TELE-TECH

Formerly the TELE-communications TECH-nical Section of

ELECTRONIC INDUSTRIES

DESIGN AND OPERATION OF RADIO · FM · TELEVISION
RADAR AND ALL COMMUNICATIONS EQUIPMENT

October · 1947

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TABLE OF NEW FREQUENCY ALLOCATIONS

CALDWELL-CLEMENTS, INC.

YOUR PRODUCT, TOO

CAN BE RADIO NOISE-PROOFED WITH C-D *Quietones*

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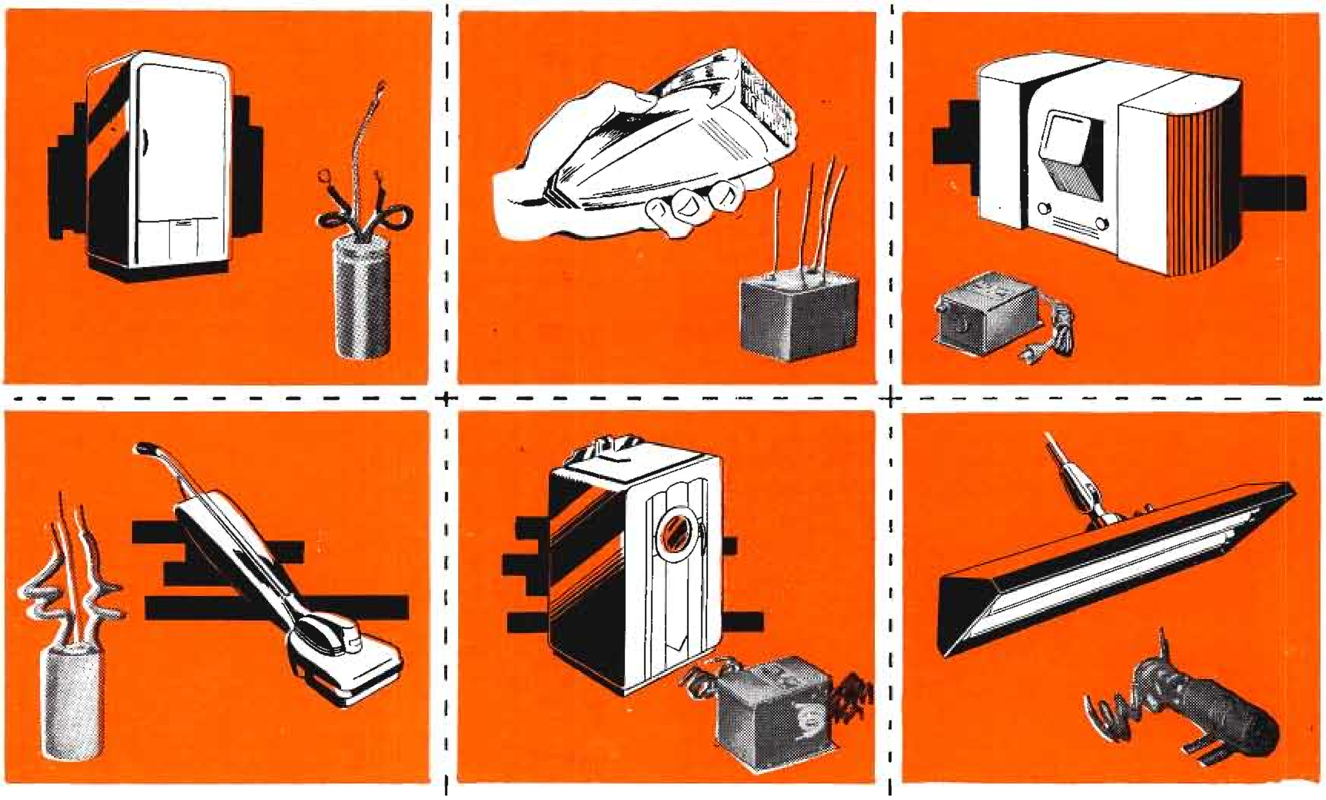
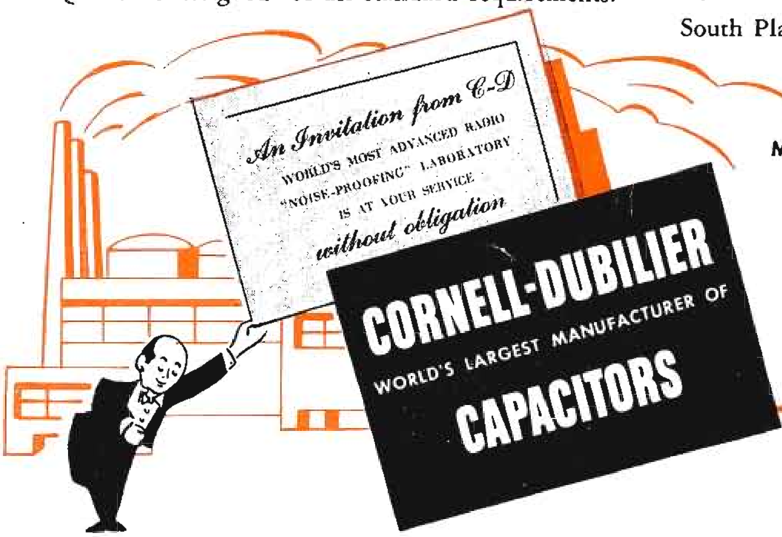


When we say Radio Noise-*Proofed*—we mean Radio Noise-*Proofed.* It's no trick at all to build a filter with high attenuation at 150 kc *or* 100 mc . . . but to build one which filters at 150 kc *and* 100 mc—*as well as all points in between*—is a horse of a different color. We know because we've done it. It is only one of hundreds of *available* types of C-D Quietones designed for all standard requirements.

Among these stock types there may be one which will bring the interference level of your product down to the level of a rabbit's bark. If not, we invite you to make full use of our Radio noise-proofing laboratory and our engineers for the development of a unit designed for your specific needs.

Your inquiries are cordially invited. Address: Cornell-Dubilier Electric Corporation, Dept. J10, South Plainfield, N. J. Other large plants in New Bedford, Worcester and Brookline, Mass., and Providence, R. I.



Make Your Product More Saleable With C-D Quietone Radio Noise Filters and Spark Suppressors

1910 — 1947

MICA • DYKANOL • PAPER • ELECTROLYTIC

TELE-TECH

Formerly the TELE-communications TECH-nical Section of

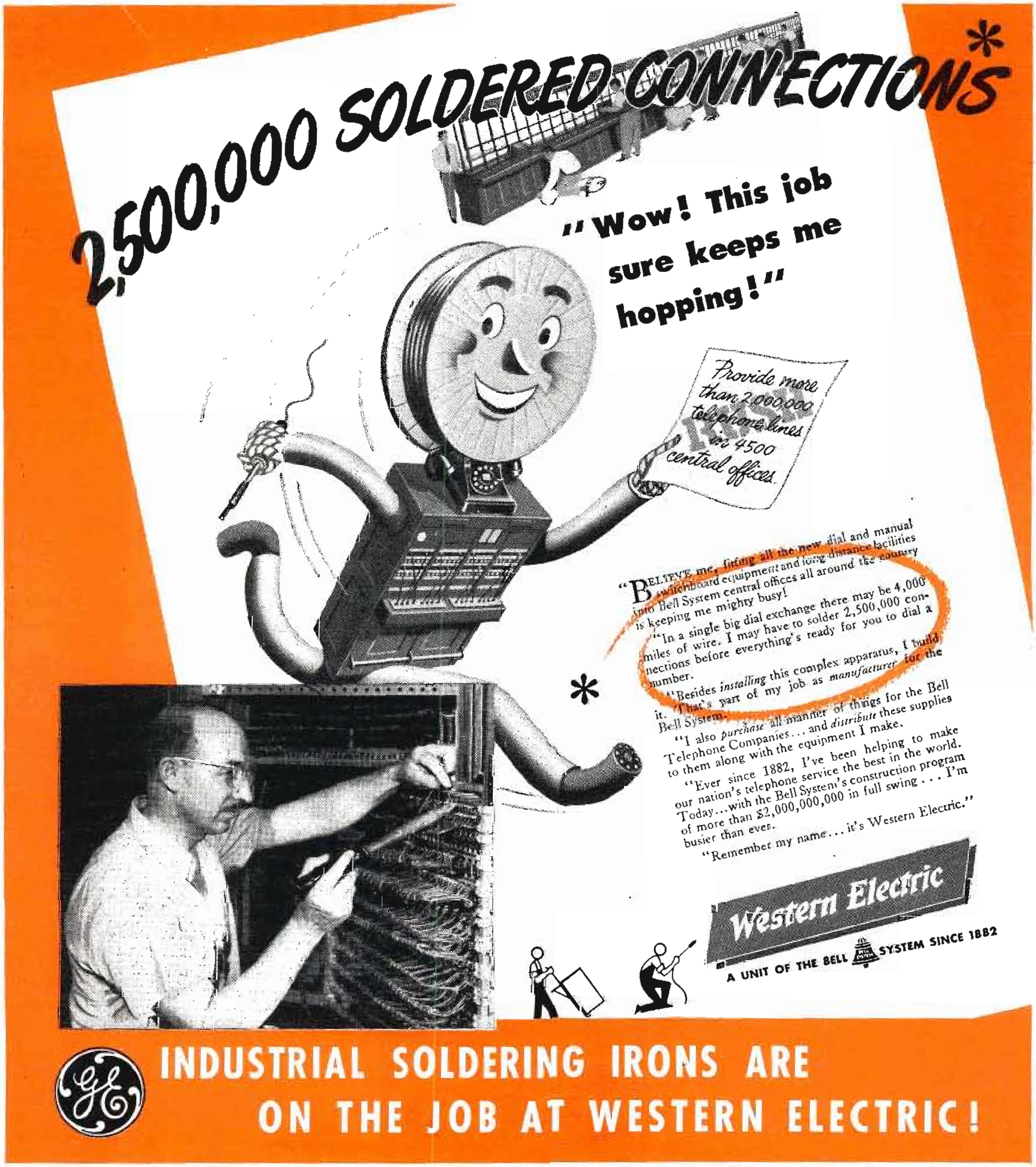
ELECTRONIC INDUSTRIES

OCTOBER, 1947

Editorial Contents

CALDWELL-CLEMENTS, INC., Publication Office, Orange, Conn., Editorial and Executive Offices 480 Lexington Avenue, New York 17, N. Y., Tel. Plaza 3-1340

BRANCH OFFICES — Chicago 6, R. Y. Fitzpatrick, 201 N. Wells St., RAN 9225; Los Angeles 5, The Robert W. Walker Co., 684 So. Lafayette Park Pl., Drexel 4388; San Francisco 4, 68 Post St., Sutter 1-5568.



Soldering the many million connections in the nationwide exchanges of the Bell System is a big job for anybody's money. That's why Western Electric has purchased almost 200,000 G-E INDUSTRIAL SOLDERING IRONS. Efficient, reliable tools are needed for the big job they have to do.

These G-E INDUSTRIAL SOLDERING IRONS are built for heavy-duty, continuous service. Famous Calrod† heaters assure fast, dependable heat and long life. Ironclad-copper tips have calorized threads to prevent "freezing in." Simplified disassembly features make them easy to maintain right on the spot.

For complete information on G-E INDUSTRIAL SOLDERING IRONS, ask your G-E Apparatus Distributor for free bulletin GEA-4519A. Or, write Dept. 675-170, *General Electric Company, Schenectady, N. Y.*

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GENERAL ELECTRIC

675-170

TELE-TECH

The TELE-communications and TELEvision TECHnical Section of
ELECTRONIC INDUSTRIES

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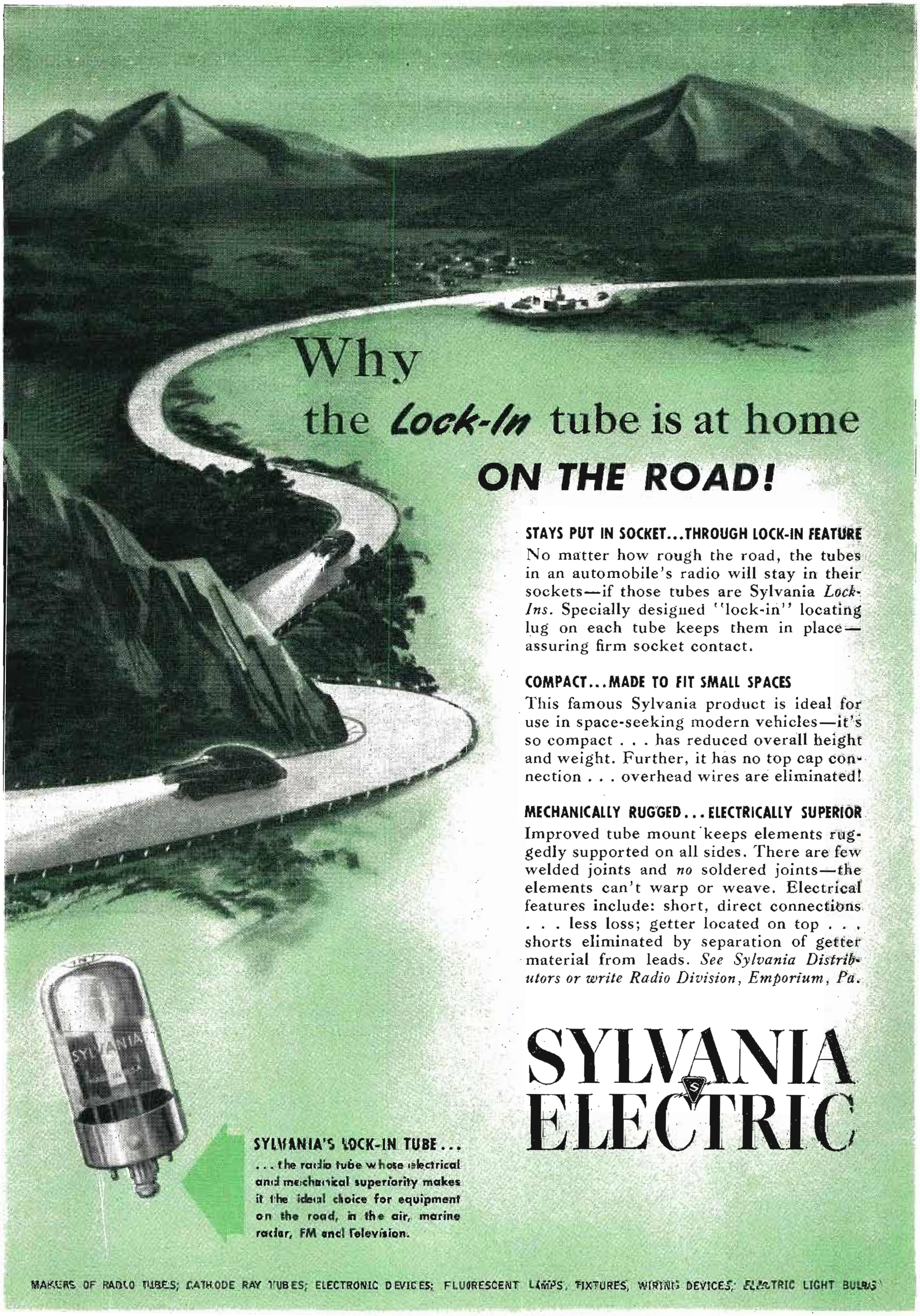
Why
the Lock-In tube is at home
ON THE ROAD!
STAYS PUT IN SOCKET...THROUGH LOCK-IN FEATURE
No matter how rough the road, the tubes in an automobile's radio will stay in their sockets—if those tubes are Sylvania Lock-Ins. Specially designed "lock-in" locating lug on each tube keeps them in place—assuring firm socket contact.
COMPACT...MADE TO FIT SMALL SPACES
This famous Sylvania product is ideal for use in space-seeking modern vehicles—it's so compact . . . has reduced overall height and weight. Further, it has no top cap connection . . . overhead wires are eliminated!
MECHANICALLY RUGGED...ELECTRICALLY SUPERIOR
Improved tube mount keeps elements ruggedly supported on all sides. There are few welded joints and no soldered joints—the elements can't warp or weave. Electrical features include: short, direct connections . . . less loss; getter located on top . . . shorts eliminated by separation of getter material from leads. See Sylvania Distributors or write Radio Division, Emporium, Pa.
SYLVANIA ELECTRIC
SYLVANIA'S LOCK-IN TUBE...
...the radio tube whose electrical and mechanical superiority makes it the ideal choice for equipment on the road, in the air, marine radar, FM and Television.
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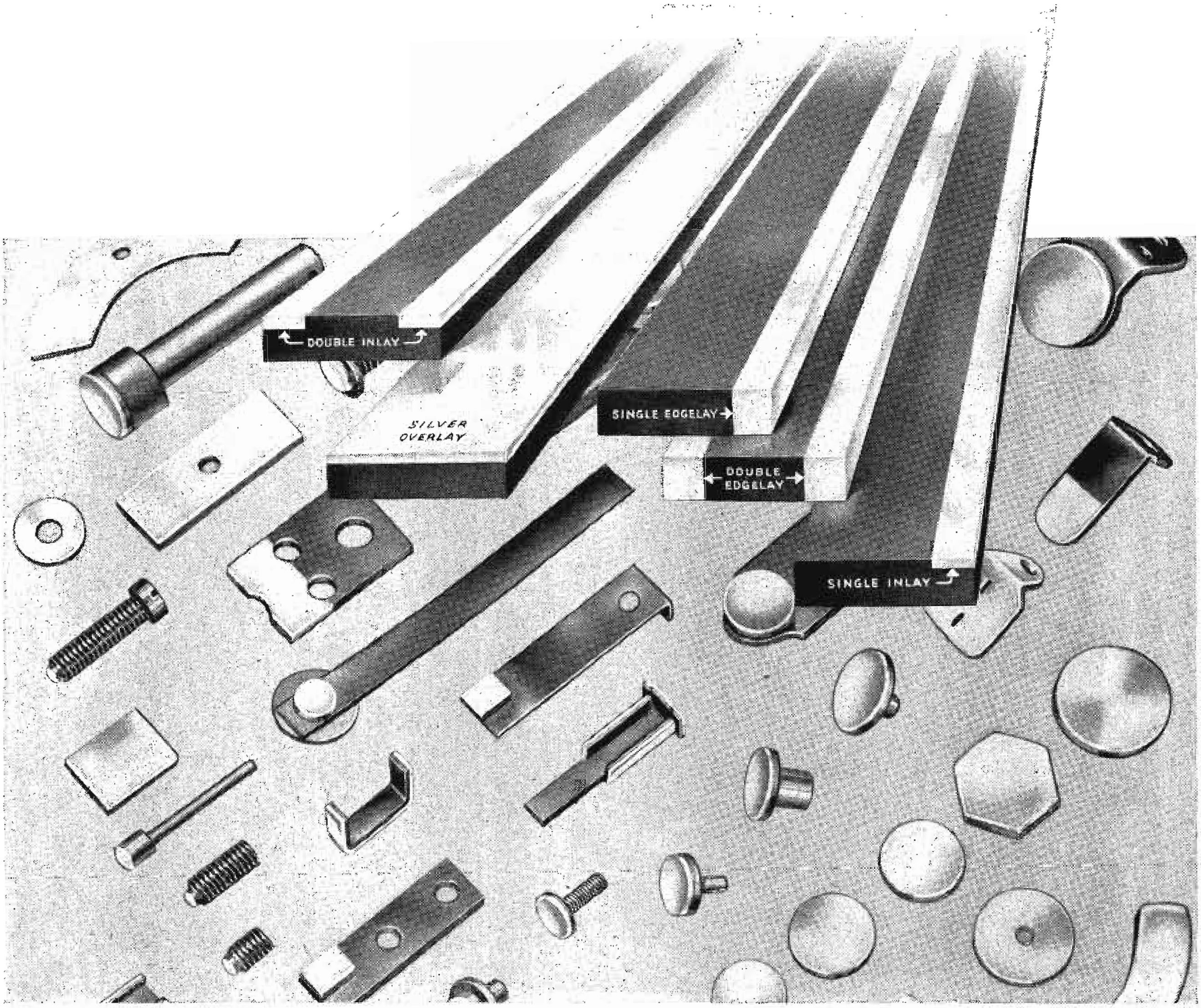

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The big advantage of General Plate Laminated Silver metals and contacts is that they give you solid silver performance at a fraction of the cost of solid silver. Why — because General Plate permanently bonds a thin layer of silver to suitable inexpensive base metal, thus providing a contact face of high electrical conductivity at the point of actual contact.

General Plate Laminated silver metals, for your own fabrication, are available with silver bonded to base metal in the following stock . . . overlay, single or double inlay and single or double edgelay. General Plate contacts and fabricated parts are made to customers specifications. Laminated contact buttons, rivets and screw type contacts are also available. Advantages include — long contact life, greater strength, easier fabrication, and easier soldering, brazing or spot welding.

Write, specifying your problems.

GENERAL PLATE DIVISION

of Metals & Controls Corporation

ATTLEBORO, MASSACHUSETTS

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400 INCHES IN A MILLIONTH OF A SECOND!

From 4000 to 29,000 accelerating volts applied by means of the new special-application indicator combination—Type 281 Indicator and Type 286 High-Voltage Power Supply—shown below.

THE IDEAL COMBINATION!

