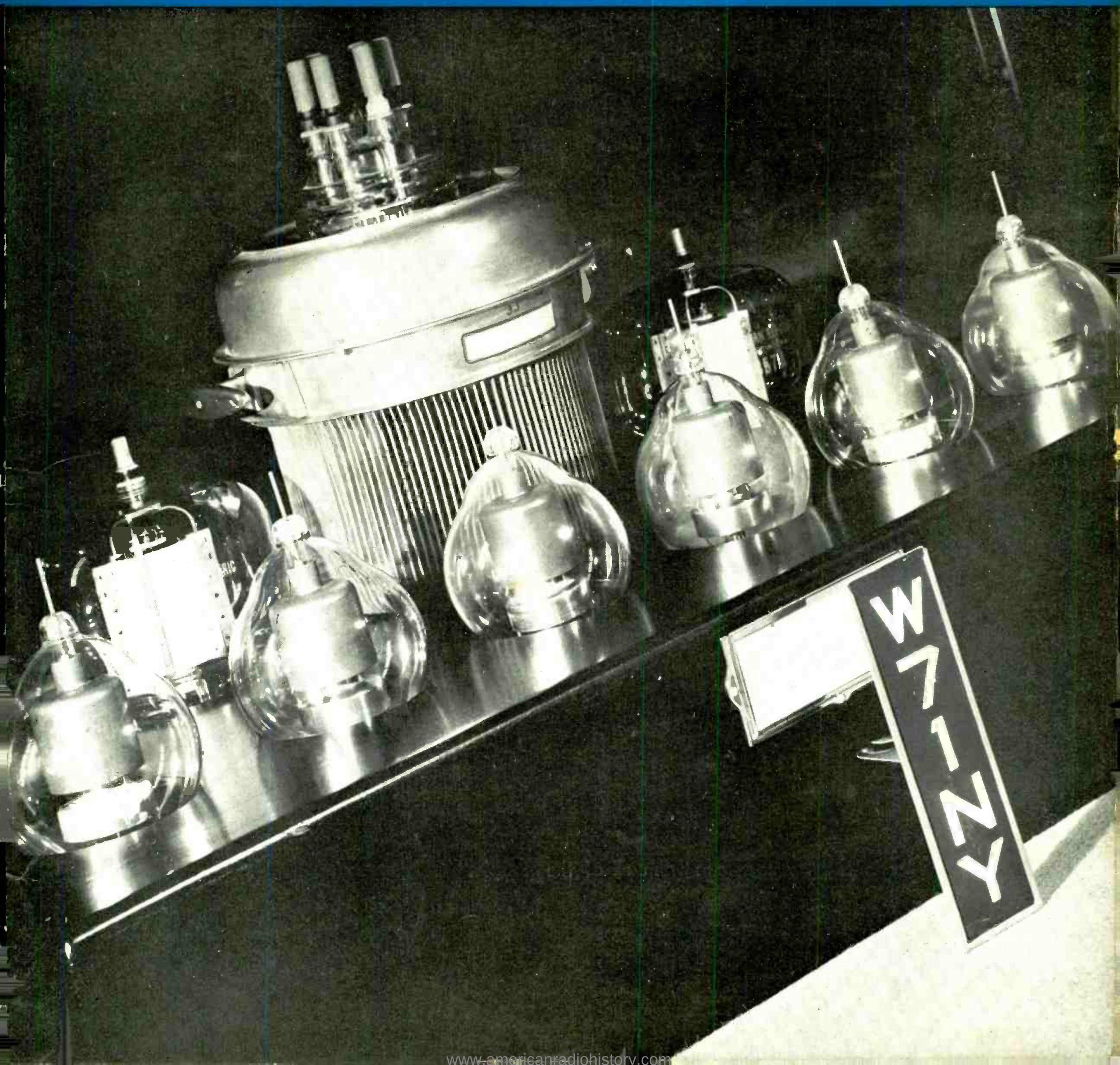
APRIL • 1942

electronics

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



More than 100 types of tubes for use in Commercial Broadcasting, Point to Point Communication, Ultra High Frequency Transmission, Electro Medical Apparatus, High Voltage Rectification and many Industrial Applications.

Now, this is a WAR!

"A TOTAL WAR! A war in which the fighting man DEPENDS upon radio for his information, his orders and his very life.

"And that odd-shaped bottle is an ultra-high frequency, high-power, air-cooled transmitting tube. Thousands of these, as well as other AMPEREX types, are in 'front line' service.

"Folks back home subordinate their civilian requirements to such military needs. It's an 'all-out' war calling for sacrifices from all of the people."

AMPEREX ELECTRONIC PRODUCTS

79 WASHINGTON STREET **BROOKLYN, NEW YORK**

A McGRAW-HILL PUBLICATION

electronics

Vol. 15 No. 4

CONTENTS—APRIL, 1942

DEPARTMENTS

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JAMES H. McGRAW
Founder and Honorary Chairman

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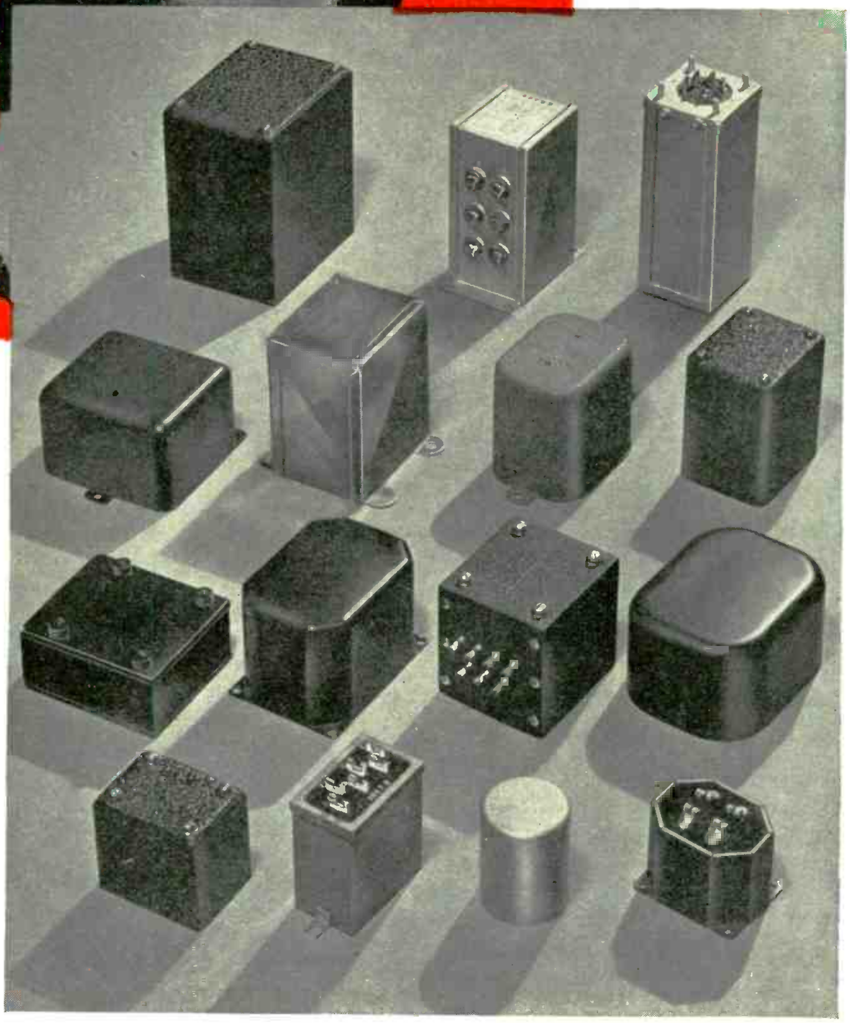
TOUGH?

Not when YOU'RE EQUIPPED TO HANDLE THEM



In addition to the electrical characteristics, many customers' application problems are related to the physical appearance and dimensions of their transformer components. Fortunately, the UTC sheet metal division supplies practically all the housings, laminations, brackets, and other devices which control the mechanical characteristics of UTC units. Instead of restricting designs to specific cases, the sheet metal division can run off a special case to more closely fit the final transformer dimensions, or to effect the particular mounting provisions required by the application.

The sheet metal division has drawing, forming, and other press facilities to cover the entire gamut of transformer housings from tiny transformer channels, to large oil tanks for broadcast and industrial service. Since these housings are produced at UTC, fast service can be given.

Illustrated are a few (just a very few) typical cases as supplied for some special applications

IF YOU HAVE A SPECIAL PROBLEM, MAY WE HAVE AN OPPORTUNITY TO COOPERATE?

UNITED TRANSFORMER CO.

150 VARICK STREET ★ NEW YORK, N. Y.

EXPORT DIVISION: 100 VARICK STREET NEW YORK, N. Y. CABLES: "ARLAB"

PHOENIX DEFIES MOISTURE GHOSTS . . .

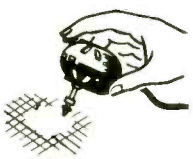
Your hands are never dry. Perspiration stains ordinary tracing cloth, producing opaque spots, or "ghosts," that show on blueprints. Water splashes make even more disagreeable stains.

PHOENIX *Tracing Cloth withstands actual immersion in water for more than 10 minutes at a time without ill effects!* Perspiration will not stain it!

PHOENIX LESSENS SMUDGE GHOSTS . . .

The improved surface of PHOENIX Tracing Cloth permits you to use harder pencils (5H and 6H) and to get sharper lines with less tendency to smudge.

Result: cleaner tracings and blueprints!



PHOENIX REDUCES ERASURE GHOSTS . . .

Ordinary tracing cloths become scarred when erased. Erased spots produce ghosts on the blueprints.

PHOENIX has a durable drawing surface that reduces working scars to a minimum.

THIS NEW TRACING CLOTH *IS*

GHOST-PROOF!

Here is a new kind of tracing cloth that won't show perspiration stains or water marks—*that holds pencil smudges and erasure scars at a minimum.* Now you can have clean tracings, in pencil or ink, free from these untidy "ghosts" that reproduce on blueprints!

For PHOENIX is ghost-proofed by a remarkable new process that defies moisture, and gives you an unusually durable working surface. You can use harder pencils with this improved cloth and get sharper lines with less tendency to smudge. Even 6H pencil lines show clearly, and reproduce sharply! Erasing does not mar the drawing surface; erased areas take pencil smoothly—and ink without feathering. The new white color and increased transparency provide excellent drawing contrast and produce strong blueprints.

Try PHOENIX for yourself on your own drawing board. See your K&E dealer or write for a generous working sample and an illustrated brochure.

K&E

Phoenix

REG. U.S. PAT. OFF.

TRACING CLOTH

for pencil *and* ink

EST. 1867

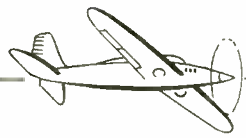
KEUFFEL & ESSER CO.

NEW YORK • HOBOKEN, N. J.

CHICAGO • ST. LOUIS • SAN FRANCISCO • LOS ANGELES • DETROIT • MONTREAL

tubular instrument pointers

stay straight



Light weight combines with extra rigidity

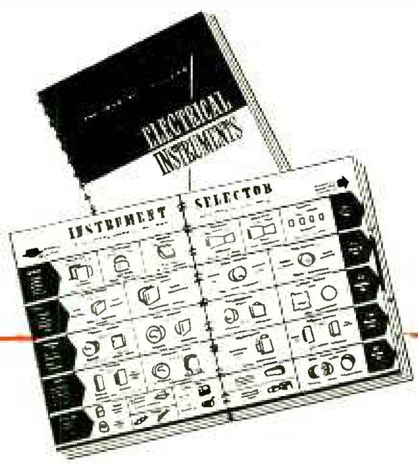
The tubular pointer, a Westinghouse development, ends instrument inaccuracies caused by bent or warped pointers. Our instrument designers achieve minimum weight with maximum strength just as aircraft designers do it—with seamless aluminum tubes.

Overswing is reduced because lighter weight means lower moment of inertia. Shock of accidental above-scale quantities is fully absorbed by the stress-free tubing.

High visibility is an added advantage of these tubular pointers, with either target or knife-edge.

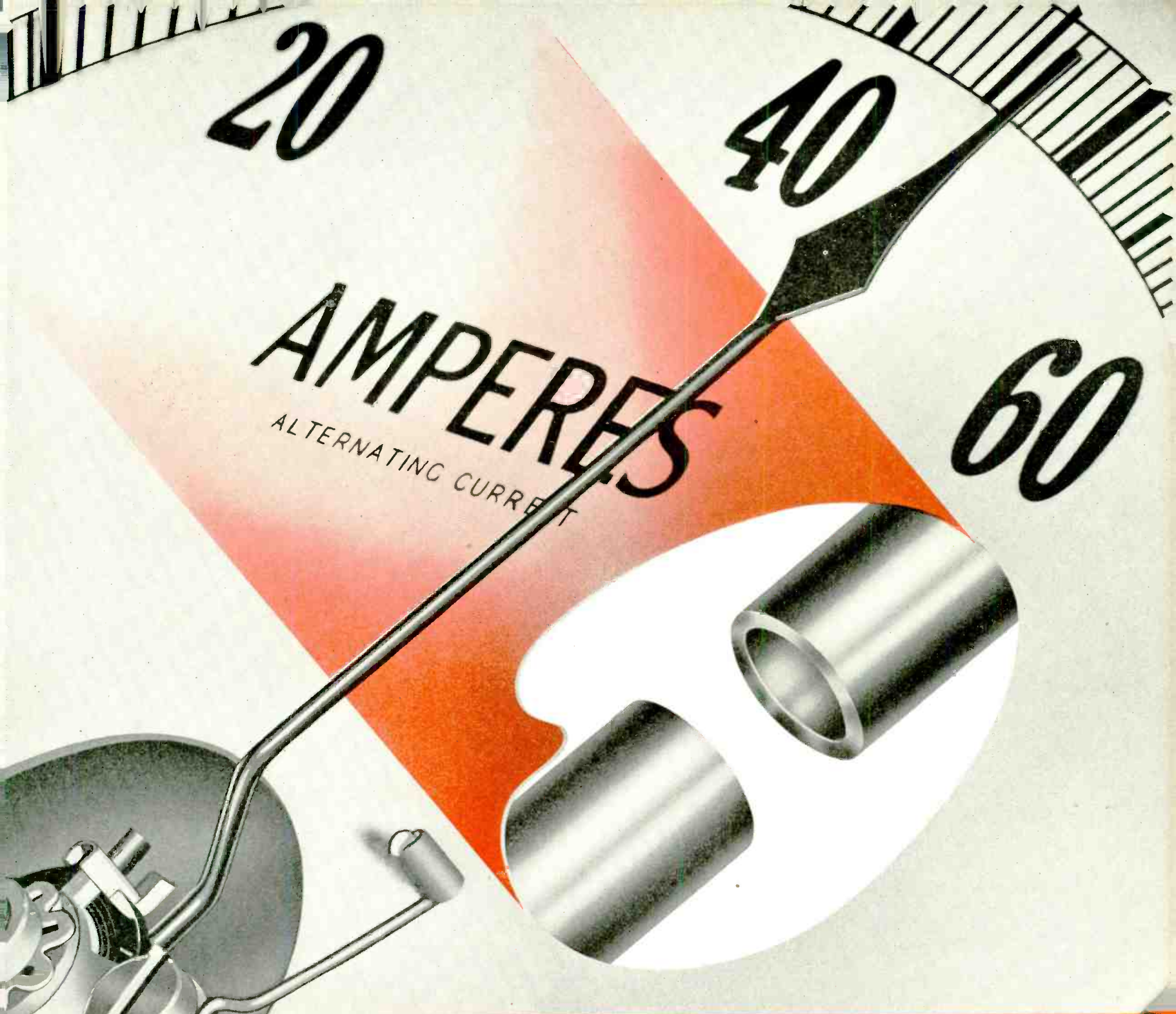
Tubular pointer construction, along with ageless springs, non-blunting pivots, white dials, and permanent magnets is typical of the extra quality in all Westinghouse electrical instruments. It is typical also of the reasons why Westinghouse instruments are in special demand today when accurate measurements are vital in conserving power, controlling production quality, and wielding the weapons for defense.

J-40332



Help for you in selecting instruments is contained in a new "Instrument Selector" chart to be found in our book B-3013. Address Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., Dept. 7-N.

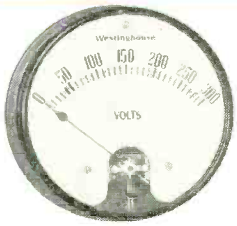
Westinghouse



INDUSTRY'S MOST COMPLETE LINE OF QUALITY INSTRUMENTS

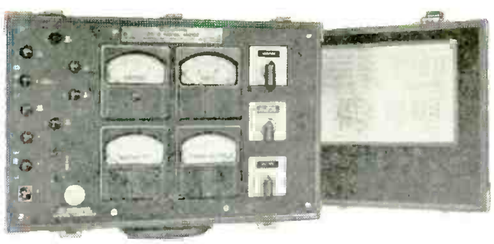
PX-5 portables provide d-c measurements with ½% accuracy for a wide range of uses.

PX-4 is a versatile, double-range, direct-current voltmeter, ¾% accuracy, in a dustproof case.



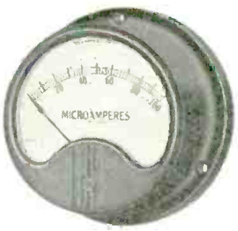
Type S instruments, 1% accuracy, for large switchboard applications, are 7 inches in diameter.

UX-25 is a 1% accuracy switchboard instrument with large scale that is easily read from a distance.



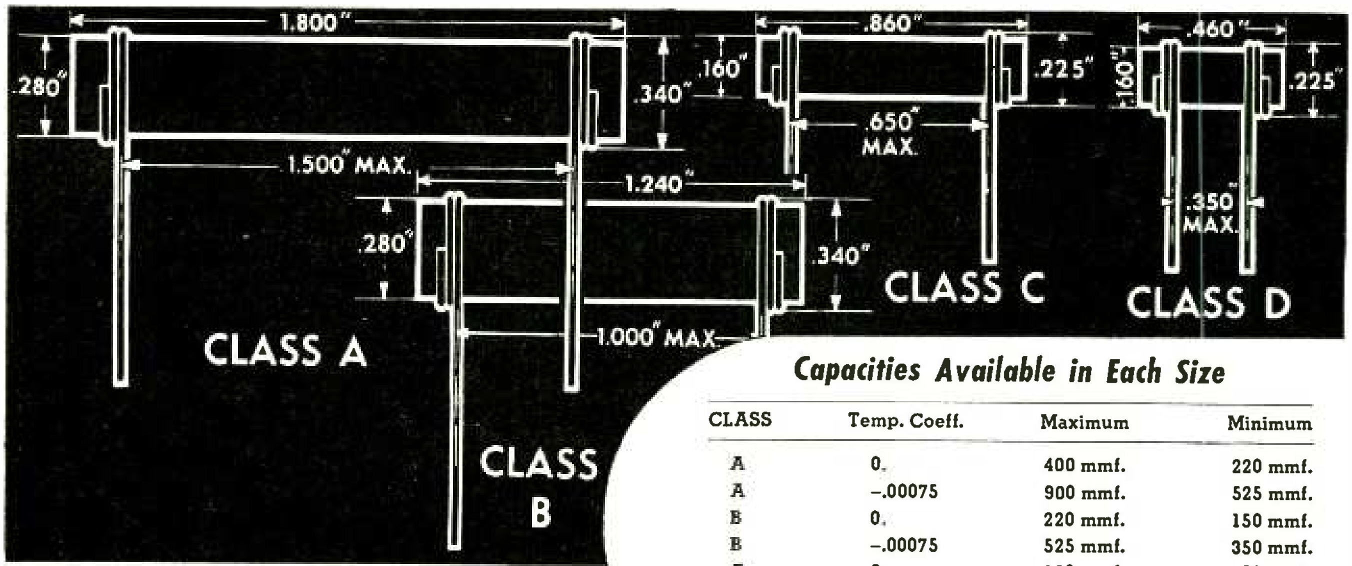
TA-Industrial Analyzer—contains in one case all the instruments necessary to obtain complete alternating-current data in any industrial plant. Requires no complicated setup wiring. Weighs only 35½ pounds.

U-35 is an attractively styled instrument for projection mounting on medium size panels. Accuracy is within 2%.



S-37 is a beautifully designed instrument of 2% accuracy for mounting on panels in various applications.

Centralab Ceramic Tubular Fixed Capacitors with Controlled Temperature Sensitive Characteristics



Capacities Available in Each Size

CLASS	Temp. Coeff.	Maximum	Minimum
A	0.	400 mmf.	220 mmf.
A	–.00075	900 mmf.	525 mmf.
B	0.	220 mmf.	150 mmf.
B	–.00075	525 mmf.	350 mmf.
C	0.	160 mmf.	50 mmf.
C	–.00075	375 mmf.	120 mmf.
D	0.	50 mmf.	1 mmf.
D	–.00075	120 mmf.	2 mmf.

STABILITY:

Ageing and humidity cause no measurable change in capacitance. There is no air film or possible mechanical movement between the plates.

RETRACKING:

Small mass and open tubular construction insure rapid and uniform changes with temperature. No measurable change in the coefficient after cycling.

POWER FACTOR:

Less than .08%. After 100 hrs. at 90% humidity . . . less than 0.2%.

VOLTAGE RATING:

500 volts D.C. Tested at 1000 volts RMS 60 cycles. Special small capacity high voltage units available on special order.

Write for special Bulletin 597

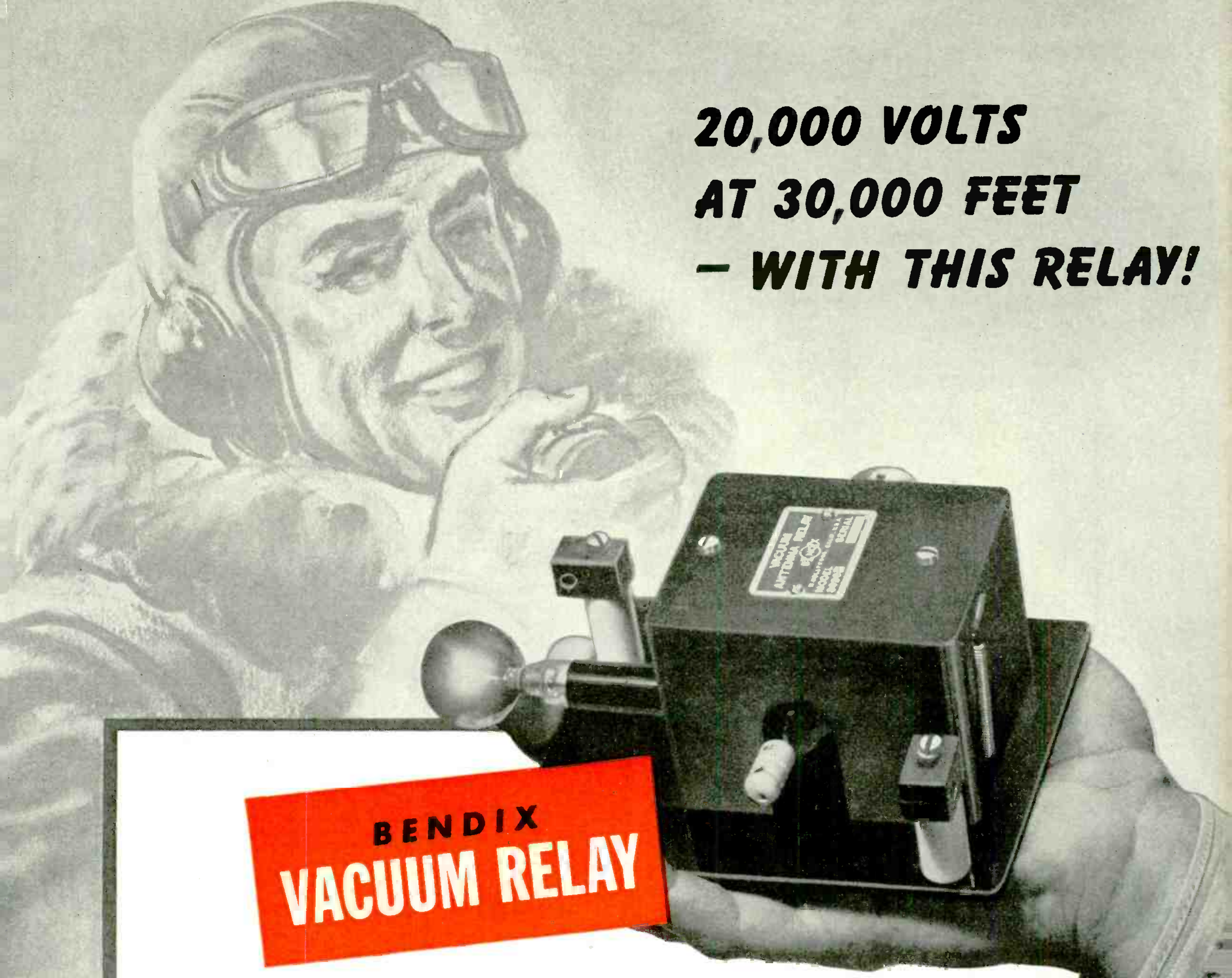
CENTRALAB Ceramic fixed Capacitors are furnished with zero temperature coefficient where absolute stability is desired, and with any desired negative temperature coefficient to a maximum of —.00075 mmf/mmf/C°.

The temperature coefficient is determined by the ingredients of the ceramic dielectric and is accurately controlled. The dielectric constant of the material increases with the amount of negative coefficient which makes possible highest capacitance per unit size in the maximum negative coefficient. (See chart).

Centralab

Division of GLOBE-UNION INC., Milwaukee, Wisconsin

20,000 VOLTS AT 30,000 FEET — WITH THIS RELAY!



BENDIX

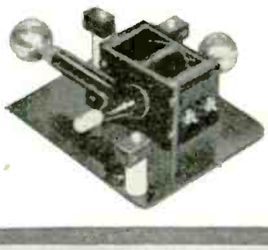
VACUUM RELAY

CAPABLE of handling an R. F. potential of 20,000 volts at 30,000 feet altitude—yet no larger than your hand is the new Model 3926D Bendix Vacuum Relay which takes the place of cumbersome heavy equipment for switching antenna circuits and other relay applications.

Unparalleled reliability already has been demonstrated by the relay in thousands of installations and the new model is even more efficient.

The Bendix Relay consists of single pole double throw switch enclosed within a highly evacuated, nonex glass envelope. This makes the unit entirely independent of climatic conditions, altitude, dirt or oxidation. The arm, or armature, when actuated by an external electro-magnet, transfers the circuit from receiver to transmitter. Because of the small mass of the armature and the small space between contacts the transfer allows instantaneous break-in. This speed of action enables keying at 40 words a minute. The spacing between the open contacts is approximately .015″, yet because of the high vacuum this space is ample to stop transfer of energy between the open contacts.

Weight of the 24-volt unit, including case, is 24-ounces. The relay measures 2 5/8″ x 5 5/8″ x 6 7/16″ overall. Coils can be supplied for any common voltage. Bendix invites inquiries regarding requirements for circuit applications or special installation problems.



BENDIX *North Hollywood*

SUBSIDIARY OF BENDIX AVIATION CORPORATION

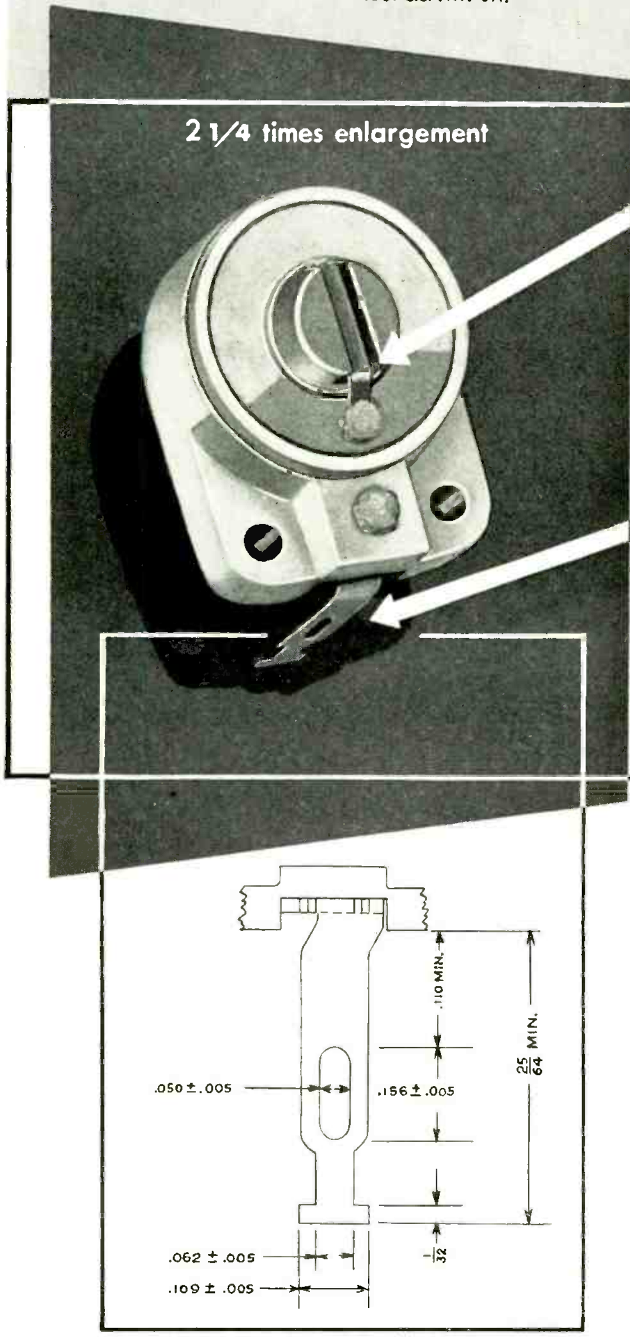
INTERPHONE SYSTEMS • TRANSMITTERS • COMMUNICATION UNITS • RANGE FILTERS • CONTROL PANELS • JACK BOXES • ANTENNA SWITCHES • MICROPHONES

VACUUM SWITCHES • FABRICATION OF ELECTRICAL CABLES • INTERFERENCE FILTERS • INSTALLATION ENGINEERING • HYDRAULIC AIRCRAFT UNITS

Recent Developments

in CERAMICON Trimmer Design

REG. U.S. PAT. OFF.



Increase Dependability

All Ceramicon Trimmers now have a semi-flexible electrical connection that is independent of the mechanical keying between the rotor and adjusting screw. This consists of a .005" x .035" hot-tinned brass strip placed along the bottom of the screw driver slot. One end is soldered to the silvered portion of the rotor and the other to the end of the slot.

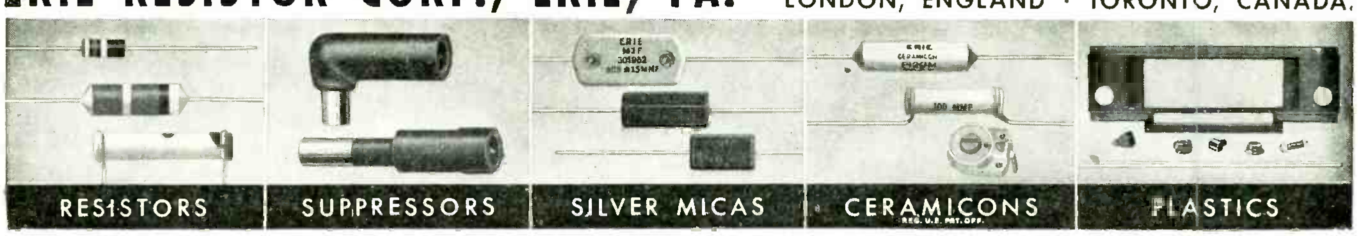
Facilitate Installation

The improved Ceramicon Terminals, illustrated at the left, have been re-designed to provide attachment of wires either through the slot, or by wrapping around the narrow portion near the bottom. Overall terminal length has been increased for easier sub-panel wiring, and a heavier metal (.025" thick) employed for greater rigidity.

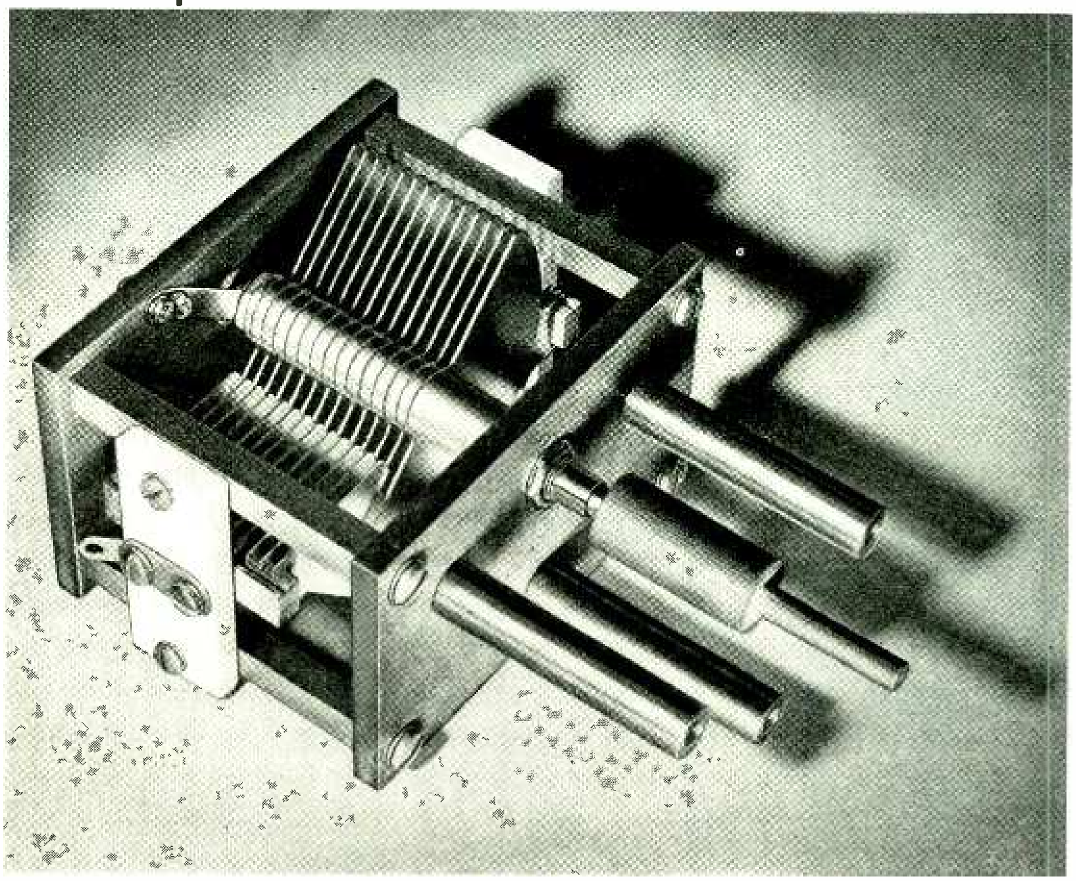
THE recent design changes, described above, add to the dependability of Erie Ceramicon Trimmers. Other features such as stability with respect to temperature change, completely covered track, and little capacity change when mounted on a metal chassis, provide a high degree of operating efficiency in military and naval communications equipment.

Erie Ceramicon Trimmers are made in single and double units in the following temperature coefficients, Zero, —.0003/°C and —.0005/°C. Write for data sheets that fully describe these small, silver-ceramic, trimmer condensers.

ERIE RESISTOR CORP., ERIE, PA. LONDON, ENGLAND · TORONTO, CANADA.



THEN AND NOW



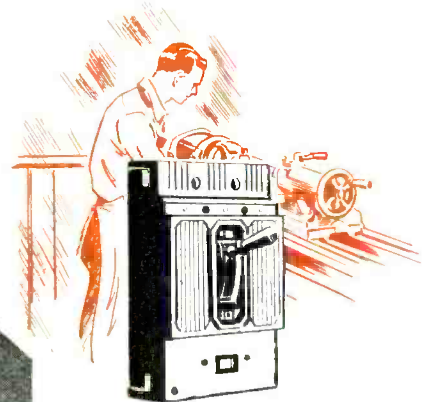
Typical Special Purpose Variable Condenser.

TIME was when you could recognize a Hammarlund condenser by its physical make-up. Now, with hundreds of special designs of all shapes and sizes, you can still identify a Hammarlund condenser by its precision workmanship.

THE HAMMARLUND MANUFACTURING CO., INC.
424-438 West 33rd Street, New York, N. Y.

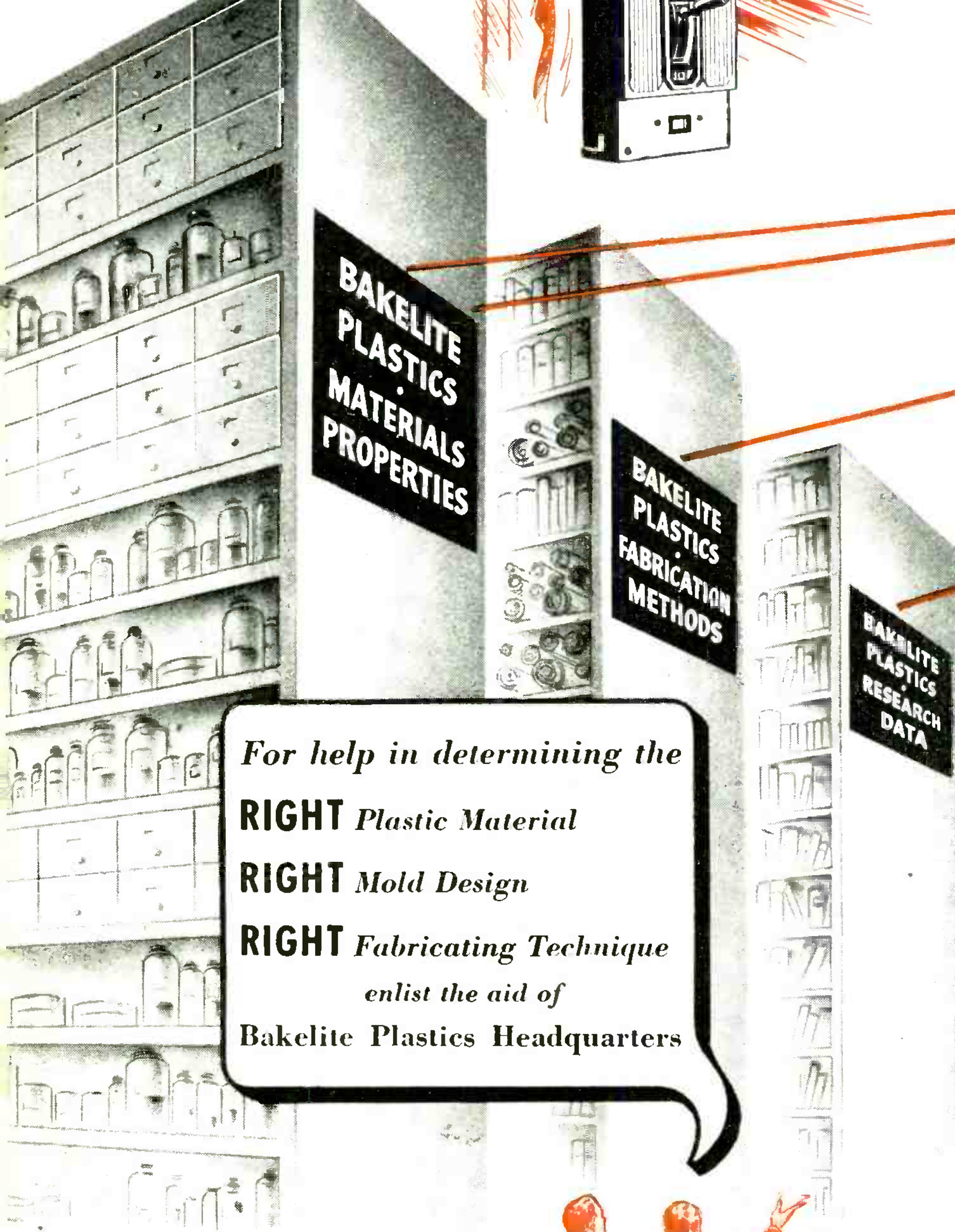
IF YOU REQUIRE

Impact Resistance



CIRCUIT BREAKER HOUSING '40

molded from a *general-purpose* BAKELITE *Phenolic* Plastic, represented sound designing and engineering. For ordinary industrial service, it fully met the need for high dielectric strength, moldability, and resistance to moisture, corrosion, and wear. *But—*



Different Properties Required

1940 Required: A plastic that could be easily preformed; one high in dielectric strength; one that could be employed in intricate molds, and providing a highly lustrous and attractive finish.

1942 Required: A plastic housing that, under test, would withstand the shock from the blow of a one-ton weight crashing into the wall behind it! Preformability, surface finish, and other properties subordinated to maximum toughness and shock resistance.

For help in determining the

RIGHT *Plastic Material*

RIGHT *Mold Design*

RIGHT *Fabricating Technique*

enlist the aid of

Bakelite Plastics Headquarters

3 WAYS

BAKELITE PLASTICS HEADQUARTERS

can help you to speed up production while conserving valuable, strategic materials

BAKELITE

TRADE-MARKS

IN PLASTICS

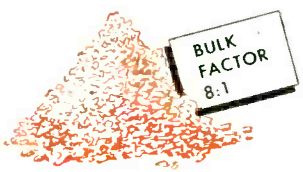
You will be interested in this story of two Circuit Breaker Housings molded from different "Bakelite" Plastics

CIRCUIT BREAKER HOUSING '42

had to be molded from a different plastic, *a high-impact* BAKELITE *Phenolic* material, because today's service conditions, for example, aboard a warship, are greatly different from those encountered in 1940. Toughness and shock resistance are now the vital factors in plastics selection.

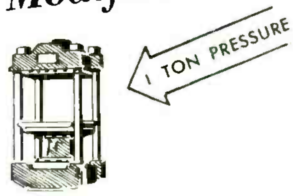
A Different Material Specified

1940 Typical material used was a general-purpose, cellulose-filled BAKELITE Phenolic plastic. Bulk Factor, i.e., the ratio of the volume of molding material to the volume of the finished piece, is 2.5 to 1, and molds were built accordingly.

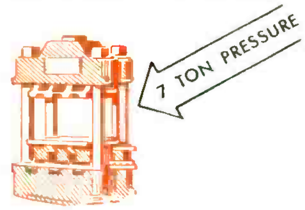


1942 The highest ranking shock-resistant plastic is demanded. Bulk Factor is 8 to 1 so that molds built previously are too shallow to accommodate the impact-type material, *even though the design of the finished piece has not been altered.* New molds are necessary.

Molding Technique Modified



1940 Molding pressure averaged 2,000 pounds per square inch. This comparatively low pressure minimized the danger of shearing-off pins. Material could be preformed thus simplifying the problem of filling-out "hard-to-get-at" corners. Flow ranged from "soft" to "very soft" permitting a fast molding cycle.



1942 Molding pressures range from 8,000 to 14,000 pounds per square inch. Molds have to be built sufficiently strong to withstand these considerably higher pressures. The material is not preformable. Because flow is "extra hard," allowances must be made in designing the mold to provide proper fillets and tapers.

Plastics Research Data and Engineering Guidance

Because no two plastics problems may be exactly alike, it is recommended that designers and engineers draw upon the knowledge and data accumulated by Bakelite Plastics Headquarters in more than 32 years' experience with plastics development and application. Here you will learn the essential differences between thermosetting and thermoplastic materials, and the fabricating methods required to convert these plastics into finished parts. Here you will learn the "Do's and Don'ts" of materials selection, mold design, and other vital factors that are so essential to satisfactory plastics performance.

1 LITERATURE *on "Do's and Don't's" of Plastics*—Helpful, technical booklets containing data on the various types and forms of BAKELITE Plastics, and the most economical and effective methods of fabrication. This literature will assist you in selecting the proper plastic for a given job, will save your time, and help you to avoid errors.

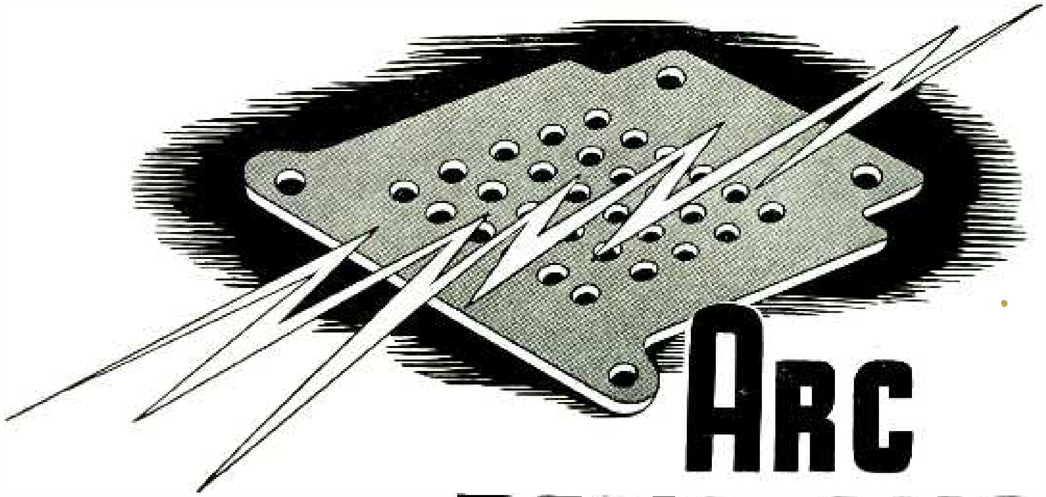
2 GEARING *our Laboratories to Yours* Bakelite Laboratories offer a two-fold service. They are ready to help you utilize present plastics in current strategic production. And, they will also develop new formulas to help solve the problems created by highly specialized applications.

3 FIELD WORK *on "Frontline" Jobs* Located at important industrial centers throughout the Nation, Bakelite Field Engineers are readily available to give prompt service to manufacturers engaged in Defense Production. These engineers are fully qualified, and frequently may be able to solve production problems right on the spot.

Plastics Headquarters

BAKELITE CORPORATION
Unit of Union Carbide and Carbon Corporation
30 EAST 42nd STREET, NEW YORK

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



ARC RESISTANCE—

Multiplied Ten Times!

Accelerated war time research on materials and processes has made it possible for Formica to produce a new grade of laminated material, emphasizing the important quality of arc resistance, which greatly exceeds any material of the type ever produced before.

Previous grades, used for electrical purposes, subjected to the American Society for Testing Materials. Test for Arc Resistance D-495-41 stood up without breakdown for from 13 to 18 seconds in the various grades.

Similar tests on the Arc Resistant Fiberglas grade will take it from 130 to 190 seconds—or approximately ten times as long.

Let us send you engineering data and prices on arc resisting grades.

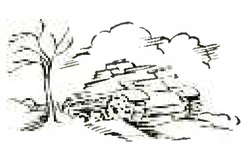
THE FORMICA INSULATION CO.
4661 SPRING GROVE AVE., CINCINNATI, OHIO

FORMICA

Arc Resistant Formica

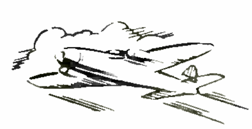
Arc resisting grades are available in all the usual types of Formica—paper base, muslin base, Fiberglas grades. Each of these grades is available in sheets, tubes and rods and can be machined in the usual way to produce insulating parts of antennas, and other high voltage radio apparatus. In all other qualtites this arc resistant grade offers values approximately equal to the standard grades of Formica. The arc resistance is accomplished practically without sacrifice of any other useful quality.

★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★



Formica for DEFENSE

Ignition parts of American tanks, planes and motor vehicles are made at the Formica factories. So are control pulleys for airplanes, insulation for signalling and communications apparatus, machined parts for devices of all kinds. Four fifths of Formica's production is now devoted to war work.



A NEW STANDARD of QUALITY

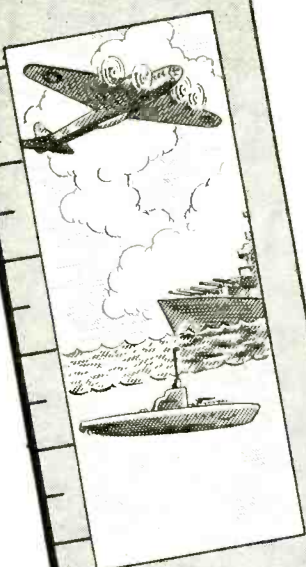
. . . for COMMUNICATIONS

Leading Communication Engineers are hailing a new standard of quality . . . the WINCO DYNAMOTOR.

Quality built in every detail, the sturdy WINCO DYNAMOTOR supplies efficient, dependable current for all types of Communication systems. Perfect operation in temperatures ranging from $-40°$ to $+65°$ centigrade ● Compactness ● Light Weight ● Minimum AC Ripple ● Low Voltage Regulation—all are inherent features of WINCO DYNAMOTORS. Specify WINCO and let over 50 assembly tests insure you of OUTSTANDING QUALITY.

. . . And, due to tremendous manufacturing expansion of WINCO DYNAMOTORS, we have facilities not only to meet current delivery schedules—but also future orders.

WINCO DYNAMOTORS are regularly available in standard outputs and sizes . . . and, special WINCO DYNAMOTORS can be quickly and easily designed to meet your exact needs. A complete free Advisory Engineering Department is at your service—why not consult us?



ONLY WINCO GIVES YOU ALTI-TEMP

The Dynamotor designed to insure maximum efficiency at all operating altitudes and temperatures.

WINCO DYNAMOTORS

WINCHARGER CORPORATION — SIOUX CITY, IOWA

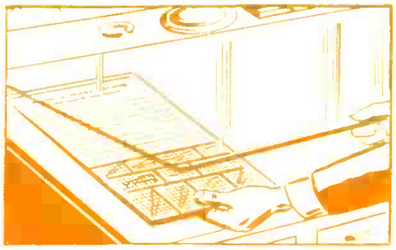
The SURVIVAL of The INFORMED

The pace of development in the electronic industries — always fast —was stepped up to lightning speed when war was declared.

Important developments began breaking thick and fast — and engineers had to have FACTS. Today, more than ever, it's a matter of the survival of the informed. Almost every new electrical development brings a new insulation problem.

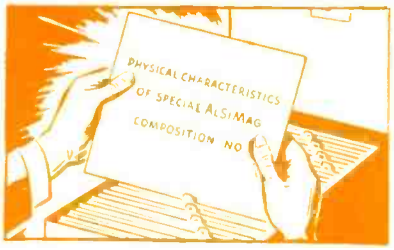
American Lava Corporation gives you needed information and help in selecting the proper AlSiMag steatite ceramic insulation in three ways:

AlSiMag PROPERTY CHART



1. A chart of Physical Properties of the more frequently used AlSiMag compositions, sent free on request. We know of no other data available with comparable detail or accuracy.

AlSiMag SPECIAL COMPOSITIONS



2. In its research department there are records of the physical characteristics of a great number of special AlSiMag steatite ceramic compositions which have been evolved for specific applications.

AlSiMag RESEARCH DIVISION

3. An Engineering Staff and Research Laboratories that are unrivalled in the industry stand ready to advise or assist in any problem involving technical ceramics.

When you have a problem, old or new, involving technical ceramics you can probably find the answer here.

ALSIMAG FROM CERAMIC HEADQUARTERS

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.

The Pathway Back to Earth ... by IT&T

Radio Instrument Landing System
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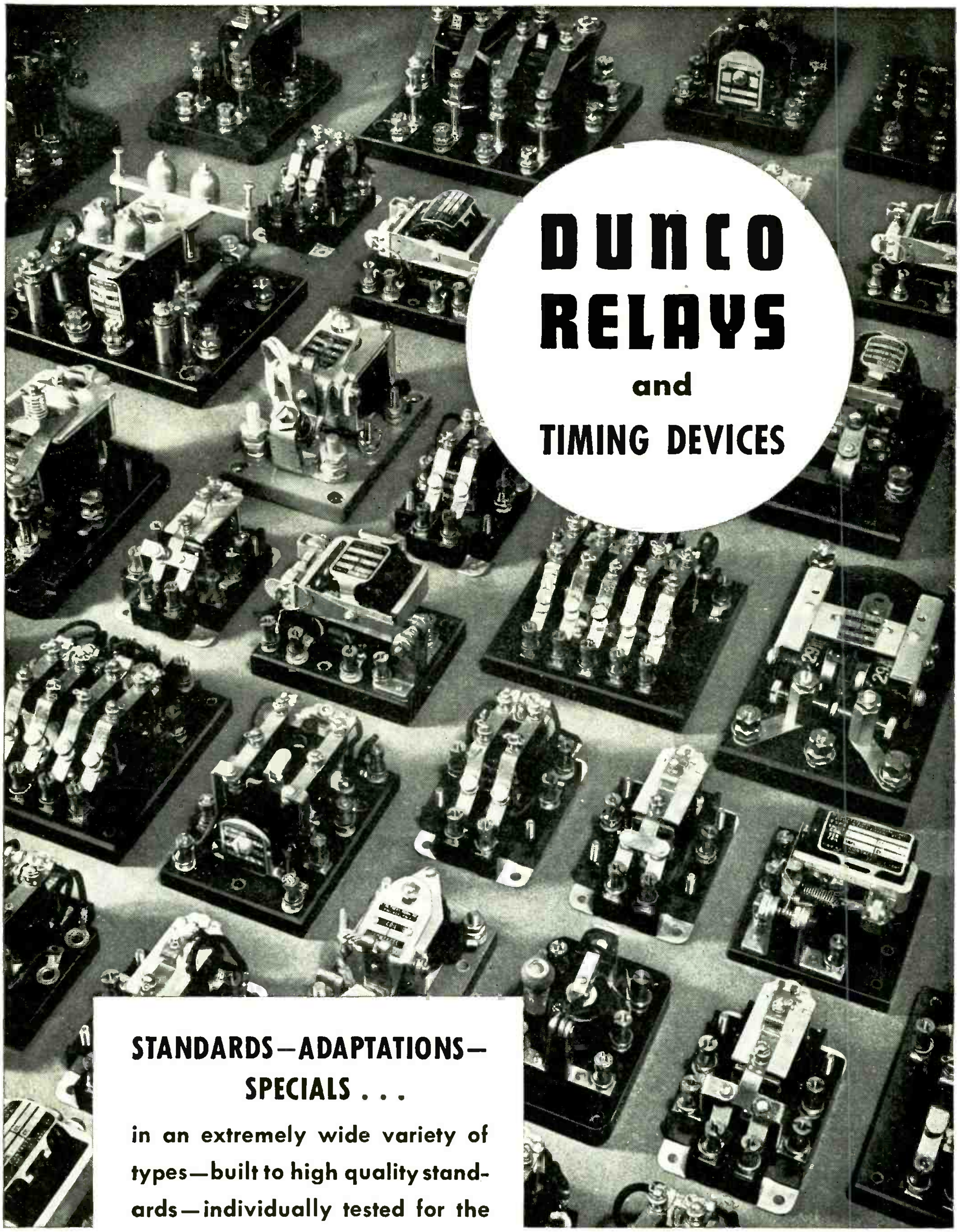

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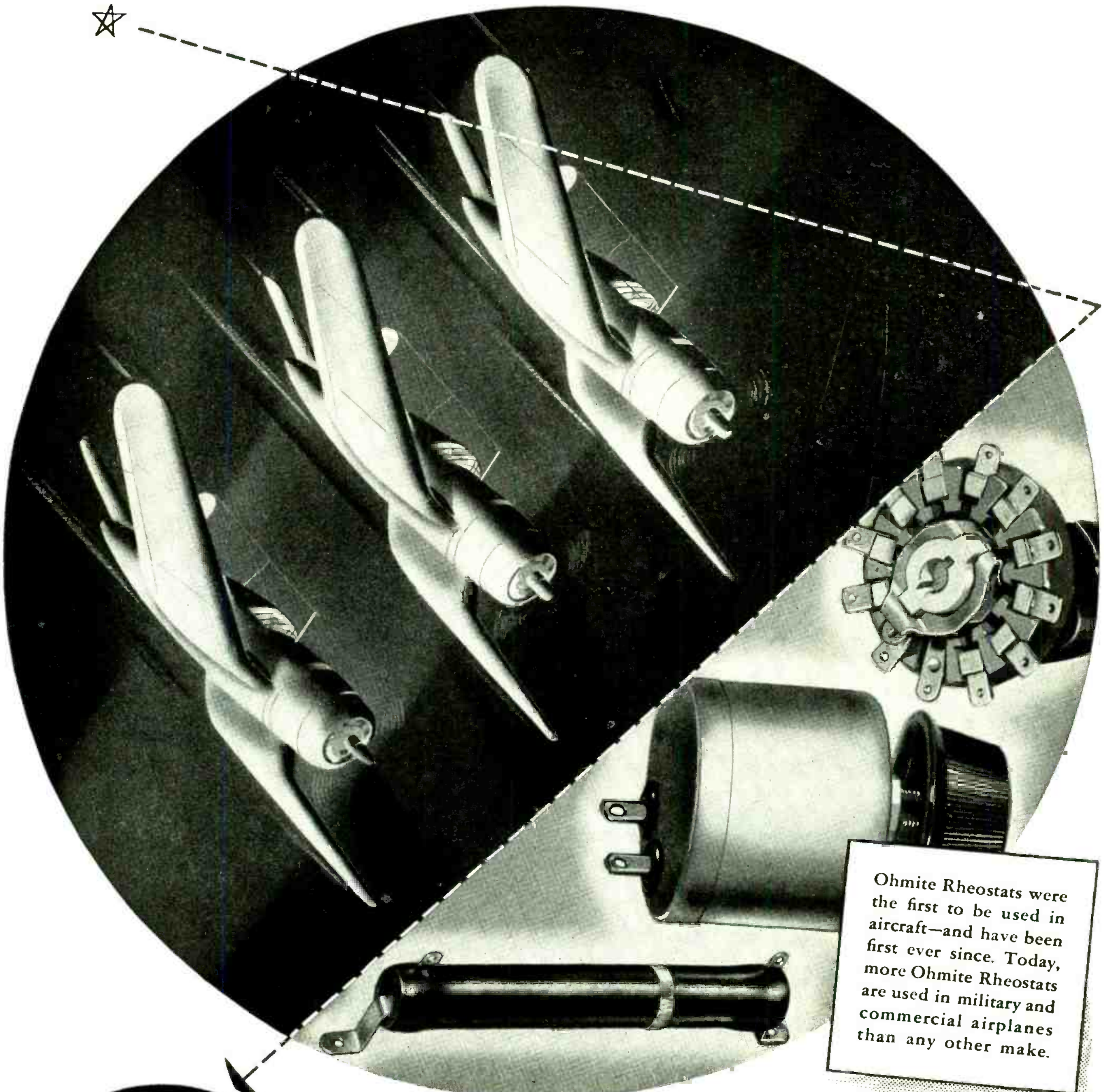

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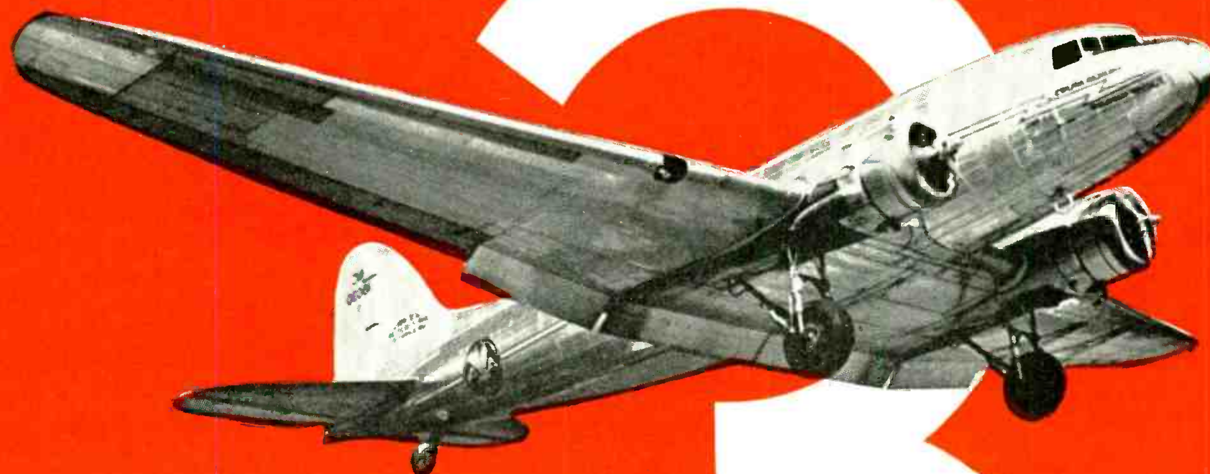

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CROSS TALK

✦ **U-H-F** . . . In this issue, we depart from our usual attempt to balance the editorial contents so that all diverse interests are covered by individual articles. The greater part of the feature pages of this issue are devoted to a summary of existing knowledge about the u-h-f region and the techniques associated with it. All over the country courses are being given in colleges and elsewhere to rapidly acquaint engineers with u-h-f fundamentals and to give "refresher" courses to men who already have a smattering of this new communication science. This summary is but one step in the program ELECTRONICS has laid down as its contribution to this educational effort. Reprints will be available at moderate cost to anyone who may want them.

