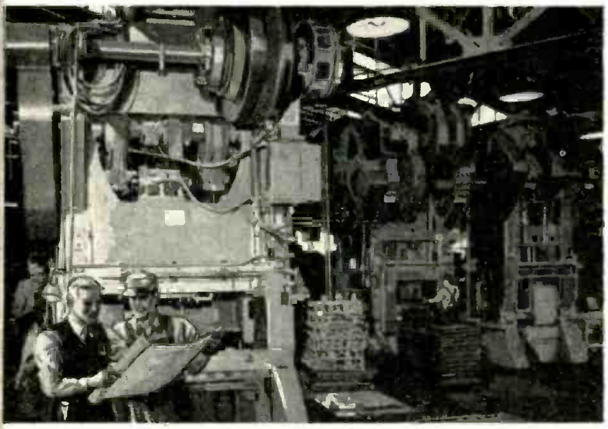
The so-called "radio nail" is a discharge of high-frequency current which can be directed through a sheet of material, generating a quick and intense heat in its path. When two sheets

[*Continued on page 66*]



ELECTRONICS RESEARCH

Technicians of Delco Radio are carrying forward pioneer research in the field of radio and electronics.



PROCESS ENGINEERING

Delco engineers are equipped through years of experience to translate swiftly the product of research and design into practical, useful products.

PRECISION ON A PRODUCTION BASIS

Delco specializes in the ability to mass-produce highly intricate products. Years of experience in the automotive radio field qualify Delco for vehicular radio production for war.

PROBLEMS

were made to be solved

For many years before the war, Delco Radio engineers were meeting and solving the problems of automotive radio . . . and putting their answers into mass production on the assembly line.

This practice gave Delco Radio technicians a head start on the problems of automotive radio for war, and prepared Delco Radio for the task of producing intricate war radio parts, components and assemblies in large quantity and of uniformly high quality of manufacture at a lower cost. Ability quickly to combine research engineering with mass-production methods has been applied in full measure to meeting the needs of the armed forces.

Whether the task at hand is one of pure research, or of mass-production methods, or a combination of both, Delco Radio is adequately equipped and experienced to do the job. Delco Radio Division, General Motors Corporation, Kokomo, Indiana.

★ ★ ★ ★ ★ ★ ★

Back the Attack—

WITH WAR BONDS

Delco Radio

DIVISION OF

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Jensen
REPRODUCERS
AID THE SCR-299
IN "Winning the Battle of Communications!"
The latest development in military communications equipment deserves the best in speech reproducers . . . it is natural, therefore, that Jensen speech reproducers were specified for the famous SCR-299, the high powered mobile communications unit as built by Hallicrafters. Jensen speech reproducers are serving with equal distinction in all branches of the armed forces.
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"BIMORPH" ROCHELLE SALT CRYSTALS AND THEIR APPLICATIONS

ROY S. SAWDEY, Jr.
Engineering Department, The Brush Development Co

PART I

★ The past decade has witnessed the wide acceptance of Rochelle salt crystal products in the fields of broadcasting, communications, sound recording and reproduction, and public address. These crystal products generally have taken the forms of phonograph record cutters and phonograph pickups, microphones and earphones and are found in the home, school, studio, and auditorium.

Other crystal products which have found considerable use in the fields of science, industry and medicine are: the Surface Analyzer, the direct-inking oscillograph, several types of vibration pickups, a fluid pressure pickup, electrical stethoscopes, and reflecting-type galvanometers. The surface analyzer and direct-inking oscillographs are playing vital roles in the present war effort. The former for the instantaneous and permanent recording of surface smoothness (in millionths of an inch) of highly finished aircraft and automobile engine parts; the latter for recording vibration and noise in engines and for recording dynamic strains.

Many applications of Rochelle salt crystals can be found in the business office, being employed in inter-office communication systems, paging systems, "one hour per side" disc recording equipment, and dictating machines.

All of those products have been made commercially possible through

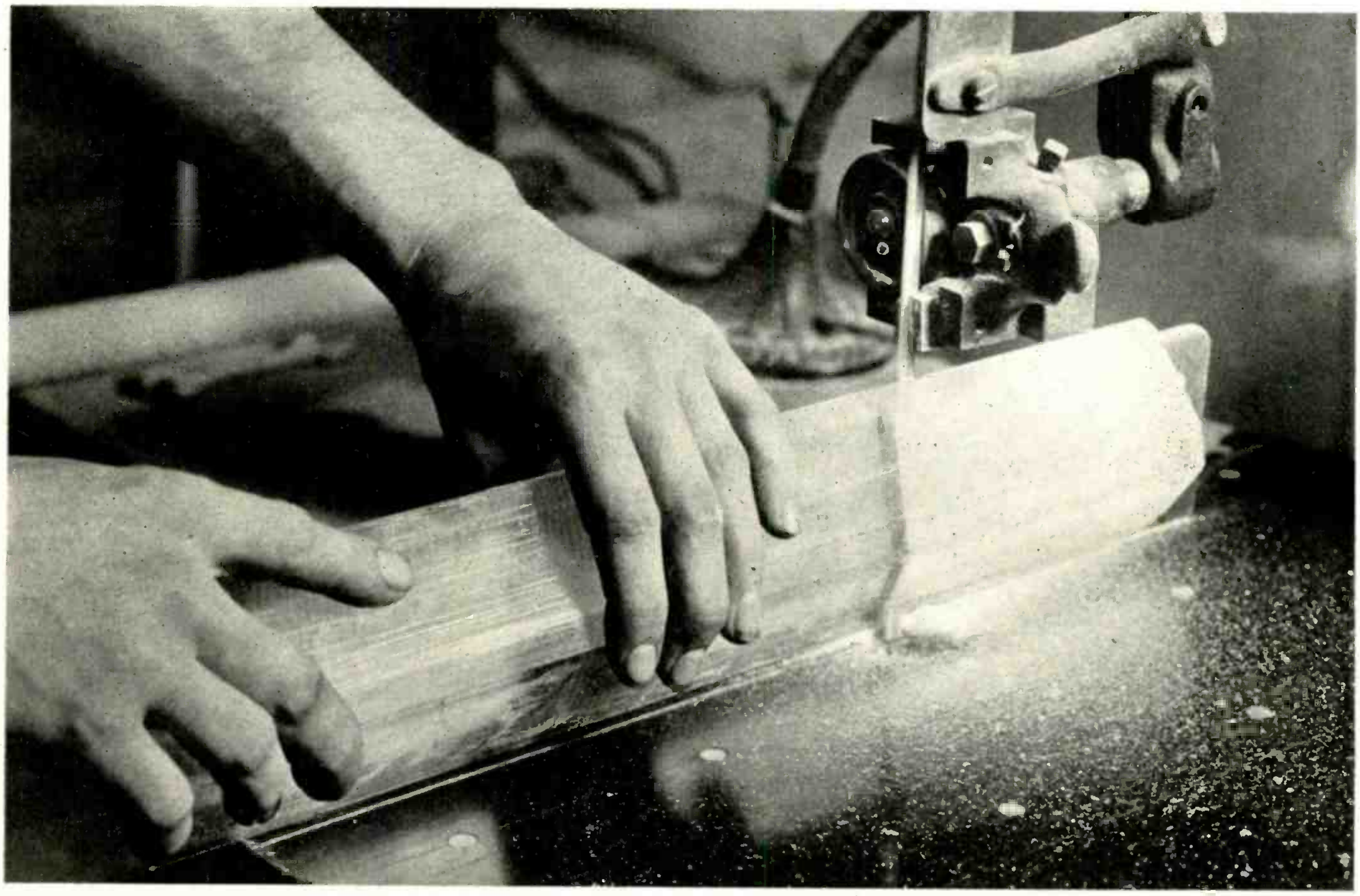

Fig. 1. Slab of Rochelle salt being cut from large homogenous bar.

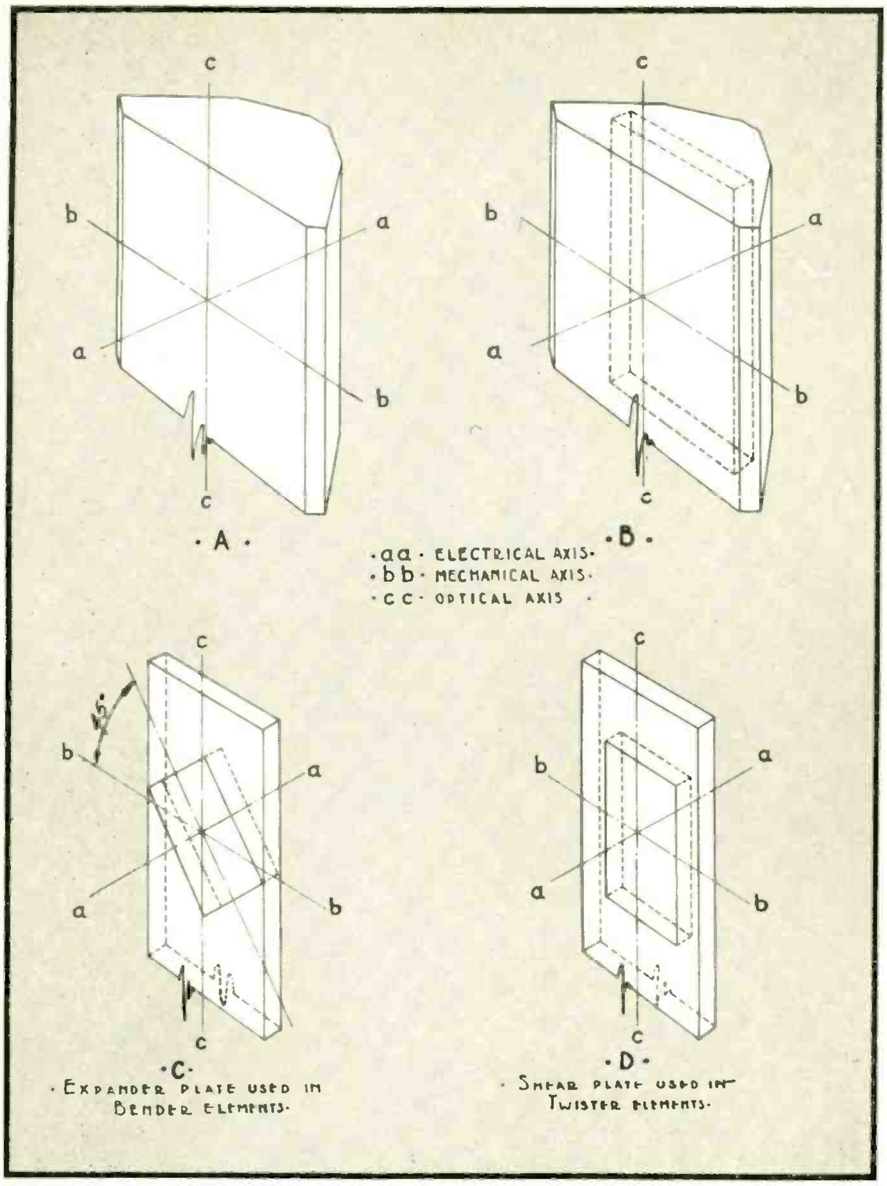

Fig. 2. Method of cutting crystal plates.

the extensive research and development work accomplished in the past few years which has resulted in a highly improved method of growing Rochelle salt crystals and of fabricating crystal elements from such crystals. This was preceded by more than a century of experimental work by many well-known scientists who provided us with many of the laws and constants regarding piezo-electric substances.

History of Development

Piezo-electricity or pressure electricity phenomenon as exhibited by Rochelle salt appears to have been perceived first by Coulomb about 1780. Work started 40 years later by Becquerel led to his report in 1833 of the measurement of the piezo-electric effect in various substances.

The Curies who later pioneered in radium research, were chiefly interested in the relationship between piezo-electricity and pyro-electricity (electricity from heat) and in 1880 published the result of their work with quartz in connection with the determination of the amount of electricity generated by unit pressure along various axes of the substance. The following year, Lippman predicted that if quartz were subjected to an electrostatic field, a deformation would result. Later this was experimentally confirmed by the Curies who demonstrated that according to the principle of the conservation of energy, any piezo-electric substance which acts as a generator of electricity in response to mechanical motion, will act conversely thereto.

Further contributions along these lines were also made by such famous men as Kelvin, Roentgen, Henkel, Braun and Voigt. Roentgen in particular suggested the possible acoustic application of piezo-electric substances. By the close of the 19th century, it was generally recognized that, of all the known substances exhibiting the piezo-electric effect, sodium potassium tartrate or Rochelle salt was by far the most active, being approximately 1000 times more active than quartz.

The application of Rochelle salt crystals commercially presented many serious difficulties. Paramount among these were hysteresis and saturation effects, wide variations in piezo-electric performance of the crystal at different temperatures, and the fact that different crystals produced different results at identical temperatures. The fact that Rochelle salt crystals are not found in a natural state such as quartz, but have to be grown artificially also presented a serious difficulty in commercial applications.

Through the introduction of the "Bimorph" crystal element and the accurately controlled processes developed for its fabrication, these difficulties mentioned have been practically overcome in present-day Rochelle salt crystal devices. Briefly the present "Bimorph" crystal element consists of two Rochelle salt crystal plates cemented together and so oriented that when a potential is applied one plate contracts while the other expands resulting in an overall twisting or bending of the whole unit.

Crystal Fabrication

The first step in the fabrication of "Bimorph" Rochelle salt crystal elements is the growing of large clear homogeneous bars. Rochelle salt is obtained commercially by refining a residue which accumulates in wine casks. The product as supplied by the refiners is granular and has to be crystallized from a solution to obtain crystals large enough for most commercial application. The Brush Development Company's crystallizing process produces crystals about 23 inches long, 3 inches wide and 1½ inches high. See *Figs. 1* & *2-A*. These bars, by the use of unique fabricating methods are then cut into slabs (see *Fig. 2-B*) and then into small plates used in the final crystal elements.

The properties of these crystal plates may be expressed in terms of three axes; *a*, *b*, and *c* as shown in *Figs. 2-A* & *2-B*. Because in Rochelle salt the electric effects along the *a* axis are the most pronounced, crystal plates cut perpendicular to this axis are the most common. The two fundamental *a*-cut plates used are known as the "expander" and "shear", which may be seen in Figs. *2-C* & *2-D*. It will be noted that the "shear" plate is cut with edges parallel to the *b* and *c* axes, while the "expander" plate is cut at a 45-degree angle to the *b* and *c* axes.

When either type of plate has electrodes attached to its faces and a voltage is applied between these electrodes, the plate changes its shape slightly, expanding in one direction at 45 degrees to the *b* and *c* axes and contracting in the other 45-degree direction. This means that the "expander" plate of *Fig 2-C* will increase its length and simultaneously decrease its width; these two actions reverse on change of polarity of the applied voltage. The cut of the "shear" plate of *Fig. 2-D* shows that a similar action occurs, but that expansions and contractions occur approximately along the diagonals of the plate instead of in the directions parallel to the edges as in the case of the expander plate.

Two or more "shear" plates properly oriented with respect to each other are cemented together to form a twister element, and two or more "expander" plates properly oriented with respect to each other and cemented together form a "bender" element. These names "bender" and "twister" have been chosen because they indicate the resulting motion of the final element when an electrical potential is applied. Both "bender" and "twister" elements come under the classification of "Bimorphs" because of their opposed multiple plate construction.

By this construction the generally undesirable effects of saturation and hysteresis are practically eliminated and the effects of temperature on the sensitivity and impedance as exhibited in single plates are greatly reduced. Such construction also permits more efficient size and shape, and makes possible an element with much higher sensitivity.

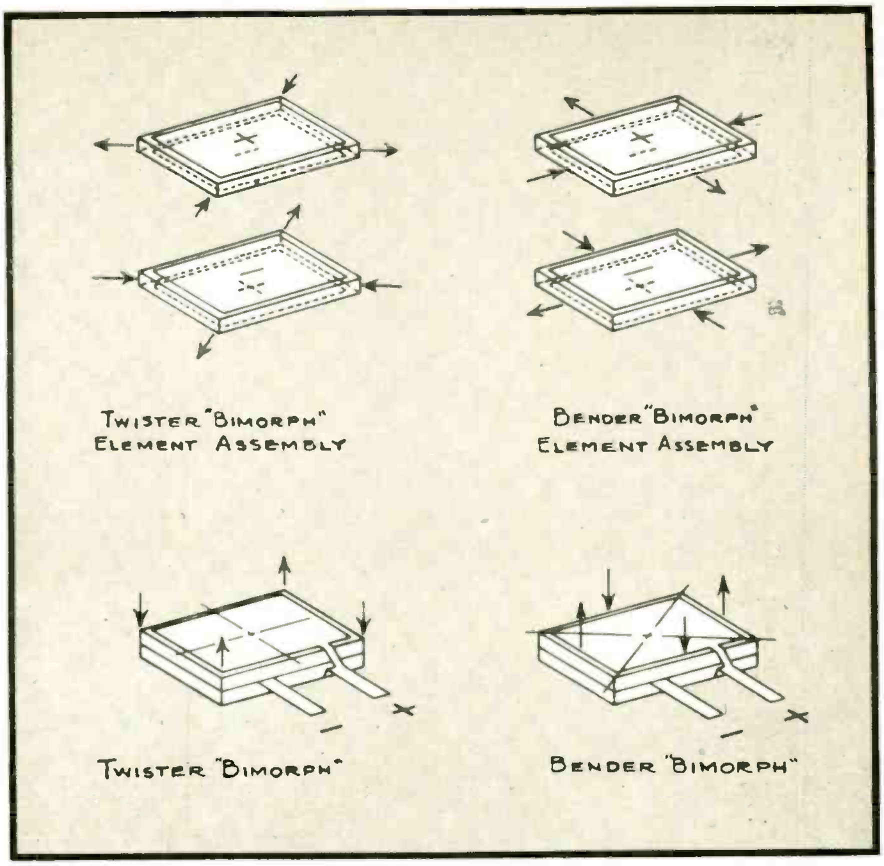

Fig. 3. Construction of "bender" and "twister" "Bimorph" elements. At top are single electroded plates in their relative preassembled positions. Arrows indicate the directions of maximum instantaneous strains for the indicated applied voltage polarity. In the lower sketches the arrows indicate the location and direction of maximum motion of the element relative to the indicated axes.

Construction of Elements

Fig. 3 shows the method of construction of "bender" and "twister" "Bimorph" elements. The two faces of each crystal plate are milled smooth and graphite or foil electrodes are applied. Metal leads are connected to the electrodes, and the plates, after proper orientation, are bonded together with a cement. The electrodes are connected either in parallel or in series depending on the application for which the final element is constructed. Elements with series-connected electrodes produce twice the voltage per given motion as those elements having parallel-connected electrodes. Their motion per given applied voltage is one-half that of those having parallel-connected electrodes and they have ¼th the capacitance of parallel elements.

The assembled crystal element is finally coated with a specially prepared moisture-proof material to insure maximum protection against deterioration under unusually dry or damp conditions of use. *Fig. 4* shows several completed "Bimorph" crystal elements of various sizes.

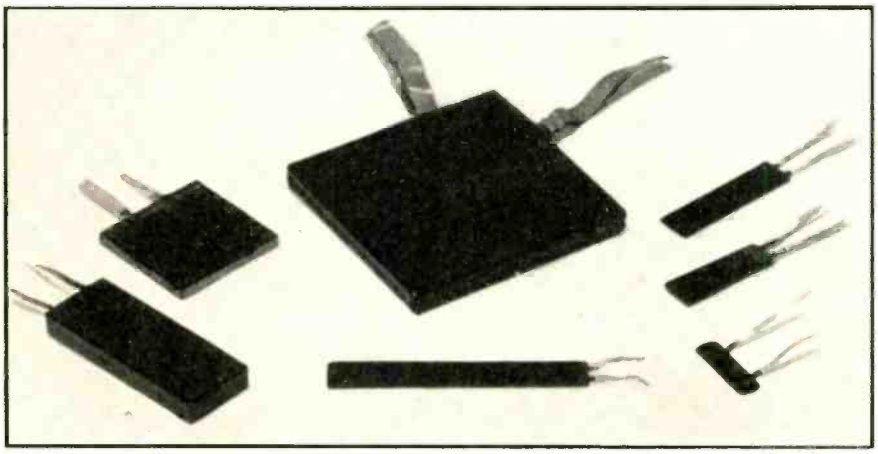

Fig. 4. Typical "Bimorph" crystal elements completely fabricated.

Rochelle salt crystals have their greatest piezo-electric activity at normal room temperature (72 degrees) although they can operate safely up to 130 degrees F. If subjected to temperatures greater than 130 degrees F. their piezo-electric properties are permanently lost. However, for practically all uses, this temperature is very seldom encountered. Temperature effects that are of major importance to the designer or user of crystal devices are the variations of the motion developed for a given voltage, and the dielectric constant with changes in temperature.

For most practical purposes the po-

[*Continued on page 73*]

MODERN THEORY OF ELECTRONS

PAUL R. HEYL, Ph.D.

PART I

★ In a recent lecture we reviewed the evidence for the existence of molecules, atoms and the sub-atomic particles called electrons. We also reviewed the experimental methods that have given us our knowledge of the mass of these particles and the electric charges which they carry, and it was shown that while this charge might be either positive or negative, it is always the same in absolute value. For this reason the electronic charge (about 4.8×10^{-10} e.s.u.) is now regarded as one of the fundamental constants of nature. It was shown also that while the charge on all these particles is the same, their mass may be quite different, some particles being about 1800 times as heavy as others. Yet all these facts tell us nothing about the ultimate nature of matter or electricity, except that they seem to be the two fundamental entities of which everything in the universe is composed. It is our purpose now to see what modern theory has to say on this subject.

Scientific Theories

A few general remarks on scientific theories may not be out of place here. Such theories excite varying emotions in different persons, ranging between the extremes of awe and contempt. Neither of these extremes is justified. Scientific theories are never perfect, but they have their place in promoting human progress; and the practical man cannot afford to neglect the theoretical side of his subject, no matter how academic it may appear. Later we shall see that one of the most important inventions of recent years had its origin in a particularly abstruse piece of electronic theory.

No matter how perfectly a theory may fit the facts known at the time when it was formulated, it has always happened that sooner or later new discoveries show that the theory is not without its defects. Sometimes it can be patched up temporarily, but eventually a new theory displaces it and reigns in its stead, only to be superseded itself in time by a better.

One of the best illustrations of this is Newton's theory of mechanics, celestial and terrestrial, as set forth in his Principia. This theory called forth universal admiration on its publication—and deservedly so. Though its scope was of cosmic breadth it was found to account satisfactorily for all celestial motions then known, and by its help important progress was made in mechanics and astronomy.

> ★ Progress in the science of micro-waves, and related phenomena close to the borderline of matter, has focused the attention of the engineer and the physicist on the basic characteristics and behavior of the electron. Hence, the work of theorists assumes new importance in the light of the most recent inroads into the flanks of this basic science. The practical applications of tomorrow may well arise from a closer study of the postulates set forth by the eminent physicists of our time.
>
> The accompanying lecture, published through the courtesy of P. R. Mallory & Company, who commissioned Dr. Heyl to deliver a series of lectures on electronics in Indianapolis, will serve to refresh the minds of many readers on the subject of modern electron theory.
> **—Editor.**

The high esteem in which this theory was held is illustrated by Alexander Pope's "Epitaph, intended for Sir Isaac Newton."

"Nature and Nature's laws lay hid in night:
God said, Let Newton be! and all was light."

For a century and a half after the publication of the Principia no flaw was found in the Newtonian theory; but in 1845 Leverrier called attention to the fact that the plant Mercury showed a slight irregularity in its motion, inconsistent with the inverse square law of gravitation, and too large to be explained as an error of observation. Various attempts were made to bring this anomaly into line with theory, but for many years it remained an unexplained puzzle. Finally, in 1916 Einstein brought forward a more general law of gravitation to which the Newtonian law was a close approximation, and which satisfactorily explained the anomalous motion of Mercury.

Einstein's theory, in its turn, did much for the practical side of astronomy, for it predicted two new phenomena, whose existence was later verified by experiment. But the theory of relativity, though not yet half a century old, has been found to have its limitations; for when it is applied to rotary motion and centrifugal force, as Eddington says, it stops explaining things, and begins explaining them away.

