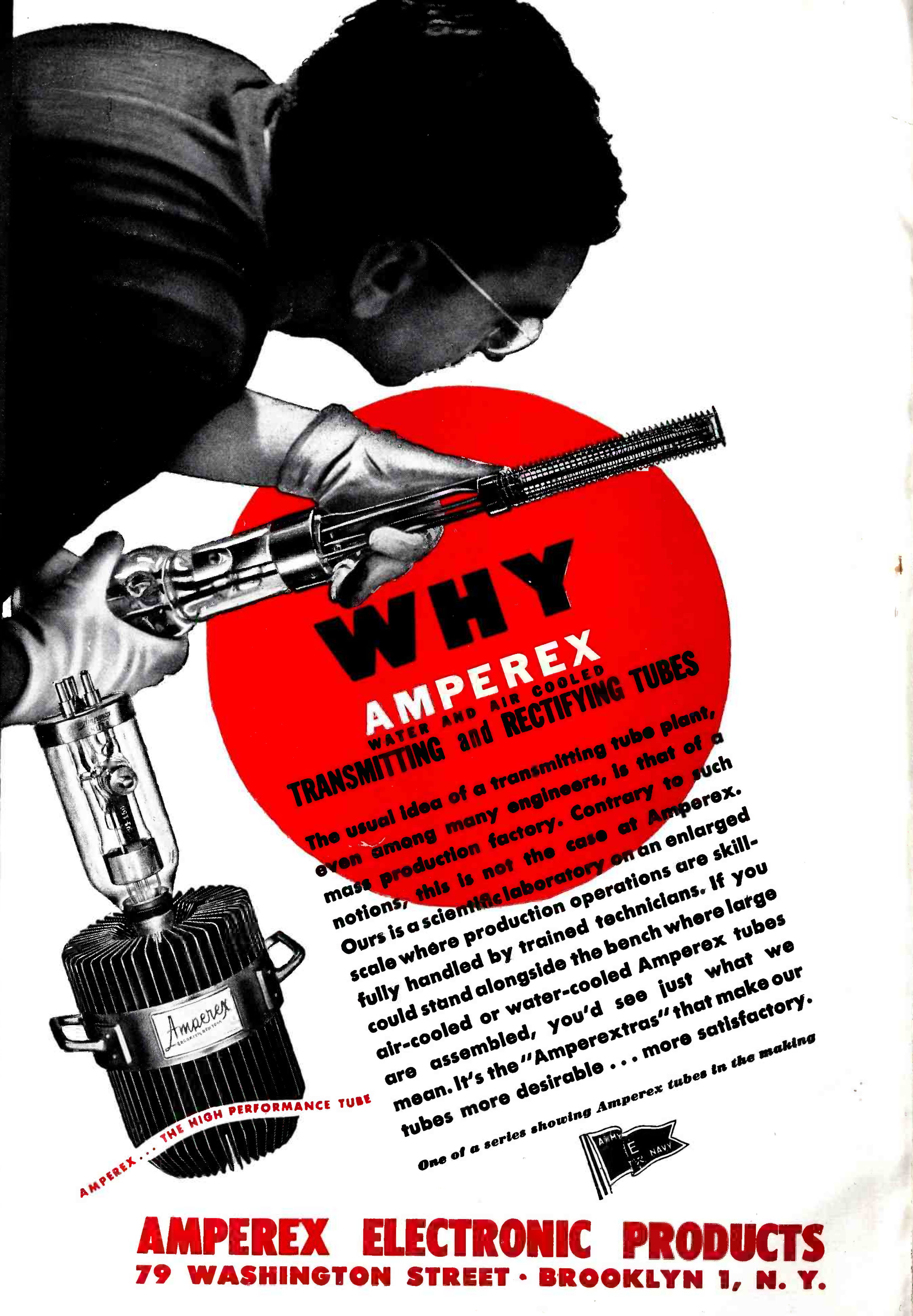
COMMUNICATIONS

NOVEMBER

★ RADIO ENGINEERING
★ ROCHESTER MEETING REPORT
★ ORIENTATION OF QUARTZ
★ PUSH-PULL DEVELOPMENT
★ MIXER, FADER CONTROL CIRCUITS
★ AIRCRAFT COMMUNICATIONS

1943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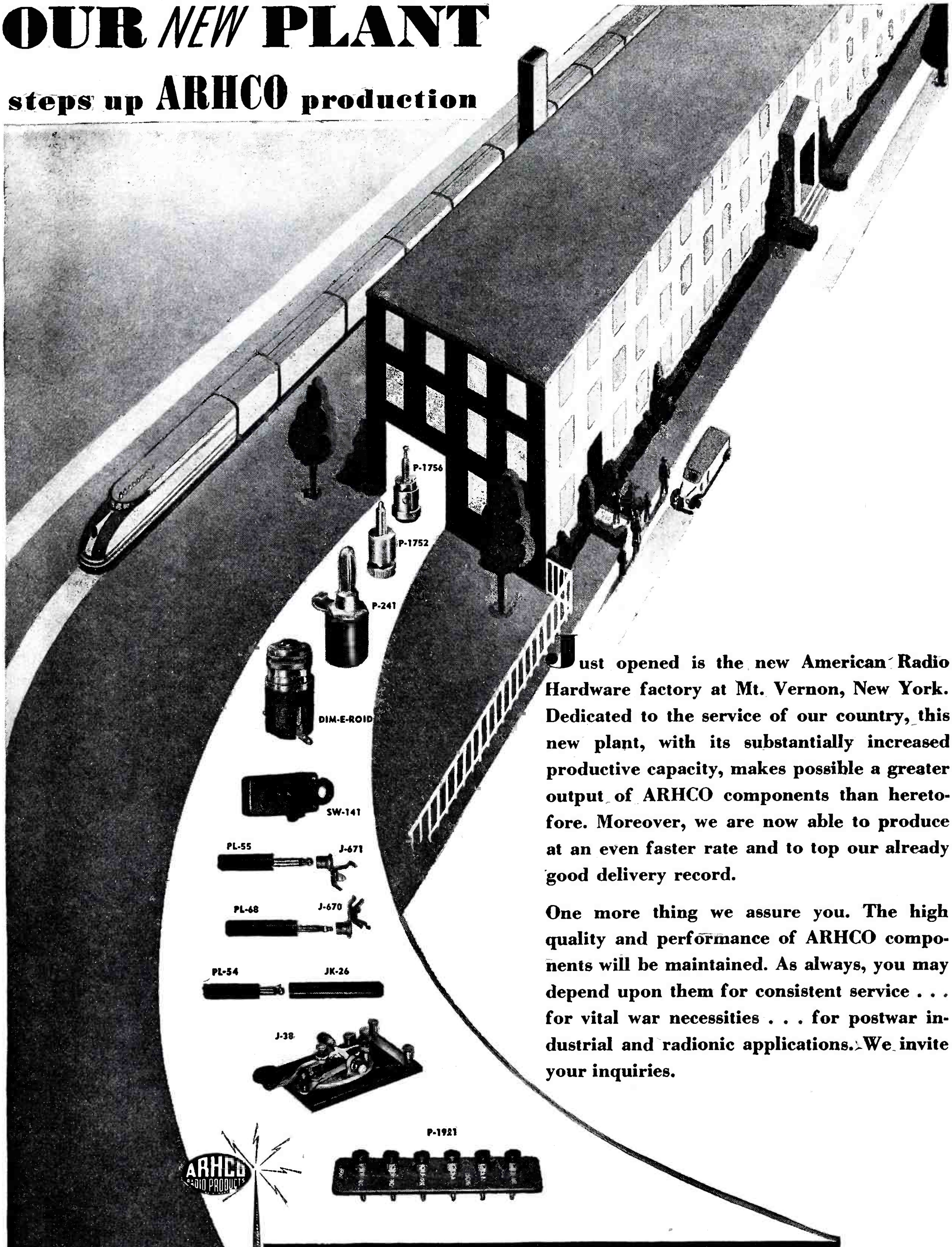

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VOLUME 23 NUMBER 11

We See...

THE RESOURCEFULNESS OF A BROADCAST STATION ENGINEER . . . on the war front . . . has won the acclaim of the nation. The engineer . . . *R. Morris Pierce*, chief engineer of WGAR, and at present chief engineer of the Psychological Warfare Branch, Allied Force Headquarters in Algiers, and the event . . . the surrender of the Italian fleet. It was Pierce who revamped a transmitter in only 15 hours, tuned it to the distress frequency of 500 kc, without the aid of calibration instruments or even suitably identified dials (the transmitter had operated on 1100 kc) and thus provided a means of transmitting the surrender terms to the Italian fleet.

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TO EFFECT ADDITIONAL CONSERVATION OF PAPER, the December issue of COMMUNICATIONS will be trimmed down to 7⅝" x 10⅝". Incidentally, in October, we began using a lighter weight of paper, 40-pound stock.—L. W.

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A radio-equipped British tank on duty in the Western desert of Africa. *(British Official Photo)*

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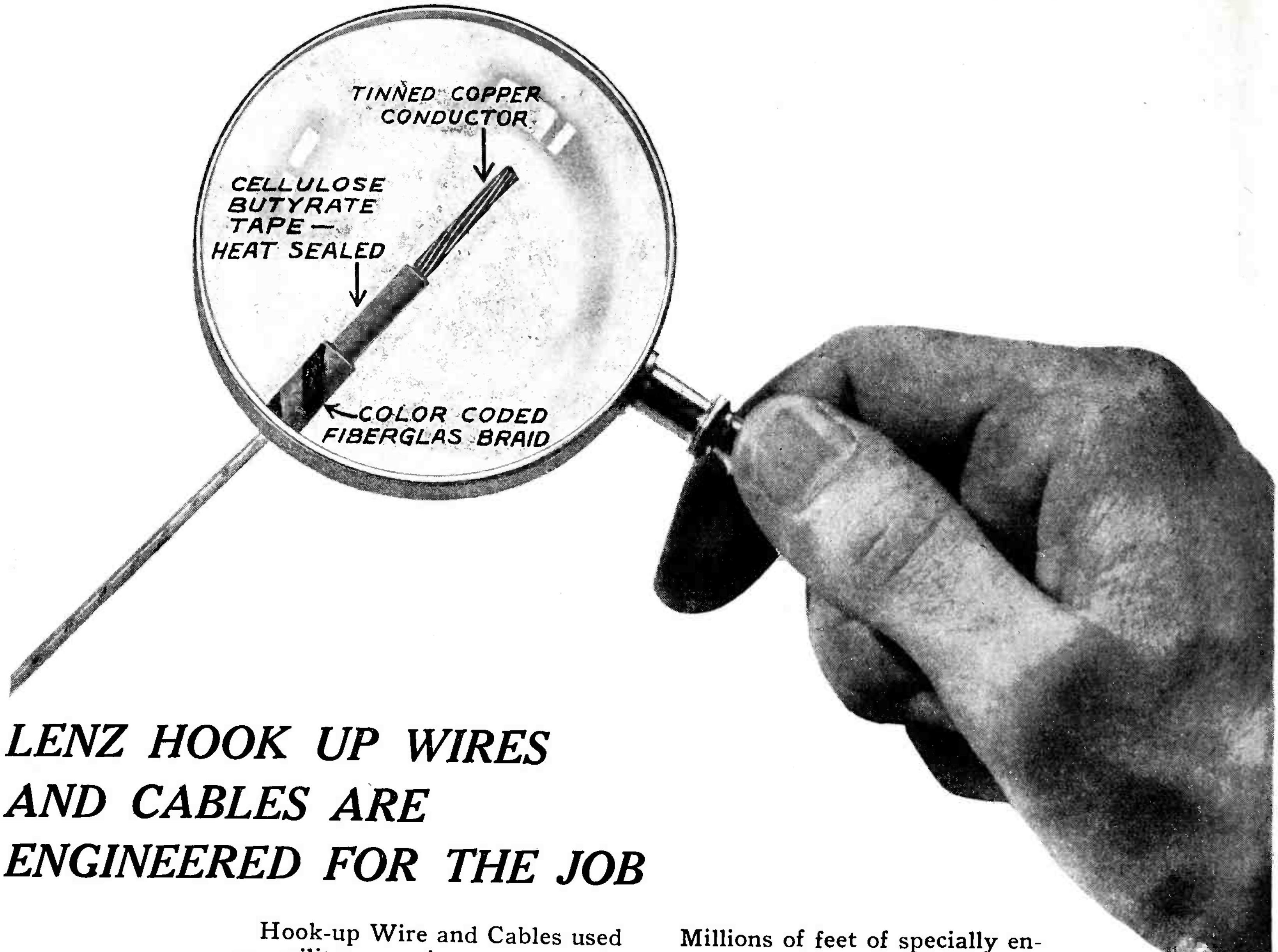

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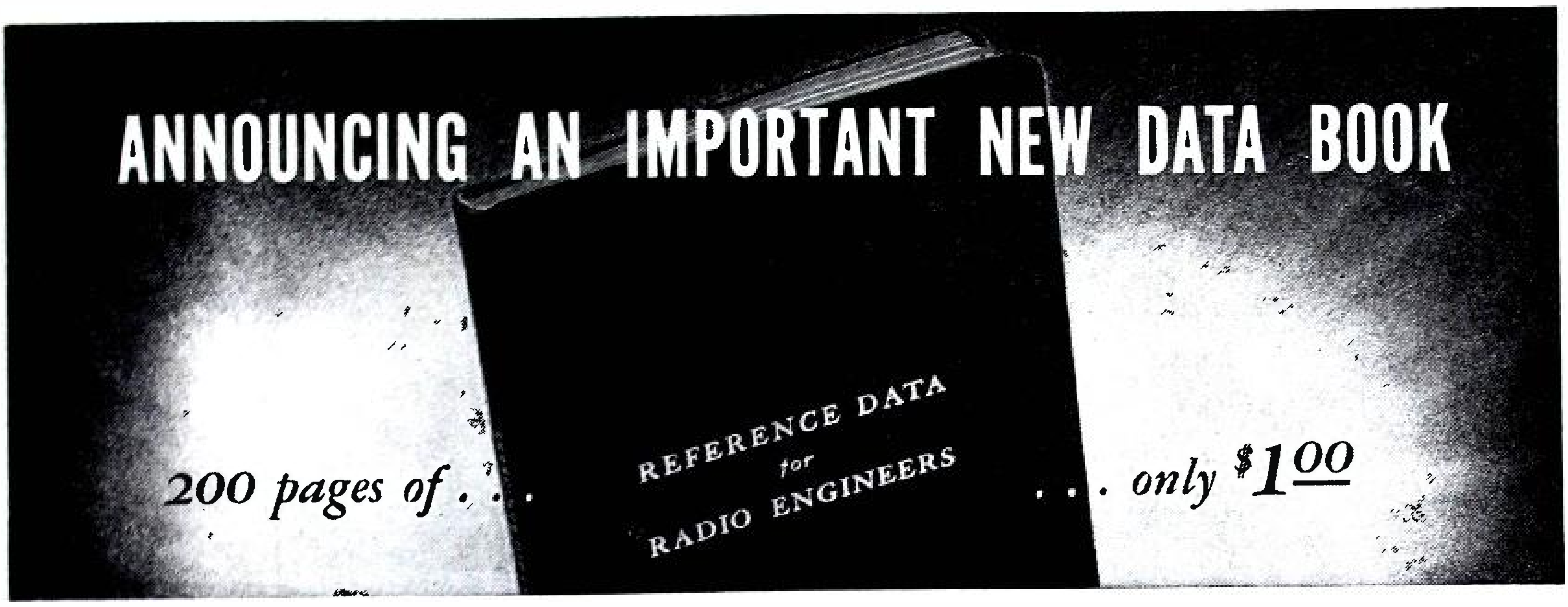

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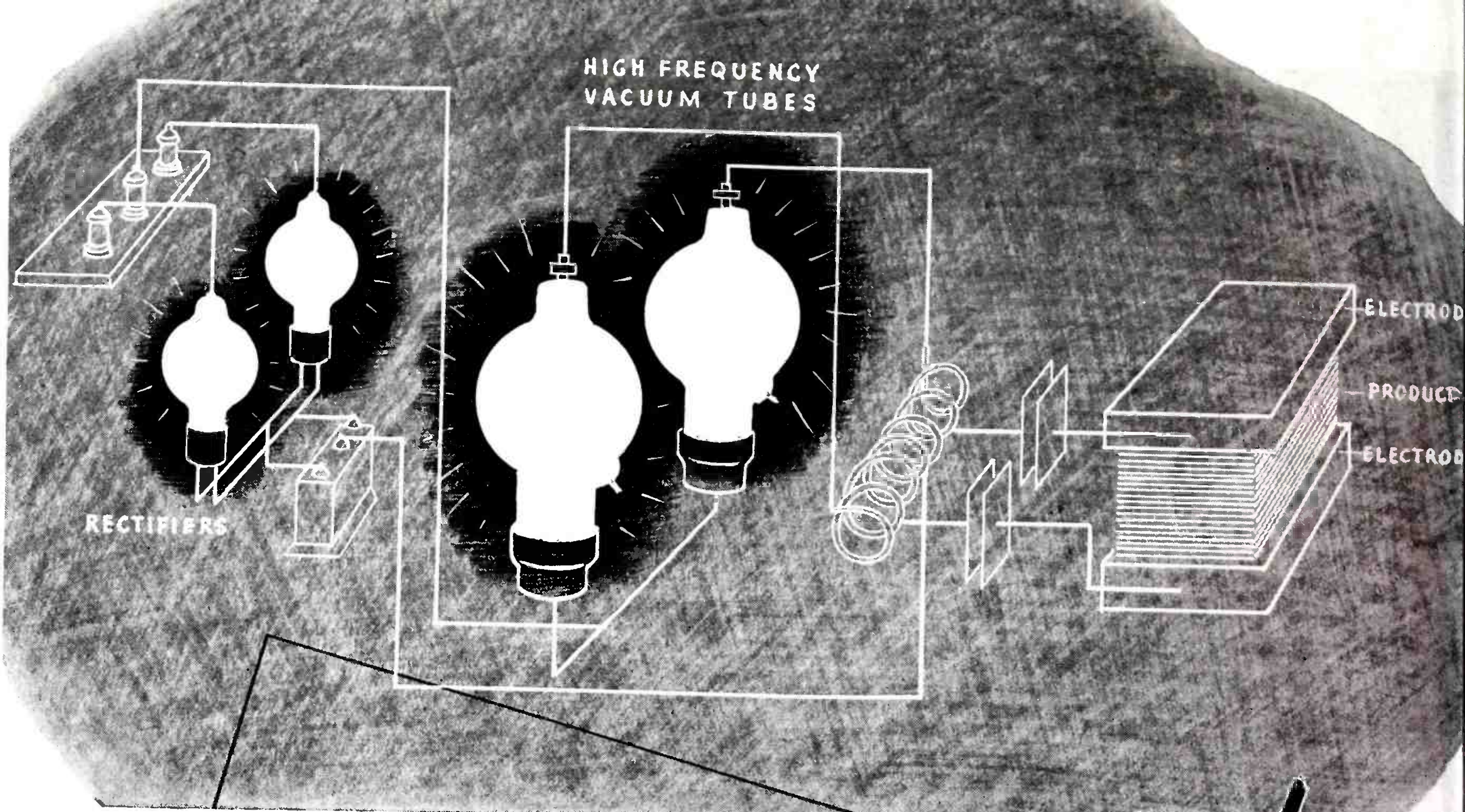

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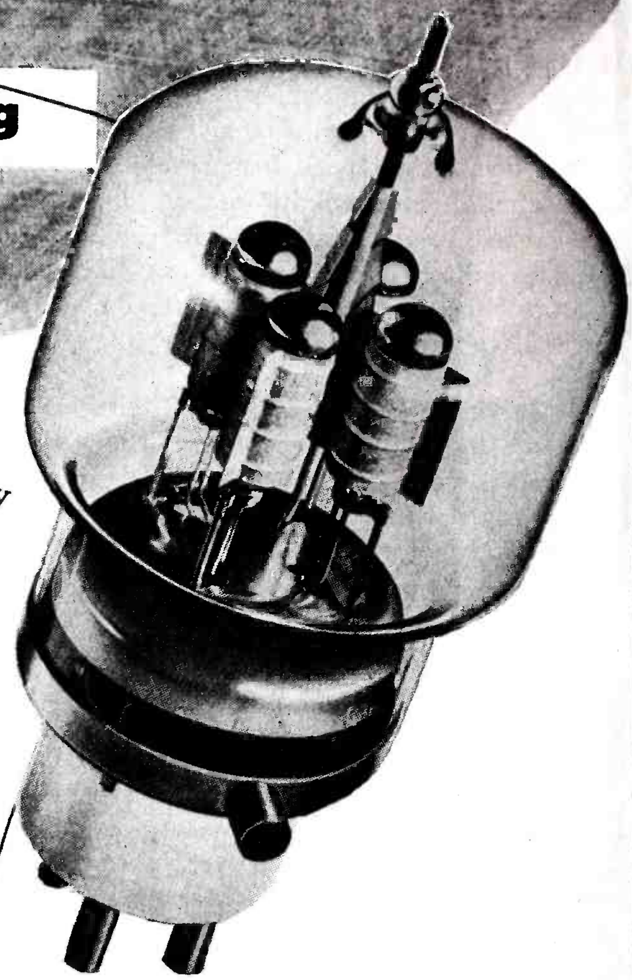

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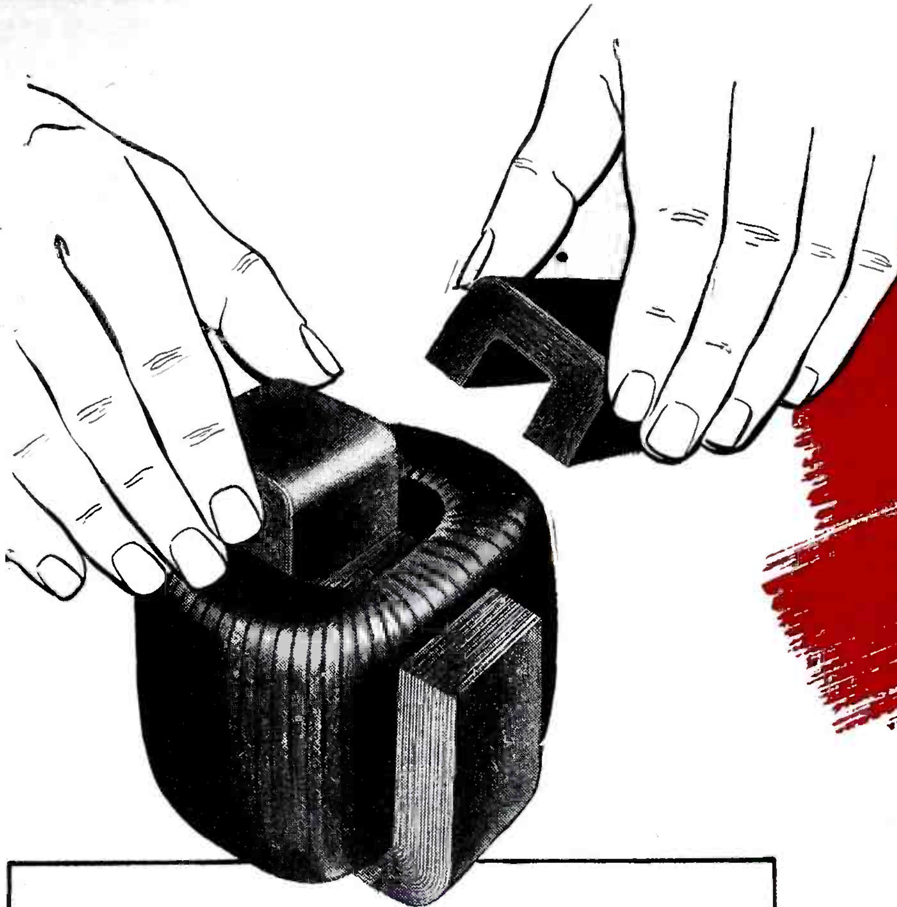

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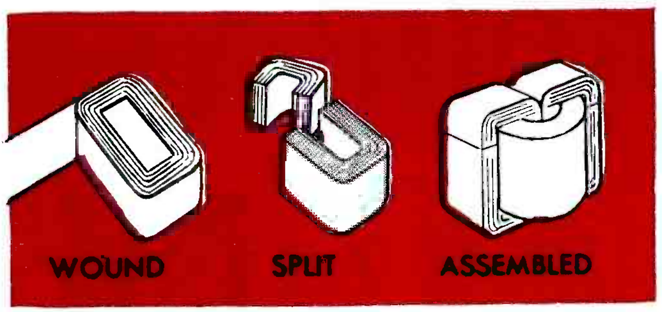

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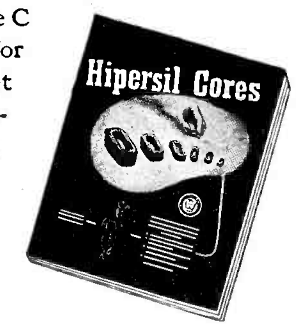

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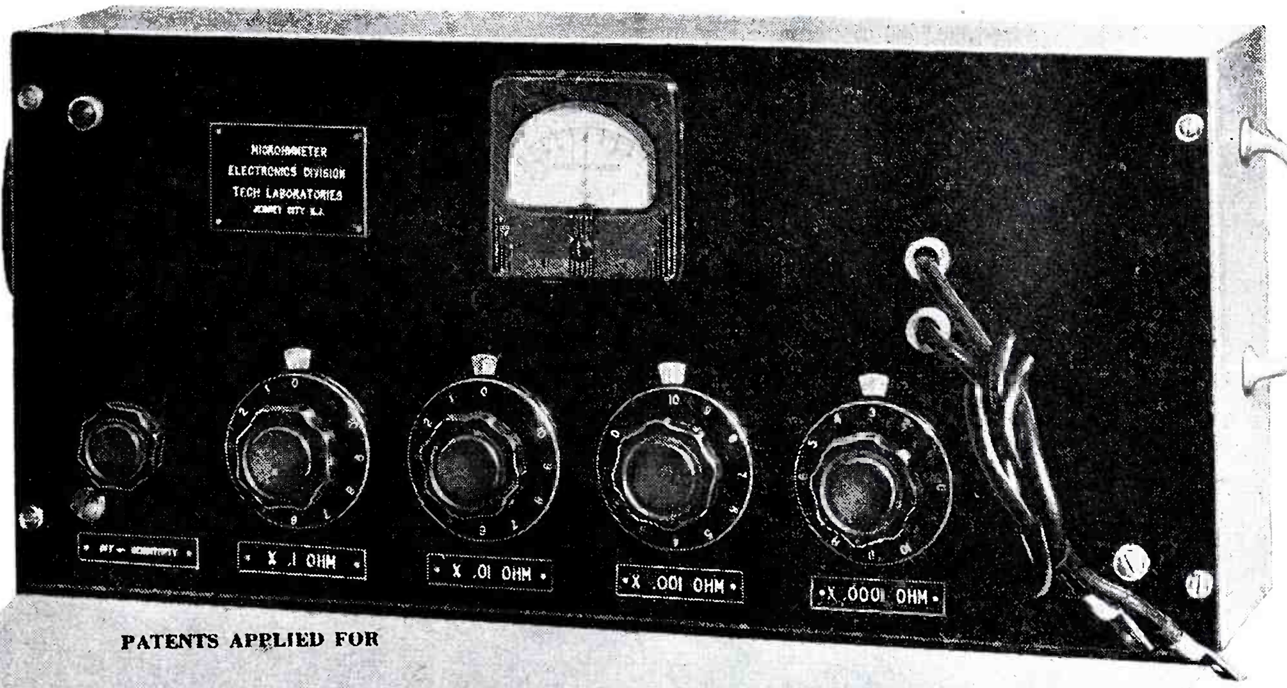

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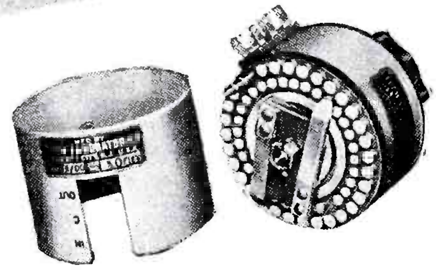

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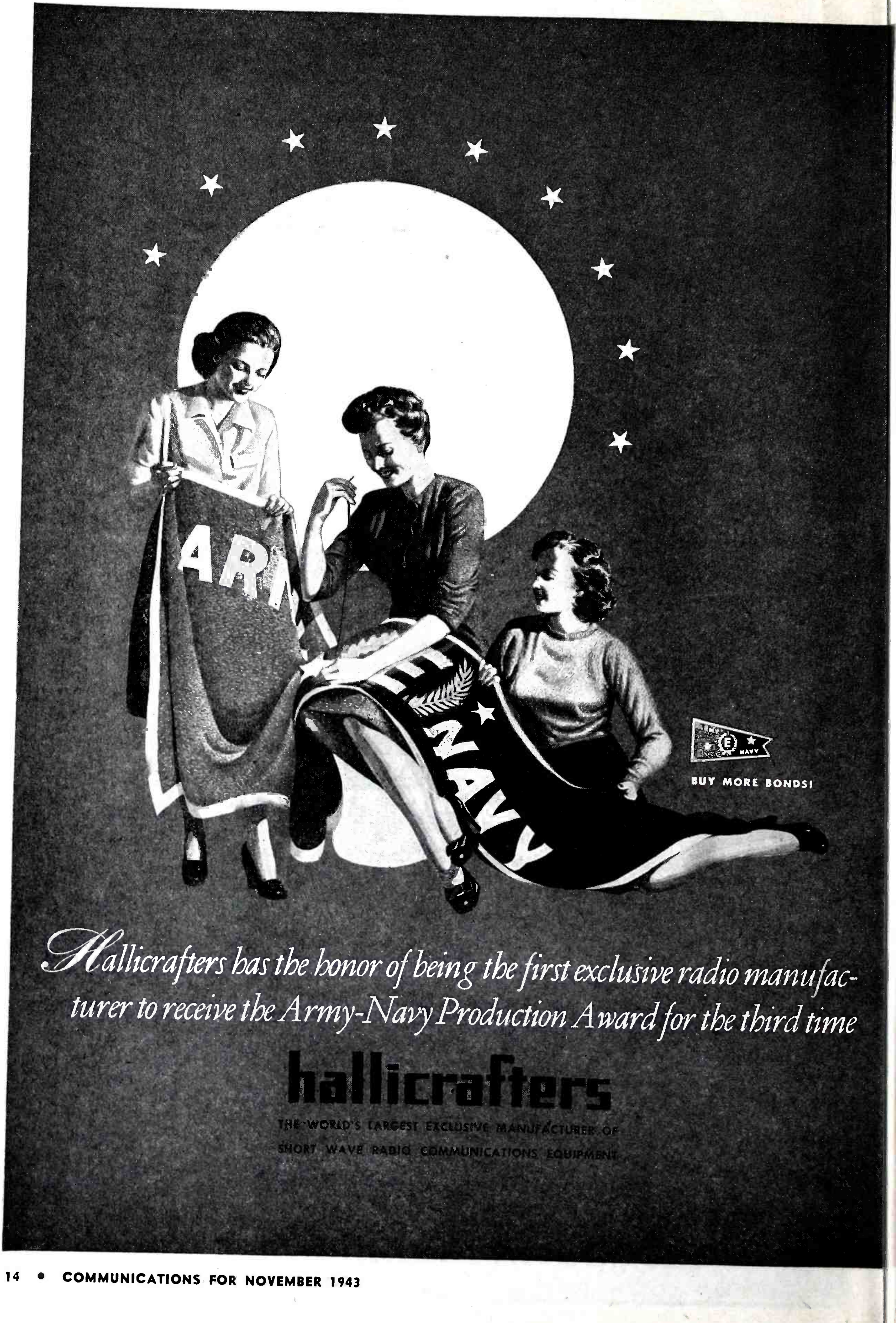
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COMMUNICATIONS

LEWIS WINNER, Editor

* * NOVEMBER, 1943 * *

THE DEVELOPMENT OF THE PUSH-PULL SYSTEM

Simple, But Vital Tool Of The Communications Engineer Involved Over Forty Years of Research and Experimenting

by DONALD McNICOL

PAST PRESIDENT, I R E

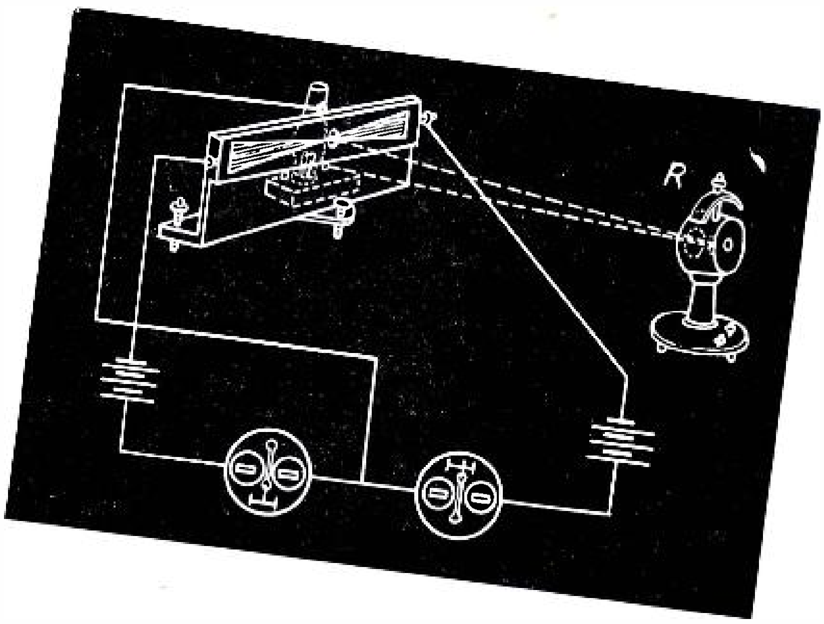


Figure 1
Muirhead's push-pull development of 1881. When the moving light beam from the mirror of the receiving galvanometer swings too far to the right or left the effect upon the respective selenium cells is such that one or the other relay, through its local contacts, will apply a reversal of battery to line or *discharge* the line to earth.

RADIO engineers have an understanding of the very great contribution made to radio by the *push-pull* circuit. And its usefulness to long-distance wire telephony and talking pictures, is respected, too. But only those engineers and experimenters who nursed and coaxed earlier amplifier hookups have an approximately close estimate of the virtue, the beneficence of push-pull when ultimately it flowered. I say ultimately, because like the rose that wasted its sweetness on the desert air, push-pull was *born to blush unseen* for many a year.

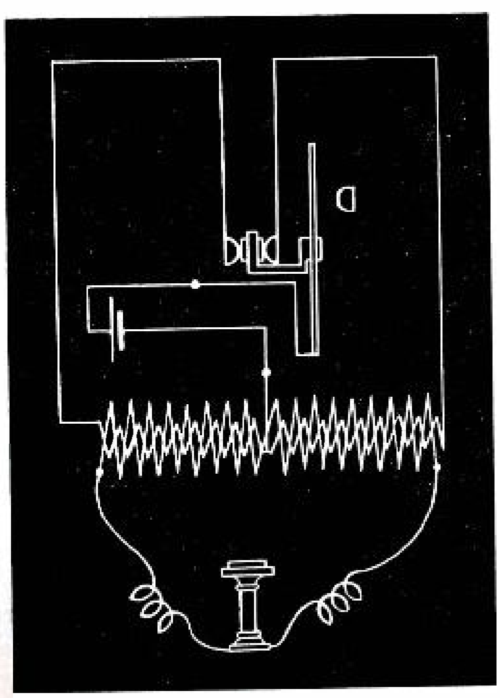


Figure 2
This inventor availed of a double-microphone to actuate the split primary to obtain a push-pull effect.

What push-pull means to radio is somewhat of the order of what the lever means in mechanics. When, in 1240 B. C. the Greek, Daedalus, puckered his brows and gazed thoughtfully at a huge stone which he desired to have shifted elsewhere, he was aware that neither he nor any other man could budge the boulder from its position of rest. His single strength was not equal to the task. But Daedalus got an idea. He conceived an invention. A smaller stone was placed close to the large one to serve as a fulcrum for a lever. The man's *pull* downward on the outer end of the lever caused the end of the lever placed underneath the large rock to *push*. The single strength of the individual, Daedalus, was thereby magnified, amplified. It was not until 1670 that Newton proved the laws of gravitation. In Ovid's Metamorphoses, it was therefore apropos to say.

> "And Daedalus was puzzled how to find
> The secret ways of what himself designed."

While the struggle upward to maturity and utility of push-pull was not prolonged for centuries, actually it was about forty years before the system came to full fruition that the first links in the chain of development were forged. A reason for the start being made about the year 1877, was that that year marked widespread experimental attention to the possibilities of the infant telephone. Operating current in telephony was small in quantity, as was the operating current in submarine telegraph cables. So much so that from the beginning a need was recognized for current magnifiers-amplifiers, to the end that there might be more definite and positive receiving-end currents, and operable over longer distances.

To place in position a first stepping-stone, the historian might stretch his imagination a little and note British patent 2909, issued to Thomas A. Edison on July 30, 1877, covering the invention of reproducing sounds at a distance. In the patent there is no mention of the word telephone, but in the drawings which accompany the patent there were depicted elements which shortly were to have a bearing upon telephone development. For our present purposes, reference to a Wheatstone Bridge arrangement of circuits in the Edison patent is the point of interest. This reference is brief, but viewed in retrospect it is possible that had the idea been developed fully, a discovery not at the time contemplated might have been made.

An Early Step

Bell's telephone was but two years old when D. D. Redmond, in Dublin, Ireland, poring over a published description of Bell's circuits, thought something more might be done to amplify the currents going to line. It was new territory for exploration, and it is likely that all over the world savants of the time took a fling at *trying something different* in the electrical framework of Bell's invention. Mr. Redmond went so far as to record his ideas and to make some theoretical sketches, which were communicated to *The English Mechanic and World of Science,* and published on September 6, 1878.

Redmond's scheme for amplification consisted of an oscillating beam with two arms insulated from each other and attached to separate fulcrums so that each arm introduced a variable resistance into a particular circuit, the circuits wound upon an inductorium (coil) in opposite directions, inducing opposite currents in the secondary coil, a part of the line circuit. It was a far cry from the device of Daedalus to this fulcrum and lever arrangement, employed for a quite different purpose than shifting weighty articles, but it contained elements of the early principle. Doubtless, even limited application disclosed that the amplification of currents by mechanical means brought to the surface natural difficulties which rendered the device at least troublesome. Not that this was the last to be heard of mechanical amplifiers and repeaters!

Needs of Submarine Telegraph

By the year 1881, compared to the extensive use and world-wide application of land-line telegraph and submarine telegraph cables, the telephone was still little more than a toy, even though it was a lusty, challenging toy destined to have a great future. Communication engineering problems of the day intrigued the vision and skill of the technicians identified with the companies handling the paying load of telegraph traffic, domestic and trans-ocean. Very long submarine telegraph cables had then been in operation for nearly twenty years. But they were slow in letters per minute per conductor. The scientific literature of that era discloses numerous ingenious efforts made to better the unit performance. It was a matter of *Speed up the cables* or begin the laying of a greatly increased number of submarine lines.

The next link in the chain of development which might informatively be introduced is that covered in Muirhead's British patent No. 1624, of April, 1881, for improvements in electric telegraphs. The Muirhead invention was to facilitate the reception and re-transmission of messages on long submarine cables, and employed a double-telephonic type repeater associated with the suspended coil of the cable recording receiver of that time.

Consideration here of this device is of particular interest because Muirhead broke away from restraining thought by incorporating automatic translating apparatus operated by light beams. Actually, it was noted that the currents available were of sufficient strength to operate magnetic relays instead of telephone receivers. The hook-up is illustrated schematically in Figure 1. The meat of the device is an arrangement of two selenium cell units subjected to light reflected from a mirror form of receiving galvanometer. Movement of the coil of receiver R to the right causes the relay to the right to close its local contact. Movement of the coil to the left causes the relay on the right to open its local contact, and the relay on the left to close its local contact. The device was beautifully ingenious, but all that was accomplished was the closing and opening alternately of two local relays. The light-affected cells operated independently, not cooperatively. The Muirhead device contained the germ of a far-reaching invention, but it remained for a later inventor to devise a selenium cell receiving system in which the light-affected cells acted cooperatively, and for another inventor to avail himself of the vacuum tube to accomplish in a different manner what the selenium cells accomplished.

Double Microphone Action

In the early days of the telephone, and since then, many experimenters have sat in profound contemplation of the phenomenon of the forward and backward movements of transmitter diaphragm, actuated by the sound waves of speech or song. If a half-century of time was to pass before someone thought of the device of attaching a small, light armature firmly to a diaphragm, the armature to extend into a magnetic coil, actuating electrically a circuit connected to the coil, it is understandable why as many as six years elapsed before attention was attracted to the idea of doing something with both sides of the diaphragm. The diaphragm moving forward compressed the carbon granules, or other medium thus varying the resistance of the circuit through the battery and primary winding of the transmitter induction coil. The notion that while the diaphragm was compressing the granules pocketed against one of its surfaces, it could simultaneously decompress a like pocket of granules on

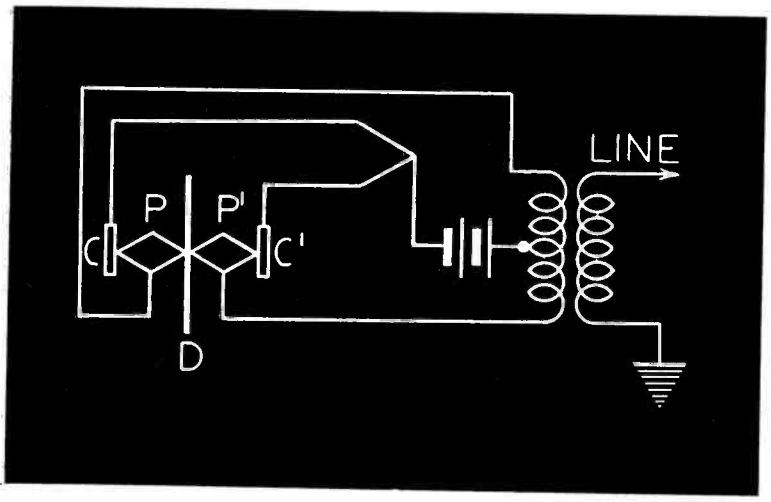


Figure 3
In this invention there is a variation in the construction of the microphone; otherwise it is much like the circuits in 2.

the other surface, in time occurred perhaps to more than one observer.

Elementary, perhaps, but we are speaking now of the thinking of comparatively primitive, of placid times. Tupper, in his *Proverbial Philosophy* reminds us: "The eye cannot make light, nor the mind spirit; therefore it is wise in man to name all novelty invention."

There was therefore at least a modicum of novelty in John Rapieff's proposal in 1882 (British patent 1020) for "An improvement in apparatus for transmitting and receiving sound." Rapieff, in his specifications refers to "Two or more groups of contacts. . . ." And further: ". . . the added or double effect of the changes of the microphone's contacts, pressure and resistance will produce a differential action of the current on the primary coil, and consequently will effect a greatly intensified variation of the magnetization of the iron core and the induced currents in the secondary winding of the induction coil." There is little of public record to show whether or not actual service use was made of Rapieff's invention. We may however conclude from what is recorded with respect to other and later proposals based upon the same idea, that the distortions introduced would have rendered talking circuits so burdened, as disturbing as a tempest.

Possibly, though, had Rapieff been in position to associate himself with Edison, Redmond and Muirhead, in this undertaking, progress along the line of development, we are discussing, might have been accelerated. Sir John Hawkshaw, president of the British Association, said, in 1885, "Many a patient investigator has puzzled his brain in trying to solve a problem which had yielded to a more fortunate laborer in the field, years before." But, until the advent of the great research laboratories, inventions recognized as being in the billion (more or less) dollar class in general, had a long ancestory, the individuals identified with them, often not on speaking terms.

Obviously, with double-button microphones it is not necessary to have a carbon button or pocket of granules in front of the diaphragm upon which the sound waves impinge. To the back of the diaphragm may be fastened an angular metallic extension so designed that a vertical element of the extension plays horizontally between two carbons, providing for simultaneous compression and de-compression of the respective variable resistance elements.

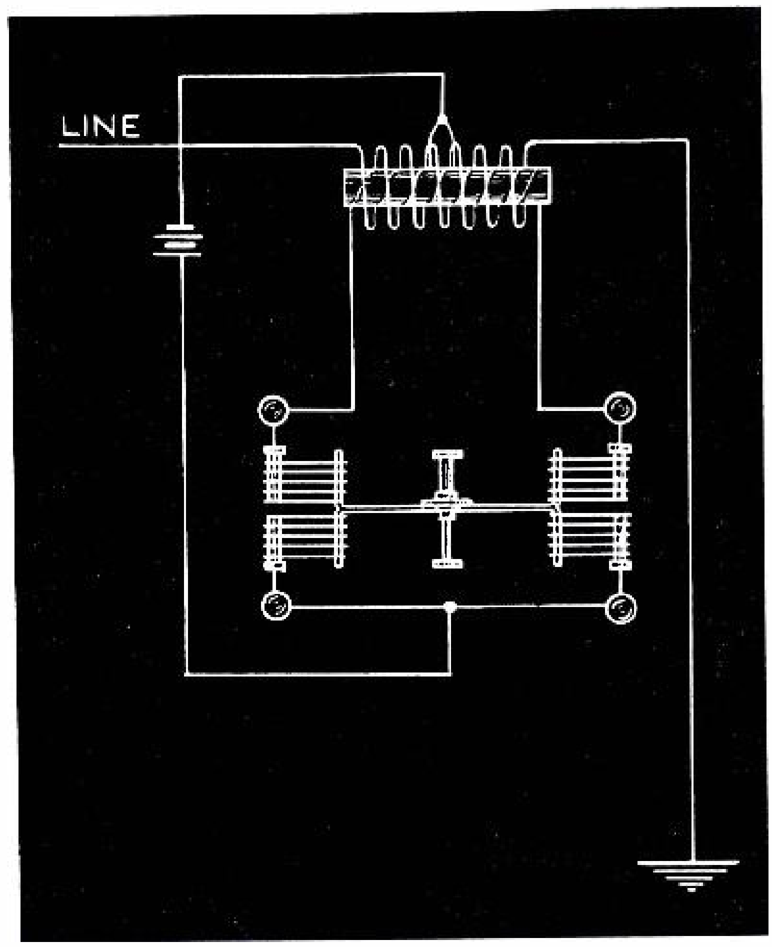


Figure 4
This system employs multiple contacts actuated by a microphone operated lever, to vary the resistances of the arms of the primary.

A Link from Germany

In Germany, von Laffert and Bautzen were granted patent 25,990 on February 29, 1884, covering a microphone providing for simultaneous utilization of both sides of the diaphragm, and the use of two primary coils both of which induced current in a common secondary winding. Thus when the current in one primary coil was increased, and the current in the other primary winding decreased, simultaneously, the two induced currents produced by the two in the secondary were added to each other. Figure 2 presents a schematic sketch of the assembly. It is possible in this development that the diaphragm extension could have been made light enough not to introduce too much inertia-sluggishness. But the telephone art was still young and there was as yet much to be done with other elements of a successful telephone system before the distortions introduced by unpredictable variable resistances could be tolerated.

Back to the United States

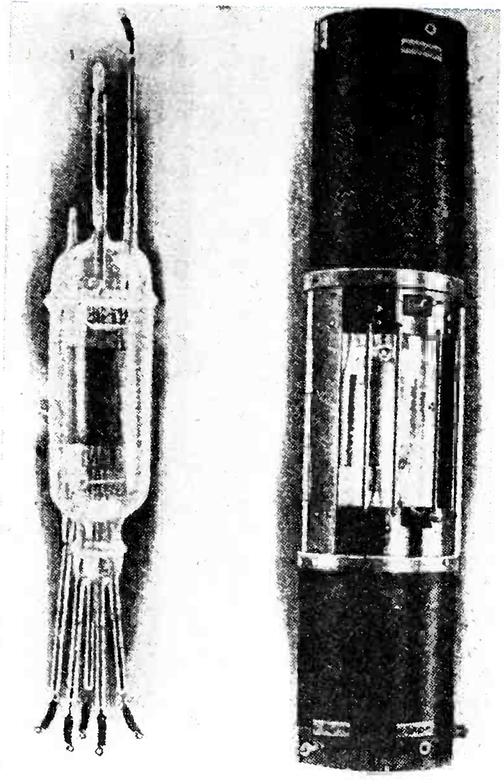
At about the same time that the attempt at amplification, referred to in the foregoing, was announced in Germany, C. D. Haskins took out U. S. patent 286,923, covering an almost identical microphone arrangement.

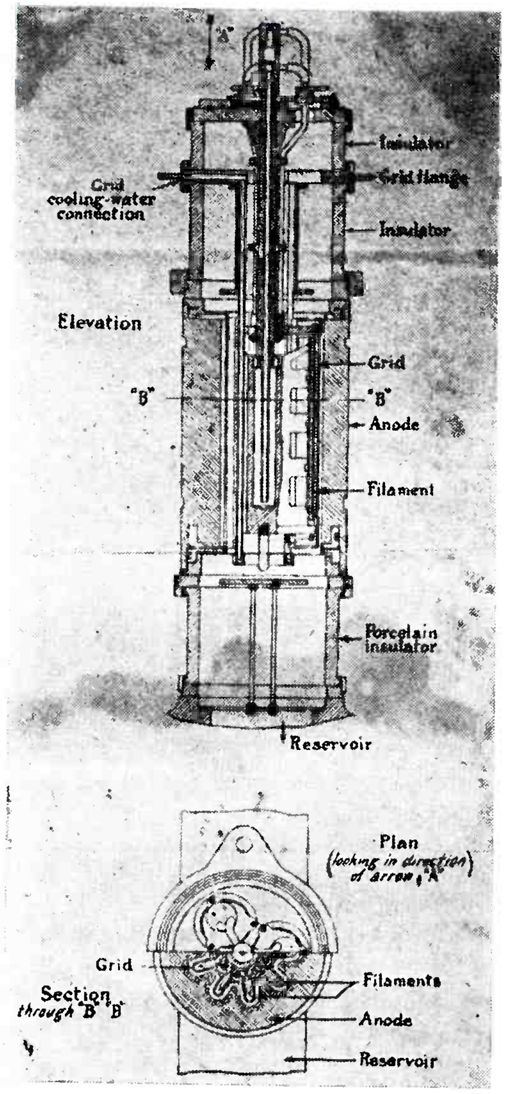
At the time the Haskins' patent was taken out telephone lines were operated as single wire, grounded circuits. The telephone transmitter most widely used was that invented by Francis Blake in 1878; a block of carbon and a metal diaphragm between which was mounted a small platinum electrode, the output induction-coil having a single primary and a single secondary winding. Haskins' offering, Figure 3, refers to two carbon blocks, C, C′, two platinum contacts P, P′ and a single diaphragm, a carbon block and a platinum contact on each side of the diaphragm.

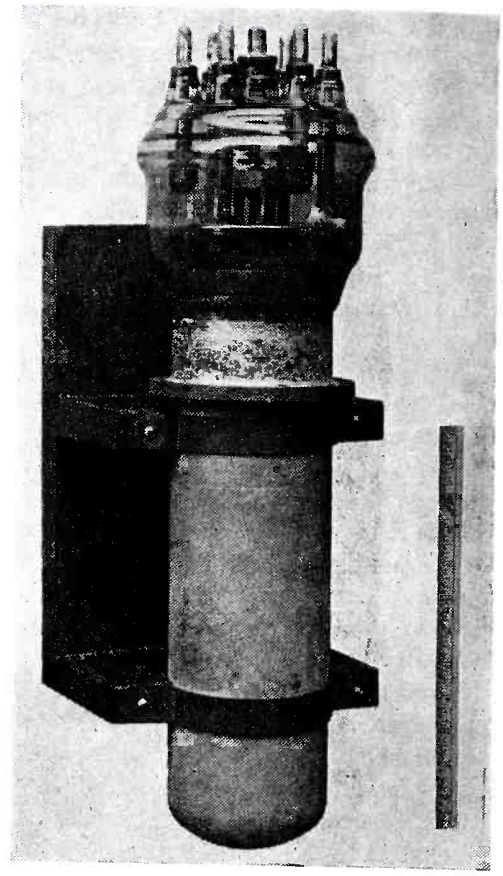
It will be noted that this is identical with the von Laffert scheme, and as Haskins' claims coincide with those of the German inventor they may be quoted here: ". . . the effective current of the differential will be in reversals, and consequently the induced voice-currents in the main line will be in *reversals* corresponding to the differential of the current in the two branches of the primary coil . . . while heretofore the current has been sent through the primary coil in one direction or in reversals." It is of importance to keep in mind the physical appearance of these early split-primary arrangements. The circuit will bob up again, later. Communication students will have in mind the words *amplifier*, and *magnifier*, but inasmuch as the von Laffert and Haskins inventions had to do with telephone transmitters, the word *booster* may also come to mind. Recalling that the Blake transmitter was a very sensitive and critical device, fairly stable when points were accurately adjusted, the fact that it required frequent adjustment suggests why Haskins could say nothing more encouraging for his double-button arrangement of the Blake transmitter

(*Continued on page* 110)

A REPORT ON THE







Figures 1 (left), 2 (center), and 3 (above)

Figure 1 illustrates a British silica type tube, without a holder, and in the holder. This was one of the earliest types of demountable high-power tubes adopted by the British Navy. Figure 2 shows an assembly of a 500-kw demountable tube. In Figure 3 appears the Westinghouse WL-895 tube with a rating of 100 kw. Incidentally, 12 tubes of this type are used in the well-known tin reflowing project developed at Westinghouse.

THE fifteenth birthday of the IRE-RMA Fall Meetings in Rochester was celebrated in distinctive fashion this year at the Sagamore. For unlike last year's one-day meeting, with no technical papers, this year's session lasted two days and saw the presentation of quite a few engineering papers.

The papers presented covered such interesting subjects as transmitting and receiving tubes, capacitors, a-m and f-m i-f systems, ceramics and crystals.

Demountable and Sealed-off Tube Analysis

Dr. I. E. Mouromtseff, assistant manager of the electronics engineering department of Westinghouse at Bloomfield, New Jersey, reviewed the characteristics of demountable and sealed-off tubes. The paper prepared by Dr. Mouromtseff, H. J. Dailey and L. C. Werner covered the history of these interesting types of tubes from the days of the first World War.

In defining the demountable vacuum tube, Dr. Mouromtseff recalled the discussion of Dr. R. V. Hansford in the textbook on *The Holweck Demountable Tube Valve* by C. F. Elwell. According to this definition, it is a tube "which can be taken to pieces and repaired like an engine" at the place of use. Dr. Mouromtseff pointed out that both the demountable and sealed-off types of tubes made their appearance about 1923. However, he explained that the idea of demountable tube was originally suggested in England during the first World War, and an experimental water-cooled tube with an external copper anode was built by Hausser in Germany in 1918 and another one in Russia by Bonch-Brouevitch in 1920. Previously, he said, only 50- to 250-watt glass type tubes were available. He recalled that in historical experiments on trans-oceanic telephony in 1915 between Arlington, Virginia and the Eiffel Tower, Paris, several hundred 50-watt tubes were used in parallel.

The need for tubes with higher outputs became evident in America soon after the introduction of long distance communication and broadcasting. It was, of course, impossible, said Dr. Mouromtseff, to follow the early pattern. It became necessary, he said, to design and construct tubes with external copper anodes suitably cooled.

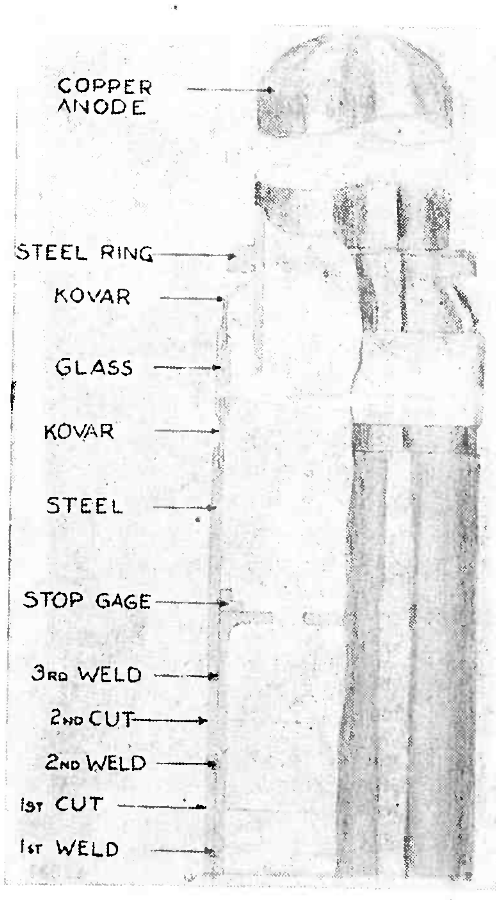


Figure 4
A semi-demountable tube construction design, using the metal, kovar.

ROCHESTER FALL MEETING

Highlights of Papers Presented By Mouromtseff, Parker, Floyd, Jones, Gray and Maynard

by LEWIS WINNER
Editor

But, he explained, it was not until 1922 that the art of making reliable joints between copper anodes and glass bulbs providing support and insulation to the grid and filament, was discovered.

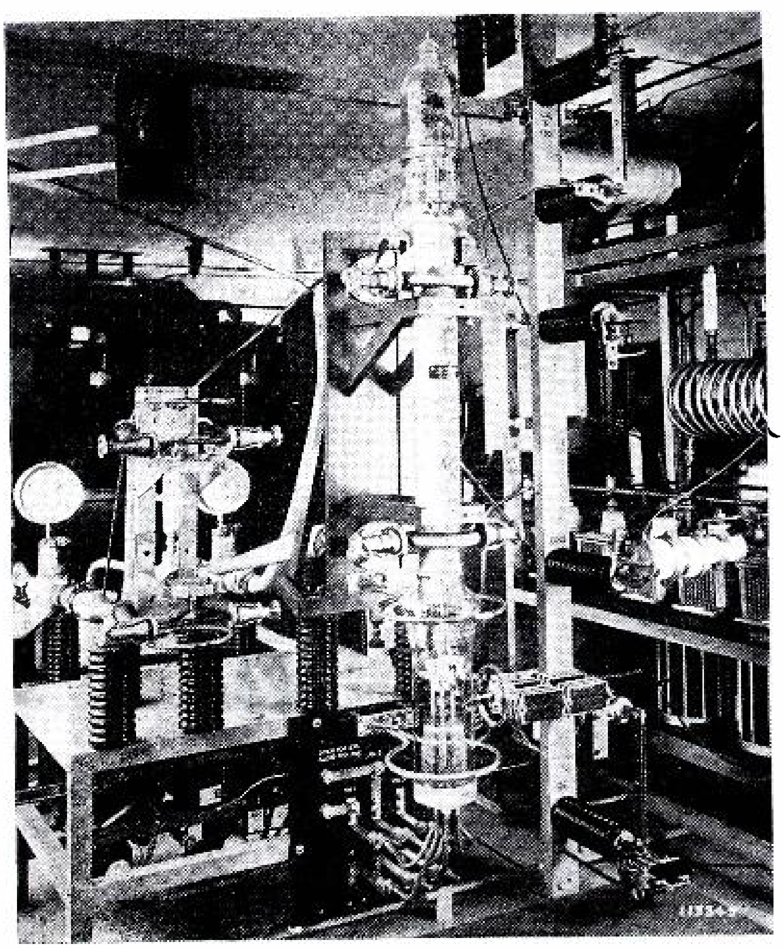
The British Navy adopted the design of *silica valves* having up to 20-kw power in an effort to solve the high output tube problem, said Dr. Mouromtseff. In describing these tubes, he pointed out that the cylindrical envelopes and hemi-spherical end portions of these tubes were made of a pure quartz and sealed together. With the aid of molybdenum rods sealed through the quartz walls, up to 100 amperes of current could be carried.

