SEPTEMBER · 1942

electronics

radio, communication, industrial applications of electron tubes . . . engineering and manufacture

MERCURY for MARS

The liquid metal must be 99.99995 percent pure for the manufacture of tubes used by essential war industries

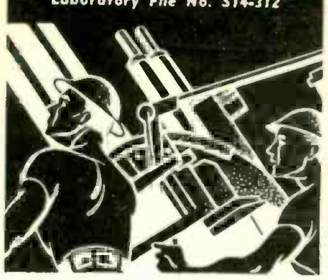
U. S. NAVY OFFICIAL PHOTOS

UTC CASE HISTORIES

Laboratory File No. S14-523

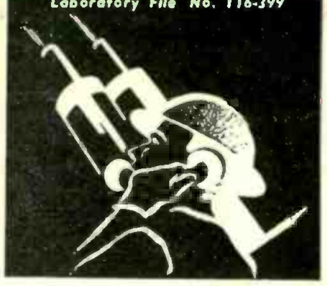
This unit helps "keep them flying." A UTC redesign combined two units in one . . . reduced quantity of critical materials 50% . . . reduced weight and size 40% . . . reduced installation time 60% . . . reduced possible trouble points 50%.

Laboratory File No. S14-312



This unit maintains ground communications at a more efficient level. Now plastic housed. Critical materials reduced 50%. UTC design reduced possible trouble points 50% . . . reduced difficulty of operation 50%.

Laboratory File No. T16-399



This unit is used at a number of points in aircraft communication. A UTC design reduced quantity of critical materials used 20% . . . reduced weight and size 20% . . . reduced possible trouble points 50%.

Laboratory File No. S9-474

This unit is a component in a piece of aircraft equipment. A UTC design reduced quantity of critical materials 60% . . . reduced weight and size 60% . . . made possible a similar reduction of size and weight in the complete equipment of which it is a component.

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UNITED TRANSFORMER CO.

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electronics

Vol. 15 — No. 9 — A McGRAW-HILL PUBLICATION

CONTENTS—SEPTEMBER, 1942

DEPARTMENTS

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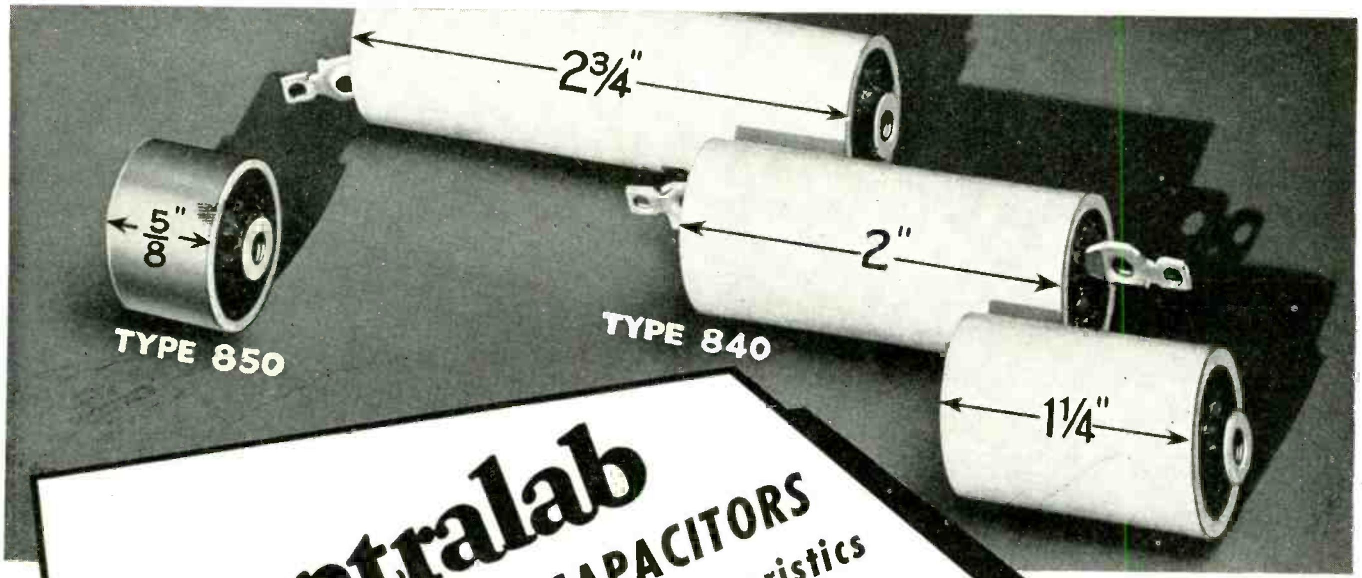


Centralab

CERAMIC TUBULAR CAPACITORS with Temperature Controlled Characteristics

Another important Centralab development in tune with our present war efforts. These parts are definitely suited to high and ultra high-frequency circuits.

Your inquiries are invited for special capacity problems in which Ceramic capacitors are indicated.

TYPE 850 High Frequency, High Voltage Unit

Capacity ranges 10MMF to 100MMF and intermediate values. Available either Zero or Max. Negative temperature coefficient. Standard tolerances as to coefficients and capacity. Size ⅝" long. .765" diameter, exclusive of terminals.

Power Factor .05% does not increase with ageing. Voltage rating 5000 volts D.C. A.C. voltage rating varies with frequency.

Terminals available in two types; same as Type 840.

TYPE 840 High Capacity

Available in any temperature coefficient from zero to —.00075 mmf/mmf/C°.

(1) Zero Temperature Coefficient up to 1500 MMF.
(2) Negative Temperature Coefficient up to 3000 MMF.

SIZE: .780" diameter Steatite tube — length varies with capacity and temperature coefficient.

500 MMF	NTC	approximately	¾" long.
1000 MMF	NTC	approximately	1" long.
500 MMF	ZTC	approximately	¾" long.
1000 MMF	ZTC	approximately	1½" long.

Power factor of .05% — does not increase with ageing.

Voltage rating — 1000 volts D.C. Leakage more than 10,000 megohms.

Terminals — two types available:

(1) Lug .030" thick threaded for 6-32 machine screw, or conventional soldering
(2) Axial mounting post with 6-32 machine screw thread.

CENTRALAB: Div. of Globe-Union Inc., Milwaukee, Wis., U. S. A.

these instruments are calibrated for

Permanent accuracy in electrical instruments took on a new meaning when Westinghouse developed the one-piece permanent magnet.

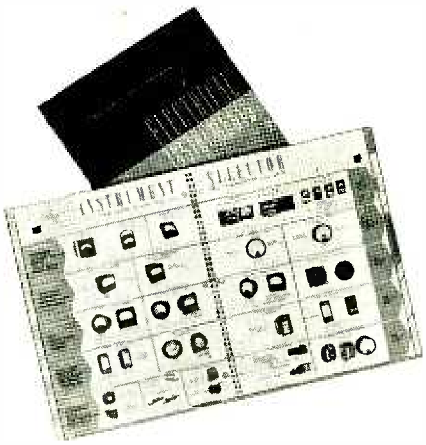
By welding soft pole pieces to the main poles, we eliminated the air gaps ordinarily left at joints. The armature gap now is the *only* air gap.

These magnets are pre-aged by special heat treatment. They keep their field strength for periods far beyond the life of the instrument. Their high coercive fields are undisturbed by even the most severe service.

Many years in a wide range of applications—schools, laboratories, railways, generating plants and industrial plants—have confirmed this permanent calibration as a special Westinghouse instrument advantage.

Our permanent magnets share honors with our nonblunting pivots and ageless springs, white dials and tubular pointers in winning for our instruments exacting responsibilities in vital production activities and in wartime equipment.

J-40335



Your selection of electrical instruments can be simplified by using this new Westinghouse Instrument Selector Book. If you do not have a copy write for B-3013 to Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa., Dept. 7-N.

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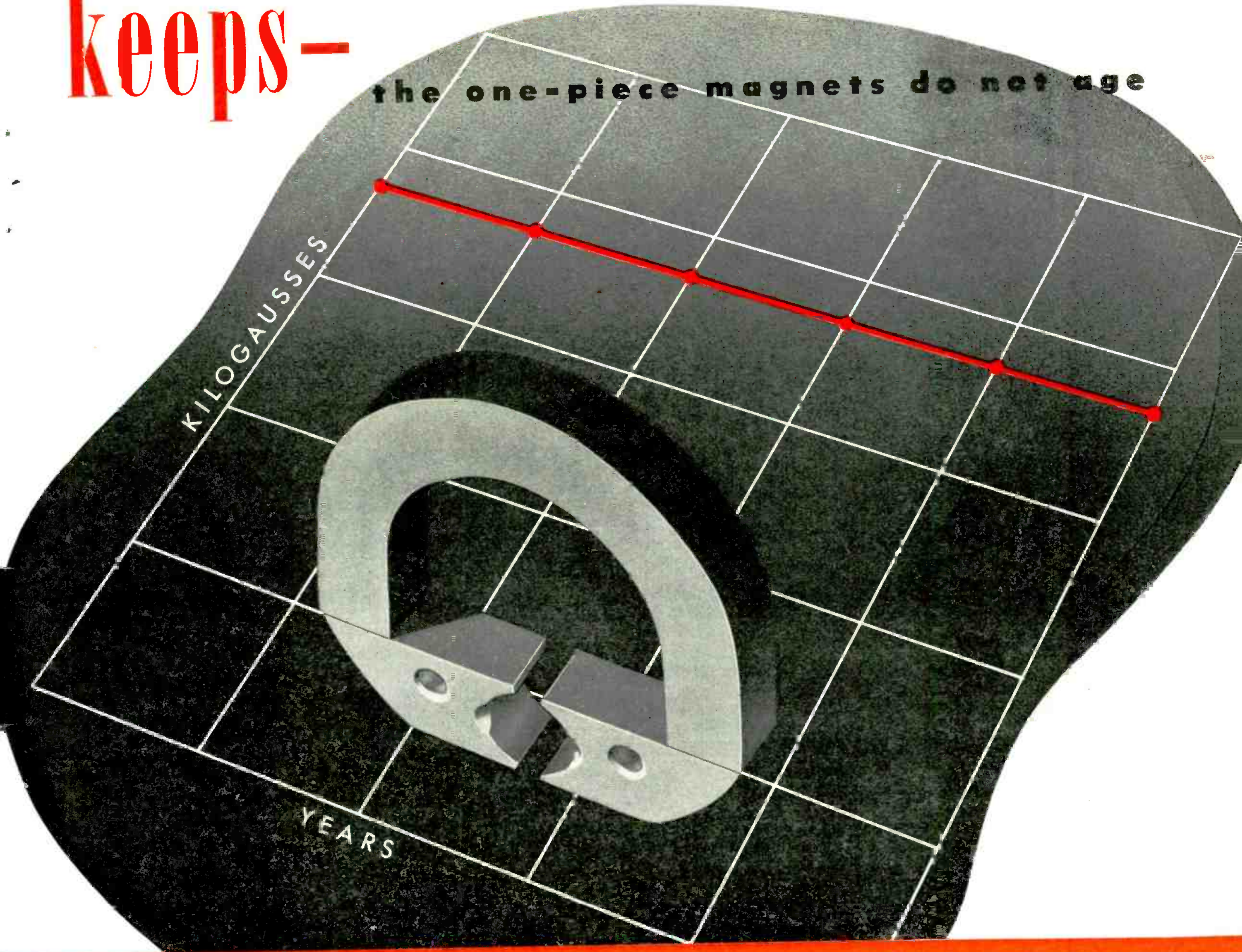
keeps—

the one-piece magnets do not age

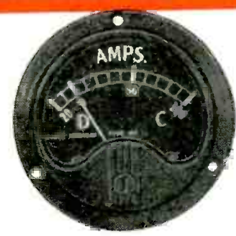


INDUSTRY'S MOST COMPLETE LINE OF ELECTRICAL PRECISION INSTRUMENTS

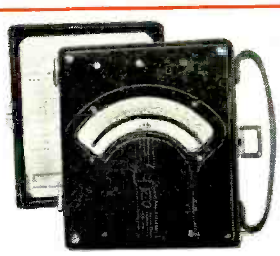
Portable potential and current transformers, of which the PV-130 and the PC-137 are examples, extend the range of measurement on portable a-c instruments.

Triple range ohmmeters, P-25, have 2% accuracy for a wide range of testing applications. Types for a-c or d-c.

High visibility switchboard instrument KA-25 with flush-mounted case 5½ inches square. Accuracy is within 1%.

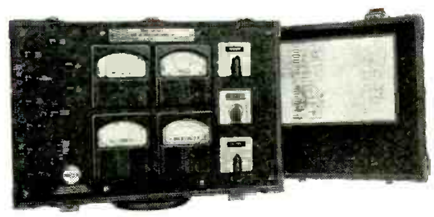


MX ammeters with 2% accuracy for aircraft service. Calibrated to show condition of d-c power. Withstands severe vibration.

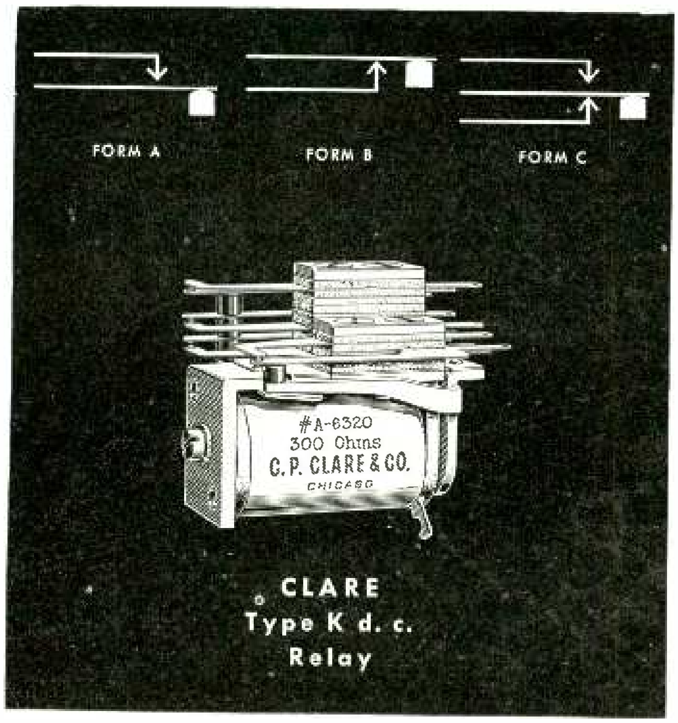


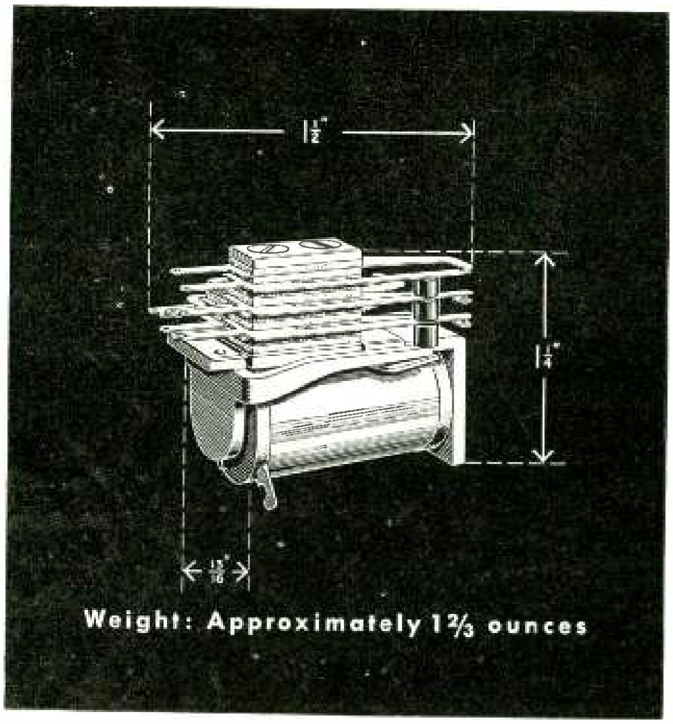
P-5 series voltmeter with five-inch double range scale has a mirror strip which facilitates accurate reading. Types for a-c and d-c.

This portable P-4 instrument with ¾% accuracy meets a wide range of requirements. A-c and d-c models available.



TA Industrial Analyzer contains in one case *all* the instruments needed for complete operating data on a-c circuits in any industrial plant.





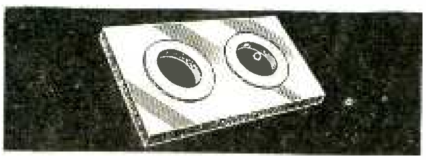
Our Customers Say It Is Better Than We Claim

This Clare Type K d. c. Relay is carefully inspected and tested before shipment. **Now, our customers, after making their own severe tests, say it is better than we claim.**

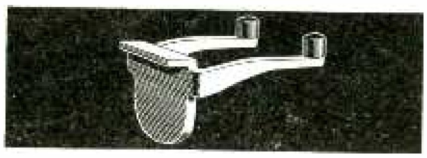
As illustrated, it is extremely small, measuring only 1½" x 1¼" x 13/16", and weighs approximately 1⅔ ounces . . . It can be furnished in the contact forms shown above with any number of springs, up to and including 12 . . . coil voltage range is from 1.5 volts to 60 volts d. c. . . . Contacts of either 18 gauge silver, rated one ampere, 50 watts, or 18 gauge palladium, rated two amperes, 100 watts can be furnished.

In addition to the typical Clare "custom-built" features illustrated at the right, this relay has additional features worthy of your consideration . . . It is unusual in the fact that the design is such that the relay itself is capable of withstanding severe vibration. Therefore, no anti-vibration springs are employed . . . The screws by which the contact spring pile-ups are fastened to the heelpiece are tightened under pressure and secured into the heelpiece by a coating of Glyptol as an added precaution . . . All metal parts of this relay are specially plated to withstand a 200 hour salt spray test.

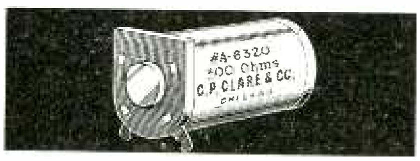
The size and weight of this relay is a very definite contribution to design problems and, like all Clare Relays, can be "custom-built" to meet your specific requirements. Write us regarding them. We will make suggestions. In the meantime, send for the Clare catalog and data book. C. P. Clare & Company, 4719 West Sunnyside Ave., Chicago, Ill. Sales engineers in all principal cities. Cable address: CLARELAY.



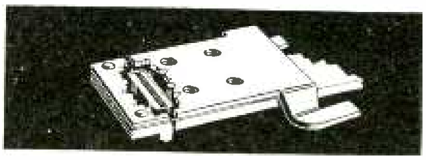
Spring insulators are made from special heat treated Bakelite that permits punching without cracks or checks and possesses minimum cold flow and low moisture absorption properties. Each Type K Relay is given a 1000 volt a.c. insulation breakdown test.



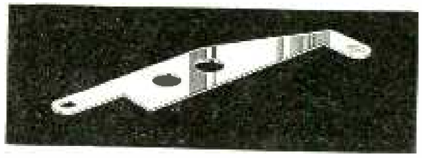
The armature assembly, heelpiece and coil core are made of magnetic metal carefully annealed. The armature assembly is available with either single or double arm.



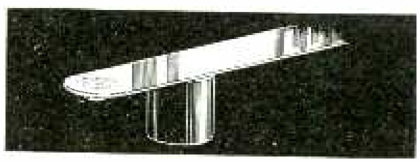
The small coil is equipped with a front spool head having a flat side. This locks the entire coil in place against the heelpiece, preventing it from turning or becoming loose. The screw holding the coil in the heelpiece is equipped with a split type lockwasher. The coil is carefully wound to exact turns on precision machines. Coils can be supplied impregnated with a special varnish. They are covered with a transparent acetate tape. Each coil shows data regarding resistance and type number.



Uniform armature movement is assured by a hinge of "fatigueless" beryllium copper, heat treated and designed to provide a wide margin of safety, insuring long life under vibration and permitting millions of uniform operations.



Contact springs are made of nickel silver to the manufacturer's specifications. The contacts are over-all welded to these springs by a special process.



Spring bushings of Bakelite are designed, constructed and attached to the springs so that the small springs used on this relay are not weakened. Uniformity of relay operation and long service life are thereby assured.

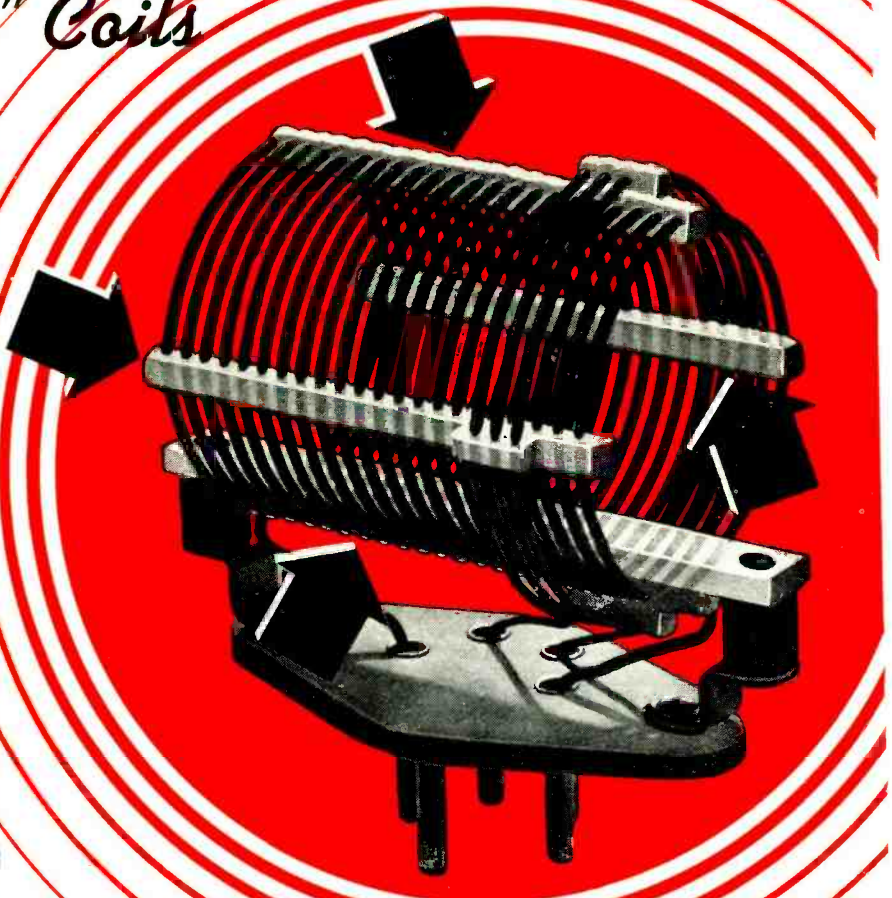
CLARE RELAYS

"Custom-Built" Multiple Contact Relays for Electrical, Electronic and Industrial Use

LUMARITH

REG. U.S. PAT. OFF.

Insulates "Air Inductor" Coils



CELANESE CELLULOID CORPORATION

This "Air Inductor" manufactured by Barker & Williamson, is one of the smallest tuning coils of a series that ranges from 1" in length to two-foot coils, a foot in diameter. These Inductors are now used in military and naval communications equipment for band-changing in transmitter circuits. They are insulated with LUMARITH plastics.

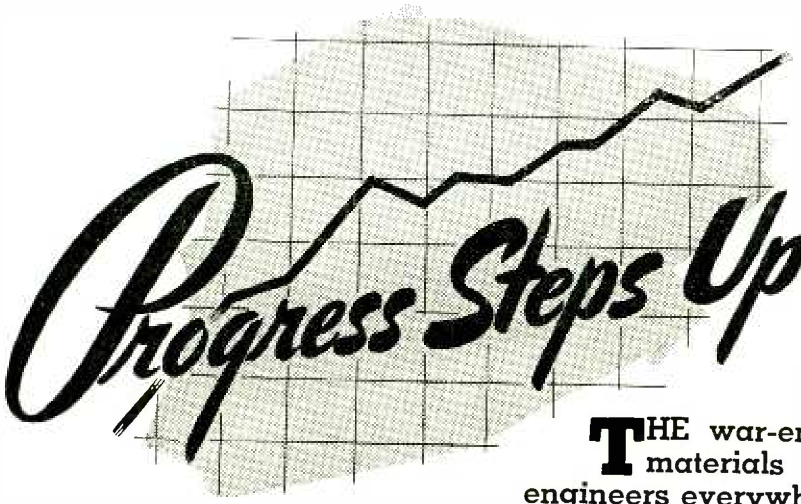
LUMARITH is available in sheets, rods, tubes, molding powders, transparent film from .0005", and dopes or coating liquids. It is being used for turn insulation on wire, as layer and slot insulation, and for molded and laminated parts in many radio, telephonic and electronic applications. Write today for data applicable to your design and production problems, especially on U. H. F. equipment.

A Few Properties of

LUMARITH

High dielectric strength. Low dielectric loss. Resistant to fresh and salt water and weak acids . . . unaffected by mineral oils and ordinary varnish solvents. High yield strength. High resistance to mechanical abrasion and impact. Cements easily, firmly (actually a weld). Write us for more data.

Celanese Celluloid Corporation, 180 Madison Ave., New York City, a Division of Celanese Corporation of America Sole Producer of Celluloid* (cellulose nitrate plastics, film base and dopes) . . **Lumarith*** (cellulose acetate plastics, film base, insulating, laminating and transparent packaging material and dopes) . . **Lumarith* E. C.** (ethyl cellulose) . . *Trademarks Reg. U. S. Pat. Off.

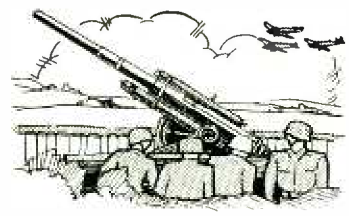


Progress Steps Up in War Time!

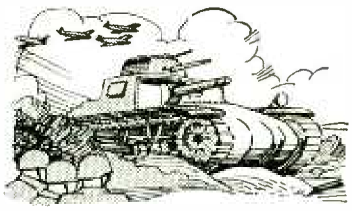
THE war-enforced necessity of trying out new materials and new methods has stimulated engineers everywhere and brought about a new speed in technological progress. Some of the new things discovered now will have important and permanent results on production. With the aid of its suppliers and customers Formica has participated in this progress and has recently been able to announce several new developments:

ARC RESISTING INSULATION

Research in synthetic varnishes has made available materials which have enabled Formica to produce an electrical insulation with far greater arc resistance than was ever available in laminated insulation heretofore. It is made in paper, cloth and glass base. The Fiberglas grade shows ten times the arc resistance ever available in such material heretofore.



FLEXIBLE PLASTIC NAME PLATES



The necessity of finding new materials to replace metal brought about the development of a thin, pliable plastic sheet, into which printed material can be introduced, which can be attached to curved surfaces and can be safely riveted without danger of shattering. The material is stable in color, unaffected by grease or solvents.

GLASS CLOTH BASE

Scarcity of ceramics created a big demand for an insulating material with a low power factor, and one of the answers proved to be a laminated sheet made of glass cloth impregnated with phenolic resins and cured under heat and pressure. The material also has exceptional stability of dimensions under variations in humidity.

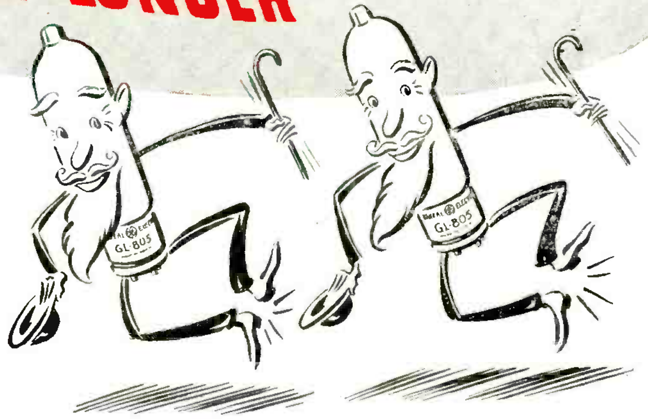
PREGWOOD REPLACES METAL

By impregnating wood with phenolic resins and curing it under heat and pressure a material of good mechanical strength and stability of dimensions, weighing only half as much as aluminum, has been made available, for aviation uses where lightness and strength are paramount.

The Formica Insulation Co.
4661 Spring Grove Avenue
Cincinnati, Ohio

FORMICA

10 Suggestions to make your THORIATED-tungsten-filament tubes LIVE LONGER



HERE'S HOW you can easily remove many of the causes of premature tube failure

1 Don't overload the tubes. Use adequate protective devices such as a fuse or relay. Heavy overloads are apt to evaporate the thorium surface from the filament, and permanently damage the tube.

2 Normal operating temperature for thoriated-tungsten-filament tubes is obtained by operating them at the *rated* filament voltage. Care should be taken to operate them *at this voltage* (except for standbys and when reactivating). Occasionally, under or over voltage will give longer life, but such operation should only be carried out after first consulting the tube manufacturer.

3 Tubes that have been momentarily overloaded, or run at subnormal filament temperature, can quite frequently be reactivated by following this simple procedure: Operate the filament at the rated voltage for ten minutes or more with no voltage on the plate or grid. This process can be accelerated by increasing the filament voltage to 20 per cent above the rated value for a few minutes.

4 Increase the filament voltage progressively (only a small percentage at a time) when a tube no longer responds to reactivation. New filament transformers may be necessary for such operation.

5 For tubes of *250-watt plate dissipation or higher*, when the load on the tube is intermittent, keep the filament at 80 per cent of normal voltage during standby periods of *less than two hours*. This helps keep the cathode surface replenished, and makes it more quickly available when raised to normal filament voltage. If the standby period is *more than two hours*, the filament current should be shut off.

6 For tubes of less than 250-watt plate dissipation, filament voltage should be removed for standbys of more than 15 minutes.

7 For all types of thoriated-tungsten-filament tubes if the off period is less than five minutes, operate the filament at full voltage continuously, as excessive heating and cooling cycles tend to distort this type of filament.

8 Keep tubes well ventilated—with fans or blowers, if necessary.

9 Run at lowest possible anode current and voltage.

10 Minimize plate dissipation by careful tuning of the transmitter.

The Navy "E", for Excellence, has been awarded to 92,780 General Electric employees in five plants manufacturing naval equipment

These Suggestions Apply to Such Tubes As These G-E Thoriated-tungsten-filament types:

GL-146	GL-276A	GL-812	GL-849
GL-152	GL-800	GL-813	GL-851
GL-159	GL-801	GL-814	GL-860
GL-169	GL-803	GL-833A	GL-861
GL-203A	GL-805	GL-834	GL-865
GL-204A	GL-806	GL-835	GL-1623
GL-211	GL-809	GL-838	GL-1628
GL-217C	GL-810	GL-845	
GL-242C	GL-811		

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General Electric, Section B161-39A
Schenectady, N. Y.

RUSH

☐ Please send me........copies of "9 Ways to Make Your Tungsten-filament Tubes Last Longer," "How to Get Longer Life from Your Mercury-Vapor Tubes," and further information on the operation of thoriated-tungsten-filament tubes.

☐ I am conducting a radio class for..................and would like a sample package of your textual manuals.

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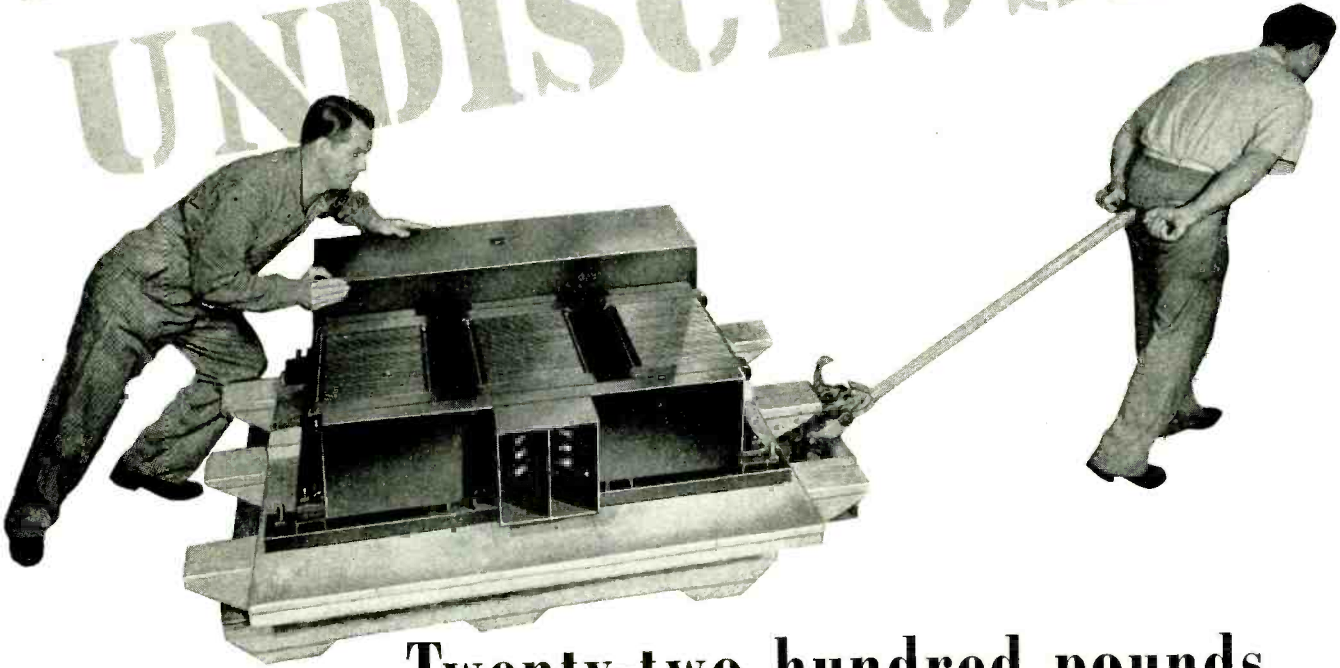
GENERAL ELECTRIC

DESTINATION UNDISCLOSED



Twenty-two hundred pounds of Constant Voltage...

Somewhere on the industrial firing line this huge 3-phase unit is taking its place with the thousands of other Sola Constant Voltage Transformers that are rendering distinguished service in winning the all important battle of production.

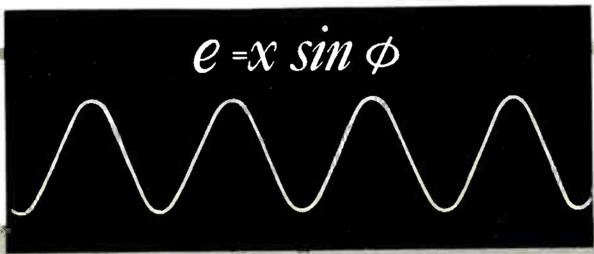
This war has placed a premium on *precision*. It demands a steady flowing production line of all materials of war.

In the industries that are geared to war production, Sola Constant Voltage Transformers are one of the principal contributing factors towards the maintenance of peak efficiency, twenty four hours a day, seven days a week.

Day and night, without manual control or supervision, Sola Constant Voltage units are transforming the unreliable voltages of heavily loaded supply lines into perfectly regulated power—on the production line, in the laboratory or in the field—protecting vital precision machines and instruments against line surges or loss of efficiency.

We have helped hundreds of industrial plants solve their most perplexing problems. We can help you solve yours

Write for Bulletin **DCV-74**



SOLA
ELECTRIC COMPANY
2525 Clybourn Avenue
Chicago

SOLA CONSTANT VOLTAGE TRANSFORMERS

C-D's SERVE
with the "SUB-BUSTERS"

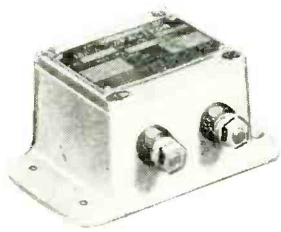
TODAY'S ***C-D Capacitors Speed Victory . . .***

TOMORROW'S ***C-D Capacitors assure more hours of use per dollar for American industry . . .***

Day in, day out, Navy blimps patrol our coastal sea lanes. When a sub is sighted, a flash brings a tough "sub-buster" to track the enemy down.

Teamwork of blimps and boats, of men and equipment, is winning the battle of the Eastern Seaboard. Here, as with a hundred other electrical and electronic devices on vital war duty, C-D capacitors are meeting the enemy challenge with the *finer* performance assured by 32 years' concentration on the building of superior capacitors.

Today, war-spurred "impossible" improvements and applications promise measureless peacetime benefits; giving a new meaning to C-D's well-known pledge to industry of "more hours of capacitor use per dollar". Cornell-Dubilier Electric Corporation, South Plainfield, New Jersey; New England Div.: New Bedford, Mass.



Special Mica Transmitter Capacitors

copied • imitated • but never duplicated

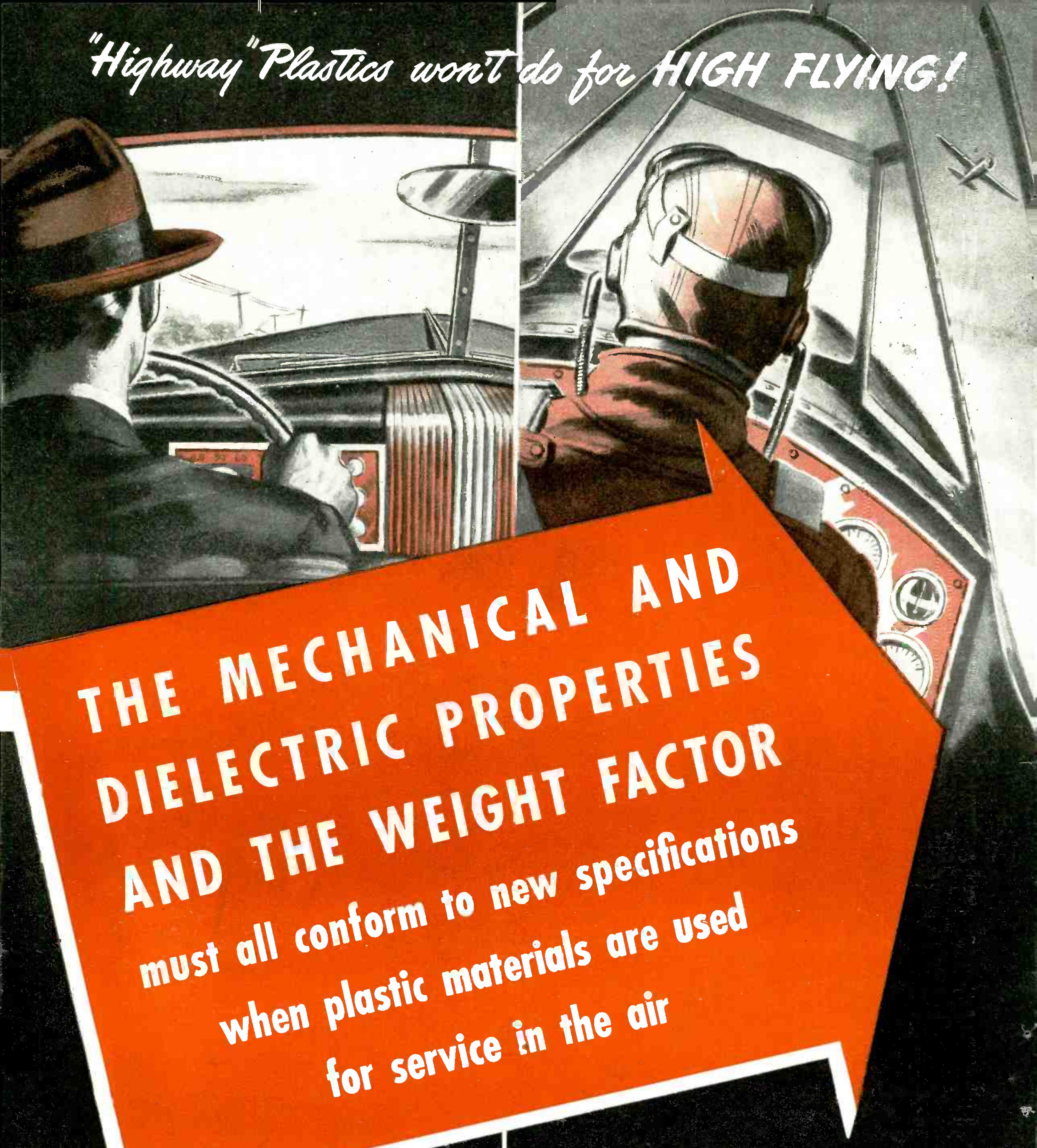
Type 21 dual-section mica capacitors are designed for filament by-pass applications in broadcast transmitters. They are encased in aluminum castings and permit mounting close to the filament terminals of power tubes. Compound filled, the type 21 mica capacitors have low inductance characteristics — thus affording excellent by-pass of r.f. current from filament leads to grounds.

Described in Catalog No. 160T free on request.

Cornell Dubilier Capacitors

MICA • PAPER • DYKANOL • WET & DRY ELECTROLYTIC CAPACITORS

MORE IN USE TODAY THAN ANY OTHER MAKE



3 Ways "BAKELITE" PLASTICS HEADQUARTERS Help Speed Production

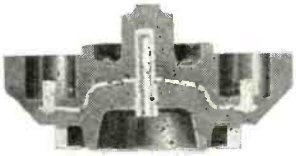
1 LITERATURE ON "DO'S" AND "DON'T'S" OF PLASTICS... Helpful technical booklets containing data on types and forms of BAKELITE plastics, and the most efficient methods of fabrication. This literature will help you to choose the right plastic for each job, save time and avoid errors.

2 GEARING OUR LABORATORIES TO YOURS ... Bakelite Laboratories offer a two-fold service. They are ready to help you utilize present plastics in war production. They will also develop new formulas to help solve the problems of highly specialized requirements.

THIS PICTURE STORY of a molded component for aircraft engines illustrates how it is possible to meet these new requirements by combining the correct plastic materials with proper designing skill and fabricating technique.

1. Material "A," the first choice of materials for this electrical part, is a low-loss type of plastic used generally for radio insulation. But, the part failed in arc-over at reduced pressures due to high elevation and also in dielectric breakdown because of incorrect design. Also, as the sectional view shows, cracks occurred when the sprue was broken while opening the mold, caused by lines of weakness set up by improper flow properties of this material in this particular molding process.

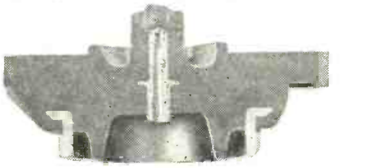
2. By a radical redesign of the plastic part and its metal inserts, dielectric failure was remedied completely. However, cracking still presented a problem which the design engineers attempted to solve by switching to material "B," and by building a proper jig to remove the molded part squarely from the mold itself.



3. Yet, cracks still occurred when the metal sections were machined after molding. Material "C" was then tested in order to obtain better machining strength. Although this tougher plastic machined satisfactorily, there was still evidence of continued cracking over the "ears" of the molded piece.

4. By filing smooth the corners of the ring inserts before they were inserted in the mold, internal strains were relieved, thus eliminating some of the cracking difficulty. This combination of material "C" with the redesigned metal inserts proved satisfactory mechanically, but the material lacked the required dielectric strength.

5. It was thereupon decided to revert to material "B." However, in order to obtain the necessary mechanical strength, the metal inserts were again redesigned to offer less resistance to the shrinkage of the plastic material. In addition, a circumferential slot was turned in the ring insert to a proper depth which made it possible to machine the part after molding without exposing sharp corners. This corrected all cracking due to machining operations.



6. Despite this improvement, two types of cracks still occurred. One was a radial crack on the face of the ring originating at the small round center insert. Another was located in the recess of the base of the tower. The recommendation that preheating time be increased and that plasticity be changed from flow 100 at 300 lb. per sq. in. to flow 100 at 500 lb. per sq. in. resulted in definite improvement.

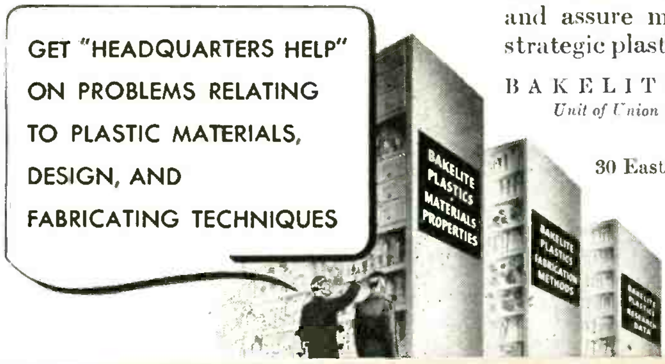
NOWHERE will you find higher standards of efficiency than in the engineering of automotive plastics. But plastics for combat flying are subjected to shocks, stresses, and climatic conditions that only products engineered for this service will withstand. Manufacture of parts that rate 100 per cent on *all counts* brings extreme problems that demand the closest co-operation between designer, materials' supplier, and manufacturer.

In the case of the aircraft component shown here, each requirement was met step by step . . . each new problem solved by experiment and test as it appeared. Molding materials were changed, and changed again, before one was found that would neither crack under unusual mechanical strains nor fail when subjected to severe electrical breakdown tests. Designs had to be altered, and revisions made in molding technique, in order to meet completely, on a productive basis, the necessary mechanical and dielectric requirements.

When you are confronted with problems such as these, Bakelite Plastics Headquarters can help to avoid costly and time-consuming experimentation, and assure maximum service life for strategic plastic products.

BAKELITE CORPORATION
Unit of Union Carbide and Carbon Corporation
UCC
30 East 42nd Street, New York, N. Y.

7. As a final step, the mold was redesigned to provide a more even distribution of the mass of the plastic material, and the area around the center insert in the face of the piece was reinforced with a BAKELITE phenolic molding blank. These changes reduced cracking to an absolute minimum. They also lightened the weight of the final molded piece—an important factor for producing parts for aircraft use.



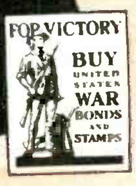
and Conserve Strategic Materials

3 FIELD WORK ON "FRONTLINE" JOBS . . . Located at important industrial centers throughout the nation, Bakelite Field Engineers are ready to give prompt service to manufacturers engaged in war production. Fully qualified, they can frequently solve production problems on the spot.

BAKELITE

The word "Bakelite" and the Symbol are registered trade-marks identifying products of Bakelite Corporation

PLASTICS HEADQUARTERS




Now! FOR THE First Time
YOU CAN ENLIST IN THE
U. S. ARMY SIGNAL CORPS!
. . . restrictions have been cut to a minimum. If you are eighteen to nineteen and physically fit, you can enlist directly into the U. S. Army Signal Corps . . . if you are nineteen to forty-five and can pass the physical examinations, you can enlist providing you have some experience in the Communications Industry and have not received your notice for induction.
the hallicrafters co.
CHICAGO, U. S. A.
Keep Communications Open

Measure TURQUOISE *quality by the reproductions it makes...*

THE QUALITY OF THE PRINT OBTAINED from an uninked pencil tracing is the ultimate test of the lead that made it.

TRY THE "PRINT TEST" FOR TURQUOISE! Here's why it wins: Precision grading from 17 basic formulas of graphite and clay gives exactly the line you want from every inch of every pencil *every time.* Erasures come clean because opacity of line is obtained without depositing any chemical in the pores of the sheet. Eagle's patented super bonding process eliminates the frequent breakage and repointing which is so often the cause of variation in line. And *Electronic graphite, refined down to particle sizes of 1 micron (1/25,000th of an inch), makes sharp lines so dense and uniform that they reproduce perfectly.

SEND FOR A FREE SAMPLE, naming this magazine, your regular pencil dealer, and the grade you desire. We'll send you a pencil *or a TURQUOISE drafting lead of the same fine quality.* Sorry, we can't send you the new TURQUOISE holder illustrated; but your dealer will be glad to demonstrate its precision-built perfection.

***EAGLE *"CHEMI-SEALED" *TURQUOISE** (SUPER BONDED) PENCILS • LEADS LEAD HOLDERS

EAGLE PENCIL COMPANY • 703 EAST 13th STREET, NEW YORK
EAGLE PENCIL COMPANY OF CANADA, LTD., TORONTO

* REG U S PAT OFF

The immediate acceptance and widespread use of our Blue Ribbon Resistors exceeded our expectations. Designed on modern lines, compact, efficient and tough,—they offer more than just higher wattage ratings for unit space required.

The resistance wire is accurately wound on a Steatite core and the ends are brazed to terminals of any of our numerous types. Standard mounting is by means of an aluminum thru-bar which is in contact with the entire internal surface of the ceramic core. This thru-bar distributes heat uniformly along its entire length,—eliminating hot spots normally found in tubular resistors with conventional mountings.

Our mounting studs are riveted to the ends of the thru-bar, and tend to conduct heat to the mounting surface—they are designed also as spacers when two or more units are stacked. This resistor and its mounting form an integral unit. Blue Ribbon Resistors cannot rotate or loosen. They are easily mounted in a minimum of space. They are the last word in ceramic core-vitreous enamel construction and design.

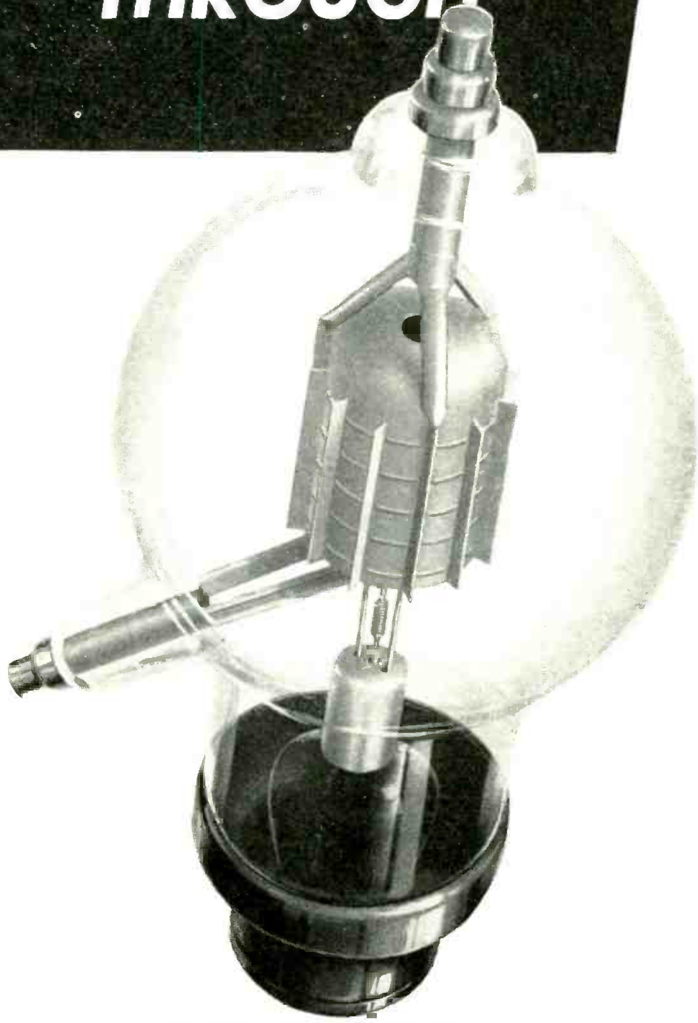
Intermediate taps, adjustable contact bands, non-inductive winding, non-standard lengths and ratings.

There are important exclusive advantages in other types of resistors and rheostats made by us. Please consult us.

HARDWICK, HINDLE, Inc.,
Newark, N. J., U. S. A.

This advertisement released for publication by the War Department, Washington

"GET THE MESSAGE THROUGH"



The troops who carry the crossed-flags-and-torch of the Signal Corps into combat are devoted to one essential task—"Get the message through!"

GAMMATRON tubes, with the same primary mission, are engineered to maintain communications under the most trying conditions.

Their sturdy mechanical construction prevents breakage from handling. Tantalum grids and plates . . . the absence of internal insulators and "getter" . . . plus improved pumping methods give positive assurance that these transmitting tubes will not fail due to accidental or intentional overload.

GAMMATRON tubes improve the efficiency of any circuit. They require a minimum of grid excitation, producing an extremely high power gain with few transmitter stages.

Today the unique performance, absolute continuity of operation, and the long life of GAMMATRON tubes are especially imperative.

Write for free booklet "13 Ways to Prolong Tube Life." It contains many helpful suggestions—and no advertising except on page 11.

HK1054 PLATE DISS. 750 WATTS
MAX. POWER OUTPUT 3000 WATTS

HEINTZ AND KAUFMAN LTD.
SOUTH SAN FRANCISCO CALIFORNIA U.S.A.

GAMMATRONS OF COURSE!

Tom is meeting familiar faces

EVEN 'OVER THERE'

TOM'S background in radio now stands him in good stead in the Signal Corps. Starting as a "ham", then a communications engineer . . . he knows how to spot and correct trouble. From the day he "joined up" he's been thoroughly at home in his new job. Even the test instruments he works with are duplicates of those in the shop back home. They bear the same name he's always banked on for measurement dependability since he built his first "ham" transmitter. And now that he's abroad, he's surrounded by these same familiar instruments even on the equipment and in the repair depots of our allies. For throughout the allied countries, too, the mark WESTON is the accepted symbol for dependable electrical measurement. Weston Electrical Instrument Corporation, 618 Frelinghuysen Avenue, Newark, New Jersey.

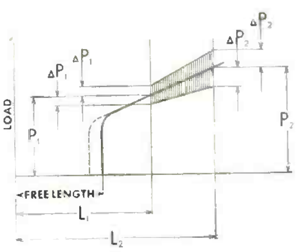
Priority restrictions have necessarily greatly curtailed the supply of WESTON instruments for many industrial needs. *Uncle Sam stands firmly at the head of the instrument line!* » » » To the great majority of instrument users not now engaged in war production, however, this has meant little, if any, inconvenience. The WESTONS they now have in service will see them through for the duration and beyond. *Long-life dependability* is built into every instrument bearing this name. » » » But for those with "emergency" needs, the instrument problem is not necessarily beyond hope. The WESTON field engineer in your vicinity may have a solution. Check with him first on any instrument need.

WESTON INSTRUMENTS

Laboratory Standards • Precision D-C and A-C Portables • D-C, A-C, and Thermo Switchboard and Panel Instruments • Instrument Transformers • Sensitive Relays • Specialized Test Equipment • Light Measurement and Control Devices • Exposure Meters • Aircraft Instruments • Electric Tachometers • Dial Thermometers

Ready Before the Shootin' Started

SPRING NEWS



LOAD GRAPH
OF AN EXTENSION SPRING
in which

P_1 = load at L_1 test length
P_2 = load at L_2 test length
ΔP_1 and ΔP_2 are allowed variations in P_1, P_2.

Spring manufacturers often like to be free to control free length and initial tension to obtain best manufacturing procedure.

(Note dotted portion of load curve.)

P.S. **We strongly recommend that these graphs be prepared when designing springs.**

BEFORE Pearl Harbor, before even Dunkirk, reliable spring manufacturers were quietly stiffening themselves for a shooting war. To most of them, the design and manufacture of a spring was no longer a matter of conjecture, but a problem in mathematics, physics, chemistry, and ingenuity.