Newton cut so closely to the line that it was over two centuries before anyone could improve on his work; and how long it will be before Einstein yields place to a successor is a matter for the present on the knees of the gods.

Modern Theory

Let us now see what modern theory has done toward shaping our concept of electrons, and of the matter and electricity of which they seem to be composed.

The questions: "What is matter?" and "What is electricity?" date far back before the discovery of electrons. To answer these questions many hypotheses have been advanced — and abandoned; so many, in fact, that though this subject is of much interest we have not time to discuss it fully at

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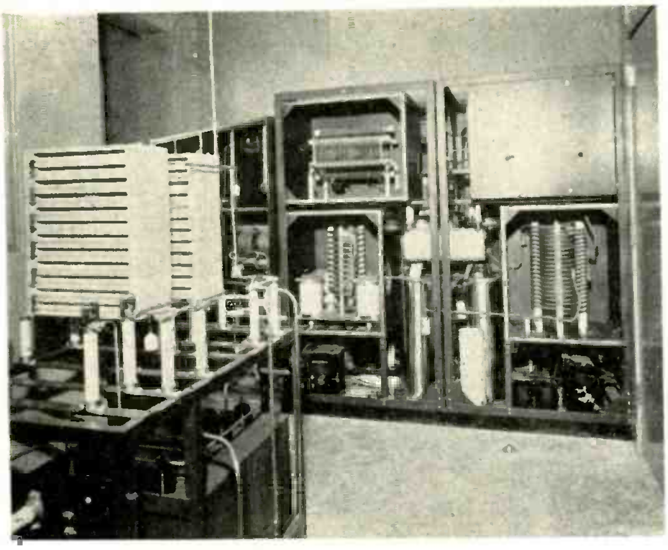
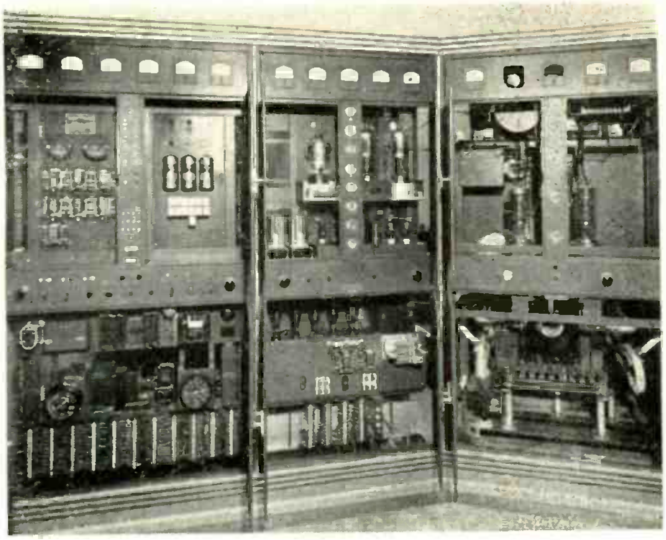
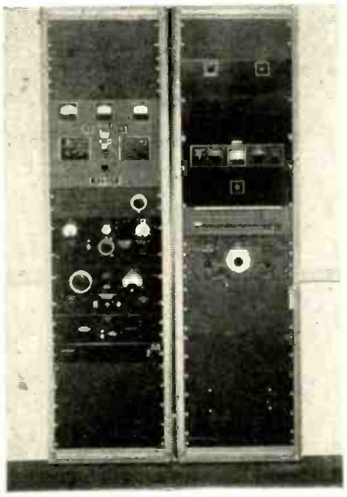


Behind the scenes at Nashville's 50-kw radio station WLAC. This view shows details of the Western Electric condenser and switch assembly and of the tank circuit components.



Three units of the equipment opened for inspection from the transmitter-room side. Left to right: The control unit, oscillator amplifier, and modulating amplifier..

WLAC'S NEW 50-KW TRANSMITTER

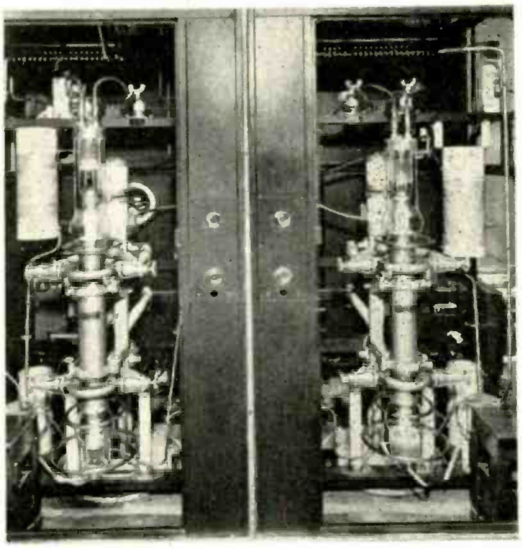


Left: Monitor and speech-input bays at WLAC, including "program operated" amplifier and phase monitor.

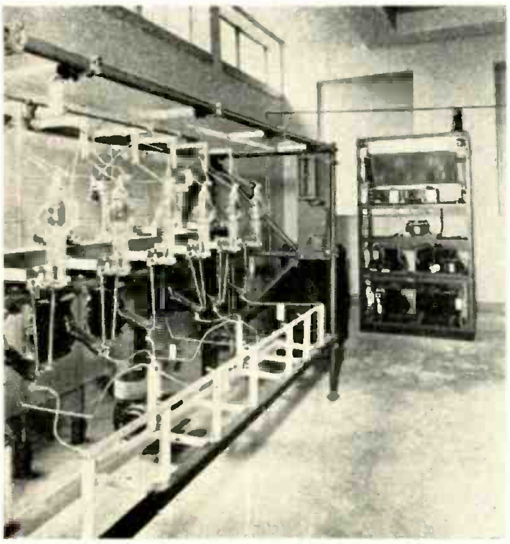
Right: Twin water-cooled 100,000- watt vacuum tubes of the power amplifier.

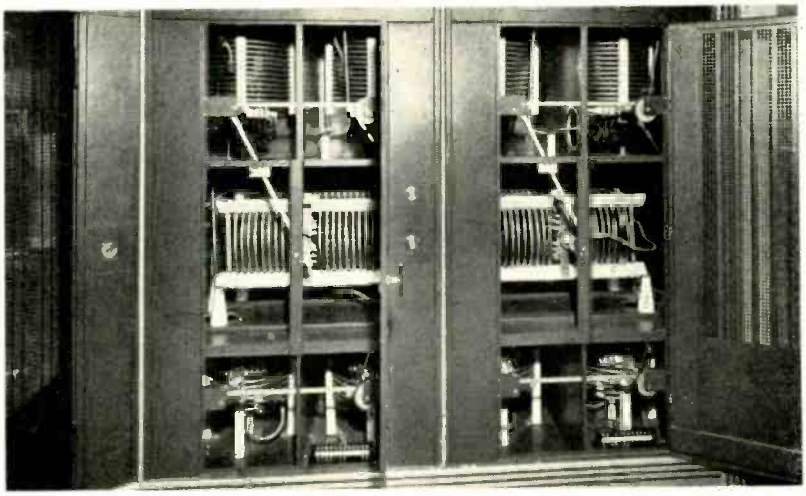
Lower left: Tubes in the high-voltage rectifier unit in the foreground handle alternating current at 18,000 volts. Grid bias rectifier in background.

Lower right: Open view of the antenna control units which govern distribution of energy to the antenna.



Photos Courtesy Western Electric Co.





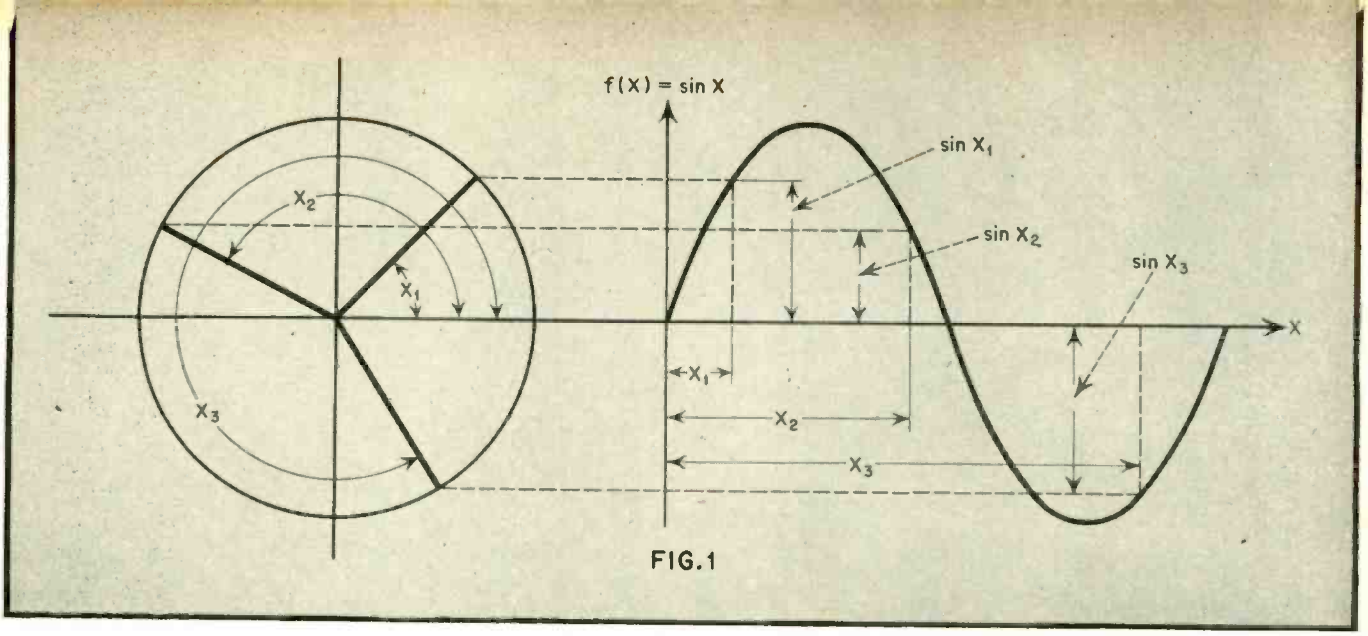


FIG. 1

THE CALCULUS AS APPLIED TO ELECTRICAL CIRCUITS

L. W. HAESLER
RCA Victor Division
Radio Corporation of America

★ An attempt will be made here to show some quantitative relationships between current, voltage and power and how these quantities behave in circuits. To be able to express electrical quantities mathematically requires some knowledge of the Calculus, because the great majority of electrical problems deal with currents and voltages which are *changing,* and the Calculus provides means for dealing with changing quantities or variables.

Many authors of technical papers assume a vast mathematical background on the part of their readers. This is unfortunate, but perhaps it is not entirely the author's fault. If he were to stop to develop all equations, and prove all the theorems he uses, his original purpose would be lost and the mature reader would be required to spend more of his time than actually necessary to understand the author's new idea. It is therefore necessary to pre-suppose a certain amount of mathematical background for an understanding of what is to follow, but an effort will be made to keep the mathematics continuously tied to the physical phenomena involved. Such background as will be pre-supposed will include simple algebra, geometry and a little trigonometry. Formulas, expressions and theorems taken from these subjects can be verified through use of a handbook such as the *Mathematical Tables* from the *Handbook of Chemistry and Physics,* published by the Chemical Rubber Co., Akron, Ohio, or any other good text.

Ohm's Law

Most of us are familiar with Ohm's law stated in its special d.c. sense: the voltage across a resistance is proportional to the current through the resistor. In mathematical notation this is

$$e = i\,R \qquad (1)$$

where e and i are in (1), the dependent and independent variables of a simple *function* known as a proportionality. We can write a general expression in functional notation as.

$$e = f\,(i) \qquad (2)$$

Equation (2) *may* represent (1) or some other relationship of the current and voltage. (2) is read: e equals f of i. In (1) R is a constant; a constant is a quantity which does not change during the investigation. In this article, resistance, capacitance and inductance will be treated as constants which do not vary with current, voltage or time unless specifically stated as doing so.

Equation (1) will appear, after some thought, as merely a special case of a more general expression relating current and voltage in a passive (i. e. containing constant elements) network:

$$e = i\,Z \qquad (3)$$

The Z in equation (3) is an expression involving the impedance of the separate circuit elements, inductance, capacity and resistance, to the current. In most cases e and i will vary with time in some manner. The most familiar case is that in which they vary *sinusoidally,* or that the current and voltage amplitudes are proportional to the sine of an angle which in turn is directly proportional to the time. In a right triangle, the sine of an angle is given by the ratio of the side opposite the angle to the hypotenuse. If the hypotenuse rotates about the apex of the angle at constant angular velocity, then its projection on a plane perpendicular to the plane of rotation changes size and direction in a manner known as simple harmonic motion. *Fig. 1* shows this relationship. Mathematically it is written,

$$y = \sin x$$

where x is measured in radians from the origin, and $y = 0$ when $x = 0$.

The reader may have wondered why alternating current generators are so designed as to produce a sine wave of voltage when they could just as easily have been designed to produce some other shaped wave. The answer is best shown by the concept of the derivative and integral and how they are applied.

In equations (1), (2) and (3) we said the voltage depended upon the current, or that the voltage is a function of the current. It is also and more usually true that the current is a function of the voltage since we usually deal with "constant" voltage sources. The term constant here refers to the fact that the regulation or internal impedance of the source is negligible compared to any circuit elements across which the voltage is impressed.

Known Circuit

It is probably worthwhile to diverge at this time to point out that a circuit analysis will produce correct results if the *real* circuit is known. A simple example is shown by the following problem: a storage battery is connected to a variable resistor as in *Fig. 2*. If this were the whole circuit, then an infinite amount of current would flow when R became zero. We know this does not happen and upon re-examination of the circuit, it is realized that the battery contains internal resistance which prevents the "short circuit" current from becoming infinite. Likewise, there are no physically realizable leads from the battery to the resistor with zero resistance. *Fig. 3* is the actual circuit. It is well to bear in mind, then, that when the apparent circuit does not behave as it should, a search for the real circuit should be instituted.

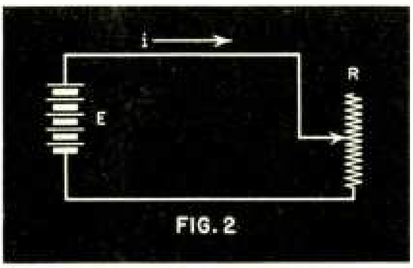


FIG. 2

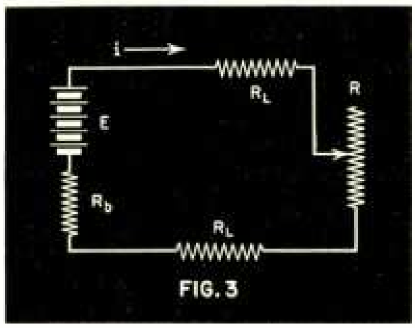


FIG. 3

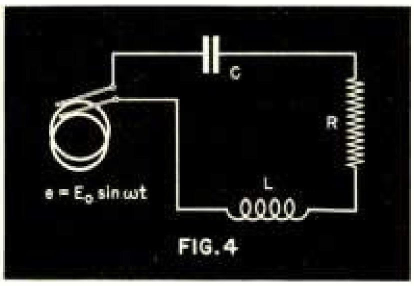


FIG. 4

Rewriting equation (3) in a still more general form and making the voltage, *e*, the independent variable for the time:

$$i = \frac{e}{f(R, L, C)} \qquad (4)$$

where $f(R,L,C)$ is a function of the resistance, inductance and capacity. If e is sinusoidal, that is, if,

$$e = E_o \sin \omega t \qquad (5)$$

where E_o = max. value of e
$\omega = 2\pi \times$ freq.
t = time

then in a series circuit, as in *Fig. 4*, the absolute value of the current is given by,

$$|I|_{\text{max.}} = \frac{E_o}{\sqrt{R^2 + X^2}},$$

$$\left(X = \omega L - \frac{1}{\omega C} = 2\pi fL - \frac{1}{2\pi fC} \right) (6)$$

a familiar formula.

But (6) is really again only a special case of (4). To be absolutely general, e can have any time variation; that is, e can be any function of the time. In this case, we must go to the fundamental definitions of inductance and capacitance in order to write (4) with a nonsinusoidal e.m.f. applied.

Inductive Factors

Most of us with circuit experience are familiar with the behavior of an inductance through which a direct current is flowing. So long as the current is constant and unvarying, there is no appreciable voltage across the inductance other than the internal resistance drop. However, when the circuit is opened suddenly, a large voltage appears across the inductance. Qualitatively this behavior is explained by the energy storage in the magnetic field surrounding the inductor. As this field commences to collapse, the lines of force cut the turns of the inductor and re-induce a voltage in them, the polarity of the voltage being such as to reinforce the original current flow. Likewise, the opposite situation is true: an attempt to increase the current flow is met with a "back e.m.f." tending to prevent this increase. This back e.m.f. of the inductor is expressed quantitatively by the expression:

$$e = -L \frac{di}{dt} \qquad (7)$$

—Where di/dt is the mathematical symbol for the *rate of change of the current with respect to time*. The minus sign means that the voltage is opposite in direction to the change in current. Mathematically di/dt is read: "the derivative of i with respect to t."

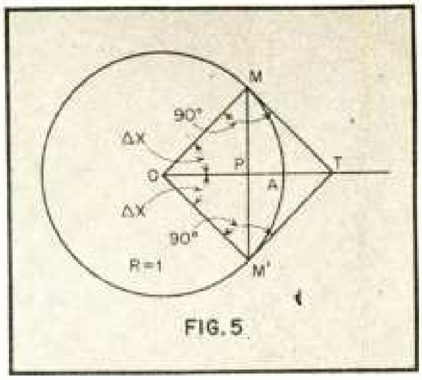


FIG. 5

The derivative is probably the most fundamental concept in mathematics. It is credited to Sir Isaac Newton and Gottfried Liebnitz, who are said to have developed the Differential Calculus simultaneously and independently. Newton's Calculus was developed by him under the name of Fluxions.*

It is probably best to define the derivative without reference to (7) so that we can apply our definition more generally in the future. If a variable quantity y depends on an independently variable quantity x, this relationship can be expressed in functional notation as in (2) or

$$y = f(x) \qquad (8)$$

Then let x change by an amount Δx (delta x), then y will change by an amount Δy, or,

$$y + \Delta y = f(x + \Delta x)$$

Then the change or *increment* in y is,

$$\Delta y = f(x + \Delta x) - y$$

or,

$$\Delta y = f(x + \Delta x) - f(x) \qquad (9)$$

since $y = f(x)$. Next divide (9) by the increment of the independent variable, Δx,

$$\frac{\Delta y}{\Delta x} = \frac{f(x + x) - f(x)}{\Delta x} \qquad (10)$$

Then the limit of this ratio (10) when Δx approaches zero as a limit is the *derivative* and is *denoted by the symbol* dy/dx, or,

$$\frac{dy}{dx} = \lim_{\Delta x \to 0} \frac{f(x + \Delta x) - f(x)}{\Delta x} \qquad (11)$$

From (10) we get also,

$$\frac{dy}{dx} = \lim_{\Delta x \to 0} \frac{\Delta y}{\Delta x} \qquad (12)$$

When (11) exists the function is said to be differentiable. We do not have to concern ourselves with non-differentiable functions for the moment,

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* See footnote, p. 19, *Elements of the Differential and Integral Calculus*, by Granville, Smith and Longley; Ginn and Co., 1934.

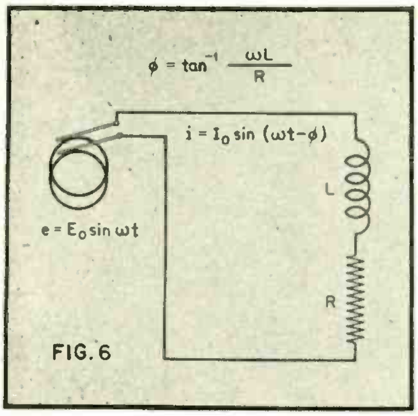

FIG. 6

because their appearance in applied mathematics is rare. A function will be considered differentiable even though its derivative becomes zero or infinite for isolated values of the independent variable.

Let us apply (11) to a function, such as $\sin x$, as follows:

$$y = \sin x$$

$$y + \Delta y = \sin (x + \Delta x) \qquad (13)$$

expand the right hand side of (13) by the trigonometric identity:

$$\sin (a + b) = \sin a \cos b + \cos a \sin b$$

$$y + \Delta y = \sin x \cos \Delta x + \cos x \sin \Delta x$$

$$\Delta y = \sin x \cos \Delta x + \cos x \sin \Delta x - y$$

Since $\qquad y = \sin x$

$$\Delta y = \sin x \cos \Delta x + \cos x \sin \Delta x - \sin x \qquad (14)$$

divide (14) by Δx:

$$\frac{\Delta y}{\Delta x} = \frac{\sin x \cos \Delta x}{\Delta x} + \frac{\cos x \sin \Delta x}{\Delta x} - \frac{\sin x}{\Delta x} \qquad (15)$$

Consider first the first and last terms of (15). If we let Δx approach zero, $\cos \Delta x \rightarrow 1$, since $\cos 0 = 1$. We have not defined the ratio

$$\lim_{\Delta x \rightarrow 0} \frac{\sin x}{\Delta x} \qquad (16)$$

but for small values of Δx, terms 1 and 3 of (15) approach each other. The ratio (16) becomes very large as $\Delta x \rightarrow 0$, but this is not important since both terms nearly cancel each other for values of Δx near zero. This leaves the 2nd term of the right hand side of (15),

$$\frac{\cos x \sin \Delta x}{\Delta x}$$

or $$\cos x \frac{\sin \Delta x}{\Delta x} \qquad (17)$$

It remains to define the limit of $\sin \Delta x/\Delta x$ as $\Delta x \rightarrow 0$. Consider the circle of *Fig. 5* whose radius is unity. Let Δx = angle AOM in radians. Then, since $r = 1$, arc $AM = \Delta x$ also. If we make arc AM^1 = arc AM and draw MT and M^1T tangent to the circle at M and M^1 respectively. Then, from geometry

$$MM' < \text{arc } MAM' < MT + M'T$$

or by trigonometry, since $MP = \sin \Delta x$ and $MT = \tan \Delta x$,

$$2 \sin \Delta x < 2 \Delta x < 2 \tan \Delta x$$

or $$1 < \frac{\Delta x}{\sin \Delta x} < \frac{\sin \Delta x}{\cos \Delta x} \equiv \frac{1}{\sin \Delta x}$$

$$1 < \frac{\Delta x}{\sin \Delta x} < \frac{1}{\cos \Delta x}$$

Replacing each term by its reciprocal and reversing the inequality,

$$1 > \frac{\sin \Delta x}{\Delta x} > \cos \Delta x$$

For small values of Δx, $\sin \Delta x/\Delta x$ lies between 1 and $\cos \Delta x$. Therefore, as $\Delta x \rightarrow 0$, $\sin \Delta x/\Delta x \rightarrow 1$. Thus as $\Delta x \rightarrow 0$, (17) approaches $\cos x$, and (15) becomes,

$$dy/dx = \cos x \qquad (18)$$

Thus the derivative of the sine wave is really another sine wave but shifted in time ¼ cycle earlier. Technically, this is known as a 90° phase advance since the cosine reaches a maximum 90° or $\pi/2$ radians before the sine. Now return to equation (7). The current given by:

$$i = I_o \sin \omega t$$

where I_o = Max. val. of current and the other variables are the same as under (5) above.

is flowing through an inductance L. Then applying equation (7), the voltage drop across L becomes,

$$e = \frac{d}{dt} (L\, I_o \sin \omega t)$$

$$e = L\, I_o \frac{d}{dt} (\sin \omega t) \quad \text{(derivative of a constant} = 0)$$

$$e = L\, I_o \cos \omega t \frac{d}{dt} (\omega t) \quad \text{(derivative of a function of a function } dv/dt = dv/dx \cdot dx/dt)$$

$$e = L\, I_o\, \omega \cos \omega t \qquad (19)$$

From trigonometry $\cos x = \sin (90° + x)$. Then (19) can be written:

$$e = \omega\, L\, I_o \sin (\omega t + 90°) \qquad (20)$$

The voltage drop thus is seen to have the same time variation as the current, and of peak value $\omega\, L\, I_o$. This voltage as read on a meter would have a value 0.707 $\omega\, L\, I_o$. The reader is probably more familiar with the circuit of *Fig. 6* by thinking of the current as *lagging* behind the applied voltage by a certain phase angle. In an actual circuit, resistance will be present, and the current will not lag by a full 90°, but by an angle depending upon the ratio of R and L.