To avoid the problem of glass and metal sealing, Professor Holweck in France in 1923, designed a demountable water-cooled tube assembled from pieces of rugged metal and glass (or quartz) with rubber gasket joints, said Dr. Mouromtseff. This interesting demountable tube, explained Dr. Mouromtseff, was adopted by the French Navy, who in 1927 installed approximately 80 transmitters with 10-kw tubes of this type.

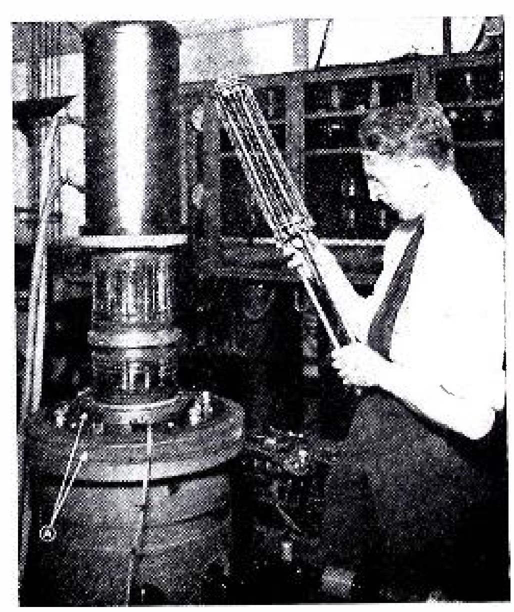
In 1929 both Westinghouse and General Electric presented the first two large tube types of the sealed-off type. And in the 1930's, explained Dr. Mouromtseff, these tubes were followed by a number of others with outputs ranging from 100 to 350 kw. Incidentally, said Dr. Mouromtseff, one notices that all tubes with more than 100-kw output except for the recent Western Electric 320A, are of foreign make. This is due to the fact that the FCC has limited the carrier output of broadcast transmitters in this country to 50 kw. Of course, said Dr. Mouromtseff, this can easily be taken care of by two tubes in push-pull with 100-kw maximum rating per tube. The need for propaganda in Europe prompted the design and production of the larger tubes made over there, explained Dr. Mouromtseff.

Although the sealed-off type of tube has grown in popularity, demountable tube construction has not been abandoned, pointed out Dr. Mouromtseff. In England a 500-kw demountable tube was developed by the Metropolitan-Vickers Company. It owes its success to the development of a novel oil condensation pump developed by Mr. Burch of the Metropolitan-Vickers Company. Incidentally, said Dr. Mouromtseff, the oil condensation pump which has been improved in this country by Dr. Hickman of the Eastman Kodak Company, is gradually replacing the old mercury pump.

In this country most of the prob-



Figures 5 (right) and 6 (left)
In Figure 5, we have a close-up view of a General Electric developmental demountable pliotron of 100-kw size. Note the demountable filament assembly held by engineer at right. This is one of the tubes mentioned by O. W. Pike in his comments, at the conclusion of Dr. Mouromtseff's paper. In Figure 6, we see a conditioning and test position at the Western Electric tube shop, with a 320A tube (the tube discussed by H. E. Mendenhall during the comment session on Dr. Mouromtseff's paper) being oscillated at 20,000 volts and approximately 375 kw input. This, of course, was a demountable tube and one of the first high-power types made in this country.



lems of broadcasting and long distance communication have been solved by the use of sealed-off tubes, according to Dr. Mouromtseff. He showed that the WLW station in Cincinnati, for some time, operated in an experimental fashion with transmitters having a 500-kw carrier or 2,000-kw peak output using simultaneous energizing of the antenna by three power amplifiers in series, each amplifier using four 862 tubes in push-pull arrangement.

According to Dr. Mouromtseff, British and American specialists believe however that demountable tubes with much lower outputs of 100 or 50 kw will be useful at u-h-f for television and f-m, operating at or about 60 mc. He explained that for suppression of parasitics, the screen grid tubes should behave better as power amplifiers, than triodes. Thus, he said, the demountable tube is better adapted to multi-electrode design than the sealed-off tube.

Demountable Tube Advantages

The *unlimited life* appears to be the main advantage claimed by designers of demountable tubes, explained Dr. Mouromtseff. When a filament in a sealed-off tube burns out, its life is at an end, pointed out Dr. Mouromtseff. But in a demountable tube, the burned-out strand can be replaced. In addition, demountable tube proponents also claim that these tubes can be overloaded about 50 percent, without fatally damaging the tube. Of course, said Dr. Mouromtseff, there are disadvantages too. For instance, there is the initial cost of the equipment for the demountable tube. In addition, he said, replacing a filament strand really means taking out the tube and allowing it to cool off before it can be repaired. This means, he explained, the loss of some hours. Auxiliary equipment, of course, is also required to make the repair. In the Metropolitan-Vickers tube for instance, he said, hydraulic jacks must be used. The pump system is, of course, the most serious objection to demountable tubes, explained Dr. Mouromtseff.

A semi-demountable type of tube using the metal, *kovar,* which was invented some 15 years ago, holds great promise according to Dr. Mouromtseff. With the aid of this metal, seam-welding is possible. With this type of tube, the burned out filament can be opened at the factory by accurately cutting away the welded portion and closing the tube again without subjecting it to high heat and hazards of glass blowing fires, pointed out Dr. Mouromtseff. In this way, it is entirely possible that we may have a semi-demountable tube that possesses the one good point claimed for demountable tubes, that of long life.

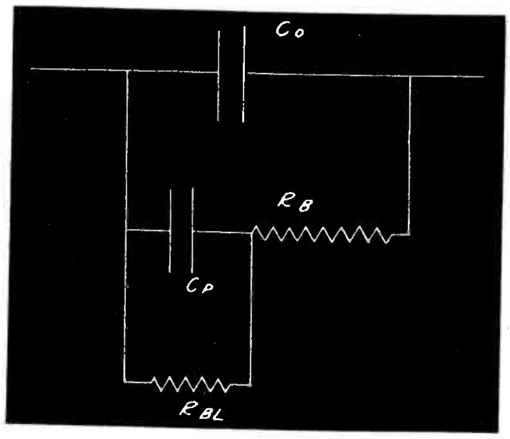
Pike's Comments on Demountable Tubes

At the conclusion of Dr. Mouromtseff's talk, O. W. Pike of General Electric commented on the work of his company with demountable tubes in international broadcasting. Power for the equipment was supplied by two developmental gaseous rectifiers.

The installation included two demountable tubes operating in push-pull on an international broadcast frequency of approximately 9,000 kc, he said. The plate voltage was 7,500 and the plate dissipation, 150-kw per tube. The filament was overwound tungsten coated with thoria oxide and was of the 3-phase replaceable variety. The useful output from the tubes was 75-kw carrier.

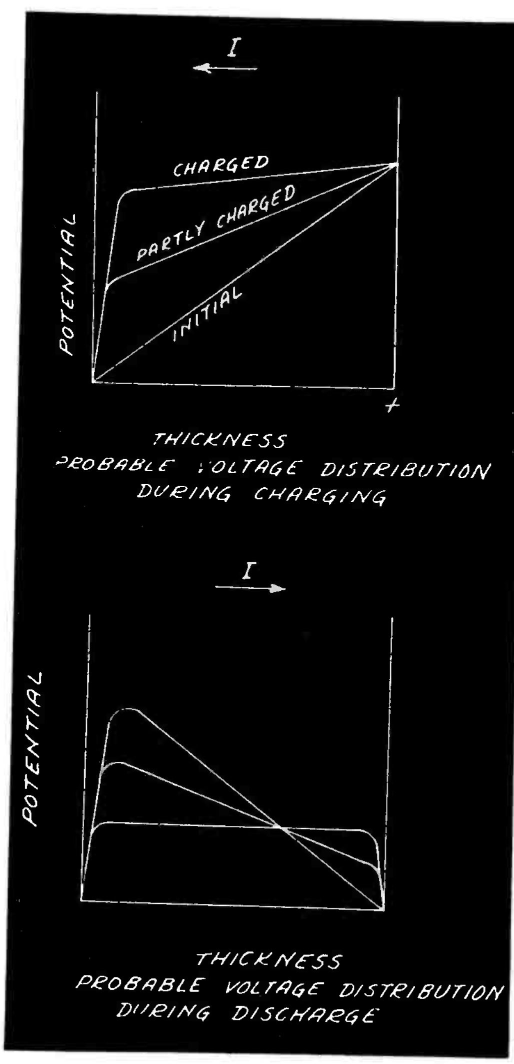
The vacuum was obtained from specially designed Apiezon oil diffusion pumps mounted in the base of the tube with an integral carbon trap.

The installation was operated for several months but was finally superseded by equipment using four GL-880 tubes, plate modulated and giving 100-kw output. In general the operation of the tubes was considered rather encouraging and the development could form the basis for further work on high-vacuum demountable tubes, although at the particular power and frequency of this installation, the 880's are more economical, he concluded.



Figures 7 (top) and 8 (below)

In Figure 7 appears a schematic circuit for polarized dielectric discussed by R. B. Gray in his paper on ceramics. Figure 8 illustrates the voltage distribution of a polarized dielectric. (See opposite page for discussion.)



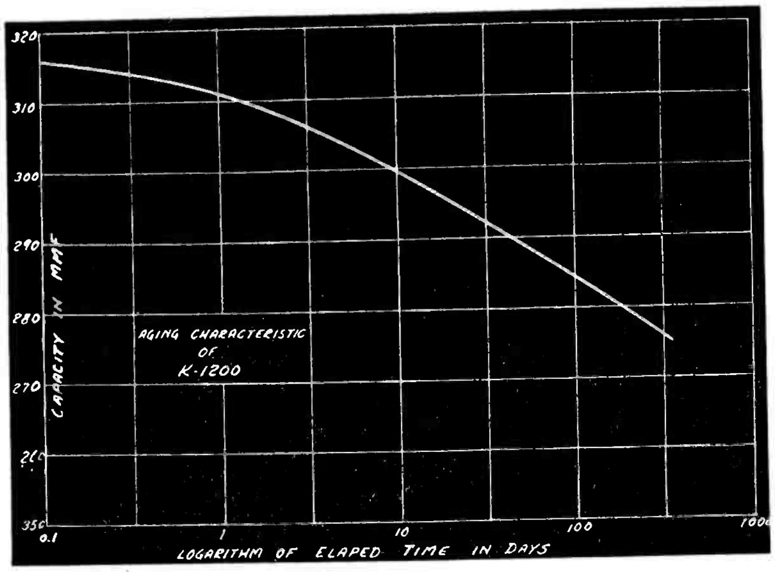
Mendenhall's Discussion

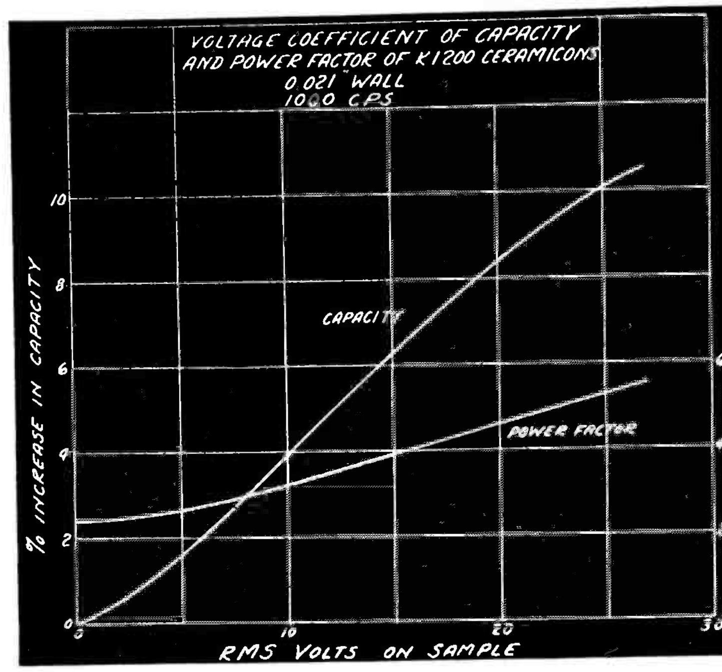
Interesting data on demountable tubes were also presented in the comment session, by M. E. Mendenhall of Bell Labs. Mr. Mendenhall said that over five years ago when there were still prospects of using higher power than 50 kw, some experience was obtained on a demountable tube. After development work was completed on a 250-kw tube to be manufactured by Western Electric as the 320A, he said, the English and French work on demountable continuously pumped tubes was reviewed.

In the light of some experience with eight 320A vacuum tubes operated in a Mexican station before the Havana Treaty, it was hoped some station in this country could be interested in trying a demountable tube installation which would operate in conjunction with their standard equipment. It was visualized, he pointed out, that the standard sealed-off tube complement would be used for relatively short intervals to carry the program during the times required for maintenance of the demountable tubes, such as filament replacement, exhaust and high voltage conditioning.

Three-phase filament power of approximately 40 kw and sufficient anode cooling area to dissipate 500 kw was built into a giant ten-foot model. Following Dr. I. E. Mouromtseff's experience at Westinghouse with the AW-220 tube, said Mr. Mendenhall, a water-cooled grid was incorporated into its design.

With the growing appreciation for the need of higher radio frequency powers for certain heating application mentioned by Dr. Mouromtseff, it seems certain, pointed out Mr. Mendenhall, that demountable tubes will





Figures 9 (above) and 10 (right)
These curves are explained in the review of Mr. Gray's paper below.

enter the electronic tube picture in this country as well as in England where we believe they have been used successfully for several years.

Gray's Paper on Ceramic Dielectrics

FEW materials have so intrigued radio engineers as ceramics, particularly those with high dielectric constants. It was with keen interest, therefore, that everyone listened to R. B. Gray's paper on *Operating Characteristics of Ceramic Dielectrics with Constants Over 1,000.*

Mr. Gray, who is a physicist with the Erie Resistor Corporation, pointed out that the highest dielectric constant material that had been known, including metals, was rochelle salt. This has a dielectric constant of 800. Ceramic dielectrics which are a little over two years old have, however, a much higher constant in certain cases, explained Mr. Gray. These materials are crystalline and generally have a crystal transformation in their active temperature range. During this crystal transformation, the structure is collapsing into a smaller volume resulting in a dielectric constant peak. The insulator materials which have constants of just over a thousand at room temperature, explained Mr. Gray, can be greatly increased in dielectric constant, converting them into semi-conductors so that they have a polarized layer. This results in a very greatly increased capacity and dissipation factor at low frequencies.

A dielectric may be represented by the schematic circuit shown in Figure 7, except that the relaxation time requires that the resistance R_B consist of a great many parallel resistances of different values so that the relaxation time of the dielectric will be spread out over a much wider frequency band. The voltage distribution of such a polarized dielectric is, in effect, shown in Figure 8. Mr. Gray explained that when the voltage is first applied, the voltage distribution will be substantially linear across the sample, but the body conductivity will result in the appearance of a virtual plate very close to the negative plate. At the same time, he said, the resistivity of this small region is increased. The result is a non-linear distribution of voltage so that the discharge will form polarized layers on the other plate and trap charge in the dielectric. If the conditions at one plate are not the same as that at the other, he explained, the sample will appear to have more or less permanent electric charge.

The materials are non-linear in their response to the applied voltage as a result of this. The capacity will apparently increase as the voltage is increased.

Another effect which changes the capacity of these materials, he explained, is the result of the crystal transformation which occurs above room temperature in the higher members. This apparently continues for extremely long times in an attempt to reach equilibrium, pointed out Mr. Gray. Figure 9 shows the decrease in capacity over a period of a year. This aging is not a moisture effect since the same curves are obtained either in a dessicator or in atmospheric air at an average of 75% to 80%, relative humidity air.

While the materials themselves are at least partially soluble in water, concluded Mr. Gray, they can be fairly well protected from the effects of humidity by the standard methods used for other ceramic condensers.

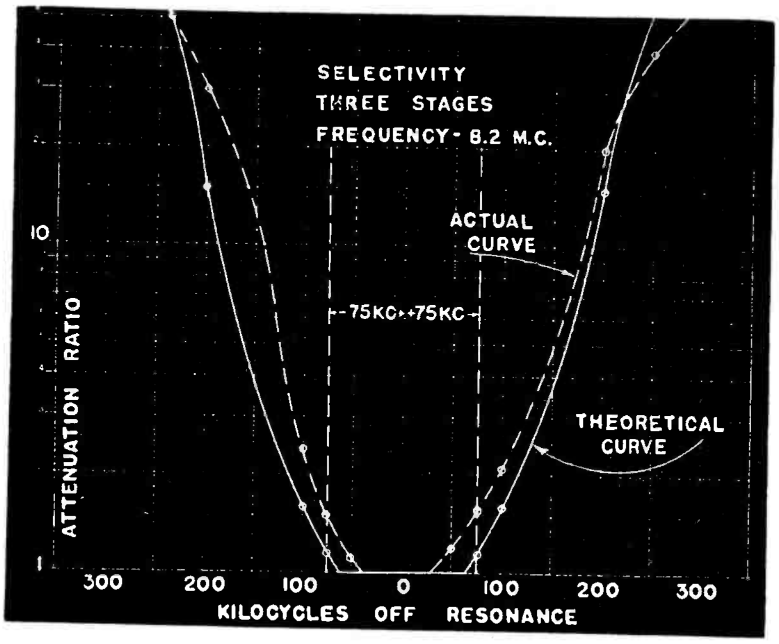
I-F Transformers for F-M

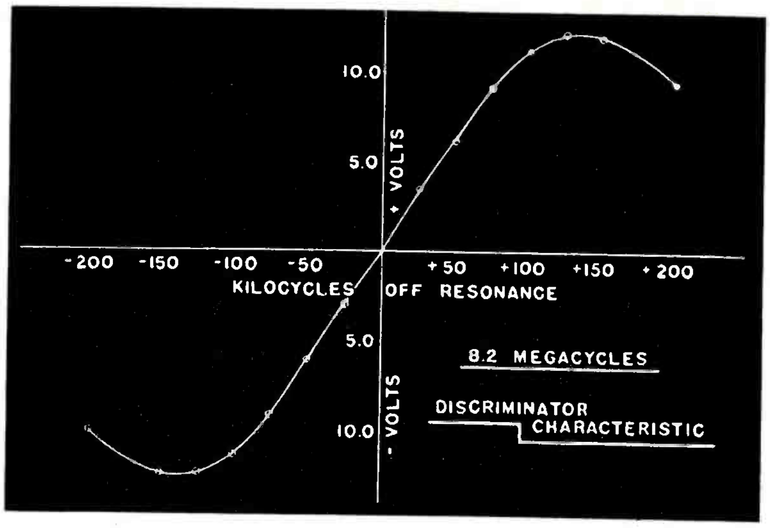
LIMITER and wide band features, characteristics of f-m receivers, require that the i-f system receive careful design consideration. With present limiters approximately five times as sensitive as earlier types and present day f-m transmitters providing a frequency deviation of plus or minus 75 kc, the i-f amplifier must possess design features that will accommodate these provisions. In a paper on *The Design of I-F Transformers for F-M Receivers,* William H. Parker, Jr., project engineer of Stromberg-Carlson Company, analyzed these and other problems common to f-m receivers.

He pointed out that it has been established in practice that an attenuation of 6 db at plus and minus 75 kc from the mean i-f is acceptable. A receiver sensitivity of five micro-volts is highly desirable, he explained, from practical considerations of a field test. Accordingly, he continued, for a value of one volt at the limiter grid, a gain through the receiver of 1,000,000/5 or 200,000 will be necessary. At 50 megacycles it is possible to obtain antenna gains of *2* and r-f stage gains of *5*, providing an overall r-f gain of *10,* he explained.

Today, the f-m band covers from 42 to 50 megacycles. To eliminate image response due to f-m stations, an i-f value greater than 4 mc would be acceptable, explained Mr. Parker. But 8 mc or greater would be more desirable since it will eliminate, in addition, response from two stations separated by the i-f. In explaining this point, Mr. Parker pointed out that if the f-m band should be extended to 60 mc, the desired value of i-f would increase proportionately. Thus, he said, a band-width of 18 mc should have an i-f of at least 18 mc.

To satisfy these conditions, explained Mr. Parker, there has been a gradual upward trend in i-f choice. A frequency of 1,700 kc was used in the first experimental receivers. This had an advantage, said Mr. Parker, in that





Figures 11 (left) and 12 (above)
The Parker overall selectivity and discriminator characteristic curves analyzed in his paper on i-f transformers in f-m receivers.

the gain per stage was good and the desired selectivity could be readily obtained. Of course at that time the f-m spectrum covered only 42 to 45 mc. The wave band expansion, however, he continued, and the additional stations on the air have prompted the upward i-f trend. A frequency of 2.1 mc was used in some early receivers. Later, explained Mr. Parker, this was changed to 3.2 or 3.3 and at present many use 4.3 mc.

The introduction of the 6SC7 and 6SH7 tubes provided considerable improvement in overall stability and aided in improving the amplifiers using 4.3 mc. Mr. Parker explained that this was due to the fact that the plate-to-grid capacitance of this tube is low, and separate cathode prongs provided for the grid and plate return circuits reduces the coupling between these two circuits to a minimum.

An amplifier with an i-f of 8.2 mc is not too difficult to construct, according to Mr. Parker. And by trying several values of circuit Q and calculating the shapes of these curves from Universal Selectivity Curves, we arrive with a Q of about 45, explained Mr. Parker. The coil used for this purpose consists of a 3/8" Isolantite form on which is wound 36 enameled wire. When resonated at 8.2 mc, the Q in air is 75. However, explained Mr. Parker, loading this coil with a 47,000-ohm resistor and placing the combination in a shield can reduces the Q to approximately 45.

In Figure 11 appears the overall selectivity curve after a modulator stage has been added. The gain through this stage at the i-f is identical to that for the preceding two stages or *35,* pointed out Mr. Parker. Therefore, if we assume that conversion gain would be 1/3 of this value, the gain for this stage is approximately *12.* Accordingly, continued Mr. Parker, the overall gain for this particular amplifier is the product of *12* times *35* times *35* or *14,700,* which is somewhat below the desired gain value of 24,000. Thus, it is safe to conclude that an i-f amplifier can be constructed at 8.2 mc by using ordinary design precautions.

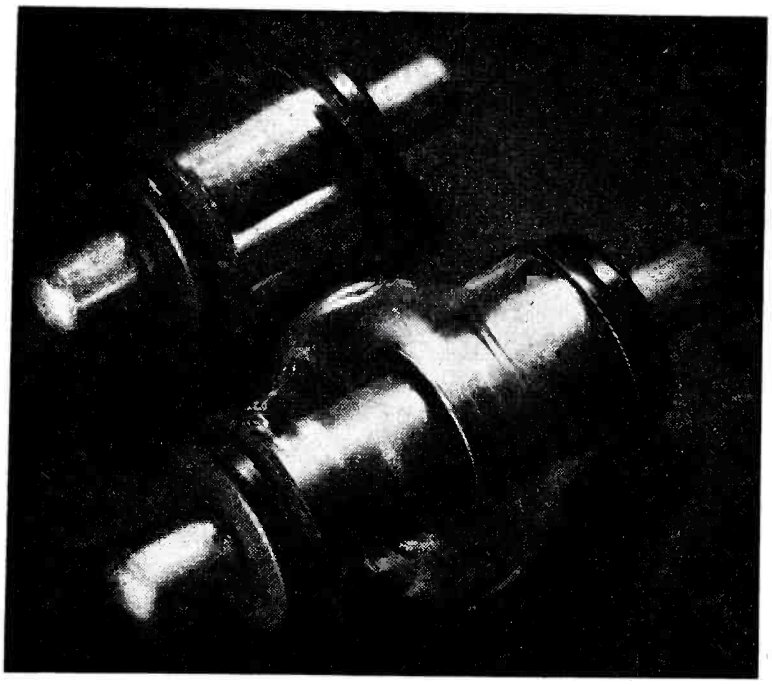
In Figure 12, appears a curve of the discriminator characteristic. This shows that good output was obtained and the characteristic is essentially linear over the operating range from plus to minus 75 kc on either side of the resonant frequency.

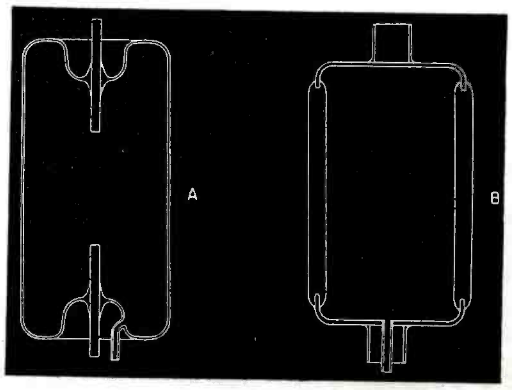
In summarizing, Mr. Parker pointed out . . . (*1*)—higher values of i-f are desirable than are now being used particularly if the present waveband is to be widened; (*2*)—a frequency of from 16 to 20 mc should afford best performance; (*3*)—an i-f amplifier at 8.2 mc is not too difficult to construct, but higher frequencies require special treatment; (*4*)—the 8.2 mc i-f channel is recommended for lower priced receivers, and 16 mc is recommended for more expensive models where more elaborate shielding can be used.

Vacuum Capacitors

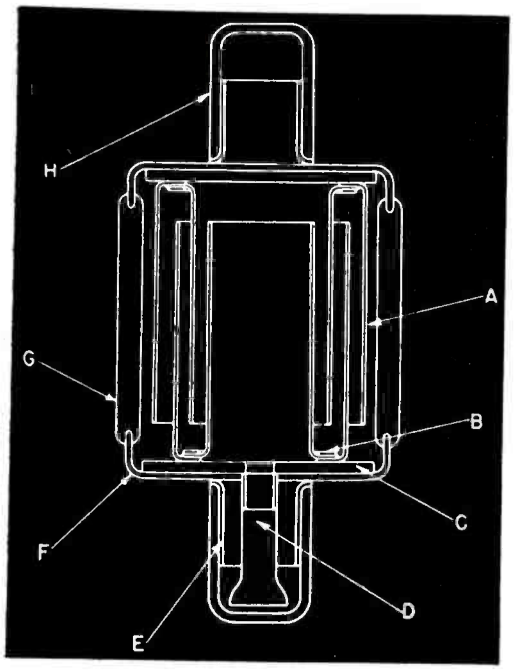
INCREASED use of communications equipment in aircraft, flying at extremely high altitudes, have required development of many unusual components. Among these we find the vacuum capacitor. This interesting unit was described by George H. Floyd of General Electric, in a paper entitled *Vacuum Capacitors.*

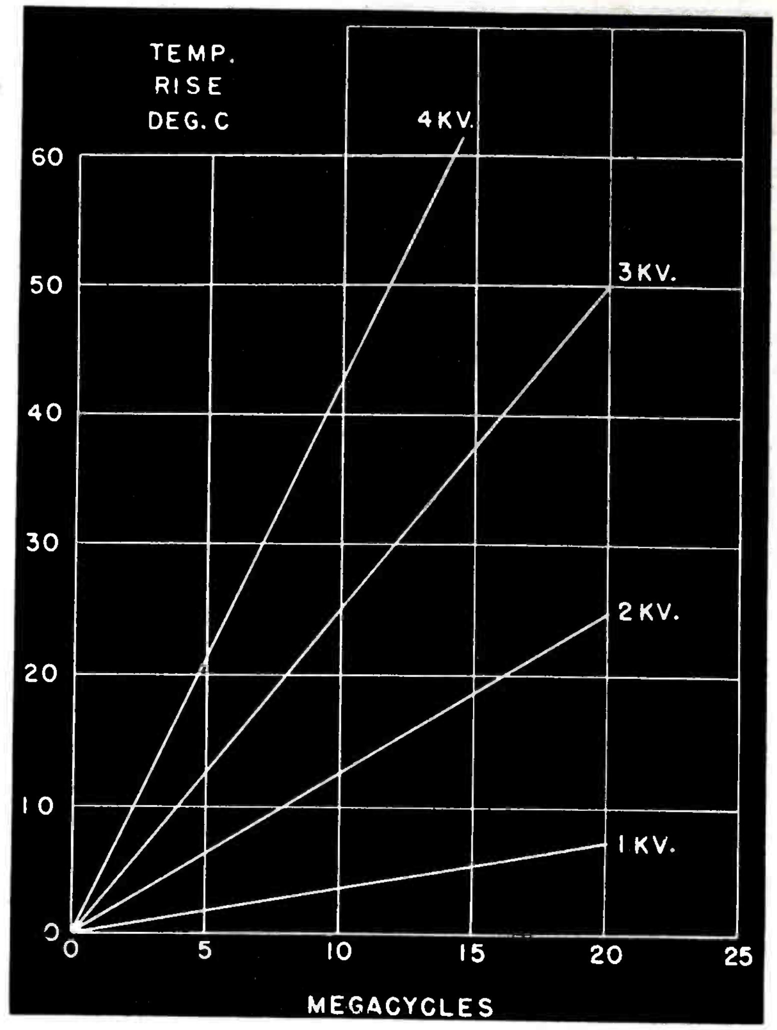
Capacitors of this type are now being produced by G. E. in sizes ranging from 25 to 100 mmfd at peak voltages of from 7,500 to 16,000. And, in many instances, these units





Figures 13 (left) and 13A (right)
In Figure 13 we have two types of vacuum capacitors developed by General Electric and described by George Floyd in his paper on vacuum capacitors. In Figure 13A are two types of evacuated envelopes used in vacuum capacitors. At *A*, a flare-to-bulb type of seal is employed, while in *B*, the fernico-to-glass, edge-type seal is used.





Figures 14 (left) and 15 (right)

In Figure 14 appears a cross-sectional view of a vacuum capacitor having a capacity of 50 mmfd. In this unit the coaxial cylinder type (A) is used. The overall length of this unit is 3 5/16" and its diameter is 1 5/8". This capacitor will have a temperature rise of 40° C when operated at 6 mc, 10 amperes root mean square current and 7.5 kv peak voltage. In Figure 15 are the results of a vacuum capacitor temperature test, showing that the temperature rise varies directly with the frequency.

are 1/10 as small as the variable capacitors of equal capacity.

There are two types of envelopes in use for these capacitors, Figure 13. In type *A* the flare-to-bulb type of seal is used and in type *B*, the fernico-to-glass, edge-type seal is employed. The first type, *A*, explained Mr. Floyd, makes use of any combination of metal and glass, whose coefficients of expansion match well enough to allow a seal to be made. The second type, *B*, uses end cups of fernico which is an alloy of iron, nickel and cobalt and a boro-silicate glass with the same expansion coefficient, said Mr. Floyd.

In Figure 14 we have a cross sectional view of a typical 50-mmfd vacuum capacitor. In this unit *A* is a coaxial cylinder. Overall length of this unit is 3 5/16" and its diameter is 1⅝".

The thickness of the coaxial cylinder is limited in one case by the strength required, explained Mr. Floyd. Cylinders which are too thin are naturally hard to mount. But on the other hand, continued Mr. Floyd, increasing the thickness of the cylinders, cuts down the spacing, decreases the voltage breakdown and increases the capacitance. In the model shown, a thickness of 0.010" was found satisfactory.

In vacuum capacitors the losses can be attributed to two sources, said Mr. Floyd. These are . . . (*1*)—resistance loss in the metallic structure and (*2*)—ionic loss to the material subjected to the high frequency field. The resistance loss at frequencies up to fifty megacycles may be considered as negligible, explained Mr. Floyd.

In Figure 15 appears results of a temperature test which shows that the temperature rise varies directly with the frequency.

In discussing voltage and current relationships, Mr. Floyd pointed out that in comparison to capacitors subject to atmospheric pressures, the breakdown voltage of a vacuum capacitor is relatively more constant throughout life. A voltage surge above the rating of the capacitor does not puncture the dielectric, continued Mr. Floyd. And the tendency is for the capacitor to clean up. Accordingly, explained Mr. Floyd, the voltage breakdown normally reverts to its original value. In operation, he said, there is no dielectric to deteriorate with time.

The vacuum capacitor diagrammed in Figure 14 will have a temperature rise of approximately 40° C when operated at 6 megacycles, 10 amperes root mean square current and 7.5 kilovolts peak voltage, said Mr. Floyd.

Humidity has no effect on the capacitance of the vacuum capacitor, pointed out Mr. Floyd. He said that since moisture can only affect the outside surface of the capacitors, high humidity may cause a slight leakage current across the outside of the capacitor.

Vibration, of course, does not affect this type of capacitor either, said Mr. Floyd. In flat-plate capacitor construction vibration does cause a displacement of the plates and consequent capacitance change which is in direct ratio to the displacement. However, in cylindrical-construction vacuum capacitors this does not occur, explained Mr. Floyd.

In concluding, Mr. Floyd pointed out that the main advantages of vacuum capacitors were . . . (*1*)—stable dielectric constant; (*2*)—stable internal voltage breakdown; (*3*)—low loss; (*4*)—ability to withstand overvoltages; (*5*)—minimum of mainte-

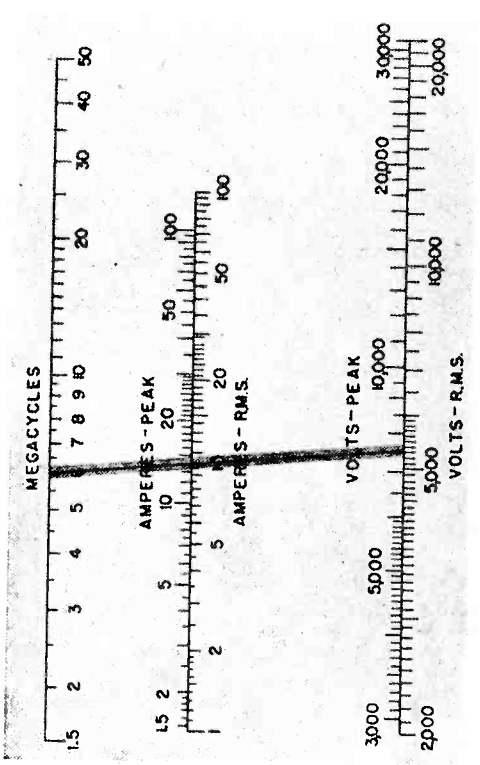
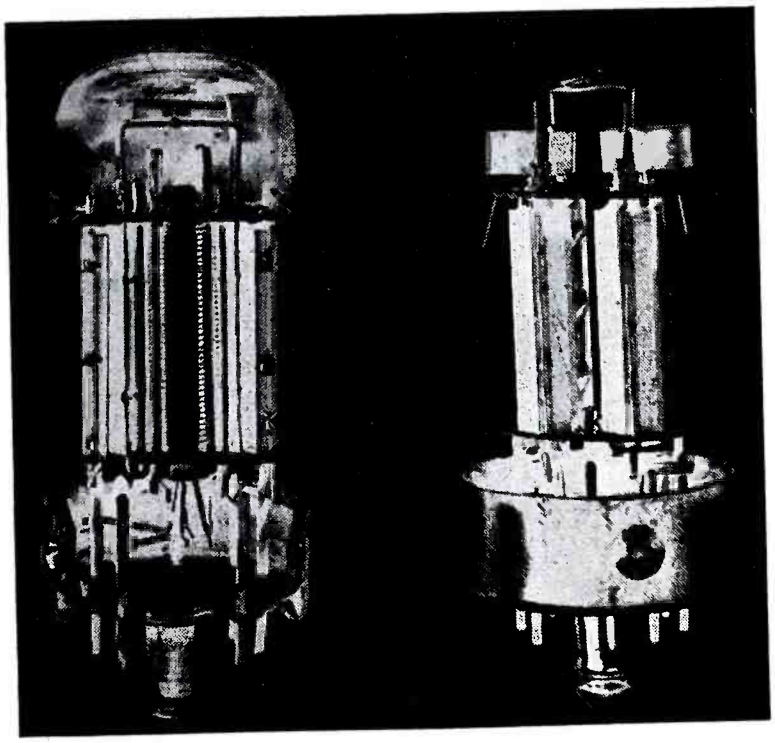
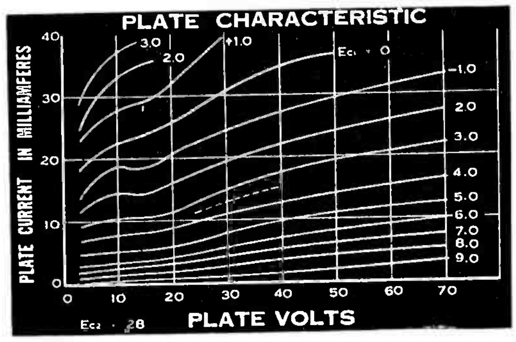


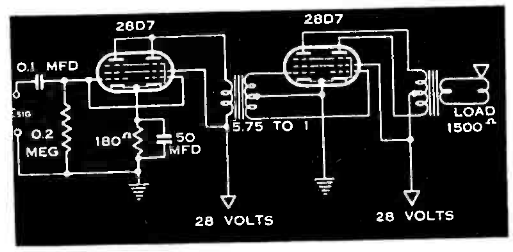
Figure 16

A nomograph for a 50-mmfd vacuum capacitor.



Figures 17 (left), 18 (upper right), and 19 (lower right)
In Figure 17 are cutaway views of the 28-volt tube, described by Walter Jones. In Figure 18 appears plate characteristics of the 28-volt tube. Figure 19 illustrates a typical transformer coupled driver, using a pair of 28-volt tubes. At .25 volt E_{sig} to the driver, the power output is 22.3 mw and the total distortion is 4.8%. When the E_{sig} drive is 1.75 volts, the power output is 600 mw and the total distortion 10.6%. Incidentally, the second harmonic distortion at this voltage input is 1% and the third harmonic is 10.5%.





nance. He also emphasized the point that these capacitors are unusually small, sturdy and interchangeable since they have been designed for plug application.

Jones' Paper on 28-Volt Tubes

AIRCRAFT communications also played a major role in the paper of Walter R. Jones, manager of the commercial engineering department of Sylvania. In a discussion on 28-volt operation of tubes, he told of the increasing use of the standard 28-volt airplane power supply for operation of radio equipment. The 28D7 double beam power tube developed by Sylvania has led to a number of interesting applications, said Mr. Jones.

This tube is operated with the plate and screen voltages obtained from a 28-volt storage battery. The operating supply voltage, during flight, varies from 27.5 to 28.5 volts and when the plane is grounded the voltage may drop to as low as 22. And, in some instances, the gasoline driven generator which may be connected to the supply source may raise the voltage to 32. However with this tube, the drop in power output is approximately 3%, with these heater voltage variations, explained Mr. Jones.

The tube consists of two beam amplifier units in the same envelope. The control grid and plate of each section are brought out to separate pins. There is a common terminal for the cathodes and for the screen grids. The heaters are connected in series internally but the cathodes are not tied to either heater terminal.

The two sections of the tube may be operated separately, connected in parallel or push-pull. Where each section is used as a single-ended amplifier, the load per section should be 4,000 ohms to insure reasonably low second and third harmonics, explained Mr. Jones. With the two sections in parallel the load is approximately half. When push-pull is used the load per section should be 3,000 ohms, for with this value the third harmonic is low and the second harmonic, although high, will cancel due to the push-pull circuit, said Mr. Jones. Accordingly, a plate-to-plate load of 6,000 ohms is necessary.

The high power output rating of this tube makes it suitable as a power supply, according to Mr. Jones. He showed that power outputs up to 725 milliwatts at medium voltages of 50 to 250 volts and output voltages of 500 to 600 for lower power requirements could be obtained by rectifying and filtering the voltage developed across a coil coupled to the tank circuit of the tube as a self-excited oscillator with only 28 volts supply.

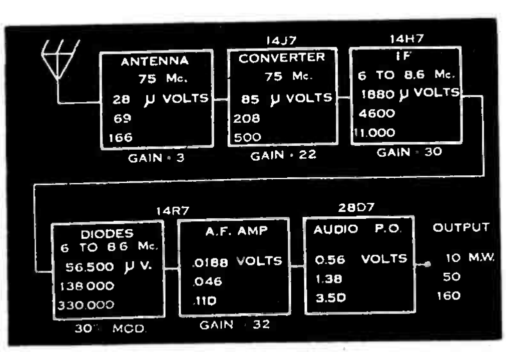
To drive the 28D7 to rated power output under low voltage conditions, a number of low mu triode tubes using resistance coupling can be used, explained Mr. Jones. Pentode tubes can be used too, he said.

In Figures 17 to 21 appear . . . an illustration of the 28D7; plate characteristics; a transformer coupled driver; transformer coupling characteristics; and a block diagram showing a typical receiver employing the low mu and pentode type tubes, used in conjunction with the 28D7.

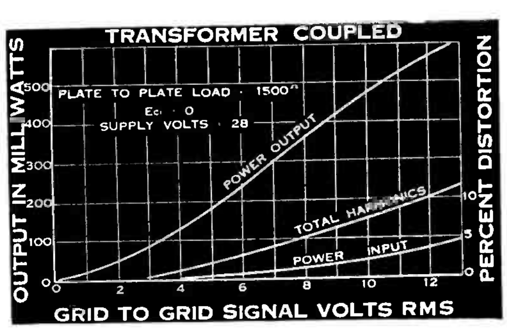
I-F System Design

THE design of i-f systems also served as the basic of a paper by John E. Maynard of General Electric. This paper, entitled *Aids for the Design of I-F Systems,* covered the problem of determining the character of the i-f system required to hold the desired signal and rejecting the undesired adjacent signal. In the October issue of COM-

(*Continued on page* 114)



Figures 20 (right) and 21 (left)
In Figure 20 appears the response characteristics of a transformer-coupled 28-volt type tube. Figure 21 is a block diagram of a receiver using low mu and pentode type tubes in association with a 28-volt tube, in a typical aircraft type receiver.



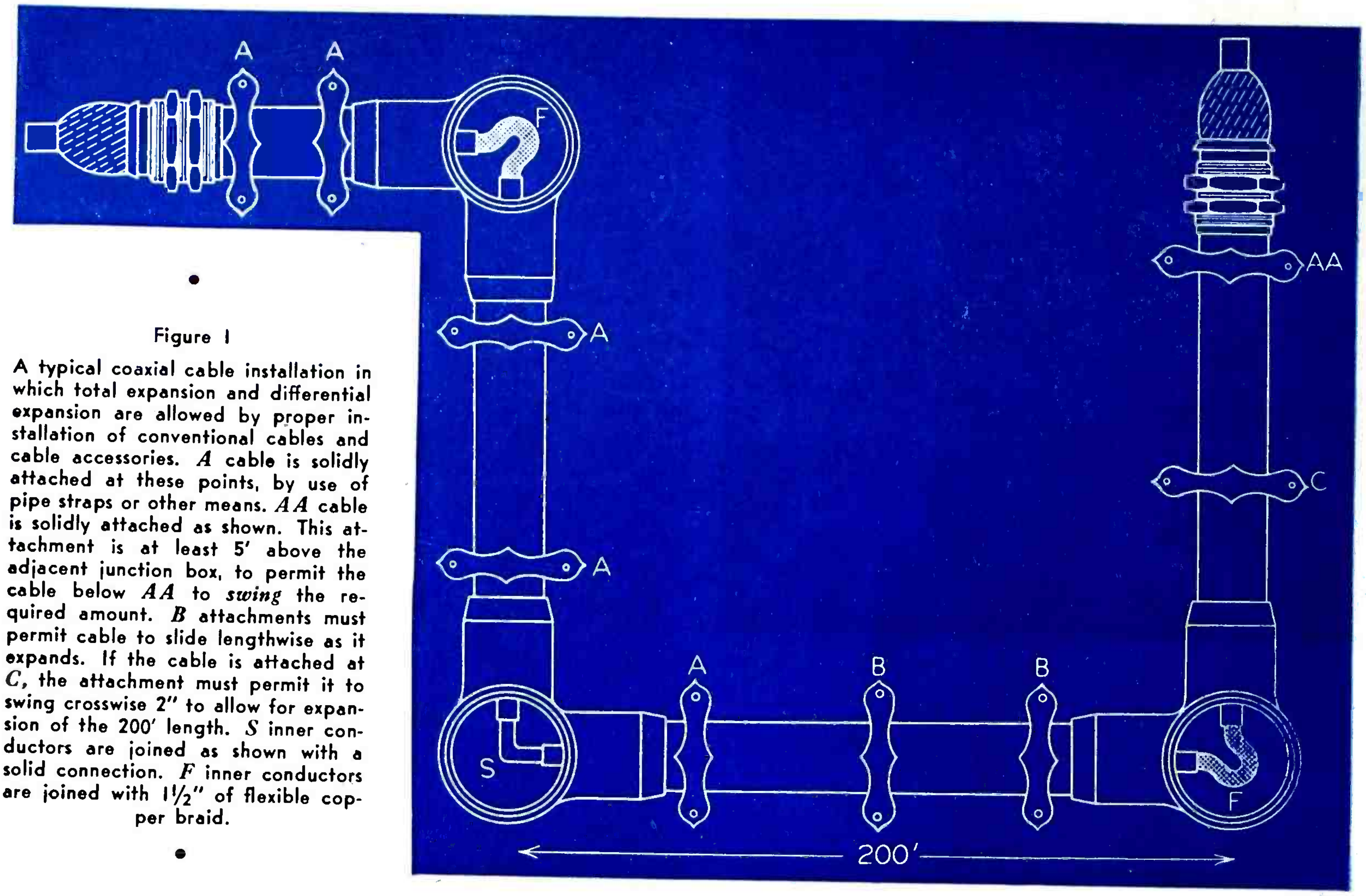


Figure 1

A typical coaxial cable installation in which total expansion and differential expansion are allowed by proper installation of conventional cables and cable accessories. *A* cable is solidly attached at these points, by use of pipe straps or other means. *AA* cable is solidly attached as shown. This attachment is at least 5' above the adjacent junction box, to permit the cable below *AA* to *swing* the required amount. *B* attachments must permit cable to slide lengthwise as it expands. If the cable is attached at *C*, the attachment must permit it to swing crosswise 2" to allow for expansion of the 200' length. *S* inner conductors are joined as shown with a solid connection. *F* inner conductors are joined with 1½" of flexible copper braid.

COAXIAL CABLE EXPANSION

by
DR. VICTOR J. ANDREW
Andrew Company

THE expansion and contraction of coaxial cables with varying temperature can cause breaks or short circuits in cables. Proper means must be provided to permit such expansion and contraction without damaging the cable.

Two forms of expansion must be considered. The first is total expansion, or the expansion of the entire cable (both outer and inner conductor). The other is differential expansion, or the difference in expansion of the outer and the inner conductors of the cable. The total expansion of a cable amounts to a variation of about one inch in 100 feet as the temperature varies between the coldest winter weather and the hottest summer weather.

The differential expansion depends on the difference in temperature between the two conductors, and is naturally very small. It may ordinarily be neglected if the cable is sheltered from direct sunshine and direct rain. In one particular case it becomes of major importance. This is in the case of a buried coaxial cable of the hard copper type. In a buried cable, the friction between the outer conductor and the soil is sufficient to prevent the outer conductor from contracting. The inner conductor, however, is quite free to move. Such installations have been known to have caused the pulling in of the inner con-

(*Continued on page* 120)

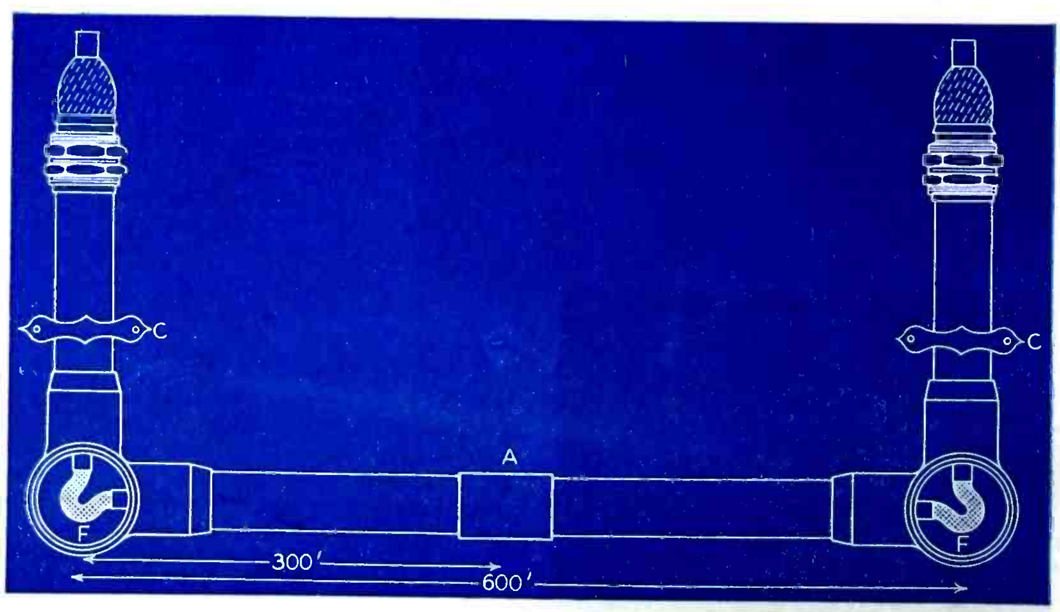


Figure 2

An installation with an unusually long straight run. The total expansion and the differential expansion are both divided into two halves. *A* is an anchor joint which solidly fastens inner conductor to outer conductor. The cable is solidly mounted at or near this joint. *F* represents flexible inner connectors. *C* represents any attachments within 5' of the junction box, which must permit necessary cross motion of the cable.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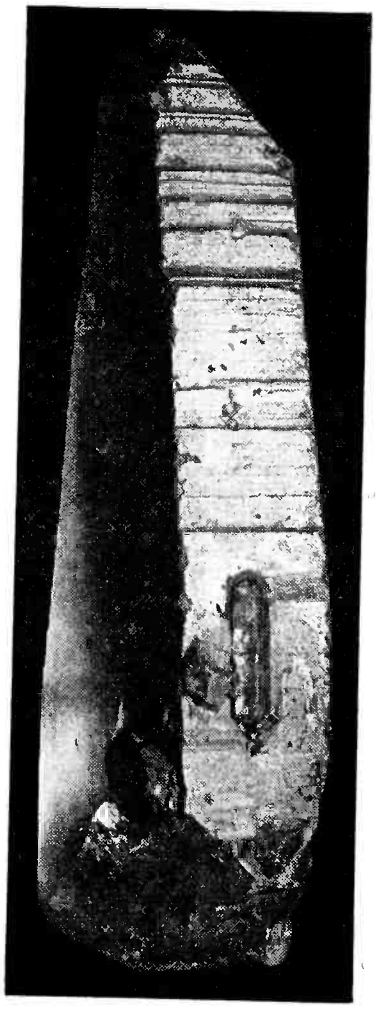
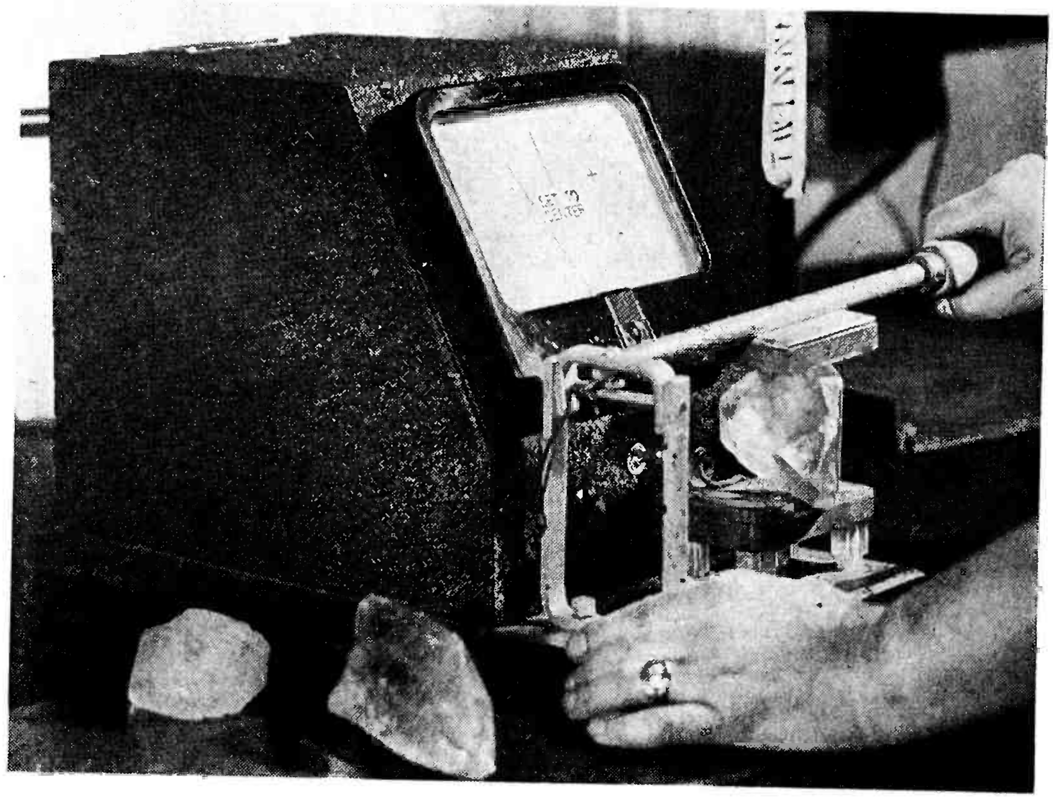
THE ORIENTATION

by SIDNEY X. SHORE

Project Engineer, Crystal Division, North American Philips Company, Inc.





Left, regular prismatic quartz showing prism side with steps commonly called growth lines. Prism side diverges towards top and terminates in minor rhomb face. Note the small crystal growing out of the prism side. Above, X-axis polarity checking electrometer. The indicator is set to center with no crystal in the vise. The crystal is set between the jaws with an X-axis approximately perpendicular to the jaws and compressed. The direction of swing of the meter indicates polarity of the lower end of the X-axis.

ORIENTATION or *set-up* of quartz is the name applied to the process of mounting the *mother quartz* so that it may be wafered or cut in any predetermined direction. There are many individual methods of orientation for various cuts of crystals. In this paper we will discuss instruments and methods of orientation for the *BT* cut crystals.

The BT cut crystal is a shear oscillator whose frequency is determined mainly by its thickness dimension. With respect to the *mother quartz* its faces are parallel to an X-axis and make an angle of 49°30′ with the Z-axis and an angle of 11°17′ with a major rhomb face.

A simple method of mounting and orientation for BT cutting uses a masonite board, ¼″ by 4″ by 4″. A cement is made of plaster of paris or a thermoplastic glue and fine sand mixture. After determination and selection of a major rhomb face of the raw quartz, the quartz is pressed into cement mixture onto the masonite board. Using two small machinists' squares, the quartz may be adjusted so that both a major rhomb face and its prism side are perpendicular to the masonite base. This sets an X-axis perpendicular to the masonite base board. The cement is then set by heat or air drying and the quartz is ready for wafering. If the masonite base is set under a saw blade which is perpendicular to it, the blade is parallel to an X-axis. The blade may be rotated about this X-axis to make any desired angle with the Z-axis.

This orientation method is primitive and useful if other orientation materials are not available. Only regular prismatic quartz having at least, one major rhomb face and associated prism side may be set up in this way. If this technique is necessary and only the apex faces of the quartz remain, an apex face marking jig and diamond pencil may be used to scribe a line parallel to the X-axis on the major rhomb face. If the quartz is twinned and an incorrect choice of major rhomb is made, the rock may be a total loss.

In order to derive the maximum accuracy and efficiency in orientation and sawing, it is necessary to utilize our physics and mechanics and in such fashion as to have a minimum of quartz waste. It is imperative that we know that the wafers cut from the raw quartz bear the proper angular relationship with the *X*- and *Z*-axes and

This is the second of a series of articles covering a detailed analysis of crystal manufacture. In subsequent papers, Mr. Shore will discuss sawing and lapping, and finishing and testing.

OF QUARTZ CRYSTALS

A Discussion of The Instruments and Methods Applied in Orientation of BT Cut Crystals

lie properly with respect to a major rhomb face.

Mounting a *mother* on some sort of solid platform with its crystallographic axes bearing a definite predetermined relationship to the mounting base, necessitates a precise orientation procedure. The base is fastened to the table of a precision quartz saw and the desired cuts are then made.

Quartz crystals have interesting and useful physical properties making possible their orientation in any desired fashion with respect to the mounting plate.

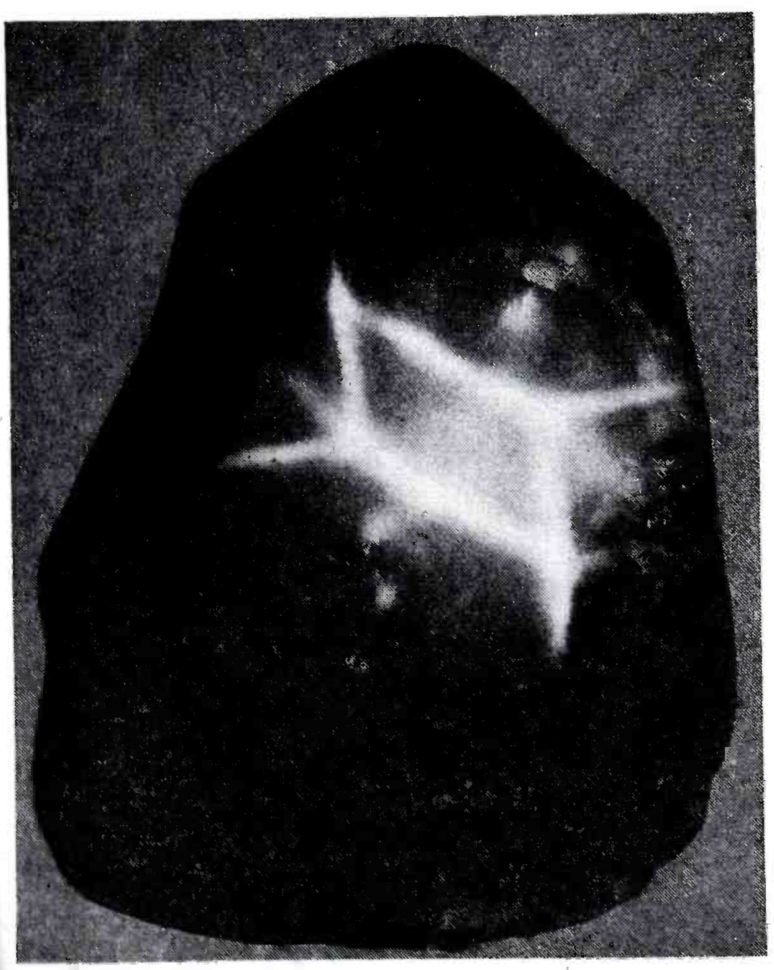
Crystalline quartz is made up of atomic spirals of silicon and oxygen whose axes are parallel to the Z-axis. It is optically active and birefrigent. During the past two years x-ray diffraction apparatus has been specially developed for the quartz crystal industry to aid in orientation.