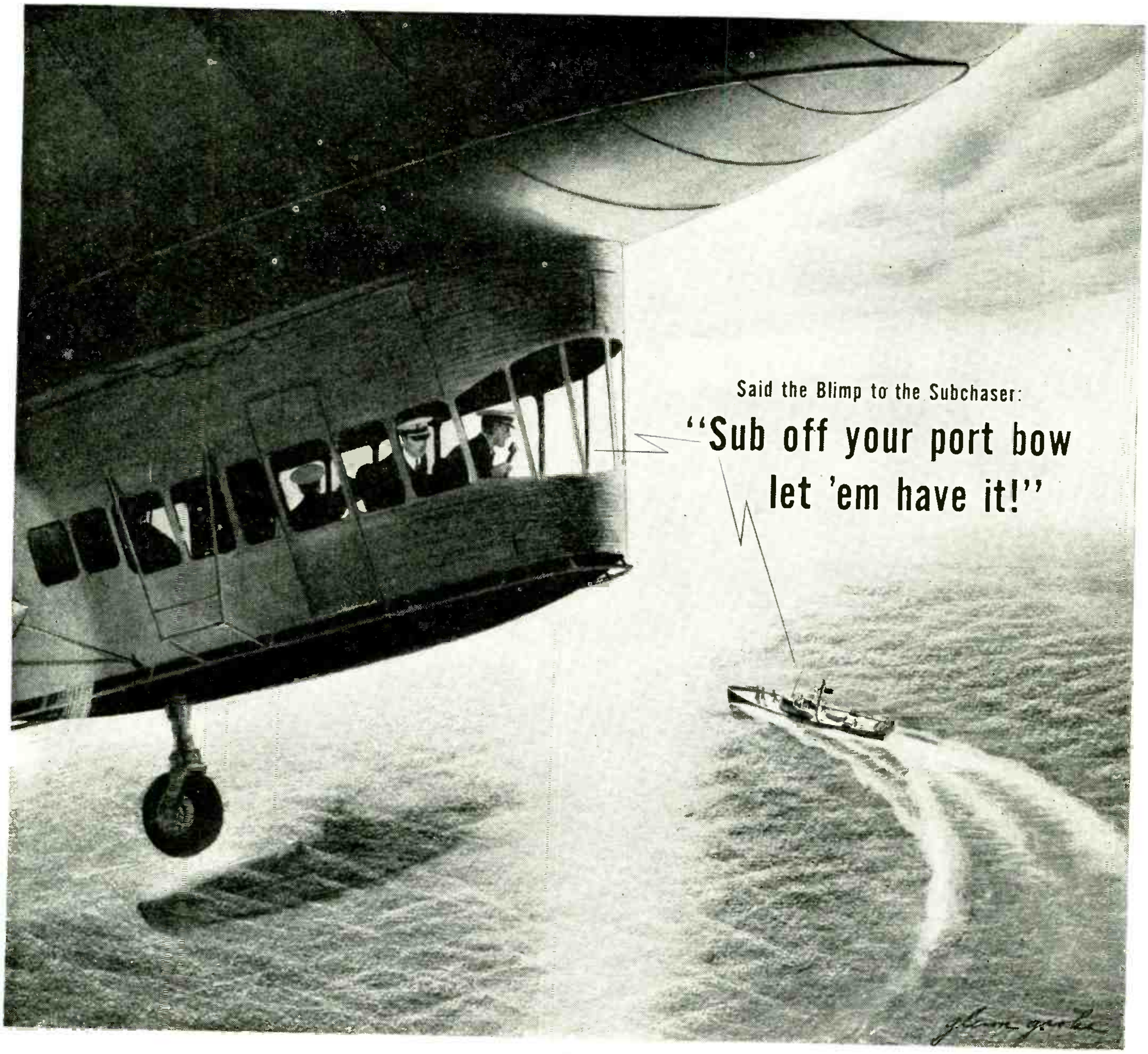
In the case of Hunter, for example, searching tests had been completed, and data compiled, on every imaginable kind of spring material, often using equipment conceived and built in the Hunter laboratory.

War demands have increased standards of precision in manufacture but none for which Hunter and other recognized spring makers are not professionally prepared. The war has greatly increased the rate of production. Precision inspection, which might have been a bottleneck, had, however, already been licked by Hunter. In the peace to come, as well as in the war at hand, anticipation is ninety per cent of the battle.

HUNTER

Science in Springs

HUNTER PRESSED STEEL COMPANY, LANSDALE, PENNA.



They work together better... because they can talk together

The blimp
From the advantage of height
Spots the shark-like shadow
Slinking below the surface . . .

And passes the word
To the Subchaser
Which wheels with roaring motors
To lay the deadly pattern
Of thunderous depth-bombs . . .

An underwater barrage
That crushes the lurking sub
As a well-aimed rock
Will finish a snake.

That's *teamwork*
Teamwork made possible
By the radiotelephone.

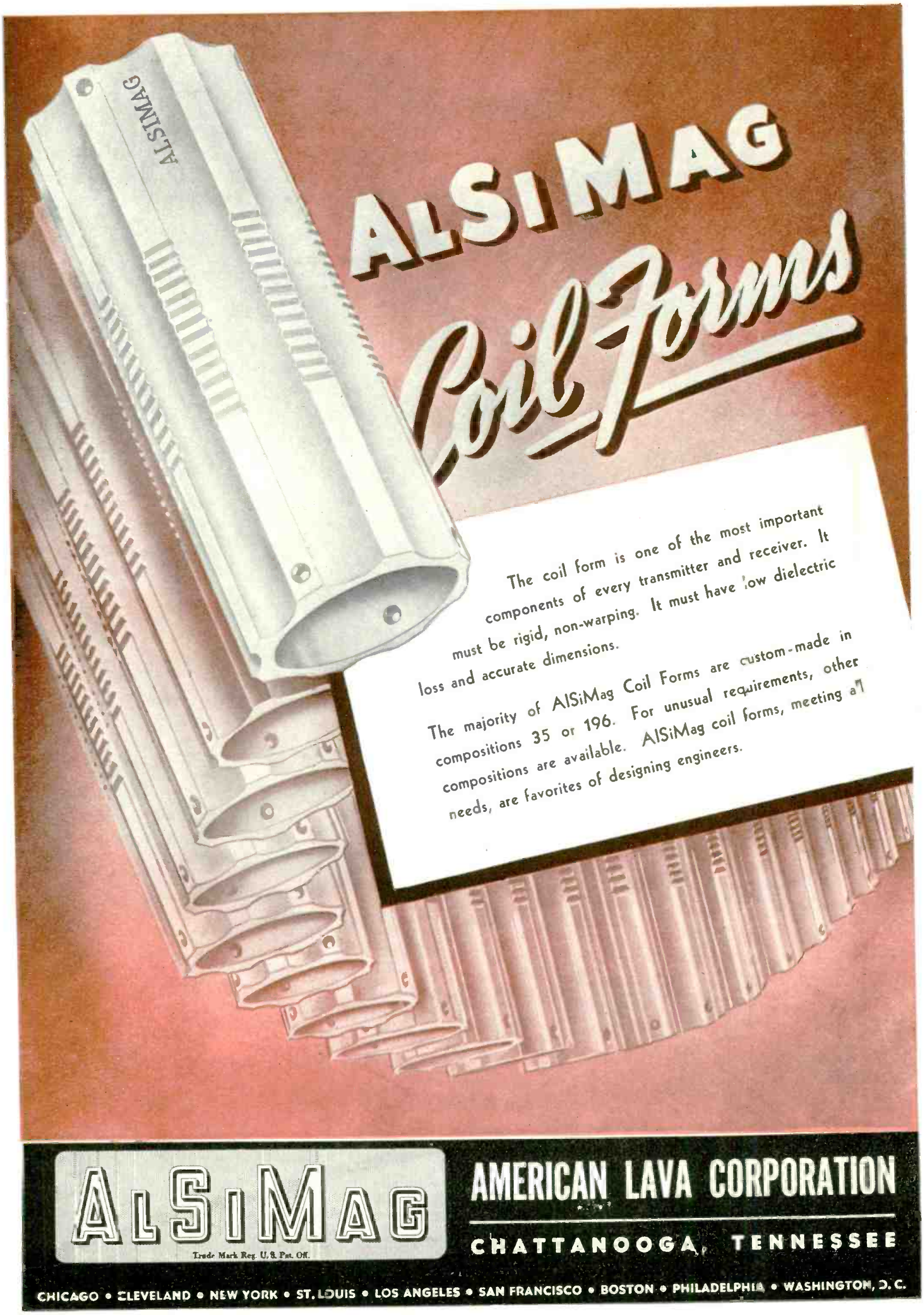
Modern communication equipment
Designed and manufactured
By I. T. & T. associate companies
Is helping Uncle Sam
Coordinate his forces
On land, sea and in the air.

The broad, peacetime experience
Of I. T. & T.
In the field of communications
Is proving its value
In time of war.

International Telephone and Telegraph Corporation *67 Broad St., New York, N. Y*

IT&T

Associate Manufacturing Companies in the United States
International Telephone & Radio Manufacturing Corporation
Federal Telegraph Company

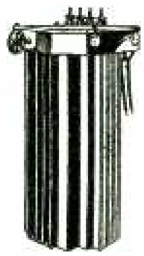

ALSIMAG
AlSiMag
Coil Forms
The coil form is one of the most important components of every transmitter and receiver. It must be rigid, non-warping. It must have low dielectric loss and accurate dimensions.
The majority of AlSiMag Coil Forms are custom-made in compositions 35 or 196. For unusual requirements, other compositions are available. AlSiMag coil forms, meeting all needs, are favorites of designing engineers.
AlSiMag
Trade Mark Reg. U. S. Pat. Off.
AMERICAN LAVA CORPORATION
CHATTANOOGA, TENNESSEE
CHICAGO • CLEVELAND • NEW YORK • ST. LOUIS • LOS ANGELES • SAN FRANCISCO • BOSTON • PHILADELPHIA • WASHINGTON, D.C.

SOME day when we have fulfilled our Government obligations, we will be in a position to tell you fully the amazing story of the improvements that are being made in AmerTran products—today.

Today, wherever the new AmerTran products are being installed in connection with the war effort, electrical men are realizing that AmerTran is producing transformers that are *new* —new in electrical design, new in mechanical features, new in efficiency and economy.

True, we have placed entirely at the disposal of the Government and customers with high priorities our new and greater plant capacity, our new and increased manufacturing facilities. But, as for the past 41 years, we are still glad to extend to you, without obligation, the advice of AmerTran Engineers to help you secure the best results from your present equipment, to help solve today's problems of operation and maintenance, and to plan for your future needs in electronic and radio applications.

AmerTran modulation transformers and reactors, oil-immersed type, for large broadcast transmitters.



AmerTran RS plate transformers and reactors, oil-immersed type, for all large installations.

AmerTran W plate transformers and reactors for all small and medium installations.

AmerTran transformers are manufactured to meet your exact electrical and mechanical requirements.

AMERICAN TRANSFORMER COMPANY, 178 Emmet St., Newark, N. J.

Manufactured Since 1901 at Newark, N. J.

AMERTRAN

"the moving finger writes"

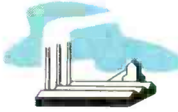
...*on* audiodiscs

HISTORY IN THE MAKING finds Audiodiscs playing major roles on home front and fighting front alike. First choice in peacetime professional applications, Audiodiscs are now selected for tremendously important wartime tasks as well—not only in America but literally *around the globe,* from the nearest to the farthest of the United Nations.

THOUSANDS OF AUDIODISCS — flying to England in bombers, sailing to Australia in convoys, speeding north and south to all the Americas—mean new hope and inspiration for oppressed millions behind enemy lines. Native-tongue Audiodisc recordings by exiled leaders, radioed to their countrymen, supplement our own round-the-clock Audiodisc transcription broadcasts—help sustain the death-defying morale that disrupts entire Axis schedules.

AUDIODISCS FREE WIRES urgently needed for wartime communications. Hundreds of local broadcasting stations use Audiodiscs for transcribed entertainment and, more important, to promote unity and a better understanding of our war effort—when reception, listening audience and other conditions are most favorable. Audiodiscs help train students in colleges and trade schools everywhere. Important adjunct to counter-espionage, Audiodiscs have trapped many a potential saboteur by his own recorded words.

AUDIODISCS IN WAR PLANTS send instructions, executive talks and vital safety messages over public address systems. From Arctic outpost and South Sea bastion, Audiodiscs bring living voices of fighting men back into the homes of their loved ones—while U S O Audiodisc recordings brighten camp life for the boys still in training. Important speeches, recorded in Washington, go home on Audiodiscs for local broadcast.



AUDIODISCS RECORD HISTORY in the making — preserve the day-by-day highlights for later transfer into permanent reference files. Future generations may well call this the "Recording Age", thanks to modern chronicling methods which Audiodiscs make possible. Research technicians of government, industry and private institutions are constantly broadening the scope of Audiodisc applications—speeding our war effort and insuring countless peacetime improvements.

AUDIODISCS WILL SERVE YOU with the same characteristic dependability, under the most exacting conditions, that wins universal acclaim wherever they go on a turntable. Whatever your particular application, the uniform high quality of Audiodiscs will *increase* recording efficiency and playback fidelity. Now patented for your protection, Audiodiscs are readily available through a nation-wide network of jobbers. Call your nearest one—or wire us for complete information TODAY. Audio Devices, Inc., 1600 Broadway, New York City.

FEATURES OF 4-HOLE, GLASS-BASE AUDIODISCS

Audiodiscs, the original 4-hole, glass-base recording blanks, incorporate *all* features essential to high-fidelity recording. Exclusive Audio-engineered developments include:

a superior coating formula and process—a flawlessly smooth, non-deteriorating surface—improved tracking—controlled thread action—reduced static—longer playback life—a thin, flexible glass base with correct strength-to-weight ratio—a center hole and all three drive-pin holes in non-chipping fibre insert (patented)—complete interchangeability with pre-war aluminum-base types—safe, dustproof packing cases—special reshipping cartons.

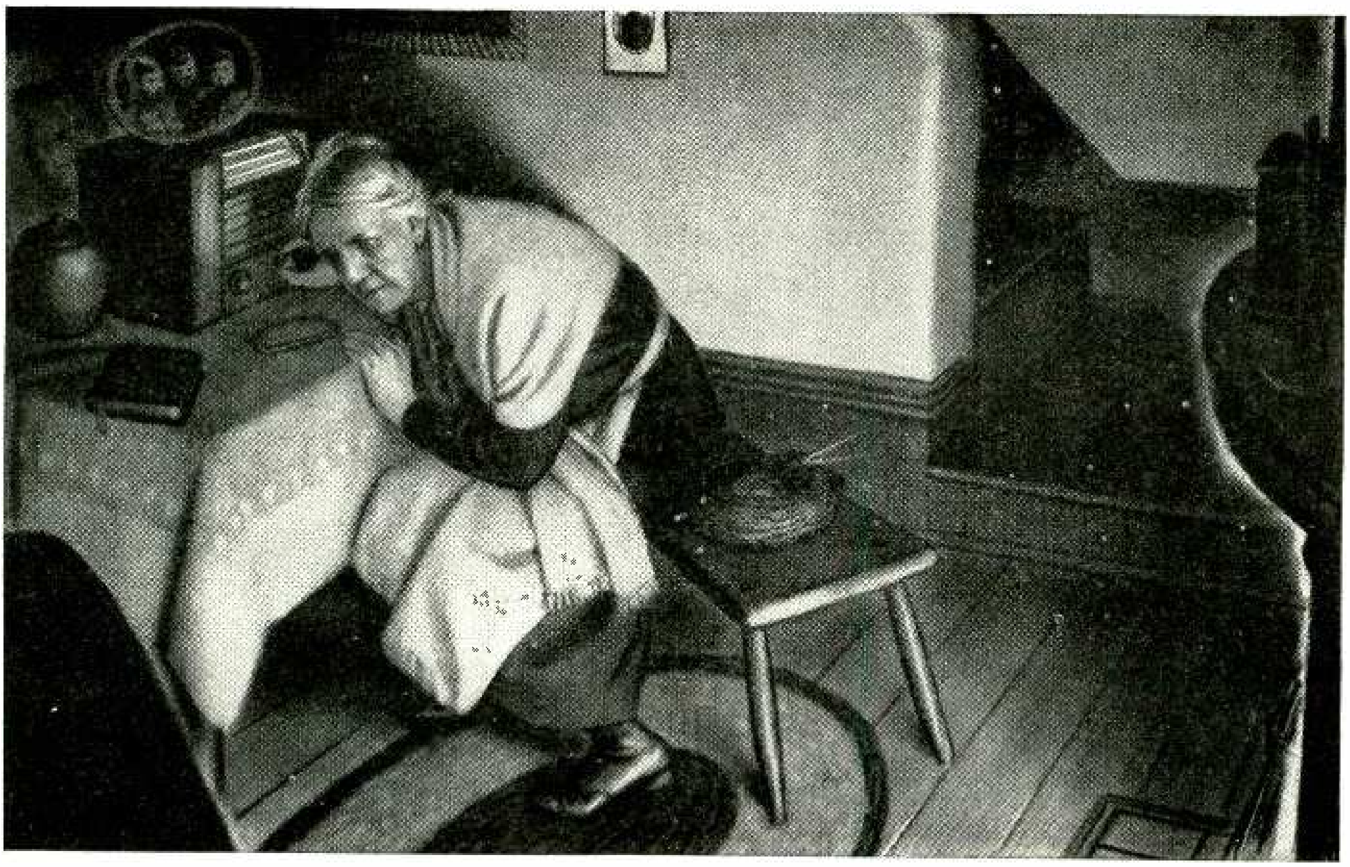
THERE'S AN AUDIODISC *designed and priced* FOR YOUR SPECIFIC NEEDS

audiodiscs

—they speak for themselves

RED LABEL · YELLOW LABEL · MASTER
REFERENCE RECORDING AUDIODISCS

All orders must show "end use" in accordance with WPB requirements.



Frau Holtz receives an American guest

[in spite of the headsman's axe!]

Until Hans died for the glory of the Fuehrer, somewhere on the Russian front, Frau Holtz knew very little of the world beyond the German borders . . . and what little she knew was wrong. Herr Goebbels saw to that.

But when her last son went the way of his two brothers, there were some things she *had* to know.

That night she turned a knob,and did a terrible thing: she brought into her lonely little home an *American* from across the sea. The Enemy. She turned down his voice to the barest whisper, but she listened far into the night . . .

And there came to light within her a dawning realization—a bitter sense of betrayal.

* * *

Tonight in Germany, ten thousand Frau Holtzes will listen to the *verboten* voice of RCA-NBC International Shortwave Stations WNBI and WRCA . . . even though whip and bludgeon and axe await them in the dungeons of the Gestapo, if they are discovered.

What are they to *believe?* Even today, perhaps, they are not quite sure.

Yet, day by day, their understanding grows. For the ways of truth are sometimes strange; but in the end the accents of truth are unmistakable.

* * *

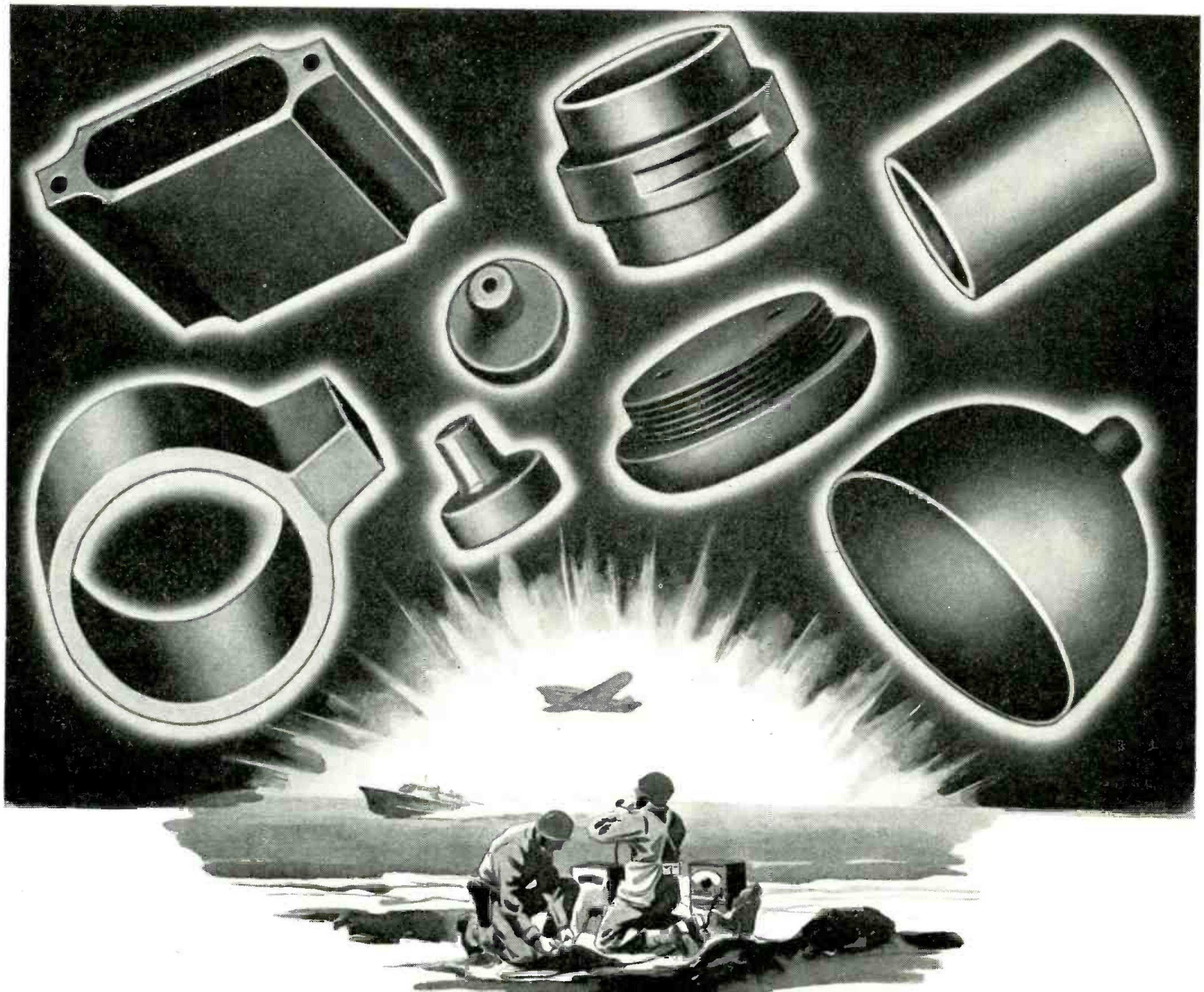
Of all the uses to which RCA equipment has been put in this greatest of struggles between freedom and tyranny, we are not least proud of this use. For that equipment is not only helping to overwhelm the physical might of our enemies in war—it is helping, too, to prepare the minds of the world for the just and enduring *peace* that must, at long last, come.

It is telling Frau Holtz that her enemies are not here, but at home.

BUY U.S. WAR BONDS

RCA **Broadcast Equipment**

RCA MANUFACTURING CO., INC. CAMDEN, N. J.



Beyond the horizon

SPEER
CARBON COMPANY
-SCC-
ST. MARYS, PA.
CHICAGO · CLEVELAND · DETROIT
MILWAUKEE · NEW YORK · PITTSBURGH

Communication between planes and ships and shore, between battle fronts and headquarters; reporting, guiding, warning and commanding — radio transmission tubes with SPEER Graphite Anodes are serving the United Nations aloft, ashore and afloat.

SPEER Graphite Anodes have blazed new trails, in radio communication. With greatly enlarged production and research facilities, now devoted entirely to winning the war, SPEER Anodes are better than ever before able to meet electronic transmission and communication requirements as can no anode of other material.

SPEER Graphite Anodes release strategic metals, add power and life to tubes. Only anodes of graphite can never fuse or even soften, will not warp, help keep tubes gas-free.

Use tubes with SPEER Graphite Anodes—for important war jobs now, for every transmission service when the American Victory has been won.

« « «   » » »

Anode Booklet and list of tube manufacturers using SPEER Graphite Anodes gladly mailed upon request.

2815

"Durationing"

VERSATILITY of thinking must be translated quickly into versatility of production for our war effort to continue its present forward pace. This means that men and machines are carrying extra burdens without relief. It has been our job to see that neither cracks under the strain.

"Durationing" is the answer at Superior Tube. We have apportioned our creative thinking and our production so that we are no longer flurried when additional burdens are added. We are staffed and equipped to absorb these extraordinary conditions—in fact we are probing into the future as we work today.

Durationing is the will to win—plus the ability to direct our energies to assure the successful conclusion of every project which we start.

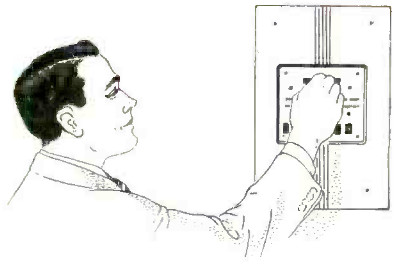
For small tubing to do a big job, remember Superior.

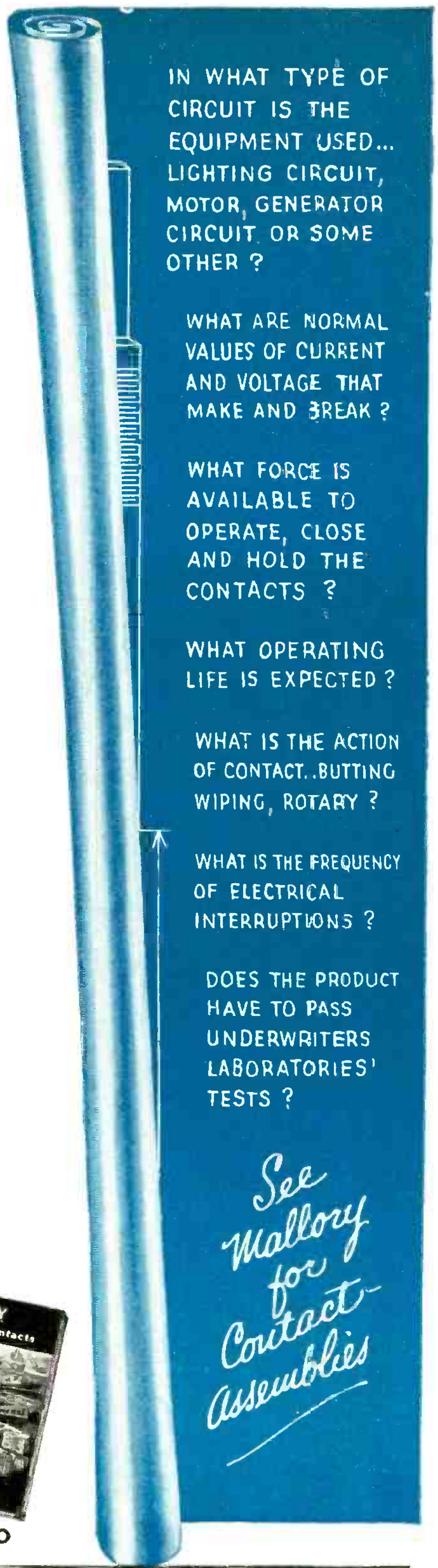
SUPERIOR

THE BIG NAME IN
SMALL TUBING

SUPERIOR TUBE COMPANY, NORRISTOWN, PENNSYLVANIA

Tubing from ⅝" OD down...SUPERIOR Seamless in various analyses. WELDRAWN Welded and drawn Stainless. BRAWN Welded and drawn "Monel" and "Inconel". SEAMLESS and Patented LOCKSEAM Cathode Sleeves.





By Writing Mallory Contacts into Their Blueprints They've Tapped a Multi-Million Market!

Electrical manufacturers used to sell plenty of fuses for household and light industrial use . . . but not because people enjoyed fussing with fuses. Has come the revolution. Ordinary switches and fuses are rapidly joining the bustle. Thousands of homes and factories are now equipped with Multi-Breakers.

These light duty circuit breakers protect vital lighting and power circuits in many states. A typical Multi-Breaker includes bi-metallic strip actuation that permits harmless overloads; quick make and break; a visible trip indicator; and other features assuring long, trouble-free, easy operation . . . a joy to electrical contractors and owners alike.

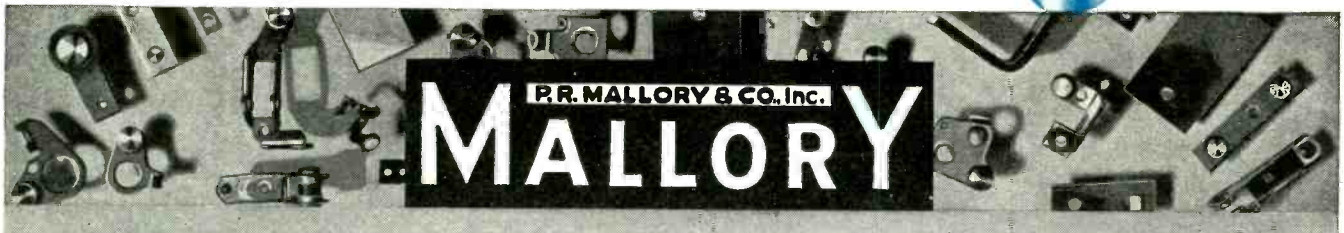
The vast majority of Multi-Breakers, made by several manufacturers, are equipped with contacts supplied by Mallory. Instead of conventional coin or fine silver as the contact material, Mallory has developed silver-tungsten and silver-molybdenum alloys that assure longer service life and better performance.

Here's a good example of how Mallory engineers . . . versed in contact and contact assembly problems . . . and with years of laboratory and plant experience . . . have supplied the right answer to a demand by electrical engineers, salesmen, contractors, architects, and ultimate users for a trouble-free product.

Can't we do the same for you? While your designs are still on the drafting board? Your Mallory representative will be glad to discuss your specific problems at your convenience.

Data-On-The-Spot! Mallory Contact Catalog. *Complete information on every phase of electrical contact selection, design and service. You need it for your technical library. Write today. No obligation.*

P. R. MALLORY & CO., Inc., INDIANAPOLIS, INDIANA • *Cable Address* — PELMALLO



ELECTRICAL CONTACTS AND CONTACT ASSEMBLIES
NON FERROUS ALLOYS, POWDERED METAL ALLOYS

The Aviation Industry is doing its job...

A Year's Production A Week—Every Week

A MERE hundred planes a month in 1938; 200 in 1939; 450 in 1940; 1,600 in 1941, and today, as this is written, plane production goes on at a rate of 5,000 a month. A previous year's production now in one single week—every week.

So begins the story of the greatest industrial expansion in history; an industrial miracle that far surpasses anything our enemies ever have done or can do. Not only did we out-produce the Axis but the acceleration in our production during the past 12 months exceeded the greatest increase in German output during their forced-draft war preparation of 1939, when their production rose from 1,100 to 1,600 planes per month.

The toughest part of our job was accomplished in 20 months. We boosted deliveries from 100 or so to 1,000 planes a week, passing the combined Axis powers. Today, Germany's curve is flattening; ours is climbing steeply. Lt. Gen. Henry H. Arnold, Chief of the Army Air Forces, assures us that Army contractors will produce not less than 148,000 planes in the remainder of 1942 and in 1943. During that same period Navy contractors will turn out at least 37,000 additional planes.

Manpower in the airframe, engine and propeller industries was increased from 125,000 to 450,000 workers during the past 20 months, with the prospect that the industry will be employing more than 1,000,000 men and women in 1943. Many manufacturers are solving their personnel problems by recruiting women workers. More than 40,000 of them—teachers, stenographers, waitresses, housewives and school girls—today are welders, assemblers, machine operators and inspectors on aircraft production lines. Productive floor space in the airframe, engine and propeller industries expanded from 18,000,000 sq. ft. to nearly 55,000,000 sq. ft. during the last 20 months. Further expansion to more than 60,000,000 sq. ft. may be expected this year and an ultimate figure of more than 100,000,000 is a distinct possibility.

To grasp the full magnitude of this task we must remember that a single medium bomber has 30,000 parts, which are built into 650 minor sub-assemblies to make 32 major sub-assemblies. The entire process involves 30,000 man hours of labor. Each of the two engines in this plane requires 50,000 specialized inspections. Every one of the 50 instruments entails many hours of precision workmanship. Yet today there is one factory turning out 4 bombers every day. Another produces fighters at the rate of nearly 20 a day.

To the amazement of the entire world these manufacturing miracles were accomplished without sacrificing the high standard of American aeronautical equipment. There has been some loose talk about the quality of our combat airplanes as compared with those of our allies and our enemies. Indisputable evidence of the superior stamina of our aircraft under fire is written between the lines of almost every war communique. Every battle record tells a story of heavy losses inflicted at small cost upon numerically superior enemy forces. The consistency of this performance on all the far-flung battlefronts constitutes the most eloquent testimony of the high calibre of our designs, our manufacturing methods and the skill and daring of our pilots.

And let us remember that our decisive victory in the battle of production was not won without headaches and heartaches on the part of management, labor and government.

When the President sounded the call for 50,000 planes in the spring of 1940, the program called for only 5,500 military aircraft. Government and industry reeled from the shock—both determined, however, that it *could and would be done.*

The Army, the Navy and the old Defense Advisory Commission set to work to draft a program. This has been revised many times—upward! Congress then proceeded, more slowly, to modify the laws that would have obstructed the realization of the objective. Then the aviation industry, without contracts, in the face of discriminatory profit-limitative legislation, and with nothing but oral assurances of governmental intentions, went ahead with its Herculean expansion plans. New factories were completed long before facilities-contracts and their funds were forthcoming.

The rugged individualists who had founded and built the aviation industry cast aside their rivalries and embarked upon a period of unselfish cooperation. Priceless engineering experience was exchanged. Material was relinquished for transfer to plants where it was needed more urgently. Successful personnel training methods and experience in the use of women workers were pooled for the benefit of all concerned. During one recent month, the cooperation among eight southern California plants averted more than 1,860 potential bottlenecks in production.

As the lessons of the war dictated the need for greater numbers of particular airplane types, many manufacturers accepted orders for planes designed and developed at rival factories. Striking examples are the long range bombers being turned out by plants where only trainers, fighters or dive bombers formerly were made.

Mindful of the risk involved in educating rivals, thereby creating future potential competition, subcontractors nevertheless were sought and trained by pioneer manufacturers. Makers of toys and wheelbarrows, automatic stokers and linoleum were among those who rallied to the call. Within a year subcontracting rose from 13 to 36 per cent of the total program. It still is rising.

When the automotive industry came into the picture, aviation manufacturers gave generously of their time and knowledge to start the newcomers. Liberal licensing arrangements enabled them to reap the full benefits of technical developments. Automotive engineers swarmed through the aviation plants in search of the exacting "know-how" of the aeronautical industry.

Each type of aircraft that reaches the production stage is the result of long periods of research, design and development. The unseen workers toiling in the wind tunnels and the laboratories of government and industry are the unsung heroes who tirelessly are striving to surpass all previous efforts. Their brilliant accomplishments are eloquent testimony of the superiority of men and women who are blessed with freedom of action and thought. Today more than 20 experimental combat airplanes are under development and will replace older types as soon as they fulfill the exacting requirements of our armed forces. Among these are aircraft that promise to outfight and to out-perform any and all of the much vaunted warplanes of the Axis military machine. And this without loss of production.

Every man, woman and child of all the United Nations may fervently be thankful that those who chart our course in aircraft production have not frozen design to such a degree as to make impossible the immediate adoption of improvements as they come out of these laboratories.

What does this brilliant record mean in terms of final victory?

Every newspaper reader has learned this basic war lesson . . . air supremacy is the essential ingredient of military success. As the balance of air power shifts, so do the fortunes of war.

In those dark days when our output was 500 planes a month, Germany's was 2,000 and the German air force was twice that of our Allies. When we reached 2,000 a month last fall, Germany had advanced to a monthly rate of 2,500. Today, as this is written, we have caught up with the enemy's backlog. The air forces of both sides are about equal numerically and United Nations' production exceeds that of the Axis by 27 per cent. Next summer (1943) both the air force and the output of the United Nations will be double those of all the Axis powers.

That is the pattern of ultimate victory!

The pattern of the peace to follow also is gaining in definition. The airplane has shriveled the world to one-fifth its former size. Its use as an instrument of destruction is but a momentary distortion of the pattern of human progress. Its potential power, as a stern preserver of peace, is beyond imagination. Today's air routes of our Army Air Force Ferrying Command are the international trade routes of tomorrow. Giant airliners, by reducing time and space, will speed fraternity among the nations and disunity will give way to better understanding and goodwill.

Flying freight trains, with aerial locomotives towing glider boxcars, will serve large cities, decentralizing population and giving to inland cities many of the commercial advantages of seaports. Air mail and passenger pick-up lines will fill the gaps between these transcontinental trunk lines and tie in the smallest hamlets. Universal fly-it-yourself services will provide airplane facilities for those who do not own low cost private aircraft. Roadable rotary wing aircraft and family planes of the fixed wing type may even run household errands.

The coming generation of business men who today is piloting our war planes will find aircraft as essential to business as it now finds them essential to victory.

Commenting on our war production record, Donald Nelson has said, "We are today in the position of men who realize that they are actually doing the impossible".

The mass production miracle that the aviation industry — management and workers alike — has performed through the all-out effort of free enterprise can and will serve civilization in peace as it has in war.

With this boundless new medium of transportation and its concurrent technological developments we shall rebuild our way of life to a rich, new fullness upon the ruins of a war-torn world.

James H. McGraw, Jr.

President, McGraw-Hill Publishing Company, Inc.

This is the third of a series of editorials appearing monthly in all McGraw-Hill publications reaching more than one and one-half million readers.

CROSS TALK

▶ **PATENTS** . . . Under this heading in this column in July some remarks were made on the descriptions of patents published each week in the U. S. Patent Office *Official Gazette*. Correspondence relating to these remarks appeared in Backtalk in August; and quite a bit more correspondence has come to the editorial office from which much has been learned.

A patent as issued contains, first, a description of what the inventor has accomplished, often with much background material.

Then come the claims. These are limiting paragraphs citing exactly what the inventor has done, step by step. To infringe one of these claims, each and every step in that claim must be performed. The claims are really a catalog of the features of the patent. The purpose of the *Gazette* is to acquaint the field with the fact that a patent has been issued on such and such a subject, and the single (sometimes more) claim printed is deemed sufficient to enable a reader to determine if he wishes to know more. If he does, then he can buy the complete disclosure for 10 cents from the Government Printing Office.

Now the fact that ELECTRONICS complained that the descriptions in the *Gazette* were not as extensive nor as clear as one might wish, while the Abstracts of the British Patent Office gave much more information, does not mean that ELECTRONICS is attacking the patent system. There is, at present, much noise about the patent system and what is likely to happen to it; many patent lawyers, many inventors, many corporations relying on research are up in arms over the present hearings in Washington and with good cause, we think. Something *is* likely to happen unless those who wish the patent system to remain as it is act with the utmost vigilance and intelligence.

ELECTRONICS will take no side in this scrap. It will try to act as an impartial judge of editorial material pertaining to the situation. It recommends that readers watch carefully the hearings now taking place in Washington.

▶ **WORDS** . . . "Electron, electronic, electronics"—three words coming more and more into popular and engineering language. Without wishing to set ourselves up as etymologists (or whatever they are) we do wish to set down our feeling about these words, and how they had best be used.

"Electron" is clear. It is a noun and it is man's description of "the natural, elementary quantity of negative electricity." It is what makes possible "that branch of science and technology which relates to the conduction of electricity through gases or in vacuo"—i.e., "electronics". These are definitions approved by the American Standards Association. "Electronics", then, is a noun from which comes the adjective "electronic". Whether one calls a tube an electron tube, or an electronic tube, is a matter of opinion, and personally, we prefer the simpler term—electron tube. A precedent is "electric light" not "electrical light".

Incidentally, and historically, the lower case *e* used on the cover of ELECTRONICS came about in this manner. The artist who made the preliminary layout for the cover, back in 1930, liked it that way; he was a modern; and to his mind a lower case *e* looked better than an upper case *E*. This is the honest truth; and not as *Science Service* later pointed out, the lower case letter was chosen because a small *e* represented the charge upon an electron.

We don't believe the word "electronics" has got into the dictionaries yet; but the war will do it if nothing else has up to this time.

Electrical Concepts At Extremely

Microwaves, lying adjacent to heat and light waves in the spectrum, introduce need for extending our concepts of electricity. Electric and magnetic fields assume greater significance in circuits where wavelengths are comparable to the dimensions of equipment

By SIMON RAMO

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THIS PAPER deals with physical pictures which many engineers have in their minds regarding current flow in conductors and vacuum tubes, transmission and radiation. In it we shall be concerned with some of the interesting things that can happen to our notions of electricity when currents alternate at the rate of billions of cycles per second, where existing mental pictures are not in every case ultimate ones. We shall discuss in some detail the nature of "microwaves", from the standpoint of *basic physics* rather than applications.

Existing electrical concepts are not to be tested at extremely high-frequencies and then, willy-nilly, "liquidated" as unsuitable. An intentional insinuation or two is admitted. Many of these concepts are carry-overs from static or low-frequency electrical phenomena. Yet it is good engineering to make certain that our ideas of electricity at extremely high frequencies are enhanced by our knowledge of what electricity is at the lower frequencies. It is, however, very easy to develop crude and unsatisfactory pictures of short wavelength electricity if we insist upon limiting ourselves to painting with a brush intended for long wavelength pictures.

Let us look at Fig. 1, a reproduction of one of the physicist's most descriptive diagrams, a plot of the spectrum of the electromagnetic phenomena. All these phenomena are cousins, different primarily with respect to frequency or wavelength. The part that interests us most today is wavelengths described in centimeters, or frequencies of billions of cycles per second—a region which (except for Hertz's impudence in producing sparks near there as the first experiment in radio) we have reached by advancing steadily higher in frequency.

Notice how far the centimeter wave region is from the power frequencies and how close it is to the heat region and even the light region. You would expect that if we are going to borrow concepts to help us understand and describe these centimeter waves we should borrow from the waves that are *shorter* as well as from those that are *longer*. And yet we all know that because we have advanced from the longer toward the shorter waves as far as radio waves are concerned, we have continued to use many concepts which began with direct current or electrostatics or the lower power frequencies. This paper itself furnishes one example of such thinking for the subject, a discussion of centimeter waves, is announced as "high-frequency electricity", not as "low-frequency light" or "low-frequency heat".

As an indication of the danger we may run into if we take a reactionary position against expanding concepts as the wavelengths become shorter and fail to examine whether the resulting physical pictures are completely satisfactory, suppose we had just arrived at what we all call electricity from the region to the right of the centimeter waves. That is, suppose that we had previously worked with light and heat waves exclusively and gradually found means to make those waves longer. In light we talk about the index of refraction, prisms and lenses and in heat we concern ourselves with the temperature of the source, black-body radiation and so on. Suppose

MICROWAVE Fundamentals

THIS timely treatise discusses the basic physics of electromagnetic waves in the centimeter region in a manner which makes it useful to men with limited radio experience as well as to engineers.

It represents additional educational material designed to further our war training program, admirably supplementing the U-H-F Technique section which appeared in ELECTRONICS for April.

HIGH FREQUENCIES

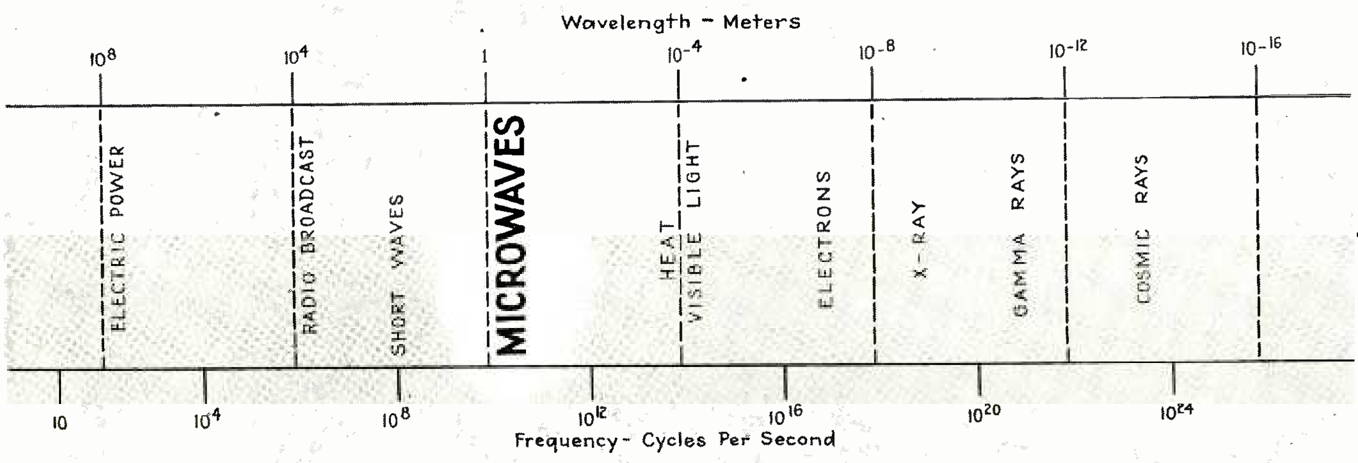


FIG. 1 - The electromagnetic spectrum. The region considered in this article is labeled "microwaves"

it had to occur to us that such things as generators and transmission lines and radio broadcasting stations could be practical devices, with our minds full only of such concepts as focal length, virtual images, probably some low-frequency extension of Plank's radiation law and a definition of entropy. Would our concepts be completely satisfactory?

Of course, this type of reasoning is exaggerated, but as we begin the task of describing basic characteristics of centimeter waves, let us keep always in mind that what we want to arrive at eventually is the best concept which can be used by engineers in identifying these waves according to their actual properties.

Current Flow in a Conductor

Let us start with what is probably the most fundamental of concepts in all electrical engineering, the flow of electric current along a conductor. The picture which the electrical engineer uses for the lower frequencies is exceedingly simple. He thinks of the current as a flow contained in the conductor. As to how the current distributes itself—that depends upon frequency. If the frequency is low, then the current distributes itself uniformly in a long conductor much as direct current would. As the frequency increases there is a tendency for the current flowing in a conductor to move toward the surface. This "skin effect" increases in importance with increasing frequency and the frequency does not have to become very high before the picture of current flow must include skin effect.

At frequencies of the order of one billion cycles per second the current comes so close to flowing entirely on the surface of conductors that below a few thousandths of an inch there is hardly any current left worth talking about. In other words, skin effect reaches its ultimate and electric currents become a surface phenomenon. Electric currents, then, do not flow *in* conductors in the microwave region. They flow *on* conductors.

Now this has a very important effect upon the engineer's thinking. Almost the first thing we want to know about centimeter waves is where they are. Where is the energy being stored and toward where is the power being guided? If nothing really goes on inside conductors, if only conductor surfaces take part in the action, then the conductors become simply boundaries enclosing regions in which the centimeter waves do their propagating and existing. So, instead of currents, or charges, or voltages, the microwave engineer thinks in terms of electric and magnetic fields. This does not mean that the concepts of current and charge and voltage have become obsolete. It does mean that these concepts begin to share the limelight with *fields* in situations in which the latter concepts had been previously in the background. Such sharing often brings with it a broader appreciation of the current and voltage concepts.

At any frequency, when you commence to deal with circuit impedances, inductances, or capacitances, somewhere in the analysis you have to pass through a consideration of the electric and magnetic field distributions. Inductance between circuits is an effect which comes about because of the magnetic fields of the two circuits which link each other. Capacitance effects are due to electric fields which occur between conductors that are electrically charged. At low frequencies the center of the problem is in the conductors and the current flow along those conductors. In our usual physical picture, the electric and magnetic fields are "feelers" which emanate from the centers of the electromagnetic effects and are useful in accounting for the interaction between different conducting systems. That this is not so good a statement of the centimeter wave situation is brought out by

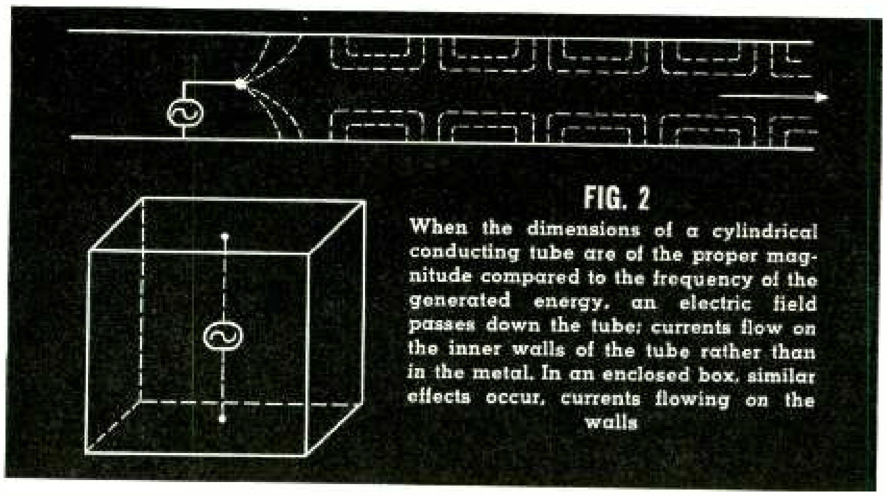


FIG. 2

When the dimensions of a cylindrical conducting tube are of the proper magnitude compared to the frequency of the generated energy, an electric field passes down the tube; currents flow on the inner walls of the tube rather than in the metal. In an enclosed box, similar effects occur, currents flowing on the walls

the examples of Fig. 2. Here we see, first, a long cylindrical conducting tube with a source of centimeter waves near one end. A small spherical probe is charged by the high-frequency. generator so that lines of electric flux from that probe end on the cylinders' walls and, if the frequency is high enough, the electromagnetic field propagates down the tube. Now we can study what goes on in the tube with the spotlight on the current flow and on the charges on the inner surface of the cylinder. Electric currents flow only on that inner boundary and it is difficult to avoid looking upon the situation as one in which the center of the problem is no longer in the metal but, rather, in the space surrounded by the metal. The figure also shows a hollow box in which there is a source of centimeter wave energy. Again there is current flow only on the inside surface of the box. The top and bottom of the box becomes oppositely charged and currents connecting these charged top and bottom plates flow up and down the walls of the box, but the center of the problem appears to be the space enclosed by the box.

Thus in a broad sense current flow becomes a boundary condition—not the central core in the picture. This begins to make electric effects in the centimeter-wave region ally closely with light waves, which we usually consider as passing through a medium with the boundaries acting as absorbers or reflectors but, nevertheless, boundaries only. We ordinarily think of light as a phenomenon taking place in a medium which will transmit light—not as something that takes place *along* mirrors or *along* other boundary surfaces.

We shall come back to this picture of centimeter wave current flow along conductors later. But for the moment this will be sufficient to give free rein to the notion that at extremely high frequencies there is practically no such thing as current flow *in* conductors. Charges and currents sit and flow *on* the conductor surfaces.

Current Flow in Tubes

Let us move now from conductors to the flow of electrons in vacuum tubes. The electron tube is the machinery of the ultrahigh-frequency engineer, even more than it is to the engineer at ordinary radio frequencies. Circuits and electron beams are so closely inter-related at these frequencies that it is essential to have a clear picture of current flow from conductors into electron beams and back out through conductors again.

Consideration of current flow at ultrahigh-frequencies in vacuum tubes may well start with a few remarks about an ordinary triode amplifier because such a tube is well known to readers of ELECTRONICS. Briefly, the usual explanation of its operation is illustrated in Fig. 3. The cathode emits an abundance of electrons and these would normally flow hurriedly to the plate, which is maintained at some positive voltage with respect to the cathode, were it not for the effect of the space charge of electrons themselves. That is, the electrons in filling the space in the region between cathode and grid exercise a repulsion effect on the electrons that have just been emitted and are anxious to start toward the plate. As a result, only a certain definite number of electrons will be allowed to migrate to the plate. The first part of the picture then, is that current flows between cathode and plate and back around through the external circuit to form a closed path. The greater the number of charges (electrons) per second reaching the plate per unit time, the greater the number of amperes the ammeter indicates.

The grid is interposed in the space-charge region between plate and cathode and, being relatively close to the cathode, it exerts a powerful control effect on the electrons near the cathode. A change in grid voltage results in a change in the space-charge condition near the cathode. Consequently a change in plate current results. No word is ordinarily mentioned of the time it takes for the grid to exert its effect on the space-charge region nor the time it takes electrons to dash from one position to another in compliance with the "orders" of the applied signal. It is assumed that for every set of values of plate voltage and grid voltage there exists a certain value of plate current and, moreover, that if the voltages are changed to new values the current will immediately change to a new value without regard to the speed with which the changes in voltage may have been made.

Now we know that this picture, with its assumption of instantaneous motion of electrons (short "transit time") is quite valid and leads to no difficulties in application for the frequency range in which most power and radio work is accomplished. We know also, from a good deal of recent literature, that the effect of transit time of electrons in vacuum tubes has not been overlooked and new tubes have been described in which the fact that the electron takes an appreciable part of a cycle or actually many cycles of the radio frequency to travel between electrodes is of prime importance. But suppose that we did not know this and we were figuring out for the first time how a simple triode operates, bearing in mind that the frequencies might really become high. We should doubtless argue as follows: The application of an oscillating voltage on the grid will result in a periodic attraction and repulsion of electrons by the grid. The result will be that the space-charge electrons near the cathode will commence to move under the influence of this periodic force. For example, we might expect that as the grid voltage approached its highest positive value, the electrons near the cathode would experience an increasing attraction toward the grid. In consequence of this attraction they would start to move toward the grid. However, the applied frequency may be such that when the electrons have travelled only a small part of the distance between cathode and grid, the grid potential will begin to reverse, and the space-charge electrons will then be repelled by the grid and begin to move away again.

In the meantime the plate remains quite puzzled as to what is expected of it. Had the grid behaved properly and removed a good measure of the space charge from in front of the cathode on each positive part of the cycle we would have expected to find a periodic increase in plate current. But with the grid wavering in its attitude so that the space charge and the electrons contemplating leaving the cathode region have to dilly-dally, it becomes a matter of some difficulty to determine just what influence, if any, the plate current will receive from such action by the grid.

If the current flowing to an electrode in a vacuum tube is viewed as resulting from the collection of electrons at the electrode then, in the case described, the plate would receive no alternating current whatsoever. Suppose we lower the frequency just a little—enough so that before the signal voltage on the grid changes its mind, a substantial number of electrons pass through the grid. Electrons will flow to the plate and there will presumably be some plate current. The implication is that there is a critical point with respect to frequency for a given amplitude of signal at which the plate current suddenly ceases to flow. These difficulties can be resolved if we reject as fundamental the concept that current flow to an electrode in a vacuum tube is a result of the instantaneous collection of electrons.

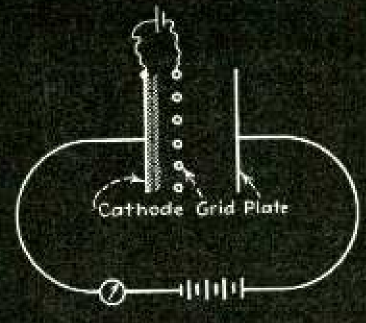
The electron collection concept may serve us well at times but, in general, it is best to use the more fundamental picture that current flow in the external circuit that connects electrodes of a vacuum tube is due to the *induced* effect of the moving charges in the space between electrodes. It is interesting to note that, although this latter concept is well understood as applying to the newer transit-time u-h-f tube generators and amplifiers the concept is not so well appreciated as applying also to more commonplace tubes, such as diodes and triodes at any frequency. But that this is so can readily be appreciated by reference to the diagrams of Fig. 4.

Figure 4 pictures an electron—a single charged body—passing between two vacuum-tube electrodes which are connected externally through an ammeter. The electron is first near the electrode at the left with lines of electric field flux from it falling upon the other electrode and ending there on positive charges which will be induced on the plate to match the negative charge of the electron. The ratio in which the positive charge divides itself between the two electrodes is dependent upon the adjacency of the electron to these electrodes. With the electron near the electrode on the left most of the induced positive charge is on that electrode. But, as the electron moves, a greater percentage of that positive charge appears on the plate to the right. This means that some of the positive charges from the left electrode must be moving through the ammeter, appearing on the electrode at the right at just the proper time to receive the flux lines that have shifted over. As the electron moves between the two plates, the amount of charge on the left electrode decreases and the amount of positive charge on the electrode at the right increases. Consequently, throughout the motion, a current which is a measure of the rate of change of charge flows through the ammeter.

Finally, as the electron nears the electrode at the right, all of the positive charge, or essentially all of it, accumulates on that electrode. At the very end of the trip, when the electron finally lands at the plate, it meets the equal positive charge resting entirely on that plate (with no charge whatsoever on the opposite plate). The electron neutralizes that charge and the flow through the ammeter becomes zero.

Current flows all the time during the electron motion. Indeed, it stops only when the electron has finally arrived. Thus, it is not necessary that an electrode be collecting electrons for there to be current flow. It must receive electrons if it is to pass a direct current, but instantaneous current will flow while the electron is merely *approaching* the plate. Had the electron turned around and gone back before it had completed all of its travel, then the instantaneous current would have reversed, but it would have been zero only at those times during the process when the electron velocity happened to be zero.