Another large story will appear in our May issue, this one devoted to a most interesting communication set-up having features of interest to all radio engineers. June will be the Reference and Directory issue and the feature editorial pages of this big issue will be devoted, largely, to that field of increasing usefulness of the electron tube —industry. After that, the editors hope to settle down a bit and relax.

✦ **WAR** . . . "On the production lines of the radio industry depends, to a large extent, the success of the communication links that knit the land, the sea and air forces into one unified fighting organization," so says a release from the War Production Board.

No one need tell us the vital part communications will play in the vast war of the type soon to be fought; and no one need tell us that nothing must stand in the way of speedy and efficient transformation of the presently allocated two billions dollars into communication equipment.

Reading the papers and listening to the radio, as we all do, day by day, we get only piecemeal pictures of the vast war; and our own share of it seems to be rather disappointing. Losses at sea, strikes at home—nothing much seems to be happening on the bright side. But, now and then the clouds blow away and we see a bit further and the vision that comes with the seeing is grand.

For all is not going wrong.

There is building in this country today the most God-awful lot of military destruction the world has ever seen; and if we could get a word to certain people in Tokyo and Berlin we would advice hurried trips elsewhere when this load of dynamite begins to fall. The war, to date, will resemble the war a year from today only as the merest creek resembles the Mississippi. The machine still creaks a bit, but it is moving fast; there are still those who gripe and stall and delay and talk when action is needed, but all these together cannot hold off the vast production of tanks and planes and munitions—and the communications that go with them —nor long delay the ultimate destruction to be produced by this equipment.

By the end of the year, production of military communication equipment will exceed a rate of $125,000,000 per month. Some two billion dollars have been allotted for this equipment; one-half is for detector equipment; one-fifth for aircraft and navigation equipment; one-fifth for walkie-talkies, tank sets, etc.; and the remainder is for telephone, telegraph and miscellaneous equipment. About 120 radio models are being made ranging in cost from $75 to $85,000 per unit.

Of the country's 55 set makers, 21 got some military business in 1941 but the volume amounted to only $10,000,000. This year 40 firms are sharing $500,000,000 worth of military business.

Stoppage of set construction except for military purposes will release 70,000 tons of steel, 10,000 tons of copper, 2,100 tons of aluminum, and 280 tons of nickel from civilian to military needs.

Communication is a vital part of the vast program unfolding; and lack of communication in a war of the type soon to be fought will be fatal.

✦ **HELP** . . . A problem presents itself to communications people, a solution to which would be very welcome. This is the problem of warning air raid wardens, auxiliary firemen and policemen and first aid people when an actual raid is in prospect. Some localities feel it unwise to blow the fire or air raid siren when preliminary warnings come through on the basis that there is no need to disturb the people unless there is really going to be a raid. On the other hand it is highly desirable to have the auxiliary services in a state of readiness, or actually at their posts, in advance of the all-out warning.

Now everyone likely to be a member of these auxiliary services has power wires coming into his home, whether it is a full-fledged house or an apartment. If a simple—and cheap—device could be attached to these power wires so that a bell could be made to ring in the homes of those who should get the preliminary and precautionary warnings, these people could collect their duds, their shillalahs and other equipment and be ready in case the final alarm goes off. This would reserve the air raid or fire siren for the real thing.

Broadcasters Discuss Wartime

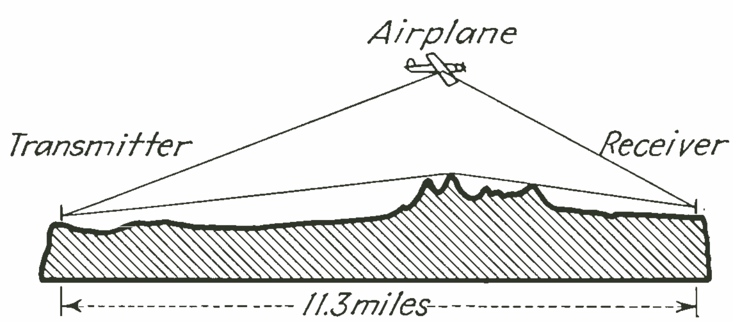
at Fifth Broadcast Engineering Conference

THE aim of the Broadcast Engineering Conference of 1942 was to help solve the problems facing broadcasters in war time. Judging by comments of those present at the Conference, this aim was achieved. The success of the Conference may be credited to W. L. Everitt, of The Ohio State University who was aided by Lynne C. Smeby, Director of Engineering of the National Association of Broadcasters. This year the Institute of Radio Engineers participated as co-sponsor; the Conference also served as the Engineering Convention of NAB.

After Dr. H. L. Bevis, President of the University, formally opened the Conference on Monday, February 23, E. K. Jett, Chief Engineer of the FCC and Chairman of the Coordinating Committee of the Defense Communications Board, outlined the accomplishments of the DCB and indicated where its activities would impinge upon those of the broadcasting industry. Among the points mentioned were the survey of available facilities, establishment of priorities for traffic, alternate services, establishment of key stations and liaison among all stations concerned, with radio or wire links to advise stations during emergencies. Some orders have already been issued by the FCC covering the situation and Mr. Jett discussed some of the provisions of these orders. Steps to improve emergency facilities of cities and other civil divisions are being taken, and efforts are being made to improve the situation with regard to repair parts and critical materials. In addition, the establishment of the large number of monitoring stations already has had a salutory effect in clearing from the air illegal or "fifth-column" stations, as well as yielding a record of a great amount of propaganda from foreign governments, which is analyzed by the proper authorities.

Orrin W. Towner, Chief Engineer of WHAS, discussed the emergency operation of broadcast stations on the basis of experience acquired during the flood of 1937. After setting the scene by showing pictures of the conditions prevailing during this emergency, when more than one hundred thousand urgent messages were handled by the station over microphones kept open continuously for 187 hours, Mr. Towner described the precautions taken at his station for operation in case such a catastrophe occurs again. To aid other stations, he summarized the points covered, including a check of the minimum power for a signal sufficient to cover the emergency service area, the minimum number of tubes to give this signal strength (in case of tube failures), the voltage limits which the transmitter will tolerate, and the minimum water supply for this temporary operation. The temperature limits of cooling air or water and the ambient temperature which must be considered, and dispersal of spare parts so that destruction of a single room or building will not wipe out the entire stock and the necessity of alert guards were stressed.

Tuesday's sessions began with a paper by Karl Troeglen, WIBW, on engine-driven emergency power plants. Two main types are available,

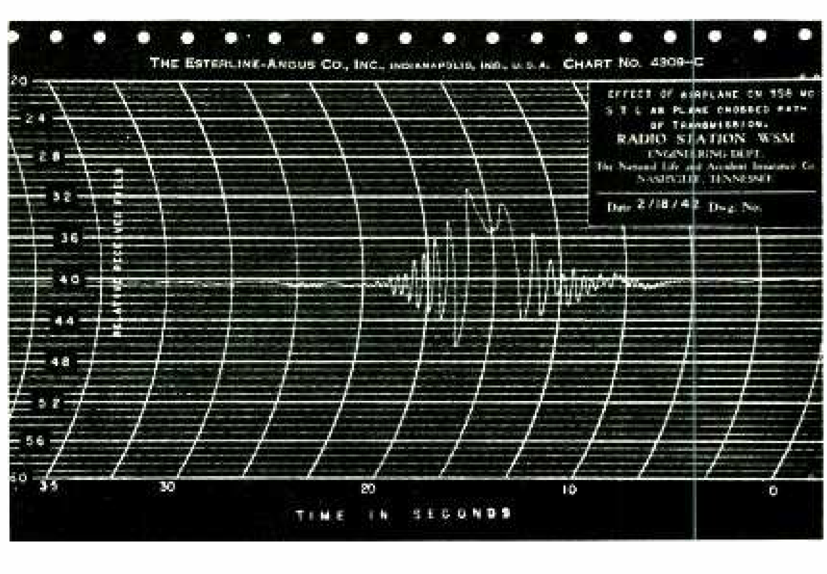


ABOVE

Terrain between transmitter (158 Mc) and receiver at WSM tests to determine value of uhf as link circuit between studio and transmitter

RIGHT

Airplane between transmitter and receiver causes changes in 158 Mc signal at receiver indicating reflections from plane in transmission path



Problems

diesel-engine driven and gasoline-engine driven, each with certain advantages and disadvantages. The emergency plant at WIBW was then described and suitable specifications for similar equipment were suggested. Important auxiliary items included a voltage regulator, quick-acting transfer switch, mounting to reduce transfer of vibration, and starting battery and motor. Maintenance and testing were emphasized to insure smooth operation and reliability.

Dr. W. L. Everitt, Ohio State University, and E. K. Jett, Chief Engineer FCC as they open the conference, the fifth held at Columbus for benefit of broadcast engineers

Mobile FM in the Field

A paper on mobile frequency modulation by Daniel E. Noble, Research Engineer of the Galvin Manufacturing Company, included a brief review of some of the fundamentals of frequency modulation and then dealt with the actual operation of f-m equipment in the field. Communication service, (especially emergency type) requires intelligibility rather than fidelity of tone, and a restricted audio-frequency range has proved adequate for these services. Phase modulation was used here rather than true frequency modulation, to utilize the inherent high-frequency pre-emphasis thus provided. The portable transmitting unit used receiving type tubes except for the final stage, and included a crystal controlled oscillator, mixer, two frequency-quadrupling stages, a doubler stage and the output stage. This unit is designed for a maximum frequency deviation of 15 kc at 500 cps (the lowest transmitted audio frequency) with a phase shift of one radian at the modulator. Multiplication of 32 times is used to attain the 15-kc deviation. By adding a second power tube and socket in a hole already provided, the output may be increased from about 30 watts to about 50 watts. Power supply units include interchangeable Genemotor, vibrator packs, and a-c supply. A single microammeter may be used rapidly to align the transmitter or localize trouble because jacks are provided in the grid circuit of each stage, with suitable shunting resistors.

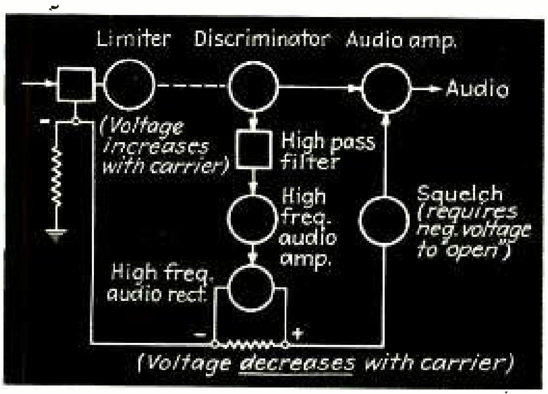
The companion receiver shown was a double superheterodyne, with two crystal-controlled oscillators, r-f stage, first mixer, first i-f stage at 4.3 Mc, second mixer, second i-f amplifier (at 455 kc) with two limiters in cascade, discriminator, audio, squelch, and noise limiter circuits. The need of high sensitivity in receivers for this service was stressed and the effective squelch circuit was described.

The squelch works in the following manner: A voltage generated by the noise is selected by a high-pass filter above the modulating frequencies used in the system. This voltage, positive in the direction of the squelch, closes the squelch, and therefore the squelch will tend to open when a carrier is introduced at the input of the receiver so that the noise output of the receiver is reduced. Further to increase the sensitivity of the squelch system, the rectifier noise voltage is connected in series with a voltage (avc) supplied by a resistor in the grid circuit of the limiter. A carrier at the input of the receiver will increase this voltage supplied by the limiter resistor and will tend to open the squelch. Thus the introduction of a carrier to the input of the receiver will result in the changing of two voltages, one of which is reduced to open the squelch and the other is increased to open the squelch, and the sum of the two voltage changes will be the voltage acting to open the squelch.

The selection of a quiet location for the station receiver was stated as of paramount importance and pains taken in finding such a location on high ground are amply repaid. Proper installation, Mr. Noble said, will often result in the f-m talk-back link exceeding the range of the higher-powered, low-frequency talk-out equipment.

The mobile transmitter is so designed that the entire unit may be used as an exciter for a higher-power installation, and examples of this use were shown. In connection with tests during this development it was found that the roof-top antenna was superior to other types of car antenas, both for effective height, and non-directional pattern of reception.

Charles Singer, WOR, Chairman of the Round Table on Transmitter Maintenance, told a story which is of interest to all in this emergency. Conservation of equipment by careful maintenance is now an imperative necessity, because of the situation presented regarding repair and replacement parts and materials. Illustrating from his own experience, Mr. Singer showed many details nec-



Squelch control circuit for receiver described by D. E. Noble of Galvin Manufacturing Co., which lowers receiver noise appreciably

essary to provide a well-organized program of maintenance for transmitter and studio which will function smoothly from day to day, which can be carried out by personnel with a minimum training period, which will secure uniformity of procedure in starting, stopping or testing equipment, and which will provide adequate provision for any contingency which may arise. Besides suggesting a detailed operating manual, Mr. Singer offered a wealth of ideas which any station might use to "put its house in order." Other members of this round table who cooperated in the preparation were Frank V. Becker, WTBO; G. Porter Houston, WOBM; and Floyd N. Lantzer, WLW.

The panel discussion on broadcast station operation during war time began Wednesday morning and continued during the rest of the Conference. The keynote was struck by Lynne C. Smeby, NAB, who emphasized the need for taking a realistic view of the present situation and possible future developments—including shortage of material, shifting or shortage of personnel, and perhaps lowering the fine record made by stations in the past.

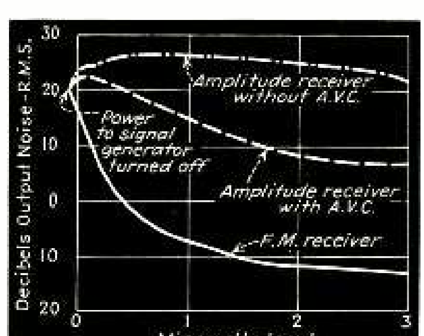
Andrew Ring, Consulting Engineer, and member of the Broadcast Committee of DCB, discussed some of the activities of this body and secured suggestions from the Conference to guide its future steps. Many questions still remain to be answered, but a working plan has been formulated and put into effect.

The panel discussion was continued by J. D'Agostino, NBC, with the topic "Property Protection and Fire Fighting." He pointed out a number of hazards often existing in transmitter and studio and outlined means for combatting them. Among the points covered were types of fire extinguishers, information on civil air defense, resuscitation, studio and transmitter guards, care of shipments from outside (possibly containing dangerous material), provision for emergency lights, and other safety precautions.

The vertical antenna of present broadcasting stations is efficient but vulnerable, stated R. F. Guy, NBC, introducing his talk upon auxiliary antennas. Few stations now have a spare antenna. One of the difficulties of installing short antennas on broadcast-band frequencies is the result of their high reactance, with consequent excessive voltage and poor radiation. Data were presented on the practical limits of power which various simple antennas might be expected to absorb. Other useful suggestions included the use of chicken wire for the ground system and the construction of "skeleton" concentric lines with groups of wires, using two or four on the outside as the grounded outer conductor and a single wire in the center for the inner conductor. By parallel operation of such groups, low impedance lines could be made.

Frank A. Cowan, A. T. and T., assured the conference that wire facilities would be furnished as nearly as possible in accordance with the high standards always maintained. In spite of the heavy increase in traffic, steps have been taken to provide alternate routes, duplicate equipment and other precautions against interruption of service.

Conservation of the material still



Effectiveness of frequency modulation in reducing noise in receiver is clearly indicated in this comparison with amplitude modulation

available is a necessary step in keeping our stations on the air, and Hector R. Skifter, Consulting Engineer, offered many practical suggestions as to how such conservation might be effected. The whole broadcasting industry must learn that unlimited replacement of parts is over for the duration. Good practice in routine maintenance and prompt repair, with improvised components if necessary, were stressed. Protective devices should be installed and all reasonable precautions against fire, storm or sabotage should be taken. This talk closed the panel discussion of broadcast station operation during wartime with emphasis on an important topic of the Conference—making the best use of what we have.

Potential Shortage of Personnel

Another problem faced by broadcasters and also by the armed forces is the imminent shortage of personnel trained for radio work. The training of engineers and technicians to fill this gap was discussed by a round table group led by W. L. Everitt, The Ohio State University, with Fred Pumphrey, Rutgers University, and G. F. Leydorf, WLW. The problem presents two aspects, the group decided; the immediate need for a large number of persons with a certain degree of skill in the radio art, and the long-term need for engineers and technicians to design, operate, and service the complex equipment used in both the military and civilian radio fields. Aptitude and intelligence tests were suggested as means of selecting those best fitted for training. Programs have already been launched to train persons in radio skills, and thus form a reservoir of talent to which both industry and the armed services may have access.

Gerald C. Gross, Assistant Chief Engineer, FCC, presented a forceful and impressive talk on broadcasting in England during war conditions.

The important topic of Standards for Recording was reported upon by Howard Chinn, CBS. The work of the Committee on Recording Standards for the past year was reviewed and two classes of proposed standards were cited—those which would be standardized on the basis of present practice or custom, and those

(*Continued on page* 117)

Non-metal Shields

Engineers searching for substitutes for metal will find useful suggestions in this paper dealing with shields for vacuum tubes, electronic musical instruments, electrostatic generators, guard rings for vacuum apparatus

By BERNARD H. PORTER *Research Laboratories, Acheson Colloids Corp. Newark, N. J.*

THERE are several scattered, but standard practices in the electronics field which with slight readaptation provide a ready means of forming non-metal shields for a variety of purposes. The more obvious of these are described here with a view to aiding engineers currently searching for metal substitutes.

Vacuum Tubes and Ground Connections

As the first example of present usage, consider the operation of the type FP-54 pliotron. This tube acquires, from simple handling alone, surface charges that tend to leak off via the control grid circuit and increase the grid current in the process. This undesirable condition is eliminated, at the manufacturer's recommendation, by applying a film of aqueous colloidal graphite directly to the pre-cleansed glass and up to within an inch of the control grid connection. The dried, electrically conductive layer, connected to a source of potential equal to that of the grid, provides the necessary dissipative path.

The obvious adoption of this practice applies as metal radio tubes and metal shields for glass tubes become increasingly scarce. The exterior surfaces of glass tubes, rendered grease-free with chromic acid followed by thorough water-rinsing and air-drying, are painted or sprayed with an aqueous colloidal graphite solution of fairly high concentration (1 part Aquadag to 3 parts H_2O).

Such coatings possess a matte-like surface conducive to heat dissipation. Since the electric-furnace graphite composing them is also a better thermal conductor than most metals, little difficulty in radiating filament heat is encountered. Graphiting the tube surface in lattice or cross-hatch fashion, leaving small areas of glass exposed, is also feasible, should the problem of heat dissipation persist.

Permanent grounding connection to the conductive film may be made, in some cases, by extending the film down over the tube base to touch or be sealed to an appropriate lead in the top of the baseboard or chassis. In other instances, contact is made with a loop of wire or a narrow band clamp placed about the tube. If these parts are first hot-dipped in dilute colloidal graphite solution, better electrical connection is assured, particularly if a final application of the more concentrated product is made to seal edges between the connection and the glass. This treatment is also recommended when the connection is made to the tube prior to the coating operation. Successive graphite layers are preferably dried with circulating warm air before fresh solution is applied.

Shield Forms and Their Grounding

Practices currently employed in the shielding of electronic musical instruments are equally as adaptable. In this instance, (U. S. Patent No. 1,927,030) the interior non-conducting walls and parts of electric pianos, organs, violins and similar devices are coated with films of colloidal graphite in distilled water to insure stable and hum-free performance. Thus, converting this procedure to broader use, fibrous board or sheets, first impregnated in dilute graphite solution, then surface coated with a more concentrated dispersion, make ideal non-metal shield partitions between stages or radio components. Slow or heat drying under pressure may be advisable directly after the impregnation treatment. Soft polishing of the dried film will both increase its electrical conductivity and contribute to improved appearance.

Similarly, glass, plastic and wood in sheet form may be surface coated for the same purpose. Tubular shields pressed or formed from glass, plastic, fibrous material or other non-conductors are likewise rendered conductive. The entire cabinet or case, whether wood or plastic, may be treated by spraying, should the use of metal chassis become restricted or this practice seem, for other reasons, expedient. The grounding of graphite films on comparatively thin supports is accomplished with metal eyelets, inserted through the piece and preferably having one end of the wire lead soldered in place before coating is made. Additional sealing or covering with concentrated colloidal graphite about the points of contact to the film is necessary, whether eyelets are inserted before or after the main application.

A useful method for making electrical connection to graphite film deposits of this class also follows from the current practice of cementing filaments to leads in carbon filament lamps wherein globules of concentrated colloidal graphite, dried at the filament-lead juncture, provide a positive, vibration-resisting contact. In this immediate instance of shield-grounding, the bare lead, preferably

(*Continued on page* 126)

Checking AUTO BREAKER-POINTS

IN the early days of automobile ignition system maintenance, it was the custom to adjust the separation of the interrupting contacts within the distributor at maximum opening by means of a feeler gauge, and this proved quite satisfactory for the low-speed motors of that time which had only four or six cylinders. Breaker point operation occurred at such a slow rate that adequate time was allowed during each cycle of operation for the current flowing in the primary of the ignition coil to build up to a satisfactory value. With the advent of higher speed operation and the use of more cylinders, less and less time was allowed for primary current build-up and in some cases where contacts had been properly set according to feeler gauges, it was found that the primary current did not build up to a value sufficient to give the necessary sparking voltage. This was the result when the ignition was on the border-line of satisfactory high-speed operation, and the contacts were not closed for a long enough interval between breaks due to the fact that the operating separation was greater than that indicated by the feeler gauge, because of irregularities in or misalignment between the working surfaces of the contacts.

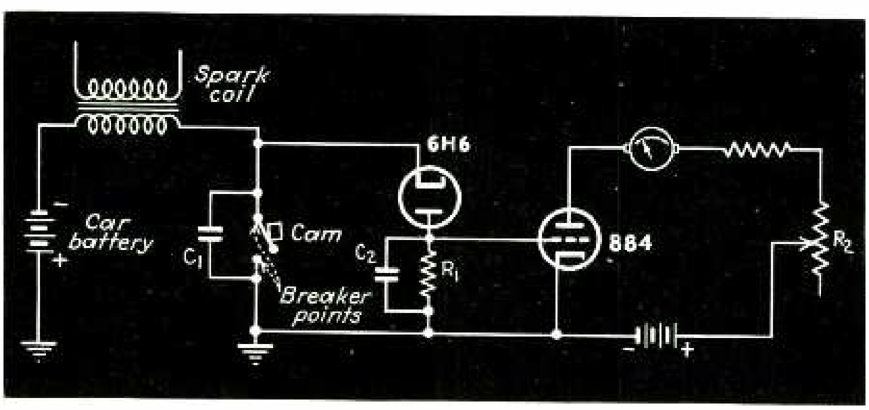


FIG. 1—Elementary diagram of the gas-tube breaker-point operation test enabling modern motor cars to be adjusted for proper engine operation without removing the distributor from the motor

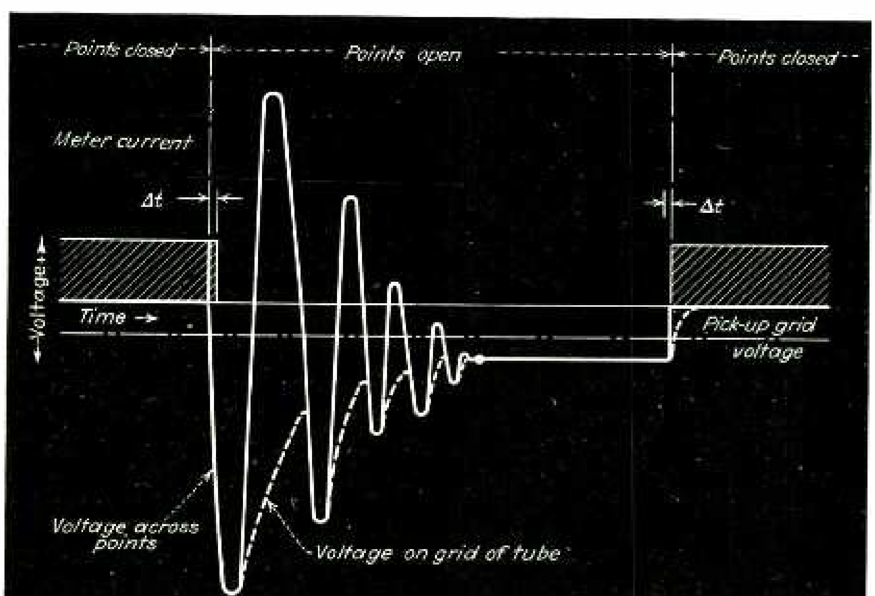


FIG. 2—Damped sinusoid wave occurring in automobile ignition circuit

This was remedied by removing the distributor from the motor and placing it in a distributor test fixture in which the distributor is clamped and the drive shaft thereof rotated by a small electric motor. The cam angle, or angle of closure, is determined by connecting an electric circuit containing a source of direct current, a limiting resistor, and a d-c indicating meter in series with the contact points and measuring the ratio between the meter current with the points closed and that indicated as the distributor shaft is rotated. For example; in a distributor having an eight-lobe cam, the limiting cam angle is 360/8 or 45 degrees. If the measured ratio of meter indications is 69 percent, the cam angle is 69 percent of 45 or 31 degrees, which is the recommended cam angle for a 1941 Buick. In like manner, the limiting cam angles for 6-, 4-, and 3-lobe cams are respectively 60, 90, and 120 degrees.

The intensity of the spark developed by an ignition coil is dependent on the current flowing in the coil primary at the time the contact points separate, and the magnitude of this current in turn depends on the time during which the primary is connected to the source of electrical energy, so that in measuring cam angle we are measuring directly the factor determining this time, rather than such an indirectly related factor as the maximum linear separation of the contacts. The ratio of labor involved in setting a pair of points by the last described method, which

by ELECTRONICS

By G. V. ELTGROTH
Bendix Radio Corp., Baltimore

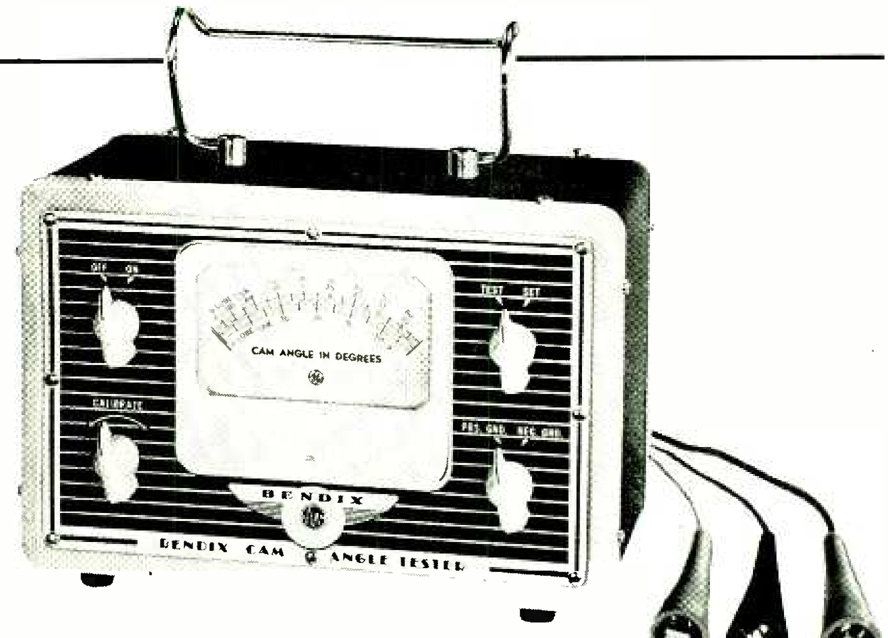


FIG. 3—Electronic cam angle tester as supplied to garage maintenance men

entails the removal of the distributor from the motor, and in setting them by the feeler gauge method, is obviously considerable and for this reason alone, the distributor test fixture has not been popular. In addition, in more recent years, the drive shaft of the distributor has been greatly lengthened, due to the practice of driving it from the oil pump, so that in event of failure of the pump, the engine cannot be operated. As a consequence the alignment of the shaft with reference to the distributor bowl has been determined by the bearing surfaces within the engine which vary from motor to motor. This, in turn, varies the position of the cam with respect to the breaker arm and results in an operating cam angle installed which is different from the cam angle obtained in the test fixture.

Unconventional Gas Tube Circuit is Used

To make measurements of the operation of the ignition system with the distributer in its normal operating position, an electronic instrument using a type 884 gas tube in an unconventional circuit was developed. It is connected across the distributer, the motor is run as usual, and the results appear on a meter in the output circuit.

Grid control gas tubes have proven very satisfactory in the fields of electronic control and electronic instrumentation, but it appears that certain of their capabilities have not been utilized up to the present time. It is widely believed that the control grid of a gas discharge tube cannot regain control after the discharge has been once initiated. For this reason, in applications where alternating current is not available for the anode supply, many ingenious and often complex circuits have been developed to provide a negative pulse on the anode for the purpose of extinguishing the discharge.

Within a certain limited range of operating conditions, it is possible to regain control of the tube, that is, to extinguish the discharge, solely through the use of the control grid as the controlling element. Figure 1 shows a circuit fulfilling the necessary conditions which are; a source of fixed bias for the control grid, a d-c anode supply, means for limiting the anode current of the gas discharge tube to less than a certain critical value and a low impedance source for supplying large negative impulses to the control element. It is necessary that the anode supply voltage be sufficiently low to prevent a discharge from starting while the control grid is maintained at its normal fixed bias and it is further required that the anode supply voltage be sufficiently high to insure the initiation of the gas discharge when the control grid bias is reduced to zero or to some selected smaller value than the bias initially present.

The discharge current through the tube is limited by the use of external resistance. The limitation set upon the current also limits the number of ions produced per unit time within the tube structure. If, now, some means is provided to collect ions more rapidly than they are formed, the total number of ions will be reduced until ultimately the number is insufficient to maintain the discharge, at which time the conduction will cease.

The control grid of a type 884 or 885 grid control tube is situated directly within the discharge path. When this grid is made strongly negative, the positive ions which neutralize the space charge immediately around the cathode are removed and control by the grid once more established. It is this principle which finds application in the apparatus to be described.

Operation of the Circuit

Referring again to Fig. 1, ignition voltages for internal combustion engines are supplied by an inductance coil whose primary is connected to a storage battery in series with a set of breaker points. The breaker points are opened periodically by a cam driven from the cam shaft of the engine, the design of the cam and the adjustment of the contacts being such that the primary circuit is opened at the instant when ignition is desired in a particular cylinder. It is customary to shunt the breaker points with a condenser to minimize burning of the contact points. The test apparatus itself includes a 6H6 half-wave rectifier connected in series with an anode resistor across the breaker points.

The anode resistor is shunted by a capacitor to minimize the error caused by the time required to deionize the 884. The 884 has its control grid connected to the anode of the rectifier while the anode of the 884 is connected to the anode supply battery through a meter, a limiting resistor, and an adjustable resistor. The voltage of the supply battery is 22½ volts as it has been found that this will serve to initiate the discharge reliably under condition of zero bias on the 884.

The voltage and current conditions in the circuit are shown in Fig. 2. When the contact points are closed, no voltage drop exists across the input to the 6H6 and no voltage appears across the RC combination in the grid circuit of the 884. When the points open, an exponentially damped sinusoidal oscillation voltage appears across the breaker-point condenser. The first half-cycle of oscillation causes the ungrounded terminal of this condenser to become negative with respect to ground, as indicated in Fig. 2. This causes a high negative potential to appear on the grid of the 884, rapidly collecting the positive ions and extinguishing the gas discharge. The rectifier (6H6) prevents the positive impulses from appearing on the grid while C_2 prevents the grid voltage from falling to zero while the thermionic rectifier is non-conductive. As the oscillations die away, there is finally left impressed on the input leads the steady d-c potential of the battery which is sufficient to prevent the initiation of discharge. The cam continues to rotate and the contact points close, short-circuiting the voltage input to the apparatus whereupon the grid voltage of the 884 diminishes and the gas discharge once more is initiated as the grid voltage crosses the pickup potential of the 884. Therefore, anode current flows at all times when the points are closed and is interrupted while the points are opened. The plate meter of the 884 may be calibrated to read the percentage of time during which the contacts are closed. The procedure followed in using the apparatus is to short-circuit the rectifier cathode to the cathode of the 884 and adjust resistor R_2 so that the meter is precisely at full scale, which may be calibrated to read 100 percent. The short-circuit is now removed and the apparatus connected to the ignition system whereupon the percentage of contact closure time may be directly read. With a cam having a given number of lobes, the time during which the contacts are closed may also be expressed as the number of degrees of cam rotation during which the contacts are maintained closed for one cycle of operation. In fact, this is the general practice in the field of automotive instruments and the meter is therefore calibrated in terms of cam angle, as it is called, rather than percentage of contact closure time.

The damping characteristics of the meter movement are such that current impulses at the rate of 25 per second give substantially steady indications. During a test, the engine is run at a speed giving at least this number of interruptions each second, corresponding to 400 rpm for an eight-cylinder engine, 550 rpm for a six-cylinder engine, etc. Taking an eight-cylinder engine for an example, it is seen that the distributor shaft rotates at 200 rpm or 3⅓ rps so that any operational irregularities due to an eccentric cam or defective bearings will be cyclically repeated at this frequency, which is sufficiently low so that the damping of the meter is without effect, and they may be readily detected.

Extinction of the discharge does not occur simultaneously with the opening of the breaker points but it is delayed by an amount which we may call Δt (see Fig. 2). This is capable of causing considerable error, particularly at high operating speeds and, for this reason, the time constant of the parallel combination of R_1C_2 is so chosen that the initiation of the discharge after the points are closed is delayed by approximately the same amount and the error from this source is thereby decreased to a negligible amount.

Figure 4 shows the schematic diagram of the instrument as manufactured in quantity. Polarity reversing switch S_1 is provided to accommodate the various types of battery installations, connecting the rectifier cathode to the negative breaker point in either positive-ground or negative-ground systems, at the same time connecting the cathode of the 884 and its associated circuits to the opposite contact. S_2 has been added for convenience in making the initial calibration setting of the meter current. The distributor, ground and battery leads are of flexible textile and rubber covered wire, and are provided with rubber sheathed battery clips at their working ends. Heater voltage for the tubes employed is derived from the electrical system of the car whose motor is being tested.

A photograph of the completed instrument appears in Fig. 3, the front panel with the four controls and the indicating meter with its scales being visible.

The outstanding advantage of this instrument over equipment previously available is the very low loading imposed on the ignition circuit, there being no perceptible diminution of the spark intensity. This is undoubtedly because the break current through the points is from 2 to 3 amperes while a peak current of only 2 milliamperes is sufficient to deionize the gas tube.

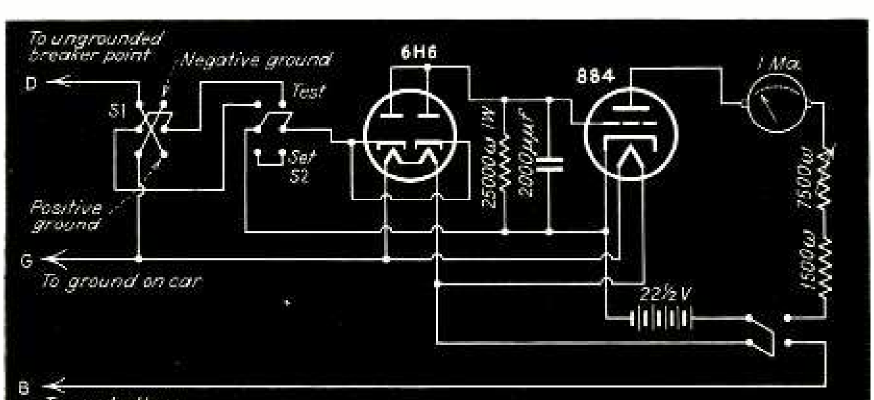


FIG. 4—Actual circuit used in the practical embodiment of Fig. 1

U-H-F TECHNIQUE

Contents

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New York, N. Y. — **April 1942**

U-H-F ···– for Victory

VICTORY guides our thinking! In presenting this outline of ultrahigh frequency practice, the editors of ELECTRONICS take cognizance of the importance which electronic engineering is playing in the nation's victory effort. New electronic devices and communication systems are being developed rapidly. Manufacturing plants are working at the heels of research laboratories, rapidly converting breadboard models into production units. Large numbers of men must be trained to take on new duties and increased responsibilities.

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Fundamentally important in this country's program of production for victory is that of training personnel to design, manufacture, test, operate, service, and repair this new equipment, much of which employs ultrahigh frequency technique. The program of training men in this field for the numerous tasks required is a vast one. But it is also one in which we, as editors and publishers of technical journals, can make our own individual contributions, for after all, we are educators as well as editors and publishers.

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Since the theory and practice of ultrahigh frequency technique differ markedly from that of radio communication at more familiar frequencies, many of the concepts and approximations which suffice at 1000 kc are no longer valid at 1000 Mc. For example, at frequencies above 100 Mc:

(1) Lumped circuits disappear and we must deal with circuit elements in which inductance, capacitance, and resistance are inextricably interwoven. Consequently, knowledge of recurrent networks and transmission lines and wave guides assumes increasing importance.

(2) The physical dimensions of circuit elements, including even tubes, may be of the same order as that of the generated waves. Therefore these circuit elements can no longer be regarded as non-radiating and field concepts are necessary to replace circuit theory.

(3) The transit time may determine the upper frequency at which a tube operates. For this reason a greater understanding of the motion of electrons is essential for the design and use of newer and better u-h-f tubes.

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Such instances could be multiplied many fold. The three examples given will indicate that the engineer, the designer, the research worker, and the manufacturer who come anew to problems in u-h-f technique, will have to reorient their thinking of communication phenomena.

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As an aid in solving these educational problems, the editors of ELECTRONICS offer their readers this compilation of u-h-f technique with its three-fold presentation:

(1) In plain, simple, understandable text, the philosophy of ultrahigh frequency technique is given to outline the nature of the problems at frequencies for which "line of sight" transmission is of paramount importance.

(2) By means of graphs, tables, and equations, the more important quantitative results are given to familiarize the technician with the general magnitude of the quantities involved—to provide a sense of quantitative proportions and the fitness of things.

(3) Finally, since u-h-f technique cannot be treated thoroughly in a 32-page booklet, a convenient bibliography is included at the end of each section.

I. Radiating Systems and Wave Propagation

By A. G. KANDOIAN *International Telephone and Radio Laboratories*

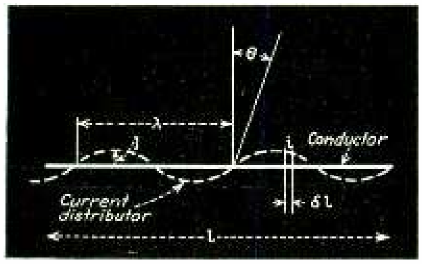


Fig. 1—Current distribution on antenna, illustrating radiation properties

I. Radiating Systems

A. General

ACCURATE treatment of radiation phenomena is complex and highly mathematical involving a careful examination of Maxwell's equations. Textbooks[1] deal with the subject for those who desire a thorough knowledge of the nature of radiation. Any current along a conductor has an associated electromagnetic field which varies along with the current. If the rate of current variation, i.e. frequency, is high enough and the configuration of the current carrying conductors is such as not to confine the resulting electromagnetic field, a considerable amount of radiation will result. Radiation from a conductor carrying u-h-f current will occur unless the resulting electromagnetic field is confined by shielding, as in a coaxial transmission line, or by an equal and oppositely directed current, as in a balanced open line. In the latter case the two conductors are spaced relatively close to one another, i.e., very much less than a half wavelength.

B. Radiation from Linear Antennas

The radiation from an elementary antenna in space (Fig. 1) carrying current i may be expressed as

$$F = \frac{60\pi}{\lambda} i\, dl \cos\theta \cos\omega\left(t - \frac{d}{c}\right) \quad (1)$$

where F is the field in volts per meter,
d is the distance in meters,
θ is the angle measured from plane perpendicular to antenna element,
λ is the wavelength in meters,
dl is the length of elementary antenna,
c is the velocity of propagation in meters per second,
t is the time in seconds, and
ω is 2π times the frequency.

The radiation field pattern from a linear conductor of any length having a known current distribution may be derived by taking at a distant point P in direction θ, the vector sum of all the fields due to each infinitesimal element dl of the conductor. The complete expression is rather complicated.[2]

When the radiating conductor is a multiple of a half wavelength, open at the far end, the expression becomes

$$F = KI\left[\cos\left(\frac{\pi l}{\lambda}\sin\theta\right)\right] / \cos\theta \quad (2)$$

for length l equal to an odd number of half wavelengths and

$$F = KI\left[\sin\left(\frac{\pi l}{\lambda}\sin\theta\right)\right] / \cos\theta \quad (3)$$

for l equal to an even number of half wavelengths. In both Eq. (2) and Eq. (3) I is the maximum current along the conductor, K is a constant. Examples of radiation patterns given by Eq. (2) and Eq. (3) for different values of l/λ may be found in many textbooks and publications (see list of references).

C. Radiation Resistance

From measured or assumed current distribution on any antenna element or array one can compute the resulting electric field E and the magnetic field H. By applying Poynting's theorem the total power radiated through a sphere which envelopes the antenna may be computed. By equating this power to the square of the effective value of the peak current carried by the radiating conductor times R_a we may solve for R_a, which is known as the radiation resistance.

The radiation resistance is one of the most important properties of any antenna system. All of the power dissipated into this resistance may be considered as useful power, since it is radiated in the form of electromagnetic waves. The ratio of radiation resistance to the total circuit resistance is a measure of antenna efficiency. Thus the efficiency is

$$\eta = R_a/(R_a + r) \quad (4)$$

where r is the ohmic resistance of the antenna circuit. It is desirable to maintain as large a ratio as possible between R_a and r.

The radiation resistance of a radiating conductor in space has been solved for any length of conductor.[2] As an example (Fig. 2), the radiation resistance of a half wave dipole is approximately 73 ohms.

Another type of antenna commonly used at ultrahigh frequencies is the loop antenna.[3] The radiation resistance of this type of antenna is given approximately by

$$R_a \leqq 320\,(\pi/\lambda)^4 A^2 \quad (5)$$

where A is the area inclosed by the loop. This equation applies when A is small compared to the wavelength. The accompanying table shows how the radiation resistance varies with the loop dimension.

$\sqrt{A}/\lambda$	R_a (ohms)
0.05	0.194
0.10	3.11
0.15	15.8
0.20	49.8

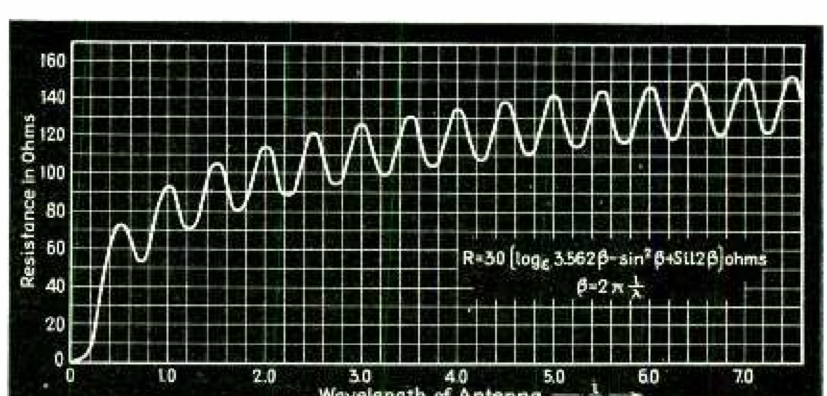


Fig. 2—Radiation resistance of antennas of various lengths

It is necessary to distinguish between radiation resistance and input impedance of an antenna. Radiation resistance is defined as the ratio of the total power radiated to the square of the effective value of the peak current in the radiating system. Hence the radiation resistance is the resistance at the peak current point. Unless the antenna is fed at this particular point, the input impedance will not equal the radiation resistance, but will be equal to the radiation resistance transformed by a ratio depending upon the surge impedance and length of conductor existing between the current maximum point and the point of feed. This is very important to keep in mind when an antenna is to be used over a frequency range, for although the actual radiation resistance change versus frequency may be small, the input impedance to the antenna can change quite rapidly.

D. Types of Antennas Used in U-H-F Work

The most common antenna element used in u-h-f arrays is the half wave dipole. The radiation from a dipole Fig. 3(a), is given by

$$F(\theta) = K\left[\cos\left(\frac{\pi}{2}\sin\theta\right)\right] / \cos\theta \cong K\cos\theta \qquad (6)$$

where θ is the angle measured from the perpendicular bisecting plane. In this plane the radiation from the dipole is circular—the same in all directions. The input impedance to a resonant half wave dipole fed at its center is a pure resistance of about 70 ohms—equal to its radiation resistance. The resonant half wave dipole is somewhat shorter than a full half wave because of the "end effect," which is small for thin wire radiators and somewhat greater for large diameter dipoles.

Sometimes, as in portable field strength measuring instruments, it is not convenient to use a full size half wave dipole. For this purpose the dipole may be folded near its center (Fig. 3b). Under these conditions the radiation is essentially the same as for a full half wave, except that the tuning is more critical because the radiation resistance is reduced considerably.

A familiar form of antenna, used widely for f-m broadcasting is the turnstile antenna. This unit is made up of two intersecting and perpendicular dipoles (Fig. 3c). The object is to obtain uniform radiation in the horizontal plane of the dipoles. The currents fed to the mutually perpendicular dipoles must be phased at 90 degrees. This type of antenna (composed of two perpendicular dipoles) radiates maximum energy perpendicular to the plane of the dipoles. When placed in the horizontal plane, the maximum energy is radiated up (and down) and not in the horizontal plane. This loss in the horizontal plane can be overcome by stacking another pair a half wave above the first pair so as to cancel the vertical radiation and reinforce the horizontal.

The loop antenna is widely used in u-h-f work. Here the object is to obtain an approximately constant current distribution around a fixed area (Fig. 4a). A loop antenna has an omnidirectional pattern in its own plane (Fig. 4f) and a doughnut shaped pattern in the perpendicular plane (Fig. 4e).

A loop of this type can be designed in several different ways, depending upon how nearly a constant current distribution is desired. Type I in Fig. 4 is the most elaborate and makes use of the maximum current regions of four half waves, one on each side of the loop. By this means a relatively large

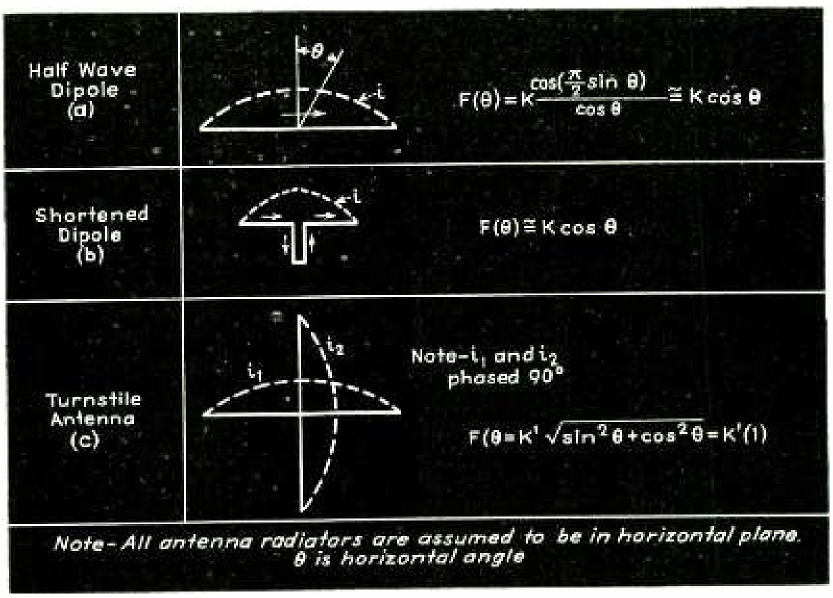


Fig. 3—Radiation pattern data for several types of u-h-f antennas

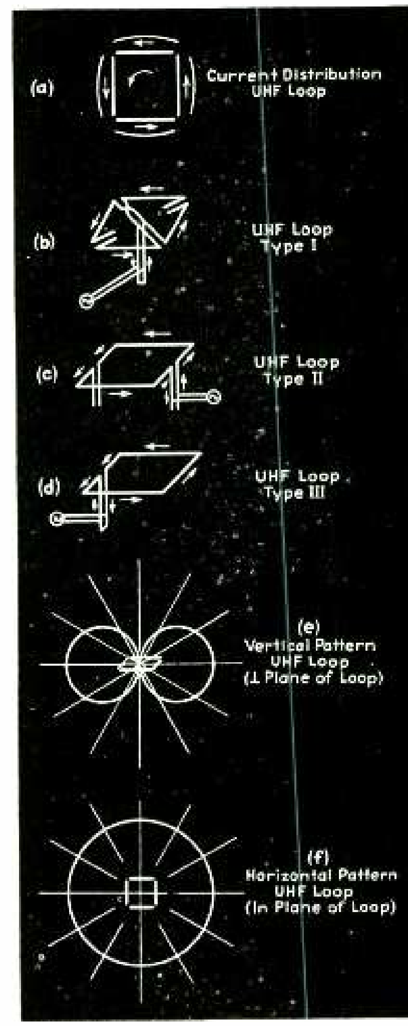


Fig. 4—Diagram illustrating construction of various types of u-h-f loops

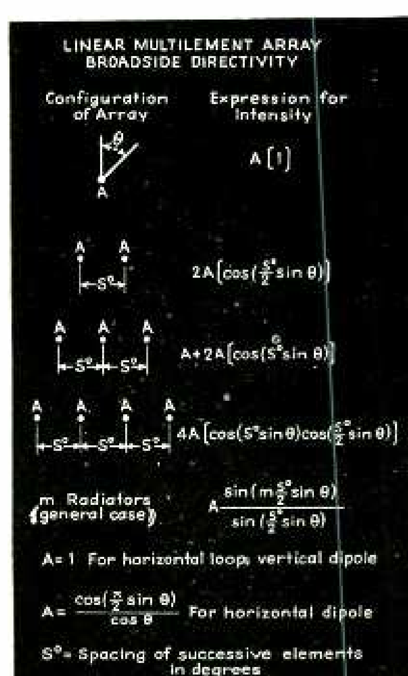


Fig. 5—Expressions for the radiation patterns of some multi-element arrays

area may be enclosed inside the periphery of the loop and a satisfactory radiation resistance obtained. In one particular design for transmitting work each side was made 0.18λ giving a radiation resistance of approximately 32 ohms.

For some applications more simplicity of design and compactness is desirable. In such a case type II loop may be used as in Fig. 4c. This is particularly useful as an aircraft receiving antenna where convenience of size is more important than radiation efficiency. A radiation resistance of 5 to 10 ohms is generally obtained.

Sometimes a very compact and simple horizontally polarized omnidirectional loop is desired for laboratory instruments or for a field intensity measuring equipment. Loop type III in Fig. 4d may be used for this purpose. This loop is no more than a balanced resonant half wave open transmission line whose far end (current maximum region) is opened up to form a loop.

E. Antenna Arrays

The u-h-f region is ideal for the use of multi-element arrays. Depending upon the particular application, any one of the antenna elements previously discussed may be used in these arrays.

The basis for all directivity control in antenna arrays is wave interference. By providing a large number of sources of radiation it is possible with a fixed amount of power to greatly reinforce radiation in a desired direction by suppressing the radiation in undesired directions.

One of the most important arrays uses a large number of equally spaced antenna elements which are fed equal currents in phase to obtain maximum directivity in the forward direction. Expressions for the radiation pattern of several particular cases and the general case of any number of broadside elements are given in Fig. 5.

Although a great deal of directivity may be obtained in this type of array there are apt to be present a large number of minor lobes which may be undesirable. The binomial array may be used for such conditions. Here again all the radiators are fed in phase. However, the current is not distributed equally between the array elements, the center radiators being fed more current than the outer ones.

The configuration and general expression for such an array are shown in Fig. 6. In this case the configuration is made for a vertical stack of loop antennas, to obtain single lobe directivity in the vertical plane. If such an array of n dipoles end to end were desired in the horizontal plane with the specified current distribution the expression would be

$$F(\theta) = 2^{n-1}\left[\cos\left(\tfrac{1}{2}\pi \sin\theta\right)/\cos\theta\right]\left[\cos^{n-1}\left(\tfrac{1}{2}S\sin\theta\right)\right] \quad (7)$$

The term binomial is due to the fact that the current distribution between successive array elements is in accordance with the binomial expansion $(1+1)^{n-1}$ where n is the number of elements. The radiation pattern of an eight element binomial array of vertically stacked loop antennas, is shown in Fig. 7. A similar 4 element array, fed with binomial distribution is shown in Fig. 8 while Fig. 9 shows how the pattern of Fig. 8 changes when each loop is fed unit current. Note the presence of minor lobes in Fig. 9.