A little thought will show that some other time variation of the current will not produce a voltage drop having the same waveshape. Suppose the current were of the shape of *Fig. 7*. Then the "front" or leading edge of the current square wave has a large rate of change; i. e., di/dt is large, and a pulse of voltage is obtained as in *Fig. 8*. Soon the voltage reaches a constant peak value and di/dt becomes zero and so the voltage becomes zero. When the current is falling to its minimum value, di/dt is again large but in the opposite direction, producing a pulse of voltage in the opposite direction to that on the current rise.

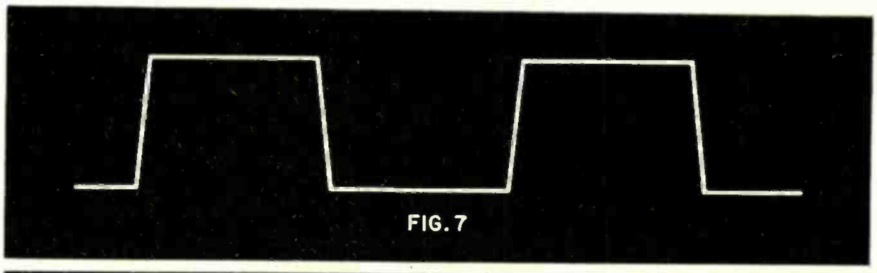
FIG. 7

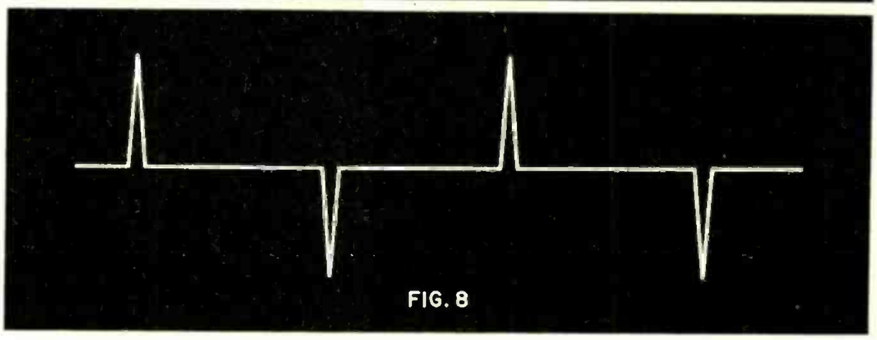
FIG. 8

The advantage of sinusoidal alternating currents and voltages for power distribution thus becomes apparent. The waveshape at the secondary of a transformer with a square wave applied would be different for different loads on the secondary, but is always a sine wave for a sine wave of applied voltage or current (assuming a perfect transformer).

Next consider the behavior of a

capacitor under conditions of changing voltage, current and charge. Charge is defined as the product of the current and time or,

$$q = i\,t \qquad (21)$$

Thus, if a current of 1.0 ampere flows into a capacitor for 1.0 second, the capacitor has acquired a charge of 1.0 coulomb. However, the current is usually some function of the time, $f(t)$, and to calculate the charge on a capacitor due to a varying current requires the concept of the integral. For a short increment of time, Δt, we will consider the current to be constant. Then, (see *Fig. 9*):

$$\Delta q_1 = i_1\,\Delta t_1$$
$$\Delta q_2 = i_2\,\Delta t_2 \qquad (22)$$

in general, $\Delta q_k = i_k\,\Delta t_k$

The actual charge on the capacitor is then nearly,

$$Q \cong \text{Sum of } (i_1\,\Delta t_1 + i_2\,\Delta t_2 + \ldots + i_n\,\Delta t_n) = \sum_{k=1}^{k=n} i_k\,\Delta t_k \qquad (23)$$

If in (23) we allow the Δt's to approach zero and n to increase without limit, then (23) becomes

$$Q = \lim_{n\to\infty} \sum_{k=1}^{k=n} i_k\,\Delta t_k = \int_{t_1}^{t_2} i\,dt =$$

$$\int_{t_1}^{t_2} f(t)\,dt = \phi(t_2) - \phi(t_1) \qquad (24)$$

where $\phi(t)$ is a new function defined in what is to follow, and $t_2 - t_1$, is the time interval over which the integration is carried out, and in which we are interested.

Equation (24) is defined by the foregoing analysis as the limit of a sum. It was noticed early in the development of the Calculus that a process was needed which would be the inverse of differentiation. Integration is such a process and the mathematical technique of integration is obtained from the corresponding rules for differentiation. For example, we proved that

$$\frac{d}{dx}\sin x = \cos x$$

or more generally,

$$\frac{d}{dx}\sin v = \cos v\,\frac{dv}{dx}$$

where v is a function of x. We now write

$$\int \cos v\,dv = \sin v + c \qquad (25)$$

(25) is known as the indefinite integral of $\cos v$ because a constant c appears. The derivative of a constant is zero; being constant, it has no rate of change. Thus,

$$\frac{d}{dx}(\sin v + 5) = \cos v\,\frac{dv}{dx}$$

$$\frac{d}{dx}(\sin v - 7) = \cos v\,\frac{dv}{dx}$$

in fact,

$$\frac{d}{dx}(\sin v + c) = \cos v\,\frac{dv}{dx}$$

Thus, upon performing the operation of integration where no limits are given, a constant appears to which any value can be assigned. The new function obtained through integrating a differential expression is thus a family of functions, each differing by a constant. Thus, $\sin x + 1$ and $\sin x + 2$ are identical in period and phase but the latter is always one unit of amplitude greater than the former.

All the integrals in a class known as *elementary functions* can be developed from the rule for differentiation of these functions. The rules for differentiation can be developed in the same manner as in equations (8) to (18), that is, by the "delta or increment" method. These rules, as well as integrals, are given in the references mentioned previously.

Now return to equation (24). If the time variation of the current flowing into a capacitor is given by

$$i = I_o \cos \omega t$$

then the charge at any instant on the capacitor will be,

$$Q = \int f(t)\,dt = \int I_o \cos \omega t\,dt \qquad (26)$$

To obtain the voltage across the capacitor, we have,

$$Q = Ce$$

or

$$e = \frac{Q}{C}$$

(26) becomes

$$e = \frac{1}{C}\int I_o \cos \omega t\,dt \qquad (27)$$

in order to evaluate (27), it is necessary that the expression following the integral sign be a complete differential expression. In other words, the dt must really be $d(\omega t)$. It is permissible to multiply inside the integral sign by ω, provided we divide by ω outside so as not to change the value of the integral. Then (27) becomes, after moving I_o outside the integral sign, which is permissable since I_o is a constant,

$$e = \frac{I_o}{\omega C}\int \cos \omega t\,d(\omega t)$$

Then applying (25)

$$e = \frac{I_o}{\omega C}\int \cos \omega t\,d(\omega t) = \frac{I_o}{\omega C}\sin \omega t + C \qquad (28)$$

In order to remove the constant of integration, we proceed as follows: From *Fig. 9*, it is evident that when $t = 0$, $\sin \omega t = 0$. In any event, $\sin 0 = 0$, and e is also zero. Thus,

$$0 = 0 + C$$

Equation (28) becomes, since $C = 0$,

$$e = \frac{I_o}{\omega C}\sin \omega t$$

The value of voltage as read on a meter would be the r.m.s. value, or

$$E = .707\,\frac{I_o}{\omega C}$$

[*Continued on page 68*]

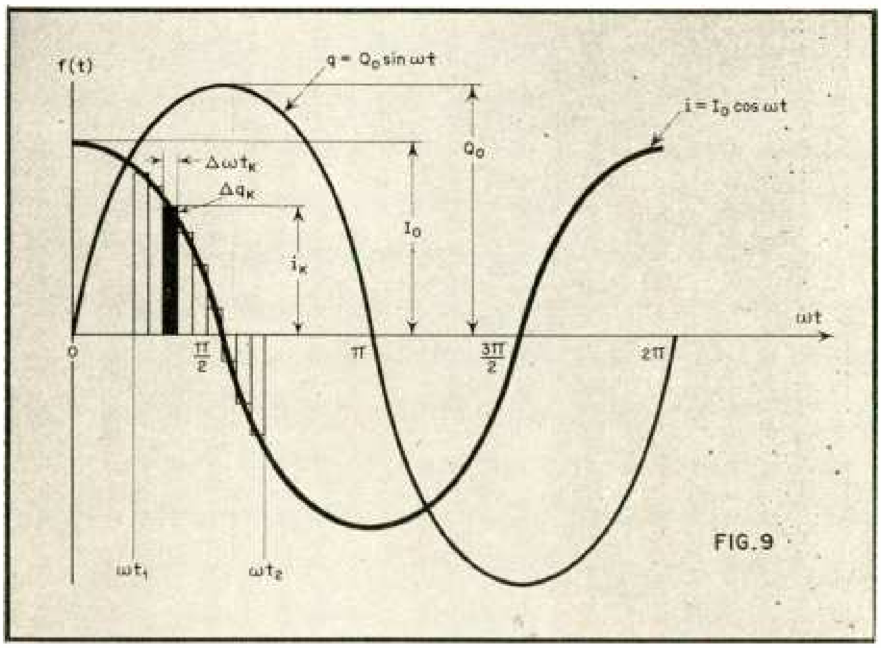

FIG. 9

PHASE MEASUREMENT BY MEANS OF THE OSCILLOSCOPE

MARK HOLZMAN

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★ When two alternating voltages are applied simultaneously to the two sets of plates of an oscilloscope, a great variety of patterns may be obtained. The exact nature of these images depends upon their frequency ratio, phase relationship and their relative amplitudes. For the purposes of this paper we shall impose the condition that the parameter frequency be identical for the two waves; at the same time we will vary the amplitudes and the phases at will independently for each wave.

Before deriving the equations for the measurement of the phase difference between two given waves, it might be well to discuss first the way in which the patterns on the screen are formed.

Graphical Analysis

Consider *Fig. 1*. The points P and Q describe simple harmonic motions within their respective orbits. Both move with the same angular velocity ω. The instantaneous projection of P is M and of Q is N. Both M and N execute simple harmonic motion along their respective axes YOY' and XOX'. To find the instantaneous value of the resultant point K, draw a perpendicular to YOY' through M, and another perpendicular to XOX' through N. The point of intersection of the two perpendiculars is the required point K. The numerals around the two circular orbits indicate the relative positions of P and Q at any instant and are therefore an indication of the phase difference.

The locus of the point K in *Fig. 1* is the line BOC. It is obvious from the arrangement of the numerals that the phase difference is zero. When M is at O, moving in the positive direction of OY, N is at O moving in the positive direction of OX.

To find the resultant pattern for any other phase difference it is merely necessary to shift the numerals on only one of the orbits by the desired number of radians. The radius of each circle, of course, is proportional to the magnitude of the voltage that it represents.

Figs. 2, 3 and *4* illustrate the results for other phase angles. Examination of these figures and scrutiny of the aforementioned procedures for their determination, might be suggestive of a method by means of which the process is reversed and the circles with their corresponding numerals drawn from a photographic replica of a given pattern. The equations derived in the next section are so simple, however, that the labor spent on perfecting such a graphical method seems to be rather useless.

Mathematical Analysis

The general equations for any two waves are

$$y' = a \sin (\omega t' + \alpha) \qquad (1)$$
$$y'' = b \sin (\omega t'' + \beta) \qquad (2)$$

For our problem, however, these equations may be written in a more convenient way. Let $y' = x$ and $y'' = y$. Let $\omega t' = \omega t'' = \omega t$. Since we are not interested in the phase angles

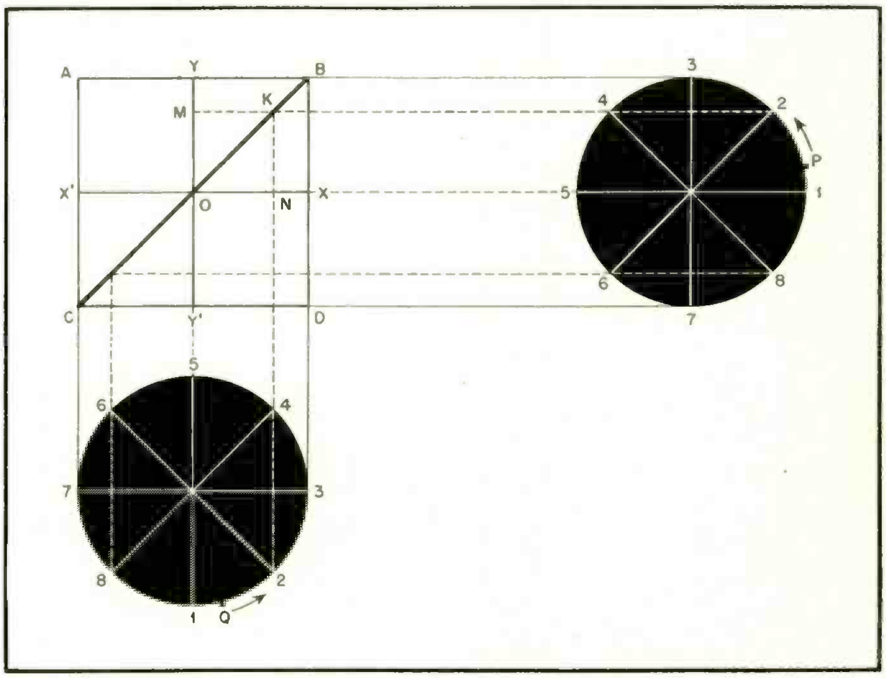


Fig. 1. Phase difference=O. Result: Line BOC.

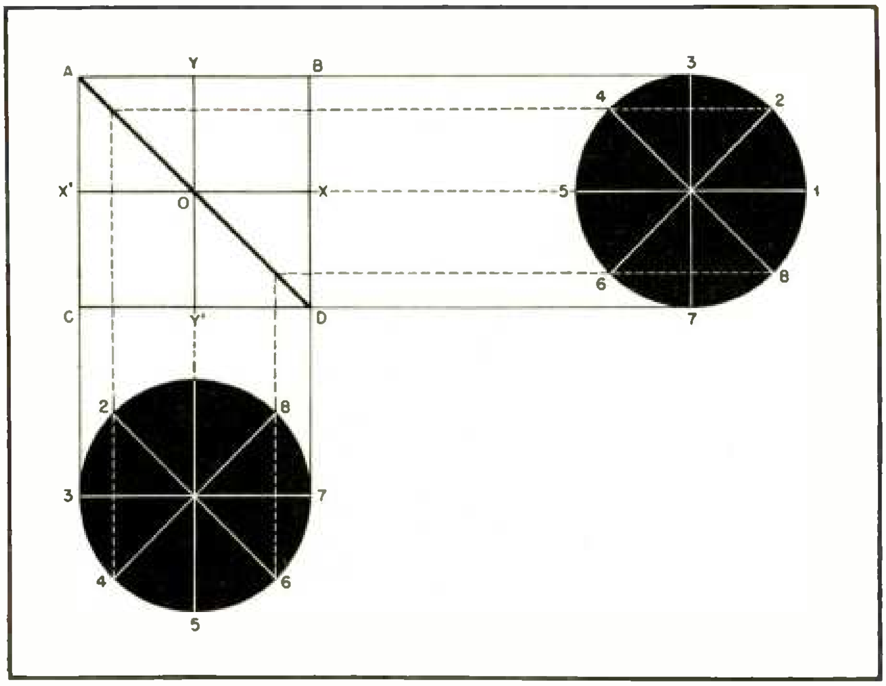


Fig. 2. Phase difference $= \pi$. Result: Line AOD.

α and β themselves but rather in the difference between them, the above equations are put into a more workable form, as follows:

$$x = a \sin(\omega t + \phi) \qquad (3)$$
$$y = b \sin \omega t \qquad (4)$$

Since waves (3) and (4) are the components in our rectangular composition, it may be recognized that eq. (3) and (4) considered together represent the parametric equations of a very general ellipse. This becomes clear when upon elimination of the parameter t from (3) and (4) we obtain the equivalent expression in rectangular coordinates.

$$b^2x^2 - 2abxy \cos\phi + a^2y^2 = a^2b^2 \sin^2\phi \qquad (5)$$

which is an ellipse provided a does not equal b and ϕ is not 0 or π. Eq. (5) is the locus of point K in *Fig. 1* for any arbitrary values of a, b and ϕ; it is also the fundamental equation of this paper.

We can now assume certain values for ϕ and obtain the equations of the resultant curves.

(a) for $\phi = 0$, eq. (5) reduces to

$$y = \frac{bx}{a} \qquad (6)$$

This is the equation of the straight line *BOC* in *Fig. 1*. It is easily seen that the slope of this line cannot be negative and that since it is proportional to b/a it is independent of the phase angle.

(b) for $\phi = \pi$, eq. (5) becomes

$$y = -\frac{bx}{a} \qquad (7)$$

This is the equation of the curve *AOD* of *Fig. 2*.

(c) for $\phi = \pi/2$ eq. (5) becomes

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1 \qquad (8)$$

which is the equation of an ellipse with a major semi-axis a, and a minor b—along with x and y axes respectively. For the special case where the two voltages are of the same amplitude, i.e. $a = b$, (8) reduces to

$$x^2 + y^2 = r^2 \qquad (9)$$
where $r^2 = a^2 = b^2$

This is the general equation of a circle (*Fig. 3*).

(d) for $\phi = \pi/4$ (5) becomes

$$b^2x^2 - \sqrt{2}\,abxy + a^2y^2 = \frac{a^2b^2}{2} \qquad (10)$$

which is the ellipse with oblique axes in *Fig. 4*.

Determination of Phase Angle

In solving for the phase angle ϕ the first tendency would be to solve eq. (5) as a quadratic in $\cos\phi$. The resulting expression, though accurate, is extremely inconvenient for practical calculations. Several better methods are suggested below.

(a) First method:

Transform eq. (5) into a new system of coordinates by means of the two rotational-transformation equations

$$x = x' \cos\left(\tan^{-1}\frac{b}{a}\right) - y' \sin\left(\tan^{-1}\frac{b}{a}\right) \qquad (11)$$

$$y = x' \sin\left(\tan^{-1}\frac{b}{a}\right) + y' \cos\left(\tan^{-1}\frac{b}{a}\right) \qquad (12)$$

Substituting (11) and (12) in (5), allowing $a = b$ and setting $y' = O$, we obtain

$$x_m^2 (1 - \cos\phi) = a^2 \sin^2\phi \qquad (13)$$

Solving this for ϕ we have

$$\phi = \cos^{-1}\left[(x_m/a)^2 - 1\right] \qquad (14)$$

where x_m equals one-half the major axis and a is the maximum value of x. The units in which x_m and a are measured are entirely arbitrary but both must be measured in the *same* units.

By an analogous procedure but setting $x' = O$ we obtain

$$\phi = \cos^{-1}\left[1 - (y_m/a)^2\right] \qquad (14a)$$

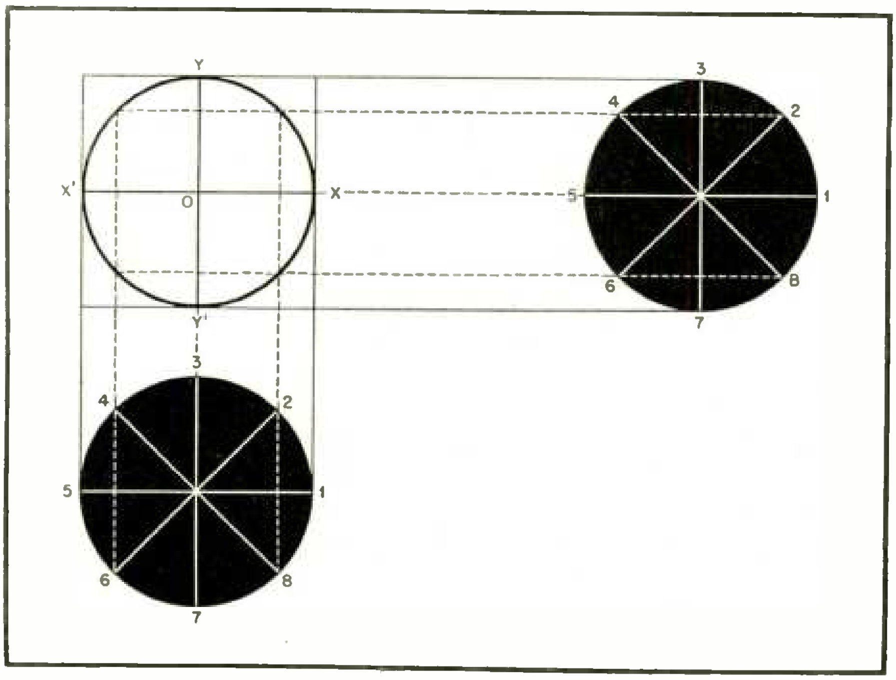


Fig. 3. Phase difference $= \pi/2$. Amplitudes equal. Result: Circle.

where y_m is one-half the minor axis of the inclined ellipse.

(b) Second method:

An even simpler expression for ϕ is obtained as follows. Solving eq. (5) for the x and y intercepts, we get respectively,

$$x_i = a \sin \phi \qquad (15)$$

$$y_i = b \sin \phi \qquad (16)$$

From these we have

$$\phi = \sin^{-1} \frac{x_1}{x_2} \qquad (17)$$

$$\phi = \sin^{-1} \frac{y_1}{y_2} \qquad (17a)$$

where x_1 and y_1 are the x and y intercepts, and x_2 and y_2 are the maximum values of x and y.

The reader will notice that equations (17) and (17a) are not limited by the condition $a = b$. Therefore the ratios $x_1/x_2 = y_1/y_2$ will yield the same answer for a given phase angle regardless of the choice of a and b.

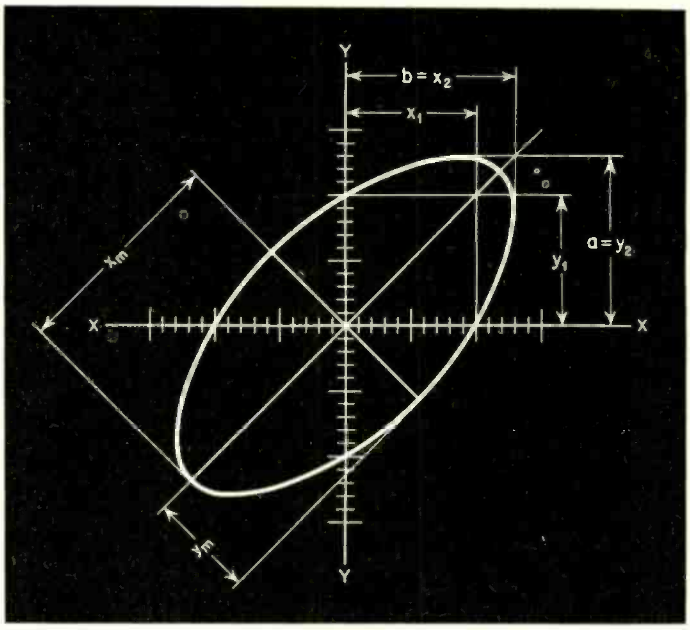


Fig. 5. Hypothetical ellipse used as an example in the calculation of phase angle.

Examples

In making these phase measurements a graduated screen will be found valuable; it simplifies the process and saves much time.

In obtaining the data required by the given equations, the error due to imperfect centering of the ellipse may be slightly reduced by taking twice the required length and dividing that by two. Thus, for example, in measuring x_m, we first measure the entire major axis — with a pair of dividers — and divide that by two, and so on. Since the circumference of the ellipse has thickness a uniform procedure should be decided upon for measuring either the inside or the outside contours. The latter usually give better results.