A safe and correct viewpoint is to consider the current in an electron



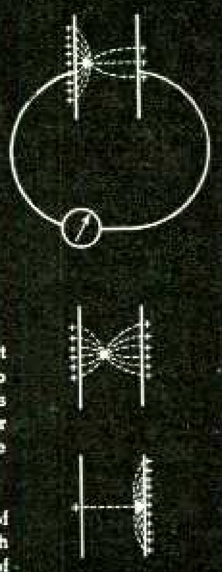


FIG. 3 (Above) Mechanism of the vacuum tube. At ordinary frequencies, it is assumed that no time is required for the passage of electrons from cathode to plate. But in the centimeter wave region, this transit time cannot be neglected

FIG. 4 (Right) A more sophisticated picture of vacuum tube operation. Current flows through the external circuit because the passage of electrons from cathode to plate induces charges on the plate. Instantaneous current flows so long as the electron moves; it stops when the electron finally arrives at the plate

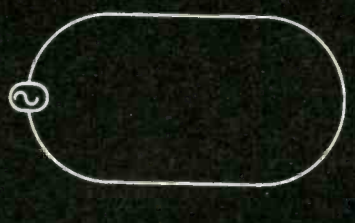


FIG. 5 (Above) An elemental electrical circuit. At low frequencies it is assumed that flow of current through the wire, and a field about the wire, is established instantaneously—but this is not true at centimeter wave frequencies

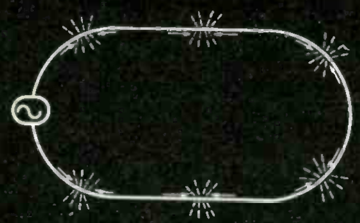


FIG. 6 (Above center) At high frequencies, charges pile up at points on the conductor because of the finite time it takes the magnetic field to build up. The field may not have time to establish itself all around the circuit before the generated current changes its direction of flow

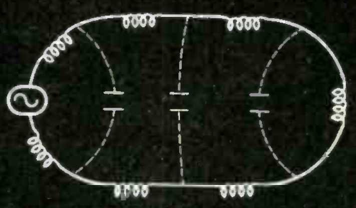


FIG. 7 (Above) At high frequencies, even a simple circuit may act as though it is made up of many series impedances and shunt admittances

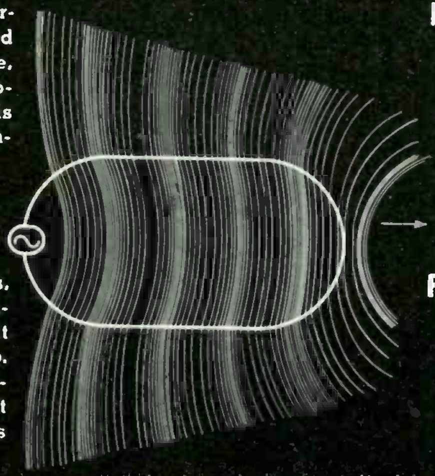


FIG. 8 (Left) Loop conductors may be thought of as guiding waves from a source of energy. Some of the energy is reflected back to the generator. Some of it is lost to the system through radiation

tube as arising from induction because of the motion of charges in the space between electrodes. When the electron is finally collected isn't the time when current flows. As a matter of fact, that is the time when current due to that electron ceases to flow.

If there is a continuous stream of electrons coming from, say, a cathode to an anode, then, as each electron moves, it transfers the matching electric charge, present on the face of the electrodes, from the cathode to the anode through the external circuit. A continuous process, a steady flow of electrons, means then that the current flowing in the circuit is equal to the number of electrons per second arriving at the plate. In this case, the two concepts agree: current flow in a vacuum tube may be regarded as due to the instantaneous collection density of electrons at the electrode, or it may be regarded as a movement through the external circuit of the induced charges on the electrode, occasioned by the electrons' presence and motion. Whichever way you look at it, you get the same answer. But notice that there is nothing in the rules which says the number of electrons leaving the cathode at any instant must equal the number of electrons arriving at the plate at that same instant. Particularly is this so if the frequency is high.

The centimeter-wave engineer, when he thinks of current flow through an electron tube, cannot overlook the fact that the current flow is due to a motion of charges, and that it is an integrated effect of all the induced current due to all the charges with which he must deal. The chief tool, the chief machine of the engineer in the centimeter-wave region, the vacuum tube, is not universally looked at as a switch or an impedance which can be varied by variation of the biasing voltages on the electrodes. Instead, the centimeter-wave engineer finds himself thinking about electron paths, electron velocities, transit-time, induced currents, and movements of waves of space charge.

Circuits and Circuit Concepts

Let us turn away from electrons and go back to more general pictures of the characteristics of centimeter waves near conductors. If we had to analyze the circuit of Fig. 5 at the lower frequencies we would probably proceed as follows. The voltage that is applied to the loop causes some current to flow. To find out how much current flows, we would contribute a certain amount of the voltage toward overcoming ohmic losses, the *IR* drop, and a certain amount towards overcoming the induced emf due to the changing magnetic field. One way to look at this is that the changing current at every point in the wire gives us a changing magnetic field and this in turn causes an induced electric field at every point of the loop. The cumulative effect of that electric field is to require a certain amount of the applied voltage to be used up in overcoming the field to permit current to flow.

Some time before radio waves had been discovered, Maxwell set up a theory of electricity and magnetism, which is still "tops" today in the electromagnetic spectrum covering the radio and power frequencies and which applies to many of the basic phenomena of heat and light waves. The most startling things about Maxwell's equations at that time, and perhaps his most important single conclusion applicable to the centimeter-wave region today, is that they predicted that electric and magnetic fields do not jump instantaneously into existence in the space surrounding charges and currents which cause them. Rather, the electric and magnetic fields travel away from their sources with the velocity of light. These equations gave rise to the electromagnetic theory of light and formed the first important link between light and electricity and it is this very basic discovery of Maxwells which yields the link that we must add to our low-frequency notions of electricity if we are to analyze properly centimeter-wave systems.

In the analysis of the last paragraph nothing was said about the time it takes for the magnetic field due to the current in one part of the loop to make itself felt at another part of the loop. It was assumed that the field travels so quickly compared to the size of the loop that the magnetic field due to the current is in exact step with that current. But what do we mean when we say that the size of a loop is small? The time it takes for an electric or magnetic field to cross the loop must be compared with the time it takes for the electricity to go through an alternation. If these times become comparable, then the loop is no longer small. It is not, in other words, the absolute size of the loop but the size of the loop in comparison with the wavelength that matters.

At wavelengths in the centimeter range the loop need not be very large before an appreciable part of the period of a cycle is required for the effects of current changes in one part of the circuit to be felt in other parts. We ordinarily think of inductance as causing a current to be ninety degrees out of phase with the voltage across it: A pure inductance takes no average power. If, however, the magnetic field takes an appreciable part of a cycle to get from one side of the circuit to another, there is going to be some delay or retardation and some change or expansion in our circuit notions. A small amount of the induced electric field will be in phase with the current in the wire. We will thus sustain a loss, not in heating up the circuit because it has nothing to do with the ohmic resistance of the circuit, but a loss that leaks out through the electromagnetic field. Perhaps an even greater setback is the realization that our friend, the pure inductance, seems to be capable of aggression on pure resistance. We do not have to throw out the inductance concept, but we do have to broaden it.

The loop might easily be several wavelengths long. Then, periodically around the loop, we shall find that the current in one part may be going in one direction while in another part it is going in the opposite direction as shown in Fig. 6. You may correctly conclude that when such a thing happens to current, charges must be "piling up" at intermediate points. It might be well to draw one other conclusion before we go on to develop this situation further. This conclusion is that circuits in the usual sense—in which our picture is one of a current flow, uniform in magnitude and phase, and lying entirely in the conductors all the way around—that concept of circuit is practically non-existent in the centimeter wave field. Since the distance from zero to the positive maximum of current along a conductor is only a quarter of a wavelength, it is very rare that centimeter wave circuits small enough physically to look like low-frequency circuits can be used.

So we accept the fact that the current is not going to be uniform around the loop of any circuit whose length is at least comparable to wavelength; but this is only a beginning.

Those familiar with transmission line theory will immediately recognize that it is usually preferable to consider a system of the type just described as a transmission line rather than as a single loop circuit. The length being too long for one simple circuit, we may think of it as made up of an infinite series of little circuits. There are series impedance effects and there must indeed be shunt admittance effects across the loop because the charges, which must gather at the current nodes, are significant in determining the overall performance of the system. So it would appear that the picture of Fig: 7, where the series impedances and shunt admittances are indicated by the many coils and condensers, is preferable.

The concept of distributed inductance and capacitance has been demonstrated to be effective and valuable for many phases of the u-h-f circuit problem. It is extremely useful, for example, in predicting approximate distributions of currents and voltages at various parts of the circuit. It has, however, one outstanding limitation: although you may distribute impedance and admittance at will over the circuit in an attempt to visualize the proper magnitude and phase differences of the currents around the loop, you still have allowed only one way in which energy can be lost, and that is in the I^2R loss of the coils and condensers. Unfortunately, our little loop is not an ordinary transmission line. It can not be thought of as guiding energy uniformly for a distance, then depositing that energy completely into a load at the end. Nor is all the energy simply reflected back to the source. Because of the non-uniformity of the transmission line and because of the factors which we have already discussed, the picture of Fig. 8 comes closer to portraying the actual situation. Here we acknowledge again that the centimeter-wave energy lies mainly in the dielectric medium around the conductor, not penetrating the conductors appreciably. The conductors serve merely as guides. We think then of the loop conductors as guiding the waves from the source along the loop, to be reflected at various points of the loop back to the source, but also to be spread out over some distance and lost from the system forever.

The writer has taken many liberties in the diagram of Fig. 8, which shows the transmission line waves progressing out from the source with an appreciable amount of energy never getting back by reflections (which are not shown) but being lost in electro-magnetic field leakage or radiation. The distributions of the wave are intended only to convey an impression and are not based on a mathematical field plot. A good deal of the energy in the transmission line waves will undoubtedly be reflected back to the source. Indeed, if all of the energy were so reflected, and we are neglecting for the moment the I^2R losses in the metal of the loop itself, then the source would see nothing but pure reactance. That it does not do so ties up with our earlier conclusion that the ordinary (low frequency) "inductance" is no longer loss-free in the centimeter wave region. Although some energy is guided up and down the loop, other energy gets away. Whether we like it or not, this circuit has become an antenna; it radiates power.

And now we have come upon another important property of centimeter-wave circuits. First, we have

AN OSCILLATOR FOR

Single pentode tube is used as a combined oscillator and reactance tube to vary the frequency of generated oscillations over a range of two percent through changes of d-c voltages applied to the tube. Discussion of design factors affecting frequency stability is given

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THE remote control of radio receivers often necessitates control of an oscillator. When the oscillator must be controlled over a wide frequency range, some form of motor-driven or flexible-shaft-driven capacitor is usually used. When the tuning range is small, however, as is the condition when adjusting a beat-frequency oscillator to obtain the desired audio-frequency output or when an adjustment of the frequency of the heterodyning oscillator associated with the first detector is necessary to compensate a frequency drift in the receiver or transmitter, simplified control systems are possible. One such system involves the use of a reactance tube connected across the oscillator tank circuit. The usual reactance tube and oscillator circuit requires the use of two tubes. Compact design such as is necessary in mobile equipment makes it desirable to use a single tube for this purpose.

The circuit shown in Fig. 1 is an oscillator and reactance-tube control system using a single pentode tube. The frequency range of the oscillator can be made controllable over a range of at least 2 percent by means of a variation in the d-c potential applied to one electrode of this tube. The absence of any r-f voltage on the controlled circuit makes it possible to use unshielded wires within a power cable for the control leads.

Theory of Operation

The cathode, grid, and screen grid of the tube are connected as a conventional triode grounded-plate Hartley oscillator. The screen is bypassed to ground for r-f and direct voltages applied through resistor R_2 to give the proper screen voltage.

Resistor R_3 in the plate circuit of the type 9001 tube used experimentally was chosen to give the maximum available r-f output voltage at the plate of the tube when the frequency control R_4 is set at the maximum direct voltage position. Too large a load resistor will cause low output voltage because of the low direct plate voltage present at the tube, while too small a resistor will cause low output voltage because of the low r-f impedence of the plate load. A tuned circuit or r-f choke may be substituted for this load although this will change the amount of frequency shift obtainable and introduce the possibility of a new mode of oscillation if the circuits are not properly adjusted.

The frequency of this oscillator may be changed by altering the effective inductance or capacitance of the parallel resonant circuit, L_1C_1. In any parallel resonant circuit a charge is first stored in the capacitor, then flows through the inductance and charges the capacitor in the opposite direction. The speed with which this change can take place depends in part upon the amount of charge which must be transferred from one side of the capacitor to the other. The charge which must be moved is usually that stored on the capacitor alone. However, some of this charge may be supplied by an auxiliary system which feeds a charge (or supplies a flow of current) through the inductance at the same time the capacitor is being discharged. Since the capacitor is being discharged through the inductance most rapidly at the instant the voltage across the resonant circuit is zero, the current (or charge) fed into the resonant circuit should, in the ideal case, be a maximum at this time. A parallel resonant circuit is resistive at resonance so the voltage driving this extra current into the resonant circuit must be in phase with the current or 90 deg. out of phase with the

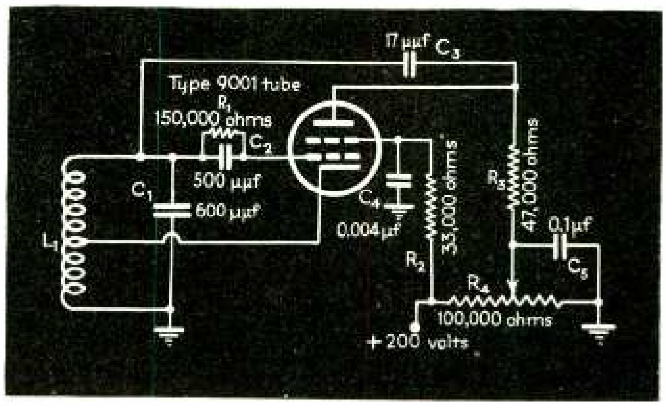

Fig. 1—A 200-kc controlled oscillator. Output voltage is taken from L_1 through either a small capacitor, a tap on the winding, or an auxiliary winding

Remote Frequency Control

oscillating voltage of the resonant circuit. Any system which will supply such a voltage will cause a shift in the frequency of oscillation. This is the principle upon which all reactance tube controlled oscillators function.

In the circuit of Fig. 1, the phase shifted voltage is obtained from the voltage developed across the plate load, R_3. This voltage is 180 deg. out of phase with that impressed upon the grid of the tube. The voltage on the control grid is that appearing across the resonant circuit and that to which all phase relations are referred. The phase of plate voltage may be further shifted by a small capacitor, C_3 connected to a resistance, which in this case is that of the parallel resonant circuit L_1C_1.

Capacitor C_3 is of such a value that a maximum reactive component of the plate voltage is fed back to the resonant circuit. Two conditions govern the value of C_3. It should be made small enough to obtain maximum phase shift and yet sufficiently large to obtain minimum attenuation. The optimum conditions are most easily obtained from the vector diagrams of Fig. 2. The plate voltage is represented by the vector E_{R3} at zero degrees phase angle. The voltage drop, E_c, across C_3, and the voltage drop E_L across the resonant circuit must add up to E_{R3}. At resonance the parallel circuit L_1C_1 appears as a resistance of magnitude $Q\omega L_1$ or $Q/\omega C_1$. The voltage across L is therefore 90 deg. out of phase with that across the feedback capacitor C_3. The reactive component of E_c has as it's locus a semi-circle, the diameter of which is E_{R3}.

It is evident that the maximum reactive component of voltage is obtained when $E_L = E_c$ and the maximum amplitude is one-half E_{R3}. Then,

$$\frac{1}{\omega C_3} = Q\omega L_1 = \frac{Q}{\omega C_1}$$

$$\text{or } C_3 = \frac{C_1}{Q}$$

where Q is that of the resonant circuit L_1C_1. When these conditions exist, a voltage is fed back from the plate to the resonant circuit 45 deg. out of phase with that normally appearing at the control grid. The plate circuit of the tube therefore appears to the resonant circuit as a capacitance. The magnitude of this capacitance depends upon the radio-frequency voltage available across R_3. This available r-f voltage is controlled by the plate voltage applied to the tube by potentiometer R_4.

An Experimental Oscillator

The oscillator shown in Fig. 1 operates at 200 kc. It has a controllable frequency range of 4000 cycles when operated from a 200-v. B supply. Three different 9001 tubes checked in this circuit gave a controllable frequency range of between 4000 and 5000 cycles. It can be seen that the degree of control will vary somewhat with the transconductance of the tube, since this value determines the r-f voltage available at the plate. The oscillator output voltage varied between 25 and 35 v. for one particular tube as the plate voltage was varied between 0 and +200 v. Screen current changed from 0.45 to 0.35 ma. and the plate current changed from 0 to 0.3 ma.

Frequency stability of this oscillator is such that when the supply voltage to the complete receiver is dropped 25 percent, the oscillator frequency varies 0.005 percent at one extreme of the frequency control and 0.067 percent at the other extreme. It is possible to design the oscillator in such a way that the frequency shift is slightly negative with a change in battery voltage at one extreme of the controllable range and slightly positive at the other extreme, giving a minimum frequency change for a change in battery voltage for all settings of the frequency control. The choice of values for screen-dropping resistor R_2, grid resistor R_1, grid-coupling capacitor C_2 and the position of the tap on oscillator coil L_1, as well as the L/C ratio of the resonant circuit will determine the stability of the oscillator. These values should be carefully determined to obtain best stability.

The output voltage of the oscillator may be maintained within closer limits by reducing the range over which the plate voltage of V_1 may be varied. It is suggested that this range always start at zero volts on the plate since this value is the condition for minimum effect of battery voltage, due to change in transconductance of the tube, upon the frequency of the oscillator. A small capacitance across R_3 will similarly stabilize the output voltage but at the same time will reduce the controllable frequency range.

Frequency Modulation

Although this circuit has not been tried as a frequency-modulation oscillator, it is probable that it will make a suitable frequency-modulated system if an a-f voltage is applied across C_5, and C_5 is made small enough to prevent its bypassing the audio frequencies.

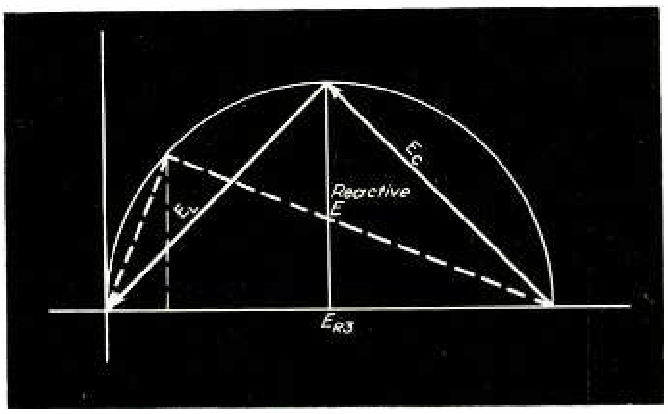

Fig. 2—Vector diagram of feedback voltage. Dotted lines show conditions for too small a value of C_3

36 and 72 ORDINATE

For General Harmonic Analysis . . .

Systematization of procedure facilitates the tedious calculations required in harmonic analysis of complex waves. The 36 and 72 point schedules, with means of checking results, presented here are applicable to use with odd and even harmonics

By R. P. G. DENMAN

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Editor's Note. This is an abstract of an article by Colonel Denman, Royal Corps of Signals, originally offered to the Royal Society of London, and favorably received by the society. It was unpublished because of the war stringency. It was then sent to Dr. F. W. Grover, Union College, Schenectady, who sent it to ELECTRONICS in October of 1940. Because of the great length and complexity of the original paper, Dr. Grover agreed to prepare an abstract. This he did. After several delays, most of which were unavoidable, the abstract is now published for the benefit of ELECTRONICS readers. It is improbable that the original paper of Colonel Denman will be published.

SIMPLIFIED harmonic analysis schedules suitable for the analysis of curves common in power circuits, where only odd harmonics occur, have long been available, but these are inapplicable to curves containing both odd and even harmonics. These, however, are nowadays of frequent occurrence in telecommunications and electronics. Since the labor of computation is considerable, it is desirable to have available a uniform series of schedules from which may be chosen one which yields just sufficient detail for the purpose in view.

The author has prepared, in a form suitable for photographic reproduction, four schedules based on 12, 18, 36 and 72 measured ordinates. The first two are due respectively to von Runge[1] and Grover[2]; those based on 36 and 72 ordinates have been derived by the author. It is believed that with these latter we approach the limits of accuracy possible in measuring oscillograms, and that thus the needs of all practical problems are satisfied. These new schedules, together with the check equations, which are an almost indispensable adjunct, are here given.

The analysis schedules systematize the calculation of the coefficients A_K and B_K in the general equation assumed to represent the ordinate of the curve to be analyzed.

$$\begin{aligned} y_1 = {} & A_1 \sin \omega t + A_2 \sin 2\omega t + A_3 \sin 3\omega t + \ldots + A_K \sin K\omega t \\ & + \ldots + A_{n-1} \sin (n-1)\,\omega t \\ & + B_0 + B_1 \cos \omega t + B_2 \cos 2\omega t + B_3 \cos 3\omega t + \ldots \\ & + B_K \cos K\omega t + \ldots + B_n \cos n\,\omega t. \end{aligned}$$

The $2n$ measured ordinates, equally spaced over a complete cycle of the curve to be analyzed, are set down in the order shown in the schedules and the sums and differences of complementary pairs of ordinates y_m, y_{2n-m}, together with other quantities specified in the schedules are computed. The coefficients A and B are then calculated by entering in its proper position on the analysis form each of the indicated quantities, *after first multiplying it by the number in the "multiplier" column which appears in the same row.* The sums, S_{oK} and S_{eK} of the two columns of these values are added to find the coefficient A_K. Their difference $S_{oK} - S_{eK}$ gives the complementary coefficient A_{2n-K}. Similarly, the cosine coefficients B_K and B_{2n-K} are obtained from the sums and differences of the totals in the columns D_{oK} and D_{eK}.

There will be no errors in the determination of the A_K and B_K coefficients, if the number of existing harmonics in the wave is less than n. A good test of the analysis is to repeat it for a set of ordinates spaced half way between those already treated. If the results disagree appreciably, the use of an analysis schedule based on a greater number of points is indicated.

The author has tested his schedules by analyzing an ideal rectilinear wave (where the Fourier series expansion is known) and also a saw-tooth wave with a finite fly-back time, for which he has given the derivation of the expansion.

(An appendix to the article, contributed by Dr. L. J. Comrie, deals with the use of centralized punched card equipment for applying the analysis schedules of the article by mechanical means.—The Editor)

(*Continued on page* 46)

[1] Von Runge, *Zeitsch. für Math. u. Phys.* 48, 1903, p. 443.
[2] Grover, *Bull. Nat. Bureau Stan.*, 9, 1913, p. 567.
A 12-ordinate scheme may be found abstracted in the "Radio Engineering Handbook," Third Edition, page 21. Original source is "Graphical and Mechanical Computation" Part II by Joseph Lipka. John Wiley & Sons Inc.

SCHEDULES

36 ORDINATE SCHEDULE FOR ODD AND EVEN HARMONICS.

ORDINATES.

Ordinates	y_0	y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8	y_9	y_{10}	y_{11}	y_{12}	y_{13}	y_{14}	y_{15}	y_{16}	y_{17}	y_{18}
Ordinates	y_{36}	y_{35}	y_{34}	y_{33}	y_{32}	y_{31}	y_{30}	y_{29}	y_{28}	y_{27}	y_{26}	y_{25}	y_{24}	y_{23}	y_{22}	y_{21}	y_{20}	y_{19}	
Sums	S_0	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S_{16}	S_{17}	S_{18}
Differences	d_0	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}	d_{12}	d_{13}	d_{14}	d_{15}	d_{16}	d_{17}	d_{18}

	S_0	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	d_0	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9
	S_{18}	S_{17}	S_{16}	S_{15}	S_{14}	S_{13}	S_{12}	S_{11}	S_{10}		d_{18}	d_{17}	d_{16}	d_{15}	d_{14}	d_{13}	d_{12}	d_{11}	d_{10}	
Sums	Σ_0	Σ_1	Σ_2	Σ_3	Σ_4	Σ_5	Σ_6	Σ_7	Σ_8	Σ_9	σ_0	σ_1	σ_2	σ_3	σ_4	σ_5	σ_6	σ_7	σ_8	σ_9
Differences	Δ_0	Δ_1	Δ_2	Δ_3	Δ_4	Δ_5	Δ_6	Δ_7	Δ_8	Δ_9	δ_0	δ_1	δ_2	δ_3	δ_4	δ_5	δ_6	δ_7	δ_8	δ_9

SINE TERMS

Angle α	Multiplier $\frac{1}{18}(\sin\alpha)$	A_1 & A_{17}	A_2 & A_{16}	A_3 & A_{15}	A_4 & A_{14}	A_5 & A_{13}	A_6 & A_{12}	A_7 & A_{11}	A_8 & A_{10}	A_9
10°	0.0096	σ_1				$-\sigma_7$		$-\sigma_5$		
20°	0.0190	σ_2	δ_1 δ_8		$-\delta_5$ δ_4	$-\sigma_4$		$-\sigma_8$	$-\delta_7$ δ_2	
30°	0.0278	σ_3		φ_1		σ_3		$-\sigma_3$		
40°	0.0357	σ_4	δ_7 δ_2		δ_1 $-\delta_8$	σ_8		σ_2	δ_5 $-\delta_4$	
50°	0.0426	σ_5				σ_1		σ_7		
60°	0.0481	σ_6	δ_3 δ_6	φ_2	δ_3 $-\delta_6$	$-\sigma_6$	φ_4 φ_5	σ_6	$-\delta_3$ δ_6	
70°	0.0522	σ_7				$-\sigma_5$		σ_1		
80°	0.0547	σ_8	δ_5 δ_4		$-\delta_7$ δ_2	σ_2		$-\sigma_4$	δ_1 $-\delta_8$	
90°	0.0555	σ_9		φ_3		σ_9		$-\sigma_9$		φ_6
Sums		S_{o1} S_{e1}	S_{o2} S_{e2}	S_{o3} S_{e3}	S_{e4} S_{e4}	S_{o5} S_{e5}	S_{o6} S_{e6}	S_{o7} S_{e7}	S_{o8} S_{e8}	S_{o9}
$A_K = S_{oK} + S_{eK}$ $A_{(18-K)} = S_{oK} - S_{eK}$		A_1 A_{17}	A_2 A_{16}	A_3 A_{15}	A_4 A_{14}	A_5 A_{13}	A_6 A_{12}	A_7 A_{11}	A_8 A_{10}	A_9

COSINE TERMS.

Angle α	Multiplier $\frac{1}{18}(\sin\alpha)$	B_1 & B_{17}	B_2 & B_{16}	B_3 & B_{15}	B_4 & B_{14}	B_5 & B_{13}	B_6 & B_{12}	B_7 & B_{11}	B_8 & B_{10}	B_9	B_0 & B_{18}
10°	0.0096	Δ_8	Σ_4 $-\Sigma_5$		Σ_2 Σ_7	$-\Delta_2$		Δ_4	Σ_8 Σ_1		
20°	0.0190	Δ_7				$-\Delta_5$		Δ_1			
30°	0.0278	Δ_6	$-\Sigma_6$ Σ_3	θ_1	$-\Sigma_6$ $-\Sigma_3$	Δ_6	$-\theta_5$ θ_4	Δ_6	$-\Sigma_6$ $-\Sigma_3$		
40°	0.0357	Δ_5				Δ_1		$-\Delta_7$			
50°	0.0426	Δ_4	Σ_2 $-\Sigma_7$		Σ_8 Σ_1	Δ_8		$-\Delta_2$	Σ_4 Σ_5		
60°	0.0481	Δ_3		θ_2		$-\Delta_3$		$-\Delta_3$			
70°	0.0522	Δ_2	$-\Sigma_8$ Σ_1		$-\Sigma_4$ $-\Sigma_5$	$-\Delta_4$		$-\Delta_8$	$-\Sigma_2$ $-\Sigma_7$		
80°	0.0547	Δ_1				Δ_7		Δ_5			
90°	0.0555	Δ_0	Σ_0 $-\Sigma_9$	θ_3	Σ_0 Σ_9	Δ_0	θ_7 $-\theta_6$	Δ_0	Σ_0 Σ_9	θ_8	θ_{10} θ_9
	Sums	D_{o1} D_{e1}	D_{o2} D_{e2}	D_{o3} D_{e3}	D_{o4} D_{e4}	D_{o5} D_{e5}	D_{o6} D_{e6}	D_{o7} D_{e7}	D_{o8} D_{e8}	D_{o9}	D_{o10} D_{e10}
$B_K = D_{oK} + D_{oK}$ $B_{(18-K)} = D_{oK} - D_{eK}$		B_1 B_{17}	B_2 B_{16}	B_3 B_{15}	B_4 B_{14}	B_5 B_{13}	B_6 B_{12}	B_7 B_{11}	B_8 B_{10}	B_9	

$\varphi_1 = \sigma_1 + \sigma_5 - \sigma_7$

$\varphi_2 = \sigma_2 + \sigma_4 - \sigma_8$

$\varphi_3 = \sigma_3 - \sigma_9$

$\varphi_4 = \delta_1 - \delta_5 + \delta_7$

$\varphi_5 = \delta_2 - \delta_4 + \delta_8$

$\varphi_6 = \sigma_1 - \sigma_3 + \sigma_5 - \sigma_7 + \sigma_9$

$\theta_1 = \Delta_2 - \Delta_4 - \Delta_8$

$\theta_2 = \Delta_1 - \Delta_5 - \Delta_7$

$\theta_3 = \Delta_0 - \Delta_6$

$\theta_4 = \Sigma_1 + \Sigma_5 + \Sigma_7$

$\theta_5 = \Sigma_2 + \Sigma_4 + \Sigma_8$

$\theta_6 = \Sigma_3 + \Sigma_9$

$\theta_7 = \Sigma_0 + \Sigma_6$

$\theta_8 = \Delta_0 - \Delta_2 + \Delta_4 - \Delta_6 + \Delta_8$

$\theta_9 = \Sigma_1 + \Sigma_3 + \Sigma_5 + \Sigma_7 + \Sigma_9$

$\theta_{10} = \Sigma + \Sigma_2 + \Sigma_6 + \Sigma_8$

$B_0 = \frac{D_{o10} + D_{e10}}{2}$

$B_{18} = \frac{D_{o10} - D_{e10}}{2}$

Reminder: Multiply each of the indicated quantities in the A and B schedules by $\frac{1}{18}(\sin\alpha)$.

A complete cycle of the waveform to be analyzed is necessary. This 36-ordinate schedule requires that the cycle be divided every 10 degrees, the heights of the curve at these points be measured; then these values fitted into the schedule above

Check Equations for the 36 Ordinate Schedule

Sine Terms. (A) S terms. Apply check for d_3 and recalculate D_{o9}. If there is any error, apply the check for d_9.

$$d_3 = 2[\{(A_1 + A_{17}) + (A_5 + A_{13}) - (A_7 + A_{11})\} \sin 30° + \{(A_2 + A_{16}) + (A_4 + A_{14}) - (A_8 + A_{10})\} \sin 60° + (A_3 + A_{15}) - A_9]$$

This checks S_{oK}, $k = 1, 2, 3, 4, 5, 7, 8, 9$, but not $k = 6$.

$$d_9 = 2\{(A_1 + A_{17}) - (A_3 + A_{15}) + (A_5 + A_{13}) - (A_7 + A_{11}) + A_9\}$$

This checks for $k = 1, 3, 5, 7, 9$ but not 2, 4, 6, 8.

(B) S_{eK} terms. Apply the check for d_2 and recalculate D_{e9}. If there is any error, apply the check for d_6.

$$d_2 = 2[\{(A_1 + A_{17}) + (A_8 - A_{10})\} \sin 20° + \{(A_2 - A_{16}) + (A_7 - A_{11})\} \sin 40° + \{(A_3 - A_{15}) + (A_6 - A_{12})\} \sin 60° + \{(A_4 - A_{14}) + (A_5 - A_{13})\} \sin 80°]$$

This checks S_{eK} for all values of k except 9.

$$d_6 = 2\{(A_1 - A_{17}) + (A_2 - A_{16}) - (A_4 - A_{14}) - (A_5 - A_{13}) + (A_7 - A_{11}) + (A_8 - A_{10})\} \sin 60°.$$

This checks all values of S_{eK} except for $k = 3, 6, 9$.

Cosine Terms. (A) D_{oK} terms. Apply check for S_o.

$$S_0 = (B_0 + B_{18}) + (B_1 + B_{17}) + (B_2 + B_{16}) + (B_3 + B_{15}) + (B_4 + B_{14}) + (B_5 + B_{13}) + (B_6 + B_{12}) + (B_7 + B_{11}) + (B_8 + B_{10}) + B_9$$

This checks all the D_{oK} terms.

(B) D_{oK} terms. Apply the check for S_1 and recalculate S_{e9}. If there is any error in S_1, apply the check for S_9.

$$S_1 = 2[\{(B_0 - B_{18}) + (B_1 - B_{17})\} \sin 80° + (B_2 - B_{16}) \sin 70° + (B_3 - B_{15}) \sin 60° + (B_4 - B_{14}) \sin 50° + (B_5 - B_{13}) \sin 40° + (B_6 - B_{12}) \sin 30° + (B_7 - B_{11}) \sin 20° + (B_8 - B_{10}) \sin 10°]$$

This checks all values of D_{eK} but D_{e9}.

$$S_9 = 2\{(B_0 - B_{18}) - (B_2 - B_{16}) + (B_4 - B_{14}) - (B_6 - B_{12}) + (B_8 - B_{10})\}$$

This checks D_{eK} for even values of k but not for odd values.

Check Equations for the 72 Ordinate Schedule

Sine Terms. (A) S_{oK} terms. Apply check for d_1.

$$d_1 = 2\{(A_1 + A_{35}) \sin 5° + (A_2 + A_{34}) \sin 10° + (A_3 + A_{33}) \sin 15° + (A_4 + A_{32}) \sin 20° + (A_5 + A_{31}) \sin 25° + (A_6 + A_{30}) \sin 30° + (A_7 + A_{29}) \sin 35° + (A_8 + A_{28}) \text{ in } 40° + (A_9 + A_{27}) \sin 45° + (A_{10} + A_{26}) \sin 50° + (A_{11} + A_{25}) \sin 55° + (A_{12} + A_{24}) \sin 60° + (A_{13} + A_{23}) \sin 65° + (A_{14} + A_{22}) \sin 70° + (A_{15} + A_{21}) \sin 75° + (A_{16} + A_{20}) \sin 80° + (A_{17} + A_{19}) \sin 85° + A_{18}\}$$

If there is no error, the S_{oK} terms are correct. If there is any error, apply the check for d_9.

$$d_9 = 2\{(A_1 + A_{35}) + (A_3 + A_{33}) - (A_5 + A_{31}) - (A_7 + A_{29}) + (A_9 + A_{27}) - (A_{11} + A_{25}) - (A_{13} + A_{23}) - (A_{15} + A_{21}) + (A_{17} + A_{19})\} \sin 45° + (A_2 + A_{34}) - (A_6 + A_{30}) + (A_{10} + A_{26}) - (A_{14} + A_{22}) + A_{18}.$$

This checks S_{oK} terms except for $k = 4, 8, 12$ and 16.

(B) S_{eK} terms. Apply the check for d_2.

$$d_2 = 2[\{(A_1 - A_{35}) + (A_{17} - A_{19})\} \sin 10° + \{(A_2 - A_{34}) + (A_{16} - A_{20})\} \sin 20° + \{(A_3 - A_{33}) + (A_{15} - A_{21})\} \sin 30° + \{(A_4 - A_{32}) + (A_{14} - A_{22})\} \sin 40° + \{(A_5 - A_{31}) + (A_{13} - A_{23})\} \sin 50° + \{(A_6 - A_{30}) + (A_{12} - A_{24})\} \sin 60° + \{(A_7 - A_{29}) + (A_{11} - A_{25})\} \sin 70° + \{(A_8 - A_{28}) + (A_{10} - A_{26})\} \sin 80° + (A_9 - A_{27})]$$

If there is no error, the S_{eK} terms are correct. If there is an error, apply the check for d_{18}.

$$d_{18} = 2\{(A_1 - A_{35}) - (A_3 - A_{33}) + (A_5 - A_{31}) - (A_7 - A_{29}) + (A_9 - A_{27}) - (A_{11} - A_{25}) + A_{13} - A_{23}) - (A_{15} - A_{21}) + (A_{17} - A_{19})\}$$

This equation checks the S_{eK} terms for odd values of k.

Cosine Terms. (A) D_{oK} terms. Apply the check for S_0.

$$S_0 = (B_0 + B_{36}) + (B_1 + B_{35}) + (B_2 + B_{34}) + (B_3 + B_{33}) + (B_4 + B_{32}) + (B_5 + B_{31}) + (B_6 + B_{30}) + (B_7 + B_{29}) + (B_8 + B_{28}) + (B_9 + B_{27}) + (B_{10} + B_{26}) + (B_{11} + B_{25}) + (B_{12} + B_{24}) + (B_{13} + B_{23}) + (B_{15} + B_{21}) + (B_{16} + B_{20}) + (B_{17} + B_{19}) + B_{18}.$$

If there is no error, this checks all the D_{oK} terms. If there is any error, apply the check for S_{18}.

$$S_{18} = 2\{(B_0 + B_{36}) - (B_2 + B_{34}) + (B_4 + B_{32}) - (B_6 + B_{30}) + (B_8 + B_{28}) - (B_{10} + B_{26}) + (B_{12} + B_{24}) - (B_{14} + B_{22}) + (B_{16} + B_{20}) - B_{18}\}$$

This checks the D_{oK} terms for which k is even.

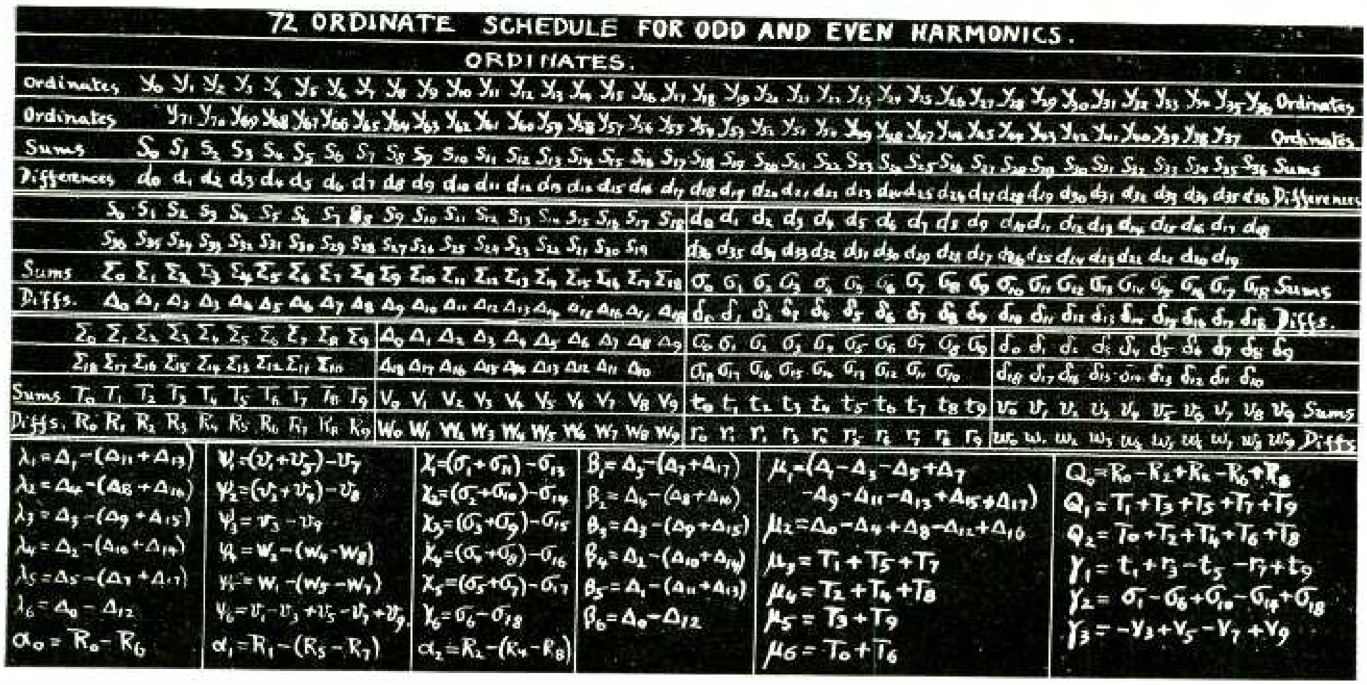
(B) D_{eK} terms. Apply the check for S_1.

$$S_1 = 2\{(B_0 - B_{36}) + (B_1 - B_{35}) \sin 85° + (B_2 - B_{34}) \sin 80° + (B_3 - B_{33}) \sin 75° + (B_4 - B_{32}) \sin 70° + (B_5 - B_{31}) \sin 65° + (B_6 - B_{30}) \sin 60° + (B_7 - B_{29}) \sin 55° + (B_8 - B_{28}) \sin 50° + (B_9 - B_{27}) \sin 45° + (B_{10} - B_{26}) \sin 40° + (B_{11} - B_{25}) \sin 35° + (B_{12} - B_{24}) \sin 30° + (B_{13} - B_{23}) \sin 25° + (B_{14} - B_{22}) \sin 20° + (B_{15} - B_{21}) \sin 15° + (B_{16} - B_{20}) \sin 10° + (B_{17} - B_{19}) \sin 5°\}$$

This checks all the D_{eK} terms. If there is any error, apply check for S_9.

$$S_9 = 2[(B_0 - B_{36}) - (B_4 - B_{32}) + (B_8 - B_{28}) - (B_{12} - B_{24}) + (B_{16} - B_{20}) + \{(B_1 - B_{35}) - (B_3 - B_{33}) - (B_5 - B_{31}) + (B_7 - B_{29}) + (B_9 - B_{27}) - (B_{11} - B_{25}) - (B_{13} - B_{23}) + (B_{15} - B_{21}) + (B_{17} - B_{19})\} \sin 45°.$$

This checks all the D_{eK} except those for which $k = 2, 6, 10, 14$ and 18.



After one has made use of the schedules, a check for the accuracy of the work may be desired. The check equations on the opposite page are for this purpose. Corresponding to the schedules, the check equations are divided into two groups

For greater accuracy, the 72-ordinate schedule for both odd and even harmonics is given below. After substituting numerical values for the ordinates, one secures the coefficients in the general equation representing the curve given on page 44

72 ORDINATE SCHEDULE FOR ODD AND EVEN HARMONICS.

SINE TERMS.

α	sin α/36	A_1 & A_{35}	A_2 & A_{34}	A_3 & A_{33}	A_4 & A_{32}	A_5 & A_{31}	A_6 & A_{30}	A_7 & A_{29}	A_8 & A_{28}	A_9 & A_{27}	A_{10} & A_{26}	A_{11} & A_{25}	A_{12} & A_{24}	A_{13} & A_{23}	A_{14} & A_{22}	A_{15} & A_{21}	A_{16} & A_{20}	A_{17} & A_{19}	A_{18}
5°	.0024	σ_1				σ_7		σ_8				$-\sigma_2$		σ_{11}				σ_{17}	
10°	.0048	σ_2	ν_1			$-\sigma_{14}$		$-\sigma_4$			$-\nu_7$	$-\sigma_{10}$		$-\sigma_{14}$	$-\nu_5$			σ_2	
15°	.0072	σ_3		χ_1		σ_{15}		σ_{15}				σ_3		$-\sigma_3$		χ_5		$-\sigma_{16}$	
20°	.0095	σ_4	ν_2		$\omega_1\ \omega_8$	$-\sigma_8$		$-\sigma_4$	[illegible]		$-\nu_4$	σ_{16}		σ_8	$-\nu_8$		[illegible]	$-\sigma_4$	
25°	.0117	σ_5				σ_1		σ_{13}				σ_7		σ_{17}				σ_{13}	
30°	.0139	σ_6	ν_3	χ_2		σ_6	ψ_1	$-\sigma_6$			ν_3	$-\sigma_6$		σ_6	$-\nu_3$	χ_2		σ_6	
35°	.0159	σ_7				$-\sigma_3$		σ_1				$-\sigma_{17}$		$-\sigma_5$				$-\sigma_{11}$	
40°	.0178	σ_8	ν_4		$\omega_7\ \omega_2$	σ_{10}		σ_4	$\omega_1\ -\omega_8$		ν_8	$-\sigma_4$		$-\sigma_{16}$	ν_4		$\omega_5\ -\omega_4$	$-\sigma_8$	
45°	.0196	σ_9		χ_3		$-\sigma_9$		$-\sigma_9$		γ_1		σ_9		$-\sigma_9$		$-\chi_3$		σ_9	
50°	.0213	σ_{10}	ν_5			σ_2		σ_{10}			ν_1	σ_{14}		σ_2	ν_7			σ_{10}	
55°	.02275	σ_{11}				σ_5		$-\sigma_{17}$				σ_1		σ_{13}				$-\sigma_5$	
60°	.02407	σ_{12}	ν_6	χ_4	$\omega_3\ \omega_6$	$-\sigma_{12}$	ψ_2	σ_{12}	$\omega_3\ -\omega_6$		$-\nu_6$	$-\sigma_{12}$	$\psi_5\ \psi_4$	σ_{12}	ν_6	$-\chi_4$	$-\omega_3\ \omega_6$	$-\sigma_{12}$	
65°	.0252	σ_{13}				σ_{17}		$-\sigma_7$				$-\sigma_{11}$		σ_1				σ_5	
70°	.0261	σ_{14}	ν_7			$-\sigma_{10}$		σ_2			$-\nu_5$	σ_2		$-\sigma_{10}$	ν_1			σ_{14}	
75°	.0268	σ_{15}		χ_5		σ_3		σ_3				σ_{15}		$-\sigma_{15}$		χ_1		$-\sigma_3$	
80°	.02735	σ_{16}	ν_8		$\omega_5\ \omega_4$	σ_4		$-\sigma_4$	$-\omega_5\ \omega_4$		ν_2	σ_8		$-\sigma_4$	$-\nu_4$		$\omega_1\ -\omega_8$	$-\sigma_{16}$	
85°	.0277	σ_{17}				$-\sigma_1$		σ_{13}				$-\sigma_5$		σ_7				σ_1	
90°	.0278	σ_{18}	ν_9	χ_6		σ_{18}	ψ_3	$-\sigma_{18}$		γ_2	ν_9	$-\sigma_{18}$		σ_{18}	$-\nu_9$	χ_6		σ_{18}	ψ_6
Sums		$S_1^o\ S_1^e$	$S_2^o\ S_2^e$	$S_3^o\ S_3^e$	$S_4^o\ S_4^e$	$S_5^o\ S_5^e$	$S_6^o\ S_6^e$	$S_7^o\ S_7^e$	$S_8^o\ S_8^e$	$S_9^o\ S_9^e$	$S_{10}^o\ S_{10}^e$	$S_{11}^o\ S_{11}^e$	$S_{12}^o\ S_{12}^e$	$S_{13}^o\ S_{13}^e$	$S_{14}^o\ S_{14}^e$	$S_{15}^o\ S_{15}^e$	$S_{16}^o\ S_{16}^e$	$S_{17}^o\ S_{17}^e$	S_{18}^o
$A_k = S_k^o + S_k^e$		A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}	A_{17}	A_{18}
$A_{36-k} = S_k^o - S_k^e$		A_{35}	A_{34}	A_{33}	A_{32}	A_{31}	A_{30}	A_{29}	A_{28}	A_{27}	A_{26}	A_{25}	A_{24}	A_{23}	A_{22}	A_{21}	A_{20}	A_{19}	

COSINE TERMS.

α	sin α/36	B_1 & B_{35}	B_2 & B_{34}	B_3 & B_{33}	B_4 & B_{32}	B_5 & B_{31}	B_6 & B_{30}	B_7 & B_{29}	B_8 & B_{28}	B_9 & B_{27}	B_{10} & B_{26}	B_{11} & B_{25}	B_{12} & B_{24}	B_{13} & B_{23}	B_{14} & B_{22}	B_{15} & B_{21}	B_{16} & B_{20}	B_{17} & B_{19}	B_{18}	B_0 B_{36}
5°	.0024	Δ_1				Δ_{11}		$-\Delta_{13}$				Δ_5		$-\Delta_7$				Δ_1		
10°	.0048	Δ_{16}	R_8		$T_4\ -T_5$	$-\Delta_4$		Δ_8	$T_2\ T_7$		$-R_2$	Δ_8		$-\Delta_4$	R_4		$T_8\ T_1$	Δ_{16}		
15°	.0072	Δ_{15}		β_1		Δ_3		$-\Delta_3$				$-\Delta_{15}$		$-\Delta_3$		λ_1		$-\Delta_3$		
20°	.0095	Δ_{14}	R_7			$-\Delta_{10}$		Δ_2			$-R_5$	Δ_2		Δ_{10}	R_1			$-\Delta_{14}$		
25°	.0117	Δ_{13}				Δ_{17}		$-\Delta_7$				$-\Delta_{11}$		Δ_1				Δ_5		
30°	.0139	Δ_{12}	R_6	β_2	$-T_6\ T_3$	Δ_{12}	α_2	$-\Delta_{12}$	$-T_6\ -T_3$		R_6	Δ_{12}	$\mu_4\ \mu_3$	Δ_{12}	R_6	λ_2	$-T_6\ -T_3$	Δ_{12}		
35°	.0159	Δ_{11}				$-\Delta_5$		$-\Delta_{13}$				Δ_1		$-\Delta_{13}$				$-\Delta_7$		
40°	.0178	Δ_{10}	R_5			Δ_2		$-\Delta_{14}$			R_1	Δ_{14}		$-\Delta_2$	$-R_7$			$-\Delta_{10}$		
45°	.0196	Δ_9		β_3		$-\Delta_9$		Δ_9		μ_1		$-\Delta_9$		Δ_9		$-\lambda_3$		Δ_9		
50°	.0213	Δ_8	R_4		$T_2\ -T_7$	Δ_{16}		$-\Delta_4$	$-T_8\ T_1$		R_8	$-\Delta_4$		Δ_{16}	$-R_2$		$T_4\ T_5$	Δ_8		
55°	.0227	Δ_7				Δ_{13}		Δ_1				Δ_7		Δ_5				$-\Delta_{11}$		
60°	.0240	Δ_6	R_3	β_4		$-\Delta_6$	α_1	$-\Delta_6$			$-R_3$	Δ_6		Δ_6	$-R_3$	$-\lambda_4$		$-\Delta_6$		
65°	.0252	Δ_5				Δ_1		Δ_{11}				Δ_7		Δ_{17}				Δ_{13}		
70°	.0261	Δ_4	R_2		$-T_8\ T_1$	$-\Delta_8$		$-\Delta_4$	$T_4\ T_5$		$-R_4$	$-\Delta_4$		$-\Delta_8$	$-R_8$		$-T_2\ -T_7$	Δ_4		
75°	.0268	Δ_3		β_5		Δ_{15}		$-\Delta_{15}$				$-\Delta_3$		$-\Delta_3$		λ_5		$-\Delta_{15}$		
80°	.0273	Δ_2	R_1			Δ_{14}		Δ_{10}			R_7	$-\Delta_{10}$		$-\Delta_{14}$	R_5			$-\Delta_2$		
85°	.0277	Δ_1				$-\Delta_7$		$-\Delta_{13}$				Δ_{13}		Δ_{11}				Δ_{17}		
90°	.0278	Δ_0	R_0	β_6	$T_0\ -T_9$	Δ_0	α_0	Δ_0	$T_0\ T_9$	μ_5	R_0	Δ_0	$\mu_6\ -\mu_5$	Δ_0	R_0	λ_6	$T_0\ T_9$	Δ_0	Q_0	$Q_2\ Q_1$
		$D_1^o\ D_1^e$	$D_2^o\ D_2^e$	$D_3^o\ D_3^e$	$D_4^o\ D_4^e$	$D_5^o\ D_5^e$	$D_6^o\ D_6^e$	$D_7^o\ D_7^e$	$D_8^o\ D_8^e$	$D_9^o\ D_9^e$	$D_{10}^o\ D_{10}^e$	$D_{11}^o\ D_{11}^e$	$D_{12}^o\ D_{12}^e$	$D_{13}^o\ D_{13}^e$	$D_{14}^o\ D_{14}^e$	$D_{15}^o\ D_{15}^e$	$D_{16}^o\ D_{16}^e$	$D_{17}^o\ D_{17}^e$	D_{18}^o	$D_{19}^o\ D_{19}^e$
$B_k = D_k^o + D_k^e$		B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}	B_{13}	B_{14}	B_{15}	B_{16}	B_{17}	B_{18}	
$B_{36-k} = D_k^o - D_k^e$		B_{35}	B_{34}	B_{33}	B_{32}	B_{31}	B_{30}	B_{29}	B_{28}	B_{27}	B_{26}	B_{25}	B_{24}	B_{23}	B_{22}	B_{21}	B_{20}	B_{19}		

$$B_0 = \frac{D_{19}^o + D_{19}^e}{2} \qquad B_{36} = \frac{D_{19}^o - D_{19}^e}{2}$$

Reminder. Multiply each of the indicated quantities in the A and B schedules by $\frac{\sin\alpha}{36}$

AMPLITUDE, FREQUENCY, and PHASE Modulation

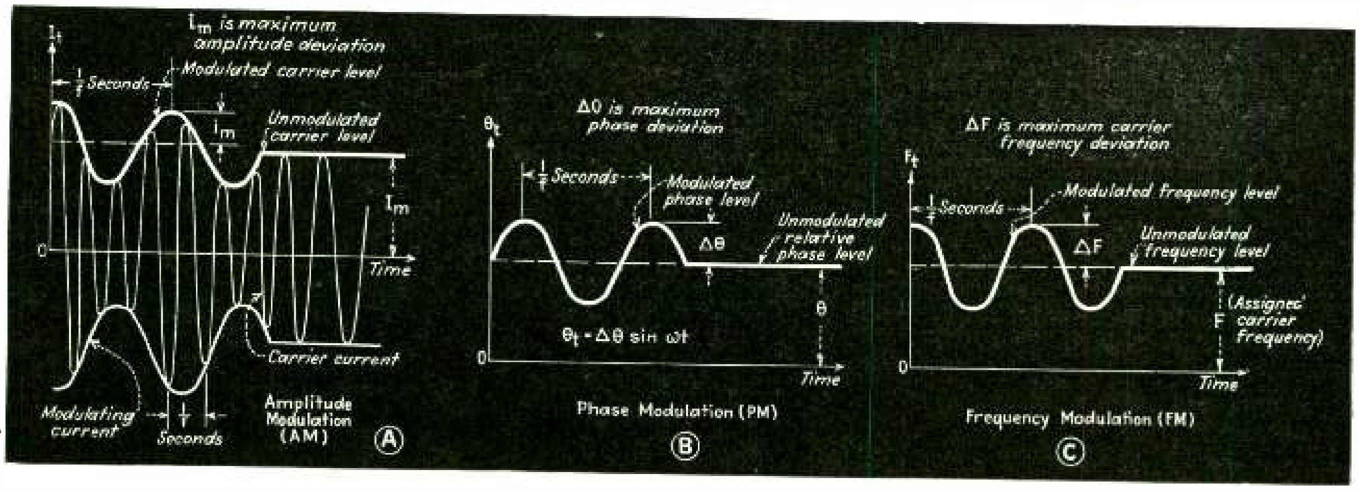


Fig. 1—Graphs illustrating the variations which take place, on a time plot, for amplitude modulation, (A), phase modulation, (B), and frequency modulation, (C). The variable factor is indicated by the ordinate in each case

THE purpose of this article is to present fundamental relations and to emphasize essential features as well as differences of the various types of modulation.

Inasmuch as a carrier frequency current is characterized by its amplitude, frequency and phase, such a current can be distorted or modulated by changes of amplitude or by frequency changes as well as by phase changes.

It is, therefore, possible to have amplitude modulation (AM), frequency modulation (FM), or phase modulation (PM). It is also possible that more than one of these types of modulations may exist simultaneously.

A clear understanding of all three types of modulation is necessary to account for undesirable superimposed modulations of either of the two undesired types or to design transmitters in which more than one modulation system is employed. Besides direct frequency modulation systems, there exists a commercial transmitter system in which AM produces the first side current pair of modulation products, which in virtue of certain circuit elements gives rise to PM effects, and in virtue of the action of another network gives a frequency spectrum distribution as though FM were the cause. This has reference to the well known Armstrong system of frequency modulation.