F. Broadcast Antennas

The recent advance of f-m broadcasting has brought about the design of antenna elements and arrays particularly for that purpose. Horizontal polarization is most commonly used even though for a fixed power the signal level is somewhat higher with vertical polarization. This is due to the fact that the noise level is a little more

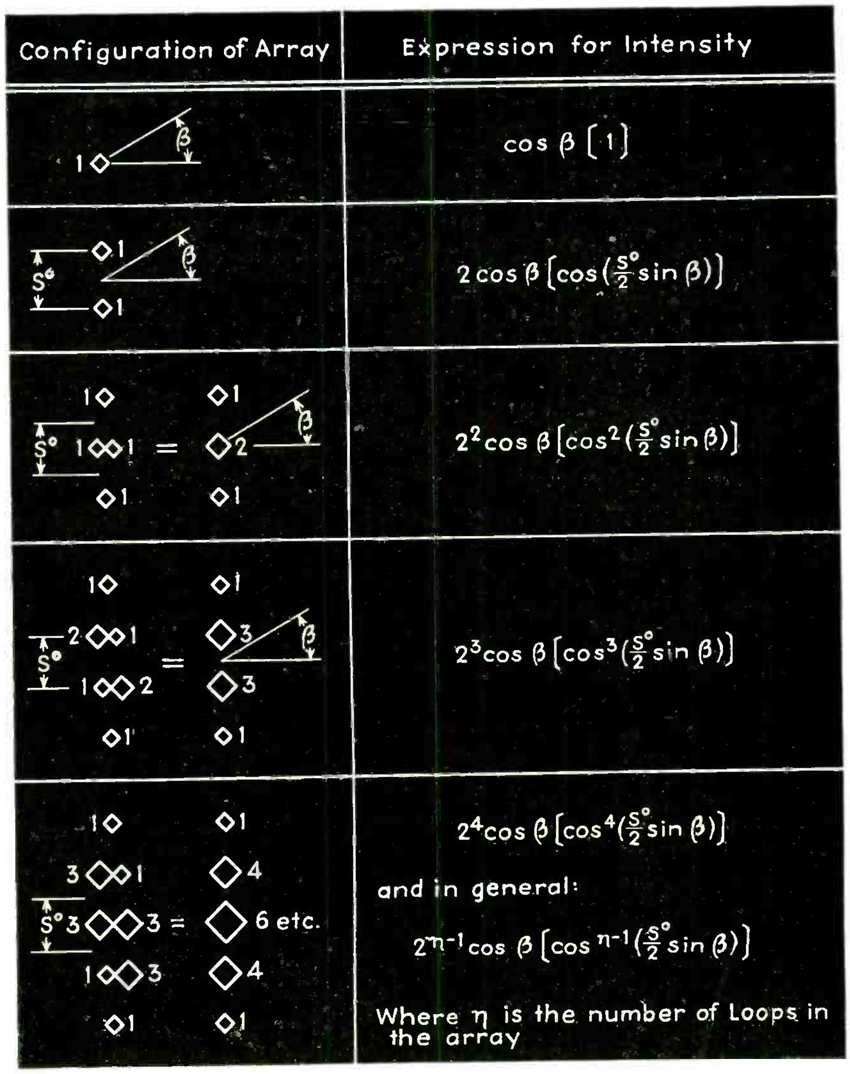


Fig. 6—Configuration and intensity for binomial array with no back radiation

Fig. 7—Eight-element binomial array pattern

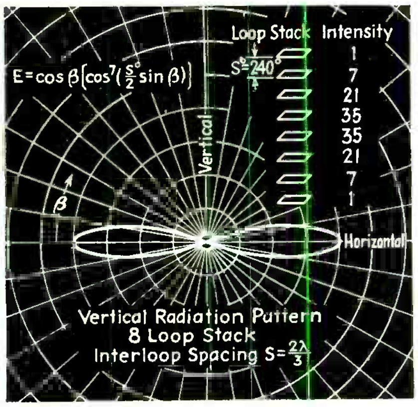


Fig. 8—Four-element binomial array pattern

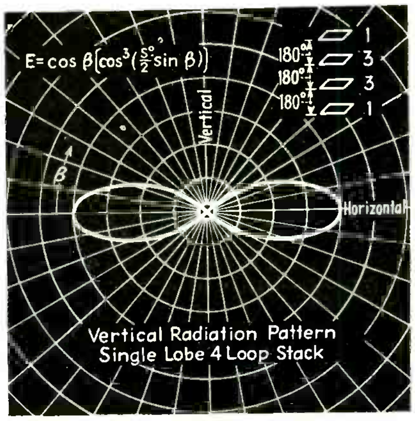
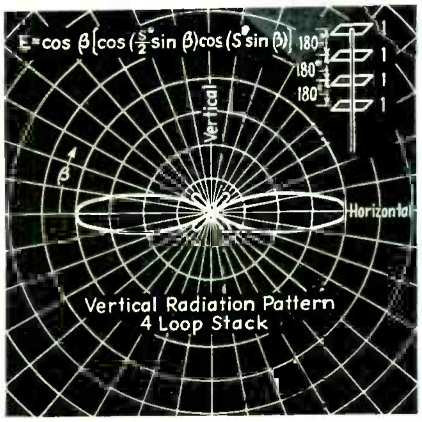


Fig. 9—Array with unit element current



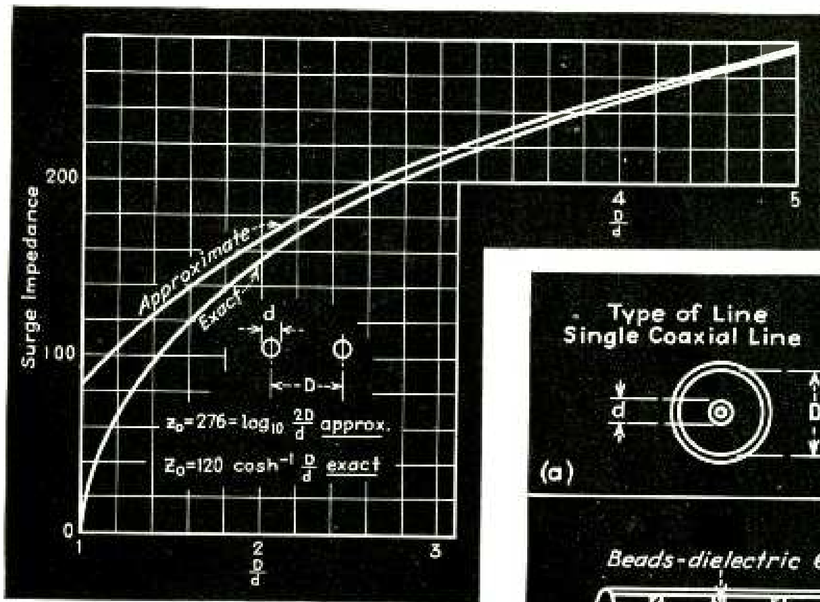


Fig. 11—Exact and approximate equations for surge impedance of open, two wire transmission lines

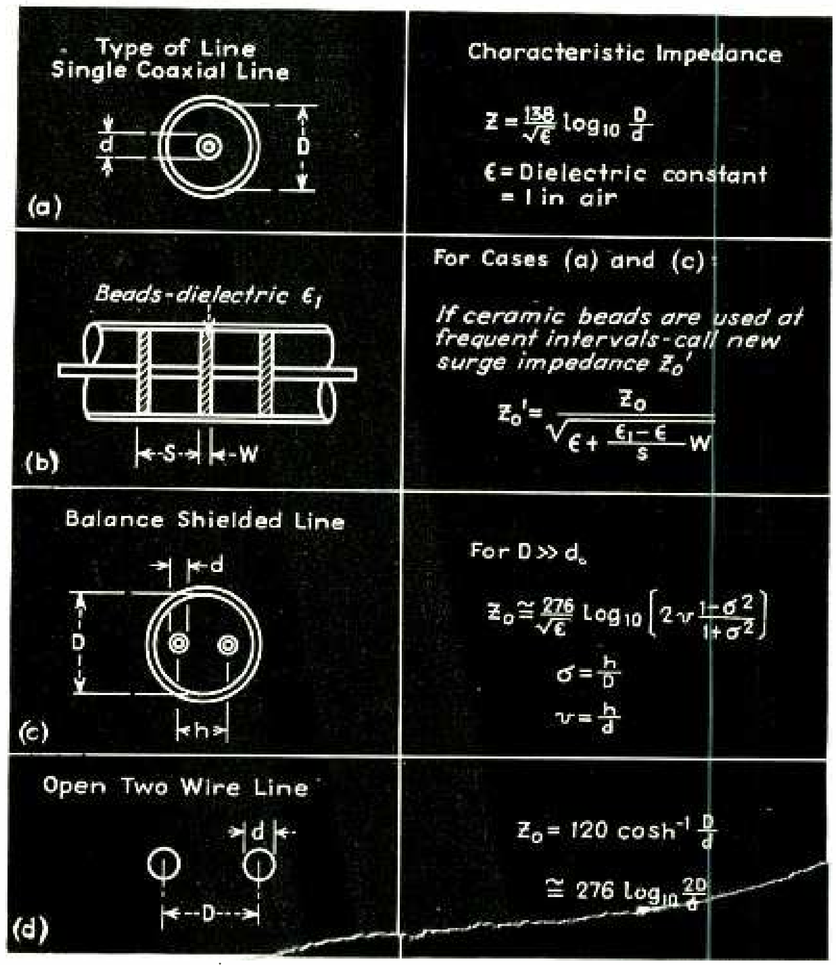


Fig. 10—Surge impedance of some common types of transmission lines

than correspondingly higher with vertical polarization.

Two types of antennas already described have been proposed for f-m broadcasting. An array made up of turnstile elements is widespread at the present time. The other is a stacked array of loop antennas. The patterns shown in Figs. 7, 8 and 9 as well as others were calculated originally for that particular application.

Some of the most interesting antenna developments in the recent past have been in connection with television. For this service the chief problem is bandwidth. The antenna must have essentially constant input impedance over a frequency band approximately 10 percent or more of the center frequency. It becomes imperative that the antenna have a large radiation resistance, then to make the radiating members large physically and shaped so as to have a minimum change of reactance with frequency. One type described by the RCA engineers is a turnstile antenna made up of ellipsoidal members.

G. Wave Guides and Electromagnetic Horns

At frequencies of the order of 1000 Mc and higher, a new type of power transmitting and radiating means may be used to advantage, i.e., "wave guides." These are either hollow tubes whose cross sectional dimensions are of the order of a half wavelength or more, or solid dielectric hose or rods in which the diameter may be made considerably smaller, depending upon the dielectric constant of the insulator. These wave guides may have circular, elliptical or rectangular cross section.

Propagation inside these guides is initiated by the terminal devices at the sending end. These generally consist of little dipoles or current loops, either singly or in combination to provide the proper type of electromagnetic field configuration inside the guide.

Electromagnetic horns used for very directive radiation at the ultrahigh frequencies are analogous to acoustic horns. Power is delivered at the sending end of the horn to an exciting rod or loop as in the case of wave guide transmission. Some piston arrangement is generally provided to match the impedance at the input end. The directivity obtainable from these horns depends upon the dimensions of the open end, in wavelengths. In general, the larger the opening the more directive is the resulting pattern. An aperture of approximately five wavelengths will provide a radiated major lobe width of approximately 30 degrees.

H. U-H-F Transmission Lines

Three types of transmission lines are commonly used in u-h-f circuits. These are the single, coaxial line, balanced shielded line and ordinary balanced open wire line. Surge impedance formulas for these transmission lines are tabulated in Fig. 10. Serious errors may result if the more familiar approximate formula for surge impedance is used for open wire lines. (See Fig. 11)

Knowing the surge impedance of a uniform transmission line, one can compute the inductance and capacity per unit length of line assuming the permeability and dielectric constant of the medium between inductors to be unity.

$$L = 1020\,Z_o\ \mu\mu\text{h per foot} \qquad (8)$$
$$C = 1020/Z_o\ \mu\mu\text{f per foot} \qquad (9)$$

I. Measurements on Lines and Impedance Matching

The input impedance of an antenna element or array very seldom equals the surge impedance of the transmission line. Unless this situation is corrected three serious difficulties will result. First the transmission line efficiency is poor, because minimum power is lost in the line only when it is

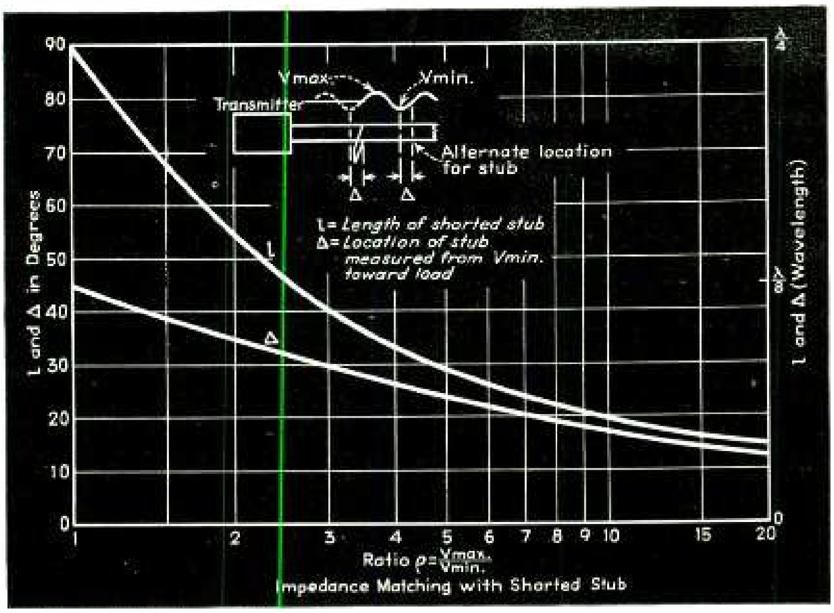


Fig. 12—Use of short-circuited stub

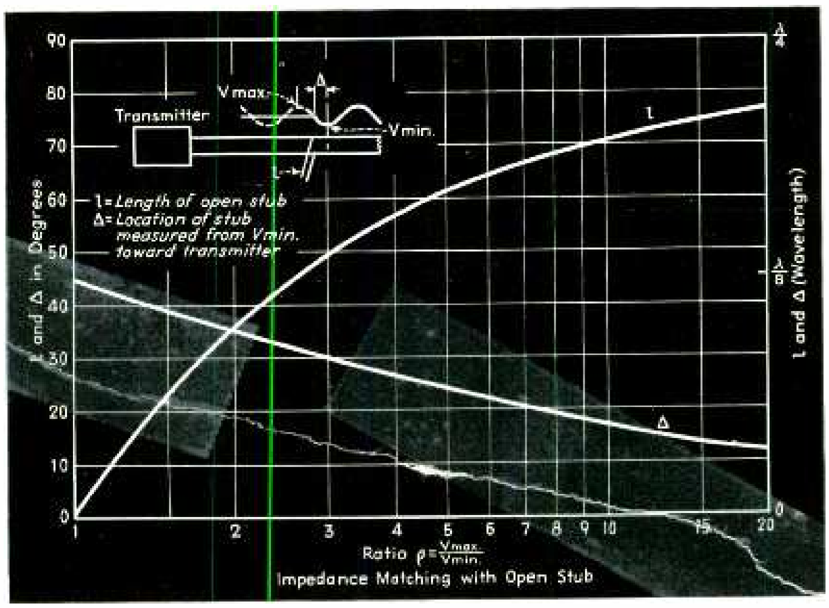


Fig. 13—Use of open-circuited stub

properly matched. Second, assuming the transmitter output circuit is properly designed one will experience difficulty in delivering power to the load. Third, the transmission line being tuned (unmatched) will be critical as to length. It is very desirable to match the antenna impedance to the transmission line somewhere near the junction of the antenna and the line.

Before attempting to match impedances it is necessary to determine two things: First the amount of mismatch, i.e., ratio (ρ) of voltage maximum to voltage minimum (or current maximum to current minimum) should be measured. Next the location of voltage minimum (current maximum) must be determined. In Section V the technique of such measurement is discussed. Knowing ρ and the location of V_{min}, by referring to Fig 12 we can find the length l of shorted transmission line section to correct the mismatch. The Δ curve shows where the stub is to be placed. If it is desired to correct the mismatch with an open stub, that may be done by reference to Fig. 13. Length l gives the stub length and Δ its location.

Another very useful means for matching impedances is by the use of the so-called quarter wave transformer. Knowing ρ, the ratio of V_{max}/V_{min} the impedance at the V_{max} point is known to be a pure resistance equal to ρZ_o. The impedance at the V_{min} point is also a pure resistance but equal to Z_o/ρ. The line may be matched by inserting a quarter wave transmission line whose surge impedance is $(Z_o^2\rho)^{1/2}$ between the V_{max} point and the remainder of the line. The line may also be matched by inserting a quarter wave line of surge impedance equal to $(Z_o^2/\rho)^{1/2}$ between the V_{min} and the remainder of the regular transmission line.

II. U-H-F Wave Propagation

The propagation of electromagnetic waves is quite a complex phenomenon and much has been written on the subject from the earliest days of radio. Given a radiating source and a fixed amount of power, the field strength at a distant point is the resultant of at least four so-called waves. One, the direct wave, is due to direct propagation from the transmitting antenna to the receiving antenna. This is equivalent to the wave occurring in free space. The second, ground reflected wave, is due to the wave which is reflected from the ground before it reaches the receiving antenna. The third or surface wave is guided and confined to a certain extent by the surface of the earth and the surrounding atmosphere. The fourth is the sky wave which is directed toward the upper ionized atmosphere, the Kennelly-Heaviside layer, but is reflected back from there to the receiving antenna. The total signal received is the vector sum of all of these various waves.

Fortunately at any one frequency, or band of frequencies, some of these modes of propagation are very small and may be neglected. For instance in the broadcast band and at lower frequencies, the surface wave is important and other modes may be neglected. From 5 to 20 Mc used for long distance communication, the sky wave is important. At the ultrahigh frequencies the space wave, composed of the direct and ground reflected waves is important, although for very low receiving heights, particularly for vertical polarization, the surface wave also must be considered.

The geometry of the propagation problem is illustrated in Fig. 14. Point A represents the transmitting antenna P the receiving antenna. The two heights are h_1 and h_2 while r_1 and r_2 are the direct and ground reflection distances between the two points, and β is vertical angle of reflected wave.

Discussion of the problem of field intensity at point P may be best accomplished under three subdivisions:

(I) For very large distances, $d >> h_1 + h_2$, and β is very small, diffraction due to earth's curvature and refraction due to surrounding atmosphere considered.

(II) Distance d, is reduced to values (20 to 30 miles) for which the earth may be considered flat, β is small and $d >> h_1 + h_2$.

(III) The vertical angle β is varied from small angles to 90 degrees, and d is only a few miles.

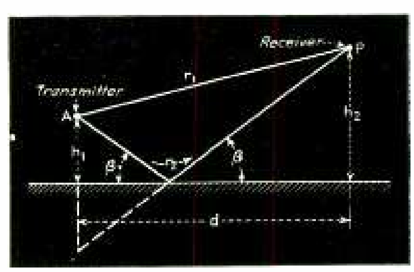


Fig. 14—Geometry of u-h-f propagation

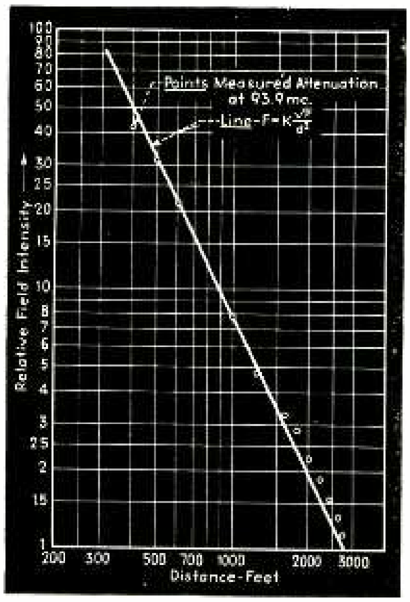


Fig. 15—Calculated and measured field intensity data for u-h-f propagation within the line of sight

Case I—Long Distance Propagation

The analytic expression for the field intensity is very complicated and is generally based on a number of simplifying assumptions. The field intensity depends upon a large number of factors including the conductivity and the dielectric constant of the ground, the curvature of the earth, the heights of the transmitting and receiving antennas and the polarization of the transmitted signal. The subject is too complex for a satisfactory discussion here. A good discussion of this subject appears in the October 1938 issue of the Proceedings of the Institute of Radio Engineers.

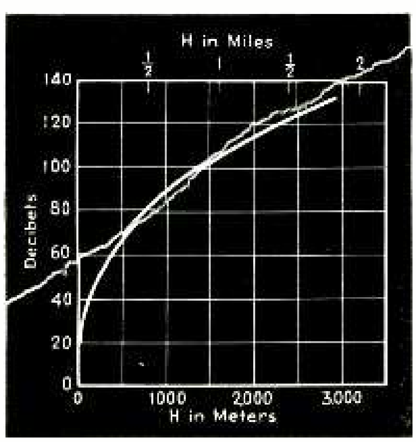


Fig. 16—Gain in field intensity due to elevation of transmitting and receiving antennas to a height *H* above the earth

Case II—Distances Well Within Line of Sight

Referring to Fig. 14 the field strength at point P may be expressed as

$$F = K P^{1/2} (1 + R e^{-j2\pi(r_2 - r_1)/\lambda})/d \quad (10)$$

where K is a constant, P is the power radiated and R is the complex ground reflection coefficient depending upon ground conductivity, dielectric constant, frequency, polarization, etc. We may make a simplifying assumption which is quite good for horizontal polarization at ultrahigh frequencies and is not a bad assumption even for vertical polarization, if angle β is low. The assumption is that $R = -1$. Then

$$F \leqq K P^{1/2} h_1 h_2 / d^2 \lambda \quad (11)$$

This equation shows that the field strength is directly proportional to the square root of the transmitted power, the height of the transmitting antenna and the height of the receiving antenna. It is inversely proportional to wavelength and the square of the distance.

Case III—Ground Reflection at Various Vertical Angles

One important aspect of the ground reflection of radiation from a u-h-f antenna is the variation of the reflection coefficient with angle of incidence of the ground reflected wave. We may discuss this by seeing what happens as point P (Fig. 14) is varied to change angle β between 0 and 90 degrees. So far as horizontal polarization is concerned, e.g., radiation from a horizontal u-h-f loop antenna, the reflection coefficient remains negative and very close to unity.

This is not true for vertical polarization. For very low values of β (near grazing incidence), the reflection coefficient is essentially the same as for horizontal polarization. But as β is increased the reflection becomes less and less and its phase advances. The minimum reflection angle is known as Brewster's angle and at this point the reflected wave bears a 90 degree phase relationship to the incident wave. For β higher than Brewster's angle, the phase of the reflected wave keeps advancing, eventually being almost equal to the phase of the incident wave. The amplitude, however, does not quite reach unity.

Brewster's angle changes with ground conditions and frequency of the transmitted wave. As an example, K. A. Norton gives Brewster's angle = 14° 25′ 30″ at 46 Mc with a reflection coefficient of less than one-tenth. The ground constants were $\epsilon = 15$, $\sigma = 5 \times 10^{-11}$ e.m.u.

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II. Ultrahigh Frequency Generators

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I. Triode Generators

A. General Considerations

ALTHOUGH there is no general agreement on the definition of the term, "ultrahigh frequencies," it is most commonly applied to all frequencies above about 40 Mc. Considering that one may dream of producing, in some not very remote future, radio waves a few millimeters in length, (above 30,000 Mc), the u-h-f spectrum is at least 1,000 times greater than the combined width of all other bands (from 0 to 30 Mc) used in radio. From this fact alone a great variety of u-h-f applications can be anticipated. At the same time, one may logically expect that essentially different types of u-h-f generators will be required for various parts of this spectrum.

A basic difference in the electronic mechanism of the three main types of the modern u-h-f generators consists in: (1) the manner of bunching electrons emitted by the cathode into a succession of electron groups which rhythmically impinge on the anode directly or through its electric field; (2) the length and the shape of the electron paths within the tube, and (3) the time spent by individual electrons on their way from cathode to the anode called the transit time and usually measured in parts of an oscillating cycle.

In the conventional cylindrical triodes the bunching of electrons is effected by the control grid which opens the gate to electrons and closes it during each cycle as grid potential swings above and below the cut-off voltage. The electrons admitted into the grid-anode space with a considerable energy are further accelerated and impart their energy to the anode; the anode potential never becomes negative and is always greater than that of the grid. Generally speaking the electron paths are radial and very short. The transit time for efficient operation must be less than one-tenth of a cycle, the shorter the better. In fact, the difficulty of keeping transit time short enough represents one of the main limitations in designing triodes for ultrahigh frequencies.

In the magnetron, due to the long sharply curved spiral paths, transit time becomes a rather ambiguous concept; individual electrons may stay in motion for a considerable portion of a cycle or even longer than an oscillation cycle. In the typical velocity modulation generators, an originally continuous beam of electrons of uniform velocity is transformed at a certain point, by application of an r-f voltage, into waves of electrons or successive bunches. Transit time here can embrace several cycles before the individual electrons are utilized for production of oscillations. In the last two types of generators, long transit time is no more a limitation—it is a corner-stone of the tube design.

One great advantage of the triode or tetrode over the other types of u-h-f generators is the convenience with which its output can be effectively modulated at audio or video frequencies while its carrier frequency is kept constant.

There are two main factors limiting the output and efficiency of a triode as the frequency is raised above a certain level: (1) the inductances and capacitances associated with tube electrodes and their internal leads (which effect is of the nature of circuit limitations incurred by the presence of the tube) and, (2) electron transit time limitation affecting the electronic mechanism of the tube and its capability of producing oscillations. Due to these limitations triode generators must be reduced in size (and likewise in power) as the generated frequency is increased. Thus, there are water or air cooled tubes delivering several kilowatts into the load at 100 Mc, but only a few hundred watts can be obtained from special tubes at 200 Mc and at 500 Mc tubes with a few watts output can be built. The limit for receiving triodes is about 3,000 Mc.

B. The Role of Vacuum Tube Capacitances and Inductances

In a vacuum tube circuit intended for the generation of high frequency oscillations the tube capacitances and inductances are integral parts of the oscillating circuit. Thus, in a circuit connected between the plate and the grid (Fig. 1) the composite tube capacitance, C_t, augments the lumped capacitance of the circuit, C, by the amount:

$$C_t = C_{gp} + \frac{C_{fg}\, C_{fp}}{C_{fg} + C_{fp}} \quad (1)$$

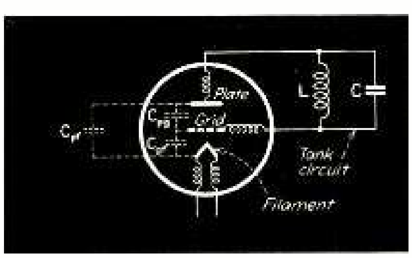


Fig. 1—Internal capacitances and inductances of triode

At lower frequencies, when C is large, the effect of the tube capacitance is negligible; so is, also, the effect of the tube inductances. The higher the intended frequency, f, the smaller must be L and C, as follows from William Thomson's formula (derived in 1853):

$$f = 1/2\pi\sqrt{LC} \quad (2)$$

The highest feasible frequency from a tube corresponds to the complete absence of external capacitance and to the circuit inductance shrunk to a direct short circuit between the anode and grid terminals. This is so called resonant frequency of the tube, f_r, and is usually found among the manufacturers' tube data. The resonant frequency may serve as a figure of merit of the tube as a u-h-f generator, but cannot be used in practical applications because at this frequency the tube output is negligible.

In addition to the frequency, every circuit is characterized by the numerical quantity, Q, which is

$$Q = \frac{1}{R_s}\sqrt{\frac{L}{C}} = R_p\sqrt{\frac{L}{C}} = R_p\,\omega\,C \quad (3)$$

where R_s and R_p are the series and parallel resistance, respectively, and $R_p = Q/\omega C$.

The correct value of the parallel load resistance, R_p, for the optimum tube operation can be determined directly from the constant-current chart of tube characteristics. The choice of proper R_p is called matching the load to the tube. If the only capacitance in the circuit is that of the tube, C_t, the matching becomes difficult with increasing frequency if tube operation is to remain efficient. Indeed, due to the increased circuit loss as a result of the increased skin effect and direct radiation, Q decreases with increase in frequency. Then, from Eq. (3) it is seen that for constant capacitance, C, the parallel resistance R_p is reduced. A low load resistance usually makes tube operation inefficient unless the tube is designed for low voltages and high currents.

In addition to having their share in establishing the resonant frequency

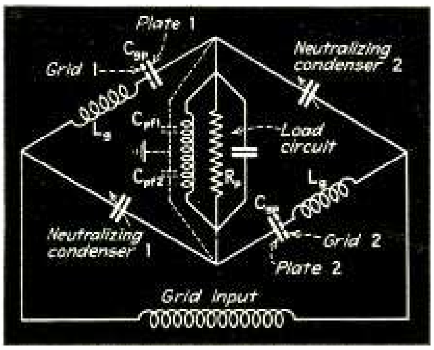


Fig. 2—Diagram of neutralized push-pull amplifier

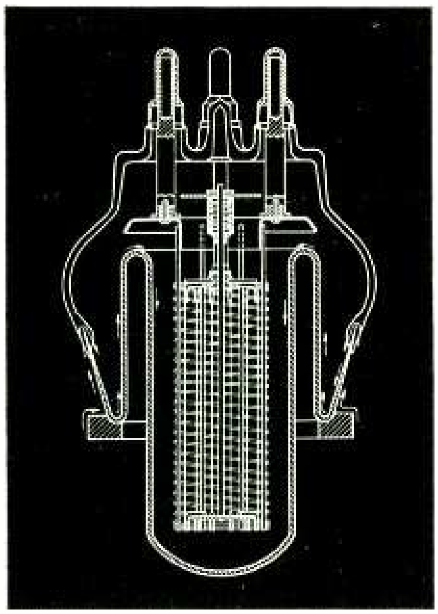


Fig. 3—High frequency water cooled triode with folded anode

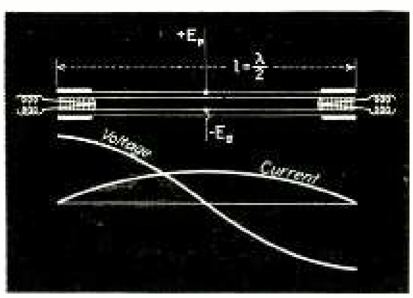


Fig. 4 — Concentric transmission line type of oscillator

of the tube the inductance of the internal tube leads may interfere with a proper neutralization of the tube used as a power amplifier. A neutralized push-pull circuit of two tubes can be represented schematically by a balanced bridge arrangement (Fig. 2). It is evident that inductances in series with the anodes and grids of the tube prevent a perfect equilibrium between the bridge arms, especially when modulation is applied to the tubes so that the frequency is variable or a wide bandwidth is obtained. The inductance inherent in the filament leads is common simultaneously to the anode and the grid circuits; therefore, it effects a degenerative coupling between the two.

To minimize the detrimental effect of the internal inductances the structural parts of the tube must consist of straight conductors short in length and large in diameter. The application of this principle to the large water-cooled tubes leads to the anode designs with the inverted or folded-up feather edges (Fig. 3). For the same length of the active anode this construction permits a considerable reduction in the length of the grid and the cathode structures. It may be noted that due to the skin effect the current between the internal anode surface and the outside circuit does not flow on the shortest path across the anode wall but follows its surface all around the feather edge, sometimes causing heating of the glass seal. The depth of penetration of electro-magnetic energy into a metallic surface, or the thickness of the film carrying the current, is given by the expression.

$$\delta = \frac{1}{2\pi}\sqrt{\frac{\lambda\rho}{30}} \qquad (5)$$

Here, λ is wavelength in centimeters and is the resistivity of the material in ohms per centimeter cube. For copper and a frequency of 100 Mc, δ is less than 0.001 inch.

In order to minimize the effect of the inner capacitances and inductances, the tube can be designed so that it is an integral and continuous part of a transmission line or Lecher system (Fig. 4). In this concentric cylindrical structure, the anodes form the end portion of the outer pipe, the grids are associated with the inner pipe. The filament can be inserted from the end. Such a system, if excited by application of direct voltages, can produce oscillations with standing waves along the pipes so that the generated wave equals very nearly twice the length of the concentric pipes. The wavelength is independent of the plate-to-grid capacitance, C_{pg}, although it may be slightly affected by C_{pf} and C_{gf} apearing as though connected across the concentric pipe ends. The tube proper can be made mechanically as a separate unit attached to the pipes, or for very short waves, the whole system can be located within a glass envelope.

Concentric pipes are structurally cumbersome; in addition, the coupling between the plate and the grid is too rigid and cannot be well regulated. Therefore, in a great many cases of u-h-f oscillators a parallel-wire Lecher system is used between the grid and the plate, or better, one or two tubes are used in push-pull arrangement with independent parallel rods or flat bars connected between two anodes and two grids (Fig. 5). The tubes can be located either at the ends of a half-wave system, or they can be put in series with each other, across a quarter wavelength line shorted at the other end by a bar. The filaments can be either short-circuited or connected by an independent Lecher system. The actual length of the plate system can be calculated from the expression

$$1/C_o\,\omega = Z_o \tan(2\pi l/\lambda), \qquad (6)$$

where $Z_o = (L/C)^{1/2}$ is the characteristic or surge impedance of the system (L and C are uniformly distributed inductance and capacitance per unit length; Z_o, L and C depend on wire diameter and wire spacing[10])

ω is 2π times the generated frequency

C_o is the tube capacitance foreshortening the line, and

l is the line length.

The equation can be sustained only for $l<\lambda 4$, because only then is the reactance inductive and capable of producing the desired resonance with tube capacitances. From this expression it is seen that the tube capacitance must be small if short wavelengths or high frequencies are to be secured. The tube leads can be so arranged that there is no discontinuity between the tube and the external transmission line.

In all previous discussions it follows that for production of u-h-f oscillations it is advantageous to make plate-to-grid capacitance as small as possible. This is important whether a tube is to be operated as a neutralized and frequency-controlled amplifier or an oscillator. However, were it not for this capacitance one could not have built many simple and convenient triode oscillators which play such a tremendous role in u-h-f applications. Most of such devices, for example the one just described, operate as tuned plate-tuned grid oscillators, in which the output and input circuits are coupled only

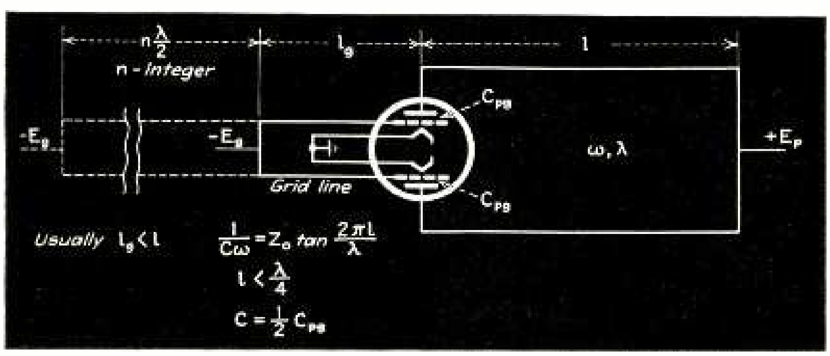


Fig. 5—Oscillator using parallel wire transmission line

through the tube capacitance, C_{pg}. It can be shown by a simple derivation[3], that with certain assumptions the feedback role of C_{pg} (Fig. 6) is equivalent to a connection of a "ghost" resistance, R_x, and of a "ghost" condenser, C_x across the grid-filament circuit. Their values are given by the following expressions:

$$C_x = (1 + A_1)\, C_{pg}$$

$$R_x = -\frac{1}{C_{pg}\, A_2\, \omega} \qquad (7)$$

The quantities A_1 and A_2 are the inphase and the reactive components of $A = E_{op}/e_{og}$, the ratio of r-f plate and grid voltages. The appropriate value of A for maximum tube output can be estimated from the tube chart; it can also be calculated from the tube and circuit data. When R_x is negative and numerically smaller than R_g, the total

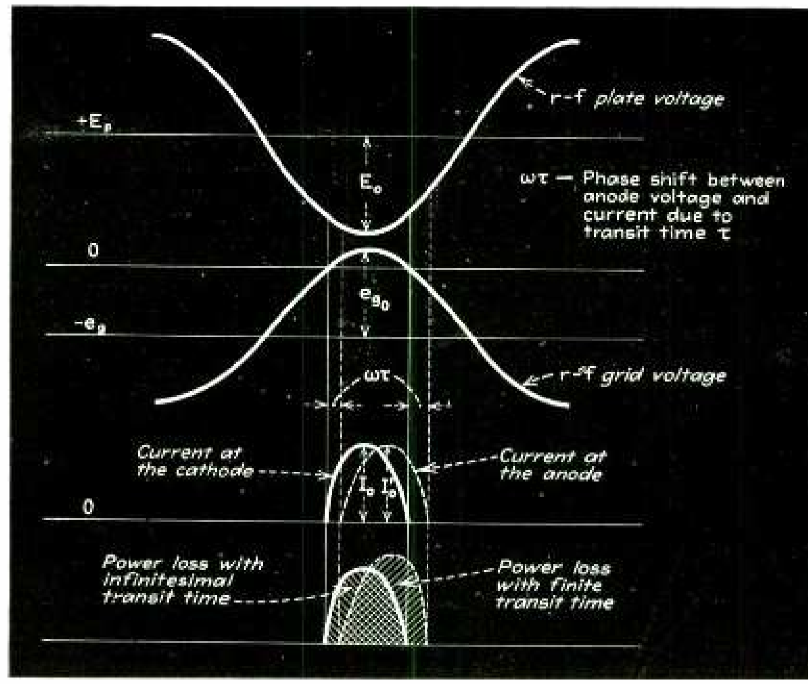
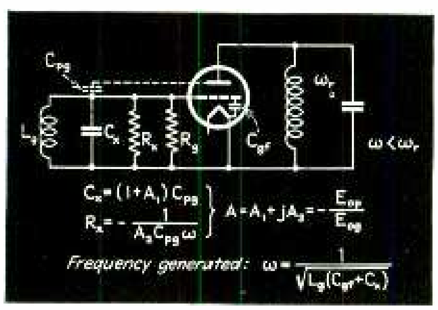


Fig. 7—Phase shift between anode voltage and current due to finite transit time of flight of electrons

Fig. 6 — Grid circuit resistance and capacitance resulting from feedback



positive grid resistance, the grid circuit becomes a generator of oscillations of frequency:

$$f = \frac{1}{2\,\pi\,\sqrt{L_g\,(C_x + C_{pg})}} \qquad (8)$$

These oscillations are amplified in the plate circuit. From Eq. (8) it is seen again that the smaller C_{pg} the higher can be the frequency of generated oscillations. On the other hand, if C_{pg} is too small R_x may become numerically larger than R_g, that is, too high to originate oscillations.

C. Transit Time

In low frequency operation it has always been taken for granted that an electron leaving the cathode reaches the anode of a tube "instaneously". A little thinking leads to the conclusion that it is not so as electrons move with finite velocity depending on the voltage applied. The reason that the question of transit time attracts our attention now with the advent of u-h-f tubes is that, short as it is, transit time becomes of the same order of magnitude as the period of the oscillation cycle and, therefore, its effect must be considered.

From a simple energy relation, work done equals energy acquired, we have the expression

$$eE = \tfrac{1}{2}\, m\, v^2 \qquad (9)$$

The velocity of an electron whose charge is e, and whose mass is m moving in the electric field, can be computed as a function of the voltage applied, E,

$$v = 6 \times 10^7 \sqrt{E} \text{ cm/sec} \qquad (10)$$

The grid-cathode transit time, t_g will be found by dividing the average velocity between the cathode and the grid into the distance separating them, d_{gf}. However, considering the effect of space charge, the actual expression becomes

$$t_g = \frac{3d_{gf}}{6 \times 10^{-7} \sqrt{E_g}} \qquad (11)$$

With $d_{gf} = 0.3$ cm and grid cathode voltage $E_g = 1000$ volts, t_g is approximately $\frac{1}{2} \times 10^{-9}$ sec. In a similar manner the transit time, t_a, between the grid and the anode may be calculated.

Experimentally, it has been found that with total transit time, T less than one-tenth of the cycle the tube would operate satisfactorily. At longer transit times the efficiency drops considerably. When the total transit time approaches a quarter of a period of oscillation the tube usually will not oscillate at all. Gavin[10] has derived a relation between the tube structural parameters, voltages used and minimum wavelength, λ_m, which can be generated by the tube:

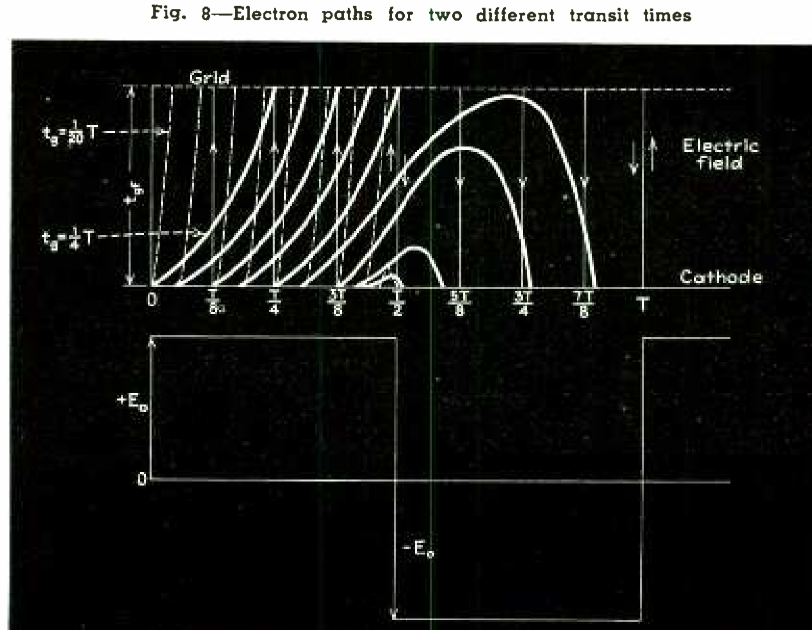
$$\lambda_m = k \left\{ 3d_{kg} + \frac{2d_{ga}}{\sqrt{\mu + 1}} \right\} \left\{ \frac{\mu}{E_a} \right\}^{\frac{1}{2}} \qquad (12)$$

where k is a constant,
μ is the amplification factor
d_{kg} is the cathode-grid distance,
d_{ga} is the grid-anode distance, and
E_a is the anode voltage.

By checking this formula on several well known types of tubes he found that the constant k is approximately 1000. This formula checks very closely on small cylindrical tubes, but gives too optimistic results on large tubes. From this expression is follows that a low μ tube is favorable for producing waves of shorter minimum length. However, other considerations may modify this conclusion. For example, if class C operation is desired, it may prove advantageous to use a tube of greater amplification. The values of μ between 10 and 20 can perhaps be suggested.

In a high efficiency self-oscillator operating at long waves, the electron

Fig. 8—Electron paths for two different transit times



current is in phase with the grid voltage and 180 deg out of phase with the plate voltage (Fig. 7). When the electron transit time becomes an appreciable fraction of a cycle, this phase relation is applicable only at that instant at which the electrons leave the cathode, but due to finite transit time they arrive at the anode after the anode voltage has passed its minimum value. Hence, the phase difference is greater than 180 deg. Power output becomes smaller and plate dissipation larger, than in the absence of this shift.

The effect of finite transit time in tube performance is not limited to the simple phenomena of phase shift[17] already described. Thus, in Fig. 8, two horizontal lines designate the position of the cathode and of the grid. On the horizontal axis time is plotted in fractions of a cycle. For the sake of simplicity a rectangular form of grid voltage is assumed. In this diagram the position of various groups of electrons leaving the cathode at different time intervals are plotted as a function of time. Thus, if the transit time is small, the consecutive positions will be given by a family of steep concave curves. With increasing transit time their average slope will decrease. For transit time equal to a quarter period ($t = T/4$) only the electrons leaving the cathode at the middle of the half cycle will reach the grid before the voltage reverses. The later electrons will find themselves in a negative electric field before they reach the grid. Then, the curves representing their position will become convex. Finally, the electrons leaving at the moment corresponding to $3T/8$ will not reach the grid at all but will turn back and land on the cathode. Thus, due to the long transit time, the cathode is bombarded by electrons producing heating or even deterioration if the tube has a thoriated tungsten or is oxide-coated cathode. Another result is that there will be a back and forth motion of electrons which, due to the variable positive charges induced on the grid, may become the cause of additional heating of the grid even if it is negative with respect to the cathode[6].

If the frequency is too high, it may happen that all the electrons will turn back before reaching the grid so the tube will give no output.

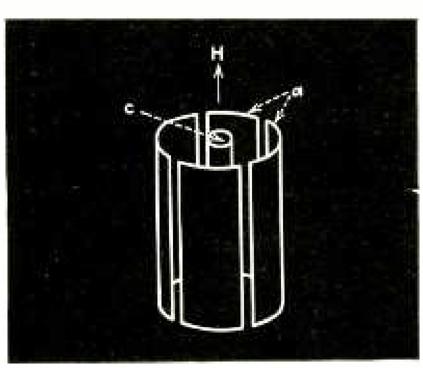


Fig. 9—Anode-cathode structure (a and c respectively) of 4-plate magnetron

II. Magnetrons

A. Introduction

As mentioned in the preceding section, the magnetron offers an alternate method of producing oscillations at ultrahigh frequencies. In this type of generator the transit time is not necessarily shorter than the oscillating cycle.

Structurally the magnetron consists of a cylindrical anode and a concentric cathode. When used for the production of ultrahigh frequencies, the anode is usually divided into several segments by means of longitudinal cuts (Fig. 9). A d-c potential is applied between anode and cathode, and a homogeneous magnetic field is applied parallel to the electrode axis. There may be two or more anode segments, between which the oscillatory circuits are attached.

The theory of operation of the magnetron is complex and an exact mathematical analysis is difficult. A fairly complete analysis and detailed discussion is given in reference (A). This book also contains an excellent bibliography of the rather extensive literature on magnetrons.

B. Motions of Electrons in Electric and Magnetic Fields

In all discussions of the operation of magnetrons, it is necessary to examine the electronic motions in some detail.

If the electron has initially a velocity v, perpendicular to H, it moves in a circular path. The radius of the path is given by $r = mv/eH$, the uniform angular velocity by

$$\omega_m = v/r = He/m \qquad (13)$$

If, in addition, the electron has a velocity component parallel to H, it will

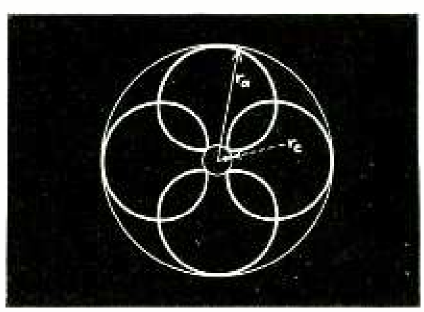
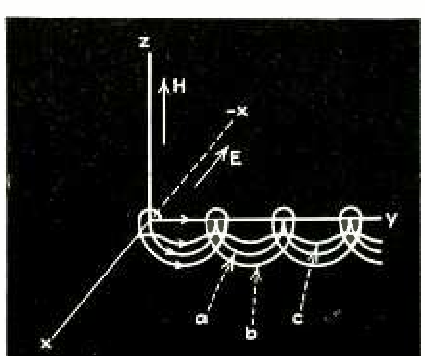


Fig. 12—Electron motion in a single plate magnetron, with magnetic field is slightly greater than the critical value

Fig. 10—Motions of an electron in perpendicularly crossed electric and magnetic fields. Possible motions for different initial velocities are represented at a, b, and c



maintain this value, so that the resulting motion is a circular helix about H as an axis. The magnetic field does no work on the electron.

If a constant electric field is added perpendicular to H, the electron will describe a cycloidal path, (Fig. 10) the average motion being in a direction perpendicular to E and to H, that is, the electron drifts along the equipotential surfaces. In the case of an electric field constant in magnitude, but radially distributed, an electron describes a cycloidal path as before, but the average motion of the electron is now on a circle. (Fig. 11.) As in the previous case, the angular velocity of the electron as seen from the center of the rolling circle generating the cycloid is $\omega_m = He/m$. But the average angular velocity as it proceeds around the cathode is given approximately by

$$\overline{\omega} = E\ Hr \qquad (14)$$

Here is assumed that $\omega_m >> \omega$

There are three classes of magnetron oscillations known:

(1) Quasi-stationary oscillations,

(2) Transit time oscillations of the first order,

(3) Transit time oscillations of higher order.

The order of oscillation is defined by $n = \omega_m/\omega$ where n is not necessarily an integer, and ω_m is as defined above, ω is the angular frequency of the oscillations produced.

C. Quasi-Stationary Oscillations

Quasi-stationary oscillations, also known as Habann oscillations after their discoverer, "negative resistance oscillations" and "dynatron oscillations", are very efficient and can be used for the production of high outputs at moderately high frequencies. They are not suitable for production of micro-waves, inasmuch as the upper frequency limit is below the micro-wave region.

D. Transit Time Oscillations of the First Order

Let us consider a simple split plate magnetron with a cathode radius r_c and anode radius r_a in a uniform axial magnetic field H and let a d-c potential V be applied between anode and cathode. First, we suppose that the tube is not oscillating. Then, an electron on leav-

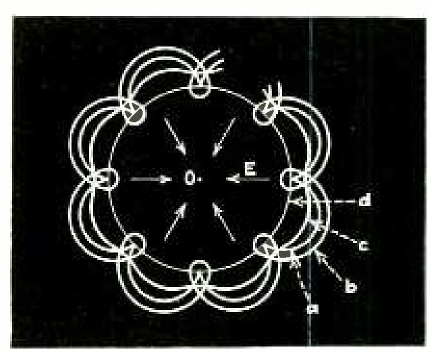


Fig. 11—Motion of an electron in perpendicularly crossed electric and magnetic fields, both of which are constant

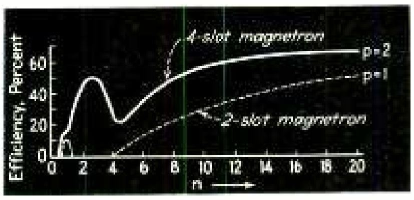


Fig. 13—Dependence of efficiency on the order of oscillation, n, for two magnetrons

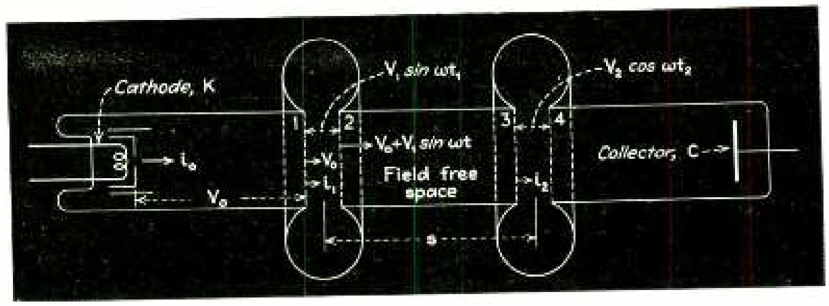


Fig. 14—Diagram showing construction of a velocity modulated oscillator

ing the cathode describes approximately a circular path and returns to the center of the tube. If it were not for the cathode the electron would trace out a four-leafed rosette (Fig. 12). For the values of V and H, called the critical values, the electrons would just graze the anode. In this case

$$r_a(1 + r_c^2/r_a^2) = 6.72\sqrt{V}/H \qquad (15)$$

When V is in volts and H in gauss. The motion of the electron produces a field whose wavelength in centimeters is obtained from $\omega_m = He/m$

$$\lambda = 2\pi c/\omega_m = 10{,}700/H \qquad (16)$$

From this expression alone one can conclude that with magnetic fields of quite practical values (several hundred gauss) very short waves can be produced. Let us assume next that there is a small alternating voltage applied between the two anode segments. The uniform radial electric field will be distorted by the superposition of the oscillating tangential field on the radial field between the segments. This will be particularly strong in the vicinity of the gaps. Those electrons which pass in front of the gaps with the a-c field receive an additional acceleration, their radii become greater according to Eq. (3) and they probably fall on the segment with the higher potential, thus contributing to the tube loss.

On the other hand, those electrons which pass the gaps with an adverse a-c field will be decelerated and give up a part of their energy to the field. This energy serves to sustain the oscillations. The decelerated electrons continue their motion on a curve with a smaller radius than originally, and by being again accelerated by the d-c field may repeat the same process during several consecutive cycles until they will be exhausted and contribute no more to the sustenance of oscillations. Experimentally it was found that a slight angle (3 to 5 deg) between the anode axis and the magnetic field considerably intensifies the oscillations by sorting out the exhausted electrons. This sorting is accomplished by a slight spiral motion of electrons along the anode axis which follows from the previous consideration of electron motion in a combined electric and magnetic field. A similar effect can be produced by applying a longitudinal electric field. In both cases, elimination of electrons gives preference to the effect of the useful electrons over these causing only a loss of energy.

From this type of magnetron only relatively small outputs at low efficiency can be obtained; yet, they are suitable for generation of waves as short as 10 cm and even down to 1 cm. In general the magnetic field serves to limit the frequency, although the anode diameter is also a limiting factor, since it diminishes with increasing frequency.

E. Transit Time Oscillations of Higher Order

In this mode of oscillation, the frequency is not closely related to the characteristic frequency of the electron, $\omega_m = He/m$ as in oscillations of the first order, nor is it determined solely by the external circuit as is the case for the quasi-stationary mode of oscillation. Although the motions of the electrons play a decisive role in the production of oscillations, the values which the operating data take are not at all critical within wide limits. High efficiencies can be realized in this mode even at short wavelengths. H must be greater than the critical value.

Since $n = \omega_m/\omega$ by definition, the frequency of the oscillation ω is less than ω_m. Inasmuch as the observed efficiencies are high, we may expect that the electrons must remain in the anode-cathode space over a period of several oscillations in order to transfer a large portion of their kinetic energy to the oscillating field. From what has been said about the motions of electrons in crossed electric and magnetic fields, when the electric field is radial and H is greater than the critical value, it may be expected that the average path of the electron would be some sort of spiral motion roughly following the equipotential lines and having the cycloidal motion superposed on it. This would lead to a general motion of the cloud of electrons around the cathode which should have variations in density if it is to induce alternating currents in the anode circuit.

If now we consider that oscillations of frequency ω exist, according to the Ferraris principle the oscillating a-c field between the anode segments may be resolved into two rotating components of frequency ω/n where p is the number of pairs or segments, the components rotating in opposite directions. In order for the electrons to have the correct phase relative to the field, their average angular velocity must be $\omega = \bar{\omega}/p$. Thus, one component of the wave rotates in the same sense and with the same angular velocity as the electrons. The field component rotating in the opposite sense has such a high velocity relative to the electrons that the net effect averages out over one cycle.

We have seen that the average angular velocity of the electrons in a radial electric field and axial magnetic field is $\omega = E/Hr$. If the electrons are to keep in phase with the wave, ω must be constant. Hence E must be proportional to r, or nearly so, in the outer portion of the anode-cathode region where the oscillating field is strongest. In this case

$$\lambda = 942\, r_a^2 H/pV \qquad (17)$$

and H must be the optimum value obtained from the relation

$$\frac{H_{opt}}{H_{critical}} = \frac{np}{2}\frac{1}{\sqrt{np-1}} \qquad (18)$$

It is apparent that the order of the oscillations, n, and the pole pair number, p, play an important role. These formulae are, however, approximate. The efficiency, likewise, depends on n and p and agrees in a general way with experimental curves which follow for $p = 1$ and $p = 2$. (Fig. 13.) The disagreement is pronounced for small values of n, but for n greater than 10, the agreement is fair. In designing tubes, one must, of course, rely on the experimental curve, especially if it is necessary to operate at small values of n.

This type of oscillation is the most useful type of magnetron oscillation on account of the possibility of operating at high efficiencies at high frequencies.

III. Velocity Modulation Generators

As already mentioned, the velocity modulation generator of u-h-f oscillations is a development of quite recent years. A velocity modulation generator contains a kind of electron gun, known in the cathode-ray tube art, by means of which a narrow beam of electrons is projected down the axis of the tube (Fig. 14.) After having been accelerated by a voltage of several hundreds or thousands of volts, all electrons move with a uniform velocity corresponding to the voltage used. However, when they pass through a narrow gap between grids 1 and 2, the electrons are subjected to an impulse of a sinusoidal voltage applied between the grids supplied by an oscillating circuit connected between the grids. Therefore, some electrons emerge from gap 1 and 2 with slightly greater and some with slightly smaller than average velocities. Space 2-3 is free of electric field as all four grids have the same d-c potential, ordinarily zero. This means that the cathode must be at high negative potential. Moving through this Faraday cage, the faster electrons catch up with the slower ones and are aggregated in groups or bunches. In fact, before they reach grid 3, the electrons can be debunched and re-bunched several times because of the different velocities. An r-f potential is also applied between grids 3 and 4. Now, (1) if this second gap is located at such a distance, S, from the first one that electrons enter it while they are bunched; and (2), if an electron bunch crosses the gap while the r-f electric field (or voltage) is adverse, the electrons will be retarded by the field; their lost energy is imparted to the field, hence, to the oscillating circuit producing it. Thus, oscillations, once started in the oscillating circuit associated with the second gap, can be sustained; of course, the consecutive electron groups must arrive in synchronism with the oscillations. The exhausted electrons fly through grid 4 and are intercepted by the collector, C, in which their residual energy is converted into heat. Obviously, the frequencies of both oscillating circuits, $f = \omega/2\pi$, must be the same, while the average velocity, v_o, and the amplitude of modulation velocity, v_1, must be so chosen that the electron bunches are formed just before they enter the gap 3-4. All these qualities are connected by the expression:

$$r = \frac{S\omega v_1}{v_o^2} = \frac{S\omega}{v_o} \times \frac{v_1}{v_o} \qquad (19)$$

Theoretically it can be shown that variation of r, by varying one or several quantities in this expression, causes changes in the shape of the electron waves passing through the gap, 3-4, hence, in the form of the current, i_2, through the gap. The wave forms of the current for $r = 0.5$, 1, and 1.5 are shown in Fig. 15. Theoretical maximum efficiency, 58 percent, corresponds to $r = 1.84$. As can be seen, in some cases the current curve has pronounced peaks; this shows that velocity modulation generators are suitable for production of harmonic oscillations, in other words, for frequency multiplication. In this case, the output circuit must be tuned to the desired harmonic frequency.

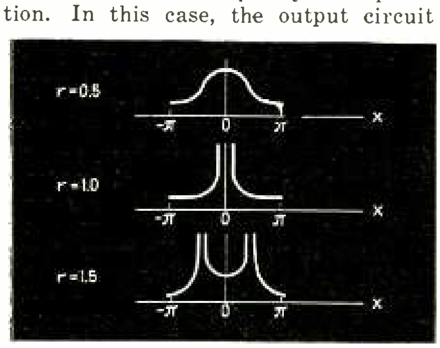


Fig. 15—Wave forms of current of velocity modulated tube

For a given value of r, Eq. (19) shows that the distance, S, between the modulating gap 1-2 and the first pronounced electron bunch, is directly proportional to the average velocity, v_o, and inversely proportional to frequency and to the percent of modulation v_1/v_o.

A theoretical derivation of the efficiency given above is made with the assumption that:

(1) There are no losses in the oscillating circuits.
(2) There is no de-focusing of the beam due to the space charge.
(3) No electrons are intercepted by the grids or walls.

All these assumptions, particularly the third one, may depart greatly from experimental conditions so that the actual efficiencies may be 20 percent and even less.

The velocity modulation principle and generation of power by rhythmic projection of electron groups against an adverse r-f field were first described in 1935 by Heil and Arsenjewa-Heil.[20] However, the brothers R. H. and S. F. Varian,[21] in this country, arrived independently at a similar solution of micro-wave generators and they improved their design decidedly by combining the velocity modulation principle with the most efficient oscillators, hollow body or cavity resonators. These have been known to science since 1897 through a paper by Lord Raleigh[22].

It has been shown theoretically and experimentally that a space totally enclosed by a metallic conductor, such as a sphere, cylinder, prism, and the like, may become a seat of vigorous electromagnetic oscillations, if these are properly excited. A basic rule is that the electromagnetic field outside of the resonator is zero, and that the tangential component of the internal electric field at the conductor is zero. Because of the latter condition, only certain discreet frequencies or wavelengths are allowed, and there always exists a minimum or cut-off frequency. The values of the resonant frequencies are determined by the size and shape of the enclosure and can be calculated[2]. The longest, or cut-off, wavelength is always comparable at least with one of the main dimensions of the resonator. Thus, for a sphere. $\lambda_{max} = 2.28r$; for a cylinder. $\lambda_{max} = 2.61r$, where r is the radius of the sphere or of the cylinder.

The great advantage of cavity resonators as compared to other forms of oscillating circuits is their extremely high Q. This is the result of low resistance loss and of the complete absence of radiation losses. For a cavity resonator, Q is equal to the ratio:

$$Q = \frac{\text{volume of inner space}}{\text{surface area} \times \delta}$$

Here δ is the thickness of the inner conducting skin of the wall; it can be calculated from Eq. (5), given before. Values of Q as high as 50,000 can be obtained with cavity resonators. Another advantage of these oscillators is a high shunt impedance permitting a better matching of the load even at extremely high frequencies.

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III. U-H-F Reception and Receivers

By **BEVERLY DUDLEY** *Acting Managing Editor, Electronics*

I. Problem of Ultrahigh Frequency Reception

ULTRAHIGH frequency communication involves point to point transmission with little or no broadcast service. There is only one receiver (or at most, only a few receivers) for each transmitter but there may be an appreciable number of transmitters in operation at a given time. In order that the frequency spectrum may be most effectively utilized with interference reduced to a minimum, it is desirable to reduce the transmitter power and increase the receiver sensitivity to the greatest extent. The factors which limit the sensitivity of receivers thus become of paramount importance. Because a relatively few receivers are in operation, mass production methods are not applicable to their construction. Cost of manufacture is secondary to results obtained so that the engineer designing ultrahigh frequency receivers faces totally different economic and design problems than the designer of broadcast receivers.