We will show now the calculation of phase angle in the hypothetical ellipse of *Fig. 5.* We have:

by (17) $\phi = \sin^{-1}\left(\frac{10}{13}\right) = 50.2$

by (17a) $\phi = \sin^{-1}\left(\frac{10}{13}\right) = 50.2$

by (14) $\phi = \cos^{-1}[(16.65/13)^2 - 1] = 50.1$

by (14a) $\phi = \cos^{-1}[1 - (7.8/13)^2] = 50.1$

It should be recalled again that if eq. (17) or (17a) is to be used the two amplitudes do not have to be equal. On the other hand they must be equal if eq. (14) or (14a) are used. For unequal amplitudes (14) and (14a) become:

$$\cos \phi = \frac{+x^2_m \pm \sqrt{(x^2_m - 2a^2)(x^2_m - 2b^2)}}{2ab} \qquad (14')$$

$$\cos \phi = \frac{-y^2_m \pm \sqrt{(y^2_m - 2a^2)(y^2_m - 2b^2)}}{2ab} \qquad (14a')$$

which are not as convenient to use.

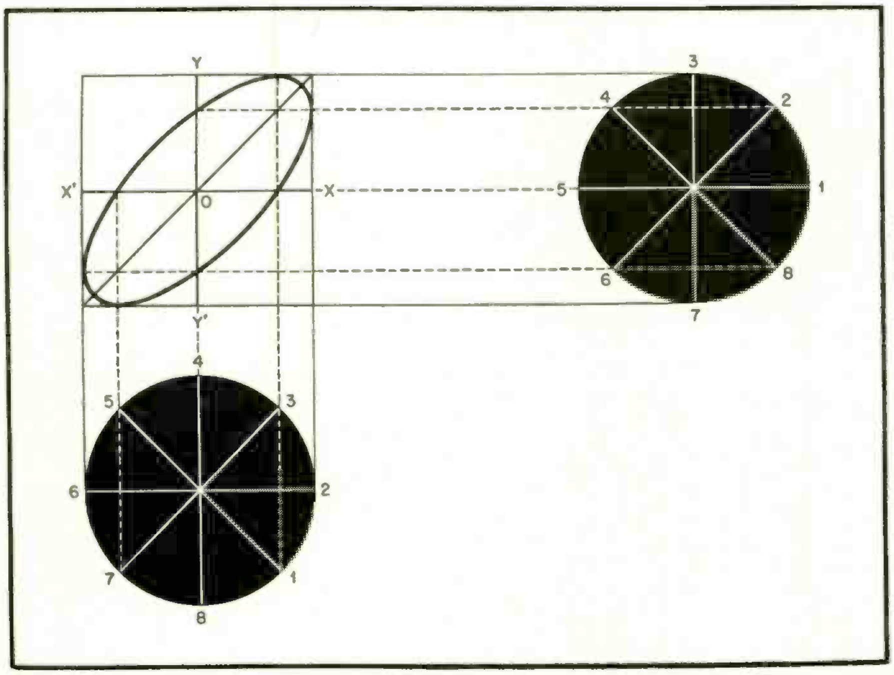


Fig. 4. Phase difference = $\pi/4$. Result: Ellipse.

WWV FREQUENCY STANDARDS

The National Bureau of Standards broadcasts standard frequencies and related services from its radio station WWV, at Beltsville, Md., near Washington, D. C. The service has been improved and extended, a new transmitting station has been built, 10-kilowatt radio transmitters installed, and additional frequencies and voice announcements added. The services include: (1) standard radio frequencies, (2) standard time intervals accurately synchronized with basic time signals, (3) standard audio frequencies, (4) standard musical pitch, 440 cycles per second, corresponding to A above middle C.

The standard frequency broadcast service makes widely available the national standard of frequency, which is of value in scientific and other measurements requiring an accurate frequency. Any desired frequency may be measured in terms of any one of the standard frequencies, either audio or radio. This may be done by the aid of harmonics and beats, with one or more auxiliary oscillators.

[*Continued on page 72*]

RADIO DESIGN WORKSHEET

No. 17—FILAMENT NOISE; CAPACITOR FORMULAE

FILAMENT NOISE OUTPUT

Problem: *Investigate the noise in the output circuit of a filament-type battery triode due to a.c. filament supply.*

Solution: The a.c. noise in the output of a filament-type triode is due to a number of causes. There are two causes, however, which are of paramount importance. These are:

1) The non-linear operational char-

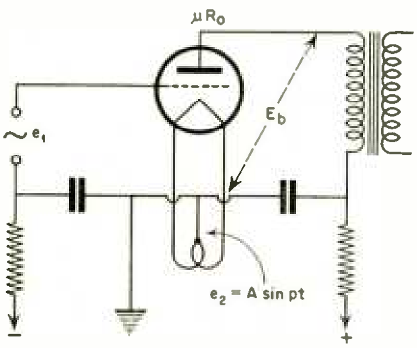


Fig. 1. Explanatory circuit of ac-operated filament-type battery triode

acteristic of the tube and its associated circuit.

2) The change of potential of grid and plate with respect to a given point on the filament with time.

Consider the circuit of *Fig. 1*, assuming the filament is homogeneous and that the active portion of the filament is symmetrical with respect to grid and plate. Let:

$e_1 = C \sin \omega t$ represent a signal voltage applied to the grid:

$E_1 = \frac{E_B}{\mu} + K$ represent the effective anode potential:

$e_2 = A \sin pt$ represent the filament supply voltage.

So that the solution will be more general, let the characteristic of the tube be:

$$i = B_1 e + B_2 e^2 + B_3 e^3 + \ldots B_N e^N$$

where e represents the total voltage applied to the grid circuit. Let the filament excited by c_2 be represented by *Fig. 2.* Then the voltage at distance X from the electrical center of the filament will be:

$$\frac{X}{L} A \sin pt$$

The differential space current for length dX of the filament will be:

$$di = K\left[E_1 + C \sin \omega t - \frac{X}{L} A \sin pt\right]^N dX$$

Whence:

$$i = K\,(E_1 + C \sin \omega t)^N \int_{-\frac{L}{2}}^{+\frac{L}{2}} \left(1 - \frac{XA \sin pt}{L\,(E_1 + c \sin \omega t)}\right)^N dX$$

Let $E_1 + C \sin \omega t = E$ to simplify the expression.

Then:

$$i = KE^N \int_{-\frac{L}{2}}^{+\frac{L}{2}} \left[1 - N\frac{X}{LE} \sin pt + \frac{N(N-1)}{2} \frac{A^2 X^2}{L^2 E^2} \sin^2 pt + \ldots\right] dX$$

Integrating we have:

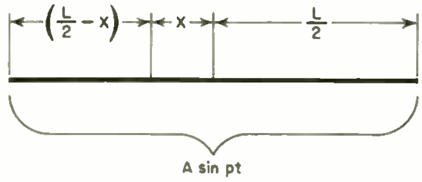


Fig. 2. Representative of filament excited by a.c.

$$i = KE^N \left[X - \frac{NA}{LE} \frac{X^2}{2} \sin pt + \frac{N(N-1)}{2} \frac{A^2 X^3}{3\,L^2 E^2} \sin^2 pt - \frac{N(N-1)(N-2)}{6} \frac{A^3 X^4}{4\,L^3 E^3} \sin^3 pt + \frac{N(N-1)(N-2)(N-3)}{24} \frac{A^4 X^5}{5\,L^4 E^4} \sin^4 pt + \ldots\right]_{-\frac{L}{2}}^{+\frac{L}{2}}$$

Let $KL = \alpha$ a tube constant.

Then:

$$i = \alpha\left[E^N + \frac{N(N-1)}{48} A^2 E^{(N-2)} + \frac{N(N-1)(N-2)(N-3)}{5120} A^4 E^{(N-4)} + \ldots\right]$$

N	DIRECT CURRENT	sin ωt	cos 2ωt	sin 3ωt	cos 2pt	sin (ω−2p) t or sin (ω+2p) t
1	αE_1	αC				
2	$\alpha\left[E_1^2 + \frac{A^2 + 12C^2}{24}\right]$	$2\alpha C E_1$	$\frac{-\alpha C^2}{2}$		$\frac{-\alpha A^2}{24}$	
3	$\alpha\left[E_1^3 + \frac{A^2 + 12C^2}{8} E_1\right]$	$\alpha\left[3CE_1^2 + C\frac{A^2 + 6C^2}{8}\right]$	$\frac{-3}{2}\alpha C^2 E_1$	$\frac{-\alpha C^3}{4}$	$-\alpha\frac{A^2 E_1}{8}$	$-\alpha\frac{A^2 C}{16}$

Table summing up the results of the noise in the output circuit of a filament-type battery triode due to a.c. filament supply.

$$+\alpha\left[\frac{N(N-1)}{48}A^2E^{(N-2)}+\frac{N(N-1)(N-2)(N-3)}{3840}A^4E^{(N-4)}+\ldots\right]\cos 2pt+\ldots$$

Replacing E with $(E_1 + C\sin\omega t)$ and neglecting small terms, we have:

$$i=\alpha\left[E^N+\frac{N(N-1)}{48}A^2E_1^{(N-2)}+\frac{N(N-1)(N-2)(N-3)}{5120}A^4E_1^{(N-4)}+\ldots\right]$$

$$+\alpha\left[NCE_1^{(N-1)}+\frac{N(N-1)(N-2)}{48}A^2CE_1^{(N-3)}+\ldots\right]\sin\omega t$$

$$+\alpha\left[\frac{N(N-1)}{2}C^2E_1^{(N-2)}+\frac{N(N-1)(N-2)(N-3)}{96}A^2C^2E_1^{(N-4)}+\ldots\right]\sin^2\omega t$$

$$-\alpha\left[\frac{N(N-1)}{48}A^2E_1^{(N-2)}+\frac{N(N-1)(N-2)(N-3)}{3840}A^4E_1^{(N-4)}+\ldots\right]\cos 2pt$$

$$-\alpha\left[\frac{N(N-1)(N-2)}{48}A^2CE_1^{(N-3)}+\frac{N(N-1)(N-2)(N-3)(N-4)}{3840}A^4CE_1^{(N-5)}+\ldots\right]\sin\omega t\cos 2pt+\ldots$$

Substituting for powers of sines and sine cosine products, we have:

$$i=\alpha\left[E_1^N+(A^2+12C^2)\frac{N(N-1)}{48}E_1^{(N-2)}+\ldots\right]$$

$$+\alpha\left[NCE_1^{(N-1)}+C(A^2+6C^2)\frac{N(N-1)(N-2)}{48}E^{(N-3)}+\ldots\right]\sin\omega t$$

$$-\alpha\left[\frac{N(N-1)}{4}C^2E_1^{(N-2)}+\frac{N(N-1)(N-2)(N-3)}{192}A^2C^2E_1^{(N-4)}+\ldots\right]\cos 2\omega t$$

$$-\alpha\left[\frac{N(N-1)}{48}A^2E_1^{(N-2)}+A^2\left(\frac{C^2}{192}+\frac{A^2}{3840}\right)N(N-1)(N-2)(N-3)E_1^{(N-4)}+\ldots\right]\cos 2pt$$

$$-\alpha\left[\frac{N(N-1)(N-2)}{96}A^2CE_1^{(N-3)}+\ldots\right]\sin(\omega t2p)t$$

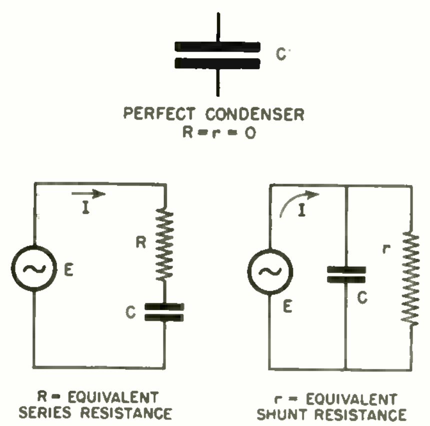
$$-\alpha\left[\frac{N(N-1)(N-2)}{96}A^2CE^{(N-3)}+\ldots\right]\sin(\omega-2p)t$$

plus a series of higher harmonics and modulation products. From which the accompanying table results.

It is evident that the alternating filament voltage adds no noise voltage to a circuit with a linear characteristic ($N = 1$) and that it adds a second harmonic of the filament supply if the circuit has a parabolic characteristic ($N = 2$). It is interesting that the coefficient of the second harmonic of the filament supply ($\cos 2pt$) is a function of the signal amplitude when the circuit characteristic is a cubic ($N = 3$). Moreover, with a third power characteristic, intermodulation between signal and power-supply voltage occurs.

CAPACITOR CONVERSION FORMULA

Problem: *Determine the relation between the equivalent series and equivalent shunt resistance of a low power factor capacitor; i. e., the formula required to convert from one to the other.*



A theoretically perfect condenser, and equivalent circuits representing series and shunt resistance.

Solution: Since the equivalent resistance represents resistance in series or shunt which will produce a power loss equal to the dielectric loss, we have:

The capacitative reactance of the condenser is:

$$X_c = 1/2\pi fC$$

$$I = E/X_c = 2\pi fCE$$

Power loss $= I^2R = 4\pi^2f^2C^2E^2R$ for equivalent series resistance

Power loss $= E^2/r$ for equivalent shunt resistance

Whence:

$$4\pi^2f^2C^2E^2R = E^2/r$$

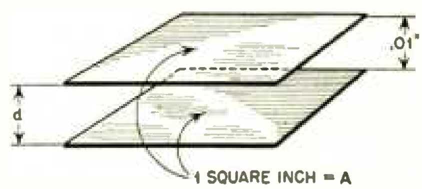
or:

$$R = 1/4\pi^2f^2C^2r$$

CAPACITANCE DETERMINATION

Problem: *Determine the capacitance of two flat metallic plates each one square inch in area and separated by a distance of 10 thousandths of an inch (10 mils) in air.*

Solution: Referring to the accompanying drawing, let K = specific inductive



Factors determining capacitance.

capacity of dielectric = dielectric constant; d the separation of the plates in centimeters; and A the area of the plates in square centimeters. Then:

$$\text{Capacitance} = C = \frac{KA}{4\pi d}\ \text{cm approximately.}$$

In this case $K = 1$ (for air), and $A = 6.54$ cm.

Whence:

$$C=\frac{1}{4\pi}\frac{A}{d}=\frac{.08\times6.54}{d}=\frac{.523}{d}$$

But $d = 10$ mils $= .01$ inch $= .01\times2.54$ cm $= .0254$ cm.

Then:

$$C=\frac{.523}{.0254}=20.9\ \text{cm}=\frac{20.9}{.9}=23.2\ \mu\mu f$$

since conversion from C.G.S. units (cm) to $\mu\mu f$ is equivalent to multiplying by $1/.9$.

This is the formula used in estimating capacities of variable air condensers.

WIDE-BAND AMPLIFIER DESIGN

E. M. NOLL

PART 2

★ The wide-band amplifier permits a linear amplification of frequencies extending from 5 cycles to 5 megacycles. It was shown in the previous article* that this may be accomplished by means of a resistance-coupled amplifier using a high gm tube with low input and output capacities, a low value of plate load resistor, and special high- and low-frequency compensating circuits.

Shunt Peaking

One of the most common forms of high-frequency compensation is the shunt peaking method, as shown in *Fig. 1-A*. The peaking inductance L is in series with the load resistor R_L. The output impedance is represented by the network shown in *Fig. 2-B*. The output impedance Z_0 will be:

$$Z_o = \frac{X_C \sqrt{R^2 + X_L^2}}{\sqrt{R^2 + (X_L - X_C)^2}} \quad (1)$$

In order to provide a linear response Z_0 must be constant over the frequency range to be amplified, or Z_0 must equal R_L over this frequency range. In the previous article it was shown that at the high frequency point where the gain was down 3 db the total shunt reactance was equal to the load resistance, or the load impedance Z_0 fell to 70.7% of its value at the middle frequency range. In order to restore Z_0 to its proper value an inductance is added in series with R_L. Using equation (1) the value of X_L required can be determined.

Assuming $Z_0 = R_L = X_{C_T} = 4000$ ohms. Then:

$$Z_o = \frac{X_{C_T} \sqrt{R_L^2 + (X_L)^2}}{\sqrt{R_L^2 + (X_L - X_C)^2}}$$

$$R_L = \frac{R_L \sqrt{R_L^2 + X_L^2}}{\sqrt{R_L^2 + (X_L - R_L)^2}} = 2X_L$$

and solving for the reactance of the series inductance it is found that $X_L = 2000$ ohms. The inductive reactance required to compensate the high-frequency end of the band is one-half the resistance of the load resistor or:

$$X_L = \frac{R_L}{2} = \frac{X_{C_T}}{2}$$

and:

$$L = \frac{R_L}{4\pi F_o}$$

and since

$$R_L = \frac{1}{2\pi F_o C_T}$$

where F_0 is the highest frequency point

$$L = \frac{R_L^2 C_T}{2}$$

To find the values of the components required to provide high-frequency compensation to 5 megacycles in the circuit of *Fig. 1*, and using the following values previously assigned:

$G_m = 1600$ micromhos
$C = 20\ \mu\mu f$
top frequency = 5 mc.

$$X_{C_T} \text{ at 5 mc.} = \frac{1}{2\pi F_o C_T} = 1600 \text{ ohms (approx.)}$$

$$R_L = \frac{1}{2\pi F_o C_T} = 1600 \text{ ohms}$$

$$L = \frac{(1600)^2 \times (20 \times 10^{-6})}{2} = 25.6\ \mu h$$

$$\text{Gain} = g_m R_L = 1600 \times 10^{-6} \times 1600 = 2.56$$

Without the peaking coil the response would be down 3 db at 5 mc; however, using the value of L as calculated, the gain remains the same at 5 mc.

In actual practice a tube would be chosen with a higher gm, thus permitting more gain. The 6SJ7 tube was chosen with the hope it would be more readily obtainable. Equipment for instruction purposes could be built using the values developed in this article.

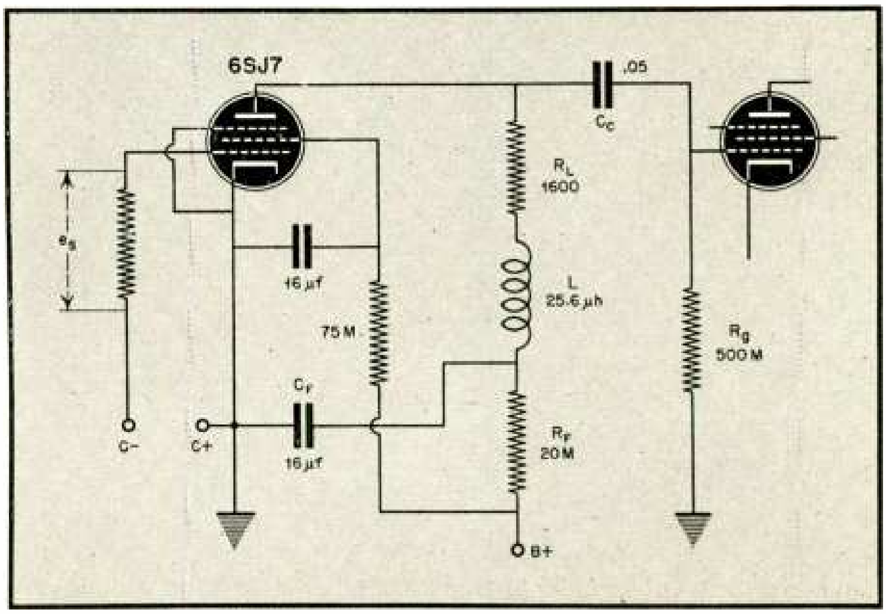


Fig. 1-A. Compensation by means of shunt peaking at the highs and compensation of interstage coupling at the lows.

* Wide-Band Amplifier Design, *Radio*, July, 1943, page 22.

Phase Shift

In the operation of the audio amplifier it is generally not necessary to consider phase shift, as the maintenance of a linear frequency response will insure a satisfactory phase shift. However it becomes important in wide-band operation. In television application it would mean the displacement of high-frequency components with respect to the middle range on the television screen, producing a blurred image.

The total distance around a circle is 2π radians where a radian is the same length as one radius set off on the circumference. In a similar manner the distance along a single sine wave can be represented by 2π radians and total distance set off each second is 2π radians times the frequency in c.p.s. or:

$$\omega = 2\pi F \text{ radians/second}$$

In any combination of inductance, capacitance, and resistance there is a certain interval between the time the signal is applied and the time when the signal reaches its proper amplitude across the network. This is generally represented in a vector such as *Fig. 3* where the voltage developed across the total impedance lags the applied voltage by the angle θ. The actual lag in radians can be found by solving the vector triangle or:

$$\tan \theta^\circ = \frac{X_O}{R_O}$$

$$\text{and radians} = \frac{\theta^\circ}{57.3}$$

where X_O represents the equivalent series reactance of the network and R_O the equivalent series resistance. In *Fig. 2-A* is represented the output network of the amplifier without the peaking coil; in *Fig. 2-B* it is represented with the peaking coil. In *Fig. 2-A* the impedance is:

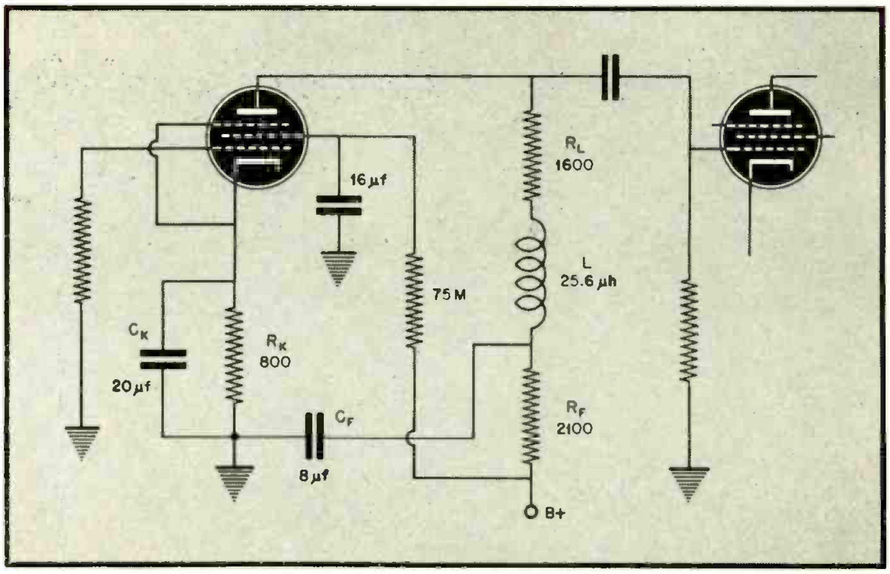


Fig. 1-B. Compensation by means of shunt peaking at the highs and compensation of the cathode bias circuit at the lows.

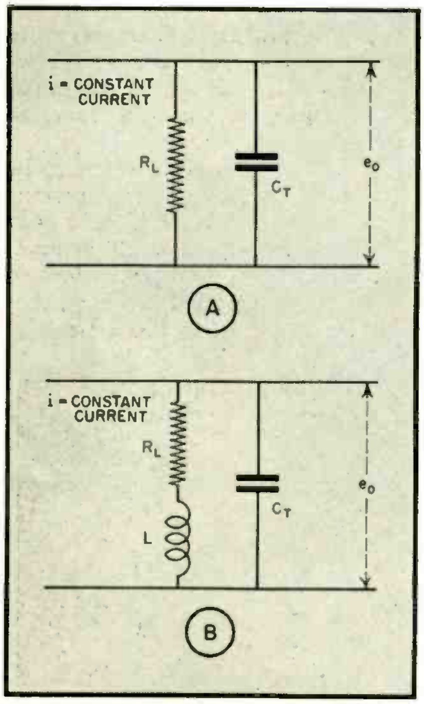


Fig 2. Equivalent circuits with and without shunt peaking coil.

$$Z_T = \frac{R\,(jX_C)}{R - jX_C}$$

$$Z_T = \frac{R\,(-jX_C)\,(R + jX_C)}{R^2 - X_C^2}$$

$$Z_T = \frac{X_C^2 R - j\,X_C R^2}{R^2 - X_C^2} = \frac{X_C^2 R}{R^2 - X_C^2} - j\,\frac{X_C R^2}{R^2 - X_C^2}$$

which is the impedance broken down into its equivalent series real and reactive components. From this the angle can be found:

$$\tan \theta = \frac{X_C R^2 / R^2 - X_C^2}{X_C^2 R / R^2 - X_C^2} = \frac{X_C R^2}{X_C^2 R} = \frac{R}{X_C} = 2\pi FCR$$

Using the component values chosen for the 6SJ7 amplifier for the uncompensated stage it is found that the angle in radians will be:

$$\tan \theta_1 = 6.28 \times 5 \times 10^6 \times 20 \times 10^{-12} \times 1600$$
$$\theta_1 = 45^\circ$$

$$\text{radians} = \frac{45^\circ}{57.3} = .785 \text{ radian at 5 mc.}$$

$$\tan \theta_2 = 6.28 \times 10^4 \times 20 \times 10^{-12} \times 1600$$
$$\theta_2 = 0^\circ 7'$$

radians = 7′/57.3 = .002 radian at 10,000 cycles

If the phase shift would increase linearly with frequency no harm would result as it would be similar to the 180° phase shift in a vacuum tube. However, due to the fact that it is not linear it will take the 5-mc component of the signal a longer time to reach its proper value than it will the low-frequency component.