A spot moving at this speed may now be photographed with the

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Details on request

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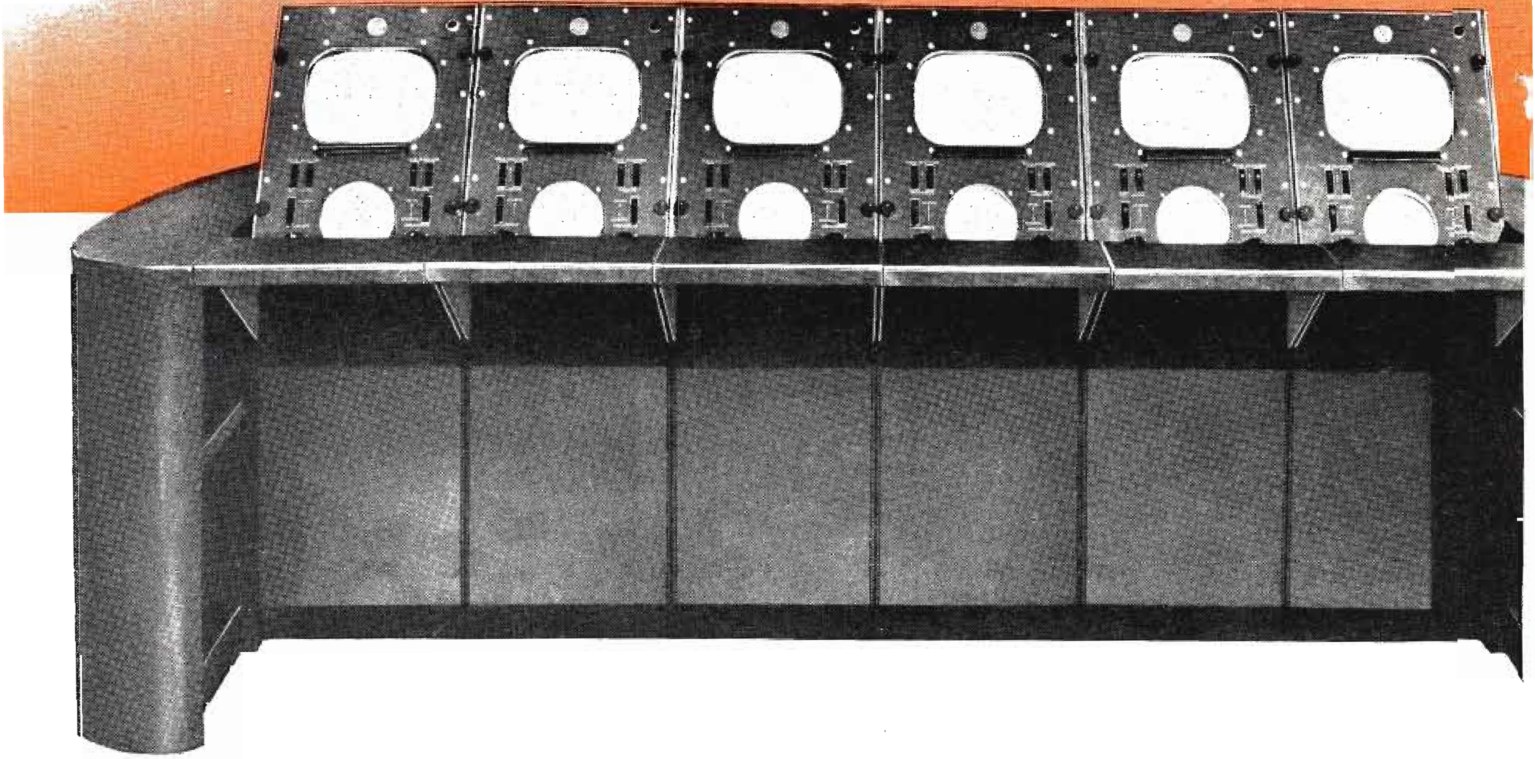
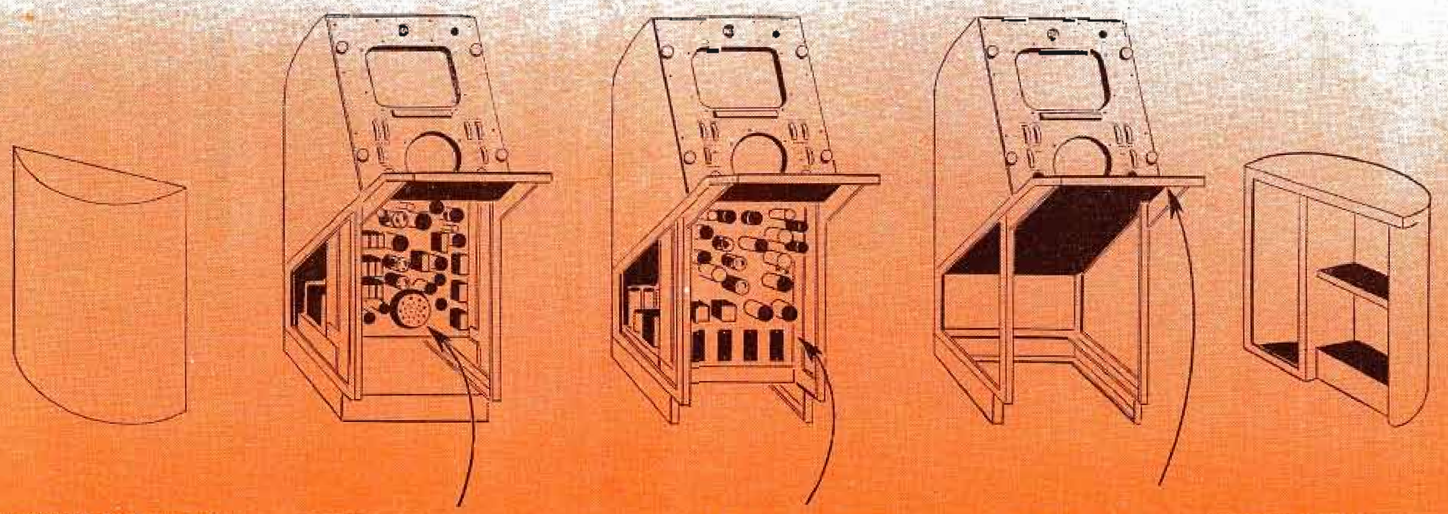


THE NUMBER OF UNITS DEPENDS UPON THE SIZE OF YOUR STATION

CAMERA MONITOR SECTION (ONE FOR EACH STUDIO AND FILM CAMERA)

PROGRAM MONITOR SECTION

PREVIEW MONITOR SECTION



HOUSING END SECTION (LEFT END)

CAMERA CONTROL UNIT

CAMERA SWITCHING UNIT

ON-THE-AIR CAMERA SWITCH

HOUSING END SECTION (RIGHT END)

Studio Console

for smooth video programming

Includes every practical facility and refinement for monitoring, dissolving, fading, and switching.

HERE'S THE CONSOLE that puts all electronic aspects of television programming "under control." It is already in production at RCA.

It contains everything needed to monitor, control, and switch the outputs of several studio cameras, film cameras, and network lines. Ten-inch Kinescopes provide for direct picture monitoring; five-inch oscilloscopes for checking video signal components. It's easy to increase picture brilliance, adjust contrast and focus, and provide proper shading.

Complete switching facilities centralize the selection of all video program material . . . permit push-button control of closeups, long shots, film commercials, station breaks, fadeouts, dissolves, wipes, special effects, and network programs.

Engineered with an eye to the future:

The number of units in the video console depends upon the size of your station. RCA's "add-a-unit" design gives you a compact, unified console, whatever your requirements . . . permits easy and economical addition of extra units as your station expands . . . without discard of any original equipment.

To co-ordinate all programming directions, provision has been made for telephone communication between key studio personnel and console operators.

This console, we believe, is a real contribution to convenient video control . . . another step by RCA to assure smoother studio programming . . . more interesting, more dramatic telecasting. We'll be glad to make specific recommendations for your station. Write Dept. 98-J.

Normally, two operators handle a 5-monitor console . . . one selects the "on-the-air" signal at the request of the program director; the other has technical control of the individual cameras.

TELEVISION BROADCAST EQUIPMENT

RADIO CORPORATION of AMERICA

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Now all Precision square and rectangular paper tubes and coil bases are DI-FORMED as a standard process. And you now get these DI-FORMED tubes at no extra cost.

Use these New Precision DI-FORMED Coil Bases to

save money — speed production and increase efficiency of your equipment—because DI-FORMED coil bases have greater strength; permit automatic stacking; eliminate forming coils after winding; and cores can be engineered closer, saving wire.

Write for new Mandrel List (many new sizes now!) and ask for samples of Precison DI-FORMED Tubes — to your specifications.

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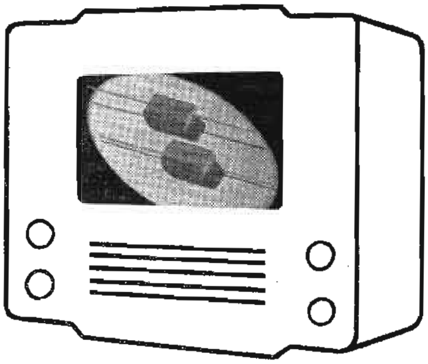
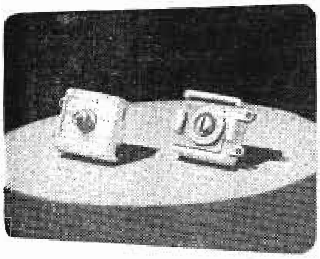
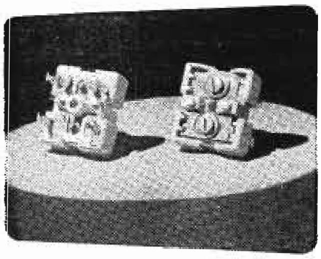
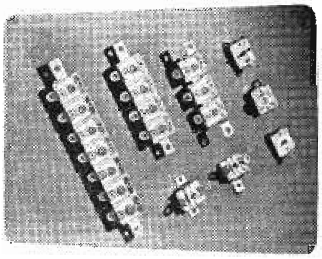


A GOOD TRADEMARK *is* BUT A REFLECTION OF *Many* OTHERS







WHEN a manufacturer puts his trademark on a product, he not only expresses pride in his own workmanship, but also his confidence in the trademarks of those who have contributed vital parts to its manufacture. For instance — on capacitors he recognizes the El-Menco branding as his assurance of trustworthy performance under all operating conditions.

Write on firm letterhead for samples and catalog.

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CAPACITORS

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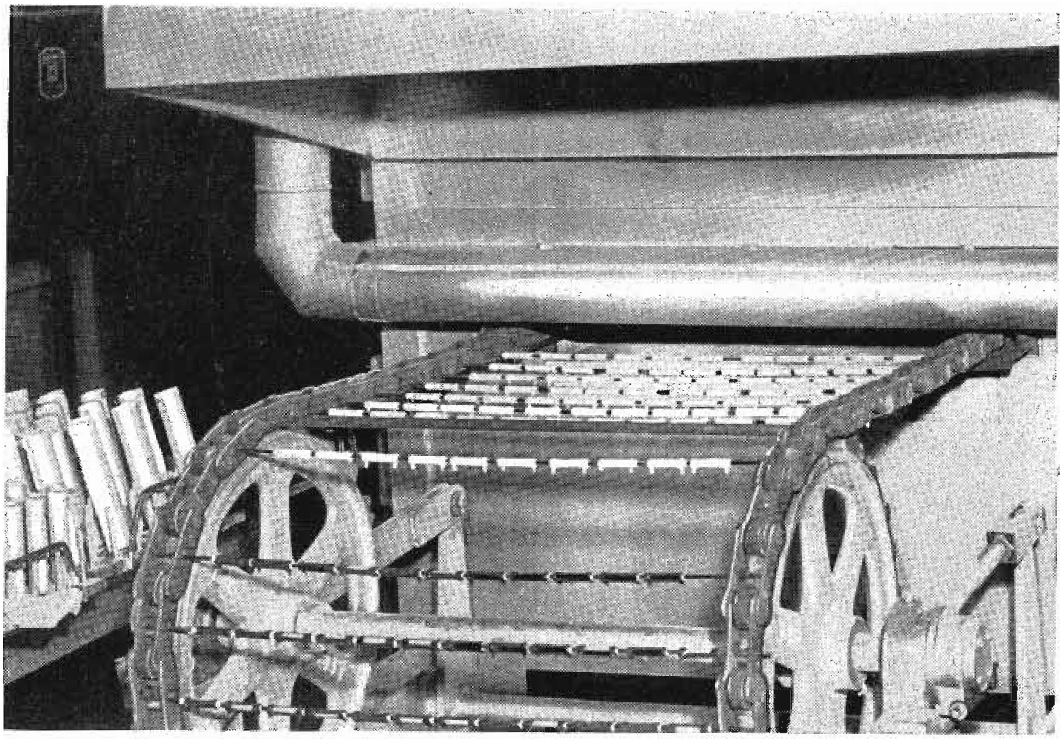

...the finest Vitreous Enamel Resistors Money Can Buy

THE accurate temperature controlled baking oven pictured here is just one of many similar ovens which constitute the most modern installation devoted exclusively to vitreous enamel resistors. This precision baking process is a final essential operation in the careful technique of producing high quality, dependable resistors.

The enamel, prepared under a carefully controlled chemical process, applied in even thickness, insuring the ultimate in protection to the winding element to afford uniform heat distribution, is then baked *just right* to insure a smooth surface of low porosity—safeguarded against moisture, fumes and heat—resulting in a resistor famous for strength and durability.

These resistors, too, employ the largest wire size obtainable, affording maximum area for heat dissipation consistent with specified resistance value. They have terminal bands of one piece, Mallory alloy construction, electrically and mechanically bonded to the resistance element. They are conservatively rated. And they include a sufficient variety of types and sizes to meet all important needs.

There are standard fixed and adjustable types . . . "RN" resistors that meet characteristics "F" of the joint Army-Navy specifications . . . ferrule resistors for use with conventional fuse mounting clips. No better resistors can be bought for the money, and you need not be satisfied with less. Get the complete story in the newly-published Mallory Vitreous Enamel Resistor Engineering Data Folder. Ask for Form No. VER-1146.

P. R. MALLORY & CO., Inc.

MALLORY RESISTORS (FIXED AND VARIABLE)

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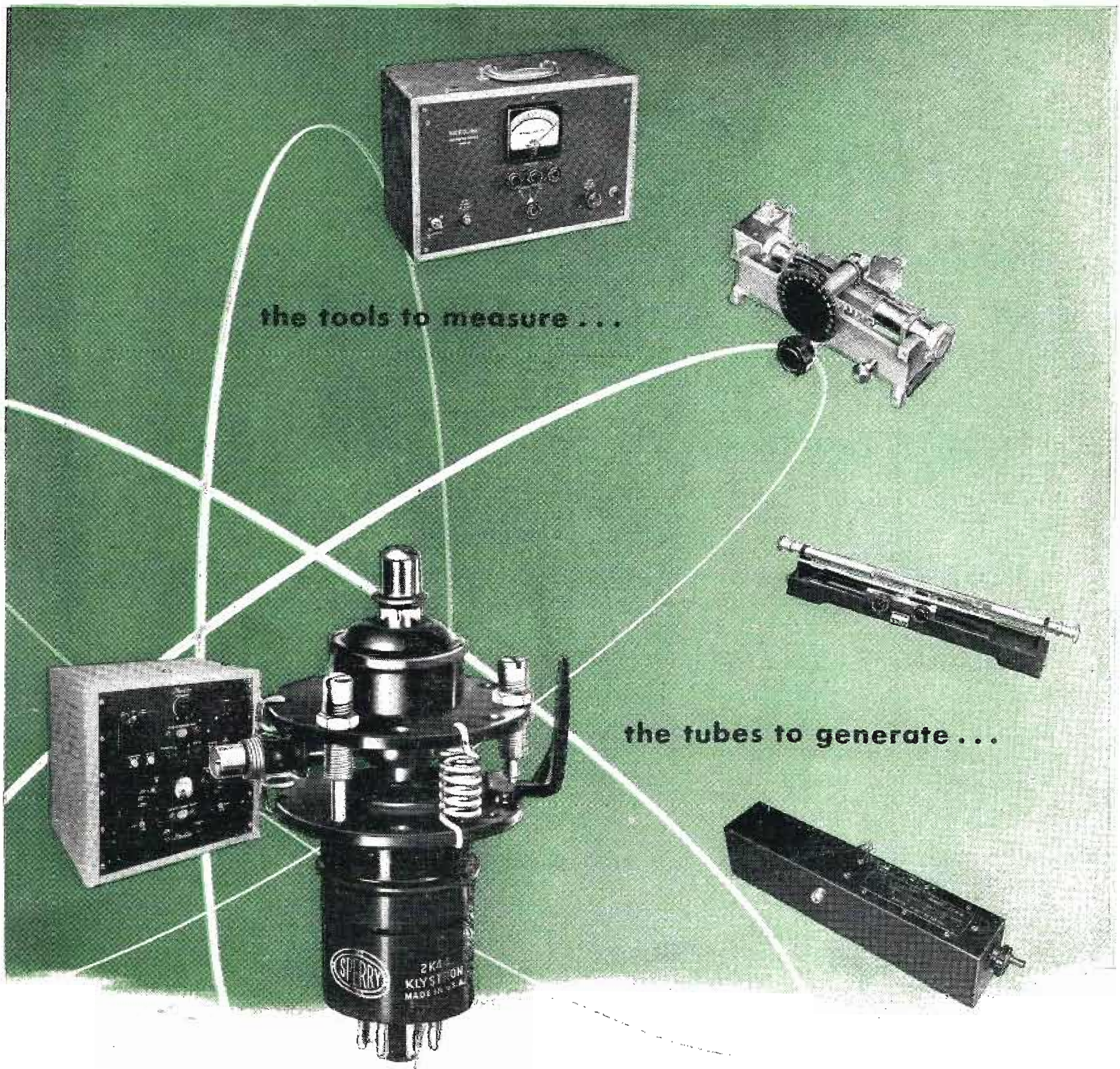

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The Sperry Klystron Tube to generate ultra-high-frequency microwaves . . .

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These Sperry products equip the research or development engineer with every essential for development or design in the microwave field.

The Sperry Klystron Tube has already opened up new vistas in navigation, aviation, medicine, radio, telephone, telegraph and other major applications. It is ready for many new local oscillator or high power uses.

The Sperry Microline includes practically every type of instrument for quick precision measurements in the microwave frequency bands.

This Sperry service — beginning with a source of microwave energy, the Klystron, and following through with every facility for measuring microwaves — opens up almost unlimited possibilities for industry.

We will be glad to supply complete information.

Sperry Gyroscope Company, Inc.

EXECUTIVE OFFICES: GREAT NECK, NEW YORK • DIVISION OF THE SPERRY CORPORATION

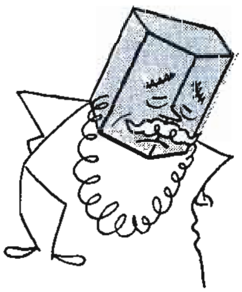
NEW YORK · CLEVELAND · NEW ORLEANS · LOS ANGELES · SAN FRANCISCO · SEATTLE

Why this team brings

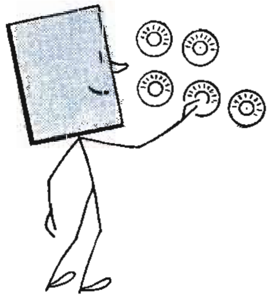
Early in the history of radio telephony, it became evident that further growth and expansion depended on accurate means of controlling frequency. The first step toward solving this problem was taken in 1915, when a Laboratories engineer developed the first master oscillator circuit for radio transmission. In 1917 came the first crystal controlled oscillator using Rochelle salt crystal, and in 1921 the application of quartz crystals.

From that day on, the Bell Laboratories-Western Electric team has pioneered in piezoelectric crystals. New cuts, new circuit applications, new methods of growing synthetic crystals . . . all have been developed by the Laboratories, and all mass-produced by Western Electric.

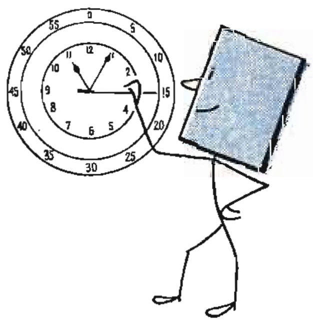
Today it is only natural to look first to this team for the finest quartz and synthetic crystals for every service



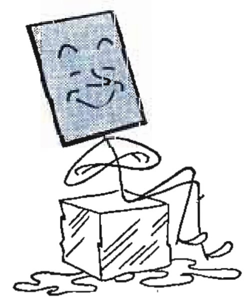
1917 A Rochelle salt crystal used by a Laboratories researcher to control an oscillator circuit was the granddaddy of all frequency control crystals.



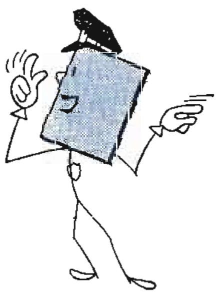
1924 Quartz crystal applied to frequency control of station WEAF by Bell Laboratories-Western Electric team greatly improved the quality of distant broadcast reception and laid foundation for more economical use of radio spectrum.



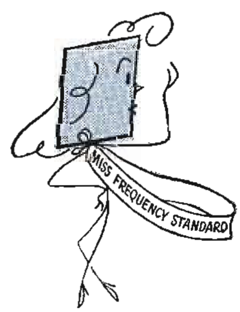
1927 Oscillating 100,000 times a second, a crystal served as the heartbeat of a clock far more accurate than any other timing device ever before made by man.



1933 Low - temperature - coefficient crystal cuts, utilizing for the first time specially selected shape, dimensions, and orientation characteristics, increased frequency stability, made temperature controls needless for certain applications.

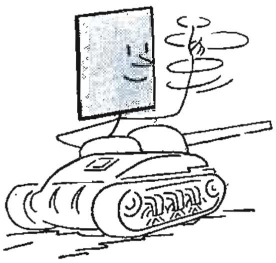


1934 "Traffic Cop" crystal filter designed by Bell Laboratories to act as separation unit for carrier systems. Led to today's 480 channel coaxial systems and single sideband radio transmitters.

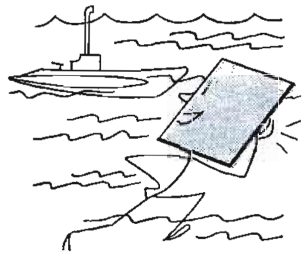


1939 GT crystal serves as a "frequency model." Used for Loran, extremely accurate time signals (stable to 1 part in 10^9), and other applications requiring utmost frequency stability.

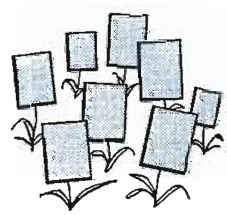
you more accurate frequency control



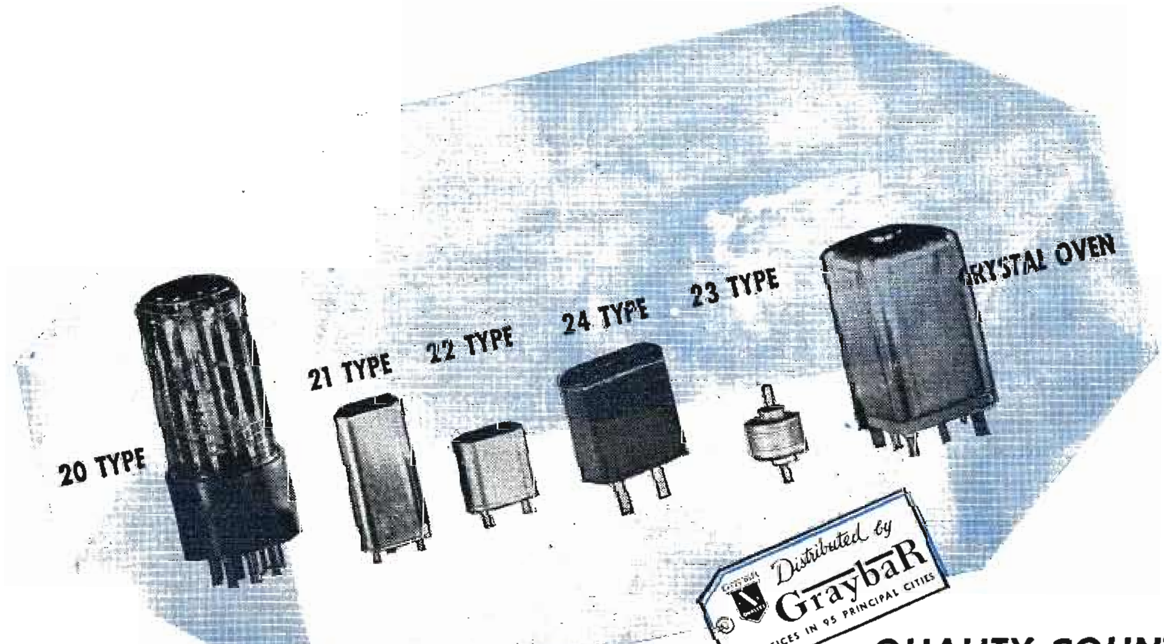
1942 Wire mounted crystal unit designed to withstand shocks and rough usage went into battle in tanks and with artillery. Western Electric produced over 10,000,000 of these.



1943 Synthetic ADP crystals, first mass-produced by this team, were also first applied by the team to underwater sound in Sonar. Change acoustic energy into electric and vice versa.



1947 EDT crystals — the first low-coefficient synthetics — are being grown on Western Electric's crystal farms to replace hard-to-get natural quartz.



— QUALITY COUNTS —

TODAY *FROM 1.2 KC to 50 MC.*—that's the extraordinary range covered by Western Electric's new line of crystal units for oscillator control. All are engineered to assure maximum frequency for a given design, with increased accuracy and stability.