Fundamental Relations

The general equation[1] for the instantaneous value I_t of an unmodulated carrier current is

$$\begin{aligned} I_t &= I_m \sin (\Omega t + \theta) \\ &= I_m \sin (2 \pi F t + \theta) \end{aligned} \qquad (1)$$

This represents a vector of constant length I_m rotating with a constant angular velocity $\Omega = 6.28\ F$. We note that in the general case, there exists a fixed relative phase, θ.

The current I_m is the quantity which will vary in the case of amplitude modulation, the phase θ varies in phase modulation, and the frequency, F, undergoes variations for the remaining type of possible modulation.

The respective variations for the three types of modulation are illustrated in Fig. 1. It is seen that for AM the carrier level swings about its unmodulated value, I_m, and the modulation "grip" is stronger the larger the ratio $i_m/I_m = K$. This ratio is known as the degree of amplitude modulation. For PM the relative phase, θ, experiences variations about its unmodulated value, θ. Also here the maximum phase swing, $\Delta\theta$, determines the degree of phase modulation but not in as simple a manner as in case of AM as will be brought out later on. For FM it is the carrier frequency which varies about its assigned value F and we deal with maximum frequency deviations $\pm\Delta F$. For FM the ratio $\Delta F/f$ determines the spectrum distribution of the modulation energy but not in as simple as a manner in case of AM.

Equation (1) also holds for all three types of modulated currents. We have to realize, however, that for AM we have the substitution $I_m = I_{mt}$ since the carrier amplitude varies with time while $\Omega = 6.28F$ and θ are constant in case of pure AM. For PM we have the substitution $\theta = \theta_t$ while Ω and I_m in Eq. (1) remain fixed. For FM we have to deal with an instantaneous frequency F_t

[1] Since in current literature on FM, several different symbols are in use for the same quantities, the nomenclature adopted in this article is that used in "High Frequency Measurements," McGraw-Hill Book Co. The symbol F stands for the carrier frequency since it is always larger than the frequency f of the signal current which modulates. Any measurable deviations from the carrier frequency F are denoted by ΔF. We then have $\Omega = 2\pi F$; $\omega = 2\pi f$ and $\Delta\Omega = 2\pi\Delta F$. This procedure seems logical and gives expressions which seem clearer to the eye than when subscripts are used.

Relations

Comparisons between the three methods of modulation are treated from the standpoint of mode of operation, modulation factor, and frequency spectrum. Graphical means of determining the frequency spectrum for frequency and phase modulation are given. Differences between FM and PM are indicated

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because of the substitution $\Omega = \Omega_t$ in Eq. (1).

In producing amplitude modulation, it is possible to have a direct effect of a current of signal frequency distorting or modulating the carrier current. Such direct action of the signal frequency current upon the carrier current is not possible in PM and FM. Consequently, an indirect method of modulation is resorted to, in which the effects of a modulating current are converted into a proportional phase or frequency changes respectively. In the case of direct frequency modulation, comparatively large frequency swings can be caused directly. Fortunately this indirect process can be accomplished readily.

Since Eq. (1) holds generally, the corresponding wave train it represents (indicated in Fig. 2) must give us a physical realization of what is actually instrumental in causing the three types of modulation. The argument of the sine function, $\alpha = \Omega t + \theta$, contains the term of carrier frequency, $F = \Omega/2\pi$ which is involved in frequency modulation, and the relative phase, θ, which is involved in phase modulation; it does not contain the amplitude current term, I_m. Consequently, phase and frequency modulation must affect the values of θ and F, respectively, but not necessarily that of I_m. Hence, for constant carrier level, I_m nothing can happen along the current or I_t axis. In other words, for either PM or FM, the carrier level remains unchanged since only values of θ and F undergo variation. This results in an important practical advantage for PM and FM, for the problem of power amplification is much simpler than for the case of AM, since the plate efficiency is not affected by amplitude variations due to modulation.

Since PM and FM produce no effects along the current or I_t axis, any effects resulting from these two methods of modulation must act at right angles to this axis, or along the time axis; they must accordingly be some function of time rather than of amplitude. It is therefore an easy matter to separate AM from either PM or FM. All that is required is a receiver which is sensitive to time variations of θ or F, but not to time variations of I_m. In fact, if variations of I_m do occur in the system, they may be removed by clipping the wave trains to the flat tops *ab*, *cd*, *ed*, as indicated in Fig. 2, without affecting the phase or frequency modulation. This leads to another practical

HIGHLIGHTS OF VARIOUS MODULATION METHODS

TRANSMITTER POWER AND EFFICIENCY . . . AM—Power output variable. Efficiency relatively low since transmitter must be designed for peak operation . . . FM and PM—Power output constant, resulting in relatively high efficiency since transmitter operates continuously at full output.

MODULATION AND DEMODULATION . . . AM—Audio frequency converted directly into voltage or current variations . . . FM—Audio frequency converted into constant intensity variations of frequency which are then converted into amplitude variations . . . PM—Audio frequency converted into constant intensity variations of phase which are reconverted into amplitude variations.

MODULATION FACTOR . . . AM—Dependent on relative amplitudes of carrier and audio voltages or currents. Distortion unavoidable on overmodulation . . . FM and PM—Dependent on amplitude and frequency of audio signal. Distortion need not occur on "overmodulation."

FREQUENCY SPECTRUM . . . AM—Depends only on frequencies present in audio signal . . . FM and PM—Depends on amplitudes and frequencies in audio signal in a rather complicated manner.

LOUDNESS AND BANDWIDTH . . . AM—Loudness of audio signal determined by amplitude of audio frequency. Bandwidth determined by highest audio frequency transmitted . . . FM—Frequency deviation changes the loudness of received signal. Ratio of frequency deviation to audio modulating frequency determines bandwidth . . . PM—Phase deviation changes loudness of received signal as well as bandwidth.

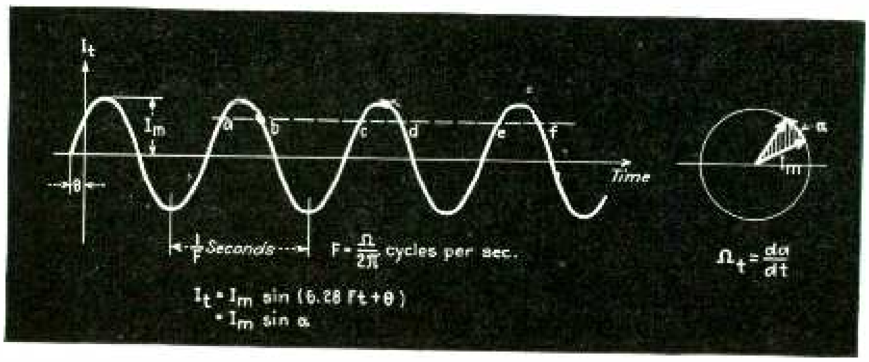


Fig. 2—Wave train of typical carrier current. Since frequency and phase modulation methods are unaffected by changes in amplitude, PM and FM may be separated from AM, by clipping the wave at points such as ab, cd, ef, and so on

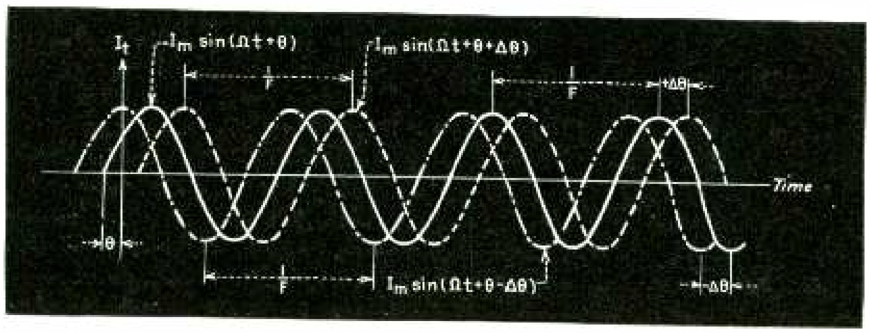


Fig. 3—Unmodulated carrier wave (solid line) with modulated carrier (broken lines) for phase modulation. The frequency of modulated and unmodulated carrier is unchanged. An instantaneous change in frequency occurs (not shown) when carrier is changed from unmodulated to modulated state, or vice versa

advantage of PM or FM, for interference which causes amplitude variations can be removed by amplitude limiters or clippers to remove changes in level.

The question now arises as to what is the difference between PM and FM. This may be illustrated by means of Fig. 3 which represents Eq. (1). To form an understanding of the basic fundamentals of phase modulation, we can assume that the indicated wave train is "rigid" or "stiff.' Hence a time axis variation can do only one thing, namely move the wave train as a whole, to and fro from left to right, from right to left and so forth. This is illustrated in Fig. 3. The fully drawn wave train denotes the instant when no phase modulation exists. The dashed wave train shows the case when the unmodulated current wave is advanced by an amount $\Delta\theta$ while the dashdot wave train depicts the case when there is a phase retardation by the same amount $\Delta\theta$. From a technical point of view such a stiff current wave exists practically when the frequency F of the master oscillator is stabilized as in case of a reliable piezoelectric source. It also happens when the modulation occurs in a high power amplifier with several stages of gain between the master oscillator of fixed frequency F and the modulation stage. In each case we deal with a current of fixed or unvarying frequency since F is stabilized. Hence, PM requires a stabilized frequency F so that the current wave as a whole can experience phase variations according to a modulating current or some other suitable modulation agency. Since the steady portion θ as shown in Fig. 1B cannot be instrumental in causing PM, it may be omitted and a phase modulated current is expressed by

$$I_t = I_m \sin(\Omega t + \Delta\theta \sin \omega t) = I_m \sin \alpha \quad (2)$$

in case of sinusoidal phase modulation with a frequency $f = \omega/6.28$. If we compare this expression with Eq. (1) we have

$$\left.\begin{array}{ll} \alpha = \Omega t + \theta & \text{unmodulated current} \\ \alpha = \Omega t + \Delta\theta \sin \omega t & \text{PM-current} \end{array}\right\} \quad (3)$$

where the fixed phase θ in the upper relation has only a reference significance and can be put equal to zero as far as its modulating effect is concerned. We note that an unmodulated current $I_m \sin \alpha$ can be considered as a vector of absolute length I_m which revolves with a fixed angular velocity 6.28 F. That this is true can be seen from the simple derivation for the instantaneous frequency F_t for which

$$F_t = \frac{1}{2\pi}\frac{d\alpha}{dt} = \frac{1}{2\pi}\frac{d(\Omega t)}{dt} = \frac{\Omega}{2\pi} = \frac{2\pi F}{2\pi} = F$$
$$= \text{constant}$$

Let us investigate phase modulation where $\alpha = \Omega t + \Delta\theta \sin \omega t$ and the instantaneous frequency is

$$Ft = \frac{1}{2\pi}\frac{d\alpha}{dt} = \frac{\Omega}{2\pi} + \frac{\omega\Delta\theta}{2\pi}\cos \omega t$$
$$= F + \underbrace{f + \Delta\theta \cos 2\pi f t}_{\text{change in equivalent carrier frequency due to PM}} \quad (4)$$

This result expresses the fact that we have to deal with an equivalent frequency variation since at any instant of time, the carrier frequency is composed of the fixed and stabilized frequency F, and a variable term due to phase flutter. It is thoroughly reasonable to expect some kind of equivalent instantaneous change in frequency in the process of phase modulation, for the rigid waveform of Fig. 3 cannot alter its phase unless somewhere along the line the instantaneous value of the carrier frequency is changed slightly. It is important to recognize that the variation in F_t is no longer proportional only to the stimulating maximum phase deviation $\Delta\theta$, but is in addition, proportional to the frequency f of the modulating current. This is equivalent to saying that for a fixed maximum phase deviation $\Delta\theta$, the equivalent frequency modulation increases with the modulation frequency. As a result, we have modulation accentuation towards the upper signal frequency range. This is not the case in FM since the degree of modulation depends only on the maximum frequency deviation ΔF.

Physical Representation of Frequency Modulation

It may be convenient to regard the process of frequency modulation as one in which the waves are squeezed closer together for a part of the modulation cycle whereas they are stretched apart for another part of the modultion cycle. At those instants of time for which the magnitude of the modulation cycle becomes zero, the carrier waves are of normal spread and are spaced $1/F$ seconds apart in time. This is illustrated in Fig. 4. In order that we may obtain a common expression for the side band distributions of both FM and PM, it is convenient to assume cosine frequency variations of modulation as shown in Fig. 1C. In this case the instantaneous frequency of the carrier is

$$F_t = F + \Delta F \cos \omega t \quad (5)$$

Note that in this case, the instantaneous carrier frequency has a maximum value of $F \pm \Delta F$, which is obtained for $\cos \omega t = 1$, and that this frequency spread is independent of the frequency, f, of the modulating current and depends only on the deviation frequency, ΔF. The master oscillator can, therefore, no longer produce a stabilized frequency F. It must generate an oscillation frequency which can be readily varied as in an ordinary tube oscillator. We may represent a frequency modulated current by a revolving vector of constant length I_m equal to the carrier level of the unmodulated current. In this case the vector will revolve with the instantaneous angular velocity F_t as expressed by Eq. (5). This would give an instantaneous current value $I_t = I_m \sin \alpha$. The argument α is then an arc in radians or the angle in degrees passed through by the vector I_m as is indicated in Fig. 2. The resultant instantaneous angular velocity in presence of FM then is $\Omega_t = d\alpha/dt$ and

$$\alpha = \int_0^t \left[\Omega + \Delta \Omega \cos \omega t\right] dt = \Omega t + \frac{\Delta \Omega}{\omega} \sin \omega t$$

The instantaneous current value in case of FM is, therefore,

$$I_t = I_m \sin \alpha = I_m \sin\left[\Omega t + \frac{\Delta F}{f} \sin (6.28\, f t)\right] \quad (6)$$

It is seen that the amplitude of the variable term is now controlled by both the maximum frequency deviation ΔF as well as by the signal frequency f of the modulating current. Hence, the band width required is not necessarily equal to the peak to peak frequency swing $2\,\Delta F$.

Spectrum Distribution for AM, PM and FM

We have now obtained the solution for the instantaneous value of an FM current and if it is compared with the instantaneous values for a PM current and an AM current, we have the relations

$$\left.\begin{aligned} I_t &= I_m \sin (\Omega t + \sin \beta t) && \text{for PM and FM} \\ I_t &= I_m [1 + K \cos \omega t] \sin \Omega t && \text{for AM} \end{aligned}\right\} \quad (7)$$

where $\beta = \Delta\theta$ for PM $= \Delta F/f$ for AM and $K = i_m/I_m$. Since i_m in case of AM, $\Delta\theta$ in case of PM, and ΔF in case of FM denote the maximum excursions about the unmodulated carrier level I_m, unmodulated relative phase θ, and unmodulated frequency F, respectively, they all have the function of modulating the carrier current. For all three types of modulations, the modulation process causes a frequency spread so far as the required channel width is concerned, but the degree of modulation K in case of AM has nothing to do with the required band width, whereas the modulating indices, $\Delta\theta$ for PM, and $\Delta F/f$ for FM definitely affect the required band widths.

For AM, as is well known, the required band width is proportional to the frequency of the modulating current, but is independent of the modulation factor K. Thus, if F is the carrier frequency, and f is the modulating frequency, the total band width required is $2f$, whether the modulation percentage is 10 or 100. The solution of the amplitude-spectrum equation for AM gives the result,

$$I_t = I_m \sin \Omega t + \tfrac{1}{2} K I_m \left[\sin (\Omega + \omega) t + \sin (\Omega - \omega) t\right] \quad (8)$$

as is well known. Since $\omega/2\pi = f$, the modulating frequency, we note that we have only one side current pair which is f cycles above and f cycles below the assigned carrier frequency, F. Besides this limited and fixed band width, depending only upon the modulating frequency (and not its amplitude) it is seen that for AM, the entire modulation energy is in the side band, and that even for 100 percent modulation, the amplitudes of the respective side currents at frequencies $F \pm f$ can never be more than 50 percent of the amplitude, I_m, of the unmodulated current. It is also seen that the amplitude of frequency, F, in the modulated state is still I_m and can therefore contribute nothing to modulation or the transmission of intelligence. Matters are much different for PM and AM, as we shall see.

In dealing with PM and FM we do not deal with a modulation factor K which is independent of the modulating frequencies, but rather do we deal with a modulation index, β which is intimately associated with the signal or modulation frequencies. The fact that the instantaneous frequency in both PM and FM depends upon the modulation index which in turn depends upon the amplitude and frequency of the modulating signal, complicates the expressions for the amplitude-frequency spectrum. In this article we shall merely state the results obtained, without offering any proof of their derivation.

The simplest case exists for PM where the phase deviation is $\Delta\theta$. In this case we have an infinite number of side current pairs due to the modulating frequency, $f = \omega/2\pi$, in addition to the carrier frequency $F = \Omega/2\pi$. This is evident from the multiplicity of terms in the expanded

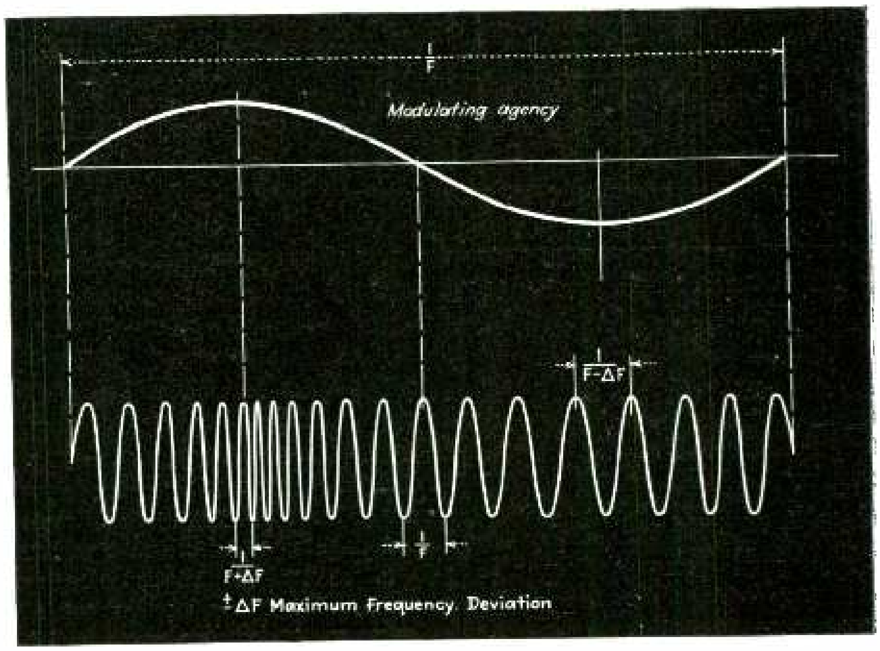


Fig. 4—Frequency modulated current showing extreme modulation conditions of the carrier for a complete modulation cycle, above

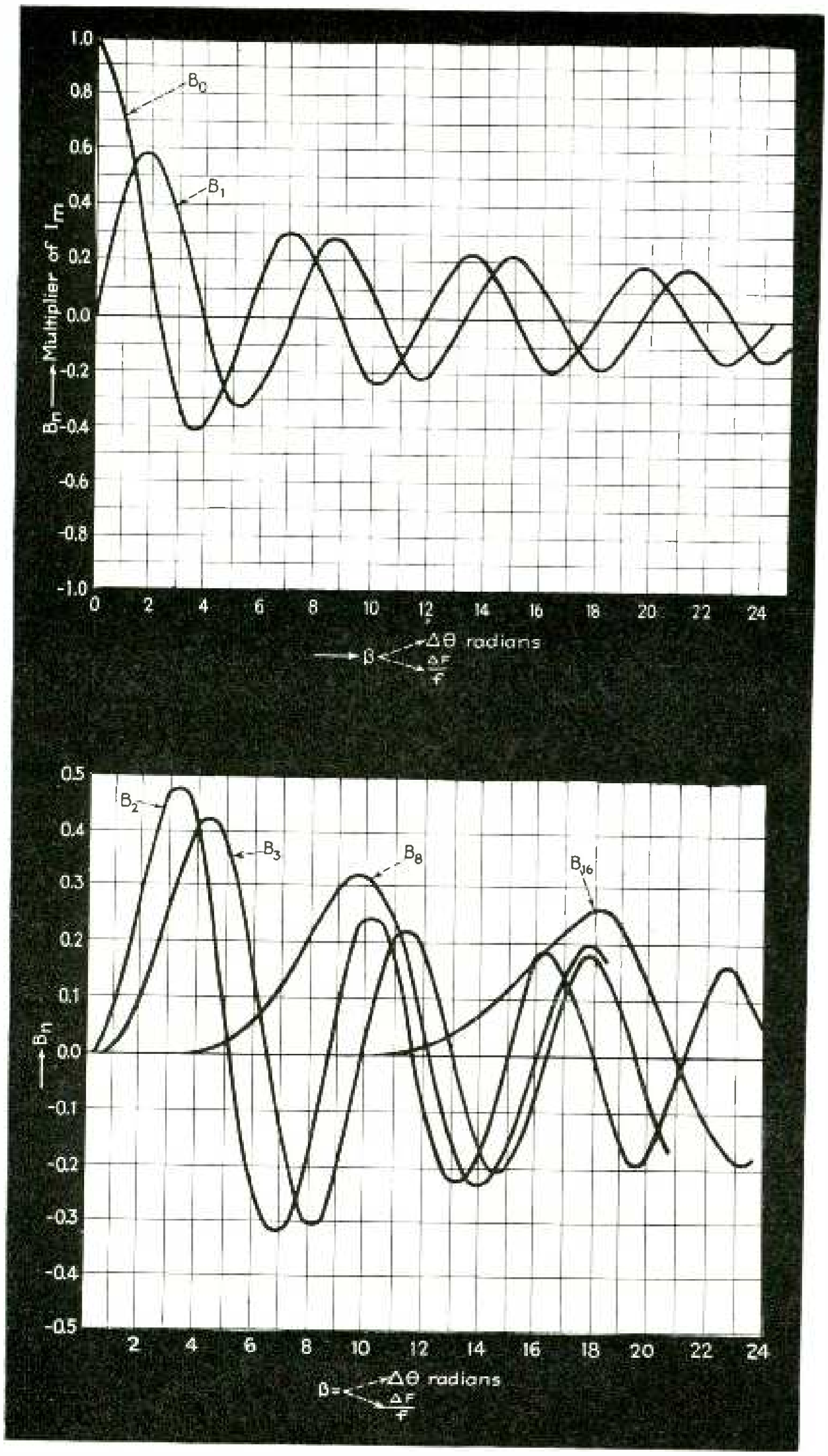


Fig. 5—Curves for the Bessel multiplier, B_n, plotted against deviation produced by modulating agency. The amplitude of the assigned carrier frequency, F is $B_1 I_m$; of frequency $F \pm nf$ is $B_n I_m$; where f is the modulation frequency and I_m is the amplitude of the carrier

amplitude-frequency expression for the modulated current, which is given by

$$
\begin{aligned}
I_t &= I_m \sin(\Omega t + \beta \sin \omega t) \\
&= I_m \Big\{ B_o \sin \Omega t + B_1[\sin(\Omega+\omega)t - \sin(\Omega-\omega)t] \\
&\quad + B_2[\sin(\Omega+2\omega)t + \sin(\Omega-2)t] \\
&\quad + B_3[\sin(\Omega+3\omega)t - \sin(\Omega-3)t] \\
&\quad + B_4[\sin(\Omega+4\omega)t + \sin(\Omega-4)t] \\
&\quad + \cdots \\
&\quad + B_n[\sin(\Omega+n\omega)t + (-1)^n \sin(\Omega-n\omega)t] \Big\} \quad (9)
\end{aligned}
$$

where the coefficients, B_n are the Bessel coefficients defined by $B_n = J_n(\beta)$.

Following up at first the simple case of PM for which $\beta = \Delta\theta$, we note that the Bessel functions B_o, B_1, B_2, B_n affect not only the respective successive side current pairs but also the magnitude of the current of the assigned carrier frequency F. The argument β of these Bessel functions is equal to the maximum phase deviation $\Delta\theta$ in case of PM and equal to $\Delta F/f$ for FM. The modulation energy distribution can, therefore, be equal in case of PM and FM only when the β-value happens to be numerically the same.

For practical applications $\Delta\theta$ is expressed in radians since this satisfies the numerical value of β in the spectrum of Eq. (9). If the maximum phase deviation is given in degrees, the degree-value has to be divided by 57.3 in order to give the β-value required in above formulas. The application of Eq. (9) is simple and especially so when Bessel curves and tables are available.* In Fig. 5 are given, for instance, the Bessel factors B_o, B_1, B_2, B_3, B_8 and B_{16} by means of which the carrier level I_m of the unmodulated current is to be multiplied in order to yield the amplitude of the spectrum current of the assigned carrier frequency F, of the first side current pair of respective frequencies $F - f$ and $F + f$, of the second side current pair of frequencies $F \pm 2f$, etc. What is of practical importance is to note that these curves resemble damped wave trains and at times intersect the zero axis. For instance, the B_o curve intersects the zero axis for β-values of 2.4048, 5.5201, 8.6537, etc. Hence, when the phase deviation $\Delta\theta$ is 2.4048, 5.5201, 8.6537 radians, there can be no amplitude of the assigned carrier frequency F since the B_o-multiplier vanishes. In a similar way, for β-values which produce zero-axis intersections with the B_1-curve, there can be no side currents of frequencies $F-f$ and $F+f$. The same holds true for any other higher order Bessel curves like the B_8 curve which gives the multiplier for the side current amplituds of frequencies $F-8f$ and $F+8f$. Since the Bessel curves are wavy and intersect the zero axis we can have spectrum currents which have negative or positive polarity depending upon the sign of the Bessel multiplier. That the particular multiplier B_n has for a certain β-value a negative value does, however, not necessarily mean that the corresponding spectrum amplitude value is negative. The reason for this is that the multiplier is only one factor of the respective product in Eq. (9). Hence, if the multiplier B_3 yields a

* Many curves and tables will be found in the author's forthcoming book "Frequency Modulation."

negative value, say for instance, $B_3 = -0.2$, then the amplitude of the upper side current of frequency $F + 3f$ becomes $-0.2I_m$ but the amplitude of the lower side current becomes $0.2I_m$ since the Eq. (9) shows a negative sign for this term which, multiplied by a negative factor, yields a positive amplitude. Fortunately, the polarity question does not always play a part, and surely not when we think in terms of the distribution of the modulation energy which is proportional to the square of the amplitude. But if we wish to find out graphically how many significant side currents have to be taken into account in order to avoid additional amplitude modulation, the polarity of the various side currents can not be ignored.

What has just been brought out with respect to PM holds, of course, also for FM since as far as the spectrum distribution of the modulation energy is concerned the expressions for β in Eq. (7) hold for FM as well as for PM. Since Eq. (9) is the spectrum solution of the upper equation of Eq. (7), it must also hold for either PM or for FM. However, it should be borne in mind that Eq. (7) was derived in the case of FM, with the assumption that the carrier frequency is varied cosinoidally. Hence, if the modulating agency causes an instantaneous frequency modulation $F_t = F + \Delta F \cos \omega t$, the spectrum solution of Eq. (9) holds. The upper expression of Eq. (7) holds only for a PM which causes a sinusoidal phase swing $\Delta\theta \sin \varphi t$ and therefore, in turn also a cosinoidal equivalent frequency variation so that one and the same spectrum solution is possible. For all other conditions, as in the investigation of simultaneous FM, PM and AM, the function of the modulation agency has to be taken into consideration.

Important Quantities in Modulation Systems

As far as AM is concerned, we have a straight forward modulation process which is well known today since we deal with a modulation factor $K = i_m/I_m$. With respect to PM and FM we have learned already that we have to use a modulation index β and the spectrum distribution depends on this index. For this reason the number of significant side current pairs can be estimated from the value of β. For values of $\beta \leqq 0.2$, Bessel curves will show that we have essentially only one side current pair as with AM. They will also show that the Bessel multiplier for the amplitude of the assigned carrier frequency F is then essentially unity. For the limitation that $\beta \leqq 0.2$, we can write down the approximations

$$I_t = \begin{cases} \overbrace{I_m \sin(6.28\,Ft) + 0.5\beta\,[\sin 6.28\,(F+f)\,t] - 0.5\,\beta\,[\sin 6.28\,(E-f)\,t]}^{\text{For frequency modulation}} \\ \underbrace{I_m \sin(6.28\,Ft) + 0.5K \sin 6.28\,(F+f)\,t + 0.5K\,[\sin 6.28\,(F-f)\,t]}_{\text{For amplitude modulation}} \end{cases} \quad (10)$$

This equation shows that in case of the FM, the modulation index β can be used directly like a modulation factor K, since K and β occupy corresponding positions in their respective equations. It is also noted that the superposition of two such currents is additive for the side currents of frequencies $F + f$ and subtractive for the frequency $F - f$. When the modulation index $\Delta F/f$ is equal to the degree K of AM, the lower side current will disappear altogether.

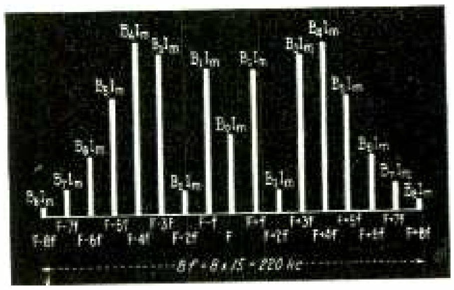
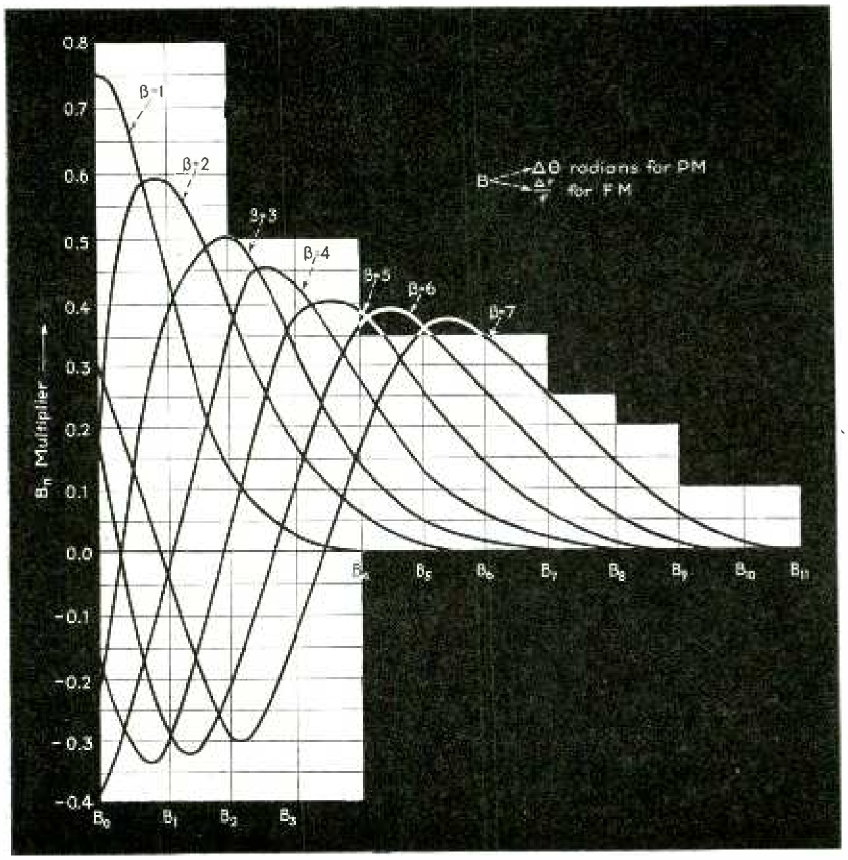


Fig. 7—Amplitude spectrum for $\beta=5$ and a modulation frequency of $f=15$ kc

More important are the effects taking place for larger values of β, but before following up this, let us examine other quantities, in order to avoid confusion which may arise.

With FM, we have the assigned carrier frequency F, the maximum frequency deviation ΔF, the modulation frequency f and the modulation current i_m cos (6.28 ft). We could also use the corresponding modulation voltage. As mentioned already, there is no practical difficulty in translating a modulation current-effect into a proportional frequency variation effect. Hence, we have only three quantities left, namely, F, ΔF and f. It may not be out of place to

Fig. 6—Bessel multiplier curves which show at a glance how many significant side current pairs play a part in the modulating process in frequency and phase modulation



emphasize the following about these three quantities. The factor F is the assigned carrier frequency about which the side frequencies due to the spectrum distribution are symmetrically paced. Hence, F may also be called the center frequency since when F should drift the entire significant frequency spectrum will drift with it. In good engineering practice, therefore, F should not be allowed to drift even though we have to deal with a varying carrier, F_t in FM.

For the legal permissible frequency deviations $\Delta F = \pm 75$ kc, the carrier frequency swings between the limits $F - \Delta F$ and $F + \Delta F$, that is, over a band width of 150 kc. At present this is the highest permissible frequency excursion and causes the loudest sound experienced in an FM receiver. It may therefore, be called full permissible modulation which is by no means 100 percent FM. That full permissible modulation is not the upper limit of FM does not mean at all that we can not receive loud signals. The reason for this is that in an FM receiver we have to translate an FM current into an AM current and demodulate the latter in the customary way. As a matter of fact the frequency discriminator can accomplish both, since a rectifier is incorporated. It is not difficult to convert an FM current of ± 75 kc swing into very high degree of AM and with very efficient subsequent audio frequency recovery. Therefore, smaller values for ΔF will cause less modulations, since ΔF determines loudness. The $\Delta F/f$ ratio determines the band width.

The signal frequency f which is also known as the modulation frequency determines with what speed the F swings occur. Hence, a 50 cps speed causes comparatively slow ΔF excursions and a low 50 cps pitch is heard in the FM receiver. A 10 kc modulation frequency causes comparatively fast ΔF excursions and therefore, a corresponding sound in the upper audio frequency range. Hence, FM does not mean that the signal frequency f modulates F as far as the degree of FM is concerned. Also in FM the amplitude i_m of the modulating current determines the modulation "grip" since ΔF must be proportional to i_m.

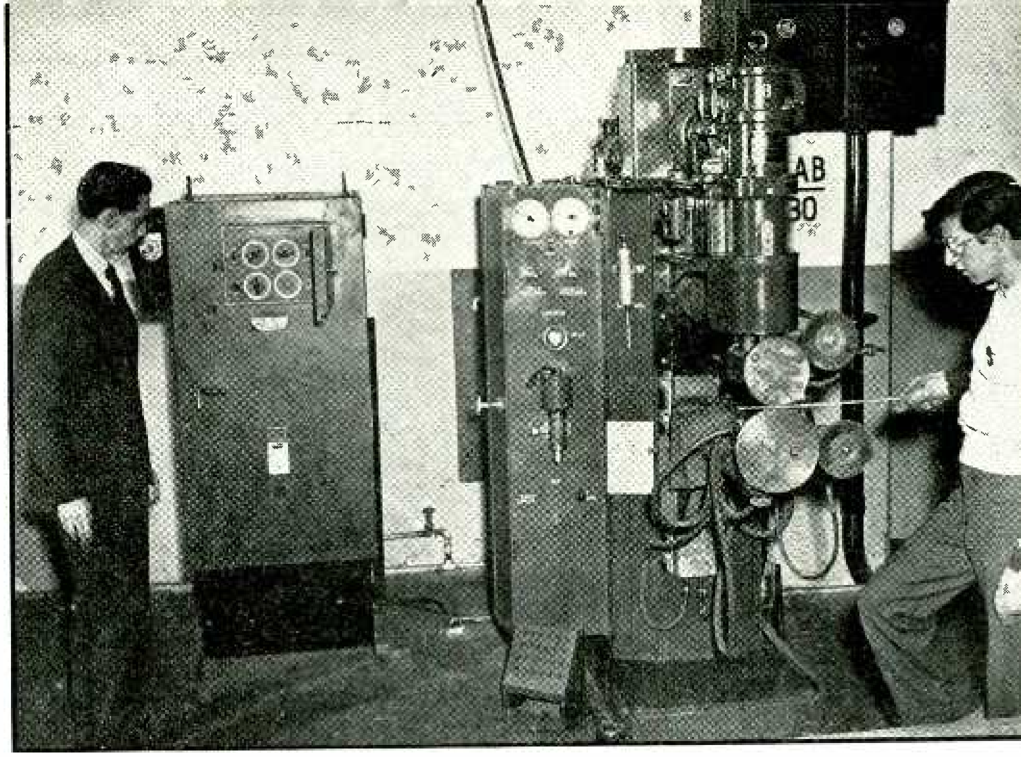
These statements may give the impression that 2 ΔF is the required band width for which the r-f and i-f stages of a receiver have been designed. Since the maximum frequency swing is not to exceed 75 kc it may, therefore, appear that 150 kc is the band width for which the transfer networks of an FM receiver ahead of the audio frequency stages have to be designed.

Equation (9) shows that the number of significant side currents is the only criterion of the required band width. Bessel curves show that the larger the modulation index β, the more side currents occur. More side currents do not necessarily mean more band width. This is clear from the following. For FM the modulation index is the ratio of the maximum frequency swing ΔF divided by the modulation frequency f. The largest value of β will, therefore, occur for a fixed frequency f when $\Delta F = 75$ kc. Since the useful audio frequency range in FM work extends from $f = 50$ cps to $f = 15$ kc we have for the latter value a modulation index $\beta = 75/15 = 5$ while for the lowest audio frequency of interest we have $\beta = 75000/50 = 1500$. The value of 5 shows, by means of the $\beta = 5$ curve in Fig. 6, that at most 8 side current pairs play a part since the $\beta = 5$ curve slides into the zero axis very closely to the B_8 ordinate. The exact Bessel multipliers are then $B_o = -0.1776$; $B_1 = -0.33276$; $B_2 = 0.04657$; $B_3 = 0.3648$; $B_4 = 0.3912$; $B_5 = 0.2611$; $B_6 = 0.131$; $B_7 = 0.5338$; $B_8 = 0.01841$ and insignificant values. The amplitude of the assigned carrier frequency F is, therefore, 17.76 percent of the unmodulated carrier level; the amplitudes of frequencies $F-15$ kc and $F+15$ kc are as large as 32.8 percent of the unmodulated carrier level I_m. It is noted that for side currents of frequencies $F-4f = F-60$ kc and $F+60$ kc the spectrum amplitude is largest and 0.3912 I_m. The spectrum distribution of all significant side currents is shown in Fig. 7. All amplitudes are drawn with the same polarity since only the band width is of concern. It is seen, therefore, that the required band width is $8f$ on each side of F, or 220 kc which is much more than 2 ΔF = 150 kc. For the other limit, which causes a β-value of 1500, produces almost a continuous spectrum with essentially 1500 side current pairs. But in this case, the modulation frequency is only $f=50$ cps and in spite of this large number of side currents the band width required is only 2x1500x50 = 150 kc. Hence, for such a large number of side currents the required band width is approaching the value of the peak-to-peak frequency swing or the value of 2 ΔF. Since for circuit design, the most severe condition has to be taken into account the other ratio namely $\Delta F/$15kc = 5 must be used and a band width as found in Fig. 7 is to be employed. As a rough design rule for wide band FM, the r-f and i-f circuits in an FM receiver should be designed roughly for a band width which is equal to 3 ΔF. It should be realized that the networks require a linear phase characteristic over the entire band width.

The spectrum of Fig. 7 shows that the modulation energy has a tendency to spread away from the assigned frequency value F. It also shows that for large values of the modulation index β, the amplitude of assigned frequency F is smaller than for no modulation. In the case of Fig. 7 the amplitude of frequency F is only $B_o I_m = 0.1776 I_m$ where I_m is the value in absence of modulation. The amplitude distribution of Fig. 7 is typical of all distributions which occur. An increase of the value of the modulation index will not only cause more symmetrical side currents but will also have a tendency to move the amplitude maximum farther away from the amplitude of center or assigned frequency F. In Fig. 7 the amplitude maximum occurs at frequencies $F+4f$. For still more remote side frequencies, the amplitudes fall off towards insignificant values. This gives a means for estimating the required band width directly from Bessel tables.

Inasmuch as the modulation index β is directly equal to the maximum phase swing $\Delta\theta$, it will be seen that the number of side currents in phase modulation is the same for all modulation frequencies if $\Delta\theta$ is fixed. But in frequency modulation we have $\beta = \Delta F/f$ and for a fixed value of ΔF, less side currents appear in the higher audio frequency range of modulation currents. As mentioned already fewer side currents do not at all mean less required band width, since the required band width is proportional to the number of side currents as well as proportional to the order of magnitude of the modulating frequency f. Hence, it is possible to cause distributions with unused frequency space. This space can now be used for many purposes.

Flexible a-c type synchronous control useful for spot, seam, pulsation or roller-spot welding. Consistent welds at high production rates result from the precise timing provided



Seam and Pulsation WELDING CONTROLS ... Part 2

Step-by-step analysis of operation. Combination spot, seam and pulsation welding controls. Typical circuits and waveform diagrams. Special control circuits. Voltage compensators, voltage-regulating compensators and current-regulating compensators. Automatic heat-adjusting controls.

By M. E. BIVENS

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RESISTANCE SEAM WELDING consists of making a series of successive welds between two layers of metal for the purpose of forming either a gas-tight line weld or the equivalent of a series of spaced spot welds. Welding current is applied intermittently at definite "heat" and "cool" time intervals as the work progresses between roller-type electrodes. Successive welds are thus made without breaking the low resistance secondary circuit of the welding transformer, therefore making it important that the impulses of welding current be free from starting transients which might become accumulative to a serious extent.

The timing circuit of one type of electronic seam welding control is shown schematically in Fig. 1. Only the most essential parts of the timing circuit are shown. Grid-to-cathode capacitors, by-pass capacitors and resistors, etc., are omitted for the sake of simplicity. Heat control by the phase-shift method (delaying the starting of the ignitrons a definite angle during each half cycle) is applied to the firing tubes as explained in H. L. Palmer's article in the August issue of ELECTRONICS, which should be used as a reference for the power tube and firing tube circuits. The purpose of the portion of the control circuit shown by Fig. 1 is to "turn on" the firing tubes in accordance with the desired timing.

Seam Welding Control Operation

A portion of this circuit, including the direct current voltage divider (R_1, R_2, R_3, and R_4), the timing capacitor C_2, the spot length timing adjustment R_5, and the method of applying the timing voltage to the timing tube 3, will be recognized as similar to the spot length timing circuit described and shown in Fig. 7 of Mr. Palmer's article. Since the timing control is to be capable of initiating the heat time intermittently at rates as high as one cycle heat and one cycle cool alternately, the spot length initiating relay of the spot weld timing circuit is not used. The "heat time" is initiated by periodically discharging the timing capacitor C_2 by means of the keying tube 2, which also serves as the "cool time" timing tube.

All of the tubes are gas filled types. Normally the relative potential of circuit points *a*, *b*, *c*, *d*, *e*, and *f* with reference to point *O* is approximately as indicated by the vertical distance of these points above the base line *O* on the diagram. Normally, the timing capacitor C_2 is fully charged, and the grid of the timing tube 3, controlling transformers T_3, T_4, *and* T_5 is negative with respect to its cathode. T_3 is a control transformer which controls the conductivity of the firing tubes for starting the ignitron power

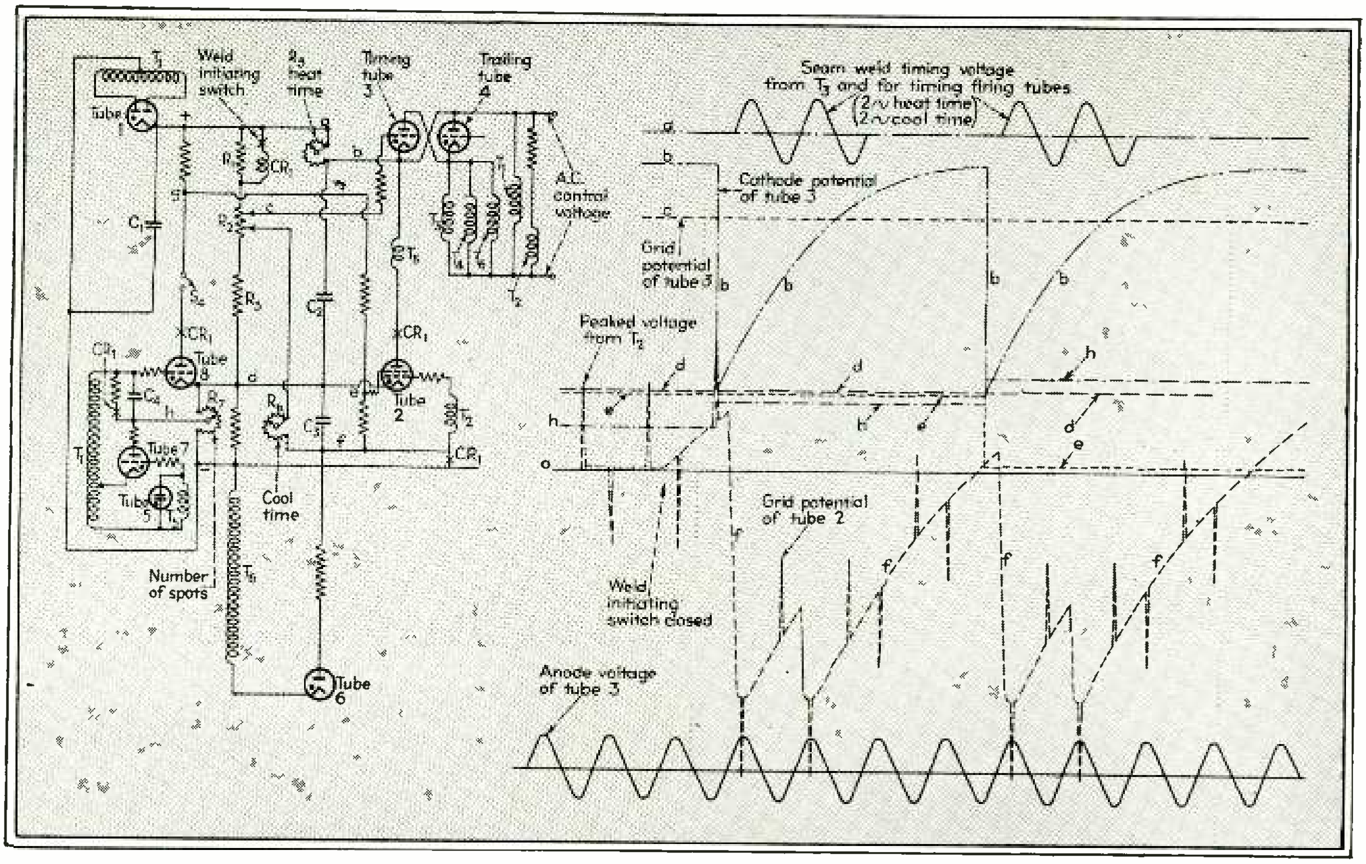

Fig. 1—Schematic circuit diagram and waveforms showing operation of spot, seam and pulsation welding control

tubes, not shown in this diagram. T_4 is the feedback transformer which triggers the trailing control tube 4 immediately following each half-cycle operation of tube 3. T_6 is a control transformer which charges C_3 through tube 6 during the "heat time" to provide the "cool time" timing grid bias on tube 2. The anode circuit of tube 2 is open and its grid is driven positive instantaneously at a definite instant during each cycle by the peaked voltage from T_2 superimposed on the negative d-c component of grid voltage across R_1.

When the initiating relay CR_1 is energized, the voltage of the timing capacitor C_2 is applied as a positive anode voltage to tube 2, which becomes conductive when the next peak of grid voltage occurs. Tube 2 instantaneously discharges the timing capacitor C_2 to zero voltage. If the timing capacitor C_2 were discharged through only resistance and tube 2, the discharge tube would continue to conduct d.c. from the d-c control voltage supply and the capacitor could not recharge. Therefore, inductance is required in the discharge circuit so that the discharge current of C_2 will be oscillatory, but tube 2 allows discharge current to flow in one direction only. However, this permits C_2 to discharge to zero voltage; it would be recharged to a voltage of opposite polarity having a value depending upon the amount of its initial charge and the circuit constants, but the inductive action of transformer T_5 and regulating action of tube 5 causes the timing capacitor to discharge to zero voltage independent of the amount of its initial charge.

Instantly following the discharge of C_2, the anode current of tube 2 is zero, and the grid of the timing tube 3 is positive. This occurs during the half cycle when the anode voltage of tube 3 is negative and therefore tube 3 conducts during the next positive half cycle and energizes transformer T_3 to turn on the firing tubes. Tube 4 trails, insuring an even number of half cycles or full cycle increments in timing.

The first half cycle that tube 3 is conductive, transformer T_6 is also energized and, through tube 6, applies a d-c charge to the "cool time" timing capacitor C_3. This drives the grid of tube 2 considerably negative, holding this tube non-conductive while the timing capacitor C_2 recharges. The charge on C_3 is maintained or replenished during each half-cycle operation of tube 3 during the "heat time" timing. As the timing capacitor C_2 charges, the grid of the timing tube 3 becomes less negative and at a definite time, depending upon the setting of the tapped rheostat R_5, tube 3 becomes non-conductive, thus terminating the "heat time" timing. The charge on the "cool time" timing capacitor C_3 is therefore no longer maintained and C_3 discharges at a rate depending upon the setting of the "cool time" adjustment, R_6.

After a definite time interval, C_3 discharges sufficiently for the peaked voltage of T_2 to trigger tube 2, which again discharges the timing capacitor C_2, thus re-initiating the "heat time". The "heat time" and "cool time"

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Spot Welding Controls

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Energy-Storage Controls

Checking Welding Controls

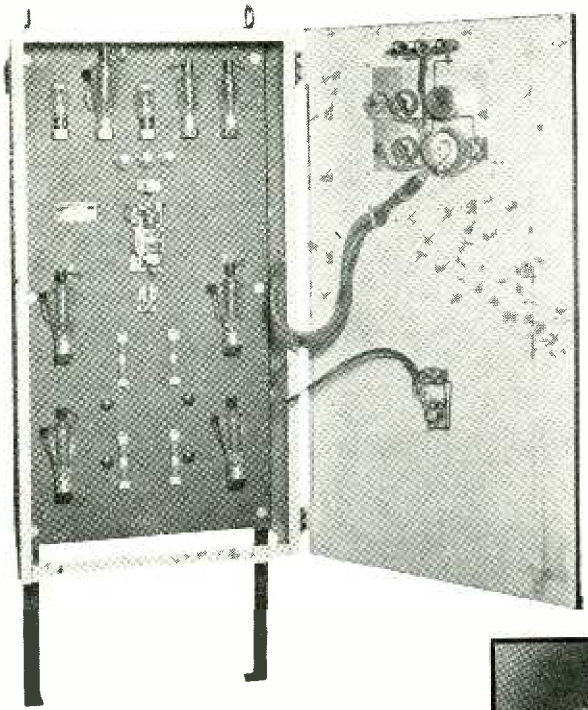
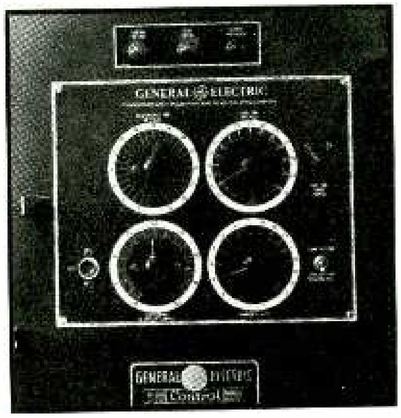


Fig. 2 — Combination spot, seam and pulsation welding control for resistance welder. Inset photo shows front panel of control



timing intervals are alternately repeated until the initiating relay is de-energized. It will be observed that the "heat time" and "cool time" timing adjustments are independent. Thus, with the "heat time" set for 1 cycle, the "cool time" may be varied from 1 to 30 cycles by merely adjusting R_6; or the "heat time" may be changed by merely changing the setting of R_5 without affecting the "cool time" adjustment determined by R_6.

Pulsation Welding Control Operation

Pulsation welding (formerly referred to as interrupted spot welding) consists essentially of making a spot weld by means of a spot welder but using seam weld timing for a definite number of current impulses —for example, 10 cycles "heat time", and 4 cycles "cool time" repeated alternately for 5 current applications requiring an overall welding time of 66 cycles. The seam weld timing circuit shown by schematic diagram Fig. 1 is used for controlling the "heat" and "cool" timing. The component circuit—including tubes 7 and 8, and capacitor C_4—is used for counting the number of current impulses or heat periods, commonly designated as the number of spots although they are used for making a single spot weld by the pulsation method.

The operation of the "heat" and "cool" timing circuits is the same for seam welding and pulsation welding, but switch S_1 is closed for pulsation welding. Preceding a pulsation weld, the anode circuit of the counting tube 8 is open, the capacitor C_4 is discharged and the grid of tube 8 is at a negative d-c potential to the extent determined by the "Number of Spots" adjustment R_7. Each instant that the keying tube 2 initiates the "heat" time interval for the pulsation weld, the operation of tube 2 through the medium of transformer T_6 triggers the grid of tube 7 during the crest of the a-c anode voltage on tube 7, which passes a one-quarter cycle current impulse into capacitor C_4. Therefore, capacitor C_4 is charged in increments at the beginning of each welding current impulse in a direction to make the grid of the counting tube 8 less negative.

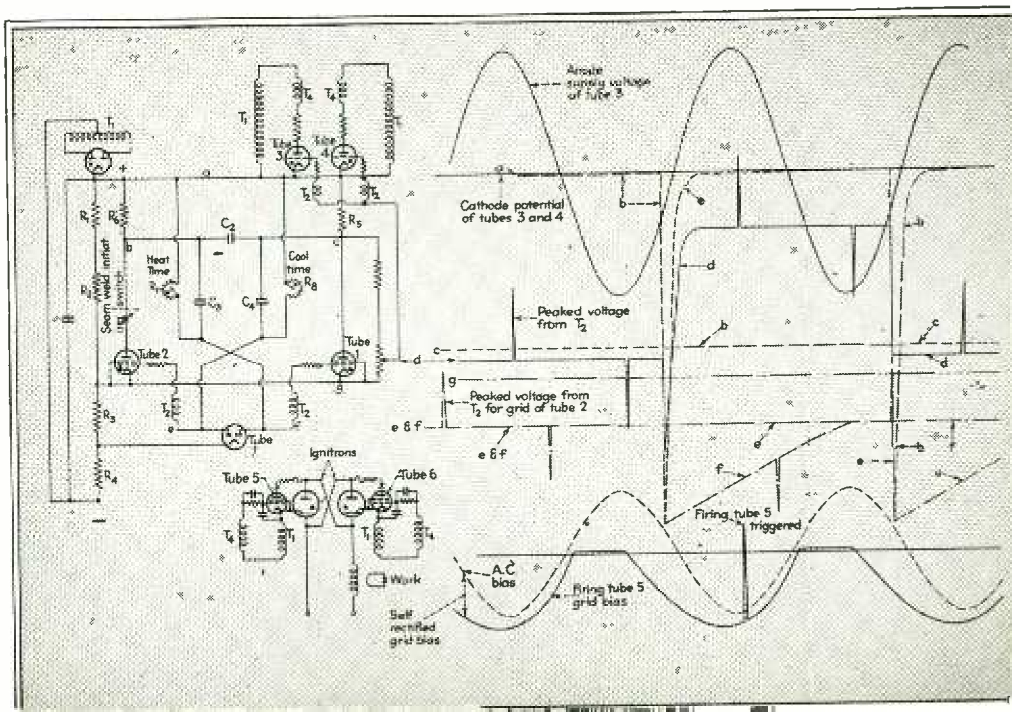
After welding current has been initiated a definite number of times, depending upon the setting of the adjustment R_7, tube 8 becomes conductive. Until tube 8 becomes conductive, the shield grid of tube 2 is substantially at cathode potential, but the operation of the counting tube 8 lowers the potential of circuit point g to approximately the cathode potential of tube 2; the shield grid of tube 2 thereby becomes considerably negative and near the potential of circuit point O. The negative shield grid potential of tube 2 will prevent its control grid circuit from initiating any additional welding current impulses but the last welding current impulse will continue under the control of timing tube 3 as in the preceding cases.

The "Number of Spots" adjustment is independent of the "heat" and "cool" timing adjustments. The number of spots is usually adjustable from 1 to 15 current impulses, the adjustment for one spot being actually a spot weld timing period instead of a pulsation weld. The control is designated as a Spot, Seam, or Pulsation Welding control. Fig. 2 shows this welding control.