The condition of propagation of radio waves in the ultrahigh frequency spectrum places emphasis on certain receiver problems which are different from those encountered in the broadcast band. At frequencies below 10 to 30 Mc, receiver noise is usually not the factor limiting its effectiveness. From 50 to 80 Mc there is appreciable man-made noise from spark, ignition and similar sources but there is little natural static. At frequencies above approximately 80 Mc, man-made noise and static decrease to such an extent that above approximately 100 Mc, noise originating within the receiver limits its effectiveness. As a result, noise becomes the factor limiting receiver sensitivity, although other factors are also of importance.

The chief problems in the reception of signals at ultrahigh frequencies are concerned with: (a) the signal-to-noise ratio, (b) the bandwidth to which the receiver is responsive, and (c) the selectivity of the receiving equipment. These three factors are interrelated. Optimum design for each one of the quantities may not always be achieved in a single receiver design.

Beyond a certain point an increase in receiver sensitivity is not useful because the noise in the receiver masks the signal. Accordingly, sensitivity is intimately associated with the signal-to-noise ratio.

In the u-h-f spectrum the wavelengths of received signals are comparable to the physical dimensions of circuit elements. Accordingly, the concept of lumped circuit constants is no longer valid. At those frequencies for which distributed circuit constants must be given consideration, the physical dimensions and mechanical construction of the receiver become of primary concern. Tuning is usually accomplished by application of transmission line principles. The operation of the receiver is appreciably affected by the presence of stray or distributed capacitance and inductances. Requirements of frequency stability necessitate the most rigid mechanical construction and frequently require voltage regulating devices.

Since the superheterodyne is used almost exclusively and only the first tube usually operates at the carrier frequency, u-h-f receiver problems are largely confined to design of the input stage. The design and construction of the i-f and audio portions of the system follow usual practice, and consequently will not be treated here.

II. Characteristics of Tubes at Ultrahigh Frequencies

The limitation of ordinary vacuum tubes at ultrahigh frequencies has been rather thoroughly investigated.[1] Thompson[2] has shown that by reducing all physical dimensions of a tube by the same scale factor, the interelectrode capacitances are considerably reduced without affecting the transconductance or amplification factor. Transit time is likewise reduced as is also the power input of a tube of small dimensions. The introduction of acorn, and other tubes of physically small dimensions, is a valuable contribution to u-h-f.

At ultrahigh frequencies, the input impedance of a tube can no longer be considered as infinite or even very large. Exact expressions for the u-h-f input admittance of a tube are extremely cumbersome, but Strutt[3] has shown that it may be expressed by a conductance term proportional to the square of the frequency, and a susceptance term proportional to the frequency.

Fig. 1—Concept of noise fluctuations produced by an equivalent voltage generator (left), or as a current generator, (right)

North and Ferris[4] have derived an expression for the input conductance which shows that this is proportional to g_m at low frequencies, and is proportional to f^2 as well as to the square of the time required for an electron to travel from cathode to grid.

At ultrahigh frequencies the grid-cathode capacitance becomes of extreme importance. Published values usually refer to this capacitance as measured when the heater is cold, but this capacitance increases above published figures when the tube is heated.

At ultrahigh frequencies the plate current is not in phase with the grid voltage. Consequently, g_m becomes a transadmittance rather than a transconductance. However, although the magnitude of the conductance and susceptance current individually vary appreciably with the frequency, the magnitude of the total transadmittance is reasonably constant with frequency. This variation with frequency may be neglected for a consideration of amplifier operation but not for oscillator operation.

The output admittance of a tube is always of much less importance than the input admittance, and consequently is usually neglected, even at the highest frequencies encountered.

III. Noise Due to Statistical Fluctuation

Because it limits the sensitivity of the receiver by masking the weakest signals, noise in the receiver is of extreme importance. Noise due to statistical fluctuation may be attributable to: (1) thermal agitation noise arising from the random motion of electrons in the conductor, (2) electron emission noise, (3) noise due to current division in the electrodes of the tube (4) noise due to emission of secondary electrons and (5) noise due to formation of gas within the tube.

Nyquist[5] has shown that noise voltages appear in many circuits because of the random motion of the electron within the conductor and that these noise voltages may be represented in terms of an equivalent noise resistance R which may be determined from the relation

$$e^2 = 4\,k\,T\,R\,\Delta f$$

where k is Boltzmann's constant
T is the temperature of the resistance in degrees absolute

R is the value of the equivalent noise resistance across which the voltage is produced and
Δf is the bandwidth of the receiving or measuring instrument

The concept of an equivalent noise resistance which is responsible for producing the noise voltage is a great convenience in the construction of equivalent circuits and the analysis of receiver operation. As shown in Fig. 1, the thermal noise may be represented by means of a voltage or current generator whose output is e_n or i_n as indicated in the diagram. It should be noted that in dealing with noise, the square of the current or voltage is referred to since it is more convenient to deal with powers than with voltages or currents.

In these equivalent noise diagrams, the resistance R is assumed to be noise-free, the equivalent noise being generated by the voltage or current generators as shown. Likewise any physical tube may be replaced by an ideal noise-free tube operated in conjunction with the equivalent noise resistance.

Another type of noise existing only at ultrahigh frequencies is the noise induced on the electrode within the tube. North and Ferris[12] have shown that the noise in the grid circuit is equal to

$$i_{gn}^2 = 5 \times 4kTg_e \Delta f$$

where g_e is the effective input conductance for the tube and the other symbols have the meaning already given them.

The noise in the plate circuit measured by i_{pn}^2 may be referred to the grid or input circuit by making use of the relationship $i_p = e_g g_m$, consequently the plate circuit noise is equivalent to that produced by a grid voltage noise

$$e_n^2 = 4kTR_{eq}\Delta f$$

where R_{eq} is the equivalent noise resistance in the grid circuit. An equivalent circuit of a tube with thermal and induced noise generators in the grid circuit is given in Fig. 2. The thermal noise is shown as being produced in the plate circuit (left) whereas at the right it is produced in the grid circuit.

In those cases where a tube is represented with suitable noise generators, it is assumed that the tube is noise free and that any noise resulting occurs because of the presence of the noise generators.

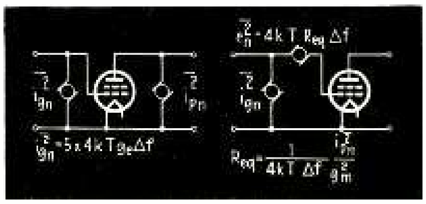

Fig. 2—Equivalent circuit of a tube with thermal and induced noise generators

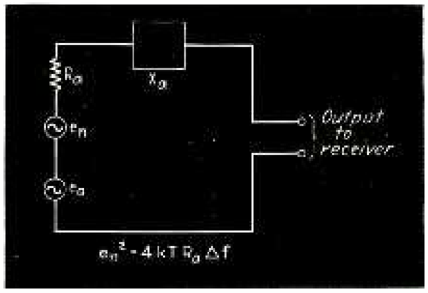

Fig. 3—Equivalent circuit of u-h-f receiving antenna with sources of signal voltage, e_a, and noise voltage, e_n

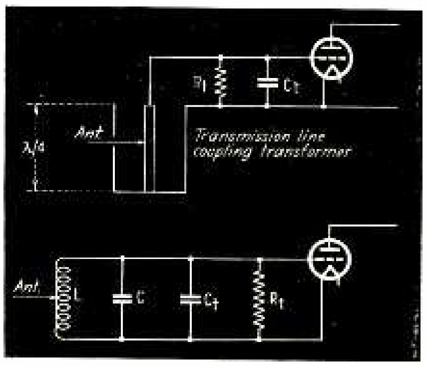

Fig. 4—Transmission line u-h-f input coupling transformer and its equivalent circuit

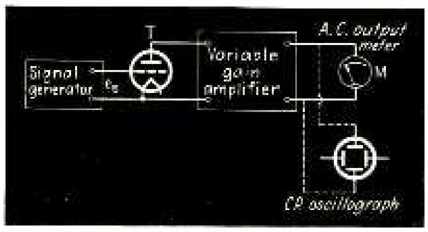

Fig. 5—Diagram illustrating concept of measurement of noise voltage in terms of signal voltage

IV. The Receiving Antenna

The receiving antenna may be looked upon as a device for coupling the receiver to the medium through which electromagnetic waves are propagated. It may also be looked upon as an impedance matching device to transfer power from free space to the receiving equipment.

Two factors are important in u-h-f antennas: (1) the power picked up by the antenna and which is transferred to the receiver, and (2) the noise occurring within the antenna circuit. The factor of merit of an antenna is the ratio of the desired signal voltage to the noise voltage.

Power picked up by the receiving antenna is given by

$$P_R = e_a^2/R_a = \lambda^2 D_a^2 S/2\pi$$

where e_a is the voltage at the terminals of the antenna
R_a is the radiation resistance
λ is the wavelength of received signal
D_a is the directivity of the receiving antenna, and
S is a factor, measured in watts per unit area, specifying the signal intensity at the location of the receiving antenna and is determined by directivity and power in the transmitting antenna, and distance between the transmitting and receiving antennas.

At any receiving location, the value of S, from a specified transmitter, will be fixed. From this equation it is evident that the power of the received signal can be increased by increasing the wavelength. However, if the frequency of the communication circuit is definitely established, the only means by which the power in the receiving antenna may be increased is by increasing the directivity of the receiving antenna, D_a. Fortunately, it is relatively easy to increase the directivity of receiving systems at shorter wavelengths. Consequently, the loss in power which occurs as the wavelength is reduced can be compensated by increasing the directivity of the system. This procedure has the further advantage of decreasing the interference due to transmission from other stations.

The noise in the antenna due to the thermal agitation is given by

$$e_n^2 = 4kTR_a\Delta f$$

where R_a is the radiation resistance of the receiving antenna and the other symbols have the meaning already assigned. Combining this equation with that given above for the power in the receiving antenna, we may express the signal-to-noise ratio as

$$(e_a^2/e_n^2) = \lambda^2 D_a^2 S/8\pi kT\Delta f$$

As is true in so many instances, the signal-to-noise ratio depends upon the bandwidth of the system.

The directivity factor, D_a, represents the voltage gain in the receiving antenna over that of a perfectly non-directional antenna. For a half wavelength dipole D_a is approximately equal to 3. The directivity of the antenna system may be increased through the use of additional elements properly arranged in an antenna array. The power obtainable from a properly constructed antenna array is proportional to the number of elements but the difficulty of construction also increases with the number of elements so that frequently a four or eight element array is the maximum which is feasible.

It is sometimes convenient to represent an actual antenna by its equivalent circuit, (Fig. 3) where X_a represents the antenna reactance, R_a represents the antenna radiation resistance, e_n represents the equivalent noise voltage on the antenna, and e_a represents the voltage of the desired signal, or the antenna voltage.

Because it is not desired to change the size of the antenna every time it is desired to receive signals of a new frequency, the effective bandwidth or frequency range of an antenna is important. Antennas for u-h-f reception are always tuned and are usually half wave dipoles.

The input circuit of the receiver usually contains a coupling transformer in the form of a section of a transmission line whose purpose is (1) to match the impedance between the antenna and the receiver, and (2) to obtain the required selectivity or bandwidth. A section of the transmission line used as a coupling transformer and its equivalent input circuit are shown in Fig. 4.

In practice the length of the transmission line forming the input transformer is usually slightly less than one-quarter of a wavelength. The Q of the transmission line coupling unit increases as the input resistance R_t and input capacitance, C_t of the tube to which it is connected are increased. When the antenna is connected to the input circuit of the receiver the added antenna resistance, R_a, produces increased loading which broadens the band to which the transformer is responsive.

To increase the selectivity, it may be desirable to connect the grid of the input tube farther down toward the grounded end of the transmission line rather than connecting it, as shown in Fig. 4 at the quarter wavelength position. When this is done, it will be found that it is also usually desirable to tap the antenna farther down the line from the position which is optimum when the grid is tapped at the quarter wave section of the coupling transformer.

V. The First Tube and Its Noise

The plate current of any vacuum tube, such as T of Fig. 5, possesses instantaneous fluctuation of plate current of a random nature, which, appearing as noise, establishes a limit to the useful operation of the tube. The mean or average value of the minute fluctuations cannot be detected directly by placing a current measuring instrument in the plate circuit of the tube since the fluctuations are usually masked by other currents and also because they occur at too rapid a rate for them to be registered by the meter. However, they may be detected when the gain of the amplifier is sufficiently high if the output meter is replaced by a cathode-ray oscillograph. The presence of fluctuations is then indicated by an irregular trace on the screen. The presence of noise, in terms of equivalent input signal voltage, may be measured by means of the circuit of Fig. 5. A signal generator producing an input or grid signal e_s, is fed to the grid of the tube whose plate circuit is connected to an amplifier of variable gain. The output of this amplifier is connected to an indicating or output meter M. For large or moderate values of e_s, indications of the meter M are proportional to the magnitude of the voltage applied to the grid of the tube.

For a signal voltage, e_s, impressed upon the grid, the plate current due to the signal is given by the expression

$$i_{ps} = g_m e_s$$

where g_m is the transconductance of the tube. Likewise, the current in the plate circuit due to random noise may be represented in terms of the equivalent noise voltage on the grid by the equation

$$i_{pn} = g_m e_n = g_m (4\, kTR\Delta f^{1/2})$$

The signal-to-noise ratio may be expressed as

$$(e_s/e_n)^2 = e_s^2/4\, kTR\Delta f$$

The signal-to-noise ratio will increase with an increase in signal strength, and with a decrease in the equivalent noise resistance and decrease in the bandwidth to which the receiver is responsive. For receivers operating above approximately 300 Mc, practically all of the noise is due to that originating within the plate circuit of the first tube. For this reason it is important to pay more than usual attention to the noise originating within the first tube.

VI. Signal Noise Ratio for Simple U-H-F Receiver

To illustrate the value of some of the noise concepts, let us investigate the signal-to-noise ratio for a simple receiver operating at frequencies of 300 Mc. The equivalent input circuit is shown in Fig. 6 in which for simplicity, only one source of noise (thermal noise) will be employed. This is introduced in the grid circuit by means of the generator labeled e_n^2. In Fig. 6, e_a is the voltage delivered by the antenna, and R_a is the antenna radiation resistance of the receiving antenna. The transformation ratio of the coupling transformer is designated as m, while C_t is the input capacitance of the first tube, and R_t represents the input loading of the first tube. For the coupling transformer to match the antenna to the tube input resistance, the equivalent ratio of transformation must be $m^2 = R_t/R_a$. For this adjustment, maximum grid voltage and maximum gain are obtained. The voltage across terminals AB is one-half of the antenna voltage so that the signal voltage applied to the grid is

$$e_s = me_a/2 = \tfrac{1}{2}\, e_a\, (R_t/\, R_a)^{1/2}$$

The signal-to-noise ratio may be determined from the square of this quantity and the square of the noise voltage as given in Fig. 6. The result is

$$(e_s/e_m)^2 = \left(\frac{e_a^2}{R_a}\right)\frac{1}{4\,k\,T\,\triangle f}\left(\frac{R_t}{4\,R_{eq}}\right)$$

The first term on the right-hand side of the equation is the signal-to-noise ratio of the antenna. For a given antenna this is fixed and cannot be modified to obtain an improved signal-to-noise ratio. Likewise, for given bandwidth, the second term is fixed. However, the third term involving R_t and R_{eq} depends entirely on the characteristics of the first tube in the receiver. Accordingly, by selecting the most suitable tube, it is possible to increase the signal-to-noise ratio appreciably. To increase this ratio we must have a tube with a high input resistance, R_t, and a low equivalent noise resistance, R_{eq}.

Although the above analysis was based on adjustment of the coupling transformer to provide maximum gain, the signal-to-noise ratio is also a function of m.

Herold[33] has shown that the coupling of the input transformer for maximum signal-to-noise ratio is less than that required for maximum gain. The relationship between signal voltage on the grid, the equivalent noise voltage, bandwidth, and signal-to-noise ratio is shown graphically in Fig. 7, for the case in which the input resistance of the first tube is 400 times the radiation resistance of the antenna. It is evident that optimum signal-to-noise ratio occurs for a smaller value of m than that required to give maximum signal voltage on the grid.

The signal-to-noise ratio for maximum gain depends only upon the input resistance of the first tube and its equivalent noise resistance. If the coupling transformer at the input of the receiver is adjusted for maximum signal-to-noise ratio rather than for maximum gain, the signal-to-noise ratio is given by

$$\left(\frac{e_s}{e_n}\right)^2 = \left(\frac{e_a^2}{R_a}\right)\frac{1}{8\,\pi\,k\,T}\left(\frac{1}{(\triangle f)^2\, C_t\, R_a^2}\right)$$

where R_a is the radiation resistance of the antenna and C_t is the effective capacitance of the input circuit.

Since both the bandwidth and the signal voltage vary with the coupling ratio of the input transformer, maximum signal-to-noise ratio will be obtained (if bandwidth is not a consideration) for that value of m corresponding to the condition of maximum efficiency. However, if a specified bandwidth is desired, some lower value of m may be required to produce a maximum signal-to-noise ratio for the specified bandwidth.

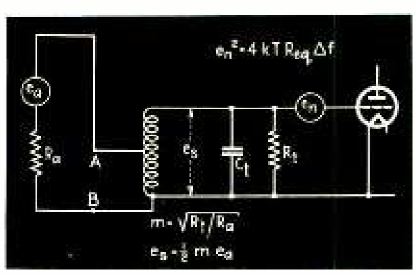

Fig. 6—Antenna and input coupling circuit

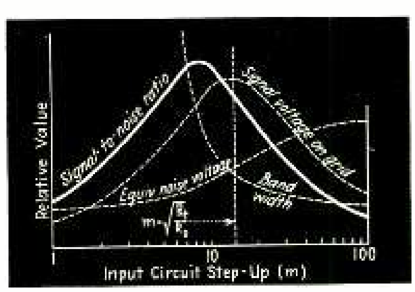

Fig. 7—Dependance of signal and signal-to-noise voltages upon input transformer coupling ratio

VII. Converter and Mixer at UHF

The non-linear device producing oscillations of intermediate frequency as a result of the combination of incoming signal and locally generated oscillations impressed upon it, may be any tube having a non-linear characteristic between two or more electrodes. The important figure of merit for the tube operated as a mixer or converter, is the conversion transconductance. If we have a circuit (Fig. 8) in which the incoming and locally generated oscillations are combined on the grid of the mixing tube and oscillations of the lower (intermediate) frequency are taken from the plate circuit then it will be possible to measure the plate current at a lower or intermediate frequency if the plate circuit is tuned to that frequency. The ratio of the plate current change at the intermediate frequency, to the corresponding change in grid voltage producing it, is defined as the conversion transconductance. Mathematically the conversion transconductance is defined by

$$g_c = \frac{di_{p_{if}}}{de_{g_{rf}}}$$

where $di_{p_{if}}$ is the change in the plate current of intermediate frequency and

$de_{g_{rf}}$ is the r-f voltage impressed upon the grid and arising from the combination of the locally generated and received oscillations. It should be observed that while the mathematical expression for the transconductance is similar to that for the more familiar grid-to-plate transconductance (g_m) the conversion transconductance involves a change in frequency, which is not the case for the ordinary transconductance. Likewise, it should be noted that in deriving the expression for converter transconductance, it is assumed that sinusoidal received and oscillator voltages are referred to. The transconductance as defined above applies, of course, to a specific set of operating voltage conditions. In general, different values of transconductance will be obtained for various values of grid and plate operating voltages.

When two sinusoidal voltages of oscillator frequency and incoming frequency are combined in a non-linear device, additional frequencies not present in the input voltages appear in the output of the device. Of the various distortion currents thus produced, only those which are equal to the sum or the difference of the two impressed frequencies are of importance in superheterodyne reception.

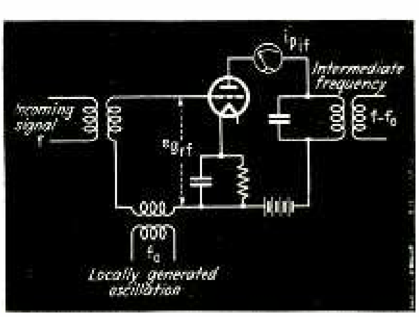

Fig. 8—Circuit for frequency converter

TABLE I—Optimum Input Circuits

	STRONG SIGNALS	WEAK SIGNALS
MODERATELY HIGH FREQUENCY	The circuit impedance for moderately high frequencies is given by the term $Z = 1/(2\pi C\Delta f)$ In this case, the gain of a radio-frequency amplifier is approximately four times that which may be obtained from a converter. Consequently, so far as gain is concerned, it is advisable to make the first tube a radio-frequency amplifier. This has the further advantage of tending to reduce the undersired image signal.	The signal-to-noise ratio is much more important than the gain. The gain consideration remains the same as for strong signals at moderately high frequency. However, the equivalent noise resistance of a converter is much greater than that of an amplifier and accordingly, the use of at least one stage of radio-frequency amplification in the input circuit is desirable.
U-H-F	The impedances at the frequency of the imput signal are much less than those which can be built up for the intermediate frequency, and for such a case, the radio-frequency gain is much less than that obtainable in an intermediate-frequency stage For still higher frequencies this condition is even more greatly exaggerated. Accordingly, above a certain transition frequency f_1 it is advisable to use a converter stage immediately at the input of the receiver.	The signal-to-noise ratio is of primary consideration. The considerations of gain are the same as for those of strong signals in the ultrahigh-frequency band. The necessity for a high signal-to-noise ratio makes it desirable to change from a tuned amplifier to a converter input stage at a lower frequency than that transition frequency designated for the case of strong signals at ultrahigh frequency.

The transition frequency, f_1, depends upon bandwidth. For a very broad bandwidth, the transition frequency will be very high, while for a narrow bandwidth, the transition frequency f_1 occurs at lower frequency. Transition frequency increases as the bandwidth increases.

TABLE II—Calculation of R_{in} and R_{eq} for Acorn Tube Mixer

Mixer	Oscillator Frequency	g_c μ mhos	R_{eq} (ohms)	R_{in} (ohms)	R_{in} R_{eq}
954	Fundamental	730	30,000	1,350	0.045
954	Second harmonic	520	72,000	2,700	0.036
955	Fundamental	785	4,600	1,350	0.293
955	Second harmonic	560	11,000	2,700	0.245

A useful empirical equation for determining the value of the intermediate frequency for u-h-f receivers in terms of the bandwidth and image ratio is

$$f = \tfrac{1}{4}\,\Delta f E_s/E_i$$

where Δf is the bandwidth of the receiver
E_s is the desired or signal frequency voltage and
E_i is the image frequency voltage

The ratio E_s/E_i is a measure of the ratio of the intensity of the desired signal to that of the undesired signal, and is expressed as a voltage ratio. The intermediate frequency should be raised as the bandwidth increases.

Instead of permitting the fundamental frequency of the local oscillator to beat with the incoming signal frequency, it may be more desirable, especially in u-h-f receivers. to utilize one of the harmonics of the oscillator to produce the beat frequency. With this arrangement it is usually possible to secure greater stability since the oscillator can operate at an integral sub-multiple of the carrier frequency.

VIII. Type of Input Tube

A problem of very practical importance in receiver operation assumes that a certain signal is to be received. The question then arises as to what type of circuit is to be used for the first tube. This tube may be used as a r-f amplifier or as a converter. Two considerations are of primary importance; (1) the signal-to-noise ratio must be as high as possible, and (2) consistent with its primary requisite, the gain must be as high as possible. It sometimes happens that the two requirements are not mutually consistent.

The choice of the most desirable type of input tube depends upon four principal factors: (1) the magnitude of the received signal frequency, (2) the bandwidth required of the receiver, (3) the field intensity or magnitude of the received signal, and (4) the nature of type of tube used in the first stage.

Table I gives an appraisal of the most suitable type of input tube under ordinary conditions for operations at moderately high frequencies and at ultrahigh frequencies, both for moderately strong and for weak signals.

IX. Classification of Converter Mixers

Frequency converters for superheterodyne receivers may be classified according to the position of the grid on which the signal is injected as: (1) converters with oscillator voltage applied to the same grid as the signal, (2) converters with oscillator voltage applied to an inner grid, (3) converters with oscillator voltage applied to an outer grid, and (4) diode converters.

Although diodes are sometimes used for mixers in u-h-f superheterodynes they are obviously incapable of providing any gain and for this reason are inferior to triodes or multi-grid tubes. They suffer from a further disadvantage in that the i-f oscillations are contained within the same circuit as oscillations of incoming and locally generated frequencies so that the intermediate frequency may beat with the local oscillator to produce additional spurious and undesired frequency components.

For converters in which the signal and local oscillator voltages are impressed on the same electrode, the signal-to-noise ratio is high, but bad interaction between signal and local oscillator circuit occurs.

When local oscillator voltage is impressed on an inner electrode with respect to that containing the signal frequency, interaction of signal and oscillator circuit is somewhat reduced but is still objectionable at the higher frequencies because of space charge coupling between the two grids. The disadvantages of these two methods may be somewhat reduced by the third method in which the local oscillator is applied to an outer electrode with respect to that containing the impressed frequency. By special tube design, this type of circuit may be still further improved.

An appraisal of the various merits of possible modes of operation of converters has been given by Herold[43] in tabular form. While this table may be used as a rough approximation for the design of converter stages, the relative merit of one type of operation as compared with another may depend somewhat upon the tube used. For this reason the table should be considered merely as a rough guide.

It has already been shown that the figure of merit for a tube, so far as concerns the signal-to-noise ratio, is given by the ratio of the input resistance to the equivalent noise resistance of the tube. Table II shows this figure of merit as well as other factors of importance for two types of acorn tubes employed as mixers and operating either at the oscillator fundamental frequency or at its second harmonic. From this table it is evident that a 955 mixer tube operating at the fundamental frequency of the oscillator is the most suitable of those listed so far as signal-to-noise ratio is concerned, with a 955 mixer operating at the same harmonic of the oscillator as second choice.

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IV. Wide Band Amplifiers & Frequency Multiplication

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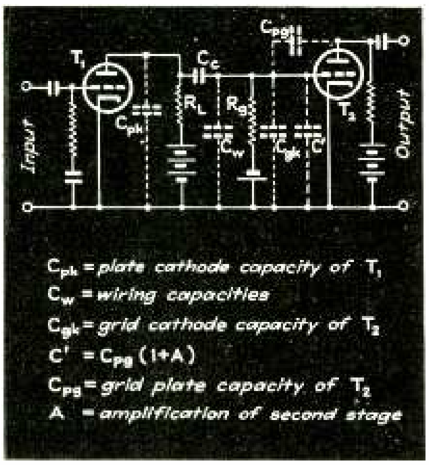


Fig. 1—Schematic wiring diagram of two stage resistance-capacitance coupled amplifier with various capacitances affecting its operation indicated

I Wide Band Amplifiers

In many ultrahigh-frequency circuit applications, a need arises for uniform amplification, with negligible phase shift, of frequencies ranging from as low as 5 cps to 10 Mc. The resistance coupled amplifier suggests itself as a solution. However, the familiar audio frequency amplifier shown in Fig. 1 presents two problems which must be solved before this method can be adapted.

The high frequency response (above 20 kc) is limited by the capacities indicated, while at the low frequencies (below 20 kc) the time constant R_gC_c must be high compared with the lowest period to be transmitted. In practice C_c may become too large if ordinary design procedures are followed so that other means must be sought. Plate decoupling in low level stages is usually desirable and unless the decoupling network is properly designed with respect to the time constant of the grid circuit of the following stage, the low frequency response will not be uniform, nor will the phase shift be a minimum.

Considering these factors we can investigate methods of modifying the circuit of Fig. 1 to accomplish wide band amplification. It is advisable to consider the high frequency operation first because certain constants, fixed by the high frequency requirements, also tend to determine the low frequency response. In the discussion that follows, linear amplification and the use of pentodes will be assumed.

A. Uncompensated Resistance Coupled Amplifier

In Fig. 2 all the capacities have been lumped together and called C_T. A variable frequency sine wave signal is applied to the grid of T_1 from a low impedance source and a vacuum tube voltmeter is connected across a low resistance R_L' (about 100 ohms). Figure 3 gives the response of the amplifier under these conditions.

The percentage of output voltage is plotted vs. frequency, for constant input voltage. Above the mid-frequency, the response falls with increase in frequency. The high frequency at which the output voltage is 70.7 percent (3 db down) of its low frequency value will be called the upper cut-off frequency f_c. The output voltage of the two-stage amplifier is related to the input voltage by the equation:

$$e_{out} = g_m R_L A_2 e_{in} / [1 + (\omega R_L C_T)^2]^{1/2} \quad (1)$$

where

g_m is transconductance of T_1

R_L is load resistance in plate circut of T_1

ω is $2\pi f$

f is frequency in cps

C_T is total shunt capacity across R_L, and

A_2 is amplification of the second stage

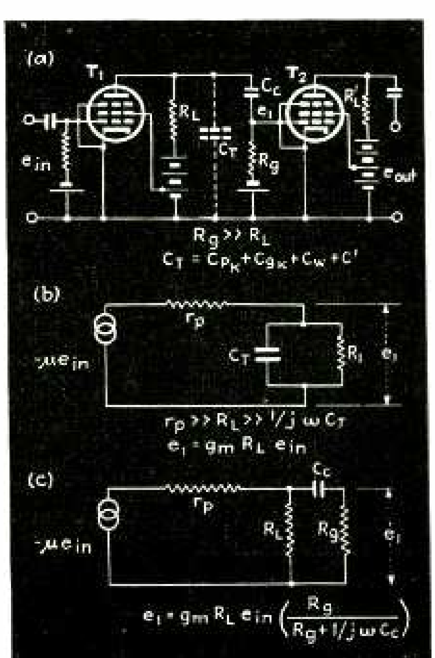


Fig. 2—Schematic diagram of two stage resistance coupled amplifier using pentodes with equivalent circuits for two conditions

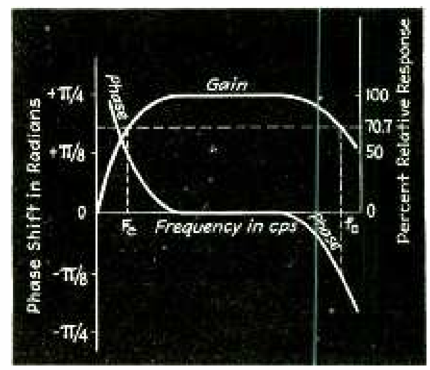


Fig. 3—Amplitude and phase response of the amplifier of Fig. 2

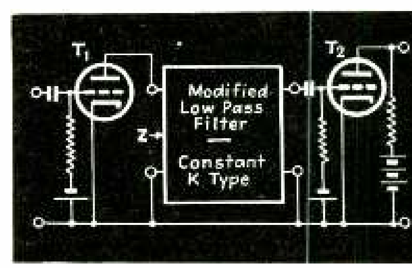


Fig. 4—A low pass filter may be inserted in the plate circuit of an amplifier tube to assist in maintaining constant gain throughout a specified frequency band

The high frequency amplification of the first stage, A_1, is given as

$$A_1 = g_m R_L/[1 + (\omega R_L C_T)^2]^{1/2}$$
$$= g_m R_L/[1 + (f/f_c)^2]^{1/2} \quad (2)$$

When the gain is reduced to 70 percent of its value at mid-frequencies, $\omega R_L C_T = 1$ whence,

$$C_T = 1/2 \pi f_c R_L \quad (3)$$

This indicates an experimental method for determining C_T. The phase shift (in radians) introduced at high frequencies is shown in Fig. 3, and is related to frequency in the following manner

$$\varphi_1 = (-\pi - \tan^{-1} f/f_c) \quad (4)$$

The low frequency amplification A_1' and phase shift φ_1' of the first stage are also shown in Fig. 3. For the low frequencies the gain and phase shift are given by

TABLE I. Vacuum Tubes Used in Wide Band Amplifiers and Their Figures of Merit

Tube	g_m (µmhos)	g_m/C_t
6AB7	5000	380
6AC7	9000	550
6C5	2000	77
6F86	2600	95
6J5	2600	108
6L6	6000	231
6V6	4100	178
6Y6G	7000	250
25L6	8200	315
807	6000	315
954	1400	234
955	2000	230
956	1800	290
1231	5500	400
1232	4000	350
1851	9000	540

$$A_1' = g_m R_L/[1 + (\omega R_g C_c)^{-2}]^{1/2}$$
$$= g_m R_L/[1 + (F_c/f)^2]^{1/2} \qquad (5)$$
$$\varphi_1' = \left(-\pi + \tan^{-1} \frac{1}{\omega C_c R_g} \right)$$
$$= [-\pi + \tan^{-1} (F_c/f)] \qquad (6)$$

where $F_c = \dfrac{1}{2 \omega C_c R_g}$ is the lower cut-off

For a given value of R_L, Eq. (2) shows that the high frequency gain increases directly with g_m and inversely with C_T. The ratio g_m/C_T should be as high as possible and is usually referred to as a figure of merit of a vacuum tube.[7, 10] Some tubes frequently used and their figures of merit, are listed in Table I.[6]

B. High Frequency Compensation

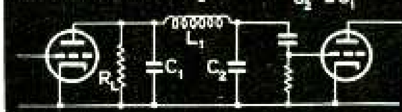
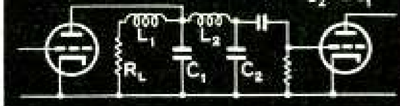
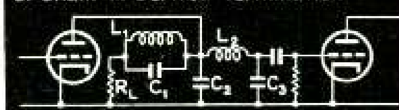
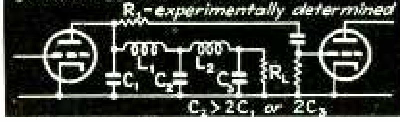
The amplification per stage of a resistance coupled amplifier using a pentode may be expressed as

$$A = g_m Z \qquad (7)$$

where Z is a complex impedance in the plate circuit. To make the gain uniform for a given frequency band, Z must be a constant, independent of frequency. To accomplish this, the plate circuit is designed to work into some modification of the mid-shunt image impedance of a low-pass filter structure (constant K type) as indicated in Fig. 4.[6] The gain is then $g_m R_L$ where R_L is the terminating impedance of the filter. Typical high frequency compensating circuits with their design formulae are given in Table II.[13] In practice they usually can be adjusted to provide compensation to the highest frequency to be amplified within ±1 db.

All of the circuits shown in Table II are straightforward in their application, except (4) and (5) which are rather critical to adjust. When using circuit (2) it may be necessary to shunt L_1 with several thousand ohms to flatten the response characteristic. When maximum possible gain is to be realized two coils will be necessary and circuit (6) is to be recommended provided the capacitances are properly distributed.

TABLE II—High Frequency Compensating Circuits

CIRCUIT	R_L	L_1	L_2	C_1	C_2	C_3
1. Shunt Peaking 	$0.5\frac{1}{\pi f_o C_T}$	$\frac{R_L}{4\pi f_o}$				
2. Series Peaking $C_2=2C_1$ 	$0.75\frac{1}{\pi f_o C_T}$	$\frac{0.1}{8\pi^2 f_o^2 C_1}$		$\frac{C_T}{3}$	$\frac{2}{3}C_T$	
3. Series Shunt Peaking $C_2=2C_1$ 	$0.9\frac{1}{\pi f_o C_T}$	$0.12 C_T R_L^2$	$0.52 C_T R_L^2$	$\frac{C_T}{3}$	$\frac{2}{3}C_T$	
4. Series M Derived Termination 	$1.0\frac{1}{\pi f_o C_1}$	$0.8\frac{R_L}{\pi f_o}$	$0.533\frac{R_L}{\pi f_o}$		$0.3 C_1$	
5. Shunt M Derived Termination 	$1.0\frac{1}{\pi f_o C_3}$	$0.3\frac{R_L}{\pi f_o}$	$1.0\frac{R}{\pi f_o}$	$0.533 C_3$	$0.8 C_3$	*Input capacity to following tube + wiring capacity*
6. Two Section Constant K, R_1—*experimentally determined* 	$1.0\frac{1}{\pi f_o C_2}$	$\left(\frac{1}{2}+\frac{C_1}{C_2}\right)\times\frac{R_L}{\pi f_o}$	$\left(\frac{1}{2}+\frac{C_3}{C_2}\right)\times\frac{R_L}{\pi f_o}$	*C_{pk} of first tube + wiring capacity*	*Greater than $2C_1$ or $2C_3$*	*Capacity across R_L + wiring capacity*

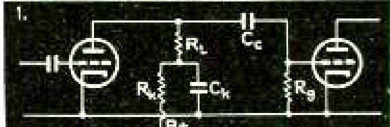
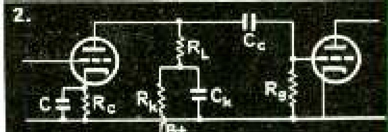
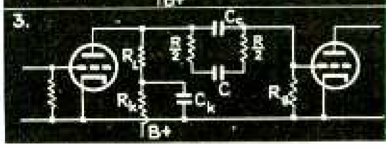
f_o is highest frequency to be amplified

Phase shift which is extremely important in wide-band amplifier applications, will be introduced as f_o is approached. It is usually necessary to keep the time delay, T = (Phase shift in rad.)/$2\pi f$ within certain specified limits to assure faithful reproduction of the amplified signal. If the frequency response up to f_o can be limited to the deviation ±(1 db)/n per stage, where n is the number of stages in cascade, the phase shift produced will not seriously affect the result desired.

C. Low Frequency Considerations

To maintain constant amplitude and a minimum of phase shift at low frequencies, any one of the circuits shown in Table III can be used.[2, 3, 10] Because of the commercial tolerance of the various components it is usually necessary

TABLE III—Low Frequency Compensating Circuits

CIRCUIT	FORMULAE
1. 	$R_o C_k = R_g C_c$; $R_o = \frac{R_L R_k}{R_L + R_k}$
2. 	$C_c R_g \gg T$; T = *lowest period to be transmitted*; $R_k = (G_m R_L) R_c$; $C = (G_m R_L) C_k$
3. 	$C \gg C_g$; $\frac{R_g}{R_L} = \frac{R}{R_1} = \frac{C_1}{C_g}$; *Ratio of about 100–300 gives practical values*

to adjust each circuit after the amplifier is built. A convenient method is to employ, as the input signal, a symmetrical square wave of the lowest frequency to be transmitted and to vary R_g until the input and output waveforms are identical. Note that R_L enters into all the determinations for the low frequency compensating networks. Thus it becomes apparent why it is desirable to do the high frequency aligning first.

D. Pulse Amplifier Frequency Requirements

The frequency band required by a pulse amplifier is determined at the low frequency end by the fundamental frequency of the pulse and at the high frequency end by the slopes of the pulse edges. The number of harmonics necessary to reproduce a pulse illustrated in Fig. 5 is given by[14, 15]

$$n = T/t \qquad (8)$$

where T is the period of pulse, and

t is the time duration of slope

The maximum frequency to be transmitted, f_o, is given as

$$f_o = F\,T/t \qquad (9)$$

where F is the pulse fundamental frequency.

E. Frequency Compensation of Power Amplifiers

The above considerations were concerned mainly with low and medium power wide band amplifiers. When the power to be dissipated in the plate circuit resistors becomes so high that their size and physical construction introduce capacitances greater than that of the tubes themselves, other means of frequency compensation must be found.

The two-terminal constant resistance type of network shown in Figs. 6(a) and 6(b) can be used to accomplish high-frequency compensation. When the constants are so proportioned that $R_1 = R_2 = (L/C)^{1/2}$, the terminal impedance is a pure resistance independent of frequency. The arrangement of

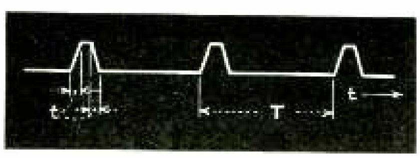
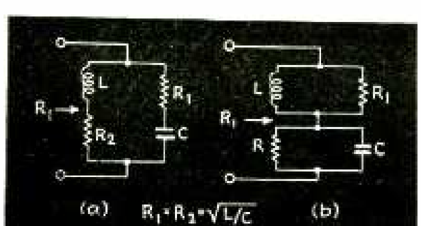


Fig. 5—Wave form of pulse requiring wide band amplifier for its transmission

Fig. 6—Constant resistance networks for high frequency compensation



two-terminal networks in a practical application is illustrated in Fig. 7.

Note that the networks are arranged in cascade so that section 1 forms the resistance element in parallel with C_2 of section 2 and so on. The plate circuit thus sees a resistance R shunted by the tube and stray capacities. The network nearest the plate supply, i.e. section 1, is usually utilized to filter the rectified high voltage. In practice each section maintains the frequency response to some value determined mainly by the choke capacities. For example in a television modulator, sections 1 and 2 used alone would give a response approximately to 1.5 Mc; sections 1, 2, and 3 maintain the frequency response to 3 Mc, while sections 1, 2, 3 and 4 operate to 5 Mc. The greatest i^2R loss will occur in the resistance nearest the plate supply. This resistance can be water cooled if necessary because the capacitance to ground at this point is small compared to that of C_1.

An application of the constant resistance type of network to plate-grid coupling is shown in Fig. 8(a). The self inductances of the two coils L_1 and L_2 are so designed that when coupled their mutual inductance is such that $L_2 - M = 0$. The impedance of C_3 is small compared to that of $(L_1 - M)$ or the resistance, R_5 for the lowest frequency to be transmitted. The equivalent circuit is shown at bottom of Fig. 7. When $R_2 = R_3 = (M/C_2)^{1/2}$ and $R_4 = R_5 = [(L_1 - M)/C_1]^{1/2}$ a resistance equal to R_4 exists between plate and grid. This type of constant resistance network will not be a pure resistance down to very low frequencies because of C_3.

F. Designing the Wide Band Amplifier

To begin the design of a wide band amplifier one must know the following:

1. Frequency response desired.
2. Signal waveform and peak-to-peak voltages of the input and output. These are necessary if optimum linearity is to be obtained. Obviously the operating points for the various tubes depend upon signal waveform and magnitude among other things.
3. Power supply ripple and amplifier gain. These must be known to properly design decoupling filters to prevent "motorboating" at some low frequency and excessive power supply ripple on the grids of the low level stages.

With a knowledge of these factors we can proceed to find the circuit constants for each stage, working from the output end towards the input after choosing a tube from Table I. An estimate of capacitances will allow us to determine the plate load resistance and the inductance of coils, using a circuit listed in Table II. Knowing the signal levels and the required hum level, a reasonable value of decoupling resistor and capacitance can be determined. The low-frequency compensation can then be calculated from Table III. The required output voltage divided by the

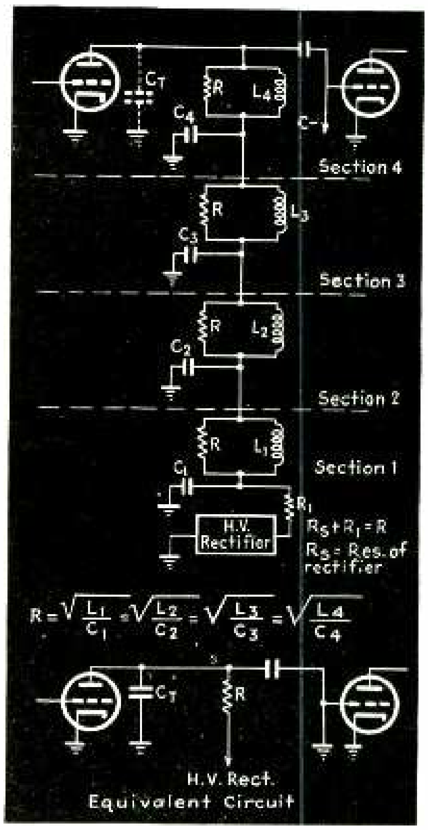


Fig. 7—Four-section constant resistance networks for extending frequency range

Fig. 8—Application of constant resistance networks to interstage coupling

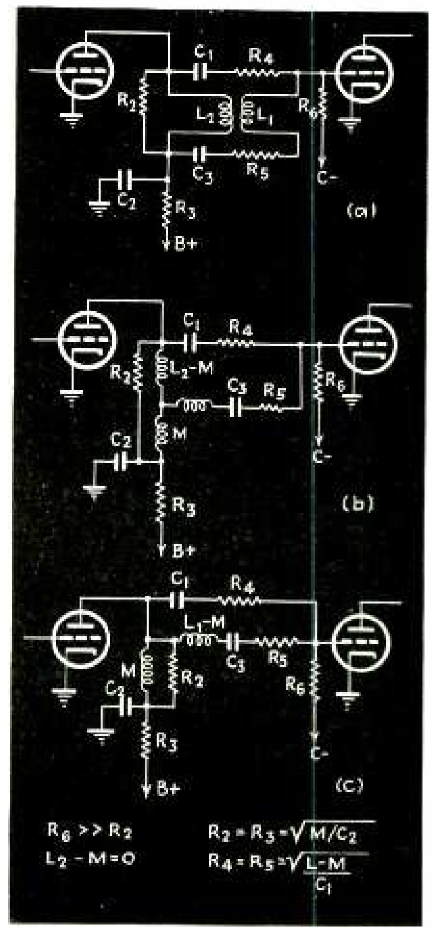


plate resistance fixes the peak-to-peak plate current swing. A suitable bias is selected using the $I_p—E_p$ characteristics, so that the plate current swing along the plate load line is linear for the wave form considered. Knowing the limits of the current swing we can easily find the grid voltage necessary to produce this change in the plate circuit. This becomes the output voltage for the preceding stage. The procedure outlined above is then repeated until the signal voltage on the grid of a tube is equal to or less than the input voltage. It is evident that the type of tube selected from a group of high g_m tubes will be determined mainly by signal level for reasons of power economy.

Before proceeding to a description of the layout of wide band amplifiers a word should be said about the cathode-follower. This circuit provides a low-capacity high-impedance input whose output is in phase with the signal input. The gain is always less than unity and equal to $g_mR_k/(1+g_mR_k)$ for pentodes, where R_k is the cathode resistance. The pentode cathode-follower, shown in Fig. 9, finds much use as a low impedance output device.[3, 11] The generator impedance of such an arrangement is $1/g_m$. Thus a 6AC7 cathode-follower shows an impedance of 111 ohms to the load. Since $e_s = (i_pR_k + e_g)$ where e_g is the grid-cathode voltage, it is necessary to add the voltage drop i_pR_k to the grid voltage determined from the $i_p—E_p$ characteristic in order to determine the signal voltage to produce a given plate current swing.

G. Wide Band Amplifier Layout

If maximum gain is desired the most important consideration in the arrangement of parts is to keep stray capacities at a minimum. Coupling condensers should be elevated from the chassis, signal leads should be made as short as possible and condensers should be mounted as close to the tube socket as practicable. For effective by-passing over the whole band, electrolytic condensers shunted by small paper condensers are used as shown in Fig. 8. This practice makes possible the placing of the paper condensers near or at the socket while the

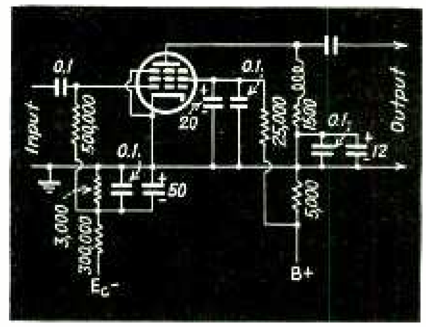


Fig. 10—At high frequencies, small by-pass condensers near the by-pass point are desirable in parallel with larger capacitances

parallel connected electrolytic condensers may be placed somewhere on the chassis where their bulk does not produce crowding. When the gain of the amplifier exceeds 40 db isolation by means of shielding is usually necessary to prevent coupling between high and low level stages. The *Q* of the coils used is not critical. Pi-wound inductances on ⅜ or ½-inch dowels work out very well. For experimental work the variable inductance type of coil is preferable.

H. Testing Wide Band Amplifiers

After the amplifier has been built it is usually aligned stage by stage both for high and low frequency response to assure compliance with the original specifications. The high frequency response of wide band amplifiers refers to those frequencies above 20 kc and depending upon the accuracy desired, can be checked by the following methods: (1) point by point method, (2) video sweep oscillator, or (3) square wave analysis.

The first method, point by point checking, compares the output and input voltages at predetermined frequencies. This method is the most accurate of the three listed above, and is limited only by the accuracy of the meters and the signal generator used. The disadvantage of this method is the time consumed where many stages are to be checked.

For experimental and developmental purposes and where frequency discrimination limits are not greater than ±1.0 db, the video sweep oscillator is to be recommended. This signal generator is an oscillator whose frequency is varied at a constant rate by means of a mechanically driven condenser. In a typical signal generator a constant voltage source is available whose frequency varies at 60 cps from 100 kc to 5 Mc. When such a signal is fed to an amplifier, it modulates the voltage from the signal generator but this can then be demodulated in the usual manner and observed on the screen of an oscilloscope. The use of a band sweep oscillator is illustrated in Fig. 11. The probe of the diode detector must not discriminate against frequencies in the band to be observed. Once the demodulation has been effected an oscilloscope whose amplifier has good low frequency response will suffice.

The high frequency response can also be checked with square waves,[12] but it assumes the use of an oscilloscope whose frequency and phase characteristics are better than those of the amplifier under test. Experience is also necessary to correlate the output wave shapes with the frequency or phase distortion introduced by the amplifier, for most rapid testing.

In adjusting the constants of the amplifier for low frequency response it is desirable to use a symmetrical square wave whose fundamental frequency is equal to the lowest frequency to be passed by the amplifier. This method is preferable to any other since a wide-band amplifier is usually required to pass square waves at the very low frequencies. The type of square wave distortion observed when the constants of an individual stage are not properly balanced is shown in Fig. 11.

In measuring the frequency response of amplifiers, overload conditions must be avoided. It is advisable to check for obvious amplitude distortion by connecting an oscilloscope across the output resistor, and varying the input signal level. The oscilloscope should be removed when checking the high frequency response. When investigating low level stages with 60 cps square

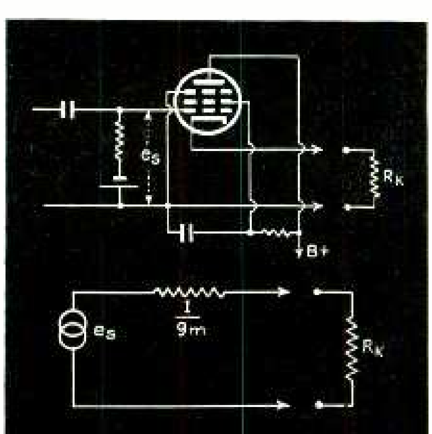


Fig. 9—Schematic diagram of cathode follower, with its simplified equivalent circuit is shown at the left

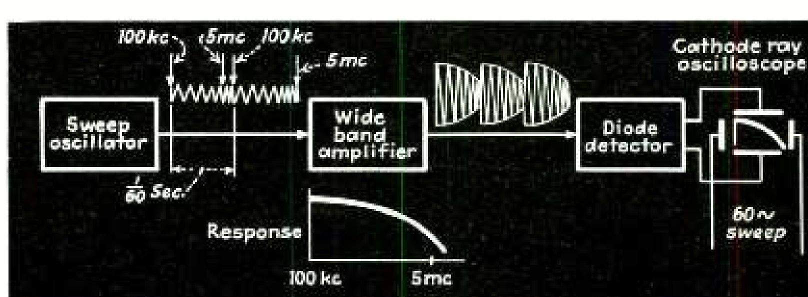
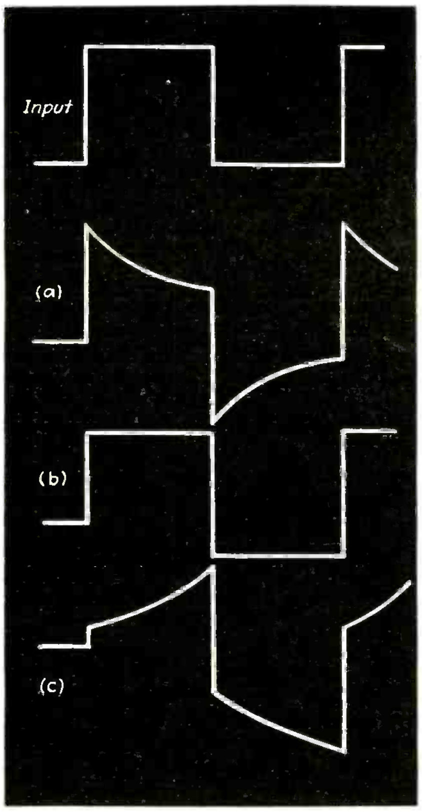


Fig. 11—Diagram illustrating the method of checking a wide band amplifier by means of video sweep oscillator



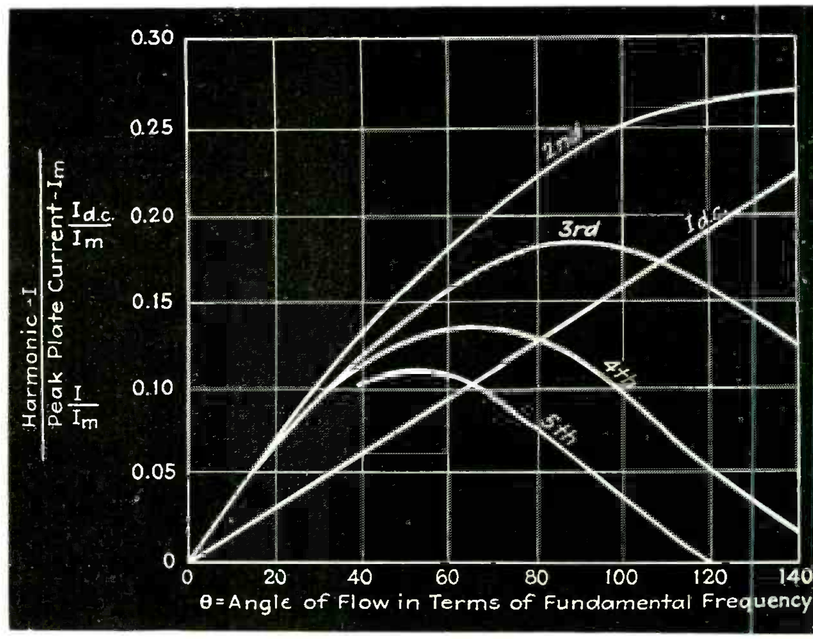


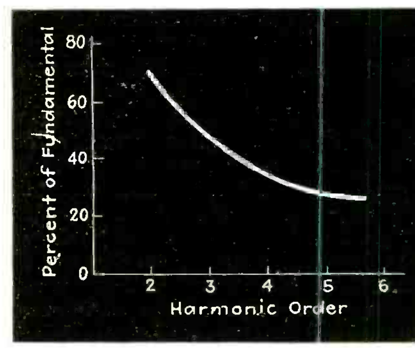
Fig. 14—Magnitudes of d-c and harmonic content for Class C amplifier

LEFT

Fig. 12—Types of square wave distortion which may be produced when amplifier constants are not properly designed

RIGHT

Fig. 15—Output of harmonic generating tube circuit at various harmonics, in per cent of output at fundamental frequency



waves, hum modulation of the output wave form may obscure the actual circuit operation. Precautions should be taken to eliminate spurious hum pick-up. This is a good practice to follow in any event.

II Frequency Multiplication and Division

High frequencies may be derived from low frequencies by certain circuit arrangements wherein the low frequency is multiplied an integral number of times. This process is referred to as frequency multiplication. The frequency of many transmitters operating in the u-h-f region is determined by some stable oscillator of relatively low frequency. The fundamental oscillator frequency is then multiplied by vacuum tube circuits, to obtain the desired carrier frequency. Practically all f-m transmitters operate in this manner.

The inverse of frequency multiplication is frequency division and is accomplished by dividing the frequency of a stable oscillator an integral number of times, by use of multivibrator or counter circuits. The object is to produce stable low frequency oscillations from a relatively high frequency source.

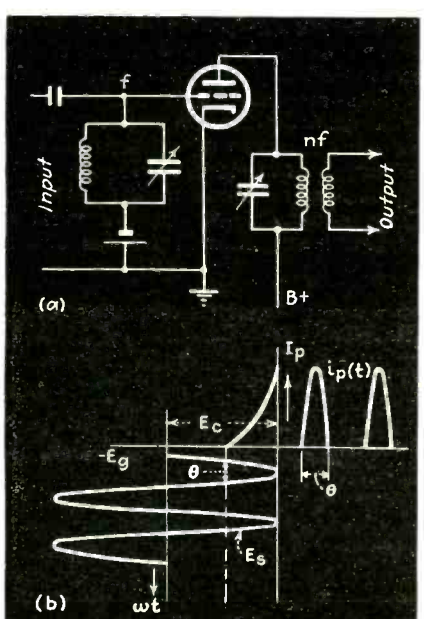


Fig. 13—Diagram of frequency multiplier, (a), and voltage and current wave forms showing appreciable distortion in output

A. Frequency Multipliers

The generic form of the usual vacuum tube frequency multiplier is the class C amplifier. Consider the triode circuit Fig. 13(a). The grid circuit is tuned to the fundamental frequency while the plate circuit is tuned to the nth harmonic. The tube is biased well below cut-off and driven slightly positive so that the plate current is produced in spurts as shown in Fig. 13(b). The angle θ is the time angle during which plate current flows. The wave form of $i_p(t)$ will be rich in harmonic content as shown in Fig. 14 where the magnitudes of the d-c and harmonic components of the space current are plotted in terms of the peak space current, I_m, versus the angle of flow, θ. Reducing the negative bias and grid driving voltage increases θ. Referring to Fig. 14 it will be seen that the harmonic output is a maximum when $\theta = 270/n$ electrical degrees, where the order of the harmonic is designated as n. However, increasing θ, lowers the plate efficiency because the plate current flows over a greater part of the plate voltage cycle. Terman [D, 10, 20] has indicated that the best angle of flow is $180/n$ electrical degrees. Where low grid driving power is available the angle of flow will have to be increased even up to $360/n$ at the expense of plate efficiency provided the rated plate loss is not exceeded. The output of a harmonic generator compared with the same tube as a class C amplifier is shown in Fig. 15. (For a class C amplifier. $\theta = 140$ deg.)

The design of frequency multipliers, where transit time effects do not have to be considered, has been amply treated. The steps to be taken in the design of a triode frequency multiplier follows below.[D]

B. Frequency Multiplier Design

1. Decide upon a tube. High μ, sharp cut-off tubes are to be preferred. From the tube characteristics determine the safe peak space current I_m. This current can also be determined knowing the type of emitter and power input to the filament. The emission current in milliamperes per watt of heating power, can be taken to be about 10, for tungsten, 62.5 for thoriated tungsten, and 100 for oxide coated emitters. For tungsten, I_m, can be determined by the full emission. For thoriated tungsten or oxide coated filaments, use factors of safety varying from 3 to 7 for the former type to at least 10 for the latter.

2. For the value I_m, determine from the tube characteristics the corresponding plate minimum volts $E_{p_{min}}$, and the maximum grid drive volts $E_{g_{max}}$.