Use of X-Rays

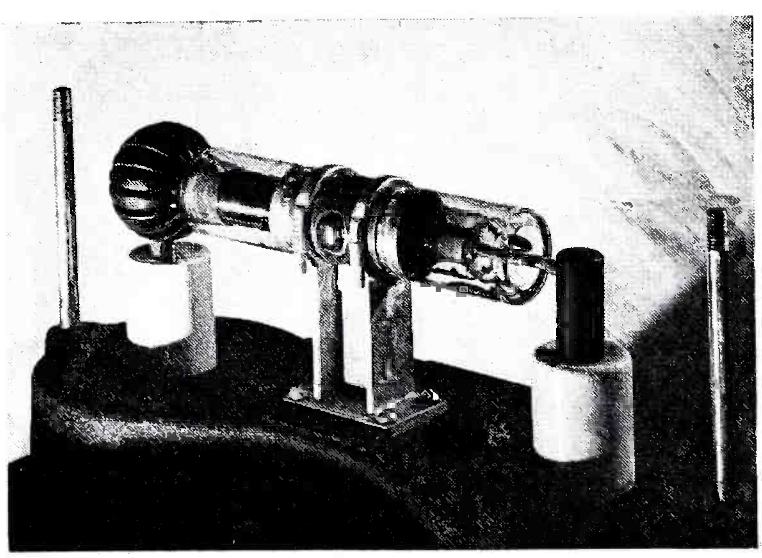
A short discussion of crystal diffraction of x-rays applied to quartz will illustrate how easily the technique may be used in orientation.

It is possible to draw planes through a quartz crystal in various directions to include large numbers of either silicon or oxygen atoms, or perhaps some of each. These directions constitute atomic planes which may act much as the slits in a visible light diffraction grating. Visible light waves are too long to be diffracted by the atomic planes, but x-rays have the proper order of magnitude of wavelength to be diffracted by the atomic planes. Bragg's law which holds for the visible light diffraction grating may be derived similarly for the atomic planes of a crystal. In Figure 3 we see these atomic planes that are made up of rows of atoms spaced a distance d apart.

Assuming a bundle or wavefront of x-rays of wavelength λ incident on the planes, at an angle θ with them, the atoms will be excited and act as secondary sources of x-rays. At a critical angle of θ, the secondary wave-fronts will be in phase and will reinforce one another. This is true when the difference in path of the x-ray beams traveling to and from atom A and atom B is one wavelength long, or any integral multiple of wavelengths. From trigo-



At left, parallelogram-etch pattern on a YZ-plane, showing the optic axis direction and the major rhomb face direction of a left-hand quartz crystal. Below, a phantom photograph of an x-ray tube mounted in place on the x-ray machine. The filament is to the right; the anode, to the left, has large black radiating fins to dissipate large quantities of heat developed in the anode. The exit window for the x-ray beam appears between the two *u* straps fastening the tube to the mounting base.



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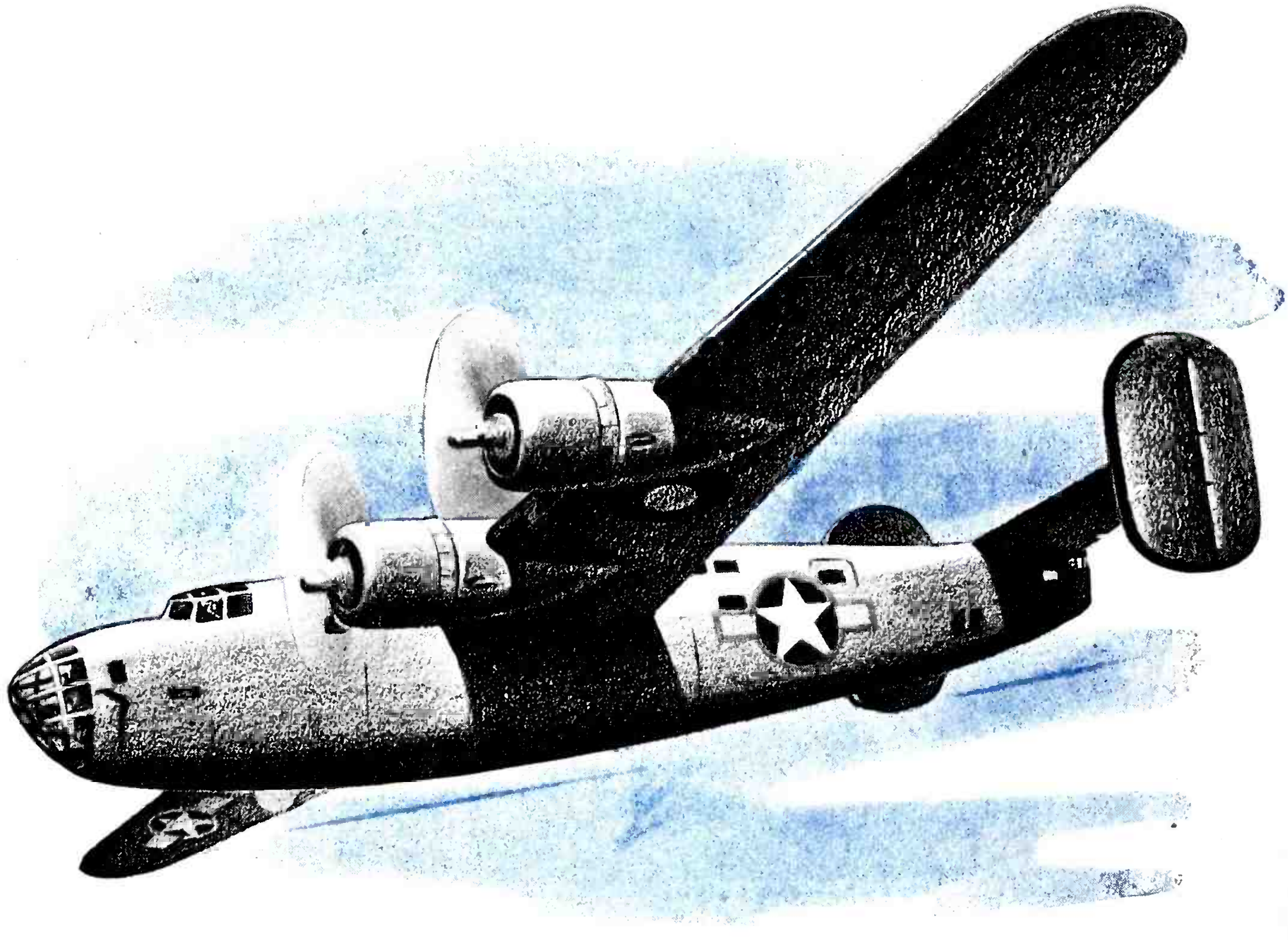

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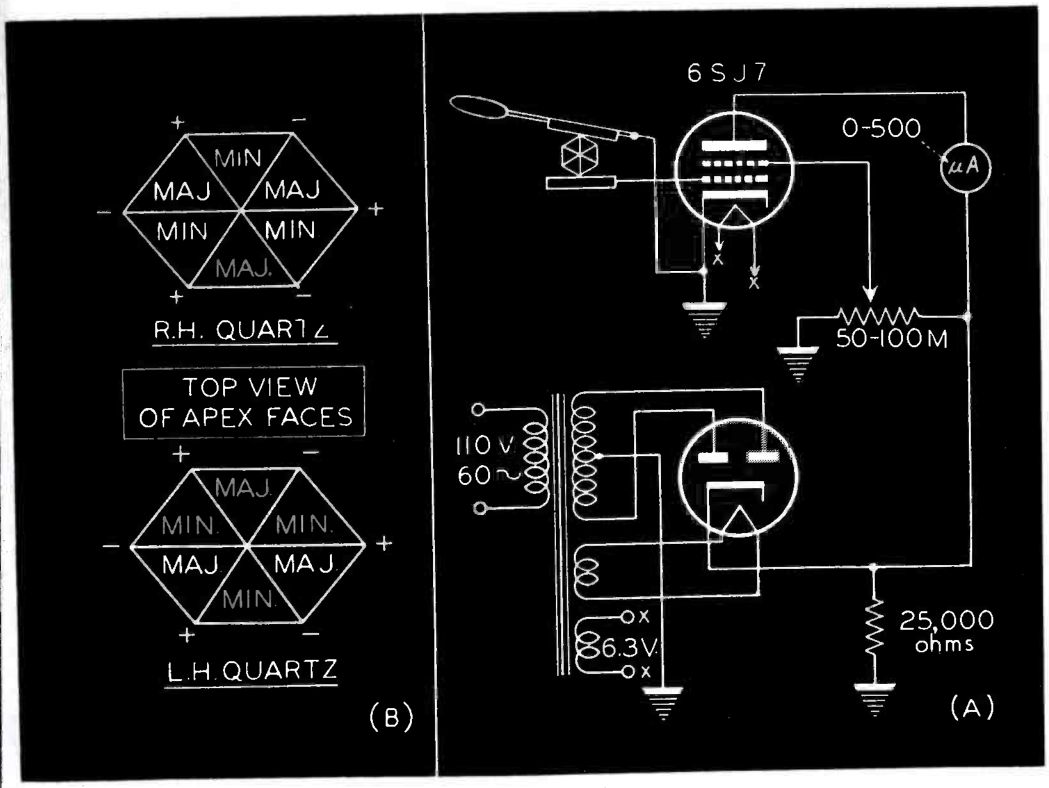
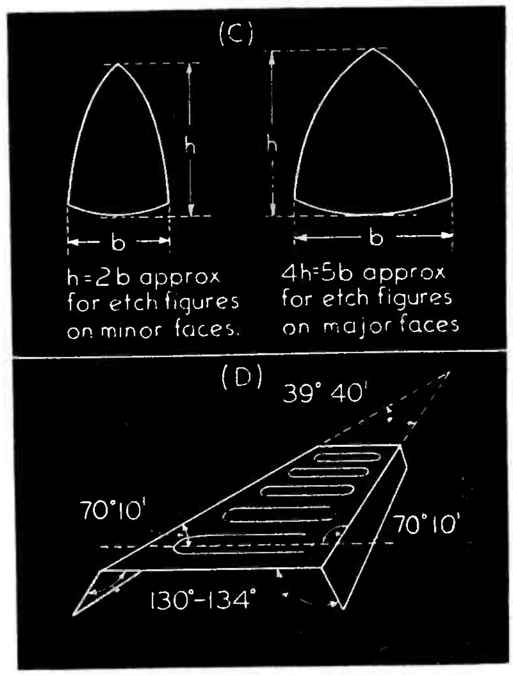




Figures 1 (left) and 2 (above)

Figure 1 (A) shows a diagram of an X-axis polarity checker. In place of the rectifier shown, power can be supplied from a 110-volt a-c line. In (B) we see the relationship of . . . *(1)*—handedness of quartz; *(2)*—the polarity of the X-axis on compression, and *(3)*—the position of major and minor rhomb faces in untwinned quartz. Figure 2(C) illustrates natural spherical triangle etch patterns on rhomb faces of quartz crystals which may be used to distinguish between major and minor faces. They do not often appear. In (D) we have an apex face marking jig that may be used with a diamond pencil to scribe a mark on a major or a minor rhomb which is parallel to an X-axis direction.

nometry we can set up the equation:

$$\sin\theta = \frac{NB}{d} = \frac{MB}{d}$$

but NB + MB = λ at critical angle θ,

$$\text{and } NB = MB = \frac{\lambda}{2}$$

$$\text{therefore } \sin\theta = \frac{\lambda}{2}$$

Most generally we write,

$$2d \sin\theta = n\,\lambda$$

Where n is any integer.

The critical angle θ, is called the Bragg angle.

The general equation has four possible variables. For a discrete set of atomic reference planes d is fixed. For a given x-ray, tube target material of the x-rays is fixed. For a first order reflection, which is most commonly used, n equals unity. This leaves only θ, as unknown and we can measure the critical angle within 1 to 3 minutes. If diffraction from another set of reference planes is desired, only d will change and θ will change accordingly. The x-ray tubes now used in the crystal industry have copper anodes with characteristic wavelength of x-radiation of the K_a line equal to 1.54×10^{-8} cm.

The atomic planes make definite angles with respect to the crystallographic axes. Identification of the planes is commonly accomplished by the use of Miller indices. Briefly, these index numbers represent the reciprocals of the intercepts of the atomic plane on the three two-fold unit X-axes of symmetry and on the unit Z-axis of three-fold symmetry. The Miller index notation of atomic planes of crystals is adequately described in various texts on crystallography. Four index numbers are needed to describe the atomic planes in quartz, and these correspond to intercepts on each of the three X-axes and on the Z-axis. For example, the atomic plane parallel to the major rhomb face is noted as the $10\bar{1}1$ plane, identified as the one, zero, minus one, one plane. Since the third index number is always the negative quantity of the algebraic sum of the first two index numbers, it is often omitted and the $10\bar{1}1$ plane may be written as the 10.1 plane. Figures 4 and 5 illustrate the characteristics of the more commonly used atomic reference planes in quartz.

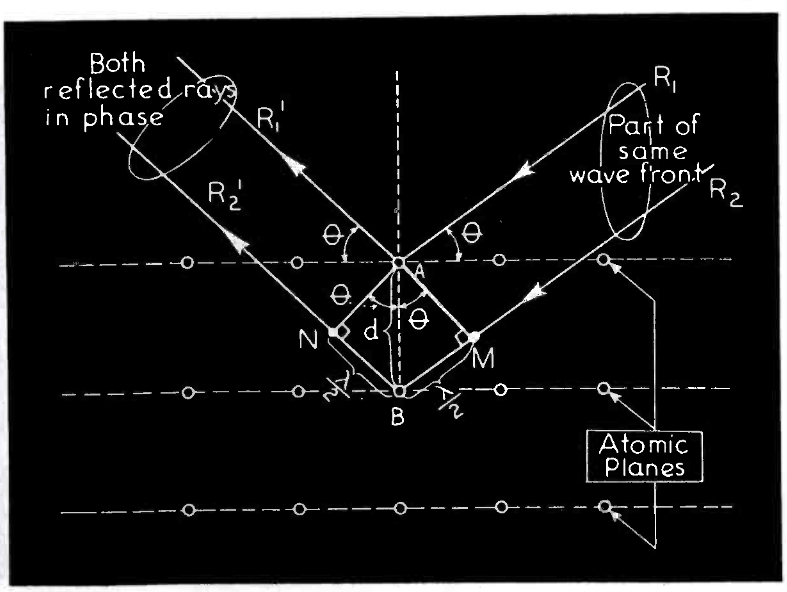
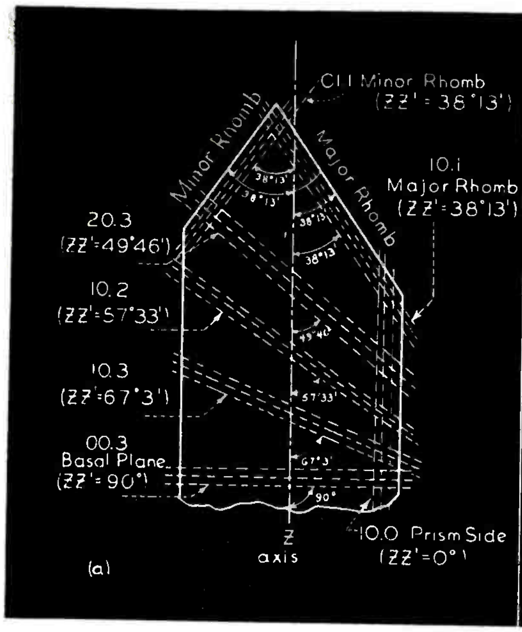


Figure 3

This drawing illustrates the method of derivation of Bragg's law for crystalline diffraction engraving.

A schematic drawing of the 10.1 plane set in an x-day diffraction apparatus is shown in Figure 6. The Bragg angle θ_1 is 13°18′. Therefore, the x-ray collector is set at $2\theta_1$ or 26°36′ with respect to the incident x-ray beam. An early type of collector was an air ionization chamber connected to a d-c amplifier, Figure 7. Since d-c amplifiers are sometimes unstable and a resistance of some 100,000 megohms is usually necessary in the ionization chamber circuit for adequate sensitivity, an admirable substitute has been found. This



ATOMIC PLANES IN QUARTZ SOMETIMES USED IN ORIENTATION

n = 1 and λ = 1.54 Å for Cu, K_α Line

	MINOR INDICES	BRAGG ANGLE θ'
MAJOR RHOMB	10$\bar{1}$1	13° 18'
MINOR RHOMB	01$\bar{1}$1	13° 18'
PRISM SIDE	10$\bar{1}$0	10° 26'
BASAL PLANE	0003	25° 21'
2nd ORDER PRISM	11$\bar{2}$0	18° 18'
67°3' with Z axis	10$\bar{1}$3	27° 40'
57°33' with Z axis	10$\bar{1}$2	19° 45'
49°46' with Z axis	20$\bar{2}$3	34° 7'
	20$\bar{2}$2	27° 28'

(b)

Figures 4 and 5 (left) and 6 (below)
Figure 5 (b) shows atomic planes in quartz sometimes used in orientation procedures. Figure 4 (a) illustrates some of the atomic reference planes shown in position in a quartz mother. In Figure 6 appears a schematic illustrating a quartz wafer placed in the x-ray machine so that reflection is picked up from the ion atomic reference plane. In effect the measurement indicates the angle between the reference plane and the physical surface of the wafer.

is the gas ionization tube, known as Geiger-Muller tube, used with a single 6C5 amplifier, or other similar amplifier, and 0-1 ma meter. This method has proved exceptionally stable and sensitive and is now in common use. The Geiger-Muller tube consists of a cylinder of brass or carbon with an axial length of tungsten wire supported at one end, enclosed in a glass envelope, and with an exceedingly thin window at the free end of the tungsten wire. It generally is filled with an atmosphere of anywhere from 3 to 20 mm pressure of argon gas. With a high potential across the cylinder and wire electrodes, an x-ray photo striking an argon atom energizes and ionizes the atom. As the ion is attracted to the cylindrical electrode, and the electrons to the wire, secondary ionizationtion occurs from collisions with other gas molecules and relatively high currents are obtainable.

The actual mechanics of measurement of crystal angles is simple and is adequately described in the operating instructions of various commercial x-ray diffraction units.

The necessity for accuracy in orientation may be illustrated by the temperature coefficient curves of Figure

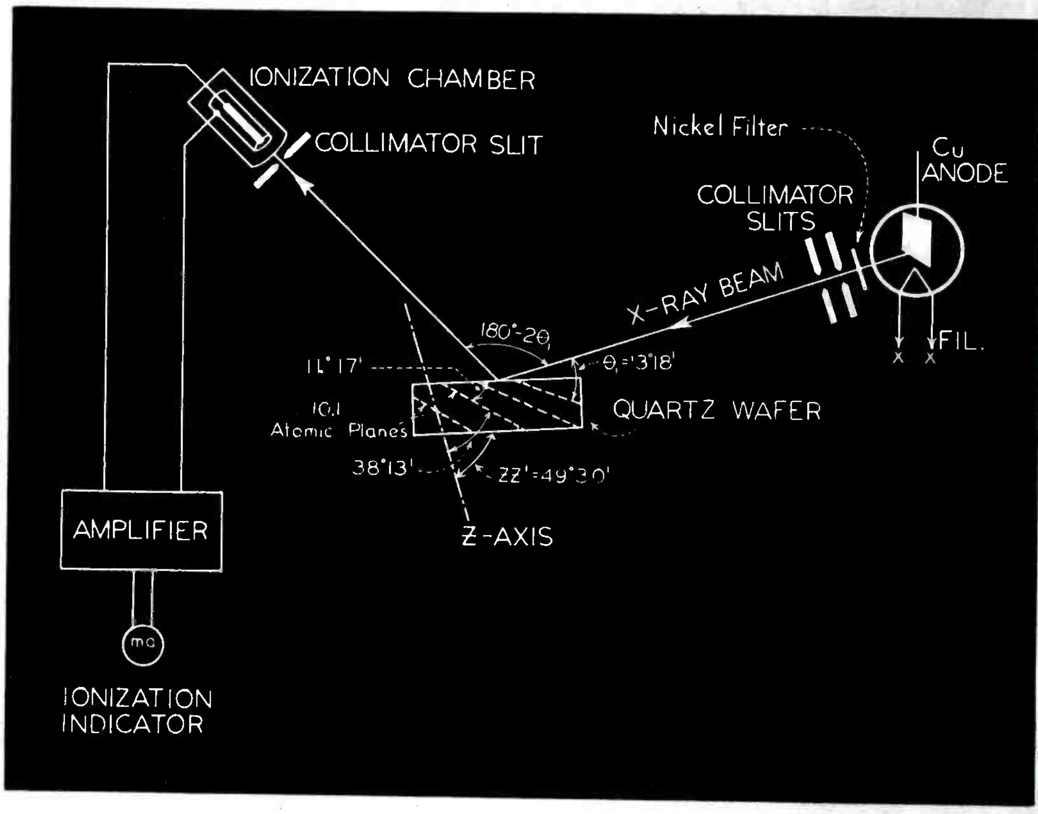
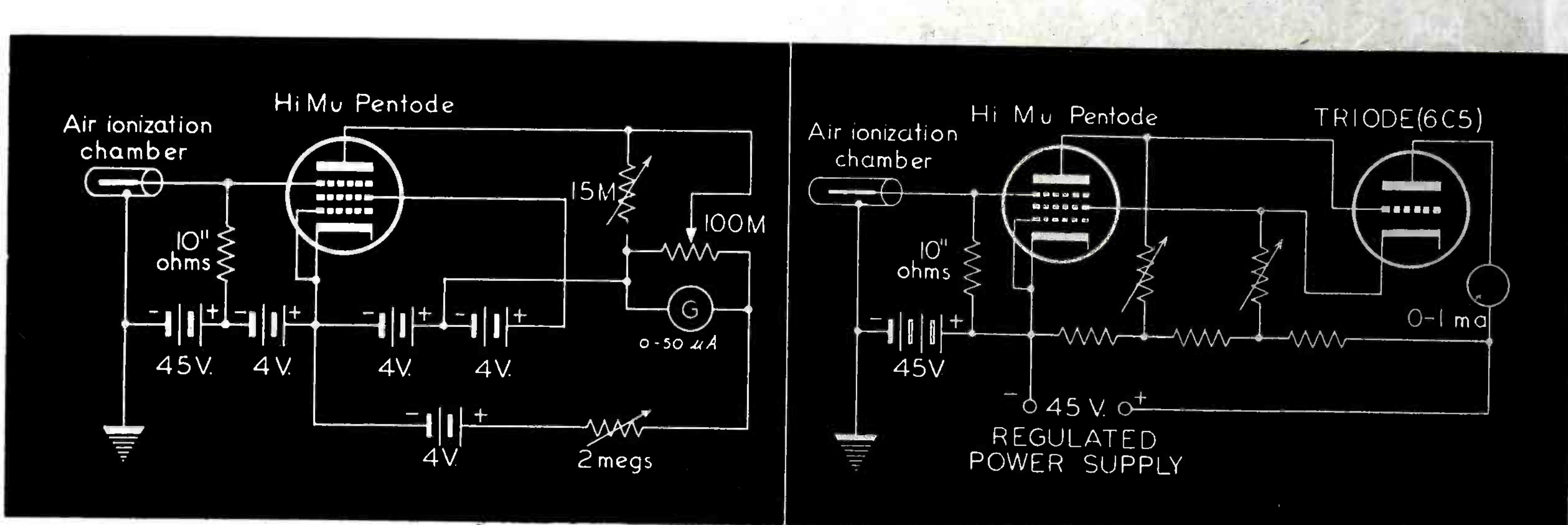


Figure 7
Two types of ionization indicators used with an air ionization chamber to measure x-ray intensities. The first is a single stage electrometer using a hi-mu pentode. The second is a two-stage d-c amplifier using a hi-mu pentode followed by a triode. In these circuits the voltage drop produced by the ionization chamber current is deevloped across a resistance of 10" ohms, and is applied between suppressor and cathode.



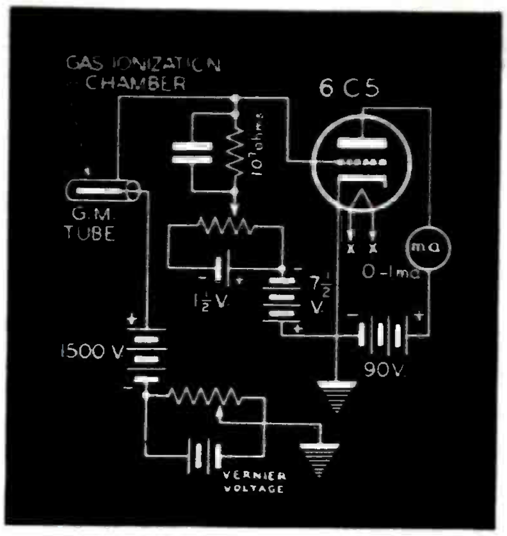


Figure 8
Wiring diagram for a Geiger-Muller tube amplifier for measuring x-ray intensities. The ionization tube load resistor in the grid circuit of the 6C5 may be much smaller than that used in conjunction with the air ionization chamber, because ionization current in the g-m tube is much greater.

Geiger-Muller gas ionization tube, showing brass cylindrical electrode surrounding the tungsten wire electrode.

9. These plot frequency versus temperature changes for BT oscillator plates cut from the *mother quartz* at various angles with respect to *Z* and *X*. The angle the oscillator plate makes with the Z-axis is called the *ZZ'* angle and that with the X-axis, XX' angle. As stated earlier ZZ' should be 49°30' and XX' should be zero. With the x-ray as an orienting tool, we obtain accuracies of 1 to 3 minutes in measurement of angles.

There is another very useful orientation device called the *conoscope*. The *conoscope* consists of a monochromatic light source, polarizer, convergent lens system, oil bath, analyzer and convergent lens system eye-piece.

This interesting instrument is used to accurately determine the Z-axis direction in a piece of quartz with a tolerance of 5 to 10 minutes. A British version of the *conoscope* is illustrated in Figure 10. This is accurate to within 5 minutes in the hands of a skilled operator.

The *conoscope* is construced so that the principal axis of the lens system passes through the intersection of two perpendicular cross hairs in the eyepiece. The optical axis of a *mother quartz* is parallel to the principal axis of the lens system when concentric light and dark rings are seen centering on the intersection of the cross hairs.

The basis of operation of the *conoscope* lies in the double refraction property of crystalline quartz. This so-called *birefringence* is commonly associated with calcite and is utilized in making the Nicol prism.

If an unpolarized light beam were passed through some crystalline quartz, it would break up into two beams on entering the quartz volume. One beam would travel faster than the other and is called the ordinary ray, *o*. The other slower ray is the extraordinary ray *e*. Both rays are plane polarized at right angles to one another. In only one discrete direction the *o* and

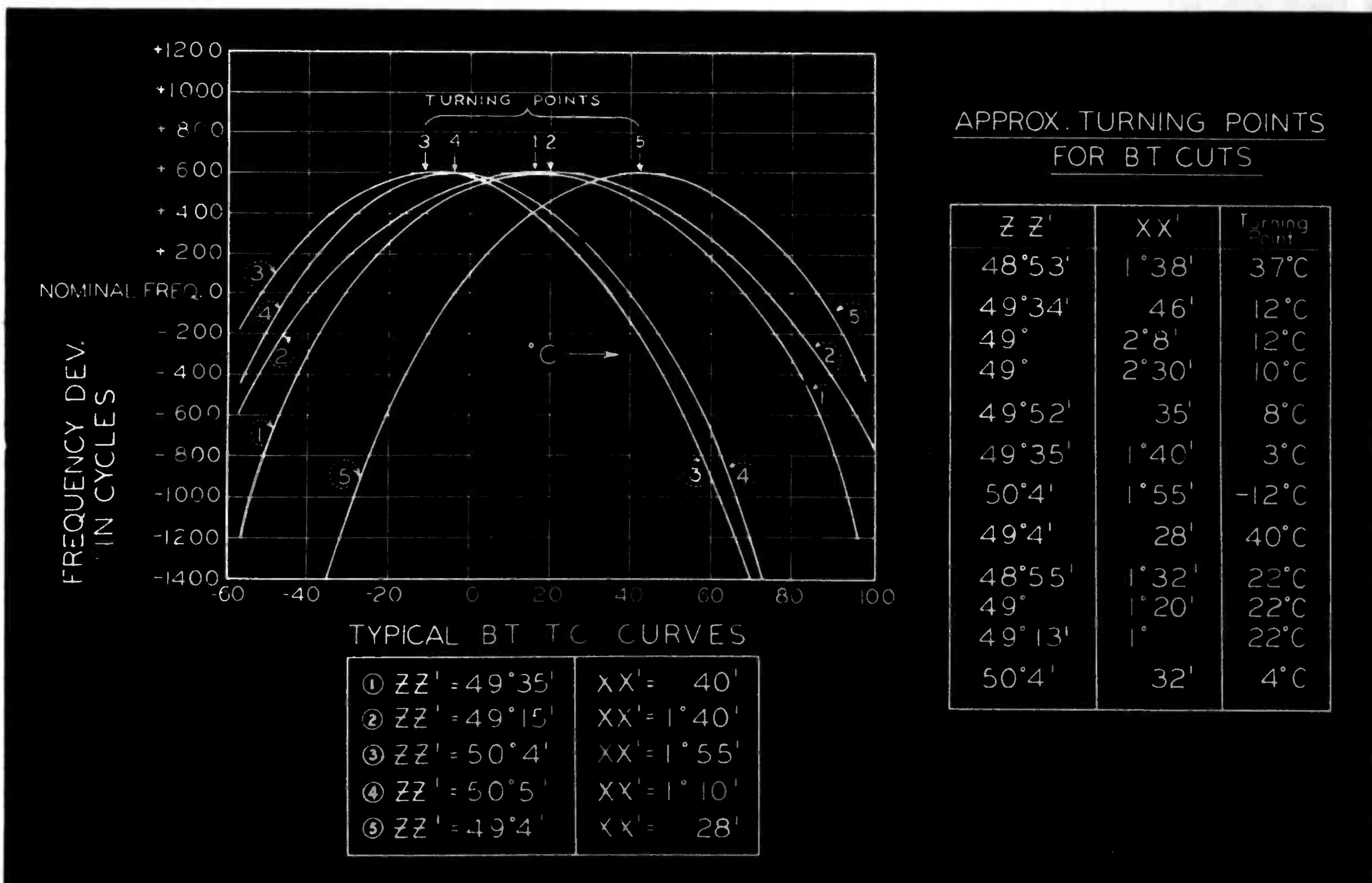
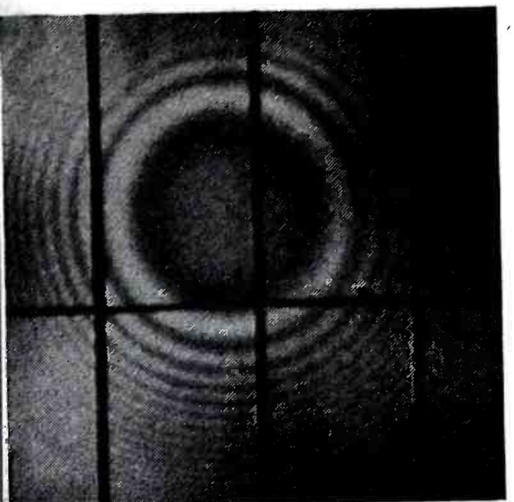
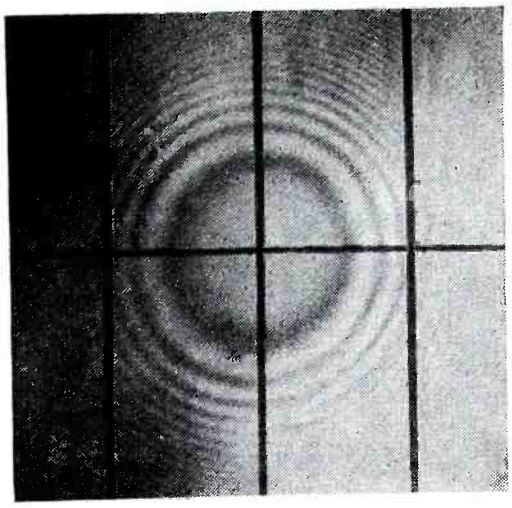
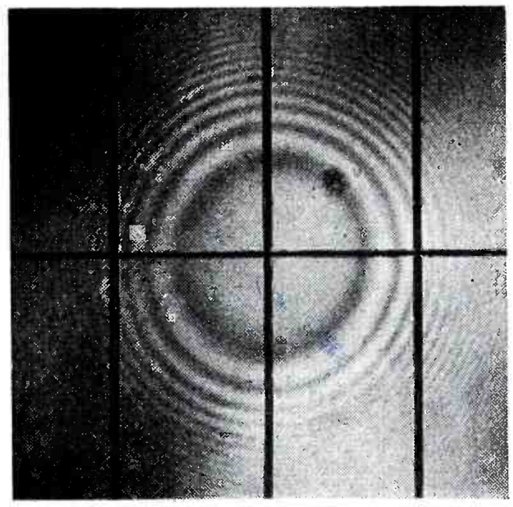


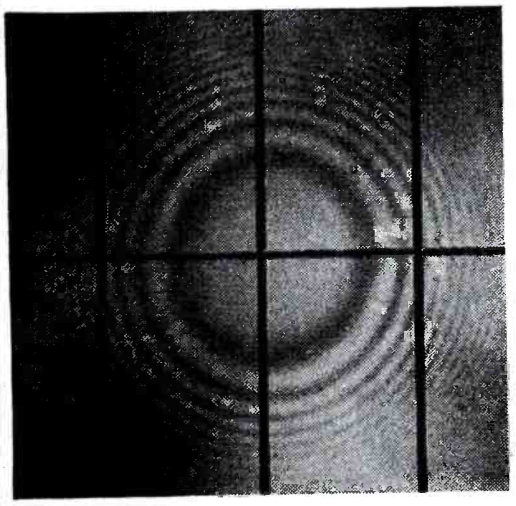
Figure 9
Here are represented typical *BT* frequency versus temperature curves, for oscillator plates having various orientations with respect to the crystallographic axes.

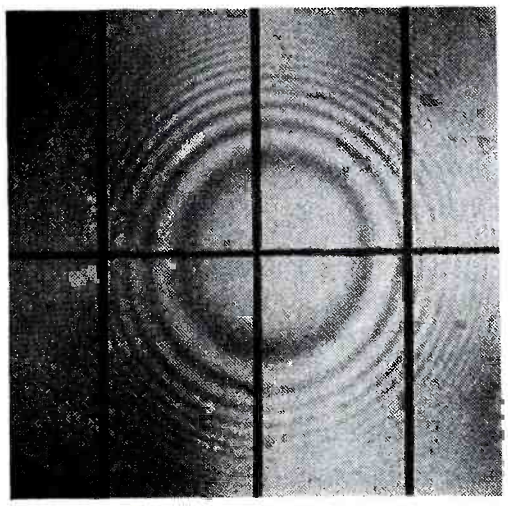


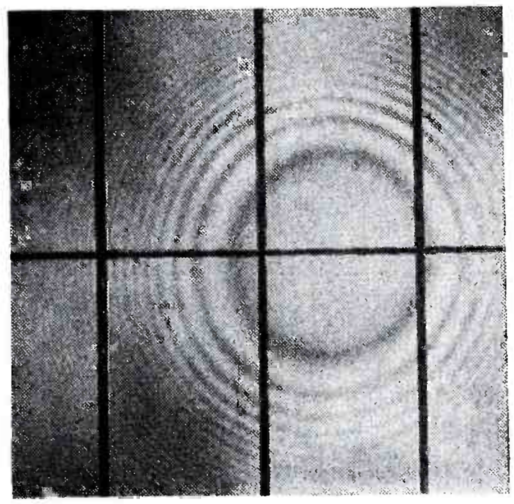




Series of views seen through the eyepiece of a conoscope, showing concentric ring patterns of a piece of quartz, indicating (from left to right, top, and left to right, bottom): Z-axis out of line with the principal axis of the lens system in both vertical and horizontal directions; proper vertical alignment with angles of 0°, 12′, 30′, 1°, and 3°, respectively, between the Z-axis and the principal axis of a lens system.







the *e* rays have the same velocity, parallel to the Z-axis.

The *o* ray has a constant velocity regardless of direction of propagation of incident light. The velocity of the *e* ray varies as the angle of the incident beam changes. If we were to draw a space-velocity diagram to represent the travel of an incident light beam on quartz in any direction, we would obtain a sphere for the *o* ray and an ellipsoid for the *e* ray. The length of the radius vectors to the surfaces represents the velocity of each ray in that particular direction. The major diameter of the ellipsoid equals the diameter of the sphere and lies along the Z-axis. The plane of polarization of the *o* ray is perpendicular to the plane containing the Z-axis and the radius vector. For the *e* ray, the plane of polarization lies in the plane containing the radius vector and the Z-axis.

When incident plane polarized light is broken into the *o* and *e* rays, these rays recombine on emerging from the quartz and may or may not be in phase as at the incident surface. The phase shift is determined by the relative indices of refraction of the *o* and *e* rays, the length of travel through the quartz and the wavelength of light used.

Viewing the quartz crystal parallel to *Z*, the projection of contours on the ellipsoid representing *e* ray velocity, V_e, or index of refraction, n_e,* would be a series of concentric circles. Convergent-plane polarized light viewed in this direction with a polarizing analyzer and lens system may be seen as a series of alternating light and dark concentric circles, spread out near the center and crowded together as their radii increase. The center of symmetry is the Z-axis.

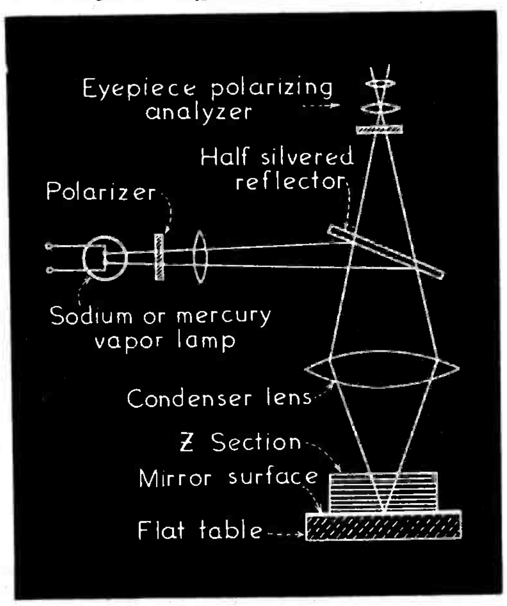


Figure 10
British version of the conoscope used to accurately locate the Z-axis in quartz crystals. This is sometimes called the Airy-Spiral conoscope.

The x-ray machine and the *conoscope* are perhaps the most widely used orientation devices at the present time. The x-ray machine may be used to orient quartz in any direction, to locate any one of the axes accurately. The *conoscope* will only locate the Z-axis.

A combination usage of the two devices may be extremely advantageous.

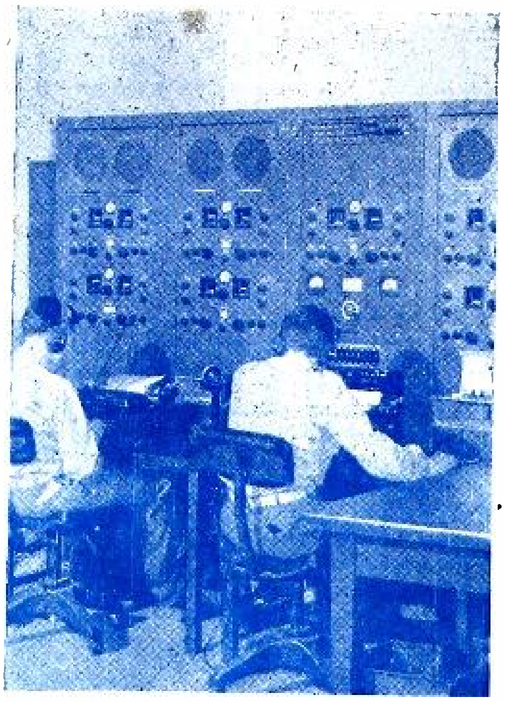
Once the Z-axis is located, if a section is cut perpendicular to *Z* and etched in hot ammonium bifluoride or hydrofluoric acid, the rodometer method may be used to locate the X-axis. In this method a point source of light projects into one surface of the Z-section. The dispersed light strikes the upper etched surface which is perpendicular to *Z*. Refraction at the etch pits occurs systematically and a light pattern is visible consistent with

(*Continued on page* 115)

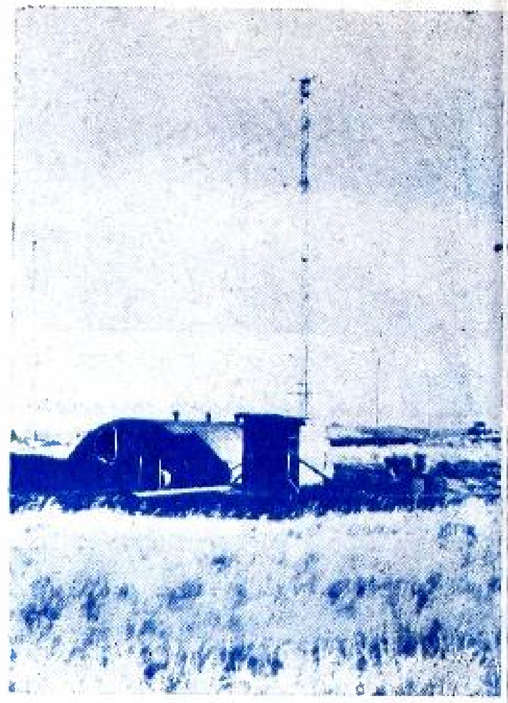
*$n_e = \frac{V}{V_e}$

where
n_e = index of refraction of *e* ray
V = velocity of light beam in vacuum
V_e = velocity of *e* ray in quartz in a specific direction

THE ARMY AIRWAYS



At left, AACS operating positions in typical small communications station. At right, AACS station at a far Northern base.



(Photos, Courtesy U. S. Army Air Force)

THE U. S. Army Air Forces have developed organized airways reaching from the United States, across four oceans, into every continent on the globe, with the single exception of Axis-held Europe.

Operated as they are by many far-flung transport and combat units, all these foreign airways are integrated by just one element—a communications network—unparalleled in history, and maintained and operated by the Army Airways Communications System, a Wing of Headquarters, Army Air Forces.

Although an airway may be loosely defined as *a designated route for aircraft plying from airdrome to airdrome,* it cannot really be said to exist on a practical scale without airways communications, airdrome traffic control, and radio navigational aids. These are the three components furnished, over some 70,000 miles of foreign military airways, by the Army Airways Communications System Wing.

From the North Atlantic's frozen wastes to the deserts of Africa and eastern Asia, in Alaska, South America, Australia and the fabled islands of the South Pacific, as well as here, the officers and enlisted men of this organization live and work in every climate and condition of hardship known to man, maintaining these three basic elements of successful airways operation.

Airways communications, including both point-to-point and air-ground circuits, are maintained by approximately 260 ground communications stations situated at airdromes along the routes. Traffic handled consists of all operational and weather data necessary for safe and efficient operation of the transportation giant.

Operational traffic includes all information on a given plane or flight of planes, such as number of planes involved, identification symbols of each individual plane, names of pilots, time of departure and estimated time of arrival at destination and at control points along the route. These control points are usually radio stations embodying navigational features enabling the aircraft to get a definite fix. The principal purpose is to prepare all stopping points with advance information, so that all necessary activities in connection with the flight may be carried out with maximum efficiency and minimum delay. This practice also provides a definite safety factor, in furnishing immediate information concerning any misadventures or accidents to planes in flight, and broadcasting requirements for action in connection therewith.

Point-to-point stations range all the way from single transmitter-and-receiver combinations to huge installations handling a million or more code groups per month. All communication is on c-w, with average operating speeds of 25 to 30 words per minute, transcribed on typewriter.

Equipment used in point-to-point operation consists of multi-channel crystal-controlled transmitters of up to 3-kilowatt power, and extremely sensitive and selective receivers of the best professional type available. Transmitters are of most modern design and construction capable of simultaneous transmission on as many as four frequency channels, while crystal control provides absolute stability of assigned frequencies.

Included in point-to-point networks is the collection of weather data from isolated observation posts, perhaps hundreds of miles from the airway in use, manned by personnel of the Weather Wing, Army Air Forces. Attached to each of these units is a single operator-mechanic of the Army Airways Communications System, who transmits the information gathered, on regular schedules, to the nearest airways station.

These reports are turned over to Weather personnel for consolidation, analysis and prediction. The combined reports are then broadcast throughout the airway, and further relayed to Weather Centrals, equipped to prepare charts and predictions covering entire regions. This information is then broadcast by the Army Airways Communications System.

Standard commercial teletype apparatus is used for point-to-point operations when leased or private wire connections are feasible. This results in greater reliability, due to freedom from atmospheric disturbances, and higher transmitting speeds of 50 to 60 words per minute. However, wire connections are available on only a relatively small portion of the Army Airways Communications System network.

A more recent development, being

COMMUNICATIONS SYSTEM

An Analysis Of Its Purpose, Operation and Equipment Employed

by LIEUTENANT WALTER W. FAWCETT, JR.

Army Air Forces Headquarters, AACS

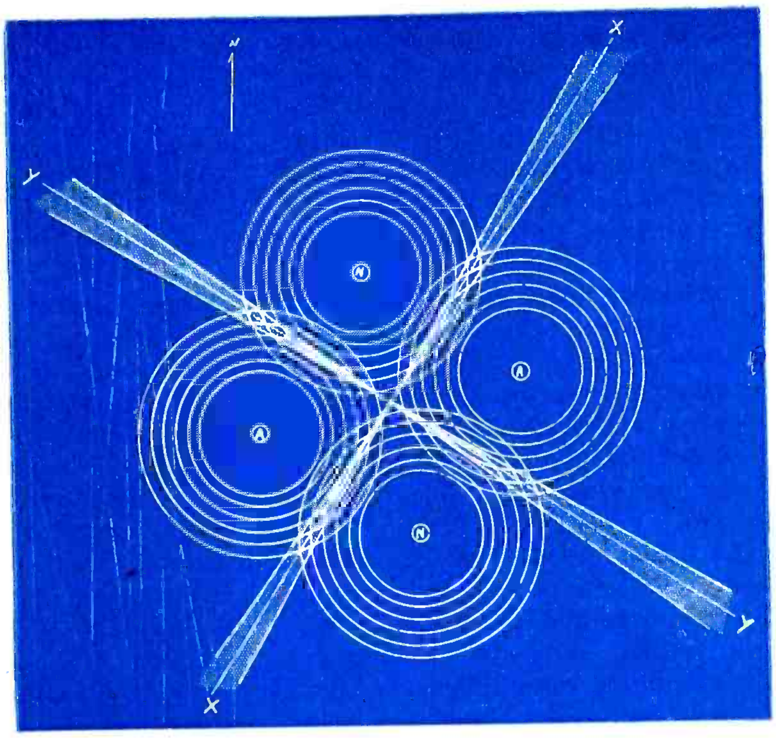
utilized as rapidly as equipment becomes available, is radio-teletype, combining many features of both methods of communications, and promising greatly increased efficiency throughout the system.

As a stop-gap until radio-teletype equipment becomes available in greater quantities, circuits carrying very heavy traffic are operated by means of high-speed automatic-keying heads, permitting actual transmission through the air of up to 250 words per minute. This system is especially valuable for traffic on regular schedules as the tape can be perforated a few minutes beforehand, transmission cleared in a very short time. And if necessary the receiving tape can be divided among several operators for transcription on the typewriter.

Air-ground communications include all communications between aircraft and ground stations, and may operate by means of either c-w or voice. Since it is the flyer's sole contact with ground agencies, emergency traffic on air-ground circuits is given priority over all other airways traffic. When an airways station is forced off the air for any cause, the air-ground position is usually last to be abandoned and first to be re-established.

Transmitters used in air-ground communications are medium powered multi-channel, crystal-controlled units operating on medium frequencies, while receivers are very similar or identical to those used in point-to-point operations. These facilities maintain constant listening watches on assigned aircraft frequencies, and broadcast weather and operational data to all planes in flight.

In addition to maintaining a listening

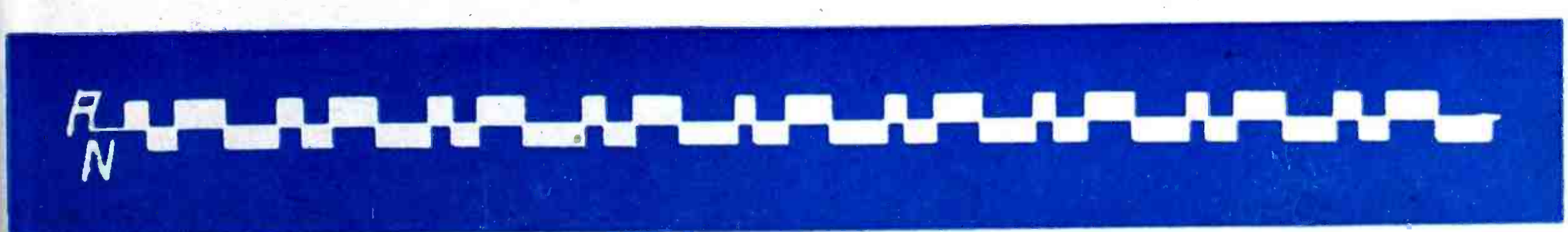


Figures 1 (right) and 2 (below)
In Figure 1, the radiation pattern of a radio range. Signals A (.—) and N (—.), chronologically synchronized and of equal audibility, produce a single continuous tone along theoretical lines X — X and Y — Y. Shaded portion shows area in which variations in relative strength between A and N signals are not apparent to the average human ear, and continuous tone is heard. Figure 2 (below) shows the chronological synchronization of A (.—) and N (—.) signals, to produce a continuous tone. Blue areas represent tone periods of each individual signal.

watch, or *guard* on the air-ground frequency, aircraft are required to report their arrivals over designated control points, usually locations where a definite radio navigational *fix may be* obtained. The flight is identified, information entered in the station log, and passed on to the point-to-point station for dissemination along the airway. Current weather, and any unusual incidents observed in flight may also be reported. If the flight is behind its estimated schedule, an explanation may be given for the delay.

The Army Airways Communications System also exercises operational control of six intercontinental broadcasting stations developed by the Civil Aeronautics Administration. These stations, among the most powerful radio installations in existence today, are located at strategic points for world coverage. They collect and disseminate, on both point-to-point and air-ground circuits, operational and weather information covering entire global areas. Great credit is due the CAA for the outstanding coöperation given, principally along engineering and technical lines, in the development of the present colossal Army Airways Communications System.

The Army Airways Communications System operates airdrome control towers at approximately 400 foreign and domestic airdromes in use by the Army Air Forces. These towers, located at strategic spots commanding a view of the entire airdrome, function as both traffic control and accident prevention centers. All traffic on the landing area and in the air within the control zone, usually a circle of 3-miles radius centered on the landing field, is



under the direction of the control tower. All landing and departure operations must be cleared through the control tower, which assigns runways, directions of movement, and sequence of operations.

Accident prevention as a corollary of traffic control, and a responsibility of the control tower, goes far beyond the primary function of assuring obstacle-free runways and clear airspace for routine aircraft movements.

Approaching planes, in trouble or needing immediate attention, must be given full priority regardless of normal traffic sequence, and in the imminence of a crash landing, directions are given to move all inflammable or explosive materials as far from the landing area as possible, to prevent spread of the damage. In the imminence or event of any accident within the control zone, the tower is responsible for immediate summoning of all rescue agencies and directing them to the scene.

The control tower must also observe any visible variations from normal operation of aircraft, notify the pilot, and stand by for action that may be necessary. Many a crash has been prevented by the tower's quiet reminder that landing gear has not been lowered.

The accident prevention factor in control tower operations assumes supreme importance in thick weather, when aircraft lacking blind flying equipment are caught off base. Through blinding snow, or fog, or heavy rain, many an almost-helpless plane has been guided, almost foot-by-foot through the opaque swirl, to a safe landing. Like a friendly voice in the darkness, the control tower leads them home.

The tower is responsible for the control of field lighting, and contains a diagram of the landing area, together with switches for the control of runway and flood lights. A *crash phone* is provided for summoning all rescue, damage-control, and medical agencies in a single call, by means of a *party-line* circuit.

Several radio receivers equipped with small speakers are installed in the tower. A great majority of the control tower traffic is carried on by means of voice, although c-w is occasionally used. Supplementary equipment includes a frequency meter, for periodical check-ups on tuning.

The single-channel, crystal controlled transmitter is usually not installed in the tower, and is remote-controlled from the operator's position. Normal tower transmission is on a medium frequency, but recently many control towers are being equipped with radio equipment on other frequencies for communicating with certain types of Army planes.

For the direction of aircraft having no radio equipment in operating condition, the control tower is equipped with a *light-gun*, having a parabolic reflector which throws a highly concentrated beam. By means of sights somewhat similar to those of a rifle, the gun can be *aimed* at the plane under direction. A handle on the light gun contains a trigger for flashing the light, while another handle enables the selection of red, green, or clear beams through the use of colored filters. For direction of ground traffic this light gun may be supplemented by megaphone, sirens, or a public address system.

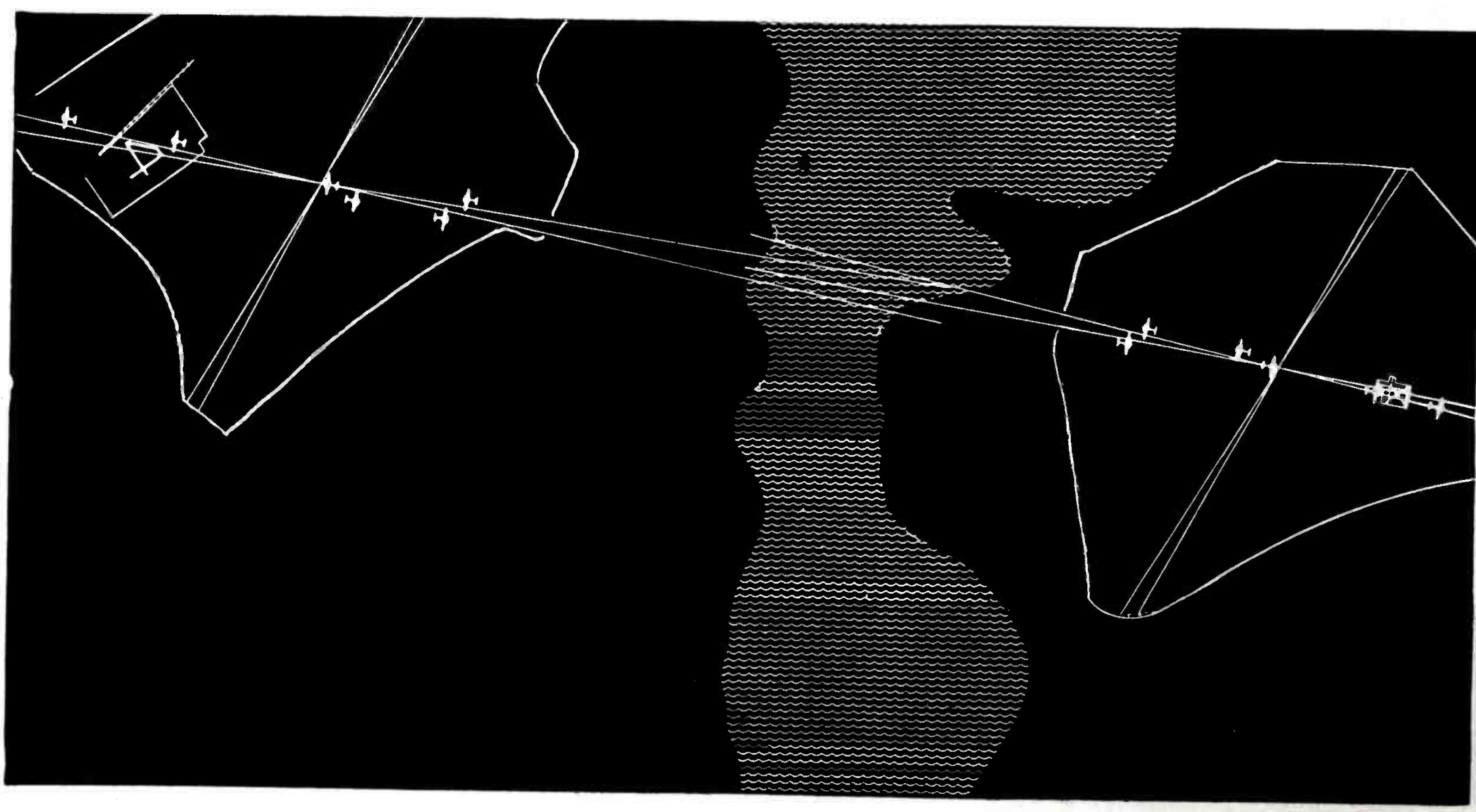
Radio aids to navigation maintained and operated by the Army Airways Communications System are of varied types, serving several purposes. Most important of these are about 160 radio ranges, the ***highways of the sky***, of which there are two principal types, differentiated by their radiation systems.

The loop radio range makes use of the basis figure-of-eight radiation pattern of the loop antenna. By means of two vertical loops, 250 to 300 feet in length, and crossing at right angles in the center of each loop, a radiation pattern as shown in Figure 1 is produced. Into one loop is keyed the signal A(.-), while the signal N(-.) is induced into the other loop. These two signals are time-synchronized to provide a constant tone, as shown in Figure 2, at all points where the fields of the two antennae meet in equal strength. These points form the straight lines X-X and Y-Y in Figure 1.

The lines along which these constant tone signals are audible, broken at intervals by the identification symbol of the individual range, from the *legs* or *courses* along which the pilot flies when *on the beam.* By the predominance of either the A or N signal, the pilot can tell when he is flying

Figure 3

Diagram of airway, including two airdromes, each equipped with a radio range. Planes are flying right-hand edge of range course, or *beam*. Range courses intersect, in this case, over body of water.



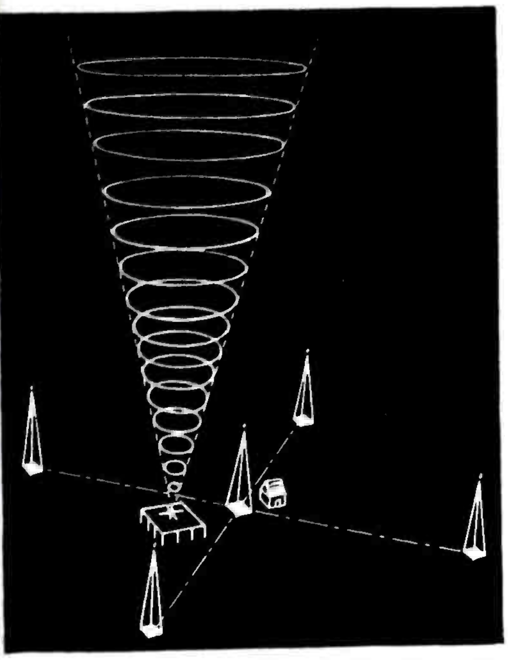


Figure 4
Radiation pattern of *Z*-marker, installed in conjunction with radio range.

slightly on either side of the theoretical *beam.* As when driving the surface highways, he is required to keep to the right. The normal human ear can detect the dominance of either signal along the sides of an angle of about three degrees, bisected by the theoretical line of absolute equality. Figure 1 shows these range courses at right angles, but they may be shifted by means of a goniometer or by using resistances to govern the relative strength of the fields radiated by the two loop antennae.

