RADIO

AUGUST, 1945

Design • Production • Operation

WITH FIRST RADAR PHOTOS

RADAR!

The Journal for Radio & Electronic Engineers

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The conventional "acoustic stethoscope," used by doctors since the horse-and-buggy days, now gives way to a revolutionary electronic stethoscope called the "Stethetron."

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RADIO

Published by RADIO MAGAZINES, INC.

AUGUST 1945 — Vol. 29, No. 8

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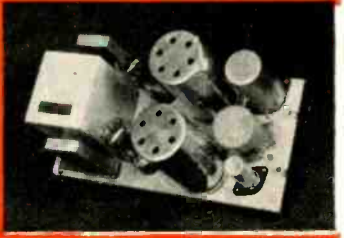
VACUUM TUBES



COMPONENT PARTS

SYLVANIA NEWS

ELECTRONIC EQUIPMENT EDITION

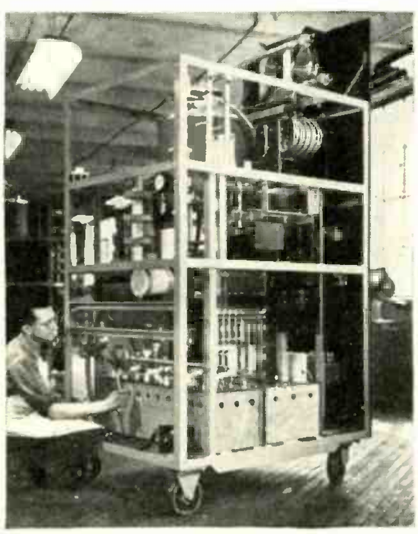
AUGUST *Published by* SYLVANIA ELECTRIC PRODUCTS INC., Emporium, Pa. 1945

HIGH FREQUENCY INDUCTION FURNACE USED IN TUBE PLANT

The bombarder or high frequency induction furnace pictured below is another example of high-precision, modern equipment manufactured at Sylvania Electric's plant in Williamsport, Pa.

Flexible in Application

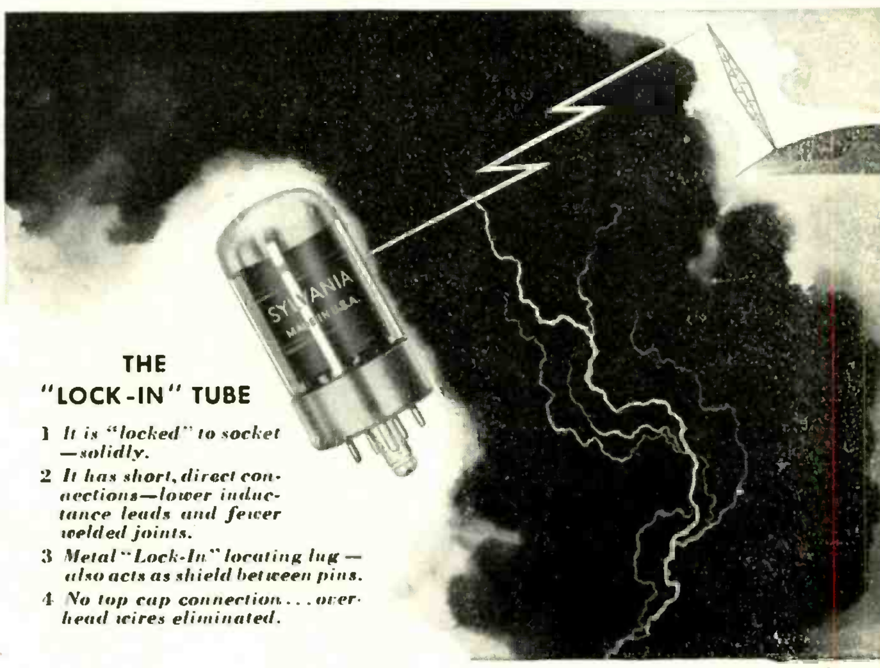
Used in all radio tube plants where exhaust machines operate, this essential apparatus may also be adapted for use in practically any application that requires high frequency induction heating by the connection of the proper heating coils. Its rated input is 25KVA, uses Type 207 tube as oscillator, frequency about 300KC.



High frequency induction furnace used in all radio tube plants where exhaust machines operate. Made by Sylvania Electric at Williamsport, Pa.

LOCK-IN TUBES PERFECTLY IN LINE WITH RECENT FCC DECISION

High Frequency Sets (FM) Will Get Benefit of Tubes' Electrical Superiority



Sylvania Electric's revolutionary type of radio tube—the Lock-In—is so mechanically stronger and electrically more efficient that it takes in its stride the recent FCC decision assigning to frequency modulation the band between 88 and 106 megacycles. The basic electrical advantages of the Lock-In construction are ideally suited to the adoption of higher frequencies.

Mechanically it is more rugged because support rods are stronger and thicker—there are fewer welded joints and no soldered joints—the lock-in lug is metal not molded plastic—the elements are prevented from warping and weaving.

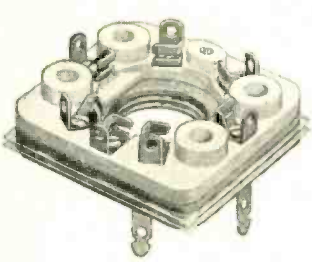
Electrically, it is more efficient because the element leads are brought directly down through the low loss glass header to become sturdy socket pins—reducing lead inductance—and interelement capacity.

Today, the many special features of the Sylvania Lock-In Tube are even more up-to-date than when they were introduced in 1938—a fact of increasing importance when considering the numerous postwar developments in the field of communications.

SYLVANIA ELECTRIC

Emporium, Pa.

MAKERS OF RADIO TUBES; CATHODE RAY TUBES; ELECTRONIC DEVICES; FLUORESCENT LAMPS, FIXTURES, WIRING DEVICES; ELECTRIC LIGHT BULBS



The versatility of Amphenol engineers is evidenced in the varied electronic applications for which they have designed and produced components. Many of the now standard sockets, connectors and cables produced by Amphenol were originally created to surpass the most exacting specifications.

Products illustrated here are but a few of the thousands of items that comprise the complete Amphenol line including U.H.F. Cables and Connectors, Conduit, Fittings, Connectors (A-N., U.H.F., British), Cable Assemblies, Radio Parts and Plastics for Industry.

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Transients

MANHATTAN PROJECT

★The development of the atomic bomb has caused many commentators to term this an atomic age. That this is merely an extension of electronic research does not appear to have been realized by any of its publicists. Most certainly this was an electronic project, and the physicists and engineers who succeeded in producing the bomb will undoubtedly speak in more accurate scientific terms when and if they are permitted to do so.

But the important point, which is driven home with the most dramatic force of any accomplishment of recent times, is that research pays. We shudder to think how the pre-war American Congress would have greeted President Roosevelt had he appeared before them and requested a sum in excess of two billion dollars to engage some scientists and supply facilities for experimentation on this project. Unquestionably the public, government and industry should back other research projects, which aim to make this a better world to live in, regardless of initial cost.

RADAR

★According to a recent announcement, we are now permitted to talk about radar provided, as Dr. Everitt puts it, we spell it backward. It is our editorial policy to present only such articles which discuss in specific terms items of interest to engineers in the radio and electronic field. Because secrecy restrictions have hitherto prohibited discussions of radar in such terms, we have preferred not to publish anything on the subject. Now that the situation has changed, we shall present photographs and descriptions of radar apparatus which we believe will be of interest.

TELEVISION BROADCASTING

★At a recent press luncheon in New York City, the Westinghouse Electric Company and the Glenn L. Martin Company presented a plan for television broadcasting from airplanes spotted at 14 locations from New York to Hollywood. By broadcasting from 30,000 feet it becomes possible to increase the line-of-sight transmission to about 250 miles, and to reduce transmitting power from 50 kw to 1 kw for the same coverage (*See page 60*).

Just how such a system will work out remains to be seen, but it is interesting to note two such prominent companies co-operating in a scheme which is such a radical departure from previous methods of attack. We wonder just what sort of reception those who reside in areas along the fringe coverage of each transmitter will secure. Where overlap exists and signals from more than one transmitter are received at the same point but out of phase, it seems trouble should result. But the sympathetic reception given this idea will encourage others to work on methods of attacking the problem which are likewise unconventional and give promise of success.

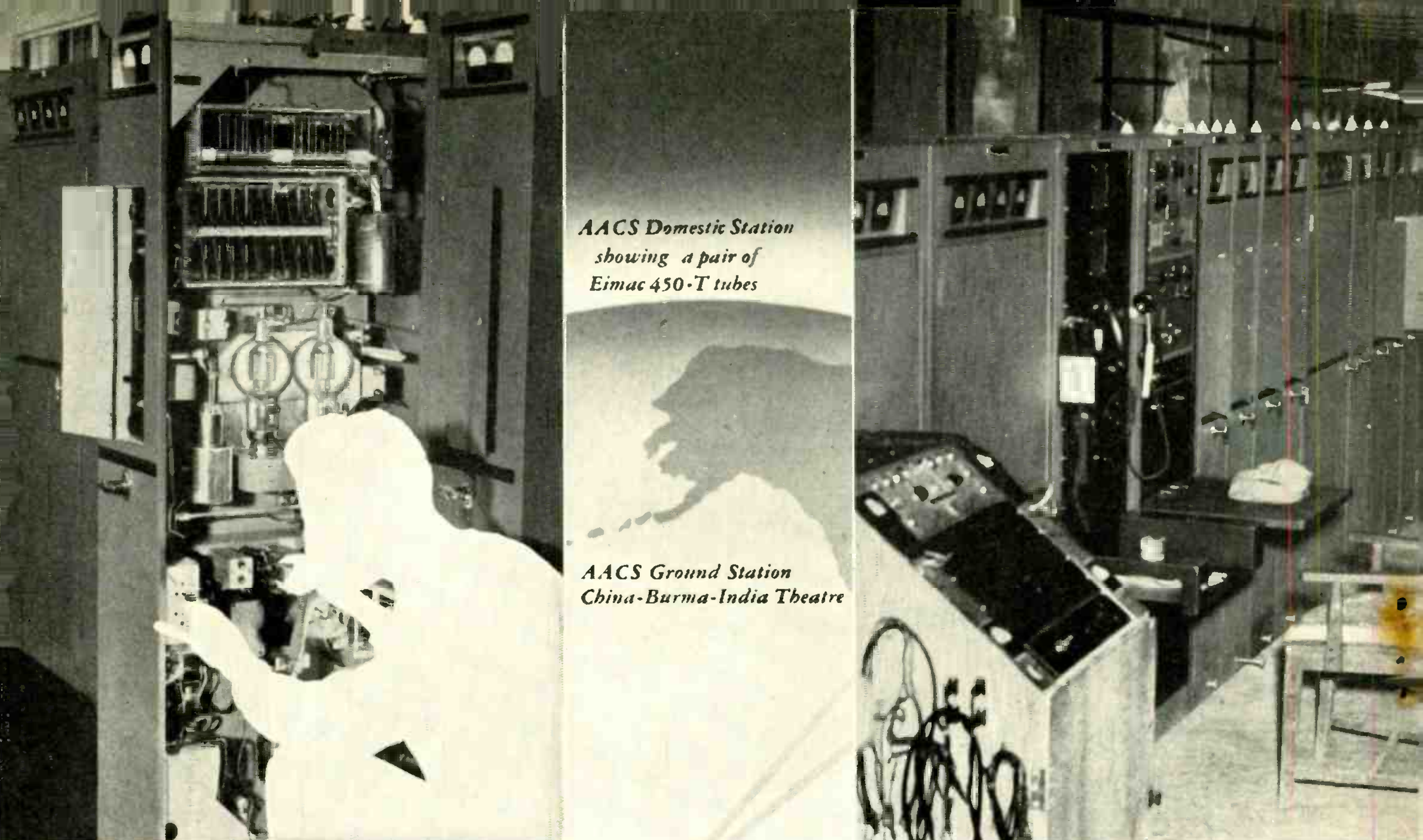
RADIO SURVEY

★According to a recent survey by the Research Department of The Curtis Publishing Company, based on interviews with families in 35 states and 118 urban centers, 95% of the families own at least one radio. Those planning to buy a new radio constitute 27.8%. More than 14% want radio-phonograph combinations, and about the same percentage expect to buy straight radios. Some will buy both types, or more than one.

It is interesting to note that the median expenditure contemplated for radio-phonograph combinations is $170.00 and for radios without phonograph $93.00. These figures are considerably higher than many manufacturers have assumed. Doubtless they will be reduced should widespread unemployment result from the early ending of the war.

The largest percentage of those who expect to buy radio-phonograph combinations plan to spend between $200.00 and $299.00 for the instrument. For radios without phonograph, the $100-$149 bracket is most popular. About one-third of those questioned did not state how much they intended to spend.

—J.H.P.



AACS Domestic Station showing a pair of Eimac 450-T tubes

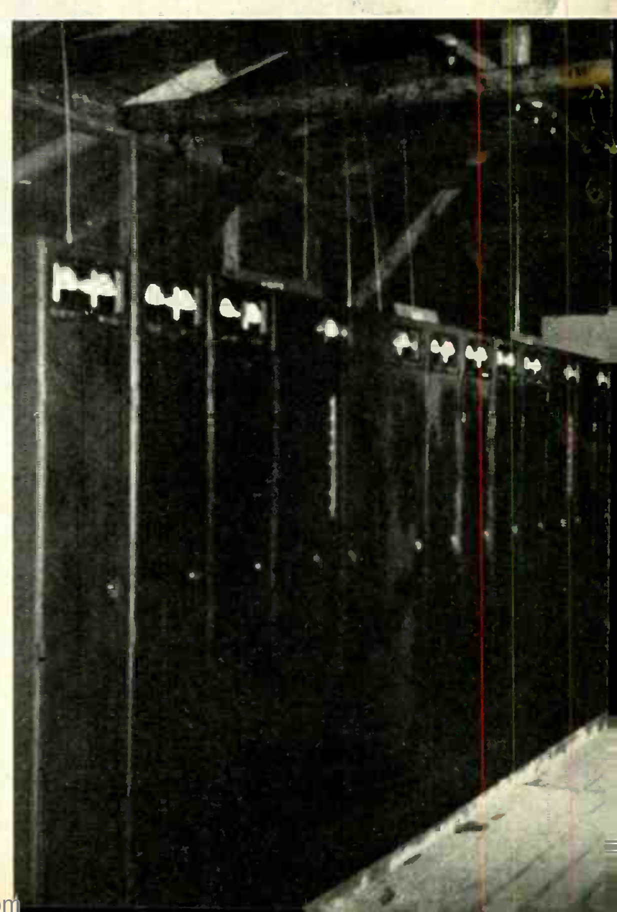
AACS Ground Station China-Burma-India Theatre

AACS* BLAZES THE TRAIL FOR SAFE FUTURE WORLD AIR TRANSPORTATION

World-wide aviation communications are an established fact today. Almost overnight a great radio network has been created. The actual physical difficulties involved were great enough, to say nothing of the variety of extreme operating conditions encountered and overcome. Needless to say, the equipment employed must be dependable, both from a standpoint of construction and performance capability.

The establishment of radio ground stations on every continent and in fifty-two different countries...overcoming the widest extremes in operating and climatic conditions (from 40 degrees below zero to 140 degrees above)...stations in jungles ...in deserts...in mountains and towns...and to have these stations constantly operating at near peak levels is a tribute to the equipment employed. On this page are shown three AACS Stations located at widely separated spots on the globe.

AACS Station on an island in South Pacific



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*A. A. C. S. (Army Airways Communications System)

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As there is no cellulose in its composition, it resists fungus growth in the tropics. And moisture absorption is so low, and has so little effect on it, that its stability of dimensions and electrical characteristics is equally unusual.

Other materials with glass fibre bases, and new and useful characteristics are also now available.

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TECHNICANA

RADIAL-BEAM TUBE

★ A new type of vacuum tube which substitutes for the mechanical commutator used in the time division system of communication is described in the April, 1944 issue of *Bell System Technical Journal* in an article entitled "Magnetically Focused Radial Beam Vacuum Tube" by A. M. Skellett.

The use of electron beams in place of mechanically rotating parts has often been contemplated, but cathode ray type electron beams offer low current density and require high voltage and the attendant complicated gun structure. This new tube uses low voltages and offers satisfactory beam currents in the order of magnitude of the space charge of an ordinary vacuum tube. The method of focusing the beam is by means of a magnetic field. Reference to *Fig. 1* shows the tube in its basic form to consist of a series of plates surrounding a cathode. When these plates are approx. 100 volts positive with respect to the cathode, and a magnetic field of between 50 to 300 gauss is applied in the direction indicated by the arrow *H*, two beams form in line with the magnetic field. Rotation of the magnetic field in turn rotates the beams.

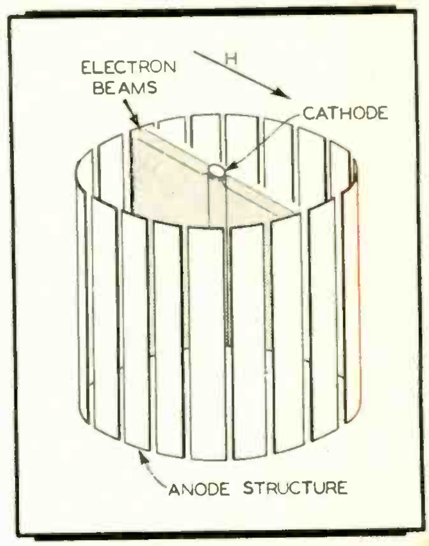
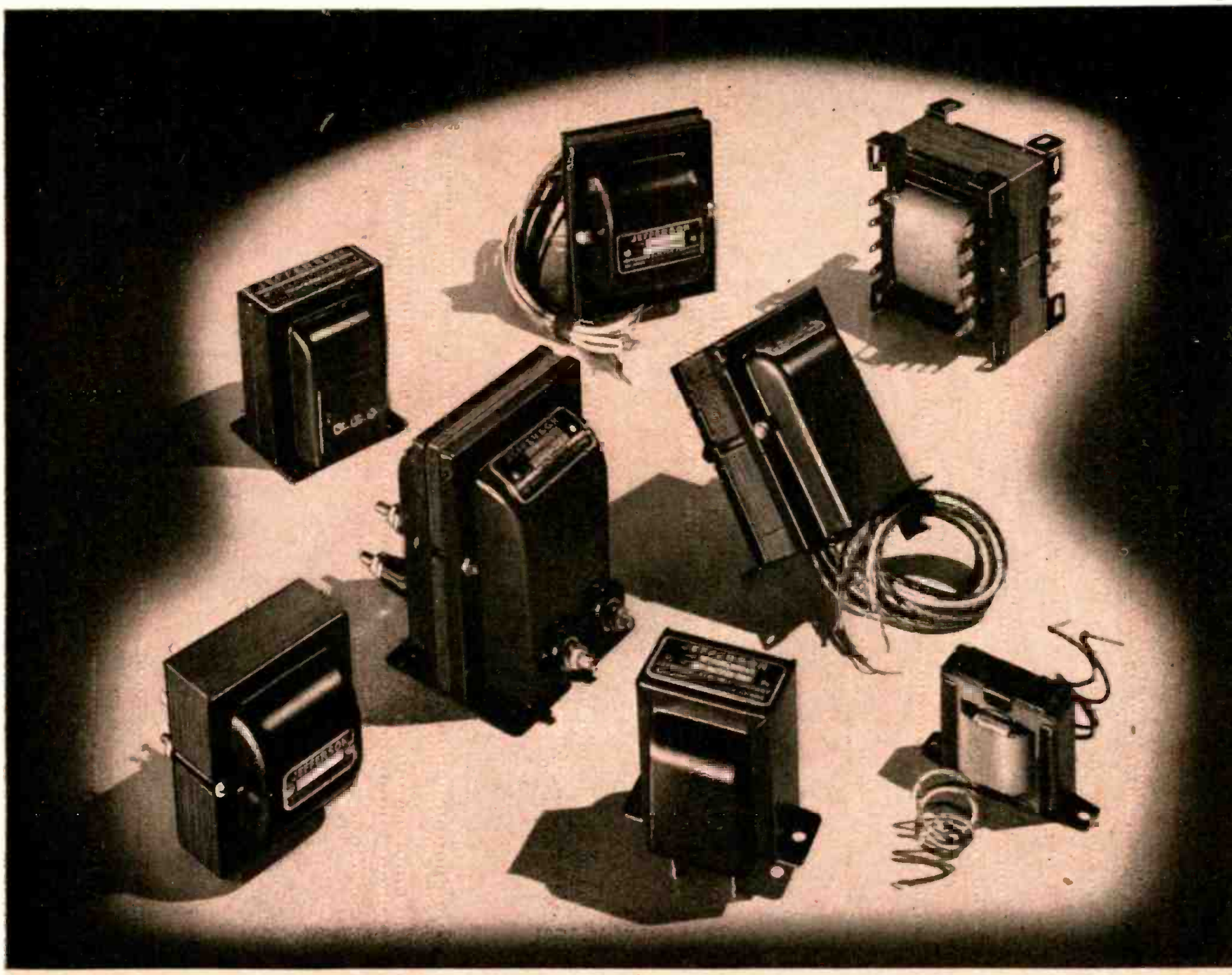


Figure 1

In order to make the tube more useful, one beam (between cathode and the plates) is suppressed. Methods of suppression will be discussed when considering the actual tube, but it should be noticed that by using an odd number of plates and spacing them so that when two beams are formed, as shown in *Fig. 1*, one of them will fall between the plates. In this scheme each plate is touched twice in one revolution.

The magnetic field used in the opera-



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War-time demands have further emphasized the ability to maintain high uniform standards of quality on a mass production basis. Under the stimulus of War effort, advanced types of machinery, and improved manufacturing technique, you can count on still better Jefferson Electric products for your post-war needs. Consulting now with Jefferson Electric transformer engineering specialists will save time for you later . . . JEFFERSON ELECTRIC COMPANY, Bellwood (Suburb of Chicago), Illinois. *In Canada:* Canadian Jefferson Electric Company, Limited, 384 Pape Avenue, Toronto, Ontario.

JEFFERSON ELECTRIC

TRANSFORMERS

TECHNICANA

[*Continued from page 12*]

tion of this tube is created by the stator of a two-pole polyphase alternating current motor. The tube, which is cylindrical in shape and approximately 2¼ inches in diameter, fits concentrically into the stator winding. The application of polyphase currents to the stator causes a rotating magnetic field revolving at line frequency. In other applications, where the beam is not rotated, the beam may be located by means of permanent magnets or by proper adjustment of the current through the two stator windings. Power consumed by the stator, at lower frequencies of 20 to 60 cycles, is due to copper loss and at higher frequencies, to core loss. In the event that polyphase power is not available, single phase power may be split in phase in the stator. Polyphase potentials for producing the electrostatic field necessary for the suppression of the second beam may then be obtained from the windings of the stator.

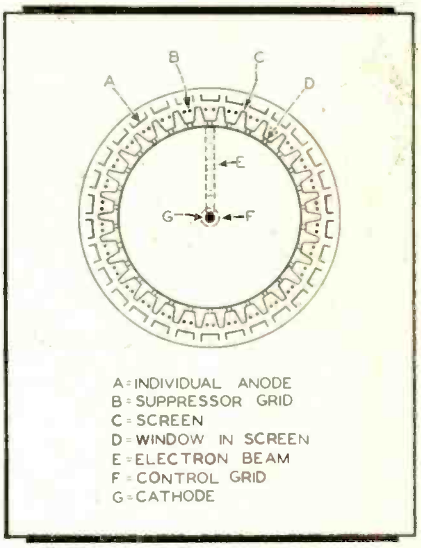
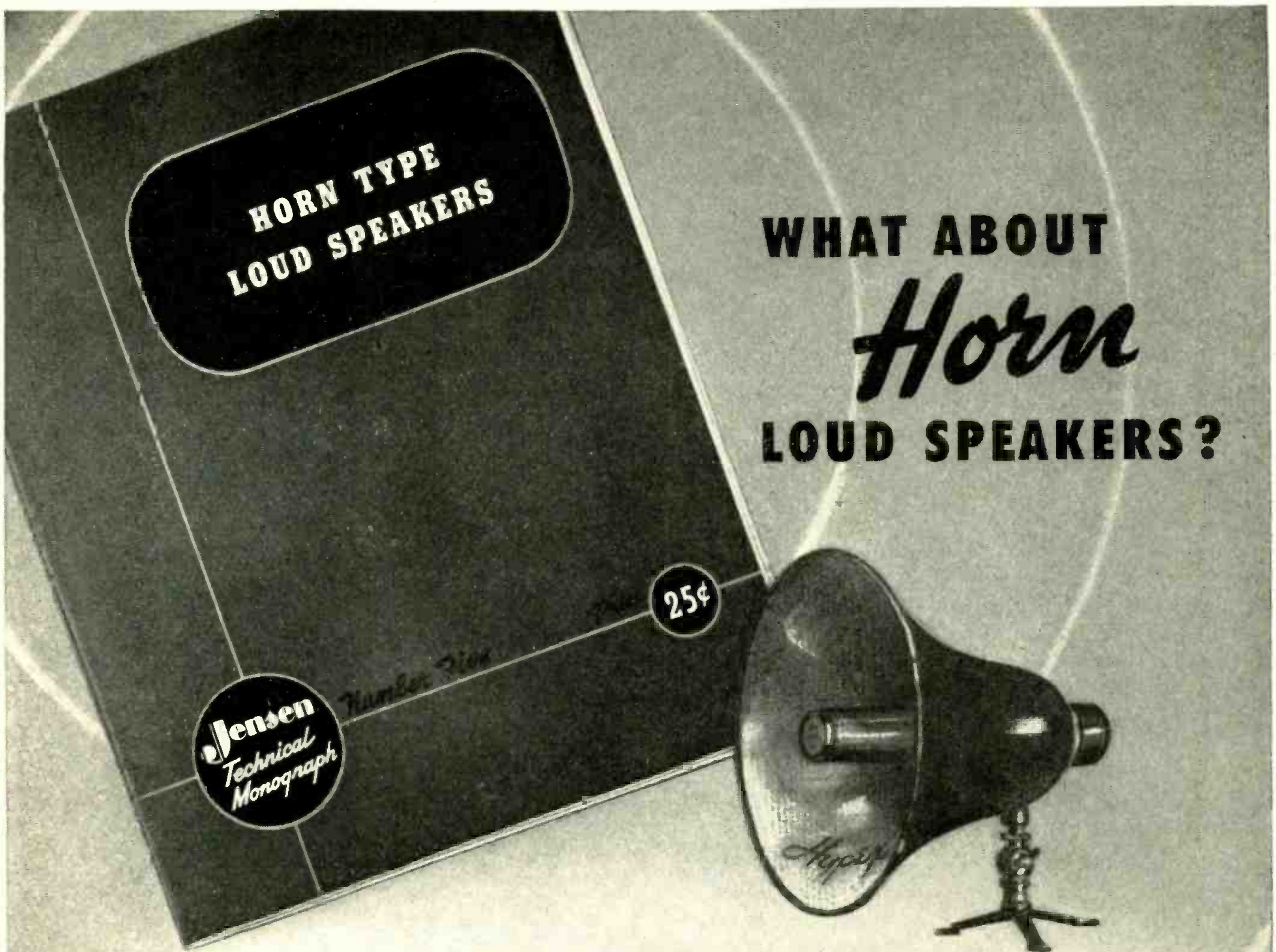


Figure 2

A practical tube is shown in *Fig. 2.* Comparison with *Fig. 1* shows that the practical tube has the addition of a control grid, screen grid, and suppressor grid. The control grid permits the tube to be used as an amplifier as well as commutator. While the suppressor grids are shown as rods, better results were obtained by welding a ladder of wires between the two upright wires, similar to a standard grid structure. Thus, with 140 volts on the screen and 140 volts on the plate, the plate current may be cut off by application of —20 volts to the suppressor. Thus a mechanism for beam suppression becomes apparent. To obtain the most satisfactory results, for beam suppression, a uniform electrostatic field must be applied to the suppressors. This field may be obtained by


HORN TYPE
LOUD SPEAKERS
25¢
Jensen
Technical
Monograph

TECHNICANA

[*Continued from page* 14]

applying to these suppressors a series of potentials that vary according to the sine of the angle taken around the axis with the maximum plus and minus potentials lining up parallel with the magnetic field. Of course the negative side corresponds to the suppressed beam. To permit this same relationship as the beam is rotated, the suppressors are connected in groups to polyphase voltages. These voltages are also connected with a d-c bias so that the combination of voltages alternately permits the suppressor to cut off the beam.

At present the limiting factor in connection with the speed of rotation of the beam is determined by the a-c losses in the stator. Estimates of 10,000 cycles per second are advanced as the limit.

Fig. 3 shows a setup of these tubes as tested over a short distance. Synchronization of the two rotating beams was accomplished by using the same power source at both ends. At the transmitting end, it was possible to modulate each channel (plate) by means of the suppressor. Thus the system of multiplex telegraphy, based on time division, instead of using elaborate filters as now required may turn to this new tube.