3. Depending upon the use of the tube as a frequency multiplier determine the angle of flow, $\theta = 180/n$.

4. Assuming the space current follows the 3/2 power law, determine the ratio I_{dc}/I_m and harmonic output ratio I/I_m from Fig. 14. Let these values be K_{dc} and K_h respectively and let I_{dc} be the zero frequency space current and I_h be the harmonic space current. Thus

$$I_{dc} = K_{dc} I_m$$
$$I_h = K_h I_m$$

5. Assume the grid current to be 15 percent of the space current so that

$$I_{g_{dc}} = 0.15\, K_{dc} I_m$$
$$I_{p_{dc}} = 0.85\, K_{dc} I_m$$

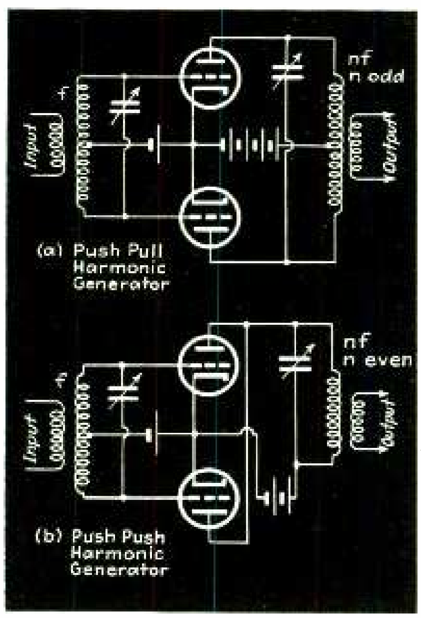


Fig. 16—Push-pull odd harmonic generators and push-push even harmonic generators differ in method of connecting output circuit

6. The harmonic component of the plate current is

$$I_h = (K_h - 0.3\, K_{dc})\, I_m$$

7. The plate input power is

$$P_i = E_B I_{p_{dc}} \quad \text{watts.}$$

where E_B is plate supply volts

8. The power delivered to the load is

$$P_o = \tfrac{1}{2}(E_B - E_{p_{min}})\, I_h \quad \text{watts}$$

9. The plate efficiency is

$$\eta_p = 100\, P_o/P_i$$

10. The plate loss is

$$P_p = P_i - P_o \quad \text{watts}$$

11. Tank impedance is

$$Z = (E_B - E_{p_{min}})/I_h \quad \text{ohms}$$

12. The tank circuit for $Q \cong 10$ inductance can then be calculated from the relationship

$$Z = \omega IQ$$

13. The grid bias can be calculated from Terman's formula

$$E_c = \frac{E_B[1 - \cos\tfrac{1}{2}(n\theta)] + E_{p_{min}}\cos\tfrac{1}{2}(n\theta)}{\mu[1 - \cos\tfrac{1}{2}\theta]} + \frac{E_{g_{max}}\cos\tfrac{1}{2}\theta}{1 - \cos\tfrac{1}{2}\theta}$$

14. The grid excitation voltage is

$$E_s = (E_c + E_{g_{max}})$$

15. The grid driving power is

$$P_g \leqq E_s I_{g_{dc}}$$

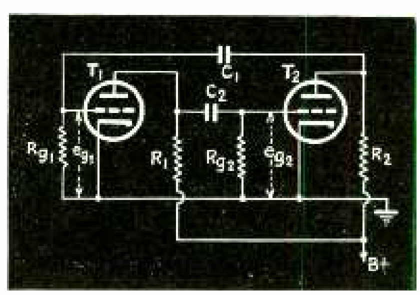
C. Push Pull and "Push Push" Frequency Multipliers

Two circuits used in the production of harmonics because of their inherent properties to produce either predominantly even or odd harmonics are shown in Figs. 16(a) and 16(b). The push pull arrangement shown in Fig. 16(a) will produce odd harmonics since the even ones tend to cancel in the load circuit. In the case of the "push push" type of frequency multiplier the grids are fed in push pull while the plates are connected in parallel. The odd harmonics tend to cancel as in the case of a full wave rectifier so that the output contains only even harmonics. The push push circuit evidently will not pass the fundamental efficiently so that this type of circuit should not be used where the frequency multiplier is sometimes used for class C amplification.

D. U-H-F Operation of Frequency Multipliers

As the frequency is increased the effect of lead inductance, inter-electrode capacitance and electron transit time will reduce the efficiency of the harmonic generator. Consequently tubes and circuits designed especially for u-h-f use will have to be employed.[23, 25] Where the transit time from cathode to plate is negligible compared with the periodicity of the grid potential, a change of grid voltage produces an instantaneous change in the rate of arrival of electrons at the plate. When the time of transit is not negligible this instantaneous action does not take place. As a result serious grid loading may be expected while the peak emission will be considerably reduced and the plate current angle of flow greatly increased. Lindenblad[24] has shown that the efficiency of cylindrical triodes operating as frequency triplers can be increased as much as three times by the use of axial magnetic fields. Two

Fig. 17—Fundamental wiring diagram of multivibrator



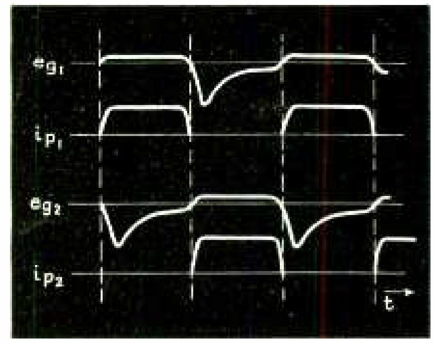


Fig. 18—Grid voltage and plate current wave forms of the two tubes of a multivibrator

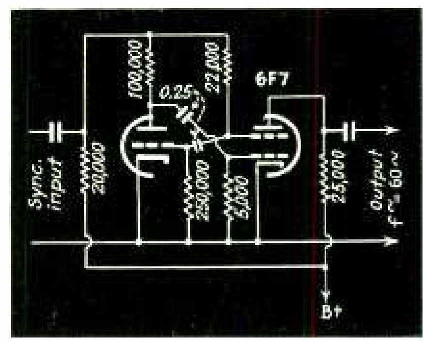


Fig. 19—A single 6F7 tube used as a multivibrator

RCA 846 tubes connected in push pull were operated as triplers from 137 Mc to 441 Mc. With an axial field of about 200 gauss these tubes delivered 115 watts at 441 Mc while without the magnetic field the maximum power output was 35 watts.

E. Multivibrators [E, 26, F]

The two-stage multivibrator circuit is shown in Fig. 17. This type of circuit is nothing more than a two stage resistance-coupled amplifier fed back on itself. A small positive change occurring in the grid circuit of T_1 will be amplified almost instantaneously by T_1 and T_2 to produce a larger positive change on the grid of T_1 while i_{p1} will grow larger until limited by plate current saturation. While e_{g1} is becoming more positive e_{g2} becomes more negative, because of the increasing volt-drop across R_1, until i_{p2} stops as a result of plate current cut-off. The amplifier is then at rest until C_2 discharges through R_{g2} sufficiently to produce a small positive change on the grid T_2 whereupon the whole sequence of events is repeated. This time the grid of T_2 becomes positive while the grid of T_1 becomes more negative until T_1 is cut off and the amplifier is once more at rest. When C_1 discharges through R_{g1} sufficiently to allow amplifier action to take place in T_1, the whole cycle is repeated again. The plate current and grid voltage waveforms for a symmetrical multivibrator (identical tubes, $R_1 = R_2$ and $R_{g1}C_1 = R_{g2}C_2$) is shown in Fig. 17.

The frequency for a two-stage mul-

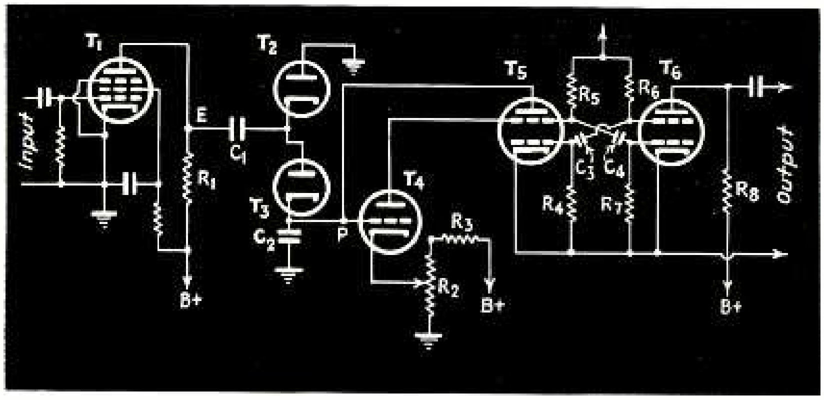


Fig. 20 Typical circuit for frequency division

tivibrator is approximately given by

$$f \cong (R_{g1} C_1 + R_{g2} C_2)^{-1}$$

Note that for a symmetrical arrangement the plate current waveform is symmetrical. For asymmetrical circuits when the coupling capacities are equal, the symmetry will be a function of the ratio R_{g1}/R_{g2}. In practice it is convenient to make $C_1 = C_2$ and by means of potentiometers in the grid circuits, to determine R_{g1} and R_{g2} to give the correct frequency and desired symmetry.

Multivibrators can be used to generate frequencies from 1 cps to 1 Mc. The upper frequency limit depends upon the type of tubes used and shunt capacities while the lower limit is set mainly by coupling condenser leakage.

A voltage of frequency f, injected in either grid circuit, may be used to synchronize the multivibrators at some frequency f_o/n, where n is an integer, and f_o is very nearly the free frequency of the multivibrator alone. Frequency divisions greater than 10 to 1 are to be avoided if good stability is desired.

Terman [E] has shown that if the injected voltage is applied in phase to each grid then the multivibrator will favor even values of n. When the injected voltage is applied to only one grid then it favors any value of n. Voltages 180 degrees out of phase applied to each grid cause the multivibrators to favor odd values of n.

A conventional asymmetrical single tube multivibrator using the 6F7 type of tube is shown in Fig. 19.

F. Counter Circuit [27]

The counter circuit is an extremely stable frequency arrangement whose stability is essentially dependent upon two condensers. Extremely stable divisions of 15 to 1 are not uncommon. All the tubes involved act as switches. Thus their characteristics do not affect the operation of the divider circuit except to determine the voltage levels at which the switching takes place. This cannot be said for multivibrator frequency dividing circuits.

A typical counter circuit frequency dividing arrangement is shown in Fig. 20.

Large positive pulses of frequency f are applied to the grid of T_1 so that the voltage at E changes from zero to practically the supply voltage. When E goes positive the diode T_3 conducts charging C_1 and C_2 in series while T_2 does not conduct. When E swings negative, diode T_2 conducts while T_3 does not, and C_1 is discharged. The cycle is then repeated, thus increasing the voltage at P in steps every $1/f$ seconds. The staircase waveform built up across C_2 is shown in Fig. 21. Tube T_4 is biased to cut-off by means of a positive cathode voltage. When the voltage built up across C_2 is high enough to make T_4 conduct the multivibrator consisting of T_5 and T_6 is triggered and a pulse developed across R_8. The multivibrator is so designed that it is esentially at rest until fired by T_4. Thus if it took n steps before T_4 conducted, the output frequency will be equal to one nth of the input pulse frequency. In practice C_1 is made approximately $C_2/20$. The voltage E_n after n steps can be calculated from

$$E_n = E_B\, K\,[1 + (1 - K) + (1 - K)^2 + \ldots + (1 - K)^{n-1}]$$

where E_B is the supply plate voltage,
n is the number of steps, and
$K = C_1/(C_1 + C_2)$ is the ratio of capacitances in the output circuit of T_1.

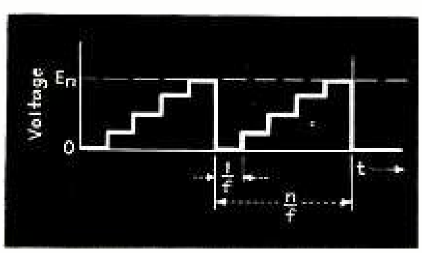


Fig. 21 Voltage-time wave forms built up in frequency dividing circuit of Fig. 19

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V. Measurements in the U-H-F Spectrum

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I. Introduction

THIS section will outline briefly measurement techniques in the u-h-f spectrum. Measurements may be made for various reasons and can be carried out in a number of ways. Thus it is evident that no fixed rules can be set forth for interpreting the conditions of measurement.

There is, however, a possible division that will aid in the problem of measurement: namely, (1) those problems relating to the transfer of energy via a transmission line to an unknown impedance such as an antenna or antenna array and (2) the problems of measuring component parts such as resistors, condensers, inductances, insulating material, etc. This is a purely arbitrary division and is made only because it is felt that the problems in the first category can be best investigated by an examination of the standing wave distribution of the tranmission line itself. The problems in the second grouping could, in some instances, fall into the first class. However, it is believed that more reliable results are obtainable if these are investigated by a tuned circuit method loosely coupled to a generator.

Other governing features of the technique of measurement might be the power available and the power limitations of the unknown impedance to be investigated. The latter consideration is important in the measurement of low wattage resistors and thermocouples for example.

II. Measuring Equipment

A. Signal Generator

Without a good, reliable source of radio-frequency energy, dependable measurements are impossible. Such a generator for u-h-f measurements should possess: (1) adequate power output, (2) freedom of harmonics, (3) satisfactory frequency stability, (4) adequate frequency range, (5) complete and thorough shielding, and (6) small size and compactness.

Other factors which contribute to convenience and speed of measurement include such items as external controls for change in coupling and frequency. In some measurements it is very convenient to have the output of the generator calibrated. It might be well to point out that for some measurements it is not necessary to adhere rigidly to above recommendations.

B. Voltage and Current Indicators

A satisfactory voltage or current indicator should have: (1) adequate sensitivity, (2) calibration independent of frequency, and (3) an impedance such that when connected to the circuit under measurement it will have no disrupting effect.

The particular problem in question will determine the most suitable indicator. If sensitivity is the controlling factor, some type of electronic device is generally best. Triode or diode detection can thus be used. If, however, there is adequate power and the problem does not require accurate measurements, a thermocouple serves the purpose. Indicating instruments should be small and compact. Thought should also be given the physical and electrical characteristics of the portion making contact to unknown impedance so that the detecting unit itself will not cause the circuit to be upset.

III. Calibration of Voltage and Current Indicators

The device used for detecting either voltage or current should be calibrated not only at low frequencies but also in the range of frequencies at which it is to be used. Low frequency calibration will be useful in making initial adjustments and approximate determinations of u-h-f voltage or current. Experience has shown that u-h-f calibration is always useful and in many instances is necessary. In calibration at u-h-f the absolute voltage or current is not usually the ultimate aim. It is much more important to know the linearity of scale calibration of the instrument since in most cases relative values of voltage or current are the primary interest, or at least, suffice.

One method of determining the linearity at u-h-f may be accomplished by measuring the voltage distribution along a transmission line on which standing waves have been established. With a given power a maximum and minimum of voltage will be observed. Let the ratio of E_{min}/E_{max} be called Q. If the power is changed, making sure that the frequency remains constant, the ratio Q, as determined from readings of the indicating meter should remain the same. In general it will be found expedient to use only that portion of the calibration scale for which Q is found to be independent of power fed to the line. Another method uses a short-circuited transmission line tuned to resonance. The voltage indicator is moved along the transmission line until a maximum reading E_{max}, is obtained. The indicator is then moved an eighth wavelength from this point and the voltage at this point E should be 0.707 E_{max}. This process is continued for various powers delivered to the line until the ratio E_{max}/E begins to differ from the value 1.414, thus establishing the linearity of the instrument.

A method of checking the input impedance of the voltage measuring instrument will be given in the section pertaining to measurements of unknown impedances. The calibration of absolute voltages is not difficult but will be left for the discussion under power measurements.

Similar tests for calibration could be carried out on current indicators. Current indicators employed to analyze standing wave distribution are not in general use at ultrahigh frequencies. The primary reason is that one of the requirements of a current indicator is that it have low impedance. For this reason it cannot be connected across the transmission line like the voltage indicator. Should a current distribution be desired, a rather elaborate setup would be required to maintain exact spacing between the coupling circuit of the instrument and the transmission line. Another drawback to the current indicator is the error which occurs when the instrument picks up a portion of the electric field as well as the magnetic field. The problem becomes complicated beyond the bounds of engineering practicality if the instrument employed responds to both the electric and magnetic fields.

IV. Determination of Wavelength

The measurement of wavelength may be accomplished by observing the waves in free space or existing on a transmission line. The measurement of wavelength in free space consists of placing a sensitive detecting indicator in the neighborhood of the u-h-f source. A plane metallic surface is then moved in the direction normal to its own surface toward the indicator. The distance between positions of the reflecting surface for two successive maximum readings on the detecting instrument is equal to a half wavelength.

Measurements of wavelength taken on a transmission line consist of measurement of the distance between two adjacent positions of a movable short circuiting bar as for consecutive current maxima indicated by a detector loosely coupled to the transmission line. The wavelength is given by:

$$\lambda = 2 \Delta l \left[1 + (r_o/2\omega L_o)^2\right]$$

where Δl is the distance between two adjacent current maxima, r_o is shunt resistance per unit length, and L_o is inductance per unit length. Since $(r_o/2\omega L_o) << 1$ on well constructed lines we can write

$$\lambda = 2 \Delta l$$

Should it be desired to use a quarter wavelength section of line to determine the wavelength it will then be necessary to include the inductance of the short-circuiting bar. The wavelength is:

$$\lambda = 4 (l_1 + L/L_o)$$

where L is the inductance of the shorting bar,

L_o is the inductance and

l_1 is the length of line to give maximum reading in the detector, measured from the position of minimum reading.

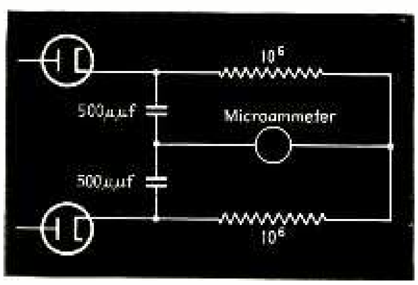

Fig. 1—Voltage detector using two diodes or acorn tubes connected as diodes for u-h-f voltage measurements

Other types of wavemeters, such as the absorption type, are useful on the lower frequency limits of the u-h-f spectrum. Such an instrument having a range of calibrated frequencies between 55 and 400 Mc is described in the *General Radio Experimenter* for Aug. 1940.

V. Voltage and Current Measurements

A. Voltage

In general, voltage measurements are used to determine unknown impedances, whether the method employs an analysis of the standing wave distribution or makes use of a tuned circuit loosely coupled to a generator.

Three types of lines are encountered: (1) open wire lines, (2) dual coaxial lines, and (3) concentric lines. The voltage distribution existing on an open wire line can be explored by employing a quarter wavelength section of line shorted at the far end. A sensitive thermocouple meter, shielded in a small metal box, is then coupled to the shorted end of the quarter wavelength section by means of a shielded loop. The open ends of the quarter wave section are fitted with a small V to form a guide on the transmission line used for the measurement.

For approximate measurements a small thermocouple meter may be shunted across the quarter wave line close to the short circuit. The limits of this type of measurement are generally governed by the unknown terminal impedance which should be such as to cause not more than a two to one change in the meter reading.

When power is limited a double diode type of voltage detector may be used. This consists of two acorn tubes in a circuit as shown in Fig. 1. Each plate is connected to one conductor of the transmission line.

Measurements of voltage on a dual coaxial line are made in much the same manner as that described in the open wire line. Slots or small holes provide a means of probing the inner conductors.

Measurements of voltage on a concentric line are invariably taken on the inner conductor either by direct contact or by capacity pickup. Instruments used in measuring the voltage on the coaxial line are generally grounded to the outer conductor. Small holes or slots in the outer conductor provide for the probe to be inserted. It is often an advantage to construct the probe so that it will have a plunger effect. This is done to conform with the irregularities of the inner conductor. When the capacity pickup is desired a small piece of insulating material can be fastened to the probe. In use, the insulator rests on the inner conductor, and provides capacitive coupling between the inner conductor and probe.

A single-ended circuit using one diode is sufficient to measure voltages on concentric lines (Fig. 2.) L is generally a section of concentric line and is used to tune the instrument, C is some small fixed capacity.

Other experimenters[1] have used a thermocouple in series with a resistance as a voltmeter. The thermocouple in this type of heater is made very short and generally of carbon wire 0.002 inch in diameter. Although this instrument has a linear response with applied voltage it is subject to error due to stray fields reaching the couple circuit. This type of voltmeter should be used only when great care has been taken to provide adequate shielding and when the measuring technique is such that the voltmeter remains in the same position throughout the test.

When voltage measurements are such that the instrument can be left in one position throughout the experiment, a calibrated receiver is very useful.

B. Current

Since current measurements are not in general use in determining an unknown impedance, power, Q or other quantities at ultrahigh frequencies, current measurement is in a somewhat undeveloped state. The drawbacks to current measuring devices are (1) the necessity of low resistance and (2) the dependence of calibration of the thermocouple on wavelength since the current distribution along the heater and the change of resistance in the heater due to skin effect are functions of wavelength. The heater can be made very short to minimize the difficulty of current distribution. However, the skin effect depends not only on the wavelength but also upon the amount of power fed to the heater.

Thus, for current measurements a number of factors enter into the problem. A separate instrument for the wavelength in question, as well as for the power that is to be delivered to the device may be desirable. With proper thermocouples and suitable precautions current measurements may be made at very high frequencies.

VI. Transmission Line as a Measuring Device

When using a transmission line as a measuring device, either for examining standing waves or as sections of a tuned circuit: it is desirable that (a) the line be composed of conductors of circular cross-section, (b) low loss materials be used in the construction of the line, (c) insulators be used in the section for measuring purposes, and (d) the line be constructed to be free of surrounding objects, particularly those of good conductivity. Since measurements may often depend upon the characteristic impedance of the line it will be well to discuss this topic at some length.

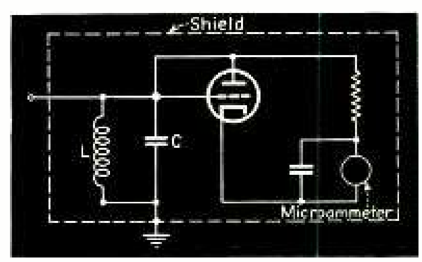

Fig. 2—Single sided circuit using diode-connected tube for measuring voltages on concentric lines

In the case of a transmission line used as a measuring device, a calculation of the characteristic impedance will suffice. The characteristic impedance of an open wire line in which the spacing between conductors is large compared to the conductor radius is given by the expression

$$Z_c \cong 120 \log_\epsilon (b/a)$$

where a is the radius of the conducting wires and

b is the distance between conductors, in the same units as a.

It may be desired to also measure this

impedance. This is particularly true when measurements are to be made on a transmission line of more complicated configuration. Literature affords many sources on the subject of the calculation of inductance and capacity of such possible configurations but they are rather complicated. Thus a method of measurement would be of advantage.[A]

It will be assumed that the transmission line in question is of such construction that the velocity of the propagation of the wave is equal to that of light. Then the velocity of propagation becomes:

$$V = (LC)^{-1/2} = 3 \times 10^{10} \text{ cm per sec.}$$

or expressed in terms of the characteristic impedance,

$$Z_c = 10^{-10}/3\,C_0$$

where C_o is the capacity in farads per centimeter of length, and may be determined by bridge measurements at 1000 cps.

The value of C_o may also be determined by an electrolytic method by measuring the leakage resistance of a short section of the line in a conductive liquid and then comparing it to the leakage resistance in the same liquid of a condenser whose capacitance is known or easily calculated. The leakage resistances are then inversely proportional to the corresponding capacitances. The edge effect when measuring the leakage between discs or plates can be eliminated by masking with a coat of paraffin or similar material.

VII. Methods of Computing Unknown Impedances

When standing wave distribution is analyzed to determine the unknown terminating impedance, charts[12, 14] can be used which will give results which are well within the scope of experimental error. Necessary measuring data to obtain a result from these charts are the ratio, Q, or the ratio of the voltage minimum to the voltage maximum (or current minimum to current maximum), the distance from the unknown load to a point of pure resistance (a position of current or voltage maximum or minimum) and the characteristic impedance of the line upon which the measurements were taken. These charts are self-explanatory in their use and space and time will not be taken up in their discussion. Some charts are designed for current measurement and the distance to a pure resistance point is determined with respect to a current minimum. If such a chart is to be used with voltage measurements it will be necessary to apply a 90 degree correction since the resultant current and voltage are 90 degrees out of phase on an unmatched line.

For more accurate calculation of the unknown impedance or in cases where the chart is difficult to read, such as for small values of Q, the above data may be used as formulas to determine the unknown terminating load, viz:

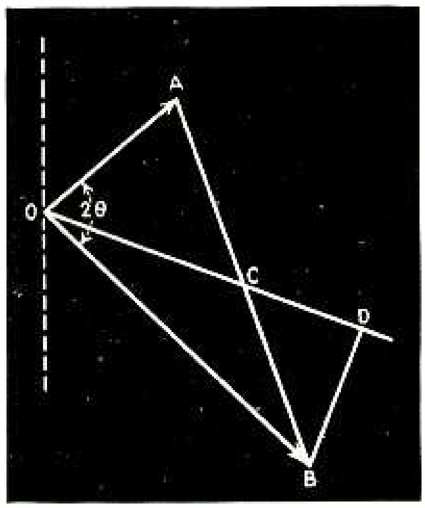

Fig. 3—Vector diagram for determining resistance and reactance from transmission line measurements when voltage maximum occurs first

$$Z_r = Z_c\left[\frac{Q}{\cos^2\theta + Q^2\sin^2\theta} + j\left(\frac{\sin\theta\cos\theta\,(Q^2-1)}{\cos^2\theta + Q^2\sin^2\theta}\right)\right]$$

$$Z_r = Z_c\frac{1 - K^2 - j^2K\sin\theta}{1 + K^2 - 2K\cos\theta}$$

where Z_r is the receiving end impedance (unknown load)

Z_c is the characteristic impedance of the line

θ is the electrical length from unknown load to a voltage minimum, and

Q is the ratio of E_{min}/E_{max} or I_{min}/I_{max} and

$$K = \frac{1-Q}{1+Q}$$

The unknown impedance may also be obtained by a graphical method. The pertinent data obtained for a measurement of the standing wave should be the ratio $Q = I_{min}/I_{max}$ or E_{min}/E_{max}, the electrical length, θ, to the first voltage minimum or maximum point and a knowledge of whether a maximum or minimum of voltage occurs first when measuring from the load toward the generator.

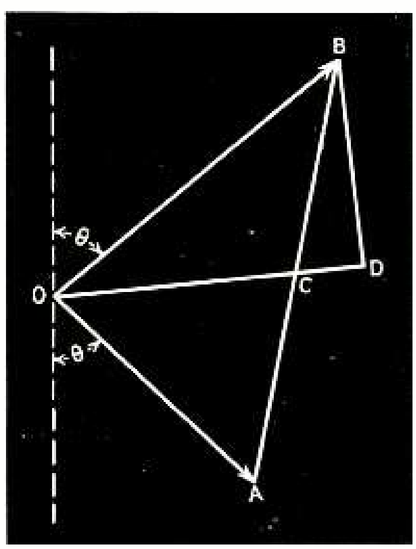

Fig. 4—Vector diagram for determining resistance and reactance from transmission line measurements when voltage minimum occurs first

1—Case when a maximum of voltage occurs first. In this case, the sign of the reactance will be positive. To construct the diagram, Fig. 3, from which the unknown impedance may be obtained let

$OA = 1 - Q$

$OB = 1 + Q$

θ = electrical length to the first maximum

2θ = angle between OA and OB

Draw AB jointing the ends of OA and OB, and bisect AB at C. Draw BD perpendicular to OCD. Then

$$R_r = Z_c\,(OD/OC)$$
$$X_r = Z_c\,(DB/OC)$$
$$Z_r = R_r + j\,X_r$$

2—Case where the minimum occurs first. The sign of the reactance will be negative. The diagram (Fig. 4) is constructed in the same manner as Fig. 3, the only difference being in the plot of the angle, which is now measured from the vertical to the two sections OA and OB rather than between them. Then

$$R_r = Z_c\,(CD/OC)$$
$$X_r = Z_c\,(BD/OC)$$
$$Z_r = R_r - j\,X_r$$

VIII. Measurements of Unknown Impedance

A. Determination from an Analysis of Standing Wave Distribution

Before entering into the subject of standing wave analysis it would be profitable to review the wave phenomena on a transmission line. For practical purposes a consideration of the wave phenomena from a vectorial standpoint under the assumption of simple harmonic distribution is most advantageous. With an ideal transmission line the voltage along the wires may be considered as due to the superposition of two waves traveling in opposite directions. The wave traveling from the generator toward the load end will be called the direct wave (main wave or initial wave) and will rotate, in a trigonometric sense, in a negative direction clockwise. The wave traveling from the load end toward the generator will then rotate in a positive direction (counter-clockwise). The voltage at any position along the line can then be represented by the vector sums of these two vectors at the point in question. The current vector associated with the voltage vector as given above is then the vector difference of the two vectors rotating in opposite directions. Then with a given terminating load the vectors of the direct wave and of the reflected wave have a fixed relative angular displacement with respect to each other at regularly reappearing intervals along the line. At such points the voltage (or current) vectors of the direct and reflected waves will become alternately linearly additive or subtractive. The position where the vectors become additive indicate a maximum of voltage (or current); likewise, when the vectors become subtractive, they indicate a minimum of voltage (or current) and are thus points of pure resistance.

The ratio of the direct voltage vector and direct current vector is equal to the characteristic impedance of the transmission line. The same is true of the ratio between the reflected voltage vector and the reflected current vector.

The characteristic of the terminal load determines the relationship between the phase and amplitude of the direct and reflected vectors. Should the line be open-circuited at the far end the reflected voltage vector is equal to and in phase with the direct voltage vector, thus resulting in a voltage maximum. If the line should be short-circuited, the direct and reflected voltage would still be equal but 180 degrees out of phase; thus the resulting voltage vector becomes zero. Since the voltage and current vectors are in phase for one direction of travel and 180 degrees out of phase for the opposite direction of travel, it is evident that where the direct and reflected voltages become additive (thus producing a voltage maximum) the current vectors become subtractive. Thus, wherever a voltage maximum exists there will likewise coexist a current minimum.

When considering a pure resistive load the reflected vectors are in phase or in phase opposition to the direct vector at the load. Should the load then be of pure resistance but less than the characteristic impedance of the line the reflected voltage vector is in phase opposition to the direct voltage vector. Similarly, if the load is a pure resistance but greater than the characteristic impedance then the reflected voltage vector is in phase with the direct voltage vector. In both the above cases the reflected voltage vector is of a lesser magnitude than the direct voltage vector. Should the resistive load be made equal to the characteristic impedance of the line then a pure traveling wave would exist; the vector which would normally be the reflected vector is now totally absorbed in the load resistor. Should the load be a complex impedance, the voltage vector (or current vector) is always rotated with respect to the direct voltage (or current) vector at the load.

The coefficient of reflection is defined as the vector ratio of the reflected voltage vector to the direct voltage vector at the load. Expressed in other words the magnitude of the reflection coefficient is equal to the ratio of the numerical values of the direct and reflected voltage vectors and the angle of the coefficient is equal to the angle of rotation of the reflected voltage vector with respect to the direct voltage vector at the load.

Since it is often difficult to establish the voltage and phase relations by measurement at the load itself, it is more convenient to establish a point of pure resistance by exploring the transmission line and obtaining a position as well as the reading of minimum or maximum of voltage. (It is generally more accurate to establish the minimum position of voltage). The resistance at the position of minimum voltage is related to the ratio of the voltage minimum and voltage maximum by the expression:

$$R_{min} = Z_c \, E_{min}/E_{max}$$

where R_{min} is the resistance at a point of minimum voltage,

$E_{min}/E_{max} = Q$ is the ratio of the voltage at the minimum to the voltage at the maximum position ϕ and

Z_c is the characteristic impedance of the line.

To find the impedance at the load, R_{min} can be substituted in the formula:

$$Z_r = Z_c \, (R_{min} \cosh \theta - Z_c \sinh \theta)/(Z_c \cosh \theta - R_{min} \sinh \theta)$$

This can be reduced to:

$$Z_r = Z_c \times \left[\frac{R_{min} Z_c - j \sin \theta \cos \theta \, (Z_c^2 - R^2_{min})}{Z_c^2 \cos^2 \theta + R_{min}^2 \sin^2 \theta} \right]$$

where Z_r is the receiving end or load impedance, and

θ is the distance from the unknown load to the position of E_{min} expressed in electrical degrees. (If the distance is measured in X inches then $\theta = 360 \, x/\lambda$ where λ is also in inches.) The use of the coefficient of reflection K can also be used to obtain the same result. The results in both the above methods give the impedance as a series combination. A method of obtaining the parallel components can be obtained from the graphical construction shown in Fig. 5. Draw a horizontal line representing the vector R_s to some convenient scale. To the same scale draw the vector X_s perpendicular to R_s, where R_s is the measured value of the resistance of the series combination. The magnitude of the series impedance, Z_s, is determined by connecting the free ends of the two vectors already drawn, and the phase angle of this impedance will be φ. To the same scale, draw X_p, perpendicular to Z_s, and draw R_p having an angle φ with respect to Z_s, as shown. Now the vector R_p represents the resistance of the parallel combination, and X_p represents the reactance of the parallel combination.

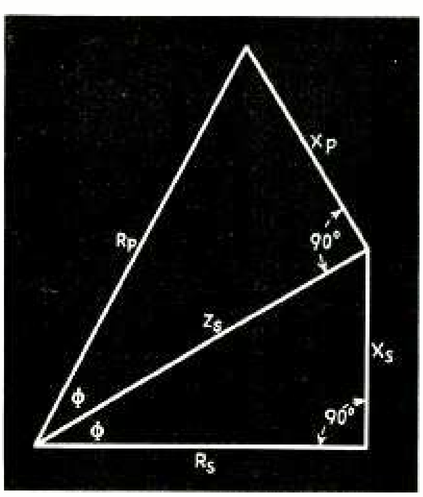

Fig. 5—Vector diagram for obtaining parallel components of impedance from measurements giving components in a series combination

If the problem is that of measuring an antenna or array simply to obtain its impedance either method will serve equally well. However, if the problem is of greater scope, for example, in which the band width, sharpness of resonance, and similar factors must be known, the method of using the coefficient of reflection lends itself more conveniently in that K represents a qualitative factor.

The attenuation and phase shift properties of transmission lines can be likewise determined by the analysis of wave distribution on an ideal line. An unknown impedance of the unknown line of length l is measured with the far end shorted and then the far end open circuited. The short circuited and open circuited impedances are

$$Z_{sc} = Z_c \tanh (\gamma l)$$
$$Z_{oc} = Z_c \coth (\gamma l)$$

where $\gamma = a + j \beta$

Since $Z_c = (Z_{sc} \, Z_{oc})^{1/2}$ an expression for γl can be found as follows:

$$\cosh (2 \gamma l) = a + j b$$

By expanding and substituting $\gamma = \alpha + j \beta$ we have

$$\cosh (2 \beta l) + j \, 2 \, \alpha l \sin (2 \beta l) = a + jb$$

where $\cosh (2 \beta l) = a$, and $2 \, al$ is small.

To determine the quadrant of the angle, notice the sign of b and a, and determine the quadrant from the table

a	b	Quadrant of $2 \beta l$
+	+	1st
−	+	2nd
−	−	3rd
+	−	4th

However, $2 \beta l$ is, equal to twice the electrical length of the line. Thus:

$$\alpha = b/2l \sin (2 \beta l)$$

The velocity of propagation on the unknown line with respect to velocity in free space is given by

$$V/c = \theta/\beta l$$

where θ is the apparent electrical length based on velocity in free space

V is the velocity on the unknown line, and

c is the velocity in free space

The attenuation is given by:

attenuation in db $= 20 \log_{10} \epsilon^{\alpha l} = 8.68 \, \alpha l$

attenuation ratio $= 4.34 \, b/\sin (2 \beta l)$

Attenuation can also be obtained by

employing two test transmission lines with the unknown line connected between them. A load impedance is placed at the end of the second test line. The values of E_{min} and E_{max} are observed on the two test lines. The relative power flowing in the first test line is given by $P_1 = \quad {}_{in\,m}/ Z_{c1}$ The relative power in the second test line is then $P_2 = (E_{min} \times E_{max})/Z_{c2}$ Thus the attenuation in the unknown line of length l is given by

$$\text{attenuation in } db = 10 \log_{10} (P_1/P_2) = \alpha l$$

If the same characteristic impedance is used on both test lines, then P_1 and P_2 are given by the respective ratios of E_{1min}/E_{1max} and E_{2min}/E_{2max}.

If the unknown line can be perfectly matched, then the attenuation is simply given by a series of voltage readings. The readings between fixed points give the attenuation as of the length between these points. Thus:

$$\text{attenuation in } db = \alpha l = 20 \log_{19} (E_1/E_2)$$

Measurement of phase shift β depends upon accurate measurement of positions of minimum voltages. The distance between these two points of voltage minimum and the phase shift then become

$$d = \lambda_x/2$$
$$\beta = 2\pi/\lambda_x = \pi/d$$

where λ_x is the wavelength which corresponds to the actual velocity of propagation along the line. In attempting to establish the points of minimum, practice has shown the required precision may be obtained by making either a plot of the voltages each side of the minimum on graph paper or a series of readings taken each side of the minimum. The two readings of each pair of observations should be of the same amplitude, so the position of minimum current will be one half the average distance between each pair of observations.

The accuracy of the results depends upon the accuracy with which the voltage minimum and maximum can be measured and the position of the voltage minimum established. Thus, if the load nearly matches the line, the position of the voltage minimum will be difficult to establish. Likewise, if the load is such that a large standing wave exists, then the linearity of the voltage device becomes the governing feature. Thus, a proper choice of characteristic impedance will improve the accuracy of the measurements. A knowledge of the limitation of the instruments at hand will govern the choice of the characteristic impedance of the test line.

B. Determination by Resonant Circuit Method

The determination of the unknown impedance in the following discussion employs the use of transmission line elements as portions of tuned circuits. The voltage indicator is likewise loosely coupled to the tuned circuit and, in general, remains at a fixed point through any individual investigation. One end of the line will be short-circuited and the energy fed to the point by loose coupling.

Resistance measurements generally fall into three categories:

(1) Substitution method
(2) Resistance-variation method
(3) Reactance-variation method

The substitution method consists of using a section of transmission line of low characteristic impedance and of a length much shorter than a quarter wavelength, the line being terminated at one end by a short circuit and at the other end by a capacity. This method is well suited to the measurement and comparison of commercial types of resistors. Let R, of small resistance, be placed across the line near the short circuit at a distance, l, from the short circuit. The line is now brought into resonance with the capacity and the voltage is read on the loosely coupled voltmeter.

It can be argued that the voltage distribution on the transmission line has not changed in shape; only the magnitude has been reduced. This same shape and magnitude can be simulated by removing the resistor R, and by placing resistor, R_1, of a much higher value across the end of the line. The magnitude of the voltage is assumed to be the same as for R when the voltage readings on the voltmeter are the same for both cases. The resistance of R_1 is assumed to be small compared to the resonant impedance of the line, and is given by

$$R_1 = R\ (l_1/l)^2$$

where l_1 = total length of line
l = distance from the short circuit to specific position on the line

Other values of resistances can be placed across the line at such positions that the voltage will always have the same value as it did when the low value resistor, R, was used. Thus a number of standard resistors may be established. Other values of resistance may be determined by comparing them with the standard resistor in the above equation.

The resistance-variation method employs known resistance, such as may have been tested by the above method. A known resistance R_k is placed across a tuned circuit and the voltage across the circuit is measured. The unknown resistor R_x is now placed parallel with the known resistor and the voltage again read. If the resonant impedance is high compared to the resistance placed across the tuned circuit, the unknown resistance R_x is given by

$$R_x = R_k\ [(E_x/E_k) - 1]$$

where R_x is the unknown resistance
R_k is the known resistance
E_k is the voltage across known resistance
E_x is the voltage across unknown resistance and known resistance

This equation makes use of the property that the voltage across the loosely coupled circuit is proportional to the impedance.

Resistance measurements employing the reactance-variation method are based on two readings of the voltmeter at some fixed position, one with the circuit in a resonant condition and the other with the reactance varied to produce a voltage of 0.707 of the value at resonance. The reactance of the transmission line can be varied by changing the capacitance of a condenser placed across the open end, by changing the actual length of the transmission line, or by changing the frequency. Since all of these methods embody the same technique only a summary will be given of the procedure and results. The values of resistance are obtained from a knowledge of the admittance of the tuned circuit with the resistance across this circuit.

The capacity-variation method consists of using either a variable condenser of known calibration at the end of the line or a specially constructed type of transmission line. If the condenser method is used, the unknown resistance is placed across the tuned circuit. The circuit is then resonated and a voltage E_1 is obtained with the condenser at some value C. The circuit is then detuned by an amount ΔC to give a voltage reading E_2 which is $0.707\ E_1$. The resistance is then given by

$$R = 1/\omega\Delta C$$

Special lines have been constructed by some experimenters to employ the capacity variation method by utilizing a section of open-ended line for the condenser. Such technique is best suited for use with concentric types of lines and is well adapted to the measurement of input impedance of single ended devices such as the input impedance of diode voltmeters.

The line-length variation is again a method of measuring the admittance of the tuned circuit. With the unknown resistance placed across the line the circuit is brought into resonance by changing the length of section to l_1. Then, if parallel conductance of the unknown resistor is much greater than the parallel conductance of the line

$$R = 1/G$$

where $G = [A - Z_c \cot (2\pi\ l_2/\lambda)]$
in which $A = Z_c \cot (2\pi\ l_1/\lambda)$
l_1 is the length to give maximum voltage (resonance)
l_2 is the length to give a voltage 0.707 times that at resonance
Z_c is the characteristic impedance of the line

The frequency-variation method consists of obtaining resonance of the circuit and then shifting frequency to an extent that allows the voltage to drop 0.707 of that at resonance. If G is the conductance of the resistor, G_L is the conductance of the line, λ_1 is the resonant wavelength of the line, and

$\Delta\lambda_1$ is the shift in wavelength to obtain a voltage reading 0.707 of the resonant value, then

$$G + G_L = Z_C \left(\frac{2\pi l}{\lambda_1}\right) \frac{\Delta\lambda_1}{\lambda_1}\left[1 \pm \frac{\sin(2\pi l/\lambda)}{(4\pi l/\lambda_1)}\right] \csc^2(2\pi l/\lambda_1)$$

when G and G_L are very small. The plus sign is used when $\beta = \omega C$ and a minus sign when $\beta = 1/\omega L$.

C. Measurement of Reactance

Reactance measurements can be conveniently carried out by using a section of transmission line short circuited at one end and open circuited at the other. Reactance, X_c is placed across the line, the value of X_c is given by

$$X_c = Z_c \cot(2\pi l_2/\lambda)$$

where l_2 is the length of the line to bring the circuit into resonance with the unknown reactance across the open circuit. In some measurements it may be necessary to include the inductance of the short-circuiting section in the calculation of reactance.

This method is used to determine the resonant wavelength of diodes and the calibration of special condensers.[1] The method consists of plotting the function $\left(\lambda \tan\frac{2\pi}{\lambda}\right)\left(l_0 + \frac{L}{L_0}\right)$ versus λ^2. The intercept on the λ^2 axis is λ_r^2 and the slope is $s = 2\pi L_d/\lambda_r^2 L_0$

where $\left(l_0 + \frac{L}{L_0}\right)$ is the correction term for short circuit,

λ_r is the reasonant wavelength, and

L_d is the inductance of the diode

Then

$$L_d = \lambda_r^2 S L_0/2\pi$$

is the series inductance of the diode and the interelectrode capacity is given by

$$C_d = \lambda_r^2/L_d (2\pi c)^2$$

c being velocity of light, 3×10^{10} cm/sec.

If the line is shorted at both ends the procedure is the same in that the line is brought into resonance giving a total length l_1. A capacity or insulating material is then placed near the center of the half wavelength section. The line is again brought into resonance. The capacity C is then given by

$$C = 1/[2\pi f Z_c \cot(360\ l_2/\lambda)]$$

where l_2 is the difference in the total length between a resonance condition and that with the capacity across the midsection.

IX. Power Measurements

Power measurements can be divided into three classes (1) powers much less than one watt, (2) powers in the neighborhood of one watt, and (3) powers much greater than one watt. This division is warranted by the fact that the instruments as well as the technique differ in the three cases.

Instruments used for these measurements should be: (a) of adequate sensitivity, (b) adequately shielded or isolated from stray capacity or inductance, and (c) independent of frequency or else calibrated at the frequency in question.

For powers of less than one watt a vacuum thermocouple is used. These thermocouples are generally specially built for power measurements. A few of the important construction considerations may be listed as follows:

(1) The heaters should be short and straight so that the current will be uniform throughout their length.

(2) Heater resistance should be large compared to that of the circuit from which the power is to be measured.

(3) The heater and the couple units should be so constructed as to minimize coupling.

(4) The elements should be self supporting to eliminate shunting effects caused by supports.

For power measurements in the neighborhood of one watt the power dissipated in the filament of a small diode can be used as an indication of power. The filaments of the diode must be short with respect to the wavelength in question to insure uniform current distribution. The anode voltage must be high enough to insure temperature limitations of current at all times. The power which can be measured by such a device is limited by the anode dissipation.

For power greater than 2 or 3 watts there are two possible methods of attack. One is the use of an incandescent lamp as a terminating load. The brilliancy of this lamp can be ascertained either visually or by photometric methods. The lamp is then connected to a 60 cps source and brought to the same brilliance thus giving an indication of the power. When the visual method is employed, two lamps operating simultaneously, one energized by u-h-f and the other by 60 cps, give a chance for quick comparison. No doubt there is an inaccuracy present with this type of measurement since the lamp filament is long with respect to the wavelength and a non-uniform distribution of current exists on the filament.

Another method is to dissipate heat in a well insulated box. A resistive load on the end of a transmission line can first be excited by u-h-f and the temperature rise is recorded against time. The sending end of the transmission line can be disconnected from the u-h-f generator and 60 cps source applied. By taking a series of runs at various powers against time a simple extrapolation will give the power at u-h-f.

A byproduct of the power measurement is the calibration of the absolute voltage of the voltage indicator. Since the power has been established and the energy fed to the load on a transmission line of some known characteristic impedance, the voltage is easily obtainable from the following:

$$R_{min} = Z_C E_{min}/E_{max}$$
$$R_{max} = Z_C E_{max}/E_{min}$$
$$E_{min} = (P R_{min})^{1/2}$$
$$E_{max} = (P R_{max})^{1/2}$$

or if the line is perfectly matched $E_{min}/E_{max} = 1$, then,

$$E = (P Z_c)^{1/2}$$

By varying the power, the voltage device can be completely calibrated in absolute voltage.

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New Books

Automatic Record Changers and Recorders

By John F. Rider, *Published by John F. Rider Publisher, Inc., 404 Fourth Ave., New York, 1941, 723 pages. Price $6.00.*

In "Automatic Record Changers and Recorders" Mr. Rider does for record changers and recorders what he has done for receivers in his famous manuals which have been published for a number of years. The load on the radio servicemen of the nation is bound to increase greatly in the future because of the unavailability of new receivers and the increased need for keeping the old receivers in working condition. Along with radio maintenance, most service men will find it necessary to repair record changers when they get out of kilter. To reduce the repair time as much as possible, the service notes of a large number of record changers and recorders have been gathered together in one volume together with a discussion of the mechanical aspects of such equipment. The fundamental design of commercial automatic record changers is discussed in the early chapters with the emphasis on the troubles which may develop. The RCA model RP-152-C record changer is chosen as a typical unit for detailed description. A number of photographs of the mechanism in various phases of its operation together with well-written captions are presented. The major portion of the book (662 out of 723 pages) is taken up with the service notes of practically all the automatic record changers and home recorders which were on the market at the time the book went to press. Any service man who has more than a few changers to repair will find this book well worth its purchase price in time saved locating troubles.—C.W.

• • •

Mathematics for Electricians and Radiomen

By Nelson M. Cooke, *Chief Radio Electrician, United States Navy. McGraw-Hill Book Co., New York, 1942, 604 pages. Price, $4.00.*

The dominant aim of this book is to furnish the electrical and radio student with a sound mathematical foundation and to show him how to apply this knowledge to the solution of practical problems. This aim is fulfilled by presenting an outline of mathematics with numerous problems and interspersing chapters dealing with the application of material covered up to that point to electrical and radio circuits. The book is suitable for self-instruction by students who have had some training in high school mathematics. With the greatly increased need for technical radio men caused by the war program, many men will find it highly desirable to increase their knowledge of mathematics for a better understanding of circuits. It is this type of man, with limited formal training, who will find this book very useful.—C.W.

• • •

Standard Handbook for Electrical Engineers

Archer E. Knowlton, *Editor-in-Chief (7th Edition, 2303 pages. 1941. Price $8. McGraw-Hill Book Co., New York.)*

Like its predecessors, the 7th edition of this well-known work is designed to present an orderly compilation of the working tool information of electrical technology which has been authenticated by research and experience, but is not generally accessible in compact form. Before undertaking the revision, more than 100 electrical engineers in well-diversified professional activities were interviewed to ascertain what they expect from an engineering handbook. The 7th edition is intended to meet the demand as expressed by the group interviewed, as well as by the experience of the various specialists who have contributed to its 26 sections.

There is a distinct difference between this edition and previous editions. Part of this, perhaps most of it, is due to the fact that many of the contributing authors have not participated in previous editions. It is particularly gratifying to observe that the communication field has fared better than in the past. Two chapters deal with the subject; Chapter 23 which is devoted to electronics and electron tubes, and Chapter 24 which deals with radio and carrier communication. These two chapters occupy approximately 100 pages, a small enough portion of the total when the importance of modern electrical communication is taken into account. Chapter 22 on wire telephony and telegraphy, of about 60 pages, should also be included as a contribution to communication systems.

(*Continued on page 74*)

CYCLOTRON PORTRAYS NEW PART

These three University of California scientists, left to right Doctors Paul Aebersold, Robert S. Stone and John H. Lawrence, are shown at the convention of the Radiological Society of America. They had an informal discussion on the encouraging results of treating cancer with radioactive substances obtained from the atom smashing cyclotron

Photo by U. S. Army Signal Corps

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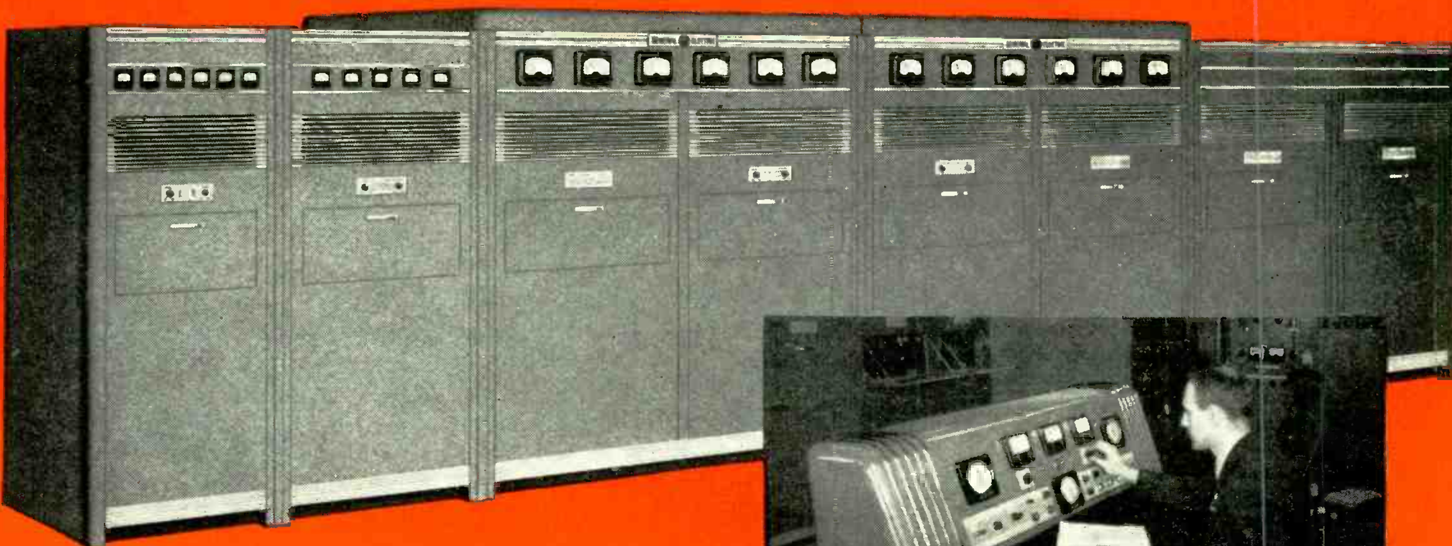

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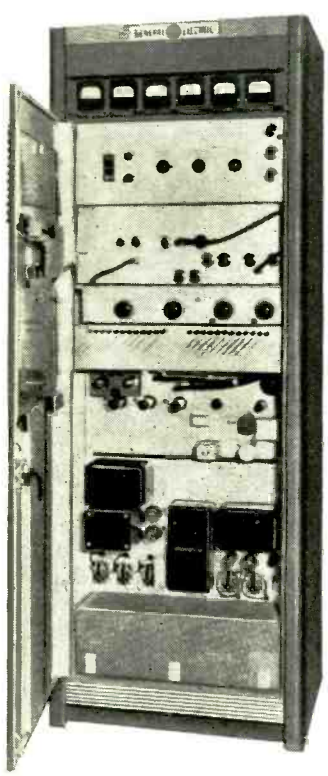

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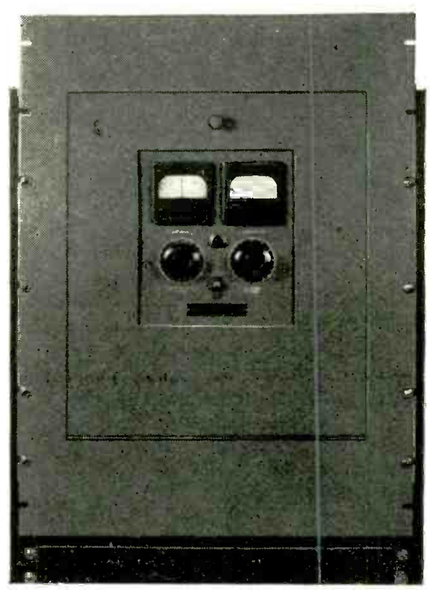

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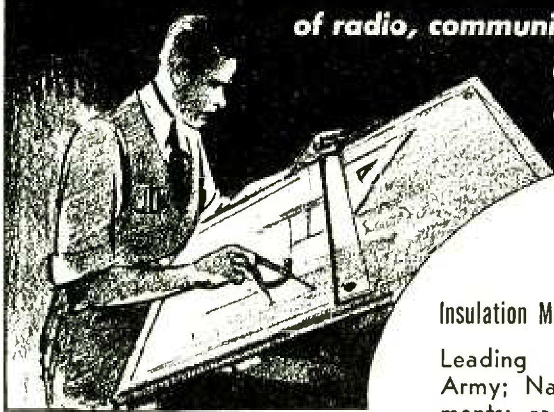

(*Continued from page* 70)

As has become practice in electrical engineering handbooks, the first several chapters are devoted to a consideration of units and conversion factors, measurements, electric and magnetic circuits, and circuit elements. Approximately 900 pages are devoted to transformers, rotating machinery, rectifiers and converters, prime movers, power plant economics, power system electrical equipment, power transportation, power distribution, and wiring, all of which might be considered of interest to the power engineer.

After this fundamental introduction and treatise on power system, the remaining chapters are, by and large, devoted to specialized applications of electricity including illumination, industrial power application, heating and welding, electricity and transportation, electrochemistry and electrometallurgy, batteries, codes and standard practices, and electrophysics in addition to the communication chapters already mentioned. Each chapter contains a bibliography to which the specialist may refer for additional information.

It is expecting too much to say that a book of this size and scope could be adequately given a critical review in the short space available for the purpose, or that even a book of this magnitude could hope to supply answers to all of the multitudes of questions which its users will encounter in their work. But as a single volume aiming to be of practical and theoretical interest to the electrical engineering fraternity, it is doubtful if a more convenient, more comprehensive reference exists. Particularly in these harassed times when engineers are under pressure to find the answer to their problems in the shortest possible time, the 7th edition of the Standard Handbook will fill an extremely important niche in electrical literature.—B.D.

The Development of Mathematics

By E. T. BELL, *Professor of Mathematics, California Institute of Technology, McGraw-Hill Book Co., New York, 1940. Price $4.50, no illustrations, 538 pages.*

TECHNICAL BOOK READERS who brave the rather prosaic title of this book will find it a fascinating account of the evolution of the important science of mathematics. Mr. Bell has done a fine job of rendering a coherent, informative and interesting account of the growth and development of mathematical concepts. He separates mathematical history into seven periods: from the earliest times to ancient Babylonia and Egypt; the Greek contribution, about 600 B.C. to 300 A.D.; oriental and semetic contributions; Europe during the Renaissance and the Reformation; the 17th and 18th centuries; the 19th century; and the 20th century. Each period is covered with an eye to trends

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RCA TEST EQUIPMENT

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This is not a "popular" history of mathematics. At times it is rather difficult reading. However Mr. Bell's profound knowledge of his subject, his keen "historical" sense, and his occasional flashes of humor is sure to hold the interest of readers with an engineering mathematics background.—E.E.G.