Other Seam Welding Controls

Those familiar with electronic control circuits will recognize the tube 2 circuit previously described as being a modified form of what is commonly designated as a one-tube thy-

Fig. 3—Schematic circuit diagram and waveforms showing operation of seam welding control



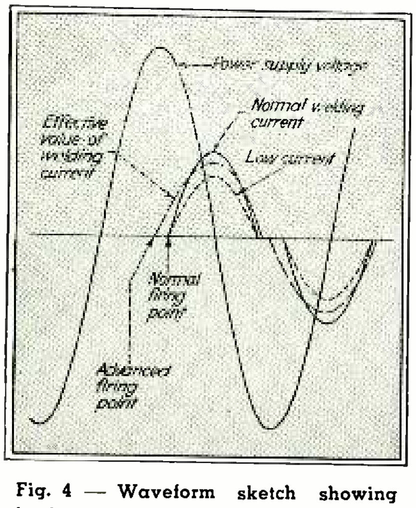


Fig. 4 — Waveform sketch showing basic operating principle of compensating and regulating controls for maintaining constant welding current

ratron inverter. A modification of the parallel type of thyratron inverter is also used for seam welding. A schematic diagram of this timing circuit is shown in Fig. 3.

In this case, tube 1 controls the "heat time" and tube 2 controls the "cool time". The operation of the control tubes 3 and 4 will be explained later but it should be observed that a negative d-c voltage is applied to their grids. While the seam weld initiating switch is open, the timing tube 1 conducts anode current continuously and there is no voltage across R_6. The grids of timing tubes 1 and 2 have a negative d-c grid bias and a peaked voltage for triggering the tubes synchronously. Timing capacitors C_3 and C_4 are maintained fully charged by tube 7. When the seam weld initiating switch is closed, the d-c voltage between points *a* and *g* is applied to the anode of tube 2, which becomes conductive when the next positive peak of grid voltage is applied to its grid.

The anode potential of tube 2 (point *b*) is thus lowered to a potential a few volts above the potential of point *g*, as determined by the tube arc drop. Capacitors C_2 and C_3 cannot discharge instantly because of the value of their series resistors and, therefore, the anode and grid of tube 1 are driven negative with respect to its cathode and tube 1 is extinguished. Capacitor C_3 provides the "heat time" timing grid bias on tube 1 and therefore C_3 will hold the grid of tube 1 negative for a definite timing interval determined by the "heat time" adjustment R_7.

The series circuit composed of capacitor C_2 and resistors R_3, R_4, and R_5 has a very low time constant so that C_2 may discharge to zero potential and charge up in the opposite direction within a small fraction of a half cycle. Thus the grids of the control tubes 3 and 4 are made less negative during the "heat time" timing interval. During this time, capacitor C_4 is kept fully charged by tube 7. When C_3 discharges through R_7 sufficiently to allow the peaked voltage from T_2 to trigger tube 1, circuit point *C* is lowered to the former potential of point *b* and point *b* is driven negative with respect to point *g* by the amount of the charge on C_2. Tube 2 is thus extinguished in the same manner as tube 1 was extinguished and the grids of control tubes 3 and 4 are restored to their former high negative voltage value for the "cool time" interval. Tube 2 will remain non-conductive for the "cool time" timing interval determined by C_4 and the adjustment of R_8. At the end of the "cool time", tube 2 again becomes conductive, thereby extinguishing tube 1 and reinitiating the next "heat time". This operation continues as long as the seam weld initiating relay remains energized.

It will be observed that the "heat time" and "cool time" timing adjustments R_7 and R_8 are still independent. Tube 7 serves to charge the timing capacitors C_3 and C_4 and, by limiting the positive potential of circuit points *e* and *f*, it insures that the timing tubes 1 and 2 are triggered only by the synchronous peaked grid voltages. Constant-voltage type transformers are used for the rectified d-c control voltage supply and for the peaked triggering voltages for the grids of the timing tubes.

The timing voltage of the "heat time" and "cool time" timing circuit has a square waveform and is applied to the grids of the control tubes 3 and 4 in such a manner as to make the grids less negative during the "heat time". The a-c anode voltages of tubes 3 and 4 are of opposite polarity and are obtained from the a-c control voltage supply. Peaked voltages from transformer T_2, having its primary in the phase shift heat control circuit, are applied to the grids of tubes 3 and 4 to trigger these tubes at a definite instant during each half cycle in accordance with the heat control setting, but the peaked grid voltages are elevated to the triggering position only during the "heat time" timing intervals.

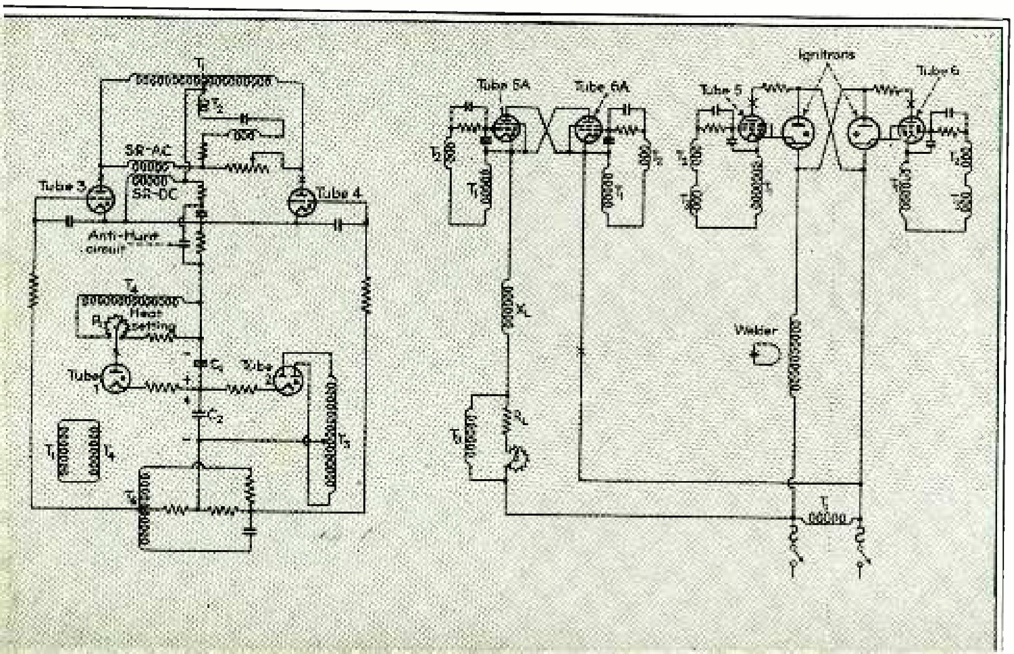
Transformer T_4, in the anode circuits of the control tubes 3 and 4, is also of the peaked voltage type. In this case, however, it is shock excited to provide peaked secondary voltages only during the "heat time" timing intervals. These peaked secondary voltages are applied to the grids of the firing tubes 5 and 6.

Each firing tube normally has a grid voltage consisting of only two components, an a-c bias and a self rectified grid bias, both of which make the grids negative during the positive half cycles of anode voltage as shown by the lower waveform sketch in Fig. 3. There are no components of grid voltage tending to trigger the firing tubes except during the "heat time" timing intervals.

Another type of seam welding control consists essentially of a synchronous motor-driven chain having extended link pins for holding removable metallic and non-metallic

(*Continued on page* 118)

Fig. 5—Schematic circuit diagram of spot welding control with auxiliary voltage-regulating compensator control



AN AUXILIARY CIRCUIT

For C-R Photography

By HOWARD C. ROBERTS

Special Research Associate, University of Illinois

THE cathode-ray oscilloscope, as an instrument for the examination of waveforms, is perhaps most useful in the study of transient phenomena, and in this connection recording by photographic means is often essential, and almost always useful. Many circuits have been devised for making this type of recording possible; most of them are rather complicated, rather expensive, and frequently difficult to keep in adjustment. This is a description of a circuit which seems to the writer to provide a desirable combination of simplicity, reliability, flexibility, and usefulness.

To make possible quantitative measurements of this type, it is essential that the time scale, if one be used, shall be accurately linear, or that complicated and in general less satisfactory means be made available for adding time indications to the record. A time scale may be applied to the record in any of several ways; for most applications it is most useful to apply the time scale to the horizontal axis by means of a linear sweep pulse applied to the horizontally-deflecting plates. For frequencies within the audible range, this linear sweep pulse is perhaps most conveniently produced by the charging of a condenser through some type of constant-current device; the voltage-time relationship existing across the condenser under such conditions is linear. The common alternative of charging a condenser through a resistor, then selecting a nearly-straight portion of the logarithmic pulse thus produced and amplifying it, is usually less desirable for measurement work. The circuit here described uses the linear increase across a condenser, C in the diagram, which is charged through a vacuum tube operating in a constant-current condition, and applies the resulting pulse directly to the plates of the cathode-ray tube. The constant-current tube, V_1 in the diagram, is a type 6SJ7, with 90 v. applied to the screen grid, and about 5 v. negative bias applied to the control grid. The tube, under these conditions, carries very nearly constant-current for potential drops across it varying from 30 v. to 400 v.

Electron Beam Cut-off

For photographic recording, and sometimes for visual examination as well, it is convenient to have facilities for keeping the electron beam in the cathode-ray tube adjusted either to a low intensity or entirely off except during the time that the recording of the event is actually in progress. It is possible, with such an arrangement, to use an ordinary camera, with a reasonably fast lens, for recording; if the room light is excluded, the camera shutter may simply be opened before the incidence of the phenomenon, and closed after it. Then, since there is no illumination of the screen of the cathode-ray tube except during the actual time the event is in progress, there is no fogging of the film, and no non-essential indications are recorded. To accomplish this action, a suitable potential (a negative bias) may be applied to the control grid of the cathode-ray tube, keeping the screen intensity down to as low a value as is desired during the waiting period; if then a suitable positive potential be applied to the grid, the beam will be made more intense, and the spot brighter. If, for example, a positive pulse of approximately square shape be applied to the grid, the beam will be suddenly intensified, kept so for the duration of the pulse, then as suddenly turned off again. If a linear timing pulse be applied to the horizontally-deflecting plates of the tube at the same time, the beam will appear for just the length of time that the brightening pulse lasts, sweep across the screen, and disappear. If there is also provision for applying the unknown event to the vertically-deflecting plates at the same time as the other two, then the record is made by a single excursion of the luminous spot across the screen of the cathode-ray tube, and there are no indications either before or after the event which might confuse the record. This type of modulation, in terms of brightness, may be installed in nearly all commercial oscilloscopes; there is one at least on the market which has such provision.

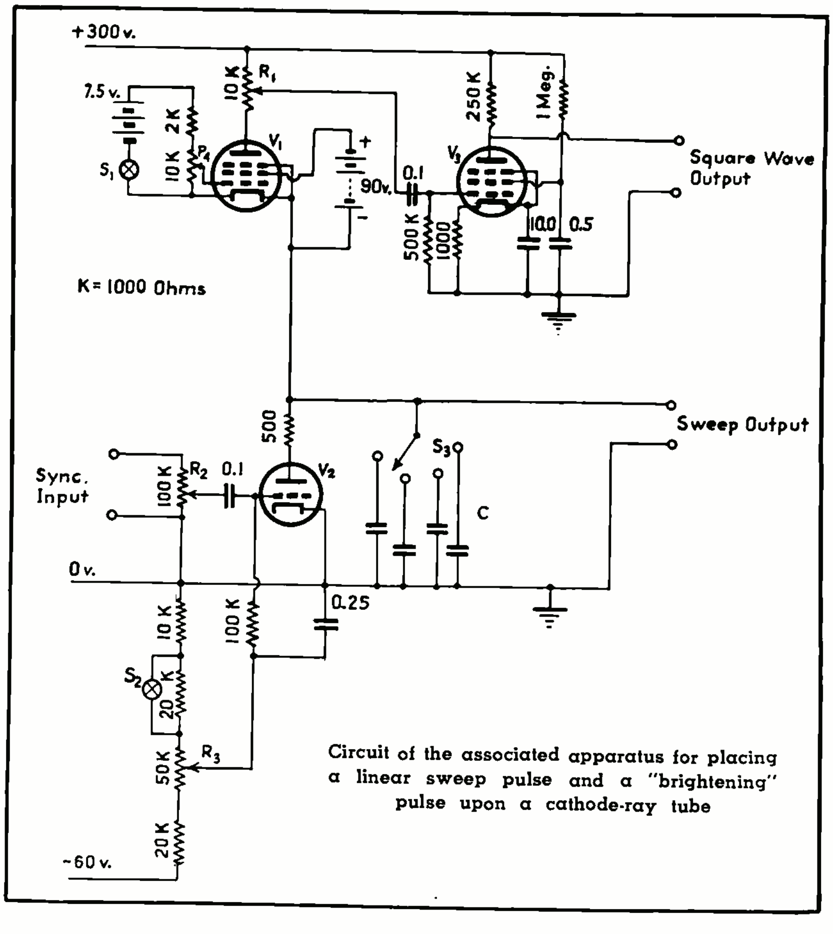
In the writers circuit, the square pulse for brightening is produced by the potential drop across a resistance, R_1, in series with the charging circuit of the sweep condenser C. Current flows through this resistance only while the condenser is being charged, and the current at those times is held to a constant value by the tube V_1. There is thus a square pulse produced to accompany each linear timing pulse. This square pulse is amplified and made positive in polarity by the amplifying pentode V_3, another 6SJ7 operating under recommended conditions as a voltage amplifier. The magnitude of the brightening pulse is controlled by the setting of the potentiometer R_1. This adjustment controls the intensity of the beam of electrons and therefore the brightness of the spot on the screen of the cathode-ray tube during recording; some care must be taken to keep the focus of the spot good. This is not difficult.

A circuit such as this, for greatest usefulness, should be so constructed that its operation may be initiated by some external signal; this will usually be the event itself, or some accompanying event. In this circuit, the provision for such initiation of action is afforded by the bias arrangement for the control grid of the gas triode tube V_2, a type 884. In the waiting condition condenser C is charged. The cycle of operation is as follows: when a signal of positive polarity is received at the grid of V_2, C is discharged very suddenly through that tube; the condenser is then recharged at a constant rate through the constant-current tube V_1, producing both the linear sweep pulse and the brightening pulse; the circuit is then back to the waiting position. A fixed bias is applied to the grid of the discharge tube, by means of R_3. This bias is so adjusted that the tube will fire when, and only when, a small positive pulse is applied to the tube control grid. An isolating circuit is introduced, so that the initiating or synchronizing pulse is applied directly to the grid. A continuously recurrent sweep may be obtained also when switch S_2 is closed, shorting out a portion of the negative voltage divider, and raising the bias applied to the control grid of V_2 to the point where it will fire each time the voltage across the condenser C reaches a suitable magnitude. To summarize, potentiometer R_2 is adjusted, with switch S_2 open, until the tube will fire each time a small positive synchronizing pulse is applied to its grid. If S_2 is then closed, the tube will fire each time the condenser reaches full charge, and a recurrent sweep is produced. At the same time, for each linear sweep pulse, whether single or recurrent, there is produced a square brightening pulse, synchronized with it, and controllable in magnitude.

A control, R_3, for the magnitude of the synchronizing pulses is provided. Although circuits are available for selecting synchronizing pulses of specified character, or for blocking the action after one or some other specified number of pulses, these have not been diagrammed, in order that the description may remain more general. The circuit shown requires positive pulses of at least one volt magnitude for reliable synchronization.

With the constants diagrammed, a sweep pulse having a magnitude of more than 100 v. is obtained. If a higher voltage supply is used, the same circuit will provide a higher voltage output pulse. The brightening pulses may be adjusted to amplitudes of more than 100 v.

Several modifications of this circuit have been tested by the writer; the one diagrammed has proved most satisfactory. It may be operated conveniently from battery supply, except that the heater current for the tubes represents a fairly high drain from batteries. The total drain from the B supply is only a few milliamperes. The unit has also been operated from power supplies from the a-c mains; but with the battery supplies for the screen and control grids of V_1 retained. It has not been found satisfactory to eliminate these batteries, and since their life is quite long in normal operation, it does not seem to be worth worrying about. The battery providing the control grid bias for V_1 has in its circuit a switch S_1 which is mechanically coupled to the off-on switch, so that there is no drain on any battery when the unit is not in operation. Potentiometer P_4 in this circuit is the fine adjustment on the duration of the pulses, and consequently the fine adjustment for the sweep frequency when the unit is producing a recurrent sweep.



Circuit of the associated apparatus for placing a linear sweep pulse and a "brightening" pulse upon a cathode-ray tube

Operating Notes

It has been the writer's experience that commercial gas triodes vary somewhat between individual tubes; it is usually necessary to make new bias adjustments when tubes are changed, and occasionally during the life of a tube.

The brightening pulse is not a perfect square wave at low frequencies, but is slightly rounded off at its terminus; this is of little consequence in any but the most exacting applications, and can be largely avoided if necessary by bringing up the low-frequency response of the amplifier V_3. No appreciable inaccuracy is introduced by the effect, since the de-

(Continued on page 144)

Simplified Inductance Chart

The inductance and Q of solenoidal or multi-layer coils wound on a cylinder are readily determined from the accompanying graphs when the dimensions of the coil are known. Effect of insulation in reducing space factor considered. Skin effect considerations are also discussed in the text

By E. S. PURINGTON
Hammond Research Corp., Gloucester, Mass.

THE accompanying chart is useful for preliminary design of air-core coils wound upon a cylindrical surface. Derived from Stefan's formula given in Bureau of Standards Circular 74, it primarily covers multiple layer coils, but as a limiting case also covers solenoids and pancakes.

With a coil of specified shape and a uniform winding, the geometric inductance is proportional to a dimension and to the square of the total number of turns. For engineering purposes, the basic dimension may well be the inside diameter in inches, here designated D, which remains fixed as the coil is wound. Shape is expressed by the ratio of the winding space W, and the thickness of the winding T, to the basic dimension D. In winding solenoids, T/D remains fixed, and in winding pancakes or multiple layer coils, W/D remains fixed. For convenience, let the two shape variables be $x = W/D$ and $y = T/D$.

The geometric inductance in microhenries, definable as the inductance at very low frequencies, is equal to the internal diameter D in inches, multiplied by the square of the total number of turns N^2, and by the shape factor $F_L\ (x, y)$. On the chart, the heavy lines of constant F_L ranging from 0.02 to 0.05 enable F_L to be determined within a very few percent for shape values of x and y up to unity. For example at $x = 0.75$, $y = 0.50$ corresponding to the illustrated coil shape, F_L is 0.028. Thus if a coil of 0.015 henry is desired on a form $D = 2$, $W = 1.5$, with T to be approximately but not exceeding 1 inch, then application of the formula shows about 520 turns are required. Since the cross section of the winding space is $S = WT = D^2\ (xy)$, or 1.5 sq. in., wire must be used giving about 346 turns per sq. in. For example the largest DCC wire which can be used is No. 18, which winds about 378 turns per sq. in. Revised estimates indicate the required inductance will be reached with 524 turns of such wire at $y = 0.46$.

The important reference shape indicated by M at $x = y = 0.5$ is that for which a given amount of specified wire yields the maximum possible inductance for this type of coil. For example, wire tables indicate a pound of No. 24 DCC wire occupies 7.07 cu. in and winds 1215 turns per sq. in. Using the volume formula $V = \Pi D^3\ (xy)\ \ (l + y)$, the value of D for a coil with 7.07 cu.in. of winding space and $x = y = 0.5$ is 1.82 inch. The cross section of the winding space $S = D^2\ (xy)$ is 0.83 sq. in. and will be filled by 1010 turns. Since $F_L = 0.035$ for this shape, the inductance is now readily found to be 0.06 henry, as the maximum possible for the specified amount of wire and the shape restrictions applying to this chart.

Since No. 24 DCC wire runs about 18.4 ohms per pound, and the maximum of 0.06 henry has been established for the pound, it readily follows that the specified material cannot yield a greater value of the quality factor Q than 20 per kc. Wire economy, however, is not always the determining element influencing the choices of the coil shape. For example a shape $x = y = 0.75$ might be used if a low frequency coil of a specified Q is desired with economy of outside diameter. Or a shape $x = 0.7$, $y = 0.4$ might be preferred if the coil is to be coupled to an additional outer winding. Or a shape $x = 0.5$, $y = 0.05$ might be chosen for use in a high frequency application. Some general information placing an upper limit on the possible Q for coils of this type is included by use of dotted lines F_Q ranging from 5 to 40. For coils wound with commercial annealed copper, the Q at 68° F, and at f kc cannot exceed $D^2 f F_Q\ (x, y)$, with F_Q as here determinable.

The upper limit for a coil with $D = 1.82$, $x = y = 0.5$ as above discussed, by the formula is $Q < 51.5$ at 1000 cycles. This is based upon the winding space being entirely occupied by conducting material. No. 24 DCC wire requires 0.00082 sq. in. of winding space per turn, but the cross section of the copper is only 0.00032 sq. in. That is, only 39 percent of the winding space is effective, and for this wire, the Q at 1000 cycles cannot exceed 0.39 times the theoretical maximum.

For reference, the cut down space factor for circular wires with the thinnest and thickest usual types of insulation can be estimated from the table.

Space Factors for Various Wires

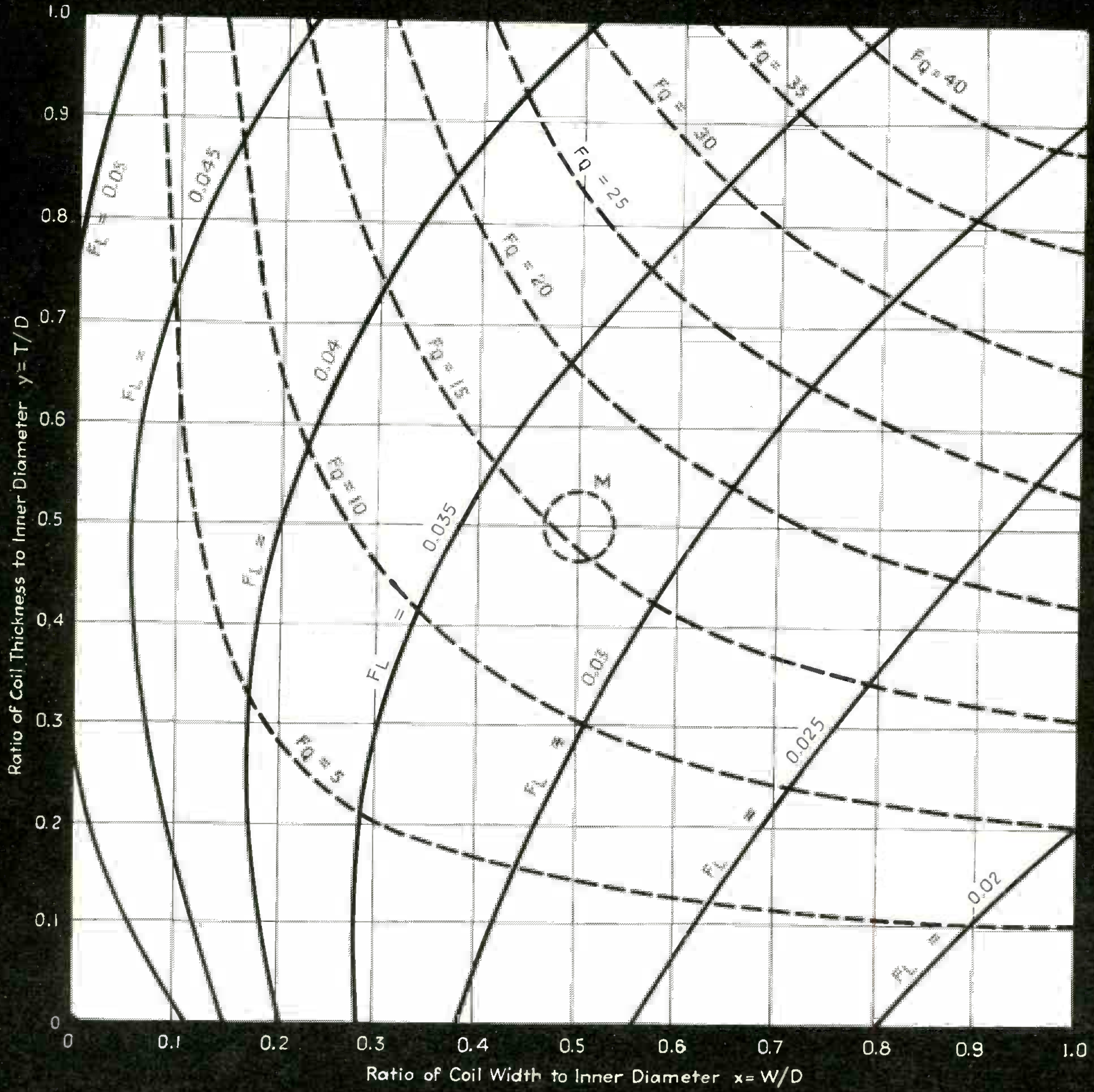
AWG Size	Enameled	Double Cotton
10	0.73	0.62
20	0.68	0.435
30	0.645	0.23
40	0.585	0.056

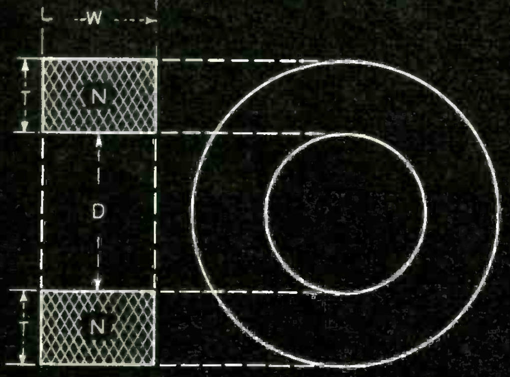
Skin Effect Considerations

At high frequencies, the non-uniform distribution of current in the conducting material itself further reduces the effective space factor. Litzendraht wire, made by paralleling several small enameled wires, improves the effective space factor by reducing the amount of copper which, due to the skin effect, does not contribute to the actual conduction. Thus a litz wire designated 4×8×38, comprising 32 strands of No. 38 wire has the same cross section of copper as a No. 23 single conductor. The physical space factor of the litz is about half that of its No. 23 equivalent with double cotton insulation, and it is therefore not at all desirable for low frequency purposes. But the total surface of the strands composing the litz wire is about seven times that of the equivalent single conductor. Therefore on the assumption that only material close to the surface actually carries current, at high frequencies the effective space factor of the litz, while not large, would be about 3.5 times that of a No. 23 DCC wire.

Other well known effects also cause the actual Q and to a lesser extent the L of practicable coils to differ from the values computable from the coil geometry and the d-c resistivity of the conducting material. Proper allowance for these effects is largely a matter of experience or application of formulas based upon experiments. What is here presented is merely graphical information based upon well established formulas, with sufficient precision for purposes of preliminary design.

INDUCTANCE CHART





Inductance in Microhenries is Given By

$$L = DN^2F_L(x,y)$$

Where D is the Inner Diameter of the Coil in Inches
N is the Total Number of Turns of the Coil, and
$F_L(x,y)$ is the Shape Factor For Inductance Calculations, as Given by the Heavy Lines of the Graph.

The Maximum Inductance for a Given Amount of Wire is Obtained For Coils Whose Shape Factor is at the Region M for Which $x=0.5$ and $y=0.5$

Upper Limit of Coil Quality is given by

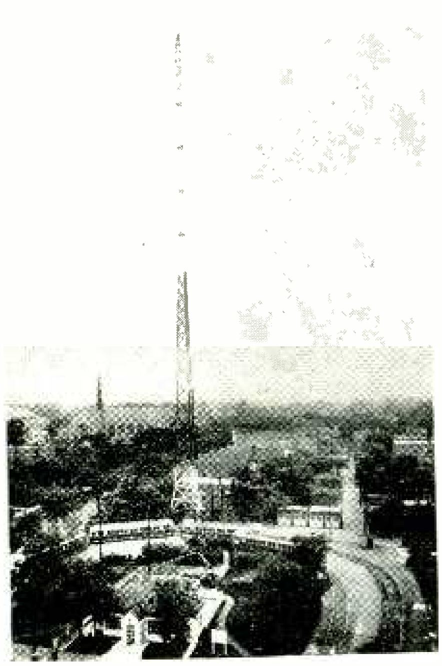
$$Q = D^2fF_Q(x,y)$$

Where D is the Inner Diameter of the Coil, in Inches,
N is the Total Number of Turns of the Coil, and
$F_Q(x,y)$ is the Shape Factor for Coil Q Given by the Dotted Lines of the Graph.

TUBES AT WORK

Electronics Serves Transportation Industry

CHICAGO SURFACE LINES, operating an extensive transit system in the city forming part of the firm's name, has installed a modern two-way radio communication system to facilitate traffic handling and equipment maintenance. The installation, according to *Transit Journal*, was made by Motorola.



WAYH, operated by Chicago Surface Lines. The tower is 250-ft. high

A 250-watt FM transmitter installed in a small building located on the company's property near the western boundary of the city and about midway between its north and south boundaries operates as WAYH on 39,860 kc, is remotely controlled and gives adequate coverage despite the fact that some surface lines are 25 miles or more long. Mobile stations at present include 18 Chevrolet squad cars equipped with receivers, 50-watt transmitters and whip antennas, 10 tower trucks similarly equipped but employing horizontal antennas to avoid interference with overhead power wires, and 5 general utility cars. The present total of 33 mobile units is eventually to be increased to 49. All radio-equipped cars have heavy-duty storage batteries and generators capable of keeping batteries charged even if radio equipment is operated continuously.

The city has been divided into 15 districts and a squad car continuously patrols each of these districts. Thus squad cars may report instantly when traffic conditions appear to warrant changes in dispatching and the dispatcher's office may issue the necessary instructions for further clearing up of jams through local action. Repair and maintenance trucks may, similarly, be dispatched to locations requiring their services with a minimum of communication delay.

Squad car transmitters and receivers are installed behind the driver's seat

A tower-truck driver calls the dispatcher

A total of 106 men employed by the transit company had received FCC operator's licenses when the system went on the air in June; 66 from the transportation department, 13 from the electrical department and 27 from the utility department. Over 100 additional men are eventually to be licensed, according to the management.

Audio Frequency Compensating Circuits

By STANLEY CUTLER

Radio Division, Air Associates, Inc.

DURING THE PAST SEVERAL years it has become increasingly clear that a flat response does not necessarily represent the ideal characteristic for an audio system terminating in an acoustic device such as a loudspeaker. Certain inherent characteristics of the human ear cause the sensation of reproduced sound to seem more realistic when both the high and low frequency ends of the audio spectrum are boosted some fifteen or twenty db above the level of the middle frequencies. The actual accentuation desired varies with the type of program material and with the average level at which it is being reproduced.

Various circuits have been devised to accomplish the above. It is the purpose of this article to briefly review in a qualitative manner a few of the more popular circuits in use, at the same time pointing to the weak points of each. Finally, a circuit will be described which accomplishes the desired results with a minimum of complication and without the disadvantages of the preceding circuits.

For most types of program material a gradual low-frequency rise from 500 cps to a peak at 50 cps, of between 15 and 20 db above the 500 cps level, is ideal. The high-frequency end may rise gradually from 1000 cps, reaching a peak of between 15 and 20 db above the 1000 cycle level at about 6000 cps. For wide-range systems it is desirable to obtain the maximum response in the 10,000 cps region.

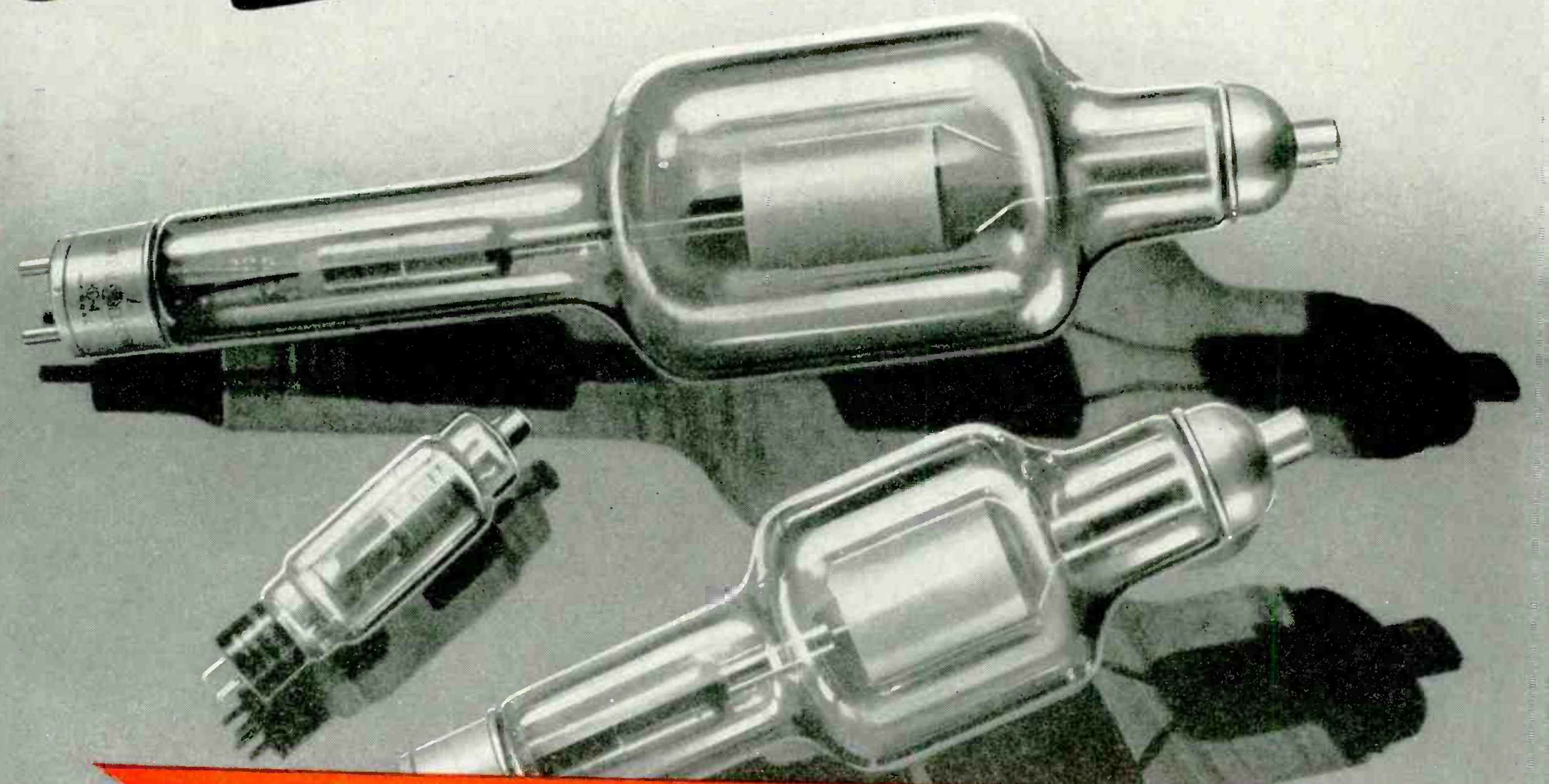
Conventional Circuits

Figure 1 shows a circuit widely used in radio receivers and public address amplifiers. It depends for its operation on the fact that the gain of a vacuum tube voltage amplifier is

$$\text{Gain} = \frac{\omega R_o}{R_o + R_p}$$

Obviously, if R_o is large compared to R_p, increases in R_o will have little effect on gain. However, in the region where R_o is small in magnitude compared to R_p, changes in R_o will have considerable effect on gain. R in Fig. 1 has a small value compared to the plate resistance of the tube and determines the gain at middle frequencies. Parallel resonant circuits tuned to approximately the peak frequencies described earlier are inserted in series with R. The gain of the stage is maximum at the resonant frequencies. Vari-

G-E KENOTRONS...



Type No.	Price	No. of Electrodes	CATHODE		PLATE		Shipping Weight in Lb	Ask for This Bulletin
			Volts	Amp	Peak Volts	Peak Amp		
GL-8013	$12.00	2	2.5	5.0	40000	0.250	3	....
GL-8020	31.50	2	5.0	6.0	40000	0.750	3	GET-988
FP-92	155.00	2	10	14.5	150000	0.3	9	GET-734
GL-411	130.00	2	10	14.5	100000*	0.3	9	GET-734
KC-4	140.00	2	20	24.5	150000	1.0	9	GET-734

*150000 volts in oil.

The sale of these tubes conveys no license either expressed or implied under patents of the General Electric Company other than those covering the tubes themselves.

YOU doubtless realize that the kenotron is one of the oldest and most useful members of the electronic-tube family. General Electric kenotrons are designed particularly for use in high-voltage rectifier circuits, where the current requirements are relatively low as compared with the heavy currents required for applications such as welding. They were quickly accepted by industry because of the wide range of voltages which they cover—up to the hundreds of thousands. Their inherent features assure ease of installation, circuit flexibility, and freedom from the bother of manual control.

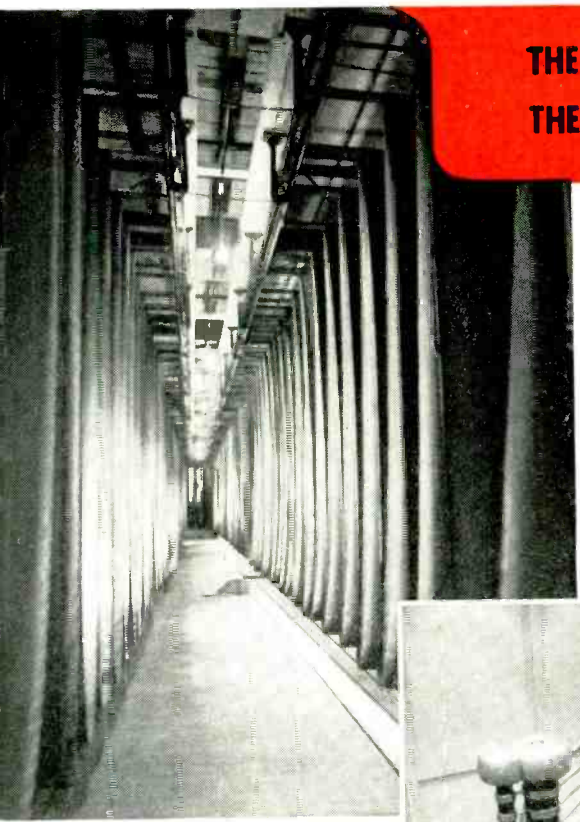
Early applications of G-E kenotrons included their use in high-voltage, d-c, cable-testing equipment, smoke precipitators, and in the power supply for X-ray equipment and for radio transmitters and receivers. More recently kenotrons have been applied also in the manufacture of abrasive papers and in air-filtering equipment for stores, factories, and homes. The impetus of war has stimulated their use in many fields. "New worlds to conquer" still lie ahead. Put G-E kenotrons to work on *new* jobs.

We invite you to write to us for technical data sheets on kenotrons and other G-E tubes, and for descriptive information on G-E apparatus using electronic tubes. *General Electric Company, Radio, Television, and Electronics Department, Schenectady, N. Y.*

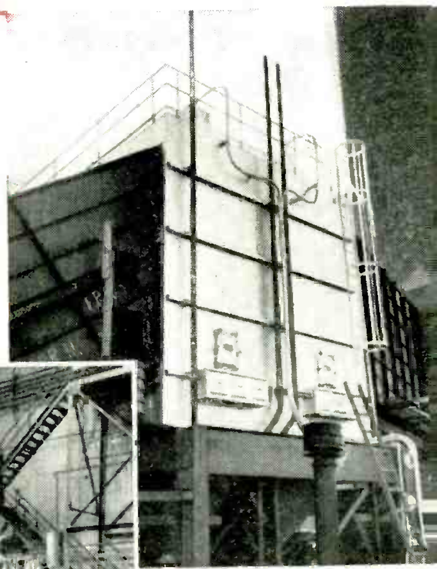
WORLD LEADER IN RADIO, TELEVISION, AND ELECTRONIC RESEARCH

HIGH-VACUUM RECTIFIERS FOR HIGH-VOLTAGE REQUIREMENTS

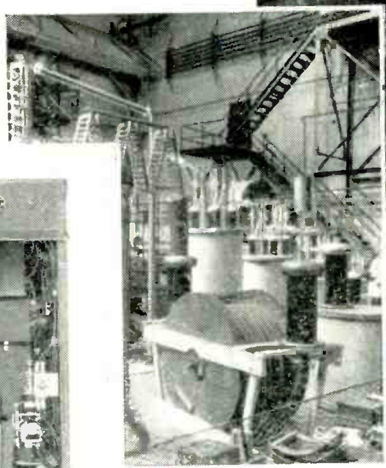
THESE DIODES HAVE ALREADY MADE THESE INDUSTRIAL PROBLEMS EASIER



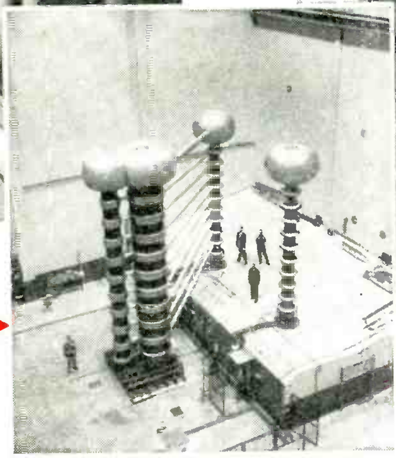
MAKING SANDPAPER. An electrocoating process using G-E kenotrons was developed by the Behr-Manning Corporation. The adhesive backing for the paper and a conveyor belt covered with finely divided abrasive particles are passed between two electrodes. The electrostatic field developed by the kenotrons between the backing and the belt polarizes the particles, and they are hurled, endwise, into the adhesive. (Picture shows paper on drying racks.)



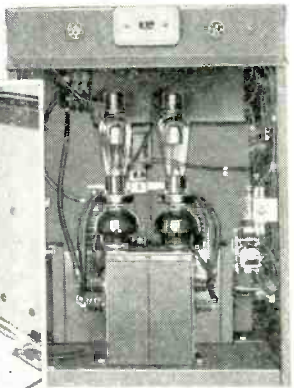
RECOVERING VALUABLE PARTICLES from flue gases in smelters, sulphuric-acid plants, cement mills, plants for de-tarring natural gases, etc. In many applications, as in the fly-ash precipitator above, precipitators powered by kenotrons are used to remove solid particles from factory smoke which would otherwise be deposited over the surrounding country.



TESTING ELECTRIC CABLE. Cable manufacturers use kenotrons to supply the high-voltage direct current necessary for testing insulation resistance. In testing installed cable, kenotrons supply power that helps locate, both quickly and accurately, poor joint work and incipient cable faults that might result in service failures. Such fault locators help speed repairs, especially for underground cable.



MEASURING X-RADIATION. The 1,400,000-volt constant potential X-ray equipment installed at the National Bureau of Standards utilizes kenotrons to develop the high potential. The d-c generator (double stack at left) consists of a high-voltage resistance potentiometer (narrower column), and 10 individual voltage-doubling rectifiers, cascaded one above the other (wider stack), using two kenotrons in each 140-kv stage. The stacks at right are 10-section X-ray tubes, one being a spare.



AIR FILTERING, in factory and home, is a highly efficient process when the principle of electrical precipitation is used. The air is ionized. The negatively charged dust and dirt adheres to positively charged plates. Even small particles that defy all other air-cleaning devices can be removed. As shown, kenotrons are used in the power supply.

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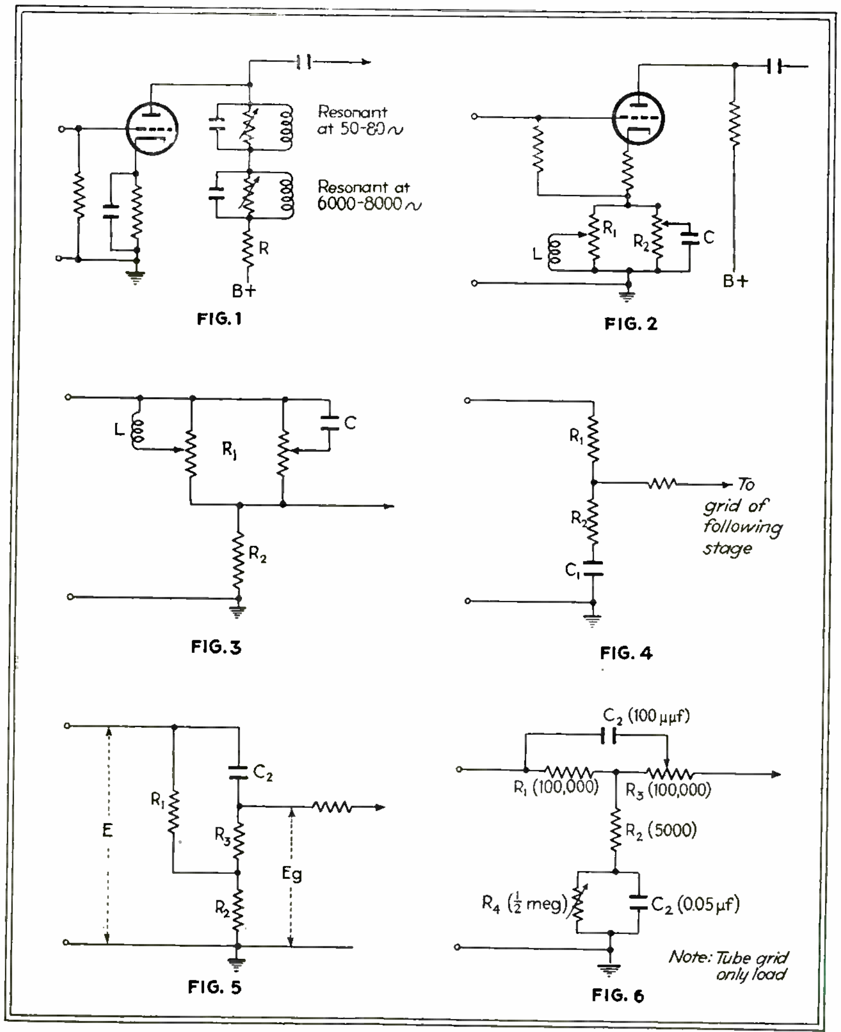


Conventional high and low frequency "boost" circuits are shown in Figs. 1, 2 and 3. Development of an improved circuit is shown in Figs. 4 and 5, with the final version appearing in Fig. 6

able resistors connected across the tuned circuits provide continuously variable control of the boost characteristic.

A major drawback of this type of circuit is the fact that in order to obtain good linearity with commonly used pentodes and high-mu triodes such tubes must be operated with inputs of not much more than one half volt. Since the gain at middle frequencies is practically nil, considerable amplification must be used after the circuit, and since the low frequency choke is quite large it is susceptible to hum pickup. The low input voltage limitation also requires that some means be used to decrease the output voltage of most crystal pickups, which usually have in the neighborhood of two volts output.

A more desirable type of circuit incorporates a fixed amount of negative feedback to establish the middle frequency level and employs some means of decreasing or removing feedback entirely at low and high frequencies. There are many variations of this type of circuit. A typical one is shown in Fig. 2. Here, feedback provides degeneration across R_1 and R_2, which determines the gain at middle frequencies. With L and C connected directly across R_1 and R_2 the feedback is decreased at low and high frequencies respectively and the stage gain is consequently greater at these frequencies.

Since the inductance L is in series with the input voltage to the tube here again a well shielded coil is usually necessary to prevent hum pickup. Circuits of this type must also be designed carefully when using elements of a reactive nature inasmuch as phase shifts may occur in sufficient degree to produce positive feedback at the extremely low and/or high frequencies, thus causing oscillation or unstable operation.

A simpler circuit, which does not involve the use of a vacuum tube to obtain the desired characteristic, is shown in Fig. 3. Here the loss at middle frequencies in passing through the network is given by

$$\text{db Loss} = 20 \log \frac{R_1 + R_2}{R_2}$$

Low and high frequencies are bypassed around R_1 by L and C respectively. Here again hum pickup may be troublesome unless special precautions are taken in the design of L.

An Improved Method

A circuit was designed in an effort to eliminate the drawbacks of the foregoing methods. The most important principle of this network, wherein the necessity for the use of inductance is eliminated, is shown in Fig. 4. At all frequencies above the frequency where the reactance of condenser C_1 becomes small compared to the resistance of R_2, the loss in passing through the network will be

$$\text{db Loss} = 20 \log \frac{R_1 + R_2}{R_2}$$

Below this frequency the voltage applied to the grid of the following stage will vary inversely with frequency because of the increasing reactance of C_1 and the network loss at any low frequency will be

$$\text{db Loss} = 20 \log \frac{\sqrt{(R_1 + R_2)^2 + \left(\frac{1}{\omega C_1}\right)^2}}{\sqrt{R_2^2 + \left(\frac{1}{\omega C_1}\right)^2}}$$

To control the amount of bass boost it is only necessary to prevent the reactance of C_1 from rising above the value necessary to produce the desired boost. This is accomplished by connecting a variable resistor, having a maximum value that is large compared to the reactance of C_1 at the lowest desired frequency, across the condenser. When the resistance is zero the loss will be uniform at all frequencies. Between zero and maximum resistance

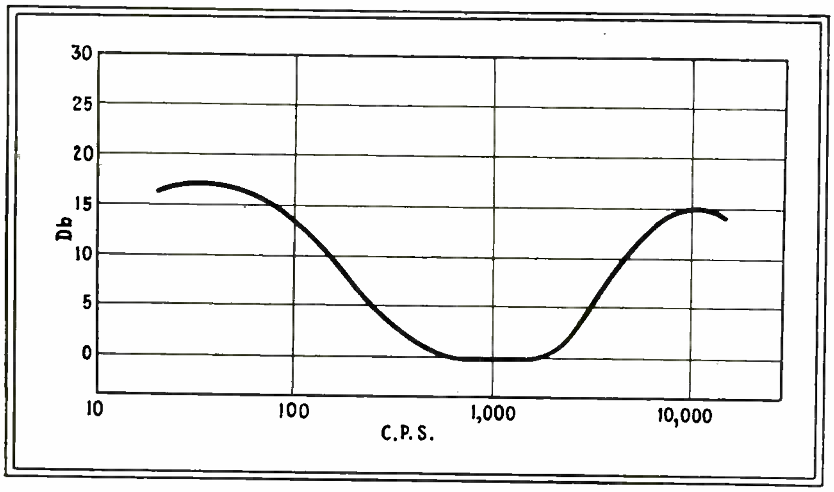
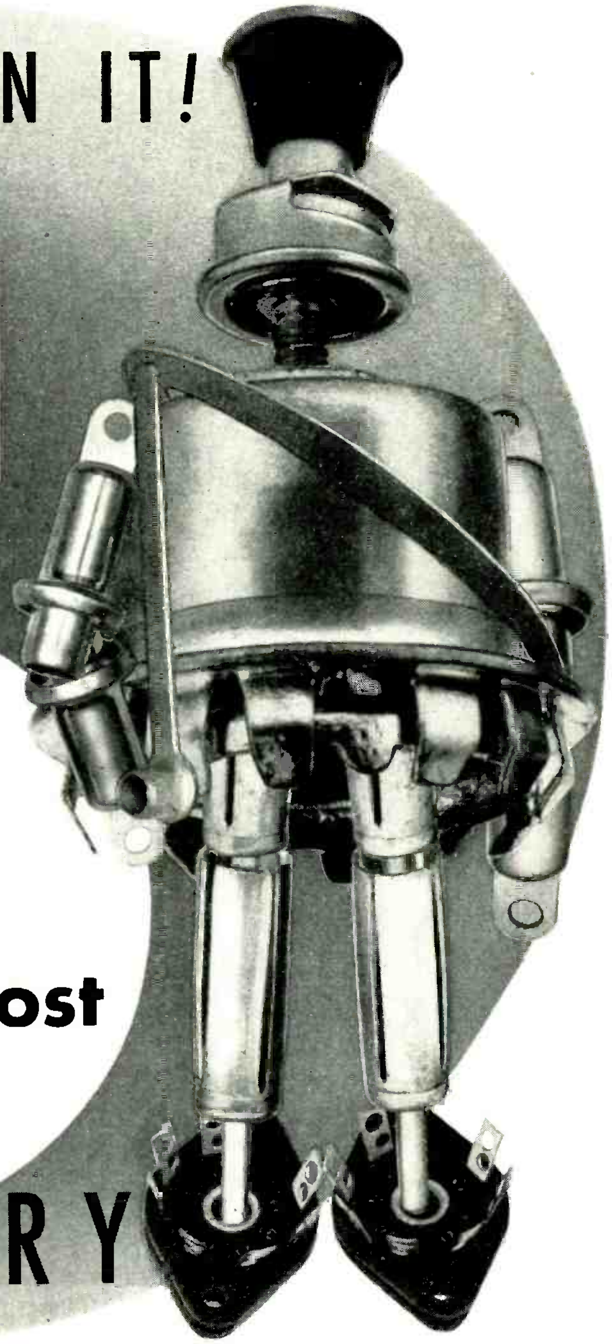


Fig. 7—Characteristics of the improved circuit with controls set for maximum high and low frequency boost



the bass boost will be continuously variable.

The equivalent circuit used for high frequencies is shown in Fig. 5. If the network is operated into a very high impedance load such as is presented by the grid circuit of a vacuum tube, the series arm R_3 may be added without affecting the characteristics predicted in the preceding paragraph. Neglecting the effects of stray circuit and tube input capacitance and assuming the reactance of C_2 is small compared to that of R_3 as is usually true in practice, the voltage applied to the grid is given by

$$\frac{E_g}{E} = \frac{R_1 R_3 + R_2 \sqrt{R_3^2 + \left(\frac{1}{\omega C_2}\right)^2}}{(R_1 R_2) \sqrt{R_3^2 + \left(\frac{1}{\omega C_2}\right)^2}}$$

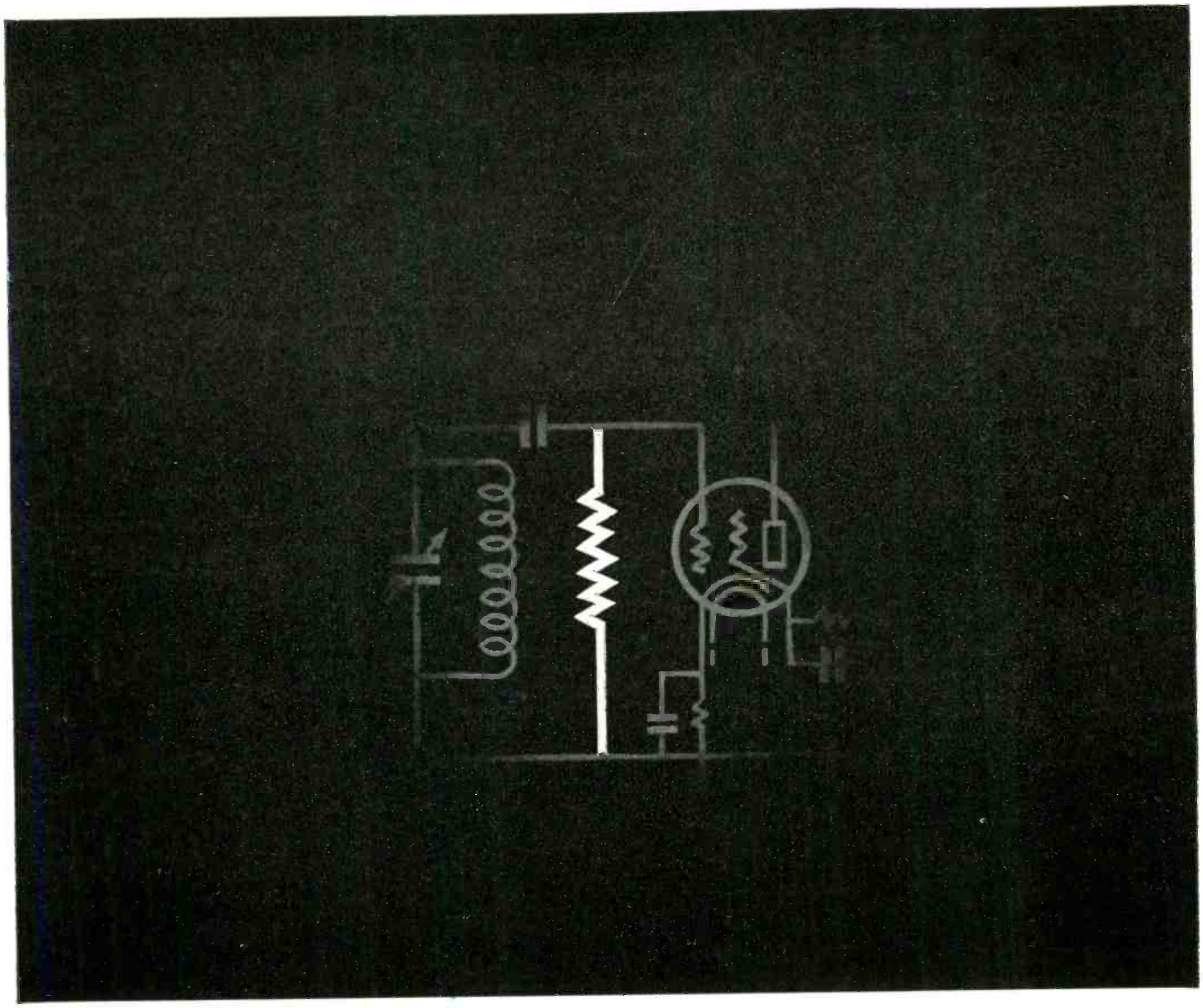
Since C_2 is small no appreciable high frequency boost occurs when it is connected to the junction of R_2 and R_3 instead of the grid. To provide continuously variable boost it is only necessary to make R_3 a potentiometer, connecting the grid end of C_2 to the variable arm.