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Purchasing of this equipment has been simplified to a high degree. These WAA Approved Distributors were selected on a basis of their ability to serve you intelligently and efficiently. Write, phone or visit your nearest Approved Distributor for information concerning inventories, prices and delivery arrangements. You'll find you can "Save with Surplus".

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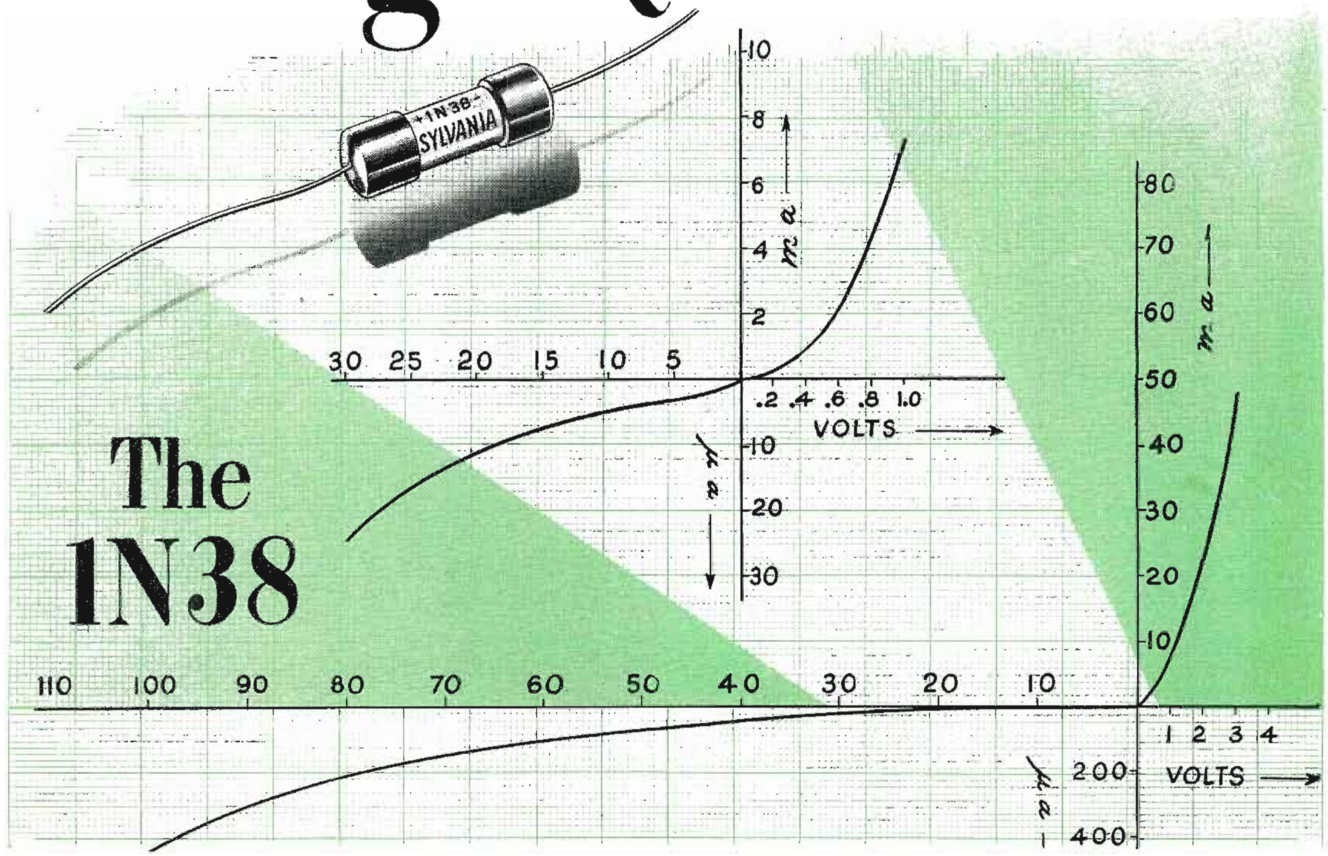

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2000	28	56	*2	25F939	$5\frac{17}{64}$	$4\frac{3}{4}$	$3\frac{3}{4}$	$4\frac{9}{16}$	5.3
2000	40	80	1	25F910	$8\frac{1}{4}$	7	$3\frac{3}{4}$	$4\frac{9}{16}$	7.8
2500	25.5	80	1	25F911	$8\frac{1}{4}$	7	$3\frac{3}{4}$	$4\frac{9}{16}$	7.8
3000	60	270	2	14F312	$15\frac{1}{8}$	$13\frac{1}{8}$	4	8	26
3350	17.8	100	1	25F912	$8\frac{1}{4}$	7	$3\frac{3}{4}$	$4\frac{9}{16}$	7.8
4000	25/50	200/400	3	14F309	$15\frac{1}{8}$	$13\frac{1}{8}$	4	8	26
4000	100	800	2	14F311	$15\frac{1}{8}$	$12\frac{7}{8}$	$5\frac{1}{8}$	$13\frac{1}{2}$	56
4000	12.5	100	1	26F906	$6\frac{3}{4}$	$5\frac{1}{2}$	$3\frac{3}{4}$	$4\frac{9}{16}$	6
5000	25/50	313/625	3	14F305	$15\frac{1}{8}$	$13\frac{1}{8}$	$4\frac{1}{8}$	$13\frac{1}{2}$	46
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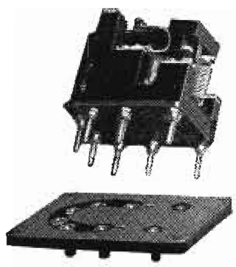

Three contact arrangements—single-pole, single-throw; double-pole, single-throw; double-pole, double-throw—provide further design flexibility. Heavy silver contacts are rated 10 amps continuous at 115/230 volts, 60 cycles, and will safely close on 45 amps and open on 20 amps maximum. Check Bulletin GEA-4668 below for further details.

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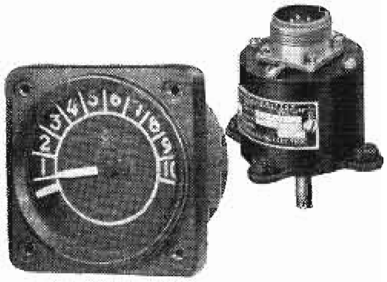
Here's a war baby that you can use. It's General Electric's d-c selsyn position-indicating equipment perfected for use in military aircraft. Transmitters will operate in ambient temperatures from −85 F to 158 F and are weather resistant. Indicators are available in two standard sizes: $1\frac{7}{8}$-inch dial with 1 or 2 pointers, and $2\frac{3}{4}$-inch dial with 1, 2, 3 or 4 pointers. Dial markings to meet your needs

GENERAL ELECTRIC

Digest

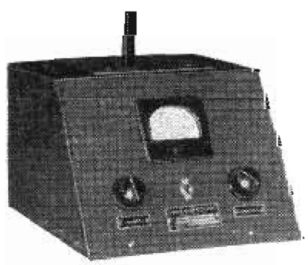
TIMELY HIGHLIGHTS ON G-E COMPONENTS



A single d-c selsyn indicating system consumes about 2 watts at either 12 or 24 volts. Any reasonable lead length may be used. Two indicating instruments can be operated from the same transmitter. Bulletin GET-1304 is a comprehensive application manual you'll find extremely helpful. Check it on the coupon.

COILS TESTED FAST . . . INDUCTIVELY

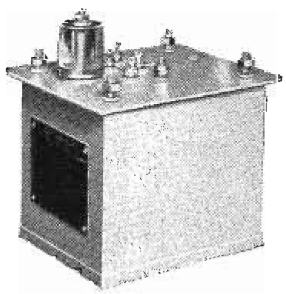
High-speed production testing of small coils is possible with this General Electric low-voltage tester which shows the presence of short-circuited turns in unmounted coils and gives an approximate indication of the number of short-circuited turns. The coil to be tested is simply slipped over the core which projects from the top of the case; the coil's leads need not be connected.



This tester was designed for manufacturers who want accurate tests of coils before assembly in small motors, relays, radios, transformers, instruments and other equipment. It is simple to operate, and connects to any 115-volt, 60-cycle supply. More information on this and another equipment for high-potential coil testing is included in Bulletin GEA-4539 . . . check it on the coupon below.

PRECISION RECTIFIER IN A SMALL PACKAGE

These new, small a-c to d-c power supplies are specially built for precision work with cathode-ray tubes, television camera tubes, radar indicator scopes, electron microscopes . . . or any job where good regulation, light weight and small size are primary considerations. These hermetically sealed, oil-filled power supplies will furnish up to 7 kv at 0.1 ma. They have a regulation of 3.5% per 0.1 ma d-c output, or better.



They easily meet Army and Navy specifications both in design and ability to withstand mechanical shock and operate continuously for long periods of time. Designed to operate in ambient temperatures from −40 C to +60 C. For quotation and further data, write General Electric Co., Section 642-15, Schenectady 5, N. Y., giving complete information on application proposed and specifications required.

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The snap-action contact construction gives the Switchette a high current rating. Because of negligible contact bounce and lightness of moving parts, it is particularly well suited to application on electronic equipment. Bulletins GEA-3818 and GEA-4259 give electrical and mechanical details; check coupon below.

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............GEA-4539	(Coil testers)	............GEA-4259	(Switchettes)

NOTE: More data available in Sweets' File for Product Designers

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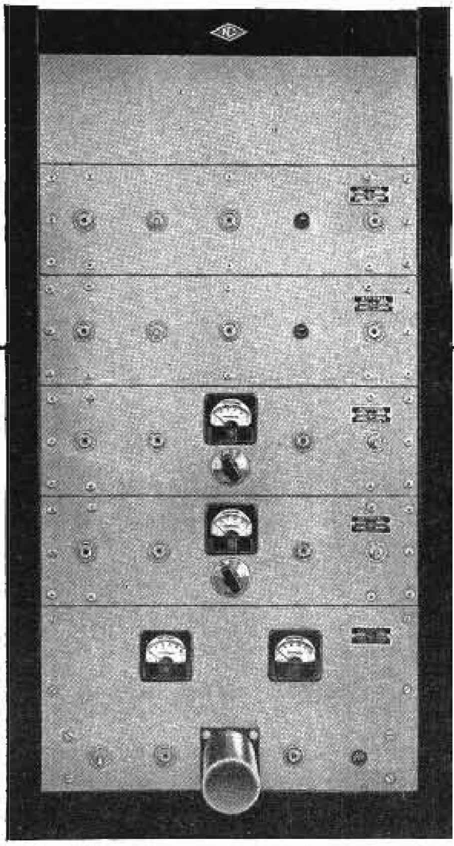

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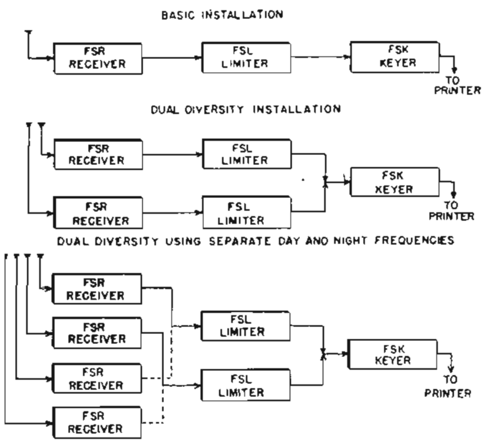

Figure No. 1 Typical FSDR Installations

The FSR Receiver, the FSL Limiter and the FSK Keyer are the three units comprising this equipment and the use of multiple FSR's and FSL's makes possible space or frequency diversity or both.

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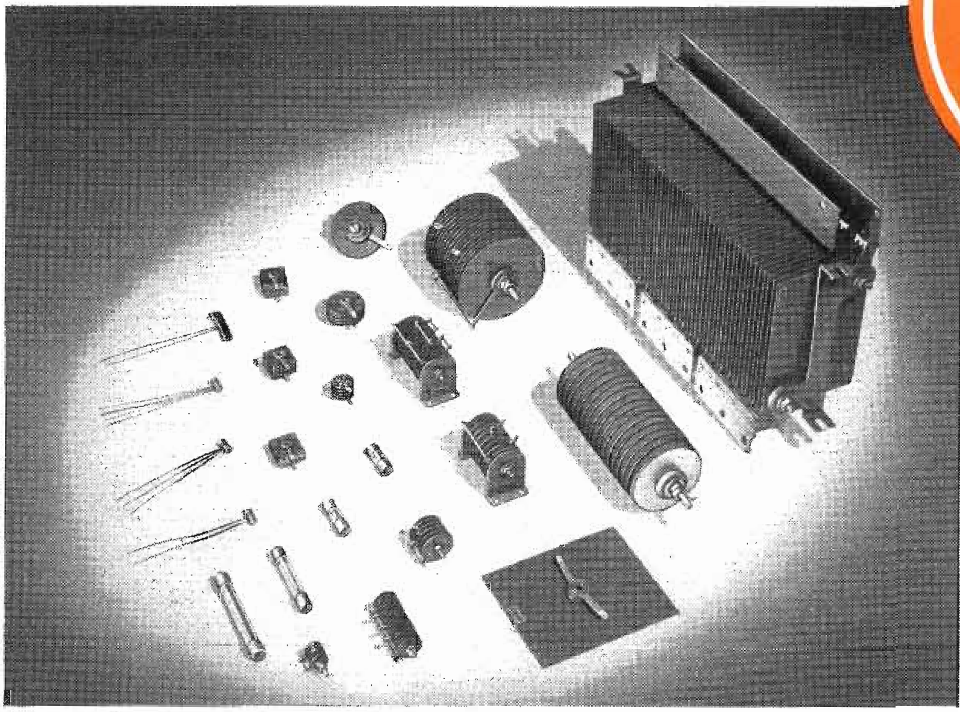

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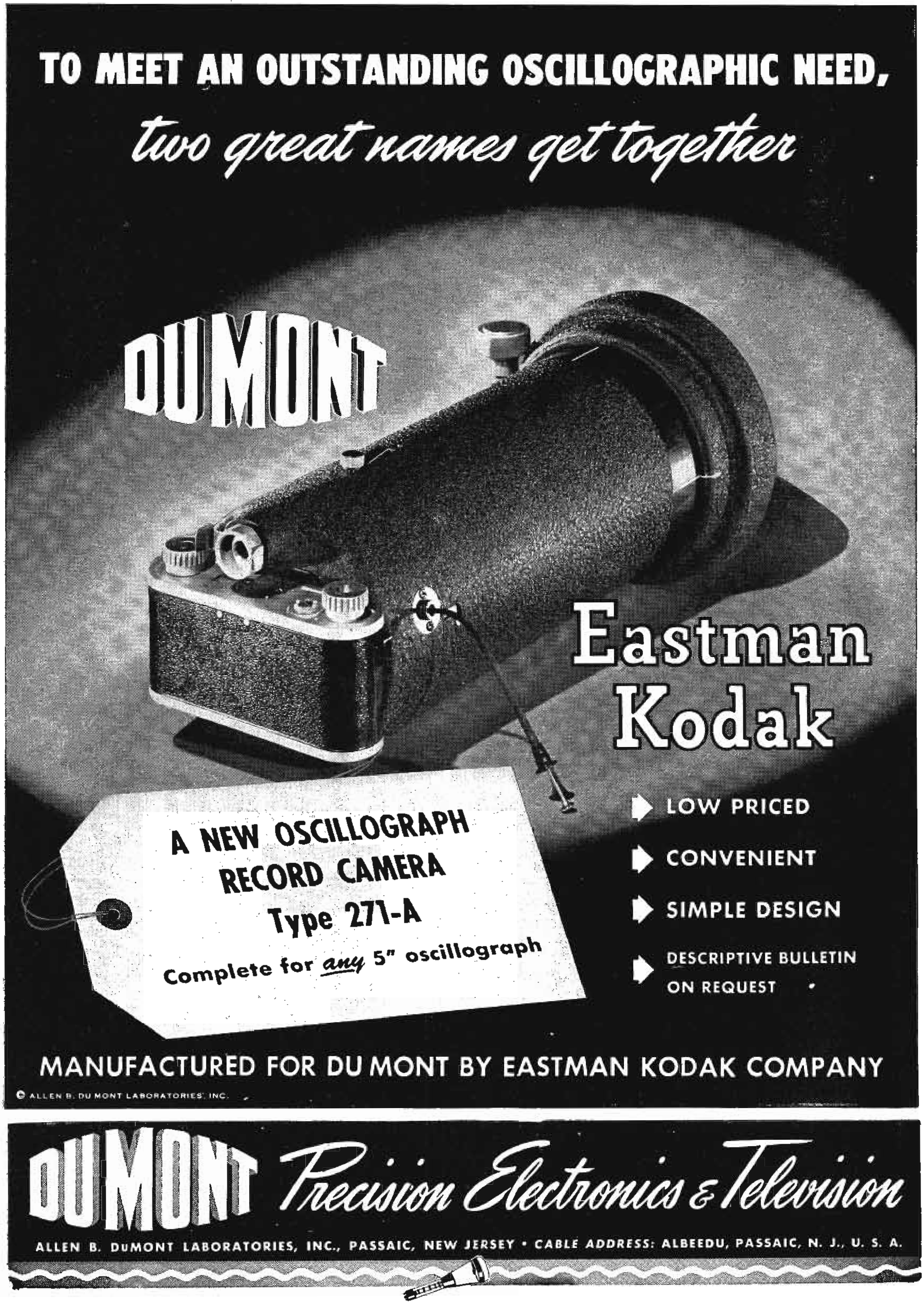
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TELE-TECH

Formerly the TELE-communications TECH-nical Section of

ELECTRONIC INDUSTRIES

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STANDARDIZE PARTS, CUT COSTS is formula for lower receiver prices being proposed by some factory engineers. If radio industry will accept simplified lines of resistors, capacitors, transformers, coils. etc., and adopt wider tolerances, parts stockpiles could be built up during slack times, spreading employment and production, while reducing unit costs. These in turn would be reflected clear through to the retail sales price.

ADD "FRE-MO-DYNE" to your list of circuit names. Hazeltine Corp. has adopted this moniker for new FREquency MOD-ulation circuit being used by its licensees to produce FM sets as low as $39. Simple additions will also make possible conversion of already-built AM table models in AM-FM sets, thus making saleable present overstock of small AM sets.

UNUSED GOV'T CHANNELS NEEDED BY TV are still being denied public use by IRAC, the Government committee which has first choice in allocation of nation's wavelengths. This Interdepartmental body has no contacts with the television industry and cannot even discuss situation with industry leaders; meanwhile FCC stands powerless to help TV applicants for these unused Government wavelengths suitable for at least 12 additional TV channels.

"IRAC No. 1, FCC GETS LEAVINGS" is situation created by U. S. radio law which gives to the President first rights to take any needed wavelengths for Army, Navy and Government use. However, it is the Interdepartmental Radio Allocations Committee (IRAC), made up of radio representatives of Washington Departments, which exercises this function for the President. After various Department bureaucrats have taken freely such channels as they think they may sometime need, remaining channels are turned over to FCC to be allocated for use of civilian public. Result is that valuable badly-needed frequencies are often long held unused, with FCC and public helpless to put these idle channels to work.

FD $15,000,000 RADIO MARKET is revealed from survey of fire departments of U.S., both regular and volunteer, showing that in next few years they plan to spend $150,000,000 on modernization and rehabilitation of fire-fighting services. Of whole amount, ten per cent of above will go for radio equipment, transmitters, receivers, transceivers, etc.

FCC's DROPPING OF TV No. 1 channel was finally determined as the best solution of the sharing problem, though Washington experts admit it does not solve a number of the interference difficulties—for example, interference from TV transmitters to the ILS receivers on aircraft about to land on fog-bound airstrips near large cities. Services moving into No. 1, when and if available, will be mostly police, fire and emergency services; no taxicabs or busses.

POINT FOR PETRILLO. When the music czar decreed that AFMusicians may not, without extra compensation, broadcast simultaneously over AM and FM stations, he dredged up one card that perked up some of his severest critics. If simultaneous AM-FM programming were permitted, Petrillo argued, it would put unmingled FM operators at a disadvantage with respect to the opulent AM-FM group. These AM-FM'ers would get their FM programs free, AM paying the way. But the pure and poor FM operators have no such sugar daddy. For their musicians they must shell out from a crimped pocketbook.

RADIO EMBARGOES. To conserve dollar credits, some foreign nations, notably Mexico, have taken steps to curtail the importation of U. S. radios. Add to this the fierce competitive struggle already being waged for the export market and it becomes remarkably clear that U. S. radio manufacturers are on the receiving end of a curved ball.

The New International *In This Issue*

FREQUENCY ALLOCATIONS FOR THE WESTERN HEMISPHERE

Just completed and adopted by the International Radio Conference meeting at Atlantic City, as this issue goes to press, TELE-TECH presents on following pages the complete tabulation of frequency assignments for the regional classification comprising North and South America

TV Intercarrier Sound System

By L. W. PARKER, Television Consultant, Little Neck, N. Y.

A simple explanation of the method of deriving sound programs in a receiver by noting difference frequency between video and sound channels

• The sound in present day receivers is frequency modulated, and is received by a more-or-less conventional FM sound receiver, where the RF and converter stages are used in common with the picture receiver. This saves from two to three tubes in the sound receiver and one tuning operation handles both signals. However, this system has, among others, the disadvantage that the sound IF is dependent on the local oscillator which has a tendency to drift, in the case of fixed tuning and suffers a small permanent change after several months of use. For this reason, it is usually necessary to provide for readjusting the frequency manually. As little as 50 kc inaccuracy of the local oscillator may result in distortion of the sound. This represents at 200 mc, a change of less than 0.025%, which can hardly be maintained over long periods of time with a continuously tuned oscillator tuned at the factory and using switches to insert the various tuning units.

Recently some continuously tuned units which improve this situation somewhat were introduced. However, such units are expensive, and do not solve the problem of frequency drift during warm-up, except when retuned, in some cases, several times.

In the system introduced by the writer, the sound intermediate frequency does not depend on the local oscillator. It is based on fortuitous relations in the modulation systems in television use: amplitude modulated video carrier and frequency modulated sound carrier transmitted simultaneously and separated by 4.5 mc. The frequency tolerances which must be maintained are still under discussion but it seems that a variation limit of about 5 kc might become standard, at least on the lower bands.

THE system described here, which is being critically studied in many research laboratories, seems to introduce a simplification of the television reception problem. The method, designated by the above title by the FCC, was proposed by Parker a few years ago. The possibility is shown of reducing the number of tubes in a receiver and of simplifying reception in other regards by the use of TRF methods.

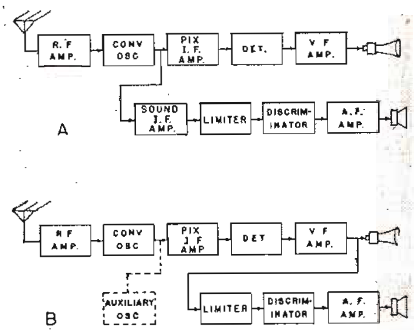

Fig. 1—Television reception by the standard (above) and by the intercarrier system (below)

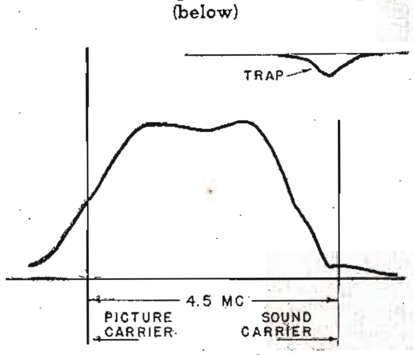

Fig. 2—Typical passband characteristics desired, showing (above) location of resonant frequency of the sound trap

By heterodyning the FM carrier, which is modulated with the sound program, with the AM carrier, a difference frequency is obtained which contains all the sound intelligence. To understand the details of its operation, let us examine the block diagrams, Fig. 1A and 1B. In Fig. 1A the conventional picture and sound system is illustrated. The RF and converter sections are common to the picture and sound. After this, however, they are separated from one another and each has its chain of components.