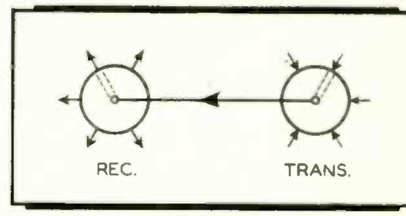


Figure 3

Reviewer's Note: Many who attended the IRE convention last January may remember a tube of this type demonstrated as a game of chance. It consisted of a tube containing about six plates and a revolving permanent magnet. Each plate connected to a neon lamp. Thus as one rotated the knob controlling this magnet, the corresponding neons lighted. A fast spin and it was a guess as to which light would be on when the magnet slowed down and finally stopped. Just shows another "practical" application of this device . . .

4-125A VHF TETRODE

★ The new Eimac 4-125A, which is a development of the Eitel-McCullough Laboratory design group, is a medium-power transmitting tetrode incorporating design features which allow operation well into the v-h-f region. A pair of 4-125A's in a conventional push-pull arrangement is capable of delivering as much as 750 watts output at frequencies as high as 120 mc. The driving power requirements are low enough to allow a great simplification in driver design.

★ *Star performance every time!*

BALLENTINE RECORD CHANGER

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Dependable, Trouble-Free Performance
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Found in No Other Changer

Star Performance in Record Changers means positive changing action, low rumble, no broken records, perfect adjustment in spite of careless or accidental handling, minimum "wow".

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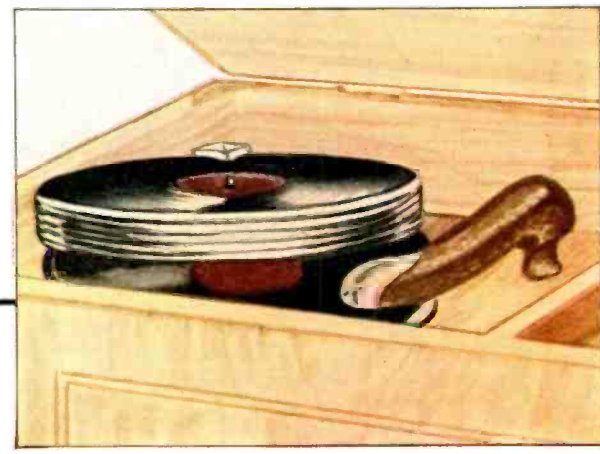
Today the Ballentine Record Changer stands unexcelled in the field, the quality record changer for the radio manufacturer, assuring complete customer satisfaction. Available in different price ranges.



The Ballentine Record Changer
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BALLENTINE RECORD CHANGER

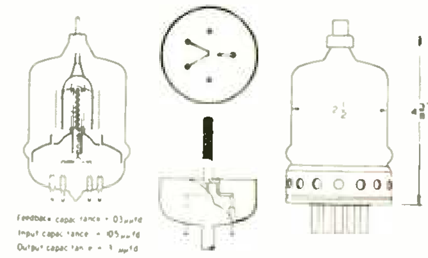
TECHNICANA

(Continued from page 16)

A total driving power of less than five watts will satisfy the requirements of two 4-125A's under maximum output conditions.

Through careful design it has been possible to keep the interelectrode capacitances of the 4-125A to rather low values for a tube having such substantial power capabilities. The plate to grid capacitance is 0.03 μμf, while the input and output capacitances measure 10.5 μμf and 3.0 μμf, respectively.

Lead inductance has been kept to a minimum in the 4-125A through the use of a "dish" type stem and short, heavy leads. To aid in holding the

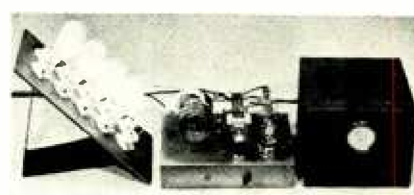


Construction of Eimac 4-125A

screen grid at ground r-f potential, two screen leads have been provided.

Physically, the 4-125A is a rather small tube, the seated height being only 4⅜ inches.

The combination of low interelectrode capacitance, low lead inductance and small physical size allow the tube to operate without neutralization and with full output at frequencies as high as 100 mc. Above this frequency, a slight amount of neutralization is required, but full power output may be

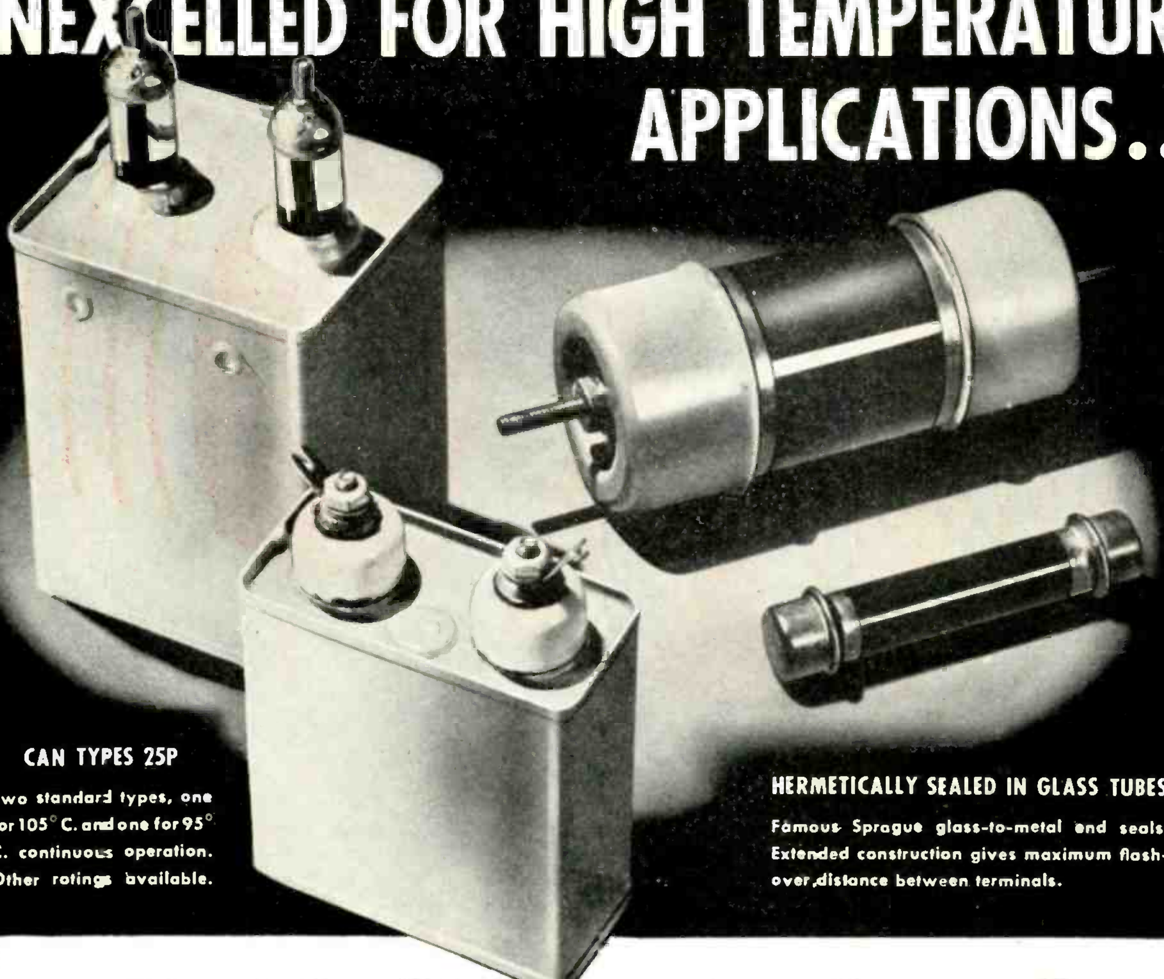


A 750-watt output, 14 mc test unit. The exciter unit is a standard Meissner Signal Shifter.

obtained up to 120 mc. Even at 160 mc it is possible to realize an output of 250 watts per tube. The ultimate capabilities of the tube at frequencies above 160 mc have not as yet been fully investigated, but preliminary tests have shown an output of 175 watts per tube at 215 mc.

The 4-125A has been constructed in a manner which permits the elimination of all internal insulators. The 32-watt thoriated tungsten filament, tantalum control grid and tantalum screen grid are supported by their leads from a dish-type stem. The plate, which is also of tantalum, is supported by a single lead from the top of the envelope. A large shield structure, which

UNEXCELLED FOR HIGH TEMPERATURE APPLICATIONS...



CAN TYPES 25P

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HERMETICALLY SEALED IN GLASS TUBES

Famous Sprague glass-to-metal end seals. Extended construction gives maximum flash-over distance between terminals.

...ideal for higher ratings in smaller sizes at lower temperatures

Sprague Capacitors impregnated with the exclusive VITAMIN Q impregnant make possible the use of much smaller units—with a substantial safety margin—on numerous high-voltage, high temperature applications ranging from transmitting to television. Where high temperature is not a factor, their unique characteristics assure materially higher capacity ratings for a given size.

Type 25 P VITAMIN Q Capacitors operate satisfactorily at thousands of volts at ambient temperature as high as 115° C. Insulation resistance at room temperature is *more than 20,000 megohms per microfarad.* Throughout the temperature range of +115° C. to −40° C. they retain all virtues of conventional oil-impregnated capacitors.

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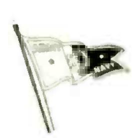
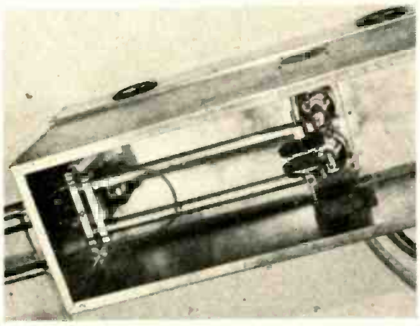


KYLE CORPORATION

SOUTH MILWAUKEE, WISCONSIN

[*Continued from page* 18]

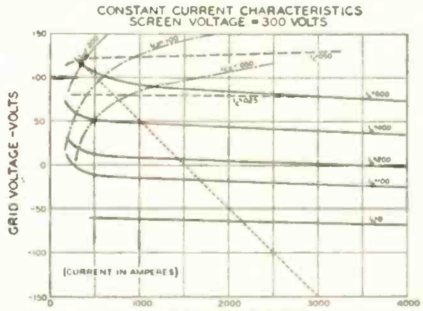
serves to join the screen grid to its supporting leads, separates the tube into two sections. Below this shield are those parts of the tube associated with the input circuit, while the output circuit is concentrated in the space above the shield. This shielding feature is carried into the external structure of the tube by allowing the metallic base shell to extend up to a point opposite



Eimac 4-125A tetrodes in test amplifier

the internal shield. When the base shell is grounded, the shielding between input and output circuits is nearly complete.

Application of the 4-125A may be illustrated by two typical test r-f amplifier units which were constructed in connection with the development of the tube. One amplifier unit, which served for several relatively low frequency tests at 14 mc was completely contained in a cabinet measuring 15 by 11 by 9 inches. This unit, which employed two tubes, was easily capable of handling an input power of 1000 watts at a plate efficiency of 75 per cent. On several occasions the low driv-



4-125A constant-current characteristics. The operating line (short dashes) illustrates a 3000-volt, 500 watt input, 75 percent efficiency operating condition

ing power requirements of the 4-125A were illustrated by driving the 14-mc amplifier to its full rated 1000 watts input by means of a standard Meissner Signal Shifter. The Signal Shifter consists merely of an oscillator-doubler unit, with a 6L6 as the output-doubler stage.

For tests at 100 mc and above, a unit utilizing linear grid and plate tank

TECHNICANA

[*Continued from page 21*]

circuits was employed. There were no significant differences between the operation of the tubes at 14 mc and 100 mc. The driving power at 100 mc was found to be less than 5 watts per pair of 4-125A's, and there was no difficulty in obtaining a plate-circuit efficiency of 75 per cent.

The 4-125A should find wide application in television and f-m equipment operating in the v-h-f range, as well as in conventional lower-frequency apparatus.

EIMAC 4-125A DATA

Filament	Thoriated Tungsten
Voltage	5.0 Volts
Current	6.3 Amperes
Direct Interelectrode Capacitances (Average)	
Grid-Plate (without shielding, base-shell grounded)	0.03 $\mu\mu f$
Input	10.5 $\mu\mu f$
Output	3.0 $\mu\mu f$

Power Amplifier and Oscillator

Class-C Telegraphy	Typical Operation One Tube		Max. Ratings
D-C Plate Voltage	2000	3000	3000 Volts
D-C Plate Current	200	167	225 ma
D-C Screen Voltage	350	350	400 Volts
D-C Screen Current	25	50	— ma
D-C Grid Voltage	—150	—150	— Volts
D-C Grid Current	8	8	— ma
Plate Power Output	300	375	— Watts
Plate Power Input	400	500	— Watts
Plate Dissipation	100	125	125 Watts
Peak R-F Grid Input Voltage	260	270	500 Volts
Driving Power (approx)	2	2.1	— Watts
Power Gain (approx)	150	178	—

(*Summary of paper delivered before I.R.E. Winter Technical Meeting by Clayton E. Murdock*)

SOUND EFFECTS

★ Advancement in the art of sound effects is noted in an article entitled "Electronic Sound Effects" which was published in the July 1945 *Electronic Engineering*.

The science of producing sound effects has now reached the point where production of apparatus for military training centers is more practical than use of some of the older and more direct methods. Electronic equipment is now employed entirely, with the use of a small number of cams, motors, and relays for timing control.

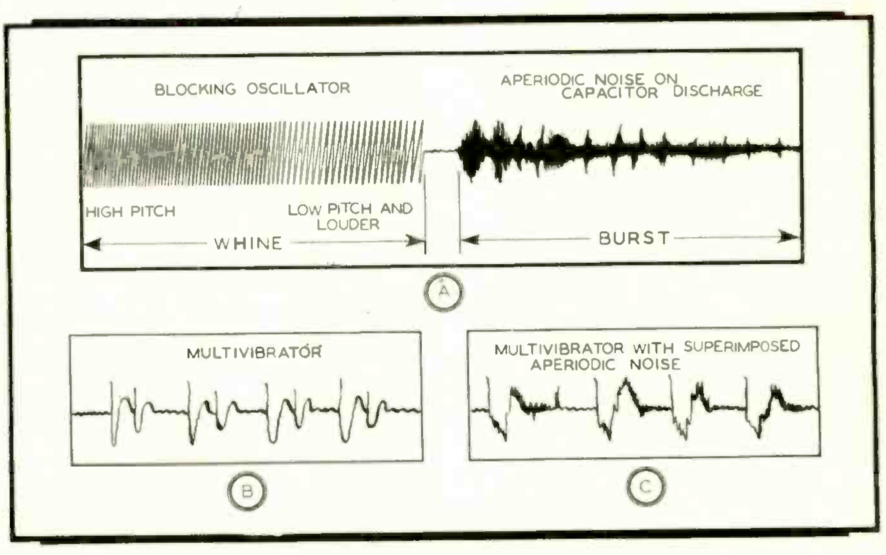


Figure 4

The method consists of generating a series of recurrent pulses of various wave forms upon which are superimposed aperiodic wave shapes which may

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[*Continued from page 22*]

be made to include any part of the audio spectrum desired.

Some examples of recorded wave shapes of military interest are shown in *Fig. 4*.

The aeroplane effect includes the sound of the engine produced by an LC oscillator containing certain harmonic components. This oscillator operates continuously and is fed through two control tubes in cascade. The first tube is normally biased to cut-off so that there is no sound until a motor-driven contact reduces the bias on this tube. When the sound becomes loudest the first tube draws grid current which loads the oscillator and reduces the frequency to produce the well known Doppler effect as the aeroplane passes overhead. The motor control then causes the cathode of the second tube to increase above ground potential and the sound eventually fades out. Front panel controls can be provided to vary the average engine speed and the time of the action.

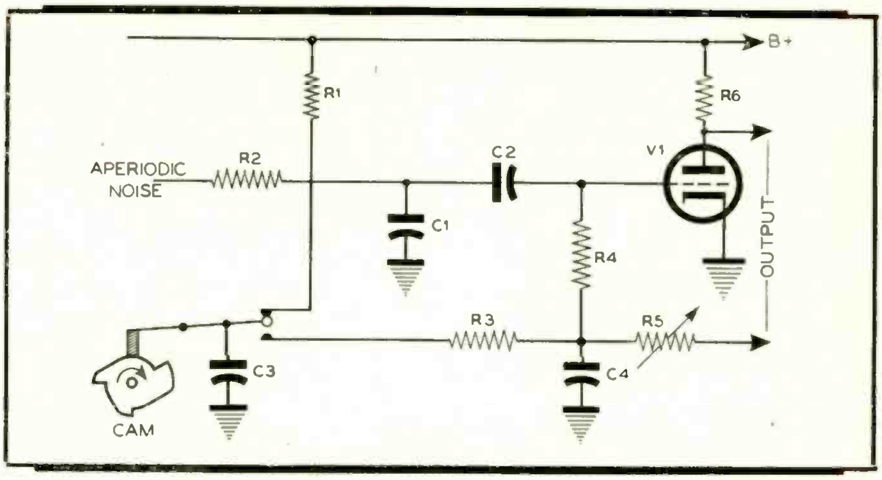

Figure 5

Methods of producing the sound of a teletypewriter and of a motorcycle are also described in this article. The complete apparatus constructed consists of a double relay rack with 16 separate chassis — 8 for the separate sound effects, 4 for the power amplifiers, and the remaining for mixing amplifiers, power supply, and local monitoring.

In the tank effect the engine noise is obtained by use of a saw-tooth wave form with a steep front. This is applied to a tube biased almost to cut-off. The grid of the tube is simultaneously modulated from a separate oscillator which operates at a fixed frequency to reproduce the "ring" of the exhaust note of the tank.

The engine speed is varied constantly by altering the bias of the blocking oscillator with a motor-driven contact. The clatter of the tracks of the tank is produced by filtering certain frequency bands from the aperiodic generator and adding these to the exhaust note. The final effect is that of a tank approaching, passing, and disappearing in the distance.

A simple circuit for producing distant shell burst noise is shown in *Fig. 5*. The aperiodic noise generator output is filtered by R_2, C_1 to remove the higher frequencies. Tube V_1 is biased beyond cut-off so that no signal is transmitted until the bias is increased. This occurs at uneven intervals when the rotating cam causes C_3 to become charged and then connect C_3 to C_4 through R_4. This

FOR REMOTE RECORDING

It is often desirable to tie in the operation of two or more pumps with a single level control, or to coordinate the operation of several pumping stations and reservoirs. In such cases, complete pump, valve, and level control systems may be supervised by the Builders Chronoflo Telemeter, which, by remote control, (using Guardian Relays) *automatically* registers temperature, pressure and flow by a three pen graph writer and on a flow totalizer unit. Chronoflo units are also used for weight control of materials handled on belt conveyors and for other purposes.

Relays BY GUARDIAN

This application demonstrates one of the most popular uses of the Guardian Series 40 Relay—its use as a magnet (without contacts). Its function is to control two clutches which govern the movement of the pen arms.

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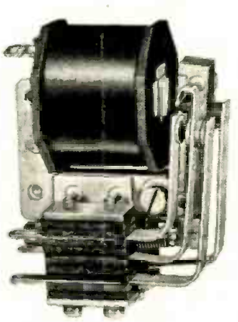

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[*Continued from page 24*]

results in a sound "attack" governed by R_3, the sound "decay" ratio depending on R_s.

TROPICAL BROADCASTING

★ Higher frequencies are required for good broadcast coverage in the tropics than in temperate zones. The high atmospheric noise level characterstic of the tropics is reduced at higher frequencies. Additionally, the higher degree of energy absorption in the ionosphere, than in temperate zones, may be overcome by going to higher frequencies.

The ground wave from a medium frequency transmitter is less rapidly attenuated than that of a short wave. But the range possible with use of an antenna properly designed for sky wave transmission is considerably greater on short wave lengths, for the same amount of power.

In the tropics, even higher frequencies are permissible than in temperate zones, because of the higher critical frequencies, below which refraction in the F layers of the ionosphere takes place.

The limiting frequencies are in general the critical frequencies, above which an undesired skip zone will be created. The critical frequencies vary with the time of day, as well as with the geographical location and with the seasons, being lower at night than at noon.

The above considerations are discussed by Mr. T. W. Bennington in an article entitled "Tropical Broadcasting" appearing in the June 1945 issue of *Wireless World*.

Mr. Bennington is concerned with economical broadcast coverage in the tropical regions of the British Empire, and points out that the frequency allocations of the 1938 Cairo Conference for tropical broadcasting should now be revised in line with our current information on the subject.

The author recommends the bands in Table 1.

The 2.5 mc band is only useful from midnight to sunrise and frequencies higher than 6.5 mc would be of use only during the afternoons.

The author points out that much wider coverage is required of a broadcast transmitter in the tropics, because the area to be covered is large in proportion to the economically developed population.

As regards noise, it is stated that the minimum requirement for tolerable reception is a signal/noise ratio of 20 db. For this value, the minimum field intensity for satisfactory reception is

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[Continued from page 26]

3600 μv/meter at 1 mc, 1550 μv/meter at 2 mc, 570 μv/meter at 4 mc and 170 μv/meter at 8 mc.

The estimated range of a 50 kw transmitter is as shown at right in Table 2.

(The values shown with an asterisk are for ground wave only, since the sky waves are rapidly absorbed at these frequencies, at noon, when atmospheric ionization is greatest. At midnight the sky wave increases the range. At the higher frequencies the ground waves are rapidly absorbed.)

TABLE 1

	3.5 mc	5.0 mc	6.5 mc
Period of use	early morning and late night according to season.	late afternoon and early evening, according to season.	From 9 am to 3 pm in Dec. and from 8 am to 7 pm in Mar. and Sept.
Approximate range (50 kw)	750 miles	600 miles	700 miles

TABLE 2

	1 mc	2 mc	4 mc	8 mc
Noon	*50 miles	*38 miles	220 miles	820 miles
Midnight	270 miles	460 miles	1350 miles	3300 miles

SQUARE WAVE MEASUREMENTS

★ The wave form output of a square wave generator or the output of an interposed network has been customarily analyzed by use of a cathode ray oscilloscope. This method presents

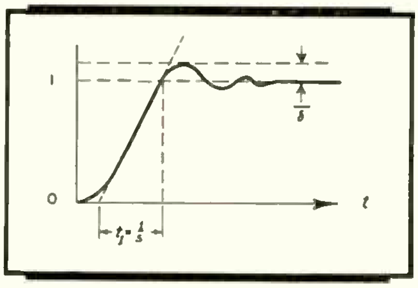


Figure 6

graphically the output wave form but does not give accurate quantitative measurements such as might be of interest in the design of a video frequency network or measuring distortion in a power amplifier.

A square wave analyzer which gives direct measurements of the overshoot in the pulse and the steepness of the wave front is described in the May 1945 issue of *Wireless Engineer* by Mr. C. C. Eaglesfield of the Mullard Radio Valve Company.

There are several variables which

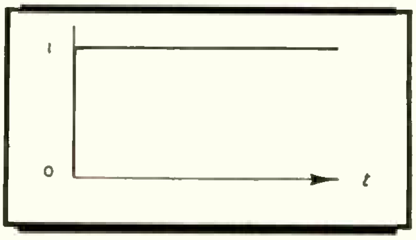
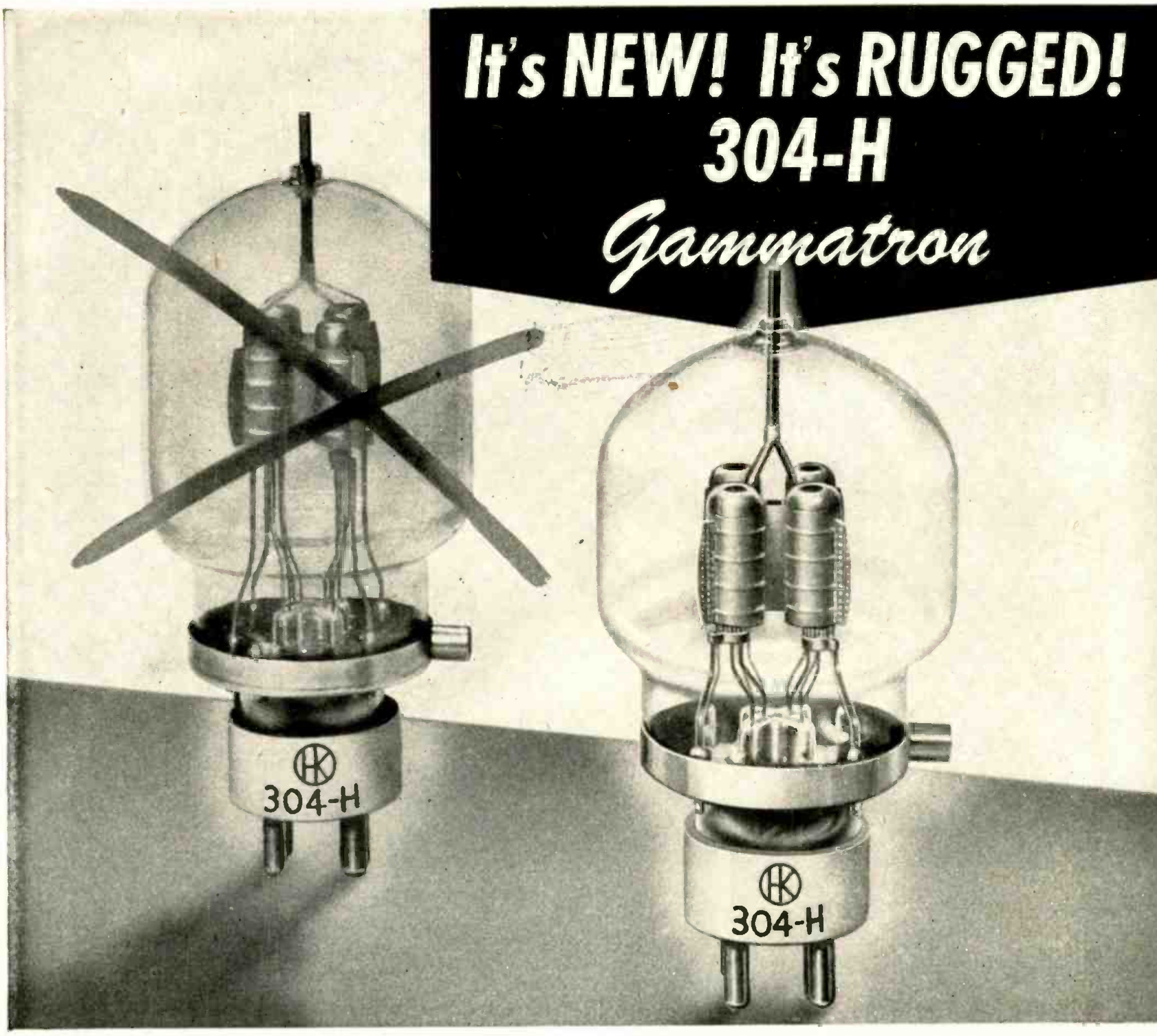


Figure 7

might be used to describe the shape of a square wave. For example one might be interested in the time of rise from the initial to the final value, the delay time introduced by a network, or the frequency of oscillation and possibly the rate of decay of the overshoot. The author finds that two figures are the practical limit, and chooses the speed of the network, s, and the overshoot, δ,



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[*Continued from page* 28]

as shown in *Fig. 6*. These two figures are believed to describe satisfactorily the response of a network to the Heaviside unit step of *Fig. 7*. The speed of the network is defined as the reciprocal of the time of rise along the maximum slope. The term δ is measured as a percentage of the final value.

Both of the above terms can be measured directly and a peak voltmeter is chosen for this purpose.

It is pointed out that the method is applicable to analysis of wave shapes other than square waves formed from the Heaviside unit step.

When the wave form of *Fig. 6* is applied to the grid of a pentode, the load

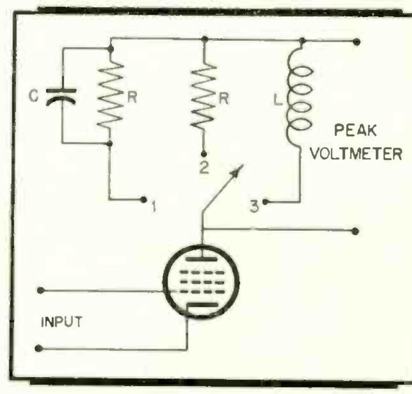

Figure 8

current will have the same wave form. The load voltage (*Fig. 8*), as measured with a peak voltmeter, will be proportional to *R* times the final voltage, for position *1* of the switch, providing the value of *C* is large. In position *2* the voltage will be proportional to *R* times the peak input voltage and in position *3* the reading is proportional to $L\,di/dt$. The voltages are shown in *Fig. 9*.