The combined circuit, with suitable values, is shown in Fig. 6. The overall response of this network when used in a wide range amplifier is shown in Fig. 7. The curve was made with the controls set for maximum low and high frequency response. With amplifiers of limited range it may be necessary to increase the size of C_2 in order to obtain sufficient rise at the upper frequency limit of the amplifier. Although a circuit of this type neces-

• • •

STEEL FLAW DETECTOR

C. S. Williams of Westinghouse demonstrates a method of detecting sub-surface flaws in heat-treated steel parts such as bearing races. The part is rotated by a motor, magnetized, and the resulting electromagnetic field induced in the coil of a pickup feeding a CRO. Flaws produce a non-uniform field, show up as a pattern variation on the screen



WHAT IS THE BEST RESISTOR?

Generally it is the resistor that most perfectly fits the special requirements of the application for which it is intended—the one that best meets the conditions under which it is used.

There are many basically good and dependable types and makes of resistors available. Each has its own peculiarities and limitations inherent in its design and construction. Each one's success or failure in service therefore depends primarily upon its suitability for the particular job it has to do.

That is why the IRC "Know-How" gained through many years of intense specialization looms even more important to many resistor users than the quality of the individual IRC product which they long ago learned to take for granted.

These users know that IRC makes types, sizes, shapes and kinds of fixed and variable resistors specially designed for almost every known service requirement. Above all they realize that IRC knows how to help them select the most dependable resistor and how to use it properly.

IRC

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sarily introduces some phase shift it is not detectable by ear.

In conclusion it is well to stress one point that is frequently overlooked in the design of audio systems with boost characteristics. In order to realize the full undistorted effect at the increased frequencies, the amplifier and reproducer must be capable of handling the comparatively high power that is necessarily expended at these frequencies. For example, a loud speaker of average efficiency requires about one quarter watt to deliver good volume in an average sized living room. If twenty db boost occurs at the low or high frequencies we have a power ratio of 100 or, in other words, 25 watts expended at these frequencies. Although this may be somewhat more boost than would normally be necessary it serves to illustrate forcibly the need for ample power. For systems providing a nominal increase of 15 db, the power capability should be at least 8 watts undistorted power.

• • •

High Speed Relay and Switch Tester

Writing in *Electrical World*, E. T. Vickerman, Jr., and Samuel E. Edelstein of the Washington Water Power Company, Spokane, describe a portable tester for determining the time characteristics of high speed protective relays and switches. The tester described is a combination of two units, a condenser charge-discharge type timer and a vacuum tube voltmeter. When these two units are inter-connected by means of a four-wire cable time in seconds

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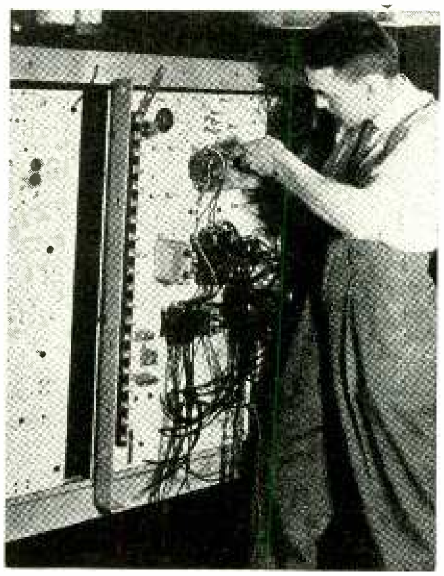
PANEL WIRING TEMPLATE



Drilling of holes, mounting of parts, installation and check of wiring on resistance welding panels is facilitated at G-E by pasting templates to the back of the panels before such work starts. Template paper is oil-resistant and all lines are drawn with special non-conducting ink so the templates can be left in place to simplify service later

can be read directly on a special 50 ma scale on the vtvm instrument.

The timer unit circuit is shown in Fig. 1. The instrument *V* in this unit, has a 0-150, 1,000-ohms-per-volt movement. Pushbutton switches make stopping relay calibrations, discharge the timing condenser, provide for external battery source where one is necessary and operate voltmeter *V* for reading charging potential. A variable resistor controls the primary voltage of the powerpack, which supplies a constant d-c potential for charging the timing condenser, and controls the a-c power to the associated vtvm unit. External accessories include a multi-range ammeter, a load box and a source of 110 v a-c supply.

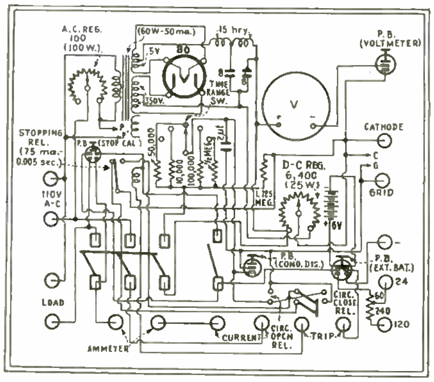


Fig. 1—Tester timing unit

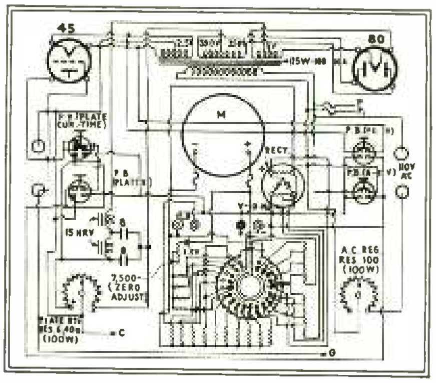


Fig. 2—Tester vtvm unit

The vtvm unit circuit is shown in Fig. 2. The instrument *M* in this unit was supplied by Triplett complete with resistor and shunt boards, selector switch, rectifier and jacks. Points on the selector switch include 1,000, 250, 50 and 10 volts d.c.; 1,000, 250, 50 and 10 volts a.c.; 500, 50, 10 and 1 ma. and 250 and 50 μa.; low ohms, 20,000 ohms and 2 megohms. This unit may therefore be used alone for making a variety of low burden tests in the field.

Errors and inaccuracies have been eliminated to the degree that time values can be determined with a maximum error of approximately 10 percent at 0.001 second, or three-fiftieths of a cycle. This small inaccuracy is more or less a fixed quantity, dependent largely upon the condition and speed of contact of all three blades of the main timer unit operating switch, so that the percentage error in readings decreases rapidly for times slower than three-fiftieth of a cycle.

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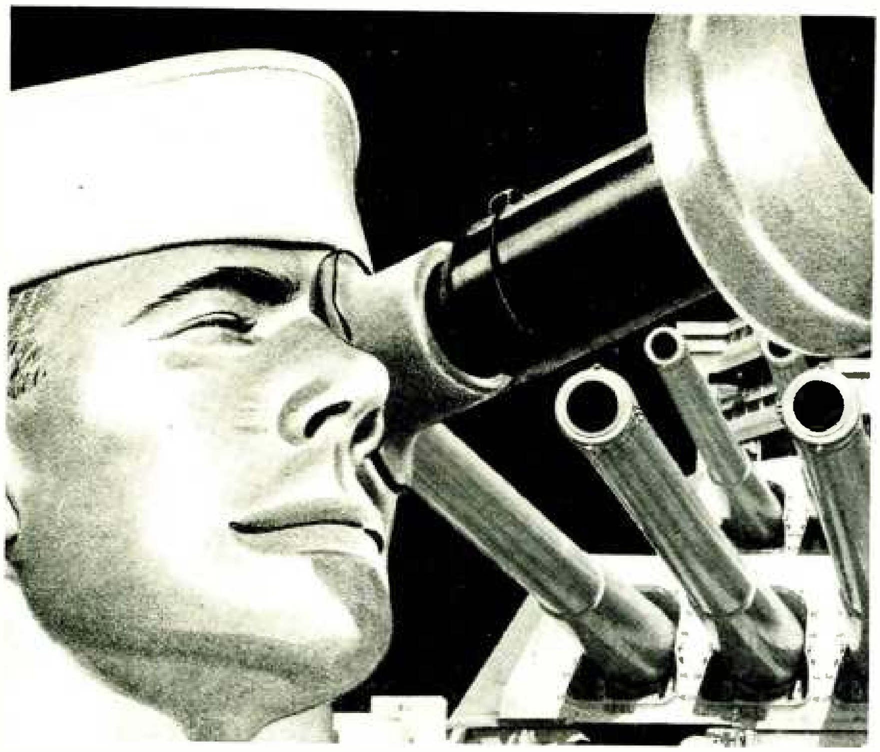

Electrical Concepts

(*Continued from page 41*)

beam must pass (broken lines) the current in that beam containing variations in density so that as each "lump" of space charge (dots) passes by, it induces current in the circuit which connects the two grids. Now we close the circuit not by a loop or by a coil, which would radiate and present low impedance at these frequencies, but rather by a self-enclosing circuit (solid lines).

Voltage Difference

And now there is a rather major concept, that of voltage differences between points of a circuit.

The notion that a conductor is always an equipotential surface, true for electrostatics, is of course totally inapplicable as a general "law" at frequencies for which currents, charges, and fields actually reverse themselves in a space measured in centimeters. For two points on a piece of metal a very short distance apart, it might seem that this law is still valid. But this is not always the case. The use of self-enclosing conducting systems, such as resonant cavities, very often brings about circumstances in which this persistent but erroneous concept is difficult to reject when one's "voltage difference" ideas have become inbred at the lower frequencies.

Since centimeter waves fail to penetrate metal to any appreciable degree, it often happens that very high currents flow on one side of a thin piece of metal (thin compared to wavelength but thick compared to the depth of penetration of the current) with resulting high fields and charges in the metal's vicinity on that side, while on the other side, the region is field-free and the surface is free from charges and currents. For example a box may be stimulated by a generator on the inside which charges the top and bottom against each other, with accompanying high electric field vertically down the center of the box. The box may be said to possess a voltage difference between top and bottom (where the voltage difference is defined as the integral of the field strength). But even a very conscientious ob-

server, seeking to measure that voltage difference between top and bottom from *outside* the box, will obtain no appreciable reading if the metal of the box has any appreciable thickness. The inside and outside of the metal in this particular case cannot be properly regarded, in other words, as at the same potential.

If we put two of these box circuits together—in fact, even if we form them so that one face of each circuit is made from the same piece of metal as in Fig. 12, we will still not have coupling between circuits. The return current between the condenser plates of this one resonator will not be coupled to the second circuit to any appreciable degree if the thickness of the metal is made a small fraction of an inch.

Transmission Lines

If the modes in which the electric charge, current and fields can distribute themselves inside a box are interesting, they are even more so, perhaps, in transmission lines or in waveguiding systems than they are in what we would call the equivalent of lumped circuits. This is especially true since the distance between two components of a piece of centimeter-wave apparatus is very likely to be many wave lengths if it is any distance at all, and, therefore, the transmission line or waveguiding system becomes as important as the circuit. As in the case of circuits, we have a problem of preventing unwanted radiation. We want to guide the energy, taking it from the source to the place where it will be used and we assume there is little reason for having it lost on the way.

The commonest transmission line in the centimeter-wave region is one in which the outer conductor completely encloses the inner conductor, as in Fig. 13. If centimeter wave energy is started at one end, it will travel down the line and, minus the I^2R losses in the conductors, will appear at the other end. If the end conditions are not such as to claim all the energy, some may be reflected back to the source. But none will leak out of the system if there is any thickness to speak of in the metal and if the system is closed at the two ends. Such a co-axial line acts like, and is indeed no different from an ordinary co-axial line used for lower frequencies. Except for the

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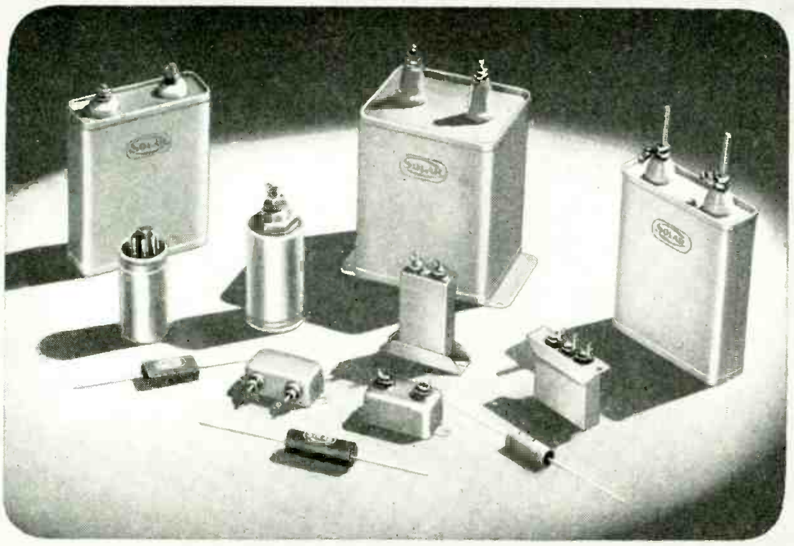
fact that minimizing of radiation must always be present in the centimeter-wave engineer's mind, there is little need for broadening the engineer's picture of electrical transmission by studying this example.

Let us look at some of the more interesting types of waveguiding systems which apply particularly to the centimeter wave regions and which, like co-axial lines, are self-enclosing but do indeed require for their appreciation a broadening of concepts of transmission on the part of the average engineer. To start with, let us do as we did with the circuit when we considered the condenser plates closed by a one-turn inductance. Take the case of a transmission line formed of two flat conductors as in the upper diagram of Fig. 14. Because of the high ratio of cross-sectional dimensions compared to the wavelength easily attainable in the centimeter wave region, we almost feel intuitively that there should be some mode of distribution of the charge and current so that the charge density will be high at the center between conductors, then fall off so that at the edges the electric field between conductors will be small. We can actually close the line, forming one rectangular cylinder instead of two lines, as shown in the lower figure, and the energy should still progress down the line.

Such indeed is the case and in Fig. 15 is shown a number of cross-sectional arrangements, both cylindrical and rectangular, showing different modes in which the electromagnetic fields may distribute themselves if the cross-sectional dimensions of the line are large enough compared to wavelength.

It is not the purpose of this paper to discuss the practical advantages of one means of transmission over others, but it is well to note that under certain circumstances the hollow cylinder, waveguide type of transmission line results in lower attenuation than can be obtained with the ordinary co-axial line. Furthermore, the need for insulators to support an inner conductor is removed. It is important to observe that this relatively new means of transmission, which applies most readily to the centimeter wave region, is one in which the transmission line is highly frequency-responsive, at least near its so-called "cut-off" point. The wavelength must



be short enough so that the waves will fit into the cross-sectional dimensions of the hollow cylinder. When this condition is not obeyed (as in the case of longer wavelength oscillations on guides of practical cross-sectional dimensions), such transmission lines will be shorted by the sides and, in general, the waves will not propagate down the line, whereas above that frequency they will propagate with only the usual I^2R attenuation. The matter of wavelength versus cross-sectional dimensions plays an important role in the centimeter-wave engineer's pictures of transmission.

Radiation and Its Control

We have discussed how the word "circuit" has expanded in its meaning to cover the centimeter-wave band and how our notions of transmission lines have been broadened to include new effects. There remains the third general division of the control and guiding of electromagnetic energy, radiation; radiation that is a desirable, intended effect, and not simply an objectionable by-product in circuits and transmission lines.

There are two rather obvious and quite well-known expansions in our notions of radiators that come about because of our work in the centimeter wave region. One is that because the wavelengths are shorter, it becomes practical to use reflectors, borrowing them from the light spectrum where such devices have long been used to concentrate wave energy in beams. Also, the acoustic analyses carry over and we find it possible to use such radiators as horns.

There are some other things, however, that are happening to our

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SOUND DETECTOR

Shown here is a sound detector which is used by the Finnish Army

notions of radiation of electromagnetic energy, primarily due to efforts in the centimeter wave range and which, although they belong properly under the heading of radiation concepts, tie in so closely with notions of circuits and transmission lines that they make a fitting summary for the whole discussion. The reader is probably now willing to accept the point of view which centimeter-wave engineers have come to know and accept; that the radiation of electromagnetic energy is a phenomenon closely akin to the guiding of such energy around a circuit or along a transmission line. If the conducting and dielectric boundaries are so situated around the source that the energy is mainly contained and dissipated in a relatively small region, then the system is usually thought of as a *circuit*. If the boundary shapes are such that the energy is guided along a somewhat longer path and absorbed or reflected at the termination, with the losses to surrounding bodies again relatively small, then it is probably best termed a *transmission line* or *guide*. If the boundaries are such as to draw the energy out of the source and encourage it to continue through free space with little or no further guidance and with relatively little reflected back to the source, then it is an efficient *radiator* or *antenna*.

These pictures are equally applicable to the lower frequencies, but radiation is so much less a factor in circuits and lines at low frequencies that it is natural for us to become accustomed to using only Kirchoff's laws and ohmic dissipation, whether for lumped circuits or distributed constant networks like transmission lines. The possibility of loss of energy by radiation is thus often disregarded in circuits and lines and regarded as an entirely separate phenomenon when it occurs in antennas. Not only the proportionately greater amount of loss of energy by radiation at ultrahigh frequencies than in ordinary circuits and lines, but also the greater need of appreciation of the wave nature of electricity, whether standing or travelling waves, on systems of small physical dimensions has emphasized the more basic picture and is serving to correlate the three main divisions in the controlling or guiding of electromagnetic energy: circuits, transmission lines, and antennas.

THE ELECTRON ART

Many new and improved courses in electronics and communication subjects offered in colleges. War stimulus partly responsible, but gains will be permanent. Survey of courses offered by accredited engineering schools

Electronics and Communication Courses in American Colleges

THERE CAN BE LITTLE DOUBT that a considerable increase in interest has been evidenced during the past several years in the electronic and communication phases of electrical engineering as contrasted to the purely power and distribution aspects. Considerable emphasis has been placed, especially during the past year, on communication subjects in the extremely high frequency spectrum, and a number of courses have been originated especially for men directly or indirectly engaged in activities for the armed services.

In an effort to ascertain the extent to which engineering colleges are offering courses in electronics and communication, an inquiry was directed, late in June, to the heads of all of the electrical engineering departments in colleges offering accredited courses of instruction leading to a degree. These college educators were asked to indicate what courses may have been added during the past year either to the physics or to the electrical engineering department and to outline those electronic and communication courses which are now being offered.

The results of this survey indicate that one or two schools have made no important changes in their electrical engineering curriculum for several years and offer relatively few courses on electronic or communication subjects. At the other extreme is one college which is now devoting practically all of its energy to training men in electronics.

Generalizations which hold in every specific case cannot, of course, be made from the results of this survey. But so far as any generalization may be useful as indicating the present trend, the following facts are significant: (1) The majority of electrical engineering colleges are increasing their instruction in electronic and communication subjects or have done so within the past year or two. (2) Some forty or more colleges have conducted or are offering communication courses under the program of Engineering, Science and Management Defense (now War) Training program as has already been recorded in the March ELECTRONICS. For the most part these supplementary courses are given in the evening or late afternoon and usually do not carry college credits for their completion. (3) At least some of the smaller colleges appear to be facing difficulties in instruction because certain of their staff members are making other and additional contributions to this country's war effort. (4) In some of the larger and better known institutions a considerable program of research and instruction has been undertaken in addition to the usual educational activities. Naturally the majority of the activities are a direct result of the great need for adequately trained scientists and officers engaged in various branches of the war effort. Many of the activities are, of course, not suitable for publication at the present time, but in such institutions the present catalog of courses of instruction by no means tells the complete activities which are in progress.

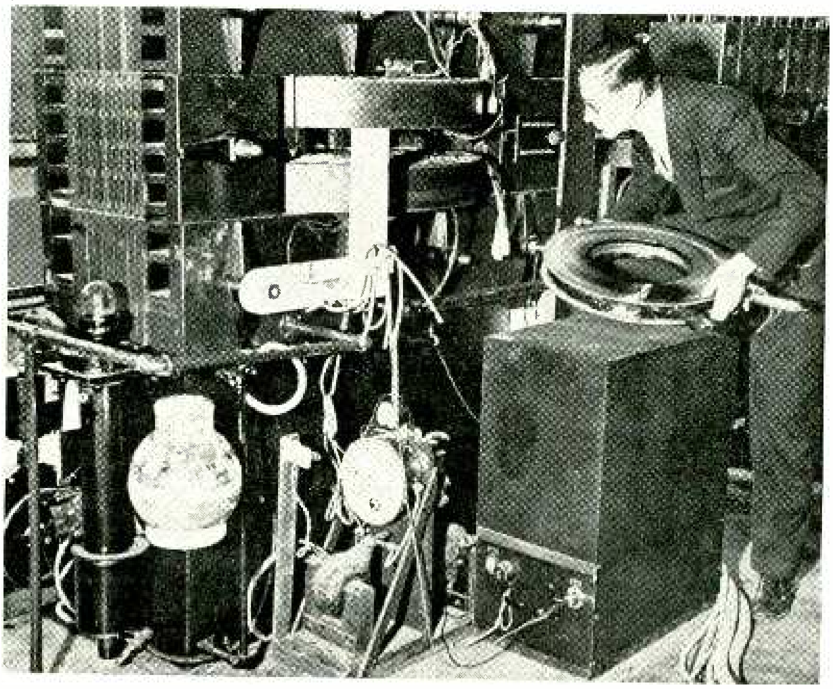
The following summary of replies which have been received up to the time of going to press, will give a general indication of the trend of affairs in electronic and communication education. The statements are arranged alphabetically according to the name of the institution providing information.

The University of Akron has expanded its curriculum to the extent of including the radio technician courses as recommended by the National Association of Broadcasters. This course is divided into basic communication and radio technician training. The first course started in February will be completed in September.

Although severely handicapped by a small electrical engineering faculty, the engineering department of the University of Arizona offers a three-unit course largely devoted to the theory of telephony. All electrical engineering students are required to take courses in electronics and in radio communication. The physics department offers a course in electronics, an introductory course on radio communication, and an accompanying radio communication laboratory course.

At the University of Arkansas a three-credit hour course in electronics in the junior year is required of all electrical engineering students. This

SUPER X-RAY



New scientific machine, 20-million volt betatron, that is a super x-ray, atom-smasher and the source of more radium-like radiations. Prof. Kerst, inventor and designer, is shown preparing to place the doughnut vacuum tube between poles of the electro-magnet (left). The vacuum tube whirls electrons to a speed within one-tenth of one percent that of light (186,000 miles per second)

course, started in September 1938, has two class periods and one three-hour laboratory period per week in the spring semester. The course covers the theory and characteristics and some of the applications of electronic devices. The three-credit hour course on the elements of communication engineering is offered as a senior elective for those students who desire to specialize in communication. A three-credit hour class and lecture course and a two-credit hour laboratory course in communication engineering, in the senior year, gives special attention to analysis of telephone and radio circuits.

In addition to the undergraduate course in electrical engineering, the Polytechnic Institute of Brooklyn has increased its graduate electrical engineering activities during the last two years to cover defense phases of the electrical engineering field. In special recognition of the present-day interest in defense training in electronics and ultrahigh frequency, the following changes are particularly noteworthy: (1) A course on advanced electrical measurement has been extended to the full year and places particular emphasis on high frequency measurements. (2) A course on fundamentals of television engineering has been added this year. (3) The course on ultrahigh frequency theory has been extended to a full year and will be given in alternate years. (4) A new course on fundamentals of electronics to be given beginning September is an advanced course suitable for physicists or engineers in the electronic industry.

Brown University reports that the only real change which has been made in their teaching of electronics is the E.S.M.W.T. course on radio communication. It is anticipated that this course will be repeated upon its completion. A very large increase in the number of undergraduate students who are taking undergraduate courses in engineering electronics has been reported.

No changes have been made in the senior and graduate courses in communication at the University of California as the present curriculum appears ample. The demand has been for additional courses at a lower level in order that non-engineering students may go into the Army with at least some understanding of the operation of radio equipment. An E.S.M.W.T. course on ultrahigh frequency technique and laboratory work has been given during the spring and summer. With the opening of the fall semester, early in October, the electrical engineering department will offer a new course in the elements of electrical circuits and machinery for non-engineering students who are headed for the Army and the Navy. This is to be a prerequisite for another new course at a similar level for non-engineering students, namely, letters and science graduates who are to enter the Signal Corps. The second new course will be in the elements of electrical communication of which the first term will be devoted to wire and the second term to radio.

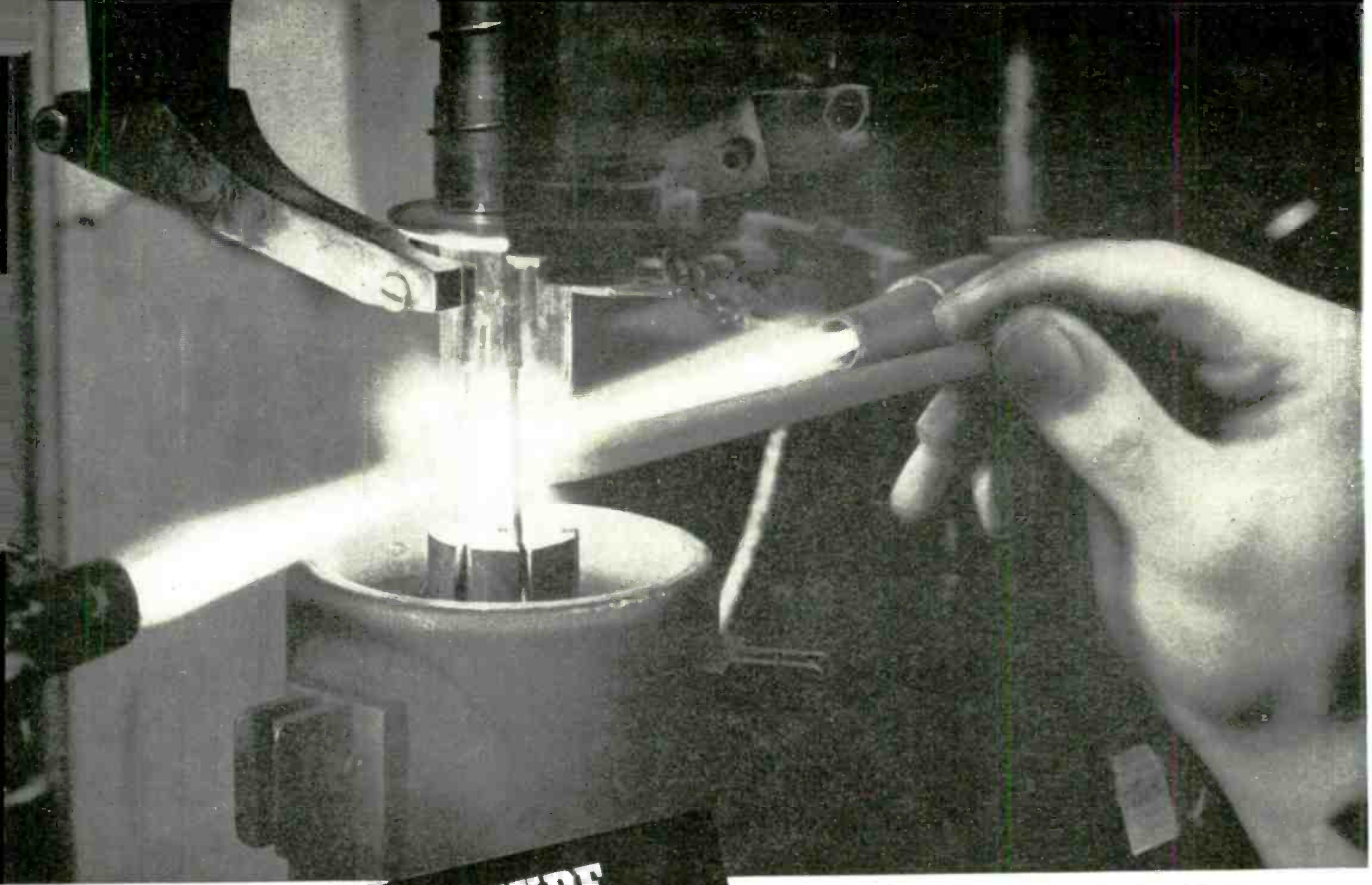
In addition to the electronic and high frequency courses regularly given at the Carnegie Institute of Technology, two new courses in ultrahigh frequency technique and in field theory have been added. These are required of all senior students who, in addition, must take courses in engineering electronics during the first term and one is communication circuits during the second term of the senior year.

At the University of Cincinnati the fundamental properties of electronic devices are studied in a course called electronics laboratory. Acoustics and sound engineering, electrical communication lectures and laboratory work, electromagnetic radiation and wave propagation and microwave technique are included in the communications courses which are available. In addition, those students who are interested may select electronics or communications problems for study in courses on advanced electrical measurements.

In addition to a number of late afternoon courses which have been given at Columbia University, several new courses have been added. A course on ultrahigh frequency technique based on the M.I.T. Conference will probably be offered again in the fall. Additional credit courses which have been recently added include the following: (1) Elements of high frequency circuits dealing with an analysis of the vacuum tube as a circuit element in radio circuits. (2) Analysis of distributed circuits dealing with long lines and circuits as applied to power, audio, radio and ultrahigh frequencies. (3) A course on electronics covering fundamentals of vacuum tubes and circuits. (4) Principles of high frequency circuits. (5) High frequency laboratory. (6) Elements of high frequency circuits and apparatus.

In the second semester of last year, Cornell University offered a five-credit hour course in ultrahigh frequency technique including laboratory work. The Department of Physics has inaugurated a special course in wave propagation with special emphasis on the application of the Maxwellian equations in ultrahigh frequency problems and a second special course in advanced electronics. Under the E.S.M.W.T. program, Cornell is supervising instruction of some 700 trainees in part-time courses in the fundamentals of radio in various localities scattered over New York State.

Duke University normally requires all electrical engineering students to take a one semester course in electronics, given by the Physics Department and a whole year course in communication given by the Electrical Engineering Department. Recently emphasis on these courses has resulted in an increase in the material at ultrahigh frequencies which trend is expected to be followed next year. College level E.S.M.W.T. courses in communication and radio engineering are also offered. During this summer a twelve-week course in communication has been given to those holding liberal arts de-



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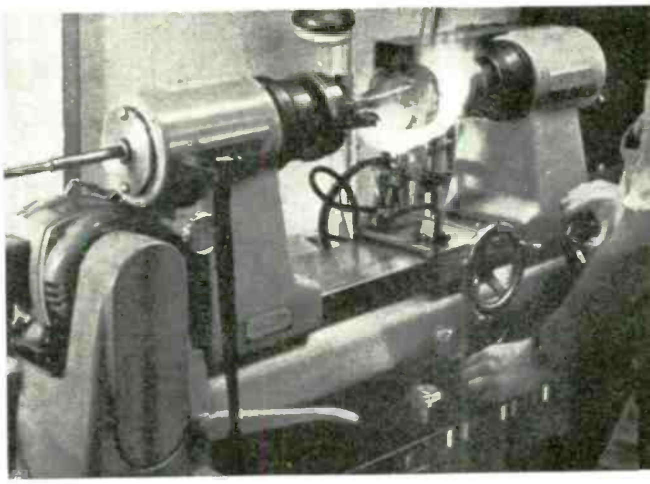
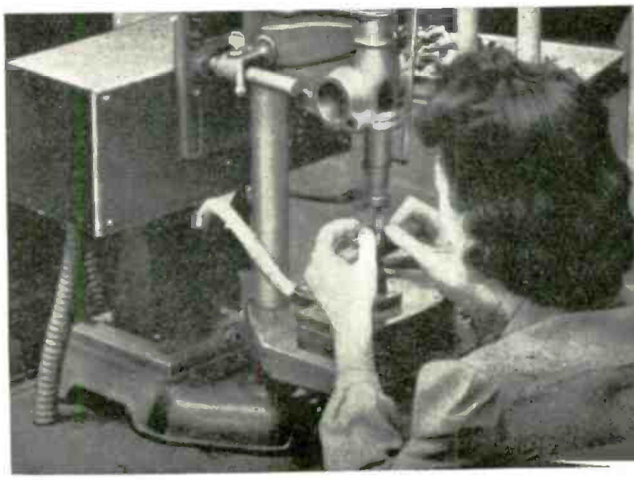


Glass bulbs are annealed after tube is fully assembled. This operation relieves stress and strain in the glass itself which may have been induced during manufacture.



Deft fingers work steadily with tiny parts which are faultlessly produced. Here plate sections are being welded together in routine production.

grees. The purpose of this course is to give sufficient background in communication to prepare graduates for those positions where highly trained engineers are now used but are not necessarily needed.

Effective this term, students at the Georgia School of Technology begin their communication option in the second half of the junior year with a three-hour course on engineering electronics. During their senior year they take courses in communication engineering, high frequency transmission, communication laboratory and telephony, during the first term, and communication engineering, high frequency measurement and communication laboratory during the second term. In addition to these courses the E.S.M.W.T. course in ultrahigh frequency technique is taught jointly by the Electrical Engineering and Physics Department to those students desiring to enter the ultrahigh frequency field. Last year 73 percent of the electrical engineering students took this communication option.

For many years Harvard University has maintained so complete a group of courses in electronics and communication engineering subjects that only recent changes can be recounted here. In these courses, which are now more readily available to undergraduate students as a result of the war, there has been a slight change in emphasis, with more stress on transient phenomena and ultrahigh frequency work.

At Harvard as in other institutions, there has been an increasing interest in the subject of electronics. To fill this demand the physics courses at Harvard have been considerably altered. New courses were offered during the summer session in order to prepare students for these courses in electronic and communication engineering. To motivate this line of education a special field of concentration in electronics has been introduced into the college outlining a direct path for entering physics through a course in electricity and magnetism, mathematics and then into the regular series of communication courses. The large increase in enrollment in the physics courses and in the summer courses indicates that classes next year promise to be at least two to three times the normal size.

A specialized war training program in electronic physics has recently been announced to fit in with the needs of the Signal Corps who will enlist junior and senior electronic physics students and electrical engineering students in the reserve corps. The subjects required in this course are a good basic training in undergraduate physics and mathematics and additional courses on electric oscillations circuit analysis, electron tubes, and electric waves.

Two changes in their regular curriculum are being made at the University of Idaho where nearly a third of the regular teaching staff in engineering has been lost to the armed forces. However, a regular course in ultra-shortwave has been added and was first offered at the beginning of the

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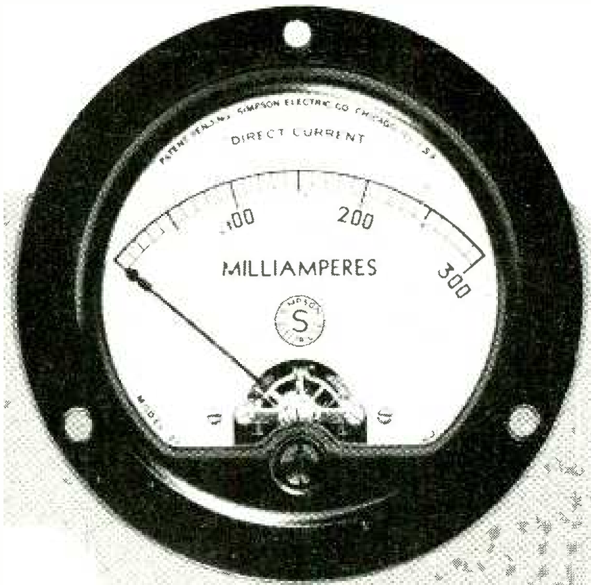

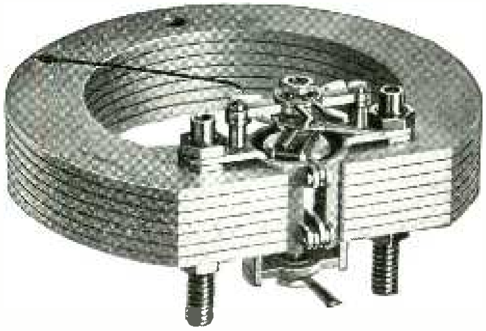

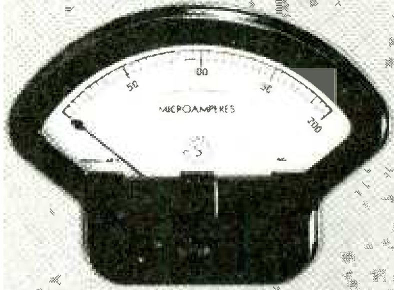

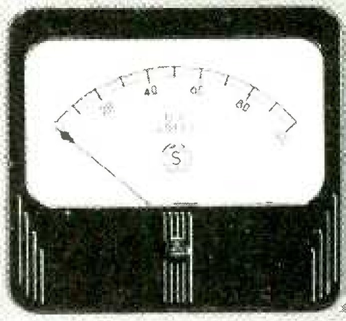

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second term, in February 1942. Communication courses regularly offered include one on vacuum tubes, elements of telephony, and radio engineering.

The subject of instruction in the electronic and communication field at the Illinois Institute of Technology includes the following topics: (1) Introduction to radio, (2) modern radio, (3) advanced radio measurements, all of which are four hours per week for ten weeks, (4) electronics, a two-hour course for fifteen weeks, (5) introduction to ultrahigh frequency technique, 4 hours per week for fifteen weeks, (6) hyper and ultrahigh frequency technique and (7) electronic and radio theory, the latter two of which are 48 hours per week for ten weeks. It is anticipated that several additional courses will be added beginning with the coming term.

Electronic and allied subjects now being offered in the Department of Electrical Engineering at Iowa State College include: (1) Electronics, (2) ultrahigh frequency technique (E.S.M.W.T. course), (3) radio engineering, (4) television engineering, (5) communication, and (6) advanced communication. Additional courses are offered when there is a sufficient demand for them.

The Department of Electrical Engineering at the State University of Iowa is giving a course of four semester hours, especially for seniors in engineering and graduate students in physics, on the subject of ultrahigh frequencies. The Department of Physics is giving two elementary courses in

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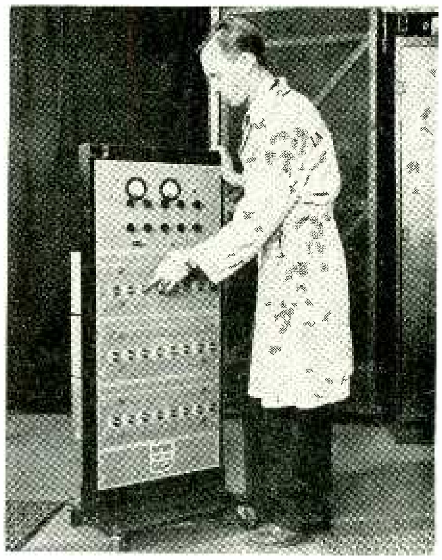
RADIO FREQUENCY TESTER



This signal generator is used for aligning the numerous circuits of all aircraft radio receivers carried aboard United Air Lines' Mainliners. E. A. Jensen, who designed the equipment, is operating the push buttons which permit the selection of any of 24 crystal controlled frequencies

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The Micro Switch assures you precise and accurate repeat operation

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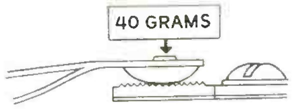


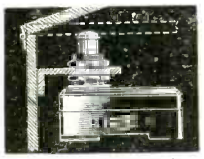
Lightning-fast contact action—

Contacts move from one position to the other in 3/1000 to 5/1000 of a second

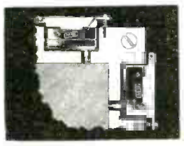
Claims of better performance are meaningless unless they are verified by actual data regarding what actually happens. The Micro Switch is accurately built to exact standards from precisely made parts. Details regarding this precision and accuracy are set forth on this page. Study the operating principle of the Micro Switch and you will understand why it will give you longer life than you will ever need...why it will operate precisely at the same point time after time...how it gives you greater contact pressure and faster contact action. The Micro Switch is listed by Underwriters' Laboratories with ratings of 1200 V.A. loads, from 125 to 600 Volts A.C.

How and For What Micro Switches Are Used

This shows an explosion proof Micro Switch used with a spray gun which automatically cuts out the entire operation of the spraying booth when the gun is shut off

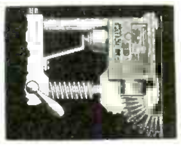


This illustration shows a Micro Switch with a pushbutton actuator being used as a safety switch in a high tension cabinet door. It is a normally open switch in which the circuit is opened as the door is opened

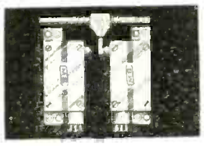


This illustration shows the use of two Micro Switches with spring type plungers to insure safe positioning of material in a punch press or a similar tool.

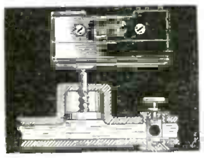
This illustration shows the Micro Switch with a spring leaf actuator serving as a break indicator as used in textile mills or paper mills.



This illustration shows a Micro Switch enclosed in a die cast housing with a synthetic rubber seal, and is being used as a lathe carriage stop.

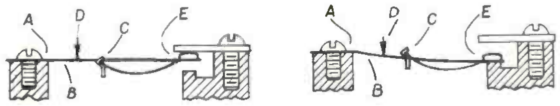


This illustration shows two steel enclosed Micro Switches which serve as overrun limit switches on a machine tool.



This illustration shows use of a Micro Switch with a spring plunger which is actuated by the pressure of a liquid in a line as the actuating medium.

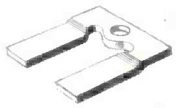
Here's the Operating Principle

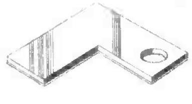


The operating principle, as illustrated here, is simple and fundamentally correct. The long member of the one piece spring "B" is supported in a cantilever at "A". The two short members of the spring and the exact shape of the V's (patented) produces a bearing of such low friction that when the plunger at "D" deforms the long tension member, the cantilever force overcomes the vertical force supplied by the two compression members and the free or contact end of the spring "E" snaps from one stop to the other with lightning-fast speed. Reverse action occurs when the deformation of the tension members of the spring by plunger "D" is removed. The cantilever force then becomes less than the vertical force supplied by the compression members.

The Micro Switch spring is made in one piece of beryllium-copper. It is held to an accurately gauged thickness of .0085" and is heat treated to provide high resistance to fatigue. Every lot is under laboratory control to insure maximum flexure life—5,000,000 operations to full overtravel for the minimum. The ends of the two compression members of the spring are especially finished to provide an extremely low friction bearing.

The short compression members of the spring pivot in the patented V-grooves of the sturdy brass anchor illustrated here. Note the special shape of these grooves. This shape, plus the specially finished edge of the compression members of the spring, reduce friction to a minimum.

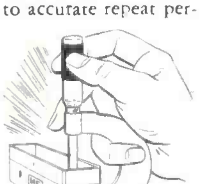




The contact end of the spring is fitted with a riveted radius type contact of 99.95% fine silver. As the plunger is actuated, this contact moves from one position to the other in 3/1000 to 5/1000 of a second with a rolling action which minimizes the effects of welding. The stationary contact is a flat inlay of 99.95% fine silver. Its large area provides maximum heat dissipation.

The operating plunger consists of a highly polished, stainless steel pin set into an accurately moulded star-shaped Bakelite head. Its size and form provide a long over-surface path to live parts, thus insuring freedom from electrical leakage. The star-shaped plunger head cannot rotate within the housing, insuring against any large variation in point of operation. The Bakelite head comes to rest against the anchor within .020" after actuation occurs, thus preventing excessive overtravel, and insuring maximum spring life.

The housing of the Micro Switch is Bakelite, moulded to high precision. The deep, box-like construction insures the rigidity necessary to accurate repeat performance for millions of operations over wide ranges of temperature. The electrical resistance of this housing (between the nearest live parts) has a minimum value of 10,000 megohms. The covers are made of vividly colored Plaskon and must meet the same precision requirements.



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Micro Switch is a trade name indicating manufacture by Micro Switch Corporation

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Branches: 43 East Ohio St., Chicago · 11 Park Place, New York City · Sales and Engineering Offices: Boston, Hartford, Los Angeles electronics, each of four semester hours of credit. These courses are designed to meet the needs of war training.

Some consolidation of courses is under way at the Kansas State College of Agriculture and Applied Science so that instruction will center around the subject of ultrahigh frequency technique as a preparation for work in aircraft warning service. Principles of electronics is given as a second term sophomore course. Courses in wire communication covering communication circuits, and in radio communication dealing with radio and electronics, are available to senior students. Both of the courses are prerequisites for the work of ultrahigh frequency technique, a new four-credit hour course which was introduced during the last year and which was outlined in a special conference held at the Massachusetts Institute of Technology last November.

Courses in communication circuits and in radio communication have been offered for several years at the University of Kansas. A new course in ultrahigh frequency engineering will be incorporated into the curriculum beginning this fall and will include laboratory work. These courses are all required in the communication option. A course on engineering electronics, which will be required of all students in electrical engineering is also being added this year.

Rearrangement of the work in electronics at the University of Louisville results in four courses now offered by this institution. These are, a course on electronics, two courses on communication engineering, and one on television. For the first three of these courses, at least, lectures and laboratory work are required.

The University of Maryland announces that they have recently introduced a required four-semester-hour course in electronics and a required six-semester-hour course in radio. A three-semester-hour course in high frequency alternating currents has been introduced as an elective course for seniors.

For many years graduate and undergraduate courses in electronics and communication subjects have been given by both the Physics and Electrical Engineering Departments at the Massachusetts Institute of Technology. The courses of instruction in these subjects which are available are too extensive to be listed here. This institution's catalog will indicate the many courses which are available for general instruction although not all matters of instruction and research are recorded.

Under recent changes which have been made in the electrical engineering curriculum, particular attention is called to the new option in electrical engineering, known as option 4, electronics application. This option recognizes the rapidly increasing use of electrical methods of measurement, control, and instrumentation of all types of engineering, as the emergence of a field of great use and importance. It pays particular attention to electro-

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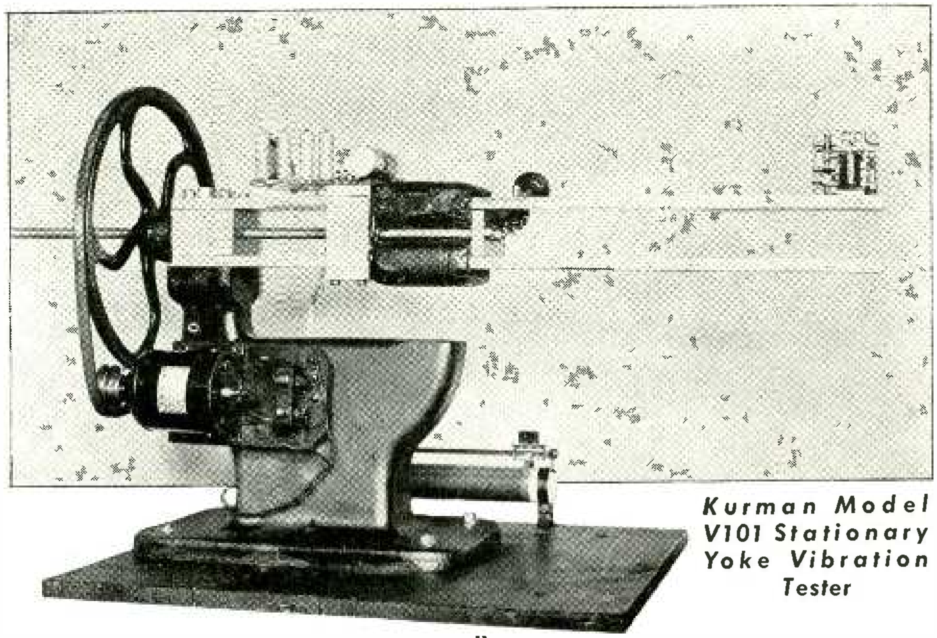

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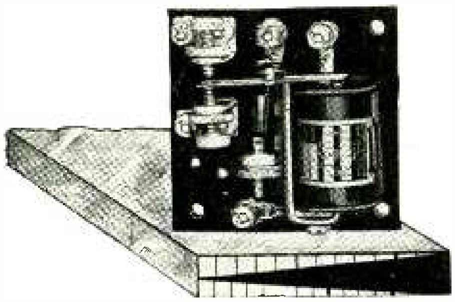

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mechanical and electro-thermal systems, principles of measurement, and electronic applications. Students may enter this option in their third year after two years of general basic foundation. It is already proving distinctly attractive to students.

Work in electronics is given by the Physics and Electrical Engineering Departments, the two being designed to be complementary. The Department of Physics offers a year's study in electronics, including both class and laboratory work emphasizing the physics of electronics and gaseous conduction of electricity and associated phenomena. Some emphasis is also placed on the electronic apparatus application, particularly of the sorts that are encountered in experimental physics. In addition, the Department of Physics offers electronics at intermediate physics grades, primarily for the electrical engineering student interested in communication.

In the Department of Electrical Engineering there is a substantial amount of work in electronics offered in both the graduate and undergraduate years. This, backed with a class and even associated laboratory treatment by all electrical engineering students, would treat electronic phenomena and the function of electronic devices as circuit elements. Further work which students not majoring in communication may select includes professional work on electronic control and measurement

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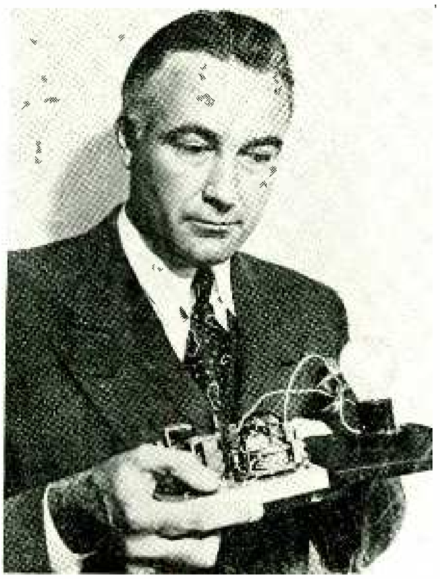
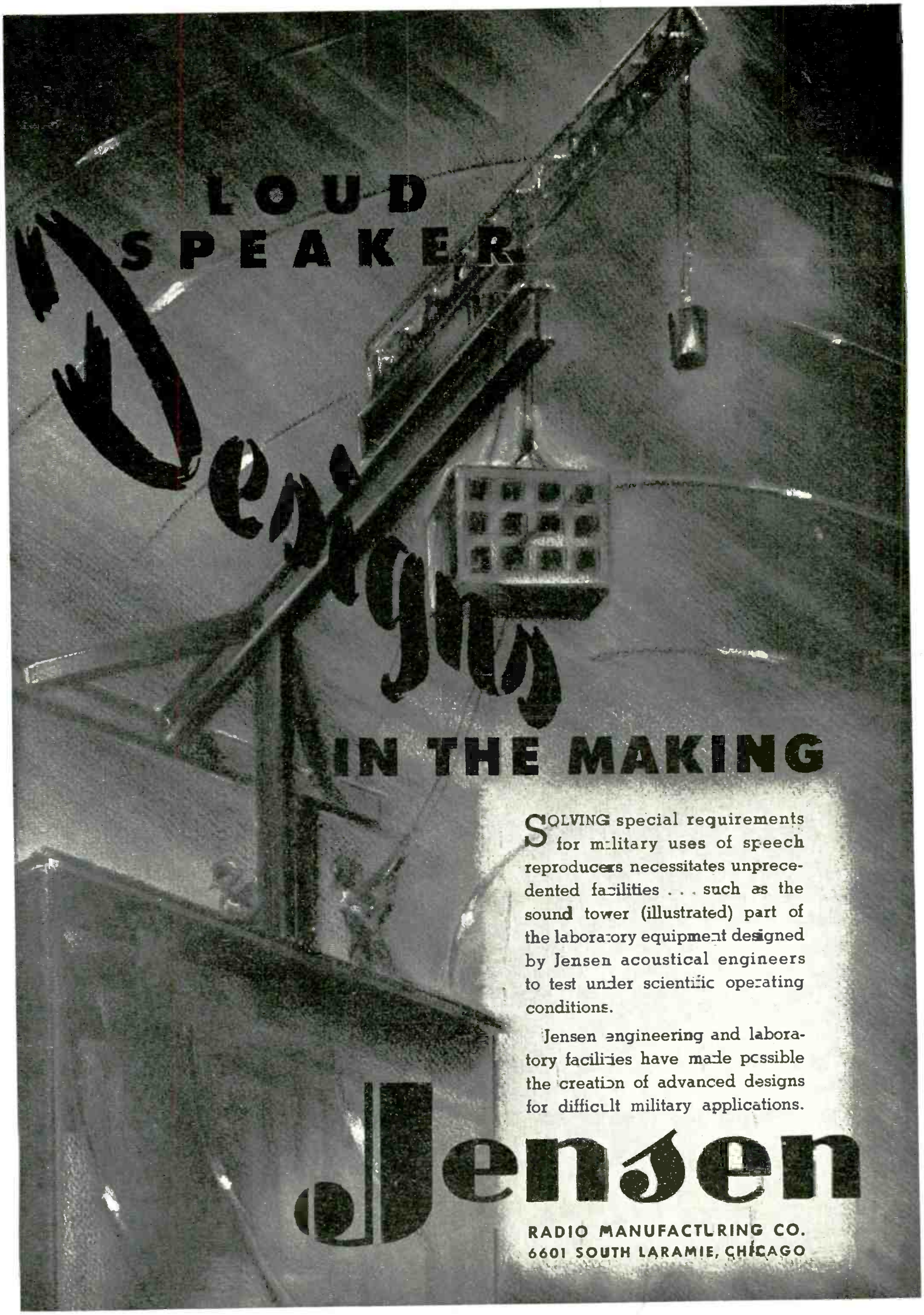
AN AID TO BLACKOUTS



In the event of a blackout this device, invented by William Sprague of Los Angeles, turns out all lights and sounds an alarm. All that is necessary to operate the device is a short interruption of service from the local power company. The momentary interruption starts the device working. The same method will turn the lights back on when the "all clear" signal is given


LOUD SPEAKER
Designs
IN THE MAKING
SOLVING special requirements for military uses of speech reproducers necessitates unprecedented facilities . . . such as the sound tower (illustrated) part of the laboratory equipment designed by Jensen acoustical engineers to test under scientific operating conditions.
Jensen engineering and laboratory facilities have made possible the creation of advanced designs for difficult military applications.
Jensen
RADIO MANUFACTURING CO.
6601 SOUTH LARAMIE, CHICAGO

with the associated laboratory; and on ultrahigh frequency technique in which a four-year work is provided, in establishing a communication foundation and giving training in the field itself. The latter subjects both include laboratory work. Together they replace and amplify the one term's work offered as an E.S.M.W.T. course during the second term of this past year, which was also offered by some other institutions throughout the country.

At the graduate level the electrical engineering department offers two years work in engineering electronics of a more advanced nature than that given to undergraduates. In addition, advanced work in any portion of the field can be undertaken as a special problem or a special laboratory course by students interested in a particular topic.

The student majoring in communication follows the first term's work in engineering electronics, including class and laboratory, in common with all other electrical engineering students. Following this they take an engineering course in electronics from the physicist's point of view. They then embark upon one and one-half year's work in the communication theory, coupled with a year's work in a communication laboratory.