Radio Troubleshooter's Handbook

By Alfred A. Ghirardi. *Radio and Technical Publishing Co., New York City, 1941. 700 pages. Price $3.50.*

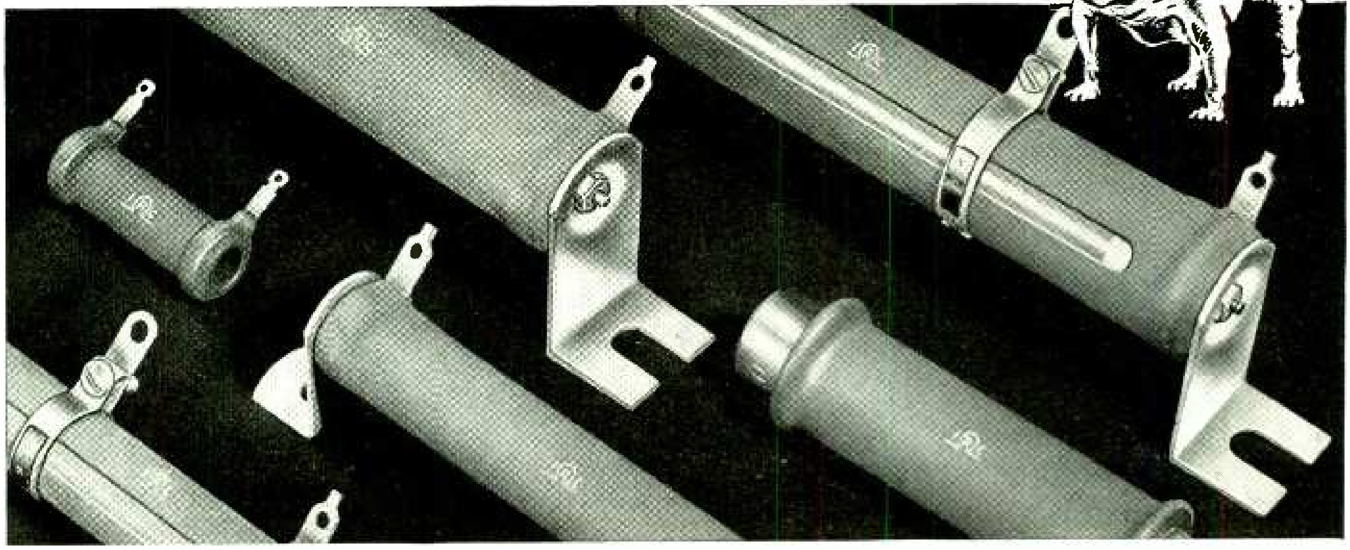
This reviewer has always stood in some awe at the huge books got out for radio service men, first at the tremendous amount of labor involved in compiling, writing, proofreading their contents, and secondly at the value these books must have to the radio repairer faced with a recalcitrant receiver. Only a brief perusal of the pages of the first half of Mr. Ghirardi's book will convince the reader that no service man could possibly keep track of the ailments of the thousands of models that the radio industry has produced. The first 386 pages contain nothing but diagnoses of ills that affect receivers still in service, some of them many years after the name of the manufacturer has been forgotten. A long list of i-f alignment peaks, an auto-radio trouble shooting reminder chart in many pages, lists of replacement batteries for portable radios, RMA codes etc., etc., fill up the remainder of this big volume.—K.H.

Mallory Radio Service Encyclopedia

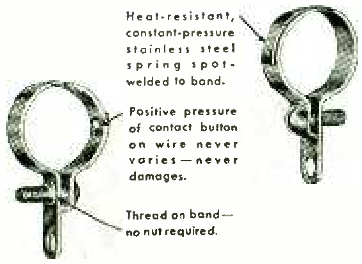
4th edition, compiled and published by P. R. Mallory & Co., Inc., Indianapolis, Indiana, 1941. Paper covers, 415 pages, illustrated. Price $1.50, ($0.95 net when purchased through any Mallory distributor).

The latest edition of this well known service engineers guide to replacement parts for commercial receivers and their associated equipment has been enlarged and brought up to date. It contains replacement information on the various parts and how they are connected in the set. Controls, condensers, vibrators, a complete tube complement, the i-f peak, and a Rider's reference for the complete circuit of the set are listed for each receiver. Diagrams of the control circuits, the power supply condenser circuits and vibrator base diagrams are listed in the rear of the book. These circuits are numbered and are referred to in the tables of replacement parts so that the trouble shooter can see at a glance how the part being replaced is connected in the circuit.—E.E.G.

IRC BUILDS THEM TOUGH



TODAY'S EXACTING CONDITIONS DEMAND *Proved Resistors*



POSITIVE CONTACT BAND ELIMINATES WIRE DAMAGE AND CORROSION

Designed for high temperatures, this IRC Positive Contact Band for adjustable resistors, has a smooth, rounded silver contact button on a heat-resistant stainless steel spring spot-welded to the band. Pressure does not vary, no matter how much the band is tightened. Button will not corrode at point of contact, or damage resistance windings. Sample resistor and band gladly sent to manufacturers of original equipment.

War conditions of use for a wide variety of radio and electronic equipment call for a more searching and comprehensive appraisal of resistor qualifications than might normally be the case.

What, for instance, happens to resistors under bomb shock?—extreme vibration?—tropical use?—salt-water immersion?. . .

Such are the questions being asked today—questions which look as though we ourselves had hand-picked them to spotlight the greater dependability of IRC Climate-Proofed Power Wire Wound Resistors for those exacting, heavy-duty applications where failure may have serious consequences. For IRC Power Resistors stand the gaff of rigorous use. They have proved this conclusively. They have proved it in the air, at sea, and on land—over a long period of time.

Their sturdy cement coating was specifically chosen because of its remarkable durability; because of its outstanding heat-dissipation and moisture-protection qualities; and equally important, because it is applied to resistors at low temperature, thereby not endangering the resistance windings or baking the temper out of terminals. IRC's will not let you down!

FIXED, ADJUSTABLE, NON-INDUCTIVE TYPES

IRC Cement-Coated Power Wire Wound Resistors are made in fixed, adjustable or non-inductive types, from 5- to 200-watts in all shapes and mountings. IRC resistance engineers have made a long-time specialty of war-equipment resistor applications and will gladly cooperate in solving any problems. Write for IRC Resistance Data Bulletin IV. Bulletins describing other IRC Fixed and Variable Resistor types also available.

IRC REG. U. S. PAT. OFF.

INTERNATIONAL RESISTANCE CO.

403 N. Broad St., Philadelphia, Pa.

TUBES AT WORK

Preamplifier-Filter for Crystal Pickup

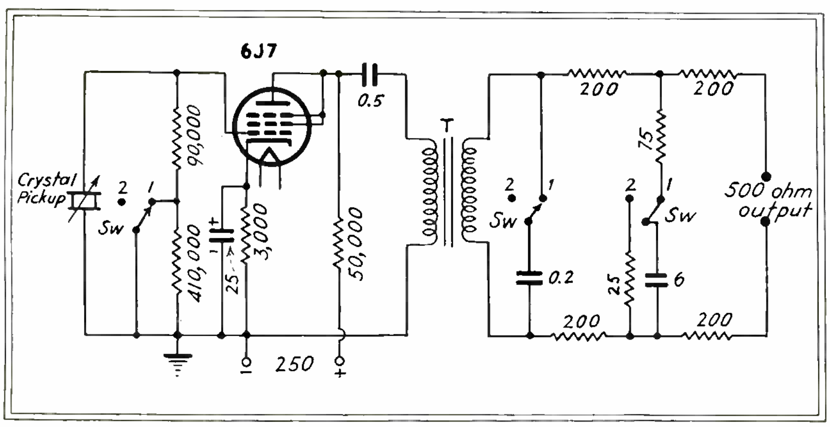
By CHARLES AFFELDER
WWSW, Pittsburgh, Penna.

THE PREAMPLIFIER-FILTER circuit illustrated permits the playing of orthacoustic transcriptions, constant-velocity transcriptions and ordinary phonograph records by means of a relatively inexpensive and readily available crystal pickup. Circuit constants shown are for use between an Astatic HP-36 pickup (LP-23 head) and a 500 ohm load. The three switches are ganged. *T* is a Western Electric 127-C output transformer.

The number one switch position is used when playing orthacoustic transcriptions which require bass pre-emphasis and treble de-emphasis, in accordance with a standard curve furnished by the manufacturer. It was found impossible to equalize in the amplifier grid circuit, so only partial compensation is made there by means of the 90,000 ohm resistor. Additional equalization is provided by the 0.2 μf capacitor, which gives high frequency compensation, and the 6μf capacitor, which governs the low frequency boost.

To play ordinary phonograph records or constant-velocity transcriptions the switch is placed in the number two position. This places 500,000 ohms in the preamplifier grid circuit and converts the network on the 500 ohm side of the transformer into a regular 20 db *H* pad.

Output volume level is approximately −30 db for number one switch position and −25 db for number two.



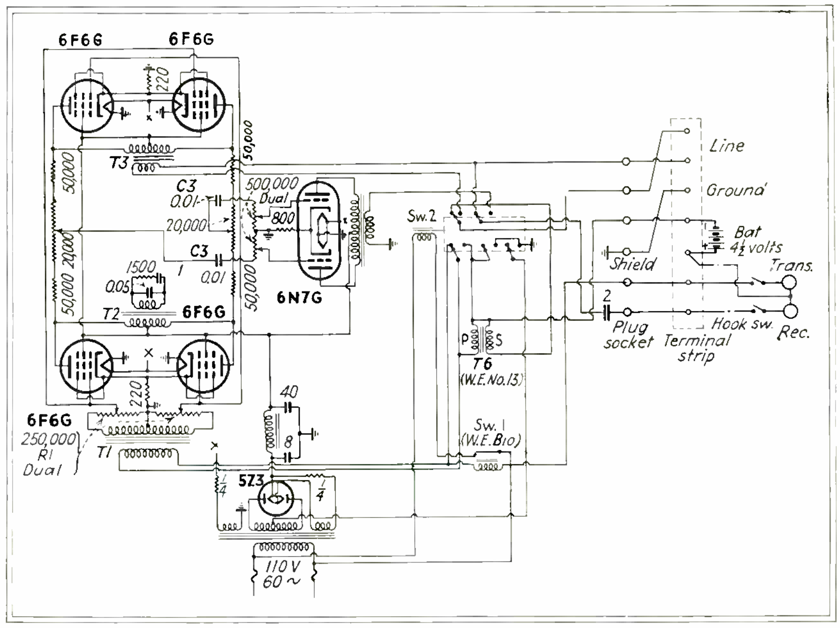
Preamplifier-filter for a crystal pickup used in broadcast station playing orthacoustic transcriptions, constant-velocity transcriptions and ordinary phonograph records

Telephone Amplifier for Power Company Circuits

By W. H. BLANKMEYER
The Montana Power Company, Butte, Montana

MANY POWER COMPANIES carry long-distance inter-office telephone lines on high voltage power line structures. Noise is frequently very high on such telephone lines, rendering them rather unsatisfactory for use with conventional handset microphones having low power output.

Amplification can be used to raise transmitted signal level above the noise. If all communication points are equipped for high level transmission fixed attenuation can be used in all receiving circuits to hold signals at the desired level. (If there are conventional telephones on the line there will be an upper limit of usable power, beyond which bells will ring spasmodically during conversations. Attenuation permissable in receiving circuits will also, in this case, be limited by the intelligibility of standard telephone signals.) Cross-talk is not encountered in this type of service as poles rarely carry more than one telephone line for any great distance.



Circuit of telephone amplifier. Should power fail the handsets operate in the conventional manner, without amplification

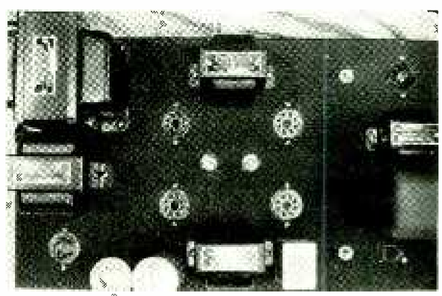
Circuit Operation

Referring to the diagram, when the handset is removed from the hook the battery circuit is completed through the induction coil T_6, transformer T_1, relay SW_1 and the transmitter. This relay operates on the transmitter button current and its contacts complete a 110 volt a-c circuit through the coil of relay SW_2, which has a five-pole double-throw contact arrangement. When SW_2 operates, it puts the amplifier output on the line, short circuits the primary of the induction coil, removes a short circuit from the primary of T_1, connects the telephone receiver to the receiver amplifier output and grounds the center tap of the power transformer high voltage winding. The amplifier is now in operation, but if there had been a failure of the 110 volt supply, SW_2 would have left the telephone handset connected into a conventional local battery sidetone circuit. In this way communication would be maintained, even if at reduced efficiency.

With the amplifier in operation, the signal coming from the transmitter is

applied to the primary of T_1. This has a 50 ohm primary and a high impedance secondary. R_1-R_1 is a dual gain control ahead of all the tube grids. Each section of R_1 feeds straight into the first push-pull stage, but the grids of the other stage are electrically crossed to get a 180-deg. phase shift. The plates of both stages are connected through the 50,000 ohm resistors and 20,000 ohm potentiometers. The combined plate circuits represent a bridge circuit which can be balanced with the potentiometers. The arms of the potentiometers feed through coupling capacitors C_3 and the dual gain control to the 6N7G grids. The output of the 6N7G goes to the telephone receiver.

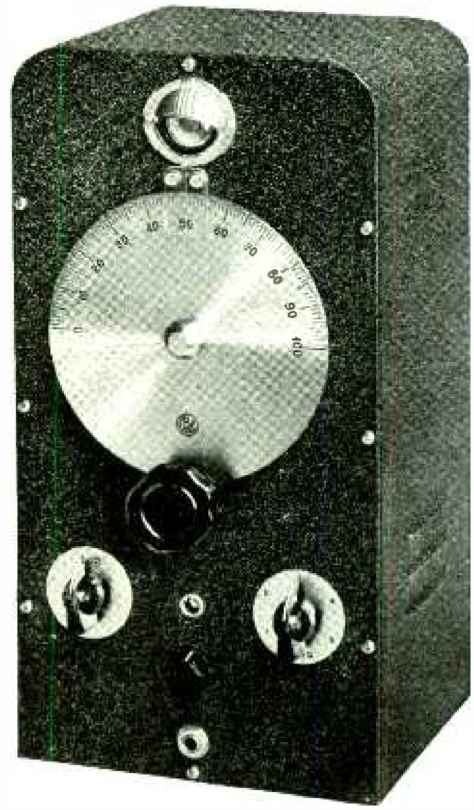
The output of one of the 6F6G push-pull stages goes into the line through T_3 and the other feeds into a network having characteristics approximately the same as the line through T_2. The network is used to load the two stages as nearly as possible alike at all frequencies. The network, to be most effective, should also duplicate any prominent line irregularities as closely as possible. When the bridge is balanced, a voltage appearing on the 6F6G grids does not appear across the 6N7G grids but does appear on the line. In other words, there is no sidetone in the receiver. However, when a signal voltage from a distant phone comes into the amplifier it appears across one end of the bridge only, so that it is unbalanced. Such a signal is amplified through the 6N7G and fed to the receiver.



Amplifier chassis, showing layout with six tubes removed. Gain and balance controls are slotted for screwdriver adjustment to discourage tampering

The heaters of the tubes are operated continuously, at 80 percent of the normal rating. Three of these amplifiers have been in operation twenty-four hours per day for 1½ years and the tubes are still in good condition. The amplifiers give plenty of output for use on extremely noisy long lines. The bridge balance is good on lines that don't have serious irregularities or impedance mismatching, which causes reflected energy to appear in the receiver. Design work is being done on an arrangement for returning the three wire input to a two wire circuit so the equipment can be used in a standard private branch exchange.

BROWNING TYPE S-2 FREQUENCY METER



✓ CHECK FREQUENCY *Accurately*

Designed Especially for Emergency, Police and Similar Services. This Instrument Is Custom Built for Individual Frequencies

1. Accuracy better than .005%

2. Will meet the F. C. C. requirements for checking the frequencies of any transmitter which requires a frequency meter accurate to .005%.

3. Employs a cathode ray indicator as well as aural means for checking zero beat. The cathode ray indicator allows much more accurate setting than can be made by means of aural determination of zero beat.

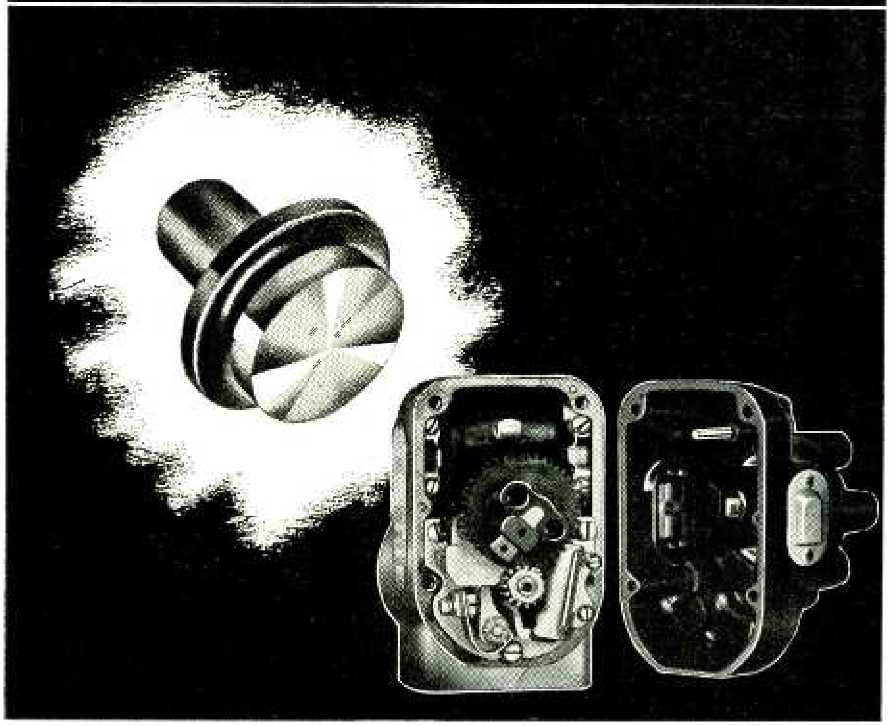
4. The Browning Frequency Meter is so designed that the precision of the apparatus at any time can be checked to at least fifty parts in five million against the Bureau of Standards Station WWV or against any reliable station operating on frequencies which are an even multiple of 100 KC.

5. Custom-built for specified frequencies. Models from 1 to 5 bands inclusive.

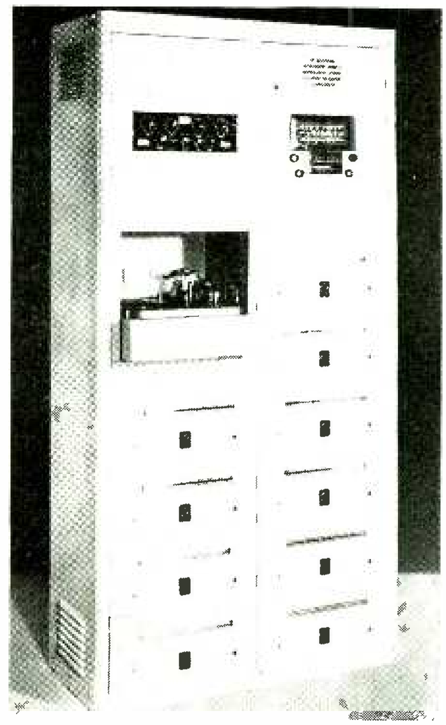
SEND FOR FURTHER INFORMATION AND PRICES

BL BROWNING Laboratories INC.
WINCHESTER·MASS·

Designers and Manufacturers of Electronic Equipment for National Defense



Ordnance Plant Sound



Installed in the new Plum Brook Ordnance Plant at Sandusky, Ohio, this 840-watt Webster-Rauland amplifier feeds microphone, phonograph and radio programs to workers via 16 miles of connecting cable and 48 high-power reproducers over an area of 30 square miles

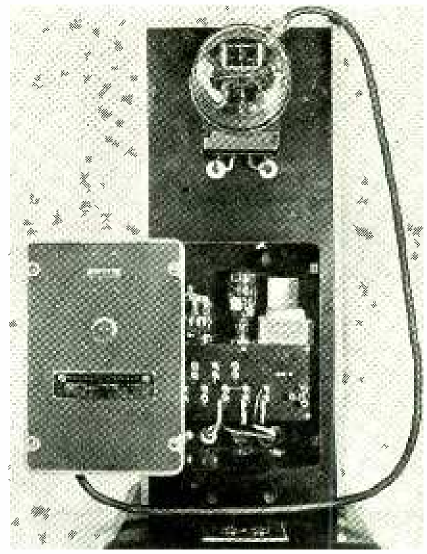
• • •

Electronic Watt-Hour Meter Tester

A NEW INSTRUMENT designed by the Wheelco Instruments Company of Chicago counts the number of revolutions made by the disc of a watt-hour meter, avoiding the use of frictional contacts which might introduce lag and magnetic metals which could readily affect accuracy if placed in the meter's field.

The testing device consists of an oscillating tube, a relay, a counter and a pickup unit at the end of a coaxial cable. A small, light aluminum or copper vane is mounted on the disc of the meter. A copper pickup coil is mounted within the case of the meter at a point where the vane will cut through its field. The pickup coil is coupled, through the coaxial cable, to the oscillator circuit of the tester. Passage of the vane through the field of the pickup coil alters the frequency of the oscillator and this alteration in frequency changes the oscillator's anode current sufficiently to actuate the relay and operate the counter.

With a known load connected to the meter under test for a definite time the accuracy of the meter may be determined by comparing the number of disc revolutions recorded by the counter with data supplied by the meter manufacturer. A meter may be compared with a master meter (a master meter



This electronic watt-hour meter tester counts the number of disc revolutions without introducing any frictional lag and without employing magnetic metals in the field of the meter

is shown in position in the accompanying photograph) by plugging it into a receptacle provided on the base of the instrument, which connects it in series with the pickup-equipped master meter. By starting the discs of both meters at a given point, permitting them to operate for a number of revolutions and then comparing, the percentage difference may be noted.

• • •

Direct-Reading Aircraft Insulation Tester

By W. N. Lambert
United Air Lines, LaGuardia Airport, New York

Ignition system insulation resistance must be maintained at a high value if aircraft engine spark intensity is to be satisfactory. It is also necessary that aircraft radio antenna insulation resistance be maintained somewhere near initial standards if transmission and reception efficiency is to be kept up.

Insulation deteriorates in use. Inspection is therefore a constant maintenance requirement and it is facilitated by the instrument to be described.

Two Test Ranges

The instrument diagrammed has two resistance ranges. For measuring resistance up to 100 megohms it operates as a conventional ohmmeter. About 950 volts d.c. is developed across four resistors constituting an internal load on the section of the 6F8G tube used as a halfwave rectifier. This voltage is impressed across the insulation under test in series with a current-limiting resistor and the O-1 ma milliameter. By choosing the series resistor properly the meter can be calibrated to read directly in megohms.

When measuring resistance between 100 and 5,000 megohms the triode sec-

Snap-Acting Controls for Radio Equipment

The heart of any temperature control is its thermal element. In Klixon thermostats, the famous Spencer snap-acting disc delivers a positive action to switches in response to temperature change. It is unique in the temperature control field.

Unaffected by motion, altitude, or position of mounting, and highly immune to shock and vibration, Klixon thermostats are finding a wide application in radio equipment today. They are small and compact, accurate in calibration, and light in weight, yet handle heavy duty electrical loads with ease. Klixon Thermostats are low in cost and flexible in application, too—it is very likely one of the many types of standard control designs is suitable for your needs.

Spencer Thermostat Company's engineering department will gladly recommend the types of Klixon thermostats best suited to meet your control requirements—or will gladly cooperate with your own engineers in the development of special disc-actuated thermostatic controls for your particular needs if practicable. Send for data sheets today.

Klixon Snap-Acting Circuit Breakers

Have you heard about Spencer Thermostat Company's latest application of the famous Spencer disc—Klixon midget circuit breakers—now used with outstanding success in military aircraft, tanks, trucks, and automobiles? Available in switch and push button manual reset types, or for automatic operation, in a variety of useful ratings, these miniature circuit breakers are already beginning to find a number of applications in radio equipment. Send for data sheets.

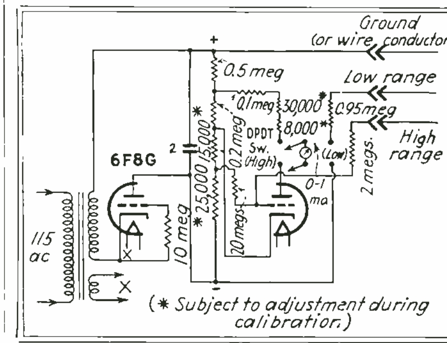
KLIXON

TRADE MARK REG. U.S. PAT. OFF.

Spencer Thermostat Co.

1404 FOREST STREET, ATTLEBORO, MASS.

tion of the 6F8G (the section with its control grid connected to the top cap) comes into use. Potentials are applied to the electrodes of this triode section through the voltage-divider in such a manner that the grid is biased just beyond the cutoff. It will be noted that the high range jack is connected to the grid through a 2 megohm resistor. Thus,



Aircraft insulation tester with two resistance ranges, 0-100 megohms and 100-5,000 megohms

when the high range jack is connected to the insulation under test, any small amount of current flowing through the insulation and through the 2 megohm resistor makes the grid less negative, causing anode current to flow. Anode current flows through the milliameter, which may be calibrated to read directly in megohms.

Accuracy, Calibration

The calibration of the instrument is somewhat affected by aging of the 6F8G and replacement of the tube is usually the solution when the instrument fails to read full scale with the

• • •

Allnight Guard

With $30 worth of G-E parts, including a phototube and a relay, Schenectady storekeeper Andrew Tessier licked the problem of how to turn display window lights out automatically in the event of an air-raid. The phototube, aimed at a nearby streetlight, does the job when the city's central station pulls the big switch

test prods shorted together. Calibration is affected to only a minor degree by differences in the characteristics of 6F8G tubes. Variation in calibration appears to be less than 5 per cent up to 1,000 megohms when tubes are changed.

The simplest manner of calibrating the instrument is to connect known resistances across its terminals and draw a suitable scale from the resulting readings. Suitable resistors are available up to 20,000 megohms. Other conventional methods of calibrating the instrument may, of course, be used but it should be born in mind that calibrating circuits employed for this purpose must draw little or no current from the device.

• • •

Sensitive Feedback Voltmeter With Rugged Milliameter Indicator

By Lawrence Fleming

A USEFUL INSTRUMENT for audio frequency measurements is the feedback voltmeter, consisting of a resistance-coupled amplifier feeding a diode rectifier and a d-c microammeter. Negative feedback is applied between the output rectifier and the amplifier input stage, to make the whole system stable

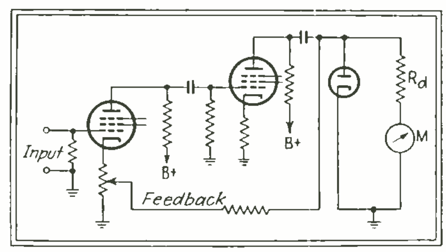


Fig. 1—Basic circuit of a typical feedback voltmeter

and linear. Figure 1 illustrates the idea. It has been described in detail by Ballantine[1] and in a patent to A. V. Wurmser[2].

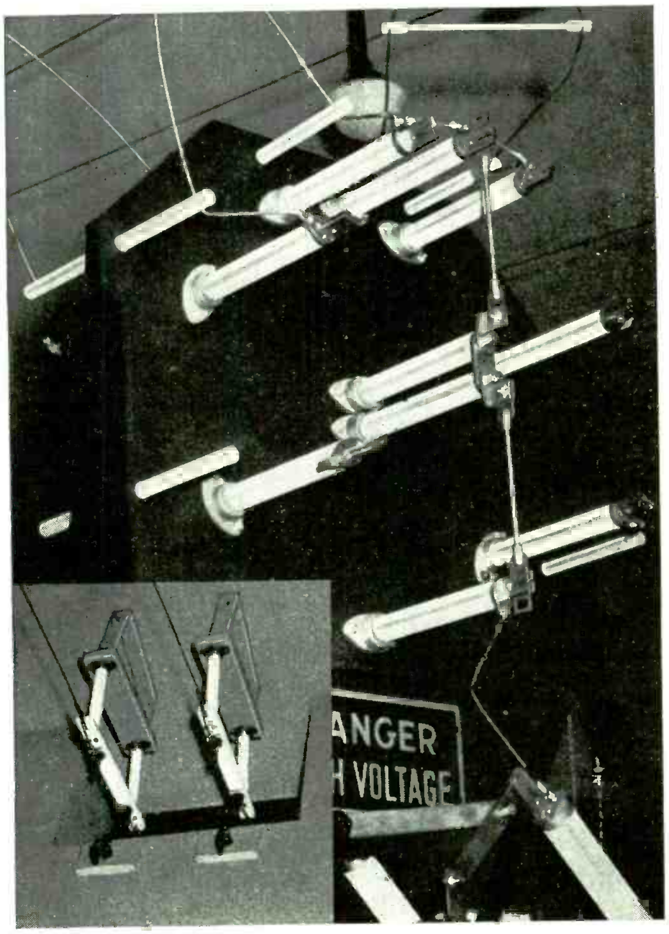
Such meters generally require a fairly high plate supply voltage and a sensitive d-c indicating instrument. This has its root in the fact that the diode load R_d should be high for linearity. A common value is 50,000 ohms, which requires a 100 microampere meter M when the plate supply is of the order of 300 volts.

Figure 2 shows a circuit variation permitting the use of a less sensitive indicating instruments. The diode is operated into a high resistance load and followed by a current amplifier stage operating the indicating meter. Negative feedback is run from the output of the current amplifier back to the input of the first stage.

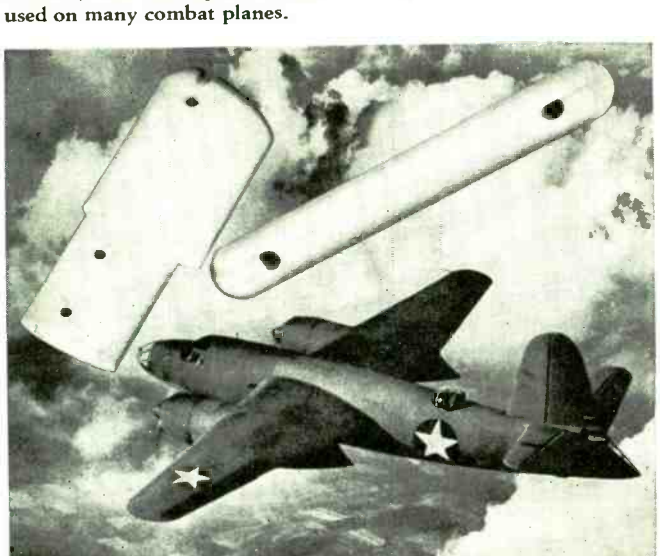
Performance

The voltmeter diagramed uses a 125 ohm-per-volt d-c instrument reading 8 ma. full scale as the indicating means. With about 22 db of feedback in use, full scale deflection requires 0.4 volts rms of signal at the input. The rela-

(*Below*) FAR-FLUNG LINES of communications are an integral part of the nation's lines of defense. To speed the dispatching of messages to such vital areas as the Caribbean, South America, and the Southwestern Pacific, additional facilities for radio-telephone service are being constructed. Representative applications of Isolantite* in such stations are shown in the accompanying photographs. Main photo shows Isolantite stand-off insulators on an antenna selector switch panel. Switches shown in inset employ Isolantite strain insulators as bases, mounted on Isolantite stand-offs. These uses are typical of the diversified ways in which increasing quantities of Isolantite are employed to serve the needs of the Victory program.

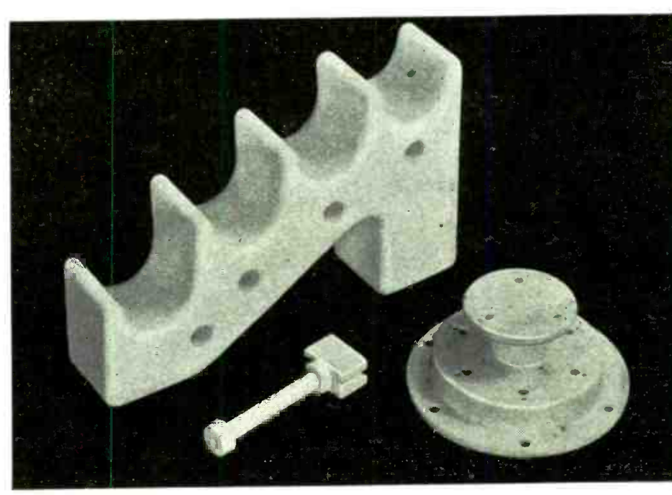


(*Below*) IN AIRCRAFT APPLICATIONS, Isolantite incorporates outstanding features in a single ceramic body. Its high mechanical strength is a doubly important advantage. It reduces the risk of insulator breakage, and permits the use of relatively small cross-sections, with consequent savings in weight. Isolantite is liberally used on many combat planes.



INSULATION HIGHLIGHTS

(*Below*) EXTERNAL CONSTRUCTION is completed on the new building at Isolantite's plant, which will provide greatly increased capacity for the production of ceramic insulators. Production facilities are planned for maximum time economy, to enable Isolantite to render more efficient service in meeting the demand for its products.



(*Above*) ISOLANTITE'S MANUFACTURING PROCESSES are adaptable to the production of a wide variety of shapes and sizes. Illustrated are a few of the many forms in which Isolantite has been produced for specialized applications in which standard designs cannot be used.

ISOLANTITE

CERAMIC INSULATORS

ISOLANTITE INC., 233 BROADWAY, NEW YORK, N. Y.

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

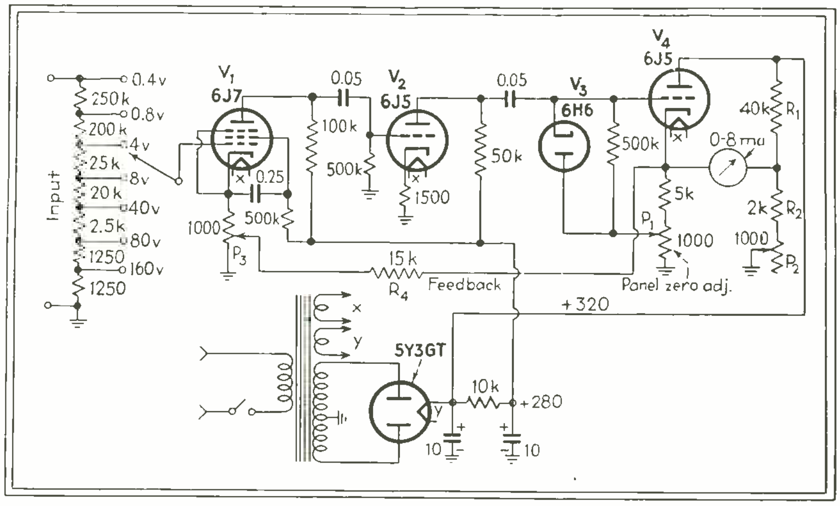


Fig. 2—Feedback voltmeter with amplification after the rectifier to allow the use of a relatively insensitive indicating instrument

tion of input voltage to meter deflection is linear over the whole scale.

Stability is satisfactory for most purposes. The apparent disadvantage of a zero adjustment (absent in the voltmeter's prototype) is not serious in practice. Decreasing the line voltage from 110 volts to 80 volts shifts the zero reading by 1 small division, only 2½ percent of full scale. On the incremental calibration this line voltage change has no discernable effect. Changing tubes in the current amplifier position V_4 may shift the zero setting by a few percent of full scale, but readjusting control P_1 readily brings the calibration back to its original value. Changing of other tubes has no detectable effect on the calibration.

With respect to frequency, no variation in response can be read over the range 40-20,000 cycles. (The upper figure was as high as the available test oscillator would go.) Below 40 cycles the meter pointer tends to oscillate with the signal. It will be noted that the signal component cannot readily be filtered out of the current amplifier because that component is used to supply negative feedback.

Construction

Tubes V_1 and V_2 are used as a conventional two-stage amplifier, feeding into diode V_3. The rectified output is applied to the grid of a 6J5, V_4 arranged as a current amplifier. V_4 is operated on the linear part of its characteristic and the no-signal direct current is balanced out of the meter by a conventional resistor network R_1, R_2, P_2. The diode is poled so that an increase in signal increases the plate current of V_4. The opposite arrangement is more common in diode-triode meters but in the present case would involve excessive bleeder currents.

The feedback circuit extends from the cathode of V_1 through 15,000-ohm resistor R_4 to the arm of potentiometer P_3, which is in the cathode circuit of the first stage V_1. The usual blocking condenser in series with the feedback resistor was omitted to reduce phase shift. Since the output end of the feedback resistor R_4 is at a fairly low positive potential, 15 to 30 volts, the bias on the 6J7 is not upset enough to affect its gain.

The zero adjustment potentiometer P_1 gives a range of adjustment plus or minus 5 percent of full scale. To properly locate this range another potentiometer, P_2, is adjusted with a screwdriver. P_2, being part of a shunt around the meter, affects current sensitivity of the stage considerably more than P_1. The feedback control P_3 is another screwdriver adjustment, covering a range of 15 to 1 in the overall gain of the system.

The writer is indebted to Dunford Kelly of the Miller Instrument Company for suggestions leading to the design of the instrument here described.

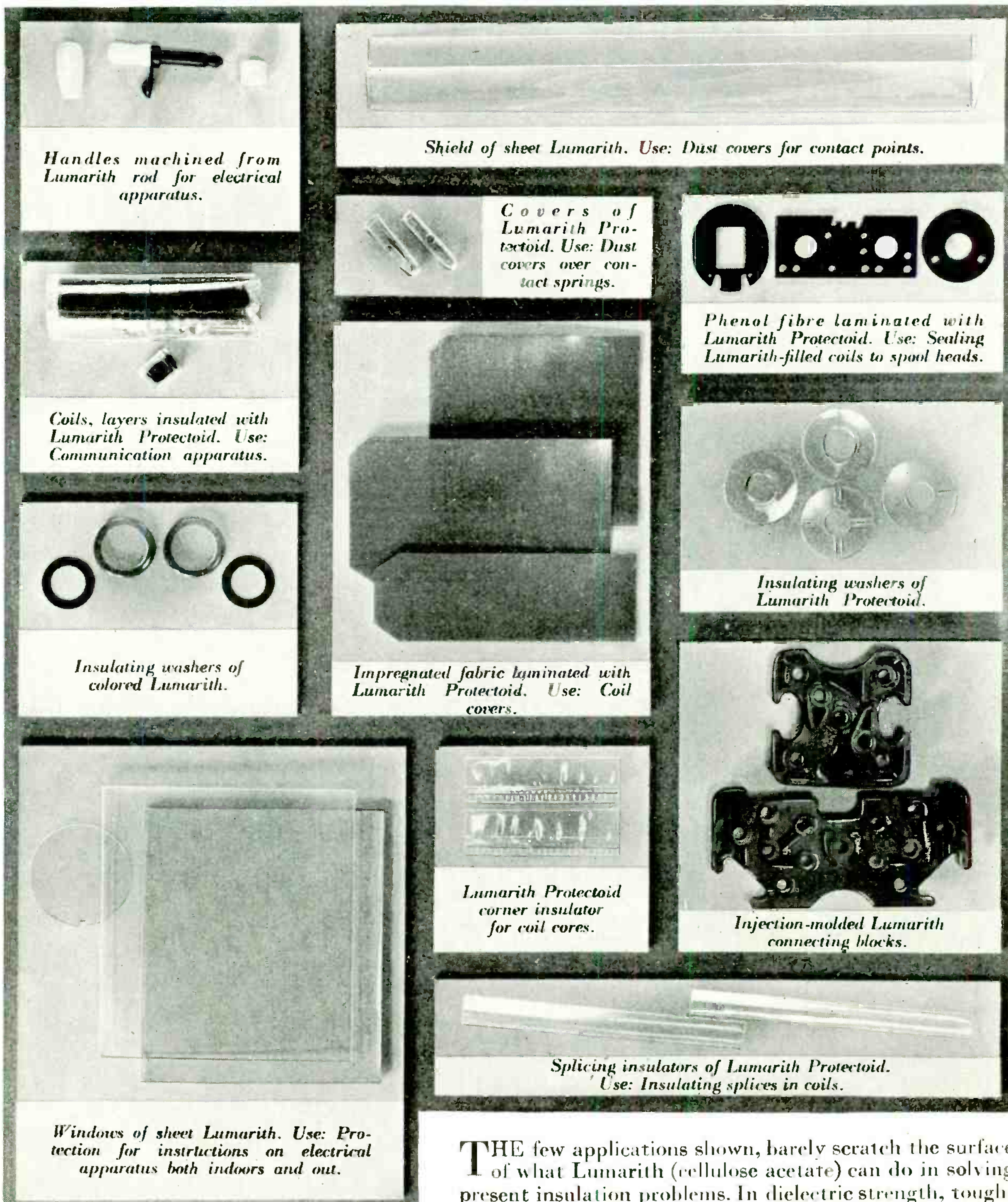
(1) Ballantine ELECTRONICS, Sept. 1938.
(2) A. V. Wurmser, U. S. Patent 2,147,724.

• • •

Fly's Footsteps Amplified

G-E's Walter Mikelson catches flies, preparatory to a demonstration of the racket they make when crawling over a microphone feeding a high-gain amplifier or sailing through the air immediately above it

Solve your insulation problems with *Lumarith Plastics*



Handles machined from Lumarith rod for electrical apparatus.

Shield of sheet Lumarith. Use: Dust covers for contact points.

Covers of Lumarith Protectoid. Use: Dust covers over contact springs.

Phenol fibre laminated with Lumarith Protectoid. Use: Sealing Lumarith-filled coils to spool heads.

Coils, layers insulated with Lumarith Protectoid. Use: Communication apparatus.

Insulating washers of Lumarith Protectoid.

Insulating washers of colored Lumarith.

Impregnated fabric laminated with Lumarith Protectoid. Use: Coil covers.

Lumarith Protectoid corner insulator for coil cores.

Injection-molded Lumarith connecting blocks.

Splicing insulators of Lumarith Protectoid. Use: Insulating splices in coils.

Windows of sheet Lumarith. Use: Protection for instrtuctions on electrical apparatus both indoors and out.

THE few applications shown, barely scratch the surface of what Lumarith (cellulose acetate) can do in solving present insulation problems. In dielectric strength, toughness, ease of processing—yes, and in availability—Lumarith suggests welcome possibilities in speeding production and in improving product performance. We have the data you need. Our technical staff will cooperate with you in development work.

CELANESE CELLULOID CORPORATION (formerly Celluloid Corporation), 180 Madison Ave., New York City . . . Sole Producer of . . . Lumarith* (cellulose acetate plastics in sheets, rods, tubes, moulding powder, transparent film and dope) . . . *Trademark Reg. U.S. Pat. Off.

CELANESE CELLULOID CORPORATION

THE ELECTRON ART

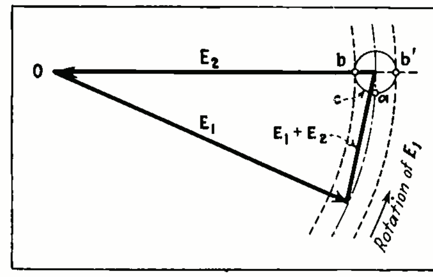


Fig. 2—Vector diagram of voltages at input of measuring circuit

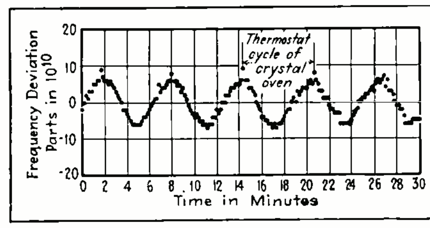


Fig. 3—Short-time frequency comparisons between two oscillators

Precision Frequency Comparisons

WHENEVER A FREQUENCY SOURCE of high precision is developed, some means of measuring the performance of the source must also be devised. Thus if a 100-kc oscillator is intended to be stable within one-thousandth of a cycle per second, the test circuit should be able to detect a variation in the order of one ten-thousandth of a cycle per second. A method which has worked satisfactorily, even when the variations occur for short durations is described in the March 1942 issue of the *Bell Laboratories Record* by L. A. Meacham.

The frequencies of two or more similar but independent oscillators are compared. If these are constant with respect to each other within observed limits and if they are truly independent, then probability assures the constancy of the individual frequencies within the same or closer limits. The circuit used to make these comparisons is shown in simplified form in Fig. 1. The two 100-kc oscillators O_1 and O_2 are adjusted to differ in frequency by about one-tenth cycle per second. Their outputs are added together in a hybrid coil and the sum is amplified and rectified to fire a thyratron once each beat cycle, in turn discharging condenser C through a spark coil. The high voltage generated by the coil causes a brief flash of light in the neck of a mercury vapor lamp. To record the time between flashes, a circular scale marked in milliseconds is rotated by a 1000-cps motor, synchronized with current from the frequency standard. Each discharge illuminates the scale and records the time on a slowly moving film.

The time elapsed during a single ten-second beat cycle is recorded to the nearest thousandth of a second, and any irregularity in the beat frequency amounting to more than one part in ten thousand becomes apparent. Since the frequency of the beat pulses is one-millionth of the frequency of either 100-kc oscillator, the precision of the comparison between the pair of oscillators is about one part in ten thousand million. As a specific example, if O_1 is set precisely at 100,000 cps and O_2 at 100,000.1 cps, then the difference will produce a beat once in ten seconds or a frequency of 0.1 cps. If the frequency of O_2 changes to 100,000.1001 cps the beat period will be shortened by 0.01 second or ten divisions on the scale. Thus very small irregularities become readily apparent.

To make sure that a recorded change is not due to any irregularity in the testing device itself, the thyratron must be fired at the same point in each beat cycle. The two oscillator outputs must be so compared that some condition for firing is satisfied abruptly and at a definite phase angle of the cycle. In Fig. 2, E_1 and E_2 are the voltage outputs of the oscillators. $E_1 + E_2$ is the sum of the two voltages added in the hybrid coil, which is constantly changing in length throughout the beat cycle. This vector is amplified and rectified to provide negative bias for the thyratron. When the bias falls below a certain value determined by the design of the tube, and represented by the radius of the circle C the tube fires, and a record is made. Thus whenever the end of vector E_1 falls inside the circle C the tube is fired. If the vector enters at a, the voltages are equal and the firing occurs earlier than if the entry is made at b or b'. Under the latter conditions the two voltages are not the same. The possible error introduced is approximately the ratio of the radius of C to the circumference of the circle swept by the end of E_1. This error is reduced by amplifying the vector $E_1 + E_2$ before rectification. This process increases the sensitivity or effectively reduces the radius C.

It is interesting to note that variations in the gain of the amplifier and the firing potential of the tube produce first order changes in the sensitivity but only very small errors in the measurements themselves. The results of using this method of frequency comparison are shown in Fig. 3. They were made on two oscillators now in use in the Bell System frequency standard. The plotted points represent frequency differences between the oscillators, and for clarity the average of the whole set of measurements has been taken arbitrarily as the zero of deviations. The measurements show a sinusoidal variation with an amplitude of about six parts in ten billion. It is believed

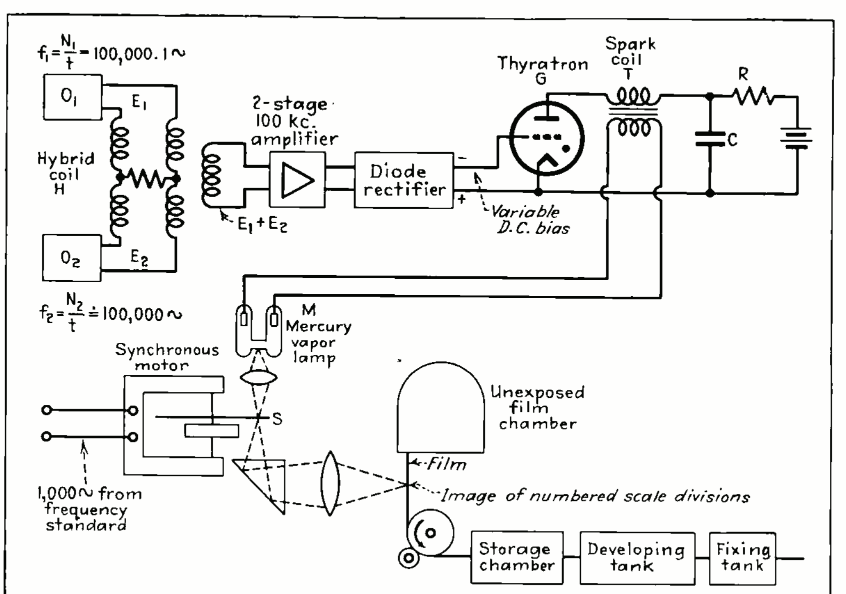
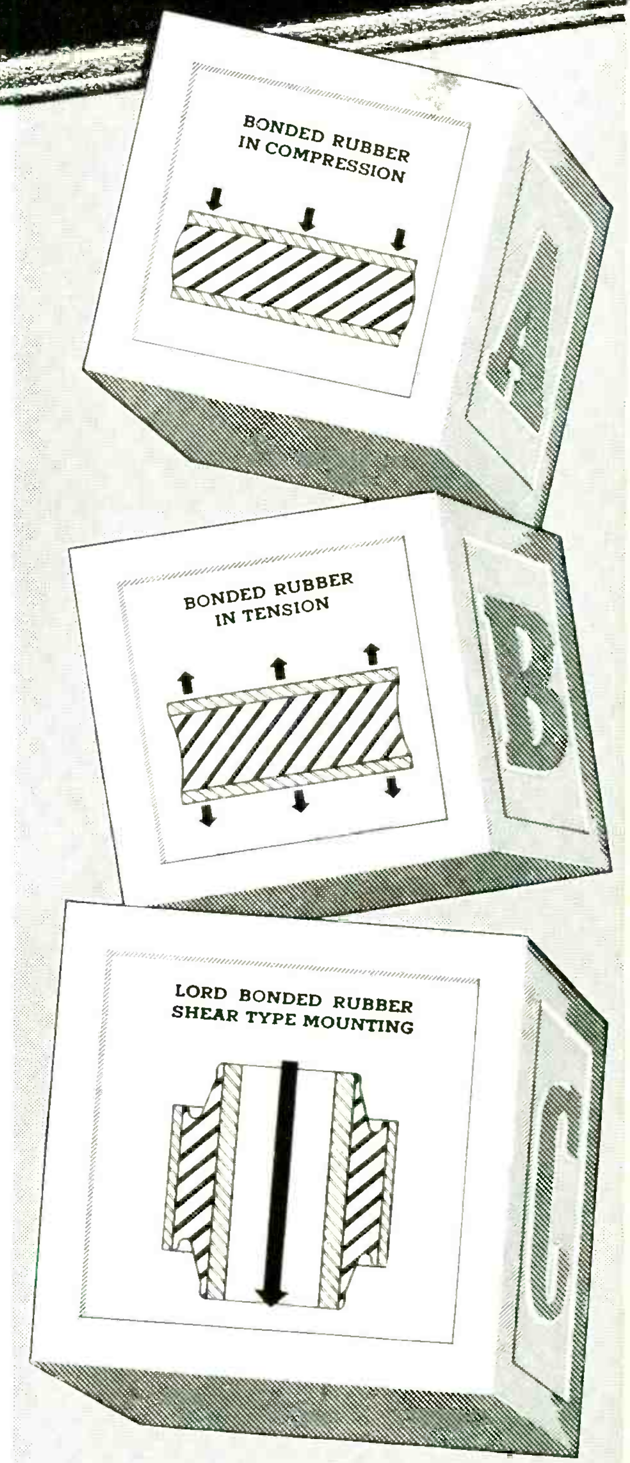


Fig. 1—Circuit for measuring short-time stabilities of standard-frequency oscillators

the ABC's of vibration control



A primary law of vibration control tells us that in any flexible mounting system, for a known load and disturbing frequency, the isolating efficiency of the mounting increases as the deflection of the mounting increases. The efficiency of bonded rubber mountings for supporting electronic equipment depends largely on this condition. One of the earliest forms of rubber mounts is the simple compression pad as indicated in Block A. As rubber is an incompressible material, provision must be made for bulge or flow of the rubber as the mounting deflects. In actual practice, compression type mountings are unstable as they are soft in all directions normal to the vibratory thrusts.

Block B shows a mounting with the load applied so as to produce tensile stress in the rubber. A mounting of this type is somewhat softer than rubber in compression, but has the same lack of stability in directions perpendicular to the vibratory thrusts. When a mounting is loaded in tension, the rubber stretches, reducing the cross sectional area. In this condition, rubber is extremely sensitive to injury and any cut or tear will cause rupture and quick failure.

Rubber stressed in shear under load, which is the operating principle of all Lord Mountings, has proved to be the most efficient design for obtaining adequate deflection under load without sacrificing other desirable characteristics. As shown in Block C, mountings operating in shear do not require a large volume of rubber and are, therefore, stable in all directions normal to the vibratory thrusts. This cross-section shows a typical Lord Tube Form Mounting, which is made in various sizes for supporting loads from a few pounds to 1500 pounds each and in special sizes for any higher load rating. For supporting lighter loads, from a few ounces up to 300 pounds each, Lord Plate Form Mountings are made in numerous sizes.

For a full description of standard Lord Shear Type Mountings and an engineering discussion of vibration control for mobile radio equipment, recorders and electronic control instruments, write for a copy of Lord Bulletin 104.

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SHEAR TYPE VIBRATION MOUNTINGS

TUBE FORM MOUNTINGS

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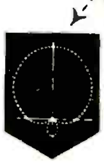
FLEXIBLE COUPLINGS

IT TAKES RUBBER IN SHEAR TO ABSORB VIBRATION



that this sine wave is associated with the intermittent heating of the crystal temperature control ovens, and this has been confirmed by correlation of the periods involved. Fluctuations in the other operating conditions cause the small scattered individual readings, and these are in the order of plus or minus one part in ten billion.

• • •

Cathode-ray Oscillograph for Frequency Comparisons

SEVERAL WAYS IN WHICH the cathode-ray oscillograph can be used in frequency measurements and comparisons are outlined in the December 1941 issue of the *General Radio Experimenter*. Where an unknown frequency is to be compared with or adjusted to a known frequency the cathode-ray oscilloscope offers a convenient and precise means of making the necessary comparison.

The simplest method is by means of Lissajous figures. If a voltage from a frequency standard is applied to one pair of plates of a cathode-ray tube, and the voltage of unknown frequency is applied to the other pair of plates, patterns of the type shown in Fig. 1 will result on the screen. These are called Lissajous figures. If the voltages are in quadrature, the third or lowest pattern of Fig. 1 will be obtained. The ratio of the horizontal tangent points *(A, B, C)* to the number of vertical tangent points *(D)* is the ratio of the frequency of the voltage on the horizontal plates to the frequency of the voltage on the vertical plates. In Fig. 1 the frequency ratio is 3:1. Using this method the tangent points can

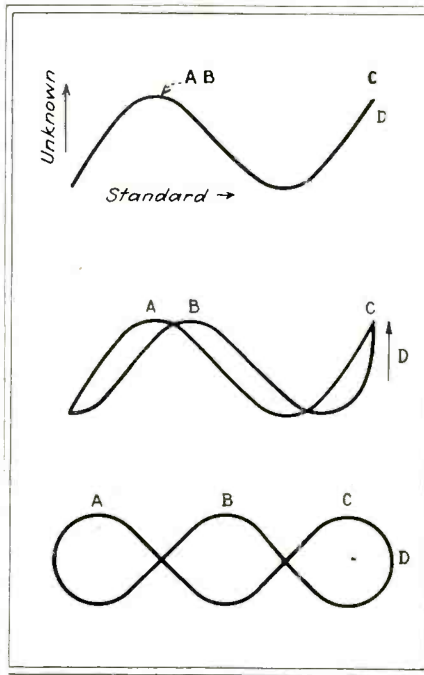


Fig. 1—Lissajous figures for a frequency ratio of 3:1. Top, the two frequencies are shown in phase; center, slightly out of phase; bottom, in quadrature

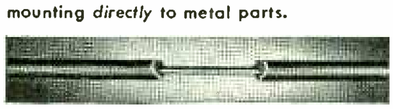
THESE RESISTORS

DO THE JOBS THAT COULDN'T BE DONE

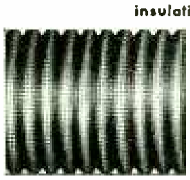
EACH TURN TOUCHES ANOTHER YET CANNOT SHORT

No "Swimming" of Turns

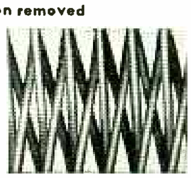
The exclusive Koolohm process of insulating the wire itself *before* it is wound, permits layer windings for higher resistance in less space; progressive windings for non-inductive resistors that are truly non-inductive even at 50 to 100 Mc.; larger wire sizes; faster heat dissipation; greater stability; extreme accuracy and greater humidity protection. No secondary insulations such as brittle cements or enamels are needed on the windings. For double protection, however, most Koolohm types are encased in a sturdy outer ceramic shell that will not peel or chip and which allows for quicker, easier mounting *directly* to metal parts.



Koolohm wire with section of ceramic insulation removed



Single layer winding



Progressive winding

TOTALLY DIFFERENT—OUTSTANDINGLY SUPERIOR

Whereas other resistors are space-wound with bare wire, Sprague Koolohms are layer-wound with wire that is insulated before it is wound with a special ceramic material. This insulation is so flexible it can be wound on small forms without cracking. It is so moisture-proof it excels in any moisture test—so heat-proof that the insulation is actually applied to the wire at 1000° C.—and so good as an insulator that it has an insulation strength of 350 volts per mil. at 400° C. Small wonder then, that Koolohms outlast, outperform old style resistors where shorted windings cause trouble, where bare wires must be protected by outside coatings of brittle cements and enamels, and where heat and moisture represent problems that have been only partially solved. Koolohms are smaller, sturdier, better protected. They are more accurate—and they stay accurate because windings will not short.

UNEXCELLED FOR DEFENSE APPLICATIONS

Not only are Koolohm Resistors approved for much military and naval equipment but, in various instances, Koolohm insulated, layer-wound construction and resulting design features have enabled defense manufacturers to meet heretofore "impossible" specifications. Koolohms have set new standards of performance under adverse salt water immersion conditions. Complete Koolohm Catalog and samples on request.

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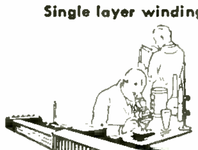

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be counted only for simple frequency ratios. The pattern will change progressively through the stages shown in Fig. 1 if there is a slight difference in frequency between the unknown and the standard frequency.

Modulated wave patterns are another means of frequency comparison. The problem of matching a low beat frequency, obtained as a result of comparing an unknown radio frequency, with a standard frequency is often simplified by resorting to modulated wave patterns. If the beat is obtained in an oscillating receiver, the oscillating fre-

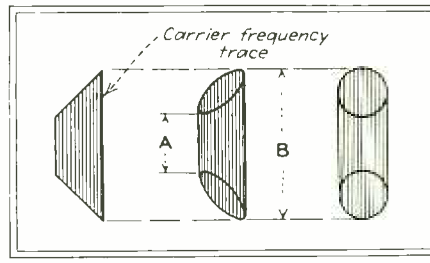

Fig. 2—Modulated wave pattern. Left, in phase; center, slightly out of phase; right in quadrature

quency being offset appreciably (by a kilocycle or so) from both of the radio frequencies, then the output of the receiver is an audible tone. The amplitude of this tone waxes and wanes at a rate equal to the beat frequency difference of the two radio frequencies. If one of the two radio frequencies has a slightly greater amplitude than the other, and if the receiver output is connected to the vertical plates while a calibrated audio-frequency oscillator is connected to the horizontal plates, then patterns of the type shown in Fig. 2 are obtained. The receiver output is equivalent to an audio-frequency carrier modu-

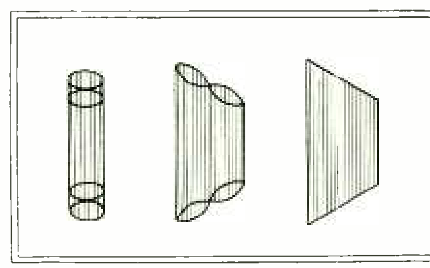

Fig. 3—Successive phase of a modulated wave pattern when the matching frequency is twice the modulation frequency

lated by the beat frequency difference. The pattern serves as a means of checking the percentage modulation and roughly indicates the quality of modulation. The patterns are for the case where one radio frequency is about twice the amplitude of the other resulting in a modulation of the audible carrier of about 50 percent. The ratio of the length A to the length B will give the percent modulation. If the matching oscillator frequency is not exactly equal to the beat frequency then the pattern will progress through the sequence shown. If the matching oscilla-

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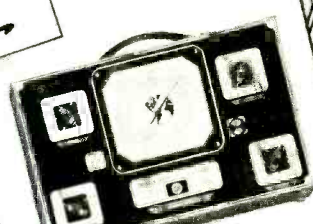

WESTON Model 776 OSCILLATOR

For testing broadcast and intermediate frequencies . . . in vacuum tube circuits. Accurate within ½ of 1% on broadcast bands— 1% on short wave bands. Has large 330° hand calibrated dial. WESTON AAC (Automatic Amplitude Control) circuit assures uniform output level regardless of frequency (no trimmers or padders used.) Triple shielding eliminates leakage.