It is shown that $\delta = \frac{1}{2}\,\frac{V_2 - V_1}{V_1}$

and $s = \frac{1}{2}\,\frac{R}{L} \times \frac{V_3}{V_1}$

In the diode peak voltmeter there is an error due to the leakage when the pulse duration is short compared to the period. The amount by which the peak voltmeter differs from the input peak is shown to be proportional to t_2/t_1, where t_2 is the period and t_1 the pulse duration. This is approximately correct for $t_2 >> t_1$ and *E* is greater than a few volts. This error can be minimized by employing as low a t_2/t_1 as possible for measurement.

A second source of error occurs in the measurement of speed and is due to stray capacitance in the inductance *L* of the differentiating circuit, position *3* of *Fig. 8*. This error is high for high speeds or large distributed capacitance,

[*Continued on page* 70]

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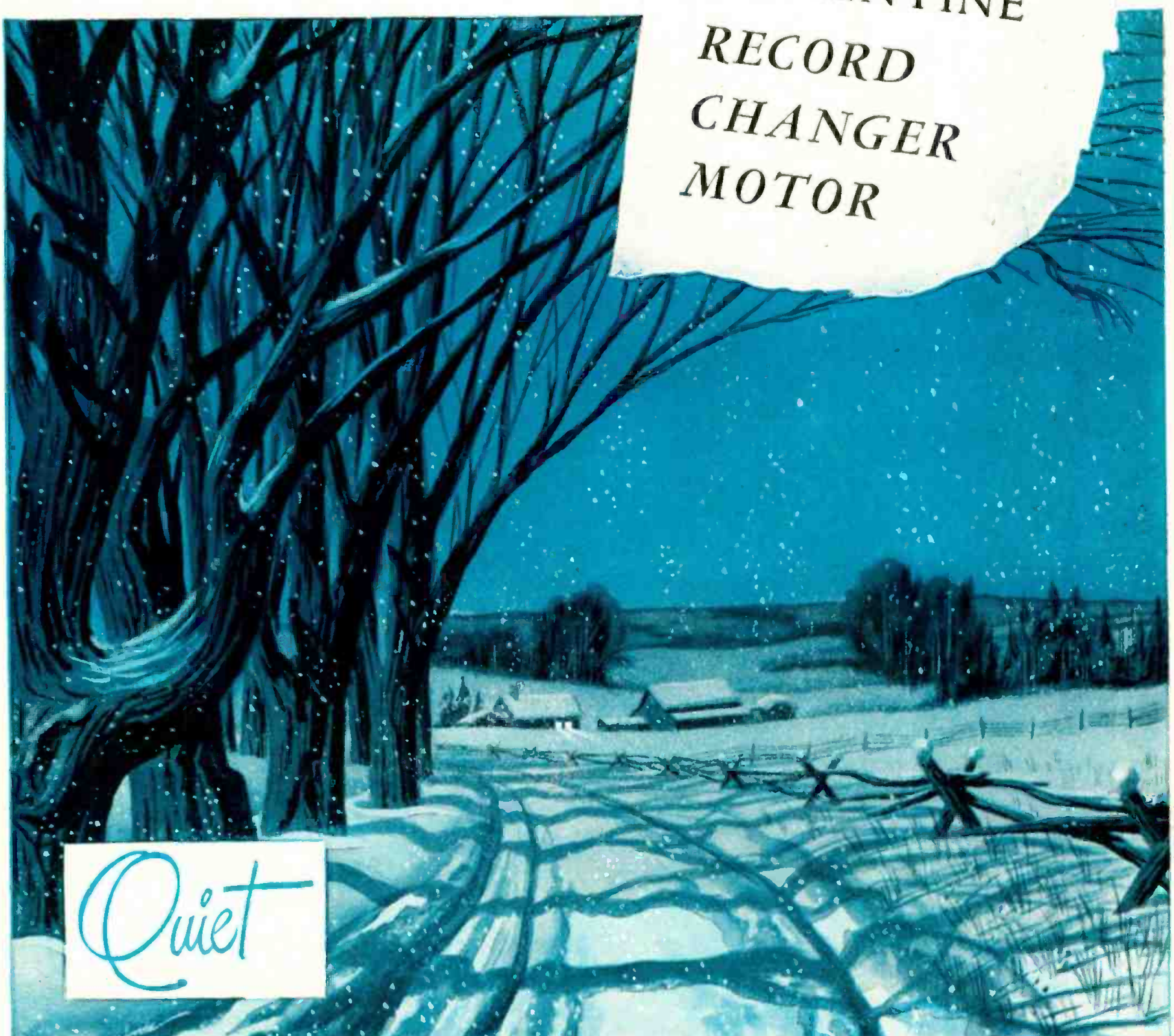


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Radio Insulating Materials

ALBERT H. POSTLE

Engineer, Sperry Gyroscope Co., Inc.

A discussion of the types, uses, properties, and limitations of certain newer plastics

PART 2

IN OUR PREVIOUS DISCUSSION of radio insulating materials,* the tendency of phenolic forms to be unsuited for certain applications was noted. Phenolics, however, can be modified to perform more satisfactorily some additional electrical functions.

Two major problems which confront the radio and electronic designer are high frequency beha.ior and arc resistance. Of equal importance, today as always, is the problem of moisture penetration.

Three types of modification of phenolics can take place in adapting the material to these uses: mixtures of new substances with the basic phenol formaldehyde resin, combination lamination, or introducing a new basic resin.

The first modification, that of the addition of new substances to the basic phenol formaldehyde resin was discussed previously. It was stated that optimum results could be achieved with phenolics if the proper resin, filler, and curing process were selected. Additional resins of the phenol (and creosol or xylenol) type can be added to modify the properties of the resin; specially pre-cured paper or other binder can be selected.

*RADIO, June 1945

TABLE 1

PROPERTY	Melamine Laminate (GMG)	Aniline Laminate (GBE)	Phenolic Laminate (PBE)
WATER ABSORPTION % IN 24 HOURS	1.30	0.60	0.90
VOLUME RESISTIVITY log ohms/cm. cube	10.2	10.2	10.2
INSULATION RESISTANCE log ohms	8.3	8.3	8.3
DIELECTRIC STRENGTH s/T - v/mil	500	300	550
s/s - v/mil	400	250	400
ARC RESISTANCE seconds	110	5	2
DIELECTRIC CONSTANT 1 kc	7.5	5.5	7.0
1 mc	5.6	5.5	5.5
LOSS FACTOR 1 kc	.52	.05	.40
1 mc	.23	.065	.20
IMPACT STRENGTH ft lbs./inch notch	10	2.0	0.4
TENSILE STRENGTH psi	15,000	9,000	10,000
FLEXURAL STRENGTH psi	15,000	14,000	16,500
COMPRESSIVE STRENGTH psi	6,000	28,000	30,000

DATA FROM JAN-P-13, JOINT ARMY-NAVY SPECIFICATION, AND PRIVATE SOURCES.

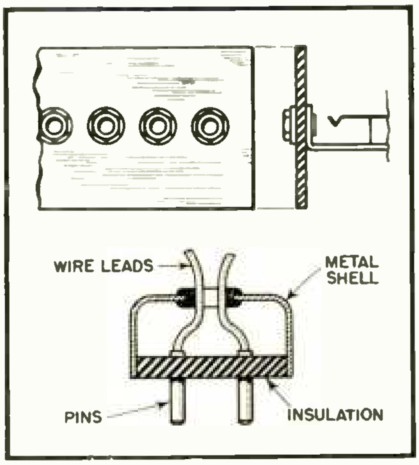


Fig. 1. Typical design uses of melamine laminates. Telephone jack panel board (above), and plug insulation

Any addition to the phenol resin must be compatible with the phenol, with the end result that such a modification will have many of the limitations of the phenol formaldehyde.

The second modification, that of combination lamination, must wait until we have considered the introduction of new basic resins.

Three thermosetting resins have a like ability to form laminates that the phenol formaldehyde has. These materials are urea formaldehyde, melamine formaldehyde, and aniline formaldehyde. The latter two are recent materials, developed primarily during the war period. The ureas have not found much favor in electrical applications as laminates for several reasons: high moisture absorption, lower physical strengths than some of the conventional phenolics, and critical molding conditions. Improvements have been made in these three properties in the last year, and it is expected that this resin will find more extensive use in the postwar field because of the improvements made, its relatively low cost, and its good dielectric properties.

Melamine Laminates

More interesting is the newer resin, melamine formaldehyde. As with the phenolics, melamine is not a material suited for all applications. Its favorable properties include high arc resistance, high dielectric strength, low moisture absorption, and higher heat distortion temperatures. It has a relatively poor high frequency response, is more difficult to machine than the phenolic laminates, and is a little more costly.

At the present moment, laminated melamine is available commercially with several types of filler: paper, linen, and glass cloth. One of the most prevalent forms is the familiar glass-cloth-based Navy type GMG, specified wherever arc resistance is of importance.

Typical properties of GMG, GBE (aniline formaldehyde laminate to be

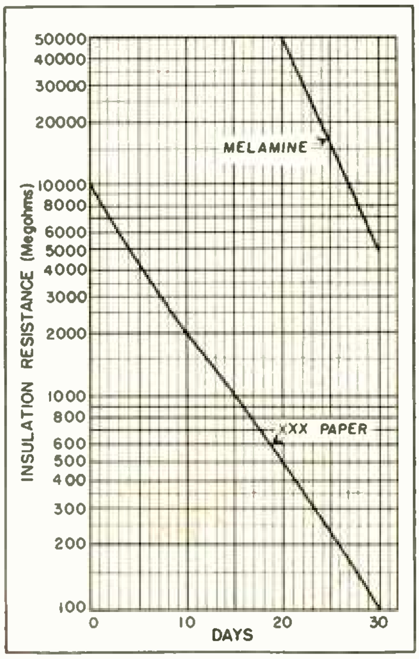


Fig. 2. Insulation resistance vs. time at 40° C. and 90% R.H.

discussed), and PBE (paper-based phenolic XXX laminate discussed in the first article* of this series) are presented in Table I.

The process of lamination is virtually identical to the process used in the manufacture of phenolic laminates. Melamine, a coke derivative, is applied in solution to the filler material and the impregnated filler, when dried and pre-cured, is formed under heat and pressure into the final laminated form.

Where shall this material find its place in radio and electronic design? *Fig. 1* illustrates two uses of melamine: a panel board and an electrical connector.

In the panel board, melamine has been specified because of its insulating properties and its high arc resistance. Minimum expected arc resistance is approximately 180 seconds by ASTM methods, whereas phenolics of the conventional form gave an arc resistance of two to three seconds. Here carbonized paths between the two outlets must be eliminated, here rigidity and dielectric strength are also of importance.

In the case of the connector illustrated, the problems are similar to the panel board. Arc resistance and insulating properties are of paramount importance — but, of almost equal importance is a low moisture absorption rate. Moisture absorption is more important here because of the confined area, the

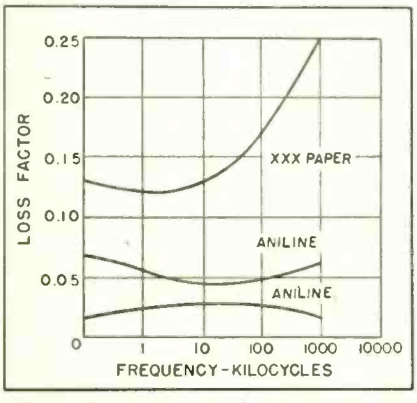


Fig. 3. Loss factor vs. frequency curves

proximity of the pins, and the damage which would be caused by swelling of the laminate. Comparative moisture absorption, plotted as insulation resistance time at 40°C. and 90% R.H., is shown in *Fig. 2*.

Melamine in linen or paper form can be machined with approximately the same techniques and tools which would be used with paper stock XXX. It does not cause trouble. When a glass cloth is added, machining difficulties and costs mount. Machining of GMG or a similar stock can best be accomplished using carballoy-tipped tools and lubricants.

Aniline Laminates

Aniline formaldehyde laminates are fast becoming more popular in radio design because of a number of advantages: good high-frequency response, lower moisture absorption, slightly higher heat distortion temperatures, and good all-around electrical properties. Outstanding disadvantages, at the moment, are relatively high cost, poor machining qualities, brittleness, and availability only as glass-based laminate.

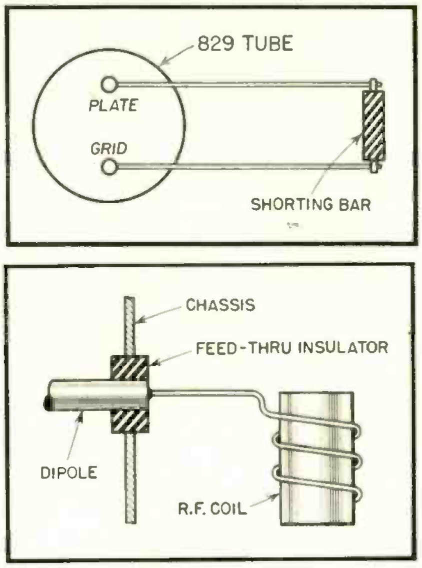


Fig. 4. Typical design applications of aniline laminates: shorting bar and feed-thru insulator

Aniline laminates have been available to the radio trade in two forms during the past several years: as a woven glass-based material and as a matted glass-based material. Material properties are similar and are presented as Navy type GBE in Table I.

Great stress has been placed on the high frequency response of insulating materials during the past several years. Let us consider briefly some of the problems involved.

Electrical leakage arises from two factors: insulation resistance and loss factor. When the loss current drain through an insulating medium becomes excessive, the material heats in proportion to its loss factor and in time disintegrates. Dielectric strength and insulation resistance, usually variables with temperature, decrease as the internal temperature increases.

It is interesting to note that the ambient temperature is not always the final determining factor in the breakdown of a dielectric. Often the internal heat rise, due to the loss and insulation resistance currents, is sufficient to cause failure.

Electrical loss factor is defined as the product of the dielectric constant and the dissipation factor. (The dissipation factor is the tangent of the loss angle and approximately equal to the power factor for low loss levels).

When a dielectric stress is placed upon the dielectric at a known frequency the power loss can be defined by the equation

$$L = 0.555 \times 10^{-12} fE^2 \frac{K}{Q}$$

where L is the power loss per cm^3, in watts, f is the frequency in cps, E is the voltage gradient in V/cm, K is the dielectric constant, and Q is the reciprocal of the dissipation factor.

Fig. 3 illustrates the loss factor of an aniline laminate vs. a conventional paper-based phenolic. It will be noted that the loss factor of an aniline at 10 mc is approximately ¼th that of a paper-based phenolic.

(Data for loss factor is for the two types of aniline formaldehydes commercially available and represents merely typical properties. Actual properties will vary from laminator to laminator.)

Where is this low loss property best used in radio circuits? *Fig. 4* illustrates three typical points where an aniline laminate can be used to a better advantage than the best paper-based stock (if the disadvantages of high cost and poor machinability can be overlooked).

In the spacing bar on the Lecher line tube support, such as may be used on an 829, the constancy of dielectric constant over a wide frequency range is of importance particularly when the tube is used as an oscillator or driver in a transmitter.

Also of importance is the loss current applied between the plate and grid. Suppose the tube is operating at 300 mc with an r-f potential of several millivolts existing between grid and plate, at this point any minor change in leakage (insulation resistance) current or loss current may seriously affect the bias of the tube.

This problem is also of importance in the feedthru insulator for the antenna, also illustrated in *Fig. 4*. Any capacity shunting the lead-in capacitor can be accounted for in design — but any capacity change will materially affect the response of the first tuned circuit of the receiver. At the same time, the leakage current (including the com-

[*Continued on page 72*]

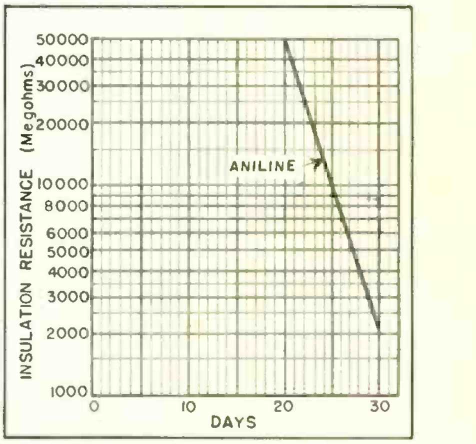


Fig. 5. Insulation resistance vs. time curve for aniline laminates

RAILROAD Radio Communication on the V. H. F'S.

This article describes the problems encountered and how they were overcome in establishing a satisfactory railroad communication system

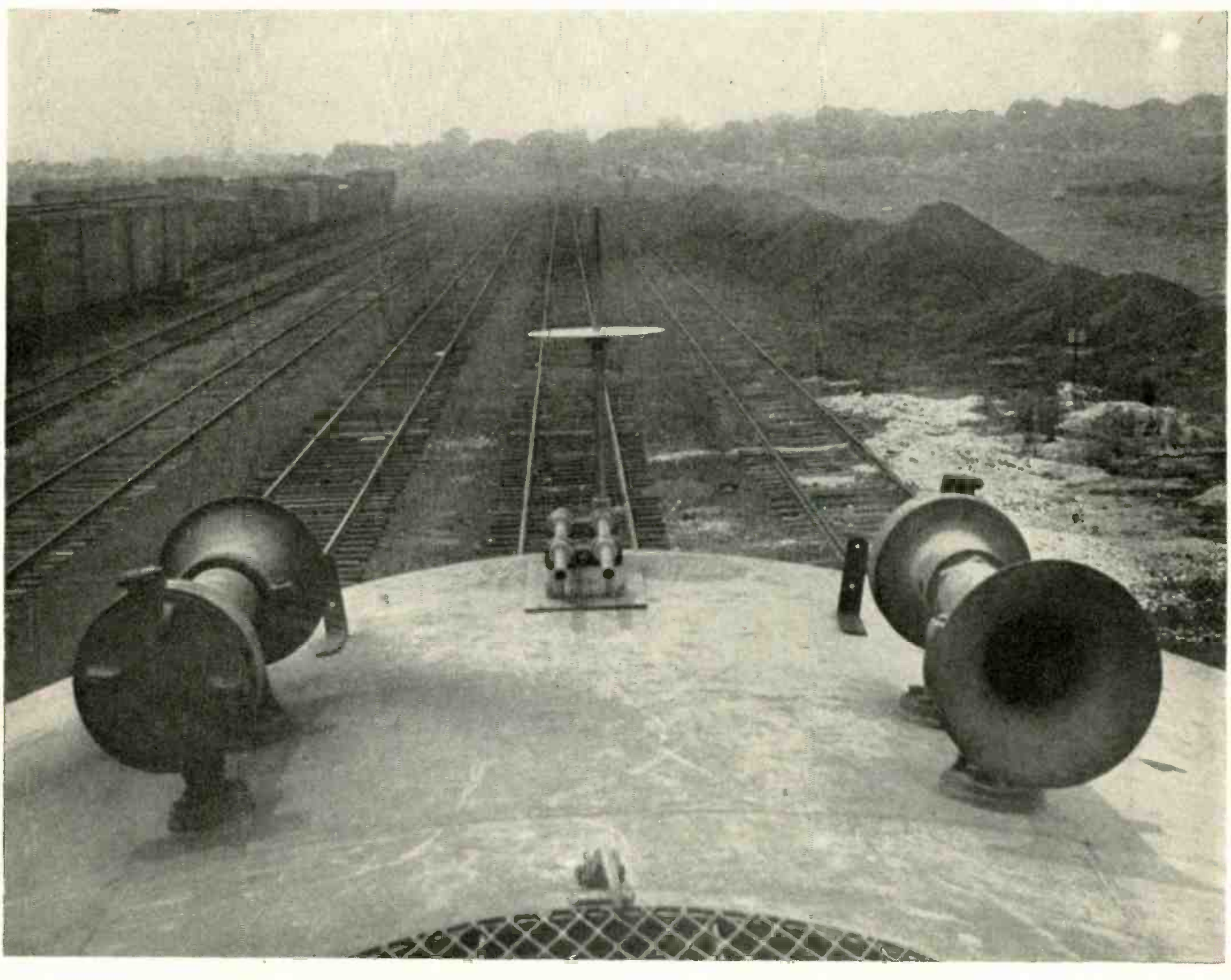
T. W. WIGTON

Supervisor of Electronics, Chicago, Burlington & Quincy Railroad Company

Early in 1944, the Burlington Railroad began extensive tests of two-way radio communication. Because much had already been done to develop the results which might have been expected in the lower frequencies, we selected 156 megacycles for these tests and conducted all experiments and concentrated our entire efforts at or near this frequency.

The Railroad's program called for a number of definite decisions to be based on our findings. First, and of great importance, we were interested in determining the dependablity of radio communication at these frequencies, the necessary power for a desired range and the design of equipment which would best be adapted to withstand locomotive vibration and other conditions not likely to be encountered anywhere but on a railroad. In addition to the actual radio experiments and from an operating point of view, the Railroad Management was eager to determine the useful possibilities and methods to which two-way radio communication might be applied in operating a long freight train to an added advantage, also in the expediting of switching

156-megacycle capacity-loaded antenna mounted on forward nose of 5400 H. P. Diesel freight engine



movements in large freight terminals. There were potential possibilities, all of which required further test and application to make them a reality.

To the best of our knowledge, the use of frequencies above 150 megacycles, prior to our experiments, had never been used commercially to any great extent, for ground communication. As a result, the work we were about to undertake was strictly research. After six months of constant use and test, most problems were solved along with others not first anticipated.

With the cooperation of engineers of the Bendix Radio Division of Bendix Aviation Corporation, and using several of their VHF transmitters and receivers, we equipped a group of Diesel locomotives and thereby established a field laboratory in which to demonstrate the actual working conditions to which the equipment will be subjected during normal operations.

Antennas

Using a few fundamental facts gained from experience on 40 megacycles and lower frequencies, many mysterious behaviors encountered became susceptible to reasonable explanation. Thus the clues to many questions as to the type of feed and type of antennas in general became clearer and many false conclusions were avoided. Very strong signal strengths have prevailed at all times within line-of-sight (horizon distance in miles equal to 1.22 times the square root of the antenna height in feet). At many points several miles beyond this distance, excellent signal strengths have been observed with consistency. This may be a function of ionosphere refraction.

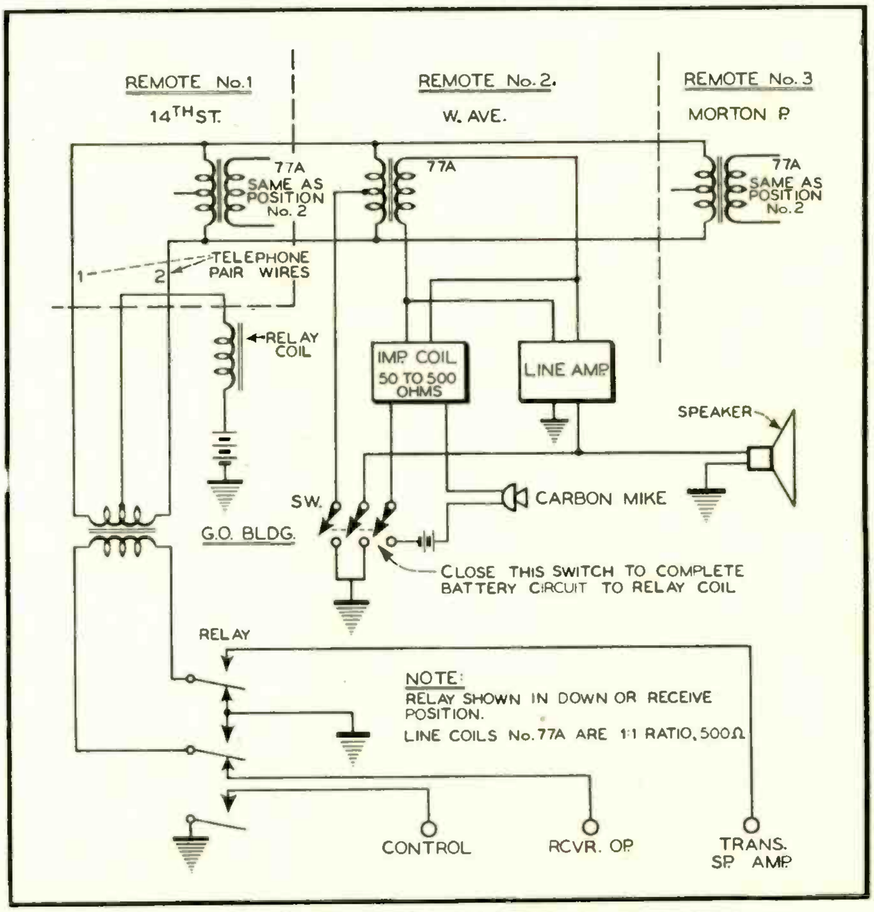
The fixed station with a power input of 15 watts (amplitude modulated) is located on the top floor of the Burlington General Office Building. A suitable telescoping pole supports the "old reliable" half-wave vertical doublet antenna 305 feet above the street level. The location of the control station was chosen based on two important facts. First, the height gained wtihout complicated antenna structure and second, the location in respect to the traversed area of terminal switch engine movements. All switching movements are confined to a south and west direction in respect to the location of the control station. This desirable condition almost immediately suggested added economy in transmitter power input by the use of a directional antenna system.

Many different types of directional arrays have been tried with excellent results. It would be difficult and perhaps incorrect to make a definite statement as to which type of antenna proved the most effective. Briefly, however, the different antennas tried, such as the square corner reflector, four element parasitic arrays, collinear Sterbas, and horizontal rhombics, followed true to past proven performances so many times described in various magazines and engineering books. Without question, the horizontal terminated rhombic gave the greatest signal gain of any of the directional antennas. It consisted of eight wave lengths per leg, fed through a quarter-wave matching section by a 72 ohm co-axial line. The one serious objection was that the resulting beam became too sharp for practical use. As a result, the required signal strength at six or eight miles distant and 45 degrees off the end was too low for satisfactory and dependable communication. This could have been corrected but further difficulties were later experienced.

Prior to the rhombic, all antennas, both mobile and on the fixed station were vertically polarized. At speeds upward of 15 MPH, rapid fade or sometimes termed signal flutter had been experienced in areas of low signal voltage but at no time became serious enough to warrant study or correction. The flutter became faster as the mobile unit speed increased. With horizontal polarization on the mobile unit and using the horizontal rhombic, at a given point in line with the directivity of the antenna, the overall signal strength was several db better than any of the other arrays mentioned. It was further proven, in spite of the increased signal strength, at any speed above 8 or 10 MPH, transmission, due to signal flutter, becomes unintelligible.

An explanation of this phenomenon can perhaps best be given by the fact that the mobile unit was closely surrounded by numerous buildings and poles spaced along the right-of-way adjacent to the tracks. It becomes a point of discussion as to whether this may be a function of multiple patch reflection but actually the reason for this condition predominating with horizontal polarization still appears to be unsolved and one requiring further study.

Various types of mobile antennas have been given intensive study and trial. Unfortunately we are definitely limited to a maximum antenna height above the locomotive roof. Obviously this limitation is governed by overhead structures such as bridges, signal towers and viaducts. The antenna height proper is, of course, dependent upon the locomotive height above the rail. Allowable heights on the Burlington range from 17 inches to 27 inches above the roof surface. At 156 megacycles a half-wave antenna in free space is approximately 35 inches long. This dic-



Schematic of remote control setup for C. B. & Q. radio installation

tates one of two types of antennas, either a quarter-wave Marconi or some form of capacity loaded vertical.

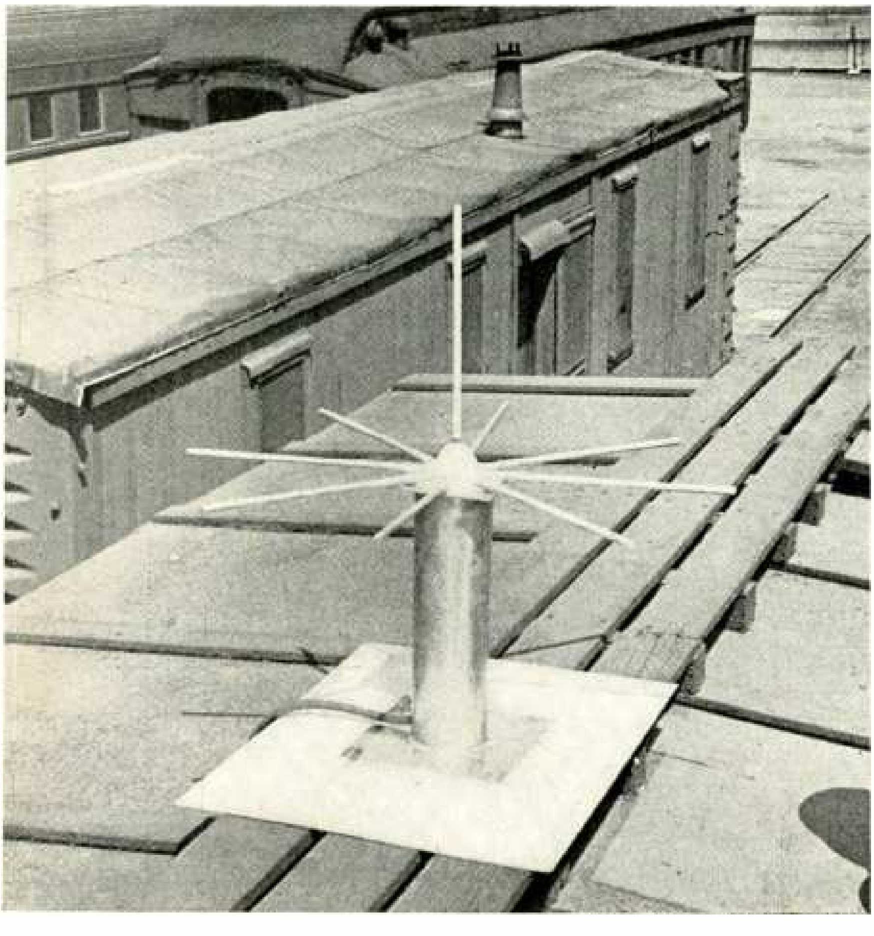
The first tests began using a quarter-wave vertical rod ground plane antenna fed against ground by an unbalanced co-axial line. Matching a concentric line to a vertical quarter-wave radiator has definite limitations. It is difficult and impractical to examine properly a concentric line for standing waves. Any radiation from such a line (due to current unbalance or mismatch) will tend to combine with the antenna radiation and result in raising the vertical angle of radiation. This is a condition we do not want at 156 megacycles.