Time Delay

In order to find the time delay in seconds it is necessary to divide the resultant phase shifts by the angular rate $\omega = 2\pi F$. At 5 mc:

$$t_1 = \frac{.785}{6.28 \times 5 \times 10^6} = .025 \text{ microsecond}$$

At 10,000 cycles:

$$t_2 = \frac{.002}{6.28 \times 10^4} = .0318 \text{ microsecond}$$

$$\Delta t = t_2 - t_1 = .0068 \text{ microsecond}$$

or the difference in time delay between the high and low frequency components will be .0068 microsecond. In television application the beam may cover 10 inches in 6 microseconds. This would mean a displacement of about .004 inch between high- and low-frequency components.

Now taking the compensated case of *Fig. 2-B*, it is found the impedance will be:

$$Z = \frac{(R + jX_L)\,(-jX_C)}{R + j\,(X_L - X_C)}$$

$$Z = \frac{(-j\,RX_C + X_L X_C)\,(R - j(X_L - X_C))}{R^2 + (X_L - X_C)^2}$$

From which the series equivalent would be:

$$Z = \frac{RX_C^2}{R^2 + (X_L - X_C)^2} + j\,\frac{X_L X_C^2 - X_C X_L^2 - R^2}{R^2 + (X_L - X_C)^2}$$

and the phase angle:

$$\tan\theta = \frac{X_L X_c - X_L^2 - R^2}{R X_c}$$

and by substitution:

θ_1 in radians at 5 mc.	= .6434
θ_2 in radians at 10,000 c.p.s.	= .001
time delay at 5 mc.	= .0204 µsec.
time delay at 10,000 c.p.s.	= .016 µsec.
difference in time delay	= .0044 µsec.

By comparison of the time delays for the compensated and uncompensated stages it is found that the shunt peak-

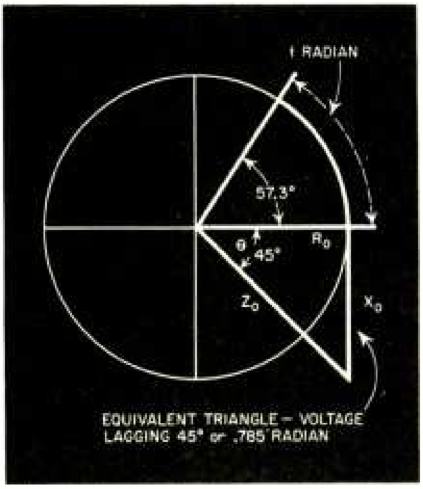


Fig 3. Sketch illustrating phase shift.

ing coil not only provides a linear frequency response but also aids in correcting the linearity of the phase delay.

Low-Frequency Response

In the case of the low-frequency response the gain is limited by the series coupling condenser C_c, its reactance being high at low frequencies. If it were possible to make C_c sufficiently large in capacity and R_g large in resistance the linear response could be extended to a very low value of frequency; however, circuit components prevent this alternative, due to the physical size of C_c and in case of R_g instability of the second pentode grid circuit. In order to provide constant phase shift and linear response with reasonable values of R_g and C_c, it is necessary to employ a decoupling circuit at the lower end of R_L equal to the time constant of R_g-C_c or:

$$R_L C_F = R_g C_c$$

In *Fig. 4* is shown the equivalent circuit of the low-frequency circuit.

As previously calculated the gain is 2.56, and if a one-volt signal were applied to the grid of the amplifier 2.56 volts is required on the grid of the next tube regardless of frequency. At the low frequencies the response is limited by C_c and if 2.56 volts is to be developed on the second grid, more voltage must be developed across the amplifier plate load at these frequencies. This is accomplished by means of the compensating circuit $R_F C_F$ on the low end of R_L. C_F also functions as a by-pass capacitor and has a reactance of 1/10 the resistance of R_L at 60 cycles, and C_F is equal to 16μ_f with the value of R_L = 1600 ohms and R_g = 500,000 ohms. Since:

$$C_c = \frac{R_L C_F}{R_g}$$

we find C_c in this case will be equal to .05µf.

Now using the method utilized in the previous article to calculate the gain of the amplifier at low frequencies we can find a value of applied voltage that will provide an output of 2.56 volts from grid to ground at 60 cycles, or, first using the value of R_g to find the current necessary to develop 2.56 volts across it. This value is 5.1 microamperes. Now taking the series C_c and R_g circuit, a certain number of volts must be applied across it in order to cause this current to flow, so that:

$$E_{app.} = 5.12 \times 10^{-6} \times \sqrt{R_g^2 + X_c^2}$$
at 30 cycles

$$E_1 = 2.61 \text{ volts}$$

Therefore the gain that must be developed across the load at 30 cycles is 2.61.

The circuit is shown in *Fig. 4*. The actual signal is developed across the series combination of R_L and C_F between plate and ground. R_F must present a resistance at least ten times the reactance of C_F at the lowest frequency to be passed to prevent the signal from being applied across the power-supply impedance.

The gain developed across the series combination of R_L and C_F at 30 cycles is:

$$\text{Gain} = 1600 \times 10^{-6} \sqrt{R_L^2 + X_c^2}$$

$$\text{Gain} = 1600 \times 10^{-6} \sqrt{(1600)^2 + (331)^2}$$

$$\text{Gain} = 2.614$$

This gain is also the amount required to develop 2.56 volts across R_g. By making the same calculations at 5 cycles it will be found that 4.34 volts output will be required to develop 2.56 volts across R_g. Now, if gm Z_L is calculated again for this frequency, the gain is again 4.34. Thus by maintaining the products $R_L C_F = R_g C_c$ the low-frequency range can be extended down to the point where R_F becomes too high for practical use. For a linear response down to 30 cycles R_F would be 10 × 331, or 3310 ohms; at 5 cycles it would be nearer 20,000 ohms. If the tube used draws any appreciable amount of current this would be an impractical size as it would drop the plate voltage to too low a value or require a power supply developing considerable voltage output.

Cathode Bias

We can also compensate for the low-frequency response of a stage using cathode bias by having the time constant $R_K C_K$ equal to $R_F C_F$. Thus the degeneration caused by the higher reactance of C_K at the low frequencies can be restored by means of the low-frequency compensating circuit $R_F C_F$, as shown in *Fig. 1-B*.

Any degenerative effects due to the signal variations across R_K can be restored by means of the corresponding increase in plate load impedance accomplished by R_F and C_F; however, the compensation which must be accomplished by R_F and C_F must be greater than the degeneration caused by C_K and R_K by the amount of the gain of the stage, so that:

$$R_F = R_K \text{ Gain} = R_K \, g_m \, R_L$$
$$C_F = C_K/\text{Gain} = C_K/g_m \, R_L$$

In the case of the 6SJ7, in order to secure the proper tube bias a resistor is required in the cathode circuit equal to:

$$R_K = \frac{-3}{.00375} = 800 \text{ ohms}$$

C_K should have a reactance 1/10 the resistance of R_K at 1000 cycles so that:

$$C_K = \frac{10^6}{6.28 \times 1{,}000 \times 80} = 20 \ \mu f$$

From this:

$$R_F = 800 \times 1600 \times 10^{-6} \times 1600 = 2100 \text{ ohms}$$

$$C_F = \frac{20}{1600 \times 10^{-6} \times 1600} = 8 \ \mu f$$

L-F Phase Shift

The phase shift at low frequencies compares with the phase shift at high frequencies insofar as number of de-

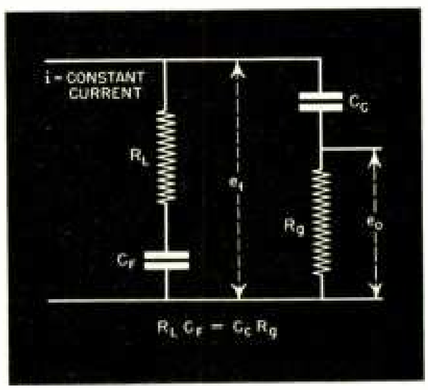


Fig. 4. Equivalent of low-frequency circuit.

grees is concerned, but it represents a much greater time delay in seconds. In television application it would produce a vertical gradation in light intensity on the picture screen background.

In the case of phase delay without low-frequency compensation the phase

[*Continued on page 67*]

Q. & A. STUDY GUIDE

C. RADIUS

STUDIO EQUIPMENT—I

Carbon Microphone

1. Describe the construction and characteristics of a "carbon button" type microphone. (III-50)

2. Draw a diagram of a single-button microphone circuit, including the microphone transformer and source of power. (II-120)

3. What are the advantages of the single-button microphone? (VI-40)

4. What is the most serious disadvantage of using carbon microphones with high-fidelity amplifiers? (IV-51)

5. What precaution should be observed in the use of a double-button carbon microphone? (II-313)

6. What may cause packing of the carbon granules in a carbon-button microphone? (II-311)

7. Why are the diaphragms of certain types of microphones stretched? (IV-52)

Condenser Microphone

8. Describe the construction and characteristics of a "condenser" type microphone. (III-46)

Crystal Microphone

9. Describe the construction and characteristics of a "crystal" type microphone. (III-49)

Velocity Microphone

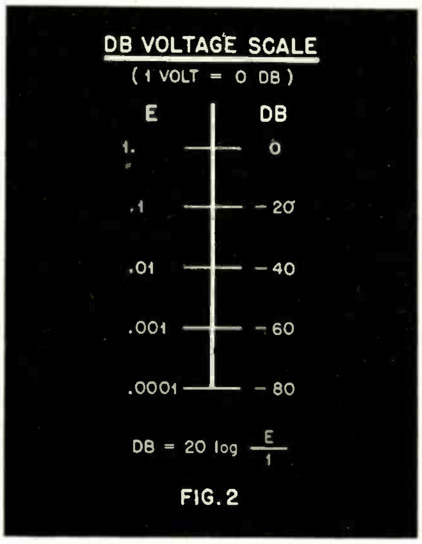
10. What is a "velocity" type microphone? (III-51)

11. Describe the construction and characteristics of a "ribbon" type microphone. (III-45)

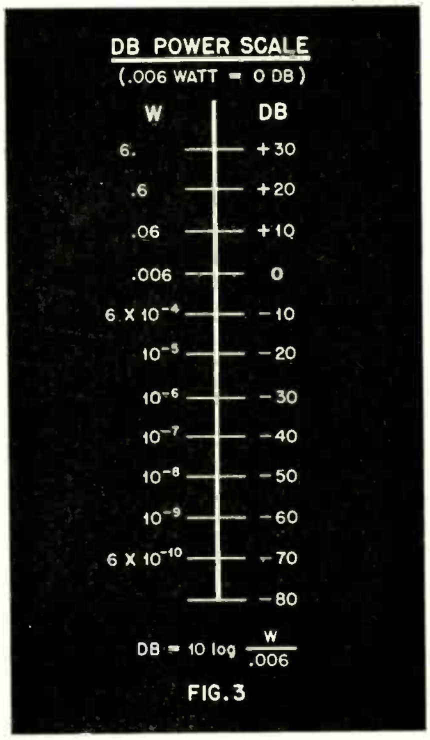
Dynamic Microphone

12. Describe the construction and characteristics of a "dynamic" type microphone. (III-44)

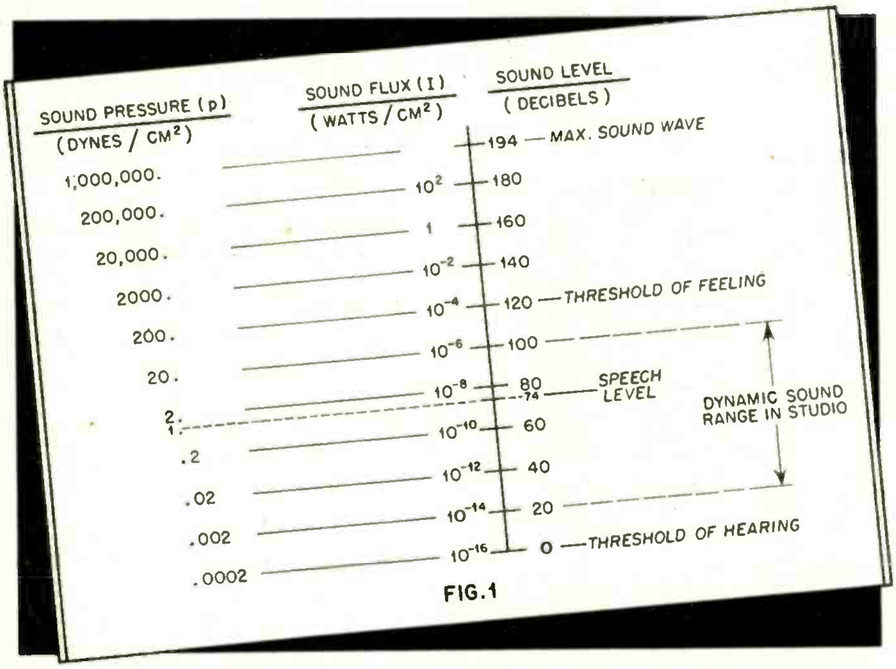
13. What type of microphone employs a coil of wire, attached to a diaphragm which moves in a magnetic field as the result of the impinging of sound waves? (IV-50)



DB Voltage Scale.



DB Power Scale.



Inter-related sound-pressure, sound-flux and sound-level scale.

Microphones may be classified on the basis of (1) requiring a current or polarizing voltage, in which case the microphone acts as a valve or relay; (2) operating as a pressure-actuated device requiring a diaphragm, or pressure difference actuated device using a ribbon; (3) having a low or high impedance output. It is possible, of course, to modify the output impedance of any microphone. However, some microphones are inherently high-impedance generators as in the case of the crystal and condenser microphones, and others are low-impedance generators as in the case of the dynamic and ribbon microphones.

The "Study Guide" questions on microphones are very general and elementary. Most readers are acquainted with the general operating principles. For a general discussion and descrip-

[*Continued on page 44*]

Echophone Model EC-1

(Illustrated) a compact communications receiver with every necessary feature for good reception. Covers from 550 kc. to 30 mc. on three bands. Electrical bandspread on all bands. Six tubes. Self-contained speaker. Operates on 115-125 volts AC or DC

ECHOPHONE RADIO CO., 201 EAST 26th ST., CHICAGO, ILLINOIS tion of the types of microphones the reader is referred to such books as "Practical Radio Communication" by Nilson and Hornung, and "The Radio Manual" by Sterling.

The remainder of this article will be devoted to a discussion of the various methods used in rating the output levels of microphones. This is a subject with which all operators should be familiar.

Microphone Output Levels

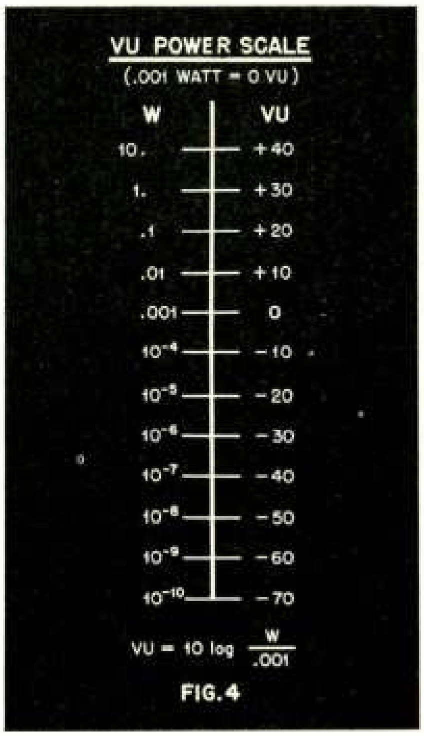
Since the output of a microphone is a function of its acoustic input, it is necessary to establish a scale upon which various input levels can be placed. *Fig. 1* indicates such a scale. Sound pressure measured in dynes/cm.^{2} or bars, and sound energy flux measured in watts/cm.^{2} are plotted logarithmically. The right-hand side of the scale is marked off linearly in decibels (db). This arrangement is based upon the fact that a somewhat linear variation in the subjective phenomenon of hearing as related to loudness results from a logarithmic variation in the objective phenomenon of pressure variation or changes in the sound energy flux. If we further assume that this scale represents conditions in the vicinity of 1000 cycles, then the sound level in db is numerically equal to the loudness level expressed in db. Average conversation at a distance of about one foot from the microphone produces a sound pressure variation average of one bar. For this reason a one-bar sound signal is both a practical and convenient signal to use in the calibration of microphones. One bar corresponds to 74 db. This relationship is given by the equation 74 db = 20 log (1/.0002).

The sound levels above 120 db have no particular significance in commercial broadcasting. Theoretically, however, the pressure scale can be continued up to atmospheric pressure which is about one million dynes/cm^2.

Two methods of measurement are used in rating the output level of a microphone; (1) an open-circuit voltage measurement (2) a closed-circuit power measurement.

The first method is used for high-impedance voltage generators such as the crystal microphone. The output is expressed as *N* db below one volt per bar on an open circuit. This measurement is made with a vacuum-tube voltmeter placed across a 5-megohm load on the microphone. *Fig. 2* indicates the db voltage scale upon which the output can be located. Various crystal microphones have outputs which range from —40 db to —60 db.

Assume that a certain crystal microphone has an output of 1.5 millivolts. This can be expressed in db by the equation db level = 20 log (.0015/1),



VU Power Scale.

whence, db level = 20 (3.175) = —56.5.

The second method gives the output of the microphone in terms of the power dissipated in a resistive load equal to the rated output impedance. The output is expressed as *N* db below 6 milliwatts. *Fig. 3* indicates the db scale upon which the output can be located. Dynamic and velocity or ribbon microphones have output levels around —70 db.

Assume that a certain velocity microphone has an output level of —78 db and an output impedance of 250 ohms. The output can be expressed in watts (w) by the equation —78 db = 10 log (w/.006) or +78 db = 10 log (.006/w), whence, $w = 0.95 \times 10^{-10}$ watts. This power, dissipated in a 250-ohm resistor, produces an output voltage of $E = \sqrt{(0.95 \times 10^{-10} \times 250)}$; whence, E = 0.157 millivolts. If this microphone is to operate an amplifier whose output is 6 watts, the power level must be raised from —78 db to +30 db. This requires an amplifier with a power gain of 108 db.

It is becoming more common to rate the output levels of microphones used in commercial broadcast in terms of vu below 1 milliwatt. The abbreviation vu stands for "volume unit" and represents the units on the calibrated scale of a standard volume-level indicator. The new zero level of 1 milliwatt has been adopted primarily for convenience. The difference between the two scales shown in *Figs. 3* and *4* can be expressed in terms of the difference in their zero levels as 10 log (.006/.001) = 7.78. Thus —78 db is equivalent to —70.22 vu.

Program

1943 ROCHESTER FALL MEETING
RMA-IRE Radio Conference

Sagamore Hotel, Rochester, New York
November 8 and 9, 1943

Monday, November 8

8:30 A.M. Registration
9:30 A.M. Technical Session
Review of the problem:
Demountable Versus Sealed-off Tubes
I. E. Mouromtseff
Westinghouse Electric & Manufacturing Company
Recent Advances In Klystrom Theory
W. W. Hansen
Sperry Gyroscope Company
12:30 P.M. Luncheon
2:00 P.M. Technical Session
The Design of I.F. Transformers for Frequency Modulation Receivers.
William H. Parker, Jr.
Stromberg-Carlson Company
Vacuum Capacitors
George H. Floyd
General Electric Company
4:00 P.M. Committee Meetings
6:30 P.M. Dinner
8:15 P.M. Technical Session
The Signal Corps Looks to the Engineer
Lt. Col. Kenneth D. Johnson
U. S. Army Signal Corps

Tuesday, November 9

8:30 A.M. Registration
9:30 A.M. Technical Session
Message of RMA Director of Engineering
Dr. W. R. G. Baker
A Chamber of Commerce War Research Committee
K. C. D. Hickman
Distillation Products, Inc.
12:30 P.M. Luncheon
2:00 P.M. Technical Session
Report of RMA Data Bureau
L. C. F. Horle
New Low Loss Ceramic Insulation
Ralston Russell, Jr. and L. J. Berberich
Westinghouse Electric & Manufacturing Company
Design of I.F. Systems
J. E. Maynard
General Electric Company
4:00 P.M. Committee Meetings
6:30 P.M. Stag Banquet
Toastmaster—R. M. Wise
(Subject and Speaker to be announced later)

An exhibit of the U. S. Army Signal Corps equipment will be a feature of both days.

MODERN THEORY OF ELECTRONS

[*Continued from page 26*]

present. Repeated failure to solve these puzzles has led to another line of attack; to reduce these two unknown quantities to one. From a philosophical point of view there is economy of thought to be gained by this process. Such a reduction, presumably, would not make the remaining puzzle more difficult of solution; and when it is finally solved we shall have killed two birds with one stone.

Strangely enough, the most successful of these attempts at reduction have not followed what would seem to be the natural path of regarding matter as the fundamental entity and giving a material explanation of electricity. That line of thought was orthodox in the eighteenth century, and some of us still speak of "the electric fluid," or, more colloquially, "the juice." Modern scientific thought has taken the opposite direction, and, strange to say, there seems to be some experimental justification for this revolutionary procedure.

In 1893 it occurred to J. J. Thomson(1) that electricity might be the fundamental entity, and that matter might be only an aspect of electricity, which it displays to a greater or less extent according to circumstances. Thomson's original paper contains several references to a hydrodynamical analogy which probably suggested the idea to his mind.

A body moving through a liquid exhibits an increase in its inertia, as though it had soaked up some of the liquid into its pores. This is not due to friction, and would be observable even in a perfectly frictionless liquid. It arises from the fact that the moving body continually sets some of the liquid ahead of it in motion. This portion of the liquid is pushed aside, but another portion takes its place. To start a submerged body in motion requires therefore more force than would be necessary were the body outside of the liquid.

This increase in inertia varies with the shape of the moving body. A long, thin cylindrical rod moving end-on sets but little liquid in motion, and exhibits but a slight increase in inertia; but the same rod moving broadside-on would set much more liquid in motion, and its increase in inertia would be much greater. The simplest case, from a mathematical point of view, is that of a sphere. Here the increase in inertia is the same for all directions of motion, and is equal to that which would result had the sphere absorbed an added load equal to one half the mass of the liquid which it displaces(2).

J. J. Thomson showed, on theoretical grounds, that there was reason to expect that a charged sphere in motion through the ether would exhibit a similar increase in inertia (or mass), due to what he called the "bound ether," carried along by the Faraday tubes of force connected with the moving charge. There is, however, one important difference in the two cases. The apparent increase in mass of a sphere moving in a liquid is independent of the speed of the sphere, but for a charged body moving through the ether Thomson's calculations indicated that the increase in mass would be very small at ordinary speeds, and would become appreciable only if the speed of the body were comparable with that of light.

In 1893 this suggestion was of academic interest only, no bodies moving with sufficient speed being then available for experiment. A few years later conditions had changed. The discovery of electrons had placed at our disposal charged particles moving with unprecedented speeds, which in some cases were comparable with the speed of light. Here, it would seem, was an opportunity to test Thomson's theory.

Mass, Charge and Speed

It was not at first possible to obtain a measure of the mass of such a particle, but only a value for the ratio of the electric charge to the mass which carried it (e/m). But in 1901 Kaufmann(3) found that for swifter particles this ratio was less than for slower ones. There were only two ways of explaining this fact, both equally radical: either the mass increased or the charge decreased with an increase in the speed of the particle.

In this dilemma opinion inclined generally to the first alternative, largely because there was in existence a theoretical reason to expect it, while no one as yet had been ingenious enough to suggest any reason why a moving charge should alter.