At the graduate level there is offered a variety of work in communication which involves electronics to a greater or lesser extent. Among the subjects are included: (1) Advanced network theory, (2) advanced communication laboratory design to meet the needs and interest of individual students, (3) sound, (4) advanced electrical communication, (5) radio lines, antennas and propagation, and (6) a study of the patent application of electrical communication in the United States.

The Physics Department of the Michigan College of Mining and Technology offers a course in vacuum and vapor tubes and their uses in which stress is laid on uses other than those for radio receiving. The characteristics and construction of the different types of tubes, together with their circuits are studied in the classroom as well as in the laboratory. The Electrical Engineering Department offers a course in electronics and another in radio engineering.

As a result of the M.I.T. Conference on ultrahigh frequency technique, Michigan State College added two one-term courses on ultrahigh frequency technique. In addition, courses also are offered on (1) electronics, (2) communication networks, and (3) radio. During the last year the percentage of engineering students taking communication subjects increased from 50 percent to 75 percent. It is expected that all electrical enginering students will be required to take communication "for the duration."

The most important changes in the curriculum at the University of Michigan in the past year has been the inclusion of a course particularly in-

New Data on S ot Welding of Nickel, Monel nd Inconel

Result of a two year res rch program at the Welding Labor ory of the Rensselaer Polytechn Institute

Definite information on the spot we ıg of Nickel, Monel* and Inconel* was presented last Octo at the Annual Meeting, A.W.S., in Philadelphia. Reprints his paper, by Wendell F. Hess† and Albert Muller‡, are now ıilable.

The results reported include data on:

1. Recommended elding conditions for producing sou spot welds in Nickel, Monel and Inc l sheet.
2. Strength of spo elds.
3. Recommended ctrodes.
4. Control of ener input.
5. Limit of perm ible distortion, and method of mea ing it.
6. Load-distortion aracteristic curve for single-spot lap- d specimens.
7. A fast, efficient ethod for evaluating quality of spot ds made in shop.

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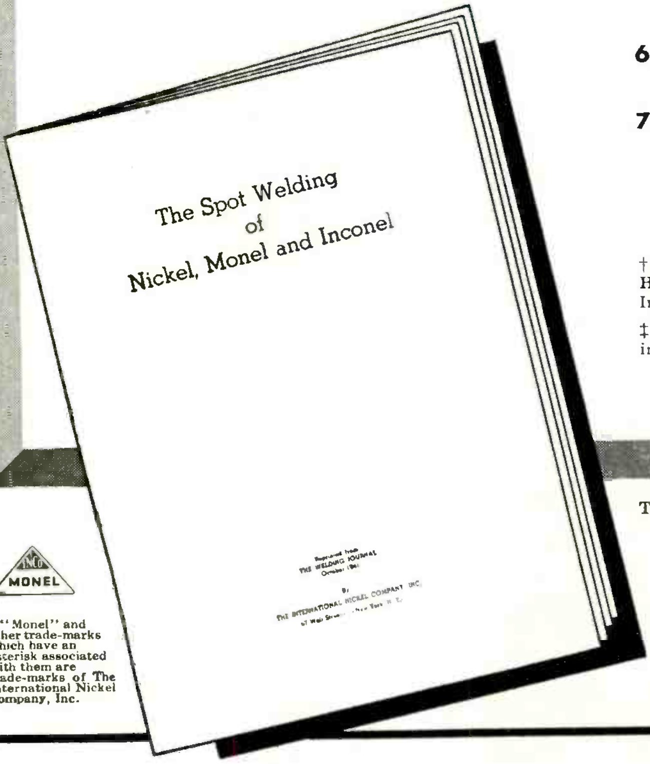
† Associate Professor of tallurgical Engineering and Head of the Welding La tory, Rensselaer Polytechnic Institute, Troy, N. Y.

‡ Research Fellow, Depar t of Metallurgical Engineering, Rensselaer Polytechn nstitute, Troy, N. Y.



MONEL

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tended to prepare men for work in the microwave or u-h-f field. This course has been introduced in the form of an extension to the standard course in radio engineering.

The courses of instruction now being offered at Michigan may be divided into five broad classifications. These are: (a) Basic courses required of all undergraduate electrical engineering students. (b) Advanced undergraduate and graduate elective courses covering fundamental electromagnetic field theory. (c) Advanced undergraduate and graduate elective courses for students specializing in communication. (d) Advanced undergraduate and graduate elective courses for students specializing in electronics. (e) Communication courses for students from other departments.

In classification (a) are courses on: (1) Principles of electricity and magnetism, (2) electronic and electron tubes, and (3) electro-mechanics.

In the classification (b) are two courses: (1) Electromagnetic field theory and (2) engineering applications of the electromagnetic field theory.

In the third classification communication students may take courses on: (1) Advanced theory of electrical circuits, (2) ultrahigh frequency technique, (3) radio communication, (4) television and (5) Heaviside operators.

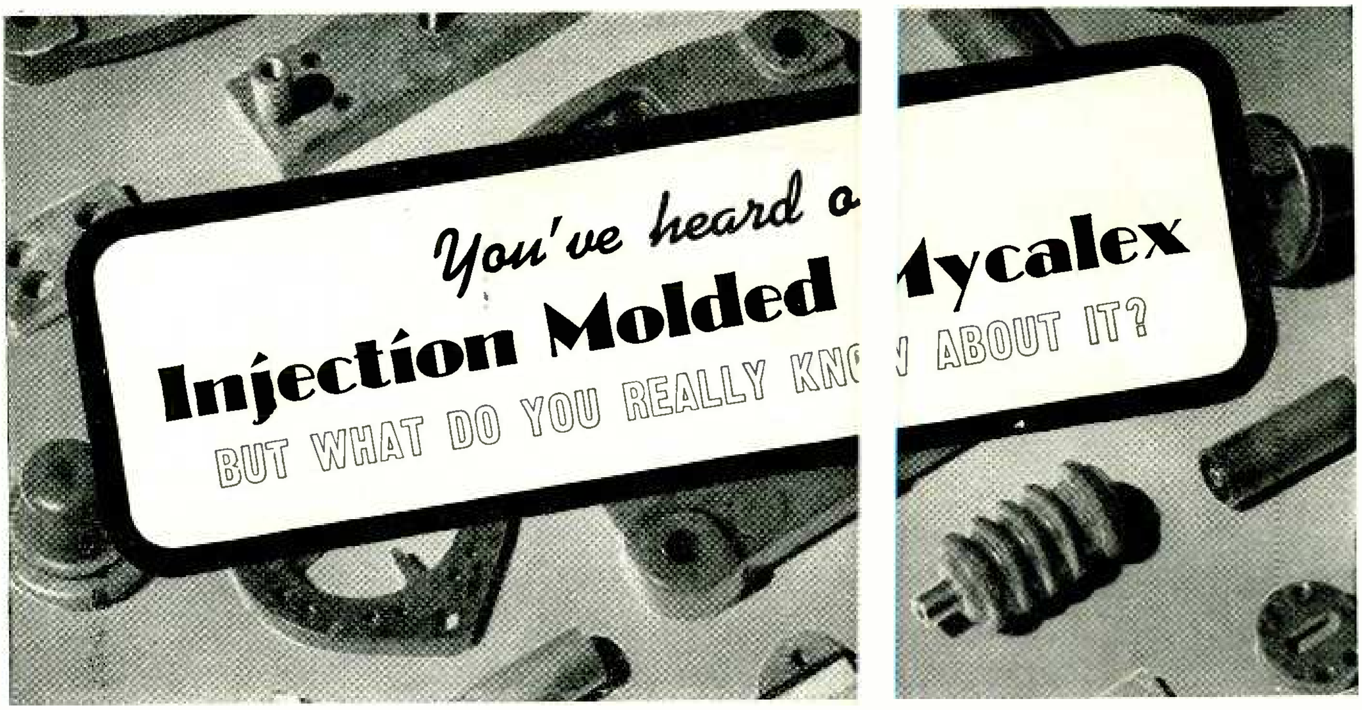
Students specializing in electronics may take: (1) Electrical communication, (2) photoelectric cells and their application, (3) theory of grid control of vacuum thermionic tubes, (4) gaseous conduction electric apparatus, (5) industrial electronics and (6) electron optics.

Communication courses for students from other departments include: (1) Elementary radio, a defense course, and (2) elements of electrical communication.

An option system is in force at the University of Minnesota and about half of the class in electrical engineering major in communication, the rest majoring in power. In the junior year all students take two terms of electronics. Those majoring in communication also take a full year of elementary communication. In the senior year the communication students are required to take two-year communication courses on radio communication and electric communication, respectively. In addition to these required courses there are several elective communication courses such as radio transmission, problems in radio receiver design, ultrahigh frequencies and sound and acoustics. An elective ultrahigh frequency technique course was started this year.

At the School of Mines and Metallurgy at the University of Missouri no additional courses have been added during the year. An introductory course of two semester hours is given in the junior year. In the senior year eight semester hours are required in radio communication and two semester hours in industrial applications of the electron tube.

The College of Engineering of the



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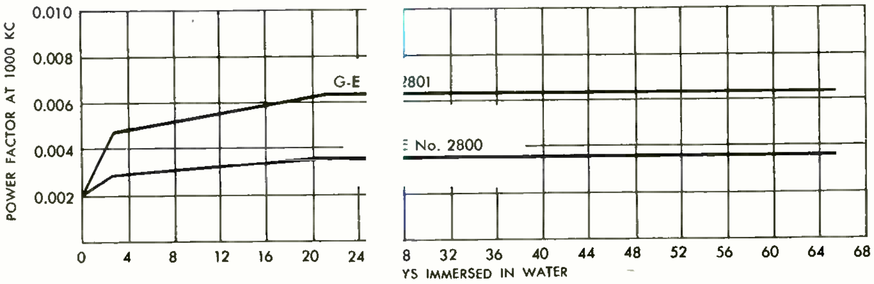
No. 2800—Low loss factor, light weight, smooth surface. Stability of power factor after prolonged immersion in water; unaffected by changing atmospheric conditions.

No. 2801—Used where mechanical strength is of primary importance.

DESIGN STANDARDS

Minimum wall thickness—$\frac{1}{16}$ in.
Minimum taper on mold walls—4°.
Minimum build-up along parting lines—0.005 in.
Minimum hole diameter—$\frac{1}{16}$ in.



EFFECT OF WATER POWER FACTOR TESTS ON 1/4 IN. THICK G-E MYCALEX

AVERAGE PROPERTY VALUES	ELECTRICAL: Dielectric Constant (1000 Kc.)	Dielectric Strength (Volts per mil. 25 C. for 0.2 in. thickness)	Arc Resistance, seconds (A.S.T.M. Method D495-38T)	MECH NICAL: Traverse Strength—modulus of rupture, lb. per sq. in.	Resistance to Impact—(Charpy—5" x 1/2"	Heat R ance—Deg. C	PHYSICAL: Density (Lb. per cu. in.)	Specific Gravity	Color	Surface
No. 2800	7.5	380	260	8,000-10,000	.10	325	06	2.95	Gray	Hard Smooth
No. 2801	8.5	325	325	10,000-13,000	.12	300	24	3.44	Gray	Very Hard Very Smooth

TOLERANCES OBTAINABLE

Nominal Dimensions (in inches)	Tolerances Above & Below Nominal Dimensions (in inches)
0.500 or less	0.002
0.500 to 2.00	0.005
2.00 or over	0.0025 per inch

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PD-52

PLASTICS DE ARTMENT
GENERAL ELECTRIC

University of Missouri has recently added a course on ultrahigh frequency analysis. Other courses regularly offered by the College include: (1) Wire communication, (2) electronics and electron tubes, (3) vacuum tube circuits and (4) high frequency circuit analysis, each of which is one semester in length. In addition a student of high standing may elect a course called "Special Problems" in which he is allowed to undertake the study of some problem of particular interest to him.

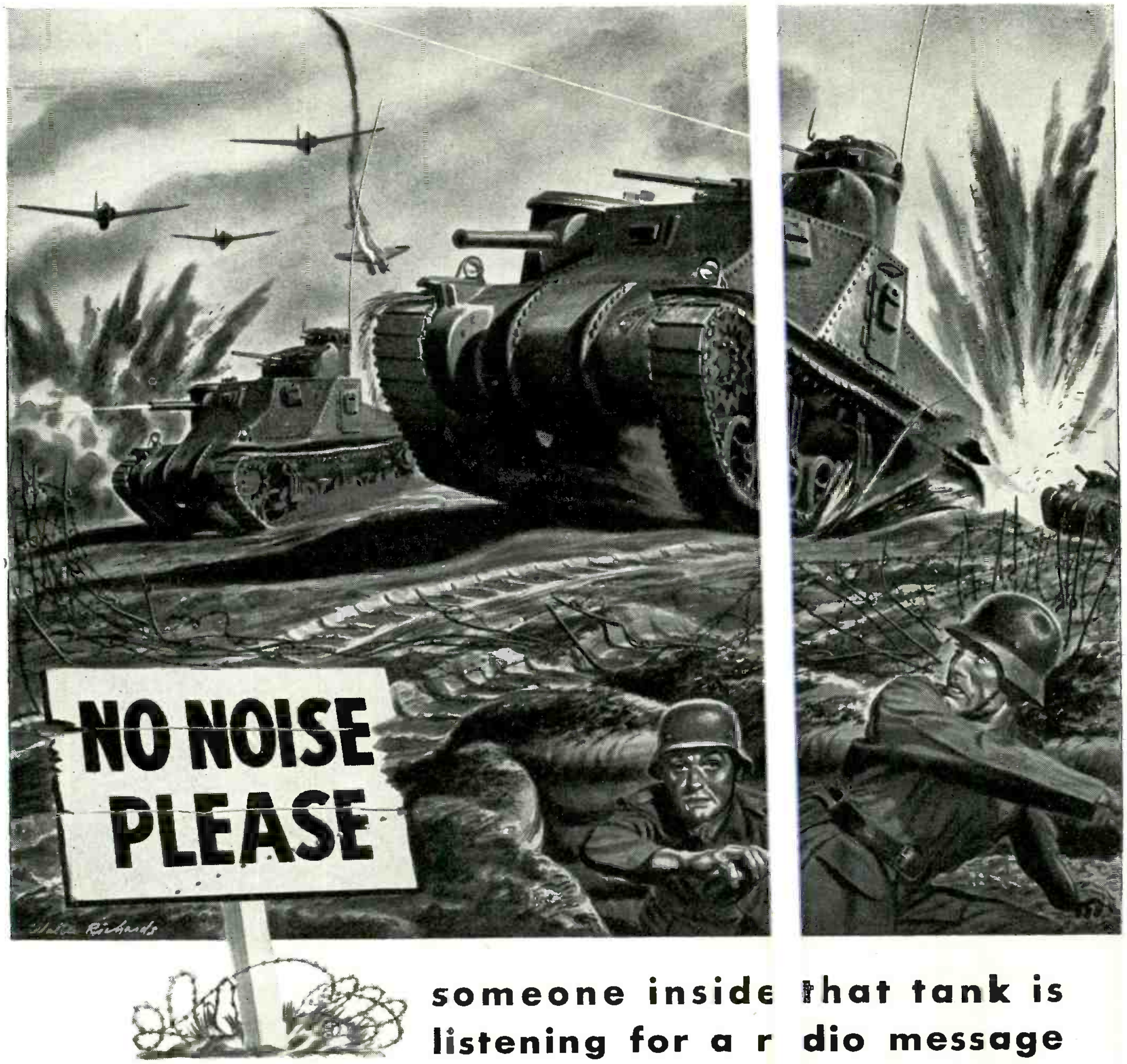
At Montana State College of the University of Montana a three-credit course of electronics has been added to that already available and radio subjects have been increased from four to seven units of credit.

No changes have been made in the regular course of instruction offered by the Electrical Engineering Department at the University of Nebraska. However, two E.S.M.W.T. courses have been added. Ultrahigh frequency technique was first given last term for senior students, but was also open to army officers during the summer. The second course, Fundamentals of Radio, is being offered as an evening course. It is anticipated that this course may be given to a group of day students this fall.

At the University of Nevada practically no changes or additions have been made in communication courses because of the difficulty of maintaining an adequate teaching staff in the face of demands by industry and the armed services for men trained in this field. Specific courses in electronics are not offered but courses in communication and in vacuum tube theory and application are offered in the Department of Physics and also in the Department of Electrical Engineering.

Two new courses, a classroom and laboratory course, have been added this year in the Department of Electrical Engineering of New York University. Other courses available in the institution include (1) Engineering electronics, (2) engineering electronic laboratory, (3) communication engineering No. 1, (4) communication engineering No. 2, (5) communication engineering laboratory, (6) radio engineering. All of the courses listed are one-term undergraduate courses.

During the past year the Newark College of Engineering has provided a number of classes in ultrahigh frequency training. Elementary courses of lectures for laboratory assistants were also given last spring, followed by a more advanced course. An extension summer course in electrical engineering has been in operation during the summer for civilian engineering aids. No striking changes have been made in the regular undergraduate courses recently. Classroom and laboratory work dealing with the characteristics and applications of electron tubes have been offered for some time. A suggested change for the coming year will be expansion and development of this material to a more extensive semester course.



someone inside that tank is listening for a r dio message

NO sound on earth can be compared to the crash and thunder of this twenty-eight ton monster roaring into action! But one man of the crew—*the radio operator*—demands "quiet!" For vital short-wave radio instructions *must* come through clear and ungarbled every time.

Yet the tank's own generator, ignition system, electrical equipment, create enough interference to "jam" even the clearest shortwave signal. The job of TOBE FILTERETTES is to suppress this Man Made Static *at the source.* And TOBE FILTERETTES are doing this job on many radio-equipped units of both the Army and Navy.

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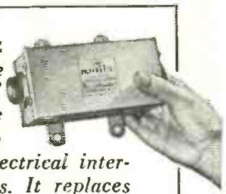
Your radio pleasure need never be marred by the blurring distortion of electrical interference. In homes, radio-equipped cars and boats, TOBE FILTERETTES will help afford enjoyable reception—clear of Man Made Static. Some day, as you tune in on long or short wave, you'll say, *"No Noise Please! Thanks to* TOBE FILTERETTES!"



he compact TOBE LTERETTE . . . *the sult of fifteen years' perience in the ppression of radio ise created by electrical interence of all kinds. It replaces lky filters and costly shielding ethods.*

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For the next term the University of North Dakota has added a three-hour course in electronics. A short E.S.M.W.T. radio technician training course, which also includes work with vacuum tubes, has been recently added.

At Norwich University, one semester of electronics is required of all electrical engineering students in the junior year. In the junior year there are two optional courses: A one-term course in principles of radio, and a second-term course in communication with particular reference to high frequency technique. A course in ultrahigh frequency technique has been added at the University of Oklahoma and as a result a previous course in electronics has been revised to fit in with the UHF course. A number of courses in communication have been added for persons desiring radio training so that they will be prepared to enter the industry or the armed services.

In the Department of Physics of Oregon State College two courses in radio are given. The first is a one-term course of lecture and laboratory work covering the elements of radio as taken up and the average text on the subject. It is offered for the benefit of students who wish to gain some knowledge of radio but who do not intend to follow it professionally. The second course, for juniors is offered as a preparation in the fundamentals in communication engineering, preceding their major professional work. In the School of Engineering, a course in ultrahigh frequency technique has been added and is taught jointly by

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EYES OF DEFENSE

These delicate instruments which serve as the eyes of American fighting planes and bomber mechanisms pass through the hands of a Westinghouse Meter Division worker for one of the final assembly operations before the final testing after which they are shipped to the U. S. Army

PERTINENT FACTS FOR ENGINEERS

ABOUT Erie Ceram icons

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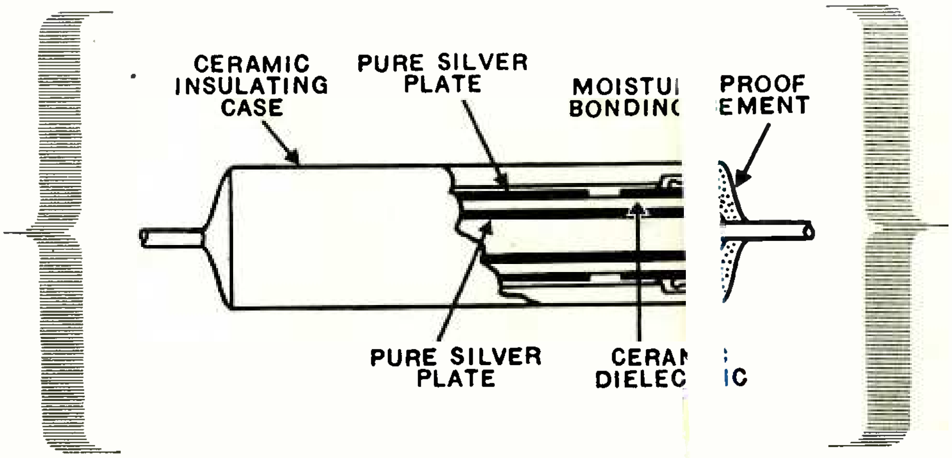

Cross section of Insulated Erie Ceramicon

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EFFECT OF HUMIDITY Increase in power factor is less than 20% and change in capacity is less than ¼ of 1% after 100 hours at 100% relative humidity at 40°C. Leakage resistance after this same test, measured at 1000 volts D.C., is over 1000 megohms.

EFFECT OF TEMPERATURE Condensers of the P120 type (maximum *positive* temperature coefficient) have a positive temperature coefficient of capacity of 120×10^{-6} per degree C. The N750 type (maximum *negative* temperature coefficient) have a r ative coefficient of 750×10^{-6} per degree C. Thes alues correspond to a rise of .36% and a drop of 2 % respectively as the temperature is raised from to 60°C. Commercial tolerance on temperature efficient is $\pm 60 \times 10^{-6}$ or ±15%, whichever is the rger.

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electrical engineering and physics departments. Courses normally offered by the electrical engineering department include: (1) Airway communication systems, (2) electrical transients, (3) electrical characteristics of transmission circuits, (4) communication engineering, (5) vacuum tubes and circuits, (6) engineering of sound systems, (7) radio engineering and (8) radio engineering practices.

Last fall the University of Pittsburgh was one of forty schools selected to give special training in ultrahigh frequency technique and took this opportunity to augment previous electronic work by the addition of the equivalent of four semester credits in ultrahigh frequency work. This recent addition has been so successful and so much in demand that it has been decided to incorporate it as a permanent part of the electrical engineering program.

Pratt Institute offers three communication and electronic courses known as: (1) Electronics, (2) electrical engineering laboratory which deals with the performance of vacuum tubes and gas tubes and rectifiers, and (3) communication engineering.

At Purdue University a number of electronic and communication courses are given under the E.S.M.W.T. program and for other governmental agencies, but in the main, these are not college credit courses. No new electronic courses have been added to the curriculum recently, since the

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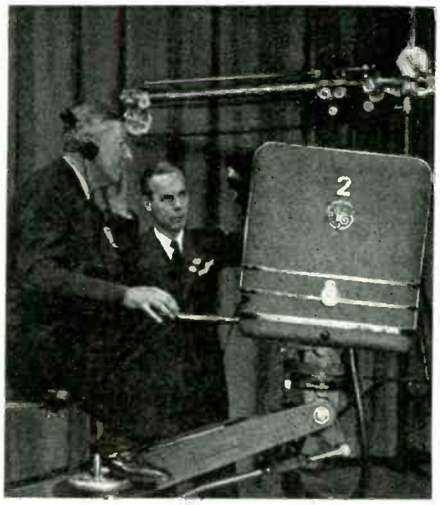
HUNT VISITS G-E TELEVISION



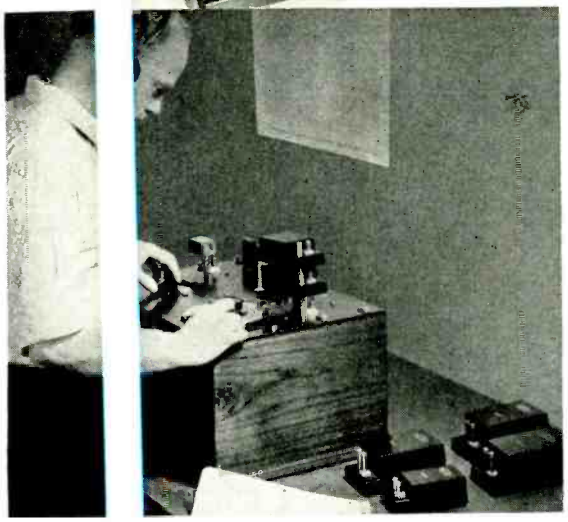
Frazier Hunt, left, famed writer and world traveler and J. G. T. Gilmour of General Electric's new television station. Mr. Hunt has conducted news broadcasts for G E over 48 stations of the Columbia Broadcasting System and selected FM stations of the American Network. Mr. Hunt visited the Schenectady plant to check up on the latest data in the expanding field of electronics

Capacitance Standards

General Radio air and mica condensers are widely used as standards of capacitance. For this reason, the General Radio Company maintains a careful supervision of the calibration standards in its own standardizing laboratory. These fixed standards cover a range of capacitance from 1000 $\mu\mu$f to 1 μf in values of 1, 2 and 5 for each decade.

These standards are kept in a temperature-controlled room. A complete intercomparison of units to detect drift of one unit relative to the others is made at least twice a year; additional measurements of selected groups are made more frequently. To detect drifts of the system as a whole, a complete set of mica standards is checked once in two years by the National Bureau of Standards, and any necessary corrections in the recorded capacitance values are made. Discrepancies are seldom as great as 0.02%. This capacitance standardization system is, therefore, internally consistent at all times to 0.02% or better.

The guaranteed accuracy of commercial standards calibrated in the General Radio laboratories is limited to 0.1% for capacitance, which is the accuracy to which the National Bureau of Standards certifies capacitance calibrations.



The techn e of comparing capacitances in our laboratories has en developed to the point where the inherent err in the comparison process are negligible in terms c e accuracy of the standards. The overall precision easurement is 0.02% for capacitance and 0.000050 f lissipation factor.

GENERAL RADIO COMPANY · Camb dge, Massachusetts

electronic program which was built up several years ago covers the field quite well.

No new courses are being offered at Rice Institute this summer except special war courses.

At South Dakota State College a three-credit course in communication circuits and a three-credit course in vacuum tubes are offered. Corresponding laboratory periods are required throughout the senior year. During the last year the amount of time spent in the communication tube and vacuum tube laboratory has been doubled. A large percentage of the students during the past year have chosen individual laboratory problems in communication in a course on "Electrical Problems". Courses in engineering physics of which electronic physics is one option are offered by the physics and electrical engineering departments.

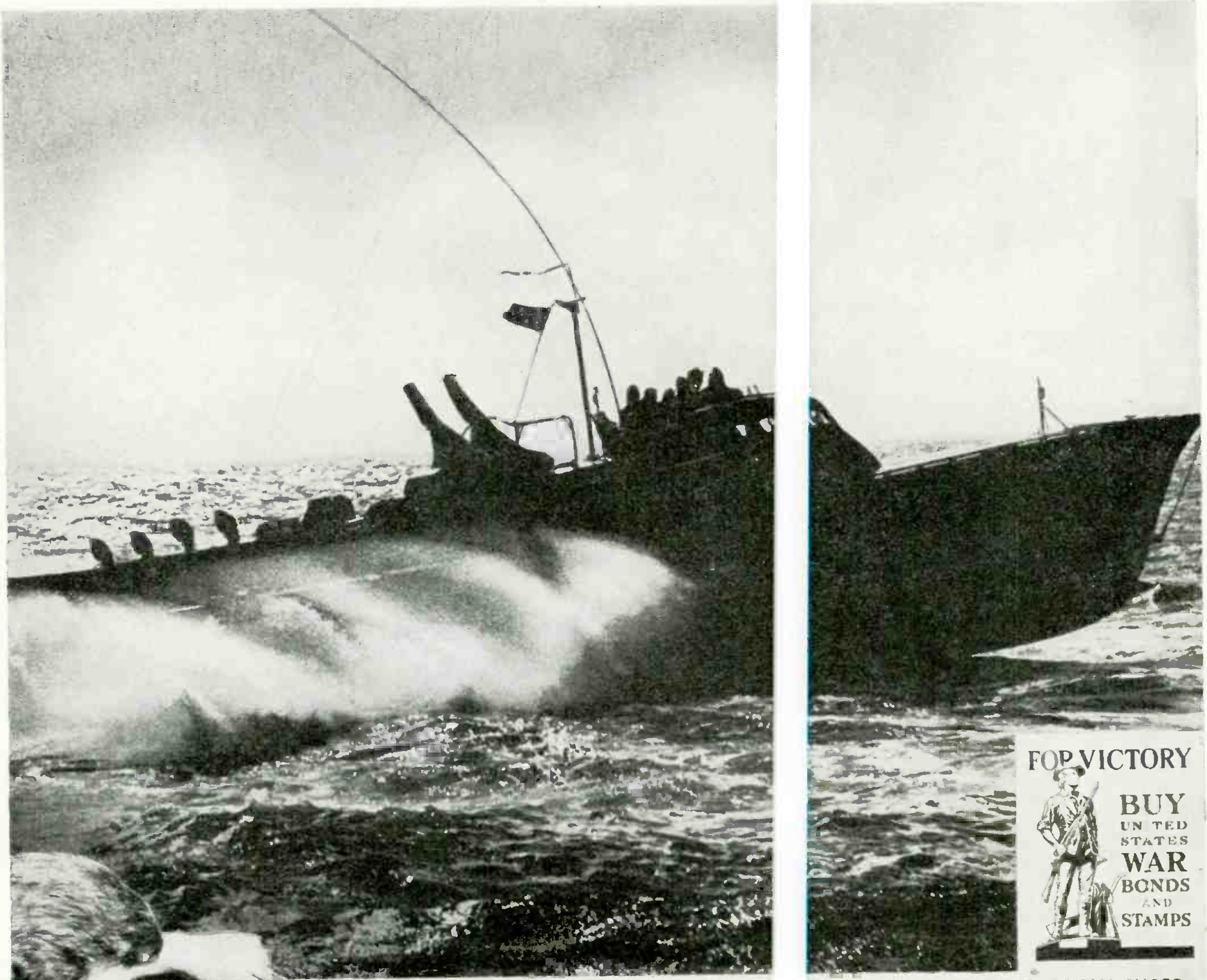
In the past Swarthmore College has offered a course in electronics, while instruction in communication was incorporated in the course on electric circuit theory. For the fall term the course in electronics will be continued in expanded form and a separate course in communication will be added. Instruction in communication will include the fundamental theory and design through an understanding of ultrahigh frequency phenomena and technique.

No recent changes have been made in course material at the University of Tennessee except the addition of an E.S.M.W.T. radio technician training course given at night. Communication courses offered at the University of Tennessee at the present time include: (1) Communication engineering, (2) telephone equipment, (3) communication transmission lines and (4) radio antennas.

There has been very little change in the general plan of communication instruction at the Agricultural and Mechanical College of Texas as courses already in operation were considered adequate. A course on ultrahigh frequency technique has been added this year. The courses now offered include: (1) Communication engineering, (2) electric transmission, (3) radio communication, (4) electron tubes, (5) communication circuits, (6) advanced communication engineering — telephony, (7) advanced communication engineering—radio and (8) ultrahigh frequency technique.

Two courses in radio are being offered at the present time in the Texas Technological College. One of these is an elementary course open to any college student, while the other is an advanced course open to senior electrical engineering students. A one-semester course in communication is required of all junior electrical students. A one-semester course in engineering electronics is required and another but shorter course on the same subject is elective. Through laboratory work additional problems in electronics may be studied by the student.

The electrical engineering department at the University of Texas offers



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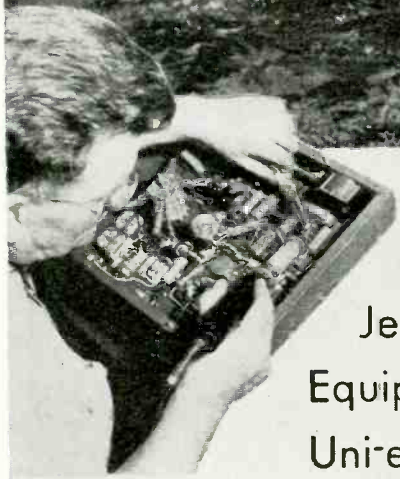

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"Design Engineer" is the modern name for the scientific descendants of men like Eli Whitney and Cyrus McCormick. America probably has more highly trained Design Engineers than the rest of the world combined.

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But U. S. Design Engineers had a late start. Enemy draughting boards were plotting today's battle machines while ours were blithely inventing and improving the thousands of mechanical aids for work and play which characterize American life.

Lost time is being made up. Research and design on weapons and machines which took years in enemy countries are compressed into weeks by sheer force of numbers of skilled minds, patriotically working without regard to hours or fatigue.

The men who put on paper the intricate mechanisms of our continuous strip steel mills, harvesting combines, gang drills and juke boxes are learning the science of war designing.

They are learning it the hard way, as all citizens of peace-minded democracies must. But we have new factories, new production machines, new ship constructions methods, new tanks, bombers and thousands of other processes and devices to prove they are doing their job well.

▶ Because American Industry had built up its great staff of mechanical engineers; because no other nation can match our skill in design engineering, the United States is winning the silent battle of Design.

But designs must be improved constantly. It is estimated that at least 12,000 members of this army of engineers are at work on improvements in military planes alone.

Into a recent improvement of an American tank went 900 pounds of blueprints, representing the work of a segment of this army of brains. Each day brings these more potent weapons closer.

Design Engineers are responsible for new planes of plywood and of steel.

To save brass and copper, some of these Design Engineers developed new uses for plastics.

▶ 700 million additional pounds of magnesium were needed, so some of them designed equipment to get it from plain seawater. The plants are at work.

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Design Engineers took the hand-fitted, laboriously-built Rolls Royce aviation engine and worked out machines and methods to produce it to closer tolerances and in amazing quantities.

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AMERICAN Business Management can work miracles of war production because American business has evolved methods through which the sum of genius can be greater than the sum of its parts.

If individual brilliance alone were the secret, airplanes would have soared over the Acropolis of Ancient Greece. There have always been bright minds.

▶ Industrial progress started when men began to share their ideas—when the inter-change of experience replaced the old habit of hoarding techniques.

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Mill Supplies
Power
Product Engineering
Textile World
Transit Journal
Wholesaler's Salesman

a series of courses in electronics and communication for undergraduates. A course in communication engineering is required of those majoring in this field. This course covers voice frequency telephony and radio communication systems. The course on ultrahigh frequency technique, originally offered as war instruction, has been permanently added to the curriculum. Graduate courses are offered in: (1) Advanced communication network analysis, (2) radio transmitters and receivers, (3) television engineering and (4) antennas and wave propagation.

During the past two years the Tulane University of Louisiana has had a gradual and steady expansion of instruction in electronics. Beginning this fall electrical engineering students are required to have three full terms of electronics, beginning in the middle of their junior year. Electronic facilities are being considerably expanded and the arts and science students majoring in physics will be required to take courses in electronics offered by the electrical engineering department. A course in electric transmission is required in the second semester of the senior year and approximately one-third of the time is devoted to wire communication systems.

At the Virginia Military Institute no courses have been added or renamed, but the subject matter has been changed to place greater emphasis on electronics. A conservative estimate places this increase at three semester hours.

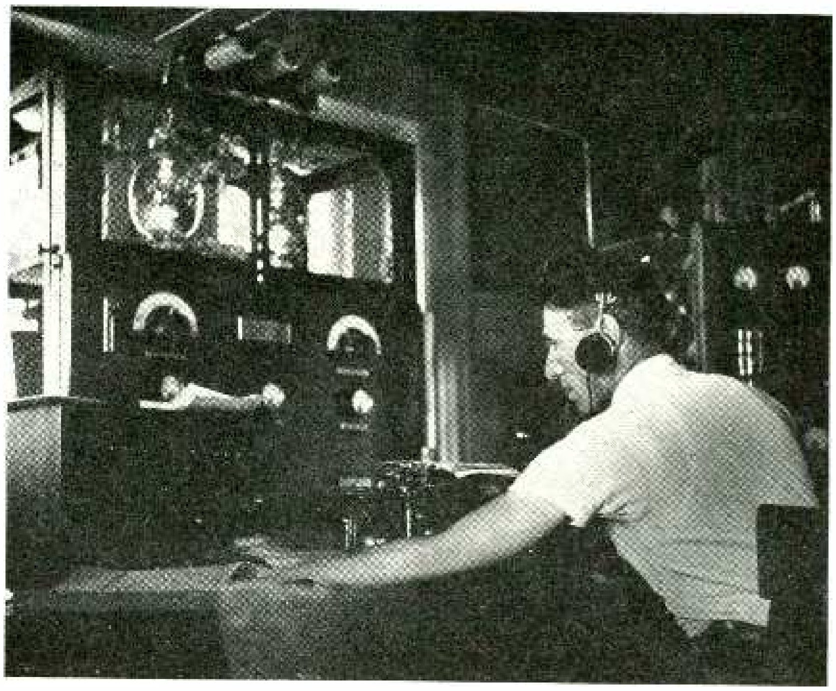
Existing courses are believed to be adequate at Virginia Polytechnic Institute so that no radical changes have been made recently. All electrical engineering students take a basic course in the theory of electronics, while those specializing in communication, may take courses in communication and radio engineering. All of the courses include laboratory as well as classroom instruction. At the present time a course in ultrahigh frequency technique is being offered for junior officers in the Navy. It is anticipated that the material of this course will be retained for the regular engineering students.

No new courses in electronics or communication are being offered at the University of Virginia. Classroom lectures are offered on: (1) Electronics, (2) advanced electronics, (3) electrical communication, (4) communication fundamentals, and (5) radio frequency measurement. Laboratory work in communication and radio laboratories is also offered.

The electrical engineering department of the University of Washington is now devoting practically all of its energy to training men in electronics. The students still receive their basic studies in alternating and direct current and regular work in transients. Electronics replaces power work for advanced study. In addition to the courses in vacuum tubes, radio and transmission lines and antennas, which have been offered for some time, two courses in ultrahigh frequency technique are now being given for the coming year. Fully 95 percent of the students will take all of the electronic courses.

Yale University offers three new courses relating to electronics and communications: electrical communication and elements of radio engineering for non-electrical students and ultrahigh frequencies for electrical engineering seniors.

HISTORIC RADIO SITE



Shown here is a radio operator at Cabot Tower, St. John's, Newfoundland. This is the site where Marconi received his first radio message in 1901

It will open . . . of course!

Because it has been folded properly. Because it has been made with care. Because it has been inspected with even greater care.

And because it has been stored in a special air conditioned room—with exact temperature and humidity control—to protect the silk fabric against mildew or other climatic damage.

Ordinary air conditioning . . . the kind of air conditioning you've known in the past . . . wouldn't do for a job like this. *More precise* . . . and *more flexible* equipment . . . the air con tioning of the future . . . had to developed.

General Electric has been specia zing in meeting the difficult conditioning problems created America's war effort. Air conditioni to preserve materials . . . to impro the operation of machinery . . . make it easier for men to work bett

When final Victory is won, ma valuable lessons learned in fighti the Battle of Production will turned to the uses of peace.

More people will be able to enjoy air conditioning in homes, offices and other places . . . because it will be less expensive, more compact. And it will be vastly improved air conditioning . . . with accurate control of *humidity* as well as temperature. *Required climates* will be reproduced at will.

When the time comes to supply the air conditioning needs of the post-war world, General Electric will be ready. General Electric Co., Air Conditioning and Commercial Refrigeration Department, Bloomfield, N.J.

Air Con itioning by

GEN RAL ELECTRIC

NEWS OF THE INDUSTRY

War Department controls Alaska communication system. National Patents Planning Commission headed by Dr. Charles F. Kettering. Additional uses of quartz crystals permitted by WPB

Communication Control

BOARD OF WAR COMMUNICATIONS has granted to the War Department control of all communications in Alaska except those operated by the Navy. Some 700 radio stations come under this order; which gives the Army complete control of interior communications. Navy has operated the coastal stations; Army has operated the major wire communications systems to and from Alaska.

BWC has also granted FCC authority to remove all apparatus and equipment of every amateur radio station in Puerto Rico and the Virgin Islands. Furthermore all apparatus not licensed by the Commission is to be removed. All such apparatus will be impounded by the Commission.

Patent Planning Commission

TO MAKE A THOROUGH study of the present patent system, to determine whether or not the present laws should be revised, and whether best use is being made of patents now granted by the U. S. Patent Office, a National Patents Planning Commission has been set up by the President. Dr. Charles F. Kettering, vice-president of General Motors in charge of research is the head of this commission; Executive Director is Dr. A. A. Potter, Dean of Engineering of Purdue University. Other members are Edward F. McGrady, vice-president in charge of labor relations, RCA; and Owen D. Young, Chairman of the Board, General Electric Company.

War Production Board

ADDITIONAL PERMITTED USES of quartz crystals have been announced as follows:

Replacements of defective, cracked or broken radio oscillators and filters and optical parts in instruments directly used for war, public health, welfare or security.

Radio oscillators and filters for use in radio systems owned by foreign governments or for commercial airlines operating in foreign countries.

Under the terms of the order, purchasers of quartz crystals or parts containing them must file a certificate that the use of the crystals will conform to the provisions of the order. This action removes the requirement for a certificate if the purchaser is a U. S. Agency or a foreign governmental agency.

HIGHER PREFERENCE RATINGS to enable communications companies to obtain copper necessary for operation, construction, maintenance and repair have been granted. The action was taken in amendments to Orders P-129 and P-130.

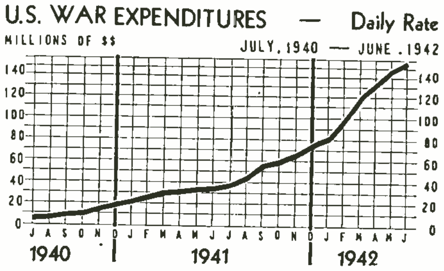
P-129 raises the rating for telephone, telegraph, cable and radio companies for copper from A-3 to A-1-j. Copper order M-9-a restricts deliveries of copper to A-1-k or higher and today's action enables these communications companies to obtain materials in conformity with that order.

P-130 gives a similar rating for deliveries of copper necessary for operating construction by telephone companies, such as connection of subscribers, changes in central office equipment, and the like.

The A-3 rating continues in effect for supplies other than copper.

Non-radiating Radios

CRAFT OF THE BRITISH Royal Navy are equipped with portable radio sets for ships' crews which do not give away the ships' position to the enemy. The sets are shielded and therefore do not radiate. The manufacturers of these sets made several modifications in a standard portable radio, giving it an exceptionally strong cabinet and fitting the chassis so the set would be able to stand up under hard usage. No storage battery is necessary, and the B-battery gives 240 hours' service. Fresh batteries can be supplied at the rate of 1,000 a week, and 10,000 replacement tubes have been sent out in the last twelve months. The Navy has 15,000 of these sets. RAF has 5,000 and the Army has 8,000.



Personnel

R. C. COSGROVE, vice-president and general manager of the manufacturing division of The Crosley Corporation, has been re-elected for a three-year period as director of the Radio Manufacturers' Association.

V. H. FRAENCKEL will have charge of the co-ordination of commercial engineering of all product lines of the General Electric Radio, Television and Electronics Department. G. F. Metcalf who had charge of this work before, is now Lt. Col., in the Signal Corps.

THE KELLOGG SWITCHBOARD and Supply Company announce the appointment of Robert M. Kalb as Chief Engineer of the Company. Mr. Kalb was at one time an instructor in the electrical engineering laboratory at Ohio State University, and was associated with Bell Telephone Labs for thirteen years doing research work on transmission and circuit problems.

THE NEW ADVERTISING manager for Sylvania Electric Products Inc., (formerly Hygrade Sylvania) radio tube division is H. C. L. Johnson, who has been assistant advertising manager.

Moves

HUGH H. EBY, INC., announces the removal of executive and sales offices to 18 West Chelten Ave., Philadelphia, Pa. The engineering, production, and purchasing department offices will continue to be located at the plant address at 4700 Stenton Ave., Philadelphia.

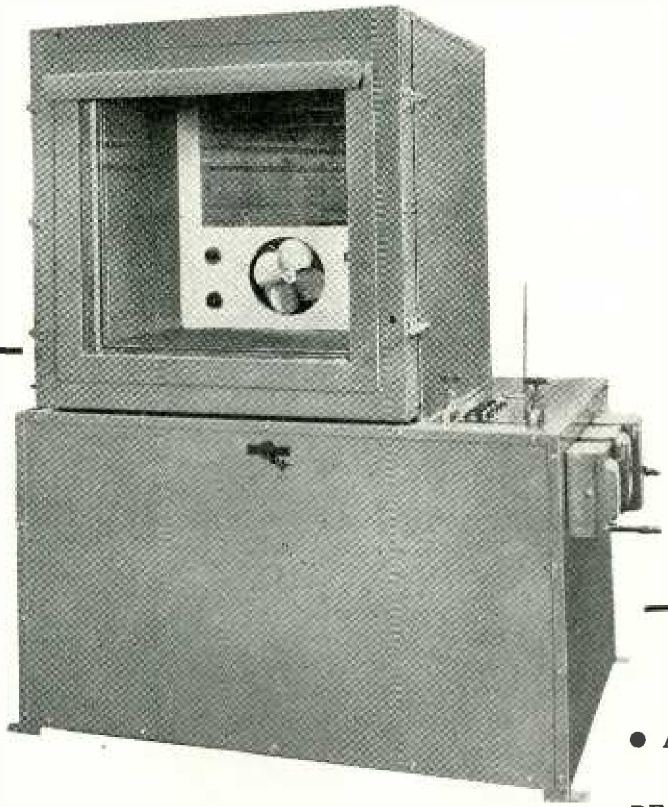
THE ENTIRE MANUFACTURING plant of the x-ray division of the Westinghouse Electric & Mfg. Co. has been moved from Long Island City, N. Y., to Baltimore, Md. The administrative offices were transferred early this year.

FOR THE PURPOSE OF assisting U. S. Government Departments with respect to radio communication equipment being manufactured under government contracts, the Jefferson-Travis Radio Mfg. Corp., announces the opening of a branch office in Washington, D. C., at 1026 17th St., N. W. Mr. F. Lee Hardesty resigned his position in the radio procurement division of the British Air Commission to accept a post in charge of this new office.

A NEW PLANT AT Providence, R. I., has been placed in operation by Cornell-Dubilier Electric Corp. The new plant

HIGH ALTITUDE . . . . .
TEST and CALIBRATIOI CHAMBERS
FOR AIRCRAFT AND ELECTROI C INSTRUMENTS

POSITIVE AUTOMATIC MECHANICAL MEANS PROVI :



- LO TEMPERATURE TO -100°F
- HIC TEMPERATURE +158°F
- TE ERATURES THERMOSTATIC- AL HELD WITHIN 2°F
- AL 'UDE 70,000 FEET
- INT NAL PRESSURES TO 30 lbs./ sq. i .
- RAT OF CLIMB TO 10,000 Ft./Min.
- HUI)ITIES AUT IATIC OR MANUAL CONTROL

- Standard Models are available in two sizes of clear visible test space:

  MR 966 V—24 in. high by 24 in. wide by 16" front to back.

  MR 965 V—12 in. high by 12 in. wide by 12" front to back.

Temperature Ranges for standard models are from +158°Fahr. to -40°F, -76°F, OR -100°F.

- Accessorie ncluded on special order:

RECORDING YROMETERS
RECORDING ACUUM GAGES
MANOMETE
VIBRATION STERS
RATE OF CL B INSTRUMENTS

- Engineerin epartment will gladly co-operate with u on any high altitude test or calibr n problem or on special size or purp chambers.

MOBILE REFRIGERA ION INC.
630—5th AVENUE NEW YORK, N. Y.

is slated to process raw materials for the C-D plants in South Plainfield, N. J. and New Bedford, Mass. The new plant will employ from 800 to 1000 employees, boosting the company's total personnel to well over 3000.

THE SIZE OF PRESTO Recording Corp. plant is being doubled to aid the engineering department in making more efficient use of shop facilities and thus increase output of military equipment.

Jobs

THE UNITED STATES NAVY is in need of civil junior, assistant and associate radio engineers; assistant and associate physicists and physicists for laboratory research and development work in conjunction with the war effort program. Salaries range from $2000 to $3800 per annum. Information or application forms may be had from The Director, U. S. Navy Radio and Sound Laboratory, San Diego, Cal.

THE LEXINGTON SIGNAL DEPOT is engaged in a training program in which several thousand civilian employees, radio mechanics and radio engineers, will be trained in the maintenance of the radio equipment used by the Signal Corps. The Depot is in urgent need of competent instructors. The eligibility of an applicant is determined by his training and experience and competitive Civil Service examinations are not given. The appointments are classified as War Department Indefinite type jobs which means that the employee does not obtain a permanent Civil Service status, nor has he the

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WITH THE RED ARMY

Walter Kerr, war correspondent, writing in the New York Herald Tribune, July 2 said, "This cavalry corps (2nd Guards Cavalry Corps) has little American field equipment, but I noticed that the field telephones used . . . were manufactured by the Connecticut Telephone and Electric Corporation. The sets, of EE-8-A type, were neatly packed in leather cases. General Krukov remarked: 'They're good; they're excellent.' "

right to expect that this work will be continued after the war has ended. Only persons in a deferred draft classification are considered for employment. Women are just as eligible as men. Salaries range from $2000 for junior instructors to $3,800 for radio electrical instructors, P-4. All communications should be addressed to Captain W. Gayle Starnes, O.I.C., Civilian Training, Lexington Signal Depot, Lexington, Kentucky.

In 1939 the Westinghouse Electric & Manufacturing Company founded at Mellon Institute an Industrial Fellowship to conduct investigational work on plastics, especially synthetic resins, for constructional purposes. Since then the Fellowship staff has been carrying on research on new raw materials, new molded products, and new processing methods, evaluating them for commercial application. In these activities particular emphasis has been placed on the employment of plastics in those fields where the uses of resinous materials are unknown, limited, or undeveloped.

Following the completion of this basic research program two specialists, H. Ross Strohecker and William B. Johnston, will conduct the subsequent investigational and developmental work of the Fellowship. Mr. Strohecker will give attention to the physical technology involved and Mr. Johnston will perfect the chemical processing included in the comprehensive project. These plasticians will have the direct and constant cooperation of experts in the Westinghouse organization.

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SHAKE TEST FOR RADIO

This is United Air Lines' newly-designed vibration generator for testing aircraft radio equipment under conditions considerably in excess of those encountered in flight. H. N. Wilcox, who developed the device, is putting a radio receiver through a typical test. An air-operated generating unit (below) actuates the test table to which the radio set is attached (above)

Welding Controls

(*Continued from page* 58)

buttons. These conducting and non-conducting buttons pass by a set of contact brushes at the rate of one button per half cycle, or one button per cycle, depending upon the motor gear box gear ratio. The brushes render the firing tubes conductive in accordance with the timing pattern set up on the motor-driven chain. (By means of auxiliary link contacts and auxiliary brushes, the timing may be initiated at a definite point on the timing chain to provide special timing patterns. Any special timing pattern can be provided by full electronic control, although there are cases where the additional complication and expense may not be justified, therefore making the chain type timer preferable.

Automatic Heat Adjusting Controls

The preceding discussion embraces a variety of timing controls and heat controls which are required for the several methods of resistance welding. Although such controls perform their functions with precision and dependability, the quality of the weld also depends on the proper control of other factors. Among these are the design and surface condition of the work, pressure applied to the work and variation in welding current magnitude caused either by changes in welder impedance, welder power factor or power supply voltage. Of these, the variation in welding current is strictly of an electrical nature; in many applications control of the welding current requires further diversification of electronic control. This refers to electronic controls classified as voltage compensators, voltage regulating compensators, and current regulating compensators.

These controls utilize the advantages offered by heat control of welding current by the phase shift method previously explained, whereby ignitrons are operated at a definite instant during each half cycle. This is done by controlling the angle of the peaked triggering voltage applied to the grids of the firing thyratrons. Referring to Fig. 4, the normal welder current is represented by the solid voltage and current waveforms while a low welding current condition is represented by the dotted waveform. Since the heating effect of the welding current varies as the rms values, the reduction in heat is considerably greater than the reduction in current. This reduction in welding current may be caused by several factors but, in any case, effective value of welding current may be restored by advancing the firing point to provide the current wave shown by the dashed waveform.

The purpose of a voltage compensator is to advance, automatically but arbitrarily, the firing point a definite angle for a given reduction in power supply voltage. Proper coordination of the relation between power-supply voltage and firing angle provides a very economical way of compensating for power-supply voltage variations but, obviously, this depends on proper coordination over the entire heat control range and for different power-factor loads. A voltage regulating compensator for resistance welders regulates the value of the voltage applied to the primary of the welder. Since the purpose of electronic welding controls is to maintain a predetermined value of welding current, a current regulating compensator is considered advantageous because it responds to all variable factors affecting the current magnitude.

Voltage compensators, voltage regulating compensators, and current regulating compensators are similar in their methods of operation in that they control the firing angle of ignitrons in accordance with an indication that the welding current is lower or higher than the heat control setting. Controls differ in the means of providing welding current indication and the method of applying this indication as a phase controlling element for the grids of the firing tubes. The operation of a voltage regulating compensator for resistance welding will be used as a typical example for explaining the operation of such controls.

Referring to Fig. 5, showing the schematic circuit diagram of a spot welding control and an auxiliary voltage regulating compensator control, it will be observed that one component of the auxiliary control consists of a pair of phase-controlled thyratrons, tubes 5A and 6A, operating a dummy load continuously. This dummy load consists essentially of a series reactor and resistor with a power-factor the same as the welder. The peaked triggering voltages from T_2, for phase controlling the thyratrons energizing the dummy load, are in phase with the peaked triggering voltages applied to the firing tubes of the main welder control. Therefore, the same effective value of phase-controlled voltage is applied to the dummy load and to the welder but the welder is energized intermittently in accordance with the spot welding demands.

The effective voltage existing across the dummy load resistors is rectified by tube 2. This d-c voltage across C_2 is compared with the d-c voltage across C_1 obtained from a portion of the secondary voltage of a constant-voltage type transformer, T_4, according to the heat control setting of P_1 and rectified by tube 1. The voltage across C_1 is used as the standard for reference. These voltages are compared by connecting them in series opposition such that the regulated d-c voltage across C_1 tends to make the grid of tubes 3 and 4 positive, while the unregulated d-c voltage across C_2 tends to make the grids of these tubes negative. An a-c grid voltage obtained from T_6, and lagging the anode voltage of tubes 3 and 4 approximately 90 degrees, is applied in series with the voltages of C_1 and C_2 in the grid circuits of these tubes. Therefore, tubes 3 and 4 are rendered conductive at instants during the positive half cycles of their anode voltages depending upon the adjustment of P_1 and the difference in voltage between the regulated and unregulated d-c components of grid voltages. The anode currents of tubes 3 and 4 flowing through the d-c winding of a saturable reactor *SR*, control the a-c impedance of the winding *SR-AC* which is connected in the phase-shifting circuit controlling the firing angle of the firing tubes 5 and 6 and the dummy load control tubes 5A and 6A. For a given value of power-supply voltage the stable firing angle of tubes 5A and 6A (and consequently firing angle adjustments for tubes 5 and 6) is determined by the heat control setting of P_1.

If the power-supply voltage decreases, the d-c voltage across C_2 decreases, advancing the conduction angle of tubes 3 and 4; this decreases the impedance of the a-c winding of the saturable reactor and thereby advances the firing angle of the tubes 5A and 6A so that the normal current is applied to the dummy load in spite of the reduction in power-supply voltage.

An increase in power-supply voltage produces the opposite effect on the saturable reactor and retards the firing angle of tubes 5A and 6A. As power supply voltage fluctuations occur, the firing angle adjustment of the welding control power tubes is advanced and retarded automatically to insure that the correct phase-controller power-supply voltage will be applied to the primary of the welding transformer. The voltage regulating compensator thus also responds to reduction in power-supply voltage caused by the welder with which it is directly associated.

A current regulating compensator operates as the name implies. It regulates the primary current of the welding transformer. The basic control element is a tungsten filament tube excited from a current transformer connected in the line. This control is designed to maintain a constant value of welding current and the actual value that goes to the welding transformer is determined

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KINE-THEODOLITE OPERATORS

A kine-theodolite is a combination of camera and theodolite that photographs a target or a shell burst and the angle of the target to the shell burst at that instant. The instruments are erected at each end of a long base and the shutters of the camera are operated electrically from a center control post or the gun post. The Auxiliary Territorial Service now employ girls to test and check the accuracy of gun fire by the ratio of the current transformer, which must be provided with a means of easily changing the effective ratio.