After a month of experimenting with the ground plane antenna it became evident that a more efficient radiator of some description was necessary to cover the required range with a dependable signal. It was apparent that the basic answer was in securing a closer match between the co-ax and antenna, using a quarter-wave radiator with more radiation by the antenna itself and less in the stub and line. Numerous configurations and feed methods resulted. These included a form of co-axial antenna popular in the 40 megacycle police installations, but modified with the lower half in the horizontal plane. Many other modified antennas commonly employed on the lower frequencies, slightly modified, were also tried, with none too good results.

As a result of many experiments the answer, at the time of this writing, appears to be a capacity loaded vertical radiator matched at the base of the antenna by an adjustable quarter-wave horizontal stub. In reality the resultant antenna resembles the voltage fed zeppelin often used on the lower frequencies. Capacity loading of the vertical radiator is done by an adjustable disc, 12 inches in diameter, and capable of being moved up or down to any given fixed point on the vertical radiator. Tuning of this antenna became very simple after a few basic principles were put in practice. Briefly, the antennas are pruned by maximum field strength indication. It proved interesting to note that maximum field strength is not a function of maximum power input based on plate current times plate voltage. In pruning this type of quarter-wave vertical, the plate current can easily be brought to twice normal by careful adjustment of the matching stub lengths. Resonance usually is found at or near a quarter wave. At this point, with the 12 inch disc at the extreme far end, a field strength reading is taken. As the disc is lowered the plate current begins to fall and the field strength rises. Moving the loading disc further down the radiator will cause continual rise in field strength and decrease of plate current to a point where resonance is found and the reverse condition will begin.

It has been found with similar antennas of this type using a quarter-wave radiator loaded to an electrical half-wave by capacity to ground, the radiation resistance and radiation efficiency is greatly dependent upon the actual point on the radiator where the loading disc is placed. Maximum field strength resulted with the disc placed approximately 1/20 wavelength below the top of the vertical radiator.

As mentioned before, this particular antenna is serving our need very well. The height above the locomotive roof is within limits and the overall radiation efficiency is ample to cover our desired range with several microvolts of signal to spare on the fringe of the talking circuit. Further experiments, no doubt, will bring to light some form of antenna far superior to this particular one developed, or any thought of thus far.



156-megacycle quarter-wave ground plane vertical antenna

Transmitter and Receiver

The transmitter and receiver units used in all of these tests were designed and manufactured by the Bendix Co. for the use of the Army air forces. For this reason the description here can only be high-lighted.

The transmitter and receiver are nothing more than straightforward design. The transmitters are amplitude modulated, employing a crystal controlled doubling oscillator at a frequency near 8000 kc. capacity coupled to the associated frequency tripler stages driving the final push-pull r-f amplifier. Plate power input to the final amplifier averages 15 watts working into a 55 ohm antenna load.

The receiver consists of one r-f stage, crystal controlled oscillator, 1st detector, three 12 megacycle i-f stages, 2nd detector, and audio amplifier with two watts of audio power. On first thought, two watts of audio does not seem quite enough power to overcome the noise of a railroad engine cab but it proves ample power for good loud speaker volume, overriding all cab noises except the whistle. This is not objectionable due to the short duration of the whistle blasts.

The necessity of generating the various voltages needed in radio equipment presents a problem on a railroad caboose or engine. There are many ways to accomplish the task but to standardize on any one method is rather difficult. The ideal arrangement calls for quick and simple interchangeable units to facilitate occasional repairs. Diesel locomotives, to which our experiments have been confined, maintain 30-volt lead batteries, some 64 volts and still a third 120 volts. A distinct advantage

Radio equipment on 1000 H. P. Diesel switch engine. Engineer holds differential microphone

is the almost unlimited current supply available but efficiency is also an important item.

Among various railroads there have been long discussions about what the most practical attack on primary power might be. It was first generally agreed to adopt 110 volts a.c. as a primary power on all engines and cabooses to operate the radio equipment. This would satisfy standardization of all radio units and each would be readily interchangeable with one another. It did seem, however, a round about way to run a rotary converter, d.c. to a.c., then through the power transformer into rectifiers for the necessary d-c voltages. This represented two pieces of equipment to accomplish one purpose. To do the entire job in one operation required a dynamotor capable of three d-c output voltages; namely, plate positive, grid bias negative and filament voltage. At the present writing we have had dependable operation with such type of machine. It delivers the three necessary output voltages in one small compact unit and has only one disadvantage, that the motor end obviously must match the battery voltage of the different locomotive battery supplies. This is easily solved and still requires only three different types of dynamotors to protect the three battery voltages.

In the past there has been no necessity for providing a source of electric power on the caboose of a freight train. Marker lights have been the kerosene type lantern which are dependable and require little maintenance. The installation of radio equipment on these cars creates a necessity for some form of power. This power must also be dependable and available both while the car is in motion and during periods when the train takes a siding or for some reason is delayed for an indefinite period of time. Generation of this power might be done by equipping the car with a strong battery and axle-driven charging generator. Another possible source of power might be a generator driven by a propane gas internal combustion engine unit mounted on the roof of the car. With this type of installation we might very well eliminate bulky storage batteries but whether an engine of this kind would be entirely dependable in all kinds of weather and conditions remains to be seen. Actually the problem of how and where to get this power is not a serious one but requires careful planning in order to meet the necessary requirements. Foremost in these requirements is 100 per cent availability and dependability. As mentioned before, primary power on all locomotives is already available.

The entire locomotive and caboose radio units must be capable of withstanding severe shock, both up and down, forward and backward. This requirement is due to slack action encountered in long freight trains as a result of four to six inches of slack between each car. Consider a hundred car freight train, the engine starting to pull forward; before the entire slack has been pulled the engine is moving perhaps 3 MPH. When all of this slack is taken up, the caboose will be required to accelerate from 0 to 3 MPH instantly. In order to retard some of this shock to the radio equipment it has been provided with rubber shock mounts. After several thousand miles of operation with conditions like this, some form of trouble might be expected. We have, however, experienced no difficulty or had any equipment failures due to violent shock or vibration, thus far, after covering approximately 18,000 miles of actual operation.

Employment of the VHF's

Frequencies in this region of the spectrum are essentially propagated over a line-of-sight path, with some exception under certain conditions, as brought out before. However, basing future railroad operations on line-of-sight propagation, it becomes practical to assign several stations to the same frequency with much less geographical separation and still maintain a minimum of mutual interference. As a result the station per channel ratio is greater than would be possible on the lower frequencies. In view of the recent F.C.C. frequency allocations (between 152 and 162 megacycles, 60 channels, each 60 kc wide) for railroad use, stations in slightly separated localities can be assigned to the same channel, thus adequate room for railroad radio is provided for a long time to come.

Perhaps there is some question of the necessity for communication beyond line-of-sight on a railroad. In the distant future this need may develop as the use of radio communication becomes better established on moving trains. In the event of such a future requirement it would become necessary, and certainly feasible, to install automatic relay repeaters at necessary intervals to cover the longer distances. This type of transmission might be somewhat more costly but still more dependable than some lower frequency channel direct transmission, due to the behavior of wave propagation.

Radio communication activities on the Burlington Railroad have to date been confined to short distances (1 to 20 miles) and there appears to be no immediate necessity of any long distance communication conducted by radio. If and when such occasion should arise it would not be too diffiult to accomplish satisfactory communication over any distance desired by the use of relay transmitters and receivers at the necessary intervals.

Amplitude or Frequency Modulation

Lengthy debates have resulted among the different railroad's communication engineers concerning merits of FM over AM and vice versa. As mentioned before, the Burlington tests have been strictly AM, so perhaps we are not fully qualified to pass judgment. However, it might be well to cite a thought or two and remain neutral.

During the past fourteen months, in the course of many cross-country tests, we have encountered and experienced many severe electrical storms. Using AM equipment we were able to maintain perfect communication at all times. During a nearby lightning flash, slight shock excitation could be noticed in the receiver output but far too low in amplitude to interrupt the voice modulation to any extent. This same condition has also been noticed with low signal to noise ratio with the transmitter and receiver separated by a distance of 15 or 20 miles.

The mention of atmospheric interference may lead to the question of man-made electrical disturbances on frequencies above 150 megacycles. Extensive tests were conducted with the thought in mind to determine what, if any, electrical devices or motors might cause trouble. Diesel electric locomotives of the type used on these tests have numerous d-c circuits and motors. Voltages range from 30 to 1000 volts. In some instances the radio receivers and transmitters have necessarily been mounted directly over and close to the field and commutator of the main direct current generator. This generator produces a large field and at maximum speeds, develops in excess of 800 volts at several hundred amperes. This obviously is a natural source of noise generation. Filtering of such equipment would become an engineering problem and added expense. It is very evident, however, the resonant output frequency of this machine and those associated with it is far separated from the VHF's. With temporary installations made, which themselves invited noise pickup, there never occurred any trace of noise that was audible in the receiver output.

The inherent characteristic of FM signals, i.e., the stronger signal prevailing over the weaker one, might not be desirable from an operating point of view, if several engines should be working in close proximity. Consider a group of 20 radio equipped locomotives working within a 30 mile radius. Obviously the channel will at times be crowded with general orders and instructions at which time any one certain engine might necessarily have some form of emergency requiring immediate contact with its home base. If this same engine happened to be on or near the fringe of the circuit where low signal strength prevailed, he would be unable to break in or attract attention and as a result his radio would be useless. This condition would be less liable to occur when using AM. Though his signal would be low, a heterodyne or beat (due to slight frequency differences) would result, which would, undoubtedly, attract the home base operator's attention.

It is apparent that satisfactory radio communication can be handled with amplitude modulation, thereby relieving the necessity of wider and more channels that would be required for suitable frequency modulated equipment.

Remote Operation

As mentioned before, the fixed station equipment is located on the top floor of the Burlington General Office Building. All of the experimental antennas are fed by co-axial cable from the transmitter room to the roof. This is an ideal condition in being able to have some 300 feet elevation with the transmitter and receiver in close proximity of the antenna itself, with minimum of r-f power loss in a short transmission line.


Yard Master Western Avenue freight yard office. Remote control position No. 2

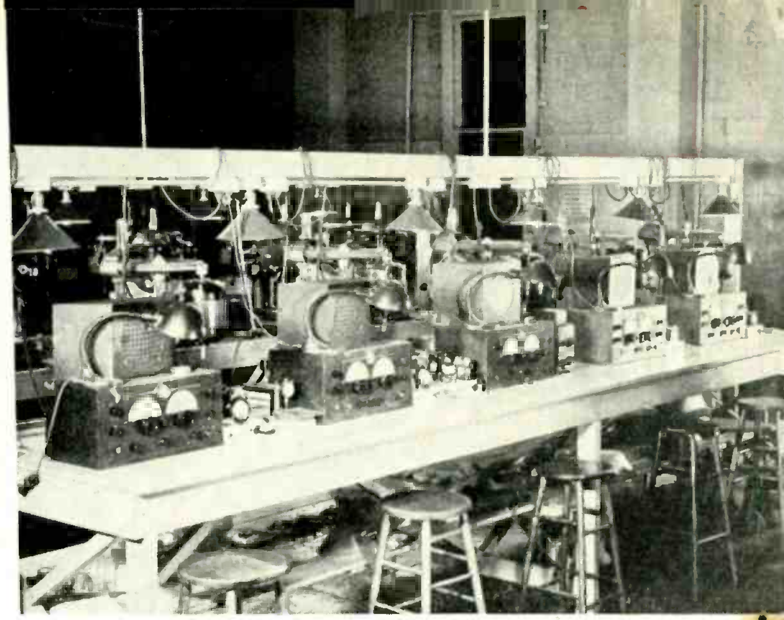
All communication and orders to the mobile units from the yardmasters at outlying terminals is handled through a 500-ohm physical telephone pair to the fixed station transmitter. At the present time there are three remote operating positions, viz., the passenger terminal yards, the freight delivery and make-up yards, and the freight inbound and outbound terminal.

There are many advantages gained by control of this kind. Any number of additional remote points can be readily set up by merely providing a drop pair into the office of "yard shanty" along the right of way where contact with the engines is desired. In this way, one radio transmitter and associated equipment handles the work of several.

Control of the fixed station transmitter is accomplished by using a simplex coil shunted across the telephone pair wires. When the circuit is idle, the receiver output is across the line continuously. At such time that any mobile unit desires contact, he addresses his call to the yard office concerned with his message. Each yard office is equipped with a standard desk telephone and push-to-talk switch. The function of the push-to-talk switch merely places the simplex coil center tap at ground potential and energizes the receive-transmit relay of the radio transmitter. To prevent crosstalk within the telephone cable, the audio gain on the line is held to within minus one or minus two db and brought back up to loud speaker volume at each remote point by a standard line amplifier. Our farthest point of control is nine miles from the radio transmitter. It might be expected that line levels would vary to some extent in relation to the lengths of the line, however, modulation of the carrier is maintained very near 100 per cent without the use of speech amplifiers or line pads at any of the remote stations.


5400 H. P. Diesel freight engine with 156-mc capacity loaded antenna

(*General Electric photo*)
Detecting flaws in quartz by Klieg light



(*James Knights Co. photo*)
Radio lapping department. Frequency of blanks is followed on communications receiver

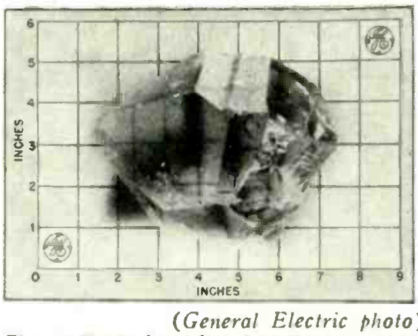
MODERN QUARTZ

RICHARD E. NEBEL

PART I

THE METHODS by which quartz crystals are produced at present represent tremendous advances over those methods in use as late as 1941 and demonstrate again to the world the boundless inherent initiative of American industry. While tremendous improvements have prevailed in all manufacturing processes, they are especially remarkable in the quartz crystal field in light of the fact that before the war the manufacture of quartz oscillator plates was more or less a laboratory project, the total annual output for commercial applications amounting to approximately twenty thousand. It is obvious that there was no need for the development of mass production methods inasmuch as orders very seldom called for large quantities of a particular type finished to the same frequency. More often a user required only one crystal at a specific frequency. Each crystal unit was therefore an individual project to be fabricated using the most precise methods the state of the art afforded, some of which, it must be admitted, were of the cut-and-try variety.

With the advent of war the need arose for quartz crystals in quantities entirely out of proportion to the capabilities of the industry. How the chaos resulting from this sudden demand was quelled and how the innumerable obstacles were surmounted to meet this demand would entail a close literary collaboration among those concerned in order to obtain a complete picture. If this ever does come about, the reader can be sure it will read like a dime novel "thriller"! That the many obstacles were surmounted is evidenced by the high efficiency and durability of military communications equipment. It has been said that a quartz crystal is the heart of a transmitter. During the first year of war over seven million "hearts" were manufactured. Subsequent years have shown twenty and thirty million!



(*General Electric photo*)
Fig. 1. Typical peak prismatic type raw quartz crystal

It is the purpose of this paper to describe in general terms the present status of the quartz crystal industry and to touch upon the individual methods involved in as great a degree of detail as is considered feasible for an article of this scope. The author acknowledges the kind cooperation of the following companies in furnishing photographs making possible the graphic illustration desired: Bliley Electric Company, James Knights Company, General Electric Company, North American Philips Company and Radio Corporation of America.

Outline of Operations

In a mass production industry as relatively new as that of quartz crystals there are bound to be variations in the methods used by different companies. As the end result is all that counts, it cannot be said that one particular system is better than another and therefore no preferences will be made in the following descriptions. As in any other field there are various methods by which the same result may be attained so the following overall picture does not necessarily represent the manufacturing procedure in any one plant. Rather, it is a cross-section of the various phases of operation employed by one or more companies, each phase being regarded individually.

The steps involved in the manufacture of quartz oscillator plates from raw quartz to finished crystal my be roughly outlined as follows:

1. Raw quartz inspection and sorting.
2. Raw quartz grading to determine usability.
3. Mounting on glass plates for sawing operation.

(*North American Philips photo*)
Fig. 4. X-Ray orientation machine

(*Bliley Electric Co. photo*)
Fig. 5. X-Ray orientation machine in operation. Two goniometers are provided for each operator

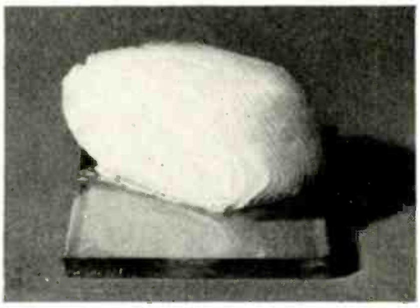
CRYSTAL PRODUCTION

Mass production of quartz oscillator plates, ground to highly precise frequency limits, is made possible by improved manufacturing and test methods. These are discussed in this article

4. Mounting in saw; trial cut made.
5. X-Ray inspection of trial cut made and angle error corrected on saw table.
6. X plane cut, quartz dismounted and etched in acid; inspection for twinning and flaws.
7. Trial wafer cut made. X-Ray checked and saw angle corrected.
8. Entire piece wafered.
9. Wafers etched in acid.
10. Twinned areas marked out.
11. Wafer layed out for dicing.
12. Dicing of blanks on trim saw.
13. Edging of blanks to required dimensions.
14. Blanks sorted in groups of equal thickness for lapping.
15. Machine lapping in two or three steps.
16. X-Ray checks on blanks for ZZ' and XX' angles.
17. Final finishing to frequency by abrasion, etching or tumbling.
18. Mounting in holders, marking and sealing.
19. Temperature, activity, moisture, drop and vibration tests.

Raw Quartz

Practically all the quartz used in radio oscillator and telephone resonator work is imported from Brazil. The wartime demand presented a serious transportation problem which was largely solved by military aircraft returning from North Africa by way of South America. Cargo plane loads were brought back to the United States making possible the necessary high production.



(*North American Philips photo*)
Sawed wafer comb. Wafers are still cemented to glass block

Modern methods have permitted the use of quartz that before the war was considered scrap. This includes small pieces weighing less than one hundred grams and unfaced material, that is, pieces having none of the nautral faces in evidence. The use of this type of material was necessitated by the increasing scarcity of radio grade quartz and was made possible mainly by the application of X-Ray techniques, the development of which are directly responsible for current mass production.

A standard system of grading quartz has been adopted and is based on the percent usability determined by inspection. Grades are designated by the letters *A*, *B*, *C* and *D* and usually carry the apendage "faced" or "unfaced". Grade *A* denotes the highest percentage usability. The grade of course determines the price per pound as does the average weight per piece. The heavier the piece the greater cost per pound. The price scale roughly extends from two to thirty dollars per pound. There are of course exceptions above and below this range.

In grading quartz the operator uses an instrument called the Quartz Inspectoscope. This consists of a tank filled with oil in which the crystal is immersed and examined under an intense arc or Klieg light and a polarized beam of light. Polarization is accomplished by crossed polaroids. A viewing system of lenses and mirror is employed. Examination in this manner will reveal optical twinning, bubbles, rutile, veils, needles, fractures, etc. The bad portions are marked out as effectively as possible to save needless cutting.

Quartz Cutting

The reader is no doubt familiar with the structure of a natural quartz crystal. This is illustrated in *Fig. 1*. The *Z* axis runs parallel to the length and the *X* and *Y* axes are perpendicular to the *Z* and spaced 60° apart. The characteristics of a finished quartz plate depends upon the accuracy to which the desired angles of cutting are held with respect to these axes. Angles may be measured to an accuracy of a few minutes of one degree by means of X-ray reflections. This process will be described further on.

Two general methods of cutting

blanks are employed. In the case of large pieces of quartz (approximately two pounds or over) rectangular blocks are cut from the mother crystal and these are sliced into blanks just like a loaf of bread. In the case of smaller pieces the piece is set at the proper angles on the saw table and wafers are sliced down, the thickness being that desired for the blank. The wafers are then examined and the blanks layed out with pencil. They are then diced out with a dicing saw.

Years ago the old time "muck" saw was used for cutting. This consisted of a metal disc, usually copper or brass, running through an abrasive mixture of emery or silicon carbide and water. The abrasive was carried to the quartz and the disc wore its way through. This was a very lengthy, laborious and uncertain process. Today diamond saws are used with a tremendous increase in efficiency. The diamond saw is a copper or steel disc the periphery of which is charged with diamond dust. The diamond dust is forced into small nicks and these nicks are then tamped closed. The saw revolving at high speed is fed to the quartz and the point of contact is sprayed with a coolant by means of a pump. Quite high speed cutting results, approximately five square inches per minute. The exact rate of cutting varies around this figure, depending upon circumstances.

After cutting by the wafer method, the wafer is layed out into blanks of the required size by use of a template and pencil and then it is diced out by means of a dicing saw. The dicing blade is usually of the resinoid bonded type, that is, the diamond particles are set in a resinoid bond instead of metal. This type of blade is about three or four inches in diameter whereas the cut-off saws run from eight to fourteen inches in diameter. One method of dicing is to cut halfway through the thickness of the wafer and then snap the blanks apart by hand. The rough edges are then removed by the edging operation.

Edging

A diamond edging wheel is used to bring the blanks to the desired dimensions. This wheel is usually about six inches in diameter and has the outer one inch of one side impregnated with diamond. The blank is then squared against the side of the wheel. A jig is used to hold the blank and only permits grinding until the desired dimension is attained. A coolant must of course be used, just as with the saw.

An alternative method is known as "loafing". The blanks are cemented together with paraffin or beeswax in the form of a loaf and the entire loaf ground to size on a diamond wheel or on a power driven iron or glass lap using an abrasive mixture. A large number of blanks may be squared at a time in this manner.

Lapping

Another factor responsible for mass quartz crystal production was the development of the mechanical lapping machine. These machines lap groups of blanks at a time to a degree of flatness and parallelism that would be difficult or impossible to attain by hand methods. One of the original methods of grinding blanks flat and parallel was to cement them in a circle to a thick block of glass. The overall thickness of blank and glass was measured with a micrometer and the known thickness of the glass subtracted from the measurement to obtain the thickness of the blank. The block was applied by hand to a motor-driven iron lap and the blanks ground to the required thickness.

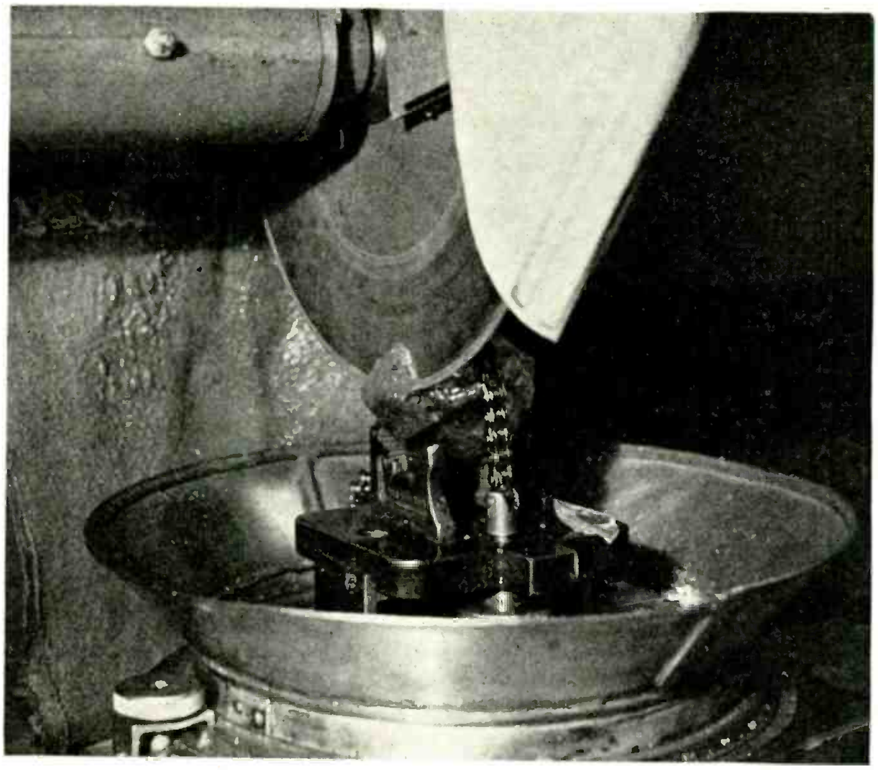
This method provided no control over the contour of the blank faces which is important to crystal activity. But precision results are obtainable if the upper plate to which the crystals are affixed is rotated mechanically with an eccentric motion. The motion of the lower iron plate imparts a rotary "walking" mo-

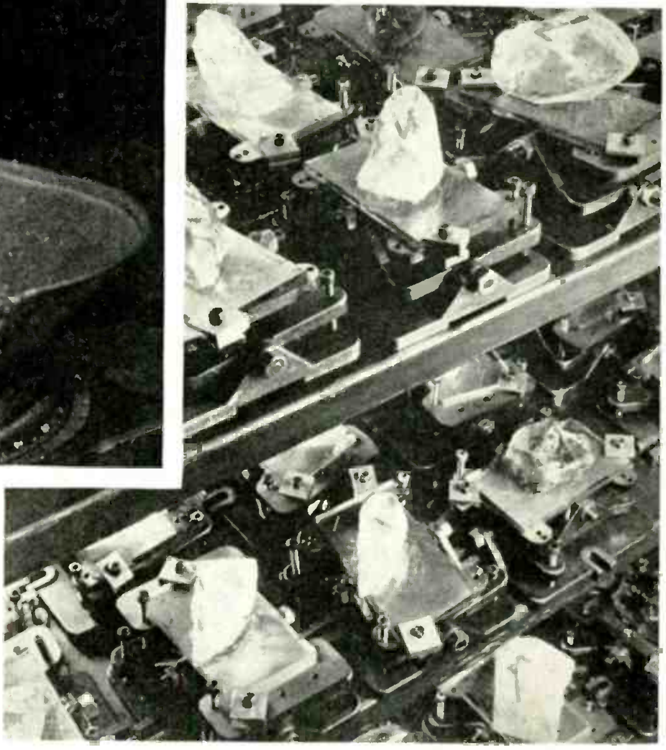
(Above) Fig. 2. Bank of optical laps
(Bliley Electric Co. photo)

Quartz about to be put into acid bath for etching. Note precautions taken to safeguard the operator
(RCA-Victor photo)

on one side this procedure places a thick one between two thin ones and vice versa, and thus serves to equalize the thickness of the entire load. In this manner one group of blanks may be ground to the same thickness within less than one ten-thousandth of an inch. All blanks in the load will then be very close to the same frequency.

It is the object of the lapping opera-





(Above). Close-up view of saw blade cutting end off raw crystal
(*North American Philips photo*)

(Right). Quartz mounted on glass plates ready for slicing into wafers
(*North American Philips photo*)

tion to the upper plate. This machine comprises a type of optical lap and is illustrated in *Fig. 2*. One advantage of this machine is the large number of blanks that may be lapped at a time.

Different types of optical lapping machines were applied to quartz crystals with varying degrees of success. Then came the "drill-press" lapping machine, so called because it consists of a modified table type drill press as will be seen from the illustrations. Twelve to twenty blanks at a time, depending upon their size, are moved around in advancing circular patterns between two serrated iron lapping plates. The element providing the driving motion is a bakelite, vinylite or zinc disc containing a pentagonal hole for each blank. This is called the carrier or nest and is driven eccentrically by a bushing coupled to the drill press spindle.