In the new system, as shown in Fig. 1B, the separation of the picture and sound channels does not take place until the very last tube in the picture receiver. Obviously, the gain of both the entire picture IF channel and video stages is effective in amplifying the sound signal in the new system, but it turns out that this gain is somewhat lower than for the picture signal.

As was stated, the FM sound signal is separated in the RF spectrum by 4.5 mc from the picture signal. About 4.3 mc of the space between the carriers is taken up by the picture signal sidebands. This additional sound signal 4.5 mc higher is treated in the new system just as another sideband and after the second detector it yields a 4.5 mc signal.

It is necessary to prevent this 4.5 mc signal from reaching the kinescope, as will be explained later. This can be done simply by placing some kind of filter ahead of it, to reduce the amplitude of the 4.5 mc signal, while the 4.5 mc FM signal can be separated from the picture signal by permitting only 4.5 mc and nearby signals to pass through a filter to the FM discriminator.

FM Program Reception

In addition to receiving sound for television, sometimes it is required that the television set be able to reproduce the frequency modulated broadcasting stations in the 100 mc band. With conventional receiving equipment this merely means the ability to work from 88-108 mc. Continuously tuned units, of course, have this ability inherently. Switch tuned units may have one or two extra switch points for this band and an oscillator trimmer to cover the range. This latter method is widely used, although the resulting FM receiver is poor, due to various reasons.

One reason for this is that the television sound discriminator is required to demodulate a 25 kc FM excursion, while the standard FM sound is three times that much. Therefore, the Q of the discriminator coil when using television sound can be higher and greater AF output voltage is obtained on a given frequency excursion. This advantage has to be lost when using the set for FM broadcast reception as well as television, unless a complicated switch circuit be added. Another reason for poor performance is the fact that unless continuous tuning is used both in the RF amplifier and converter stages, in addition to the oscillator, low RF gain and poor image rejection may be expected. In spite of these and a number of additional disadvantages, many sets are still being made to perform dual functions.

When using the new sound system for FM broadcast reception, an additional carrier has to be generated to take the place of the picture carrier. For example, if the sound IF is to be 21.25 mc and the picture IF is 25.75 mc, then a local oscillator at this latter frequency is required in order to help generate the 4.5 mc beat frequency. This oscillator may be one of the 25.75 mc IF amplifier stages, made to oscillate by switching the appropriate values of reactances into its circuit or there may be a separate oscillator tube for this purpose. This latter arrangement is preferred.

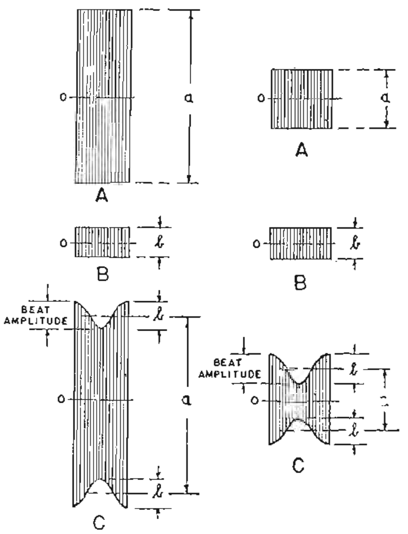

Fig. 3—(left) Heterodyning effects with large amplitude CW signals, compared with smaller amplitude signal levels in Fig. 4 (at right)

In Fig. 1B the additional oscillator intended for FM broadcast reception is indicated with dotted lines. The use of such an oscillator is, of course, optional. It is not expected that after FM sets become popular the television receiver will be used for receiving FM broadcasting. The application of the above described principles present a number of new problems.

Conventional video IF amplifiers contain sound traps to eliminate audio frequency interference from the picture. In this system the sound signals must not be eliminated or reduced too much since they need to appear in considerable amplitude at the output of the picture receiver. Therefore, the sound traps are used to reduce the slope of the resonance curve in the neighborhood of the sound frequency, putting in a small shelf as shown in Fig. 2.

This can be made by tuning an absorption trap near the sound IF frequency. The curve of absorption for such a trap is shown at the top of the figure.

As is readily seen, the point of greatest absorption is not exactly on the sound carrier but a little off toward the picture carrier. The final result is a resonance curve with unchanging amplitude near the FM carrier. This eliminates the partial demodulation of the FM

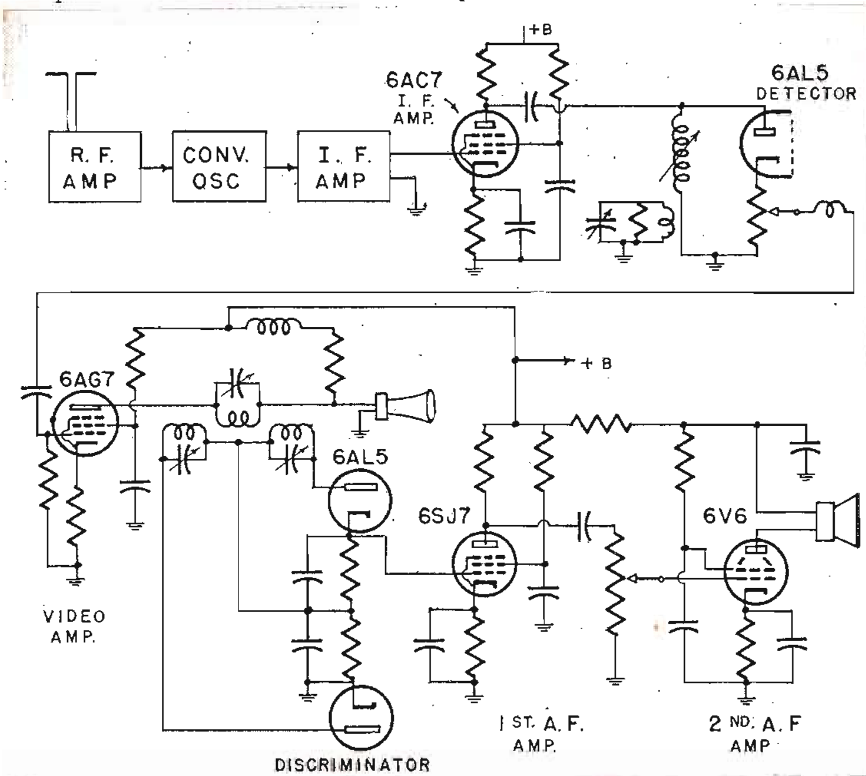

Fig. 5—Simplified diagram of an intercarrier television receiver. The 6AG7 video stage is shown connected to the modulation grid of a conventional cathode ray tube through a special sound filter

signal. Such demodulation would generate audio frequencies which would be amplified by the video frequency amplifier and degrade the picture.

Three factors need adjustment in these absorption traps: The frequency, the coupling, and the Q. By using a frequency modulated signal generator (wobbulator), it is possible to obtain an oscillogram of the resonance curve; then by empirical adjustment of the above constants, the desired curve can be made. It is expected that in mass production the coupling and Q will be set without testing, and a simple screwdriver adjustment for the frequency will be sufficient to obtain the desired curve.

The importance of proper adjustment of these traps should not be over-emphasized. It was found that even if the traps were tuned directly on the sound frequency, the receiver still operated fairly. The AF signal dropped considerably, but by using the full gain of the circuit, as shown in Fig. 5, there was enough volume to give satisfactory performance in a not too noisy room.

Limiter is Optional

The use of the limiter ahead of the discriminator is optional. If a great enough ratio of amplitudes is maintained between the picture and sound carriers before they reach the second detector, substantially no amplitude modulation occurs on the 4.5 mc FM carrier, even when the picture carrier is amplitude modulated. Since this usually appears as a paradox to most people not well acquainted with the heterodyne phenomenon, it will be explained further and demonstrated graphically.

In Fig. 3A is the envelope of a large-amplitude continuous wave. Under it at Fig. 3B is the envelope of a small-amplitude continuous wave of slightly different frequency. This frequency difference is not illustrated, but has to be assumed. The sum of these two envelopes is shown in Fig. 3C. Due to the difference in the frequency of the two heterodyning waves, there is a ripple on top of the resultant envelope. As one frequency changes relative to the other, there is a point where they are in phase. Here the resultant is the arithmetical sum of the two waves. On another point in Fig. 3C the two waves are exactly in opposing phase. This is in the valley of the envelope, where the resultant wave of Fig. 3C is the arithmetical difference of the two heterodyning waves. Therefore, the peak-to-peak amplitude of the beat frequency is equal to the peak-to-peak amplitude of the smaller one of the two heterodyning waves.

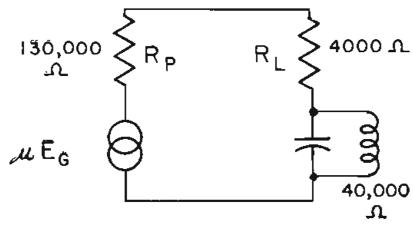

Fig. 6—Equivalent circuit of the final video amplifier tube, type 6AG7, of Fig. 5

In Fig. 4, the large-amplitude wave was reduced to twice the amplitude of the smaller one. The sum of these two waves in Fig. 4C still has the same ripple or beat amplitude as before. Obviously then, wave A may be amplitude modulated and vary between the limits shown on Figs. 3 and 4, without transferring this modulation to the resultant beat amplitude.

While it can be shown mathematically that this is not strictly so, due to the beat frequency containing harmonics, for our purpose it is near enough to be considered true.

The only condition that must be met is, that the smaller of the two waves must always remain considerably smaller than the larger wave. This must be so even when the larger wave drops its amplitude due to modulation.

Sound May Be AM

It is interesting to note that the sound need not be FM when using this system. It could be separated from the amplitude modulated picture carrier by the above described means even if it were itself amplitude modulated.

Separation of the two modulations is inherent in the system. Consequently, the use of a limiter to eliminate amplitude modulation from the FM signal at times may not be justified. If a limiter is used its function is mainly to eliminate extraneous noises. These noises, however, are in most cases not very disturbing. For this reason cheaper sets may be made without limiters. In such cases the sound carrier amplitude has to be more attenuated than when a limiter is used.

It is not practical to set an accurate upper limit for the sound carrier amplitude since this amplitude varies between sets due to production variations. For this reason, wide limits, such as the following, are advisable. The amplitude of the sound carrier, as shown in Fig. 2, should be between 1% and 5% of the full amplitude of the resonance curve. This results in a considerable variation of audio sensitivity but it can be compensated for by higher audio gain in the AF amplifier. All receivers of the same vintage, of course, have the same kind of AF amplifier; they differ only in the adjustment of the volume control.

Functional Diagram

Fig. 5 illustrates a combination circuit and block diagram of a simple television receiver using this system. The parts unchanged by the use of the new system are indicated as blocks. All the new information is in detail.

The last tube in the stagger-tuned IF amplifier is shown in detail to illustrate the use of the absorption trap. This trap helps to eliminate the sound from the picture and was described above.

The diode detector following the last IF amplifier is conventional. The video amplifier is also conventional except for the parallel resonant circuit in series with its plate. This is the resonant circuit that takes off the 4.5 mc frequency modulated carrier for the sound.

It was stated before that the sound carrier is attenuated to the point where its amplitude may be in the order of 1% to 5% of the picture carrier. Since this can vary over wide limits, we may assume for the following discussion that it happens to be 1% of the greatest picture signal. This greatest picture signal is 80% of the peak

(*Continued on page 94*)

New Frequency Allocations Set

Atlantic City Conference completes global spectrum master-plan dividing World into four Regions for 10 kc to 10,500 mc

• After four months of continuous work, delegates to the 71 countries participating in the International Radio Conference which opened in Atlantic City, N. J. on May 15 this year, have determined on what is generally believed to be an equitable division of the radio spectrum from the low end at 10 kc to the extreme high end at 10,500 mc. There has accordingly been issued a new table of frequency allocations designating the particular bands in which all services may operate throughout the world.

Prime object of the new allocations, of course, has been to assure operation of the maximum number of essential services without interference between them. To this end, the general rules for the assignment and use of frequencies specifically state that "the countries that are members of the Union adhering to the regulations agree that in assigning frequencies to stations . . . they will make assignments in accordance with the table of allocations".

One important change has been made in the method of making allocations. Under the new set-up there are three Regions and a Worldwide category. Heretofore there have been but two Regions—General and European. The Worldwide category takes the place of the two former Regions. The three new Regions have been added for the purpose of permitting certain exceptions to the Worldwide allocations.

Region 1 under the new arrangement covers most of Europe and all of Africa; Region 2, in which the United States will have greatest interest, includes North America, South America, Hawaii, Greenland and all the northern islands. Region 3 includes Asia and Oceania.

The complete table of allocations with its voluminous explanatory footnotes is designated Document 874 and comprises some 33 typewritten pages. As compiled for presentation with this issue of Tele-Tech. the table includes only those allocations designated for Region 2, which includes Worldwide as a matter of course.

The allocations table was to be signed by each country's delegate about Sept. 15, after which each government would ratify the assignments. It is likely that the new allocations will not become effective until some time in 1949, probably with little or no change.

Frequency Allocations for the Western Hemisphere

Frequency KC	Service
10-14	Radio Navigation*
14-70	Fixed, Maritime Mobile* (1)
70-90	Fixed, Maritime Mobile (1)
90-110	Fixed, Maritime Mobile (1) (4) Radio Navigation*
110-130	Fixed, Maritime Mobile
130-150	Fixed (8), Maritime Mobile
150-160	Fixed, Maritime Mobile
160-200	(13) Fixed
200-285	Aeronautical Mobile, (14) Aeronautical Radio Navigation
285-325	(16) Maritime Radio Navigation (radio beacons)
325-405	(17, 18, 19, 20) Aeronautical Mobile* Aeronautical Radio Navigation*
405-415	(23) Aeronautical Mobile, Aeronautical Radio Navigation, Maritime Radio Navigation, (radio directing fiuding)
415-490	(24, 25) Maritime Mobile*
490-510	(26) Maritime Mobile, (distress and calling)*
510-525	Mobile
525-535	Mobile
535-1605	Broadcasting*
1605-1800	Aeronautical Radio Navigation, Fixed, Mobile
1800-2000	Amateur, Fixed, Mobile Except Aeronautical Mobile (33) Radionavigation
2000-2065	Fixed, Mobile
2065-2105	(7) Maritime Mobile
2105-2300	(37) Fixed, Mobile
2300-2495	Broadcasting. Fixed, (37) Mobile
2495-2505	Standard Frequency
2505-2850	Fixed, Mobile
2850-3025	Aeronautical Mobile*
3025-3155	Aeronautical Mobile*
3155-3200	Fixed, Mobile Except Aeronautical Mobile
3200-3230	Broadcasting*, Fixed*, Mobile Except Aeronautical Mobile*
3230-3400	Broadcasting*, Fixed*, Mobile Except Aeronautical Mobile*
3400-3500	Aeronautical Mobile*
3500-4000	Amateur, Fixed, Mobile Except Aeronautical Mobile
4000-4063	Fixed*
4063-4438	(39) Maritime Mobile*
4438-4650	Fixed. Mobile Except Aeronautical Mobile
4650-4700	Aeronautical Mobile*
4700-4750	Aeronautical Mobile*
4750-4850	Broadcasting Fixed
4850-4995	Broadcasting*, Fixed*, Land Mobile*
4995-5005	Standard Frequency*
5005-5060	Broadcasting*, Fixed*
5060-5250	Fixed*
5250-5450	Fixed, Land Mobile
5450-5480	Aeronautical Mobile
5480-5680	Aeronautical Mobile*
5680-5730	Aeronautical Mobile*
5730-5950	Fixed*
5950-6200	Broadcasting*
6200-6525	Maritime Mobile*
6525-6685	Aeronautical Mobile*
6685-6765	Aeronautical Mobile*
6765-7000	Fixed*
7000-7100	Amateur*
7100-7300	Amateur
7300-8195	Fixed*
8195-8815	(42) Maritime Mobile*
8815-8965	Aeronautical Mobile*
8965-9040	Aeronautical Mobile*
9040-9500	Fixed*
9500-9775	Broadcasting*
9775-9995	Fixed*
9995-10005	Standard Frequency*
10005-10100	Aeronautical Mobile*
10100-11175	Fixed*
11175-11275	Aeronaulical Mobile*
11275-11400	Aeronautical Mobile*
11400-11700	Fixed*
11700-11975	Broadcasting*
11975-12330	Fixed*
12330-13200	Maritime Mobile*
13200-13260	Aeronautical Mobile*
13260-13360	Aeronautical Mobile*
13360-14000	(46) Fixed*
14000-14350	Amateur*
14350-14990	Fixed*
14990-15010	Standard Frequency*
15010-15100	Aeronautical Mobile*
15100-15450	Broadcasting*
15450-16460	Fixed*
16460-17360	(42) Maritime Mobile*
17360-17700	Fixed*
17700-17900	Broadcasting*
17900-17970	Aeronautical Mobile*
17970-18030	Aeronautical Mobile*
18030-19990	Fixed*
19990-20010	Standard Frequency*
20010-21000	Fixed*
21000-21450	Amateur*
21450-21750	Broadcasting*
21750-21850	Fixed*
21850-22000	Aeronautical Fixed* Aeronautical Mobile*

Frequency kc	Service
22000-22720	Maritime Mobile*
22720-23200	Fixed*
23200-23350	Aeronautical Fixed* Aeronautical Mobile*
23350-24990	Fixed*, (50) Land Mobile*
24990-25010	Standard Frequency*
25010-25600	Fixed*, Mobile Except Aeronautical Mobile*
25600-26100	Broadcasting*
26100-27500	Fixed*, (53) Mobile Except Aeronautical Mobile*
27500-28000	Fixed Mobile
28000-29700	Amateur*
Megacycles	
29.7-29.44	Fixed, Mobile
29.44-29.50	Broadcasting, Fixed, Mobile
29.50-29.54	Amateur
29.54-29.72	Broadcasting, Fixed, Mobile
29.72-29.76	Fixed, Mobile
29.76-29.88	Broadcasting, Fixed, Mobile
88-100	Broadcasting*
100-108	Broadcasting
108-118	Aeronautical Radio Navigation*
118-132	Aeronautical Mobile

Frequency mc	Service
132-144	Fixed, Mobile
144-146	Amateur*
146-148	Amateur
148-174	Fixed, Mobile
174-216	Broadcasting, Fixed, Mobile
216-220	Fixed, Mobile
220-225	Amateur
225-235	Fixed, (85) Mobile
235-238.6	Fixed*, Mobile*
328.6-335.4	Aeronautical Radio Navigation*
335.4-420	Fixed*, (86, 87) Mobile*
420-450	Aeronautical Radio Navigation*, (88, 89) Amateur*
450-460	Aeronautical Radio Navigation, Fixed, (89) Mobile
460-470	Fixed*, Mobile*
470-585	Broadcasting*
585-610	Broadcasting
610-940	(91, 93) Broadcasting*
940-960	Fixed
960-1215	Aeronautical Radio Navigation*
1215-1300	(94) Amateur*
1300-1660	(97) Aeronautical Radio Navigation

Frequency mc	Service
1660-1700	Meteorological Aids (Radio Sonde)
1700-2300	Fixed*, (98) Mobile*
2300-2450	(99) Amateur*
2450-2700	(99) Fixed*, (100) Mobile*
2700-2900	(100) Aeronautical Radio Navigation*
2900-3300	(101, 102) Radio Navigation*
3300-3500	Amateur
3500-3900	Fixed, Mobile
3900-4200	Fixed* Mobile*
4200-4400	(103) Aeronautical Radio Navigation*
4400-5000	Fixed* Mobile*
5000-5250	Aeronautical Radio Navigation*
5250-5650	(104, 105) Radio Navigation*
5650-5850	Amateur*
5850-5925	Amateur
5925-8500	Fixed* (107) Mobile*
8500-9800	(108, 109) Radio Navigation*
9800-10000	Fixed* Radio Navigation*
10000-10500	Amateur*
Above 10500	Unalloeated

NOTE—An asterisk(*) following a service designation indicates that allocation has been made on a Worldwide basis. Explanatory notes are nnmbered and include only those notes which apply specifically to Worldwide and Region 2 allocations. Notes referring to other Regions have been omitted. Where the number in parenthesis (1, etc.) appears at the left of a section the note refers to all the services listed under that allocation. Where the number in parenthesis appears at the right, the footnote applies to that specific service.

(1)—Limited to coastal telegraph stations using unmodulated emissions (A1).

(4)—The development of long distance radionavigational systems is authorized in this band which will become exclusively allocated wholly or in part for the use of any one such system as soon as it is internationally adopted.

(7)—Limited to ship stations (telegraphy exclusively).

(8)—The fixed service is authorized, provided no harmful interference is caused to ship telegraphy in the North Atlantic and the Mediterranean areas.

(13)—Priority is given to the aeronantical fixed service in northern areas which are subject to auroral disturbances.

(14)—Priority is given to the aeronautical radionavigation service in Region 2, China, India, and Pakistan.

(16)—In Region 2 the aeronautical radionavigation service is permitted in the band 285-325 kc provided that no harmful interference is caused to the maritime radionavigation service.

(17)—The aeronantical radionavigation service has priority except in New Zealand.

(18)—In Region 1, the frequency 333 kc is the general calling frequency for aircraft stations operating in the band 325-405 kc.

(19)—This band is allocated exclusively to the aeronautical mobile and aeronautical radionavigation services. Nevertheless, in the European Area, subject to authorization by the Convention concluded by the next European Administrative Broadcasting Conference and the conditions specified in that Convention, the Administrations concerned may place in the bands 325-365 kc and 395-405 kc those of the following broadcasting stations which will not cause harmful interference to the aeronautical mobile and aeronautical radionavigation services. The broadcasting stations now in operation in the whole of the band 325-405 kc are:—Banska Bystrica, Bergen, Finnmark, Lulea.

(20)—The fixed stations in Scandinavia now operating in the band 385-395 kc may continue to do so by special arrangement.

(23)—In Region 2, the aeronautical radionavigation service has priority over the aeronautical mobile service.

(24)—The band 415-490 kc is allocated exclusively to the maritime mobile service on a world-wide basis and the band 510-525 kc is allocated exclusively to that service in Region 1. Nevertheless, in the European Area, subject to authorization by the Convention concluded by the next European Administrative Broadcasting Conference and to the conditions specified in that Convention, the Administration concerned may place in the bands 415-485 kc and 515-525 kc such of the following broadcasting stations as will not cause harmful interference to the maritime mobile service:—Geneva, Hamar, Innsbruck, Oestersund, Oulu.

(25)—Limited to telegraphy.

(26)—The frequency 500 kc is the international distress and calling frequency.

(33)—In any particular area the LORAN system of radionavigation operates either on 1850 or 1950 kc, the band occupied being 1800-1900 kc or 1900-2000 kc. Any of the authorized services may employ whichever of these two bands is not required for LORAN on condition that they do not cause harmful interference to LORAN.

(37)—In Region 2, provision will be made for coastal telegraphy in the maritime mobile service by special arrangement.

(39)—In the bands 4063-4133 kc and 4408-4438 kc, fixed stations of limited power may operate provided that, in order to minimize the possibility of causing harmful interference to the maritime mobile service, they are situated at least 600 km from the coast.