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WESTON Model 787 UHF OSCILLATOR

For testing transmitters and receivers — stationary and mobile — AM and FM types operating in high frequency bands. Inductive tuning system provides fundamental frequencies with higher resonant circuit voltages and broad tuning range. High order of stability and resetability over entire frequency band. Reads 40 kc. per division at 40 mc. Modulation frequencies 400-1300 and 3000 cycles. Compact, Portable, battery operated.

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For measuring voltages in vacuum tube circuits where frequency is a factor. Has low input capacity of 5 microfarads with 6" leads. All ranges operate direct to measuring tube grid, providing a maximum input resistance and impedance device. Loading effect on circuit under test is only that of the tube itself, as no grid resistors are used on 0-1.2-3-6-8-12-16 volts ranges. Phone jacks provided for making audible tests. Ranges 0-12-30-60-80-120-160 volts full scale with multipliers.

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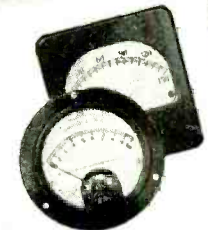

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WESTON improved design of heating elements provides extreme accuracy on high frequencies (frequency error less than 2% up to 65 mc). Available as ammeters and milliameters in ranges for all transmitters including portables. Also a complete line of ultra-sensitive portable instruments for high frequency laboratory measurements.

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tor frequency is adjusted to a multiple of, or in simple ratios to, the beat frequency, the pattern developed at the ends of the figure corresponds to the Lissajous figures for the same ratios. The appearance of the pattern when the matching oscillator is adjusted to twice the beat frequency is shown in Fig. 3. The two-to-one pattern is developed at the ends of the modulated wave pattern. If the frequency ratio is not exactly two to one the pattern will change progressively through the sequence shown.

Very useful patterns are obtained if a circular sweep is used. Here frequency ratios are easily identified, even when the ratios are not small integers. To produce a circular sweep, it is necessary to obtain two equal voltages having a phase difference of 90 degrees from the standard frequency source. One method is shown in the circuit in Fig. 4. The standard frequency is supplied through transformers T_1 to match

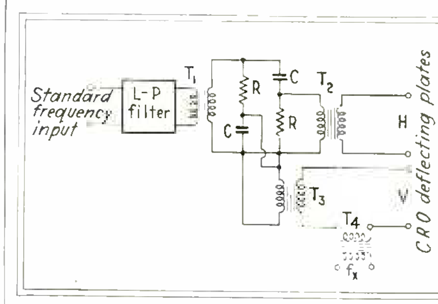


Fig. 4—Connections for obtaining a circular sweep

the total load. Resistances R, and reactances C are made equal in magnitude, about 10,000 ohms at the standard frequency. The phases of the voltages on the primaries of T_2 and T_3 are 45 degrees ahead and behind of the voltage supplied from T_1, thus they have a phase difference of 90 degrees. If the impedances of T_2 and T_3 are high (interstage coupling transformers with a step-up ratio of 6:1 are suitable) then connecting them across the elements R and C will not materially affect the phase of the voltages. The combined effects of the transformer loading and the impedances across the secondaries generally makes it necessary to readjust the elements of the phase shifter slightly.

Since a distorted waveform will not give a circular sweep a low-pass filter is used in the input. The unknown frequency is introduced to the vertical plates through T_4. The kind of patterns obtained with a circular sweep are shown in Fig. 5. With no unknown frequency introduced the pattern is a circle, the spot traveling around once for each cycle of the standard frequency. If a frequency which is five times the standard is introduced on the vertical plates the second figure will result. The frequency ratio is determined by counting the tops of the waves (A, B, C, D, E). If radial deflection is used then the pattern is not

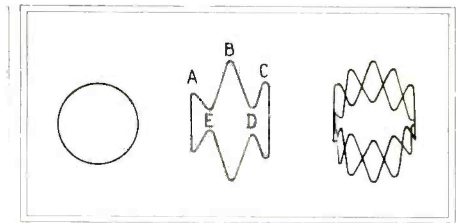


Fig. 5—Circular sweep patterns. Left, standard-frequency circular sweep; center, circular pattern with superimposed frequency equal to five times the standard; right, with superimposed frequency equal to 9/2 the standard

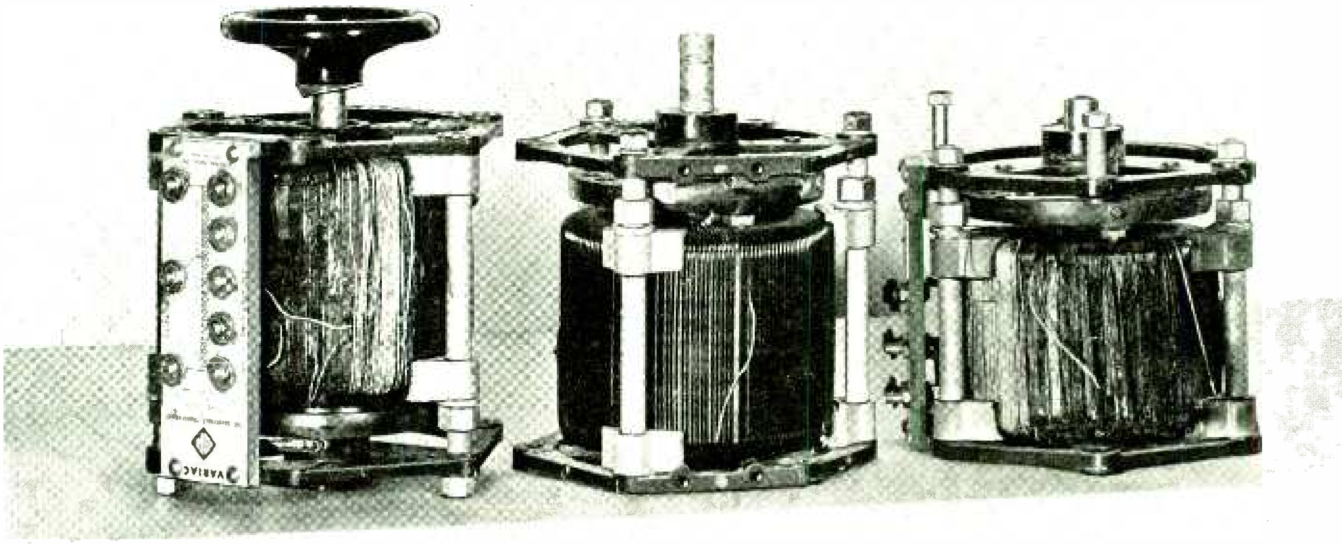
distorted and the frequency ratio is found by counting the outer tips of the waves. If the unknown frequency is not exactly five times the standard frequency then the pattern will retain its shape, but will rotate slowly. The one-line pattern is very convenient for calibrating equipment which is known to be nearly accurate. The error will govern the rate of rotation of the pattern. An audio-frequency oscillator can be calibrated using single line patterns at every 100 cycles (from a 100-cycle standard) up to the highest frequency at which successive waves on the pattern can still be distinguished. If the oscillator is set at odd multiples of one-half the standard frequency then a two-line pattern such as the third diagram in Fig. 5 is obtained. Three-line patterns occur when the oscillator is set at one-third and two-thirds of the way between successive 100-cycle points. Four-line patterns are produced when the oscillator is set at one-quarter and three-quarters of the way between successive 100-cycle points. The sequence of the patterns are repeated in each 100-cycle interval.

• • •

Liquid Column Varies Quartz Plate Resonance Frequency

THE RESONATING FREQUENCY of a piezoelectric X-cut quartz plate may be shifted by varying the surrounding temperature, pressure, and by varying the air gap between the plate and one of the electrodes in a holder. An article in the January 1942 *Proceedings of the I. R. E.* called "A Quartz Plate with Coupled Liquid Column as a Variable Resonator" by Francis E. Fox and George D. Rock explains how an extremely wide frequency variation may be secured by using a liquid column coupled to the plate instead of an air gap.

The equivalent electrical constants of such an oscillator are changed when the height of the liquid column is varied. The variation obtained in the experimental setup was from 2.2 to 3.0 Mc. At the same time it was found that the sharpness of resonance also was affected. A diagram of the resonator is shown in Fig. 1. An X-cut plate having



KEEPING THEM IN SERVICE

VERY FEW Variac auto-transformers give trouble even after years of fairly continuous use. Certain operating and maintenance precautions are necessary, however, to keep any Variac from passing out of the picture as did these in the illustration.

The five things to watch when using Variacs are:

- **WORN BRUSHES**
- **DIRT ON EXPOSED SURFACE OF WINDINGS**
- **CONTINUAL OVERLOADS**
- **GROUNDED OUTPUT CIRCUITS**
- **HIGH-VOLTAGE SURGES**

The brushes should be inspected regularly and replaced before excessive wear causes the brass holder to come in contact with the winding. When this happens the holder short-circuits several turns; immediate fusing results and the Variac is ruined.

Variacs, when exposed to dirt, dust, grit and corrosive fumes, must be cleaned frequently to insure positive contact between the brush and the winding, and to prevent arcing.

When the windings become blackened or corroded they should be cleaned with crocus cloth or very fine sandpaper. All rough spots must be smoothed. Loose particles can be removed with a fine brush; the windings should then be cleaned with carbon tetrachloride or some similar cleaning fluid.

Overloading may cause excessive heating. While the winding may not be damaged if the load is removed quickly, the carbon brush may disintegrate. A new brush should be installed. Lengthy overloads may cause a turn or two of the winding to be displaced and raised from the core with danger of damage to the brush.

To keep surges from damaging the Variac when it is used in the primary circuit of a high-voltage transformer or other highly inductive load, it is necessary that either the voltage setting of the Variac be reduced to zero or the *output* circuit opened before the line circuit is broken.

Since the Variac is an auto-transformer, it should not be connected to a load circuit containing a ground, *unless* the same sides of the line and the load are grounded.

With these simple precautions, and an adequate supply of replacement brushes and line- and load-circuit fuses, the users of the Variac should expect many years of service from these transformers.

To assist users of General Radio equipment to obtain the greatest possible life from G-R products, the Service Department has prepared a comprehensive manual of "Service and Maintenance Notes" for a number of instruments. We would like very much for you to have a copy of these notes gratis. Merely request a "Service Notes" order form.

GENERAL RADIO COMPANY CAMBRIDGE MASSACHUSETTS its thickness vibration frequency close to 2.5 Mc was cemented to a brass disk, over an opening slightly smaller than the plate. The upper face was sputtered with platinum, the film forming a continuous connection to the brass disk. A film was also sputtered on the face showing through the opening, but a wax coating, about one millimeter wide was placed around the edge of the plate before sputtering. Later this was removed, leaving an insulating space between the edges of the film and the supporting plate. The disk was used as the base of a container for a liquid in which a metal reflector attached to a micrometer screw, could be moved to adjust the length of the liquid column between the quartz and the reflector.

The measuring circuit is the usual one, consisting of an inductance L_1, a variable standard condenser C_1, and a thermogalvanometer, in series, with the

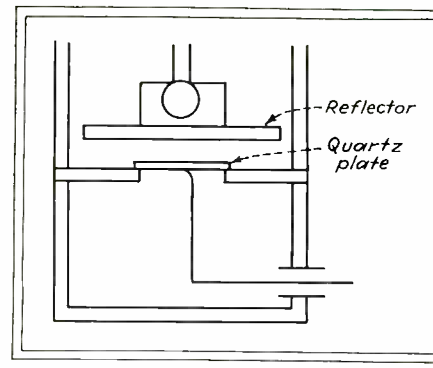


Fig. 1—Diagram of the liquid-column quartz-plate resonator

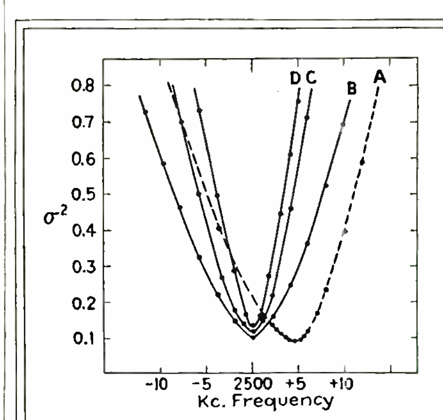


Fig. 2—The frequency difference may be read directly from these curves

resonator connected across C_1. The total resistance of the circuit, including the galvanometer is R_1. When C_1 is adjusted so that the L_1C_1 circuit has the same resonant frequency as that of the mechanical resonator the curve of the current (i) plotted against the frequency rises as the frequency approaches the resonant frequency of the L_1C_1 circuit. Then it dips sharply to form a crevasse at the resonant fre-

VACUUM

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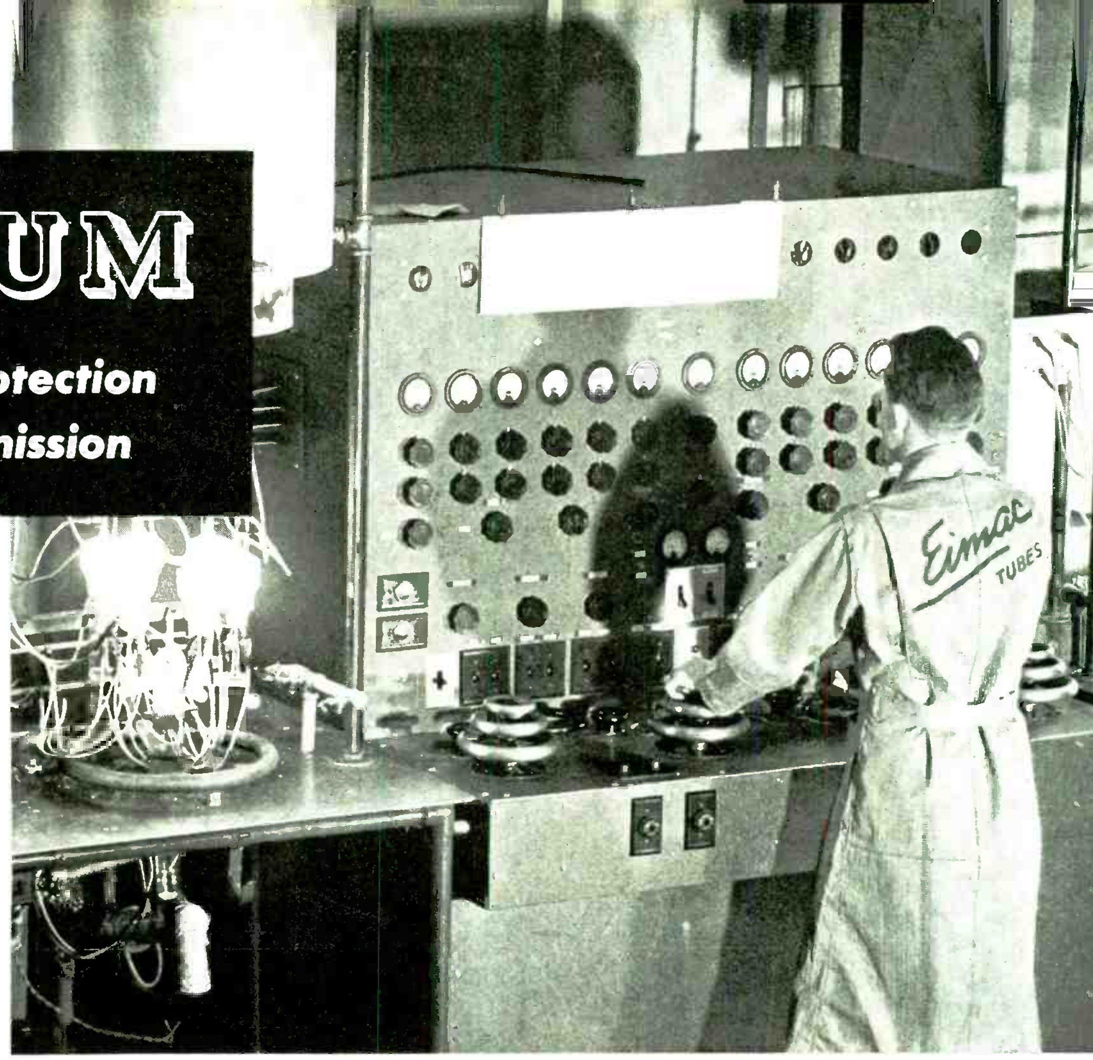

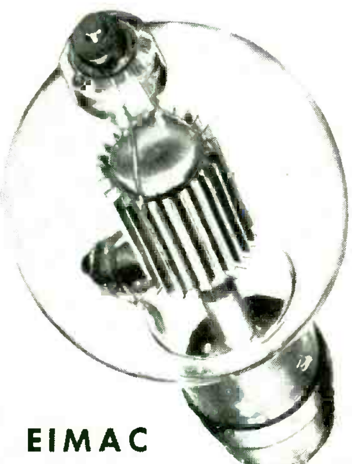

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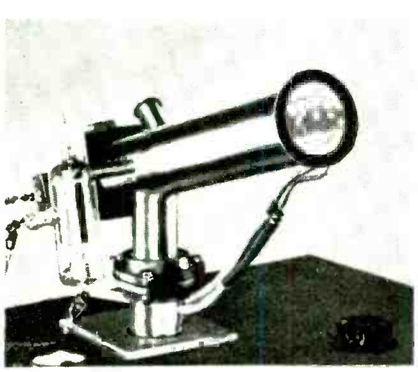
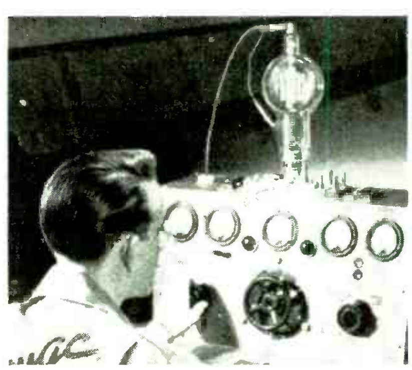
Filament Voltage	10 volts
Plate Voltage	up to 6000 volts
Plate Dissipation	2000 watts
Power Output (75% eff.)	6000 watts

Like a solid coat of armor-plate, hard, high vacuum protects filament emission in every Eimac tube. Extremely efficient evacuating pumps developed and built in the Eimac laboratories for the precise purpose of producing the highest possible degree of vacuum are shown in action above. It is this excellent vacuum that proved the idea fallacious that plate temperature destroyed emission...caused premature failures. Chiefly because of this processing, Eimac tubes today, and for the past number of years, have provided longer life, greater stamina and vastly superior performance.



ELECTRON MICROSCOPE virtually gives a moving picture projection of the action of electrons being emitted from a heated filament. Such observations enable Eimac engineers to constantly produce better filaments.



PEAK EMISSION TESTER measures the flow of electrons from the filaments of completed Eimac tubes. Of the long series of gruelling tests made to insure more efficient filament emission in every Eimac tube, this is the final test.

FLASH FILAMENT TESTER checks filaments before tubes are assembled and pumped. Here tubes are placed under a temporary vacuum, heated to much higher temperatures than will ever be required in normal use. Only perfect filaments reach the final stages of manufacture.

In Peacetime or Wartime...wherever you look...in the air, on land and at sea...you'll find Eimac tubes doing their bit. Right now the Armed Forces get first call on our facilities and Eimac tubes are receiving enthusiastic acceptance from all quarters.

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quency of the mechanical resonator, rises again and then falls off more slowly as the frequency increases beyond the neighborhood of resonance for the L_1C_1 circuit. When the two resonant frequencies coincide, the crevasse divides the L_1C_1 resonance curve symmetrically. Assuming R_1, L_1, and C_1 are known, the following relationships are used to determine R, L, and C of the mechanical resonator.

$$R = \sigma_m [(1 - \sigma_m)\, \omega_0^2\, C_1^2\, R_1]^{-1}$$
$$C = \phi\, (R\omega_0)^{-1}$$
$$L = (C\omega_0^2)^{-1}$$
$$\phi = M\sigma^m\, f_0^{-1}$$

Where:

R is the equivalent series resistance
C is the equivalent series capacitance
L is the equivalent series inductance
σ_m is the ratio i/I where I is the maximum current at resonance and i is the current at the bottom of the crevasse. This is the minimum current ratio.
ω_0 is $2\pi f_0$ where f_0 is the resonant frequency.
Φ is the reciprocal of the sharpness of resonance (Q) of the mechanical resonator. This may be determined accurately by plotting σ or σ^2 against the frequency in the region of the crevasse. One may read directly from the crevasse curve the frequency difference (Δf) for $\sigma^2 = (1 + \sigma_m^2)/2$. This is M.

The experimental results of measuring the characteristics of liquid column

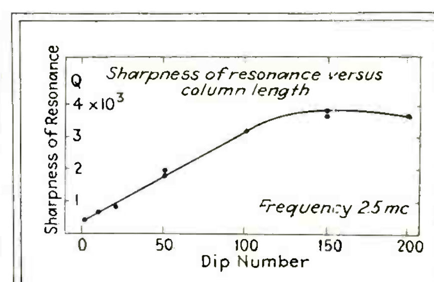

Fig. 3—Curve showing the sharpness of resonance versus column length

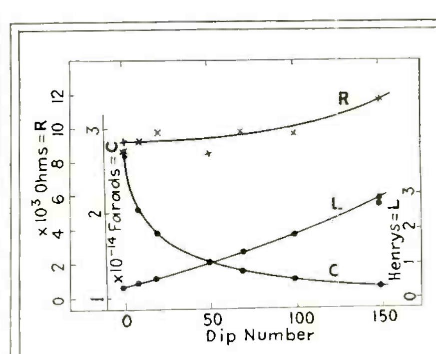

Fig. 4—These curves show how the equivalent R, L, and C of the resonator varies with the column length

resonators are shown in Figs. 2, 3, and 4. The dip numbers refer to points when the liquid column plus the quartz plate is in resonance. A sharp dip in the current to a minimum value of σ_m^2 occurs at these points. The first dip occurs when the liquid column is approximately $\lambda/4$, where λ is the wavelength in water of the sound generated by the vibrating quartz. Successive dips occur at intervals of $\lambda/2$.

• • •

F-M Carrier Telegraph System

How the principle of frequency modulation is applied to a carrier-current telegraph system is described in the January 1942 issue of *Electrical Engineering* by F. B. Bramhall and J. E. Boughtwood in an article called "Frequency-Modulated Carrier Telegraph System". The system employs true frequency modulation to derive the advantages of polar current signalling, with the same spectrum efficiency as in conventional amplitude systems, and at the same time obtains freedom from attenuation change in the transmission medium and greater immunity from extraneous disturbing currents.

There are two basic types of operation in almost all telegraphic communication circuits. The first is the single-current type of operation where transmission of current indicates a marking signal and absence of current indicates a spacing signal. The other is polar operation where transmission of current of one sense or sign indicates a marking signal, and current in the opposite sense or sign indicates a spacing signal. The relative power requirements of these two systems are such that there is a two-to-one reduction in average power, and a four-to-one reduction in peak power in favor of the polar system for equal interference susceptibility.

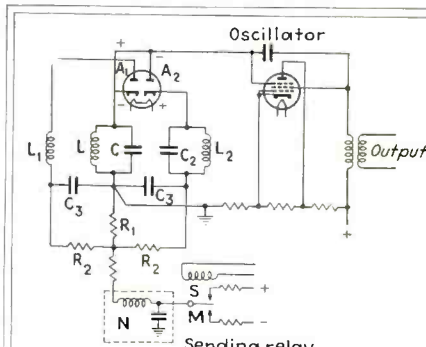

Fig. 1—Schematic diagram of frequency modulator

In the new system it is proposed that one frequency, f_m be used as the marking signal, and another frequency, f_s be used as a spacing signal. A schematic diagram of the frequency modulator is shown in Fig. 1. With the transmitting relay on spacing, the positive battery is connected to the control circuit establishing across R_1 a potential, positive with respect to ground and of magnitude slightly greater than the

peak oscillating voltage existing across LC. Under this condition the impedance of rectifier A_2 approaches infinity, effectively isolating L_2C_2. Simultaneously, A_1 becomes conductive, and R_2 limits the control current to a value slightly greater than the peak oscillating current flowing through A_1. As C_3 presents a low impedance to the carrier frequency, L_1 effectively parallels LC and the frequency approaches

$$\frac{1}{f_s} = 2\pi\left[\frac{LL_1}{L + L_1}\right]^{1/2}$$

Similarly the marking or negative battery applied by the transmitting relay isolates L_1, and L_2C_2 effectively parallels LC. The frequency approaches

$$\frac{1}{f_m} = 2\pi\left[\frac{LL_2}{L + L_2}(C + C_2)\right]^{1/2}$$

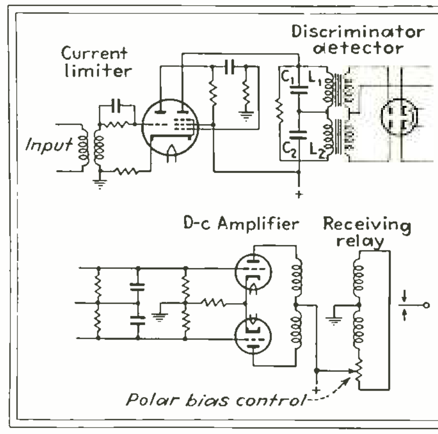

Fig. 2—The frequency-modulation receiver

In practice, L_1L_2 and C_2 are so proportioned that $f_n - f_m = f_s - f_n = 70$ cps. The network N is used to restrict the rate of change of the control circuit voltage to an approximately sinusoidal shape at the maximum modulation frequency. Failure to provide this network introduces a distortion component in the received signal.

The receiving circuit is shown in Fig. 2. L_1C_1 and L_2C_2 are tuned respectively to the marking and spacing frequencies. The current limiter uses regenerative action to secure a high order of sensitivity. The two discriminator output voltages, after being separately detected, are differentially added before being applied to a d-c power amplifier stage to operate the receiving relay.

A comparison between amplitude and frequency modulated systems shows that the latter is far superior in many respects. Using the f-m system, the signal loss at the point of greatest susceptibility to single-frequency crosstalk decreases 8.3 decibels from the maximum loss with amplitude modulation for interference of this character. Signal loss caused by fluctuating noise produced by batteries, shot effect, etc., is reduced about 9 decibels, and losses caused by impulse noise produced by lightning are reduced by about 10.5 decibels; both for large signal-to-noise ratios.

How to build an inexpensive **Tube Conditioner***

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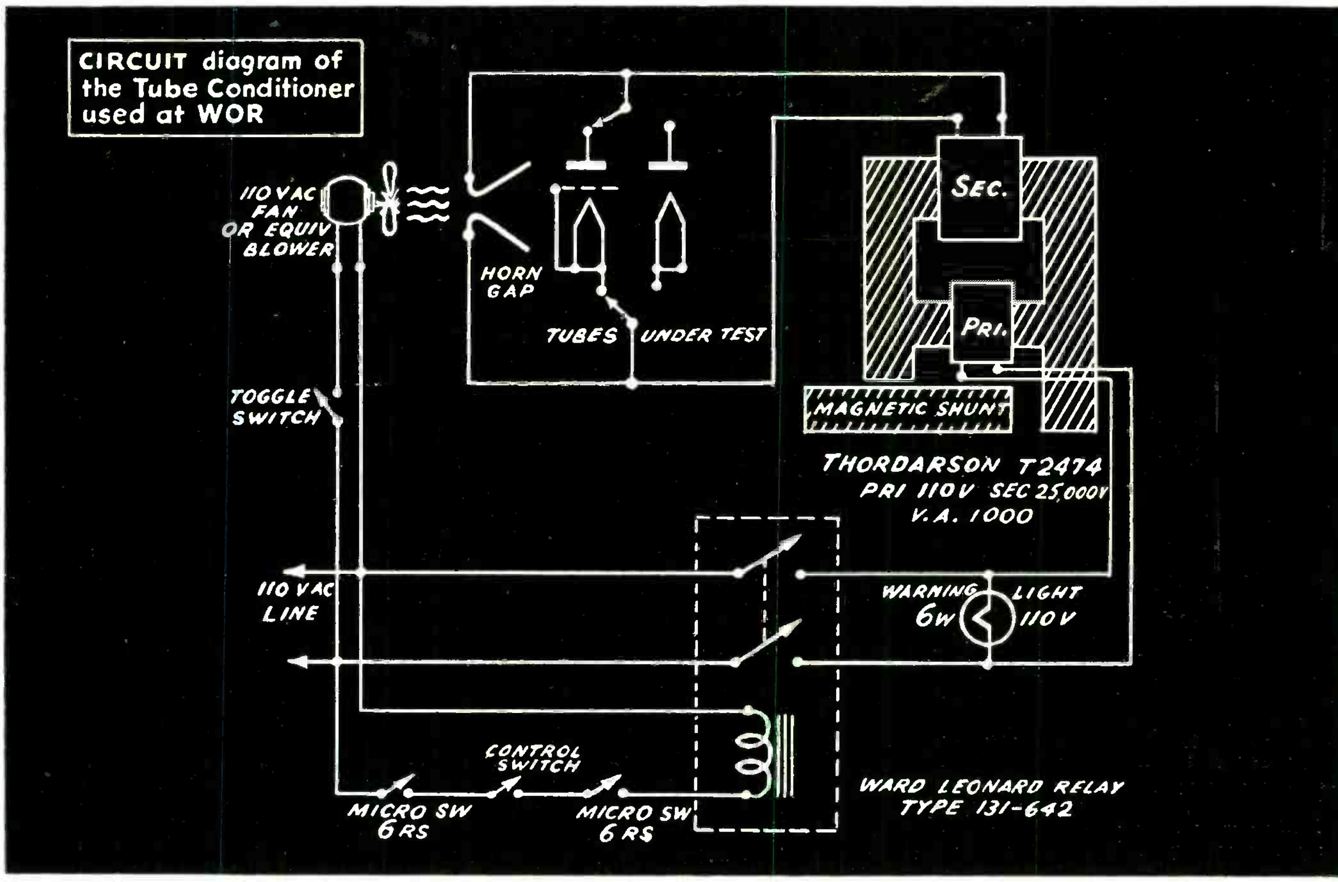

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You bet I want a reprint of the article on How to Recondition Vacuum Tubes.

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TUBES

Characteristics of cathode-ray and television picture tubes are presented this month. No new receiving tube types were registered by the RMA Data Bureau during February 1942

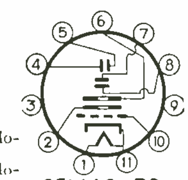
Cathode-Ray Tubes

Type 2514D9

DuMont

CATHODE-RAY tube; medium-persistence, white fluorescent screen; electrostatic focus and deflection; usual application —oscillographic, high voltage, and television; diameter 9 inches; 11-pin magnal base.

E_f = 6.3 v
I_f = 0.8 amp
E (anode 1) = 2000 v (max)
E (anode 2) = 5000 v (max)
E (grid) for cutoff = − 75 v
E (intensifier) = 10,000 v
Deflection Factor
$D_1 - D_2$ = 21 v (d.c.)/kilovolt-inch
$D_3 - D_4$ = 20 v (d.c.)/kilovolt-inch



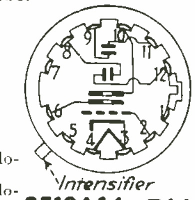
2514A9-B9
C9-D9

Type 2519A14

DuMont

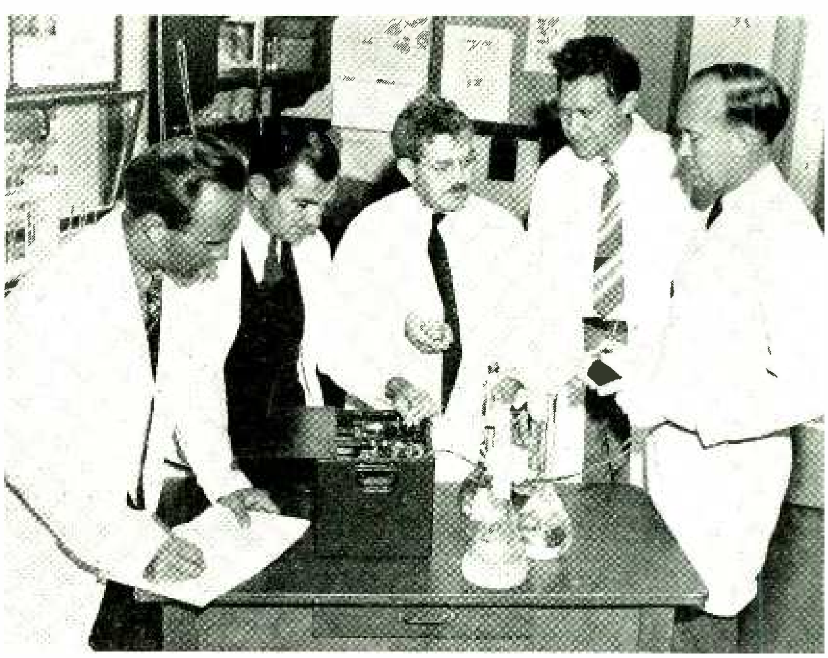
CATHODE-RAY tube; medium-persistence, green fluorescent screen; electrostatic focus and deflection; usual application —television; diameter 14 inches; 12-contact peripheral base.

E_f = 2.5 v
I_f = 2.1 amps
E (anode 1) = 2000 v (max)
E (anode 2) = 6000 v (max)
E (grid) for cutoff = − 75 v
E (intensifier) = 12,000 v
Deflection Factor
$D_1 - D_2$ = 17 v (d.c.) kilovolt-inch
$D_3 - D_4$ = 15 v (d.c.)/kilovolt-inch



2519A14-B14
C14-D14

RESEARCH SCIENTISTS FORM FIVE-MAN TEAM



Made possible by a $250,000 gift to the University of California, a modern research plan establishes the first medical-physics laboratory in the world, representing a union of physics, medicine, chemistry, bacteriology, biology and genetics, governed by a five-man team of scientists. Leader of the group is Dr. John H. Lawrence in charge of medical investigation with the Cyclotron developed by his Nobel prize winning brother, Dr. E. O. Lawrence. Left to right, the five-man research team is composed of Dr. Joseph G. Hamilton, medical chemist; Dr. Paul Aebersold, physicist; Dr. Robert F. Stone, radiologist; Dr. Alfred G. Marshak, animal biologist and genetist; and Dr. John H. Lawrence, clinical investigator in charge of medical work with the Cyclotron

AS THE MEASUREMENTS "PRESCRIBE"

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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.

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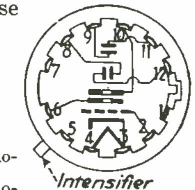
DuMont

CATHODE-RAY tube; long-persistence, green fluorescent screen, electrostatic focus and deflection; usual application —television; diameter 14 inches; 12-contact peripheral base

E_f = 2.5 v
I_f = 2.1 amps
E (anode 1) = 2000 v (max)
E (anode 2) = 6000 v (max)
E (grid) for cutoff = − 75 v
E (intensifier) = 12,000 v
Deflection Factor
$D_1 - D_2$ = 17 v (d.c.)/kilo-volt-inch
$D_3 - D_4$ = 15 v (d.c.)/kilo-volt-inch

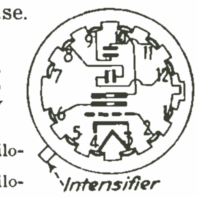


2519A14-B14 C14-D14

Type 25D19D14
DuMont

CATHODE-RAY tube; medium-persistence, white fluorescent screen; electrostatic focus and deflection; usual application —television; diameter 14 inches, 12-contact peripheral base.

E_f = 2.5 v
I_f = 2.1 amps
E (anode 1) = 2000 v (max)
E (anode 2) = 6000 v (max)
E (grid) for cutoff = − 75 v
E (intensifier) = 12,000 v
Deflection Factor
$D_1 - D_2$ = 17 v (d.c.)/kilo-volt-inch
$D_3 - D_4$ = 15 v (d.c.)/kilo-volt-inch

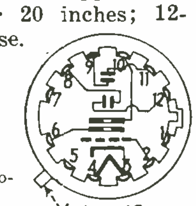


2519A14-B14 C14-D14

Type 2520C20
DuMont

CATHODE-RAY tube; short-persistence, blue fluorescent screen; electrostatic focus and deflection; usual application —television; diameter 20 inches; 12-contact peripheral base.

E_f = 2.5 v
I_f = 2.1 amps
E (anode 1) = 2000 v (max)
E (anode 2) = 6000 v (max)
E (grid) for cutoff = − 75 v
E (intensifier) = 12,000 v
Deflection Factor
$D_1 - D_2$ = 15 v (d.c.)/kilo-volt-inch
$D_3 - D_4$ = 14 v (d.c.)/kilo-volt-inch

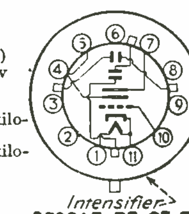


2520A20-B20 C20-D20

Type 2529A5
DuMont

CATHODE-RAY tube; medium-persistence, green fluorescent screen; electrostatic focus and deflection; usual application —oscillographic, high frequency; diameter 5 inches, 11-pin magnal base.

E_f = 6.3 v
I_f = 0.8 amp
E (anode 1) = 600 v (max)
E (anode 2) = 2000 v (max)
E (grid) for cutoff = − 50 v
E (intensifier) = 6000 v
Deflection Factor
$D_1 - D_2$ = 28 v (d.c.)/kilo-volt-inch
$D_3 - D_4$ = 25 v (d.c.)/kilo-volt-inch



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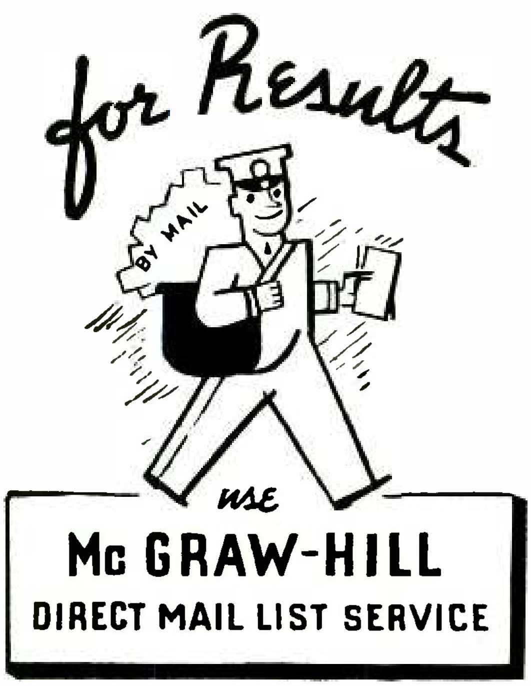

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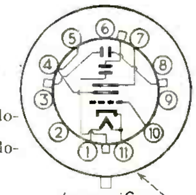
DuMont

CATHODE-RAY tube; long-persistence, green fluorescent screen; electrostatic focus and deflection; usual application —oscillographic, high frequency; diameter 5 inches, 11-pin magnal base.

E_f = 6.3 v
I_f = 0.8 amp
E (anode 1) = 600 v (max)
E (anode 2) = 2000 v (max)
E (grid) for cutoff = − 50 v
E (intensifier) = 6000 v
Deflection Factor
$D_1 - D_2$ = 28 v (d.c.)/kilo-volt-inch
$D_3 - D_4$ = 25 v (d.c.)/kilo-volt-inch



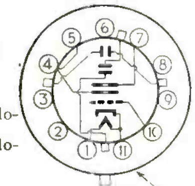
Intensifier
2529A5-B5-C5-D5

Type 2529C5

DuMont

CATHODE-RAY tube; short-persistence, focus and deflection; usual application focus and deflection; usual application —oscillographic, high frequency; diameter 5 inches, 11-pin magnal base.

E_f = 6.3 v
I_f = 0.8 amp
E (anode 1) = 600 v (max)
E (anode 2) = 2000 v (max)
E (grid) for cutoff = − 50 v
E (intensifier) = 6000 v
Deflection Factor
$D_1 - D_2$ = 28 v (d.c.)/kilo-volt-inch
$D_3 - D_4$ = 25 v (d.c.)/kilo-volt-inch



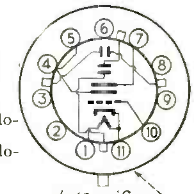
Intensifier
2529A5-B5-C5-D5

Type 2529D5

DuMont

CATHODE-RAY tube; medium-persistence, white fluorescent screen; electrostatic focus and deflection; usual application —oscillographic, high frequency; diameter 5 inches; 11-pin magnal base.

E_f = 6.3 v
I_f = 0.8 amp
E (anode 1) = 600 v (max)
E (anode 2) = 2000 v (max)
E (grid) for cutoff = − 50 v
E (intensifier) = 2000 v
Deflection Factor
$D_1 - D_2$ = 28 v (d.c.)/kilo-volt-inch
$D_3 - D_4$ = 25 v (d.c.)/kilo-volt-inch



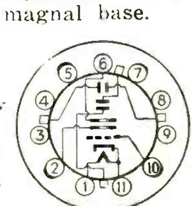
Intensifier
2529A5-B5-C5-D5

Type 2530A9

DuMont

CATHODE-RAY tube; medium-persistence, green fluorescent screen; electrostatic focus and deflection; usual application, oscillographic, high-frequency; diameter 9 inches; 11-pin magnal base.

E_f = 6.3 v
I_f = 0.6 amp
E (anode 1) = 2000 v
E (anode 2) = 5000 v
E (grid) for cutoff = − 125 v
E (intensifier) = 10,000 v
Deflection Factor
$D_1 - D_2$ = 36 v(d.c.)/kilo-volt-inch
$D_3 - D_4$ = 34 v(d.c.)/kilo-volt-inch



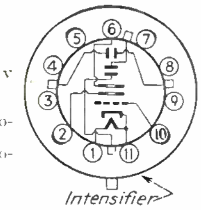
Intensifier
2930A9-B9-C9-D9

Type 2530B9

DuMont

CATHODE-RAY tube; long-persistence, green fluorescent screen; electrostatic focus and deflection; usual application, oscillographic and high frequency; diameter 9 inches; 11-pin magnal base.

E_f = 6.3 v
I_f = 0.6 amp
E (anode 1) = 2000 v
E (anode 2) = 5000 v
E (grid) for cutoff = − 125 v
E (intensifier) = 10,000 v
Deflection Factor
$D_1 - D_2$ = 36 v (d.c.)/kilo-volt-inch
$D_3 - D_4$ = 34 v (d.c.)/kilo-volt-inch



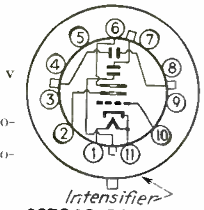
2930A9-B9-C9-D9

Type 2530C9

DuMont

CATHODE-RAY tube, short-persistence, blue fluorescent screen; electrostatic focus and deflection; usual application, oscillographic and high frequency, diameter 9 inches, 11-pin magnal base.

E_f = 6.3 v
I_f = 0.6 amp
E (anode 1) = 2000 v
E (anode 2) = 5000 v
E (grid) for cutoff = − 125 v
E (intensifier) = 10,000 v
Deflection Factor
$D_1 - D_2$ = 36 v (d.c.)/kilo-volt-inch
$D_3 - D_4$ = 34 v (d.c.)/kilo-volt-inch



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ARMY WALKIE-TALKIE

A 7-lb. portable receiving and transmitting radio set, capable of sending voice and code in reconnoitering distances of about a mile, has been developed at Fort Ord, Calif., by Capt. Joseph W. Stilwell, who is shown with the apparatus. This new "walkie-talkie" is 16 lb. lighter than other models and is about fifteen times as expensive as other models

Engineering Conference

(*Continued from page 32*)

which were controversial or upon which data were lacking now being considered by the committee.

J. H. DeWitt, WSM, described the results of his experience with a studio-transmitter link operating in the u-h-f band. Such alternate circuits take on increased importance under present conditions. The terrain to be spanned presented a difficulty in the shape of a hill high enough to exclude a line-of-sight path from studio to transmitter building. Thus it was necessary to mount the receiving antenna at the top of the WSM tower and so an extensive study of the u-h-f antenna, transmission line and filter circuits was carried out. The 300-Mc transmitter used a concentric line for frequency control, which was found to give adequate stability due to careful design. The transmitting antenna consisted of a stacked dipole array with reflectors. Measurements made with an airplane showed that the field strength was relatively high at 2000 feet altitude but dropped below a useful level halfway down the WSM tower.

Experience gained in the use of this equipment and other considerations led to the design and construction of an f-m link at a frequency of about 150 Mc. An unusual feature of the transmitter was its 450 kc oscillator modulated with a reactance tube. The modulated carrier was then added to the output of a crystal-controlled oscillator running at 12.75 Mc in a mixer tube, to give a resultant frequency of 13.2 Mc. The latter was multiplied as necessary to the final carrier frequency. The system was said to have the advantages that the frequency-modulated oscillator could be built for greater stability at the low frequency used, and any frequency variation would be an extremely small fraction of the output frequency even after multiplication.

The antenna used comprised stacked folded dipoles, with reflectors, arranged four high. Both reflector and antennas were supported without insulators, and were constructed from standard fittings. Folded dipoles offered greater impedance than simple dipoles, thus facilitating operation in parallel on relatively high impedance lines.

Experience with this system shows that the receiving antenna location should be picked with great care to be in an area where the signal is as strong as possible and uniform; the largest signal strength possible at the receiver should be sought; and antennas should be used which are designed for maximum gain and directivity.

Data were presented upon the effect of an airplane crossing over the line of the studio-transmitter link. First small and rapid oscillations of the signal strength were observed; these increased in amplitude and slowed down in time as the plane approached the transmission path, and the whole action was reversed as the plane flew beyond the line of transmission.

The Alert calling system was described by A. F. Van Dyck and S. W. Seeley, RCA License Laboratory. The technical features, including the generation and reception of the subaudible frequencies for its operation were considered and uses of the device were described and demonstrated with the cooperation of a local broadcasting station, WCOL.

In addition to the sessions of the campus of The Ohio State University, two evening meetings were held. The first featured a popular scientific lecture by Dr. Phillips Thomas, Westinghouse Electric and Manufacturing Company. On Thursday evening the annual Banquet was held at the Fort Hayes Hotel, with nearly 200 attending.

• • •

HIGH SCHOOL STUDENTS BROADCAST

The students of Lafayette High School broadcasted an American history story in accordance with the literature they are studying. The school station is installed in the Brooklyn Technical High School, but the students are from several different high schools

RECENT U.S. PATENTS

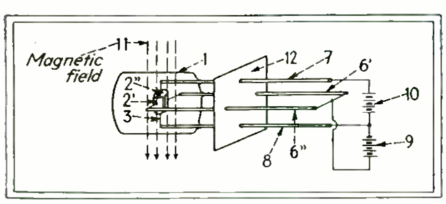
Each week the United States Patent Office issues grants to many hundreds of inventions that pass the acid test of that office. A few of those relating to electronics are reviewed here

High Frequency Systems

High Frequency Generator. A tube connected to an elongated conductive shell having a conductive closure at each end, a conductive linear member coaxially secured at one end to each closure in conductive relation therewith, one of the members being longer than the other; a coaxial resonant line made up of capacity, etc. The electrical length of the shell and the capacitively loaded linear members is substantially one-half wavelength of the desired frequency while the physical length is much less. H. W. Kohler, Washington, D. C. Mar. 16, 1940. No. 2,272,211.

Relay System. A relay station made up of a receiving antenna and a transmitting antenna with amplifying means between and a metal shield between antennas for preventing feedback; antennas and amplifier supported above ground on a conductive support, connected to the shield. A tuned circuit connected between shield and ground maintains the shield at zero radio frequency potentials. Harry Tunick, RCA. May 20, 1939. No. 2,272,312.

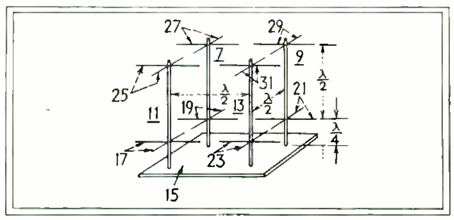
U-H-F-Tuning System. A metallic shield with holes therein through which connections to the tube elements protrude. Shield is adjustable along the



leads so that the shield and the leads constitute the sole high-frequency tuned circuit of the system. A. G. Clavier and E. Rostás, International Standard Electric Corp. Apr. 1, 1939. No. 2,272,599.

Turnstile Antenna. Four radiator elements located in the same plane and attached at 90 deg. intervals to a support, two phase splitting circuits connected between adajacent radiator elements to apply currents of quadrature phase to radiator elements, and a pair of transmission lines for applying currents of opposite phase to the phase splitting circuits. Jesse Epstein, RCA. No. 2,275,030. Oct. 17, 1940.

Directional Antenna. In a marker system for radiating a field in a vertical direction, several turnstile antennas spaced a half wavelength apart, each antenna comprising several vertically disposed pairs of crossed horizontal dipoles, and means for establishing a



phase quadrature relation between energizing currents for upper and lower dipoles of each turnstile lying in one plane with respect to energizing currents for dipoles lying in a plane perpendicular thereto. E. A. Laport, RCA. Aug. 30, 1940. No. 2,270,130.

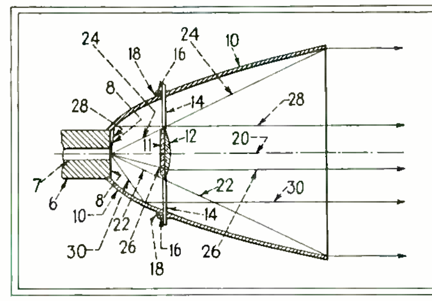
Amplifier. A connection from the center of a filament of an amplifier tube to a point of zero r-f potential, and means associated with the connection for series tuning the reactance between the center of the filament and the point of zero potential to provide a path of low impedance. O. E. Dow, RCA. June 30, 1939. No. 2,272,060.

Relay System. A receiver, an amplifier and a transmitter so located that a small amount of undesirable feedback occurs from the transmitter to the receiver over several paths around the edges of a directive structure. The reflectors have their edges so constructed that energy fed back over some of the paths neutralizes the energy fed back over others of the paths. H. O. Peterson, RCA. June 30, 1939. No. 2,270,965.

Generator. Means for producing ultrashort waves by projecting toward each other particles charged with different potentials to cause them to meet at a common point. Fritz Schroter, Telefunken. Jan. 25, 1941. No. 2,270,479.

Amplifier. A multistage u-h-f amplifier using tuned coaxial lines as coupling impedances between stages with means for tuning all stages simultaneously. R. W George, RCA. Mar. 1, 1939. No. 2,272,062.

Wave Guide System. Means for producing a unidirective beam of energy comprising a cylindrical wave guide having an internal diameter approximately 0.7 times the wavelength to be used, a paraboloid reflector having a



diameter at its normal focal plane large with respect to the internal diameter of the wave guide, and a focusing lens having a diameter substantially equal to the diameter of the reflector at its normal focal plane. R. S. Ohl, BTL, Inc. Sept. 7, 1939. No. 2,273,447.

Non-Communication Applications

Measurements. Apparatus responsive to the volt-amperes in an a-c circuit. L. Michaelis and D. M. Davis, G. E. Co. Dec. 6, 1939. No. 2,275,860.

Frequency Indicator. For indicating the frequency of a low frequency source containing several other frequencies, a method comprising filtering for selecting the low frequency, a pulse generator responsive to the selected frequency, a variable speed driving means of high speed stability, and a second impulse generator having a pulse frequency proportional solely to the speed of the variable speed means. C. A. Lovell, BTL, Inc. Dec. 2, 1938. No. 2,273,532.

Measuring and Control Apparatus

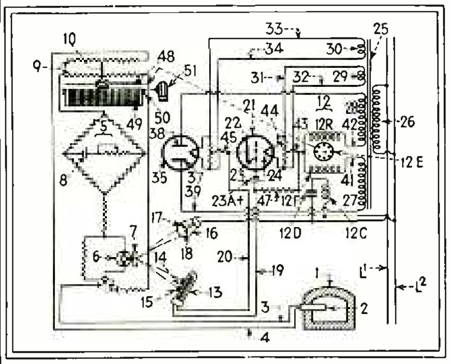
Resistance Measurement. Voltage across a lamp is sufficiently low so that the lamp is not illuminated. A means dependent upon the magnitude of the unknown resistance decreases the grid bias of an amplifier to raise the voltage across the lamp until it illuminates. W. J. Delmhorst, Jersey City. Sept. 19, 1939. No. 2,272,239.

Defect Location. Use of an amplifier for testing rails for defects. A. E. F. Billstein, Pennsylvania Railroad Co. No. 2,276,011. Nov. 9, 1940.

Burner Control. Method for controlling the supply of fuel to a burner, involving a four element tube. W. F. Scanlan, Chicago. Mar. 26, 1941. No. 2,274,384.

Photometric Analysis. A recording apparatus for recording variations in a process producing a product having several components, one of which is characterized by a strong absorption band in the infrared spectrum, by transforming variations of concentration of the compounds into electric currents and means of comparing an unabsorbed infrared beam with a beam which has passed through the absorbing material, producing electric currents from these infrared beams which actuate a galvanometer, the movement of the mirror of which is proportional to a function of the difference in infrared energies striking the two detectors. Urner Liddel and R. B. Barnes, American Cyanamid Co. Aug. 22, 1939. No. 2,269,674. No. 2,273,356, A. L. Holven and T. R. Gillett, Crockett, Calif. is on a somewhat similar subject comprising a photo-electric light absorption measuring device.

Measuring Apparatus. A reversible motor driven by rectified current in response to variations in light intensity



and direction falling on a photoelectric cell. T. R. Harrison, Brown Instrument Co. Dec. 23, 1937. No. 2,273,191.

Dielectric Study. Method of determining the power factor of a capacitor by applying an alternating emf to the capacitor and removing the out-of-phase component and measuring the in-phase component of the current. E. H. Povey and E. A. Walker, Doble Engineering Co. No. 2,273,066. Apr. 26, 1938.

Condenser Analyzer. An instrument for testing a condenser for open, intermittent and shorted connection, comprising an electron tube oscillator. A continuation of oscillation denotes an open connection and a flickering of an indicator between balance and unbalance denote an intermittent connection. J. H. Fisher, Solar Mfg. Co. Mar. 6, 1940. No. 2,271,292.

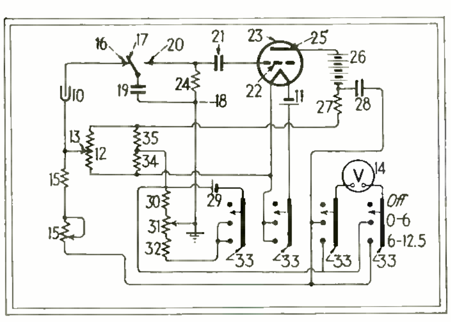
Welding System. No. 2,269,460 to Hans Klemperer, Raytheon Mfg. Co., Feb. 5, 1940, a condenser welding system; No. 2,275,419 to O. R. Carpenter, The Babcock & Wilcox Co., Mar. 15, 1938, involving tubes in a method of manufacturing composite clad plate; and No. 2,275,948 to J. W. Dawson, Westinghouse E&M. Co., Jan. 28, 1938, spot welding control means.

Measuring Device. A single phase induction motor having field poles and coils so arranged that the motor is normally not self-starting but is self-stopping, and means responsive to input energy which shifts the phase of a part of the motor field, thereby starting the motor which rebalances a network so that the motor comes to rest at a position commensurate with the value of the input energy being measured. S. Bagno, Kurman Electric Co. June 22, 1938. No. 2,270,991.

Power Applications. Patents Nos. 2,274,364 and 2,274,365 to P. C. Gardiner, G. E. Co. Both of March 8, 1940, on electron tube means of controlling a direct current voltage. No. 2,275,165, Charles Wasserman, Baltimore, Md., Jan. 27, 1939, is for a system of controlling the voltage of a dynamo-electric machine. No. 2,270,894 to W. P. Overbeck, Raytheon Mfg. Co., Jan. 29, 1938, and 2,271,738, Feb. 27, 1939, to M. F. Leftwich, Charlotte, N. C. are for electron tube systems for controlling battery charging. Nos. 2,275,941; 2,275,971 and 2,276,033 all to Westinghouse E&M Co. involve the application of electron tubes to pilot channel protective relaying systems.

Air Speed Indicator. Device for indicating velocity including a source of sound waves, a pair of pickup devices responsive to the sound waves, and means for indicating the velocity of the medium passing the source as a function of the phase of the sound waves. Further, means for changing the frequency of the sound as a function of temperature of the medium to thereby indicate the velocity within limits independent of said temperature. Irving Wolff, RCA. May 31, 1939. No. 2,274,262.

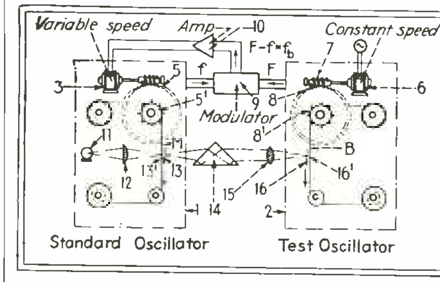
Hydrogen Ion Indicator. Apparatus for indicating a balance between a pair of opposable electric potential sources, one of which is variable in magnitude, by impressing the potential difference



on a condenser and comparing this potential to the potential of a second condenser connected in the output of an amplifier. K. R. Eldredge, Berkeley, Calif. Apr. 13, 1940. No. 2,271,478.

Registering Device. Method for insuring proper registration on a printing press. Hermann Kott, Speedry Gravure Corp. Sept. 6, 1939. No. 2,272,376.

Scale Calibration. In a system for calibrating an instrument having a blank scale, a standard instrument including a master scale, means for varying the magnitude of a condition represented by one of the instruments, and



means for inter-connecting the instruments so that the instrument to be calibrated represents a condition of corresponding magnitude whereby the second scale is continuously calibrated. W. J. Means and T. Slonczewski, BTL, Inc. Sept. 28, 1938. No. 2,275,977.