In addition to the eccentric arcs described each blank is continually rotating due to the five-sided hole in which it nests. The carrier of course must always be thinner than the blanks. The travel is such that the entire surface of the lapping plates is covered equally and thus the laps are held flat and true. The plates must of course be trued occasionally by lapping them together by means of an attachment. A third plate is brought in for this trueing operation. Grinding of the blanks is accomplished by the weight of the upper lap plate (fifteen to twenty pounds) and an abrasive mixed with an agent such as oil. The contour of the blanks may be controlled by the contour of the lapping plates.

Another type of machine is the planetary lap illustrated in *Fig. 3*. It is so called because five carriers follow a planetary path around the axis. Each carrier contains a group of crystals and is driven by a gear system. In this machine the carriers must have toothed edges. The planetary lap is a bit more precise in operation although more cumbersome than the drill press lap.

After blanks have been diced and dimensioned they are sorted into thickness groups and fed to the lapping machines. The blanks put in each load must be of nearly equal thickness. Lapping may be done in two or three stages, each stage using a finer abrasive. The procedure depends upon how much material must be removed. At frequent intervals the blank positions in the carrier are transposed, i.e., every other one exchanges place with the opposite one. If they have been ground a bit lower tion to bring blanks as close to the desired frequency as possible. As all blanks will not be at the same frequency due to the mechanical tolerances of the machine, it will be observed that lapping must cease when a goodly portion of the load is still on the low side of the finish frequency if none of them are to be overshot. The finishing operation must then take them the rest of the way.

An interesting function of piezoelectricity is utilized in connection with the last (fine abrasive) lapping machine. Here the input to a communications receiver may be connected to the two lapping plates which are insulated electrically from each other and form a sort of condenser with the blanks and air acting as the dielectric. When quartz crystals are stressed or compressed they generate on their surfaces an electric charge at a frequency corresponding to their thickness. As all blanks are continually stressed in the grinding operation they may be tuned in on the receiver dial and their approximate frequency noted. The receiver response is in the form of "hash". Tuning is extremely broad as all blanks are not on exactly the same frequency. However, frequent transposition of the blanks and adequate shielding of the system will permit the blanks to be followed up the dial to a fairly close approximation of the desired frequency. Still better results are obtained by use of predimensioned blanks to be described in the section on finishing methods.

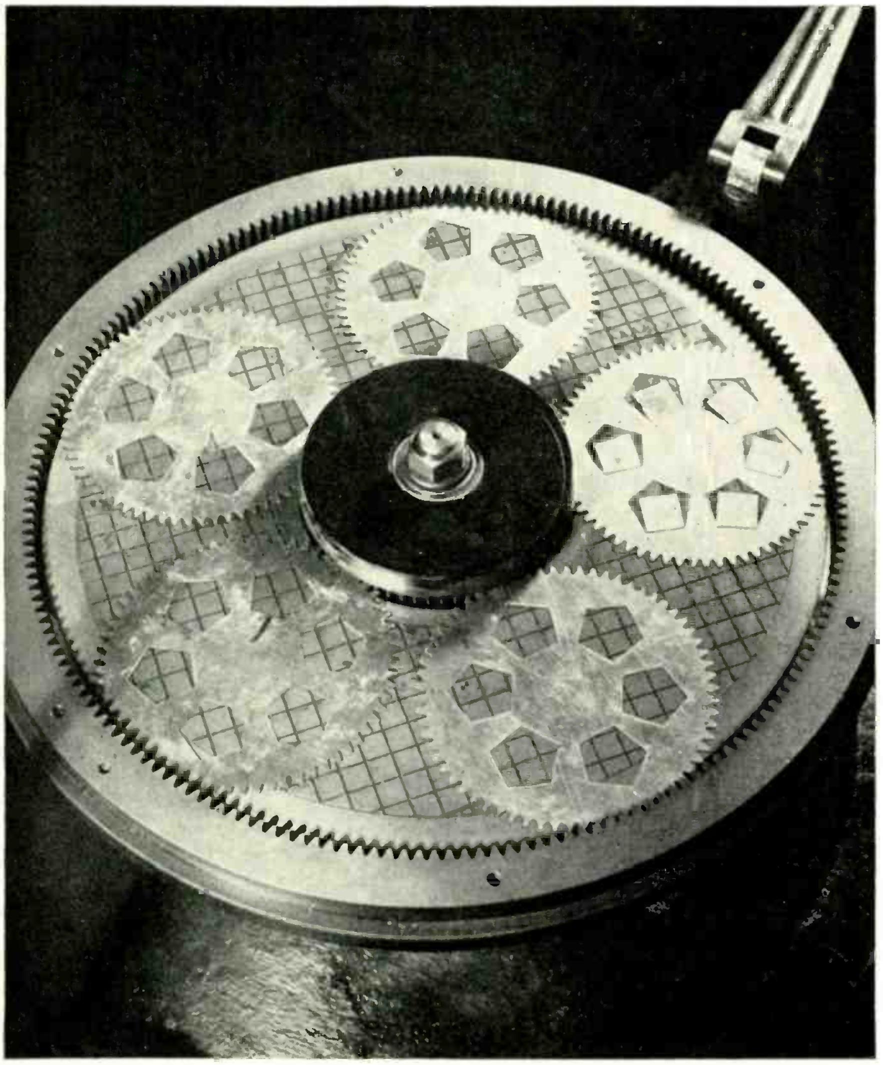
X-Ray Techniques

Quartz, like all other crystalline substances, is composed of a definite and unvarying atomic structure. There are a number of atomic planes that bear a definite angular relationship to the several natural axes of the crystal. If these atomic planes can be precisely oriented, the exact direction of the desired axis may be determined by adding or subtracing the angular difference between the atomic plane measured and the axis in question.

A method of accurately locating the various atomic planes is provided by use of X-ray reflections. These reflections are focused upon a part of the instrument called the ionization chamber which indicates the intensity of the reflected X-ray beams. As the piece of quartz being checked is slowly rotated in the X-ray beam the intensity of the reflected beam will vary. At maximum intensity the atomic plane sought has been located and thereby the desired axis is located precisely. It is seen that the accuracy of setting depends upon the sensitivity of the ionization chamber circuit. This part of the instrument has been developed to a very high degree of sensitivity and permits settings to within a few minutes on the goniometer. The goniometer comprises the work holder attached to an arm which moves over a graduated protractor scale on which the angles are read.

Sorting blanks into thickness groups preparatory to lapping
(RCA-Victor photo)

Fig. 3. Principle of planetary lapping machine
(North American Philips photo)



In actual use the goniometer may be set to read zero when reflection from a certain plane is utilized. Thus the angle of deviation from the desired axis may be read directly on the scale. A quartz block is mounted on a glass plate and fastened in a definite position on the saw table, which is also fitted with a protractor. A test wafer is cut and the angle measured by means of X-rays. The goniometer will show the error exactly, plus or minus, and the error is then corrected by revolving the saw table the required amount in the required direction. The entire block is then wafered, the correctness of the angle being assured.

X-ray equipment designed specifically for quartz crystal manufacture is illustrated in *Figs. 4 & 5.*

Part 2 of this paper will describe and illustrate methods and equipment used in determining twinning and orientation in addition to finishing and testing procedures.

Notes on AUDIO AND SUPERSONIC FREQUENCY MEASUREMENTS

Practical data on the technique of frequency measurements for these ranges

A. K. MC LAREN

THE EXACT MEASUREMENT of freqencies starting at fractions of a cycle up into the low radio frequencies requires a different approach from that used in measuring the higher frequencies, due to the fact that marker stations operating on assigned frequencies and standard frequency transmissions are few and far between.

Reactance-Resistance Method

Preliminary measurements can be made by the reactance-resistance method. The circuit is shown in *Fig. 1.*

By means of reactance-resistance charts or direct reading slide rules, calibrations of the lower frequencies may be made which will help to establish the range that can be covered by an oscillator or other generating device.

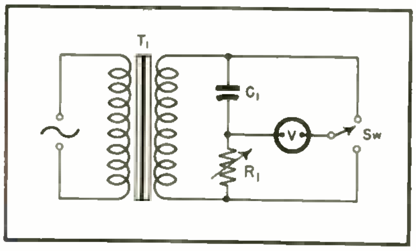


Fig. 1. Simple comparison method of measuring reactance

In *Fig. 1, T1* is a coupling transformer used in order to give an ungrounded source of signals, and *R1* is adjusted until the voltage is the same when the voltmeter is switched from one side of the transformer to the other. The resistance of *R1* is then read on an ohmmeter and is equal to the reactance of the capacitor *C1* at the frequency being used in this adjustment. The reactance slide rule can be used to give rapid readings. For instance, a .1 μf capacitor has a reactance of 1000 ohms at 1600 cycles. A .2 μf capacitor will have a reactance of 500 ohms at the same frequency.

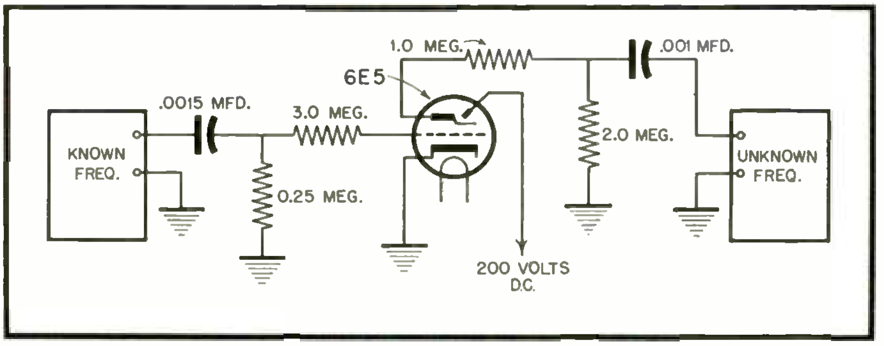


Fig. 2. Schematic of simple indicator for matching frequencies

It must be borne in mind that these calculations are based on sine wave forms and do not hold true for waves of other shapes.

Of course capacitors of accurately known capacity must be used to make these measurements.

If a calibrated source is available for comparison the problem is simplified, but other means must be used to measure accurately the very low and comparatively high frequencies.

The range of frequencies between 100 cycles up to three or four thousand cycles can be compared by ear. Below this, and above four or five thousand cycles, other means of more accurately indicating beat frequencies or wave forms are necessary because the human ear cannot easily discriminate between harmonics on the higher frequencies; on the lower frequencies, beat notes are hard to determine.

A Simple Indicator

An oscilloscope may be used but simpler apparatus will serve just as well. The circuit for a simple indicator

[*Continued on page* 69]

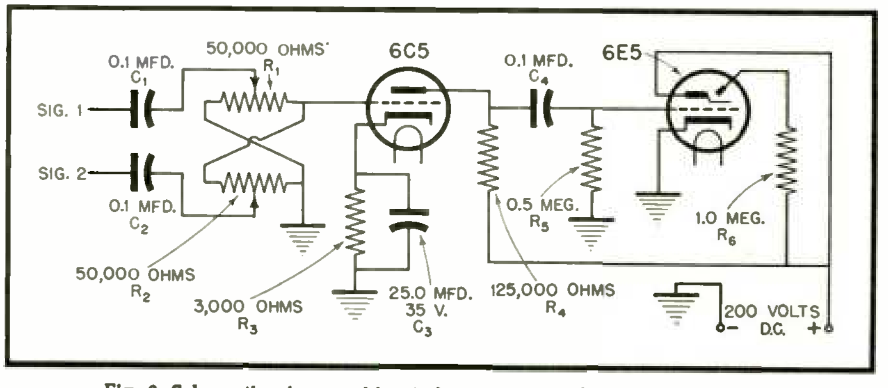


Fig. 3. Schematic of a sensitive indicator for synchronizing frequencies

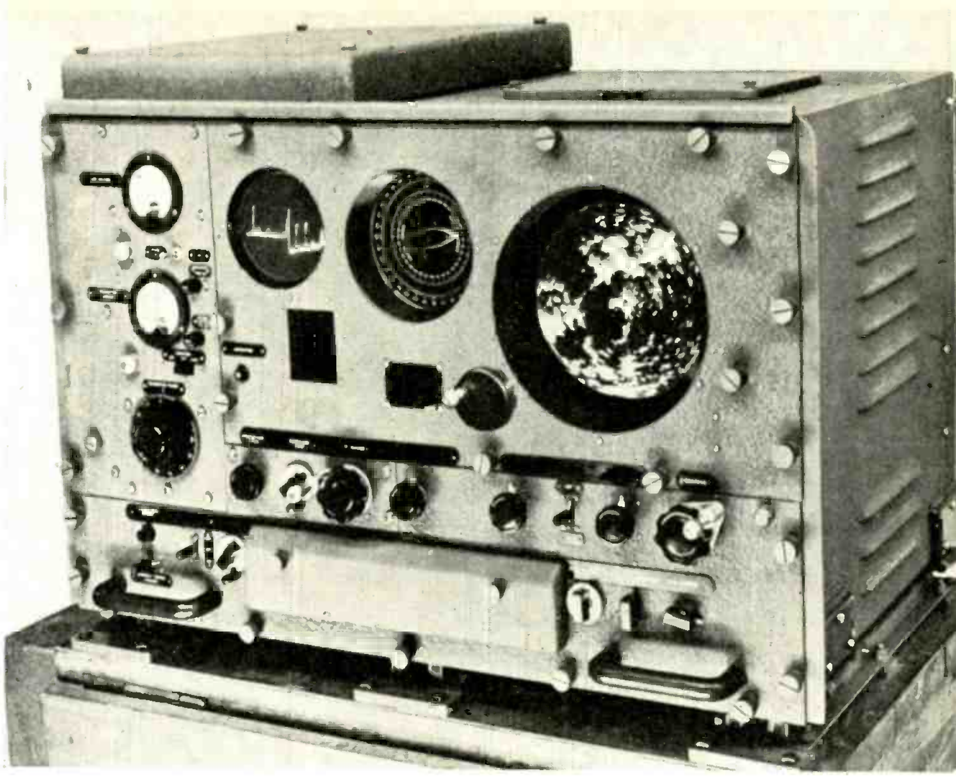
RADAR — FIRST FOTOS

Above—View of top of precision radar repeater. Enlarged screen images shown at sides

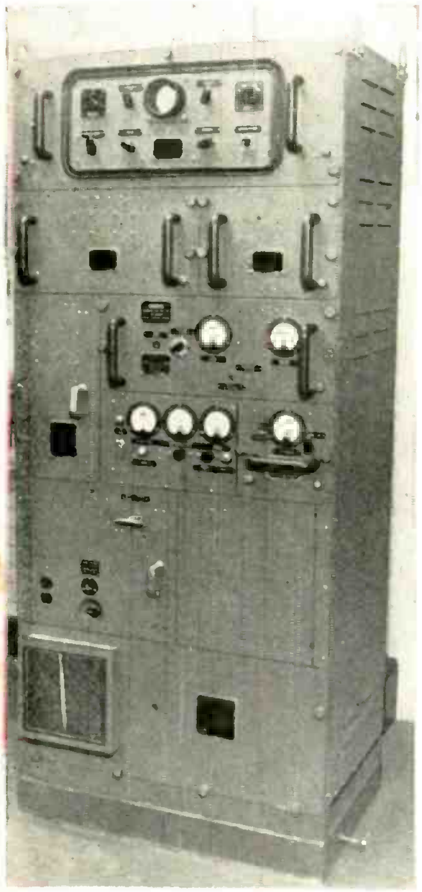
Left—Precision radar repeater. This repeater obtains information from the SG radar. Any sector of the screen image may be enlarged for inspection of details

RELEASED

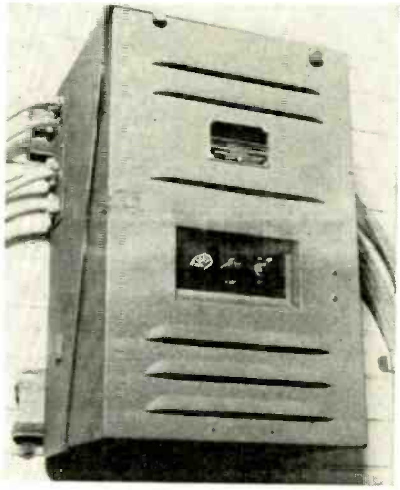
ALL PHOTOGRAPHS REPRODUCED ON THIS AND FACING PAGE REPRESENT RAYTHEON RADAR APPARATUS



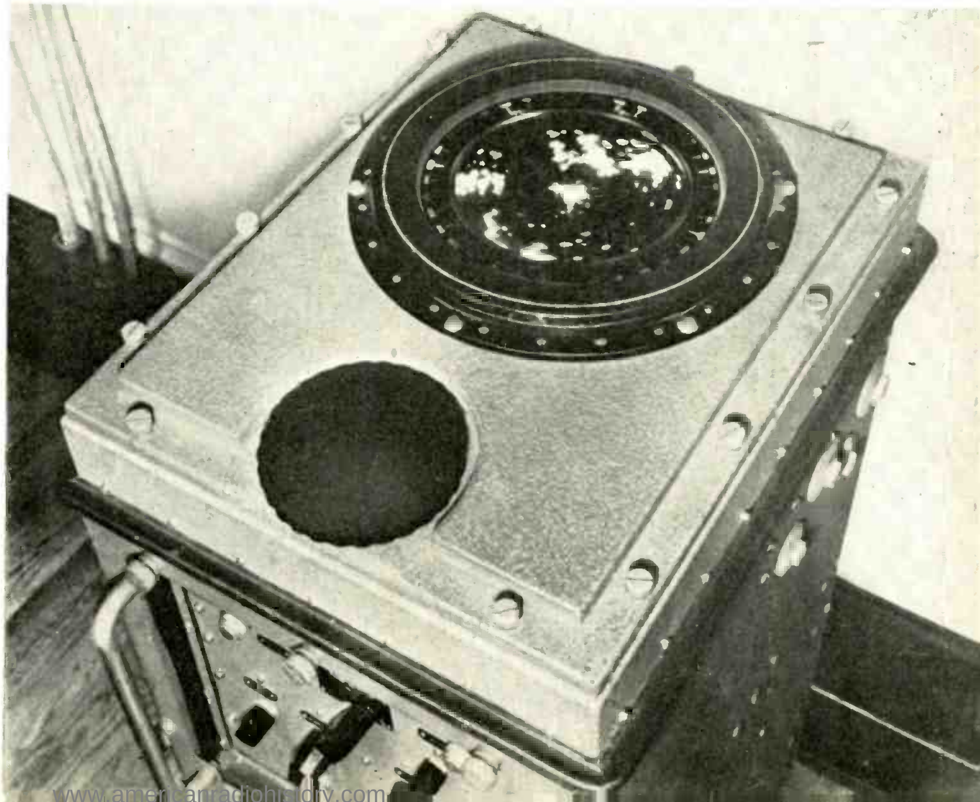
Main SG radar indicator for obtaining accurate range and bearing of target



Raytheon SG Main frame. This unit comprises the main component instruments of the radar apparatus



Raytheon SG Adapter Amplifier. This instrument is designed to transmit information, obtained from the master SG-1 radar, to remote repeaters



Radar repeater. This unit may be located anywhere on the ship and enables the navigator to obtain a full view of his surroundings right at his chart table. Any number of repeaters may operate from one master repeater, which in turn obtains its information from the SG master radar

RECTIFYING

ARTHUR C. GARDNER

IN THE DEVELOPMENT of radar and microwave radio many crystal rectifying units have been used. They are essentially the same as the crystal detectors of radio's early days but nevertheless are a greatly improved item insofar as mechanical construction and dependability are concerned. While not as good as vacuum tube mixers and detectors at low radio frequencies, they make possible extremely low capacitive loading which is so important at frequencies above a few hundred megacycles. At microwave frequencies, rectifying crystals are virtually the only satisfactory mixing or detecting elements known. They are independent of transit-time difficulties which so constantly plague anyone who tries to develop ordinary vacuum tubes for use at UHF. They yield a reasonably good signal-to-noise ratio, and are no worse than vacuum tubes insofar as their ability to maintain constant characteristics over an extended period of time. The chief inconvenience in their use is that they can be burned out rather easily. It is necessary to take precautions to insure that they are not accidentally exposed to strong radio frequency fields and, for this reason, they are normally wrapped in metal foil until actually installed in equipment. When this is done and the equipment is properly designed, the chance of burnout can be kept negligibly small.

Method of Construction

In *Fig. 1* is shown a diagram illustrating the construction of a rectifying crystal. The crystal material itself is silicon or sometimes some other similar mineral, such as galena. The fine wire, commonly called the cat's whisker, is made of tungsten and is one electrical terminal of the device. The metal base in which the crystal is mounted serves for the other connection and is usually made of some soft metal such as lead. As anyone who has worked with adjustable cat-whisker crystals knows, it is quite possible to build actual units very much like that shown in *Fig. 1*, but such a construction is far from rugged. Several years ago, such units were considered to be best when they ended up with several knobs and carefully cut screw threads which would allow the radio operator to move the crystal to predetermined points and adjust the cat-whisker pressure for best results. Adjusting the crystal was as much a part of tuning the radio as was the changing of the tuned circuits. The criterion for the best mixing or rectifying action of the crystal was primarily what was heard in the earphones. The problem of finding a good spot on the crystal surface was an indoor sport, but not an enjoyable one when dependability and portability were urgently

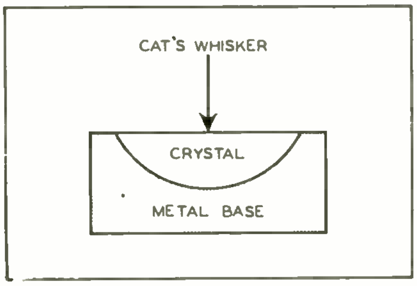


Fig. 1. Components of simple crystal rectifier

necessary. In addition to improving the treatment of the crystal material and surfaces, the biggest single improvement to be found in modern units has to do with the rugged and compact form now commercially available.

In *Fig. 2* is shown a sample of a crystal rectifying unit made in the latest form. It is distinguished by its cartridge-like construction and by its complete lack of adjusting screws. Its center portion is a ceramic insulating material and its two metallic ends serve as terminals for the electrical connections. Because of its small size, it can conveniently be mounted into either a hollow wave guide or coaxial resonant cavity and the geometry can then be so arranged that a low intensity signal is efficiently subjected to the rectifying action. Its ruggedness and simplicity are chiefly due to methods of test and adjustment used during construction, and to a special compound which is flowed in around the cat whisker. This hardens promptly and holds the adjustment precisely as it was fixed. The exact interior arrangement of the cat whisker and crystal are unimportant and vary from manufacturer to manufacturer, but in all cases adjustment is made in the final assembly line in accordance with electrical measurement. Then that adjustment is frozen in place by a sealing compound, introduced through a hole left in the side of the cartridge for that purpose. Because so many units have been manufactured, it has finally become possible to work out techniques that hold manufacturing shrinkage to a surprisingly low percentage.

It was not possible to make such rectifiers a few years ago, not because the idea of doing away with adjustments was unheard of, but only because the demand for rectifying crystals did not justify the expense of setting up sufficiently elaborate manufacturing facilities. The demands of radar and microwave have changed all that.

How They Work

To understand something about the way in which crystal rectifiers work, it is necessary first to speak of the theory concerning conduction electrons in metals and the restraints which electrons encounter in insulators and semiconductors. We now know that all matter, even though it is, as a whole, electrically neutral and in no way associated with an electrical circuit, nevertheless contains both a positive and negative charge. In the case of copper, for example, the smallest piece of copper which can still in principle be recognized as copper is an atom which contains 29 electrons and a positive charge whose strength is equal to the total charge on the 29 electrons. In tungsten there are 74 electrons and a correspondingly stronger positive charge. It is because of an equality of positive and negative charge in each microscopic portion of a material that we say the material is uncharged. When a body is maintained at a high negative or high positive potential with respect to ground, extra electrons have been added or some have been taken away. For potentials ordinarily encountered it is necessary to add or subtract a negative charge, which is a remarkably small percentage of the residual charge of which we have already spoken. This is chiefly because of the very large number of atoms in a small volume of metal. An average metal contains about 10^{22} (ten thousand billion billion) atoms per cubic centimeter.

All that has just been said applies to any material, whether it be a metal

CRYSTALS

The characteristics of crystal detectors adapt them to microwave receiver design. This article describes the theory, design features, and application of these rectifiers

or an insulator. Conducting materials are distinguished by the fact that some of the electrons are not as strongly attracted to the associated positive charge as they are in the case of insulators. These electrons which are relatively free to move about in a metal are called conduction electrons, and it is by virtue of their motion that electrical energy may be transferred through metals. If an isolated positive charge is approached by a small negative charge, a force of attraction is felt between the two. If it is later desired to separate the particles again, energy is required to overcome this attraction and perform the separation. At atomic levels this energy is usually measured in terms of a unit called the electron volt.

The electron volt is defined as the energy necessary to force an electron to move to a point with a potential one volt more negative than the conductor from which it is taken. The electrons in an atom which are closest to the positive charge require relatively large amounts of energy to break them away, but those which in effect are added last find the attractive force of the positive nucleus much reduced by the shielding effect of the electrons already there.

In a given kind of atom, a definite amount of energy may be associated with each electron. It is the energy which is needed to remove that electron

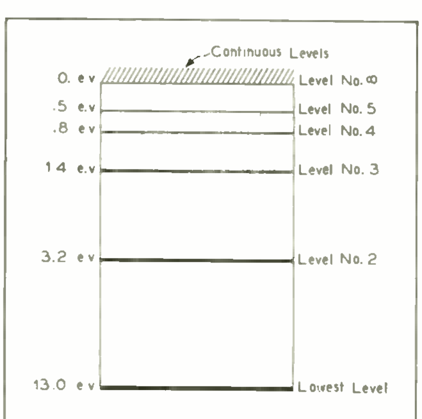


Fig. 3. Energy diagram of hydrogen atom

from the atom. We say that the electrons of the atom inhabit energy levels. This is illustrated in *Fig. 3,* where we show an energy diagram for the simplest of all atoms. The hydrogen atom contains only one electron associated with a positive charge of the same strength. When the atom is in its normal condition, the electron is in the lowest energy level and requires 13 e.v. (electron volts) of energy to separate it from its associated positive charge. If the atom is excited (for example, when an electrical discharge takes place through hydrogen gas) the electron may inhabit some higher level and require only one of the lesser energies in order to completely divorce itself from the atom. The strangest thing about the behavior of particles of atomic dimensions is the fact that discrete energy levels do exist. In the case of pure hydrogen, the electron is never bound by 8 e.v. or by any amount except those shown in *Fig. 3.* This fact is well established from studies of spectra and is referred to as quantization.

Energy levels exist for more complicated atoms, just as they do for hydrogen, but of course they are very much more numerous. In copper or tungsten, where there are many electrons in each atom, each electron will normally inhabit a level and, under certain circumstances, be able to move to other levels. The amount of energy associated with a given electron depends upon many things in addition to its nearness to the positive charge. To name a few, there is a dependence upon the spin of the electron itself, upon the gross motion of the atom and the molecule or crystal of which the atom is a part, and upon the presence of impurities which represent adjacent atoms that are dissimilar. In metals the most loosely bound electrons are located in energy levels which are very close together (about 10^{-22} volts apart). This makes it very easy for the so-called conduction electrons to move about and transport electrical energy while doing

Fig. 2. The type 1N21-B crystal, a typical example of modern crystal rectifier construction

so. In good insulators, the energy levels are well separated and no mechanism is provided for motion from one to another. Only when very high potentials are present is the transfer forced and the insulator said to have broken down. Semi-conductors lie somewhere between these two extremes and allow transfer between levels only after the absorption of energy. Two types of semi-conductors are often distinguished.

In *Fig. 4,* we have shown somewhat idealized energy level diagrams for the several types of materials. In *A* is represented a metal which we there say has a small work function. By this we mean that empty, as well as full, energy levels are not only numerous, continuous, and close together, but also that they extend almost all the way up to zero. This means that it is not only easy for an electron to move about in the material by swapping back and forth a small amount of its own energy so as to change up and down on the levels of adjacent atoms, but also that it is easy for it to get into or out of the metal in the first place.

In other metals, the situation may be more like that in *B.* Electronic conduction is still good because of the abundance of filled and empty levels but all levels lie somewhat below zero. This means that a certain amount of energy is involved in the transfer of electrons into or out of the metal itself. Such a metal to said to have a large work function.

Work Function

The work function of a metal is generally a difficult thing to measure because it depends critically upon the surface. Minute traces of oxygen on the surface of a metal will greatly increase the work function by forming a negative dipole layer there which must be overcome by electrons which pass through. Barium or thorium, on the other hand, form positive dipole layers and tend to reduce the work function of any metal on which they are deposited. That is the reason for using thoriated tungsten filaments in some vacuum tubes. Very careful measurements in vacuum have been made, however, and work functions for most common metals are now well known. For copper, the work function is 4.1 e.v.; for tungsten, it is 4.52 e.v.