Kaufmann calculated that such particles as he worked with might have, when moving slowly, an "electrical mass" equal to about one fourth of their total mass. In making this calculation he assumed that the particle behaved like a little metallic conductor, but he was careful to point out that a different assumption might lead to another result.

And so it happened. J. J. Thomson(4), on the assumption that a particle had no metallic conductivity, but acted like a point charge, found that Kaufmann's results indicated that the whole of the mass might be accounted for electrically. According to this, an electron would be a sort of a disembodied ghost—an electric charge without any matter to carry it.

This was the origin of the electrical theory of matter, which in the first few years of the present century rapidly acquired an outstanding position in physical theory; but forty years is a long life for any theory in these days, and this doctrine, like all other scientific theories, has not proved to be free from theoretical difficulties.

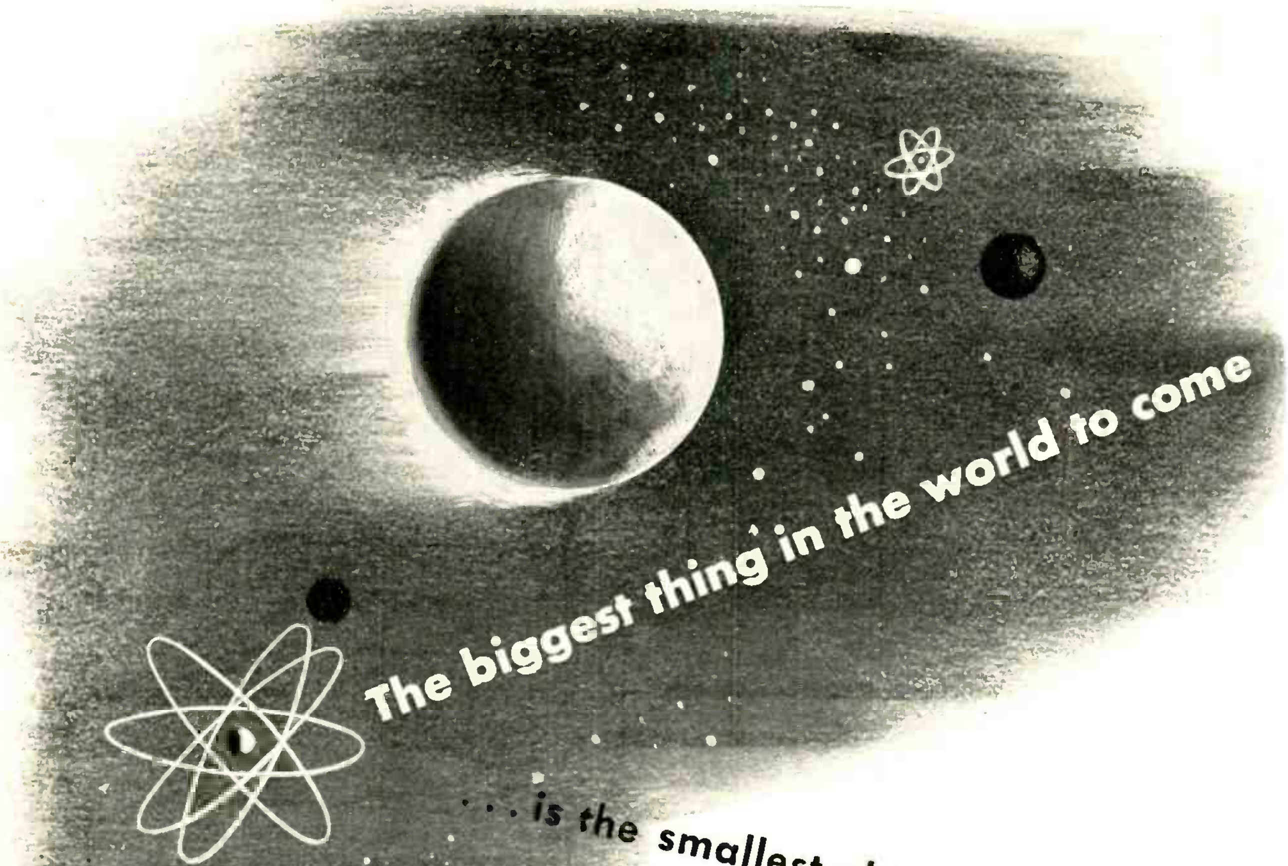
One of the difficulties arose with the discovery of the neutron in 1932. The nature of the neutron is still uncertain. There are but two possibilities: either it is or it is not made up of electrically charged components.

We shall consider the last alternative first. If the neutron is non-electrical in structure, it is then to be regarded as a piece of ordinary, old-fashioned matter, in the sense in which that word was used before Thomson suggested the idea of electrical mass. We would then have two kinds of mass—ordinary and electrical, and Thomson's attempt to reduce two unknowns to one would be a failure; the number of puzzles would remain the same, and in addition we would have loaded ourselves with an additional complication in theory. Here we are reminded of what Newton says in his Principia(5): "We are to admit no more causes of natural things, than such as are both true and sufficient to explain their appearances. To this purpose the philosophers say, that Nature does nothing in vain, and more is in vain, when less will serve; for Nature is pleas'd with simplicity, and affects not the pomp of superfluous causes."

On the other alternative, the neutron would be a combination of two oppositely charged components, such as a proton and a negative electron. The electric field between these closely spaced components would be very intense, and may be visualized as a closely packed and almost parallel bundle of lines of force stretching from one component to the other. This bundle of lines would, however, be extremely short, as the neutron is very small, about one hundred thousandth of the size of a hydrogen atom.

Now a hydrogen atom, when ionized, splits up into a negative electron and a proton. Its structure, then, qualita-

[*Continued on page 48*]



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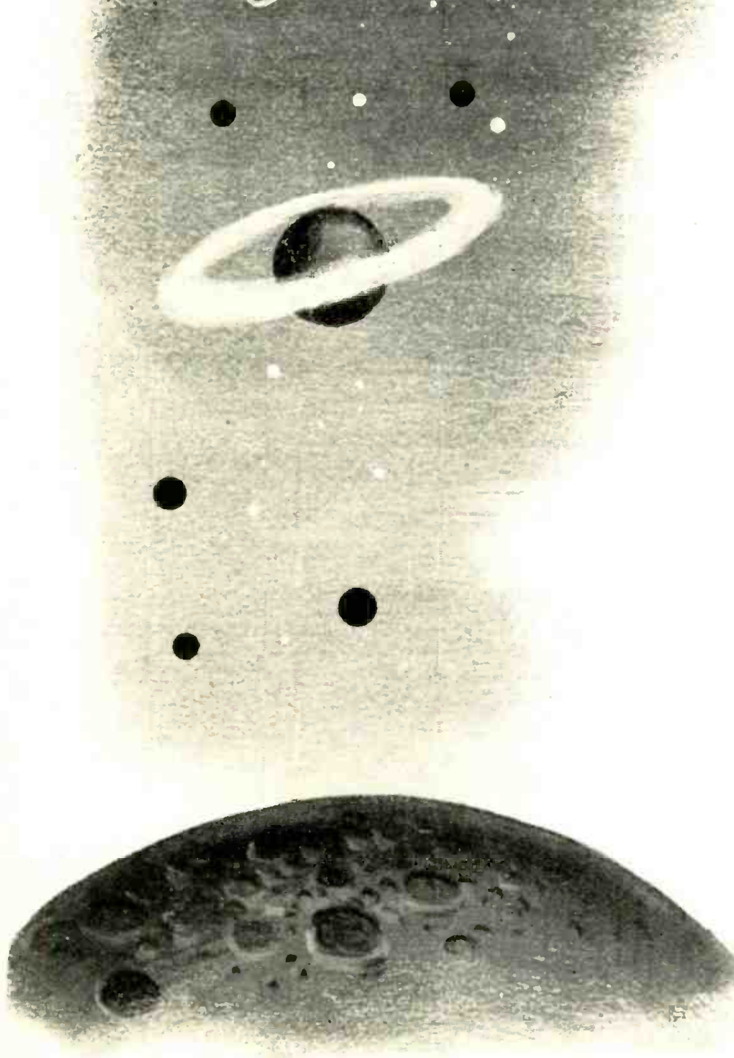

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ELECTRONS

[*Continued from page 46*]

tively speaking, must be similar to that of the neutron; but quantitatively speaking, it is much larger, and the bundle of lines of force joining its positive and negative components must be a hundred thousand times longer than that in the neutron. Now the mass of a hydrogen atom and that of a neutron are practically the same, and the question arises: "Why does not the hydrogen atom drag along much more bound ether than the neutron, and have a proportionately greater mass?"

But we cannot escape the experimental fact discovered by Kaufmann—that the ratio e/m becomes less as the speed of the charged particle increases; if this change is not due to an increase in mass, may it not be due to a decrease in the charge?

At first sight, this seems a more revolutionary idea than the other. It is admitted that the idea of a change in electrical charge is wholly unsupported by laboratory evidence at present; but so was the idea of increasing mass in 1893. Only when particles moving with speeds comparable with that of light became available for experiment did we realize what might happen under such circumstances.

But has there not been later evidence showing that the electronic charge is one of the fundamental constants of nature?

It has sometimes been said that Millikan's oil-drop experiments, by which he measured the charge on a single electron, prove the constancy of this charge, and hence the variability of the mass alone in Kaufmann's experiments. It is true that Millikan found that the charge on an ion after it had been transferred to the oil-drop was the same whatever the source of the original charge. Ions of different gases, unquestionably of different speeds, gave the same charge to the drop. But it is to be remembered that the measurement of this charge was made, not at the speed of the ion, but at that of the slowly falling oil-drop, which was of the order of a few hundredths of a centimeter per second.

Theory of Relativity

The special theory of relativity is sometimes quoted in support of the constant charge and variable mass. It is true that Einstein(6) in his original paper of 1905 gives a formula for the change of mass with speed which, like J. J. Thomson's formula, becomes infinite at the speed of light, and it is also true that he gives no similar formula for a change in the charge. It will be interesting for us to see how he obtained this result.

In section 10 of his paper Einstein gives the following formula for the x-component acceleration of a moving charged particle:

$$\frac{d^2 x}{d t^2} = \frac{e}{m} \frac{1}{\beta^3} X$$

in which e is the charge on the particle, m is the mass of the particle at rest, X the component of the electric vector and β the familiar relativistic expression

$$1/\sqrt{1 - v^2/c^2}$$

It is evident that the quantity e/m is altered by the factor $1/\beta^3$, but whether the charge or the mass or both are changed is not obvious. Einstein, without comment, assumes e to remain constant and m to bear the full effect of the modifying factor, and on this basis derives his formula for the change of mass.

This assumption, of course, was orthodox in 1905, but it is of interest to note that as a matter of logic the electrical theory of matter can claim no supporting evidence from the special theory of relativity.

On the basis of this result of Einstein's, Sommerfeld(7) introduced a modification into Bohr's theory of the atom. In Bohr's theory the hydrogen atom was regarded as consisting of a negative electron revolving in a Keplerian ellipse around a positively charged nucleus, the attraction between the two charges being balanced by the centrifugal force of the revolving electron. Sommerfeld (page 43 in his paper) makes the orthodox assumption that the electrical charges remain constant, but that the mass of the revolving electron varies with its speed in the orbit according to the formula given by Einstein. In consequence, the mass of the electron is greatest at perihelion and least at aphelion, and its centrifugal force will have a similar fluctuation. Because of this the orbit becomes an ellipse with a moving perihelion, like that of the planet Mercury. The effect of this is to split up the spectral lines, producing what Sommerfeld called the relativistic fine structure.

This predicted effect has actually been found in the spectra of hydrogen and helium, the number of the component lines and their relative separation being in accordance with Sommerfeld's theory.

As to the value of this result as a confirmation of the electrical theory of matter, it is to be observed that Sommerfeld would have obtained exactly the same modification of the Keplerian ellipse if he had assumed the charge to decrease and the mass to remain constant, thereby disturbing the balance by reducing the centripetal attraction instead of increasing the centrifugal force.

To sum up, the logic of the whole situation is that the electrical theory of matter can claim no independent support from either Millikan, Einstein or Sommerfeld. It rests for the present on J. J. Thomson's theory, and this theory tacitly assumes that the charge is unaltered by the motion. It is remarkable that every one we have mentioned, from J. J. Thomson onward, when confronted with the necessity of making a choice, prefers to keep the charge constant and let the mass take the consequences, and this without comment or apology.

Positive-Negative Dependence

Of course there must be a reason for this; and although it is explicitly stated by no writer that I have seen, the reason is doubtless to be found in what has come to be regarded as an axiom in electricity—the conservation of electrical charge, with its corollary, the exact equivalence of positive and negative electricity. This law states that no one has ever produced the slightest trace of a positive charge without the simultaneous production of an equal and opposite negative charge somewhere, usually in the immediate neighborhood.

It may be admitted that the facts are as stated; but attention must be called to the additional fact that in none of the experiments upon which this law is based did the electric charge have a velocity at all comparable with the speed of light.

There is also another basic objection to be raised to the experiments upon which this law is founded. We may, for instance, operate within a large conducting cube, such as was built by Faraday at the Royal Institution; perform within it all the usual electrical experiments, excite a glass tube by rubbing it with fur, draw sparks from an electrical machine, and yet a sensitive gold leaf electroscope connected to the cube will remain undisturbed. It seems impossible to create or destroy an electric charge without a compensating creation or destruction of an equivalent charge of opposite sign.

It is well to remember that all such experiments have started with neutral bodies. The glass tube and the fur were at first neutral, but exhibited equal and opposite charges after being rubbed together; the electrical machine was at first neutral, but on being operated its two sides became equally and oppositely charged.

[*Continued on page 67*]

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[*Continued on page 52*]

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Even the Big Inch Needs IRC RESISTORS

Vital arteries of supply in this mechanized war are America's pipelines. To maintain capacity flow, sludge and gummy deposits must be cleaned out at intervals. For this purpose a screw-type scraper propelled by the oil pressure is employed. When occasionally the scraper becomes stuck and plugs the line, the point of stoppage must be located to release the flowing oil.

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[To be continued]

the amateur is still in radio

He's not at his haywire rig in the attic...he's holding down key engineering spots in the laboratories, the factories, the army, navy and marine corps. Today the radio amateur is the top electronic engineer who is doing the impossible for his country and for the world. And why not?...the radio amateur has always done the impossible. He's the one who refused to obey the rules...demanded more and ever more from his "ham" rig. The equipment that he used...especially the tubes...had to have greater stamina and vastly superior performance capabilities. Thus the radio amateur literally forced electronics forward. For the products created to stand up under his gruelling treatment represented real advancement. Eimac tubes are a good example, for Eimac tubes were created and developed in the great amateur testing grounds. That's one reason why Eimac tubes have proved so vastly superior for commercial and war uses. Yesterday the leading radio amateurs throughout the world preferred Eimac tubes. Today these radio amateurs are off the air as amateurs but wherever they are, as the leaders in electronics, they're still using Eimac tubes.

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It has wide applications as a laboratory test instrument, for testing quartz crystals, for use in a wow meter for phonograph motors and for experimental work as the base of a frequency-modulation indicator.

When combined with a photoelectric cell, light source and amplifier, the instrument can be used as a speed indicator to read speeds usually difficult to determine such as encountered with ultra speed centrifuges.

This Norelco frequency meter drives a recorder without use of auxiliary amplifiers. An overload cut-out protects recorder from damage.

The maximum frequency is 50,000 cycles with six ranges, 0-100; 0-500; 0-1000; 0-5000; 0-10,000; and 0-50,000. Each frequency range can be individually adjusted for maximum accuracy.

Frequency is indicated directly on front panel of meter or on separate recorder. The meter has an input impedance of 100,000 ohms or over. It will measure frequency regardless of input signal voltage variations between ½ and 200 volts. Stability is maintained with line voltage variations between 105 and 125 volts.

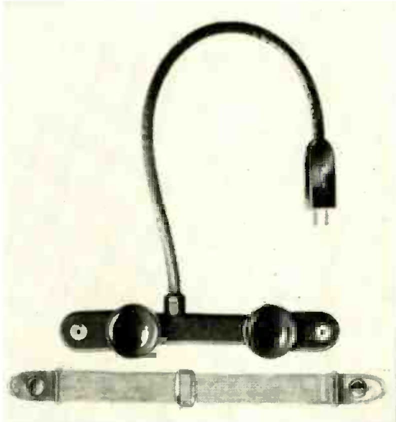
The meter, which does not use d.c. amplifiers, is designed either for relay rack or cabinet mounting.

★

"UNIVERSAL" T-30 THROAT MIKE

Universal Microphone Co., Inglewood, Cal., is now making its T-30 microphone available in bulk orders to sub-contractors and prime government contractors. Originally conceived and designed to specifications for the U. S. Army Signal Corps communications circuits, the instrument can now be secured for use on army radio equipment with early deliveries.

The T-30 is a carbon type, dual element, mounted in synthetic rubber neckpiece complete with elastic neckband. This microphone allows the use of both hands by the



operator, such as in the case of pilots, dispatchers, etc.

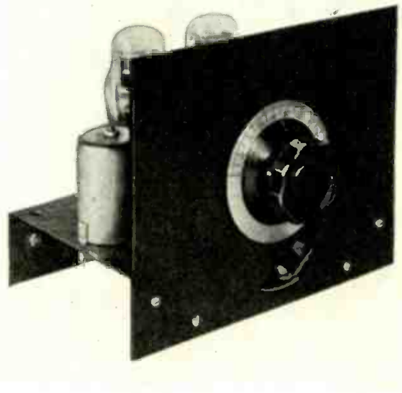
The plug is a midget two-prong break-away type PL-291. Being non-locking, it is easily disconnected. The microphone, to be complete, requires an extension cord (CD-354) and switch assembly CD-318 or CD-508, which contains the press-to-talk switch for the microphone and control relay circuit.

★

LAFAYETTE TRAINING KITS

Lafayette Radio Corp. of Chicago and Atlanta, is now able to offer radio training kits in quantity, to military and private training programs. The one and two tube regenerative kits (illustrated) are designed to provide complete basic receiver training at the lowest cost.

The one tube kit, when assembled, demonstrates grid leak detector operation and the effects of regeneration on a detector circuit. With the addition of a minimum of parts an r.f. stage can be added without



redrilling the chassis or moving any component parts of the detector circuit. Alignment procedure can then be demonstrated in its simplest form. These kits may be operated either from power supplies or from batteries when proper tubes are used.

THORDARSON "FLASHTRON"

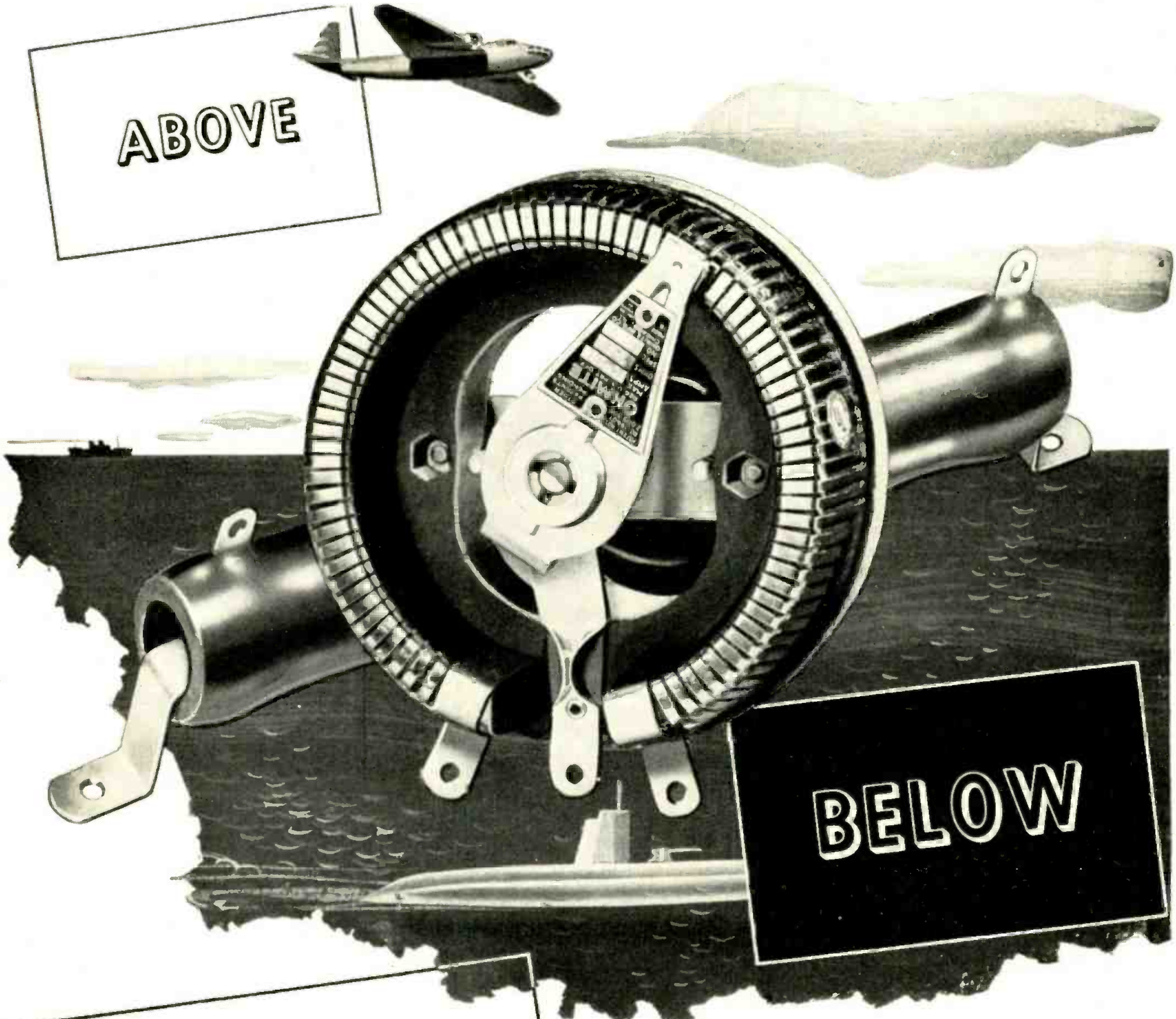
Thordarson Electric Mfg. Co., of Chicago, are offering "Flashtron," an electronic package unit, as the means of bringing about greatly improved performance in many types of automatic control setups. Flashtron is not, in itself, a control "system." But it is literally the electronic nerve center which makes it practicable to closely approach zero tolerance in regulating variables occurring in industrial processes, such as pressure, temperature, liquid level, flow, speed, motion, voltage, air, fuel relation, specific gravity, gas analysis, etc.

The Flashtron may be considered a sort of "buffer" control element operating between the primary sensitive element and

the power operating (in many cases the final) control element. It requires negligible power for actuation and furnishes the power necessary for actuation of power-operating elements. It allows the energizing of these power-control elements without necessitating the use of the slower acting and less dependable types of primary control elements which would otherwise be required in many applications.

One of the two output circuits is always energized but both cannot be energized simultaneously with contactor type actuating devices. Its dual circuit output energizing system is especially suitable for the control of proportioning or positioning control elements such as valves operating from reversible motor drives. Since one or the other circuits must be in operation at any given instant, the valve will be constantly reset to the desired position in exact response to the performance of the primary sensitive element which is actuating the Flashtron unit. While the Flashtron cannot compensate or correct for lag

[Continued on page 60]



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in any of the other control elements in the system in which it is used, it does not in any way limit the full utilization of the performance of any of these other elements. One of its greatest advantages accrues from its high speed operation and its immediate response to sensitive actuation.

Being electronic in nature, there are no mechanical moving parts, and consequently no inertia. Using no relays in its makeup, Flashtron is silent in operation, hence especially advantageous where noise-free applications are required.

The Thordarson Flashtron is housed in an all-steel box of streamline appearance and provisions have been made for the easy connection of a 115-volt 60-cycle a.c. power line, the actuating circuit and the two control sections. It is light in weight, only 11½" x 7⅛" x 3⅝" in size, and lends itself readily to almost any physical setup of a control system.