(42)—Between 8615 and 8815 kc, the U.S.S.R. will meet their special requirements for the fixed service with due regard to technical provisions (power, location, antenna, etc.) with a view to minimizing the possibility of harmful interference with the maritime mobile service. Coastal stations in the maritime mobile service will also have due regard to technical provisions (power, location, antenna, etc.) with a view to minimizing the possibility of harmful interference with the fixed service in the U.S.S.R.

(46)—The frequency 13560 kc is designated for industrial, scieutific and medical purposes. Emissions must be confined within ± 0.05% of this frequency. Radiocommunication services operating within these limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment.

(50)—Inter-ship telegraphy in the maritime mobile service is permitted in the band 23350-24000 kc.

(53)—In Region 2, Australia, New Zealand, and the Union of South Africa and the territory under mandate of Southwest Africa, the amateur service will operate within the band 26960-27230 kc.

(85)—In Region 2, distance measuring equipment in the aeronautical radionavigation service may be operated in the band 220-231 mc until January 1952 in accordance with appropriate bilateral or multilateral arrangements.

(86)—The meteorological aids service (radio-sonde) may be operated in the band 400-420 mc.

(87)—In the U.S.S.R., the band 412-460 mc is allocated for the radionavigation service.

(88)—In the band 420-460 mc the aeronautical radionavigation service has priority. The other services are admitted to this band only on condition that harmful interference is not caused to the aeronautical radionavigation service.

(89)—In Region 2, the allocation for the aeronautical radionavigation service in the band 420-460 mc is temporary and is exclusively for altimeters.

(91)—In France, the band 585-685 mc is allocated for the fixed and broadcasting services.

(92)—In China, the band 585-610 mc is allocated for the radionavigation service.

(93)—In Region 2, the fixed service may operate in the band 890-940 mc.

(94)—In the U.S.S.R., the band 1215-1300 mc is allocated for the fixed service, primarily for relaying television.

(95)—In Region 2, the band 1300-1660 mc is intended for an integrated system of electronic aids to air navigation and traffic control. Administrations of the other Regions should envisage the possibility of the future application of such a system on a world-wide basis.

(96)—In the U.S.S.R., the band 1300-1600 mc is allocated for the aeronautical radionavigation service.

(97)—In Region 2 and the United Kingdom, the use of the band 1300-1365 mc is restricted to surveillance radar.

(98)—In Regions 1 and 3, the meteorological aids service may be operated in the band 1700-1750 mc.

(99)—In Region 2, Australia, New Zealand, Northern Rhodesia, Southern Rhodesia, the Union of South Africa and territory under mandate of Southwest Africa, and the United Kingdom, the frequency 2450 mc is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ± 50 mc of that frequency. Radiocommunication services operating within those limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment.

(100)—In the U.S.S.R., the band 2450-2700 mc is allocated for the aeronautical mobile and the aeronautical radionavigation services. The meteorological aids service may be operated in the band 2700-2900 mc.

(101)—The band 3246-3266 mc is designated for racons.

(102)—In the band 2900-3300 mc shipborne radar in merchant ships is confined within the band 3000-3246 mc.

(103)—In China, the band 4200-4400 mc may be used for the fixed service provided that harmful interference is not caused to the aeronautical radionavigation service.

(104)—The band 5440-5460 mc is designated for racons.

(105)—In the band 5250-5650 mc shipborne radar in merchant ships is confined within the band 5460-5650 mc.

(107)—In the U.S.S.R., the band 6900-7050 mc may be used for the meteorological aids service.

(108)—The band 9300-9320 mc is designated for racons.

(109)—In the band 8500-9800 mc shipborne radar in merchant ships is confined within the band 9320-9500 mc.

The Theory of Antenna Design for FM Broadcasting

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A systematic review of the main features and characteristics of the principal types with a mathematical analysis of their properties

• There are in use at present several distinct types of FM broadcast antennas. Some information concerning the more important properties of these antennas may be found in the literature. Unfortunately, this information is usually limited to one particular antenna type, and there is no uniformity in the treatment of various antenna types by different authors. It appears, therefore, important to attempt a more systematic review of the main features and characteristics of FM broadcast antennas. Obviously, a review of this type involves an extensive use of already published material. It is not possible to acknowledge explicitly every source used, but more important references are given in the end bibliography. In line with the present FCC regulations, this survey is restricted to antennas for horizontally polarized radiation within the frequency band of 88-108 Mc.

Each type of antenna may be characterized by its horizontal and vertical radiation patterns. The horizontal pattern determines the shape of the coverage area. The vertical pattern determines its radius. The radiation patterns, as presented here, are relative field intensity patterns. They represent the ratio of a magnitude of the total electric field in the given direction to the magnitude of the electric field in the direction where it is maximum.

To compare the different types of antennas, a power gain is used. It may be defined as a ratio of powers which must be radiated by the reference dipole and the actual antenna to produce the same field intensity in the direction where it is maximum. Horizontal polarization requires horizontal radiating elements, such as dipoles or loops. These, therefore, constitute the basic FM antenna elements.

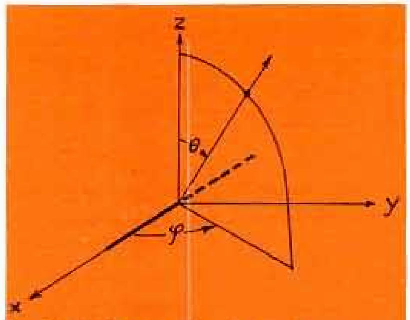


Fig. 1—Half-wave dipole and coordinate system

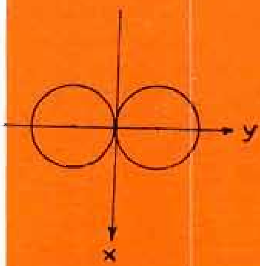


Fig. 2 — Horizontal pattern of half-wave dipole

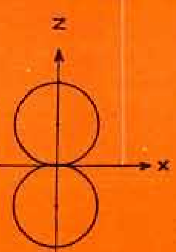


Fig. 3—Vertical pattern of half-wave dipole in x-z plane

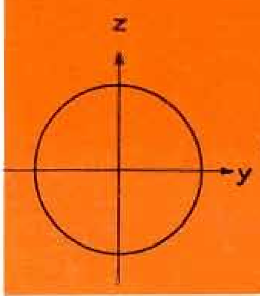


Fig. 4—Vertical pattern of half-wave dipole in y-z plane

Consider a half-wave dipole with its center located at the origin of the coordinate system and parallel to the x-axis (Fig. 1). To the first approximation, the relative field intensity pattern is* $E = (\cos^2\varphi\cos^2\theta + \sin^2\varphi)^{1/2}$. In the horizontal, x-y plane, $\theta = 90$ degrees and, therefore, the relative horizontal field intensity pattern is $E_h = \sin\varphi$ or has a familiar, figure-of-eight shape (Fig. 2). The maximum of field intensity occurs in the direction perpendicular to the dipole axis ($\varphi = 90$ degrees).

In the vertical, x-z plane, $\varphi = 0$ degrees and, therefore, the relative vertical field intensity pattern is $E_{x-z} = \cos\theta$ or has again figure-of-eight shape (Fig. 3).

In the vertical z-y plane, $\varphi = 90$ degrees, and therefore the relative vertical field intensity pattern is $E_{y-z} = 1$ or has circular shape (Fig. 4).

The power gain of the dipole, by the definition, is unity. It has to be noticed that the horizontal dipole is not a particularly efficient radiator insofar as the concentration of radiation in the horizontal plane is concerned; in x-z plane, for example, there is as much radi-

*In this article, θ is consistently an elevation angle counted from the vertical z-axis and φ is azimuth angle counted from the horizontal x-axis towards y-axis.

ation toward the zenith as toward the horizon.

In general, the loop radiators used in FM broadcasting have their linear dimensions comparable to the wavelength and, therefore, their radiation properties differ from those of the ordinary loop, very small in comparison to wavelength.

Square Loop

Consider a square loop with its center located at the origin of the coordinate system and with sides parallel to x and y axis (Fig. 5). To a first approximation‡ and provided the loop sides carry equal currents, the relative field intensity pattern is

$$E = \frac{J_1(\beta l \sin \theta)}{J_1(\beta l)} \left[1 - \frac{J_3(\beta l)}{J_1(\beta l)} - \frac{J_3(\beta l \sin \theta)}{J_1(\beta l \sin \theta)} \cos 4\varphi\right]$$

where $J_1(x)$ and $J_3(x)$ are first and third order Bessel functions of the first kind. Their ratio $J_3(x)/J_1(x)$ is shown in Fig. 6. $\beta = 2\pi/\lambda$, λ = wavelength; l = half side of the loop. In the horizontal x-y plane, $\theta = 90$ degrees and

$$\Re[E_h] = 1 - \frac{J_3(\beta l)}{J_1(\beta l)} (1 + \cos 4\varphi)$$

If it were not for the second term on the right side, the horizontal pattern would have a circular shape. The degree of the departure from the circularity increases with the increase of βl. Fig. 7 shows the horizontal field intensity pattern for the most common case of $\beta l = \pi/2$.

The vertical field pattern (x-z plane) is shown in Fig. 8. Since $J_1(0) = 0$, there is no zenithal radiation. In general, it may be stated that the square loop has approximately circular horizontal pattern and approximately figure-of-eight pattern in any vertical plane.

It has to be noticed, therefore, that the square loop, when compared with the horizontal dipole, has a more desirable field pattern since the radiation is more efficiently concentrated around the horizon. This statement should not be understood as claiming higher gain for the loop: The loop radiates more or less uniformly in the horizontal plane, whereas the dipole concentrates radiation in the direction perpendicular to its axis and there is no radiation in the direction of the dipole.

Since the horizontal field pattern of the loop is not circular, it is customary to speak about its average power gain, that is power gain based on the average field intensity in the horizontal plane. The average power gain is

$$(PG)_{av} = \frac{4}{3} \frac{\beta l \, J_1^2(\beta l)}{{}_0\int^{2\beta l} J_0(y)dy - 2J_1(2\beta l)}$$

The integral appearing in the denominator is a tabulated function*. Fig. 9 shows the average power gain versus βl. For $\beta l = \pi/2$, $(PG)_{av} = .885$.

Consider a circular loop with its center located at the origin of the coordinate system and in the x-y plane—Fig. 10. To a first approximation and under the assumption of the transmission line current distribution, the relative field intensity pattern is

$$E = \frac{1}{\left[16(A^2 + C^2)\left(\frac{2}{\beta^2 a^2} + 1\right)^2 + 8(AB + CD)\left(\frac{2}{\beta^2 a^2} + 1\right) + (B^2 + D^2)\right]^{\frac{1}{2}}} \times$$

$$\times \left\{ \begin{array}{l} (A^2 + C^2) \sin^2 2\theta \sin^2 2\varphi + 2(AB + CD) \sin 2\theta \cos \theta \sin 2\varphi \sin \varphi \\ + (B^2 + D^2) \cos^2 \theta \sin^2 \varphi + 16(A^2 + C^2) \sin^2 \theta \left(\frac{2}{\beta^2 a^2} + \cos^2 \varphi\right)^2 \\ + 8(AB + CD) \sin \theta \cos \varphi \left(\frac{2}{\beta^2 a^2} + \cos^2 \varphi\right) + (B^2 + D^2) \cos^2 \varphi \end{array} \right\}^{\frac{1}{2}}$$

‡The formulas presented in this and the following sections are taken from the author's yet unpublished paper on the theory of loop antennas.

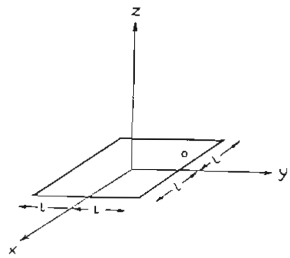


Fig. 5 — Square loop and coordinate system

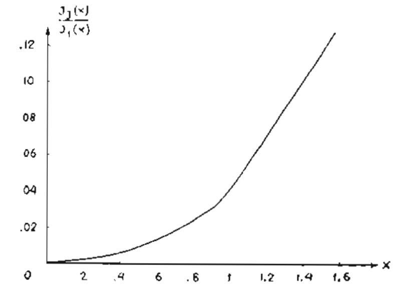
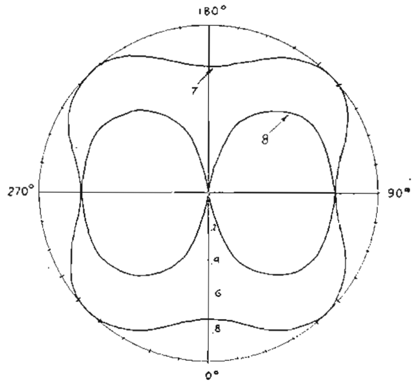


Fig. 6—Graph of $J_3(X)/J_1(X)$



Figs. 7 & 8—Patterns of square loop with $L = \frac{\lambda}{4}$; (7), horizontal pattern; (8) vertical pattern in x-z plane

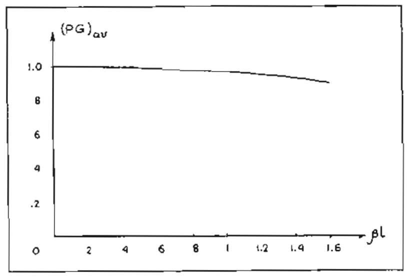


Fig. 9—Graph of power gain of square loop

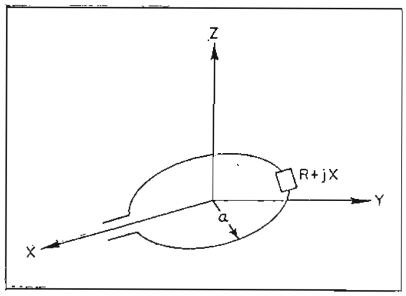


Fig. 10—Circular loop and coordinate system

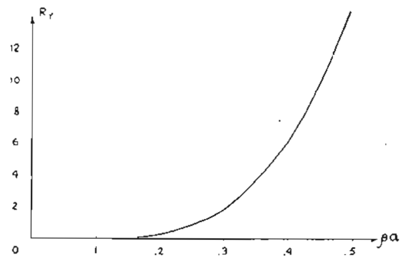


Fig. 11—Graph of radiation resistance of short-circuited circular loop

* A. N. Lowan and M. Abramowith. Table of Integrals ${}_0\int^x J_0(t)dt$ and ${}_0\int^x Y_0(t)dt$. Journ. Math. and Phys. Vol. 22, pp. 2-12, May 1943.

Where $A = -bm_1 J_1\left(\frac{\beta a}{2}\right) \sin\frac{\beta a \pi}{2}$

$$B = -cm_2 J_0\left(\frac{\beta a}{2}\right) \cos\frac{\beta a \pi}{2}$$

$$C = bl_1 J_1\left(\frac{\beta a}{2}\right) \sin\frac{\beta a \pi}{2}$$

$$D = cl_2 J_0\left(\frac{\beta a}{2}\right) \cos\frac{\beta a \pi}{2}$$

$$b = \frac{\beta a}{4 - \beta^2 a^2}$$

$$c = \frac{\beta a}{1 - \beta^2 a^2}$$

$$l_1 + jm_1 = \left(\cos\frac{\beta a \pi}{2} - x \sin\frac{\beta a \pi}{2}\right) + jr \sin\frac{\beta a \pi}{2}$$

$$l_2 + jm_2 = r \cos\frac{\beta a \pi}{2} + j\left(x \cos\frac{\beta a \pi}{2} + \sin\frac{\beta a \pi}{2}\right)$$

$$r + jx = \frac{R + jX}{Z_0}$$

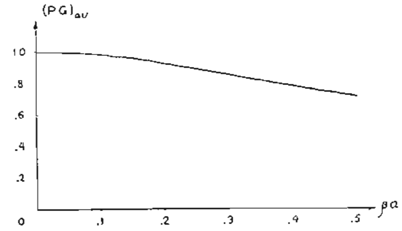
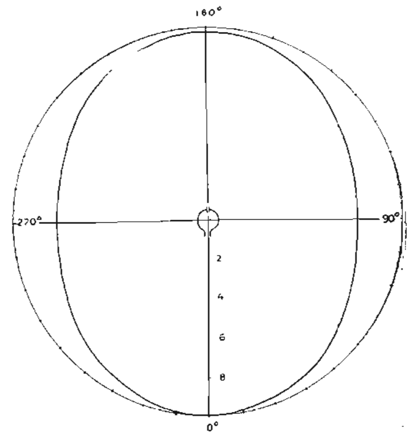
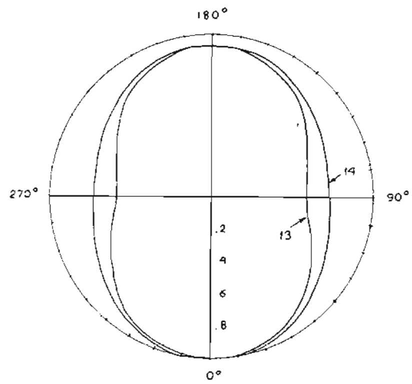


Fig. 12—Graph of power gain of short-circuited circular loop

Fig. 15—Horizontal pattern of capacitively loaded circular loop with $\beta a = .314$ and $\chi = -1.54$ →



Figs. 13 & 14—Patterns of short-circuited circular loop with $\beta a = .5$; (13), horizontal pattern ("O" degrees corresponds to feeder end); (14), vertical pattern in x-z plane ("O" and "180" degrees line corresponds to x-axis, "90" and "270" degrees corresponds to z-axis) ↓



R + jX = impedance terminating far end of the loop.

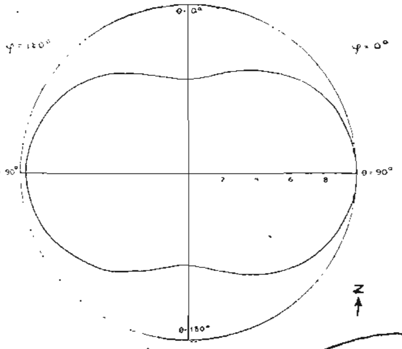
Z_0 = loop characteristic impedance:

$Z_0 = 276 \log a/d$

a = mean loop radius

d = loop conductor diameter

In the horizontal x-y plane, θ = 90 degrees, and



↑

Fig. 16—Vertical pattern in x-z plane of capacitively loaded circular loop with $\beta a = .314$ and $\chi = -1.54$

$$E_h = \left[\frac{16(A^2 + C^2)\left(\frac{2}{\beta^2 a^2} + \cos^2\varphi\right)^2 + 8(AB + CD)\cos\varphi\left(\frac{2}{\beta^2 a^2} + \cos^2\varphi\right) + (B^2 + D^2)\cos^2\varphi}{16(A^2 + C^2)\left(\frac{2}{\beta^2 a^2} + 1\right)^2 + 8(AB + CD)\left(\frac{2}{\beta^2 a^2} + 1\right) + (B^2 + D^2)}\right]^{\frac{1}{2}}$$

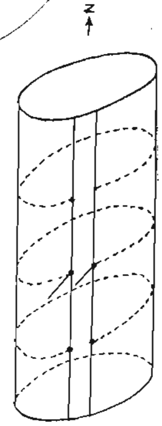


Fig. 17—Physical presentation of the slot antenna →

The maximum field intensity in the horizontal plane is for $\varphi = 0$ degrees (feeder end of the loop). (In the same horizontal plane, but for $\varphi = 180$ degrees

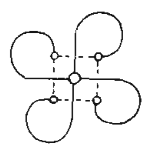
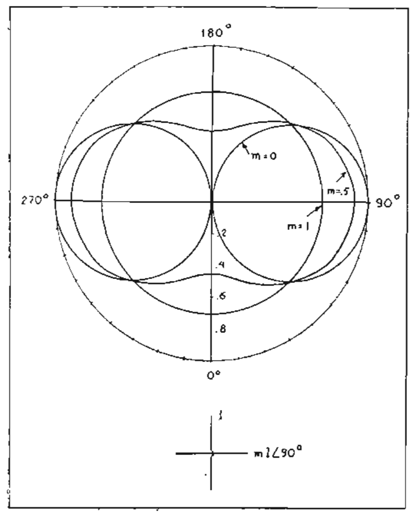


Fig. 18—Top view of a single element of Clover-Leaf antenna →

$$E_{h,180^\circ} = \left[\frac{16(A^2 + C^2)\left(\frac{2}{\beta^2 a^2} + 1\right)^2 - 8(AB + CD)\left(\frac{2}{\beta^2 a^2} + 1\right) + (B^2 + D^2)}{16(A^2 + C^2)\left(\frac{2}{\beta^2 a^2} + 1\right)^2 + 8(AB + CD)\left(\frac{2}{\beta^2 a^2} + 1\right) + (B^2 + D^2)}\right]^{\frac{1}{2}}$$

In the same horizontal plane, but for $\varphi = 90$ degrees (or 270 degrees):

Fig. 19—Horizontal patterns of turnstile element with different current ratios m →



$$E_{h,90^\circ} = \left[\frac{16(A^2 + C^2)\frac{4}{\beta^4 a^4}}{16(A^2 + C^2)\left(\frac{2}{\beta^2 a^2} + 1\right)^2 + 8(AB + CD)\left(\frac{2}{\beta^2 a^2} + 1\right) + (B^2 + D^2)}\right]^{\frac{1}{2}}$$

It follows, therefore, that the horizontal pattern is symmetrical about the x-axis. In general, it has a maximum toward the feeder end of the loop ($\varphi = 0$ degrees).

The zenithal value of the field intensity (for θ = degrees) is

(See next page)

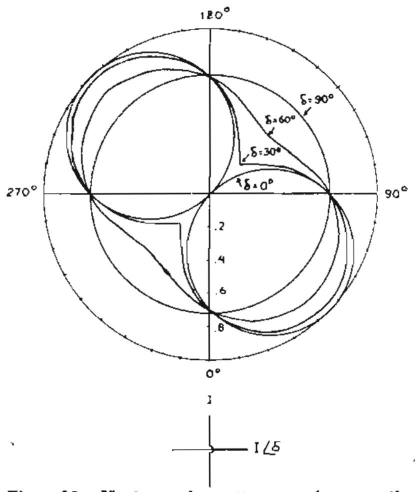
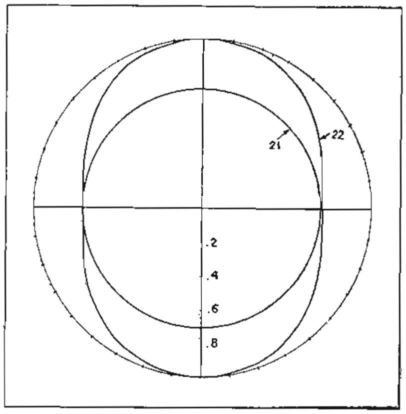


Fig. 20—Horizontal patterns of turnstile element with different phasing δ



Figs. 21 & 22—Patterns of turnstile element; (21), horizontal pattern; (22), vertical pattern

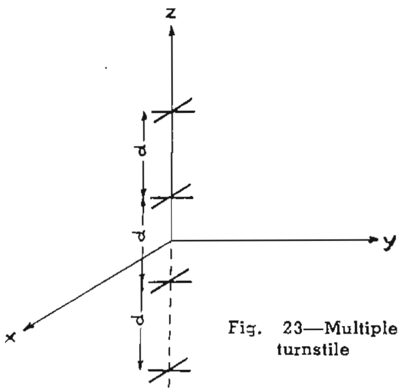


Fig. 23—Multiple turnstile

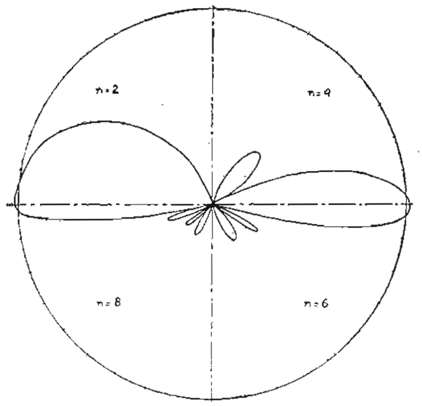


Fig. 24—Vertical patterns of multiple turnstile with different number of elements n (for each n only one quadrant is shown)

$$E_z = \left[\frac{B^2 + D^2}{16(A^2 + C^2)\left(\frac{2}{\beta^2 a^2} + 1\right)^2 + 8(AB + CD)\left(\frac{2}{\beta^2 a^2} + 1\right) + (B^2 + D^2)} \right]^{\frac{1}{2}}$$

In general, it may be said, therefore, that the circular loop has a pear-shaped horizontal and vertical field pattern. That is, the circular loop with non-uniform current distribution has patterns intermediate between those of the dipole and the square loop with uniform current distribution.