The Adcock radio range operates on the same general principle, but uses vertical steel Adcock towers as radiators. These vertical towers are placed at the corners of a square about 425 feet along each side, and are connected to the transmitter by shielded ground cables.

The use of Adcock radiators eliminates the secondary fields radiating from the horizontal wires of the loop antennae. These secondary radiations, reflecting from the earth's heavyside layer have a tendency to cause false courses, particularly at night. The Adcock type range is more difficult and expensive to install, and entails the transportation of a great deal of heavy material, but wherever feasible its use is justified by increased efficiency and safety in flight.

Another great advantage of the Adcock range is that, by the erection of a fifth tower, centered in the square, simultaneous voice broadcasting can be accomplished on a frequency identical, or closely adjacent, to the range frequency. This permits the pilot to receive weather or operational information broadcast from this fifth tower without re-tuning his radio and losing the range signal.

Normally, radio ranges are placed as close to the airport as permissible, limited primarily by the accident hazard constituted by their antennae or vertical radiators. Under ideal conditions one leg will lead into the range from the direction of approach of the maximum traffic using the field, while opposite (Figure 3) legs lead directly over the principal runway.

Normal radio range frequencies are within the low frequency band, and the range transmitter may be either operated continuously or switched on at the request of aircraft, made through an air-ground communications facility. Transmitters are crystal-controlled to assure maximum frequency regulation.

The *airway* itself, in modern practice, is considered to be the air space occupying the horizontal area extending five miles to either side of the theoretical line of absolute equality of relative strength. Aircraft flying these airways follow the right-hand side of one range course until a leg of the next range is intersected, following that until over the range station and so on until reaching their final destination.

An inherent radiation characteristic of radio ranges is the *cone-of-silence* directly above the range station. This cone-of-silence provides only a negative sort of navigation *fix,* since other zones of silence caused by atmospheric, geologic, or geographic conditions can easily be mistaken for the true one.

To provide a positive navigational fix, a radio beacon known as the *Z*-marker has been developed and is used with most Army Airways Communications System ranges. This beacon, located within the ground area of the range itself, consists of an u-h-f transmitter feeding into a highly directional antenna, beneath which is a reflector of wire mesh.

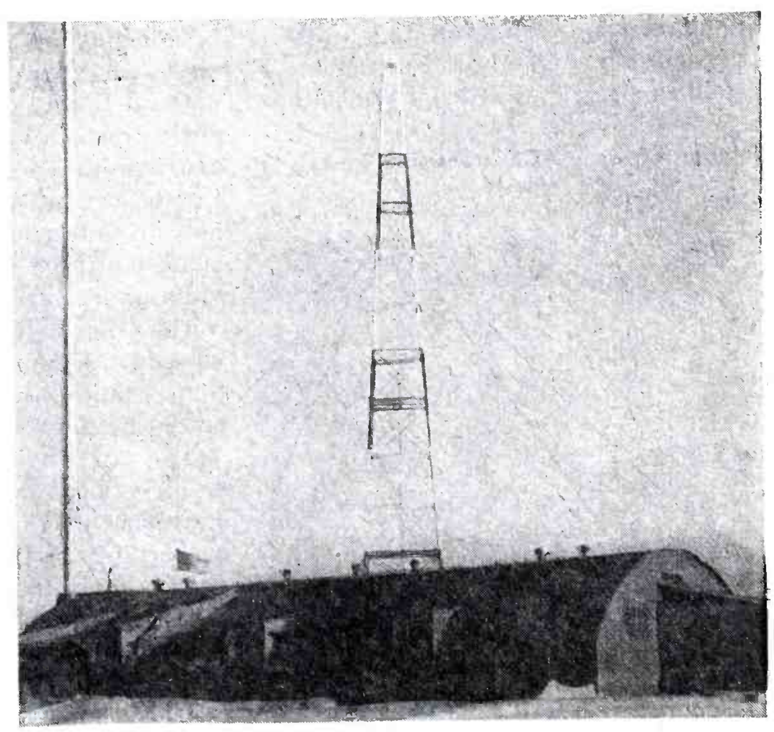
The radiation pattern produced by the *Z*-marker is in the form of a vertical cone (Figure 4), which is intercepted by a special receiver, tuned only to the *Z*-marker frequency, in the cockpit of the plane. The signal produced is both visual and aural, a light flashing on the instrument panel while an individual identification signal is heard on the earphones.

The fan-marker, a variation of the *Z*-marker, projects a fan-shaped pattern, producing a horizontal oval across the airways, customarily used to indicate distance from a designated landing field.

Homing beacons provided by the Army Airways Communications System are merely standard c-w radio transmitters, radiating a field of equal strength in all directions, with a designated identification symbol. These units are located at certain points along the airways where radio ranges are unreliable, due to atmospheric or geographic conditions. The signal is received by means of the aircraft radio compass, providing a direct bearing to the beacon. The homing beacon, like the range, may operate continuously or be activated upon request.

Actually, any radio transmitter may be used as a homing beacon, which accounts for the shut-down of radio broadcast facilities during an air raid. Control tower transmitters have served as homing beacons in emergency.

Ground-radio-direction-finders, or d/f equipment, operated by the Army Airways Communications System reverses the operation of the homing beacon. Transmissions from the aircraft are received by means of an extremely directional antenna, and the bearing relayed back by a ground-air communications station. The plane may hover within a small circle until



A far Northern AACS communications station.

(Photo, courtesy United States Army Air Force)

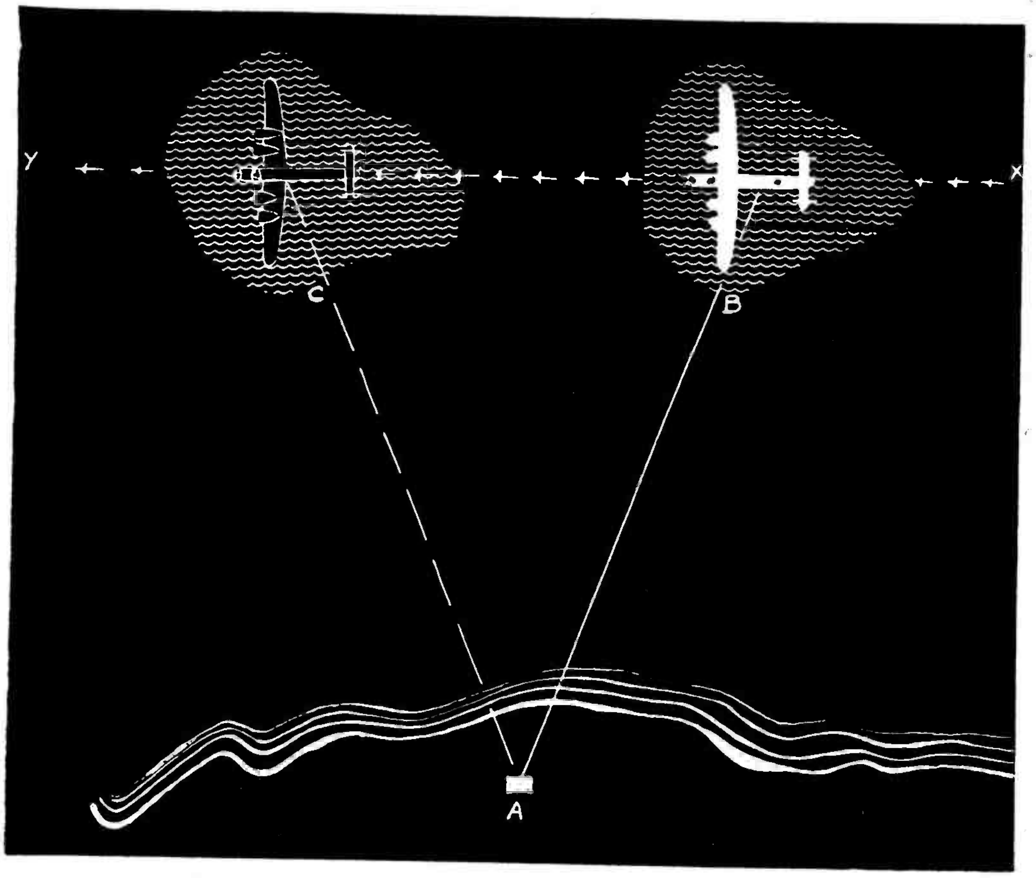


Figure 5

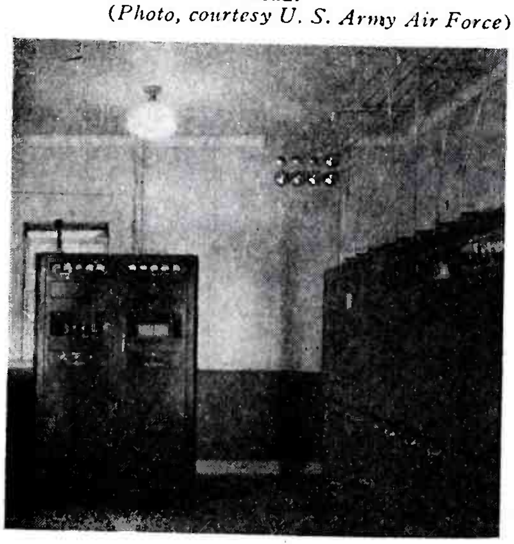
Procedure with one d/f unit. Plane flying course X-Y, receives bearing A-B and continues on course to C, where bearing A-C is received. Time of each bearing is recorded, giving distance B-C. With base and two angles, triangle ABC can be charted, with apex at A, which is known location of d/f unit. This gives exact position of plane at time each bearing was taken.

it receives the bearing, though a single bearing gives only the direction to the d/f station, and not a definite navigational fix, since distance is not shown.

In order to provide a definite fix by triangulation, the aircraft contacts the d/f station while moving at normal speed. The bearing is transmitted, with exact determination, and another bearing is taken a short time later. By plotting the two bearings, with the known distance traveled between readings, a triangulation establishing an exact navigational fix can be accomplished (Figure 5).

More recent d/f procedure developed by the Army Airways Communications System provides for the use of two or more semi-portable d/f units operating as a team. These units, located some distance apart, take simultaneous bearing on the aircraft transmission, and almost immediately establish a navigational fix by triangulation. This calculated position is then relayed back to the aircraft by an air-ground communications station operating in conjunction with the d/f apparatus (Figure 6). Completely portable d/f stations, mounted on trucks, have also been developed.

Interior of an AACS transmitter room in Alaska.
(Photo, courtesy U. S. Army Air Force)



The latest d/f development of the Army Airways Communications System, in which several semi-portable d/f units and one central evaluating station operate as a net covering roughly the area of a circle 1,000 to 1,500 miles in diameter, takes advantage of the proven theory that the accuracy of a navigational fix increases in direct proportion to the number of bearings, within reasonable limits, secured from separate locations.

Not less than four nor more than eight of these semi-portable units are installed at sites as nearly as possible equidistant on the perimeter of the circle enclosing the area for which the net's d/f service is intended. The evaluating station, which also includes a d/f unit, is located somewhere near the center of this circle. Complete nets are interconnected to provide adequate coverage for large world areas. Each individual d/f unit operates in conjunction with, and is located in the vicinity of, an airways communications station, with which it is connected by a direct telephone line.

The aircraft desiring a fix contacts an air-ground station, which alerts the entire net and instructs the lost plane concerning the transmission of d/f signals. Each individual d/f unit then takes a series of bearings which are relayed through airways point-to-point channels to the evaluating station.

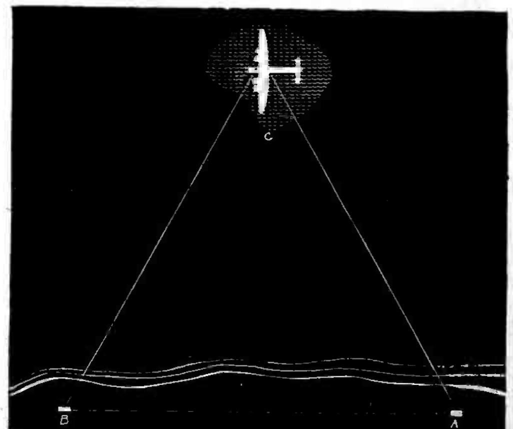
The bearings received from each d/f unit, including the one attached to the central evaluating station, are immediately plotted on a master chart, evaluated, and the position of the plane determined within an extremely brief period of time. The plotting and evaluating personnel are especially trained for this work, and have no duties or responsibilities in connection with radio operation or maintenance. The finally determined position is relayed back to the aircraft through the air-ground communications net with which the d/f net is connected.

The equipment installed in each of these d/f units provides an instantaneous visual bearing indication with a minimum of the operator's time and attention, through the use of the cathode-ray tube. Bearings are continuous while the aircraft is transmitting, and are automatic in that they shift immediately with any change in direction of the received signal.

The system of airways communications, airdrome traffic control, and radio navigational aids developed and operated by the Army Airways Communications System Wing probably exceeds in size all previous such systems combined. It extends directly into the theatres of action in every quarter of the globe, and as the fighting fronts move forward into enemy-held territory, the Army Airways Communications System moves right along with them. It will continue doing so until the final victory is won.

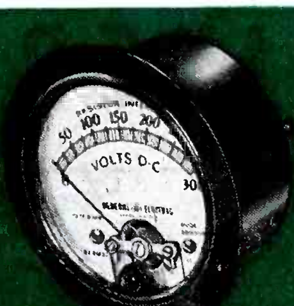
Figure 6

Procedure with two d/f units working as a team. Plane at C transmits signal enabling simultaneous bearings to be taken by d/f units at A and B, which have established intercommunications. With base A-B, and angles CBA and CAB, triangle with apex at C is charted. Triangulation is accomplished by d/f personnel, and position at time of contact is given to plane. Plane does not need to know location of d/f units.

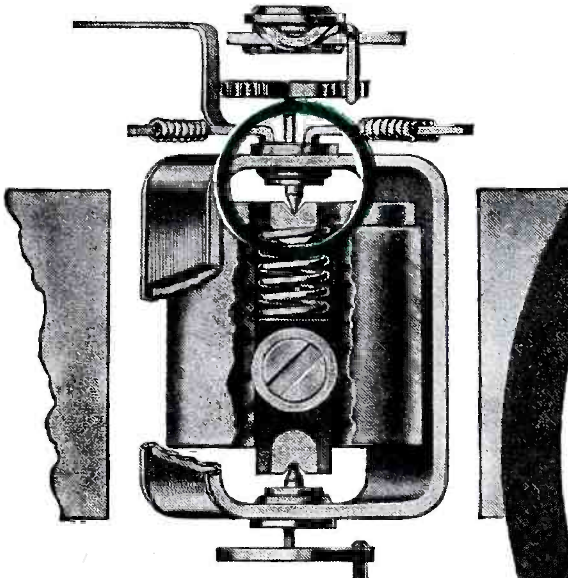


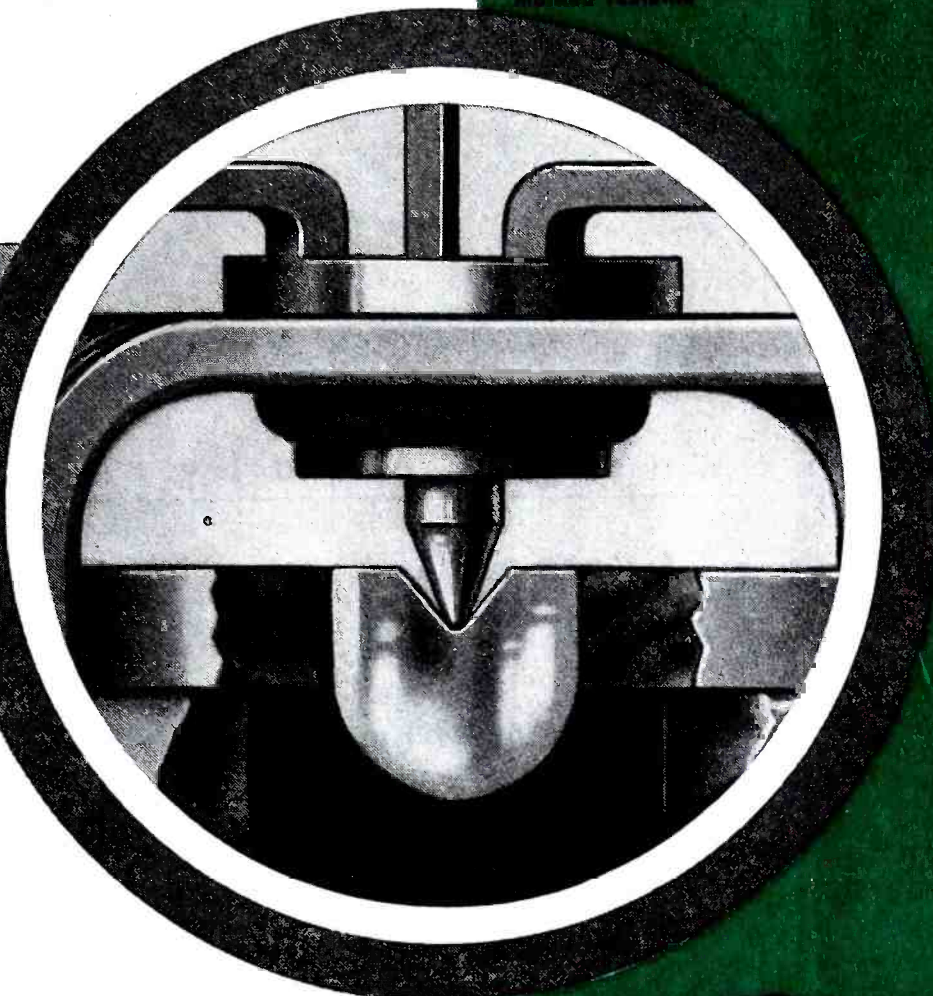
New INTERNAL-PIVOT ELECTRIC INSTRUMENTS

2½-inch - - - 1 inch deep



For radio and other communications service: d-c voltmeters, ammeters, milliammeters, microammeters, and radio-frequency ammeters and milliammeters (a-c thermocouple type). Cases are brass or molded Textolite.





(Above) The new internal-pivot bearing construction. (Right) Top bearing (pivot and jewel) magnified 20 times. Note strong, solid construction.

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IN THESE new G-E instruments, the pivots are solidly mounted on the *inside* of the armature shell instead of being cemented to the outside of the armature winding. The result is a rigid construction that helps to maintain accurate alignment.

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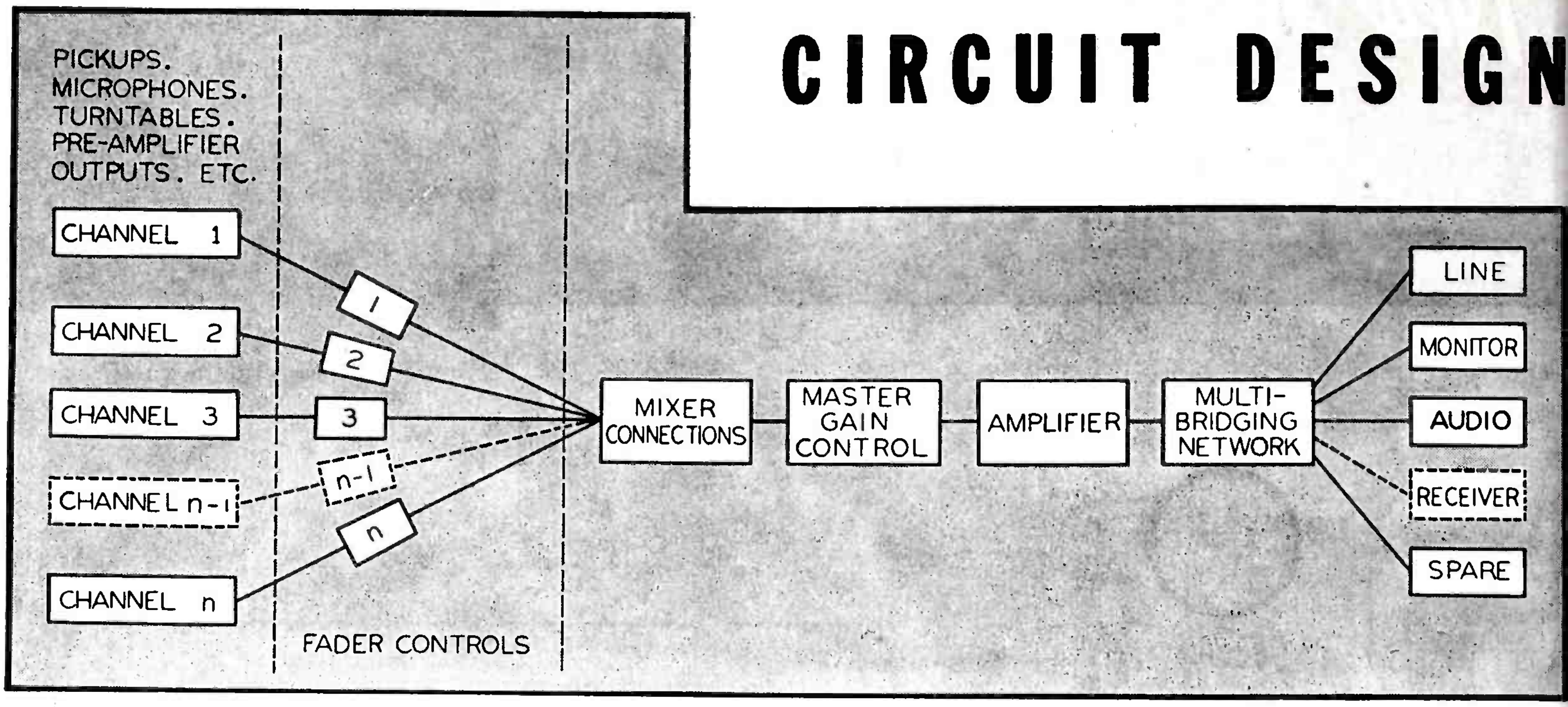
MIXER AND FADER CONTROL CIRCUIT DESIGN



A Thorough Analysis, With Tables To Facilitate Application and Design

(PART ONE OF A TWO-PART PAPER)

by PAUL B. WRIGHT
Communications Research Engineer

SINCE the earliest days of broadcasting, there has always been a need for combining two or more sources of energy such as microphones and amplifiers into a common load impedance, and of controlling the various levels of energy relative to and independent of each other. And the general procedure of those days is still in use. That is, the resultant of the mixing is controlled by another piece of equipment which is finally connected to an amplifier. The output of the amplifier is then fed through some form of distribution system to a number of locations as required.

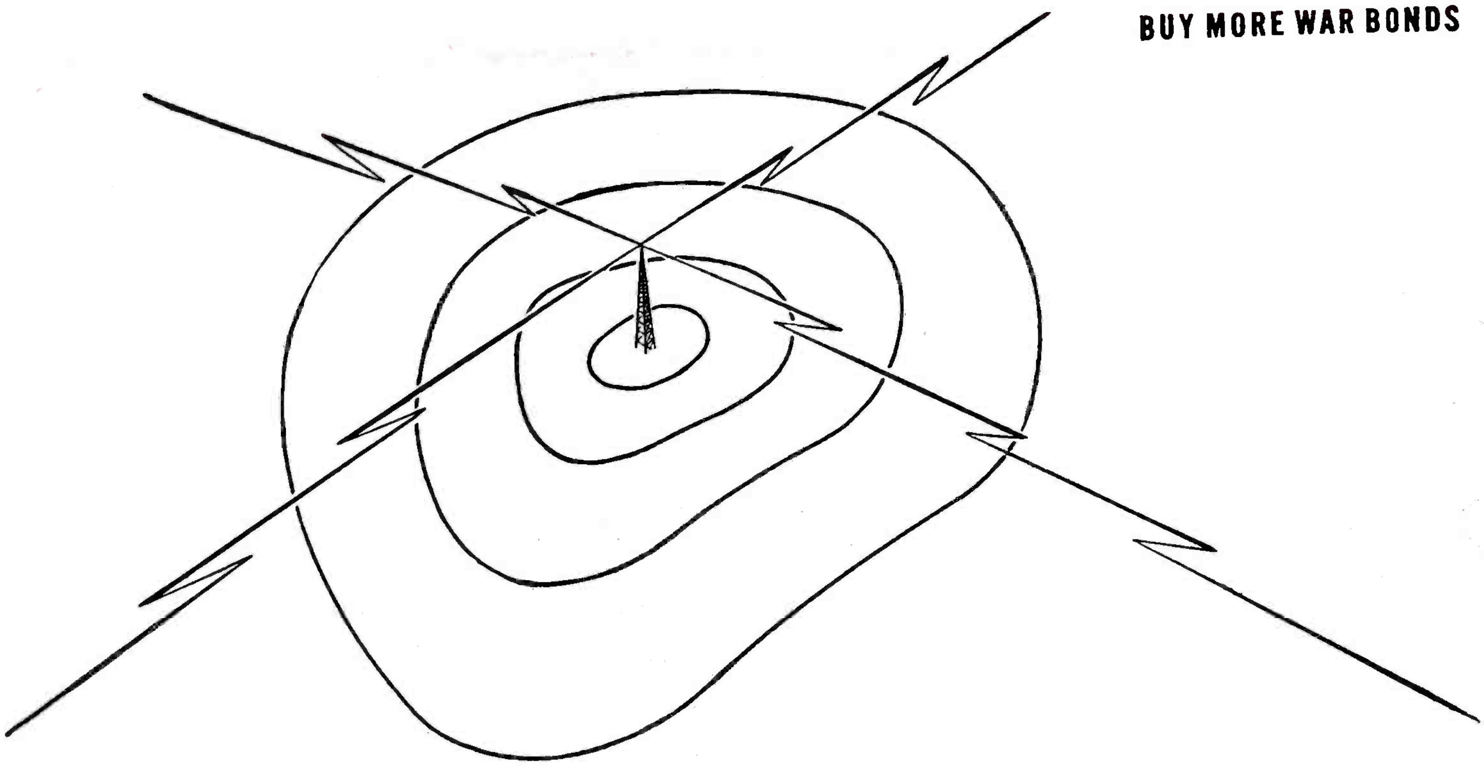
Some of the earlier methods of mixing utilized simple series or parallel connections of microphones and associated equipment. These gave generally high insertion losses and high distortion because of the tremendous degree of mismatching which quite frequently occurred at the junctions of each unit of the connected equipment. Each mixer added increased the difficulties of producing high quality program material, no matter how excellently rendered at the studio or pickup point.

A number of different corrective methods were tried with varying success; each had some impedance mismatching or deficiency which gave generally poor to indifferently good quality. Gradually, improved methods of design of the units and component parts of the mixer systems by the application of circuit analysis, mechanical stability, metallurgical research upon reduction of contact potentials in air, greater care in shielding and grounding, and rearrangements of equipment in general, brought about improvement in quality, freedom from switching and operation clicks, and a reduction in the amount of noise and cross-talk formerly experienced.

The devices which control the relative levels of energy of each channel are known as faders, and are simply variable attenuators which may be smoothly changed over a range of attenuation from (ideally) zero insertion loss to infinite loss. Practically, the loss may be made to approach 80 to 100 decibels with moderate care in design and wiring for the maximum loss, and zero for the minimum loss of some types of attenuators. The objective of the fader is largely what its name implies. That is it provides the auditory sensation of a gradually diminishing sound, fading imperceptibly into the background noise and vanishing as the attenuation is increased to the maximum loss setting of the attenuator. The reverse condition is experienced when the attenuator loss is decreased from its maximum amount.

Devices which accept the energy of the combined groups of faders are known as master gain controls or mixers. However, the actual mixing may be done through the connections of the faders. The master gain control is another attenuator and used to regulate the overall level of the total output of all channels. The output from the master gain control is then fed to an amplifier which in turn has some form of multiple outlets, such as a multiple bridge, or separate windings

Figure 1 (above)
A typical arrangement of mixer and fader control equipment with associated circuits.



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- TRANSMITTER
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from an output transformer. Figure 1 shows in block form a typical arrangement for mixer and fader control circuits.

Mixer and fader control circuits are composed of two general types of networks. These are (*a*)—active networks furnished by electronic devices, and (*b*)—passive networks composed of resistive elements in which there are no internal sources of emf.

Electronic mixers are variable-controlled amplifiers utilizing one amplifier or more per channel. The output sides of the amplifiers may be fed through a suitable mixing network; or as is commonly done the outputs may be tied together either directly or through coupling condensers. If triode tubes are used it is better to use some form of mixing system other than direct coupling because of the relatively large variation in plate-to-cathode impedance resulting with high level signals. If screen grid or pentode tubes are used, the coupling condenser or direct connection may be used satisfactorily, since the plate impedance remains quite high with even high level signals.

Electronic mixers have a number of advantages. Some of these are: (*1*)—Freedom from direct interaction between supply or microphone circuits (when mixing takes place on the plate side of the circuit), but not necessarily so when mixing is done on the grid side of the circuit. (*2*)—Because of the gain available, mixing may be done directly from low energy sources such as the crystal, velocity or ribbon types of microphones. This permits the output level of the channels to be fed over a loop or line at a level that is well above the normal noise and cross-talk volumes. (*3*)—Ease of use with variable equalization schemes for enhancing, expanding, or compressing program material. Some of the disadvantages of these mixers, compared with the resistor types of mixing are: (*1*)—Relatively high initial cost. (*2*)—High maintenance costs. (*3*)—Inflexibility caused by power supply difficulties, since some localities have power of different frequencies; others have d-c; still others have none at all. This necessitates battery powered units, and batteries are heavy, cumbersome, and difficult to obtain. (*4*)—Hazards of service failures caused by loose connections, bad tubes, breakdown of condensers, and other component parts.

Resistive element circuits have the advantages of: (*1*) relatively low initial cost. (*2*)—Negligible maintenance cost. (*3*)—Light weight and compactness. (*4*)—Ease of construction. (*5*)—High flexibility for most

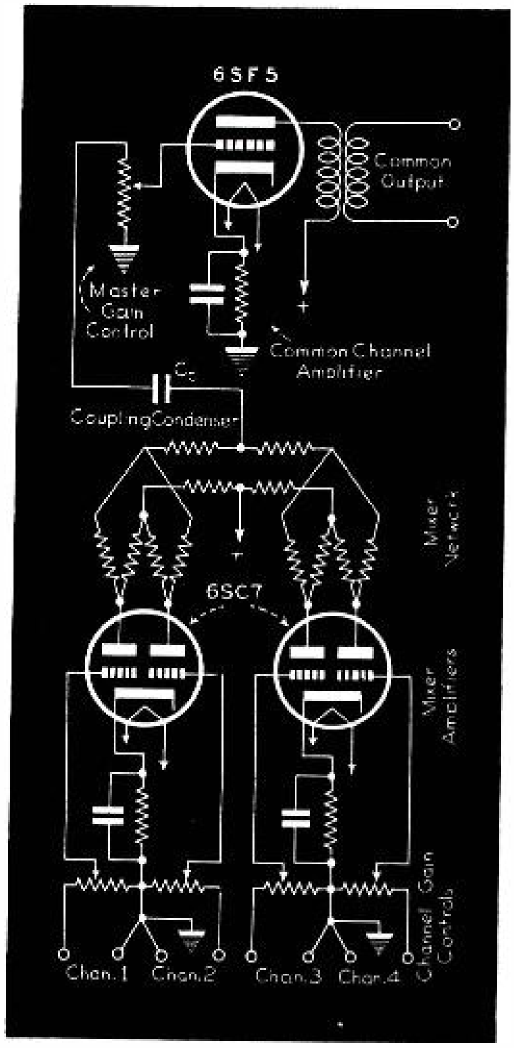


Figure 2

An arrangement of an electronic mixing and gain control.

general purposes. Some of the disadvantages of these circuits are: (*1*)—They may not be used for mixing low level signals without an accompanying amplifier, if the channel outputs are to be transmitted over a loop or line; the signal would then be below the normal line noise and crosstalk volume levels. (*2*)—Relatively high losses which must be compensated for by a pre-amplifier in low level mixing, or by extra gain in the main amplifier following the master gain control in high level mixing. (*3*)—Noise caused by dirty contacts.

This paper is largely concerned with the passive types of mixer networks, and of the methods of design and application which may be used in each case, to have matched image impedances at each and every junction throughout the networks. A price must inevitably be paid for such matching, however, in the form of definite, fixed and relatively high amounts of insertion loss. Such losses must be made up by means of extra gain either preceding or following the mixer system.

In choosing what type or design of mixer circuit to follow, a number of factors must be fairly considered before making the choice. Among these considerations are:

(*1*)—Number of channels needed.

(*2*)—Impedances of inputs and output, either available or required.

(*3*)—Limits of insertion loss, both maximum and minimum. The minimum desired is of course zero, but is rarely attained in practice.

(*4*)—Whether low level to operate directly from microphone or pickup heads, or high level to operate from amplifiers on the input sides of the channels.

(*5*)—Constant fader impedance over the complete attenuation range.

(*6*)—Smooth control of volume from minimum to maximum settings of both fader and master controls; 1 db variation is permissible since that is the lower limit that the best ears can detect and then only under special conditions of background noise, signal volume and character of the program material being used.

(*7*)—Grounding of the system, and whether balanced or unbalanced to ground.

(*8*)—A minimum of 45 db for the maximum loss setting of each fader and master gain control, with (ideally) infinite loss in the final position.

(*9*)—Flexibility as to patching and switching arrangements for operation, with particular attention being paid to speed of restoration of service in case of the failure of any individual channel.

(*10*)—No frequency discrimination should take place regardless of the position of the controls.

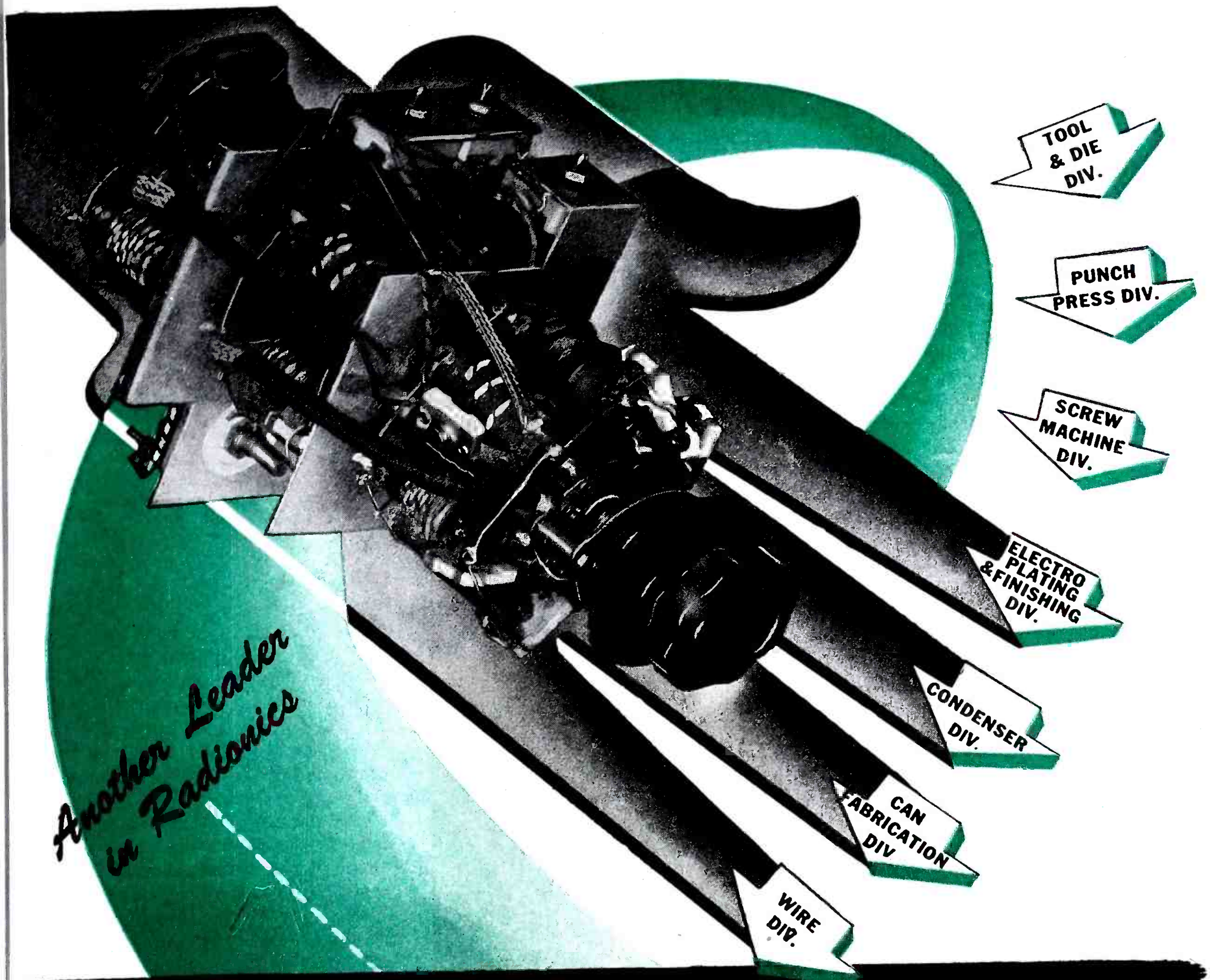
(*11*)—Freedom from interaction between fader attenuators, even for settings of the faders approaching their minimum insertion losses.

(*12*)—Wiring of the mixer system should be carefully done to minimize the pickup interference from extraneous stray fields. Thus very careful choice of grounding and shielding should be made.

(*13*)—Rigidity and ruggedness of construction.

(*14*)—Ease of operation, maintenance and installation.

(*15*)—Compactness and light weight,



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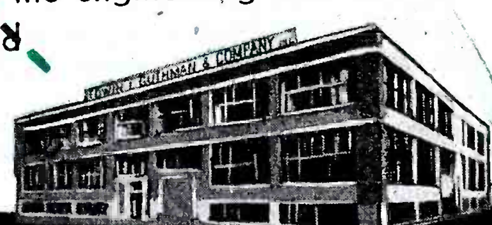

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(*16*)—Last but not least, the system should be as reasonable in cost as the above requirements will allow.

The attenuators which should be used for the fader portions of the mixer system may be any of a number of configurations. The exact one that will be used will depend upon the considerations just outlined. Each installation will have particular requirements which will make it more desirable to use one type rather than another. The simple voltage divider and the *L* types are not used in high quality stations because of their lack of constancy of impedance with variable setting. The major source of grief with all of the earlier systems either directly or indirectly was caused by variable matching and mismatching of the impedances at the junctions of the connected mixer equipment. The types of networks which meet the constant impedance requirement or permissible variation in impedance are the *T, H,* π, *O* and the ladder types. The *H* is a balanced *T,* and the *O* is a balanced π type attenuator. The ladder attenuator may be also balanced or unbalanced and is composed of a large number of sections of artificial line having pure resistance components, which may be tapped at a number of points along its length. The *T* may be used for low level mixing as may the π type. The ladder type is generally recommended for use with high level mixing, although the newer types having slider arms and contact points made of the same metals have made the problem of mixing at low levels much easier.

The master gain control should be given the same considerations as the fader control. Any of the standard forms of attenuators given above will suffice for this unit of the mixing system.

Any of the attenuators used in the mixer system may be required in either balanced or unbalanced form. A balanced circuit is one which has both sides of equal impedance, and of equal impedance to ground. An unbalanced circuit is one having one side of (ideally) zero impedance, and having zero impedance to ground. This implies that each common ground connection should be connected directly by the shortest possible lead lengths to the grounding bar or system used.

The types of mixers in common usage in passive networks are: (*1*)—Series. (*2*)—Parallel. (*3*)—Series-Parallel. (*4*)—Parallel-Series. Some of the lesser known ones are: (*5*)—Multiple Bridging. (*6*)—Lattice. There are a number of other special forms used in some commercial and governmental service applications.

This paper is concerned with only the six forms mentioned above. The objective is to show by analytical methods how the various network parameters are derived for each type of mixer in order that each and every mixer input will be matched with its image impedance, and each mixed output will also be matched on an image basis. Further, it is the objective to present all of these derivations in tabulated form by means of tables to enable the engineer, experimenter and amateur to design any of the forms of mixers described by using the constants given, in conjunction with the impedances of the circuit and the number of channels desired.

Analytical Design

The following nomenclature will be used throughout this paper:

$k^2 = P_Z/P_z$, the ratio of the power entering the mixer system channel to the power delivered to the load or master mixer.

db $= 10 \log_{10} (P_Z/P_z) = 20 \log_{10} k$ decibels insertion loss of each mixer channel.

[*subscripts s, p, sp, and ps refer to series, parallel, series-parallel, and parallel-series respectively.*]

n = No. of channels in series, or in parallel.

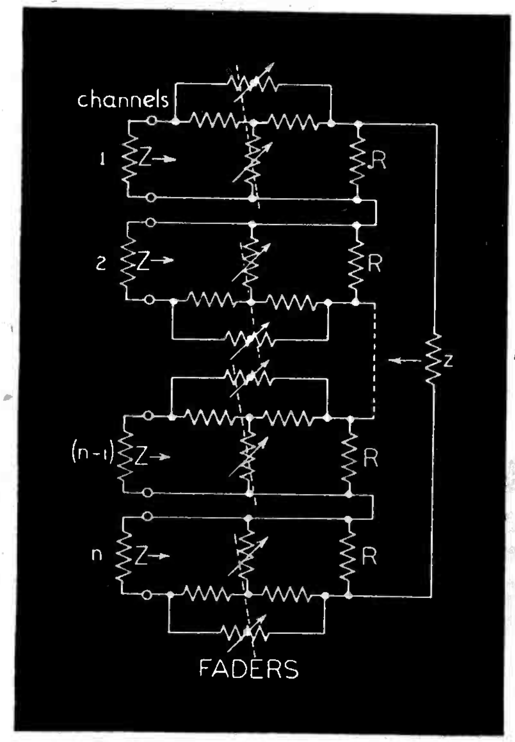
N_s = No. of channels in series in the series-parallel case, and the no. of groups of parallel channels in series in the parallel-series case.

[*Subscripts Z and z refer to input and output respectively.*]

Z = Mixer channel image impedance.

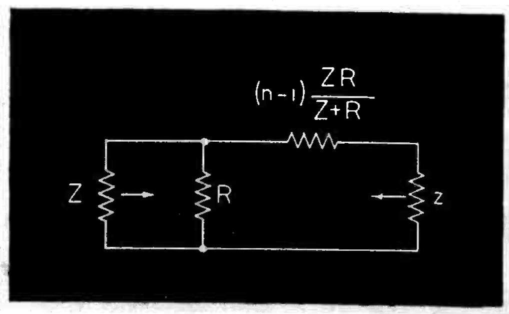
z = Mixer system output image impedance.

[*R with associated subscripts refers to the compensating resistances used either with series mixers, or with parallel mixers.*]



Figures 3 (above) and 4 (below)

In Figure 3 appears a series mixer circuit of *n* channels with compensating resistance to maintain constant impedance relationships of inputs and load. In Figure 4 we have the equivalent of Figure 3 with constant impedance, with bridge T faders removed.



Series Mixers

Let us consider *n* mixer channels, each having an input impedance of *Z* ohms, and each shunted with a resistance *R,* with the series sources or mixers supplying a common load such as a master mixer or attenuator connected ahead of and feeding the input of an amplifier, as shown in Figures 1 and 3.

It is assumed that only constant resistance attenuators are used for the faders of the system, and except for an additional loss which must be added algebraically to the insertion loss of the mixer, the removal of the fader will not affect the image impedance relationship. Hence for analytical purposes, the fader may be removed and the schematic form shown in Figure 3 may be shown on an individual channel basis as Figure 4.

The impedance of the load is, from Figure 4,

$$z = n\frac{RZ}{R+Z} \qquad (1)$$

The impedance of each source is

$$Z = \frac{R\left[z + (n-1)\dfrac{RZ}{R+Z}\right]}{R + z + (n-1)\dfrac{RZ}{R+Z}} \qquad (2)$$

Substituting *1* into *2,* and solving for R in terms of Z and n, we obtain

$$R = Z\frac{n}{n-1} \qquad (3)$$

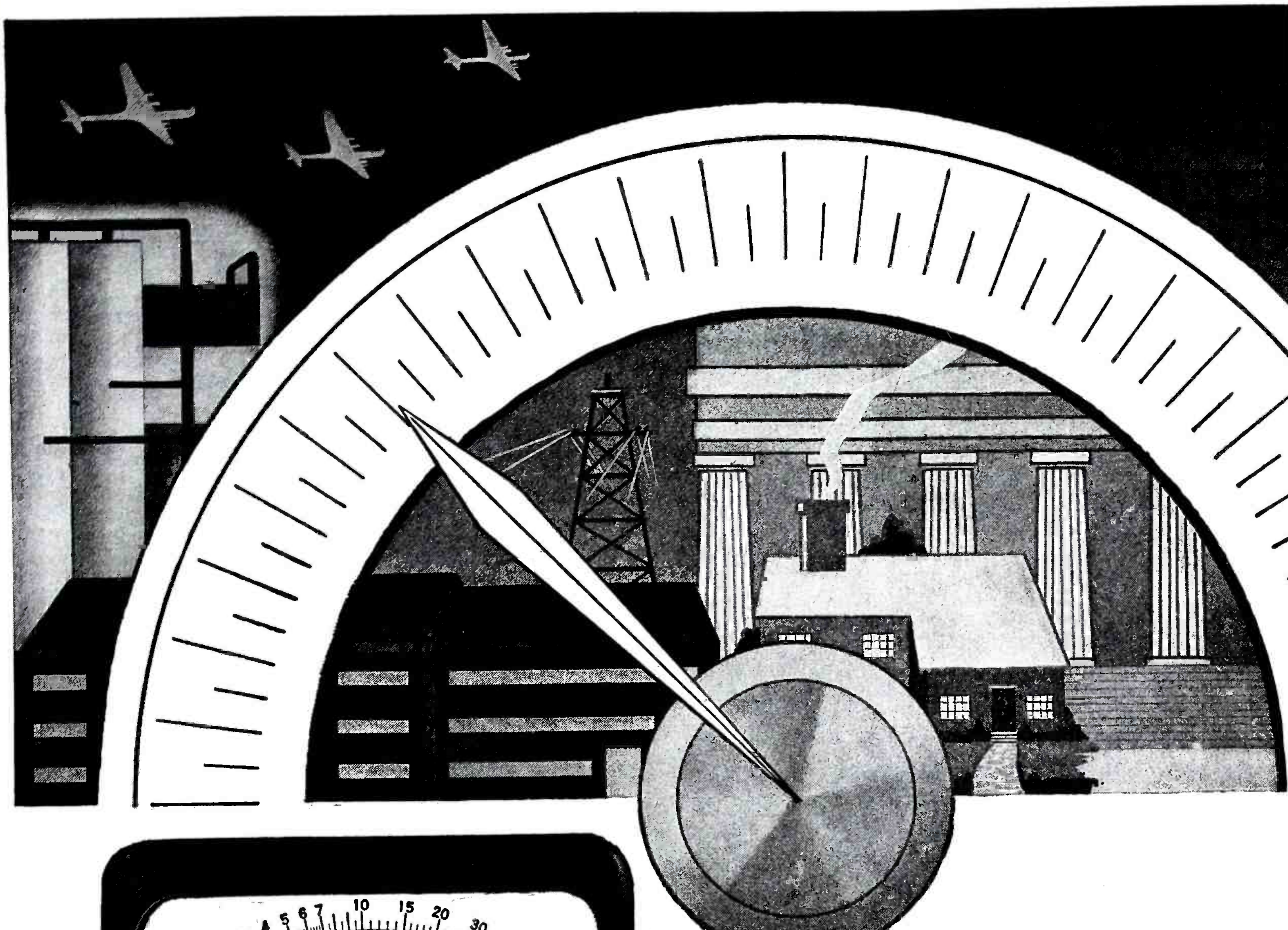
Reducing and simplifying *2*

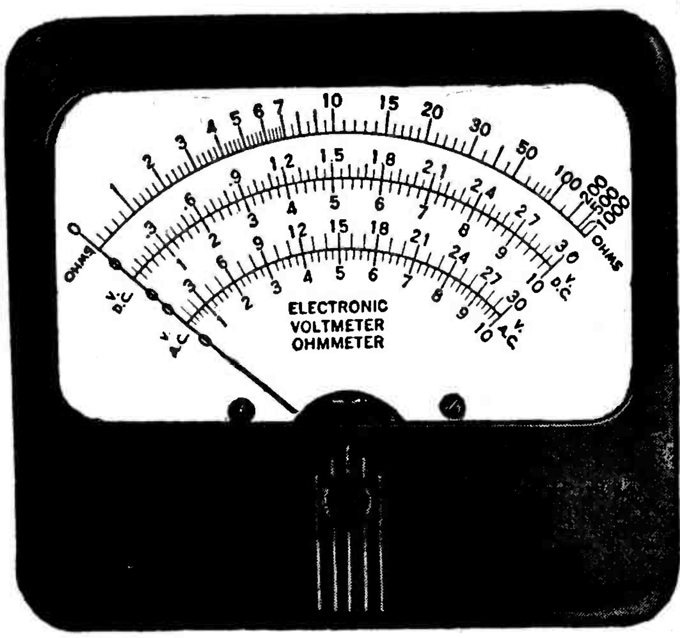
$$(2Z - nZ - z)R^2 + nZ^2R + Z^2z = 0 \qquad (4)$$

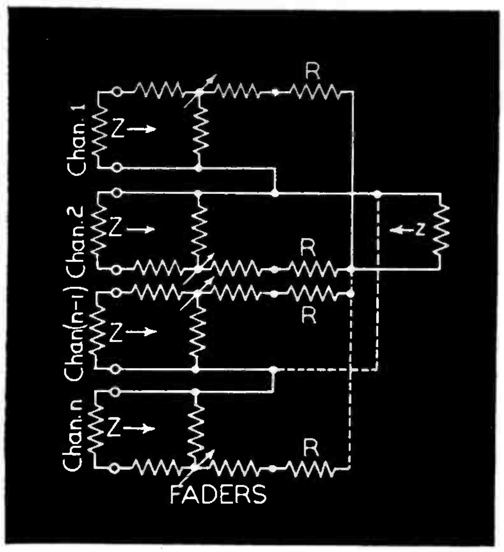
Substituting *3* in *4,* and solving for *z,*

$$z = Z\frac{n^2}{2n-1} \qquad (5)$$

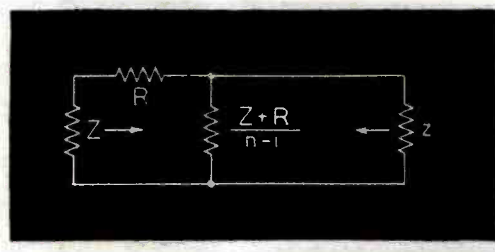
Equations *3* and *5* are used when *Z*




ELECTRONIC
VOLTMETER
OHMMETER



Figures 5 (left) and 6 (right)
A parallel mixer of *n* channels with impedance compensating resistance to avoid impedance mismatching of the system at all inputs, and output. In Figure 6 we have the equivalent of Figure 5 with constant impedance *T* network faders removed.



and n are known or assigned, but when z and n are known instead, we solve for Z and R from *5* and *3* respectively, obtaining

$$Z = z\frac{2n-1}{n^2} \qquad (6)$$

and

$$R = z\frac{2n-1}{n(n-1)} \qquad (7)$$

The voltage across Z = that across R, hence,

$$e_Z = e_R \qquad (8)$$

or

$$Zi_Z = Ri_R \qquad (9)$$

From *9,* the ratio

$$\frac{Z}{R} = \frac{i_R}{i_Z} \qquad (10)$$

but from *3*

$$\frac{Z}{R} = \frac{n-1}{n} \qquad (11)$$

equating *10* and *11*

$$\frac{i_R}{i_Z} = \frac{n-1}{n} \qquad (12)$$

The current through the load is

$$i_z = i_Z - i_R = i_Z - i_Z\frac{n-1}{n} \qquad (13)$$

or

$$i_z = i_Z \cdot \frac{1}{n} \qquad (14)$$

The power delivered to the load is, using *5* and *14*

$$P_z = i_z^2 Z = \left(i_Z^2 \cdot \frac{1}{n^2}\right)\left(\frac{n^2}{2n-1}\right)Z \qquad (15)$$

or

$$P_z = i_Z^2\frac{Z}{2n-1} \qquad (16)$$

The power available at the load, were there no other series mixers, and the load impedance z = Z, the source impedance would be

$$P_Z = i_Z^2 Z \qquad (17)$$

The insertion loss of the mixer is the loss which is incurred because of the series combination of units being used, instead of a single matched source and load impedance. The ratio of the powers gives the ratio of the power which would be available at the load, were no other network inserted between the source and the load. The insertion loss in decibels is therefore, from *17* and *16,* and using common logarithms,

$$db = 10\log_{10}\frac{P_Z}{P_z} = 10\log_{10}\frac{i_Z^2 Z}{i_Z^2\dfrac{Z}{2n-1}} \qquad (18)$$

or

$$db = 10\log_{10}(2n-1) \qquad (19)$$

Letting the power ratio,

$$\frac{P_Z}{P_z} = k^2 \qquad (20)$$

From *19* and *20*

$$k^2 = 2n-1 \qquad (21)$$

Solving *21* for n,

$$n = \tfrac{1}{2}(k^2+1) \qquad (22)$$

Substituting *22* in equations *3, 5,* 6 and *7,*

$$\left\{\begin{aligned} R &= Z\frac{k^2+1}{k^2-1} \\ z &= \frac{Z}{4}\,\frac{(k^2+1)^2}{k^2} \end{aligned}\right\} \qquad (23)$$

$$\left\{\begin{aligned} R &= 4Z\frac{k^2}{k^4-1} \\ Z &= 4z\frac{k^2}{(k^2+1)^2} \end{aligned}\right\} \qquad (24)$$

Equations *23* and *24* may readily be

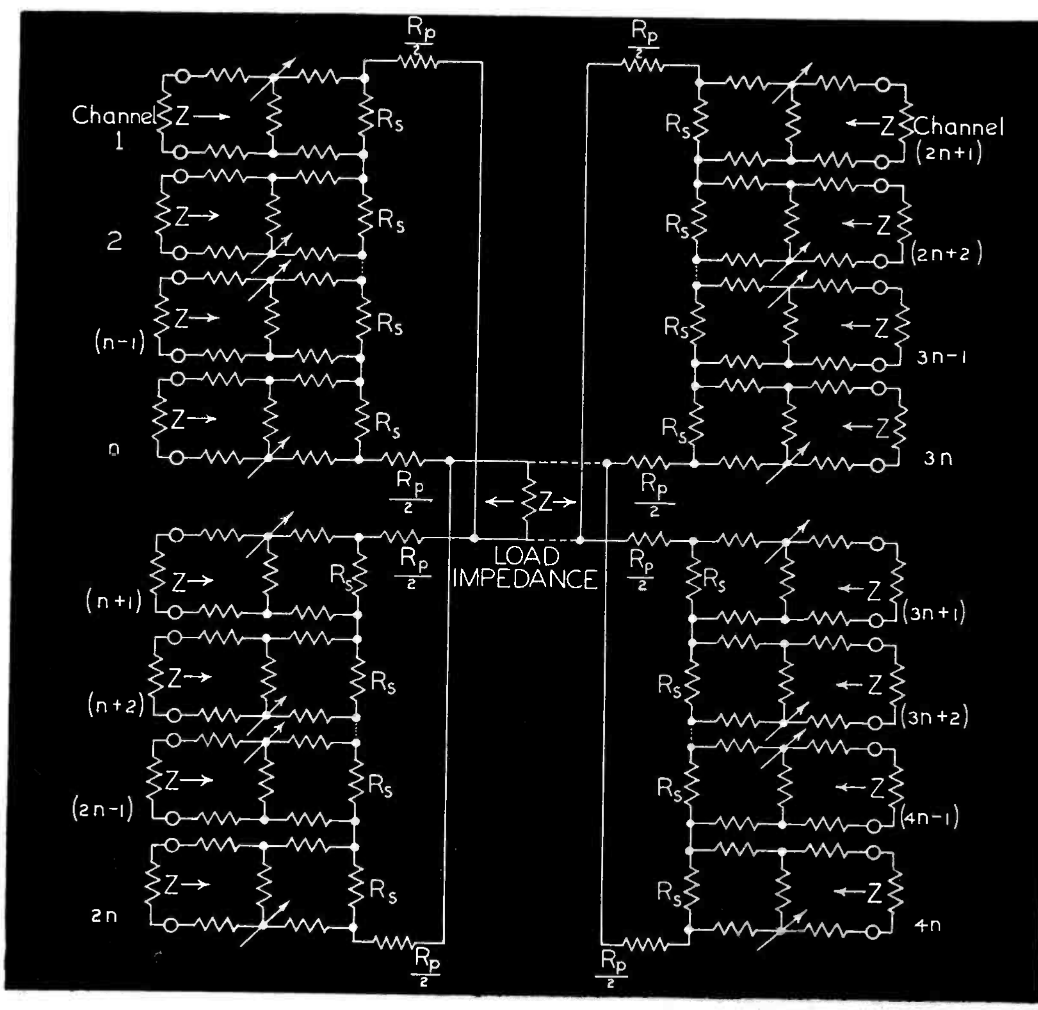


Figure 7
Series parallel mixers of *n* channels in series, in parallel with *m* groups of series-arranged circuits.