Fig. 4C represents the energy level diagram of a good insulator. Here only filled levels are found, and no levels either filled or empty exist near zero energy. This allows no mechanism for additional electrons to get in or for those there to get out except under extreme stress which is capable of rupturing the level arrangement.

In *Figs. 4D* and *4E* are illustrated the two general types of semi-conductors. Both bear strong similarities to the insulator diagram inasmuch as they too have filled levels far removed from zero and separated from zero by regions containing no levels at all. Due to their own peculiar atomic arrangement (intrinsic semi-conductors), or due to the presence of impurities (lattice imperfection semi-conductors), they also have a band of energy levels quite near to zero.

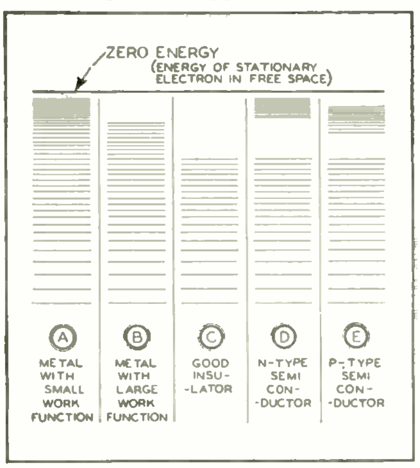
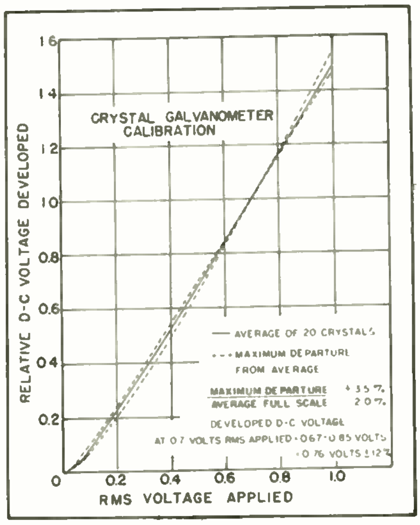


Fig. 4. Characteristic energy level diagrams for various kinds of materials

Semi-conductors which have levels close to the zero level are called donator or *n*-type semi-conductors, since it is relatively easy for electrons to leave such a material. Semi-conductors like the one shown in *Fig. 4E* are called acceptor or *p*-type semi-conductors because energy is available to receive electrons, not to remove them. Very pure silicon is now believed to be an *n*-type intrinsic semi-conductor with very low conductivity. But when a 1% aluminum impurity is added, silicon becomes a *p*-type semi-conductor, and it is in this form that it is successfully used in rectifying crystals.



(*Courtesy General Radio Co.*)

Fig. 6. Curves of average characteristics of 20 crystals

The explanation of how crystal rectifiers work is easy after all this discussion. A rectifying junction between a metal and a semi-conductor occurs when (*a*) an *n*-type semi-conductor is in contact with a metal having a sufficiently large work function, or (*b*) a *p*-type semi-conductor is in contact with a metal having a small work function. The two cases are illustrated by the energy level diagrams of *Fig. 5*. In *A*, electrons in the metal find it easy to get out over the work function and drop into the unoccupied levels of the semi-conductor but the mainly unoccupied semi-conductor levels are removed from the zero potential point, and for this as well as other reasons, it is difficult for electrons to move into the metal. In *B*, rectification occurs in the opposite direction. The large work function opposes flow out of the metal but the donator levels of the semi-conductor make it easy for electrons to enter.

In a practical rectifier device some rectification in both directions is liable to occur. In *Fig. 1*, for example, there is not one but two rectifying junctions. One is between the cat whisker and the crystal and the other is between the crystal and its metal base. This is the reason for using a cat whisker. Reverse rectification at the base junction does occur but the contact is so large in comparison to the size of the cat whisker that the contact resistance there is negligibly small even in the rectifying direction.

Operating Characteristics

In *Fig. 6* is shown the average operating characteristics of 20 crystals of the type illustrated in *Fig. 2*. It will be noticed that values are only given as high as 1 volt rms. This is the practical limit for the 1N21 type unit. Higher voltages will overload the unit and usually cause permanent damage.

An extremely important part of the characteristic curve of a modern crystal rectifier lies below the 0.1 volt rms where the characteristic curve bends like a section of a hyperbola. There the crystal is often said to have square-law response. By that it is meant that the d-c output from the crystal varies as the square of the input a-c voltage. If .01 volts are applied to the crystal and then the input increased to .02 volts, the d-c output is quadrupled. If the crystal is used to deflect a very sensitive galvanometer, the reading will in this region be proportional to the square of the applied voltage or since power is also generally proportional to voltage squared, a low level crystal generates a d-c current which is proportional to the power reaching it. When a crystal is used in a radar receiver as a detector, this is usually the situation because the received radio signals are necessarily weak.

Two criteria are of general interest in discussing any detector or converter. They are the efficiency of detection or mixing which the device possesses and the lowest signal-to-noise ratio which can be obtained when completely noise-free signals are fed in. Of these, the latter is much the more important in judging relative merits of crystals now used for microwave radio work. Ordinary vacuum tubes can easily be used for amplification after conversion or detection has been accomplished and, if the signal-to-noise ratio is high enough, it is easy to add more amplification to compensate for a smaller sig-

[*Continued on page 68*]

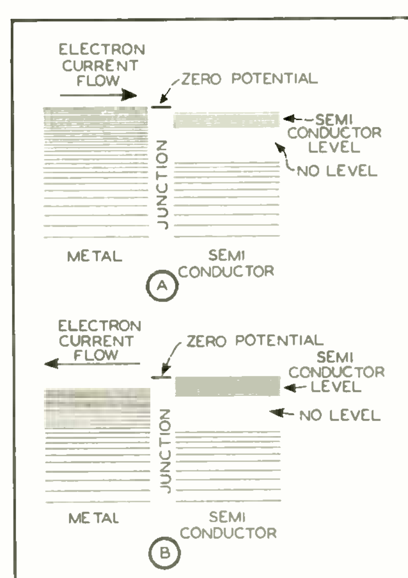


Fig. 5. Energy level diagrams of two types of rectifying junctions

RADIO DESIGN WORKSHEET

NO. 39—DETECTORS

DETECTORS

In many early radio receivers both for broadcast and commercial use, grid leak detectors were used because of their sensitivity. As a matter of fact, the grid leak detector is actually the forerunner of the modern diode detector. The most common value of the grid leak capacitor combination was 1 megohm and 250 μμf. This combination discriminated against the higher audio frequencies, resulting in poor fidelity, but was about optimum for sensitivity at 1000-cycle signal. If the grid leak is reduced by half, say to 500,000 ohms, the sensitivity will drop by 3 to 6 db but the high frequency response will be materially improved; (see *Fig. 1*). This process can be continued reducing both *R* and *C* until at 300,000 ohms and 100 μμf good fidelity to perhaps 8000 cycles may be obtained.

In *Fig. 1*, detection occurs in the grid circuit. That is, the grid and cathode act like a diode, the resulting audio voltage which appears aross the grid leak *R* will be amplified by the triode acting as an audio amplifier. However, since the tube of *Fig. 1* is usually operated at or near zero bias and since the high frequencies are also amplified by the tube, the resulting audio output is small. Like all diode detectors the circuit of *Fig. 1* has a parabolic characteristic at low inputs and, since high inputs would overload the triode, the circuit of *Fig. 1* never really operates linearly.*

*A modification of this detector which was never used to any great extent in this country called "High Level Plate Circuit Rectifier" is described by Cocking in *Wireless World*, May 7, 1930.

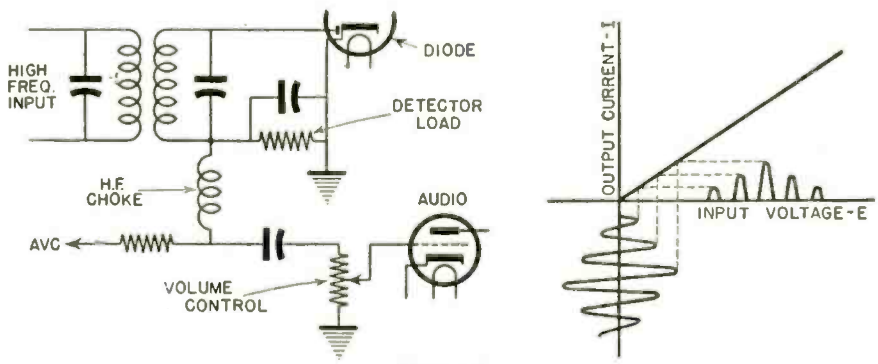


Figure 2

Another type of square law detector used in some degree in radio receivers a few years ago is the biased grid or plate circuit detector. In this case the tube is biased to nearly cutoff. Most sensitivity will occur if the tube is biased to the point of greatest curvature, i.e. when

$$\frac{\delta ip}{\delta eg} = 0$$

The point of greatest curvature is at about zero plate current. This type of detector becomes more nearly linear as the signal input voltage is increased. It has a high input impedance since in normal operation it does not draw grid current. It likewise has a high output impedance compared to the grid-circuit rectifier discussed above. It is also much less sensitive than the grid-circuit rectifier. In this connection it is well to remember that, for a linear detector, doubling the input voltage will double the audio output voltage. For the square law type, however, increasing the input 100% will increase the audio output 300%.

Screen grid and pentode tubes have been used to a limited extent as biased grid or plate circuit detectors. They have better sensitivity than triodes, but due to the extremely high output impedance, it is extremely difficult to realize much gain.

Diode detectors are more popular than any other type for a number of reasons, some of which are:

1. They are essentially linear at high inputs, where they are nearly always used. As a result, non-linear distortion of the audio signal is negligible.
2. Intermodulation of the signal by power supply ripple is greatly reduced.
3. They require no bias voltage.
4. The direct current output is directly proportional to carrier amplitude, so that the diode will furnish a-v-c voltage.
5. Cross modulation and beat note interference are at a minimum.

Fig. 2 shows the schematic circuit arrangement of a diode detector, arranged to supply a-v-c voltage.

If the high frequency input be a modulated wave, it may be represented by:

$$E = A \cos \omega t \, (1 + K \cos pt)$$

Obviously if the detector characteristic is as shown in *Fig. 2* it may be represented by

$I = ME$ for all positive values of E
$I = O$ for all negative values of E

This is equivalent to stating that the detector input is multiplied by a square

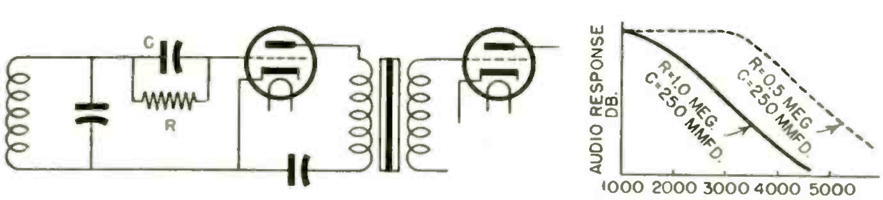


Figure 1

wave having the same frequency as the input and having positive amplitude of M and negative amplitudes of zero. Such a square wave may be represented by

$$\frac{M}{2}+\frac{2M}{\pi}\left[\cos\omega t-\frac{1}{3}\cos 3\omega t-\frac{1}{5}\cos 5\omega t-\frac{1}{7}\cos 7\omega t\ \ldots\ldots\ \frac{1}{N}\cos N\omega t\right]$$

Multiplying the modulated input voltage E by the square wave yields

$$I=\frac{MA}{2}\cos\omega t+\frac{MAK}{4}\cos(\omega+p)t+\frac{MAK}{4}\cos(\omega-p)t+\frac{2MA}{\pi}\cos^2\omega t+\frac{MAK}{\pi}\cos at\cos(\omega+p)t+\frac{MAK}{\pi}\cos\omega t\cos(\omega-p)t-\frac{2MA}{3\pi}\cos\omega t\cos 3\omega t-\frac{MAK}{3\pi}\cos(\omega+p)t+\cos 3\omega t+\ldots\ldots$$

$$=\frac{MA}{\pi}+\frac{MAK}{2\pi}\cos pt+\frac{MA}{2}\cos\omega t+\frac{MAK}{4}\cos(\omega+p)t+\frac{MAK}{4}\cos(\omega-p)t+\frac{MAK}{2\pi}\cos(2\omega-p)t+\ldots.$$

Whence it is evident that the d-c output is proportional to the amplitude of the carrier and may be employed for a-v-c bias. It is also evident that there are no audio harmonics. Actually this holds only for large inputs since the diode characteristic is parabolic near the origin. Diodes are generally heavily loaded, however, so that the effect of the curvature of the characteristic near the origin is of little practical importance.

It is interesting to compare the diode with the square law detectors previously discussed. This is equivalent to comparing a diode lightly loaded with

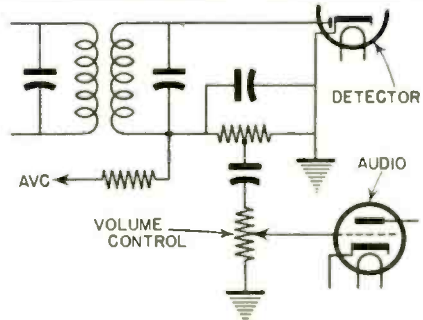


Figure 4

one heavily loaded. Again assume an amplitude-modulated input and we have

$$E=A\cos\omega t\,(1+K\cos pt)=A\cos\omega t+\frac{AK}{2}\cos(\omega+p)t+\frac{AK}{2}\cos(\omega-p)t$$

The square law detector characteristic may be represented by

$$I=ME^2$$

Whence

$$I=ME^2=MA^2\cos^2\omega t+\frac{MA^2K^2}{4}\cos^2(\omega+p)t+\frac{MA^2K^2}{4}\cos^2(\omega-p)t+MA^2K\cos\omega t\cos(\omega+p)t+MA^2K\cos\omega t\cos(\omega-p)t+\frac{MA^2K^2}{2}\cos(\omega+p)t\cos(\omega-p)t$$

$$=\frac{MA^2}{8}(2K^2+4)+MA^2K\cos pt+\frac{MA^2K}{2}\cos 2pt+\ldots.$$

In this case the d-c output is proportional to the square of the carrier amplitude plus the square of the side band amplitudes which makes it unsuitable for a-v-c bias. Moreover it will be noticed that a large second harmonic of the signal results. At 100% modulation the amplitude of the second harmonic is 25% of the fundamental amplitude.

Another factor which causes distortion in detector circuits, even those of linear detectors is their modulation capability. In the case of the diode, the modulation capability is a function of the value of the load resistor and the ratio of d-c load to a-c load. In a circuit of *Fig. 2* for example the audio volume control shunts the detector load resistor through the blocking capacitor. If the detector load resistor is equal in value to the volume control, the ratio of d-c load to a-c load is 2. It is generally considered good practice to keep this ratio as near unity as possible. This means that the volume control must have a very high resistance or the detector load may be low or both. *Fig. 3* shows the effect of loading the detector on modulation capability of the diode. If the diode load resistor is too low, the shunting effect on the last intermediate frequency amplifier may cause it to be overloaded. Consequently a high detector load resistance is advisable. One method of improving the situation is taptapping th audio circuit into the detector load as shown in *Fig. 4*. This again requires the intermediate frequency amplifier tube to be driven harder but it does

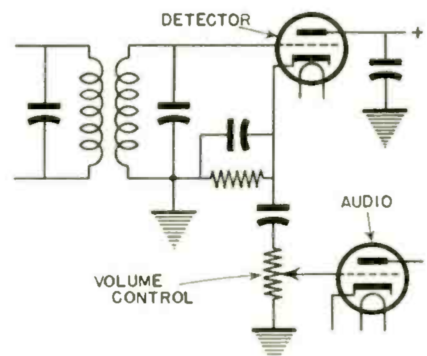


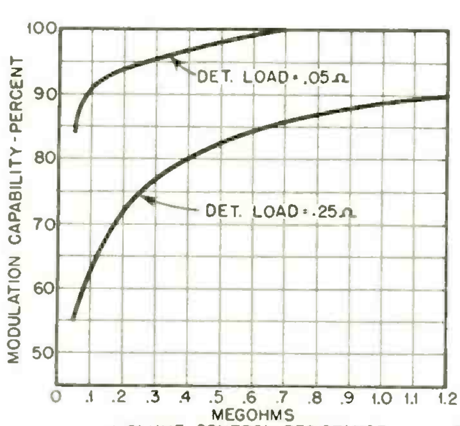
Figure 5

improve the modulation capability of the diode. As a result it is seldom used.

Direct coupling is another approach. In this case the detector load resistor becomes the volume control. Such volume controls however are usually noisy and while these circuits have been used they are not generally considered good design.

Another type of detector which has received some publicity but little use is the infinite impedance detector. The schematic circuit for this type is shown in *Fig. 5*. It consists of a plate circuit detector using a triode tube but employing degeneration to reduce distortion. Degeneration is accomplished by using a high cathode bias resistor without sufficient by-pass capacitance to prevent degeneration. It presents a high impedance to the driven circuit, thus improving the gain. In addition the modulation capability of this circuit is appreciably better than that of this diode. This circuit functions as a linear detector and from that standpoint is as good as the diode.

One disadvantage of this circuit which probably accounts to some extent for its lack of popularity is that it will not furnish a-v-c bias and consequently another tube is required for this purpose.



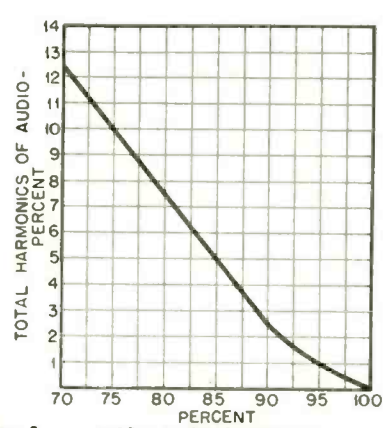
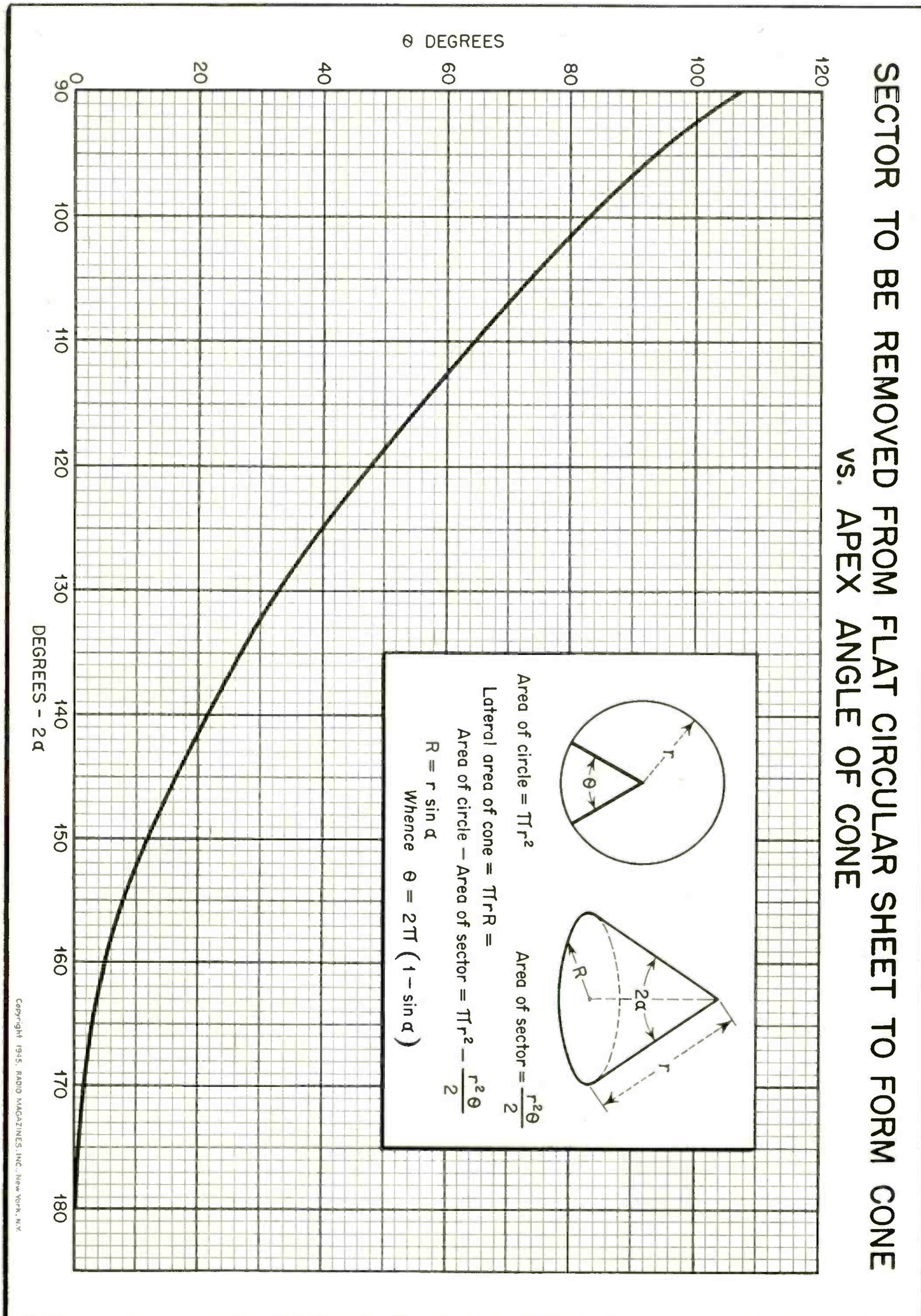


Figure 3


SECTOR TO BE REMOVED FROM FLAT CIRCULAR SHEET TO FORM CONE
vs. APEX ANGLE OF CONE
θ DEGREES
0
20
40
60
80
100
120
90
100
110
120
130
140
150
160
170
180
DEGREES - 2α
Area of circle = πr²
Lateral area of cone = πrR =
Area of circle − Area of sector = πr² − r²θ/2
R = r sin α
Whence θ = 2π (1 − sin α)
Area of sector = r²θ/2
θ
r
R
2α
r
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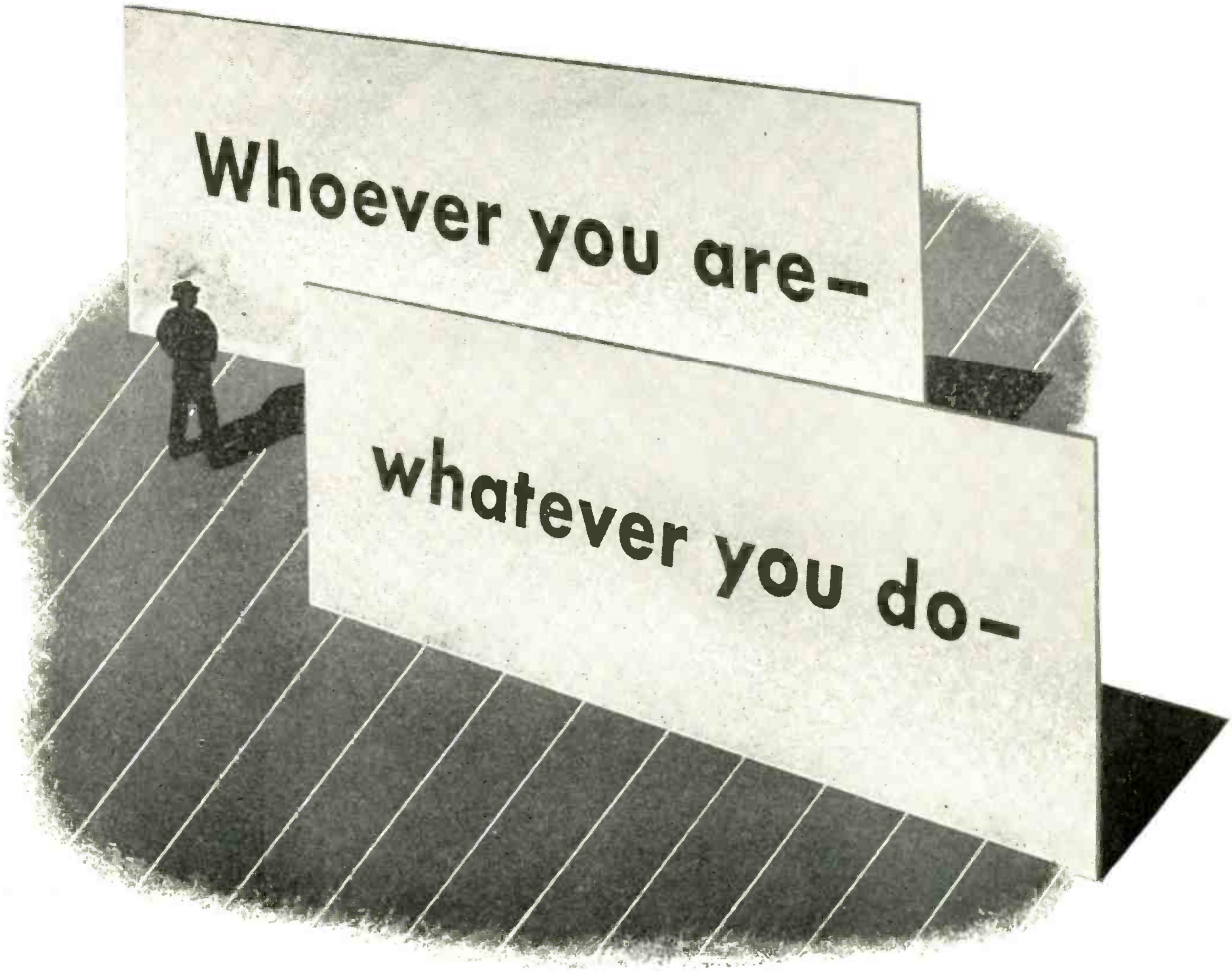

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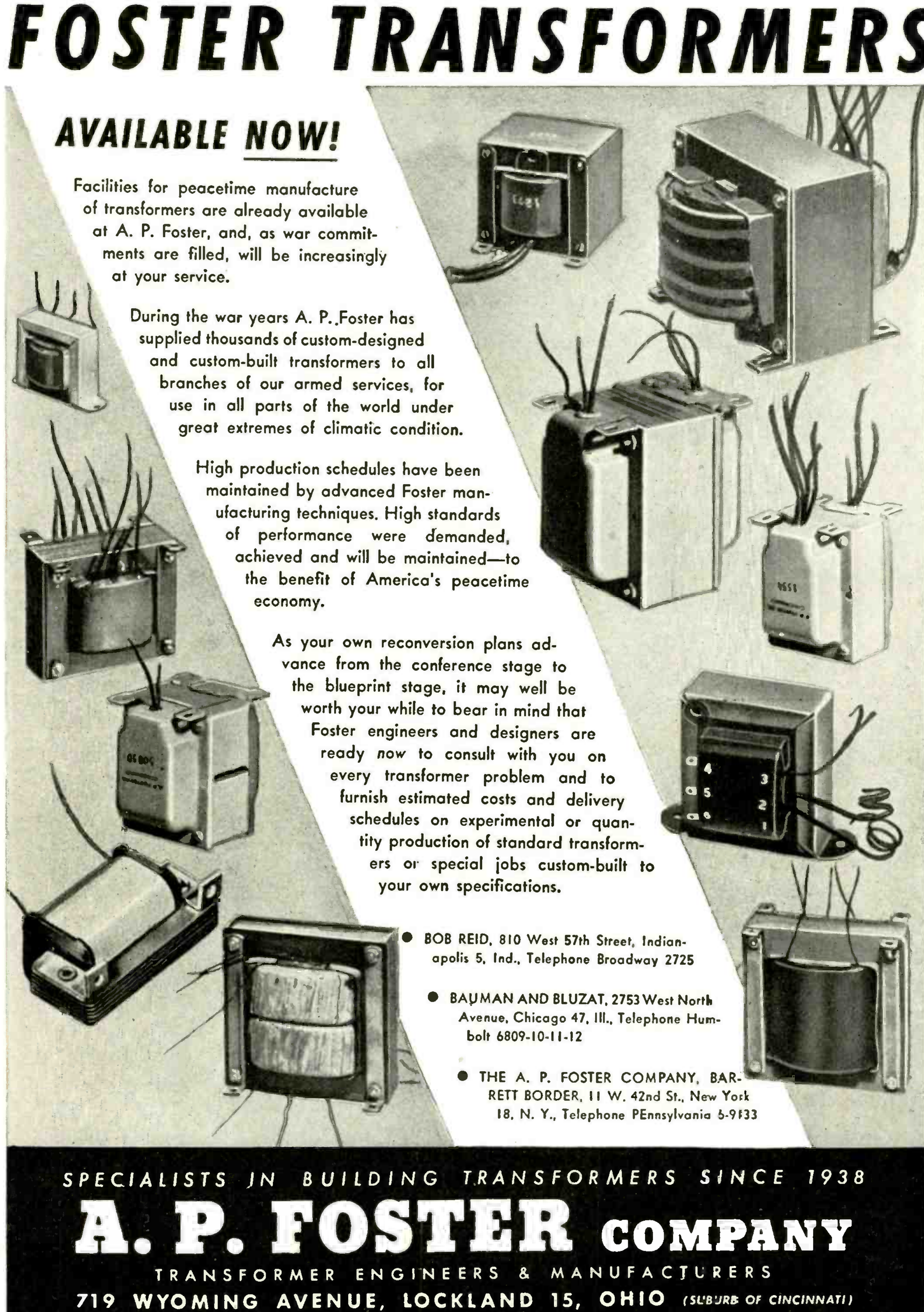
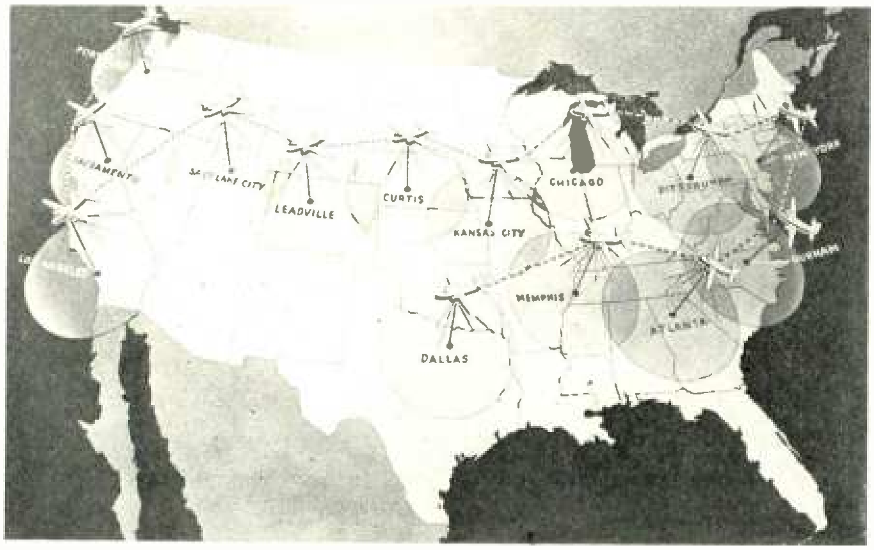

FOSTER TRANSFORMERS
AVAILABLE NOW!
Facilities for peacetime manufacture of transformers are already available at A. P. Foster, and, as war commitments are filled, will be increasingly at your service.
During the war years A. P. Foster has supplied thousands of custom-designed and custom-built transformers to all branches of our armed services, for use in all parts of the world under great extremes of climatic condition.
High production schedules have been maintained by advanced Foster manufacturing techniques. High standards of performance were demanded, achieved and will be maintained—to the benefit of America's peacetime economy.
As your own reconversion plans advance from the conference stage to the blueprint stage, it may well be worth your while to bear in mind that Foster engineers and designers are ready now to consult with you on every transformer problem and to furnish estimated costs and delivery schedules on experimental or quantity production of standard transformers or special jobs custom-built to your own specifications.
● BOB REID, 810 West 57th Street, Indianapolis 5, Ind., Telephone Broadway 2725
● BAUMAN AND BLUZAT, 2753 West North Avenue, Chicago 47, Ill., Telephone Humbolt 6809-10-11-12
● THE A. P. FOSTER COMPANY, BARRETT BORDER, 11 W. 42nd St., New York 18, N. Y., Telephone PEnnsylvania 6-9133
SPECIALISTS IN BUILDING TRANSFORMERS SINCE 1938
A. P. FOSTER COMPANY
TRANSFORMER ENGINEERS & MANUFACTURERS
719 WYOMING AVENUE, LOCKLAND 15, OHIO (SUBURB OF CINCINNATI)

This Month



Airborne television and FM broadcasting system. This system, developed jointly by Westinghouse Electric Company and The Glenn L. Martin Compan, proposes to beam *(solid lines)* programs originating in ground studios to planes for broadcast. Similarly beamed plane-to-plane connections *(dotted lines)* would form a nationwide network

MAGUIRE ACQUIRES MEISSNER

Purchase for cash of all stock of the Meissner Manufacturing Company of Mt. Carmel, Ill., by Maguire Industries, Inc., and its merger into the latter were announced today by Russell Maguire, president of Maguire Industries, Inc.