The average power gain (since the horizontal pattern is not circular) is

$$(\mathrm{PG})_{av} = \frac{5}{2}\,\frac{4(32 + 16\beta^2a^2 + 3\beta^4a^4) + \beta^4a^4\,\frac{B^2 + D^2}{A^2 + C^2}}{32(10 + 5\beta^2a^2 + \beta^4a^4) + 5\beta^4a^4\,\frac{B^2 + D^2}{A^2 + C^2}}$$

It should be pointed out that the coefficients A and D in the formulas of this section are, among others, functions of the unitized resistive component of the load. In the derivation of these formulas, it was assumed that the current distribution in the loop is equivalent to that of impedance-terminated, non-attenuating line. Since the loop radiates, the actual current distribution must be rather as in the attenuating line. But, as is known, the attenuating line may be approximated by the non-attenuating line with the properly modified load. This is done by lumping the effect of radiation into an additional resistive component of the load equal to the radiation resistance (referred to the load current) of the loop. The expression for this radiation resistance is:

$$R_r = 80\beta^2a^2J_0^2\left(\frac{\beta a}{2}\right)\left[32\,\frac{10 + 5\beta^2a^2 + \beta^4a^4}{5\beta^4a^4}\,(A^2 + C^2) + (B^2 + D^2)\right]$$

If, as is normal, there is no external resistive load, then $R = R_r$. Since the coefficients A and D are the functions of R through the coefficients m_1, and l_2, the last formula may be used for the determination of R for given loop.

If the loop is short-circuited at the far end, the general formulas of the previous section may be considerably simplified. To a first approximation, the radiation resistance, as defined in the previous section, is

$$R_r = 80\beta^2a^2J_0^2\left(\frac{\beta a}{2}\right)\sin^2\beta a\pi\left[32\,\frac{10 + 5\beta^2a^2 + \beta^4a^4}{5\beta^4a^4}\,b^2J_1^2\left(\frac{\beta a}{2}\right) + c^2J_0^2\left(\frac{\beta a}{2}\right)\right]$$

The radiation resistance versus βa is plotted in Fig. 11. To the same approximation, the average power gain is (see next page)

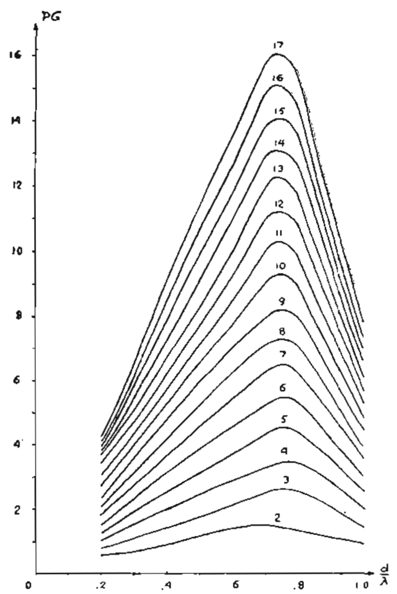


Fig. 25—Power gain of multiple turnstile for different number of elements ↑

$$(\mathrm{PG})_{\mathrm{av}} = \frac{5}{2}\,\frac{4(32 + 16\beta^2a^2 + 3\beta^4a^4) + \beta^4a^4\left[\dfrac{cJ_0\left(\frac{\beta a}{2}\right)}{bJ_1\left(\frac{\beta a}{2}\right)}\right]^2}{32(10 + 5\beta^2a^2 + \beta^4a^4) + 5\beta^4a^4\left[\dfrac{cJ_0\left(\frac{\beta a}{2}\right)}{bJ_1\left(\frac{\beta a}{2}\right)}\right]^2}$$

The average power gain versus βa is plotted in Fig. 12. The combinations of coefficients A, B, C and D appearing in the field pattern formulas of the previous sections are now:

$$B^2 + D^2 = 4c^2J_0^2\left(\frac{\beta a}{2}\right)\cos^2\frac{\beta a\pi}{2}\left(\sin^2\frac{\beta a\pi}{2} + r^2\cos^2\frac{\beta a\pi}{2}\right)$$

$$A^2 + C^2 = 4b^2J_1^2\left(\frac{\beta a}{2}\right)\sin^2\frac{\beta a\pi}{2}\left(r^2\sin^2\frac{\beta a\pi}{2} + \cos^2\frac{\beta a\pi}{2}\right)$$

$$AB + CD = 2berJ_1\left(\frac{\beta a}{2}\right)J_0\left(\frac{\beta a}{2}\right)\sin\beta a\pi$$

Field patterns may be found by substituting these expressions into the general formulas of the previous section. Figs. 13 and 14 show the horizontal and vertical patterns for one particular loop.

Capacitively Loaded Circular Loop

In this case, to a first approximation, the radiation resistance is

$$R_r = 320\beta^2a^2J_0^2\left(\frac{\beta a}{2}\right)\left\{32\,\frac{10 + 5\beta^2a^2 + \beta^4a^4}{5\beta^4a^4}\left[b^2J_1^2\left(\frac{\beta a}{2}\right)\sin^2\frac{\beta a\pi}{2}\left(\cos\frac{\beta a\pi}{2} + -x\sin\frac{\beta a\pi}{2}\right)^2\right] + \left[c^2J_0^2\left(\frac{\beta a}{2}\right)\cos^2\frac{\beta a\pi}{2}\left(\sin\frac{\beta a\pi}{2} + x\cos\frac{\beta a\pi}{2}\right)^2\right]\right\}$$

To the same approximation, the average power gain is

$$(\mathrm{PG})_{\mathrm{av}} = \frac{5}{2}\,\frac{4(32 + 16\beta^2a^2 + 3\beta^4a^4)\left[b^2J_1^2\left(\frac{\beta a}{2}\right)\sin^2\frac{\beta a\pi}{2}\left(\cos\frac{\beta a\pi}{2} - x\sin\frac{\beta a\pi}{2}\right)^2\right] + \beta^4a^4\left[c^2J_0^2\left(\frac{\beta a}{2}\right)\cos^2\frac{\beta a\pi}{2}\left(\sin\frac{\beta a\pi}{2} + x\cos\frac{\beta a\pi}{2}\right)^2\right]}{32(10 + 5\beta^2a^2 + \beta^4a^4)\left[b^2J_1^2\left(\frac{\beta a}{2}\right)\sin^2\frac{\beta a\pi}{2}\left(\cos\frac{\beta a\pi}{2} - x\sin\frac{\beta a\pi}{2}\right)^2\right] + 5\beta^4a^4\left[c^2J_0^2\left(\frac{\beta a}{2}\right)\cos^2\frac{\beta a\pi}{2}\left(\sin\frac{\beta a\pi}{2} + x\cos\frac{\beta a\pi}{2}\right)^2\right]}$$

The coefficients in the general field pattern formulas are:

$$A = -2br\sin^2\frac{\beta a\pi}{2}J_1\left(\frac{\beta a}{2}\right)$$

$$B = -2c\left(x\cos^2\frac{\beta a\pi}{2} + \sin\frac{\beta a\pi}{2}\cos\frac{\beta a\pi}{2}\right)J_0\left(\frac{\beta a}{2}\right)$$

$$C = 2b\left(\sin\frac{\beta a\pi}{2}\cos\frac{\beta a\pi}{2} - x\sin^2\frac{\beta a\pi}{2}\right)J_1\left(\frac{\beta a}{2}\right)$$

$$D = 2cr\cos^2\frac{\beta a\pi}{2}J_0\left(\frac{\beta a}{2}\right)$$

The field patterns may be found by substituting these coefficients into the general formulas. Figs. 15 and 16 show the horizontal and vertical patterns for one particular loop; its average power gain is .84.

Consider a section of balanced transmission line along the vertical z axis, short-circuited at each end, and fed at the center. If this line is shunted by a number of equi-distant loops short-circuited at the far end, (Fig. 17), the loops will carry circumferential currents and will radiate. Assume now that the loop spacing decreases indefinitely and at the same time the number of loops increases indefinitely.

In the limit, the loops will form a metallic cylindrical surface and the balanced line will represent an axial slot in this cylinder. This slotted cylinder is known under the name of slot antenna. It is obvious that the horizontal pattern of such a slot antenna will be similar to that of a single circular short-circuited loop, considered previously. As far as vertical pattern is concerned, it will be a resultant of field patterns of the individual loops. It will be considered, therefore, later in the section concerned with the vertical pattern shaping.

Horizontal Pattern Shaping

At present, unless there are some special considerations, an FM antenna is required to have an omnidirectional horizontal pattern. A horizontal dipole obviously does not provide such a pattern. Therefore, the combination of at least two dipoles is required to obtain an omnidirectional operation. A combination of two crossed dipoles is known under the name of a turnstile antenna. A loop produces nearly omnidirectional horizontal pattern. If more perfect circularity is desirable, a combination of several loops may be used. For example, a set of four loops forms an element of what is known as a clover-leaf antenna—Fig. 18.

If a directional horizontal pattern is required and the turnstile is used as an antenna, the shape of the pattern may be modified either by the proper choice of the ratio of current magnitudes or of their relative phase. If loop antennas are used, the horizontal directivity

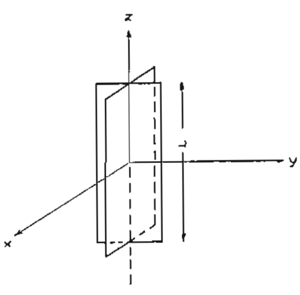


Fig. 26—Continuous Turnstile. This is the counterpart of the continuous loop or slot antenna

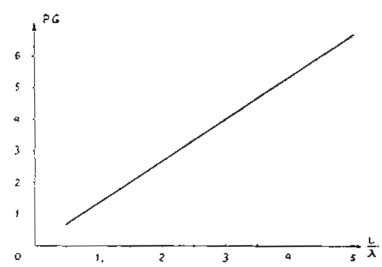


Fig. 27—Power gain of the continuous turnstile. For a given wavelength, the power gain is proportional to the antenna length

may be obtained by the use of two or more properly located and phased antennas in the way similar to that for directional arrays of ordinary broadcasting.

Turnstiles

Consider first two dipoles directed along x and y axes and with currents I and $mIe^{j90°}$, respectively, ($m \leq 1$). The relative field intensity pattern is

$$E = \left[\frac{\cos^2 \varphi \cos^2 \theta + \sin^2 \varphi + m^2(\sin^2 \varphi \cos^2 \theta + \cos^2 \varphi)}{1 + m^2}\right]^{\frac{1}{2}}$$

In the horizontal x-y plane, $\theta = 90$ degrees and the horizontal intensity pattern is

$$E_h = \left[\frac{\sin^2 \varphi + m^2 \cos^2 \varphi}{1 + m^2}\right]^{\frac{1}{2}}$$

The horizontal patterns for m = 0, .5 and 1 are shown in Fig. 19.

Consider now two dipoles directed as previously but with currents I and $Ie^{j\delta}$ respectively. The relative field intensity pattern is

$$E = \left[\frac{1 + \cos^2 \theta + \sin^2 \varphi \sin^2 \theta \cos \delta}{2}\right]^{\frac{1}{2}}$$

In the horizontal x-y plane, $\theta = 90$ degrees and the horizontal field intensity pattern is

$$E_h = \left[\frac{1 + \sin 2 \varphi \cos \delta}{2}\right]^{\frac{1}{2}}$$

The horizontal patterns for $\delta = 0$, 30, 60 and 90 degrees are shown in Fig. 20. In the case of an ordinary turnstile, m = 1 and $\delta = 90$ degrees. The horizontal relative field strength pattern is circular (Fig. 21). The vertical relative field strength pattern (Fig. 22) is

$$E = \left[\frac{1 + \cos^2 \theta}{2}\right]^{\frac{1}{2}}$$

Since each dipole of the simple turnstile radiates only half of the transmitter power, the power gain of the simple turnstile is only 1/2.

As mentioned before, for FM broadcasting, the only useful part of radiation in vertical plane is that near the horizontal equatorial plane. From this point of view the circular vertical pattern of a simple horizontal dipole is very inefficient. A nearly figure-of-eight vertical pattern of the horizontal loop is slightly better in this respect. A more efficient vertical pattern may be obtained by the superposition of properly fed and spaced simple turnstile elements or horizontal loops one above another.

Consider n equi-distant (spacing d) turnstile elements with their centers stacked along the z-axis with current of equal magnitude and phase—Fig. 23. The horizontal relative field intensity pattern remains the same as for the simple turnstile. The vertical relative field intensity pattern, in any φ plane, is now

$$E = \left|\frac{\sin \frac{\beta nd \cos \theta}{2}}{n \sin \frac{\beta d \cos \theta}{2}}\right| \left[\frac{1 + \cos^2 \theta}{2}\right]^{\frac{1}{2}}$$

These vertical patterns, for various n and usual spacing $d = \lambda/2$ are shown in Fig. 24. The power gain is

$$PG = \frac{1}{2\left[\frac{1}{n} + \frac{3}{n^2}\sum_{r=1}^{n-1}(n - r\left[\frac{\sin r\beta d}{r\beta d} + \frac{\cos r\beta d}{(r\beta d)^2} - \frac{\sin r\beta d}{(r\beta d)^3}\right]\right]}$$

The comparison of this formula with the formula for the power gain of a broadside array shows that the power gain of the multiple turnstile is exactly half that of a corresponding broadside array. This is obvious since each turnstile panel carries only half of the total transmitter power. Power gain versus element spacing for n from 2 to 17 is shown in Fig. 25. Notice that for a given number of elements the power gain is maximum in the vicinity of $d = .75\lambda$. In practice, $d = .5\lambda$ spacing is preferred since it simplifies the problem of feeding the elements in proper phase relationship.

Continuous Current Distribution

In the multiple turnstile of the previous section, let n increase and d decrease indefinitely in such a way that the total length $L = nd$ of the array is unchanged. In the limit the array assumes the shape of two continuous metal strips at right angle to each other—Fig. 26. The horizontal relative field intensity pattern remains the same as for the simple turnstile. The vertical relative field intensity pattern (in any φ plane) is

$$E = \left|\frac{\sin \frac{\beta L \cos \theta}{2}}{\frac{\beta L \cos \theta}{2}}\right| \left[\frac{1 + \cos^2 \theta}{2}\right]^{\frac{1}{2}}$$

Notice that for given L the shape of the pattern is the same as that for the multiple turnstile with $nd = L$ therefore, the patterns shown in Fig. 24 correspond also to the case of the turnstile with continuous current distribution with $L = \lambda$, $L = 2\lambda$, $L = 3\lambda$ and $L = 4\lambda$ respectively. The power gain is

$$PG = \frac{1}{3\left[\frac{Si\ \beta L}{\beta L} + \frac{\cos \beta L}{(\beta L)^2} - \frac{\sin \beta L}{(\beta L)^3}\right]}$$

where Si x is a sine integral function. Power gain versus L/λ is shown in Fig. 27.

Consider n equi-distant (spacing d) horizontal loops with their centers stacked along the vertical z-axis with currents of equal magnitude and phase — Fig. 28. The horizontal relative field intensity pattern remains the same as for the individual loop. The vertical relative field intensity pattern is

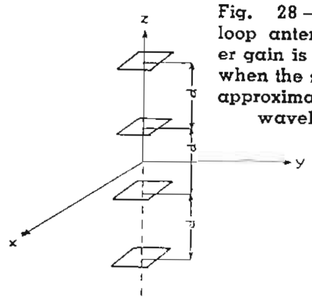


Fig. 28 — Multiple loop antenna. Power gain is maximum when the spacing is approximately one wavelength

$$E \left|\frac{\sin \frac{\beta nd \cos \theta}{2}}{n \sin \frac{\beta d \cos \theta}{2}}\right| E_l$$

Where E_l = relative vertical pattern of the individual loop. Notice that for a given value of the product nd, the "space factor" $\sin nx / n \sin x$ for the multiple loop is identical with that of multiple turnstile. Apart, therefore, from the effect of the term E_l, the shape of a multiple loop vertical pattern is similar to that of a multiple turnstile with the same value of the product nd. Since the usual spacing is d = x (that is twice that for the turnstile), the patterns shown in Fig. 24 correspond now to n = 1, 2, 3 and 4, respectively. Power gain versus loop spacing for n from 2 to 14 is shown in Fig. 29.

To a first approximation, the power gain is

$$PG = \frac{1}{\frac{1}{n} - \frac{6}{n^2}\sum_{r=1}^{n-1}(n-r)\left[\cos\frac{r\beta d}{(r\beta d)^2} - \frac{\sin r\beta d}{(r\beta d)^3}\right]}$$

In this formula it is assumed that the power gain of the individual loop is unity. Therefore, for the loops of larger (in comparison to the operating wavelength) linear dimensions, the power gain from the above formula should be multiplied by the actual gain of the individual loop.

The comparison of the above formula for the power gain with the power gain formula for the collinear array of half-wave dipoles shows that they are identical. This could be expected since the radiation pattern of the small loop is identical (except for the polarization) with that of the vertical dipole.

Slot Antenna

As mentioned before, the slot antenna is equivalent to a vertical stack of continuously distributed horizontal loops. Also in the light of the remark of the last section, the slot antenna is equivalent to a continuous collinear array of elementary dipoles. Under the assumption of the uniform current distribution, the relative vertical field intensity pattern is

$$E = \left| \frac{\sin\frac{\beta L\cos\theta}{2}}{\frac{\beta L\cos\theta}{2}} \right| E_l$$

Where E_l = relative field pattern of the elementary loop; L = antenna height.

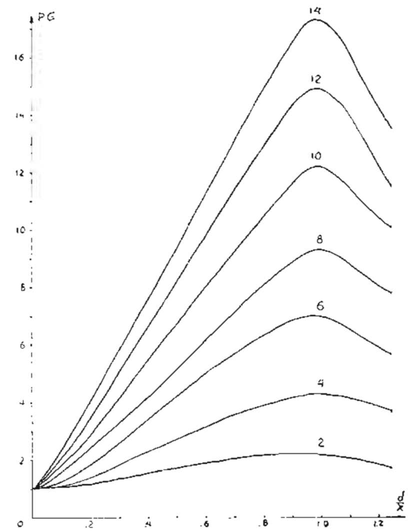
Notice that apart from the effect of the term E_l, the vertical pattern of slot antenna is similar to that of continuous turnstile with equivalent length (Fig. 24). The horizontal pattern is, of course, the same as for the elementary loop. The power gain is

$$PG = \frac{\quad}{3\left[\frac{Si\,\beta L}{\beta L} + \frac{\cos\beta L - 2}{(\beta L)^2} + \frac{\sin\beta L}{(\beta L)^3}\right]}$$

Where Si x is a sine integral function.

In this formula, it is assumed that the power gain of the elementary loop is unity. Therefore, to obtain the actual power gain, the power gain from the above formula should be multiplied by the actual gain of the elementary loop. Power gain versus antenna length is shown in Fig. 30.

Fig. 29—Power gain of multiple loop for different number of elements



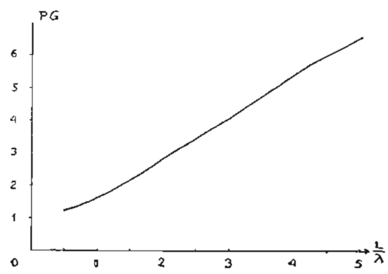


Fig. 30—Power gain of slot antenna

Effective Field Intensity

The relative field intensity patterns given above do not convey any information as to the effective value of the field strength for the given set of conditions. This effective value E of field strength (in free-space) may be found, however, from the formula

$$E = \sqrt{PG}\,E_d$$

In this formula, E_d is a free-space field intensity in the horizontal (equatorial) plane of the vertical reference dipole:

$$E_d = 132\frac{\sqrt{W}}{d}\text{ millivolts per meter}$$

Where W = radiated power, kilowatts; d = distance, miles.

Conclusions

The reader might pose the question: It seems that there are many different types of FM antennas, but which one is the best? The trouble with answering that is that "the best" might have many meanings. If, for instance, "the best" would mean "maximum theoretical power gain per given antenna height", then the answer would be that any one is almost as good as any other. If, however, "the best" would mean "the most economical" the answer would be more definite but, unfortunately, outside of the scope of this survey.

The trouble with the multitude of different commercially available FM broadcast antennas is in the fact that the whole FM art is still in a rather floating state. As the problem stands now, the question is not "which antenna is the best?" but rather "whose antenna is the best?" The day will undoubtedly come, however, when, similarly to the situation in the present AM broadcasting, there will be essentially only one type of FM antenna. This type will emerge from the present multitude through the action of the law of natural selection.

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Loudspeaker Design by Electro-Mechanical Analogy

By ARTHUR J. SANIAL, Acoustic Consultant, Flushing, N. Y.

The practical application of theoretical derivation in the design of dynamic vibrating systems for the reproduction of voice and music

• The design of acoustical instruments involves electrical, mechanical, and acoustical problems which require both theoretical and practical knowledge for their solution. Such design problems are usually approached by utilizing the dynamic theory of vibrating systems in some manner. The communication or electronic engineer oftimes has difficulty with the mechanical concepts or the nomenclature and symbols used in the literature.

Many authorities in this field, who are also well versed in electric transmission systems, have recognized this condition. The vast store of accumulated knowledge and data of electric transmission systems can also be applied to mechanical transmission systems as can combinations of the two. This is because the fundamental equation of motion is the same in form for any such system, the significance of the variables and parameters depending on the type of transmission or vibrating system under consideration.

By means of mathematical transformation, the electric, mechanical and acoustical sections of a vibrating system therefore can be represented by coupled networks in conventional electrical transmission network form. There are several methods by which this can be done, and detailed mathematical treatment of the various approaches to electro-mechanical analogies of this type will be found in the literature. (See references.)

One method commonly used and perhaps more adaptable to electrical engineers' thinking is treated herein with an outline of the mathematical basis. This method considers mechanical force and electrical voltage to be analogous. It should be said that no such system of analogies is strictly rigorous as several assumptions are made. For example, the representation of mechanical and acoustical elements as lumped constants in the equivalent electrical circuit is not representative of their distributed nature. This, however, is of secondary importance as such approximations are recognized and do not vitiate the value of the method.