Such a regulator would be comparatively simple if the current flowed continuously. However, welding current occurs intermittently and some means must be used to take care of the regulator when no current is flowing. If this were not done, the regulator would advance the phase the full amount during the "off time" and the first half cycle would be entirely too large. To overcome this difficulty, the filament of the current regulator tube is heated by a separate source during the "off-time" and switched to the current transformer when current starts to flow. This means the first cycle or two may not be correct, but will be nearly so; by limiting the use of this control to long spots, this starting error causes no trouble.

To accomplish required switching typical current regulators use a relay energized by the current transformer or by the welding control. The limitation put on these controls at present is that the length of spot should be at least 15 cycles and the minimum time between spots should be 7 cycles. This limits regulator use to large heavy spot welding which is, in general, where it is needed the most. It should be noted that this limitation does not apply to either the voltage compensator or the voltage regulating compensator. This is because they are operating continuously and do not have a starting error.

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INSPECTION TOUR

Lieut. General Wm. Knudsen discussing the production of radio and other electronic equipment with General Electric officials during a visit to one of the company's plants making equipment for the armed forces

NEW PRODUCTS

Month after month, manufacturers develop new materials, new components, new measuring equipment; issue new technical bulletins, new catalogs. Each month descriptions of these new items will be found here

Transient Analyzer

TYPE TA-2 TRANSIENT analyzer is for accurate and instantaneous investigation of transient phenomena of very short time duration (2/10 second or less). The entire transient from beginning to end is automatically recorded on a short endless loop of steel tape by means of a new method of magnetic recording which gives uniform response, with no phase distortion, over a frequency range of from 0 to 300 cps. Upon completion of the recording, a facsimile of the transient is immediately reproduced as a steadily and rapidly repeating pattern on the screen of a cathode-ray oscillograph (not furnished with analyzer). The pattern may be repeated as many times as is desired, and then may be completely obliterated from the tape and replaced with a new record, or the tape loop may be removed and stored for future reference. No record processing is required.

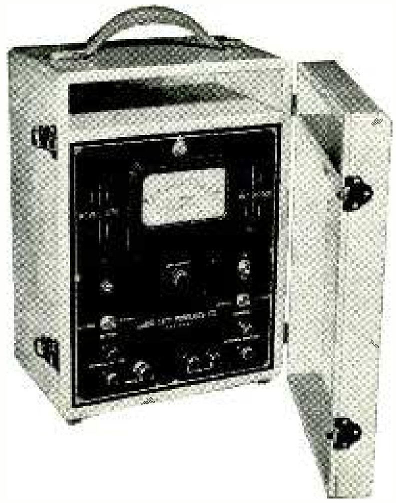
The analyzer comprises two units, a modulator-amplifier unit and a recorder unit. It is designed on the carrier frequency principle to insure uniform response for all frequencies within the range of the instrument. With appropriate direct electrical coupling or electro-mechanical pickup, the instrument may be used to analyze transients and surges in electrical circuits of transmission lines, welding, motor, relay and timer circuits.

The Brush Development Co., 3311 Perkins Ave., Cleveland, Ohio.

Electronic Limit Bridge

HIGHLY ACCURATE RESISTANCE measurements can be made speedily with Model No. 670 electronic limit bridge. A direct reading is given of the percent deviation, in either plus or minus direction, of resistance values compared to any predetermined standard. The dial is calibrated from zero center to ten percent deviation on either side. With each main division on the dial indicating one-half of one percent, fractional divisions showing deviations of one-tenth of one percent can be read quickly and easily, and approvals or rejections promptly determined.

Comparison is made against a predetermined internal standard of any arbitrary value selected. While this is supplied as part of the bridge, provision is also made for using any other value of resistance desired by switching to external standard and connecting the new standard value to the corresponding terminals. Component resistors are



accurate to one-tenth of one percent and the indicating meter is a 4½-inch galvanometer having a sensitivity of 25-0-25 microamps.

The instrument is battery operated and completely self-contained and comes in carrying case. Bulletin No. 126 more thoroughly describes the unit.

Radio City Products Co., Inc., 127 West 26th Street, New York, N. Y.

Automatic Electrical Timer

A SIMPLE ELECTRICAL timing device for use in industrial plants has an automatic switch which is arranged to close an electrical circuit after the expiration of a pre-determined time. It can also be adapted for opening a circuit by simply reversing the position of the mercury switch element. When used on a-c circuits, it has a capacity of 1200 watts, sufficient to control a 1 h-p motor of the repulsion induction type. The setting operation requires the turning of a knob to the time (a.m. or p.m. —up to twenty-three hours in advance) that the switch is to operate. A series connector with five feet of heavy-duty cord is supplied to simplify connections to plug-in types of electrical equipment.

Philco Corp., Tioga and C Streets, Philadelphia, Pa.

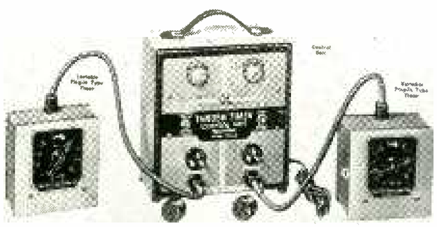
Plastic Nameplates

PLASTICS NAMEPLATES for instruments, etc., are being made in Vinylite, and injection molded cellulose acetate. The Vinylite nameplates are made by the laminated method, which means that there is a sheet of transparent protected material composited to the top of the name plate, thus preventing erasure and permitting easy washing or cleaning. The nameplates can be cold stamped with steel tools to indicate numbers. The injection molded nameplates of cellulose acetate are available in either opaque with lettering filled in, or die-stamped. They can be made of transparent material with the lettering stamped or engraved on the underneath side and with a background color. Both types of nameplates come in various shapes such as round, oblong, hexagon, etc.

The Emeloid Inc., 287 Laurel Ave., Arlington, N. J.

Timing Device

THE "TANDEM TIMER" IS a timing device for use in production departments, laboratories, and for life testing of electrical apparatus. It permits practically any timing sequence. The instrument is essentially a control unit (Type CU-2 control unit is illustrated) with two individual variable plug-in type timing elements. With the timing elements adjusted to their correct respective time intervals, each cycle of operation will follow the other continuously in regular sequence. When the timer dials are once set at the time interval desired, further adjustments are unnecessary until a new sequence is required. The automatic reset features of the unit makes a continuous, as well as a single cycle of operation possible. Plugging in of different timing elements is accomplished in a matter of seconds.



Six standard models of timing elements are available. These are types TE-14S with a minimum setting of from ¼ second to 14 seconds; TE-55S, 1 second to 55 seconds; TE-5M30S, 5 seconds to 5 minutes, 30 seconds; TE-14M, 15 seconds to 14 minutes; TE-55M, 1 minute to 55 seconds; and TE-2H45M with a minimum setting of 5 minutes to a maximum setting of 2 hours, 45 minutes. Longer time cycles are built to specifications. The timing elements are synchronous motor driven, automatic resetting timers.

Industrial Timer Corp., 113 Edison Place, Newark, N. J.

Portable A-C and D-C Instruments

WHERE AN INEXPENSIVE unit is required for general field service use, new (type P-14) portable a-c and d-c instruments are available either with or without covers. Accuracy, sturdiness and reliability are the features of these units. The scale length is 3.2 inches a.c., and 2.8 inches d.c. The instruments have an accuracy of plus or minus 1 percent of full scale. A mirrored dial and a knife-edge pointer aid in making close and

accurate readings. P-14 embodies a variety of single, and multi-ranges providing for the measurement of a-c volts, amps and milliamps: d-c volts, amps, milliamps, and micro-amps. Ranges and combinations of ranges have been chosen to meet the needs of test men, laboratory technicians and research engineers. Combinations of four current and three voltage ranges are available. The molded cases are fully insulated and magnetically shielded from stray field influence.

Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Heavy Duty Rheostats

NEW 50-WATT POWER rheostats are available, in any resistance value up to and including 10,000 ohms, for extra heavy duty. The design of the new rheostats is similar to the manufacturer's 25-watt rheostats introduced two years ago. The selected resistance wire is wound on an insulated metal core which distributes the heat at intermediate rotational settings. The resistance element is firmly imbedded in a ceramic housing with an inorganic cement, resulting in a solid thermal mass. A graphited-copper contact shoe rides the collector ring and the winding, assuring two positive sliding contacts. Contact pressure is provided by a helical spring, concentrically mounted about shaft whose action is evenly distributed by use of a tripod-type contact carrier. The contact is insulated from the metal shaft by a center ceramic insulator, providing a "dead" shaft and mounting bushing.

Clarostat Mfg. Co., Inc., 285 North 6th Street, Brooklyn, N. Y.

Rheostats

SEVERAL NEW TYPES of rugged rheostats for the armed forces are available in wattage sizes of 6, 11 and 20 watt ratings, in resistance ranges from 1 to 200,000 ohms. Panel and table mounting may be accomplished with ease since tapped inserts moulded into the bakelite frame make it unnecessary to reach inside the unit for mounting necessary nuts. The rheostats are fully protected against all elements of corrosion, and have a maximum number of steps per degree of resistance winding. The contact wiper adjustment is designed to assure constant uniform pressure against winding without noisy circuit conditions. The manufacturer states that in life cycle tests results indicated a minimum of one million rotations in all sizes.

The rheostats can be used in any type of electrical circuit requiring rheostat or potentiometer, or in vacuum tube circuits. Special lengths of shafts, slotted, insulated or metal, can be furnished. A bulletin is available which describes types 270, 270D, 275, 265T, 260 and 275. (Types 260 and 275 were described in ELECTRONICS last month and type 270 rheostat is similar to the 260 and 275 units except that it has a power rating of 20 watts.)

DeJur-Amsco Corp., Shelton, Conn.

Limit Switch for Aircraft

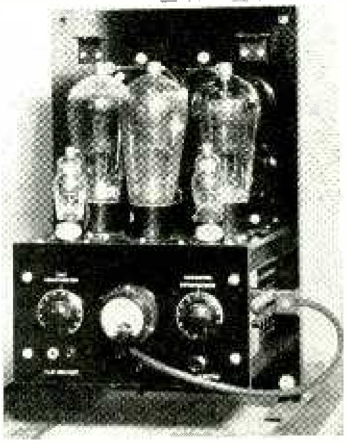
THE G-E SWITCHETTE IS the contact mechanism used in a new lightweight limit switch for aircraft applications. Snap action and double-break operation give the switch a high current rating. The plunger operates with a $\frac{7}{32}$ inch overtravel. The aluminum housing is made dustproof by the use of a gasketed cover and there is ample space inside the housing for easy wiring. The switch

is available in three contact arrangements: single-circuit, normally open or normally closed; and single-pole, double-throw. Each form can be furnished with a contact air gap of 0.010, 0.020, or 0.030 inch. The switch weighs 0.13 lb and meets all U. S. Army Air Force stipulations.

General Electric Co., Schenectady, N. Y.

Electronic Voltage Regulator

THE DT-5 ELECTRONIC voltage regulator is a sensitive electronic device which regulates the output voltage of a-c and d-c generators, providing the output voltage is more than 46 volts. The unit operates from a three phase a-c power supply and acts as a grid-controlled rectifier to supply the d-c field current to the generator, or the exciter of the generator, being regulated. Sensitivity

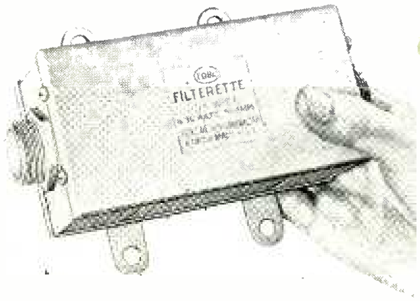


is ± ½ percent when a-c supply voltage does not vary more than ± 5 percent from nominal rating. The regulator is built on a Micarta panel one inch thick and is designed for master panel mounting. No enclosing cabinet is provided but the tubes are protected by a screen cover. Outstanding features of the regulator are low maintenance, reliability of operation and a high degree of regularity. An anti-hunt circuit is built into the regulator. This circuit prevents the regulator from overshooting when close regulation is required.

Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Filterettes

ILLUSTRATED BELOW is type 1107-TDE filterette which is a compact 55 amp, 30 volt unit covering a frequency range of 0.5 to 30.0 mc. It is housed in a steel case and is provided with standard ¾ inch conduit fittings. The unit is constructed to satisfy the mechanical and electrical requirements of aircraft generator service.



Tobe Deutschmann Corp., Canton, Mass.

Small Electric Motor

A NEW TYPE (MODEL LD3R) electric motor for aircraft is illustrated. It is wound for 1/13 hp at 8500 rpm and is available for either 12 volts or 24 volts. Its application is for aerial antennae reel. Specifications are: Diameter of housing is 2.306 ins; overall length, not including the shaft extension, is $2\frac{15}{16}$ ins; it weighs 1 lb and 3 oz; the shaft diameter is 0.250 ins; the shaft extension is 0.766 ins. The motor is equipped with ball bearings and is reversible (3 leads).

Signal Electric Mfg. Co., Menominee, Mich.

Wood-Moisture Determination

A SIMPLE, MODERATE cost instrument (designated as Model MB-L Megohm-Bridge) supplies direct readings in moisture-content percentage terms for meeting various specifications covering precise condition of lumber. Model MB-L is a modified Wheatstone bridge which uses a cathode-ray tube as the null or balance indicator. The combination switch and control knob is rotated until the null indicator flashes, at which point moisture content is read directly on the dial. The bridge circuit is self-compensating, and therefore there are no variables such as voltage fluctuations or varying tube characteristics to contend with.

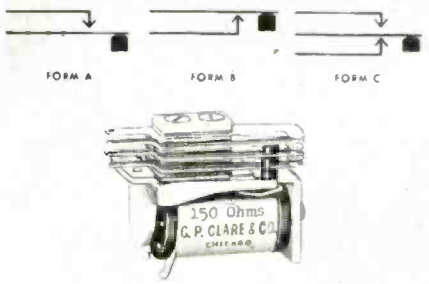
The standard pin-type electrode furnished with the instrument will not permanently mar the surface of material under test as it is readily driven into and extracted from the lumber or wood by the hammer-extractor furnished with the instrument. If progressive checks on various lumber stacks are to be made throughout the curing period, leads may be soldered to properly placed and spaced nails, and tied into a panel board located near the instrument for periodic readings.

Two models are available: MB-LA calibrated 7 to 25 percent moisture in wood, operating on 105-130 volts, 50-60 cps, a-c supply; the other, a portable Model Megohm Bridge MD-1, calibrated 8 to 24 percent moisture in wood, operated on a self-contained small dry battery with an estimated life of from six months to one year.

Industrial Instruments, Inc., 156 Culver Ave., Jersey City, N. J.

Small Aircraft Relay

TYPE "K" D-C RELAY was designed for aircraft use, or for use wherever minimum weight and space is a factor. It measures $1\frac{1}{2} \times 1\frac{1}{4} \times \frac{13}{16}$ ins, and weighs approximately $1\frac{2}{3}$ ozs. It can be furnished in many contact forms up to and including twelve springs per relay. The coil voltage range is from 1.5 volts to 60 volts d.c. Contacts of either 18

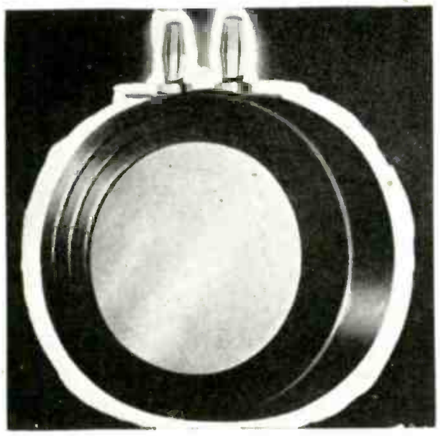


gauge silver, rated 1 amp, 50 watts; or 18 gauge palladium, rated 2 amps, 100 watts, can be furnished. All metal parts of the relay are specially plated to withstand a 200 hour salt spray test, and each relay is given a 1000 volt a-c insulation breakdown test.

C. P. Clare & Co., 4719 Sunnyside Ave., Chicago, Ill.

Self-Generating Photoelectric Cells

SELF-GENERATING PHOTOELECTRIC cells that generate sufficient current to operate meters and relays without use of amplifiers are available in eight stand-



ard sizes to suit different needs. Plastic housings with contact prongs are provided so that the cell can be easily connected to a current meter.

Emby Products Co., 1800 West Pico Blvd., Los Angeles, Cal.

Literature

Resistance Welding. This brochure tells all the facts about electronic control for resistance welding: what it is, what it does and why it speeds and improves production. A story on various kinds of resistance welding, the kinds and types of electronic control devices made. Useful information for those considering the addition of resistance welding equipment. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Beat-Frequency Oscillator. In the July 1942 issue of the *Experimenter* a thorough description is given of the type 913-A beat-frequency oscillator. Its important features are: convenience and ease of frequency control, constant output voltage, a high degree of stability, and low distortion. It is well adapted for running frequency characteristics (with a recorder, if desired) and also for all normal types of distortion measurements. General Radio Co., 30 State St., Cambridge A, Mass. Also included in this issue is an article "Recent Priority Orders of Interest to Buyers of GR Equipment."

Electrical Capacitors. Bulletin 1031 covers various types of capacitors for use in regular industrial and military services. Oil, wax, electrolytic and motor starting condensers for all applications are described and illustrated. Industrial Condenser Corp., 1725 W. North Avenue, Chicago, Ill.

Paper Capacitors. Catalog 12—Section C is a forty-eight page catalog devoted to illustration and description of paper capacitors. The types and characteristics of impregnants are given, analysis of catalog numbers and the variations available on quantity orders. Solar Mfg. Corp., Bayonne, N. J.

Resistors. This twelve page bulletin presents information on fixed, adjustable, "rib-on-edge" and ferrule terminal resistors, power line and r.f. chokes, brackets, bushings, terminals and washers. Also illustrated and described are solder pots for continuous operation in radio, motor and similar electrical equipment plants. Bulletin No. 98 obtainable from Lectrohm, Cicero, Ill.

Paper Tubing. A list of paper tubes which gives sizes for coil form and other uses. These tubes are available in square, round and rectangular shapes. The list contains over 650 sizes, convenient for experimental and production requirements. Paramount Paper Tube Co., 801 Glasgow Ave., Fort Wayne, Ind.

Suppressors. This data sheet gives descriptions and characteristics of suppressors and includes charts showing suppression efficiency and life tests. Erie Resistor Corp., 640 W. 12th St., Erie, Pa.

Copper Fuse Clips. This four page folder gives a description of fuse clips and screw terminals made from a new alloy of beryllium and copper. The properties, design and construction are also given, along with detailed drawings and specifications. Littlefuse Inc., 4757 Ravenswood Ave., Chicago, Ill.

Durez Plastics. An eight page folder on Durez plastics which gives the story, in nontechnical style, of the manufacturing process from the raw materials to the finished products. Durez Plastics & Chemicals, Inc., North Tonawanda, N. Y.

Electrodes. In a thirty-six page booklet the nature and properties of electrodes are discussed. Tables of standard sizes and weights of electrodes are given. Also data which will be helpful to electrode users in selecting the product best adapted to their requirements. International Graphite & Electrode Corp., St. Marys, Pa.

House Organ. "Transformerless Power Supplies" is an article describing the various transformerless power supply circuits which have been adapted to radio receivers, electrical test instruments, photoelectric and electronic equipment and small radio transmitters. This is published in two parts—Part I in February 1942 and Part II in March 1942 *Research Worker*. Copies obtainable by writing to Aerovox Corp., New Bedford, Mass. Also, an article "Transmitter Bias Supplies" in the April 1942 *Research Worker* tells the details for the proper operation of the audio-frequency and radio-frequency stages of a transmitter.

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MIRROPHONE

A new Western Electric magnetic recording device is now being used by many as an aid to speech improvement. The subject's speech is recorded magnetically on a steel tape. By turning the switch immediate playback is possible, which enables the detection and correction of errors of pronounciation, emphasis, or tone. As it records, the mirrophone automatically erases or demagnetizes previous recordings

Reference Guide to Ultrahigh Frequencies. Here is a pocket size 54-page booklet which will prove its value many times over to those engineers and scientists who may now be engaged in the design, testing, or production of equipment in the ultrahigh frequency spectrum. A very considerable amount of material has already been published on different aspects of ultrahigh frequency technique, but most of it is so scattered throughout the technical literature that it is not readily available to engineers in convenient form. This is a decided handicap at the present time when the need for personal efficiency of all technical personnel is of paramount importance.

In compiling this bibliography on ultrahigh frequency technique, Miss E. Kelsey, Engineering Coordinator of the Zenith Radio Corporation, has made a valuable contribution. The booklet contains a brief introduction to ultrahigh frequency technique, followed by a list of books which is up to date as of early summer.

The bibliography proper is divided into two sections, the first of which lists those articles on u-h-f which have appeared in past issues of the Proceedings of the Institute of Radio Engineers. This division of the pamphlet is divided into the following sections:

1. Antennas, Transmission Lines, and Wave Guides
2. Wave Propagation
3. Generators
4. Receivers
5. Measurements
6. U-H-F in Aviation
7. Miscellaneous Articles on U-H-F
8. U-H-F Tubes and Associated phenomena
9. Crystals and Associated Phenomena.

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WOMEN IN DEFENSE

Mrs. Ricker conducts classes at the 'Y' as well as under the direction of the Women's Radio League for the purpose of teaching women radio code, theory and mechanics. She was the first woman to rank as an officer in the United States Navy during the first World War

The second portion of the u-h-f bibliography is made up of articles which have appeared in other engineering publications, and is likewise divided into several sections. These sections are the same as those already enumerated above, except that one additional section is added:

10. Foreign Publications.

In each section, the number of items listed varies with the degree to which the subject has been treated in the technical literature, but perhaps, on the average there are twenty-five articles in each.

Concluding the bibliography is the list of 134 articles on frequency modulation also prepared by Miss Kelsey and already made available in pamphlet form.

In general the bibliography appears complete. It certainly represents a considerable amount of labor, and, we feel certain, will be most welcome to the engineer who is anxious to locate articles which have already been published on u-h-f technique.

Copies of the "Reference Guide to Ultra High Frequencies" may be obtained upon request, upon application to E. Kelsey, Zenith Radio Corporation, Chicago, Ill.

Current Flow Test Sets. A 4-page bulletin describes current flow test sets which are instruments designed to provide convenient, rapid and accurate means for determining the flow of current through the winding of various types and sizes of relays. Shallcross Mfg. Co., Collingdale, Pa.

Oscillograph Accessories. Such accessory apparatus as Type D5RR9 combination oscillograph, Type PA114 preamplifier, angular sweep potentiometer, pressure pickup, detonation amplifier, and attenuator-calibrator are illustrated and described in Form 32-B available from Rowe Radio Research Lab. Co., 4201 Irving Park Blvd., Chicago, Ill.

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RAF FERRY COMMAND

This radio ground station is one of many which keep in constant touch with ferry pilots while they are in the air. The ferry command's job is to fly American built bombers to England

RECENT U.S. PATENTS

Each week the United States Patent Office issues grants to many hundreds of inventions that pass the acid test of that office. A few of those relating to electronics are reviewed here

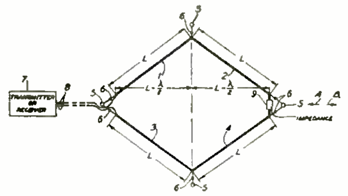
Antennas

All-wave Antenna. Dipole normally giving maximum response in certain bands of frequencies higher than 1500 kc, anti-resonant circuits in each arm resonant to frequencies intermediate to the natural responses of the dipole, the circuits located one quarter wavelength of the desired frequencies from the down lead. Amy and Aceves. July 10, 1937. No. 2,282,292.

Vehicle Antenna. Retractable antenna with mechanical connections to knob with indexing means for frictionally retaining the antenna in one of several positions. S. H. Watson, Jr. RCA. Jan. 4, 1940. No. 2,284,782.

Wideband System. Antenna comprised of horizontal arms conductively connected, the length being one-eighth of the operating wavelength. E. C. Cork, E&MI Ltd. Nov. 29, 1939. No. 2,285,395.

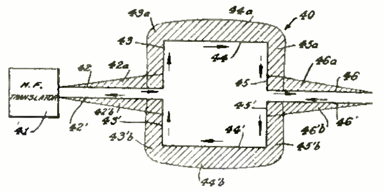
Directional Antenna. Two oblique conductors of equal length positioned in a horizontal plane, the length being greater than a half wavelength, and equal to a half wavelength plus the projection of the conductor on a vertical



plane including the distant cooperating station and the antenna, one terminal of each conductor being positioned in a plane perpendicular to the vertical plane and the other conductors being superposed. Edmond Bruce, BTL Inc. Feb. 3, 1931. No. 2,285,565.

Wideband Antennas. Several patents relating to structures responsive over wide wavelength ranges. No. 2,283,914 to P. S. Carter, RCA; No. 2,285,669 to G. Lehmann, Paris, SADIR; No. 2,286,179 to N. E. Lindenblad, RCA; No. 2,283,938. Each structure except the last is a folded antenna composed of two parallel conductors closer together than the length of the shortest wave to be received, one conductor broken in the center for a lead-in, the other unbroken. The Lehmann antenna has an impedance equal to the characteristic impedance of the antenna inserted in the unbroken conductor. The Carter patent illustration in the *Gazette* shows the following dimensions, overall length 69 cm, lead-in two wires 5 cm apart, each wire 32 cm from the end of the unbroken wire, the two antenna wires being 2 cm apart.

Antenna System. Peripherally arranged planar radiant acting linear conductor of small dimensions relative to the operating wavelength arranged along a planar periphery, a transmission line directly connected to and forming a continuation of conductor, said section being dimensioned to tune system to the operating frequency to produce uniform current distribution in



radiant conductor, energy transfer to transmission line at a point such that if energy were supplied thereat current would circulate about periphery in the same sense at all points, whereby radiant action of system is substantially uniform in all directions about periphery and has everywhere a polarization substantially parallel to the plane. A. Alford, IT & R Mfg. Corp. Apr. 26, 1939. No. 2,283,897.

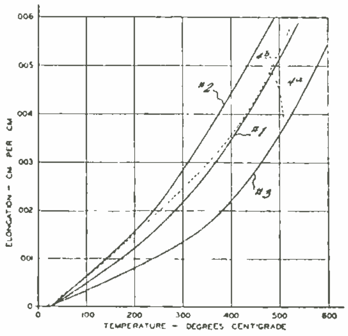
Resonant Structure. Pair of similar disc-like members face to face with a conductive hub at the center, the members being so close together that the inductive reactance of the hub is negligible in comparison with the lumped capacitive reactance of the members; a tube connected to the members at a point to insure proper transfer of energy; the radial distance r_p between the region of connection of the electrodes and the line of centers of the disk-like members being related to the radius r_0 of the hub by the equality

$$\frac{J_0(2\pi r_0/\lambda)}{N_0(2\pi r_0/\lambda)} = \frac{J_1(2\pi r_p/\lambda)}{N_1(2\pi r_p/\lambda)}$$

where J_0 and J_1 represent Bessel function of the first kind and respectively of the zero and first orders, N_0 and N_1 represent Bessel functions of the second kind and respectively of the zero and first orders, and λ represents an operating wavelength corresponding to the said particular frequency. E. D. McArthur, GE Co. Aug. 17, 1940. No. 2,284,405.

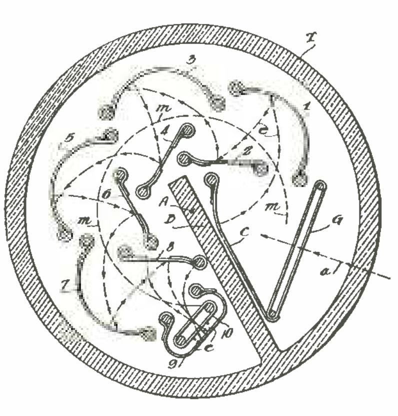
Electronic Devices

Tube Construction. A unitary stem base for closing off a radio tube bulb or the like comprising a button-shaped member of soft glass, and a plurality of rigid metal rods sealed through the glass, said rods being of an alloy composed of 38 to not more than 45% nickel; 3 to 15% chromium; 0.1 to 2% metal



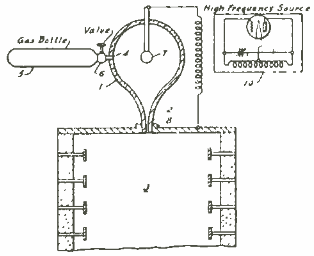
of the group consisting of aluminum, zirconium and calcium; and the balance substantially of iron, the alloy having sufficient hardness and tensile strength to permit said rods to be used directly as external plug-in prongs without danger of weakening the seal. W. E. Kingston, Hygrade Sylvania. April 25, 1939. No. 2,284,151.

Electron Multiplier. A source of electrons, a bent plate having a secondary-electron emissive inner surface circumscribing a space toward which electrons from said source are directed, said plate having a pair of inwardly directed marginal portions defining an opening which faces the source and through which electrons from source pass in



traveling to emissive inner surface, and a collector electrode for secondary electrons supported within enclosed space behind the marginal portions of the plate. J. A. Rajchman, RCA. July 28, 1939. No. 2,285,126. See also No. 2,285,848 to van den Bosch, Vacuum-Science Products, Ltd. on an electron multiplier tube.

Ion Source. An ion generator for supplying high energy ions to a low pressure ion consuming device comprising a vitreous chamber, a source of heavy hydrogen connected to said chamber, a capillary tube outlet of dielectric material connecting said chamber to the consuming device, an electrode in said chamber, an electrode adjacent said outlet and a source of high frequency power connected to said electrodes for producing a high frequency discharge through said outlet. J. Slepian. WE&M Co. June 14, 1940. No. 2,285,622.



Photoelectric Surface. A method of manufacturing a photoelectrically sensitive surface which consists in depositing upon a supporting surface a layer of bismuth, depositing upon said bismuth layer a layer of silver, oxidizing the silver, heating the composite bismuth-silver oxide layer so that the bismuth is oxidized, and finally depositing an alkali metal on said composite layer so that the bismuth oxide is reduced to bismuth. A. Sommer, Cinema-Television, Ltd. July 29, 1939. No. 2,285,062. See Also No. 2,285,058 to K. A. R. Samson on method of making mosaics.

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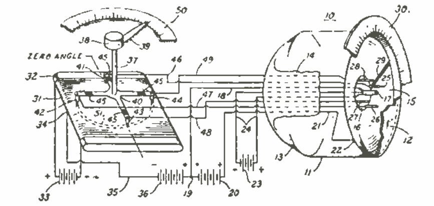
A HOBBY GOES TO WAR

This young lady, Maureen Miller took up telegraphy as a hobby. Now she is on duty as a telegraph operator. She studied in night classes to perfect her training as a WAC soldier (Canadian Women's Army)

Cathode. Emissive layer on one side of a flat metallic carrier, the other side of which is fitted with a polished metal layer having an optical radiating capacity less than that of the carrier, as a radiation inhibiting means. Felix Herriger, C. Lorenz. Sept. 24, 1940. No. 2,284,655.

Indicator. Thermionic cathode, annular anode coated with fluorescent material, several control electrodes arranged symmetrically about the cathode, a transmitter having stator and rotor



with connections between stator and control electrodes, electrons constrained into beams, and means for indicating on anode position of rotor of transmitter as it moves. A. A. Stuart, Bendix, Dec. 30, 1940. No. 2,283,103.

Cavity Resonator. Means for projecting a beam of electrons into a cavity within which is a field of standing waves and means for shielding the electrons so that alternate half cycles of the field react upon the electrons. E. G. Linder, RCA. Aug. 31, 1939. No. 2,284,751.

Electron Camera. Two patents on camera and receiving tubes to T. W. Sukumlyn, Los Angeles. April 2, 1938, No. 2,281,637 and May 17, 1940, No. 2,-281,638.

Wave Guide. Directive transmission or reception by separately and concurrently guiding adjacent portions of the wave front of the electromagnetic waves, altering the velocities of propagation of the portions so that the shape of the wave front is modified and finally projecting all of the guided portions into coalescing relation to form a unitary wave. A. P. King, BTL Inc. April 29, 1938. No. 2,283,935.

Tube Applications to Measurements

Humidity Measurement. Application of electron tube generator and amplifier to a humidity measuring device. F. W. Dunmore, U. S. Govt., June 8, 1940, No. 2,285,421.

Measuring System. Unknown voltage is measured by intermittently changing the potential of a tube control grid in accordance with the unbalance between the unknown and a known voltage at intervals greater than the half period of the galvanometer. Felix Wunsch, Leeds & Northrup. Feb. 24, 1939. No. 2,285,482.

Integrating Photometer. Combination of current-producing photoelectric cell, a coil to rotating freely in a magnetic field, amplifier and counter mechanism. A. H. Lamb, Weston El. Inst. Co. Jan. 10, 1940. No. 2,286,036.

Balance Indicator. In a voltage measuring system, unbalance voltages produce a periodic variation in the charge of a condenser whereby the amplifier produces a periodic voltage variation of such a phase that it indicates the direction of unbalance of the system. J. R. MacKay, Wallace & Tiernan Products, Inc. May 31, 1938, No. 2, 284,476.

Depth Measurement. Two patents to Submarine Signal Co., No. 2,284,654 for measuring distances under water and No. 2,284,649 means for maintaining frequency and voltage of a motor generator under varying operating conditions.

Thickness Measurement. Tube equipment for measuring thickness of dielectric material by change in capacitance of a condenser. F. A. Firestone, Owens-Illinois Glass Co. Nov. 18, 1939, No. 2,285,152.

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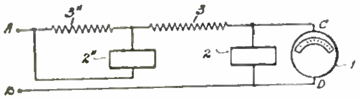
SECRET RADIO

Shown left to right are Raymond P. Merchant, technician, Ellison S. Purington, physicist and John Hays Hammond, Jr., inventor of a new type radio transmitter and receiver. The transmitter sends out a spiral wave which turns either to the right or to the left according to the operator. The receiver selects waves of either polarization and affords secret communication between points

Voltmeter. Voltmeter circuit including a current responsive meter having a scale compressed at both ends with respect to the center, a pair of multiplying resistances connected in series with meter and a shunt across meter, said shunt having a resistance which decreases with increasing potential ap-



plied thereacross whereby the sensitivity of meter is decreased for large potentials, one of said multiplying resistors having a resistance which decreases with increase in voltage thereacross for decreasing the sensitivity of said meter for small potentials. C. W. Hansell, RCA. June 1, 1940, No. 2,284,-423.

Voltage Indicator. A commutating arrangement for simultaneously indicating several d-c voltages on the screen of a cathode-ray tube. K. C. Ripley, Washington, D. C. June 28, 1939. No. 2,283,-951.

Phase-shift Indicator. A cathode-ray system. B. D. Loughlin, Hazeltine, Aug. 3, 1940. No. 2,285,038. Also No. 2,284,-219 to A. V. Loughren, Hazeltine, on a signal waveform indicator using cathode-ray tube.

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AIR PRECAUTION AGAINST JAPS

Radio communication is maintained constantly to prevent invasion by the Japs on the West coast. The Army maintains posts, such as this, for observation flights. All planes, except transport lines, have been grounded

NEW BOOKS

American Standard Definitions of Electrical Terms

Published by American Institute of Electrical Engineers (311 pages. Price, $1.00 in the United States)

IN 1928 THE AMERICAN Standards Association approved the initiation of a project covering "definitions of technical terms used in electrical engineering, including correlation of definitions and terms in existing standards." Under this authorization the appropriate committees and subcommittees were established under the sponsorship of the American Institute of Electrical Engineers, and for the past thirteen years have been engaged in the establishment of standard definitions of electrical terms. During 1932 copies of the reports of the various committees were circulated for comments, and from the response received from this preliminary report, many additional changes were considered and, where feasible, such changes were incorporated. The present report, a 300-page volume, 8x11 inches in size represents the standard definitions of terms as finally approved early in 1941. The report represents the time and thought of scores of men, freely given as their contribution to the advancement of electrical engineering, for a period of more than thirteen years. Only one who has had some acquaintance with the time-taking (and frequently tedious) procedure under such a standardization program can appreciate the vast amount of work which has been expended on this report.

The introduction to this volume states that, "the primary aim in compiling this glossary has been to express for each term the meaning which is generally associated with it in electrical engineering work in this country. When possible, the definitions have been generalized so as not to preclude the different specific interpretations which may be attached to the term in particular applications, the greatest weight naturally being given to the strictly engineering applications. Also, it was agreed that the preferred definition is a simple one and the tendency has been toward the simple statement of function rather than to the explicit description of all properties included and excluded." The first group of definitions on general (fundamental and derived) terms necessarily employs a certain amount of mathematics, but the remaining sections are word definitions without the use of mathematics. The definitions are divided into eighteen separate sections covering: general terms; rotating machinery; transformers, regulators, reactors and rectifiers; switching equipment; control equipment; instruments, meters, and meter testing;

generation, transmission, and distribution; transformation; electromechanical applications; electric welding and cutting; illuminating engineering; electrochemistry and electrometallurgy; wire communication; radio communication; electronics; radiology; electrobiology, including electrotherapeutics; and miscellaneous.

By far the larger portion of the volume is devoted to definitions of electrical terms used in the generation, transmission, and distribution of power. The space devoted to electrical communications is 30 pages, or 10 percent of the book; that devoted to electronics is 6 pages, and these definitions appear to be similar to those established by the Institute of Radio Engineers. But perhaps it is natural that the newer branches of engineering should have time to become settled before attempting too much standardization.

To the student, the engineer, the technical writer or editor in the field of electrical engineering, these standards should do much to clarify the real meaning and significance of technical statements.—B. D.

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The Spectrum of Hydrogen

By WILLIAM MAYO VENABLE, *Consulting Engineer, Blaw-Knox Co., Pittsburgh, Pa. Paper bound, 184 pages, 1942.*

ACCORDING TO THE AUTHOR, "this is the only book that gives a complete analysis of the hydrogen band systems, showing their relationships to the primary system, relationships hitherto not considered possible. The book also contains the first serious attempt to account for spectra without disregard of the fundamental concepts of electromagnetic theory."

It is definitely a book for the physicist. Chapter headings are Classification of lines and levels of hydrogen spectra, Stages in excitation of pure hydrogen, Spectroscopic evidences of hydrogen in other elements, Theoretical atoms and the electromagnetic theory, and The electromagnetic theory and continuous spectra, plus the tables.

To any one of the proper background this little book will make reading that is not only interesting but speculatively stimulating.—K.H.

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Introduction to Physics

BY HARLEY HOWE, *Professor of Physics, Cornell University (559 pages. Illustrated. Price, $3.75. McGraw-Hill Book Co.)*

HERE IS AN ELEMENTARY textbook on physics from the modern point of view. Its forty-five chapters contain discussions on the general topics of mechanics, hydrostatics, sound, heat, electricity, atomic phenomena, and light and optics. Considerable attention appears to have been devoted to the development of text and illustrations which would give the student a pictorial grasp of the subject as an aid in understanding, rather than memorizing, the text. To this end, pains are taken to show that Newton's laws are applicable to subjects besides mechanics, and that the various divisions of physics are not separate and isolated pigeon holes, but rather that they provide a different point of view or a different medium in which the fundamental attributes of energy, power, resistance, and so on are expressible.

The text appears to be largely descriptive for it "uses no mathematics beyond the elementary algebra and plane geometry supposedly mastered by all college entrants. Many of the formulas familiar to physics teachers do not appear and the illustrative problems have been kept fairly simple". The extremely elementary mathematics which is employed is a weakness as well as an advantage of the book, for while relatively simple concepts can be treated non-mathematically, the student is asked to accept without explanation or interpretation some of the more difficult subjects, as for instance the current in an oscillating circuit as given on page 397.

The illustrations are well done throughout, although special mention must be made of the diagram illustrating the diffraction of waves passing through a grating on page 534. The illustrations, as well as the examples in the text, are chosen not only to illustrate some principle of physics but to make the student aware of modern applications in his everyday life.

All in all, the "Introduction to Physics" should prove to be highly suitable for trade schools, the liberal arts colleges, or for many of the refresher courses now being taught as a part of our war effort. The elementary nature of the work will probably not make it well suited to the needs of first class schools of engineering or technology.
—B. D.

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The "Particles" of Modern Physics

By J. D. Stranathan, *Professor of Physics, University of Kansas (571 pages. Illustrated. Price, $4.00. The Blakiston Co.)*

Prof. Stranathan's volume, based on lectures given to junior, senior, and graduate student at the University of Kansas, seems to be ideally suited for use by technically trained personnel who can profit by a knowledge of recent advances in sub-molecular physics but who have not had the opportunity to follow this field in detail. The number of "particles" has increased at an accelerated rate in the past few decades, and the usual undergraduate texts do not ordinarily devote much attention to a unification of this subject.

The chapter headings, which indicate the scope of the volume, include: gaseous ions and their behavior, the electron, the electrical discharge, cathode-rays and the ratio e/m for electrons, positive rays — isotopes, photons—the photoelectric effect—radiation and absorption, x-rays, δ, β, and γ rays—natural radioactivity, the positron, the neutron, atomic nuclei—artificial disintegration, cosmic rays, the mesotron, and a final chapter particles?—or waves? setting forth the argument for both cases.

The author makes no claim for originality of material, but the literature has been thoroughly searched and evidences of this fact are to be found in the numerous foot-note references and in the various compilations of experimental results which have been achieved. Occasionally, too, early experimental results are interpreted and the reasons for success or failure are pointed out. The type of writing employed is not that of the usual textbook, and the items for the student to grasp are not so readily marked with sign posts as in other college texts. Nevertheless, the student should obtain a good knowledge of the subject at hand, and, what is more, should form some appreciation of the development of what has come to be called "modern physics".—B.D.

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ROBOT ALARM SYSTEM

Shown here is the master control board of the "acoustic fence" which helps protect a war production plant of the E. I. duPont de Nemours Co. somewhere in the United States. A light glows on the "map" outlined on the control board which notifies the guard that someone is tampering with some part of the miles of high wire fence surrounding the plant

C-R Photography

(*Continued from page 60*)

flection sensitivity of the cathode-ray tube is not affected appreciably by its control grid potential. It is advisable, however, to ascertain whether or not the accelerating potential applied to the tube changes as the control grid bias is changed, due to regulation in the power supply. It is also advisable to check for any defocusing effect caused by lack of perfection of the brightening pulse.

The sweep pulses may be given a balanced aspect to ground, if battery supply is used, by grounding a suitable tap on the battery, or a suitable point on the voltage divider. This expedient may also be used with an a-c power pack, but there is some tendency to 60-cps pickup.

The most satisfactory operation thus far has been given when the control-grid bias on V_1 is kept between limits which will insure that the current carried by that tube will not be greater than 1.0 ma. nor less than 0.3 ma. Outside these limits, the linearity of the sweep pulse, and the squareness of the brightening pulse, may suffer somewhat, and their amplitude may be restricted. For this reason, the bank of fixed condensers comprising *C* should vary in steps of not greater than 3 to 1. Control of sweep pulse duration, or of the frequency of the recurrent

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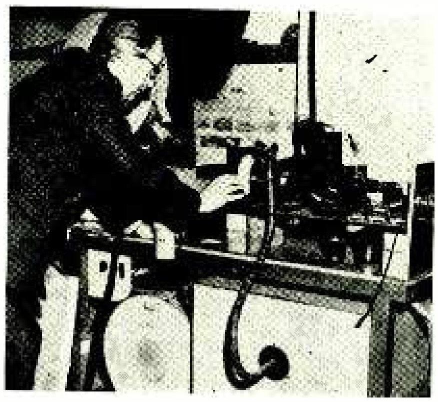
COLOR TELEVISION APPARATUS



John Logie Baird, early worker in television, has perfected a color television set. He intends to market the machine himself after the war for 20 pounds ($100) each

sweep, is made in steps by tap switch S_3, and the fine adjustment by R_1.

The amplitude of the sweep pulses cannot be adjusted in this circuit except by altering the voltage applied to the circuit. For recording work, this is not a disadvantage.

No output condensers are included in either output circuit; for some uses they are undesirable. They can easily be introduced when needed.

The circuit is not intended for extremely high or for extremely low frequencies; it has given excellent pulses 0.0001 second in length, and also 0.3 second in length. The upper limit in frequency is dictated by the stray capacities introduced by the batteries and other items, and by the length and lack of constancy of the deionization time of the gas triode. The square-wave output suffers at the lower frequencies, due to the somewhat limited low-frequency response of amplifier V_3.

This circuit, while not having quite the capabilities of some others, has proved itself satisfactory for a large percentage of measurement work on transients, and for simplicity and reliability it leaves little to be desired.

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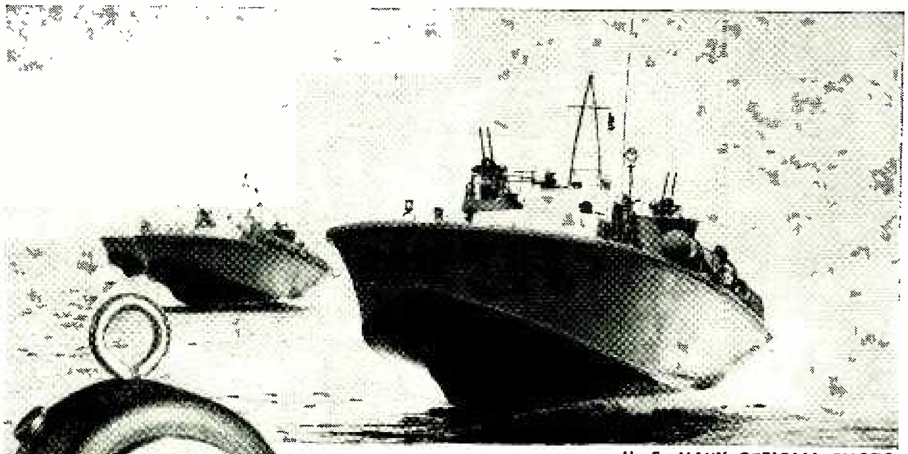
LET ME TALK, TOO

A recording machine operated by the American Safety Razor Corp. provides an interchange of messages between soldiers and their families. Over 25,000 6½-inch records have been made at nearly every army camp in the country. Charles Feldman is addressing a message to his son who is stationed at Fort Benning, Georgia



Backtalk

This department is operated as an open forum where our readers may discuss problems of the electronic industry or comment on articles which ELECTRONICS has published

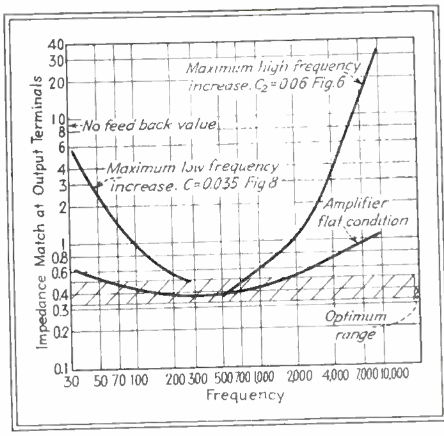
Feedback

BEGINNING ON PAGE 36 of your July issue is described an amplifier which presumes to live up to the design considerations outlined in an early paragraph including, "5 constant and resistive input and output impedances." It is my impression that the intelligentsia of high fidelity now agree that the output impedance of an amplifier feeding a loudspeaker should be between 2 and 3 to 1 mismatch on the low side. It is also well known that 6L6 pentodes work into a much lower load impedance than their own plate impedance. In fact taking figures from the R.C.A. tube manual for the voltage used by the amplifier described, the mismatch would be about 9 to 1 in the wrong direction.

Now it is also well known that the output impedance of an amplifier with degeneration proportional to output voltage is reduced by the factor $1-\mu\beta$. Also, the gain of the amplifier becomes $\frac{\mu}{1-\mu\beta}$ where μ was the gain before feedback was applied. This may be read directly from Fig. 7 by changing ordinates to read about 48 db at peak of curve. In the flat case β is 1/11 and the peak gain is reduced to about 20 db. The reduction factor $1-\mu\beta$ for both gain and output impedance comes out about 23.7 at the peak of the gain curve of Fig. 6 and of course falls off as one departs from the peak in either direction, and may be similarly calculated for any point on the curve. If the original 6L6 characteristic mismatch of 9 to 1 be divided by this factor the quotient will be the actual impedance mismatch of the amplifier.

This I have done and plotted the results on attached curve marked "flat." You will note that it meets the above mentioned so called optimum condition between about 60 cps and 1700 cps which, it seems to me is hardly to be called constant output impedance over audio range.

Similar calculations may be made for the high and low frequency boost curves, Figs. 6 and 8 respectively. They are plotted as noted. In the case of the high frequency boost the feedback goes through zero and actually becomes positive at about 6000 cps with



consequent very high output impedance and a slope to the curve that would lead one to suspect that the output impedance couldn't possibly be "resistive."

The seriousness of this variation in impedance can hardly be over-estimated in the case of an amplifier using 6L6 tubes where the gain varies through wide limits as a function of load impedance and if the excitation is held just short of grid current the industrial power output varies widely with load impedance. Since the μ that appears in the equation is not the internal relatively fixed μ of the tube but rather the effective gain between points about which the feedback loop is to be applied, a variation in load impedance varies the effective gain and also the output impedance in a most unfortunate manner. In the case of a conventional loudspeaker it is fairly common to have 8-ohm voice coils show as high as 30 or 40 ohms at resonance which usually falls between 40 to 70 cycles and again at high frequency the 8 ohm may become 40 or 50 ohms due to inductance.

There seems to be a prevalent notion that a little negative feedback is the complete cure for any and all troubles. This is not true. Properly used it is perhaps the most valuable tool that has been added to the designers kit in years. Improperly used it can cause many more headaches than it cures.

BEN DRISKO
Hingham, Mass

Electrolysis

ON PAGE 72 OF June 1942 issue with the abstract of the article by Davis and Wainwright a serious error was made with respect to the application of the anti-electrolysis relay in combating pipe line corrosion. According to the authors, pipe lines suffer corrosion when they are at a positive potential with respect to adjacent structures such as trolley rails. This is correct. However, the authors make the mistake of stating that this condition results in a current flow from rails to the pipe line. Actually, it is just the reverse, for the pipe line is anodic to adjacent structures when it corrodes.

Note that this device does not constitute cathodic protection, since it only furnishes a convenient low resistance path for currents to return from pipe line to rails during periods when the pipe line is positive to the rails. When this polarity reverses, the path is interrupted by the relay, thus interposing a relatively high resistance soil path in the way of any currents tending to leave the rails and accumulate on the pipe line.

It should be emphasized that during this period of accumulation, the inflowing currents have to be discharged somewhere along the pipe line, and usually this happens at wet, swampy locations, or near other metal structures that are negative with respect to the pipe. Hence, at such locations, unless forced drainage is installed, very severe, rapid, and hazardous pitting will result. If a line is carrying gas, gasoline or crude oil the extreme danger can be visualized. For this reason, this application of the anti-electrolysis relay is only to be recommended in connection with a complete forced drainage program against such stray currents, lest the user be deluded into believing it alone will completely cure the corrosion.

Forced drainage is usually effected by connecting the pipe line to zinc bars, or the negative pole of a motor generator, windmill generator, or Rectox unit, and connecting a ground bed of iron or carbon to the positive pole of such auxiliary devices (not with zinc bars). The output of such devices is set to maintain the pipe line at least 0.25 volts negative to a steel ground rod.

HAROLD P. HELLER,
General Parts Engineering,
RCA Mfg. Co., Camden, N. J

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RC Oscillator

I HAVE FOUND the articles on the transitron oscillator of great interest to me. The difficulty with them is that calculus was used in the analysis. I don't know that much calculus yet.

I am enclosing a sample analysis to show how simple an algebraic solution can be. This is only one of several possible solutions using only complex algebra. Another solution would be to consider the circuit as series resonant. The resistance will cancel out.

I hope that you find this analysis of value.

For a particular value of E_g, $E_p =$

$$\frac{-E_{g1}\, g_m\, R_p\, Z_L}{R_p + Z_L}$$

$$E_{g1} = \frac{E_p}{-g_m}\left(\frac{1}{R_p} + \frac{1}{Z_L}\right)$$

E_p causes a voltage to be fed back to R_1

$$E_{g2} = \frac{E_p\, R_1}{R_1 + \dfrac{1}{j\omega C_1}} \times \frac{R_b}{R_a + R_b}$$

Oscillation will result when

$$E_{g1} - E_{g2} = 0$$

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NOTICE

The American Lava Corporation has expressed great regret that its June advertisement in Electronics was, in part, a copy of an admirable institutional advertisement previously used by the Varnish Products of Cleveland, Ohio. This inadvertence is contrary to their long established policy and they wish by this means to give due credit to the originator of such a brilliant inspiration.

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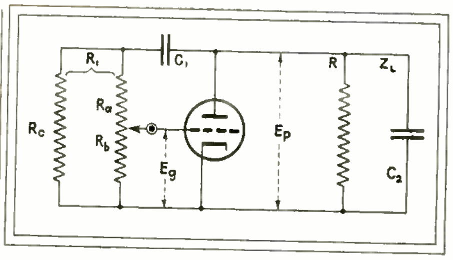

Equivalent circuit for the controlled transitron oscillator

Substituting

$$\frac{E_p}{-g_m}\left(\frac{1}{R_p}+\frac{1}{Z_L}\right)-\frac{E_p R_1}{R_1+\frac{1}{j\omega C_1}}\times\frac{R_b}{R_a+R_b}=0$$

Or

$$\frac{1}{R_p}+\frac{1}{Z_L}+\frac{R_1}{R_1+\frac{1}{j\omega C_1}}\times\frac{g_m R_b}{R_a+R_b}=0$$

Neglecting R_1 and C_1 as part of Z_L

$$\left(\frac{1}{R_p}+\frac{1}{R}\right)+j\omega C_2+\frac{R_1}{R_1+\frac{1}{j\omega C_1}}\times\frac{g_m R_b}{R_a+R_b}=0$$

$$\left(\frac{1}{R_p}+\frac{1}{R}\right)=\frac{1}{R_2}$$

Reducing

$$\frac{1}{R_2}+\frac{1}{R_1}\times\frac{C_2}{C_1}+\frac{g_m R_b}{R_b+R_a}+j\left(\omega C_2-\frac{1}{\omega C_1 R_1 R_2}\right)=0$$

This shows that g_m must be negative. If the solution had been complete and R_1 and C_1 had been included in Z_L then $\frac{C_2}{C_1}$ would be changed to $\frac{C_1+C_2}{C_1}$

BEN E. BUSH, JR.,
Ogden, Utah.

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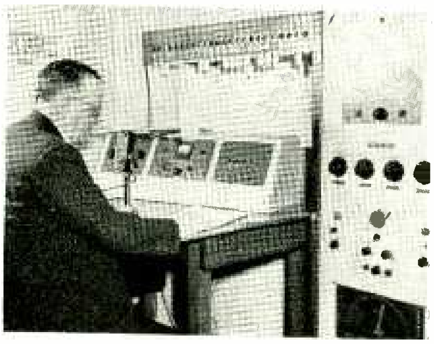
RADIO SPEEDS UP NEW YORK TRAFFIC



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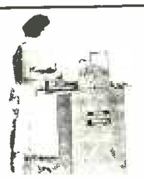

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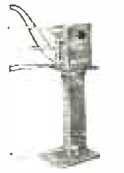

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Departmental Staff, ELECTRONICS, *New York City*

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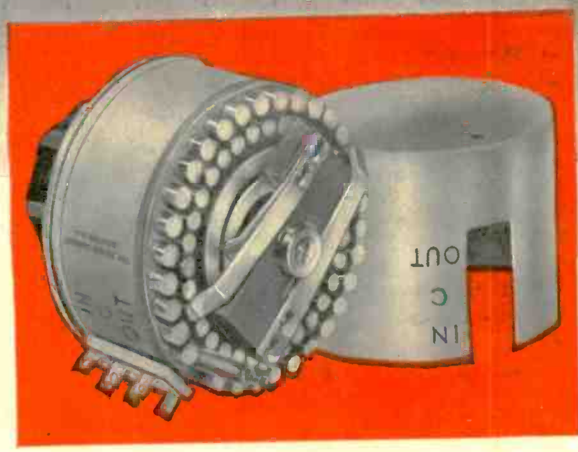

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