★

HIGH-VOLTAGE TUBULAR CAPACITORS

New Type '26 high-voltage capacitors for X-ray, impulse generator and other intermittent d.c. or continuous a.c. high-voltage applications such as indoor carrier-coupler capacitors, test equipment and special laboratory work, are announced by Aerovox Corporation of New Bedford, Mass.

These Type '26 capacitors are oil-impregnated oil-filled with Aerovox Hyvol vegetable oil. The capacitors are built with adequately insulated and matched sections of uniform capacitance, connected in series. Equal voltage stresses are maintained for all sections, with a uniform voltage gradient throughout the length of each capacitor. High-purity aluminum foil with a generous number of tab connectors provides high conductivity with low inductive reactance. Capacitor sections are dried and impregnated under high vacuum in a closely-controlled long cycle. This eliminates voids and also provides for high insulation values and lower losses.

The case is of special laminated bakelite tubing, protected by a high-resistance insulating varnish for high dielectric strength and maximum safety from external flashover. Long creepage path between terminals means an exceptionally conservative and safe rating for these units. Dependable operation and long service life is assured at rated voltages and ambient temperatures up to 65° C.

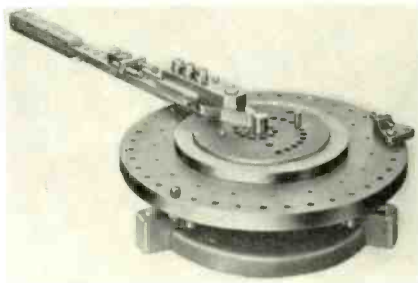
The terminals are two-piece cast-aluminum end caps with bakelite-treated cork gaskets, which are locked in to provide leak-proof hermetic sealing. Caps are available with mounting feet for space-saving assemblies in series, parallel or series-parallel arrangements. Also obtainable with plain end caps.

★

DI-ACRO DOUBLE-ACTION BENDER

The O'Neil-Irwin Mfg. Co., Minneapolis 15, Minn., have placed on the market the Di-Acro Bender No. 3, for large radius bending, and especially designed for aircraft and marine work.

This Bender incorporates all of the features of the smaller benders. The new unit is heavier and more rugged throughout than the smaller models and has a considerably greater radius forming capacity.



Accuracy guaranteed to tolerance of .001" in all duplicate work. Right or left hand mounting or operating. Automatic and reversible forming nose. Length of operating leverage is 35". Increased leverage up to 80" may be added. Capacity, ½" round cold rolled steel bar, formed cold to 1" radii or larger.

Catalog sheet available on request to manufacturer.

★

THERMEX HIGH-FREQUENCY HEATING EQUIPMENT

Almost any non-metallic material can be heated uniformly throughout and in minutes where ordinarily it requires hours, with the new Thermex High Frequency Heating Equipment. Heating is accomplished within the article or molecule itself by reason of its molecular resistance to the high voltage, high frequency current passed through it from flat electrode plates covering opposite sides or top and bottom of the mass to be heated. All coils, tubes, controls, etc., are housed within a compact safety cabinet, certain models of which are portable and mounted on casters. Any average-good workman can be trained to operate the largest units; simplest units have single-knob control.

Already thoroughly established in the wood-working or wood-fabricating field, where it is revolutionizing the processing of plywoods and laminated woods used in airplane and ship construction, particularly. Extensive, modern laboratory facilities are available for making test applications under simulated operating conditions, and large production facilities exist for manufacture. For further data write The Girdler Corporation, Thermex Division, Louisville 1, Kentucky.

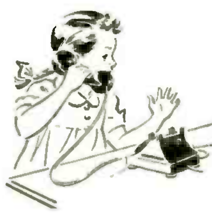
★

NEW "INDUSTRIAL" SUPER CAPACITORS

The Industrial Condenser Corp., of Chicago, is now in production on a new line of heavy-duty, high-voltage capacitors for continuous operation up to 150,000 volts working. The pictured 0.5-mf unit is a 50,000 volt d.c. capacitor; it is 28 inches high and weighs 175 pounds. It is constructed for 24 hours continuous operation and total submersion in salt water.

These units can be used in surge and lightning generators. They are equipped with the famous solder seal terminals for operation at highest altitudes and under the most humid conditions encounterable.

Your plane will have a 'phone!



After the war...

. . . the two-way radiotelephone will be employed by American industry as a convenience, a safeguard and a business requirement. This modern method of communication has many proven applications in the following fields:

Aviation	Railroading
Marine	Mining
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Public Utilities	

If you think you may be able to employ two-way radiotelephone communication in your field, we would be pleased to discuss your problem without cost or obligation. We have nothing to sell since our entire output has been placed at the disposal of the United Nations all over the world!

•

Requests for information and literature from responsible parties may be addressed to:
Industrial Engineering Dept.
Jefferson-Travis Radio Mfg. Corporation,
245 East 23rd Street
New York, N. Y.

SOUNDS fantastic, doesn't it? Yet the incredible wartime development of the two-way radiotelephone in military aviation is striking evidence that it will be widely used by the planes, cars and trains of tomorrow. Jefferson-Travis was in the forefront in the development of this unique form of communication long before Pearl Harbor. Today our entire facilities are devoted to producing this type of equipment for the United Nations, thus hastening the day when we will be again building two-way radiotelephones for you and your peacetime purposes in Tomorrow's World!

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RADIOTELEPHONE EQUIPMENT

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THIS MONTH

NEW CALL LETTERS FOR FM BROADCASTERS

A new system of Call Letters for Frequency Modulation broadcast stations, like that currently used by standard broadcast and commercial television stations, was adopted August 24 by the Federal Communications Commission. The change in FM station calls, to become effective November 1, next, will affect approximately 45 high-frequency broadcast stations in operation and all future licensees.

This system of Call Letters for FM stations will replace the present combination of letter-numeral calls (such as W47NY, W51R, etc.) presently used by FM broadcasters. In cases where a licensee of an FM station also operates a standard broadcast station in the same city, he may, if he so desires, retain his standard call letter assignment followed by the suffix "FM" to designate broadcasting on the FM band. Thus, if the licensee of a standard broadcast station with the call letters "WAAX" (hypothetical), also operates an FM station in the same location, he will have the choice of using the call "WAAX-FM" or he may, on the other hand, be assigned a new four-letter call—say, WXRI. Similarly, an FM broadcaster on the West Coast, who also operates a standard broadcast station "KQO," may, if he likes, use the call "KQO-FM" or he may ask for a new four-letter call "KQOF" for his FM station. This choice will remain entirely with the FM operator.

FM licensees may inspect at the FCC a list of the approximately 4000 four-letter calls which are available for assignments. This number appears ample to supply calls for all additional standard, commercial television, FM stations and non-broadcast classes for some time to come. (The Commission wishes to call attention to the fact, however, that all three-letter calls have already been assigned.)

All call letters beginning with "W" are assigned to stations east of the Mississippi River; all station calls beginning with "K" are located west of the Mississippi and in the territories. A breakdown of the 4000 four-letter calls available shows approximately 2900 "K" calls and 1100 "W's" still unassigned.

FM stations are asked to have their requests, indicating a preference in call letters, filed with the Commission by October 1. If no request has been received from an FM licensee by that date, the FCC will, at its discretion, assign a new four-letter call to that station.

It is recommended that FM operators, who wish a new four-letter call, list their first, second and third choices, and in the event two stations seek identical call letters the request first received by the Commission will be honored.

Ted McElroy and Bill McGonigle during the VWOA Marconi Memorial broadcast over WOR.

★

ACTIONS BY THE FCC

Meter Requirements

In view of the present shortage of electrical indicating instruments and the need for uninterrupted production of marine radio equipment for war uses, the Federal Communications Commission has amended Subsection 8.142 of its Rules, effective immediately, deleting the requirement for additional meters for a main transmitter completed by the manufacturer after January 1, 1944.

The amended Subsection 8.142 now reads: "Subsection 8.142(d) A main transmitter shall be equipped with suitable indicating instruments of approved accuracy to measure (1) the current in the antenna circuit, (2) the potential of the heating current applied to the cathode or cathode heater of each electron tube or a potential directly proportional thereto, and (3) the anode current of the radio-frequency oscillator or amplifier which supplies power to the antenna circuit, or in lieu thereof, the anode current of such oscillator or amplifier plus the anode current of any other radio or audio-frequency oscillator(s) or amplifier(s) normally employed as part of the transmitter."

A-3 Emission

The Commission has modified its Rules Governing Fixed Public Radio Services, Part 6, deleting the reference to the term "A-3 emission" (telephony) in the definition of "radiotelegraph" in Section 6.9, and adding a new Section 6.11 to incorporate this stricken material and to permit the use of A-3 emission for the control of the transmission and reception of facsimile material. At the same time the Commission deleted from Section 6.10 the reference to emissions which are used for telegraph services, and incorporated the stricken material in a new Section 6.12.

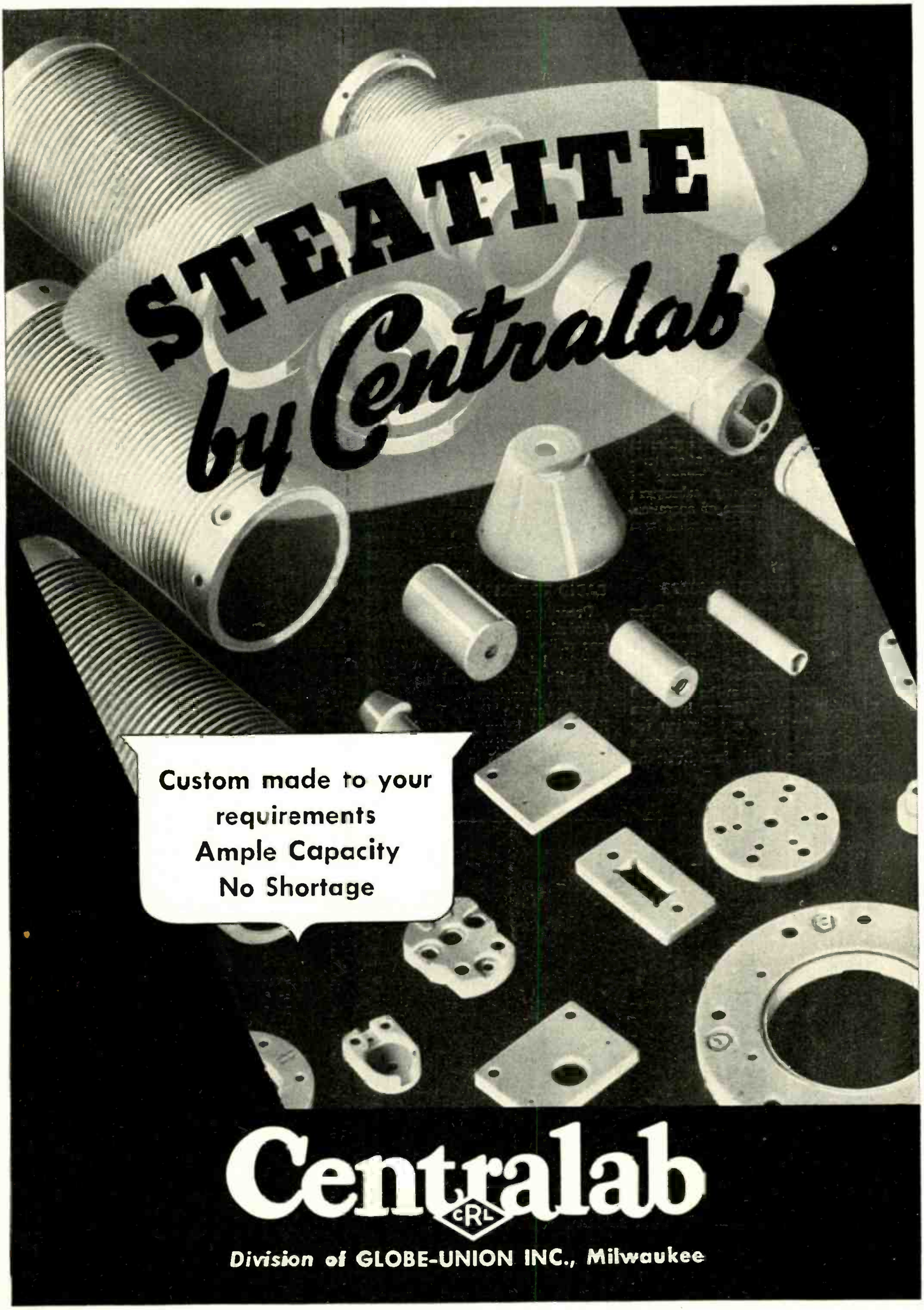
The modified sections and new sections read as follows:

"Section 6.9 Radiotelegraph—The term 'radiotelegraph' as hereinafter used shall be construed to include A-0, A-1, A-2 and A-4 emission."

"Section 6.11 *Use of A-3 Emission by Radiotelegraph Stations*—The licensee of a point-to-point radiotelegraph station may

[*Continued on page 64*]

Interesting mural depicting the broad expanse of the radio-electronic field, that greets the visitor to the penthouse plant of the Electronic Corporation of America, in New York City. ECA is an old-line concern with a new name, headed by S. J. Novick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be authorized to use type A-3 emission for the purpose of transmitting addressed program material as set forth in Section 6.51 and for the purpose of controlling the transmission and reception of facsimile material."

"Section 6.10 Radiotelephone—The term 'radiotelephone' as hereinafter used shall be construed to include type A-3 emission only."

"Section 6.12 *Use of A-0, A-1 or A-2 emission fy Radiotelephone Stations*—The licensee of a point-to-point radiotelephone station may be authorized to use type A-0, A-1 or A-2 emission for test purposes or for the exchange of service messages."

Notice of Status

The Commission has adopted a new Section 2.66 of its General Rules and Regulations to require written notice to the FCC Inspector in Charge of the district in which a radio station operates two days prior to the voluntary removal of that station, temporary or permanent discontinuance of operation, and within two days subsequent to involuntary discontinuance of operation. Radio stations in Alaska are excluded from this requirement.

★

UTAH PROMOTES ELLITHORPE

Mr. F. E. Ellithorpe becomes Sales Manager of the Carter Division of the Utah Radio Products Company, according to a recent announcement of O. F. Jester, Vice-President in Charge-of-Sales.

Having wide experience in the radio and electrical fields, Mr. Ellithorpe has been connected with the Utah organization for a number of years. He will be in charge of industrial sales of Utah Jack Switches, Utah Vitreous Enameled Resistors, Utah Phone Plugs, and Utah Wirewound Controls and other Utah-Carter Parts. This division is devoted to the production of parts for the armed forces.

F. E. Ellithorpe

★

RADIO TECHNICAL PLANNING BOARD

Procedure to establish a radio industry technical planning organization, for post-war radio services and products, has been completed by committees of the Institute of Radio Engineers and the Radio Manufacturers Association.

Plans for the "Radio Technical Planning Board" are being submitted to other industry organizations concerned and a meeting September 15 in New York to formally inaugurate the Board's work is scheduled.

The "R.T.P.B." will be a technical advisory body to formulate recommendations to the Federal Communications Commission and other government, also industry, agencies on the technical future of radio developments, including spectrum utilization and systems standardization for many public services, such as television and frequency modulation. The R.T.P.B. will develop studies, investigations, recommendations and standards as are required, submitting them to the F.C.C. and other agencies having final authority.

Chairman James L. Fly, of F.C.C., originally proposed the industry technical organization now being established. The R.T.P.B. will be a representative, democratic all-industry body. Initial "sponsors," in addition to R.M.A. and I.R.E., now being invited to participate in its organization Sept. 15 include: American Institute of Electrical Engineers; American Institute of Physics; American Radio Relay League; F. M. Broadcasters, Inc.; Natl. Assn. of Broadcasters; Natl. Independent Broadcasters.

Other major, non-profit radio organizations, as well as communications, aeronautical and similar groups concerned also may be included later.

The organization plans for the R.T.P.B. were completed and approved by the R.M.A. and I.R.E. Committees at a conference August 11th at New York. The respective chairmen are A. S. Wells of Chicago and Haraden Pratt of New York, who now are submitting the plans to other industry groups prior to the formal organization meeting on September 15th.

The other members of the R.M.A. Committee are H. C. Bonfig, Camden, N. J.; W. R. G. Baker, Bridgeport, Conn.; R. C. Cosgrove, Cincinnati, Ohio; Walter Evans, Baltimore, Md., and Fred D. Williams, Philadelphia, Pa. The other members of the I.R.E. Committee are Alfred N. Goldsmith, New York, N. Y.; B. J. Thompson, Princeton, N. J., and H. M. Turner, New Haven, Conn.

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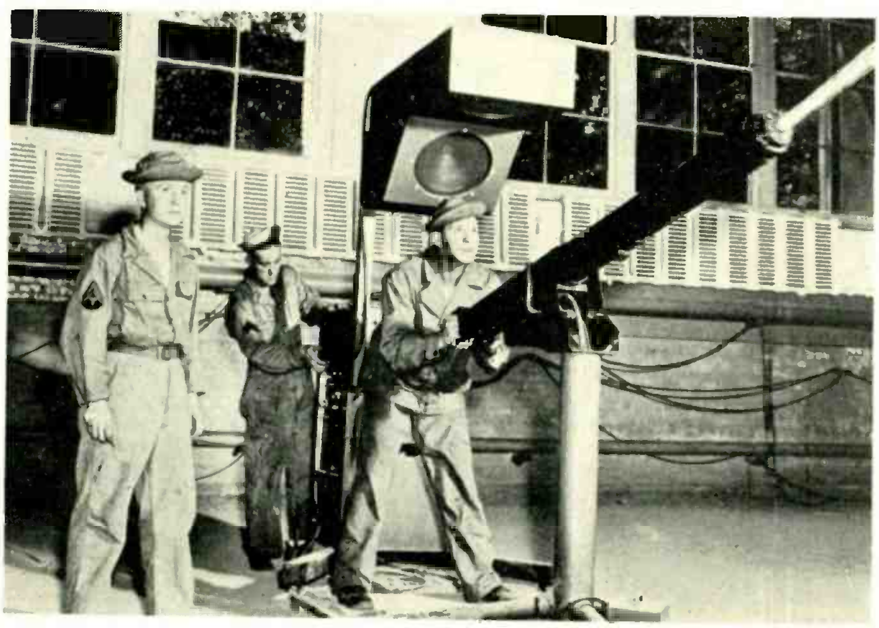


Machine-gun trainer, joint development of Edison General Electric Co. and Operadio Mfg. Co.; an electro-hydraulic device that reproduces the report of an actual 50-calibre machine gun with background noises of tanks, dive bombers, etc.

SOLAR MOVES GENERAL OFFICES

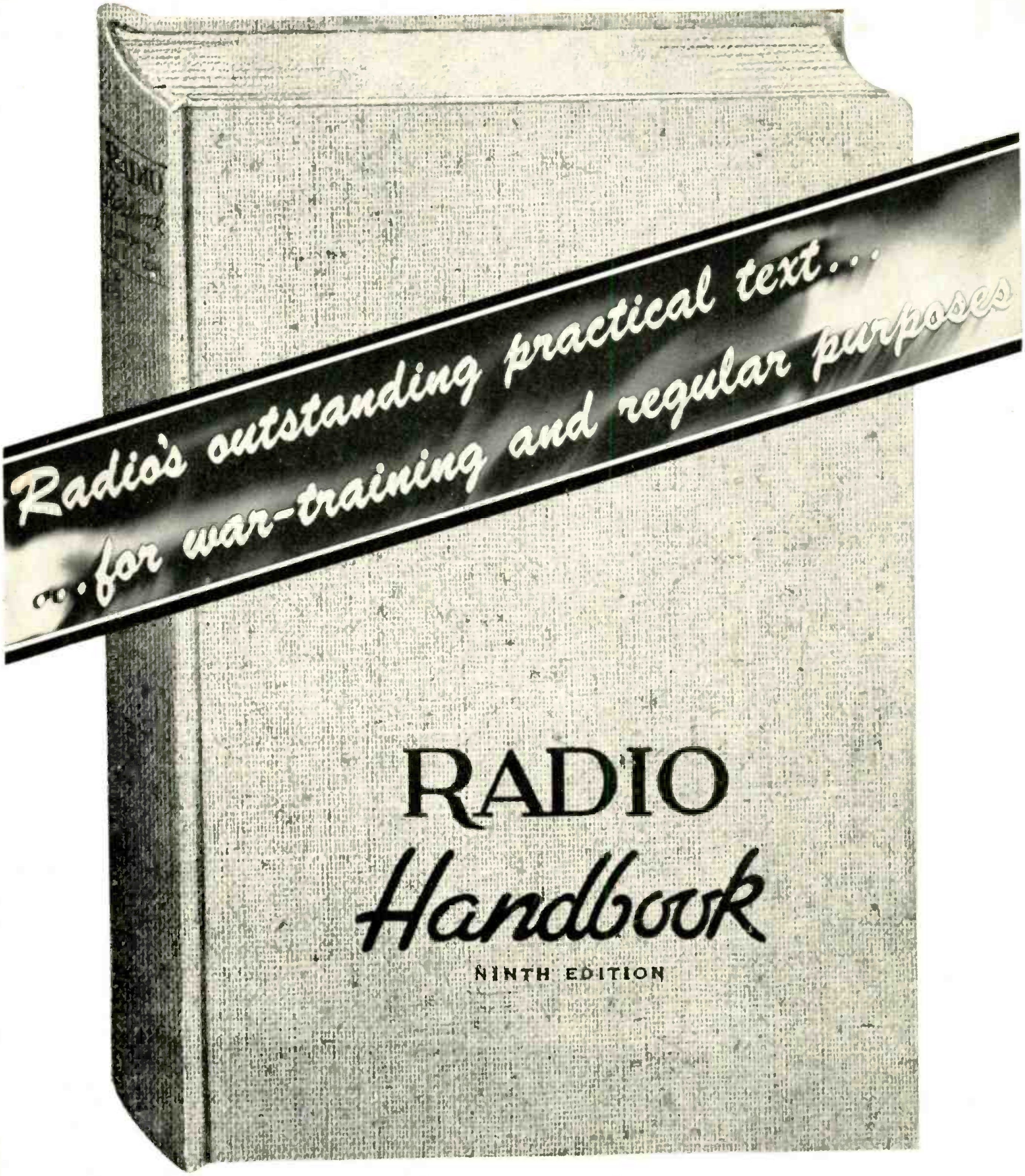
Solar Manufacturing Corporation and Solar Capacitor Sales Corporation announce the removal of general offices to 285 Madison Avenue, New York 17, N. Y., from the Bayonne, New Jersey, plant. Manufacturing activities continue in this plant as well as in Eastern Plant No. 2 at Bayonne, West New York, and in Plant No. 3 at Chicago. The departments occupying the new quarters are Accounts, Credits, Sales and Export.

★

JIM QUAM NAMED DIRECTOR

The Nichols Steel and Wire Company, manufacturers of steel wire, galvanized sheets, etc., has just announced the election of Jim Quam, President and General Manager of Quam-Nichols Company, as director of that organization.

[*Continued on page 74*]



NINTH EDITION

Revisions in this edition adapt it even better than ever before for war-training and general use; contains added and simplified theory in the simplest possible language; added test equipment which can be home- or field-constructed; and a review of mathematics for solving simple radio problems.

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TECHNICANA

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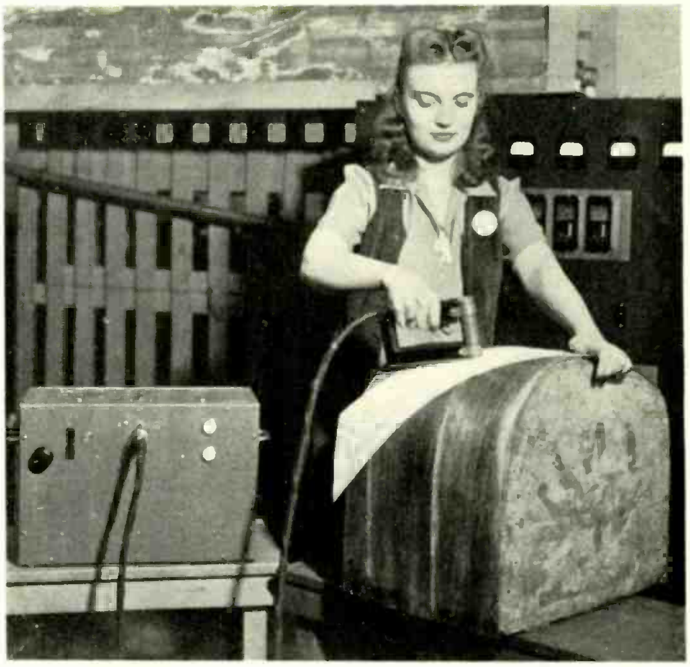
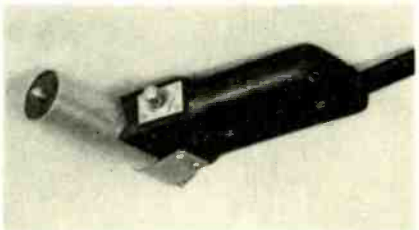


Tacking thin veneers with the "flat-iron" type of radio-frequency heating unit. The r-f generator is shown at the left, connected to applicator by a cable.

of material are placed together with a coating of plastic glue between them, heat thus induced can be used to form a bond at the point of application.