Temperature Control. Use of a Wheatstone bridge with a resistance in one of the arms subject to temperature changes, and means for utilizing the variable bridge output to control the supply of heat. A. W. Krause, Aug. 27, 1937. No. 2,275,368.

Reeling System. Electron tube circuit responsive to the variation in the tension of a material being reeled and means for controlling a motor thereby to counteract the variation in tension. C. A. Bailey, G. E. Co. Dec. 16, 1939. No. 2,275,192.

Time Recording Machine. Method for stamping a record when a light beam is interrupted as by placing a record sheet between a light source and a phototube. H. N. Deane, E. M. Pritchard and E. W. Sherman. Simplex Time Recorder Co. March 5, 1940. No. 2,-271,914.

Inspection System. Use of lenses to project radiation from an article being inspected onto areas of high sensitivity and for effecting a relative movement in a fixed direction between the article and the lenses. C. E. Smith, Westinghouse E&M Co. Feb. 29, 1940. No. 2,272,097.

Color Reproduction. Taking several color separation photographs of the same subject, modulating several electric currents in accordance with the variations in tone of the different color-separation photographs and using electric currents to control a single recording machine. A. C. Hardy, Interchemical Corp. Sept. 4, 1936. No. 2,272,638.

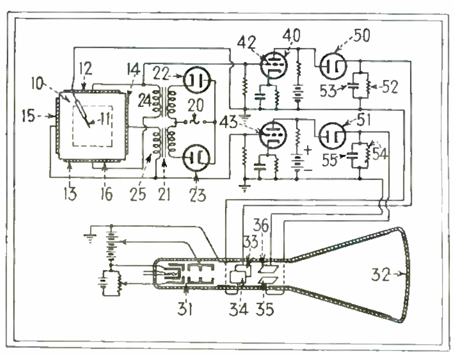
Induction Heating. Transformer having secondary cut into segments with an inductor element at each cut, said inductors joining the segments to provide a continuous heating effect. F. S. Denneen, and W. C. Dunn, Ohio Crankshaft Co. No. 2, 271,916. Aug. 2, 1940.

Frequency Meter. A tuned circuit energized by the alternating current circuit, the frequency of which is to be measured, the power factor of said single tuned circuit changing with the frequency, and tube apparatus for measuring the power factor of the tuned circuit, including an instrument calibrated in terms of frequency. T. A. Rich, G. E. Co. July 13, 1940. No. 2,271,991.

Musical Instrument. A device for transposing music to sound in keys other than that in which it is written, comprising rotating tone generators, speed control means for quickly and accurately changing the speed of the system throughout a number of predetermined fixed ratios. S. T. Fisher, WECo. Oct. 15, 1940. No. 2,273,768.

Hemadynamometer. A pneumatic arm-bandage, a hermetically closed chamber, etc., and means for applying the measurements of pressure to an amplifier and an oscillograph. Hans Gerdien, Siemens & Halske. Feb. 24, 1938. No. 2,272,836.

Telautograph System. A resistance tablet having substantially uniform lateral resistance over an exposed area,



amplifiers, a cathode-ray tube, etc. H. C. Moodey, RCA. Dec. 27, 1940. No. 2,269,599.

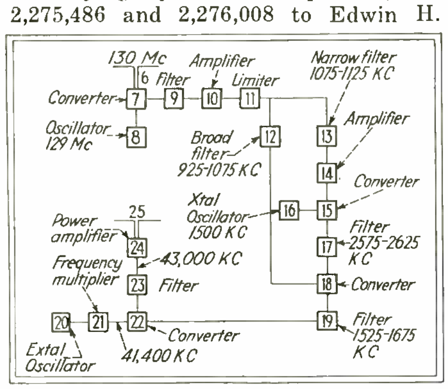
Signaling System. An electro-acoustic device for use by vehicles prior to overtaking one another, comprising a biased rectifier to eliminate noise beyond a certain point and means comprising a microphone having a resonant range for frequency ranges characteristic of a horn signal for obtaining selective reception of characteristic frequency signals. Ommo Schmidt, Stuttgart, Germany. Mar. 5, 1940. No. 2,275,161.

Frequency Modulation

Monitor. Method of visually indicating several frequency components of a frequency modulated wave by generating a second wave having a mid-frequency differing from that of the frequency modulated wave by a given intermediate frequency, automatically varying with frequency of the second wave above and below its mid-frequency in a linear manner, beating the second wave of varying frequency with the frequency modulated wave to produce a series of beat frequencies spaced apart in accordance with the frequency component of the frequency modulated wave. R. J. Pieracci, Cedar Rapids, Iowa. Jan. 8, 1941. No. 2,269,126. See also No. 2,272,768 to H. M. Crosby, G. E. Co. on a method of analyzing frequency characteristics of electrical waves whose frequency is varied over a band of frequencies as a function of modulating potentials by means of a cathode-ray tube.

Communication System. Method of signalling by frequency modulation from one station to another station which is receiving signals from a third station having the same carrier frequency as that transmitted by said one station and having an intensity more than twice as great as the intensity of the signals received from the first station by frequency modulating the carrier wave of one station by an amount greater than the frequency modulation of the third station and at a rate greater than the rate of frequency modulation of the signals from the third station. Hans Roder, G.E. Co. Nov. 12, 1938. No. 2,270,899.

Relaying System. Two patents, No. 2,275,486 and 2,276,008 to Edwin H.



Armstrong, for relaying frequency modulated signals.

Detector. In a frequency modulation detector, means to produce a voltage in the circuit whose phase varies with the frequency variations. W. v. B. Roberts, RCA, Oct. 16, 1940. No. 2,273,144. See also No. 2,273,771 to Seymour Hunt, RCA. April 10, 1941, on a frequency modulated carrier detector.

Direction and Location Indicators

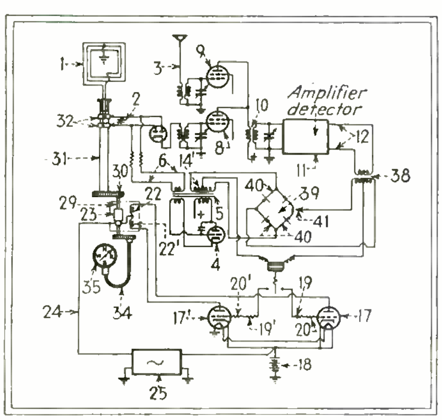
Course Indicator. A device for indicating visually the deviation from a radio course of the complementary signal type which includes receiving the signals, transforming them into impulse signal combinations with the relative polarity of the impulse signals dependent upon the direction of deviation. E. H. Hugenholtz, RCA. Nov. 16, 1939. No. 2,275,298.

Direction Finder. A directive antenna, a second directive antenna angularly disposed with respect to the first antenna and a non-directional antenna together with radio receiver and a switching means for combining in successive order the currents of one of said directive antenna with the currents of the non-directive antenna. G. B. Hagen, Telefunken. Feb. 7, 1939. No. 2,275,296.

Navigation System. Transmitting an unmodulated radio frequency wave whose carrier frequency varies periodically within predetermined limits, the rate of carrier frequency variation being predetermined and the limits of frequency variation being characteristic for each of several stations, all of which operate within a given frequency band. Visual means for individually and simultaneously indicating within the frequency spectrum the respective limits of frequency variations of each of the several signals. Marcel Wallace, Panoramic Radio Corp. Apr. 26, 1938. No. 2,273,914.

Distance Determination. Means of frequency modulating a wave and for receiving the wave after reflection from an object whose distance is to be determined by converting the received frequency modulated wave into an amplitude modulated wave whereby the distance of the object is a function of the amplitude of the demodulated wave. M. G. Crosby, RCA. Oct. 25, 1939. No. 2,268,643.

Radio Compass. An angularly movable directional antenna moved by a motor with a pair of reversing field windings and a radio receiver to regulate the direction and speed of operation of the motor. A. H. Lamb, Weston Elec. Inst. Corp. Oct. 23, 1939. No. 2,276,235.



Angle Determination. A method of determining with a loop antenna the vertical angles of incidence of energy waves having components of the magnetic flux polarized vertically and horizontally in the plane or front of propagation of the wave. W. L. Clemmer, Monroe, Wis. May 26, 1937. No. 2,269,437.

Non-metal Shields

(Continued from page 33)

small in gauge, is bent spring fashion to the graphited surface in question and cemented in position with the heavy dispersion. A spot of nitro-cellulose varnish applied over the dried globule further aids in strengthening the connection.

Many experimenters currently apply colloidal-graphited water to the porcelain tower constructions and non-conducting high vacuum parts of electrostatic generators as a shield against radial fields. Inflated rubber inner tubes or similar loop constructions of neutron generators are also protected in this way. These and similar practices common to recent physical investigations substantiate the propriety of the foregoing suggestions for shielding and in addition suggest that both glass and rubber tubing, treated in this way, may conceivably assure an effective substitute for tubular metal shields. The minute graphite particles assist in stopping microscopic glass cavities—a feature of practical value when high vacuums are also involved; and, in the case of rubber, do not impair flexibility or produce a film susceptible to flaking. Should the two types of tubing require splicing, both the exterior of the larger tube and the interior throughout the length of the joint are coated to insure good electrical connection to the coated smaller tube. Grounding is accomplished with metal eyelets inserted in the walls of the rubber tube, and with the lead embedded or sealed by heating into the glass tubing.

Research workers have long employed colloidal graphite films for guard rings whenever, in vacuum techniques, it was inconvenient to prepare metal ring strips that would properly fit the encased parts. Should metals become unavailable for this use, the practice of painting guard ring formations with aqueous colloidal graphite is worthy of more universal acceptance. Such rings can be employed on certain types of photo-electric cells and in all other instances where metal rings are customarily used. In fact, the facility with which graphite films are applied, together with their adhesive properties with respect to glass, porcelain, bakelite and enamel, frequently makes them much preferred to metal.

Permanent electrical contact to film rings is easily effected by coating over, or cementing by means of the concentrated product, the connecting wires previously sealed into the glass for this purpose. The difference in coefficients of expansion involved between the base material and the graphite is preferably kept as small as possible, even though, within limits, the graphite particles tend to slide over one another.

Methods of producing ionization and counting tubes, insulation-measuring contacts, thermopiles, and means of coating complicated form-joints of vacuum apparatus is too fully described elsewhere[1] to warrant treatment here. Methods of coating the interior of vacuum and cathode-ray tubes, making counter electrodes for photocells, and producing focusing anodes from non-conductive base materials is well known. It is sufficient to mention that all of these applications have, at some stage in their development, employed metals and metal foils, which have been, for various reasons, supplanted by graphite films. With an increasing number of non-conductors being presently demanded for new uses, normally served by conducting bodies, the electrical conductivity obtainable from graphite colloidally dispersed in suitable carriers will be more extensively utilized.

[1] B. H. Porter, "Research Applications of Colloidal Graphite," *Rev. Sci. Instruments*, 7, 101–106 (1936).

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MUSIC WHILE YOU WORK

Naval officials are convinced that men working in rhythm add to construction speed. Music pours through loud speakers placed throughout the battleship which is now under construction at an East coast shipyard. The Alabama is a sister ship to the U.S.S. North Carolina

NEWS OF THE INDUSTRY

Conversion of radio plants to war production in England. Year-end reports of producers show increases in sales and profits over previous year

Quotes

SIR CLIVE BAILLIEU, Director-general British Raw Material Mission and British Representative the Allied Joint Raw Materials Board, before a conference of business publishers and editors, February 13.

"The first industry we took over entirely was the automobile industry. During the first 11 months of the war, two-thirds of its capacity was converted to making Army trucks, scout cars, airplane engines and components. The other one-third was permitted to continue passenger car production in order to make use of parts and materials on hand and to hold the labor force in the plants pending complete conversion. In July, 1940, all new cars were reserved for essential civilian needs and exports were slashed 90 percent and later eliminated entirely. By August, 1940, 100 percent of the productive capacity of the automobile industry was engaged in war work. It still is and will continue to be until the war is over.

"The radio and television industry, which normally produces 2,000,000 sets annually, was converted with almost the same speed, and is now manufacturing radiolocation instruments, telecommunication apparatus and various secret devices. The industry now produces only 150,000 radio sets a year, and these are all for the Government. Women have been trained to do that work, thereby releasing skilled workers and technicians for other war work and for maintaining military communications. Since February, 1941, no radio tubes have been available for civilians, and consequently thousands of private sets now are useless."

Chairman James L. Fly of the FCC, "We have so many radio sets in this country if there is anything like an equitable distribution there should not be any difficulty for some years. We, both on the Commission and on the Defense Communications Board, feel that an adequate number of receiving sets is utterly essential."

Lee McCanne, Stromberg-Carlson, "Deliveries of radio sets will not cease automatically on April 22. In the first place, some chassis put into production on April 22 will not be set into cabinets with record changers for possibly two or three months beyond that date." Mr. McCanne stated before a meeting of the FM Broadcasters, Inc., that fully one-third and possibly more than one-half as many f-m sets would be made available in 1942 as in 1941. Stromberg-Carlson, who delivered 10 percent of all f-m sets sold by industry in 1941 will produce more in 1942. According to him General Electric deliveries in March, April, May and June will total about two-thirds as many as the company shipped during the height of the 1941 radio season. Zenith will deliver about as many sets as Stromberg-Carlson in 1942. Philco will ship as many f-m sets as they did in the last quarter of 1941 and will then cease production. Capehart will ship as many as they did during the last quarter of 1941.

Charles E. Wilson, president of General Electric, "Electronics has been no gift. Then men of science learned its secrets and earned its blessing during decades of unremitting toil, patience, trial and error and brain work. The electronic tube, so innocent and mysterious to a layman's eyes, will touch you in the years to come wherever and however you live."

Production

TO BETTER MEET SOME of the demands for industrial paging systems, intercommunications systems and various special equipment for the Army and Navy departments, Mr. Floyd W. Bell, president of Bell Sound Systems, Inc., Columbus, Ohio, reports that his company is now completing an addition to the present plant which will approximately double their previous production capacity. Installation of all necessary equipment is being completed and the additional capacity will be put into immediate production.

A broad line of aircraft control devices is now available from General Electric, according to G. R. Prout, Manager of G. E.'s industrial control division. Included in the line are solenoids, relays, contactors, and pressure and limit switches, some of which are also applicable to tank and other installations.

A significant part of the company's industrial control engineering, production, and research facilities are being devoted to the new line. The latest advances in metals and fabrication are being used in the design and production of aircraft control devices to assure minimum weight and size for operation at great altitudes under wide ranges of temperature and very severe vibration conditions.

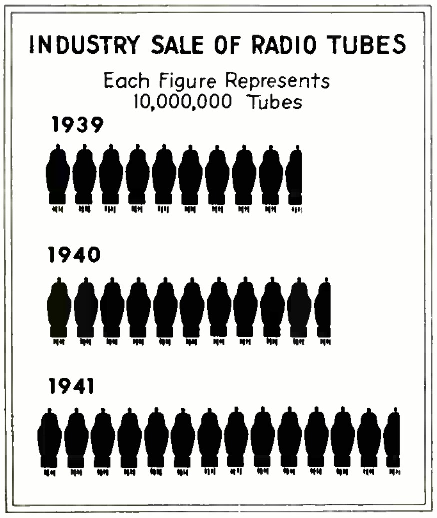
Victor J. Andrew Company, formerly at 6429 South Lavergne Ave., Chicago, has moved offices and factory to larger quarters at 363 East 75th Street, Chicago. Technical Appliance Corporation has moved into larger quarters at 516 West 34th Street, New York City, where they will have 20,000 square feet of floor space. Tech Laboratories, 7 Lincoln Street, Jersey City, has completed an expansion to their plant which doubles present space. With additional equipment and by dint of a night shift, Tech Laboratories expect to triple present output. Electronic Transformer Company has moved to 515 West 29th Street, New York City, where 10 times their old area will be available. Acoustics Division, Burgess Battery Company is now at 2815 West Roscoe Street, Chicago.

Facts and Figures

Hygrade Sylvania—Sales in 1941 increased 43 percent over 1940; net in-

Five Graces Illustrate Five Senses

Electronic instruments can see, hear, taste, sense by touch and smell. Devices which have these characteristics are here dramatized in a picture taken at a recent G-E dinner



come after all charges and taxes was 21 percent greater than 1940. Late in the year increasing radio tube requirements for war purposes made necessary the construction of about 20,000 square feet of additional floor space for this purpose. Hygrade Sylvania continues to be second largest producer of radio tubes in this country. 1941 taxes amounted to $341.06 per employee.

Kellogg Switchboard and Supply—Net income for 1941, $564,000 compared to $303,000 in 1940. Because of the growth of the independent telephone industry due to war conditions, this company experienced a vast growth in business which, added to the increasing share of plant activities resulting from Government requirements, continues to keep company at full speed.

Crocker Wheeler—Orders booked in 1941 were 233 percent over the previous year. Net income for the year was $731,562 compared to a deficit of $509,405 for the previous year.

Western Electric—Sales increased 60 percent over 1940; net earnings decreased from $32,787,000 in 1940 to $18,428,000 in 1941. Taxes increased from $14.8 million to $57 million. Nearly 40 percent of the value of the contracts secured by the company for war equipment was distributed to other companies on a sub-contract basis. Taxes in 1941 amounted to $1,078.48 per employee.

A T & T—About 1,360,000 telephones were added in 1940, 409,000 more than ever added before in one year; telephone conversations per day increased to 84,692,000, 5.3 million more than in 1940; one million miles of long distance circuits were added in 1941; 4000 miles of new cable, two-thirds under ground; 60 new transcontinental circuits. Taxes in 1941 amounted to nearly $15 per share of stock.

Speaking of the work of the Bell Laboratories, Mr. Gifford's annual statement has this paragraph:

"The science underlying electrical communication is at the very heart of modern war. It is responsible for plane locators, submarine detectors, gun-fire control systems, communication between planes moving in the air and tanks on the ground and ships at sea, and the means of quick control of vast numbers of men and units of equipment, as well as for the instantaneous communication in a war front stretching around the world. The contest between the scientists of free people and those of the Axis powers is one of the real battles of the war."

United States Steel—Loss of production resulting from strikes and work stoppages during 1941 was estimated by Chairman Olds as the equivalent of 300,000 tons of steel, 5,000,000 tons of coal and 19 days of ship production. Dollar volume of sales in 1941 was $1.6 billion. Wages and salaries amounted to about $1,647,000 for each day of 1941.

People

To DEVOTE HIS WHOLE time to his duties as chief-engineer of the Roller-Smith Company, J. D. Wood has resigned his position as president of that company. Reg Halladay, a director of the company since 1939, becomes president.

The honor of Fellow Grade in the Australian Institute of Radio Engineers has been conferred upon Virgil M. Graham, director of the radio tube application engineering department Hygrade Sylvania Corporation. Only 22 persons have been made Fellows of this organization.

Fellowships have been awarded by the Charles A. Coffin Foundation to the following men to work in the field of electronics:

Boris D. Abramis, University of California, to continue at same school the theoretical and experimental study of hyper-frequency wave guides; Robert W. Hull, Yale University, to study at Massachusetts Institute of Technology the chemical nature of thermionic emitters, such as oxide cathodes, and the effects of impurities on their properties; and Arthur E. Snowdon, Carnegie Institute of Technology, to study at same school the design of variable, smooth model transmission lines.

Henry C. Beal, manager of Western Electric Kearny works became engineer of manufacture for the company on March 1. George K. Throckmorton, for the past five years president of RCA Manufacturing Co., has been elected Chairman of the Executive Committee of the company. This committee will act in the intervals between meetings of the Board of Directors, thus keeping very closely in contact with the multitudinous activities of the company. Robert Shannon, former executive vice-president, becomes president of RCA Manufacturing.

Three years with WEAF, two years in transatlantic broadcasting with A.T.&T., seven years with the Bell Laboratories and six years in the field—such is the experience of D. B. McKey recently appointed general communications engineer in charge of broadcasting sales for Graybar Electric.

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

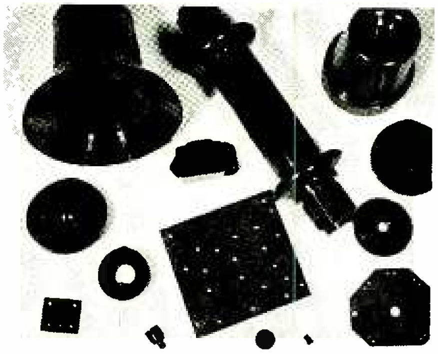
New U-H-F Insulation

DILECTENE IS A PURE, synthetic resin, red-brown in color, which contains no cellulose filling materials such as paper, fabric or wood flour. Since the presence of fillers is one of the primary causes of water absorption by plastics, their absence means that this material is highly resistant to moisture and consequently is very stable electrically. Electrical stability is also inherent in the material itself, as can be seen from the data presented in the accompanying table.

This new u-h-f insulation material is available in two grades: Dilectene 100 and Dilectene 160. The latter is a plasticized grade. The choice as to which grade is more suitable for a given application depends upon the requirements of the application itself. Where resistance to moisture and especially where tendency to resist cold flow is important, Dilectene 100 will be the better material. Where ease of working is the prime factor, Dilectene 160 should be used. The tabulated data given will generally indicate which of the two grades will be found more suitable.

Dilectene is available as sheets and as rods, but not as tubes. Sheets, which are supplied approximately 15 x 33 inches, are made in thicknesses from 1/16 to 1 inch. Rods under 1 inch in diameter are cut from sheet stock, and from 1 to 2 inches in diameter are molded. Rods of Dilectene 100 are available up to 1 inch diameter, rods of Dilectene 160 are made up to 2 inches diameter.

The material can be machined readily, if the special instructions given by the manufacturer are carried out. It is not recommended for punching. Sheet stock can be formed to simple shapes in molds.



Parts made of Dilectene

Because of present conditions, sample orders for Dilectene must be restricted. A 2 x 2 x 1/16 inch sample is available for inspection purposes and a sample 4x6x1/16 inches may be obtained for test. Address Continental-Diamond Fibre Company, 13 Chapel St., Newark, Delaware.

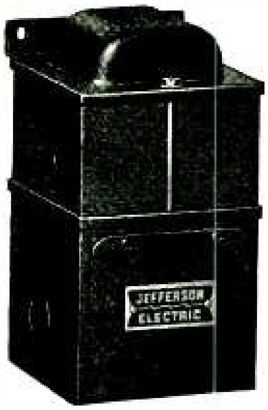
PROPERTIES OF DILECTENE*

	GRADE 100	GRADE 160
SPECIFIC GRAVITY	1.21	1.31
HARDNESS (Rockwell)		
Room temperature	M-110-125	M-110-115
90° C.	M-105-115	Too soft
Scleroscope	85-95	83-90
WATER ABSORPTION (3 x 1 inch, ASTM)		
24 hours	0.08	0.03
144 hours	0.21	0.06
TENSILE STRENGTH, psi	10,500	9,000
FLEXURAL STRENGTH, psi	20,000	16,000
MODULUS OF ELASTICITY IN FLEXURE, psi	7.4×10^5	1.8×10^6
COMPRESSION STRENGTH, flatwise, psi	20,000	20,000
IMPACT STRENGTH (½ x ½ inch specimen. Izod in ft. lbs. per inch width at notch, parallel to molding pressure)	0.33	0.38
COLD FLOW (Bell Labs. method. ½ x ½ x ⅜ inch pileup, % reduction in height after 24 hours)	0.17	16.35
DIELECTRIC STRENGTH (VPM)		
short time,		
as received	640	470
100° F.	600	570
150° F.	720	550
step by step,		
as received	410	430
100° F.	520	490
150° F.	650	480
INSULATION RESISTANCE (Megohms) (After 4 days at 90% RH, 95° F.)	96,000†	62,000‡
DISTORTION POINT (ASTM) (10 mil deflection under 5# load) °F.	210	125
LINEAR COEFFICIENT OF EXPANSION (Parts per million per °F. Specimen 18 inches long x 3 inches wide by ⅜ inches thick	30	30

* ⅛ inch sheet.
† Unaffected by continued exposure.
‡ Decreased by continued exposure.

Power Circuit Transformers

FOR OPERATING 115-VOLT DEVICES from 230, 460 or 575 volt power circuits, this line of indoor air-cooled circuit transformers have been extended to include capacities from 25 to 150 VA, inclusive. They are designed to provide 115-volts for operating lighting circuits, individual lighting for machine tools, welding machines, and other production machinery, as well as for electrical devices such as small motor-driven equipment, magnets, controls, relays, etc. Their design makes unnecessary the installation of complete low-voltage systems, saves copper and conduit, and the installation time and power costs are reduced.



The transformers are self-contained and are equipped with roomy wiring compartments for primary and sec-

ondary connections which have been insulated. Thirty-two volt secondaries are available for lower voltage lamps. These transformers are listed as standard by Underwriters' Laboratories, and are available from Jefferson Electric Company, Bellwood, Ill.

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G-E Products

Three new products are available from General Electric Co., Schenectady, N. Y.

LIGHT IN WEIGHT and small in size, a new line of variable-voltage autotransformers is designed to provide smooth, adjustable control of uninterrupted voltage at small amounts of power. This equipment is mechanically strong and is for use in factories, laboratories, schools, or for assembly with other equipment. Although designed for panel and bench mounting, they can be supplied without the enclosed cases for use with built-in applications. Other features of these autotransformers are

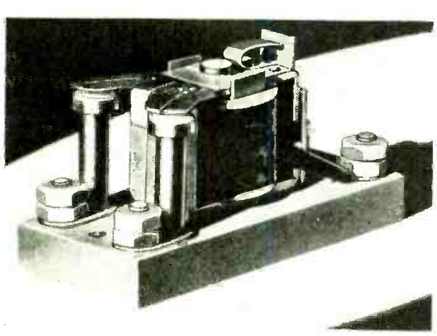
Adjustable-voltage autotransformer

high efficiency, good regulation throughout the entire range from no load to full load. Low input-power and low exciting current is made possible by a circular core, wound from low-loss silicon-steel strip to provide the magnetic circuit. The input circuit is connected to a winding made up to spaced turns of the round conductor insulated by tough Formex enamel. Connection to the output circuit is provided by a carbon brush which is kept in constant contact with a non-insulated portion of the inside of the winding. Each turn of the conductor gives a different step in voltage. By changing the position of the brush, the output voltage can be varied uniformly without interrupting the load current. The dial on the cover is calibrated to indicate from 0 to 100 percent of the maximum output voltage.

The other two new products are a contactor (for starting and stopping dynamotors) and a relay, designed as Model CR2791-A100A (for high altitudes and severe vibration conditions). Both of these items are for aircraft applications or for tank installations, and meet Government specifications, with mechanical frequency ratings of 5 to 55 cps at a maximum of 1/32-inch amplitude (1/16-inch total travel) in any direction. The single-pole, normally open contacts are designed to stay open when the coil is not energized and closed when the coil is energized, at rated voltage, even when subjected to linear acceleration of 10 times that of gravity.

D-c magnetic dynamotor contactor

The contactor is available for either 12 or 24-volt d-c circuits and measures approximately 2½ x 4 inches, weighs 2.3 lbs, and can be mounted in any position. It is totally enclosed, with the contacts in the upper compartment and the coil and plunger in the lower compartment. Copper-lead-alloy contact tips are used to assure good high current inrush performance. The contact rating is 50 amps on an 8-hour basis. Inrush current rating is 500 amps at 32-volts direct current. Coil wattage is 9.5. The contactor is suitable for use in ambient temperature ranging from 60 deg C to —40 deg C. All ferrous parts are treated to resist corrosion.



Model CR2791-A100A single-pole relay

The relay measures 3⅛x1⅝x1⅜ inches, and weighs 4½ ounces, and can also be mounted in any position. It may be used in altitudes from sea level to 40,000 ft and in ambient temperatures ranging from —40 deg C to 93⅓ deg. C. It is rated at 25 amps, at 12 or 24-volts. The coil operates at 1.2 watts.

Reference Recorder

CONTINUOUS RECORDING for a period of two hours may be made on a reference recorder which consists of four standard recording units within a single cabinet. The units are interconnected by means of a timing control system to provide the continuous operation of these turntables in sequence. The records may be changed at the operator's convenience any time during the two hour period. Each unit gives thirty minutes recording time (at 22 rpm and 300 grooves per inch) on each side of a 7-inch diameter disc. The

recording turntables operate at a constant angular velocity, and the recording is done by embossing the sound grooves into the recording material. The recording discs are a vinyl plastic 0.010 inches thick.

A playback head on each recording unit permits immediate playback of any portion of the disc by using a playback amplifier which is independent of the recording amplifier. There is also an independent playback turntable for playing records at any time completely independent of the recording process. SoundScriber Corp., 82 Audubon Street, New Haven, Conn.

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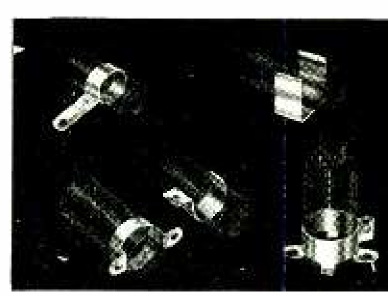
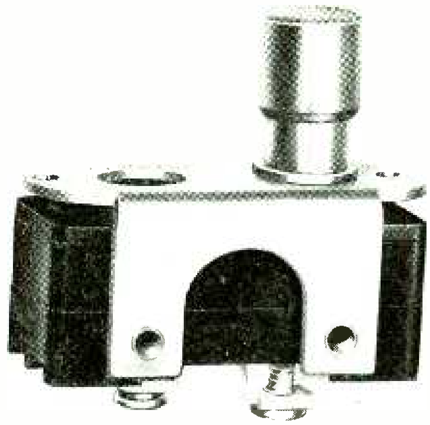


Any standard type of capacitor can be securely mounted in any desired position by the use of Cornell-Dubilier's universal mounting hardware. Each of the units shown is adaptable to a reasonable variety of capacitor diameters. Large and small mountings are also available. These may also be used to hold flashlight cells

Air Corps Type Switch

A NEW AIR CORPS TYPE switch assembly (designed to meet the requirements of U. S. Air Corps specification 94-32249) consists of a basic Mu-Switch with wide contact spacing mounted in a cadmium plated steel bracket to which is rigidly attached an over-travel plunger mechanism having a pre-travel of 1/16 inches minimum and an over-travel of 1/8 inches plus or minus 1/32 inches. The pressure required to operate this switch is 1 lb minimum and 8 lb maximum over the entire operating range. Electrical rating is 25 amps at 28 volts direct current (for elevations up to



40,000 ft), alternating current 17 amps at 125 volts and 8.5 amps at 250 volts alternating current non-inductive loads. Wiring connections can be supplied normally open, normally closed, and single pole, double throw. Special mounting lugs are provided on the bottom of the switch to allow the use of ring type wire connectors. The standard switch member can easily be replaced at a very much lower cost than with older assemblies. The characteristics and dimensions of the over-travel plunger mechanism can be changed to adapt this new switch assembly to practically any type of application.

Mu-Switch Corporation, Canton, Mass.

Arc Resistant Insulating Materials

A NEW TYPE OF LAMINATED insulating sheets, tubes and rods made with newly developed materials show, under test, approximately ten times the arc resistance that has been available in laminated insulating material. Under A.S.T.M. arc resistance test, this material is rated from 130 to 190 seconds in the fiberglass grade, in comparison to previous materials which have a rating of from 13 to 18 seconds. The material is available in bases of paper, canvas, muslin and fiberglass, and is made in sheets, tubes, rods and parts that may be machined from those forms.

Formica Insulation Company, Cincinnati, Ohio.

Counter

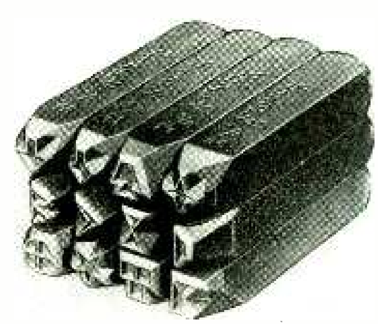
Monitor Model PDC-E electric counter will count objects passing on a conveyor or delivered from a machine. Electrically actuated, the counter may be located near to, or at a distance from, the objects being counted. Any number from 1 to 9999 can be quickly set up by simply turning knob pointers to the proper digits. When the count reaches the predetermined number set up, a control and signal circuit is closed (or opened). This circuit may be used to sound an alarm or operate a relay to perform any desired function. Counting ceases at the predetermined number until a reset lever is depressed which makes the instrument ready for a new count. To change the predetermined number, the knob pointers are turned to the proper digits before resetting. Resetting time is less than half a second.

The counters are actuated by any switch, relay or photoelectric unit with a closed period of 0.035 seconds or more, and an open period of 0.040 seconds or more.

Production Instrument Company, 710-12 W. Jackson Boulevard, Chicago, Ill.

Inspectors Stamps

One hundred new symbols of Inspectors Symbol Stamps have been designed in sharp and distinct markings. The simplicity of each symbol design gives maximum strength to each stamp and permits an included number to be used in the same operation in different inspection shifts. Each stamp is engraved for hard service, and the steel is tapered to the symbol so that an inspector can see where he is marking.

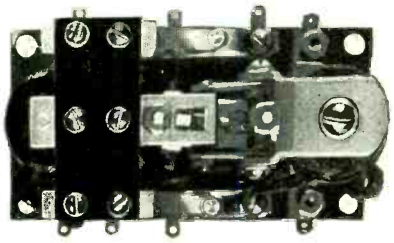


Where it is necessary to use the same symbol for the same operation by several inspectors, the stamps may be had with a number inside each symbol. On the front of each stamp there is a symbol identification number and size so that marks won't be stamped wrong side up, and also to assist in classifying the stamps. These stamps may be carried in the pocket of an inspector. Boxes are available to hold any number of stamps, at extra cost.

The Acromark Corp., 251 North Broad St., Elizabeth, N. J.

Electrical Reset Relay

ESPECIALLY DESIGNED FOR aviation purposes (and tested to withstand aircraft vibrations), is a new mechanical latch-in, electrical reset relay designated as Dunco Type CX3190, which operates from a brief impulse without the necessity of keeping the coils energized. Double-pole, double-throw contacts are rated at 6 amps at 12 or 24-volts, direct



current. An auxiliary contact breaks one coil circuit. All contacts are insulated from the frame for radio frequency. The coils are for d-c operation only. The unit weighs 7 lbs. and measures $3\frac{5}{16}$ x $1\frac{3}{4}$ x $1\frac{3}{8}$ inches. Other types of contact arrangements are also available.

Struthers Dunn, Inc., 1335 Cherry Street, Philadelphia, Pa.

Expanded Range Conductivity Bridge

SPECIFIC RESISTANCE VALUES up to 2.5 megohms, in six ranges, are obtained from a new Model RC-1-C conductivity bridge. It is a sturdy, simple, moderately-priced ($90) instrument for industrial and laboratory measurements. A six-point switch covers the six resistance ranges. A single dial control provides direct resistance readings in conjunction with the multiplying factor of the range switch. Accuracy is guaranteed within 1% (except for extreme ends of calibration) and is independent of line-voltage variations. The unit has an a-c bridge with a cathode-ray visual null indicator. The scale length of about 14 inches, or a total of 84 linear inches of calibration over the six ranges, permits close readings.

This instrument was originally developed for a manufacturer of organic chemicals but the new adaptation of the Wheatstone bridge permits wider application than the previous model which covered values up to 250,000 ohms in five ranges. If the instrument is used as a conductivity bridge in connection with the proper cell, it is sufficiently sensitive to detect impurities in distilled water in the order of 1 part of chloride ion in 2,000,000 parts of distilled water. It is also useful for measuring high conductivity solutions such as strong acids or alkalis. Its high range is suitable for working with very dilute aqueous electrolytes and organic liquids.

Industrial Instruments, Inc., 156 Culver Ave., Jersey City, N. J.

High-Powered Amplifier

Model E-75 high-powered amplifier features dual construction originally presented in the manufacturer's Deluxe Model EX-70. The new model is designed for multiple requirements for emergency sound equipment. It consists of two 35-watt amplifiers, each equipped with its own independent power supply rectifier, filter circuits and output channels. Each 35-watt channel has individual power controls and therefore can be used as a single 35-watt amplifier, or two 35-watt amplifiers, or both outputs can be paralleled to deliver a total of 70 watts for maximum high power.

It has three input channels (for two microphones and a phono-jack) and is equipped with a bass-treble tone control. It uses seventeen tubes and both output channels use double push-pull 6L6 circuits with inverse feedback and separate fixed bias. Each output provides tapped terminals of 4–8–15–250 and 500 ohms. These amplifiers are available in systems with a choice of microphones and with four 12-inch PM speakers, walnut baffles, or with four weatherproof outdoor reflex trumpets and units.

David Bogen Company, 663 Broadway, New York, N. Y.

Quick-Heating Soldering Iron

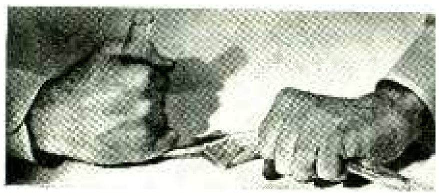
A new fast-heating soldering iron consists of a high current, low voltage transformer with its primary circuit controlled by a trigger action switch. Across the transformer secondary terminals is shunted a soldering tip of No. 11 B&S guage copper wire. The iron reaches soldering temperature in

five seconds, and consumes 80 watts of power. The tip can be bent to various shapes for reaching difficult spots. Some variation of heating time and temperature can be made by changing the length of the tip. One minute is required to change tips. The current is turned off by the trigger switch when the unit is not in use. No stand is needed.

Weller Brothers, 516 Northampton Street, Easton, Pa.

Insulation Tubing

"TRANSFLEX" IS A NEW transparent tubing which has good resistance to brittleness (down to —50 deg. C). Although it was designed to give continued, effective insulation on aircraft flying in high altitudes, it may be used for industrial or electrical applications because of its transparency which permits quick location of wire breaks. It is available from size No. 12 to ⅝-inch inside diameter. Its tensile strength is 3000 lbs per sq in, and its dielectric strength (conducted on a tubing with a wall thickness of approximately 0.020 inches) is 850 VPM when dry and 815 VPM when wet. Other characteristics are: water absorption, 0.4% weight after twenty-four hours immersion; Wemco Oil Test (48 hrs at 100 deg. C); and continuous operating temperature of 150 deg F.



Irvington Varnish & Insulator Company, Irvington, N. J.

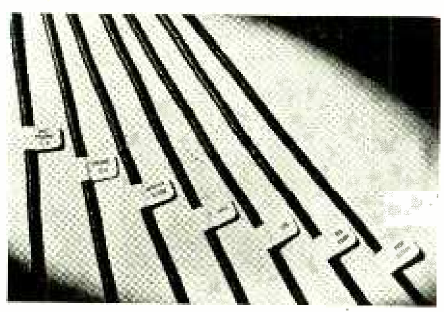
Silent Mercury Plunger Relay

A RELAY DESIGNED and improved to insure long life under severe conditions of vibration and shock. The new design eliminated the metal cap and support frame which held the mercury tube. The tube has been made secure by a single metal band which is more stable. The area for terminal fastening and connecting has been tripled to eliminate the danger of tube breakage and to simplify installation. The relay has one moving part and is available for either alternating or direct current. It is rated at 30 amps, 110 volts, 1 hp. and is listed under Re-examination Service of the Underwriters' Laboratories.

The manufacturer, H-B Electric Company (2530 North Broad Street, Philadelphia, Pa.) states that it has been tested to ten million operations without a failure.

Stickers

A NEW STICKER for electrical wire identification (or for warnings, carry instructions, patent numbers, manufacturer's identification) is available. These stickers may be applied without moistening. They will permanently adhere to any smooth surface and will stay on under extreme heat or humidity, but may be easily pulled off without leaving a mark. Available blank or printed from Avery Adhesive, 451 East 3rd Street, Los Angeles, Cal.



Mobile Generating Plant

COMPLETE CENTRAL STATION power houses on wheels which can be readily transported for instant power generation whenever needed. Each mobile unit carries two 50 kw electric plants, a switchboard, fuel oil storage tank, electric fuel transfer pump, lubricating oil rectifier, starting batteries, station transformer and both a-c and d-c station lighting system, as well as a substation with transformer, lighting arrestors and air break switches.

The plants can be operated alone, or in parallel with other mobile plants, or as boosters in parallel with central station power. They carry their own fuel, have a power operated fuel supply pump for fuel transfer from tank wagon or other supply source, and as they are completely muffled, they can be operated in congested districts without creating a noise nuisance. The International Harvester Diesel engines used in these mobile plants are started on gasoline with an automotive-type starting motor. After a brief warming-up period the engine is thrown over to full Diesel operation. Starting is quick, and in case of battery failure, the engine may be cranked by hand.

The Ready-Power Company, 3826 River Avenue, Detroit, have available Bulletin 522-B which illustrates and describes these mobile plants.

Capacitor Weld Unit

"REVERS-O-CHARGE" IS THE NAME of a power and control unit for use in capacitor-welding, particularly in the welding of aluminum for aircraft. It operates at high power-factor with a balanced 3-phase load and a minimum peak KVA demand. With 480 μf of capacity, the unit is capable of a maximum of 100 spot-welds per hour, or a maximum of 42 spots per minute, and a sustained rate of 1,200 spots per hour with 2,640 μf connected. It is designed for operation on 230/460 volts 3-phase, and is available for either 60 or 50 cps.

Weltronic Corp., East Outer Drive, Detroit, Mich.

Correction

A TYPOGRAPHICAL error in last month's New Products department would lead the reader to believe that the General Radio Co. and ELECTRONICS have been around longer than is actually the case. It was stated that the GR Type 759-P50 power supply was described in the June 1910 issue of ELECTRONICS. Now many of our charter readers were born since that date and it stands to reason that there never was a June 1910 issue. General Radio Co. dates from 1915. Please note that what was meant is the June 1940 issue.

Literature

Comparison Capacities. A condensation of an original article, "Capacity Comparison Using a Cathode-Ray Tube" by Dr. Robert H. Cole which appeared in *Review of Scientific Instruments* is condensed in a recent issue of *Oscillographer*, published by Allen B. DuMont Labs., Inc., 2 Main Avenue, Passaic, N. J.

Reactance Charts. These simplified charts have a frequency spectrum from 1 cps to 1000 Mc per second and all the scales are plotted in actual magnitudes so no computations are required to locate the decimal point in the final result. They have been broken down into three parts. Chart I covers the range from 1 cps to 1000 cps, Chart II from 1 kc to 1000 kc and Chart III from 1 Mc to 1000 Mc. Engineering News Letter No. 70 is obtainable from Hygrade Sylvania Corp., Emporium, Pa.

Electronic Devices. Another issue of The Aerovox Research Worker is devoted to the subject of "Industrial Applications of Electronic Devices." This is part two of a series of three such articles. This particular issue deals with the design and characteristics of several tubes, not conventional vacuum tubes, and the manner in which they work. Aerovox Corp., New Bedford, Mass.

Pyrometers. Catalog No. 1101-G illustrates and describes electric thermometers, pyrometers, photoelectrically balance recorders, indicators, controllers, recording controllers, potentiometers for thermocouples, slide-wire Wheatstone bridges for resistance thermometers. This may be obtained from C. J. Tagliabue Mfg. Co., Park and Nostrand Ave., Brooklyn, New York.

Specification Folder. This specification sheet No. 234, released Jan. 1942 explains the Aero-Thread screw thread system so far as workmanship, general and detail requirements, inspection and application are concerned. It is for use by design engineers and procurement departments and may be obtained from Aircraft Screw Products Co., Inc., 47–23 35th St., Long Island City, New York.

Priorities and Pyrometers. This bulletin is intended to explain, to all users of temperature measuring and control instruments, how the National Defense Program affects these instruments, their purchase, use, maintenance, and the replacements necessary. It points out the present scarcity of various materials and lists other materials which may be substituted. Properties of the original and substitute materials are compared. How to maintain present equipment for maximum efficiency and uninterrupted service is also pointed out. This Defense Bulletin No. 1 may be obtained from Wheelco Instruments Co., Harrison and Peoria Sts., Chicago, Ill.

Precision Test Equipment. A 1942 booklet on test instruments for radio, television, electrical, industrial and laboratory equipment has been released by Precision Apparatus Co., 647 Kent Ave., Brooklyn, New York.

Lead and Tin Products. Describing the various alloys-solders, extruded shapes, pipe and tubing and other specialties which may be needed for defense orders, a folder entitled "Alpha Lead and Tin Products" is available from Alpha Metal and Rolling Mills, Inc., 363 Hudson Ave., Brooklyn, N. Y. The folder also contains lead-tin alloy tables.

Vibrational Phenomena. A copy of *The Experimenter* is devoted to the subject of "The Measurement and Analysis of Linear and Torsional Vibrations with Electronic Instruments" as well as "A 100-Watt Output Meter" and "Rubber Covered Cables." General Radio Co., 30 State Street, Cambridge, Mass.

Safety Code. A reprint from *Industrial Standarization*, February 1942 issue, announces the revision of the Fifth Edition of National Electrical Safety Code which has been approved by American Standards Association. The Code, which comes in five parts, outlines safety rules for the construction, maintenance, and operation of systems supplying electrical energy for light, heat, and power, as well as for communication and signal systems and radio installations. Rates, copies of the Code and the reprint, are available from American Standards Association, 29 West 39th Street, New York, N. Y.

Electronic Gadgeteering. Since radio amateur activities are being seriously curtailed for the duration of the war, so far as 'ham' communications are concerned, Aerovox engineers are compiling and releasing practical data on electronic gadgeteering as an outlet for the equipments, skill and ambition of the radio hobbyist. Articles on radio control circuits and the industrial applications of electronic devices are currently appearing in the monthly *Aerovox Research Worker*. Aerovox Corp., New Bedford, Mass.

Electrical Control Apapratus. A catalog and reference book which includes comprehensive data on thirty major types of relays and their mountings, stepping switches of various types and capacities, and electrical control parts such as switching keys, signal lamps and sockets, cords and plugs, dials, microphones, handsets, solenoids and coils is available to engineers and product designers from American Automatic Electric Sales Co., 1033 W. Van Buren St., Chicago, Ill.

Graphite. Two separate booklets on this subject include "Graphite" which describes a few of the more common uses of this material, and "Graphitar" which tells of a few of the present successful applications of Graphitar, a molded carbon-graphite. United States Graphite Co., Saginaw, Mich.

N. U. Literature. Five pieces of literature, on the subjects of "Cathode Ray Tubes", DeLuxe Amplifier" (of the W15A Series), "Radio Receiving Tubes", Condensers" (paper, wet, dry, electrolytic and mica), and "Standard Sound Amplifiers and Accessories" (a 12-page booklet) are available from National Union Radio Corp., 57 State Street, Newark, N. J.

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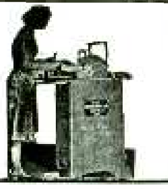
PHOTOTUBE PRODUCES SYNTHETIC MUSIC

In the variaphone, invented by two Russian physicists, two wheels rotate in front of a phototube. The shape of the tube is determined mathematically to produce a fundamental and harmonic in accordance with the instruments which the gear is to simulate. A different gear is required to produce the music of each individual instrument

CONTACTS

FOR THE FIELD OF ELECTRONICS



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COLLEGE GLASS working units for students and laboratory

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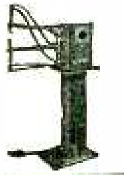

EISLER ENGINEERING CO.
751 So. 13th St. (near Avon Ave.) Newark, New Jersey

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Three different units designed especially for use with G.E. Neon Glow Lamps, types S14, G10 and T4½. All for single hole panel mounting.

G10P Unit
Overall Dia. 2"
Overall Depth Behind Panel 1¾"
Uses 1 or ½" Watt Lamp on 120 V. 1 Watt Lamp on 220 V.

Our Latest Catalogue Describes All Neon Type Units in Detail.

We have many types of heavy duty indicating lamp units that are extensively used by a host of well known concerns, who cheerfully pay more to secure the best.

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Wound on low loss ceramic cores. Mounting legs furnished when requested.

SEND FOR SAMPLES
Give complete data regarding resistance, maximum current, voltage drop required and mounting space available.

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of Tungsten and Molybdenum

Molybdenum in widths .006" to 1"
in thickness to .0005"
Tungsten Ribbon to specification

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Factory—2035 Charleston Street, Chicago, Ill.

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Chemicals
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General Luminescent Corp., 732 Federal St., Chicago

MICROMETER FREQUENCY METER for checking transmitters, from 1.5 to 56 mc., within 0.01 per cent.

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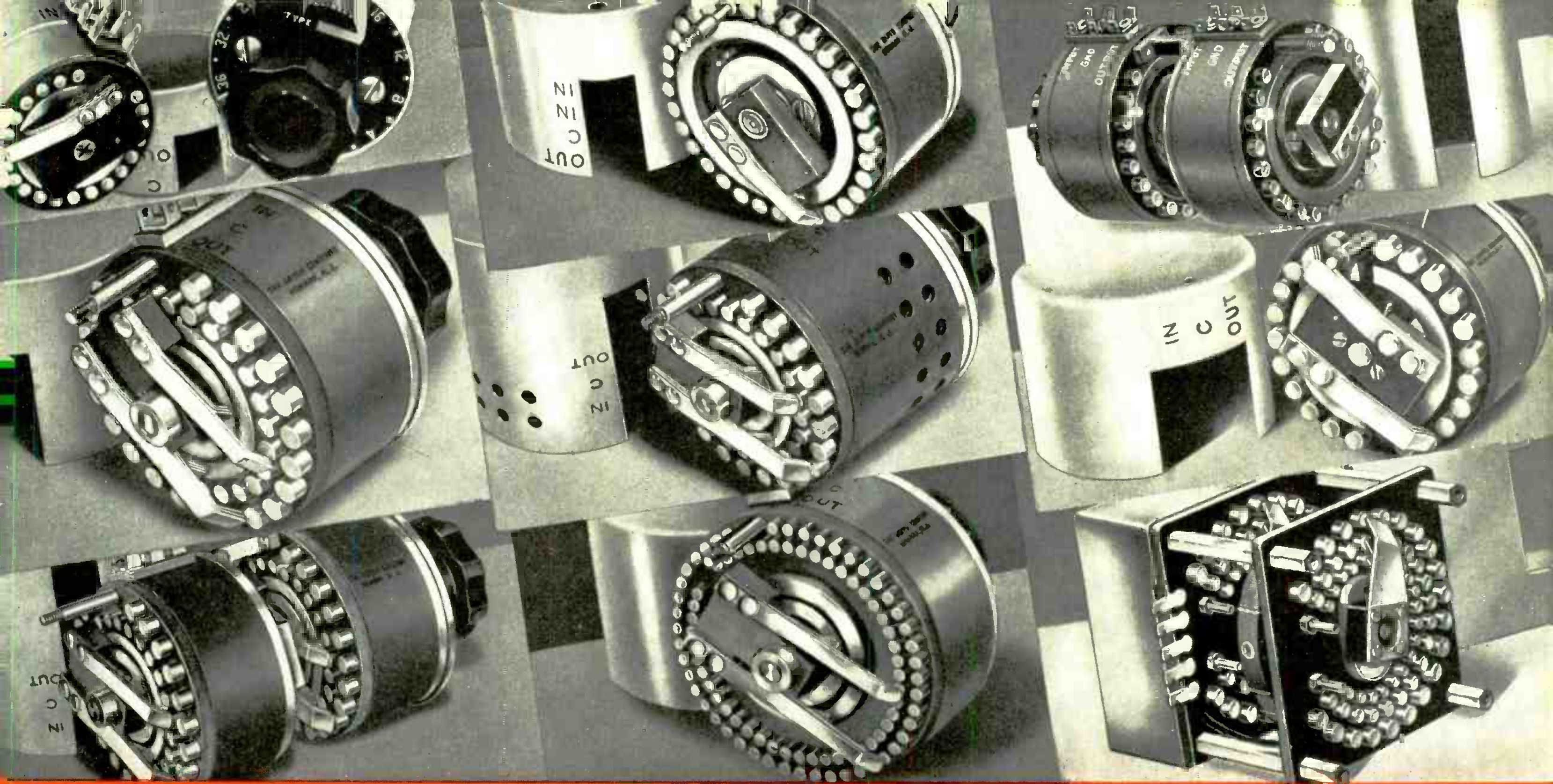

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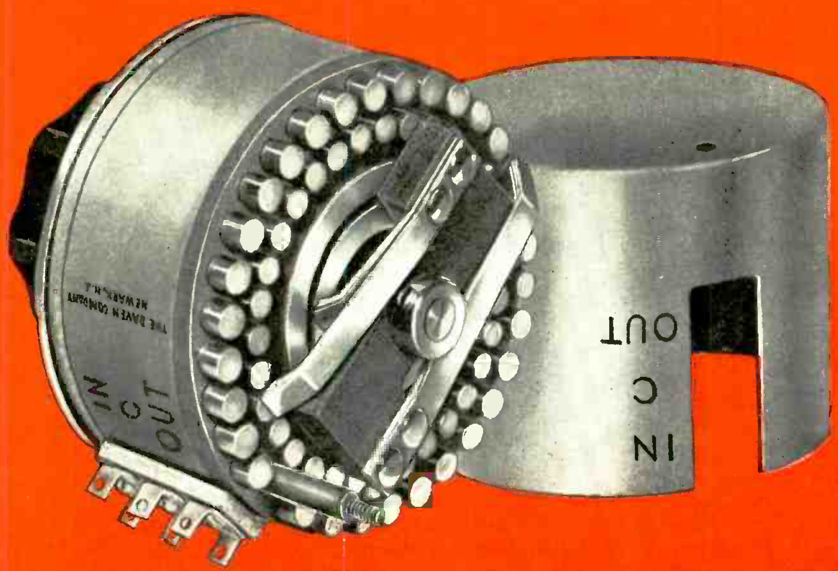

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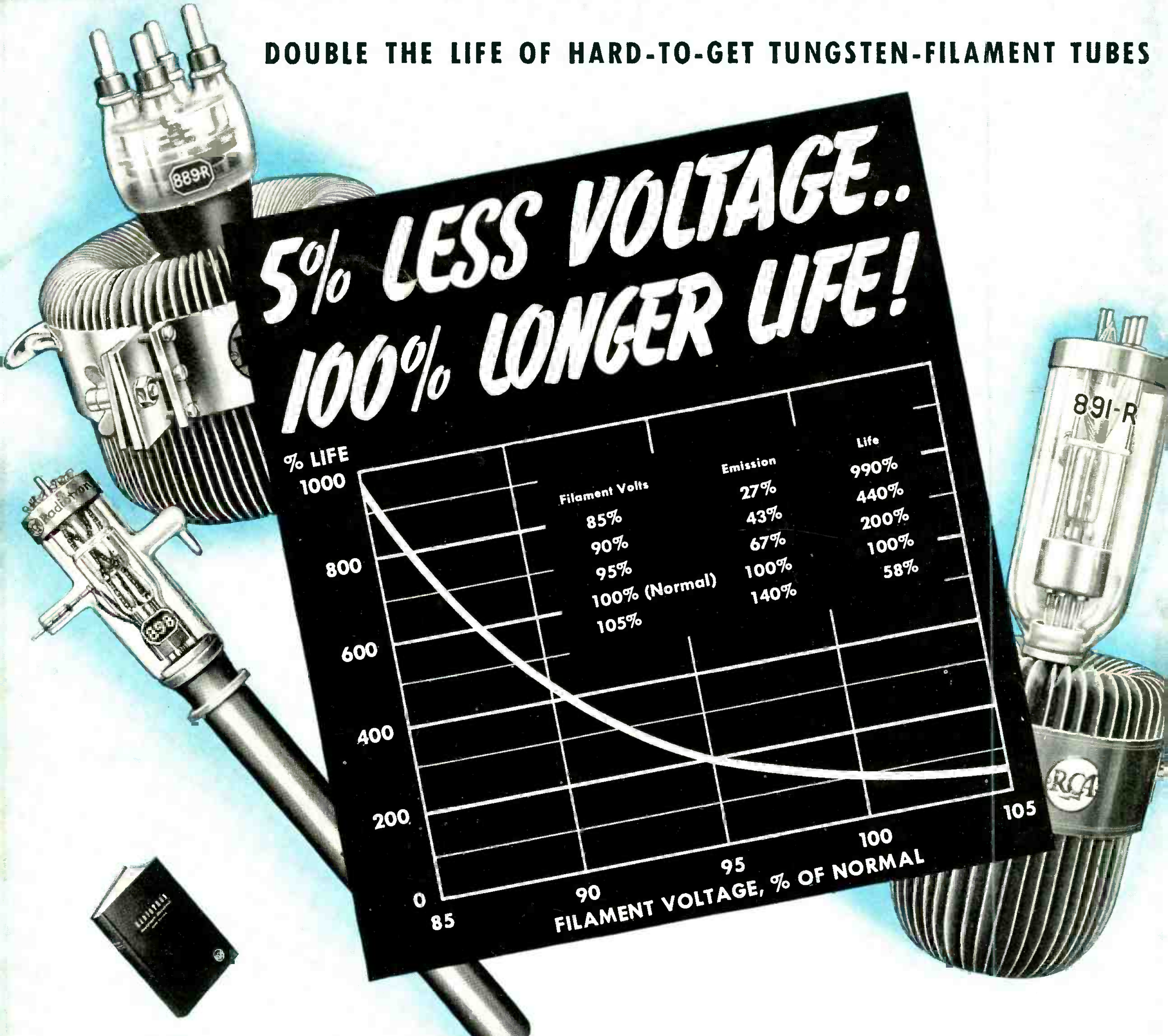

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Edited by F. Langsford Smith especially for the radio set designer, this book (now in its Third Edition) is equally valuable to others interested in the fundamental principles of practical radio circuit design. Chapters cover Audio Frequencies; Tests and Measurements; Valve Characteristics; General Theory, etc. Contains 356 pages, with many illustrations, numerous reference charts, tables, and other data. Send your remittance to RCA Manufacturing Company, Harrison, N. J. Price $1.00 postpaid.

The accompanying chart showing how the life expectancy of pure-tungsten-filament tubes increases by leaps and bounds as filament voltage is reduced, serves as a convincing illustration of how simple precautionary measures can often add thousands of hours of life to tubes already in use. In tungsten-filament tubes, reduction of only 5% in the filament voltage doubles tube life. A reduction of 15% increases it almost tenfold!

Obviously, a 15% filament-voltage reduction with its resultant decrease of 73% in tube emission would hardly be feasible in most applications. On the other hand, a less drastic reduction might. Admitting that maximum signal quality is important to a broadcast station, it is well to recognize that these are days when circumstances might well alter cases. In many instances, it may prove highly advisable to adjust station operation conditions closer to the maximum permissible distortion in order to operate tungsten-filament tubes at the lowest possible filament voltage and thus add materially to the life of units which may be difficult to replace.

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