Meissner, which is well known in the radio and communications fields, will continue its operations as an independent division of Maguire Industries. Mr. Maquire announced that there will be no change in any of the policies or operations of Meissner except that there will be some expansion of volume of sales due to the greatly increased capital available for this program.

The Meissner Manufacturing Company was founded in 1922 by the late William O. Meissner, famous for his inventions in the communications and electronics fields. Its products include coils and assemblies, radio receiver kits, frequency modulation converters, amateur equipment, public address tuners, and television receiving sets.

This is the third acquisition in the radio field by Maguire Industries, Inc., in the past four months, other acquisitions including Thordarson Electric Manufacturing Co., Ferrocart Corp. of America and the Micro Products Corp.

Personal Mention

The appointment of Francis X. Rettenmeyer as chief components engineer has been announced by Federal Telephone and Radio Corporation, affiliate of International Telephone and Telegraph Corporation. An authority on radio receivers and wired radio systems for power and telephone lines, Mr. Rettenmeyer's work will involve the engineering of Selenium Rectifiers, quartz crystals, transformers and coils, special purpose and transmitting tubes, Intelin cables and other components. He joined the Newark organization July 1.

Previously, Mr. Rettenmeyer had been for ten years chief receiver engineer and staff engineer for the RCA Victor Division of the Radio Corporation of America, at Camden, his work covering the design and manufacturing in six plants of component parts, radio transmitters and receivers and sound motion picture equipment. He also spent ten years with Bell Telephone Laboratories, where he was responsible for the design and development of all radio receivers, navigation equipment, mobile and fixed unattended station radio communication equipment, ship to shore radio receivers and marine direction finders, power line carrier telephone equipment and measuring equipment. He developed a wired radio system to be used with the transmission of entertainment programs over power lines or telephone systems without interruption of the regular telephone service.

F. X. Rettenmeyer

Born in Oklahoma and educated at Colorado University and Columbia in New York, Mr. Rettenmeyer first became interested in electrical engineering while serving in the Naval Aviation Section at San Diego, California, during the first World War. Upon receiving his discharge he proceeded at once to the Colorado college and emerged with a science degree in electrical engineering. This he supplemented with a Master's. Today he holds about thirty patents on radio and wire communication and is the author of some thirty-five technical papers of note on radio and allied subjects. He is a Fellow of the Institute of Radio Engineers and of the Radio Club of America; member of the Institute of Aeronautical Sciences, Franklin Institute and the National Aeronautics Association. He holds membership in Tau Beta Phi and Eta Kappa Nu, is married and lives at Moorestown, New Jersey.

Royal V. Howard

Royal V. Howard, who has just returned to San Francisco after a year's leave of absence for overseas duty in the European Theatre of Operations for the United States Army, has been elected Vice President in charge of Engineering for both The Associated Broadcasters, Inc., and the Universal Broadcasting Company of San Francisco, California, it was announced by Wesley I. Dumm, President. Associated owns and operates Station KSFO and International Stations KWID and KWIX.

Howard headed a special scientific staff at ETOUSA headquarters in London and Paris, working through the Office of Scientific Research and Development. He was hospitalized a few months ago as a result of enemy action and returned to the United States the first of the year.

Besides being one the industry's better known radio engineering executives, he is also an inventor. One of his most recently

[Continued on page 67]

HOW WE SAVE 45 MINUTES OUT OF AN HOUR

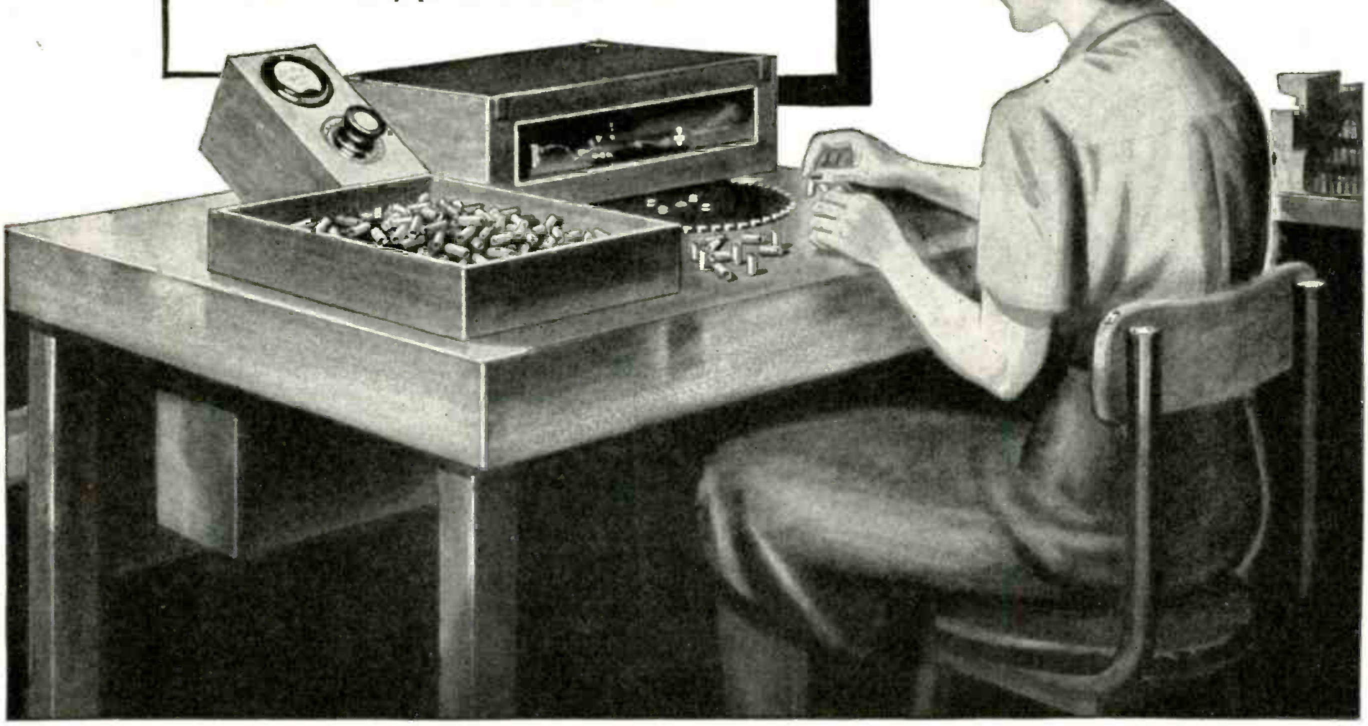
When Connecticut Telephone & Electric Division began to make aircraft ignition terminals for a famous engine manufacturer, we knew that standard testing procedure could not keep pace with our mass production methods. Even a score of trained inspectors, each equipped with high-voltage testing equipment, would soon fall hopelessly behind.

Again Great American Industries engineers overcame a stubborn wartime bottleneck. They designed an electro-mechanical tester which accurately checks four parts faster than former methods could check one. Five such testers, operated by unskilled persons, have a capacity of 12,500 tests an hour . . . with a degree of error almost too small to measure.

This is but one of many new methods, contributed by G. A. I. engineering to speed the war effort. It will be equally important to efficient electrical manufacturing in time of peace.

HERE'S HOW IT'S DONE

Operator places terminals to be tested in slots at edge of turntable. As each part reaches test point, one electrode of a 10,500 v. circuit contacts the conductor element of the terminal . . . while another encircles its insulating shell. Current leakage through minute cracks or porous sections of the insulation operates a relay which ejects the faulty piece. If the terminal meets specifications, it automatically falls into a chute and is conveyed to the packing bench. This swift, foolproof tester lends itself to many production tests of insulation.



CONNECTICUT TELEPHONE & ELECTRIC DIVISION

GREAT AMERICAN INDUSTRIES INC. • MERIDEN, CONNECTICUT

New Products

RESISTOR BRIDGE

Ready means for rapid comparison of large quantities of resistors having comparable values. For volume testing up to 2,000 pieces an hour. Particularly adapted for testing resistance values of motor windings, transformer primaries or secondaries, rheostats, potentiometers, lamps, shunts or multiplier resistors, etc.

Battery operated. Extremely flexible. Overall adjustable range from ¼ ohm to 10,000 ohms. Adjusting ratio arm, sensitivity control, production test fixture with automatic on-off switch. Indicator a sensitive zero center galvanometer. Sensitivity control range ±¼% to ±10%. Self contained in compact grey wrinkle finished metal cabinet. Size 8"x 8" x 12". Weight 18 lbs. Manufactured by Associated Research, Inc., 231 S. Green st., Chicago 7, Ill.

NEW TRIODE

A new type 304TL (3-300B2) Multi-Element Triode is announced by Eitel-McCullough, Inc., of San Bruno, California. The new 304TL incorporates a new design plate and a non-emitting grid, which insure maximum tube life plus high efficiency.

The inherent characteristics of this new vacuum tube are ideally suited for many applications, including television and industrial heating.

Data sheets are available upon request from Eitel-McCullough, Inc., 478 San Mateo Ave., San Bruno, California.

NEW FREQUENCY METER

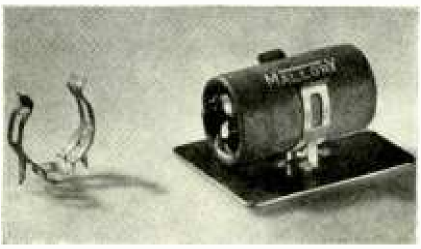
J-B-T Model 39-VTF Vacuum Tube Frequency Meter is designed to provide the maximum degree of accuracy in measuring frequencies located within certain definite bands. A special multivibrator circuit in the electronic unit divides the incoming frequency by 2, 3, 4, 6 or 9. The resulting frequency is measured by a standard vibrating reed frequency meter.

This combination will measure frequencies in the 400, 800, 1200, 1600, 2400 and 3600 cycle bands with a stated accuracy of 0.25% or better, independent of line voltage. Furthermore, this accuracy is permanently inbuilt at the factory—no subsequent calibration or standardization is required at any time. No initial stabilization period is required, and no protection is needed against accidental frequencies above the range being measured.

For futher information, write the manufacturer, J-B-T Instruments, Inc., 441 Chapel St., New Haven 8, Conn.

CAPACITOR MOUNTING CLIP

P. R. Mallory & Co., Inc., Indianapolis, Indiana, has announced a new capacitor mounting clip that requires no tools for



assembly. Among other advantages incorporated in the bracket are its low price, small space required, and the simplicity in which the capacitor may be attached.

LIGHTHOUSE TUBE PAMPHLET

A new eight-page publication (ETR-7) on the General Electric Company's disk-seal electronic tube, widely known among radio engineers in the military services as the "lighthouse tube," has been announced by the Tube Division of the company.

The pamphlet describes the basic principles of design and operation of the tube and its advantages in the fields for which it is designed. The tube, now being used in war applications, will be applied to television, FM radio and other fields in the ultra-high frequency spectrum.

Copies of the publication are available free on request to the Publicity Section, General Electric Electronics Department, Schenectady, N. Y.

RESISTOR CATALOG

A new resistor catalog of 32 pages has been issued by Ward Leonard Electric Company, Mount Vernon, N. Y. The booklet describes and illustrates various types of units, gives sizes, resistance values, mountings and enclosures. A copy will be sent on request to the manufacturer.

BROAD-BAND FILTER

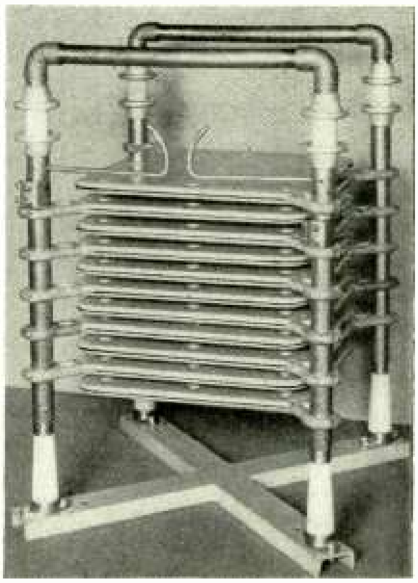
A new power-line filter for use with screen-rooms prevents entrance of objectionable line noise at all frequencies from 150 kilocycles to 400 megacycles. Originally designed to meet the severe performance requirements of the Filterette Division of the Tobe Deutschmann Corporation, Canton, Massachusetts, for a line filter adequate to keep factory noise out of their own production and laboratory test rooms, this new unit is stated to provide attenuation better than 60 db over the entire band.

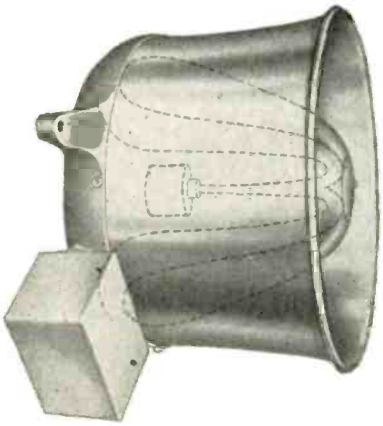
Detailed information on performance in special frequency bands is obtainable on application to the Tobe Deutschmann Corporation Filterette Division, Canton, Massachusetts.

NEW HIGH POWER CONDENSER

Utilizing a new style of construction, this high power, high capacity condenser has just been announced by the E. F. Johnson Company of Waseca, Minnesota. The condenser is available in various spacings up to 1½". For a spacing of one inch the breakdown rating is 45,000 volts peak at 2 megacycles.

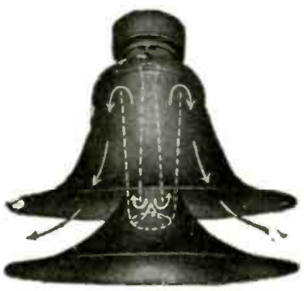
The condenser plates are 18 inches square, made of fabricated sheet metal. The frame rods are heavy 1-5/8" copper tubing, and are fitted with heavy strap connectors capable of carrying a high current. A tank





Left—MARINE SPEAKER; approved by the U. S. Coast Guard, for all emergency loudspeaker systems on ships. Re-entrant type horn. Models up to 100 watts. May be used as both speaker and microphone.

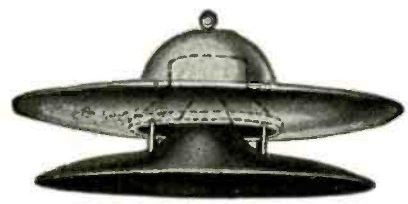
Right—RE - ENTRANT TRUMPET; available in 2½-3½-4½-6 ft. sizes. Compact. Delivers highly concentrated sound with great efficiency over long distances.



Left—RADIAL HORN SPEAKER; a 3½' re-entrant type horn. Projects sound over 360° area. Storm-proof. Made of RACON Acoustic Material to prevent resonant effects.

Right—AEROPLANE HORNS; super-powerful and efficient P. A. horns for extreme range projection. 9-4 and 2 unit Trumpets available.

Left—PAGING HORN; extremely efficient 2' trumpet speaker for use where highly concentrated sound is required to override high noise levels. Uses P.M. unit.



Right—RADIAL CONE SPEAKER; projects sound over 360° area. Cone speaker driven. Will blend with ceiling architecture. RACON Acoustic Material prevents resonant effects.

SEND FOR CATALOG

RACON

RACON ELECTRIC CO. 52 EAST 19th ST. NEW YORK, N. Y.

coil may be mounted on top of the condenser and supported by the cross pieces.

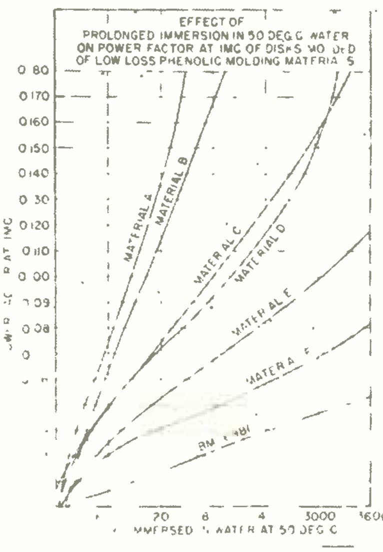
A protective gap is built into the condenser to protect plates in the event flash over occurs. Top steatite insulators have corona shields. The condenser illustrated has a capacity of 1200 mmf. and stands 40 inches high. Models may be supplied having higher and lower capacities at various spacings.

NEW "BAKELITE" LOW-LOSS PLASTIC

Bakelite Corporation has announced the development of a new low-loss phenolic plastic molding material, designed specifically to provide stable electrical insulation values even when used under conditions of elevated temperature and high relative humidity. Designated as BM-16981, this phenolic, mica-filled molding material is especially suitable in high-frequency circuits where the loss factor must be held to a minimum under a wide range of operating conditions.

In a recent test conducted by Bakelite Corporation, specimens molded of BM-16981 and various other mica-filled phenolic materials were immersed for a period of 3,600 hours in water heated to 50 deg. C. The volume resistivity of BM-16981 remainde high, decreasing from 1 x 10^6 megohms to 1.6 x 10^5 megohms—a slight loss in efficiency as compared to the accelerated decrease in volume resistivity of the other materials. At 1 megacycle, the power factor of BM-16981 was 0.055.

These and other test readings indicate that, in retaining superior low-loss electrical characteristics under warm, humid



conditions, BM-16981 appear to surpass all other phenolic materials. In addition to this characteristic, BM-16981 possesses the following desirable properties as indicated by laboratory tests:

Specific Gravity—1.86—1.92
Molding Shrinkage—0.002—0.004 in. per in.
Izod Impact Strength—0.30 to 0.34 ft-lb. per in. of notch—A.S.T.M. D-48-43-T
Flexural Strength—9,000—11,000 lb. per sq. in.—D-48-43-T
Compressive Strength—18,000—24,000 lb. per sq. in.—1/2 inch cube
Power Factor @ 1 kc—0.010—0.015—A.T.S.M.—D-48-43-T
Power Factor @ 1 mc—0.0065—0.0075—A.S.T.M.—D-48-43-T
Water Absorption—Max. gain in weight—0.05 per cent—A.S.T.M.—D-48-43-T

Pieces from which these data were obtained were molded under conditions conductive to the best finished properties. While these data are indicative of the properties of the material, no guarantee of such properties in finished commercial articles is implied, due to the infinite variety of molding conditions arising from various part, and mold designs.

NEW ELECTRIC TIMER BULLETIN

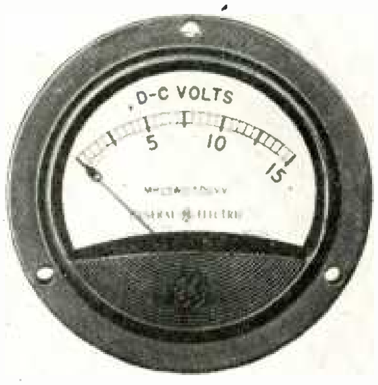
A new electric timer bulletin, No. 1100, has just been released by the C. H. Stoelting Company, Industrial Division, 424-P North Homan Avenue, Chicago 24, Illinois.

The new bulletin describes table model stop clocks, wall model stop clocks, precision chronoscopes, combination timers and impulse counters, stop watch controllers, and spring wound X-ray timers.

These Stoelting timers have wide application in industrial and laboratory testing, such as in measuring start-to-stop intervals of relays and instruments and for checking sequence operations. Circuit diagrams are included to show correct methods of connecting the various timers in test circuits.

HERMETICALLY SEALED METERS

A new line of 2½-inch hermetically sealed panel instruments, housed in steel cases and immune from the effects of humidity, moisture, chemical fumes, and other harmful agents, has been announced by the General Electric Company, Schenectady, New York. These new instru-



ments, for direct-current voltmeters and ammeters and for a-c radio-frequency ammeters, can be furnished in all standard ratings mentioned in, and conform to the performance requirements of, American War Standard ASA Specification C-39.2-1944. They especially meet the urgent demand of the Armed Services for moisture—and fungus-proof indicating instruments so vital for long-time service under tropical climatic conditions.

In obtaining a hermetically sealed enclosure, a thick, special, strain-free glass window is sealed to a metal ring, obtaining a glass-to-metal seal, and this in turn is sealed to a case by a soft-soldered joint. Hermetic sealing of the two terminal studs is obtained by a glass-to-metal seal between each metal stud and metal eyelet. The whole hermetic assembly is sealed to the steel base by a silver-solder operation.

The metal base is secured to the case by means of a synthetic-rubber gasket that is coated with a special sealing compound. The seal is obtained by a crimped-over metal ring, which compresses and retains the gasket.

The glass seal, the soldered points, and the metal ring form a completely hermetic enclosure for the instrument. According to laboratory tests, this means of sealing is unaffected by thermal shock, mechanical shock, or fatigue vibration.

The final assembly is evacuated, filled with an inert gas through a seal-off tube located in the base, and is sealed off at a pressure slightly above atmospheric.

Made for flush mounting on nonmagnetic or steel panels, these new instruments incorporate the standard 2½-inch internal-pivot element in a steel case which shields them from stray magnetic fields. They are capable of withstanding a thermo-shock test of at least 10 alternate exposures in salt water at 85 C and then at zero C, without evidence of moisture penetration or damage to the finish or enclosure.

Additional information on the new hermetically sealed 2½-inch panel instruments will be furnished upon request to the General Electric Company, Schenectady 5, N. Y.

TEST GLO

A new circuit tester called the "Lo-Volt" Test Glo, intended for testing circuits from 5 to 50 volts, is announced by the Ideal Commutator Dresser Company, 4027 Park Avenue, Sycamore, Illinois.

It simplifies the testing of open circuits, burned out fuses, and can be used for indicating the relative value of line voltage.

The incandescent "glow" lamp is protected by a transparent plastic housing. Overall length is only 7". It is compact so it can readily be carried in the pocket. Fully insulated test leads are 4" long.

This tester is particularly suitable for telephone repair men, automotive and aircraft mechanics and electricians.

POWER BOOSTER

The new and improved HP-16 Power Booster, latest development of the Talk-a-Phone Electronic Laboratories, enables the busy executive to now have *both* his office and factory at his fingertips *without* going through the central switch-board.

The HP-16 is capable of delivering a minimum of 15 watts "voice range" power. This is more than sufficient to cover the average paging system requirements, however, more than one booster can be used in a system where greater power levels are necessary. In addition, special type speakers (see catalog) are available for use with Boosters when necessary.

The X-tra Power Booster will work with the majority of inter-communication systems; however, certain of the Talk-A-Phone models have been specially designed so that when the HP-16 is used it becomes an integral part of the system, and not only does it provide the regular advantages of an office inter-communication system, but in addition paging facilities. When, for example, when model C-410 is used, operation of the Booster is extremely simple. By merely pressing one of the buttons marked "Power" the voice goes out into the factory penetrating the high noise levels. The unit is so designed that when the answer is received from the outlying station, the voice comes through at regular reduced office volume so as not to disturb the occupants of the central office.

An eight page catalog which illustrates the new improved HP-16 Booster and its accessories as well as the complete Talk-A-Phone line of the time-savnig intercommunication equipment manufactured by the Talk-a-Phone Mfg. Co., 1512 So. Pulaski Rd., Chicago 23, Illinois.

RECORDERS

A new group of recording instruments designated Televac has just been announced by Precision Scientific Co. of 1750 N. Springfield Avenue, Chicago 47, Illinois.

The type "MR" instrument with a range of 0-500 mcirons utilizes the new Televac #500 Thermal Gauge with specially treated elements. Features of latter include coated filaments to prevent "off calibration" periods due to water, oil vapor or other contaminating vapors, or other contaminating vapors, increased sensitivity gained through use of two filaments in both standard and variable tubes of the vacuum gauge, all gauges are interchangeable without recalibration, and the user is assured of duplicate readings in terms of absolute pressure in microns. The gauge is supplied with a special Leeds and Northrup Micromax Strip Chart Recorder calibrated directly in microns.

The type "S" recorder for ultra vacuum contains two ranges—0-500 microns for pressures above 1 micron, and utilizing the #500 thermal gauge in this range and an industrial type ionization gauge for the range 0 to 0.4 microns. Accurate readings may be obtained down to 10^{-6} mm Hg (.001 micron). The type "S" instrument also features a safety circuit which makes it impossible to turn on the ionization gauge until a vacuum of 1 micron has been reached. Average life of ionization gauge is 3000 hours.

With this group of instruments a new line of fixed and calibrated variable leaks are to be listed.

A new brochure is now being prepared containing all high vacuum instruments and accessories now available, and further information may be had by writing Precision Scientific Co., 1750 N. Springfield Avenue, Chicago 47, Illinois.