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Table 1

Series mixer for:		No. of Channels 2	3	4	5	6	7	8	9	10	
Z and n assigned	C_{Rs1}	2.00000	1.50000	1.33333	1.25000	1.20000	1.16667	1.14286	1.12500	1.11111	$R = Z \cdot C_{Rs1}$
Z and n assigned	C_{zs1}	1.33333	1.80000	2.28576	2.77778	3.27273	3.76923	4.26667	4.76470	5.26316	$z = Z \cdot C_{zs1}$
z and n assigned	C_{Rs2}	1.50000	.83333	.58333	.45000	.36667	.30952	.26786	.23611	.21111	$R = z \cdot C_{Rs2}$
z and n assigned	C_{Zs2}	.75000	.55555	.43749	.36000	.30555	.26531	.23437	.20988	.19000	$Z = z \cdot C_{Zs2}$
Loss of each channel	db_s	4.77	6.99	8.45	9.54	10.41	11.14	11.76	12.30	12.79	$db_s = 10 \log_{10}(2n-1)$

Where: R = Value of resistance to be added in shunt across each channel
Z = Mixer input impedance of each channel
z = Mixer common output impedance
n = No. of channels of the mixer
db_s = Insertion loss of each mixer channel in decibels
$C_{Rs1} = n/(n-1)$; $C_{zs1} = n^2/(2n-1)$
$C_{Rs2} = (2n-1)/n(n-1)$; $C_{Zs2} = (2n-1)/n^2$

Table 2

Parallel mixer for:		No. of Channels 2	3	4	5	6	7	8	9	10	
Z and n assigned	C_{Rp1}	.50000	.66667	.75000	.80000	.83333	.85716	.87500	.88889	.90000	$R = Z \cdot C_{Rp1}$
Z and n assigned	C_{zp1}	.75000	.55555	.43749	.36000	.30555	.26531	.23437	.20988	.19000	$z = Z \cdot C_{zp1}$
z and n assigned	C_{Rp2}	.66667	1.20000	1.71428	2.22222	2.72727	3.23077	3.73333	4.23529	4.73684	$R = z \cdot C_{Rp2}$
z and n assigned	C_{Zp2}	1.33333	1.80000	2.28576	2.77778	3.27273	3.76923	4.26667	4.76470	5.26316	$Z = z \cdot C_{Zp2}$
Loss of each channel	db_p	4.77	6.99	8.45	9.54	10.41	11.14	11.76	12.30	12.79	$db_p = 10 \log_{10}(2n-1)$

Where: R = Value of resistance to be added in series with each channel
Z = Mixer input impedance of each channel
z = Mixer common output impedance
n = No. of channels of the mixer
db_p = Insertion loss of each mixer channels in decibels
$C_{Rp1} = (n-1)/n$; $C_{zp1} = (2n-1)/n^2$
$C_{Rp2} = n(n-1)/(2n-1)$; $C_{Zp2} = n^2/(2n-1)$

transformed into hyperbolic functions of a real variable by means of the substitution

$$k^2 = e^{2\theta} \qquad (25)$$

Where

$$\theta = 0.11529 \times \text{No. of decibels} \qquad (26a)$$
$$= \log_e (2n-1) \qquad (26b)$$
$$= 2.303 \log_{10} (2n-1) \qquad (26c)$$

Using *25* in *23* and *24*, we obtain,

$$\left\{ \begin{array}{l} R = Z \coth \theta \\ z = Z \cosh^2 \theta \end{array} \right\} \qquad (27)$$

$$\left\{ \begin{array}{l} R = 2z \operatorname{csch} 2\theta \\ Z = z \operatorname{sech}^2 \theta \end{array} \right\} \qquad (28)$$

By comparison with Table 1, it may be noted that

$$\left\{ \begin{array}{l} C_{Rs1} = \coth \theta \\ C_{zs1} = \cosh^2 \theta \end{array} \right\} \qquad (29)$$

$$\left\{ \begin{array}{l} C_{Rs2} = 2 \operatorname{csch} 2\theta \\ C_{Zs2} = \operatorname{sech}^2 \theta \end{array} \right\} \qquad (30)$$

Table *1* has been prepared to facilitate the design of series mixers without the necessity of complete understanding of the basic theory from which the tabulations were prepared. The answer for any set of conditions within its scope is obtainable by the simple product of two numbers.

Parallel Mixers

Referring to Figure 5, we have a resistance-compensated parallel type of mixer of *n* channels using constant resistance faders or attenuators. The *T* type is shown, although no restriction need be made to that type of fader. Any of the standard forms may be used as long as the loss requirements and constant resistance with image impedance termination are met.

Since all source impedances or pickups are, on an image basis, assumed equal to *Z*, and if not actually so they may be made equal by suitable transformers; and, the load impedance is matched on an image basis; we may for analysis purposes remove the fader by turning it to the position giving zero insertion loss.

The equivalent of Figure 5 with faders removed is shown in Figure 6. This shows that the effect of the additional channels with the compensating resistances, is to cause an insertion loss which is dependent upon the number of channels only for any given value of *R* and *Z*.

The analysis follows a similar procedure to that of the series case. Equating the image impedances to their respective network parameters, from Figure 6,

$$Z = \frac{Z + R}{n} \qquad (31)$$

and

$$Z = R + \frac{z\,(Z+R)/(n-1)}{z + [(Z+R)/(n-1)]} \qquad (32)$$

Solving these equations in terms of the source impedance, *Z*, and the number of channels of the mixer *n*, we obtain for the compensating re-

Table 3

Series parallel mixer		No. of channels, Ns in series; or No. of series groups in parallel 2	3	4	5	6	7	8	9	10
$N_p = N_s$	C_{s1}	2.00000	1.50000	1.33333	1.25000	1.20000	1.16667	1.14286	1.12500	1.11111
$N_p = N_s$	C_{p1}	.66667	1.20000	1.71430	2.22222	2.72727	3.23077	3.73333	4.23529	4.73684
Insertion loss	db_{sp}	8.54	13.98	16.90	19.08	20.83	22.28	23.52	24.60	25.57

$R_s = Z \cdot C_{s1}$ where $C_{s1} = N_s/(N_s-1)$
$R_p = z \cdot C_{p1}$ where $C_{p1} = N_p(N_p-1)/(2N_p-1)$
$db_{sp} = 20 \log_{10} (2N_s-1) = 20 \log_{10} (2N_p-1)$

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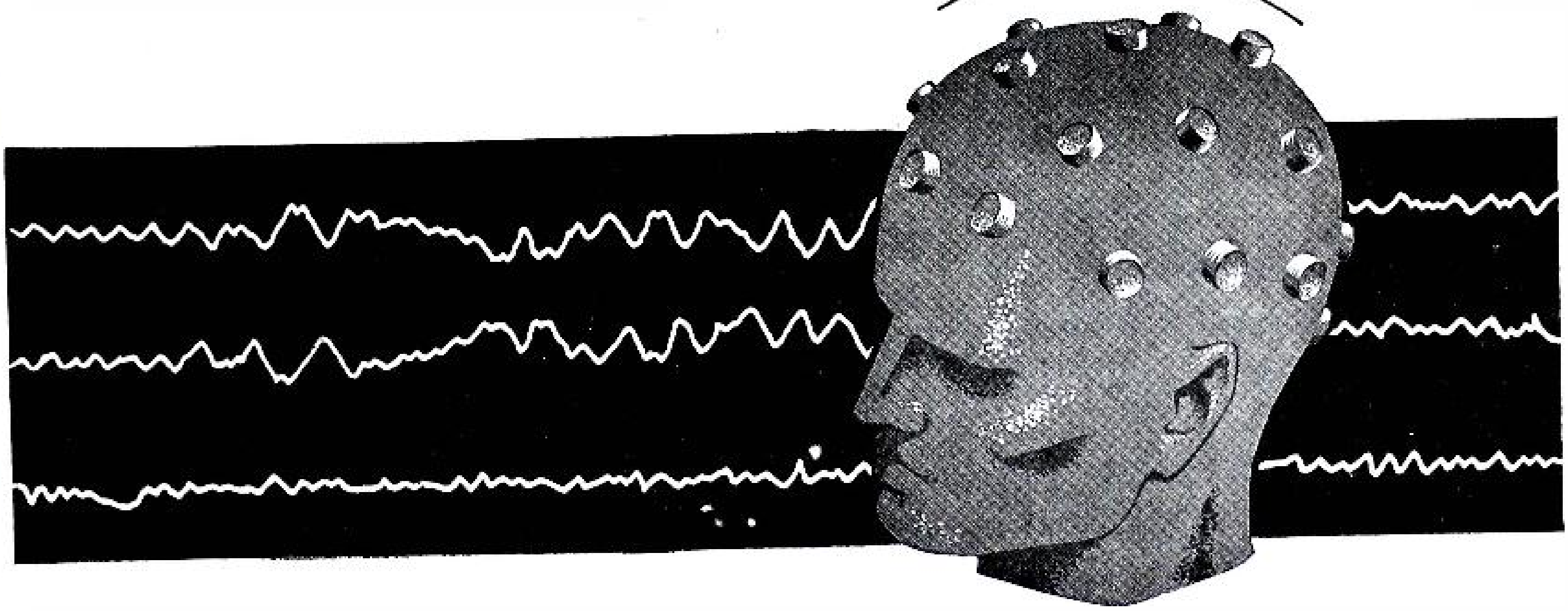

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Table 4

***C_{s2}* Series Parallel Mixer**

No. of series groups, N_p, in parallel	No. of channels, N_s in series: 2	3	4	5	6	7	8	9	10
2	2.00000	1.11111	.77778	.60000	.48889	.41270	.35714	.31481	.281482
3	2.70000	1.50000	1.05000	.81000	.66000	.55715	.48215	.42500	.38000
4	3.42865	1.90476	1.33333	1.02857	.83810	.70748	.61226	.53968	.48254
5	4.16667	2.31481	1.62038	1.25000	1.01852	.85979	.74405	.65587	.58642
6	4.90918	2.72727	1.90913	1.47275	1.20000	1.01300	.87664	.77274	.69091
7	5.65387	3.15000	2.19872	1.69612	1.38202	1.16667	1.00960	.88995	.79572
8	6.40000	3.55555	2.48892	1.92000	1.56448	1.32067	1.14286	1.00741	.90076
9	7.14694	3.97062	2.77940	2.14412	1.74703	1.47477	1.27624	1.12500	1.00588
10	7.89474	4.38596	3.07022	2.36843	1.92983	1.62906	1.40978	1.24270	1.11111

$$R_s = z \cdot C_{s2}$$

$$\text{where: } C_{s2} = \frac{N_p^2\,(2N_s - 1)}{N_s\,(N_s - 1)\,(2N_p - 1)}$$

C_{p2}

No. of series groups, N_p, in parallel	2	3	4	5	6	7	8	9	10
2	.66667	.90000	1.14286	1.38889	1.63639	1.88459	2.13338	2.38231	2.63158
3	.88889	1.20000	1.52381	1.85185	2.18188	2.51282	2.84444	3.17647	3.50877
4	1.00000	1.35000	1.71430	2.08333	2.45459	2.82686	3.20010	3.57347	3.94742
5	1.06667	1.44000	1.82859	2.22222	2.61821	2.84382	3.41343	3.81170	4.21053
6	1.11111	1.55555	1.90476	2.31481	2.72727	3.14100	3.55568	3.97046	4.38596
7	1.14286	1.54285	1.95917	2.38095	2.80528	3.23077	3.65724	4.08397	4.51121
8	1.16667	1.57500	2.00000	2.43055	2.86369	3.29800	3.73333	4.06910	4.60533
9	1.18518	1.60000	2.03174	2.46914	2.90917	3.35042	3.79261	4.23529	4.67836
10	1.20000	1.62000	2.05715	2.50000	2.94550	3.39224	3.84000	4.28816	4.73684

$$R_p = Z \cdot C_{p2}$$

$$\text{where: } C_{p2} = \frac{N_s^2\,(N_p - 1)}{N_p\,(2N_s - 1)}$$

sistance and load impedance respectively,

$$R = Z \cdot \frac{n-1}{n} \qquad (33)$$

and

$$z = Z \cdot \frac{2n-1}{n^2} \qquad (34)$$

Dividing *33* by *34*, we get

$$R = z \cdot \frac{n\,(n-1)}{2n-1} \qquad (35)$$

and solving *34* for *Z* in terms of *z* and *n*,

$$Z = z \cdot \frac{n^2}{2n-1} \qquad (36)$$

The output or load current is, from Figure 6,

$$i_z = i_Z \cdot \frac{(Z+R)/(n-1)}{z + [(Z+R)/(n-1)]} \qquad (37a)$$

$$= i_Z \cdot \frac{1}{z\dfrac{n}{Z+R} - \dfrac{z}{Z+R} + 1} \qquad (37b)$$

Table 5

Series—Parallel Mixer

No. of channels in series, N_s — ***Insertion Loss in Decibels, db_{sp}***

No. of Series Groups, N_p in Parallel	2	3	4	5	6	7	8	9	10
2	8.54	11.76	13.22	14.31	15.18	15.91	16.53	17.08	17.56
3	11.76	13.98	15.44	16.53	17.40	18.13	18.75	19.29	19.78
4	13.22	15.44	16.90	17.99	18.86	19.59	20.21	20.76	21.24
5	14.31	16.53	17.99	19.08	19.96	20.68	21.30	21.85	22.33
6	15.18	17.40	18.86	19.96	20.83	21.55	22.17	22.72	23.20
7	15.91	18.13	19.59	20.68	21.55	22.28	22.90	23.44	23.93
8	16.53	18.75	20.21	21.30	22.17	22.90	23.52	24.06	24.55
9	17.08	19.29	20.76	21.85	22.72	23.44	24.06	24.60	25.09
10	17.56	19.78	21.24	22.33	23.20	23.93	24.55	25.09	25.57

$$db_{sp} = 10 \log_{10} (2N_s - 1)\,(2N_p - 1)$$

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Table 6

Series—Parallel Mixer

No. of series groups, N_p in Parallel	No. of channels in series N_s: 2	3	4	5	6	7	8	9	10
	C_{sp1}								
2	1.00000	.74074	.58332	.48000	.40740	.35374	.31250	.27984	.25334
3	1.35000	1.00000	.78750	.64800	.55000	.47755	.42187	.37779	.34200
4	1.71428	1.26983	1.00000	.82285	.69840	.60641	.53571	[illegible]	.43428
5	2.08333	1.54319	1.21527	1.00000	.84875	.73697	.65102	.58300	.52778
6	2.45454	1.81817	1.43182	1.17818	1.00000	.86830	.76703	.68688	.62182
7	2.82693	2.09400	1.64904	1.35693	1.15169	1.00000	.88339	.79109	.71616
8	3.20000	2.37035	1.86667	1.53600	1.30368	1.13200	1.00000	.89549	.81066
9	3.57353	2.64702	2.08456	1.71529	1.45585	1.26412	1.11670	1.00000	.90529
10	3.94737	2.92394	2.30263	1.89473	1.60816	1.39637	1.23352	1.10463	1.00000

$$\frac{Z}{z} = C_{sp1}$$

$$\text{where: } C_{sp1} = \frac{N_p^2\,(2N_s - 1)}{N_s^2\,(2N_p - 1)}$$

From equation *31*

$$\frac{n}{Z + R} = \frac{1}{z} \qquad (38a)$$

and
$$\frac{z}{Z + R} = \frac{1}{n} \qquad (38b)$$

Using equations *38* in *37b*, we obtain

$$i_s = i_z \cdot \frac{n}{2n - 1} \qquad (39)$$

The power entering the network from each source impedance, *Z* is

$$P_Z = i_z^2 \cdot Z \qquad (40)$$

while that delivered to the load is,

$$P_s = i_s^2 \cdot z \qquad (41)$$

which becomes, using equations *34* and *39*

$$P_s = i_z^2 \cdot \frac{n^2}{(2n - 1)^2} \cdot Z \cdot \frac{2n - 1}{n^2} \qquad (42a)$$

$$= Z \cdot \frac{1}{2n - 1} \cdot i_z^2 \qquad (42b)$$

The power ratio is, from *40* and *42b*

$$\frac{P_Z}{P_z} = 2n - 1 \qquad (43)$$

The insertion loss in decibels is obtained by taking ten times the common logarithm of each side of equation *43*, and is, for the right hand side,

$$db = 10 \log_{10} (2n - 1) \qquad (44)$$

This is the identical loss obtained in the case of the series mixer.

If we define the ratio in *43*

$$\frac{P_Z}{P_z} = k^2 = 2n - 1 \qquad (45)$$

and substitute

$$n = \frac{k^2 + 1}{2} \qquad (46)$$

in equations *33, 34, 35,* and *36,* we get the equations,

$$\left.\begin{aligned} R &= Z\,\frac{k^2 - 1}{k^2 + 1} \\ z &= Z\,\frac{4k^2}{(k^2 + 1)^2} \end{aligned}\right\} (47) \text{ and}$$

(*Continued on page* 76)

Table 7

Series—Parallel Mixer

No. of series groups, N_p in parallel	No. of channels in series, N_s: 2	3	4	5	6	7	8	9	10
	C_{sp2}								
2	.33333	.44444	.50000	.53333	.55555	.571433	.58333	.59260	.60000
3	.60000	.80000	.90000	.96000	1.00000	1.02859	1.05000	1.06667	1.08000
4	.85714	1.14284	1.28572	1.37142	1.42855	1.46940	1.50000	1.52382	1.54284
5	1.11111	1.48146	1.66667	1.77778	1.85182	1.90482	1.94437	1.97535	2.00000
6	1.36363	1.81817	2.04546	2.18182	2.27273	2.33775	2.38628	2.42429	2.45454
7	1.61539	2.15382	2.42308	2.58462	2.69225	2.76926	2.82681	2.87185	2.90771
8	1.86667	2.48886	2.80000	2.98667	3.11105	3.20000	3.26663	3.31858	3.36000
9	2.11765	2.82349	3.17648	3.38822	3.52934	3.63033	3.70574	3.76472	3.81174
10	2.36842	3.15786	3.55264	3.78947	3.94737	4.06026	4.14459	4.21062	4.26316

$$\frac{R_p}{R_s} = C_{sp2}$$

$$\text{where: } C_{sp2} = \frac{N_s\,(N_s - 1)\,(N_p - 1)}{N_p\,(2N_s - 1)}$$


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FILTER DESIGN BY THE CIRCLE DIAGRAM METHOD

Application Of Method To The Design Of A Narrow Channel Band Pass Filter At 500 kc

(PART TWO OF A TWO-PART PAPER)

by PAUL J. SELGIN

Instructor, Electrical Engineering, Polytechnic Institute of Brooklyn

Data relating to each frequency:

Key subscript denoting frequency	A	B	C	D
$f = f_0\left[1+\frac{1}{2}\frac{W}{100}+\frac{1}{8}\left(\frac{W}{100}\right)^2\right]$ c p s	500,000	502,506	505,025	507,556
$W=100\left[\frac{f}{f_0}-\frac{f_0}{f}\right]$ Bandwidth %	0	1	2	3
$\left[\frac{QW^2}{200}+\frac{50}{Q}\right]$ Ordinate of center frequency circle	0.25	1.25	4.25	9.25

Data relating to each section:

Key subscript denoting section	f_∞, upper frequency of peak attenuation	$W_\infty=100\left(\frac{f_\infty}{f}-\frac{f}{f_\infty}\right)$ Abscissa of center for circle	$\frac{QW_\infty^2}{200}$ ordinate of center for circle	$S=\frac{1}{100}=\frac{1}{2W_c}\left[\frac{W_\infty}{W_c}-\frac{W_c}{W_\infty}\right]$		A		B		C		D	
1	515,225	6	36	.666	u:(*), v:(*)	.0416	0	-.2	.35	-1.3	.8	-3.4	1.65
					U:, V:	.0277	0	-.133	.233	-.865	.533	-2.27	1.1
					α db, β°	2.9	0	4.9	51°	8.8	76°	18.5	147°
2	510,100	4	16	.375	u, v	.0625	0	-.31	.55	-2.05	1.6	-6.7	6.05
					U, V	.0234	0	-.116	.206	-.77	.6	-2.51	2.27
					α db, β°	2.7	0	4.6	47.5°	9.25	105°	21.75	131°
3	507,556	3	9	.208	u, v	.0833	0	-.4	.8	-2.75	3.3	4.55	17.8
					U, V	.0173	0	-.083	.166	-.572	.686	.946	3.7
					α db, β°	2.25	0	4.1	41.5°	9.75	100.5°	24.1	69°
4	506,289	2.5	6.25	.1125	u, v	.1	0	-.5	1.0	-26	.6	-10	6.25
					U, V	.01125	0	-.056	.112	-.292	.675	1.125	.7
					α db, β°	1.8	0	3.3	34°	9.8	122.5°	16.9	25°
					Σα	9.65		16.9		37.55		81.25	
					Σβ	0		174°		404°		372°	

Data relating to entire filter:

Midband frequency: $f_0=\sqrt{f_c f_c'}$ = 500 kc

Channel width (nominal): $f_c - f_c'$ = 10 kc

% Channel width: $100\frac{f_c - f_c'}{f_0}$ = 2 %

Matching impedance : R = 7 ohms

Coil "Q" = 200

(*) When W = 0 u and v are given by : $u=\frac{10{,}000}{W_\infty Q^2}$, v = 0

Figure 1

Design data for a four-section symmetrical band-pass filter.

THE theory which forms the basis for the circle diagram of wave filters was explained in the first part of this paper.* Very briefly, it may be summarized as: the behavior of an image-connected section of filter is fully determined by the value of the complex quantity

$$Z_1/4Z_2 = U + jV$$

It is possible to represent this quantity geometrically as a point of coordinates U and V, or as a vector of projections U and V. Expressions for U and V are available, but their evaluation is extremely laborious except in cases when the resistance of coils is neglected.

It is found, however, that for many types of filters the point U+jV moves in a circle as the frequency is varied (the *filter circle*, characteristic of a particular filter or filter section); it also describes a circle if we imagine the filter design to be varied, at constant frequency, so as to *fit* successively all the possible sections of the same filter. This second circle, characteristic of a given frequency, is the *frequency circle*. Therefore, it is relatively easy to locate U+jV, the *filter point*, at the intersection of two circles. The circles themselves have center positions which depend on the frequency (for the frequency circle) or on the frequency of maximum attenuation (for the filter circle).

The so called *confluent* filter sections (of which the symmetrical band-pass type is the foremost example) behave differently; the *filter point* in this case does not fall at the intersection of two circles, but, considered as a vector, it is the resultant of two vectors each of which, aside from a scalar coefficient S independent of frequency, can be so obtained.

Usefulness of Method

Thanks to the circle diagram method, the analysis of the dissipative filter may be carried out almost entirely by graphical means, as demonstrated in the charts which accompanied part I of this paper. On page 60 appears one of these charts covering the type filter being discussed. It should be stressed, however, that the method becomes very

*COMMUNICATIONS, October 1943; pp. 20-25, 78, 80, 82.

clumsy when the effect of dissipation is slight. In such instances it is often possible to neglect dissipation or compute its effects in the pass band by approximate methods.

Circle Diagram Use

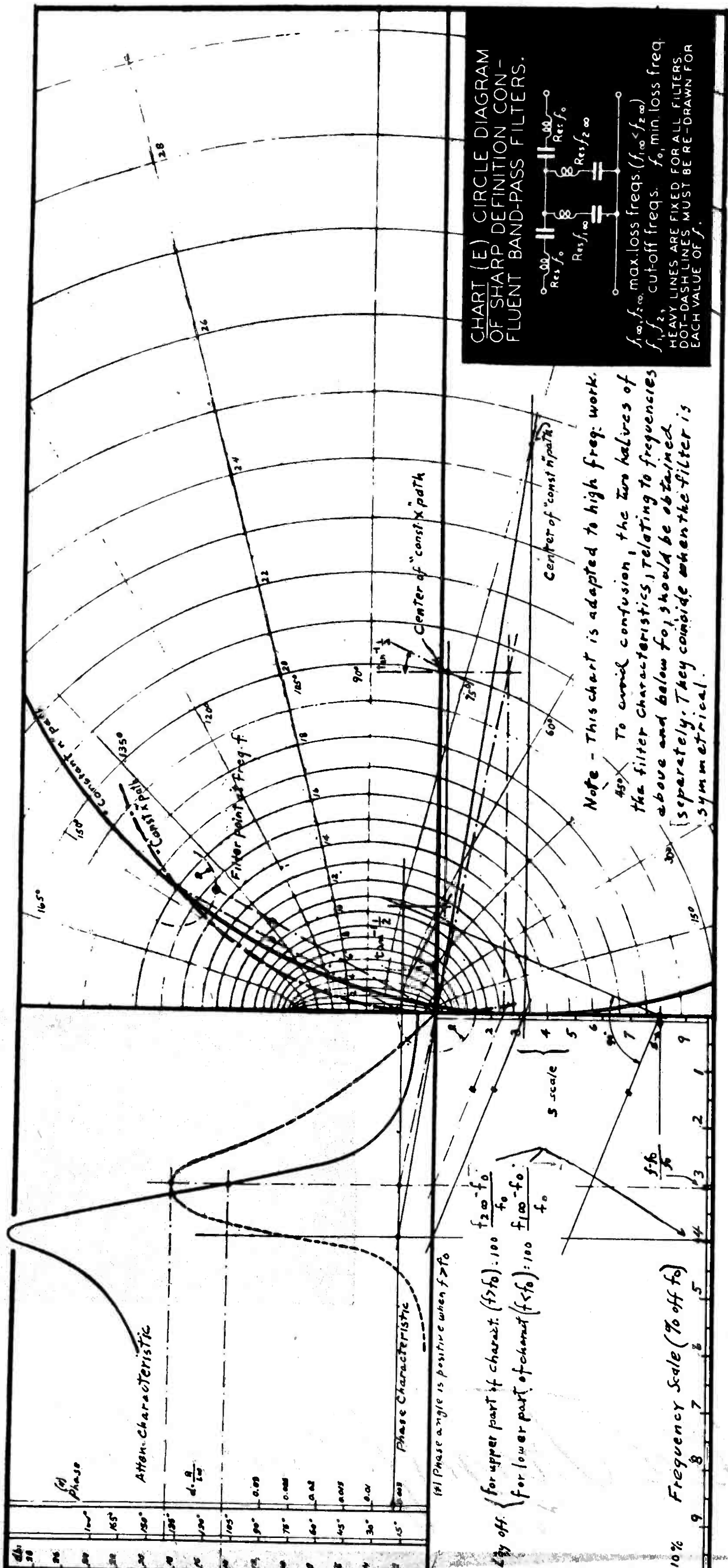
The circle diagram is useful when the effect of dissipation is very pronounced. This is particularly true when the *channel* (range of transmitted frequencies) is exceedingly narrow in a relative sense; for example, when the filter is designed for high frequency multi-channel systems. In such cases actual filter performance cannot be predicted even approximately by theory which neglects dissipation, since this is a major factor. Such filters cannot be built to very exacting specifications unless crystals are used. However, there are probably many borderline cases in which coils are used (in temporary installations for example, or in cases when crystals are unobtainable). It would seem that in such cases, the circle diagram method could be of considerable usefulness. It should be noted that the method is applicable to u-h-f filters in which the *resonant units* (see Figure 3) are replaced by line *stubs*.

Procedure

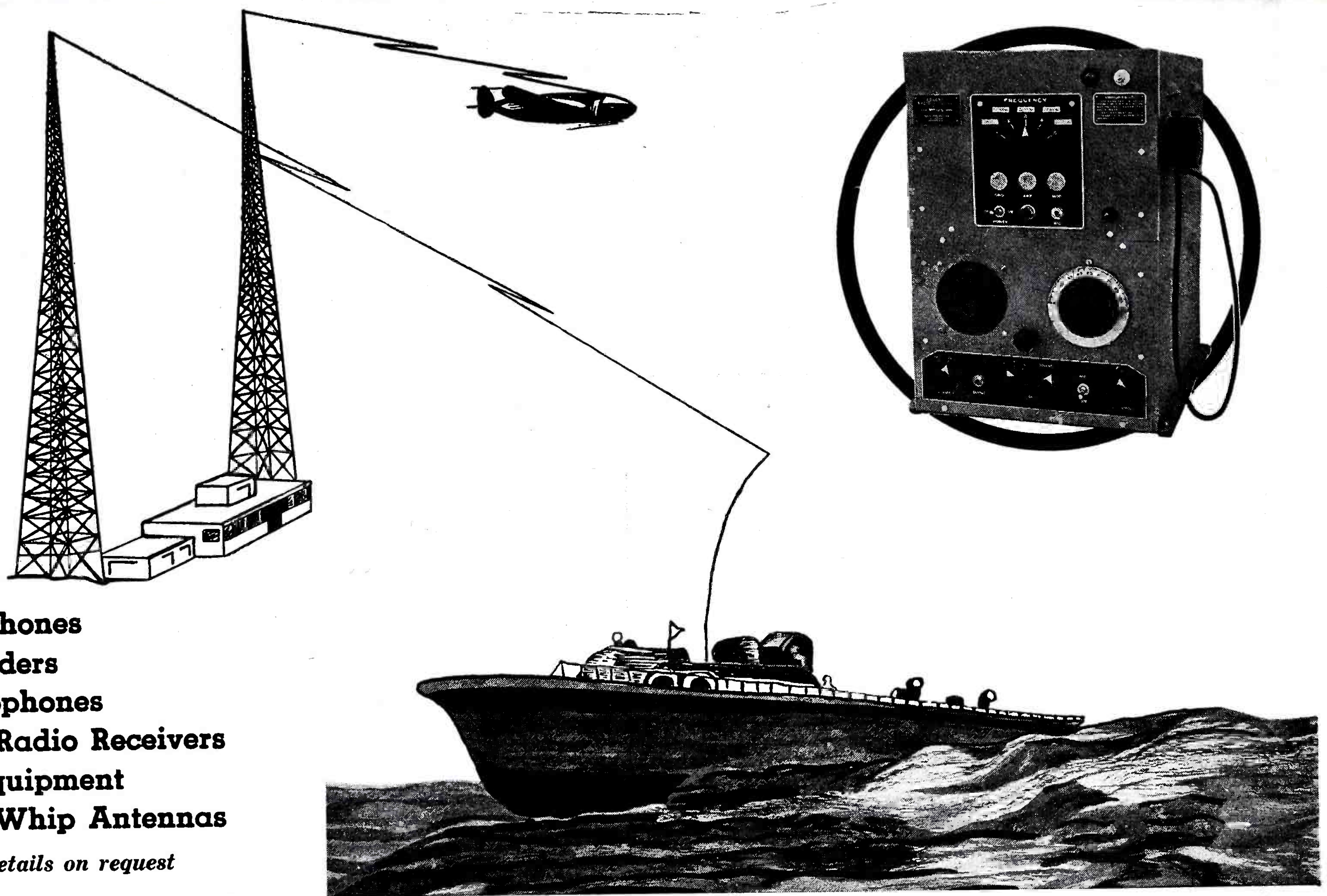
A band-pass filter for a *nominal* channel width (interval between cut-off frequencies) of 10 kc, and 500 kc mid-band frequency, has been selected as the basis for this illustration. Such a filter is very difficult, and its design would probably not be attempted. It provides a good example, however, as the circle diagram need not be made very large for accuracy. Filters of average characteristics would require the circle diagram to be drawn on a sheet the size of a drafting board, using stretched wires or similar devices to draw the actual circles. Such large diagrams could not be reproduced successfully on a printed page.

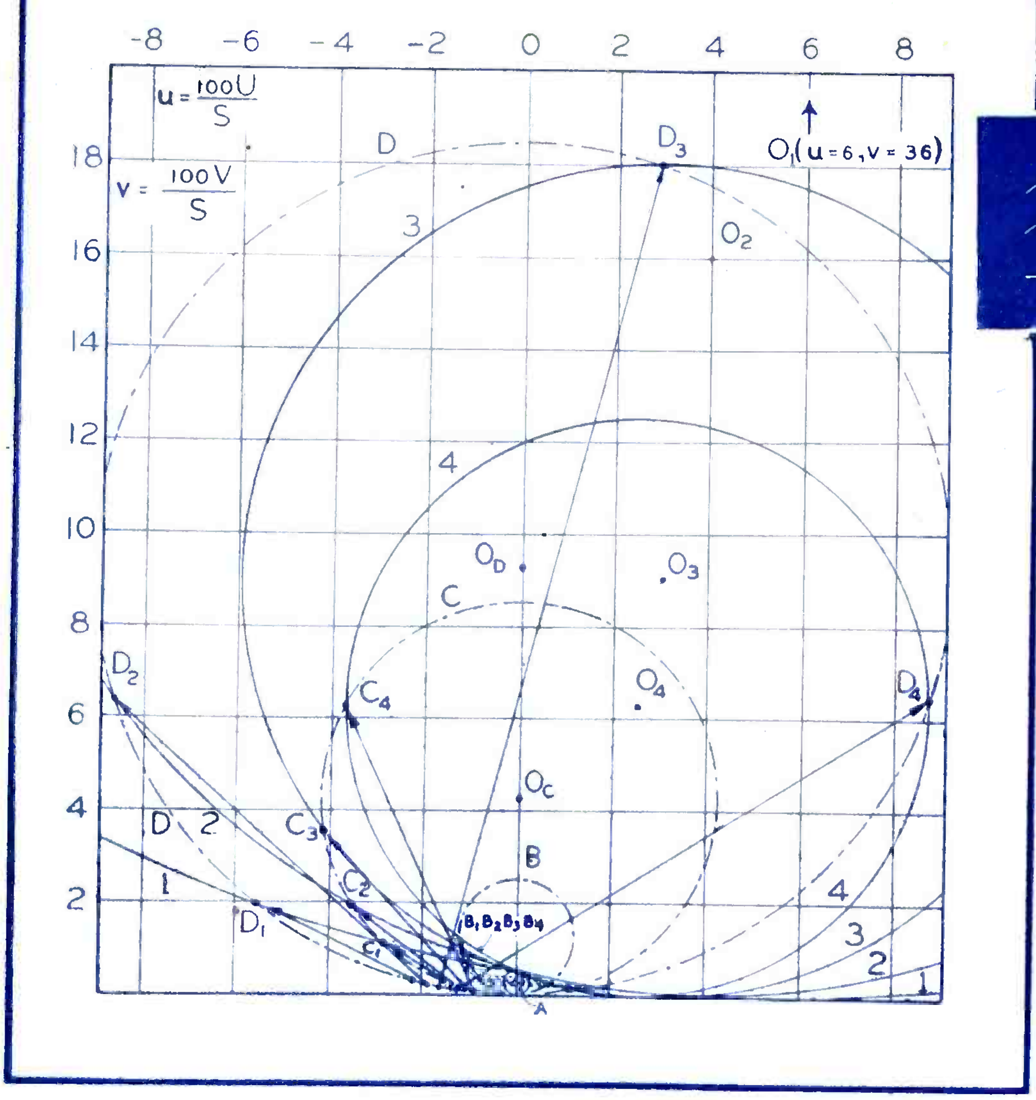
The actual computation is done on a *work sheet* (Figure 1). This is a tabulation in which each column corresponds to a value of frequency; each row to a section of the filter. It may be expanded, of course, to cover any number of frequencies, but *4* only have been considered.

The centers of the circles are obtained by the formulas given on the work sheet. In these formulas, *W* stands for the *per cent bandwidth.* This quantity may be used very conveniently in place of frequency in connection



A circle diagram chart which can be used to determine filter behavior.





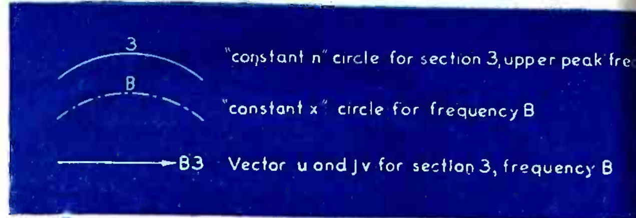


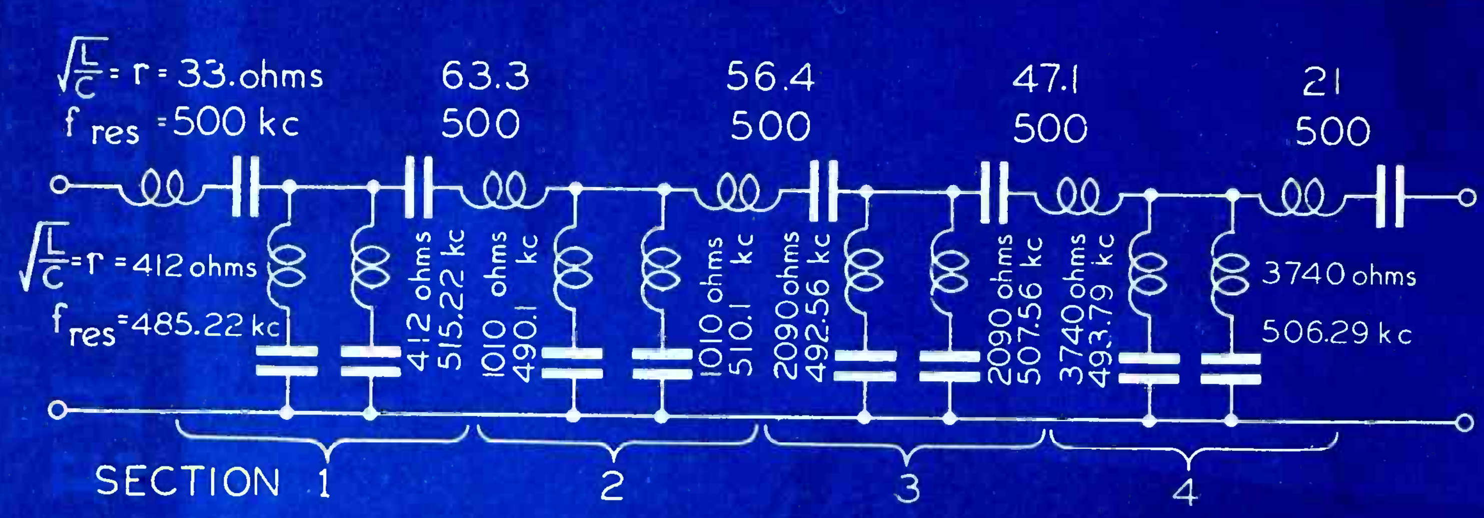
Figure 2
The circle diagram covering the design of a four-section symmetrical band-pass filter.

with band-pass filters and resonant circuits.

Have located the centers and drawn the circles (Figure 2), the intersections are marked and the *vectors* u+jv are obtained as shown. The values of *u* and *v* for each frequency and section are entered in the work sheet; then these values are multiplied by *S* (actually, by *S*/100, since the factor 100 has been used up to this

(*Continued on page* 116)

Figure 3 (below)
Specification data for resonant units used in the design of a four-section symmetrical band-pass filter.



SECTION	Resonant frequency of shunt arms: Lower f'_∞ (c p s)	Upper f_∞ (c p s)	W_∞ bandwidth $100\left[\frac{f_\infty}{f_o} - \frac{f_o}{f_\infty}\right]$	S $\frac{100}{2W_c}\left[\frac{W_\infty}{W_o} - \frac{W_c}{W_\infty}\right]$	$r = \sqrt{\frac{L}{C}}$ series $\frac{1}{2}$ arm $r_s = 10R_o\sqrt{\frac{2S}{W_\infty}}$ (ohms)	shunt arms $r_p = \frac{10^4}{r_s}\left(\frac{R_o}{W_\infty}\right)^2$ (ohms)
1	485,225	515,225	6	.666	33	412
2	490,100	510,100	4	.375	30.3	1010
3	492,556	507,556	3	.208	26.1	2090
4	493,789	506,289	2.5	.1125	21	3740

NOTE. Unit inductance and capacitance (nominal values) are given by:
$L = r/2\pi f_{res}$. $C = 1/2\pi f_{res} \times r$

PLOTS OF U+jV ON THE a,B PLANE

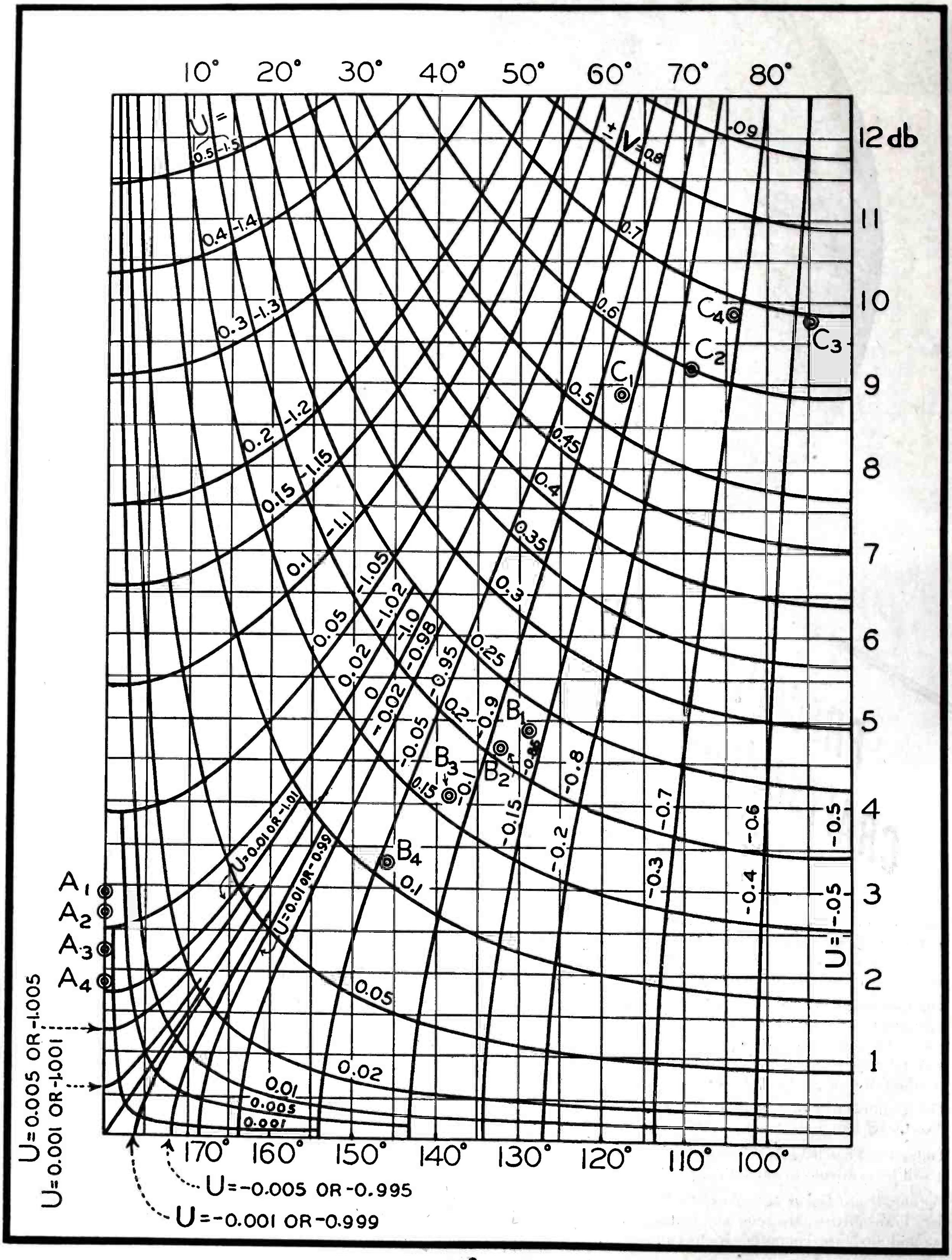
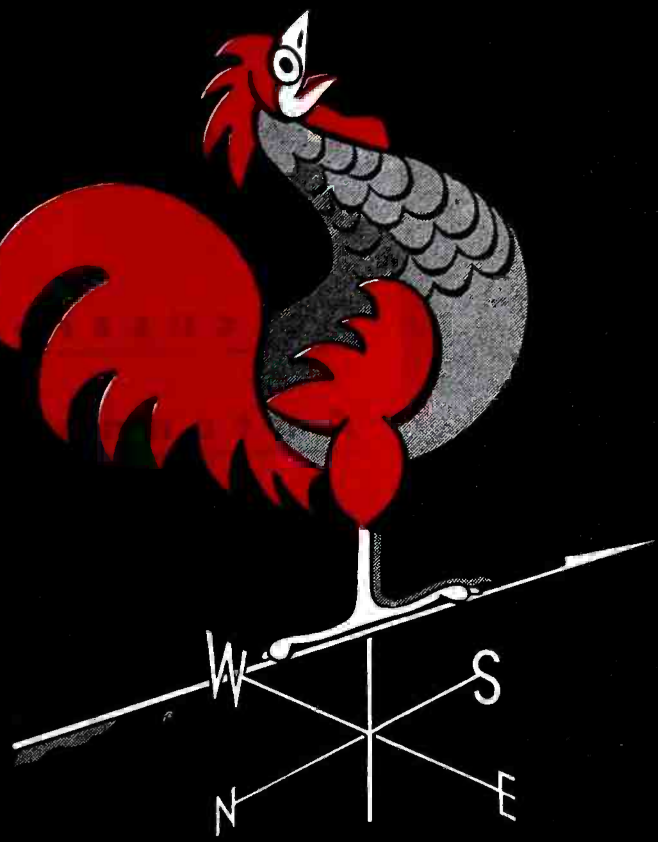


Figure 4
The graph that provides immediate values of a and β corresponding to each value of U and V.

SENSITIVE...



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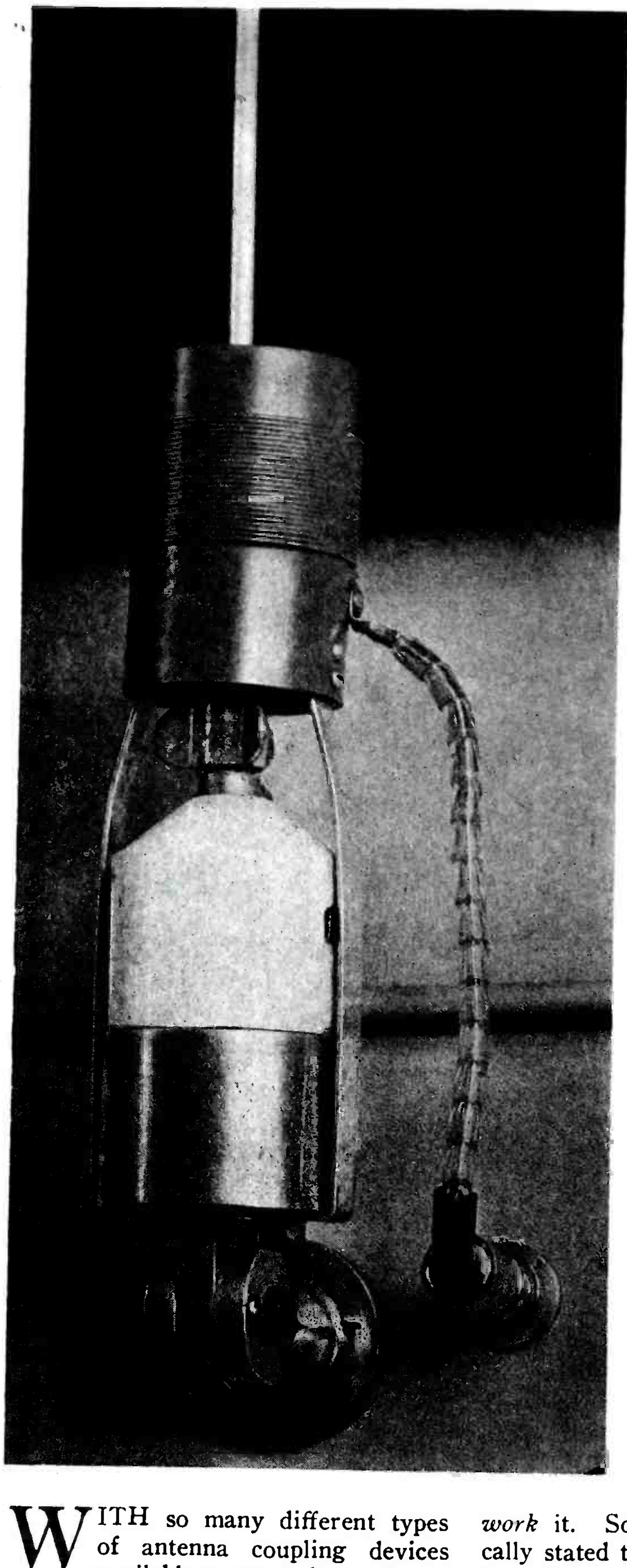

Discussion of Types of Antennae Possible For Mobile Installations Operating Between 1,500 and 5,000 kc

by KARL A. KOPETZKY

A base-loaded antenna developed to meet the whip problem on low-frequency transmission. The load coil placed outside the vehicle assists radiation. Under the load coil is a very large insulator. This is provided since large antenna currents and voltages are encountered for even small output powers.

(Photo by Black Box)

WITH so many different types of antenna coupling devices available to the radio engineer, it would generally seem that the use of terminal frequencies between 1,500 kilocycles through 5 megacycles would present no particular difficulties. However, at once the designer is faced not only with a greatly shortened antenna, but one so small as to be practically non-radiating.

It is axiomatic that if the other station cannot *copy* yours, you won't *work* it. So it might be parenthetically stated that no matter how excellent the transmitter unit, no matter how well-built or designed, only that radiation from the transmitter which activates the receiver's antenna is what should interest the communications specialist. In other words, it is what leaves your transmitting antenna that counts.

Broadly stated, and considering power output as unity, antennae radiate in direct ratio to the impedance match between the radiation element and the final amplifier tank. When the match is poor, or whenever there is little or no match at all, or when more power tends to be dissipated through the *ground* than through the antenna, then the best transmitter in the world will not perform satisfactorily. In some cases, the choice of tank circuit for the *final* has been such that even under ideal coupling conditions radiation from the antenna has been found to be poor, because the circuit selected was not suited to short antenna coupling.

One of the most difficult problems of portable transmitters whose terminal frequencies lie in the 1,500-5,000 kc spectrum appears with using a commercial 7-foot whip antenna as the radiator. A quarter-wave matching antenna would be between 165 and 50 feet long, depending on the frequency of operation. A 7-foot antenna is, therefore, no ordinarily usable resonant part of a radiator. This presents the problem of impedance


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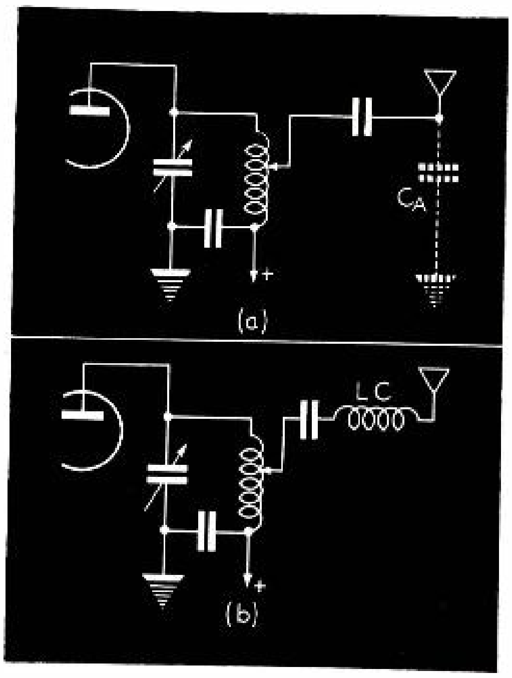
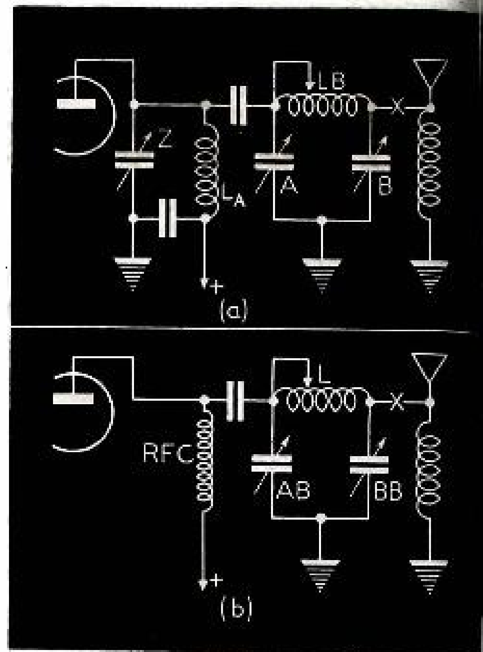


Figures 1 (left) and 2 (right)

In Figure 1 appears the simplest of all antenna coupling circuits. In (a), the antenna is fed through a d-c isolating capacitor directly from the tank coil of the amplifier tube from a tap placed close to the plate end of that coil. Experience with this type of coupling shows that usually the antenna is too small to load the circuit properly. In (b) we see the same type of feed except that a loading coil has been inserted in the antenna lead. This addition in effect lengthens the antenna, permitting suitable loading of the final plate tank. Figure 2 (a) illustrates the π or Collins antenna matching network, wherein the antenna is to be matched to the impedance of the final tank. In (b) we have a modification of this network where coil L has replaced inductance L_A as well as coil LB. Capacitors AB and BB are the same as A and B in 2 (a).



matching to the final tank circuit for reasonable radiation, as an almost insurmountable task. However, there is a redeeming feature in portable work. The transmission line length from transmitter to radiator is so short as to present no problem in feeder losses.

By the same token, however, it is not possible to vary the length of the antenna for matching purposes which, if there is to be any practical radiation, should be kept at the maximum height possible commensurate with the terrain. In the continental United States this is about 7½ feet. Antennae of this height will, when mounted in the rear of a passenger car or small quarter-ton truck, clear most of the underpasses and tunnels. Where in fixed stations it is customary to trim the antenna and its associated feeders to the operating frequency, as previously stated, this is not possible in the mobile installation.

As a rule, the mobile antenna should not be tested on anything other than the car or truck on which it is to be used. The only exception is that engineering data may be gathered to determine if the antenna system can be fed by means of a simple *mock-up* on the laboratory bench. Such a *mock-up* is a vertical rod stretched out to equal the antenna length. In using the *mock-up,* great care must be exercised by the laboratory personnel to avoid shocks and r-f burns that occur when touching supposedly *grounded* or *cold* chassis, cases, microphones and terminals which surprisingly may turn out to be r-f-*hot.* In fact about 90% of the 7-foot antenna *mock-up* installations used in mobile work (as set up in the laboratory) will show the *ground* not to be that at all, but an excellent radiator. Some of these units when finally changed over to car installations will cause an r-f-hot car or truck.

There is no cure for an r-f-hot chassis except to choose an antenna length and an antenna circuit which bring a *low* impedance between the antenna and ground, preventing the r-f from dividing and *loading* the chassis and car. Since it has been found that if one circuit develops a *hot* chassis and car, there is a great possibility that the others will also. The only corrective method possible is to hack off lengths from the antenna or increase the lead-in until the r-f disappears from the vehicle. It is of utmost importance to remember that all tests should be made on the vehicle and not on the laboratory bench. Many a laboratory bench mock-up will be r-f-*hot* whereas a vehicle will not.

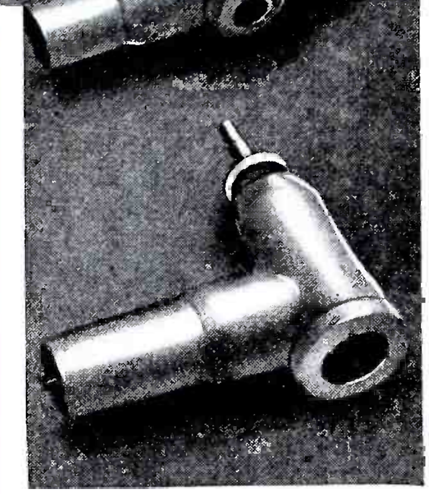
Actual experience with more than ten different ways of energizing mobile antennae showed that the end result, insofar as r-f-feedback or a *hot* ground was concerned, was the same in each instance. Not too much attention need be paid to r-f-*hot* chassis conditions at the outset and on the laboratory bench, as long as this disappears on actual installation and in field use.

Tests should be made on the feeder from time to time to insure the absence of standing waves.

In the final analysis, the type of coupling between the final tank circuit, and the antenna (and hence the impedance match) depends upon the final tank circuit chosen. If one type of plate circuit is employed, a corresponding type of antenna coupling may be used. Some forms of antenna circuits permit more than one type of antenna coupling. It is therefore imperative that the antenna coupling ar the plate tank circuit be considered a single unit. If this is clearly know at the *drawing-board* stage of the d sign, little difficulty will be had understanding the end results wh the unit is built.

Field tests will show the advantag of one system over another. The data, correlated with the laborato tests, should be used in making t final choice of circuit.

The simplest of all antenna co pling circuits is to be found in Figu 1. Note the grounded variable co denser shaft in the tank circuit pe mitting easy mechanical mounting the condenser by doing away with i sulators, and releasing the unit fro hand-effects. The antenna is f through a d-c isolating condenser d rectly from the tank coil of the an plifier tube, from a tap placed clo to the plate end of that coil. T closer this tap is taken to the tu plate, the greater will be the loadin Experience with this particular type coupling shows that in most cases, t antenna alone is too small to load t circuit properly. The tap could placed directly on the plate of t transmitting tube without any appr ciable increase in plate current. Hen no load worth mentioning results. this circuit, the antenna has a capac tive effect to ground as indicated the dotted line condenser C_A. Th capacitance is comparatively sma and therefore acts to change t plate loading very little. (*Incidentall on ultra-high frequencies from abo 30,000 kc up, this particular type feed is extremely advantageous, b cause the greater antenna length a proaches a resonant ¼ wavelength im pedance and, is sufficiently large to e*



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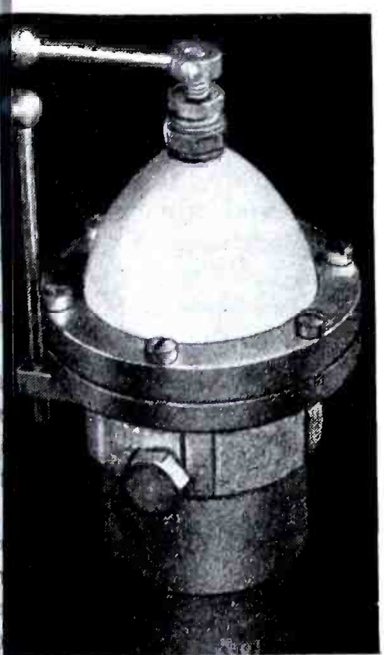

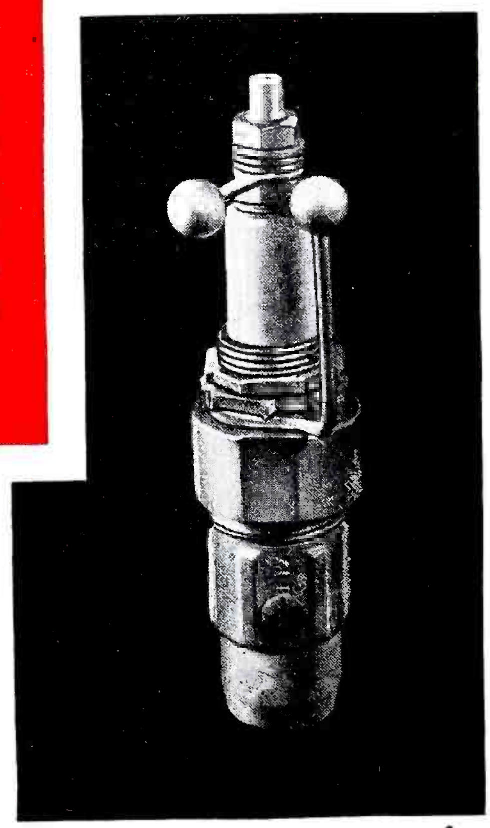

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E. F. JOHNSON COMPANY • WASECA • MINNESOTA *fect proper loading. However, before employing it, it is wise to consult FCC regulations on the subject. In some instances this type of antenna coupling arrangement is prohibited.*)

Figure 1b shows the same type of feed except that a loading coil has been inserted in the antenna lead. This in effect *lengthens* the antenna sufficiently and it is possible to load the final plate tank properly. It will be found, however, that a large portion of the antenna current is being dissipated in the loading coil as heat and there is very little power being radiated by the whip.

Collins Network

Figure 2 presents the π or *Collins* antenna matching network. In this system the antenna is to be matched to the impedance of the final tank. However, in most cases where extremely short whip antennae are used in the frequencies described, the actual impedance of the antenna lies between 3 and 8 ohms, making a match with the high impedance tank unusually difficult, if not well-nigh impossible. Sometimes a match can be effected by condensers which are not commercially available. Thus condensers *A* and *B* might have to have maxima and minima capacitances which are difficult to build into them. A little help is sometimes obtained by inserting a load coil at the point marked *X*. In any event, the system is hard to tune. Distributing the antenna impedance between the coil and the antenna results in poor radiation. This condition is not easy to trace.