The "radio nail gun" or spot gluer which RCA has developed is an experimental device which has not as yet been offered commercially, but its operating principles bear promise of varied industrial usefulness. One field of use now foreseen, for example, is in the fitting together of thin veneers in the manufacture of molded plywood aircraft parts.

Before assembly, such sheets are coated with plastic glue. They are then "laid up," one at a time, on a wooden mold, and each sheet is cut and trimmed to fit the mold before the next is applied. To prevent shifting of the veneers during this operation, the conventional procedure is to tack each sheet in place with metal tacks or staples, which must be pulled and reset as each successive layer is added to build up the preformed piece. The use of "radio nails" in place of metal fasteners would eliminate this tedious and time-consuming procedure.



Tacking applicator shaped like short-barreled automatic—a gun that shoots "radio nails". The pin and casing are the electrodes.

Resembling a short-barreled automatic pistol or a narrow-based electric flatiron in the two styles thus far designed, the "gun" or applicator is attached by a cable to a portable radio-frequency generator. Maneuverability

[Continued on page 71]

WIDE-BAND AMPLIFIERS

[*Continued from page 39*]

angle becomes the simple series circuit of C_c and R_g or:

$$\tan \theta = \frac{X_C}{R_g}$$

θ at 1000 cycles $= 0° \; 22'$
phase shift $= .00637$ radian
time delay $= 1.01$ microseconds

θ at 5 cycles $= 51° \; 53'$
phase shift $= .905$ radian
time delay $= 28{,}800$ microseconds

Hence the difference in time delay = 28,799 μseconds.

In the case of the compensated stage it is found that:

$$Z_0 = \frac{(R_L - jX_{C_F})\;(R_g - jX_{C_C})}{(R_L - jX_{C_F}) + (R_g - jX_{C_F})}$$

$$Z_0 = (R_L - jX_{C_F})\;(R_g - jX_{C_C})\;[(R_g + R_L)^2 + j(X_{C_F} + X_{C_C})] \div (R_L + R_g)^2 + (X_{C_F} + X_{C_C})^2$$

$$\tan \theta = X_{C_F}{}^2 X_{C_C} + X_{C_F} X_{C_C}{}^2 - R_g{}^2 X_{C_F} - R_L{}^2 X_{C_C} \div R_L{}^2 R_g + R_L R_g{}^2 + 2R_L X_{C_F} X_{C_C} + 2R_g X_{C_F} X_{C_C} + R_g X_{C_F}{}^2 + R_L X_{C_C}{}^2$$

θ at 1000 cycles $= 0° \; 21'$
phase shift $= .00622$ radian
time delay $= 1$ microsecond

θ at 5 cycles $= 7° \; 33'$
phase shift $= .132$ radian
time delay $= 4200$ microseconds

The improvement in phase can be seen at once. However, this is assuming the ideal case when R_F approaches infinity. By increasing the product $R_F C_F$ better gain can be obtained at a lower frequency and the low value phase shift extended to a lower frequency.

With $R_F = 20{,}000$ ohms, as shown, there will be an additional phase shift of about 5° and a drop in gain of a few per cent.

ELECTRON THEORY

[*Continued from page 48*]

Suppose a chemist should announce that as a result of the analysis of several thousand neutral salts he had come to the conclusion that acid and basic radicals existed in equal amounts in nature; we would likely think him ignorant of such syntheses as that of the acid radical cyanogen (CN) from its elements in the electric arc.

But is there any known electrical analogue of such a synthesis or its reverse dissociation?

No, nothing that we have so far been able to produce in the laboratory; yet if we imagine some race of children of the gods who could play with planets as we with pith balls, something of this kind might come to their notice.

Among the phenomena of atmospheric electricity there is an unsolved mystery. Many fruitless attempts have been made to explain it consistently with the principle of conservation of electrical charge. Continual failure has led more than one physicist to look for the explanation in a slight departure from this principle, and it has been shown that a departure so slight as to be beyond laboratory detection would yet, on the large scale, solve this mystery. The difficulty in question is to account for the negative charge of the earth.

Our earth is not a neutral body. Its entire surface is negatively charged to such an amount that there exists near the surface a potential gradient of 150 volts per meter. The conductivity of the atmosphere is small, but not zero; and because of this conductivity and the potential gradient there is a continual conduction of negative electricity away from the earth, amounting over the whole of the earth's surface to a current of about 1000 amperes, five millionths of an ampere per square mile. Small as this may appear, it is sufficient to bring about a loss of ninety per cent of the earth's charge in ten minutes if there were no means of replenishing the loss. The nature of this replenishment is the mystery referred to.

So great has been the difficulty of accounting for this replenishment that in 1916 G. C. Simpson(8), now director of the British Meteorological Office, raised the question of a possible spontaneous production of a negative charge in the earth's interior, but offered no suggestion as to how this could be brought into line with existing theory.

In 1926 Swann(9), the present director of the Bartol Research Foundation of the Franklin Institute, who had worked unsuccessfully with the same problem, followed Simpson's lead, but chose the other alternative of a slight annihilation, or, as he called it, "death" of positive electricity. He brought this into line with existing theory by generalizing Maxwell's equations. His fundamental idea was that there might be a very slight difference in the properties and behavior of the two electricities.

This suggestion was not without precedent. Lorentz(10), in 1900, had postulated a difference between the attraction of unlike charges and the repulsion of like charges to account for another mystery—gravitation. It must be admitted that the accepted idea of the absolute equivalence of the two electricities had weakened somewhat when three such men could join in expressing doubt of its accuracy(11).

Swann showed that to account for the known electrical facts there would be necessary an annihilation of less than one proton per cc per day, equivalent to a loss of 0.5 per cent of the earth's mass in 10^{20} years. Such a change would be beyond detection on a laboratory scale. Whatever may be thought of Swann's fundamental postulate, it must be admitted that his theory is experiment-proof. Moreover, it should have the lasting merit of impressing upon us caution in extrapolating laboratory results to the cosmic scale.

To sum up, it is an experimental fact that the ratio e/m for rapidly moving electrons is less than for slower ones. Whether this is caused by a change in mass or in charge (or both) is still an open question.

"Well, then," I think I hear you say, "whichever way the theoretical cat jumps, we can at least visualize an electron as a particle of something or other—either matter or electricity."

[*To be continued*]

APPLIED CALCULUS

[*Continued from page 31*]

The voltage drop is seen to be of the same time variation as the current but lagging the current by 90°. This is the reverse situation of the inductance where the voltage drop led the current by 90°. Since the voltage drop across a capacitor is the integral of the current, then according to our definition of integration as the inverse of differentiation, the current through a capacitor must be the derivative of the voltage. Accordingly, if we apply a square wave of voltage to a capacitor, pulses of current are obtained at the leading and trailing edges of the applied square wave much as in the case of a square wave of current through the inductance. *Fig. 7* and *8*.

Conclusion

The value of the Calculus as a tool for dealing with changing quantities becomes apparent. The principles of differentiation and integration are very valuable to the technician and engineer from the standpoint of background, even though he possesses little knowledge of the technique of their manipulation. Alternating current theory is based on what has been said here plus a good bit more, but these mathematical methods can be used to deal with any waveshape whatsoever and provide means for explaining the performance of a circuit which would otherwise remain a mystery.

OPERATING STANDARDS

[*Continued from page 41*]

music, and these men should be assigned to the performance of technical maintenance or transmitter duty. It is nevertheless important that the transmitter technician understand that a great amount of modulation during classical music will be below 20 per cent.

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

Loudness Of Speech and Music

The problem of correlating volume levels with comparative loudness of speech and music has appeared as an item of major importance and should no longer be ignored by broadcast station personnel. *Table 1* was compiled as a result of "group tests" of comparative loudness of different types of music with that of male speech. (See: Chinn, Gannett and Morris, "Volume Indicator and Reference Level", *Proceedings IRE*, January, 1940). The peak factor of speech waveform is very great in comparison to that of musical waveform. It is apparent therefore that 2 to 3 db more power may actually exist in speech waves in a circuit monitored by an rms meter than is indicated by the meter itself.

This will explain the results shown in *Table 2*, taken from the article mentioned above. It becomes obvious then that when speech and music levels are adjusted in correct ratio to avoid overloading, the loudness should be the same.

Table 1 contains a discrepancy with the author's personal experience, and is mentioned here with the hope of further research and clarification. It will be noticed that results of the tests on this particular group of listeners dictated the need for a 2.8-db higher level for dance orchestra, and a 2.7-db higher level for symphony orchestra over that of male speech.

If the author were to compile a similar table for equal loudness from several years experience of watching VI's on various types of programs, he would choose approximately a 3-db higher level for dance orchestras, and 4 to 6 db higher for symphony orchestras over that of male speech. The author feels that this is not due to a different physical response of the ear itself, but rather to a possible difference of acoustical factors involved, plus the fact that certain psychological factors were not considered in the original tests. By this is meant the important difference in listening technique between the symphony audience and the dance music listener.

As was mentioned before, due to the nature of the classical type of music, the symphony listener at home will operate his receiver on the average a good deal higher in level than he would for ordinary programs. Five minutes of symphony music will have perhaps 3 to 4 minutes of low to very low levels; the average intensity level over a period of time being far lower than the average intensity level of a dance orchestra in the same time interval. It should then be obvious that a greater difference should exist in the ratio of music to speech levels for symphony programs than for dance music.

Perhaps if tests were carried out with this difference in receiver volume considered, as well as the type of music on the program, the results would be more nearly in agreement with the above argument.

Studio Acoustics

The acoustical treatment of the studio from which the program is broadcast will affect to a great degree the loudness of voice and music for a given intensity level, and in different ratio. A studio overtreated with absorbant material deadens the room, and becomes an outstanding enemy to musical programs. Music from "dead" studios is "down in the mud", lacking in brilliance and generally dull to listen to. The effect on speech, however, is not so pronounced as that on music, since speech originates within a few feet of the microphone, whereas the space between the source of the music and the microphone is greater, and many things happen to the musical waveforms that must eventually be translated into perceptions of loudness.

Fig. 7 is a graph drawn on the assumption of a necessary 2-db difference of voice and music levels on an rms meter under normal acoustical conditions. The optimal reverberation time will vary according to the size of the studio, but, in general, for a studio of medium proportions intended for musical pick-ups, is about 0.8 second for speech and 1.5 seconds for music, based on the assumption of a full audience. The curve is drawn on a probability basis, correlating known facts concerning reverberation time with loudness sensation of voice and music.

This graph shows the necessity of a lower peaking of voice in relation to music for less reverberation time than normal, and at the same time shows that for twice the optimal reverberation time, where a great amount of reinforcement of the original musical waves takes place, the voice should be peaked at the same level as the music.

The newer "live-end, dead-end" studios, with musical instruments placed in the live end, and microphones spotted in the dead end, are apparently the best solution to date for proper controlled reverberation. In most of these studios, voice and music peaked at approximately the same level will appear the same in loudness sensation.

(To be continued)

TECHNICANA

[Continued from page 66]

is enhanced by the use of a principle which makes it possible to locate both electrodes in the "muzzle" of the gun, whereas earlier dielectric heating devices have required passage of the material to be heated between two electrodes.

In the spot gluer, a pin extending lengthwise down the center of the barrel forms one electrode, while the casing of the barrel is the other. In operation the muzzle is pressed against the material over the spot to be bonded and the current is applied by pressing the trigger. Since the material to be bonded is a better conductor than the air between the pin and the casing of the barrel, the current, following the line of least resistance between the electrodes, follows a curved line through the material.

In laying up veneers on a molding form, as well as in some other operations, it may be desirable to advance the resin only enough to set the glue to a thermoplastic state — a sufficient bond to prevent accidental shifting of the sheets while handling, but with enough flexibility to allow for necessary shifting when pressure is applied to effect the permanent bond.

To permit such variation in the degree of fastness or permanency of the original bond, the spot gluer is equipped with an electronic timer which can be set to control the interval of application. The spot gluer has an output of approximately 50 watts and an operating frequency of about 200 megacycles.

Joseph E. Joy, development engineer in RCA's Camden, N. J., plant, has had a leading part in the company's experimentation and developmental work on the spot gluer, although others in the organization have participated.

WWV TRANSMISSIONS

[*Continued from page 34*]

The service is continuous at all times day and night. The standard radio frequencies are:

5 megacycles (= 5000 kilocycles = 5,000,000 cycles) per second, broadcast continuously.

10 megacycles (= 10,000 kilocycles = 10,000,000 cycles) per second, broadcast continuously.

15 megacycles (= 15,000 kilocycles = 15,000,000 cycles) per second, broadcast continuously in the daytime only (i.e., day at Washington, D. C.).

All the radio frequencies carry two audio frequencies at the same time, 440 cycles per second and 4000 cycles per second; the former is the standard musical pitch and the latter is a useful standard audio frequency. In addition there is a pulse every second, heard as a faint tick each second when listening to the broadcast. The pulses last 0.005 second; they may be used for accurate time signals, and their one-second spacing provides an accurate time interval for purposes of physical measurements.

The audio frequencies are interrupted precisely on the hour and each five minutes thereafter; after an interval of precisely one minute they are resumed. This one-minute interval is provided in order to give the station announcement and to afford an interval for the checking of radio-frequency measurements free from the presence of the audio frequencies. The announcement is the station call letters WWV in telegraphic code except at the hour and half hour when the announcement is given by voice.

The accuracy of all the frequencies, radio and audio, as transmitted, is better than a part in 10,000,000. Transmission effects in the medium (Doppler effect, etc.) may result in slight fluctuations in the audio frequencies as received at a particular place; the average frequency received is however as accurate as that transmitted. The time interval marked by the pulse every second is accurate to 0.00001 second. The 1-minute, 4-minute, and 5-minute intervals, synchronized with the second pulses and marked by the beginning and ending of the periods when the audio frequencies are off, are accurate to a part in 10,000,000. The beginnings of the periods when the audio frequencies are off are so synchronized with the basic time service of the U. S. Naval Observatory that they mark accurately the hour and the successive 5-minute periods.

Of the radio frequencies on the air

at a given time, the lowest provides service to short distances and the highest to great distances. For example, during a winter day good service is given on 5 megacycles at distances from 0 to about 1000 miles, 10 megacycles from about 600 to 3000 miles, and 15 megacycles from about 1000 to 6000 miles. Except for a certain period at night, within a few hundred miles of the station, reliable reception is in general possible at all times throughout the United States and the North Atlantic Ocean, and fair reception over most of the world.

Information on how to receive and utilize the service is given in the Bureau's Letter Circular, "Methods of Using Standard Frequencies Broadcast by Radio," obtainable on request. The Bureau welcomes reports of difficulties, methods of use, or special applications of the service. Correspondence should be addressed to the National Bureau of Standards, Washington, D. C.

ROCHELLE SALT CRYSTALS

[*Continued from page 25*]

tential generated by the crystal for a given stress is proportional to the stress and the factor of proportionality remains constant over the temperature range provided the load impedance for all conditions is considerably greater than the impedance of the crystal. Should the load impedence be comparable to that of the crystal, temperature change will cause variations of the terminal voltage, since the capacitive reactance or impedance of the crystal varies with change of temperature thus causing a variable voltage loss.

When the crystal elements are used as motors, the displacement or motion developed by the crystal elements of any given temperature and frequency is practically proportional to the applied voltage. However, the motion of the crystal element produced by a given applied voltage varies somewhat with temperature. Where extreme accuracy of calibration is required, thermostatically controlled heater elements have been used with crystal elements for temperature stabilization. In such devices the temperatures are usually adjusted above those normally encountered (i.e. approximately 95 degrees F).

[*To be continued*]

THIS MONTH

[*Continued from page 64*]

RCA PROMOTES TEEGARDEN

As part of the Company's broad-gauged postwar program, the appointment of L. W. Teegarden to Assistant General Sales Manager was announced by Henry C. Bonfig, General Sales Manager of the RCA Victor Division of the Radio Corporation of America.

In his new capacity, Mr. Teegarden will have direct supervision over the selling, distributing and warehousing of all RCA products. In addition, the Company's four Regional Directors in the Eastern, Central, Western and Southern territories will report to him.

★

KAAR AND NEVIN PROMOTED BY G. E.

I. J. Kaar and G. W. Nevin have been appointed managers of the Receiver and Tube divisions, respectively, of General Electric's Electronics Department, it has been announced by Dr. W. R. G. Baker, vice-president in charge of the department. The Receiver division is located at the company's Bridgeport, Conn., works, while the headquarters of the Tube division are located in Schenectady, with manufacturing plants in four cities.

★

G. E. PROMOTES PETERSON

E. F. Peterson has been placed in charge of design engineering of receiving tubes, according to O. W. Pike, engineer of the Tube Division of the General Electric Electronics department at Schenectady, N. Y.

"K. C. DeWalt, designing engineer, Tube Division, will continue his responsibility for design engineering of all other product lines of the division." Mr. Pike explains.

★

FATTIG NAMED ACTING SUPERVISOR OF G-E RECEIVER DIVISION; P. R. BUTLER IN NAVY

W. L. Fattig has been appointed acting supervisor of the Technical Service section of the General Electric Receiver Division, Bridgeport, Conn., according to a recent announcement by I. J. Kaar, division manager. P. R. Butler, former manager of the section, is now a lieutenant in the U. S. Navy.

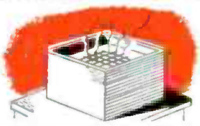
ADVERTISING INDEX

The Hytron 807—peacetime all-purpose favorite—is now a veteran. Before it joins its battle-scarred brothers, however, like all Hytron tubes it must pass Hytron factory specifications which weed out the 4-F's as efficiently as Army doctors at an induction center. Unless a Hytron 807 is in top fighting condition, it never leaves the factory. Let's look at a few of the many test hurdles it must surmount.

BUMP TEST

Ever stop to think of what a leaping, bouncing jeep or peep can do to a tube's "innards"? One answer to the question of a tube's ability to withstand such punishment, is the Bump Test. Several resounding smacks by a heavy, swinging hammer loosens up the weak sisters pronto!

IMMERSION TEST



A "PT" boat leaning back on its stern, and plowing a foaming furrow through steaming tropical waters would spell disaster to poorly-cemented bases and top caps. That is why Hytron 807's are thoroughly soaked in a hot bath, before they are O.K.'d.

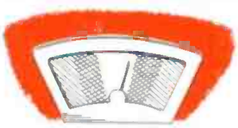
LIFE TEST

Day and night, Hytron 807's on life-testracks are proving that they can give long, dependable service. Soaring skyward in our big bombers, these tubes have a big investment in men and matériel to protect. Long after the big fellows have been patched for the last time, these tubes are still doing their jobs.

VIBRATION TEST

Link-trainer for 807's aspiring to tank service is a motor-driven eccentric arm which shakes the tube like an angry terrier while a v.t. voltmeter in the plate circuit records the ability of the elements to take it like the iron men who ride those clanking, thundering monsters.

HYTRON TOLERANCES **tighter than** **CUSTOMER TOLERANCES**



No manufacturer makes all tubes of a given type exactly alike. Hytron does manufacture its tubes to tight specifications which insure against slight inaccuracies due to meters and the human element. Engineered to these narrower limits, Hytron tubes fit exactly the circuit constants with which they must operate.

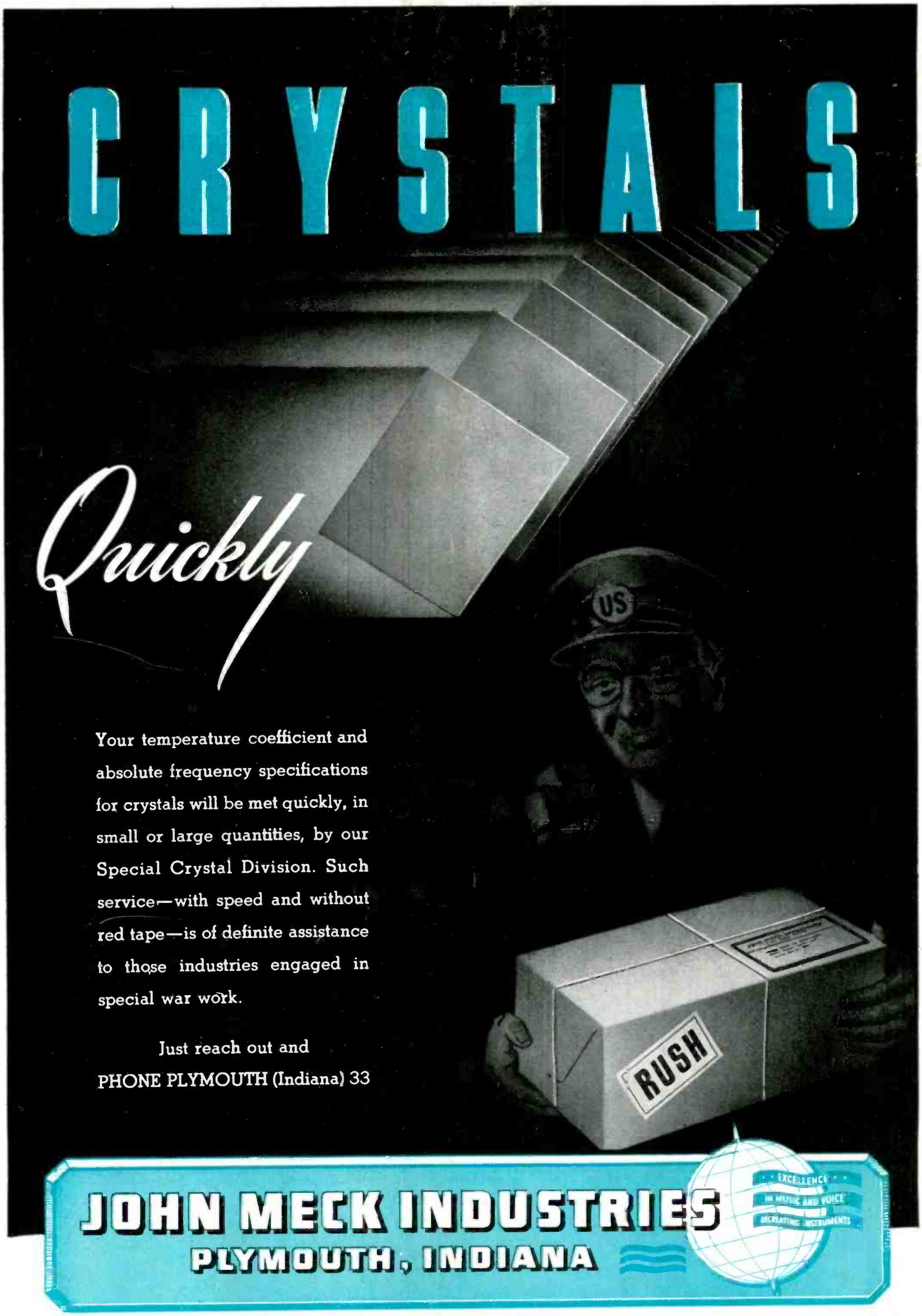
OLDEST EXCLUSIVE MANUFACTURER OF RADIO RECEIVING TUBES

HYTRON RADIO TUBES

HYTRON

ELECTRONIC AND RADIO TUBES **CORPORATION**

SALEM AND NEWBURYPORT, MASS.


CRYSTALS
Quickly
Your temperature coefficient and absolute frequency specifications for crystals will be met quickly, in small or large quantities, by our Special Crystal Division. Such service—with speed and without red tape—is of definite assistance to those industries engaged in special war work.
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