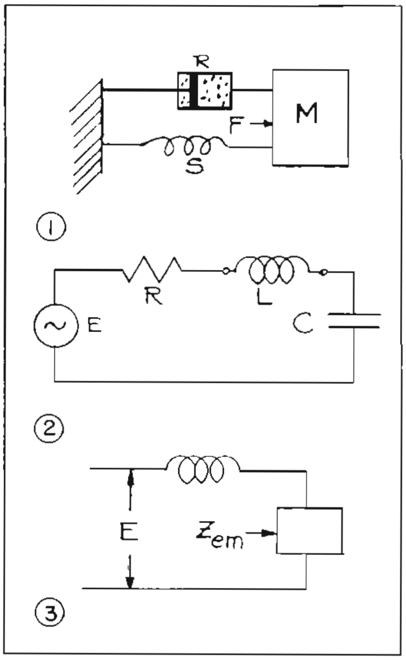


Fig. 1—A simple mechanical system, with (2) the electrical equivalent, and (3) the loudspeaker circuit from the electrical side

To illustrate the analogy which relates force to voltage let us first consider the simple mechanical system shown in Fig. 1, where M is a mass, S a spring and R, a mechanical resistance such as friction. The differential equation of motion in this system with a periodic force applied is:

$$M\frac{d^2x}{dt^2} + R\frac{dx}{dt} + Sx = F_o \sin\omega t \qquad (1)$$

The corresponding equation for the simple electrical circuit (Fig. 2) of R, L and C in series with a periodic applied voltage is:

$$L\frac{d^2q}{dt^2} + R\frac{dq}{dt} + \frac{q}{C} = E_o \sin\omega t \qquad (2)$$

The equivalent form of these two equations is obvious, as well as the correspondence of displacement x and electric charge q. It also follows that

Velocity, $\frac{dx}{dt} \equiv \frac{dq}{dt} = i$ or current.

and Acceleration, $\frac{d^2x}{dt^2} \equiv \frac{d^2q}{dt^2} = \frac{di}{dt}$ or rate of change of current.

The familiar steady state solution of these equations is:

Mechanical: Velocity, $V = \frac{F}{Z_m}$

$$\text{Where } Z_m = \sqrt{R^2 + \left(\omega M - \frac{S}{\omega}\right)^2} \qquad (3)$$

Electrical: Current, $I = \frac{E}{Z_e}$

$$\text{Where } Z_e = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega E}\right)^2} \qquad (4)$$

The only difference in the above forms is between S and C. S is the stiffness of the spring, but use of the spring compliance (which is the reciprocal of S) will make the equivalence complete. It is somewhat more convenient for some to use S in design work, however. The impedances in both cases consist of real and imaginary components that also have equivalent form.

In this system of mechanical-electrical analogy, equivalent terms are expressed in the units shown in the table at right.

It must be recognized that the magnitudes of electrical and mechanical impedances differ; electrical ohms are expressed in the practical system of units, mechanical ohms, in the absolute or c.g.s. system. In magnitude, electrical ohms are 10^9 times mechanical ohms, so that in cases where the electrical circuit impedances are transformed to the mechanical circuit, electrical ohms must be multiplied by this factor.

EQUIVALENCE TABLE

ELECTRICAL		MECHANICAL	
QUANTITY	**DIMENSIONS**	**QUANTITY**	**DIMENSIONS**
Voltage	E, in volts	Force	F, in dynes
Current	I, in amperes	Velocity	V, in cms/sec.
Impedance	Z, in electrical ohms	Impedance	Z, in mechanical ohms
Quantity	Q, in coulombs	Displacement	X, in cms
Inductance	L, in henries	Mass	M, in grams
Capacity	C, in farads	Compliance	C, in cms/dyne or 1/S, where S—Stiffness in dynes/cm.
Resistance	R, in electrical ohms	Resistance	R, in mechanical ohms
Inductive Reactance	$j\omega L$, in electrical ohms	Mass Reactance	$j\omega M$, in mechanical ohms
Capacitive Reactance	$1/j\omega C$, in electrical ohms	Stiffness Reactance	$S/j\omega$, in mechanical ohms
Resonant Frequency	$1/2\pi\sqrt{1/LC}$	Resonant Frequency	$1/2\pi\sqrt{S/M}$

Reactance Analogy

Mechanical reactances are computed just as electrical reactances, except for this difference in magnitude. Just as the value of inductance must be available to compute electrical X_L so we must have the value of mass to compute mechanical X_M. If the mass of a simple vibrating system is 1 gram, the numerical value of the mass reactance at 1000 cycles per second is 6280 mechanical ohms. In like manner, the reactance due to compliance (or stiffness) is computed.

The compliance of a spring is the amount that the spring is deflected, in centimeters at the point of applied force, per dyne of applied force. The stiffness is the reciprocal of this ratio. Thus, if a force of 100 dynes (approx. 0.1 gram weight) applied to the spring causes a deflection of .0001 cms., the static stiffness is 10^6 dynes per cm. If the force is periodically applied at 1000 cycles per second, the corresponding stiffness reactance would then be 159 mechanical ohms.

Formulas for the computation of static stiffness of elementary beams with various loadings can be found in handbooks. These are often useful in working with leaf spring designs and the like, as the stiffness is found from the relations between width, thickness, length, and Young's modulus. For vibrating plates and discs, however, the relations are more complex, as will be found by consulting the references given.

The mechanical impedance of an acoustic compliance of an air volume can be computed from the dimensions. Using stiffness S for the constant again, the numerical value can be found from

$$S = A\rho c^2 / x \qquad (5)$$

Where

A = Area of the volume, sq. cms.

x = Height of the volume, cms.

ρ = Density of air in grams/c. c.

c = Velocity of sound in air, cms./sec.

For an area of 1 sq. cm., 1 mm high, the stiffness coefficient S is 14×10^6 dynes/cm., approx., and the reactance at 1000 cycles is S/ω and has a numerical value of 2.25×10^3 mechanical ohms.

It should be pointed out that mass and stiffness reactances computed as above from static measurements are not usually exactly equal to the values obtained from dynamic measurements of diaphragms and the like. The dynamic values vary with magnitude and period of the force, shape of the vibrating member, how it is supported, and many other factors. This is a highly complex problem, and is treated by such authorities as Lamb, Kennelly, and others given in the references. It will be seen later, however, that a fairly close approach to a required design still can be made, even when simplifying approximations such as these are resorted to.

In the case of mechanical resistance, there is no simple way of computing this from the data usually available when a new design is first initiated. It is usually derived from circle diagram measurements etc., on the actual mechanical system, by methods described in the literature. In the present simplified treatment, mechanical resistance, other than that due to the air load radiation re-

Speaker Criteria

"THE most commonly accepted criteria for high quality loudspeaker development can be grouped under the following general headings:

1—A wide frequency range must be reproduced;

2—Uniformity of response over the range reproduced is extremely desirable;

3—All forms of distortion must be reduced to very low levels;

4—A high degree of damping is desirable for faithful reproduction of transients and to improve the linearity of the system;

5—Uniform distribution of energy over an appropriate angle is required;

6—The power capacity must be adequate to cover the peak powers expected."—R. S. Lanier, Western Electric Co.

sistance, can be, and is, considered negligible.

To represent an electro-mechanical vibrating system in the form of a conventional electrical circuit, the above principles can be applied, with the addition of a transformation factor to account for the coupling between the electrical and mechanical sections of the system. The system can then be set up as a network of impedances, and solved by appropriate electrical transmission network theory methods.

The reason for using this transformation factor can be understood by going back to basic principles. For example, when electrical power is applied to a loudspeaker voice coil, a force is set up across the mechanical elements which the coil actuates, and these move with a resultant velocity. In such a system, the force is expressed in the form

$$F = Bli \qquad (6)$$

in which B represents the steady magnetic flux density in the air gap in gauss, l the length of voice coil wire in centimeters, and i the current in the voice coil in abamperes. The e.m.f. set up by the movement of the voice coil in the air gap is

$$E = Blv \qquad (7)$$

where v is the velocity of the voice coil and E is in abvolts. It is seen that in each case the electrical and mechanical variables are related by a common product, Bl. It is customary to term this the force factor. This force factor is, therefore, the link between the electrical and mechanical sections of the vibrating system.

It has been shown in the literature that the variables and the constants of both the electrical and mechanical sections can be set up in two equations, one for electrical voltage and one for mechanical force.

When solved for the steady state condition the voltage in practical units is expressed as

$$E = i\left(j\omega L + \frac{(Bl)^2 \times 10^{-9}}{Z_m}\right) \text{volts} \qquad (8)$$

where L = inductance of the voice coil in henries

i = current in amperes

$\omega = 2\pi f$

Z_m = total mechanical impedance in the moving system.

In other words, this shows that the whole system can be represented by an electrical circuit in which the mechanical vibrating section is in the form of an impedance, the latter being the (force factor)^2 in practical units multiplied by the reciprocal of the mechanical impedance. This could be shown in circuit form as in Fig. 3 where

$$Z_{em} = \frac{(Bl)^2 \times 10^{-9}}{Z_m} \qquad (9)$$

from which it is seen that the mechanical impedance appears in the electrical circuit in a transformed value, Z_{em}. This can be seen in another way by using the basic force and e.m.f. relations above, from which

$$e/i = \frac{Blv}{(F/Bl)} = \frac{(Bl)^2}{(F/v)} \qquad (10)$$

as e/i is an electrical impedance due to the mechanical system it is equal to Z_{em}, and as the quotient of force by velocity is the mechanical impedance, Z_m, then

$$Z_{em} = (Bl)^2 \times 10^{-9}/Z_m \qquad (11)$$

(The factor 10^{-9} is necessary to express the result in practical units, where Z_{em} is in electrical ohms and Z_m in mechanical ohms).

In design work it is more convenient to represent the mechanical section as an equivalent electrical impedance network directly, using the proper transformations to convert electrical and other section constants into equivalent mechanical units in this circuit. This is particularly desirable with electro-acoustic apparatus as there are usually three sections in all practical devices of this kind. The mechanical section is the middle link between the electrical and acoustic sections (or vice versa), hence a more straightforward equivalent representation is effected by referring both the electrical and acoustic terms to it.

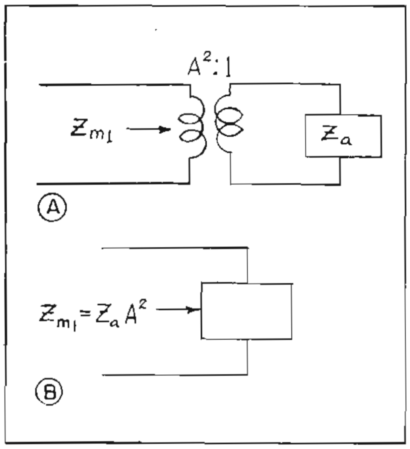


Fig. 4 (a)—Acoustic to mechanical transformation, and (b) equivalent circuit

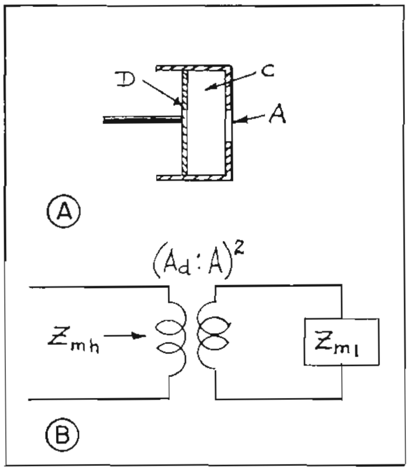


Fig. 5 (a)—Piston D vibrating in air chamber C, having an opening of area A; (b) equivalent electrical circuit

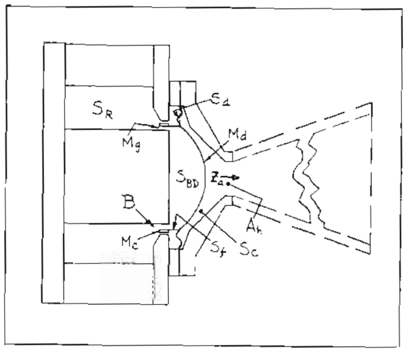


Fig. 5 (c)—Diagrammatic section of loudspeaker unit and horn, with constants

Acoustic Impedance

This requires another transformation, as the acoustic impedances of diaphragms, horns, etc. which radiate the mechanical energy as sound (or the opposite in microphones) are in different units than are those of the mechanical impedances. Briefly, acoustic impedance Z_a is proportional to impedance per unit area divided by the area (of the directly radiating diaphragm or cone, or of a specified cross section of a loudspeaker horn), while in terms of mechanical impedance Z_m it is expressed as the product of the impedance per unit area and the area. For an area A, if Z is the impedance per unit area, then

$$Z_a = Z/A \quad (12)$$
$$Z_{m1} = ZA \quad (13)$$
hence $$Z_{m1} = Z_a A^2 \quad (14)$$

To illustrate how the acoustic and mechanical impedances of a cone or a diaphragm, open to the air, are determined, it is customary to consider that these devices behave as an equivalent piston of the same diameter mounted in an infinite wall, as a first approximation. In such a device, the resistive component of the air load at frequencies where the diameter of the piston is large compared to the wavelength, approaches the value of the characteristic impedance of air:— $\rho c = 41$.

In this frequency range, then, assuming a shallow cone 14 in. in diameter, and vibrating as a disc to 1100 cycles, the average value of ρc will be about 41 (the impedance per unit area), and the total resistive component of the acoustic impedance will be 41 divided by the total exposed area of the cone. Thus the total acoustic radiation resistance of this cone would be about .02 acoustic ohms. As the resistive component of the mechanical impedance is 41 multiplied by the total area, its mechanical radiation resistance would be 81,000 mechanical ohms. For a more detailed study of the variation of impedance of acoustic radiators with dimensions and wavelength, one of the textbooks on Sound should be referred to.

Thus, from equation (14) to convert the acoustic impedances to the proper value for insertion in the mechanical circuit, when the latter is set up in electrical conventions, an ideal transformer of the ratio A^2 must be inserted as shown in Fig. 4a, with the result as in Fig. 4b.

Fig. 4 shows schematically how the transformation of acoustic to mechanical impedance is made for a direct radiator, such as a cone or open diaphragm. However, the addition of a horn to a vibrating radiator increases the radiation efficiency at frequencies below that at which the wavelength is small compared to the diameter of the radiator. This assumes that the horn mouth is appreciably larger than the area of the radiator. Although an infinite exponential horn would afford a loading of 41 mechanical resistance units per sq. cm., for all frequencies above the cut-off frequency, in finite horns, this value rises from a fraction of ρc (= 41) at the cutoff frequency, approaching the value of 41 asymptotically in a series of maxima and minima.

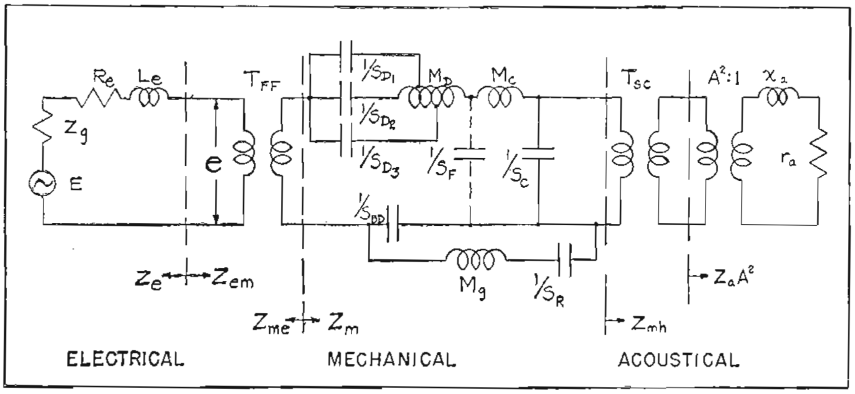


Fig. 5 (d)—Equivalent electrical circuit of loudspeaker unit and horn shown diagrammatically in Fig. 5c

The degree and character of the fluctuation of the characteristic resistance (and the reactance) depend upon the shape and dimensions of the particular horn. The general effect is similar to that exhibited by the radiation characteristic of a piston, and for examples of horn and piston characteristics, and methods for computing impedance variations for a particular horn, the text books should be consulted. These fluctuations in impedance can be taken into account where important—usually in the low frequency range—when working out the design of the driver unit that is to be used with the horn.

Equations for Horns

The finite horn, which meets the practical limitations of a particular condition can be designed sufficiently accurately by utilizing the equations for horns, which relate dimensions, flare, and cut-off frequency, or by taking the values from published charts and tables which have been worked out from these equations. The equation giving the length of an exponential horn (in cms.) from the throat to any given section is as follows:

$$L_x = 2.302/m \ (\log_{10} A_x/A_t) \quad (15)$$

Where

A_t — Area of horn throat

A_x — Area at section L_x from throat

m — Rate of exponential taper, $4\pi f_c/c$

c — Velocity of sound in air, 34,400 cms./sec.

f_c — Theoretical cut-off frequency (low end).

Now, as the constants of the mechanical circuit components of a loudspeaker usually require working at a higher impedance level than that provided by a horn having a throat diameter equal to the diaphragm diameter, it is generally desirable to step up the value of the mechanical impedance of the horn throat as seen from the diaphragm. A sound chamber is used for this purpose as it acts as a fluid transformer between the diaphragm area and the relatively smaller area of the horn throat. In Fig. 5a, D represents a piston or diaphragm of area A_d vibrating in the air chamber C, which has an opening (e.g. for coupling to a horn) of area A. If the opening A, has a mechanical impedance of Z_{m1}, the mechanical impedance Z_{mh} presented to D is Z_{m1} multiplied by the square of the respective areas, that is:

$$Z_{mh} = Z_{m1} \ (A_d/A)^2 \quad (16)$$

From equation (14) and letting the ratio $A_d/A = T_{sc}$, and also as $Z_a = \rho c/A$ (for any given value of ρc depending on the conditions noted previously) then the resistive component of Z_{mh} is

$$R_{mh} = \rho c A \ (T_{sc})^2 \quad (17)$$

The equivalent electrical circuit representation of a sound chamber coupling a diaphragm impedance and a horn throat impedance, is shown in Fig. 5b.

The electrical-mechanical-acoustic system can then be represented by an electrical network, working between an impedance on one side Z_{me}, the transformed electrical impedance, and an impedance Z_{mh}, the transformed acoustical impedance, on the other. An example of such a vibrating system, and its equivalent circuit is shown in Figs. 5c and 5d, in which the diagrammatic sketch is that of a typical horn-driver loudspeaker.

The designations in this circuit, other than those described, are as follows: E is the open circuit generator voltage such as would be supplied by an amplifier. Z_g is the impedance of the generator. R_e is the dc resistance of the loudspeaker voice coil, and L_e its inductance.

Acoustic Power

The power available for producing acoustic output is derived from e, the voltage across the motional impedance, Z_{em}. The transformation of impedance from electrical to mechanical, due to the force factor Bl, occurs in the transformer, T_{ff}. The mechanical circuit source impedance, due to damping in the electrical circuit, is Z_{me}, and from equation (10), in the ideal case,

$$Z_{me} = (Bl)^2 \times 10^{-9}/Z_e \qquad (18)$$

$(M_d + M_c)$ is the total mass of the moving system, M_d being that of the diaphragm and M_c that of the voice coil. If the diaphragm can be made to vibrate as a plunger over a good portion of its frequency range, the measured mass in grams of the portion within the clamping diameter can be safely taken as near enough to its effective mass. Any departure from this will in general be a lower effective value, which is in a favorable direction as far as an ideal speaker design is concerned. The desired plunger action is usually approached sufficiently close in practice by stiffening the center of the diaphragm, and corrugating the suspension edge outside of the voice coil in a variety of ways. The chief errors occur at high frequencies, where the diaphragm breaks up into nodal patterns instead of moving as a plunger.

S_d is the total suspension edge stiffness. The corrugated suspension edge can be represented by

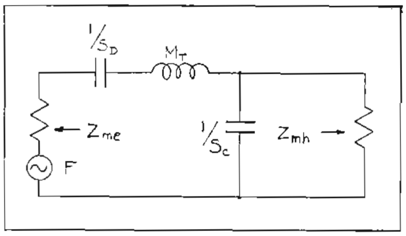


Fig. 6—Equivalent circuit of loudspeaker system with constants in mechanical units, showing similarity to electrical bandpass filter

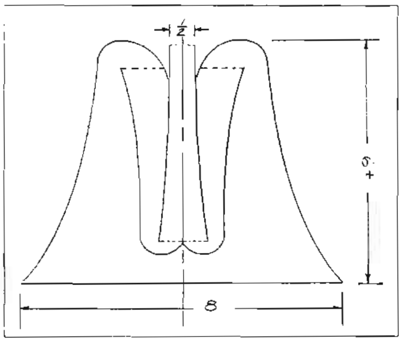


Fig. 7—Cross section of short folded horn

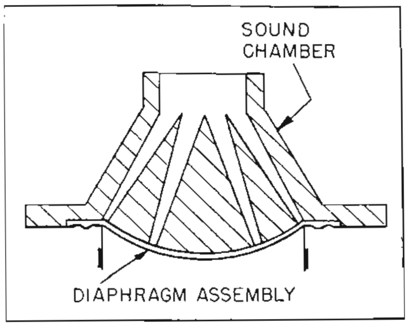


Fig. 8—Multi-channel type sound chamber

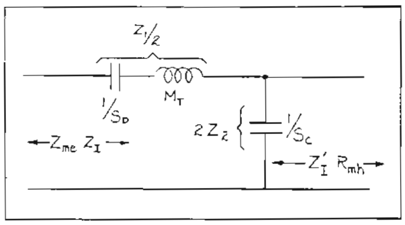


Fig. 9—Correspondence of electric wave filter impedances and loudspeaker constants

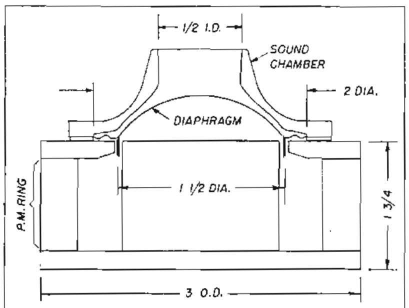


Fig. 10—Cross-sectional sketch of completed driver unit

separate small masses (parts of the total mass) coupled with compliances, if special designs require this refinement for analysis. At low frequencies, these small portions of M_d have a negligible effect, and the separate edge compliances, all in parallel are equal to $1/S_d$. The compliance of the voice coil form, $1/S_f$, can cause loss at high frequencies unless kept very small. The air coupling compliance to the diaphragm on the sound chamber side is $1/S_c$. The air coupling compliance to the back of the diaphragm is $1/S_b$. M_g is the mass of the air in the air gap, which forms a narrow slit passage to the rear cavity whose compliance is 1/SR. The magnetic air gap flux is B.

It will be noted that some factors are neglected as being insignificant, such as the air compliance under the suspension edge and the air mass in that side of the gap. These and other possible refinements merely complicate the equivalent circuit unduly and have little practical effect except in special cases as, for instance, in some microphone designs.

Design Procedure

The various assumptions made in such an equivalent circuit representation are not strictly rigorous, but this does not detract from its value in working out initial designs. The circuit, for instance, assumes lumped impedances, and the design procedure assumes that the diaphragm moves with piston action. The assumption is also made that the compliances are linear, and that the air in the sound chamber does not compress. As these assumptions are made in most designs of this nature whether electro-mechanical equivalences are used or not, this method of equivalences loses nothing by these assumptions, while it retains the value of affording an orderly and logical method of design. Even further simplifications can be made before initiating a new design to meet a given set of requirements if a few preliminary calculations show they are warranted.

Suppose, for example, a loudspeaker is required whose low frequency cut-off is such that the rear stiffnesses have negligible effect in the pass band. The network $1/S_{bd}$, $1/S_r$, M_g, can then be omitted. If desired, and considered important, computations can be made to find the effect of this network afterwards. If the effect of resonances in the suspension edge is negligible in the pass band, as indicated before, $1/S_{d1}$, $1/S_{d2}$, etc., can be eliminated, and a single compliance $1/S_d$ used. If it is intended to use a voice coil form which previous experience or measurements have shown to have a stiffness high enough so that no appreciable shunting effect is encountered at the highest frequency required, $1/S_f$ can also be omitted. Then with these simplifications, and combining all parameters in the mechanical circuit the equivalent electrical circuit of this hypothetical loudspeaker can be represented by Fig. 6.