Figure 2A shows the popular *modified* π or *Collins* network. Here coil *L* replaces inductance L_A as well as coil L_B, of Figure 2, while condensers *AB* and *BB* are recognized as similar to those marked *A* and *B* in Figure 2. Since condenser *AB* actually replaces tank condenser *Z* in Figure 2, and since it is in series with condenser *BB* across the coil, with the common ground connection, it will have to have twice the capacity of condenser *Z* if it is to operate with a coil *L* equal to inductance L_A. Then again if condenser *BB* does not have a small minimum capacity, the circuit will not load well. Thus condenser *BB* must at once have large maximum and as well small minimum capacity limits, which are not always commercially available. In addition to this, a load coil inserted at *X* is always used if coil *L* is not to get too large and have too many taps for practical operation. Further difficulties are encountered at frequencies higher than 3000 kc. The antenna presents a high impedance to ground

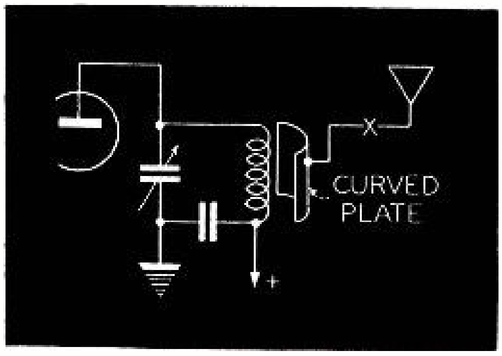


Figure 3

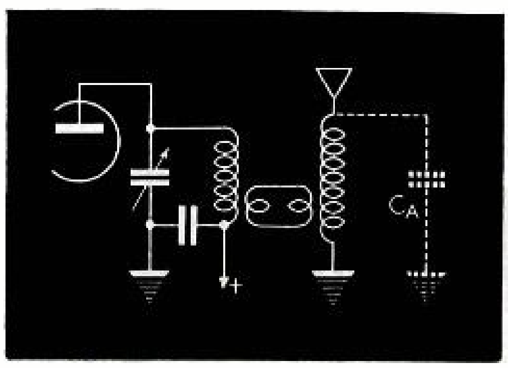
An unusual type of coupling wherein a curved plate is used, acting in the same manner as a shield in a r-f stage.

(as differentiated from a high impedance to the tank circuit) and so the *tank current* may divide at condenser *BB* sending more and more r-f into *ground*, making all chassis *hot* and getting into the speech. In that case the audio will become distorted and trouble develops. Sometimes there will be *more* r-f in the ground and chassis than in the antenna itself. Since this cannot be corrected by installation, being circulating tank current, the circuit must be treated with the greatest care, and should be investigated carefully before being used.

An unusual type of coupling is shown in Figure 3. Here a curved plate is brought close to the tank itself. The curved plate is identical in effect to a shield can in an r-f stage. The coupled inductive effect has a tendency to reduce the apparent inductance of the tank coil, and the r-f circulates through both, in much the same way as in an r-f coil with an untuned secondary. It would seem that this is not practical for use in mobile installations. Nevertheless the circuit is included because of at least two such installations which were known to have been very successful.

Figure 4

An interesting form of antenna coupling that is used in some far Western police department installations. Loading of the tank circuit can be increased by tightening the link.



Incidentally, all of the circuits shown in connection with this digest are tuned in the orthodox manner. That is, the tank condenser is always returned to resonance after the circuit is *false-loaded* by the antenna load circuit. The one exception is the Collins network circuit (Figure 2), where once the tank condenser *Z* is resonated, it must be left that way throughout the entire tuning procedure. Naturally, the network is disconnected in obtaining resonance for condenser Z in the first place.

When no setting of the antenna condensers or the placing of taps leave the tank condenser in resonance at proper load on the final amplifier tank then that combination of taps and condenser settings is said *not to load*. The combination must be changed until one is found which provides proper tank loading at resonance. The size of each loading coil mentioned depends largely on the size of the antenna whip and the respective values in microhenries and micromicrofarads of the tank coil and condenser. An excellent rule of thumb to follow for load coil size for the frequencies under discussion, is to add two-thirds the number of turns to the number of turns in the tank coil, using the same wire size, as well as the same diameter form and wire spacing.

Figures 4 through 7 show types of antenna coupling which are extremely popular with police department installations in the far West. All make use of the capacity of the anntenna-to ground. By *tuning* the antenna itself the antenna is placed electrically into the circulating current path. The effective capacity of the antenna is shown in each case by the symbol C_A. The above mentioned circuits are termed *base-loaded* and are shown with various methods of coupling the antenna to the tank coil. Note that *solid* antenna whips *cannot* be utilized in any of these systems because they cannot be *tuned* mechanically. Since these systems make use of the fact that the antenna is part of the circulating current path, a low impedance transfer means, such as a link must be used. If a link can be used, tremendous transfer of energy to the antenna is possible. Link coupling is easily accomplished when combined with concentric feeders.

A setup at a good distance from the vehicle should be made with a field strength meter or a receiver with an *S* meter before any tests can be attempted not only with the *base-loaded* antennae, but with any of the coupling devices described in this article. The distance should approximate at least a quarter-wavelength length (of the frequency of operation)

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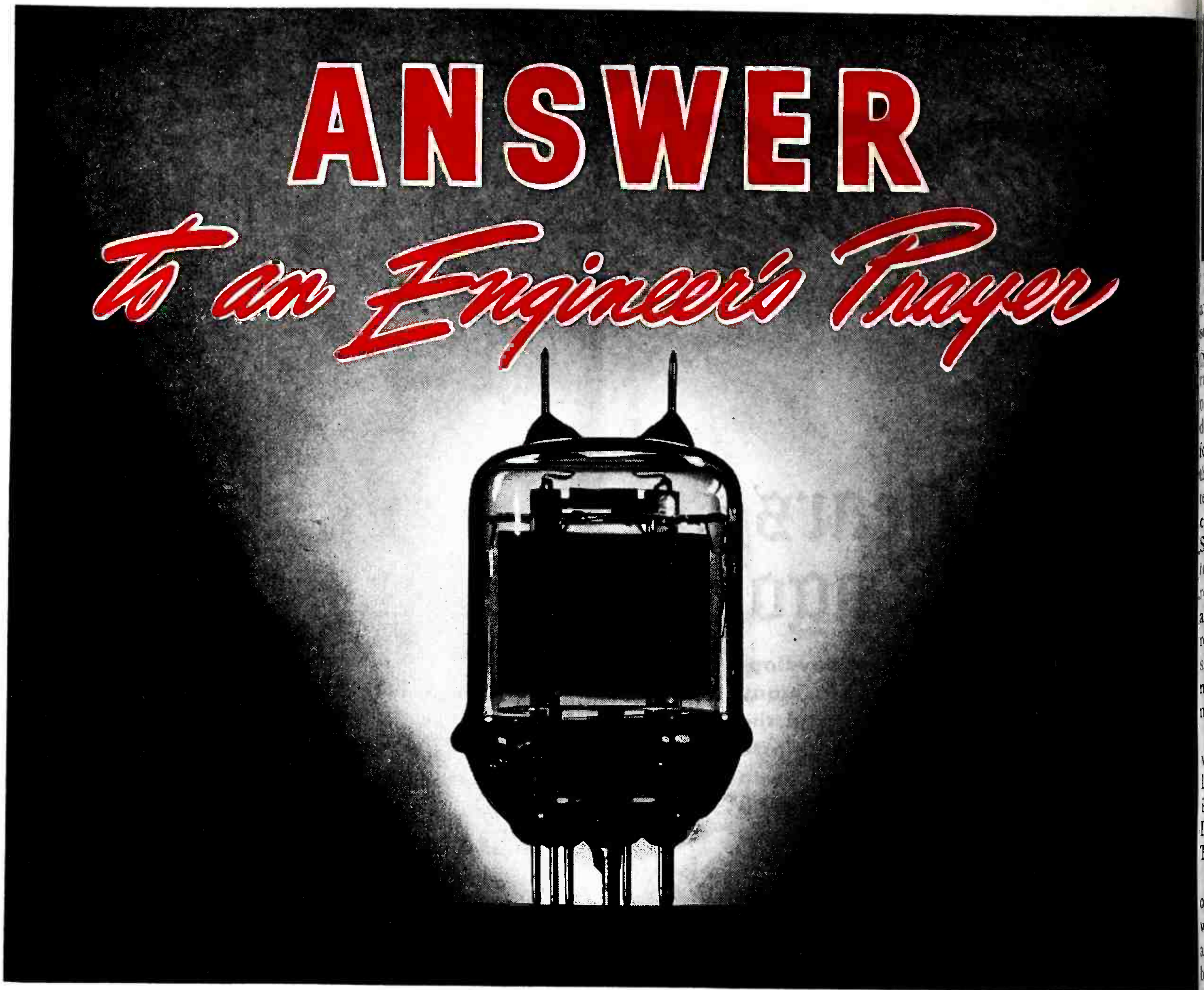

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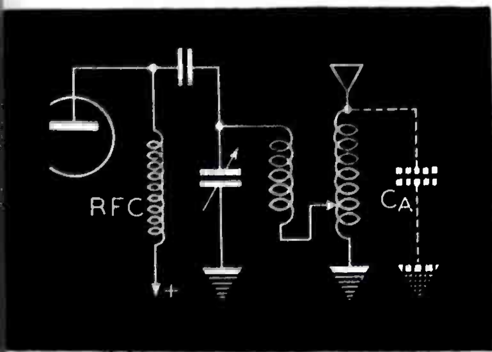
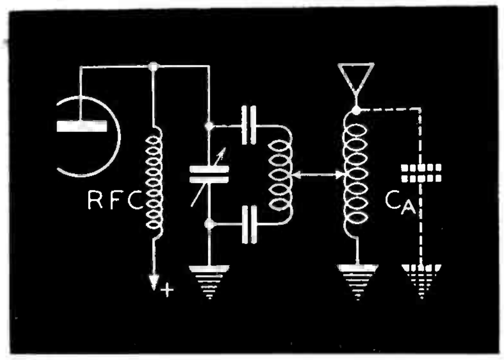


Figures 5 (left) and 6 (right)

In Figure 5, loading of the tank circuit can be increased by moving the tap towards the plate of the amplifier tube, while in 6 the loading can be increased by raising the tap toward the antenna. These two circuits are also popular in many police department installations, particularly in the far West.



away from the car or truck. Having set up the field-strength meter or receiver, it is best to adjust it so that the radiation from the tank coil itself cannot be read into the final results. To do this, it is necessary to compensate for any reading caused, by turning on the transmitter *without* either the antenna or the coupling device in the circuit, mechanically or electrically. Such compensation may consist of *tuning to false zero,* or noting the reading caused by the transmitter alone without antenna. Once this reading has been made, no changes should be made in the meter setup, nor should either the vehicle or the meter be moved throughout the tests.

To tune the base-loaded antenna, the whip should be collapsed to somewhat less than its full length in the mounting provided for it on the vehicle. Later it may be extended full length. This is how it is *tuned.*

Theoretically, the capacitive effect of the antenna-to-ground together with antenna loading circuit creates a parallel-resonant circuit at the base of the antenna. In these circuits, the antenna current increases as the L-C ratio of the loading circuit is increased. The lower the *C,* the higher the current. In order to lower the *C* to a minimum, the *L* is increased until the *C* is only the capacity of the circuit plus the capacity of the antenna. Thus the antenna becomes the capacity of the parallel-resonant circuit with the circulating current in the antenna circuit appearing between the antenna and ground.

In *base-loaded* circuits, the circulating current divides between the parallel condenser and the antenna in proportion to the respective capacitances to ground. Thus it may be stated that as the parallel condenser becomes smaller, the circulating current in the antenna becomes larger; yet the antenna current itself is low. If the parallel condenser be eliminated entirely, the antenna current will be high and the voltage also; an ideal radiating condition.

Proceeding with the reduction of theory to practice, a suitable *base-loading* coil would hit resonance when paralleled by a condenser of between 25 and 35 mmfd capacity. The condenser must not be permanently mounted, but due to high voltage and current, unusual care must be taken to provide good insulation. Furthermore, once the antenna is adjusted, the condenser will be discarded, so any good laboratory standard may be utilized.

The antenna base-loading coil can be coupled to the final tank by any method shown in Figures 4, 5, 6 or 7. (If a center-loaded antenna is desired, Figure 7a can be followed with the same results as a base-loaded antenna, provided only that each half of the dipole will equal at least 7 feet in length). Loading of the tank circuit can be increased by tightening the link (Figure 4), moving the tap towards the plate of the amplifier tube (Figure 5), raising the tap towards the antenna (Figure 6), or by both raising the tap towards the plate of the tube and also towards the antenna (Figure 7a). Sometimes it will be necessary to add a few turns to the link to obtain a good load. Usually two to three turns should suffice, although there have been cases where at least five turns were needed. All loads must be calculated with the antenna temporary condenser set to approximately one-fourth full capacity and the tank condenser resonated. When the maximum loading required has been obtained by means of the link and condenser setting, a reading of the field strength meter should be taken. This will be the reference point, the exceeding of which will become the goal of the final tests. Once this point has been found (maximum field strength at minimum temporary antenna condenser setting, plus resonant position for the tank condenser), the link and tank condenser should not be touched further. The temporary antenna condenser can be then removed and the antenna extended. If this does not bring the circuit into resonance at a higher reading of the field-strength meter, the antenna can be returned to its *shorter* position, and a turn at a time can be removed from the load coil. After taking off each turn, tests with the antenna fully extended should be made. At some time, the field-strength meter should show maximum, with the antenna *shortened,* and the tank condenser at resonance. Then just a single turn can be taken off the load coil. This should swing the field-strength meter *just past maximum.* By extending the antenna to full length, the field-strength meter should indicate maximum radiation, while the tank condenser is resonated. The antenna is then tuned. All meter readings must be made with the engineer at some distance from the antenna because of the body effect which will change the meter's reading.

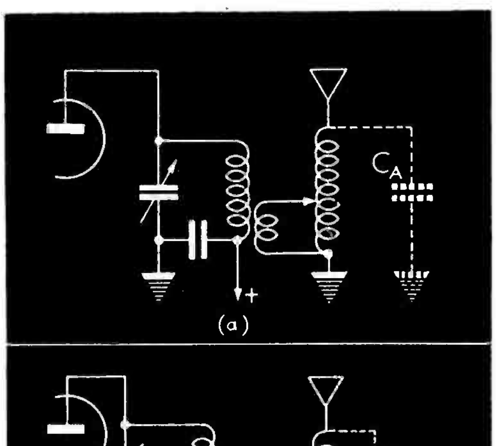
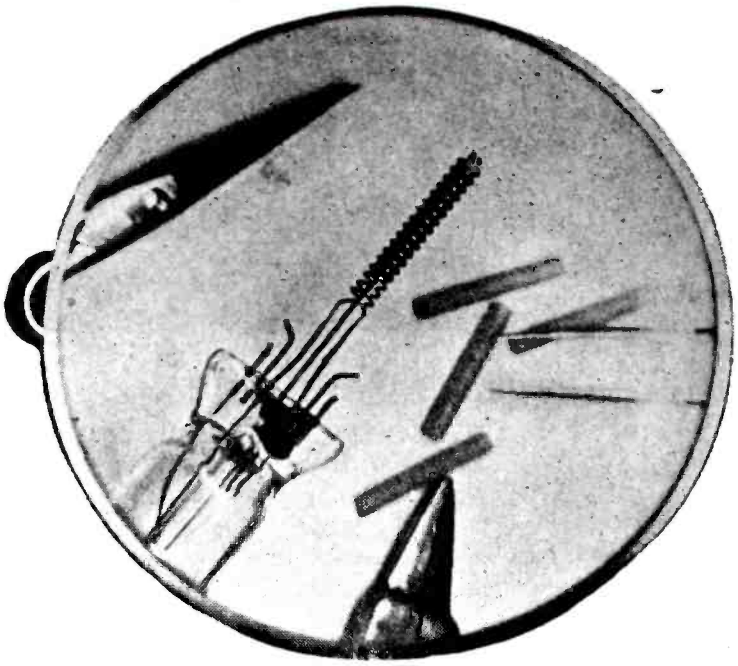


Figure 7

If a center-loaded antenna is required, the circuit shown in (a) or (b) can be used to provide the same results as a base-loaded antenna, provided that each half of the dipole approaches at least 7' in length. Incidentally, the loading of the tank circuit can be increased here by either raising the tap toward the plate of the tube as well as toward the antenna. In (b) a capacitor is connected temporarily between the legs across the load coil. Each leg can then be shortened or lengthened to reach resonance.

As said before, the *center-loaded* antenna (Figure 7b), of which each leg should approach 7 feet in length, is tuned exactly the same as the *base-loaded* antenna. The 25-35 mmfd condenser is temporarily connected between the legs across the load coil. Each leg is then *shortened* and *lengthened* to reach resonance. But each leg must be *shortened* the same amount and the end result must be such that the legs are equal in length. Some cases will show a *center-loaded* antenna to have better radiation characteristics than a *base-loaded* unit. But

(*Continued on page* 118)



ON THE PRODUCTION FRONT

SPAGHETTI, the popular food, has taken its place as a production aid alongside of spaghetti, the insulating fabric tubing. At the Westinghouse lamp division, William A. Hayes has discovered that spaghetti, the food, can be used to expedite tube production. It is inserted inside of the wire coil, thus supporting the coil while it is being welded. Formerly a piece of steel was used. It was however difficult to remove. However, the stick of spaghetti can be removed in a flash.

This method, according to Westinghouse authorities, produces 50% more filaments. Because of the important savings in time, manpower and materials, Mr. Hayes has been recommended for a WPB Award of Individual Production Merit.

In experimenting with spaghetti Mr. Hays found that spaghetti can be made with fair precision and is strong enough not to break if handled carefully; it can be machined on a lathe. For the first experiments, a stick of spaghetti was placed on a lathe and was machined to the correct diameter. The spaghetti maker now uses a die to enable him to produce sticks the correct diameter for the tube operation. From now on spaghetti is in war production.

Although spaghetti first was applied to the assembly of filaments for only one type of tube, Westinghouse officials plan to extend its use to other types as soon as possible and make it a permanent practice.

Figure 1 (upper left) and 2 (right)

In Figure 1 appears a magnified view of the filament of a tube with household type spaghetti inserted to support the coil while it is being welded to the rest of the tube parts. At right (Figure 2) appears William Hayes of Westinghouse, who developed this unique procedure. According to Westinghouse production specialists this new method has sped production of filaments 50%.

(Courtesy Westinghouse)

Cable Forming

Cable forming, or *harnessing,* has been brought to a high degree of efficiency for the mass production of wiring used in communications equipment. At Federal Telephone and Radio Corporation, cables are formed in numerous sizes and designs on special guide boards, with as many as scores of individual wires, tracer colored, being used in turning out the finished job. After the cables have been laced to hold the wires firmly in place, they pass down assembly lines where lugs and other connections are attached.

Hydrogen for Cathode-Ray Tube Sealing

From War Production Drive Headquarters of WPB have come many interesting and effective tube production suggestions that have won awards. We find, for instance, the suggestion of John Socolosky, RCA, proposing that the gas used for the main seal on cathode-ray tubes should be hydrogen to eliminate bubbles in the seal. Tipping off the tube with hydrogen instead of exposing it to the air was also suggested. This was accomplished by

(Continued on page 119)

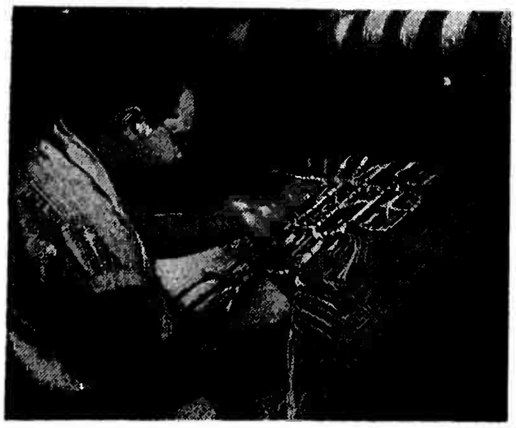
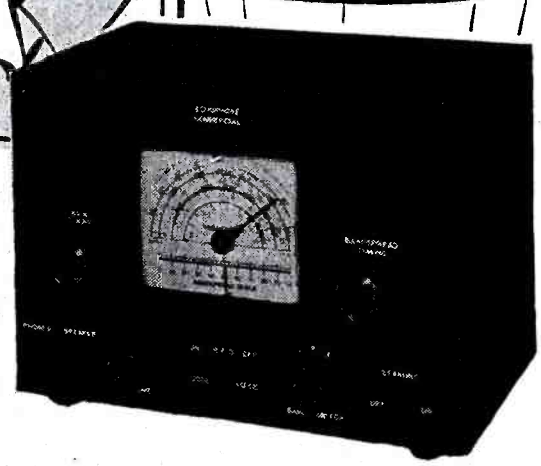


Figure 3 (left) and 4 (above)

In Figure 3 we have the harnessing method of cable forming employed at Federal Telephone. Above, a unique filament spraying process developed by Van Wagoner of RCA.



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. 115-125 volts AC or DC.

ECHOPHONE RADIO CO., 201 EAST 26th ST., CHICAGO, ILLINOIS

MIXERS AND FADERS

(Continued from page 56)

$$R = z \frac{k^4 - 1}{4k^2}$$

$$Z = z \frac{(k^2 + 1)^2}{4k^2} \qquad (48)$$

As in the series case, if we use the substitution

$$k^2 = e^{2\theta} \qquad (49)$$

where

$$\begin{aligned} \theta &= 0.11529 \times \text{No. of Decibels} && (50a) \\ &= \log_e (2n - 1) && (50b) \\ &= 2.303 \log_{10} (2n - 1) && (50c) \end{aligned}$$

in equations *47* and *48*, there are obtained the sets of equations in terms of hyperbolic functions of a real variable,

$$\left\{ \begin{aligned} R &= Z \tanh \theta \\ z &= Z \operatorname{sech}^2 \theta \end{aligned} \right\} \qquad (51) \text{ and}$$

$$\left\{ \begin{aligned} R &= \frac{z}{2} \sinh 2\theta \\ Z &= z \cosh^2 \theta \end{aligned} \right\} \qquad (52)$$

Observation of the equations involving *n, k,* and θ in the two cases of the series and the parallel mixers reveal the interesting relationships that these portions of the equations are completely reciprocal. This means that the following pairs of equations are reciprocal in *n, k,* and θ respectively, namely *3* and *33*; *5* and *34*; *6* and *36*; *7* and *35*; *23* and *47*; *24* and *48*; *27* and *51*; and finally *28* and *52*. Hence if the equations for one case ar[e] known, the other may be obtained im[mediately]. The *Z* or *z* portion of th[e] equations remain unchanged in ever[y] transformation from one to the other.

By comparison of equations *51* an[d] *25* with Table 2, it may be noted tha[t]

$$\left\{ \begin{aligned} C_{Rp1} &= \tanh \theta \\ C_{zp1} &= \operatorname{sech}^2 \theta \end{aligned} \right\} \qquad (53)$$

$$\left\{ \begin{aligned} C_{Rp2} &= \tfrac{1}{2} \sinh 2\theta \\ C_{zp2} &= \operatorname{Cosh}^2 \theta \end{aligned} \right\} \qquad (54)$$

Table 2 has been prepared to enabl[e] anyone who has the need for paralle[l] mixers to readily arrive at a solutio[n] to problems which may arise in prac[tice]. For example, what insertio[n] losses will be obtained for variou[s] numbers of channels? What ratios o[f] input or source to load impedance[s] be necessary for perfect matching? What value of resistance will b[e] needed to accomplish this matching? What price will have to be paid i[n] terms of insertion loss because of th[e] necessity of having matched im[pedances] at all junctions?

[To Be Continued]

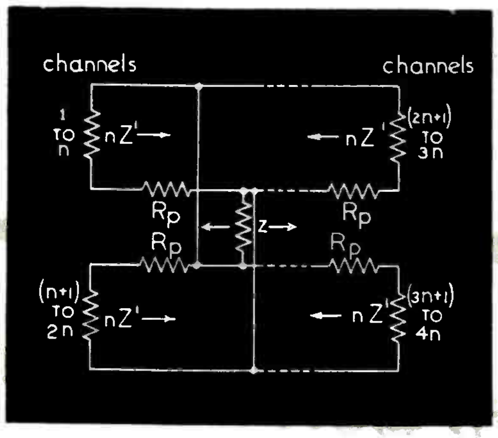


Figure 8
Equivalent of Figure 7, where $Z' = ZR_s/(Z + R_s)$.

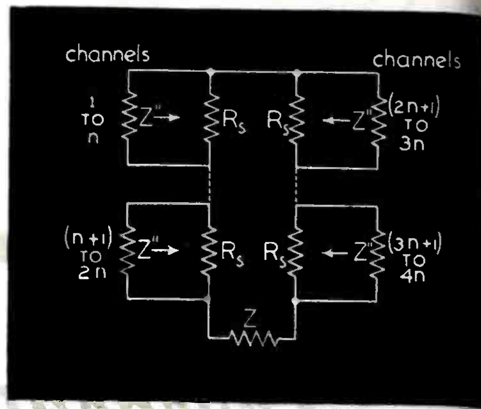


Figure 11
Equivalent of Figure 10, where $Z'' = (Z + R_p)/n$.

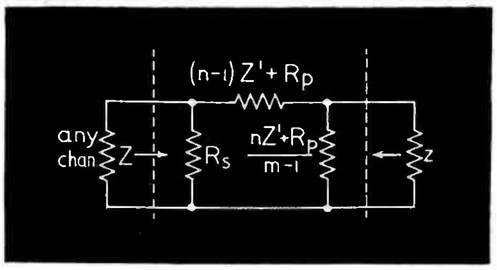


Figure 9
Equivalent circuit of Figure 7 for any single channel representation.

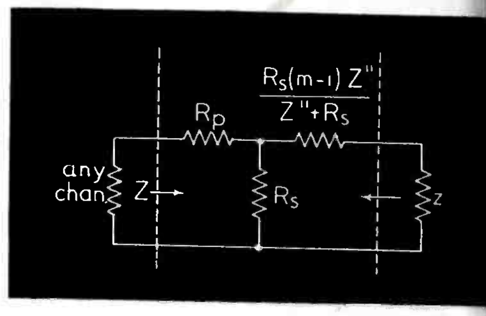


Figure 12
Equivalent circuit of Figure 10 for an[y] single channel representation.

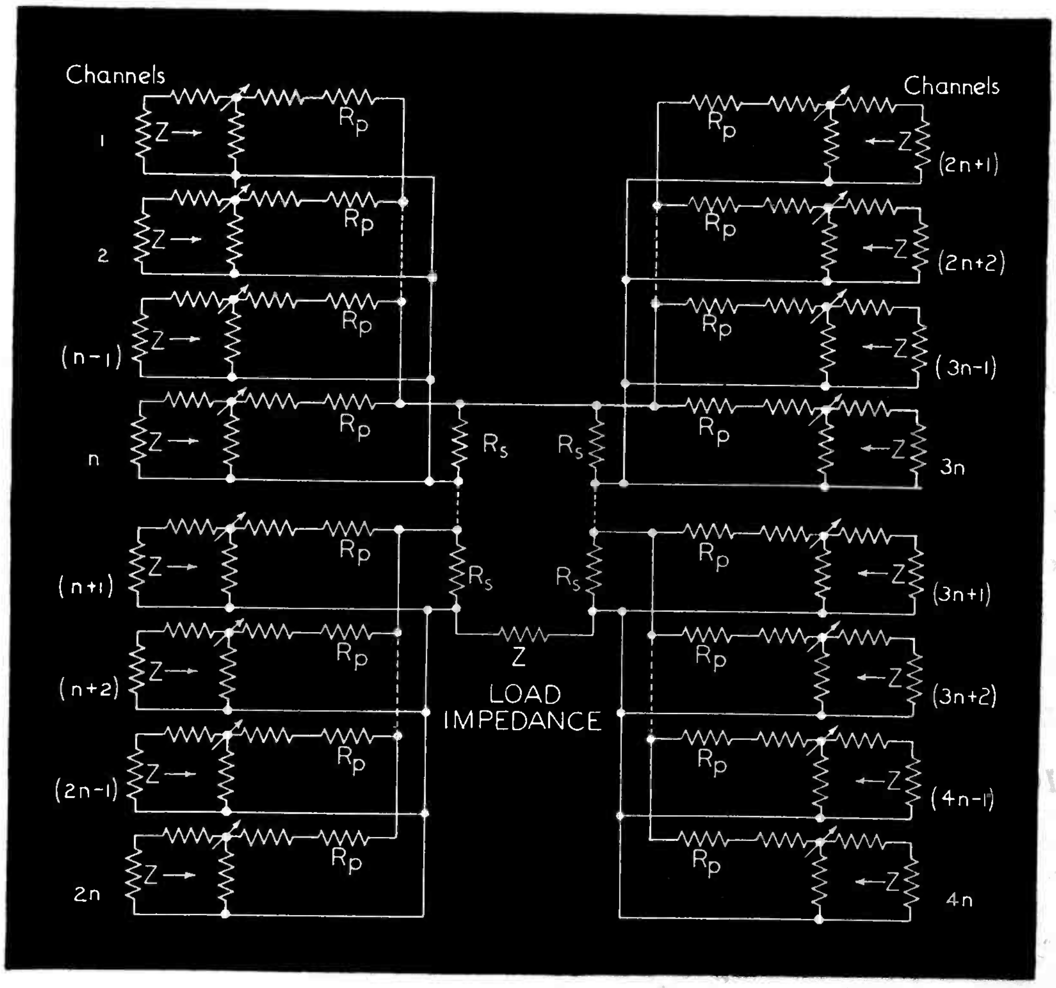


Figure 10
Parallel series mixers of *n* channels i[n] parallel, in series with *m* groups o[f] parallel-arranged circuits.

STACKS OF POTENTIAL POWER!

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THE KEY to many a puzzling new industrial development is frequently the right application of Power Conversion. At the heart of many of today's electrical marvels is a Metallic Rectifier Stack. Equipment designs once believed impossible or impractical are now in common daily operation—rendering efficient, dependable service.

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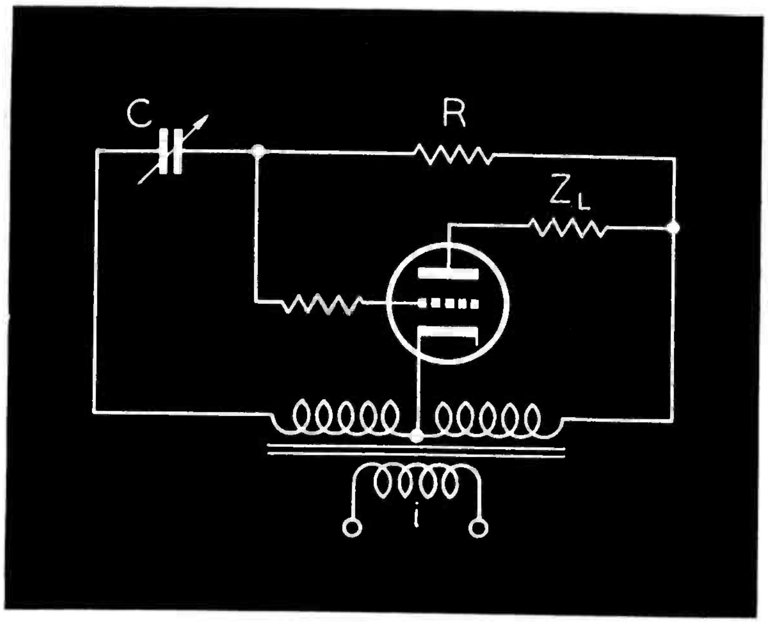
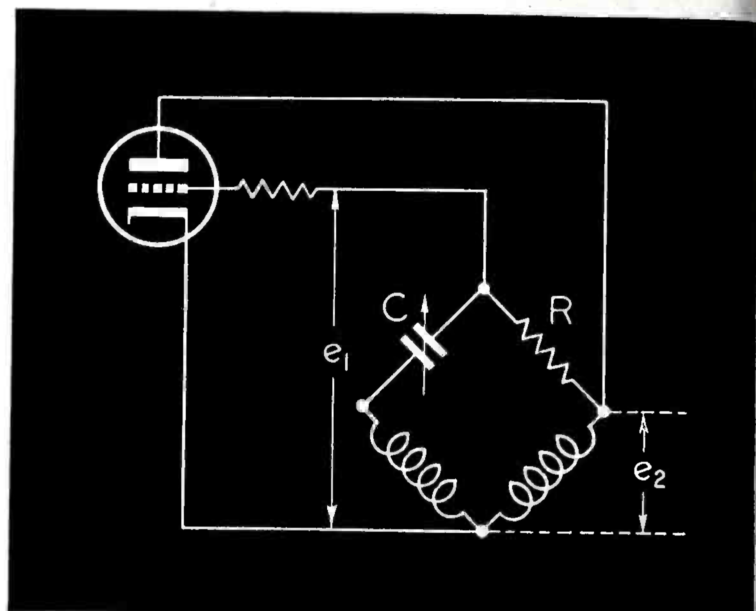
Designers and manufacturers of Copper Sulphide and Selenium Rectifiers, Battery Chargers, and D.C. Power Supplies for practically every requirement.

THE PHASE-





Figures 1 (top left) and 2 (top right)

THE last few years have seen increasing use of the thyratron and other gas-filled tubes. One of the reasons for this arises from the facility with which they can be controlled. Changes in the output current result when the value of a resistance or a capacitance or an inductance changes. These parameters generally control the phase relations between the grid voltage and the plate supply voltage, both of which are a-c.

A typical, simple basic circuit of such a *phase-control* system is shown in Figure 1. This circuit seems, at first sight, rather complex, and does not readily show why a slight variation in the setting of the condenser should affect phase relations between grid and plate supply voltages.

This paper attempts to indicate, in a simple mathematical way, what effect the setting of a resistor or condenser or inductor can have on the grid-to-plate-supply voltage phase relations.

One could rewrite the diagram of Figure 1 in a way that would suggest the basic circuit operation more clearly. This is shown by Figure 2.

The reader will recognize in this a *Wheatstone bridge*. What is desired, then is the ratio of e_1 to e_2. To cover all possible variations of this circuit, the general case is taken. The diagram for it is shown in Figure 3.

From Figure 3,

$$e_1 = i_1 Z_1 - i_2 Z_2 \qquad (1)$$

$$e_2 = i_2 Z_4 \qquad (2)$$

$$i_1 (Z_1 + Z_3) = i_2 (Z_2 + Z_4) \qquad (3)$$

The following information can then be derived from these three equations:

$$\frac{e_1}{e_2} = \frac{i_1 Z_1 - i_2 Z_2}{i_2 Z_4} = \left(\frac{i_1}{i_2}\right)\left(\frac{Z_1}{Z_4}\right) - \left(\frac{Z_2}{Z_4}\right) = \left(\frac{Z_2 + Z_4}{Z_1 + Z_3}\right)\left(\frac{Z_1}{Z_4}\right) - \frac{Z_2}{Z_4}$$

Since in most cases Z_2 equals Z_4,

$$\frac{e_1}{e_2} = \left(\frac{2 Z_2}{Z_1 + Z_3}\right)\left(\frac{Z_1}{Z_2}\right) - \left(\frac{Z_2}{Z_2}\right)$$

$$= \frac{2 Z_1}{Z_1 + Z_3} - 1$$

$$= \frac{2 Z_1 - Z_1 - Z_3}{Z_1 + Z_3}$$

$$= \frac{Z_1 - Z_3}{Z_1 + Z_3}$$

$$\frac{e_1}{e_2} = \frac{(R_1 + jX_1) - (R_3 + jX_3)}{(R_1 + jX_1) + (R_3 + jX_3)}$$

$$= \frac{(R_1 - R_3) + j(X_1 - X_3)}{(R_1 + R_3) + j(X_1 + X_3)}$$

$$= \frac{(R_1 - R_3)(R_1 + R_3) + (R_1 - R_3)(X_1 + X_3) + j(X_1 - X_3)(R_1 + R_3) + j(X_1 + X_3)(R_1 - R_3)}{(R_1 + R_3)^2 + (X_1 + X_3)^2}$$

$$= \frac{(R_1^2 + X_1^2 - R_3^2 - X_3^2) + j\,[Z X_1 R_3 - 2 X_3 R_1]}{(R_1 + R_3)^2 + (X_1 + X_3)^2}$$

This then gives the value of the angle by which the grid voltage leads

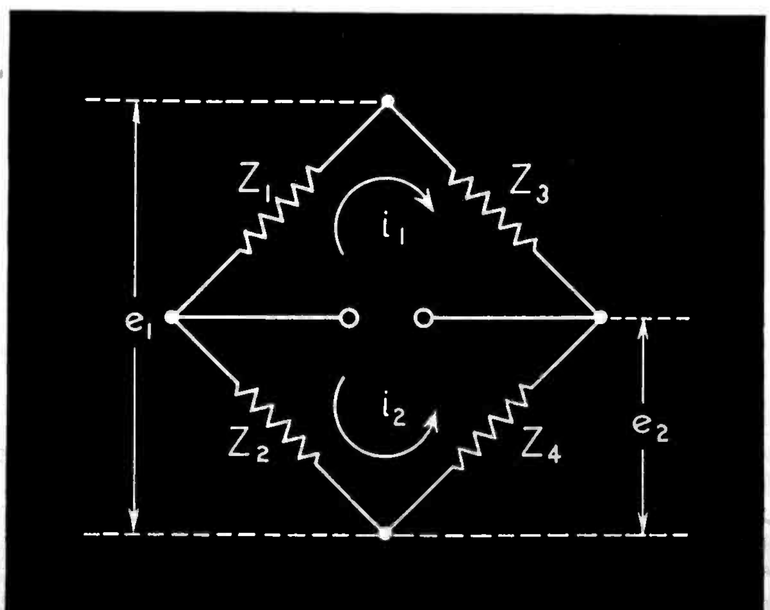


Figure 3

In Figure 2 appears the Wheatstone bridge, which suggests basic circuit operation. Accordingly the ratio E_1 to E_2 is then desired, so that all possible variations of the circuit can be covered. The circuit shown here is thus applied.

CONTROL CIRCUIT

by S. R. GOLDWASSER

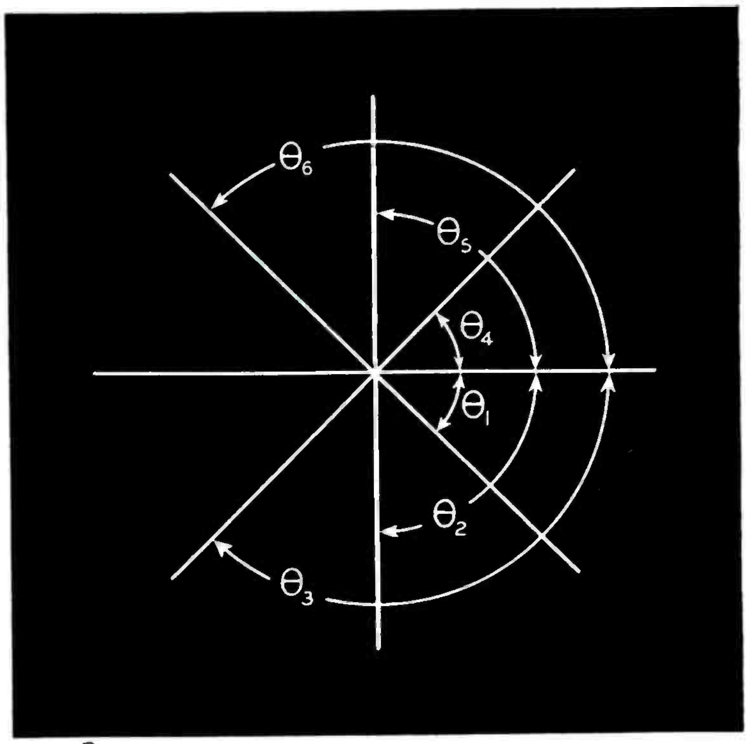
or lags the plate supply voltage.

$$\theta = \tan^{-1} \frac{2\,(X_1 R_3 - X_3 R_1)}{(R_1^2 + X_1^2) - (R_3^2 + X_3^2)} \qquad (4)$$

Equation *4* shows that the angle of lead or lag depends on only four quantities, the resistances of Z_1 and Z_3, and the reactances of Z_1 and Z_3. Generally, one of the legs is reactive while the other branch is resistive, in order to make θ large. However, a number of arrangements is possible. For one thing, it makes some difference which of the two branches is the resistive one and which the reactive. Also, the relative values of resistance and reactance affect the phase angle. And lastly, either capacitive or inductive reactance is possible. A tabulation of the phase angles resulting in the several cases is given in Figure 6.

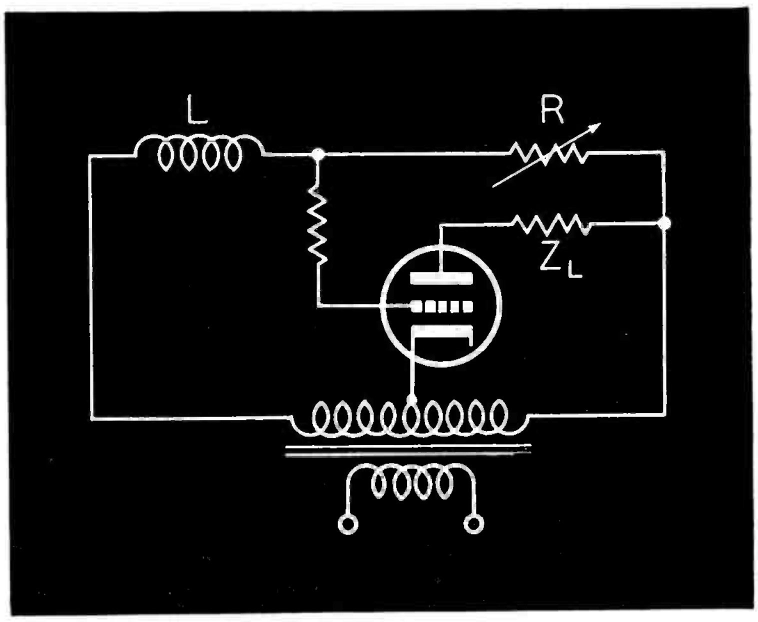
These angles can then be plotted, as in Figure 4. The angles of lead are θ_4, θ_5, and θ_6. The angles of lag are θ_1, θ_2, and θ_3. Of these, only θ_3 and θ_6 are useful. *On-off* control is obtained by the latter, while *gradual* control is given by the former.

As an example of the way this material can be applied, suppose *on-off* control is desired by changes in value of resistance. Figure 4 indicates that θ_6 will be the angle. From Figure 6, an inductive circuit is indicated, with R_3 much larger than X_1. The circuit used is shown in Figure 5.



Figures 4 (upper right), 5 (lower right) and 6 (below)

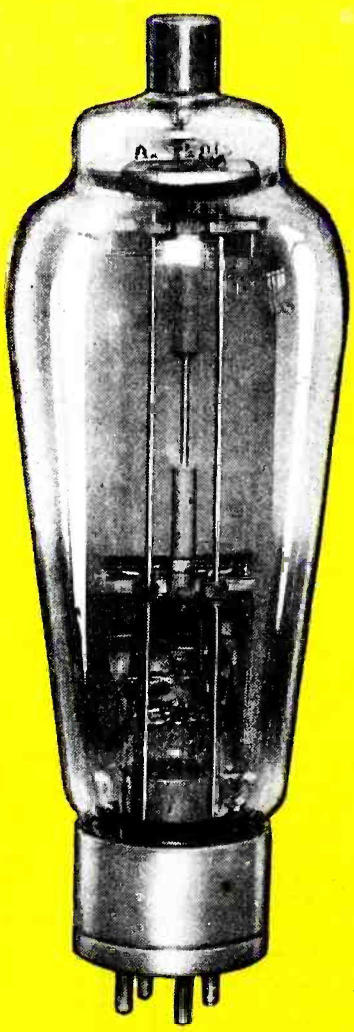
In figure 4 appears the plots of the angles Θ. The angles of lead are Θ_4, Θ_5, and Θ_6. The angles of lag are Θ_1, Θ_2, and Θ_3. Of these only Θ_3 and Θ_6 are useful. *On-off* control is obtained by the latter, while gradual control is given by the former. As an example of the way this material can be applied, suppose *on-off* control is desired by changes in value of resistance. Figure 4 indicates that Θ_6 will be the angle. The circuit used is shown in Figure 5. A tabulation of the phase angles resulting in the several cases is given in Figure 6.



	$X_1 = 0$, $R_3 = 0$			$X_3 = 0$, $R_1 = 0$		
	$R_1^2 \gg X_3^2$	$R_1^2 = X_3^2$	$R_1^2 \ll X_3^2$	$R_3^2 \gg X_1^2$	$R_3^2 = X_1^2$	$R_3^2 \ll X_1^2$
X is Inductive	$\Theta_1 = \tan^{-1} \frac{-2}{R_1}$	$\Theta_2 = \tan^{-1} -\infty$	$\Theta_3 = \tan^{-1} \frac{+2}{X_3}$	$\Theta_6 = \tan^{-1} \frac{-2}{R_3}$	$\Theta_5 = \tan^{-1} +\infty$	$\Theta_4 = \tan^{-1} \frac{2}{X_1}$
X is Capacitive	$\Theta_4 = \tan^{-1} \frac{2}{R_1}$	$\Theta_5 = \tan^{-1} +\infty$	$\Theta_6 = \tan^{-1} \frac{-2}{X_3}$	$\Theta_3 = \tan^{-1} \frac{2}{R_3}$	$\Theta_2 = \tan^{-1} -\infty$	$\Theta_1 = \tan^{-1} \frac{-2}{X_1}$

ADVANCED DESIGN—IMPROVED MANUFACTURING METHODS—MODERN PRODUCTION FACILITIES—PLUS LONG AND CONSTANTLY GROWING EXPERIENCE . . . ENABLE GENERAL ELECTRIC TO ANNOUNCE

SUBSTANTIAL PRICE REDUCTIONS IN G-E TRANSMITTER TUBES



GL-169 (and GL-159)

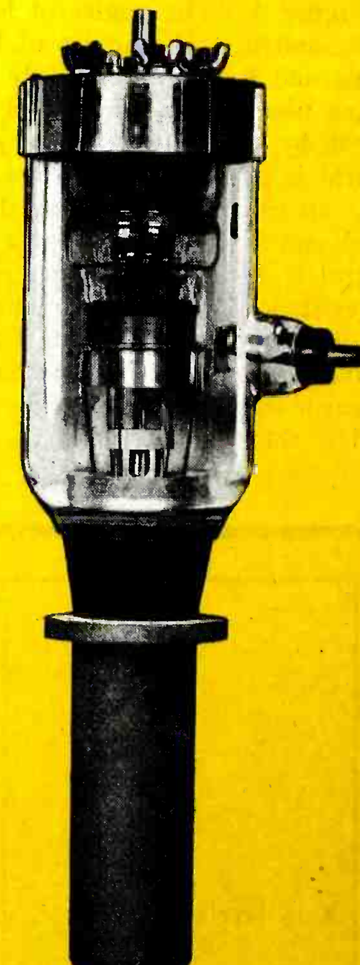
Transmitting triodes — for police radio

Old price $80
NEW PRICE $60

GL-880

High-frequency triode — for international short-wave, frequency modulation

Old price $850
NEW PRICE $600



GL-893

Transmitting triode — for broadcast, international short-wave, and also for high-frequency heating

Old price $750
NEW PRICE $650

THERE'S A G-E ELECTRONIC TUBE FOR EVERY PURPOSE

NEWS BRIEFS OF THE MONTH . . . —

SIGNAL CORPS ADOPTS F-M WALKIE-TALKIE

A new and improved model of the *Walkie-Talkie,* with f-m is now being supplied to troops at home and overseas according to the War Department.

Two antennas are provided instead of one. In addition to the standard vertical antenna, a goose-neck type is included. This permits the soldier using the set to operate it while he is prone on the ground or in a slit trench.

A headset is included with the new model, enabling the operator to *listen in* for a call, while a handset is available for use by the officer in command.

Carrying qualities are improved through an extra strap that goes around the abdomen of the soldier, thus distributing the set's weight more evenly. The entire set is carried like a haversack.

The set is so treated that rain and immersion in water for short periods will not impair its operating efficiency.

With all the improvements, the weight of the set remains the same as that of the old model, about 35 pounds.

Signal Corps Photo

* * *

TELEVISION BROADCASTERS ASSOCIATION PLANNED

Plans for a Television Broadcasters Association have been submitted to the members of the industry. The format for the association was suggested by a committee of the Society of Television Engineers, of which Klaus Landsberg, television director of Paramount Pictures, is chairman.

A proposed constitution has already been mailed to stations and other affiliates.

TURNER ELECTED IRE PRESIDENT

Hubert M. Turner of New Haven, has been elected president of The Institute of Radio Engineers for the coming year. He succeeds Dr. Lynde P. Wheeler, of the Federal Communications Commission, Washington.

At present, he is associate professor of electrical engineering at Yale University. During the first World War, professor Turner organized technical instruction for the U. S. Army Signal Corps at the University of Minnesota, and later at the Signal Corps School for Officer Candidates at Yale.

Ralph A. Hackbusch, of Leaside, Ontario, has been elected vice president of IRE. He is vice president in charge of radio, for Research Enterprises, Ltd.

Directors elected for three-year terms were: Raymond F. Guy, radio facilities engineer of National Broadcasting Company, New York; Lawrence C. F. Horle, of New York, consulting engineer; and William C. White, engineer of General Electric's Electronics Laboratory, Schenectady.

* * *

UBC ENGINEERS FORM SCHOOL

To train men for broadcast station operation and specialist positions in the Signal Corps, Walter E. Scholz and James S. Hill, United Broadcasting Company engineers have formed a school, the *Broadcast Technical Institute.*

Classes are conducted in the WHR-WCLE studios. Students are tutored on pre-amplifiers, mixers and telephone circuits, faders, repeater amplifiers, etc. Actual studio control is taught. Theoretical and laboratory work is also included in the courses, which consist of three sixteen-week semesters. Motion pictures are also used to teach certain subjects.

* * *

GHIRARDI SELLS PUBLISHING COMPANY TO FARRAR & RINEHART

Alfred A. Ghirardi, author of many books on theory, maintenance and repair, has sold his Radio & Technical Publishing Company to Farrar & Rinehart, Inc., 232 Madison Avenue, New York 16, N. Y. A subsidiary, the Radio & Technical Division of Murray Hill Books, Inc., will continue to publish the present Ghirardi radio books as well as new ones.

Mr. Ghirardi will continue to write books for the radio-electronic field. He will also be editorial consultant in electronics for Farrar & Rinehart.

* * *

WESTINGHOUSE PLANS QUICK CONVERSION TO PEACE PRODUCTION

Complete plans for reconversion to civilian production as soon as war production demands slacken are in readiness at Westinghouse, according to a report issued at the company's annual conclave of officers and managers.

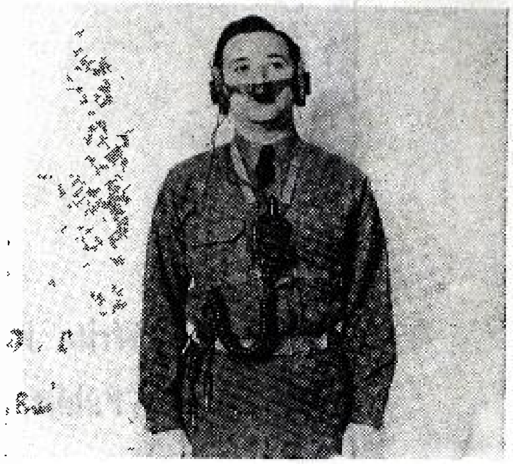
The report stated that while a period of readjustment to peacetime conditions must take place, it should be no more difficult than our adjustment to wartime conditions; pent-up demands for the goods of peace will be unprecedented; means of purchasing will exist after the war as never before—in cash, bonds and credit.

ARMY USING LIP MICROPHONE

A midget microphone, worn on the upper lip, which eliminates outside noises and leaves the hands free, has been adopted for use by the Army Ground Forces and is now in production under the supervision of the Signal Corps, Army Service Forces. It operates on a new noise-canceling principle.

To increase clearness in reproduction the microphone is provided with breath shields in front and back, acting as buffers against puffs of air from the mouth which would otherwise cause confused or unintelligible sounds. Outside noises enter at both sides of the microphone's diaphragm in equal volume, and thus cancel themselves, while speech enters the opening nearest the mouth with much greater intensity than on the opposite sides. The frequency response is from 200 to 4000 cycles at normal altitude. It can withstand total immersion for about ten minutes without injury to its mechanism.

The microphone is supported by metal mounting brackets with two upstanding metal arms attached to loops of cord which fit over the user's ears. Both loops and bracket may be adjusted to bring the instrument directly opposite the lips of the wearer.



Signal Corps Photo

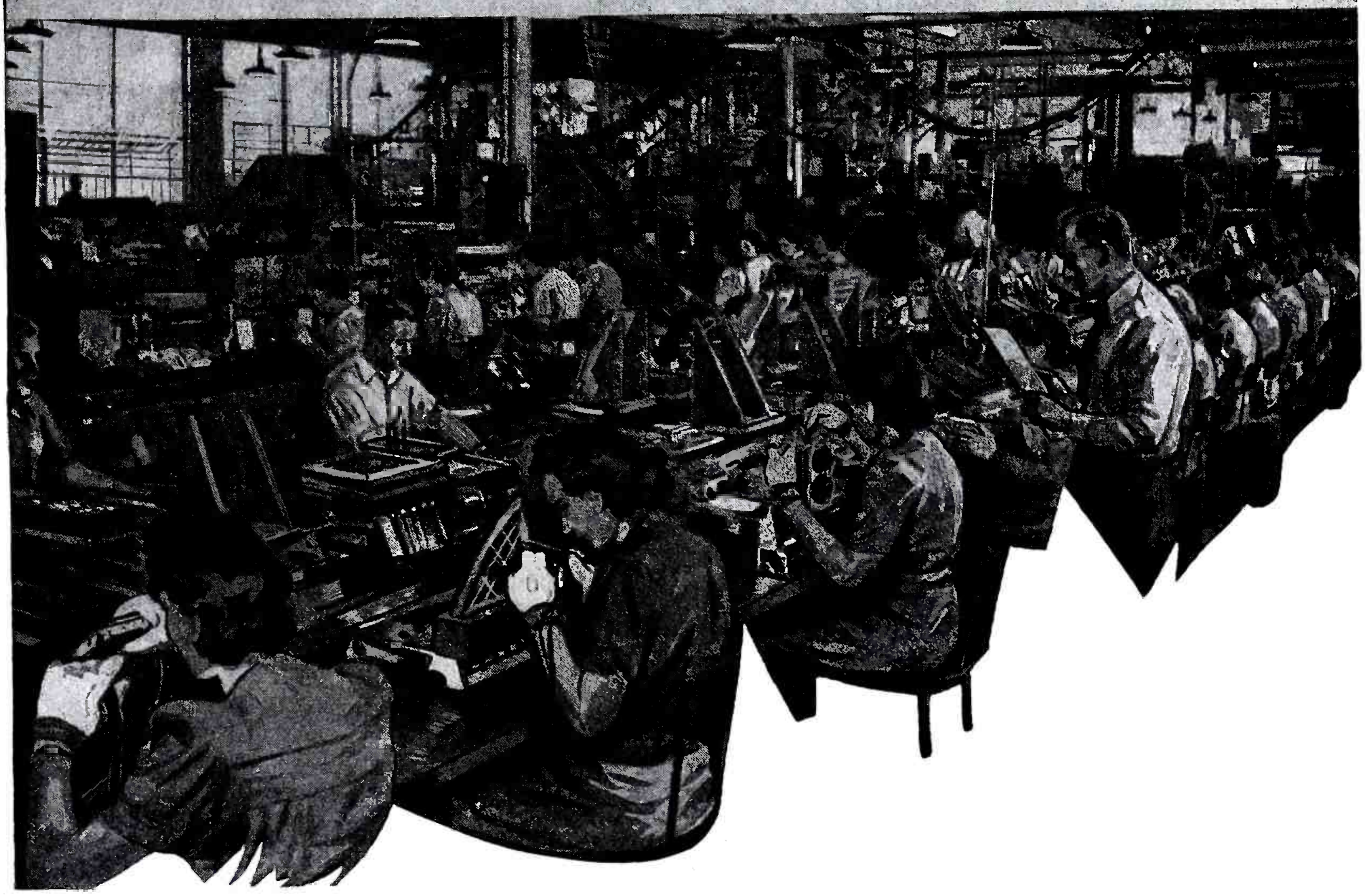
* * *

ASA ISSUES STEATITE STANDARDS

The American Standards Association has announced a series of standards (C75.2-1943) for steatite insulators. Details which have been standardized include outline dimensions, such as length and diameter of cross sections, hole diameter, hole tap (size, pitch and depth). The standards also state practices, requirements, manufacturing tolerances and inspection procedures for the use of industry and the armed forces inspectors. An appendix has also been included in which appears design criteria as recommended by various insulator manufacturers.

Among the members of the group who participated in the development of this standard are: E. A. Domber, Isolantite, Inc., Belleville, N. J.; C. H. Crawford, General Electric Company, Schenectady, N. Y.; F. E. Hansen, Western Electric Company, Kearny, N. J.; D. G. Little, Westinghouse Electric and Manufacturing Co., Baltimore, Md.; C. L. Snyder, General Ceramics and Steatite Corp., Keasbey, N. J.; Frank J. Stevens, American Lava Corp., Chattanooga, Tenn.; and (*Continued on page 86*)

There's More to Engineering than Design



It's one thing to concentrate the combined forces of research and engineering on a problem, and thereby come up with the answer—and quite another thing to put that answer into mass production on an assembly line.

This teamwork between research engineering and mass production is a Delco Radio specialty, developed through years of experience in the exacting manufacture of peacetime automotive radios. It is being applied to highly intricate wartime assignments which include volume production of receivers and transmitters for mobile artillery and tanks . . . straight-line assembly of pushbutton tuning for vehicular radio receivers . . . mass manufacture of relays, plugs, receptacles, rotary switches, shock mountings . . . and volume production of components for air-borne communication and electronic navigation equipment.

Today, when the ability to discover and design must be teamed with the ability to produce in great quantity with highest quality, Delco Radio finds itself well prepared for wartime industry's needs. Delco Radio Division, General Motors Corporation, Kokomo, Indiana.

Back Our Boys By Buying Bonds!