AIRTIGHT STEEL-TO-GLASS SEAL

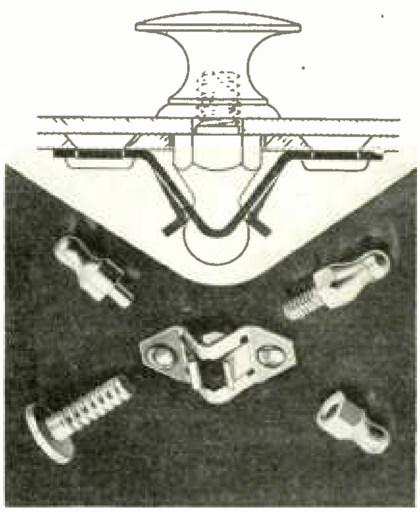
A new method of fusing steel and glass in a permanent airtight seal for metal electron tubes has been revealed by Dr. G. R. Shaw, Chief Engineer of the Tube Division of the Radio Corporation of America. The method provides a more foolproof process, he said, in addition to permitting the use of a staple metal for the glass-to-metal seal in place of special alloys which are more costly and sometimes scarce.

The principle which now permits the use of steel for the header insert involves the fact that glass is a solvent for oxides. By applying intense heat from fine jets of gas flame to the outside of the oxidized steel band, after the glass has been softened and pressed into a button inside the band, it is possible to cause any excess oxides to dissolve into the glass. Before this principle was applied, too much oxidation was as serious an obstacle as too little, the latter preventing adhesion, while the former left a porous interface between the metal and the glass.

SPRING STEEL LATCH

The new Spring Steel Speed Nut Latch No. 1663 has been developed for instant attachment and removal of box covers, access doors, panels and inspection plates. The spring arms of the Speed Nut snap over ball or grooved studs to provide firm attachment, yet studs may be quickly withdrawn.

The Speed Nut is available in five degrees of pull-out tension. Three styles of



ball studs are available . . . drilled and tapped for #6-32 screws, threaded shank, (#6-32 thread) and plain shank for riveting. These, as well as the grooved stud, are provided in various lengths to suit application requirements.

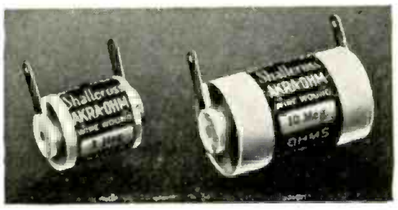
When writing for samples, please specify (a) pull- out tension required (3½, 8, 12, 18, or 30 lbs.); (b) thickness of panel to which Speed Nut will be attached, (c) type of stud, and (d) length of plain or threaded shank, or length of grooved stud.

Manufactured by Tinnerman Products, Inc., 2154 Fulton Road, Cleveland 13, Ohio.

RESISTORS

The Shallcross No. 1100 Series Hermetically Sealed Accurate Fixed Wire-Wound Resistors (Patent Applied for) represent the culmination of a long period of research designed to overcome the many obvious disadvantages of conventional attempts at resisistor sealing. The result is a series of hermetically sealed units impervious to moisture, fungus, vibration, and rough handling. They are constructed without glass, without the use of fragile "floating" or stud-locked resistance elements, and without ferrule terminals or caps which give rise to possibility of strain and consequent sealing failure. In size, due to the fact that they can be layer wound, the Shallcross No. 1100 Series compares favorably with the corresponding standard BX Shallcross impregnated Types 190 and 196 Akra-Ohm Accurate Fixed Wire Wound Resistors. Moreover, they utilize *standard* mounting facilities. They are at present available in two designs and in all resistance values from 1000 ohms to 10 megohms. High ohmic value non-induction resistances can without danger of diffiuulties due to leak-be enclosed in this type of construction age.

Both the resistance form and the pro-



tective shell are of sturdy ceramic. The resistance winding element and outer shell are a complete, integral unit without internal leads or floating wires, thus affording complete protection even against severe vibration. Positive solder-sealing without the use of ferrule caps or glass drawing gives absolute protection against moiture and fungus. Windings are of the standard non-inductive pi type, thus permitting any resistance values possible in the comparative Type Shallcross 196 and 110 commercial units. Terminals are of the standard solder lug type. Mounting is accomplished by means of the standard mounting hole, thus permitting standard mounting throughout any piece of equipment. Insulation resistance to ground is exceptionally high.

Details will be sent on request to the manufacturer.

THIS MONTH

[*Continued from page* 60]

granted patents is for the Progar, a robot monitoring system for radio stations which has been in use on KSFO for the past several years. This robot monitoring unit, no doubt, will gain wide acceptance during the post-War development period.

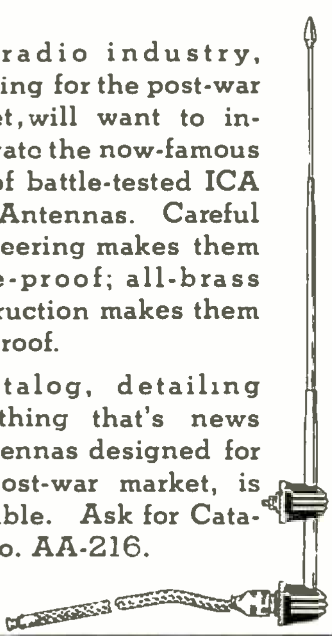
MERGER OF UTAH AND DETROLA PROPOSED

A proposal to merge Utah Radio Products Company, Chicago, and Universal Cooler Corporation, Marion, O., into International Detrola Corporation was approved today by the Boards of Directors of all three companies.

"Meetings of stockholders to vote on the proposal will be held soon," C. Russell Feldmann, Detrola President and Board Chairman, said.

"The merger proposes uniting industries," he explained, "which in their last fiscal year had aggregate sales of $132,-000,000.00. They possessed net current assets on May 31, 1945 totalling more than $8,000.000.00 and have 7500 shareholders. They and their subsidiaries own or operate a total of nine manufacturing plants in this country and two in Canada. There is also an affiliated manufacturing and sales company in Argentina. They have distributed their products in many countries."

The program provides for exchange of one Utah share for six-tenths of a share



of Detrola, one share of Universal Cooler Class A no-par stock for one of Detrola, and one share of Universal Cooler Class B no-par stock for one fourth of a share of Detrola.

International Detrola, which recently acquired controlling ownership of Rohr Aircraft Corporation, California producer of aircraft power plants and sub-assemblies, normally manufactures home and automobile radio receivers, automatic record changers, other electronic items, and machine tools. It has plants in Detroit, Elkhart, Ind., and Indianapolis.

Rohr recently has been granted, by the governmental agency in charge of such allocations, permission to produce in the third quarter of 1945 a limited quantity of domestic refrigerators. It has applied for permission to build domestic washing machines.

BROADCAST SERVICE INCOME

A total broadcast service income of $68,888,110 for 1944—or more than a 47 per cent increase over their 1943 total and more than a 125 per cent increase over their 1942 total—was received by 836 standard broadcast stations reporting to the Federal Communications Commission, it was announced recently.

Average broadcast income per station rose from $36,488 in 1942, to $55,948 in 1943, to $82,402 in 1944.

Only 33 of these stations reported losses during the year 1944, while 85 lost money in 1943, and 188 in 1942.

Seven hundred and sixty-five stations reported increases in 1944 over 1943 amounting to $22,678,087, while 71 stations reported decreases amounting to $562,558, making o total increase in 1944 over 1943 $22,115,529.

(Seven hundred and forty-two stations reported increases in 1943 over 1942 amounting to $16,689,719, while 94 stations reported decreases amounting to $421,032, making a total increase in 1944 over 1943 $16,268,687.)

During the year 1944 there were 919 standard broadcast stations operating in the United States, Alaska, Puerto Rico and Hawaii, which number included 35 non-commercial stations. Twenty-four of the 884 commercial stations have not submitted their 1944 financial reports to the Commission, and 24 stations were not in operation in all three years included in the following summary. The summary also excludes operations of 9 key stations of major networks.

RECTIFYING CRYSTALS

[*Continued from page* 50]

nal out of the crystal. It is quite possible at present to construct microwave receivers so that thermal noise arising in the crystal mixer is the only limitation on the weakness of a signal which may be detected. It is generally considered that this means a crystal output signal of at least 2 microvolts is required.

Most microwave receivers are of the superheterodyne type with no initial amplification which would correspond to r-f amplification in an ordinary radio. The received microwave signal is carried from the antenna through a hollow pipe wave guide or coaxial line directly to a resonant cavity, in which is mounted a crystal rectifier.

The resonant cavity is nothing but a hollow metal enclosure that is carefully designed and so dimensioned that wave lengths of the desired radio signal fit into it exactly and hence are able to resonate and build up to fair strength. The cavity also receives a microwave signal from a local oscillator. The local oscillator differs in frequency from the desired signal by a predetermined amount, and the non-linear response of the crystal causes it to act as a converter so as to supply the difference frequency to an intermediate amplifier. Except for the frequency magnitudes involved, the theory is the same as in ordinary superheterodynes where the conversion properties of rectifying diodes are well known.

FREQUENCY MEASUREMENT

[*Continued from page* 45]

is shown in *Fig. 2*. When the two frequencies are equal, and at multiples of the comparison frequency, the eye will stay open.

The 60-cycle line voltage may be used for comparison of the lower frequencies. Beat frequencies every 60 cycles will be obtained and comparisons up to several hundred cycles may be made.

Standard frequencies of 440 and 4,000 cycles may be received from WWV and used in the same way. Beat notes will be generated every 440 cycles or every 4,000 cycles. In this way calibrations up to about 20 kc may be obtained.

If calibration above 20 kc is desired an audio mixer stage will be required between the two signals and the ray tube indicator. This circuit is shown in *Fig. 3*.

The two controls, *R1* and *R2*, are ganged to form a mixing control. They are so connected that the volume of one signal is increased while that of the other is decreased and vice versa. This feature is not necessary but gives a convenient method of balancing the two signals. Only enough signal should be applied as will cause the eye to just close.

Using the points found in this way, a calibration curve may be drawn on graph paper.

The indicator described may be useful in cases where exact frequencies must be spotted for test purposes. Most 60-cycle lines are accurate to within a fraction of a cycle, and of course the standard frequencies from WWV are accurate to within one part in 10,000,000.

TECHNICANA

[*Continued from page* 30]

and a table of correction values can be employed.

The circuit of the square wave analyzer is shown in *Fig. 10*.

The 500-ohm variable resistor is used for gain control in tube V_1. For various positions of S_1 the several types of load are connected to the peak voltmeter consisting of diode V_2 and amplifier tube V_3.

The meter is first adjusted to zero, with S_1 in position *0*, by varying the bias on V_3. With S_1 in position *1*, S_2 is closed to introduce a "smoothing" capacitance C_A to remove the overshoot. S_2 is then opened and the meter indicates the value of the overshoot. In position *2* the speed, as indicated on the meter, ranges from 0.2 to 1.0 × 10^6. In position *3* the speed range is 1 to 5 × 10^6. In position *4* the range is 5 to 25 × 10^6. In position *2* the low resistance value, 280 ohms, provides critical damping. In all positions some resistance is required so that the voltage levels off before the next pulse occurs. For overshoot the range on the meter is 0 to 50%.

In the actual circuit described S_2 is replaced by another switch ganged to S_1 and is closed only when the smoothing capacitor is to be introduced, and C_A consists of 11 fixed capacitors, ranging from .0002 µf to 0.5 µf, which are controlled by a third switch.

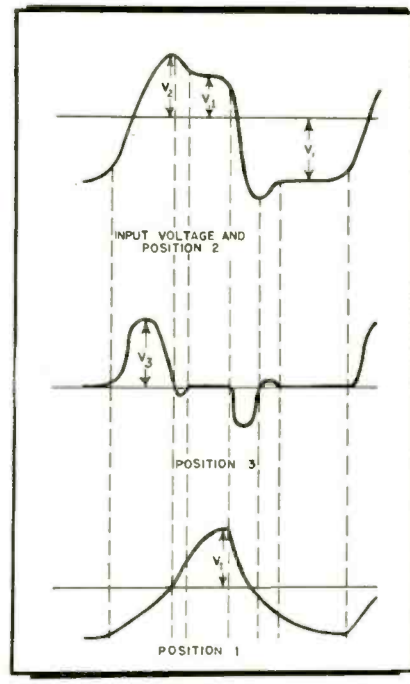


Figure 9

In practice this switch is calibrated in frequency rather than in capacitance since the capacitance selected must be large enough to remove the overshoot

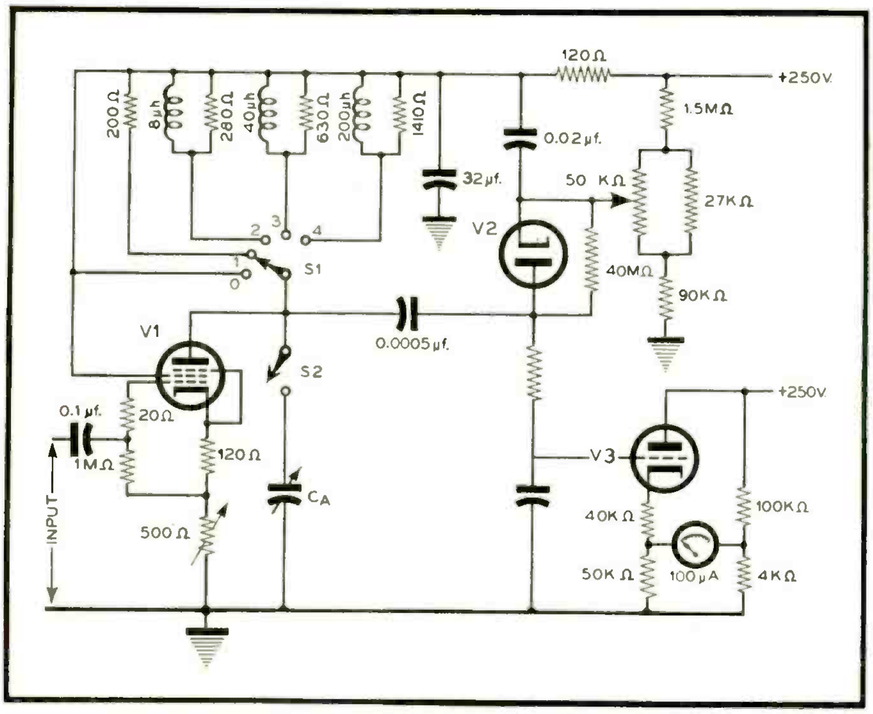


Figure 10

without reducing the value of the square wave peak. This can be done when the frequency is as high as 1/10 the speed, for a 10% overshoot, but not for a 50% overshoot. If the input frequency is smaller in proportion to the speed, this result can be attained even with a 50% overshoot. Consequently the dial is marked to indicate the maximum frequency that can be employed at that particular setting.

With .0002 μf for C_A the maximum frequency is 500 kc, and for 0.5 μf the maximum frequency is 0.2 kc.

MATERIALS

[*Continued from page* 34]

bination of insulation resistance and loss currents) can be so great as to "sap" the signal.

Probably the most important use of an aniline formaldehyde laminate is the terminal board illustrated also in *Fig. 4*. There are many requirements for a terminal board in theory, but there are also many difficult requirements to meet in practice.

Let's consider the basic terminal board problem: A terminal board must have high insulation resistance regardless of the conditions of humidity or temperature encountered; it must have high surface resistivity regardless of the conditions met. It must have high dielectric strength perpendicular to the laminations. It must (if it is to be used at some advanced frequency) have a low loss factor and a constant dielectric constant. It should have moderate arc resistance.

Mechanically, it must be stable, non-brittle, rigid, and must be satisfactory under high temperature conditions. It must have a low moisture absorption. It must be readily machinable. It must be low in cost and readily obtainable.

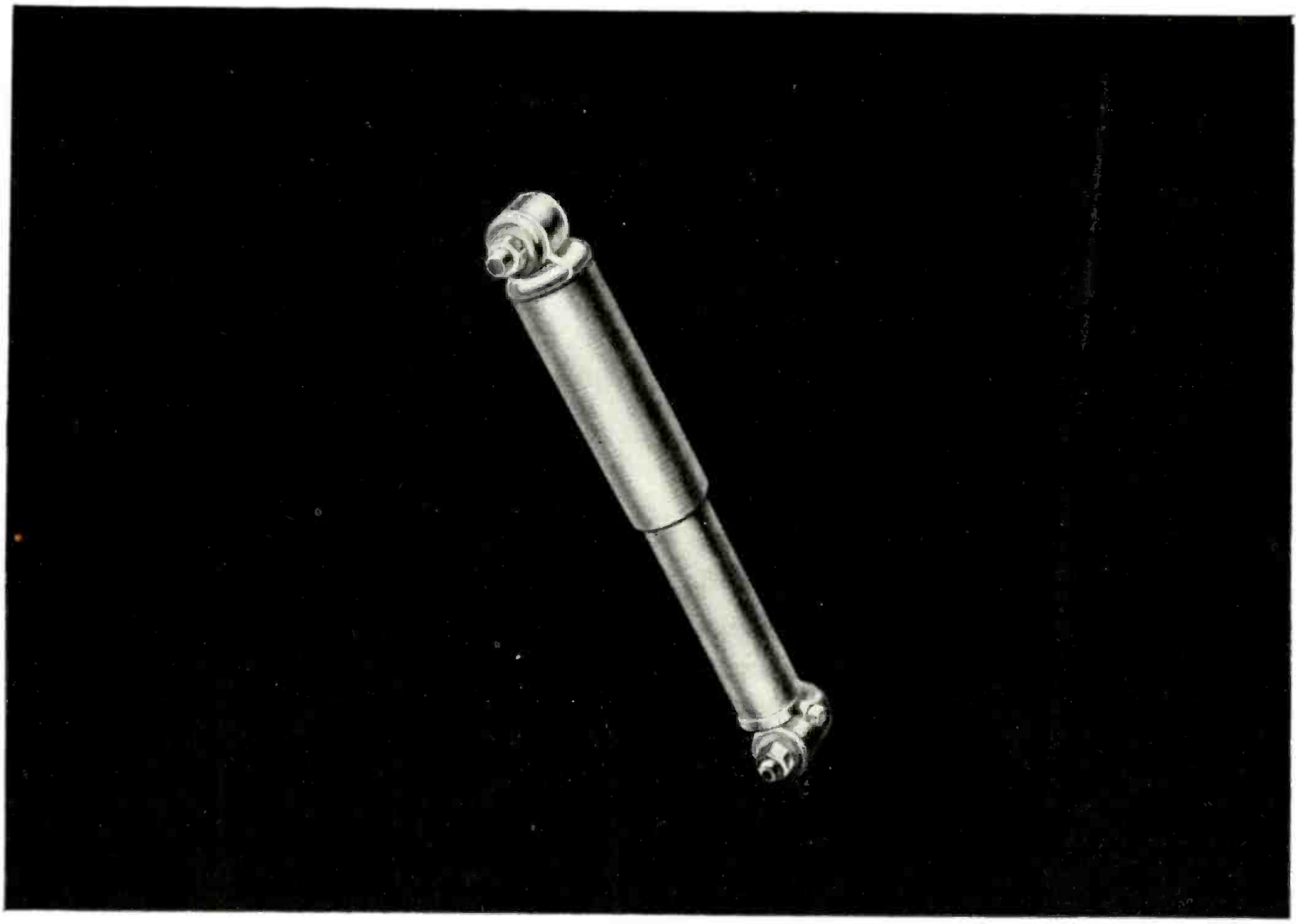
No material, obviously, has all these properties. Let us consider only the materials we have this far discussed to evaluate these in terms of the criteria proposed. (The author suggests that the designer keep open mind at all times in choosing such materials. During the war our thoughts have changed tremendously regarding a terminal board material. Tomorrow, some of the newer ceramic or plastic forms may more nearly approach our new criteria).

Consider the electrical merits of XXX or XXXP, paper-based phenolic stock, against GMG, glass-based melamine stock, and against LTS-E-6, glass-based aniline stock. All are recognized as superior electrical materials.

All the materials in question will have sufficiently high dielectric strength properties to meet the conditions of terminal board usage. The remaining properties are tabulated subjectively:

	XXX	*GMG*	*E-6*
Arc Resistance	Poor	Excellent	Poor
Loss Factor	Average	Poor	Excellent
Constancy of Dielectric Constant	Average	Poor	Excellent
Moisture Absorption	Average	Good	Good
Insulation Resistance	Average	Average	High
Constancy of Insulation Resistance & Humidity	Average	Excel'ent	Excellent
Surface Resistivity	Average	Average	Below Average
Heat Distortion	Average	High	Above Average

From such a tabulation, it can be seen that the best all-around material is a carefully selected XXX stock. However, when moisture absorption and loss factor enter the design problem, the better material is an aniline laminate; when the moisture absorption and arc resistance enter the design



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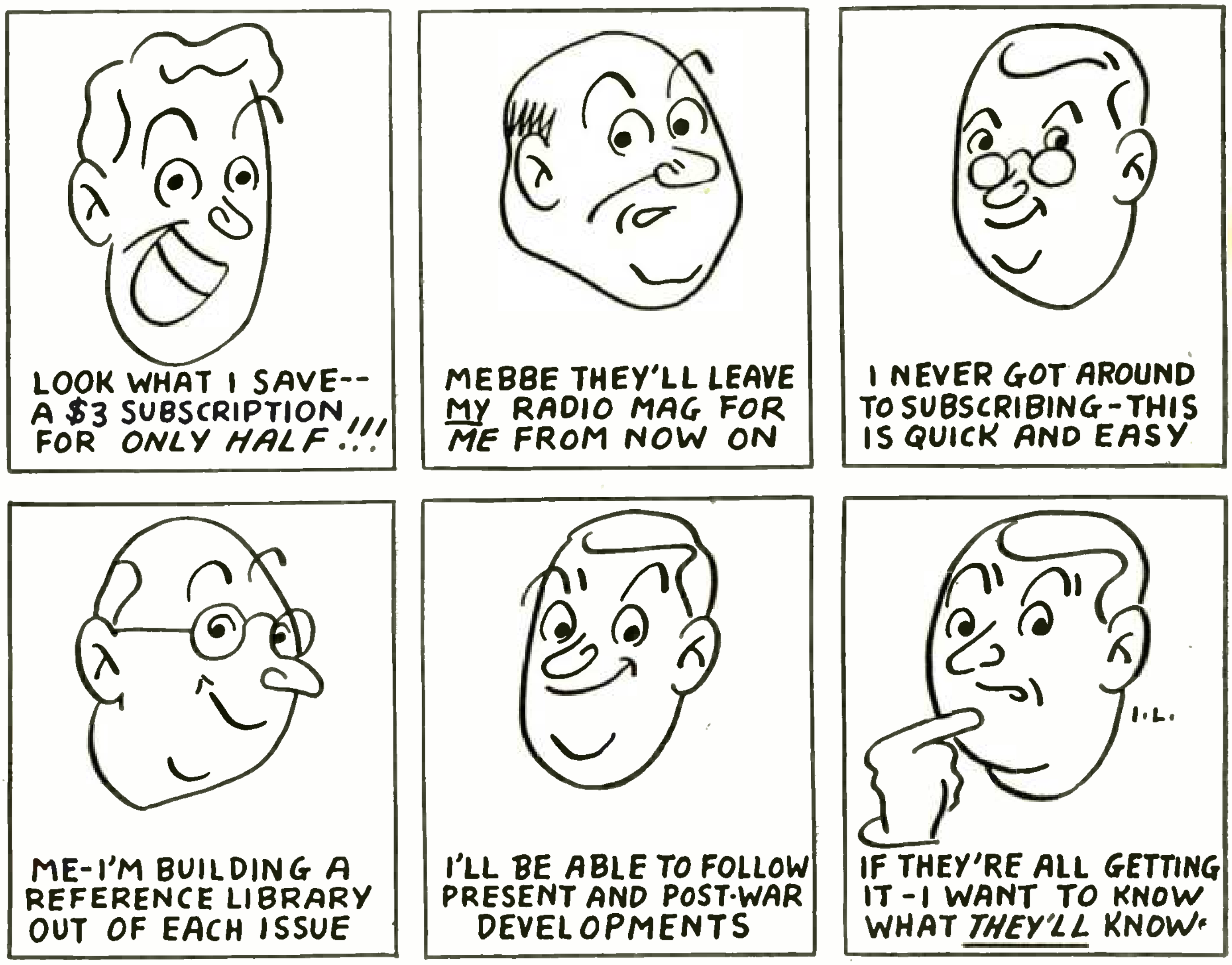

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problem, the better material is a melamine laminate.

Follow the analysis still further. Mechanically, the three laminates are substantially equivalent: melamine has a harder surface and a higher impact strength; aniline tends to be more brittle. More important than the physicals of these materials are the following two properties: cost and machinability.

	XXX	*GMG*	*E-5*
Cost	Low	High	High
Machinability	Average	Poor	Poor

From the point of postwar design, both of the newer materials seem to have limited application because of poor machinability and high cost. Primary explanation for both of these handicaps is the filler material, glass. Due to manufacturing conditions, glass for the laminating trade is expensive and probably will continue to be for some time. The cost of the glass is reflected, of course, in the price of the finished laminate.

Machinability, rated as poor by comparison with the other thermosetting plastics, is no serious drawback. Although carballoy-tipped tools are required because of the glass filler, certain machining methods have been improvised to lighten this burden. When more experience has been gained, machining costs will decrease tremendously — but the materials, glass-filled, will never be as easy to machine as paper- or linen-based stocks.

Despite the high cost and poor machinability, aniline laminates have been used extensively where difficult conditions of moisture resistance obtain. Reason for the success of this material can be found in the insulation resistance graph of *Fig. 5*. Note that this material has high insulation resistance even after exposure to continuous humidity.

Combination Laminates

Many forms of combination laminates are available. The core material, e.g., can be a paper-based phenolic with an outer surfacing layer of melamine-impregnated paper to improve the arc resistance. These forms are special but can be manufactured by any laminator where special properties are desired, particularly at low cost.

Analysis of any combination laminate involves a complete knowledge of the core material as well as the surfacing material.

But these materials and many related materials are new, brand new. As yet, a full evaluation of their properties and uses cannot be made. Of the ceramics and phenolics we know much more.

Any evaluation, such as contained in this article, must be revised in terms of more recent thinking as time progresses.

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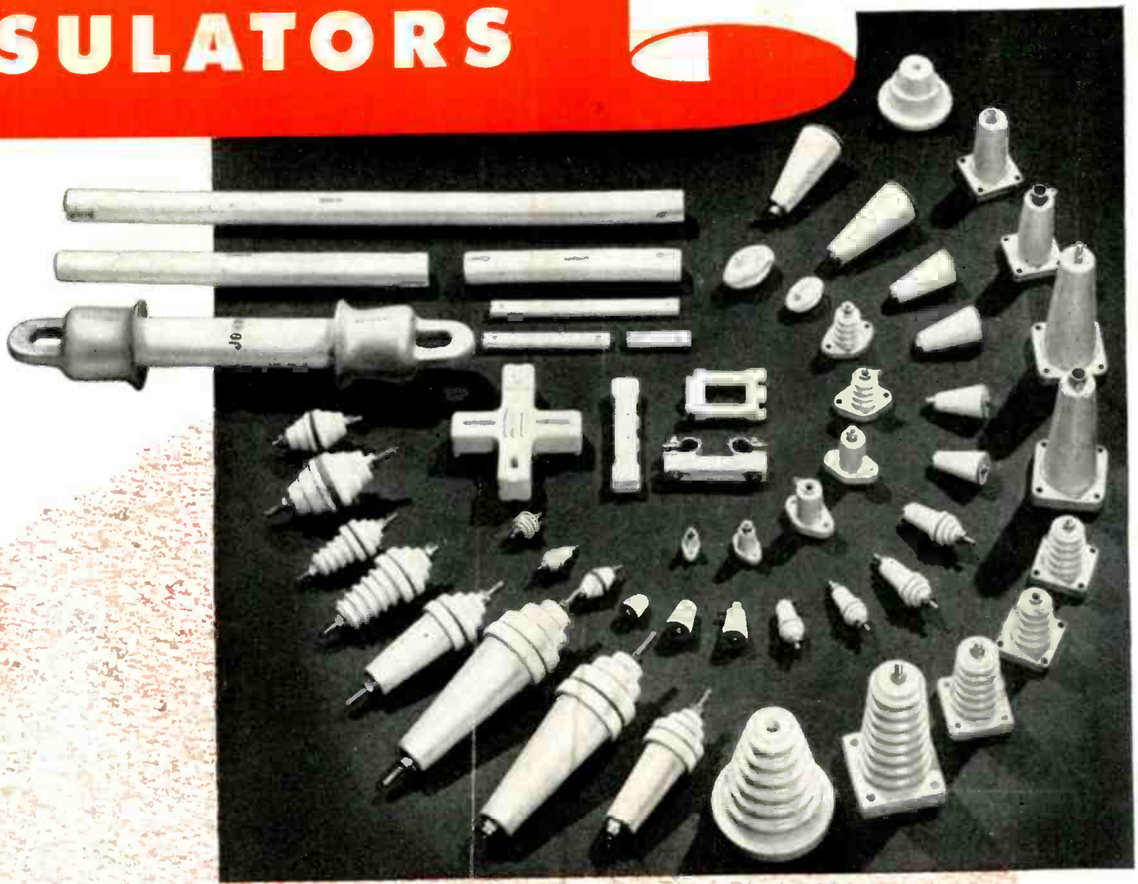

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