Delco Radio
DIVISION OF
GENERAL MOTORS

THE INDUSTRY OFFERS . . . —— . . . —— . . ——

GUARDIAN ADJUSTABLE OVERLOAD RELAY

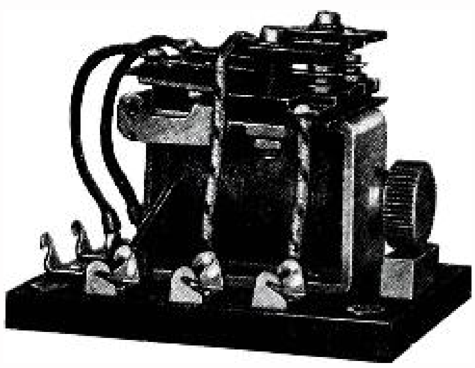
For overload protection in circuits with varying current demands, Guardian Electric, 1621 West Walnut Street, Chicago, Ill., has developed an adjustable overload relay, series 445, G-33393. The relay is said to be adjustable to close at any value from .200 to .750 amp. by means of adjustable core which varies the reluctance of the magnetic circuit.

Its rating is 5 amps. at 115 volts, 60 cycles; up to three pole double throw.

The coil can be wound to operate on current or voltage ranges where the minimum wattage is over .32 watt and the maximum wattage is under 4.5 watts. Resistance is 8 ohms. Temperature rise is 52° C. at .750 amp.

Vibration resistance is said to be 8 times gravity, energized or de-energized; tested at 45 cycles per second at .080″ excursion.

Size is 1 3/16″x2⅜″x2⅞″. Weight is 9 ounces.



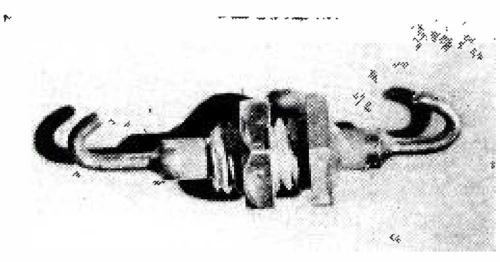
* * *

CENTRALAB BUSHING-MOUNTED CAPACITORS

Bushing-mounted capacitors, type 817, for use in high frequency circuits where a capacity ground to the chassis and a *lead through* is desired, have been released by Centralab, division of Globe-Union, Inc., 900 East Keefe Avenue, Milwaukee, Wisconsin.

The ceramic capacitor tube is plated internally and externally with silver and then with copper. The tube is a snug fit in the brass bushing and the external capacitor plate is soldered to the bushing. The tinned copper wire is also a snug fit inside the capacitor tube and is soldered to the internal plate. The entire unit is wax impregnated after assembly.

Capacitance is 55 mmf plus or minus 10%. Temperature coefficient is .00052 mmf/mmf/°C; test voltage is 2000 v d-c; working voltage is 1000 v d-c.



AEROVOX HIGH ALTITUDE OIL CAPACITORS

High-altitude oil capacitors are now being produced by Aerovox Corporation, New Bedford, Mass.

One of these capacitors is similar to the standard Aerovox type '12 round-can barrier-cap units, except that one terminal is a short screw post. The other is a tall insulator post with corona shield at top. The cover assembly is a one-piece ceramic cap, with the can top spun over a rubber gasket and the cap for hermetic sealing. The arrangement of terminals, corona shield and ceramic cap is said to minimize surface leakage, corona losses and probability of voltage breakdowns even at extreme altitudes.

This aircraft type '12 capacitor utilizes Aerovox Hyvol vegetable oil for the impregnant and fill.

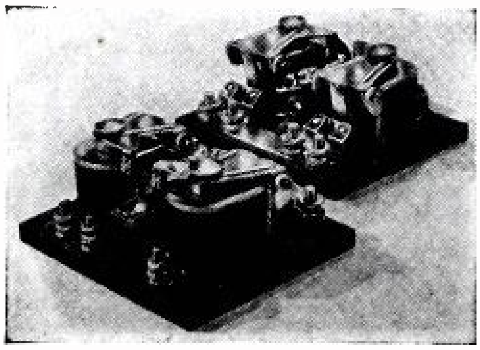
* * *

STRUTHERS-DUNN DYNAMIC BRAKING RELAY

Two relays, types 68HX100 and 67HXX100, affording instantaneous dynamic-braking with split-series field motors, have been released by Struthers-Dunn, Inc., 132 Arch Street, Philadelphia, Pa.

These relays are suited for applications utilizing reversing motors.

The relays are of the Struthers-Dunn *Nutcracker-construction*. There are no sliding contacts. Positive *memory* contacts select the proper field winding to give reverse torque for braking. The relays are said to operate in all positions.

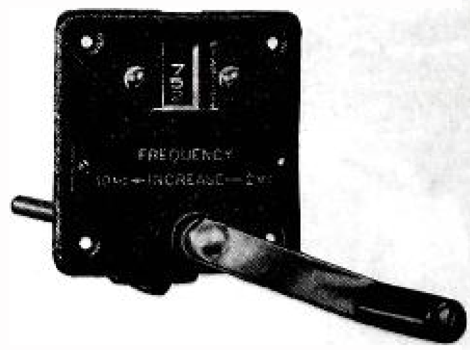


B & W CYCLOMETER TYPE COUNTER ASSEMBLY

A cyclometer type counter unit, designed for registering rotary coil turns, is now available from Barker & Williamson, 235 Fairfield Ave., Upper Darby, Pa. The unit is said to be adaptable to practically any application where a shaft must be turned a pre-determined number of times, or set at any pre-determined position. The exact number of turns, down to tenths of a turn, are recorded on the counter.

Standard counters record 10 turns. Others, also available, record up to 100-1000 turns.

These counter assemblies have direct shaft drive (1:1 drive shaft to driven unit). Shafts can be any length. A Veeder-Root counter is used. The gear drive is direct, with precision cut steel gears. Units are 8 oz. in weight. They are available with either right or left hand rotation, and can be supplied with name plates to suit the application.



* * *

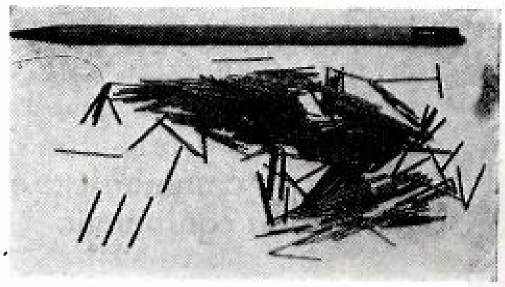
STELLITE ALLOY FOR SMALL MECHANISMS

An alloy of tungsten, chromium, and cobalt is now being offered by Haynes Stellite Company, Kokomo, Indiana, a unit of Union Carbide and Carbon Corporation, in a form adaptable to instrument bearing pivots, phonograph and recording needles, needle valves, and similar applications. This stainless metal is said to be resistant to many corrosive media and all normal atmospheric conditions. As it is not possible to machine it in small parts, these are cast close to size and approximate shape and finished by grinding, and lapping if necessary.

The properties of this Stellite alloy, according to the manufacturer, include a tensile strength of approximately 65,000 lb. per sq. in. and hardness of Rockwell C-60 to C-62.

The material is said to be virtually non-magnetic, and can readily be brazed or welded to steel or other base metals.

(*Continued on page* 104)




A GOOD MATCH FOR TODAY'S SPECIFICATIONS
. . . plus a few items for which specifications have not been written
SPRAGUE
ARMY E NAVY
ELECTROLYTIC CAPACITORS—All capacity and voltage ratings and combinations in containers to meet every requirement.
PAPER DIELECTRIC CAPACITORS—Wax or oil-impregnated sections in potted or oil-filled containers, A.C. and D.C.
MICA DIELECTRIC CAPACITORS—Low and intermediate voltage molded types.
RADIO NOISE-SUPPRESSION FILTERS
HIGH-VOLTAGE NETWORKS
KOOLOHM RESISTORS—Wire-wound power types, hermetically-sealed power types, precision meter multipliers, bobbin-type resistors, etc.
SPRAGUE SPECIALTIES COMPANY
NORTH ADAMS, MASS.
SPRAGUE CAPACITORS
QUALITY COMPONENTS • EXPERTLY ENGINEERED • COMPETENTLY PRODUCED

NEWS BRIEFS

(*Continued from page* 82)

H. R. Terhune, Radio Corporation of America, Camden, N. J.

* * *

NEW RUST-PROOFING PROCESS

A new rust-proofing process known as *corronizing* has been developed by Standard Steel Spring Company, Coraopolis, Pa.

The process essentially consists of electroplating on base stock a very thin layer of nickel, approximately .000050", and then plating over this a layer of nickel-zinc alloy. The thickness of this layer varies from .000100" to .000500".

Either ferrous or non-ferrous metals or alloys can be *corronized.*

* * *

WESTINGHOUSE TUBE OUTPUT UP 1100 PER CENT

The Westinghouse Lamp Division, Bloomfield, N. J., recently reported that its production of electronic tubes is 11 times as great as it was just two years ago.

Total sales of Westinghouse electronic tubes this year will exceed $22,000,000 as compared with $1,873,000 in 1941, according to an estimate by Ralph C. Stuart, division manager.

* * *

SCIENTIFIC RADIO WINS "E"

Scientific Radio Products Company of Council Bluffs, Iowa, has been awarded the Army-Navy "E."

The company is operated by Leo Meyerson of Council Bluffs and E. M. Shideler of Ft. Dodge, Iowa, both former radio amateurs, and Samuel Meyerson, Council Bluffs businessman.

Leo Meyerson, right center, general manager; Miss Rose Paluka, left center, crystal finisher; Lt. Col. John M. Niehaus, left, and Lt. Comdr. George Norwood, right.

* * *

SETH PARKER 1-KW TRANSMITTER SERVING WAR EFFORT

The 1-kw transmitter installed ten years ago by WMAQ engineers in the auxiliary schooner Seth Parker is now on duty in the Mediterranean area for the armed forces.

Badly damaged in Pacific storms, the Parker was stranded near Samoa. Salvaged from the hull's equipment, the transmitter was sent back to Chicago and put in dead storage. Four years later, in 1937, it was overhauled for another journey, this time to Canton Island, a spot of coral in the far Pacific. There the transmitter made it possible for NBC to cover the important 1937 solar eclipse. On the way back to Chicago storage, the apparatus was accidentally dropped overboard and pretty well ruined before recovery. But the unit was still good enough to be reclaimed and used as an

WHEN YOU CHANGE YOUR ADDRESS

Be sure to notify the Subscription Department of COMMUNICATIONS at 19 E. Forty-seventh St., New York 17, N. Y., giving the old as well as the new address, and do this at least four weeks in advance. The Post Office Department does not forward magazines unless you pay additional postage, and we cannot duplicate copies mailed to the old address. We ask your cooperation.

auxiliary to WMAQ's 50,000 watt station.

Several months ago, a former NBC engineer, serving with the armed forces in North Africa, remembered the outfit and put in a requisition for it when the army needed a 1-kilowatt transmitter.

* * *

WPB PUBLISHES SALVAGE MANUAL FOR INDUSTRY

A comprehensive manual on industrial salvage has just been published by the Technical Service Section, Industrial Salvage Branch, Salvage Division, War Production Board.

The new book, entitled *Salvage Manual for Industry,* contains 245 pages of data—most of it of a *how-to-do-it* nature—on industrial salvage practice in all its ramifications. Material is presented in twenty-six chapters, grouped into six major sections; two chapters on organizing and planning the salvage department, three on the administrative factors, twelve on methods of handling (finding, identifying, segregating, collecting, reclaiming, storing, selling, etc.) metal scrap, three on non-metallic waste, seven case histories demonstrating exemplary practice, a seventeen-page compilation of practical hints for handling specific waste materials, and a nine-page index.

It is procurable through the Superintendent of Documents, Government Printing Office, Washington, D. C., at $.50 per copy.

* * *

CHICAGO TELEPHONE AWARDED "E"

The Chicago Telephone Supply Company, Elkhart, Ind., has been awarded the Army-Navy "E". Lt. Colonel J. M. Niehaus, Regional Labor Officer of the Signal Corps, made the presentation speech at plant ceremonies. Floyd Best, president, accepted the award.

Lieutenant Commander W. P. Burleigh, head of Academic Department, Naval Reserve Midshipmen's School, Notre Dame, Indiana, presenting "E" pin to F. C. Best, president, Chicago Telephone Supply Company.

* * *

J. L. HEROLD, M. L. LEVY ON EMERSON STAFF

Jerome L. Herold, former G. E. electronics department purchasing agent, has joined Emerson Radio and Phonograph Corporation, New York City, as chief purchasing agent.

Maurice L. Levy, formerly chief engineer of the radio division of Stromberg-Carlson, has been appointed manager of Emerson's special equipment division.

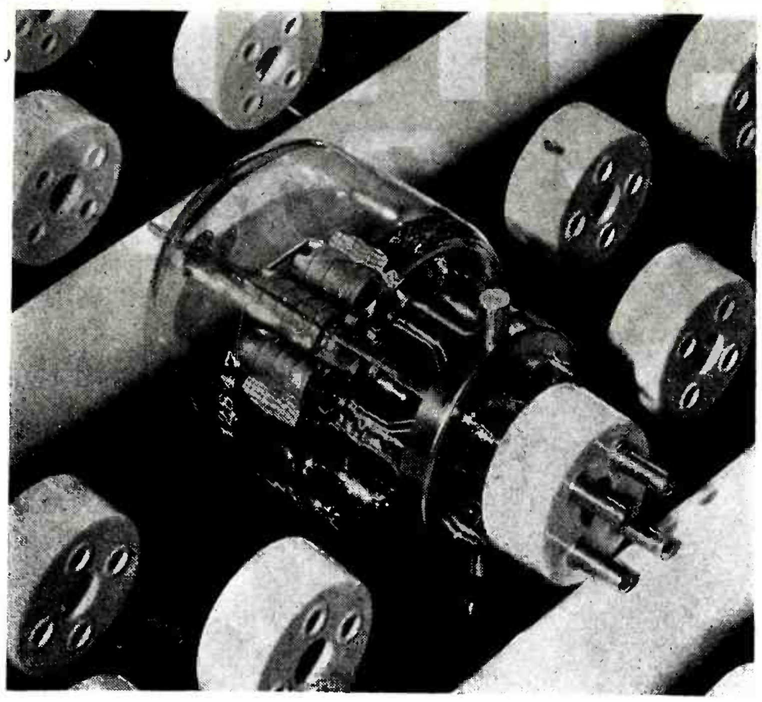
* * *

MEYERS NOW RCA ASSISTANT GENERAL COUNSEL

Robert P. Meyers, senior attorney in the legal department of NBC, has been ap-

(*Continued on page* 90)

TRENDS IN DESIGN AND SHOP PRACTICE



At left, the new ceramic plastic, *prestite*, now being used for bases on high frequency tubes. This material is said to have the electrical and mechanical strength of wet process porcelain, with the molding qualities of dry process porcelain. Heavy hydraulic pressure is used in forming these bases. (*Courtesy Westinghouse*)

Women technicians have become very active in maintenance and repair work for the armed forces. At right we have Elizabeth A. Blakeney, T/5th, a member of the WAC, repairing an audio oscillator.

Police departments are among the most important users of radio communications systems. Not only have such systems been installed in large cities, but smaller towns and communities as well. Below appears an interesting installation made recently in a typical moderate sized town. The transmitter is a 50-watt a-m unit. It was designed by Dr. C. D. Haigis, who is now serving the Government in a consulting capacity. The complete transmitter, in its streamlined housing, is shown at right, below, while at left, below, appears the compact control box.

NEWS BRIEFS

(*Continued from page 87*)

pointed assistant general counsel of the Radio Corporation of America.

* * *

T. I. PHILLIPS HEADS PITTSBURGH WESTINGHOUSE DIVISION

Thomas I. Phillips, vice president of Westinghouse, has been appointed head of the Pittsburgh divisions. He succeeds A. C. Streamer, who was named assistant to the president. Mr. Phillips joined Westinghouse in 1915 as a tool maker.

* * *

KLICPERA UNIVERSAL MICROPHONE REPRESENTATIVE

M. F. Klicpera has been appointed factory representative for Universal Microphone Co., Inglewood, Cal. He will cover Texas, Louisiana, Arkansas and Oklahoma.

* * *

ROLA HOLDS "E" FLAG CEREMONIES

The "E" pennant was presented recently to Rola Company, Inc., Cleveland, during ceremonies held in the Masonic auditorium.

Major R. S. French of headquarters Fifth Service Command, presented the flag to B. A. Engholm, president. Lt. Richard S. Howes presented the "E" pins. Jesse Hawley, president of Hawley Products, St. Charles, Ill., presided at the ceremony.

* * *

WIGGIN RETURNS TO SEARS, ROEBUCK

Parker E. Wiggin, who has been with the War Department as chief business adviser, Procurement and Distribution Service, U. S. Signal Corps, has returned to Sears, Roebuck and Co., Chicago. He will be in charge of the parent radio and musical instrument buying organization.

* * *

SIEMENS NAMED CHIEF ENGINEER OF RCA IN ARGENTINA

R. H. Siemens has been appointed chief engineer of RCA Victor in Argentina. He succeeds Paul Bennett, who has returned to Camden headquarters.

* * *

STAR ADDED TO CLAROSTAT "E" FLAG

A white star has been added to Clarostat's Army-Navy "E" pennant.

* * *

PIPE AND TUBE BENDING HANDBOOK

An 80-page handbook showing methods and devices for bending pipes and tubes of copper and its alloys has been released by the Copper and Brass Research Association, 420 Lexington Ave., New York

City. The text is well illustrated, and covers hot and cold bending, minimum radii, temper, the use of mandrels of various types and many other essential factors.

* * *

REEVES APPOINTS PINKERTON PUBLIC RELATIONS DIRECTOR

Fred H. Pinkerton is now director of public relations of Reeves Sound Laboratories, Inc., 67 West 47th Street, New York City. Mr. Pinkerton will also continue to serve the National Electrical Wholesalers Association as public relations counsel.

* * *

STAR ADDED TO BELMONT RADIO "E" FLAG

The Belmont Radio Corporation, Chicago, has been awarded a second white star for its Army-Navy "E" flag.

* * *

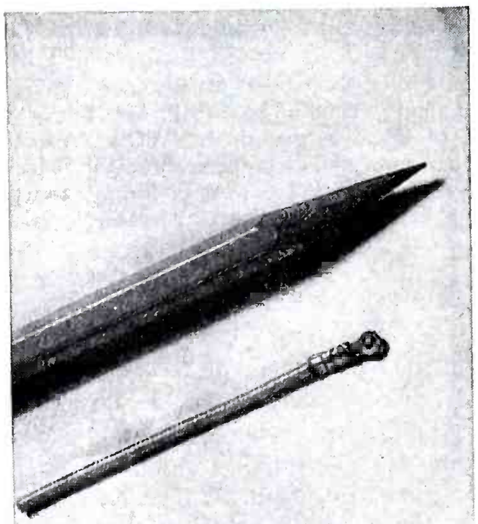
SEARLE MANAGER OF PHILCO'S SIMPLEX RADIO DIVISION

Lionel M. Searle has been named manager of the entire Simplex Radio Division of Philco Corporation, Sandusky, Ohio.

* * *

SOLDERLESS TERMINAL BULLETIN

A data sheet describing a solderless terminal for 26-22 wire has been published by the Aircraft-Marine Products, Inc., 286 N. Broad Street, Elizabeth, N. J. Information presented includes stud size, clearance, tongue width, etc. Described, too, are the hand and power tools that may be used to apply the terminals.



* * *

TUCKER AND FRANKEL NOW WESTINGHOUSE STAFF ASSISTANTS

R. F. Tucker and Adolph Frankel have been appointed staff assistants to manager Ralph C. Stuart, of the Westinghouse lamp division, Bloomfield, N. J.

* * *

HALLICRAFTERS CLEARING PLANT INSPECTED

The new Clearing plant of the Hallicrafters, Chicago, was recently inspected by officers of the Army and Navy, during a production drive rally. Visiting the new plant were Colonel G. P. Bush, Deputy Commander, Chicago Signal Depot; Captain H. T. Chin of the Chi-

(*Continued on page* 95)

VETERAN WIRELESS OPERATORS ASSOCIATION NEWS

W. J. McGONIGLE, President — RCA BUILDING, 30 Rockefeller Plaza, New York, N. Y. — GEORGE H. CLARK, Secretary

At Army-Navy "E" award to McElroy Manufacturing Co., Boston, Mass, in grand ballroom of Hotel Kenmore. Members of VWOA attending were, right to left: W. J. Halligan, president, The Hallicrafters; J. R. Poppele, chief engineer, WOR, New York; Mr. Briggs of Boston chapter; Guy Entwistle, president, Massachusetts Radio School; A. Stockelburg; William J. McGonigle, president, VWOA; Warrant Officer F. C. W. Lazenby, USNR; J. Frank Rigby, RCA Communications, Inc., New York; Mark MacAdam, chief engineer, Brockton, Mass., Police Department; Theodore R. McElroy, president, McElroy Manufacturing Co.; Walter Butterworth, FCC, Boston; A. E. Ridley, charter member, Boston chapter VWOA; Col. K. B. Lawton, Chief of Pictorial Section, Office of Chief Signal Officer; G. H. Clark, secretary, VWOA.

Personals

WE had recently a very pleasant visit with Lieutenant Commander Arthur F. Wallis, executive officer of the Maritime Radio Training Station. "Steve" spoke of a recent visit to Washington when he saw Commander Boucheron, a VWOA life member, and Lieutenant Commander Karl Baarslag, author of *S O S to the Rescue* and other best sellers. . . . Our best wishes to Charles D. Guthrie, who has completed so many years in Government radio service that it is difficult to compute the total. He was one of the first radio inspectors, later radio supervisor of the Shipping Board during the first World War and for many years after. And since inception he has been radio supervisor in New York for the War Shipping Administration. . . . In the *Saturday Evening Post* appears an interesting article by VWOA member Josef Israels II. He was publicity chairman of our association for several years and has been in the publicity field since he left radio some years ago. . . . Another radio man, who is now an outstanding personality in the advertising field is Mr. Belding of Foote, Cone and Belding. He was formerly an operator. . . . And we shouldn't forget that in the business of disseminating valuable technical radio data we have in our midst our own LW (Lewis Winner), editor of COMMUNCATIONS, who is also an old-timer in the radio operating field. . . . Perhaps we should all envy the fact that David Sarnoff, our first life member is a frequent visitor at the White House, most recently as one of the *ten industrial leaders to consult with the* President on economic conditions now and after the war. . . . A phone call came in recently from Peter Podell, the original member of VWOA asking when the next meeting would be held. Said he was getting kind of lonesome for the old gang. "Pete" is now with the confidential section of the Federal Communications Commission. The recent notice of the meeting in November at Fusco's, which we all hope you will have attended, should keep PP happy. . . . We have learned that Sam Schneider, who was once termed *perpetual treasurer,* until Bill Simon came along, is now with the Overseas branch of the Office of War Information. We hope the Arabs don't get you, Sam. . . . E. K. Cohan, director of engineering of the Columbia Broadcasting System — recipient of the VWOA Marconi Memorial Medal of Achievement in 1940—is on leave of absence from CBS on a government assignment. . . . As is William S. Paley, president of CBS, an honorary member of our Association. He has been assigned to OWI activities in North Africa. . . . Haven't heard for a long time from G. B. Rabbitts, one of the oldest of old-timers—and still active—for a long time. GBR recently returned from an eleven months' trip to the East. Let's hear from you GBR. . . . Hal Styles, chairman of the Hollywood-Los Angeles chapter of our Association is now with NBC in Hollywood. . . . Wonder how Gilson Willetts, chairman of the

(*Continued on page* 94)

From telegraph boy to head of the world's largest plant producing automatic radiotelegraph apparatus . . . is Ted McElroy's* own success saga. And the creed that drove him on—NEVER BE SATISFIED WITH MEDIOCRITY. This same spirit prevails throughout the McElroy organization where inquisitive engineers never copy and never imitate. They create, design, build . . .

Typical of the work they do is the new McELROY MODEL SR-900 SL-990 . . . a superior commercial recorder including an automatic noise limiter and signal leveller. Embodying new principles of design and operation, it will record clean, readable signals at speeds up to 350 words a minute under the most adverse conditions.

Your inquiries are invited. If a McElroy engineer can be of service to you, ask for one.

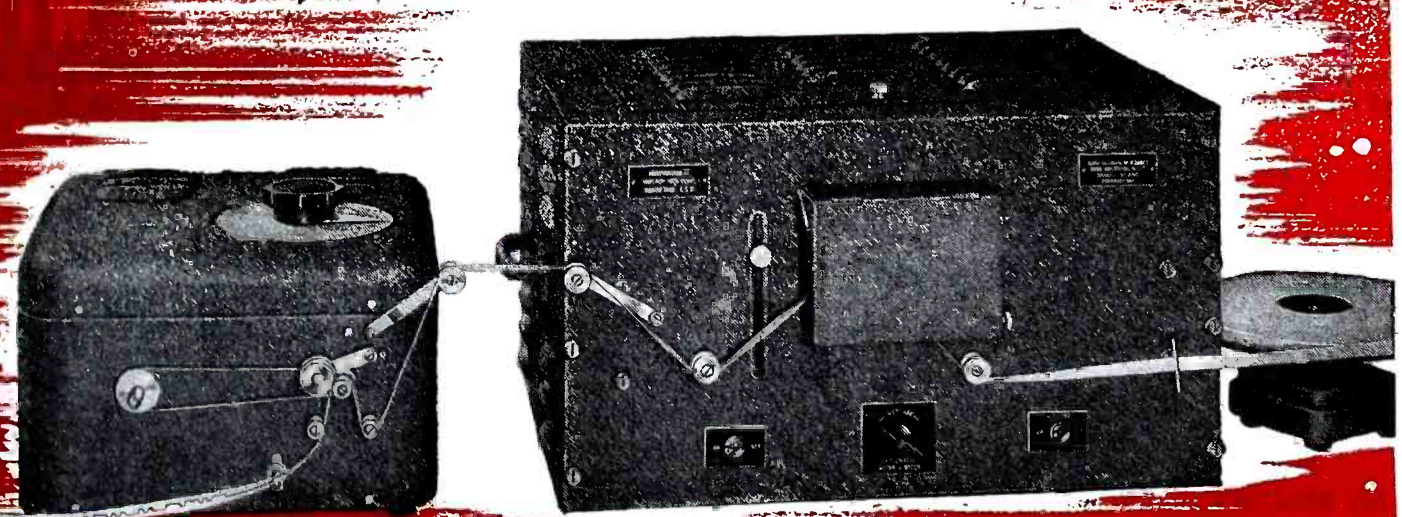
*WORLD CHAMPION RADIO TELEGRAPHER FOR MORE THAN 20 YEARS

McElroy MANUFACTURING CORP.
82 BROOKLINE AVE., BOSTON, MASS.

WORLD'S LARGEST MANUFACTURER OF AUTOMATIC RADIO TELEGRAPH APPARATUS

BUY MORE WAR BONDS

ARMY E NAVY



VWOA NEWS

(*Continued from page 92*)

San Francisco chapter is enjoying his stay at "Boys' Town," Nebraska. Imagine it is quite an experience. We shall enjoy reading his account of it in his forthcoming book. . . . In a chronological history prepared by Donald McNicol for the *Telegraph and Telephone Age* we noted that the memorial tablet for operators at Battery Park was mentioned. The tablet which was dedicated May 12, 1915, pays tribute to "George Eccles, of Almonte, Ontario, Canada, as the first man so to die; his ship, the *Ohio*, foundered in Pacific waters in 1909." Since then many wirelessmen have made the supreme sacrifice and many of their names appear on the Monument in Battery Park. All of the trustees of the original Wireless Operators Monument Fund are members of our Association. . . . For some years past the VWOA has conducted annual memorial services at the monument. Present plans call for the removal of the monument from its present location to a more central location in Battery Park and the inclusion of a memorial to Marconi. The Association inaugurated a Marconi memorial fund shortly after the death of Marconi which will be used to establish the new Battery Park memorial. Contributions from interested individuals and organizations should be made payable to the Marconi memorial fund, Veteran Wireless Operators Association, Radio City, New York, N. Y. . . . The Marconi memorial scholarship plan is an additional tribute to the memory of the *number one wireless man*. J. R. Poppele, chairman of the scholarship committee, informs us that through the courtesy of E. H. Rietzke, president of the Capitol Radio Engineering Institute, our Association will award a home study scholarship in the Institute to outstanding radiowomen of the WAC, WAVES, MARINES and SPARS. . . . Our grateful appreciation to F. P. Guthrie, chairman of our Washington chapter, for the fine job at the testimonial dinner to pioneer W. D. Terrell upon his retirement from the Federal Communications Commission. . . . Interesting to note that Lord Louis Mountbatten, recently appointed Supreme Allied Commander for Southeast Asia, performed extremely creditable service as Wireless Officer of the British Mediterranean Fleet in the 1930's. Our best wishes to a former Wireless Officer for success in the immense job at hand.

NEWS BRIEFS

(*Continued from page* 91)

nese Army and at present a member of the Tank Corps; Commander E. N. Dingley, Jr., Radio Division, Bureau of Ships, Navy Department; and Lieutenant Charles J. Bates, senior surviving officer of the U. S. Destroyer Meredith, which was sunk off Guadalcanal last year.

* * *

CATHODE-RAY BIBLIOGRAPHY

An extensive bibliography covering textbooks and published papers on cathode-ray equipment and tubes appears in the current issue of the *DuMont Oscillographer*.

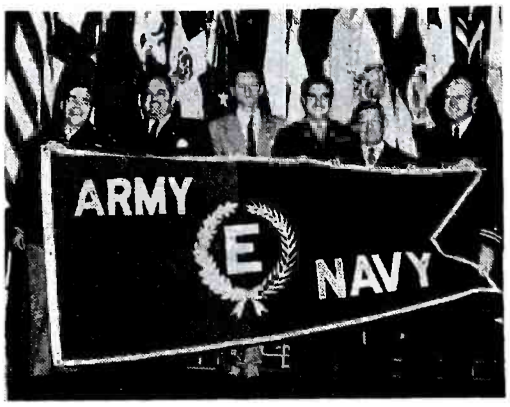
* * *

REEVES SOUND LABORATORIES HOLD "E" CEREMONIES

The Reeves Sound Laboratories, Inc., 67 West 47th Street, New York City, have been awarded the Army-Navy "E". Ceremonies were held in the grand ballroom of the Waldorf-Astoria, New York City.

The presentation of the flag was made by Colonel C. E. Snow, Signal Corps Officer in charge of the Legal Branch, Matériel Division, to Hazard E. Reeves and Laurence D. Ely.

The presentation was broadcast over WOR.



Left to right: Colonel Conrad E. Snow, Laurence D. Ely, Hazard E. Reeves, Sgt. Alex. J. Kolonics, wounded veteran who attended; Louis Bourguignon, chief electrician, Reeves Laboratories, and Lt. Ralph Whitney.

* * *

VINYL PLASTIC FILM DATA

The October issue of the *Bakelite Review* features an analysis of thin vinyl plastic film. This issue also contains data on a process for molding resin-bonded plywoods, bakelite plastic antenna masts, etc.

The *Review* is published by the Bakelite Corporation, 30 East 42nd Street, New York 17, N. Y.

* * *

RADIO AGE FEATURES PAPER ON TELEVISION RELAYS

In the October issue of *Radio Age*, published by RCA, New York, appears an analysis of television relays by Ralph R. Beal, RCA director of research.

Appearing in this issue, also, are papers by H. W. Leverenz on phosphors; Harry E. Leroy on crystals; Henry E. Hallborg on weather prediction; and Clifford Eddison on chemistry in war work.

Other subjects covered in this issue include OWI recording unit and postwar television plans.

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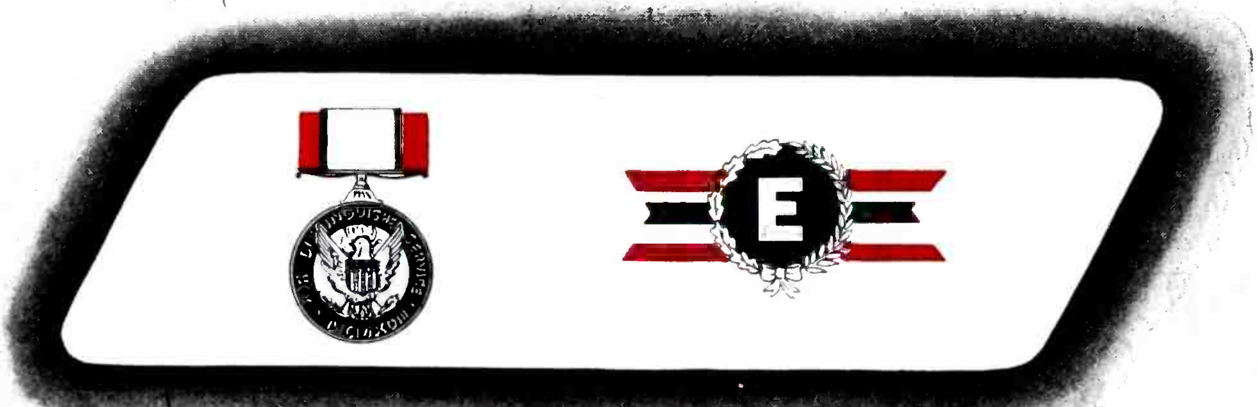
CENTRALAB TUBULAR CAPACITOR BULLETIN

An eight-page bulletin, *Ceramic Tubular*

(*Continued on page* 101)



WORN WITH *Equal Honor*

Awarded for distinguished service . . . to employees of

SCIENTIFIC RADIO PRODUCTS COMPANY

The fighting man with the Distinguished Service Medal on his breast is proud. For it denotes exceptional bravery beyond the call of duty—a personal EXTRA contribution toward Victory.

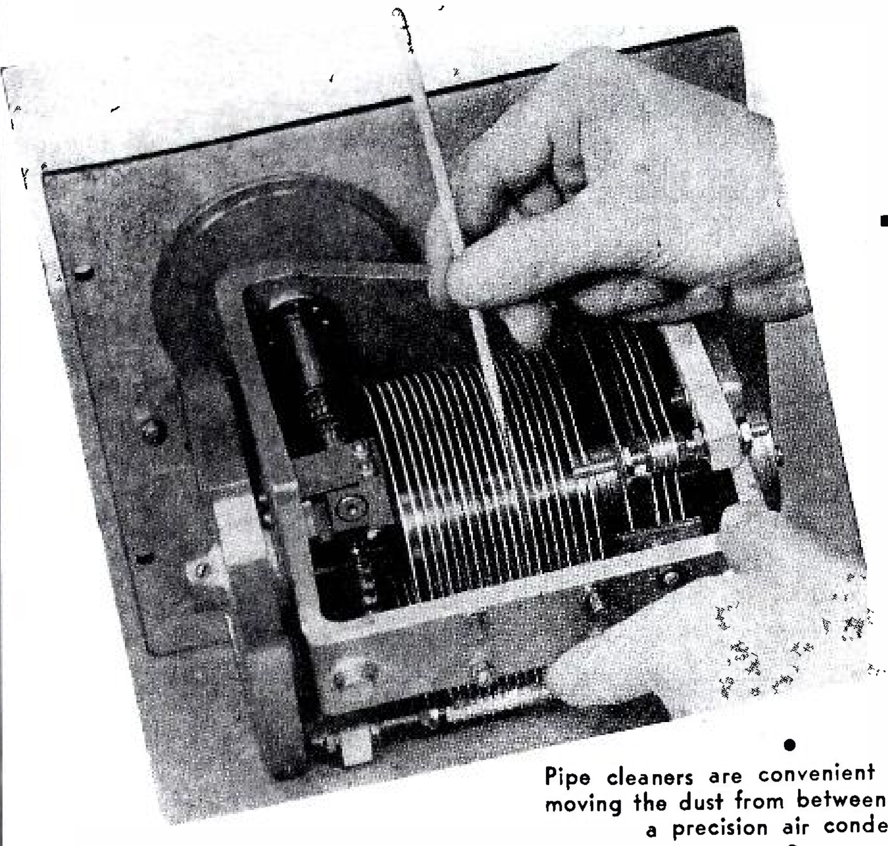
Our workers can be proud that their exceptional contribution too has been recognized. For the "E" pins they now wear signifies distinguished service, individual excellence on the production front. To them, not we, must be given credit for outstanding service to the nation.

SCIENTIFIC RADIO PRODUCTS COMPANY ★

738 West Broadway — Council Bluffs, Iowa

MANUFACTURERS OF PIEZO ELECTRIC CRYSTALS AND ASSOCIATED EQUIPMENT

CARE AND MAINTENANCE OF TEST EQUIPMENT



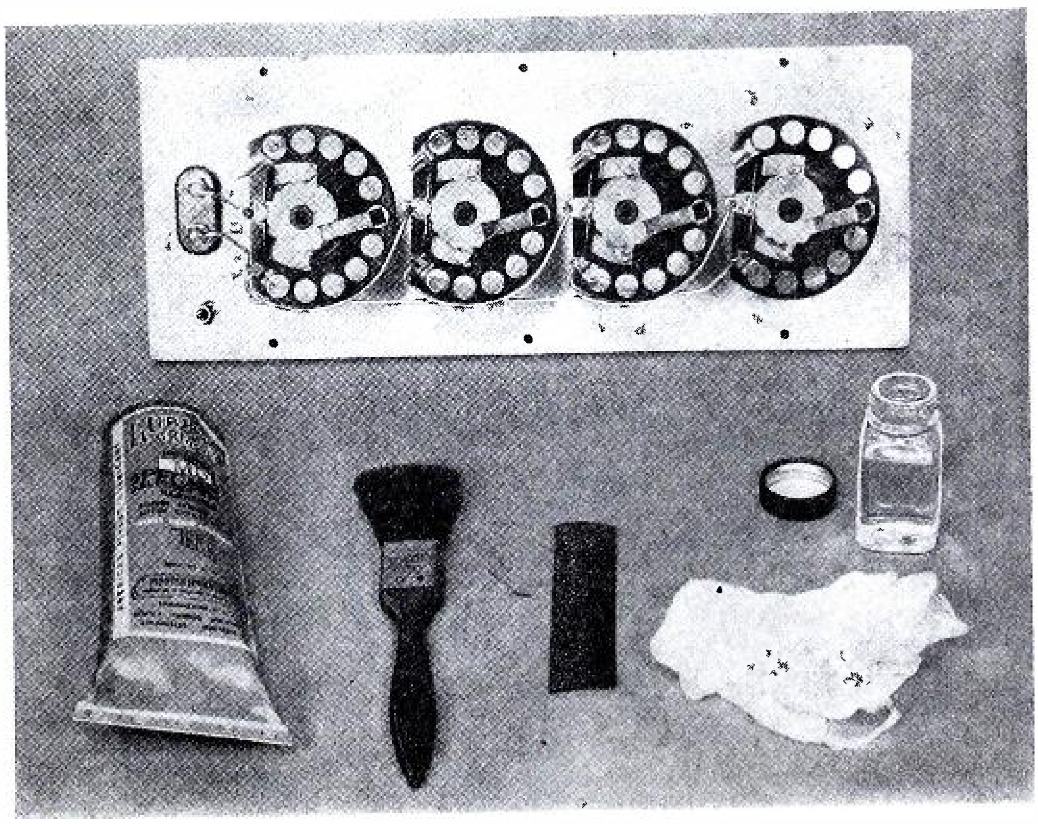
Pipe cleaners are convenient to use in removing the dust from between the plates of a precision air condenser.

by H. H. DAWES
Service Manager,
General Radio Company

PROPER care and maintenance are obviously necessary if optimum performance and long life are to be obtained from electrical and mechanical instruments. Yet our experience with returned instruments (and we believe the other manufacturers will agree) indicates that most users of instruments do not follow a definite maintenance program.

The fine degree of accuracy of most instruments is dependent in part upon the smooth operation of controls free from backlash, clean contacts, and the exclusion of dust and foreign matter. A large part of the charge made by manufacturers for reconditioning instruments is for the labor of replacing parts that have not been properly cared for, cleaning contacts, lubricating moving parts, and removing foreign matter such as dust, grit, insects, bits of metal, salts from corrosion, and the like. Much of the inconvenience and expense of returning instruments for repair could be avoided if the user followed a program of periodic inspection and adjustment in his own laboratory. In applications where operating conditions are such that wear and corrosion are inevitable, a definite maintenance program is essential and will help to minimize deterioration and failure. Although individual conditions of use will determine the details of any maintenance program, the following suggestions are offered to assist the user of test equipment in any servicing he may choose to do.

Equipment used for continuous production testing demands frequent servicing. Constant use will eventually result in the wearing of moving components, deterioration of tubes and batteries, changes in the values of resistors and capacitors, and the collect-



Moving contacts should be cleaned and lubricated periodically. This photograph shows a complete kit for lubricating decade switches. From left to right we have . . . tube of lubricant, brush, strip of crocus cloth, cloth, and solution of half alcohol and half ether. On the decade box shown here, the upper five contacts on the right-hand switch have been cleaned with the alcohol-ether solution. Note the difference in appearance.

ing of dust and grit throughout the assembly. These conditions occur very gradually, and the effects are not noticed until errors become serious or performance deteriorates. Only by periodic inspection can failure be anticipated and worn parts replaced without serious interruption to service.

On the other hand, an instrument operated occasionally may have to be serviced each time it is used because of the oxidation of contacts, switches, etc., and the presence of dirt and moisture. Lack of lubrication and an accumulation of foreign matter on switches, contacts, bearings, controls, and mechanisms can cause considerable difficulty even when an instrument is relatively new.

Cleaning

Moving parts should be kept as clean as possible and cleaned before lubricating. A solution of half alcohol and half ether is recommended for switch and relay contacts, contact surfaces of wire-wound controls, slide wires, and mechanical contact surfaces of various types such as attenuators, detent mechanisms, chain drives, gear trains, shafts, and bushings. The use of carbon tetrachloride is not recommended because of the corrosive effects of any free chlorine that may be present. Any residue that accumulates should be removed by wiping before lubricant is applied. To remove oxidation or corrosion, a fine abrasive such as crocus cloth may be used, but its use is limited to relatively large contact surfaces such as those on variable autotransformers, attenuators and relay contacts.

Most of the variable autotransformers returned for repair have damaged windings. Broken brushes, or poor contact between the brush and a corroded or blackened winding surface, will produce arcing, with eventual damage to the winding. Periodic inspection and cleaning can prevent this.

A very fine grade of sandpaper is recommended on certain types of contacts, although the residue must be removed with a fine brush for smooth operation. Fine sandpaper may be used on wire-wound controls (provided the wire is not too small), key switches, push switches, anti-capacity switches, and multi-blade-contact rotary switches; also on contact buttons and relays.

Some assemblies, such as syncro-clocks, piezoelectric crystals, motors, and meters require special attention. Syncro-clocks should be carefully cleaned by one acquainted with fine mechanisms of this type. Quartz crystals are difficult to service in the field and should be returned to the factory.

Electric motors demand the usual attention to commutator surfaces, brushes, and bearings. Meters should not be cleaned except by one skilled in meter repair work.

The presence of dirt and lint on the plates of air condensers increases the losses. And in a precise impedance bridge, this will seriously affect the accuracy of measurement. The plates can be easily cleaned with pipe cleaners. In cleaning calibrated condensers, however, care must be taken not to bend the plates. Foreign matter between terminals on a fixed condenser should be periodically removed. Otherwise, the combination of dirt and moisture will produce a low value of leakage resistance.

Lubrication

Proper lubrication is very important in the maintenance of precision instruments. Some bearing surfaces require a grease, while for others oil is best. When new, our instruments are lubricated with either *Lubriko** or a fine grade of clock oil. The use of these lubricants is recommended in maintenance.

Lubriko has been selected because it is acid free and because it adheres to moving parts better than most lubricants. It is recommended for use on wire-wound controls, button contacts, attenuators and small variable autotransformers. However, a very thin film should be applied, as a large quantity will cause foreign matter to collect.

For detent mechanisms, chain drives and gear trains, ball bearings, shafts, vernier drives, etc., a larger amount should be used. These moving parts require lubrication more frequently to prevent wear.

The use of a fine grade clock oil is recommended for slide wires, pushbutton switches, syncro-clocks, and condenser contact surfaces of the slip-ring type. This type of lubricant should be applied in very small quantities. A thin film applied with the finger will suffice for a slide wire but this should be done frequently because of evaporation. The small gear on the shaft of the rotor of a syncro-clock requires lubrication every few months. Likewise the bearings should be oiled to insure proper operation. Bearings in small condensers require occasional lubrication.

Expendable Parts

Tubes and batteries should be tested frequently and replaced if necessary.

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*Density MD, manufactured by Master Lubricants Company, Philadelphia, Pennsylvania.

Only such types as recommended by the manufacturer should be used.

Finish

Lacquered dials usually do not require much attention. However, the use of an oil polish will improve their appearance. For smooth operation, slow motion drives of either friction- or gear-type must be cleaned occasionally. A fine brush and a cloth saturated with carbon tetrachloride are satisfactory.

An oil polish may be used on wood cabinets, panels and dust covers to improve appearances. Panel finish can be restored to its original appearance by using an oil polish and carefully wiping afterward.

Performance Checks

In addition to inspection, cleaning and lubrication, the well-equipped laboratory should be able to measure the overall performance of the instrument. Deterioration of tubes, wear in slide-wire resistors, and increased leakage in condensers can combine to impair overall accuracy, power output, waveform, etc. Where the necessary additional test equipment is available, the accuracy and output characteristics of an instrument can be measured and any departures from catalog specifications corrected by readjustment. For the laboratory interested in accurate measurements, regular checkups of this sort are essential.

Service Manuals

When service manuals are available from the manufacturer, they provide a guide to maintenance and trouble-shooting that will save a good deal of time for the plant instrument man. Point-to-point circuit checks and testing for defective components are considerably simplified if these manuals are used as testing guides.

Complaints

For specific instruments, these general suggestions often must be supplemented by more specific information, usually included in instruction books. Whenever additional service or maintenance instructions are needed, the manufacturer will gladly supply the necessary information.

When you write a manufacturer about failures or inaccuracies in instruments, be specific. Describe the trouble clearly, and the steps taken to locate it. Above all, *read* the operating instructions and tell the manufacturer just where in the operating procedure the failure shows up. This will save your time as well as his, and may obviate the returning of the instrument to the factory in order to diagnose the trouble.

NEWS BRIEFS

(*Continued from page 95*)

Capacitors, form 630 revised, has been issued by Centralab, division of Globe-Union, Inc., 900 East Keefe Avenue, Milwaukee 1, Wisconsin.

* * *

SOLAR APPOINTS McKINLEY AS REP.

J. E. McKinley, 401 No. Broad St., Philadelphia, Pa., has been appointed sales representative for Solar Capacitor Sales Corporation in Eastern Pennsylvania, Maryland, and the District of Columbia.

* * *

SECOND WHITE STAR TO PHILCO BATTERY DIVISION

The Storage Battery division of Philco Corporation, Trenton, New Jersey, has been awarded a second star for its Army-Navy "E" flag.

* * *

HALLICRAFTERS WINS 2D STAR

William J. Halligan, president, and Myrtle Wilner, veteran employee of Hallicrafters, with the two-starred Army-Navy "E" flag.

* * *

G. E. MYCALEX BOOKLET

An eleven-page bulletin describing properties and applications of G. E. mycalex has been published by the specialty division of G. E.

G. E. mycalex made from mineral ingredients and used extensively as an insulator is produced in plates, rods, strips and disks. It also can be compression-molded into simple shapes with and without metal inserts.

* * *

GUARDIAN RELAY REFERENCE BULLETIN

A bulletin, OF112, with thumbnail descriptions of seventeen types of relays used in aircraft, radio, Signal Corps, and general industrial applications, has been issued by Guardian Electric Manufacturing Company, 1623 W. Walnut Street, Chicago, Illinois. A short explanation of two popular time delay methods is also included. Another section tells about the new lightweight solenoid contactors built to U. S. Army Air Force specifications. Following this is a paragraph on solenoids giving plunger stroke, lift, and power requirements for eight standard types of intermittent and continuous duty a-c and d-c solenoids.

* * *

BURNSIDE OF WESTINGHOUSE RECEIVES HONORARY DEGREE

C. J. Burnside, manager of the Westing-

(*Continued on page 102*)

NEWS BRIEFS

(*Continued from page* 101)

house Radio Division in Baltimore, Md., received the honorary degree of Doctor of Engineering at the recent commencement exercises of the South Dakota School of Mines in Rapid City, South Dakota.

* * *

J. G. KELLOG NOW PRESIDENT OF KELLOGG SWITCHBOARD

James G. Kellogg has been elected president of the Kellogg Switchboard and Supply Company, Chicago, to succeed Major Maurice K. McGrath, who resigned for reasons of health.

* * *

FOUCH PRAISES FACTORY WORKERS

James L. Fouch, president and general manager of the Universal Microphone Co., Inglewood, Cal., reports that the best ideas in employees' suggestion contests come from assembly line workers and not from *white-collar* people.

* * *

FRAZAR-HANSEN EXPORT REP. FOR ANDREW COMPANY

Frazar and Hansen, San Francisco, Calif., have been appointed export representatives of the Andrew Company, Chicago, Ill.

* * *

ROBERT D. KIRKLAND DEAD

Robert Douglas Kirkland, communications engineer of Mackay Radio and Telegraph Company, died recently.

* * *

SPRAGUE WINS "E" STAR

The Sprague Specialties Company, North

Adams, Mass., has won its second white ştr for the "E" pennant.

* * *

IRC WINS SECOND WHITE STAR

For the second time International Resistance Company has been awarded a white star for their "E" flag.

* * *

RAY JEFFERSON ISSUES MARINE RADIO BULLETIN

A four-page leaflet describing model 425 marine radio telephone has been issued by Ray Jefferson, Inc., 40 East Merrick Road, Freeport, Long Island, N. Y.

A 25-watt crystal controlled transmitter and 6-tube 5-channel (pretuned) receiver are contained in the 425 unit.

* * *

GIANT-SIZE WEEKLY CALENDAR

A 15¾" x 24½" calendar with large size weekly dates has been issued by The Frederick Post Company, Box 803, Chicago, 90, Ill.

A section of technical data for the engineer and draftsman is also included, containing charts on wire and sheet metal gauges, screw threads, etc.

This new ccalendar with its 52 weekly sheets is being offered free to those who request it on their business letterhead.

* * *

"E" TO ESPEY

The Espey Manufacturing Company, Inc., 305 East 63rd Street, New York City, has won an "E" award. Presentation was made at the New York Times Hall, New York City.

Lt. Colonel Walter B. Brown, Chief of Employees Relations Section, Office of the Chief Signal Officer, presented the "E" pennant to Harold Shevers, president of Espey.

Harold Shevers, president of the Espey Manufacturing Co., receiving the "E" flag from Lt. Col. Walter B. Brown, Chief of Employees Relations Section.

* * *

A. G. KOBER DEAD

Albert G. Kober, assistant advertising manager of the Stromberg-Carlson Company, Rochester, N. Y., died recently. He had been with the company for 38 years.

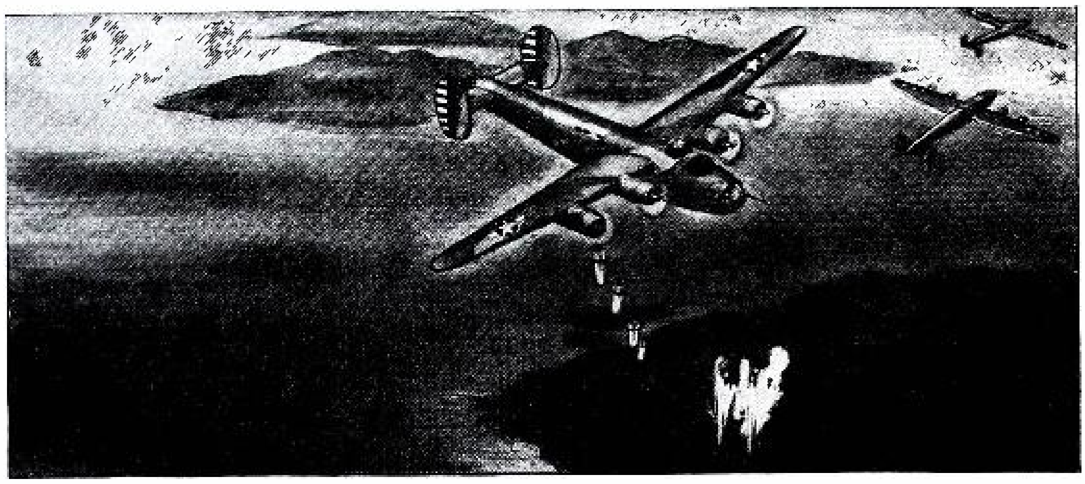
* * *

SYLVANIA TUBE SUBSTITUTION CHARTS

Charts and data on radio tube substitutions appear in a pamphlet compiled by Sylvania Electric Products Inc., Emporium, Pa.

The pamphlet includes substitution charts for 150 milliampere a-c/d-c receiver tubes, 300 milliampere a-c/d-c receiver tubes, and battery tube types,

(Continued on page 113)



THE INDUSTRY OFFERS . . . —

(*Continued from page 84*)

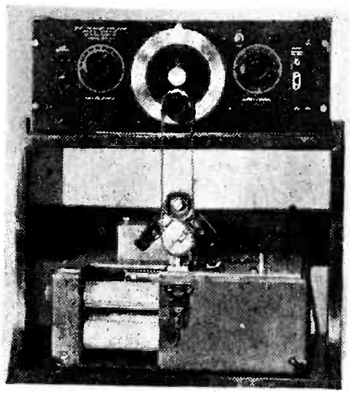
It is also said to have a low coefficient of friction.

* * *

AUTOMATIC FREQUENCY RESPONSE RECORDER

Application of the latest G. R. audio beat frequency oscillator with Sound Apparatus' automatic frequency response recorder has been announced by Sound Apparatus Company, 150 West 46th Street, New York City. This measuring setup is said to be labor-saving.

The setup is said to provide a complete automatic frequency run from 20 to 20,000 cycles covering a range of either 20, 40, or 60 db; recording forward and backward. It stops automatically at any predetermined point of the frequency scale. The record (ink) is written on standard semi-log paper. Recorder and oscillator can be used at any time as separate units.

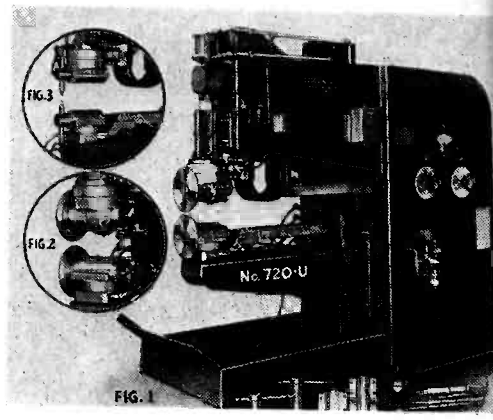


EISLER SEAM-SPOT WELDER

A universal resistance welder for heavy duty has been produced by the Eisler Engineering Co., Newark 3, New Jersey. It incorporates an air operated, water cooled, automatic press-type welding machine of high capacity, and is adaptable for circular and longitudinal seam welding and spot welding. The adjustment from one to the other seam welding position is manually performed by loosening four nuts on the upper as well as lower turret holder, and rotating and fixing both turrets again in the desired position, according to a matching notch which marks the correct alignment. Conversion from seam welding to spot welding is accomplished by removing the caps from the upper and lower turret and replacing the seam wheel shafts with proper spot welding horns. Since seam welding is principally a spot welding process, all factors governing spot welding are equally applicable to seam welding.

The welding transformer is available in 100, 150 and 200 kva and larger sizes, 200 or 440 volts, 60 cycles. Other ranges of voltage and frequencies are available.

The overall dimensions of the 100 kva machine are . . . height 88", length 93" and width 47"; weight is 6200 lbs. Fig. 1 and Fig. 2 illustrate circular and longitudinal seam welding respectively; Fig. 3 spot welding application.



* * *

R-F CAPACITOMETER

A radio frequency capacitometer for precision measurements of small capacitance and inductance has been announced by the specialty division of G. E.

The instrument measures directly at radio instead of audio frequency, with measurements being performed with the aid of an oscilloscope instead of ear phones. The scale on the unit can be read from 0 to 1000 micromicrofarads when measuring capacitance, with inductance measured in the range of 0 to 1000 microhenries.

The instrument weighs 55 pounds. The front panel and base can be withdrawn from the cabinet as a unit for standard rack mounting.

* * *

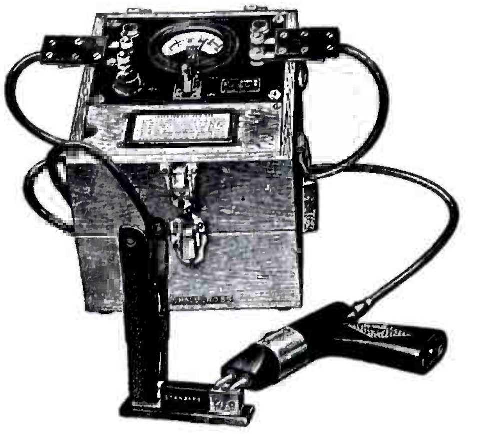
SHALLCROSS LOW-RESISTANCE TEST SETS

Two new low-resistance test sets, type 645 and type 653 have been produced by Shallcross Mfg. Company, Collingdale, Pa.

The test unit containing the meter, batteries, switches, control, etc., is suported, in front of the operator, by means f adjustable shoulder straps. Bond or ontact resistance measurements as low s .0001 ohm can be made by attaching he fixed clamp to one side of the bonded urface, and touching the hardened oints of a pistol grip exploring probe to he other side.

Both hands are free at all times to djust and operate the instrument.

Type 645 is 0.005 and 0.5 ohms, full cale; type 653 is 0.003 and 0.3 ohms full cale.

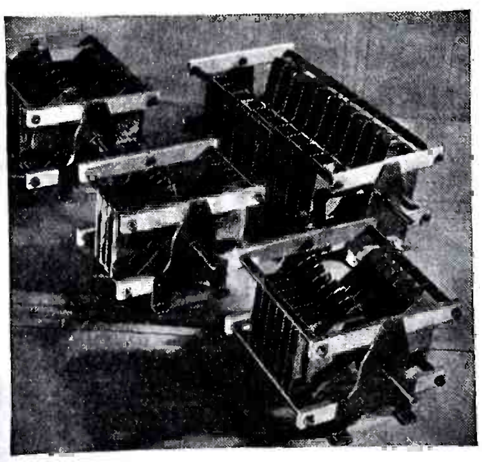


* * *

B & W VARIABLE CONDENSERS FOR ELECTRONIC HEATING

A line of heavy duty variable air condensers for electronic heating applications has been developed by Barker & Williamson, 235 Fairfield Ave., Upper Darby, Pa.

Known as B & W type CX, these units feature built-in neutralization. They are available in almost any required capacity for electronic heating use up to 5 kw, 12,500 volts.



* * *

LOW TORQUE ROTATABLE TRANSFORMER

The application of the Kollsman Telagon unit as a rotatable transformer for installations in which very little torque is available has been announced by Kollsman Instrument Division, Square D Company, 80-08 45th Avenue, Elmhurst, New York.

The rotor weighs .06 ounce. The complete weight of the unit is five ounces.

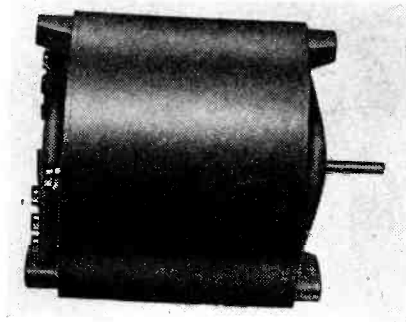
Most commonly used is the Telagon, type 315S-971, operating at 110 volt, 400 cycles, requiring an input current of .018 amp and input power of 1.3 watts. It has six external solder terminals. Other units are available operating from 85 volt, 400 cycle or 26 volt, 400 cycle sources.

Applications of this nature ordinarily call for feeding a high frequency alternating current into the rotor excitation

THE INDUSTRY OFFERS . . . —

(*Continued from page* 105)

winding, and taking an induced voltage from the 2-phase winding, which varies roughly proportional to angular movement. This voltage is amplified and fed to a variety of devices. An ideal application for the Telegon would be field control in an Amplidyne type unit.

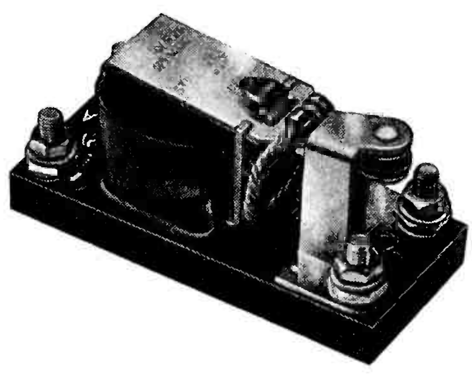


* * *

STRUTHERS-DUNN SHOCKPROOF RELAY

A relay, type 17AXX, for rough airplane applications is now available from Struthers-Dunn, Inc., 1321 Arch St., Philadelphia, Pa.

According to the manufacturer, actual tests show that it will withstand acceleration tests of better than 90 gravitational units. Units of this type are regularly supplied with series coils for any direct current, or with shunt coils for use on 12 or 24 volts d-c.



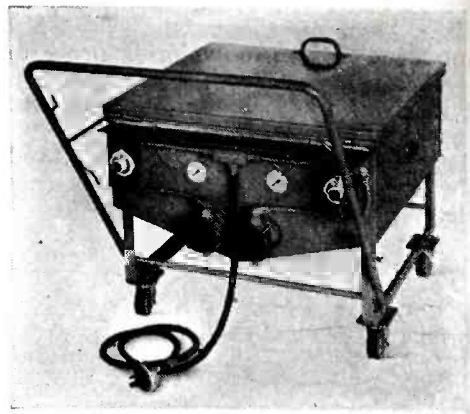
* * *

PORTABLE METAL CLEANING RINSING TANK

A portable, electrically heated, insulated dipping tank, affording both cleaning and rinsing, has been produced by Aeroil Burner Company, West New York, N. J. The unit, known as the Twin Dipmaster, is equipped with two insulated compartments separated by a partition that is also insulated. It has two removable immersion tube heating units (one for each tank) that deliver all the heat in the cleaning solution and rinse water. Separate, automatic heat control for each compartment is supplied by two thermostats regulating any required temperature from 110-550° F., operating independently of one another. In addition there are two built-in thermometers registering temperatures from 100-600° F. and four dipping baskets.

Scum gutters, draw-off cocks, an insulated cover, pipe connections for the addition of fresh water to the rinse compartment as well as to drain off contaminated liquids, and two work grilles on which bulky parts can be rested during the cleaning and rinsing processes, are included in the equipment.

Plugs in on 110 or 220 volts a-c or d-c for instant heating.



* * *

GATES COMMUNICATIONS TRANSMITTER

A 200-watt c-w or standard phone, 150-watt heavy-duty phone transmitter for from 2 to 20 megacycles has been developed by Gates Radio and Supply Company, Quincy, Ill.

It is known as Type MO-2535.

Keying speed is 60 wpm (higher on special order); modulation capability is 100 percent with a safety factor allowance for normal overload. Dimensions are 36" x 21" x 19"; weight is 350 pounds.

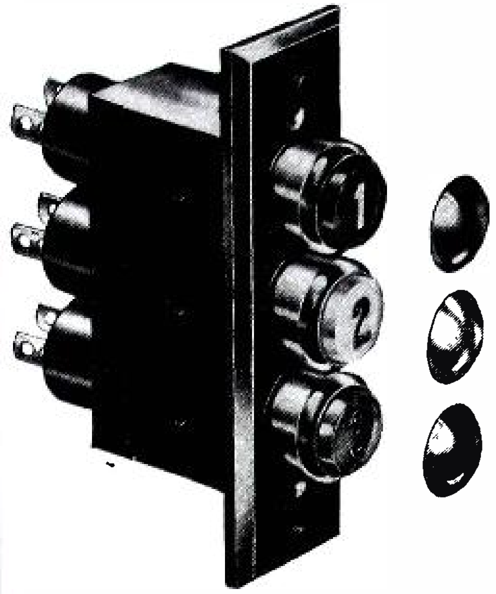
* * *

MULTIPLE DIAL LIGHT

A pilot light assembly, *Trio-Light*, for multiple circuits is now available from the Dial Light Company of America, Inc., 90 West Street, New York 6, N. Y.

Obtainable in any size bank, in multiples of 3 pilot lights to each *Trio-Light*. Thus, if an installation has 12 circuits, a bank of 4 *Trio Lights* will be required.

Features include color-coded flat lenses with etched numbers, letters, or words; half-round lenses may also be used. Choice of lens colors are red, green, amber, blue, yellow, opal, white, and clear. Lamp sockets of pilot lights accommodate bayonet base lamps which are removable from front of panel. The unit may be obtained grounded or ungrounded. Terminals are silver-plated.



* * *

INSULATION-RESISTANCE METER

An insulation-resistance meter for measuring the resistance of insulation in apparatus during the manufacturing process has been announced by the Special Products Division of General Electric.

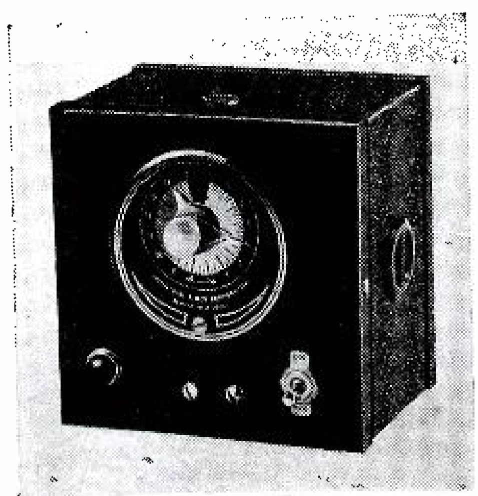
The instrument consists of a conventional electronic rectifier, a Thyrite bridge circuit, and an electronic-tube voltmeter. It is available in two types. One type has a scale calibrated from 1 to 50 megohms and measures resistance at 500 volts d-c. The other type has a 0 to 20,000-megohm total range and measures resistance over four different resistance intervals—from 0-5 megohms at 0-250 volts d-c and 5-200, 50-2000 and 500-20,000 megohms at 500 volts d-c. Any range may be quickly selected by a panel-mounted rotary switch.

* * *

SIGNALLING TIMER

A signalling timer providing visual and audible notice when a time interval has been completed is available from Industrial Timer Corporation, 117 Edison Place, Newark, New Jersey.

Operates on alternating current, 115 to 230 volts, 25, 50 and 60 cycles; 1000 w, voltage and frequency to be specified.

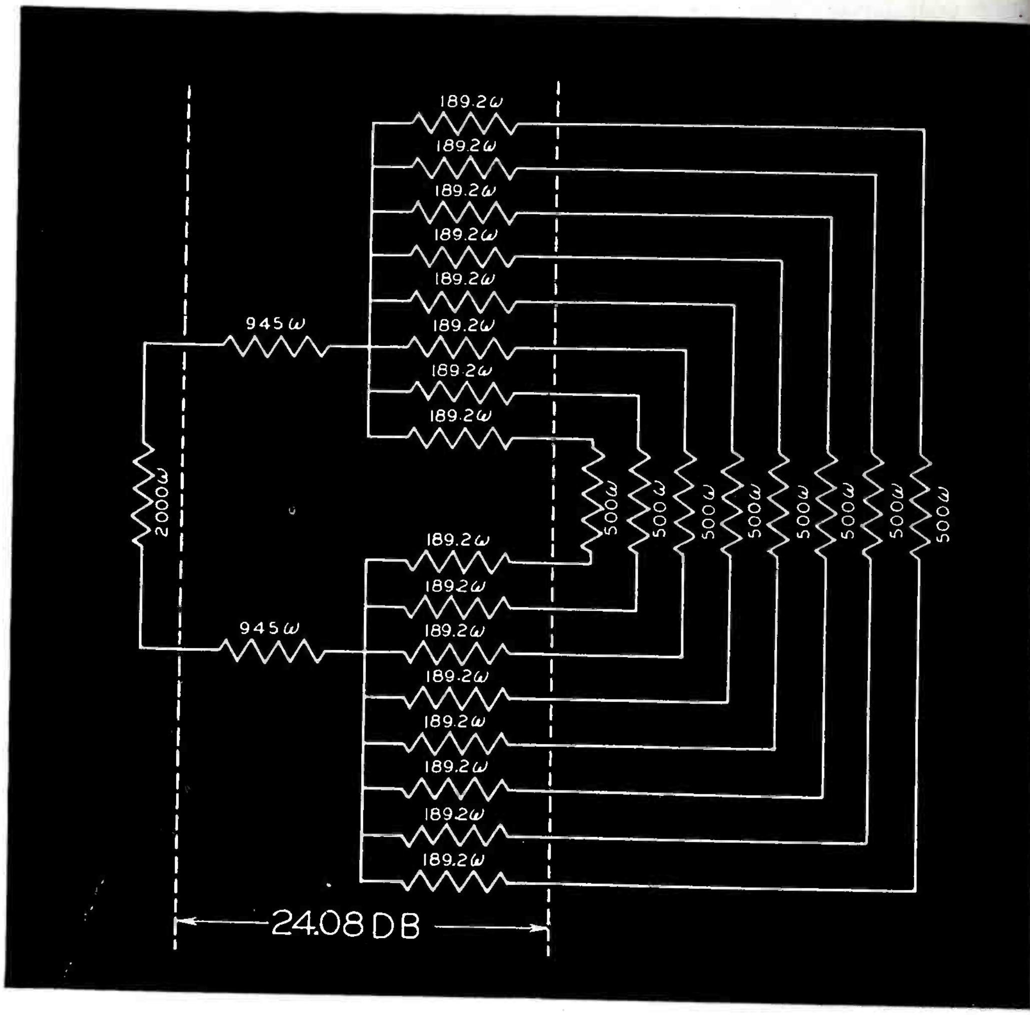


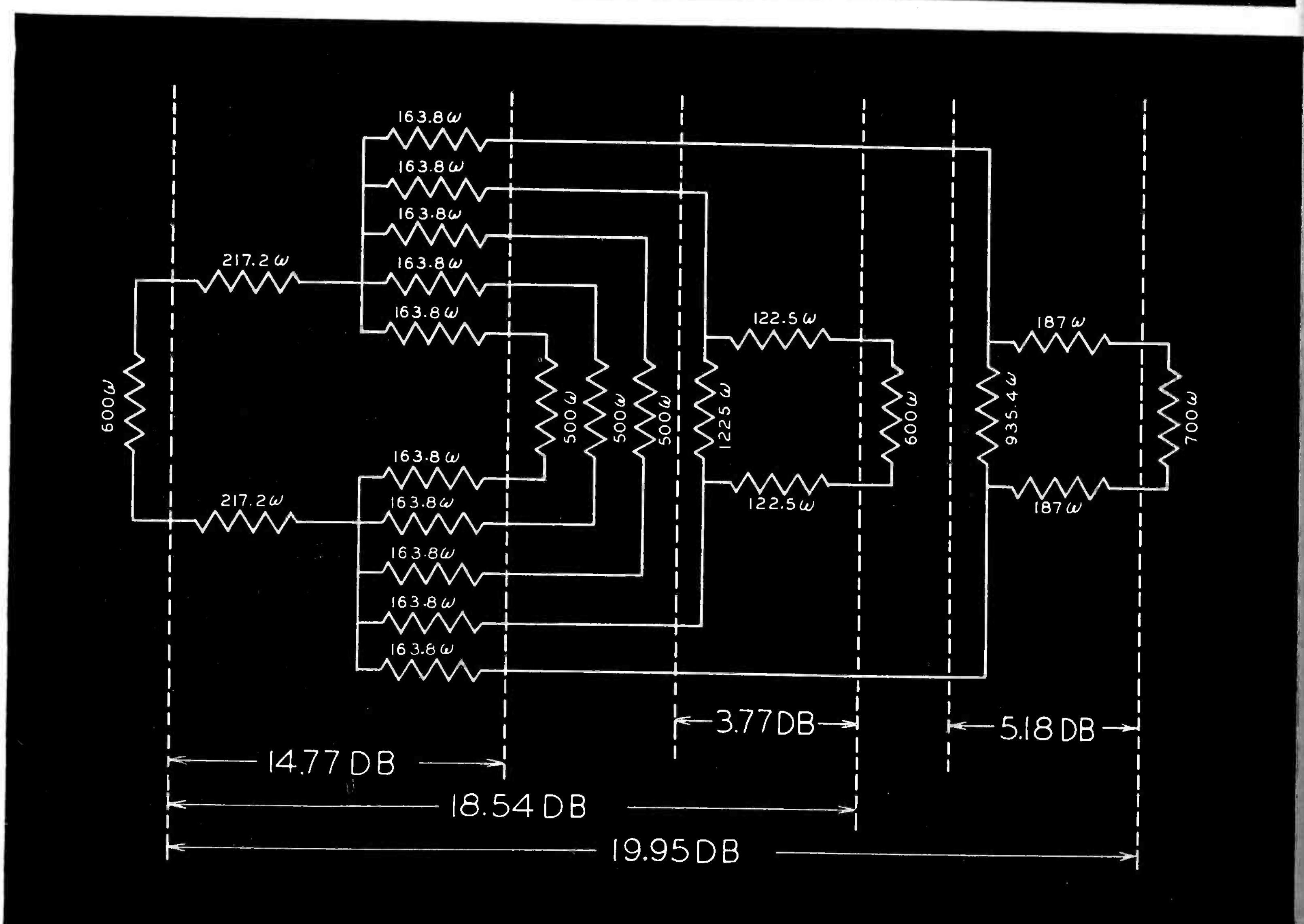
BRIDGING NETWORKS

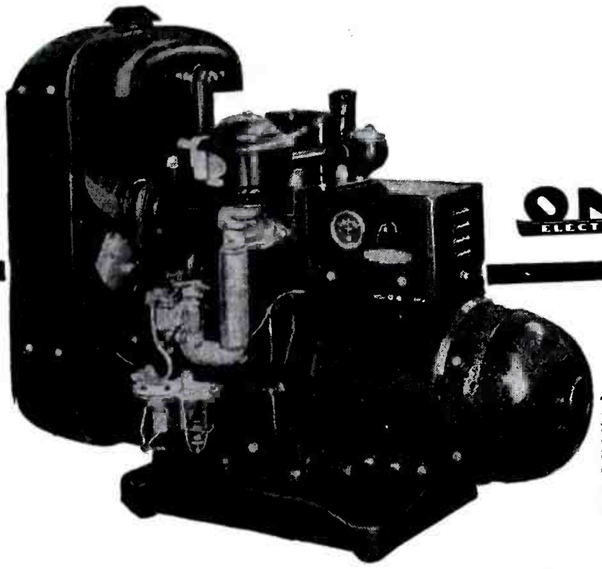
In the September issue of Communications, Paul B. Wright presented a paper on *Multiple Bridging Networks*. He provided several examples to illustrate the methods employed in the actual design of bridging networks. Many inquiries have been received requesting the publication of diagrams that would graphically explain these examples. These diagrams are shown herewith.

The illustration at the right shows the results obtained in solving the following example: Given a source impedance of 2000 ohms from which it is necessary to supply 8 outlets or branches, each having a nominal impedance of 5000 ohms, what values of R to r should be used and what loss will be obtained from the source to each load?

In the diagram below appears a graphical solution to the following example: Assume that it is necessary to distribute program material from a 600-ohm source to 5 branches. Three of the branches have impedances of 500 ohms; one an impedance of 600 ohms and the remaining one has an impedance of 700 ohms. The problem is how can all of these be properly matched and what loss will be obtained to each of the branches.







ONAN
ELECTRIC PLANTS

The Army-Navy "E" has been awarded to each of Onan's four manufacturing plants.

ELECTRICITY for ANY JOB ANYWHERE

★ **ONAN GASOLINE DRIVEN ELECTRIC GENERATING PLANTS** provide electricity where power lines are not available and for emergency service.

They're doing a war winning job on all the fighting fronts generating light and power for communications work and other war tasks.

Sizes from 350 to 35,000 watts. 50 to 800 cycles, 110 to 660 volts, A.C.—6 to 4000 volts, D.C. Also A.C. and D.C. output models.

Your inquiry regarding present or post-war needs will receive prompt attention.

D. W. ONAN & SONS

1262 ROYALSTON AVE. MINNEAPOLIS, MINN.

"R·9" Quartz Crystals

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and

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Accurate, and Dependable

We are equipped to handle any type or size order. May we quote you on your future requirements? Immediate delivery.

R9 Crystal Company, Inc.

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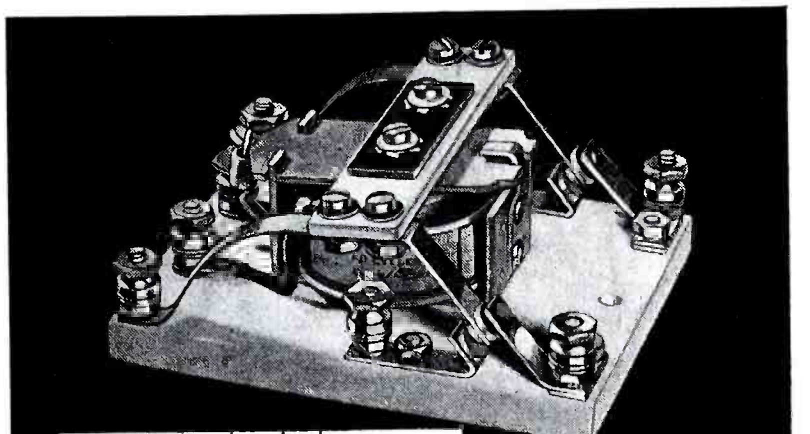
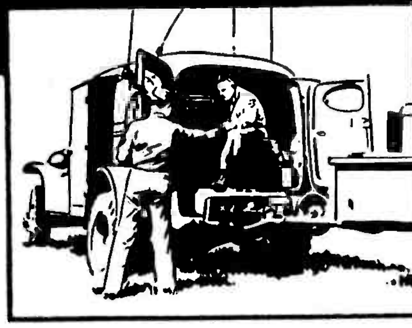




NERVE CENTER OF EVERY BATTLE FRONT

TO WIN battles today, there has got to be constant clear radio communication between the Command and all fighting units. Every Headquarters has one or more big mobile Signal Corps Communication Sets, marvels of unfailing efficiency, to receive radioed field reports and beam out orders and so insure correlation of effort. Vital components of these "nerve centers" are Advance Type 400 Relays . . . thousands of them in active action on all Allied fronts.

ADVANCE TRANSMITTER RELAY TYPE 400

THIS new relay, incorporating many improvements, is ideal for transmitting purposes where high radio frequency is being used, It is constructed to provide the same quiet, dependable operation on *alternating* current, free from all "hum" and "chattering" that is normally expected only on *direct* current. Assembly methods and skillful adjustments eliminate any necessity for changing the tension on either the armature spring or moving contact leaves, both of which are set to provide perfect "balance" and complete wiping of the stationary contacts. For further data, write for Bulletin: *Advance Transmitter Relay Type 400.*

Other Advance Relays are made for general circuit control applications. Orders, on proper priority, are given prompt attention, and deliveries are on schedule.

Having what it takes for War, Advance Relays may well be what you will want in Peace!

Advance Relays

ADVANCE ELECTRIC COMPANY

1260-1262 West Second Street • Los Angeles 26, California

PUSH-PULL

(*Continued from page* 19)

than: "... *corresponding* to the differential of the current."

Effort Diversity and Result Duplication

Tupper's philosophic observation imposed upon someone from age to age the responsibility of determining whether or not a proposed improvement contained novelty, and as the arbitrament we fall back upon for finality are the non-technical courts, there is always grist for the mills of the law in awarding or denying the palm of novelty, of invention. Engineers themselves may and do differ in their expressed opinions bearing upon novelty, and/or priority. Particularly do they differ when individually they represent rival claimants.

The links in the chain of development of push-pull were not in a single straight series. Upon occasion there were a few parallel links, and again there were a few links which converged upon the principal chain. In the development of, in the growth of the idea of push-pull, there was much duplication of effort. But it is a free world, and anyone who has the ambition, the facilities, the patience, and the time is at liberty to dissect other men's inventions with the thought of making improvements. This, even though it is the genuineness, the validity of *improvements* upon other men's inventions which afford much profitable employment for lawyers and judges, to say nothing of pensive juries.

Labored Contributions

Moses G. Farmer, in April, 1885, was granted U. S. patent 316,133 for a telephone transmitter employing contact pressure between the electrodes, Figure 4. In this patent the lever appears again in the form of a pivoted arm connected to the diaphragm. It was a multiple-contact microphone acting through a split-primary. That was all.

There was a variation in construction details in a patent issued in February, 1888, to Hammond V. Hayes; U. S. patent 377,612. But the unstable Blake transmitter was still the favorite on the laboratory dissecting table. An innovation was the introduction of a double-primary winding. Push-pull was on the march.

And then along came Charles Denton Hall, who procured British patent 7,331, in 1891, the application for which was communicated from Paris, France. Contemporary thought abroad

[illegible]

Then followed in 1915 [illegible] U. S. patent [illegible] figure [illegible]. It was a double-button, double-inductance cell assembly, [illegible]. [illegible] constant transmitting current was possible [illegible] elements [illegible] with the [illegible] induction coil. [illegible], however, made no mention of advantages [illegible] by using a split-primary winding. Instead, he employed [illegible] induction coils. The device had all the [illegible] features of previous, and [illegible] developments of the same type [illegible] employing mechanical pressure on pockets of carbon granules [illegible] the resistance of a circuit [illegible].

● New Departure

In August 1919 a new departure [illegible] came to the attention of engineers. It will be recalled that [illegible] earlier than this, Whitehead employed a light beam and selenium cells to accomplish a particular purpose. The Adams proposal had to do with galvanometer [illegible] readings. In the operation of a [illegible] galvanometer of the early types, the beam had a habit of swinging unnecessarily far to the right and to the left upon [illegible]. This slowed down the readings, particularly when the [illegible] galvanometer was employed for signalling.

Adams proposed mounting a selenium cell at the extreme right and another cell at the extreme left of the reading scale, the cells connected through a battery to [illegible] damping mechanism. When the light beam impinged upon one of the selenium cells the resistance of the cell was [illegible] due to an inherent quality of selenium. The device was ingenious, and when [illegible] designed, effective.

If little attention was paid to the possibilities of selenium cells at the time, it may be said that a short link was added by Adams to the already lengthened chain of development which was to stretch onward to a [illegible]

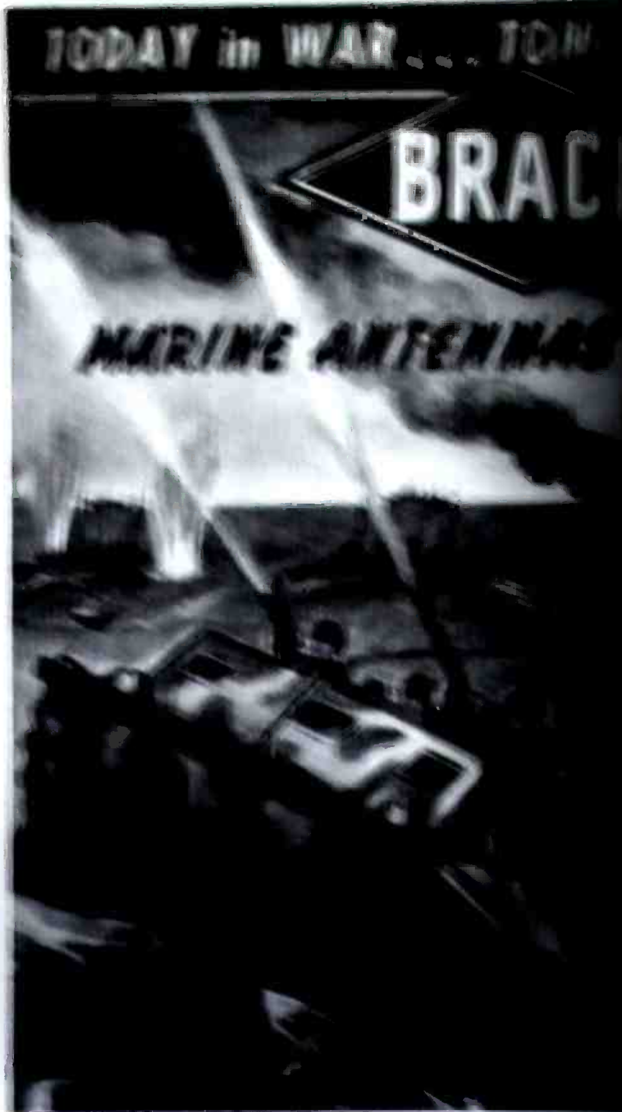


Figure 5
[illegible]

of its swaddling habiliments with the determination to set up service beyond the range of what was, to say the least, limited service. A quickened quest was afoot in the search for a telephone repeater. A rich reward was set up as the succulent plum for whoever should first come forth with a promising relay or repeater. We shall not here, however, digress far into that field. Rather we shall note only a step or two taken along this line which connect what has been recorded herein with what was to eventuate in the domain of push-pull.

Isidor Kitsee, versatile, industrious and prolific inventor of communication gadgets, filed a patent application in January, 1903, in which there is evidence of the gathering up of prior thought for the purpose of making a new use of the elements of old devices, such as some of those touched upon herein. Figure 6 tells the story.

Here, an incoming single line acting upon the receiver magnet attracts an armature which compresses the traditional pocket of carbon (or other medium) granules. In response to the incoming voice currents there will be therefore compression on one side of the armature and de-compression on the other side. This action alternates in correspondence with the arriving alternations. The armature, the variable-resistance elements and the cores of the receiver magnets are in circuit with batteries connected respectively to the primary windings of the output induction coil, and so to outgoing line. There you have it. The double-element, double-primary transmitter has worked its way to the other end of the line, and has become a receiver, with hope of being a repeater.

[*To Be Continued*]

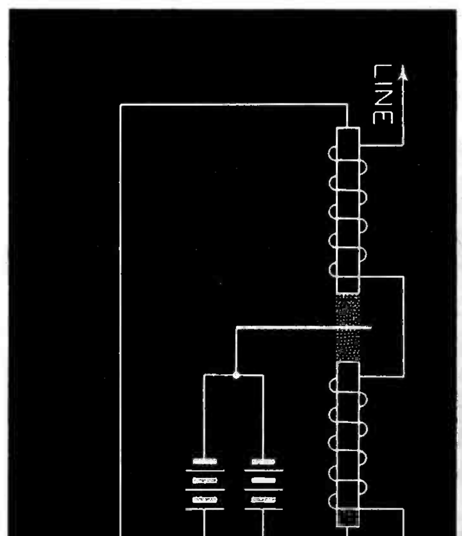


Figure 6

NEWS BRIEFS

(*Continued from page 103*)

edited to conform with the WPB civilian radio tube program.

* * *

GALVIN WINS SECOND WHITE STAR

The second white star has been added to the Army-Navy "E" flag of the Galvin Manufacturing Corporation, 4545 West Augusta Boulevard, Chicago, Illinois.

* * *

RADIO INCLUDED IN WPB CONSUMER SURVEY

Data on radio shortages among consumers is being secured in the present WPB consumer survey by the Bureau of the Census. In a nation-wide survey of 7,000 households the public is being asked to detail their shortages of radio sets, excluding automotive sets; radio tubes, farm radio batteries, and also radio repair service. The extent of shortages will serve as a basis for future civilian production to be authorized by the WPB Office of Civilian Requirements, headed by vice chairman Arthur D. Whiteside. The questionnaires inquire whether there has been real hardship, inconvenience, or no difficulty in the supply of 115 items.

* * *

RCA HARRISON PLANT WINS SECOND STAR

A second white star has been placed on the Army-Navy "E" flag at the RCA Harrison plant.

* * *

MC MURDO SILVER WITH GRENBY MFG. CO.

A radionics division has been formed at Grenby Manufacturing Company, Plainville, Conn., with McMurdo Silver as vice-president and chief engineer. Mr. Silver will work in close collaboration with Carl A. Gray, president, and Ralph W. Soby, vice president.

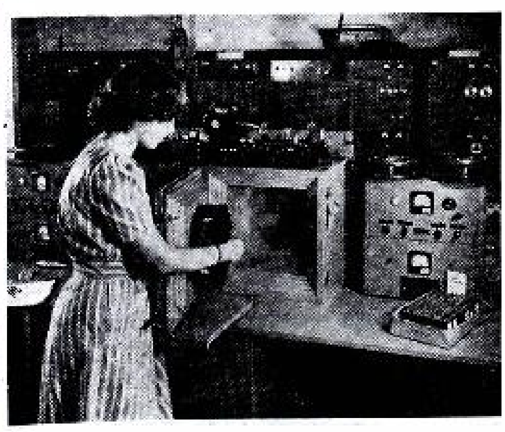
* * *

AMPEREX HOLDS "E" CEREMONIES

The "E" award ceremonies of Amperex Electronic Products, Inc., were held recently at the St. George Hotel in Brooklyn, N. Y. Lt. Col. C. J. McIntyre, Chief of Special Activities Branch, office of the Chief Signal Officer, presented the "E" flag to Nathan Goldman, partner.

* * *

DRY ICE TEST FOR CRYSTALS



A dry ice test unit used to test crystal wafers under temperatures as low as minus 10°C in the John Meck Industries plant, Plymouth, Ind.

* * *

TECH LAB BULLETIN

A four-page bulletin, No. 431, describing attenuators, potentiometers, and a microhmmeter, has been released by Tech Laboratories, 7 Lincoln Street, Jersey City 7, N. J.

* * *

LAND PURCHASED FOR SYLVANIA RESEARCH CENTER

A tract of land on Long Island has been purchased by Sylvania Electric Products, Inc., for the building of a research center. Because of wartime restrictions there will be no immediate building program, although two structures now on the property will be renovated for use by a small research group.

* * *

DR. W. A. LEWIS LEAVES CORNELL

Dr. William A. Lewis, Jr., director for the past five years of the School of Electrical Engineering in the College of Engineering at Cornell University, is leaving this post to return to the field of engineering research.

Dr. Lewis was formerly with Westinghouse.

* * *

SECOND WHITE STAR TO G. E.

The appliance and merchandise division of the General Electric Bridgeport plant, has won for the second time the Army-Navy white star award.

* * *

C. G. STOLL ON NEMA BOARD OF GOVERNORS

Clarence G. Stoll, president and director of the Western Electric Company, has been elected to the board of governors of the National Electrical Manufacturers Association.

Mr. Stoll has been president of NEMA since January, 1940.

IRE REPORT

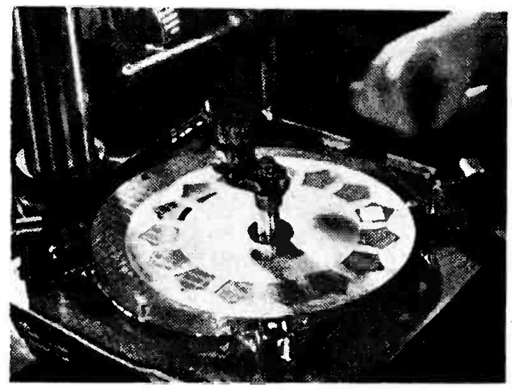
(*Continued from page 27*)

MUNICATIONS, pp. 26 and 84, appeared a digest of this paper.

[*Note: In the Universal Selectivity Curves on p. 84, October,* COMMUNICATIONS, *attenuation below* 1 *should be* .7, *not* 7.]

Motion Picture on Crystals

A technicolor motion picture depicting a step-by-step study of crystal manufacture, was presented through the courtesy of the Reeves Sound Laboratories. The film, prepared in cooperation with the U. S. Signal Corps, presented an analysis of types of crystals and the modern methods of production today. Fred Pinkerton, of Reeves, who presented the film, announced that accredited persons or companies could have use of the film by writing to him at 62 West 47th Street, New York City.



Views from the Reeves technicolor motion picture on crystals shown at the Rochester Fall Meeting. At top, blanks being placed in the holder of an Atlas lap. Below, putting crystals through a temperature run test.

CRYSTAL ORIENTATION

(*Continued from page 37*)

the X-axis directions of the *mother crystal*. If the etch is carefully controlled and a precision locating system is used, the X-axis may be located and marked with a fair degree of accuracy.

Etch patterns are useful mainly in locating general directions of the axes or rhomb faces. For example, a quartz *mother* may be cut twice along the YZ-direction to form a slab from ½" to 2" thick. The slab should be etched for several hours in hydrofluoric acid, or, preferably hot ammonium bifluoride. The two cut surfaces are YZ-planes and are perpendicular to the X-axis. If the slab were compressed in the lever vise of the polarity checking electrometer, the polarity of the X-axis would be determined. By placing the YZ-pane of the quartz slab on an opaque plate with a pin hole in it and a lamp behind it, a light pattern would be visible looking at the top etched surface of the slab. A variety of patterns may be seen, depending upon factors such as etch time, etch speed, etch solution concentration, etch solution composition, etc. But the general nature of the patterns, as illustrated in Figure 11 is such that a simple and rapid determination of the major rhomb and Z-axis directions is possible. If electrical twinning exists so that the twin boundary traverses the upper etched YZ-plane, the etch patterns will be different in each portion of the twinned surface. Since the polarity of the X-axis is reversed for the electrically twinned sections, there exists in effect an inversion of the X-axis polarity towards the light source. Therefore, the etch pattern will be a parallelogram for one section and a Z pattern for the other, indicating different major rhomb directions. For optical twinning both the X-axis polarity is changed and the handedness is changed, and although a twin

(*Continued on page 117*)

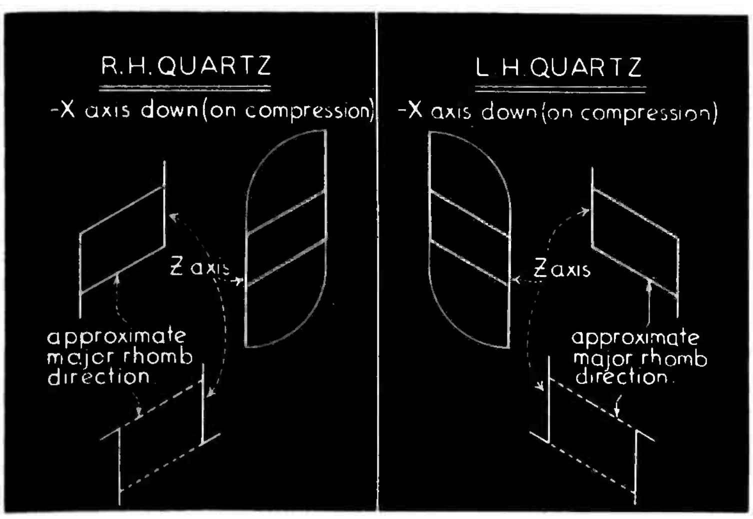
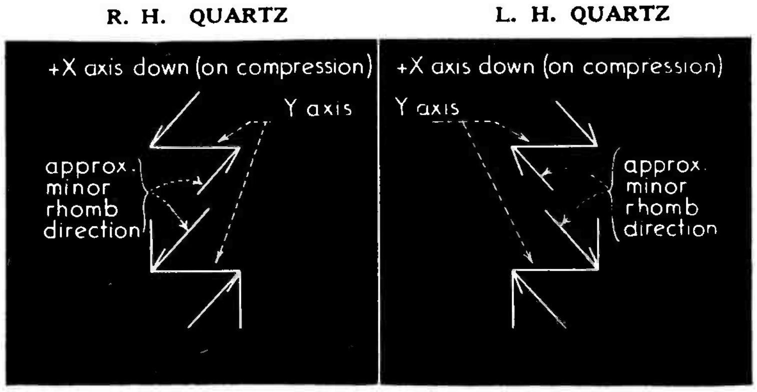


Figure 11

These drawings represent, schematically, typical etched patterns on an etched YZ-plane, viewed over a pin-point source of light.

R. H. QUARTZ L. H. QUARTZ



THE CIRCLE DIAGRAM

(*Continued from page 62*)

point for convenience), and the values of U and V result. These are carried over to the graph of Figure 4, which is universally valid for all ladder networks. This is a transformation of the graph used in the preceding installment and current in the literature. This graph gives immediately the values of α and β corresponding to each value of U and V. Attenuation and phase shift are then entered in the work sheet, for each section and frequency. Finally, these values are added together and the *overall* values are obtained. Plots of overall attenuation and phase shift for the filter in question are shown in Figure 5.

Thus far, the actual values of the filter elements have not entered in the computation. They are, however, very easily obtained from the values of W and S, and from the matching impedance (Figure 3). In our example, it has been supposed that the filter works, between terminations, of only 7 ohms; had this value been higher the required inductance for some of the coils would have been too high. It should be remembered that at radio frequency the *effective inductance* cannot be made high unless large dimensions are used.

The characteristics of Figure 5 show how the actual behavior of a filter of this type differs from that of an ideal filter free of resistance. In commonly used filters, operating at lower frequencies, the departure is less marked, but still considerable.

The filter performance could probably be improved by altering the design. Such alterations may be carried out on the circle diagram, by drawing the four *filter circles* in different positions (always so as to be tangent to A, the *envelope* circle). After practicing the method, it becomes possible to predict the effect of changes almost at a glance.

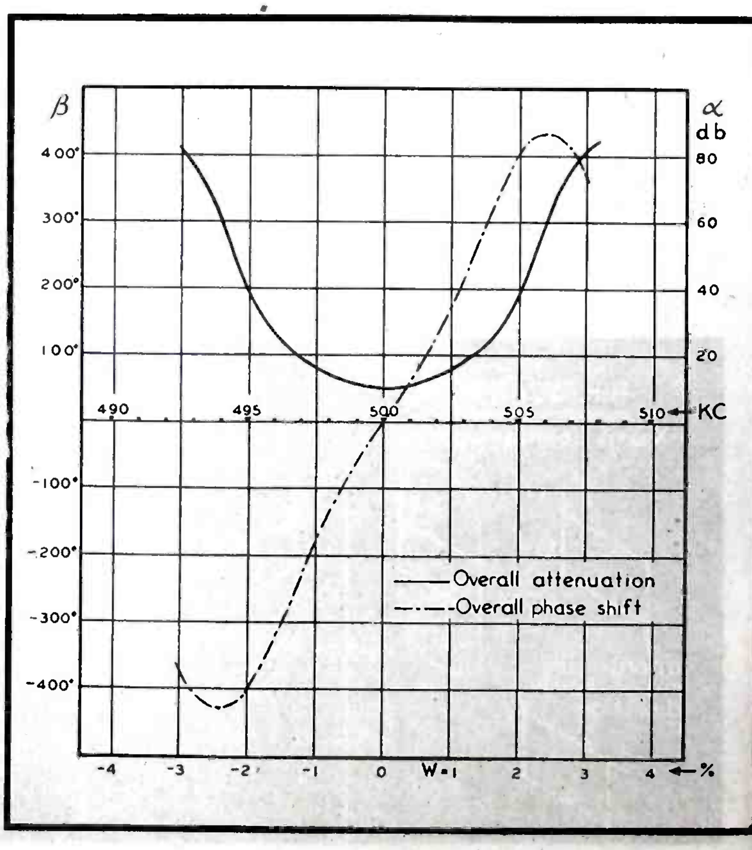


Figure 5

The attentuation and phase characteristics of the four-section symmetrical band-pass filter. In this graph we see how the actual behavior of a filter of this type differs from that of an ideal filter free of resistance.

CRYSTAL ORIENTATION

(*Continued from page* 115)

boundary will be visible, the patterns on each side of the boundary will indicate the same major rhomb direction. These patterns are widely used in the industry and will be referred to later.

The *stauroscope* is a polarized light instrument which has an interesting possibility for raw quartz orientation. Briefly, it consists of a source of plane polarized light, a rotating table perpendicular to the direction of propagation of the light beam to support the specimen under observation, and a polarizing medium as analyzer crossed with respect to the light source. If a piece of quartz were placed upon the rotating table with Z approximately parallel to the table, rotation of the table would show four positions of complete extinction of the light beam. These lie 90° apart and occur when the Z-axis lies in the plane of polarization of the light, or when its projection on the plane of polarization is perpendicular to the direction of polarization. The instrument utilizes the phenomenon of birefringence and polarization of the o and e rays at right angles to each other.

The possibility of raw quartz orientation may be accomplished by the use of two stauroscopes with light beams perpendicular. The quartz may be mounted on a swivel fixture in such manner as to allow each beam to go through its volume. The Z-axis will be absolutely defined in space as perpendicular to the plane formed by the directions of polarization of the light beams when the quartz is positioned for maximum extinction of each beam. Accuracy of measurement or orientation of Z is mainly dependent upon, first, accuracy of determination of polarization directions; second, nature of the surface of the quartz; third, accuracy of determination of the extinction positions. Sodium light would be quite suitable for such an instrument. The stauroscope may be used for determining the direction of Z', the projection of Z upon the wafer being examined. This use will be described later.

There are certain specifications which must be met by the final product, the *BT* oscillator plate. Predetermined angles of cut must be held to close tolerances in mass production. The use of the various orientation devices and techniques necessary to maintain orientation accuracy will be discused next month.

(*Photos by John Derbyshire*)

MOBILE ANTENNAE DESIGN

(*Continued from page 73*)

the center-loaded coil presents mechanical problems because of the winds produced by car speeds in mobile installations.

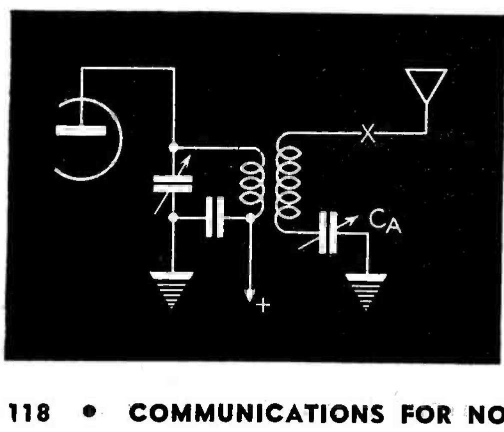
Figures 8 and 9 present old standby circuits which still hold first place as the easiest and best method of feeding the short whip. These will be recognized as the *Marconi* type. Of distinct advantage is the placing of the load coil exterior to the vehicle so that it can add its radiation to that of the whip. There may be those who will cavil at this small radiation addition, but actual tests reveal that the placing of the load coil outside the car or truck has often added 2 to 5 miles to the range.

The laboratory tests may present difficulties, since r-f feedback is quite bad. But the actual installation has usually been found to be docile as a kitten. This is aided by keeping the leadin under 3 feet, wherever possible.

In determining which circuit to use, it will be found that with the exception of the circuit shown in Figure 3, almost all may be easily set up for test in the vehicle and just as simply changed by shifting only a wire or so. A setup with the field-strength meter will reveal which is the best from the point of radiation and which suits the vehicle and transmitter installation from the standpoint of, (*a*) the terminal frequency, (*b*) the vehicle itself, and (*c*) the antenna. Having adjusted the field-strength meter to a standard of, say, the *Marconi type* coupling (Figure 9), each circuit may be tried in rotation for determination of the best characteristics.

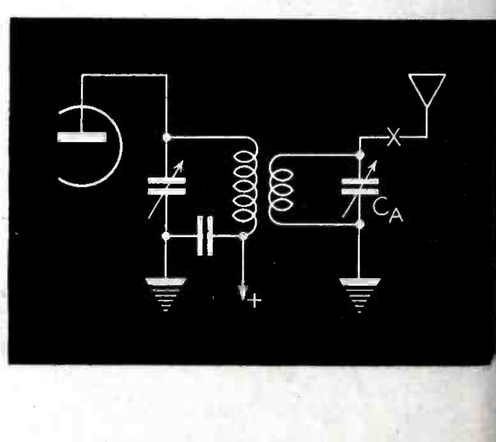
In passing, it is well to consider the ease of tuning, if the installations are to be multiple and inexperienced persons are to do the tuning. Another point to remember is that non-collapsible antennae should be easily demountable *without the use of tools* so as to permit rapid housing of the car.

In actual practice and over a long period of time the *Marconi* and the *base-load* circuit have been found to be practically equal in efficiency. These systems provided from 15% to 50% greater output for the same power output at the transmitter tank. However a number of trucks equipped with medium high powered sets (300-watts output) have been successful with the Collins network and long whips.



Figures 8 (left) and 9 (right)

Here we have the familiar Marconi circuits. With these systems it is possible to place the load coil outside of the vehicle so that it can add its radiation to that of the whip antenna. In actual practice the Marconi and the baseload circuits have been found to be practically equal in efficiency. These systems have provided from 15% to 50% greater output for the same power output at the transmitter tank.



(Continued from page 74)

placing the tube in a nitrogen flush after the main seal is made.

Both these ideas will provide an estimated yearly saving of $1,999.30 in material and 1,141 man hours.

Filament Spraying Process

A supervisory and engineering cost reduction suggestion on tubes submitted by George Van Wagner of RCA involves a filament spraying process.

Previously filaments for a high production power tube were sprayed in a single row fixture. The possibility of adapting this fixture to double row spraying was worked out. As a result of the above change, there will be a saving of $2.86 or 4.28 hours per thousand assemblies. On a yearly production of over 320,000 the result will be $915 or 1,360 hours.

Ceramic Production Suggestion

A production drive suggestion on ceramics of B. W. Kinyon, RCA, will provide a theoretical labor saving of approximately $.52/1000 ceramics. An annual saving of 3,000 hours of direct labor will be obtained.

Mr. Kinyon's suggestion covers the elimination of the counterbore on half of ceramic units. Previously both top and bottom ceramics were counterbored. However, the counterbore is necessary only on the top ceramic for various power tubes. Tests have been run, standardization notices sent through, and the counterboring on the bottom ceramic has now been eliminated.

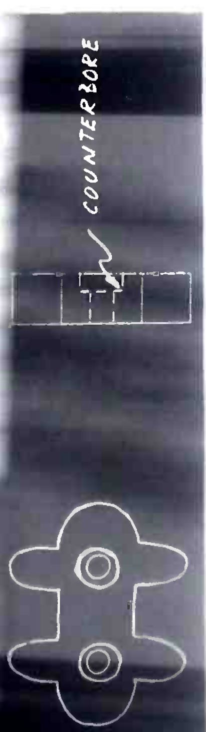


Figure 5

The ceramic production suggestion of B. W. Kinyon of RCA. With this new method, the counterbore on half of the ceramic units are eliminated. It will be possible to affect a saving of some 3000 hours of labor a year, with this new procedure.

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC., REQUIRED BY THE ACTS OF CONGRESS OF AUGUST 24, 1912, AND MARCH 3, 1933, OF COMMUNICATIONS

Published monthly at New York, N. Y., for October 1, 1943.
County of New York, }
State of New York, } ss.:

Before me, a Notary Public, in and for the State and county aforesaid, personally appeared B. S. Davis, who, having been duly sworn according to law, deposes and says that he is the Business Manager of COMMUNICATIONS, and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management, etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, to wit: 1. That the names and addresses of the publisher, editor, managing editor, and business manager are: Publisher, Bryan Davis Publishing Co., Inc., 19 East 47th Street, New York, N. Y.; Editor, Lewis Winner, New York, N. Y.; Managing Editor, None. Business Manager, B. S. Davis, Ghent, N. Y.; 2. That the owners are: Bryan Davis Publishing Co., Inc., 19 E. 47th St., New York, N. Y.; B. S. Davis, Ghent, N. Y.; J. C. Munn, Union City, Pa.; A. B. Goodenough, Port Chester, N. Y.; P. S. Weil, Great Neck, L. I., N. Y. 3. That the known bondholders, mortgagees, and other security holders owning or holding 1% or more of the total amount of bonds, mortgages, or other securities are: None. 4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company, but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also, that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

(Signed) B. S. DAVIS, Business Manager.

Sworn to and subscribed before me this 25th day of September, 1943.

(Seal) FRANKLIN B. GOOLD, Notary Public.

Commission expires March, 1944.

COAXIAL CABLE EXPANSION

(*Continued from page* 28)

ductor, prompting extreme bends. This naturally happens in the coldest night of the winter, a most inconvenient time to repair a buried cable.

When planning a cable installation, it is necessary to consider both total expansion and differential expansion, and to make suitable plans to permit the necessary motion of the cable. Usually this can be done by proper routing and attaching of the cable.

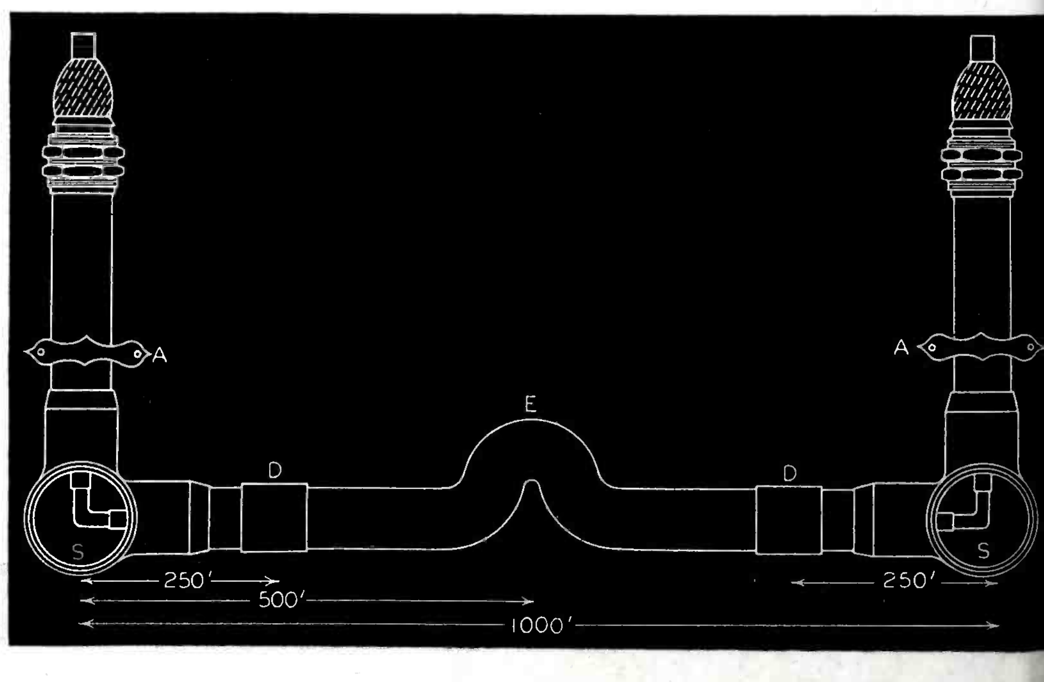


Figure 3
An installation in which expansion joints are used. *A* cable is attached solidly; *E* expansion bend for total expansion. This also serves as an anchor which solidly attaches the inner conductor to the outer conductor. *D* differential expansion joint permits inner conductor to move with respect to the outer conductor; *S* is a solid inner connector.

Sometimes, especially constructed expansion fittings are used.

End Terminations

In each straight run of cable, the ends terminate either in some sort of cable bend, or a cable end. In either case, proper mounting attachments will usually permit the end to move back and forth a short distance. Allowance must be made for the total motion, one inch for each 100 feet of cable. The cable may be firmly attached at one end, and the other end mounted so that it may move the necessary distance. In a particularly long installation, say over 300 feet in a straight run, it may be desirable to fasten the cable solidly at the center and permit each end to take some of the motion. Where it is necessary to attach both ends of the straight run firmly, the cable may be provided with some form of expansion joint. Such joints may take the form of a long U-shaped curve, or may be a device with a metal bellows, a sliding contact joint, or other similar arrangement. These various expansion joints have not been entirely satisfactory, and it is preferable to simply mount the cable so that the end can vary the necessary amount, if mounting conditions make this possible.

Differential Expansion Revisions

The proper revisions for differential expansion are quite similar. That is, we can use either a special joint in which the two conductors may move with respect to each other, or an installation arrangement whereby the inner conductor is fastened rigidly to the outer conductor at one point and is free to move at all other points. If the point where it is fastened rigidly is at one end, it can consist of a sealed terminal, or of a right angle junction box in which the inner conductors are rigidly fastened to each other. At the end of the straight run, the inner conductor can be permitted the necessary amount of motion by making a connection in a junction box with a piece of flexible copper braid. In a particularly long run, the inner conductor may be fastened rigidly to the outer conductor at the center by what is called an *anchor joint*. Then at both ends the conductor can be permitted to move.

Semi-Flexible Cable

The soft copper or *semi-flexible* type of cable rarely offers any trouble due to expansion. After this type of cable has been coiled for shipment and has been uncoiled for installation, it is by no means perfectly straight. The irregularities in it are quite sufficient to allow for the expansion and contraction which it will experience. The differential expansion and contraction is also not a troublesome factor, because friction of the bends is great enough to keep the two conductors from moving with respect to each other.

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Make up your own posters to spread the "War Bonds for Christmas" story across your plant. Tell the story again and again on bulletin boards, in your plant magazine, and on pay envelope stuffers.

But don't forget your basic, all-important Pay-Roll Savings Plan. How's it going, these days? Perhaps it needs a bit of stoking-up right this very minute, to hold its full head of steam against the competitive demands of the holiday season.

Well, you're the man to stoke it! You can't expect it to keep running indefinitely on last summer's enthusiasm. See to it that your participation percentages, and your deduction percentages, *both* end up the year at new levels.

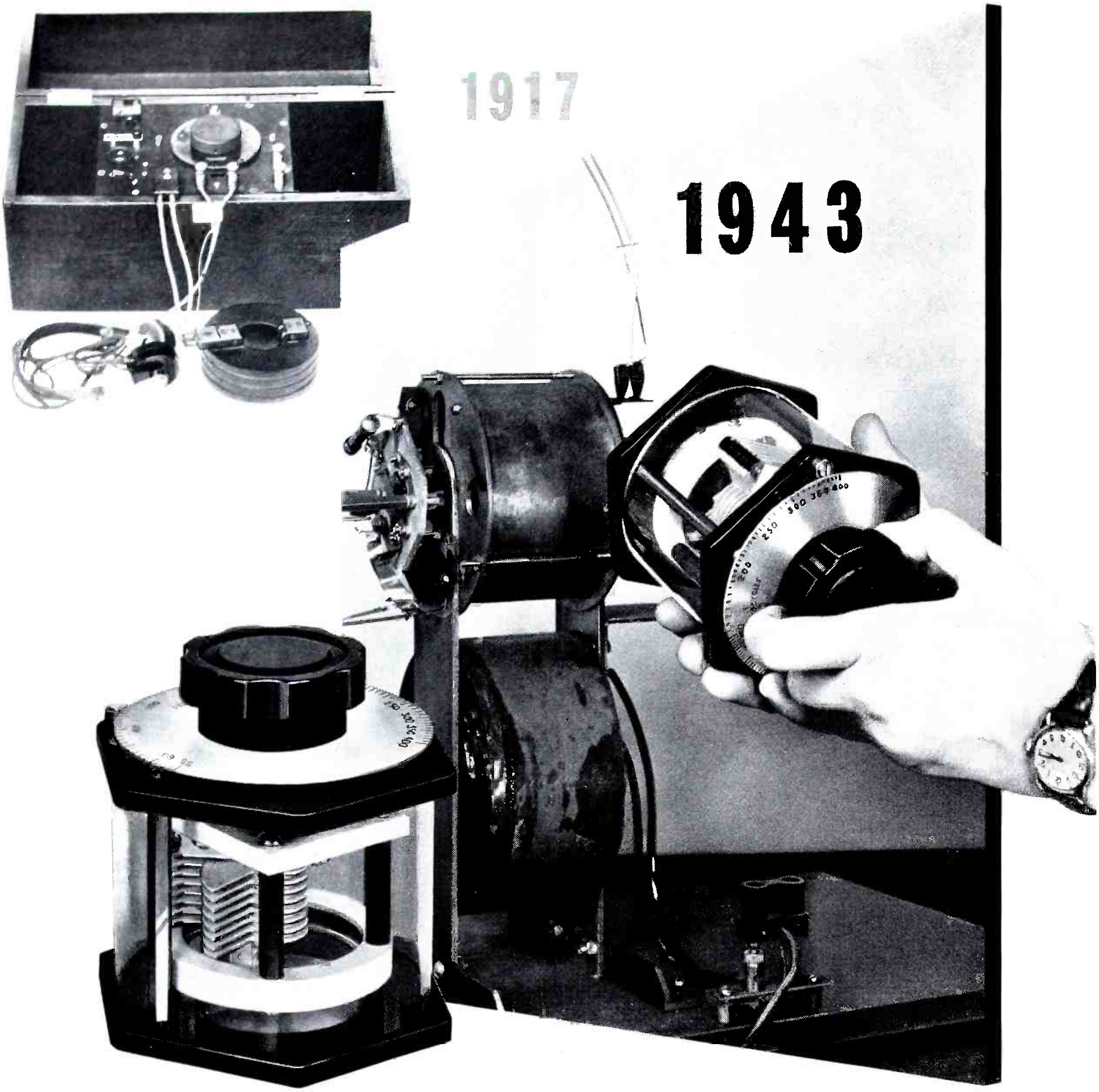
Every month, now your Pay-Roll Savings ought to run well ahead of the preceding month. *For so many families that formerly depended on the earnings of a single worker, now enjoy the combined earnings of several.* Such *family* incomes are doubled, trebled, even multiplied many times.

Now's the time to turn as much as possible of these increased earnings into War Bonds—War Bonds for Christmas . . . and War Bonds the whole year 'round!

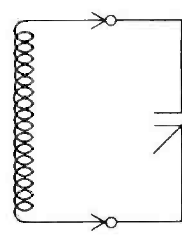
GIVE THE PRESENT WITH A FUTURE—WAR BONDS!

This space contributed by COMMUNICATIONS

This advertisement prepared under the auspices of the United States Treasury Department and the War Advertising Council



WAVEMETERS



These two instruments mark the initial and present boundaries of a development program that has produced, in the last twenty-six years, some twenty-five separate types of wavemeters, each filling a definite niche in the communication industry's need for simple-to-operate, frequency-measuring instruments.

Between the Type 105-B Wavemeter of wartime 1917, and the Type 758-A U-H-F Wavemeter, a wartime 1943 instrument, there is superficially little resemblance. Both, however, embody the accuracy and high-quality construction that is characteristic of General Radio instruments — accuracy made possible by General Radio's pioneer development of accurate primary frequency standards, and quality based on years of experience in building reliable electronic instruments.

The General Radio Company builds a variety of wavemeters, each designed for a definite type of measurement. These instruments cover a frequency range of 16 kilocycles to several hundred megacycles, and range in accuracy from 2% to 0.01%.

Because all our facilities are devoted to war projects, wavemeters, at present, are available only for war work.

GENERAL RADIO COMPANY Cambridge 39, Massachusetts
NEW YORK 6 LOS ANGELES 38