Here M_t is the total mass of the moving system and F the force (Bli) due to the electro-magnetic circuit. Transmission engineers will recognize this as the schematic of an electric wave filter, the constants of which can be found provided the terminating impedances, pass band, dissipation requirements, etc., are specified. Unfortunately, all these factors cannot be specified in electro-acoustic design work, due to the limitations of materials, the absence of standard lumped components corresponding to capacitors, transformers, etc., in the electrical field, and most important, because of the interdependence of the filter element constants and the factors determining the values of the terminating impedances.

Determining Values

However, the design specifications usually set up requirements which limit the manner in which the problem can be approached. Starting at this point, the method followed involves a process of tentative computations, which are successively corrected as the design proceeds. In this way, the best possible values for the various interrelated factors can be obtained. The procedure can be illustrated concretely by one method of approach used in designing a typical horn loudspeaker which is suitable primarily for voice reproduction, and also for music if the lack of full bass response is acceptable. The requirements set for this loudspeaker are as follows:

1—Maximum input power — 12 watts;
2—Minimum frequency range — 300 to 5000 cycles;
3—Efficiency—High as practicable to-day, within reasonable cost;
4—Impedance—Suitable for connection to a low impedance output tap of a standard amplifier;
5—Size—Not to exceed 8 to 9 in. in length, and about 8 ins. bell diameter;
6—Low manufacturing cost.

First of all, the dissipation in the voice coil is determined. As loudspeakers of this type can be made to-day with an efficiency of 30 to 35%, about 8 watts must be dissipated as heat. When the voice coil size is computed, as shown later, its ability to dissipate this power without excessive heating can be checked in accordance with electrical engineering practices. In conventional designs, a figure of approximately .1 to .2 sq. in. of exposed conductor area per watt is sufficient to keep the temperature rise within acceptable limits.

The specifications on size, and the low frequency requirement, restricts the horn to fairly definite limits. A tentative theoretical horn cut-off frequency of 250 cycles is suitable, and as the length limitation allows only about six inches for the horn section, it is necessary to fold it into three annular re-entrant sections. With a mouth diameter of 8 in. and an acoustic path length of about 20 in., a required throat diameter of ½ in. is found from horn theory, in the manner explained before. A diagrammatic sketch of this horn section is shown in Fig. 7.

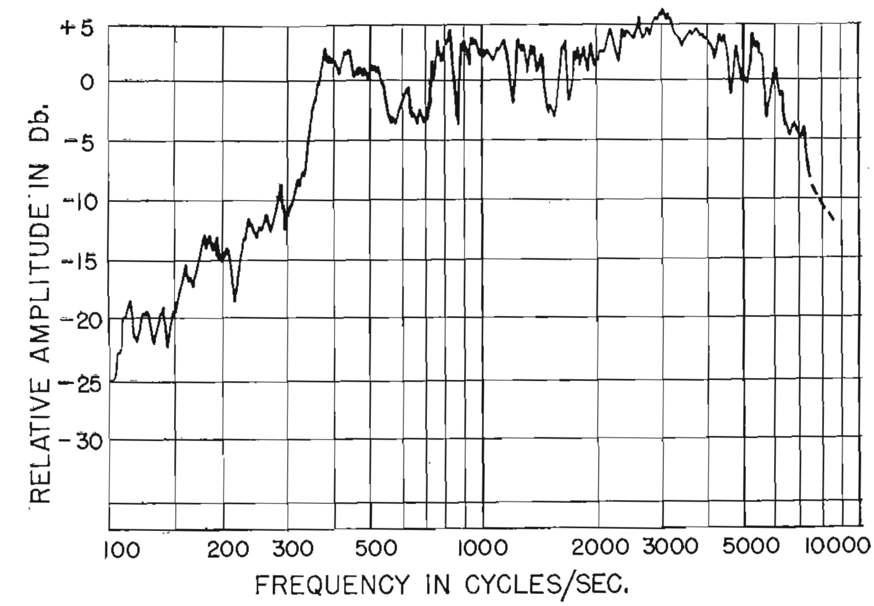


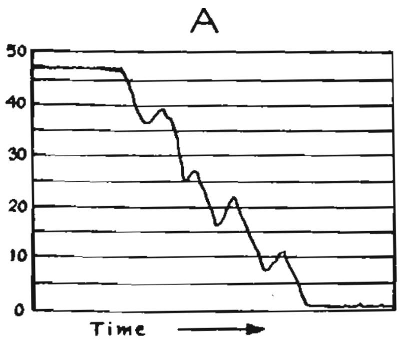
Fig. 11—Frequency response curve of loudspeaker output pressure at 4 ft. on the horn axis

Diaphragm Size

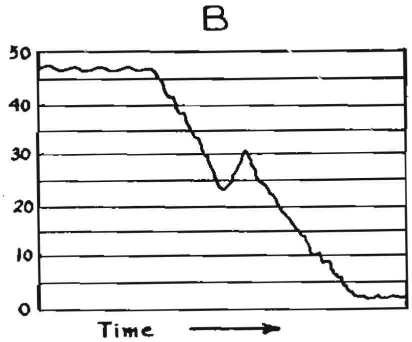
A tentative value of diaphragm size can be chosen, based partly on experience and partly on the requirements. Its suitability may then be checked from the standpoint of power output, permissible deflection, etc., as will be shown below. First, however, to hold manufacturing cost low, the sound chamber cannot be too complex. One of the refinements used in loudspeakers designed for high frequency reproduction, is the use of a sound chamber which has several openings or channels between the diaphragm and horn throat. A sketch of one type is shown in Fig. 8.

Briefly, the openings are spaced some fraction of a wave length of the highest frequency required, so proportioned as to prevent phase cancellation of the sound in the chamber. This is a relatively expensive construction. The single opening type is much less expensive, but for the same diaphragm and throat dimensions, starts to

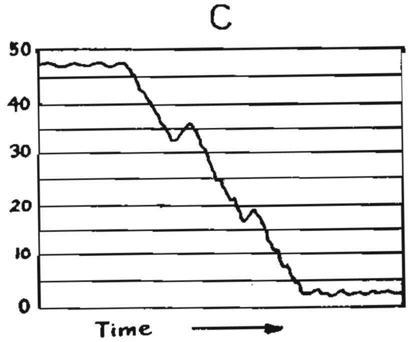
(*Continued on page 97*)



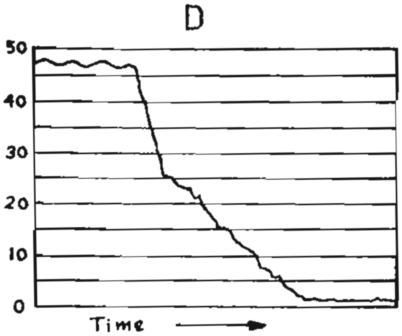
Sound decay curve with a pure tone



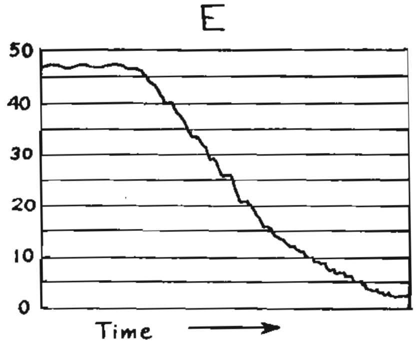
Warbletone decay curve with single echo



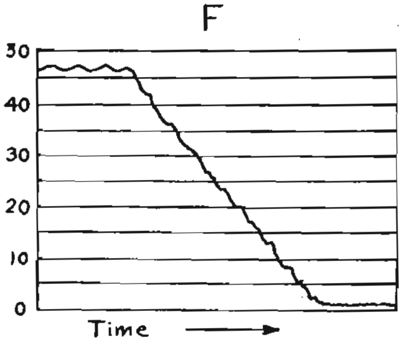
Warbletone decay curve with double echo



Incident sound wave decay followed by reverberation



Reverberation curve with high noise level



Typical reverberation decay curve

Making Reverberation Time Tests in Broadcast Studios

By L. P. REITZ, Acoustical Engineer
Sound Apparatus Co., New York

The use of high-speed level recorders in determining studio characteristics and as an aid in proper acoustic designing

• Architectural acoustics is a product of modern times. Although it should have been of importance at any time and place where construction was done, it was neglected for a long time and has only recently come into its own and become "modern."

After the early pioneer work in acoustics in the beginning of the 20th Century, it needed the challenge of proper acoustical design of motion picture theaters and broadcast studios to advance architectural acoustics and to improve measurement technics. The stopwatch, ear and organ-pipe method of measuring reverberation time was no longer adequate. Fortunately, with the invention of the vacuum tube, acoustical engineers could make use of audio-frequency oscillators, amplifiers, attenuators, loudspeakers and microphones for their experiments on sound, and research work has progressed not only in a number of laboratories but in industrial manufacturing plants of acoustic materials as well.

An outstanding recent contribution to the advancement of sound measurement was the design and construction of graphic high-speed level recorders, instruments which not only enable the accurate measurment of acoustical phenomena but produce a graph of the result of the investigation.

It is the purpose of this paper to acquaint engineers with the advantages of graphic recorders in the task of creating acoustically correct auditoriums, theaters and studios, and to illustrate how such a reverberation analyzer can be adapted to the modern acoustical problems of the architect and building-material manufacturer.

Considering the acoustic properties of present buildings, the defects are fourfold: reverberation, echo, dead spots and sound focal points, and high noise levels.

In making a study of these defects, a reverberation analyzer is practically the only instrument which will give a complete analysis of all four of these common architectural faults. Furthermore, it is a substantial aid in designing new buildings through experience gained on present construction.

Reverberation has been defined as the persistence of sound due to repeated and diffused reflections. Too long a reverberation is undesirable inasmuch as it makes an unintelligent jumble of speech sounds and in a somewhat lesser degree impairs the quality of music. If the reverberation is too small, it causes a flatness in speech and music and in large auditoriums makes it difficult for a speaker to be heard because most of the sound is absorbed.

It is common to measure reverberations by what is termed the reverberation time. This is the length of time required for the original sound to decay to one-millionth of its original intensity. Acceptable limits for various size rooms and auditoriums are given in Tables III and IV.

Measuring Reverberation

Sample charts with an explanatory analysis of the curves for both reverberation and echo are illustrated in Fig. 1. Reverberation time can be measured from the high-speed level recorder charts as shown in Fig. 2, using the Reverberation time scale.

Echo is the reflection from smooth surfaces as a mirror reflects light. Audibly, it is described as a reflected syllable or word arriving at the ear at the same moment as a later sound arriving by the direct path, causing a disturbing and unintelligible effect. The surfaces causing this echo can be located by examination of the reverberation decay record as shown in B and C in Fig. 1.

Dead spots and focal point patterns can be made on the chart by using the microphone as a roving detector throughout the room space. This investigation will reveal any dead spots or excessively loud points in the room. If these occur, they probably are caused by curvatures in the walls or ceiling which act as a focussing mirror concentrating sound at one point. This in turn will impart to the surrounding area a lack of reflected sound and dead spots. A geometric analysis of the borders of the room will aid in locating the fault.

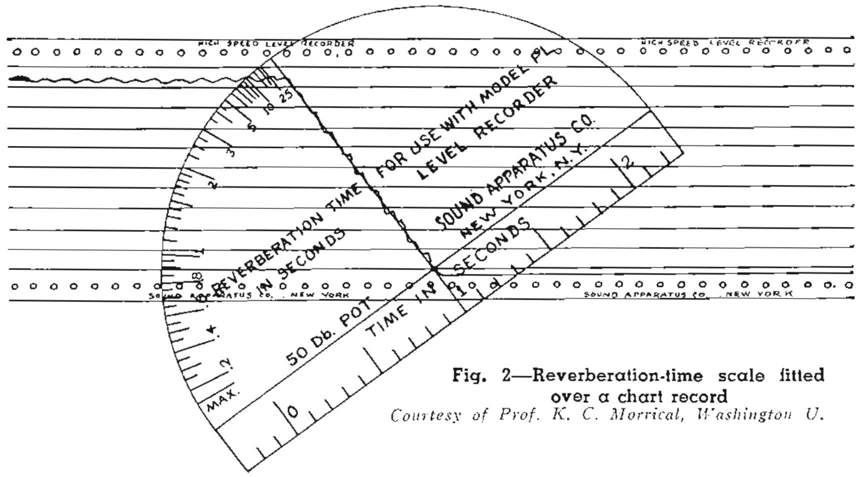


Fig. 2—Reverberation-time scale fitted over a chart record
Courtesy of Prof. K. C. Morrical, Washington U.

Noise level may negate an otherwise acoustically acceptable auditorium. This is particularly disturbing in theaters, hospitals and churches. This, also, can be measured in a similar manner to the measurement of sound distribution, but without the oscillator. Relative loudness of noises is given in Table I, and can be compared with the readings obtained on the chart to give a clear picture of the amount of annoyance this unwanted sound will cause.

In order to acquaint the reader with the type of problems encountered, a simple analysis of sample records is given and a few typical calculations are made to illustrate the various ways this analyzer may be used.

The tracings in Fig. 1 serve to illustrate the various types of decay curves normally encountered. The curve A shows a typical decay using a pure tone as the sound source. Notice the many reinforcement and cancellation tendencies as the sound "bounces" about the room. A comparison with the other curves, which were obtained using a warble tone oscillator, shows the effectiveness of using this type of sound source.

Echos appear on the curves B and C. If the elapsed time from the initial drop to the echo peak is measured by the bottom time scale of the Reverberation-time scale, it serves as a clue as to what causes the echo. In B, this time is .35 seconds. Inasmuch as sound travels 1100 feet a second, this equivalent distance is 1100 x .35 = 385 feet. A path is then sought which is 385 feet from speaker to microphone by way of some smooth reflecting surface. The microphone and speaker can be relocated to establish further this exact surface.

TABLE I
CORRELATION OF THE DECIBEL WITH LOUDNESS AND INTENSITIES

Decibels	Volts Input	Sound Pressure dynes/cm²	Loudness
0	.00003	.001	Rustling of leaves
10	.0001	.003	Quiet whisper
20	.00032	.01	Quiet Home
30	.001	.03	Quiet Street
40	.0032	.1	Normal Conversation
50	.01	.3	Average Office
60	.032	1	Department Store
70	.1	3	Average Automobile
80	.32	10	Average Factory
90	1.0	30	Lion's Roar
100	3.16	100	Subway Noise

The decibel (abbreviated db) is the logarithm of the ratio of the corresponding intensity to that of the reference intensity level. It is given exactly by the equation:

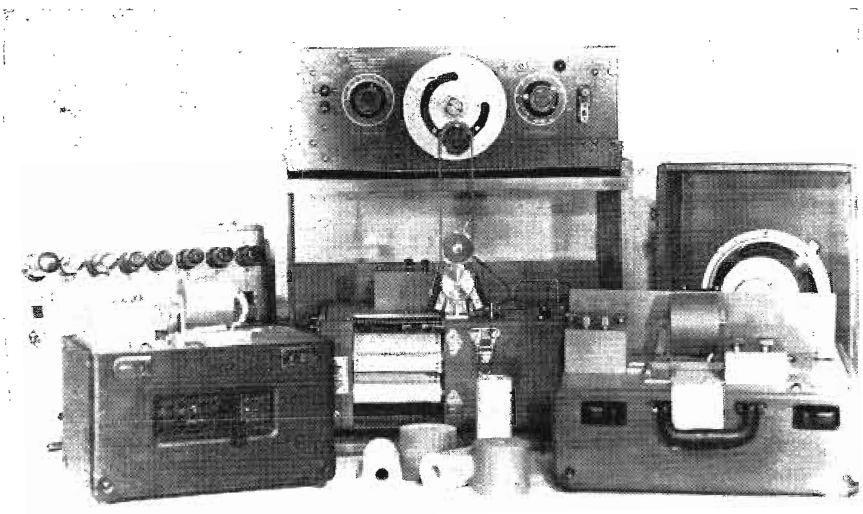
$$\text{Decibels} = 20 \text{ Log}_{10} \frac{\text{Intensity}}{\text{Intensity Reference}}$$

The logarithmic function was chosen because the human ear is very nearly logarithmic in the perception of sound intensities. A change in intensity of one decibel corresponds very closely to the smallest change in intensity that the ear can detect, regardless of the loudness of the sound. The chart above is a correlation between the decibel and voltage input to the pre-amplifier, sound pressure, and recognizable loudness levels.

Curve Interpretation

It frequently occurs that the microphone and speaker are placed too close together and the incident sound directly from the speaker decays more rapidly than the reverberation as shown in D. In making reverberation time measurements this is to be avoided either by moving the speaker and microphone apart or by inserting a baffle in the direct path.

Insufficient initial sound level or too high a noise level will result in a curve similar to E. The curve tends to flatten out as the noise level is approached, giving a false



High and low speed sound-level recorders, warbletone oscillators, mikes, speakers, etc., comprise typical test set-up

reverberation time if the slope is measured at this lower level. The curve in F is an example of a good record made with ample level and in a room relatively free of echo, and is the result strived for in obtaining an accurate measurement of reverberation time.

In the calculation of reverberation time, the dimensions of the room and absorption coefficients of the room materials must be known and tabulated. Room dimensions: 20 x 80 x 125 Volume V: 200,000 cu. ft.

The reverberation time is given by the formula:

$$T = .05 \frac{V}{A},$$

where V = volume in cu. ft., A = total absorption.

The total absorption is the sum of the products of each area of the sides of the room, times its absorption coefficient. A list of these coefficients appears in Table II.

The various values of absorption (A) are listed in the table below, where: Reverberation time T = .05 V/A = .05 x 200,000/5130 = 1.95 seconds.

	Area	Absorption Coefficient at 1000 c.p.s.	Absorption Product
Ceiling Celotex A:	80 x 125	.22	2200
½ floor linoleum:	40 x 125	.03	150
½ floor cork:	40 x 125	.12	600
Side walls hard plaster:	20 x 125	.03	75
Side walls hard plaster	20 x 125	.03	75
Rear wall celotex B:	20 x 70	.46	644
10 in. rear opening:	20 x 10	.5	100
Front area, plaster:	20 x 20	.03	12
Front stage opening with plaster walls:	20 x 60	.25	300
200 empty seats:	—	.17	34
200 occupied seats:	—	4.7	940
		TOTAL (A)	5130

If it has been established by measurement that the reverberation time is too long, the formula below gives the amount of additional square feet of absorbing materials required:

$$S = \frac{.05V}{A_2 - A_1} \frac{(T_1 - T_2)}{(T_1 x T_2)}$$

where V = Volume of the room,
A_2 = absorption coefficient for the added material
A_1 = absorption coefficient for the material to be replaced by the new material
T_1 = present reverberation time measured by analyzer
T_2 = desired reverberation time

TABLE II
ABSORPTION COEFFICIENTS

Materials	at 200 cps	at 1000 cps
Average Acoustic Plaster over gypsum plaster	.25	.60
Hard Plaster	.02	.03
Lime Plaster with rough finish over wood laths	.04	.08
Brick Wall Unpainted	.02	.04
Brick Wall Painted	.01	.02
Glass	.02	.03
Masonite ½" Board	.21	.30
Felt 1" Thick 100 percent hair	.32	.62
Rock Wool, 1" Felted	.45	.72
Wood sheathing, pine	.11	.08
Cork flooring	.03	.12
Linoleum	.02	.03
Draperies, draped to ½ area	.35	.72
Carpet, lined	.14	.42
Balsam Wool	.25	.63
Poured Concrete	.01	.02
Acoustical Westfelt	.17	.62
J-M Sound Insulating Blanket MK	.72	.78
Celotex Type A	.20	.22
Celotex Type B with perforations exposed	.21	.46
Objects		
Openings (depending upon furnishings beyond)	.25 to .80	
Ventilators	.40	.50
Average adult person	4.3 sq ft.	4.7 sq. ft.
Seat, plywood	.15 sq. ft.	.17 sq. ft.
Seat, upholstered (average)	2.0 sq. ft.	2.5 sq. ft.

As a practical problem, let us take a room of 100,000 cu. ft. which has a measured reverberation time of 3 seconds. It is desirable to reduce this to 1.5 seconds. The amount of acoustic plaster to be added to the hard plaster of the ceiling is to be calculated: Present reverberation time $T_1 = 3$, Desired reverberation time $T_2 = 1.5$, Hard plaster coefficient $A_1 = .03$, Acoustic plaster coefficient $A_2 = .60$

$$S = \frac{.05V}{A_2 - A_1} \frac{(T_1 - T_2)}{(T_1 x T_2)} = \frac{.05 x 100{,}000}{.60 - .03} \frac{(3 - 1.5)}{(3 x 1.5)} = 3{,}000 \text{ sq: ft.}$$

If the ceiling measures 50 by 100 ft., or 5000 sq. ft., then 3000 sq. ft. must be covered by the acoustic plaster to give the desired reverberation time. After this has been done, the reverberation analyzer can be used again to substantiate the results.

Many ways have been advised to measure the absorption quality of acoustic materials using the high-speed recorder, but a simple and direct method is described which will give a quite accurate absorption index of the material.

A quiet rectangular room of high reverberation time is required (about 5 seconds minimum). If a reverberation time record is made before (T_1), and after (T_2), the addition of a given number of square feet (A) of unknown material has been added to the room, the equation of the absorption coefficient (α) is:

$$\alpha = \frac{.05V}{A} \frac{(T_1 - T_2)}{(T_1 x T_2)}$$

Of course, if any degree of accuracy is to be obtained the difference between the two values of reverberation time should be a significant factor. This can be accomplished by beginning with a very reverberant room, or using a larger area of the unknown material.

The basic principle of operation of these graphic recording instruments is dependent upon a variable dc voltage impressed upon a bridge circuit which operates the stylus or pen through a servo system. The stylus is connected to the potentiometer which restores the input voltage to the balance level.

The recorder is schematically

shown in Fig. 3. The input potentiometer P is interposed between the input terminals and the amplifier. The signal from the potentiometer connects to the amplifier through the flexible lead L and the contact point K. The output of the amplifier is a balanced rectifier from which dc current flows through coils S_1 and S_2. These coils are wound on the two sides of magnetic disc M. The two prongs of the magnetic fork G slide on the edges of the disc forming a magnetic clutch whose gripping power is dependent on the signal. This fork carries the potentiometer contact K and a scribing point which is always in contact with the waxed paper R.

When there is no output signal across the terminals there is an initial unbalance in the rectifier circuit which causes a relatively large current to flow in the coil marked S_2 in Fig. 3, while the current through S_1 is very small. This attracts the fork prong to the disc on the side of the disc where S_2 is located, increasing the friction between this prong and the disc. This friction causes the fork to move with the disc, carrying the scriber and potentiometer point to the end of the scale where the attenuation of the potentiometer is zero. This makes the instrument ready to receive a signal with the sensitivity at its maximum value. If a signal voltage is applied to the input terminals, it is amplified and rectified and the rectified output causes the current through S_2 to decrease.

Recorder Operation

If the signal level is raised to a certain point, the current through S_2 becomes very small and that through S_1 increases to the point where the friction on the other prong of the fork is greater. The fork moves to the right which reduces the voltage on the amplifier and restores the balance of currents through S_1 and S_2. The distance the potentiometer moves in restoring the balance is recorded by the scriber on the moving wax-paper strip. Thus a measurement of the amount of change in input signal is made and recorded. These operations are repeated for any increase or decrease in the signal and are carried out at very high speeds. The balancing of the bridge for every signal change is accompanied by the inscription of the amount of change on the wax paper making a continuous record of the changes of the input level.

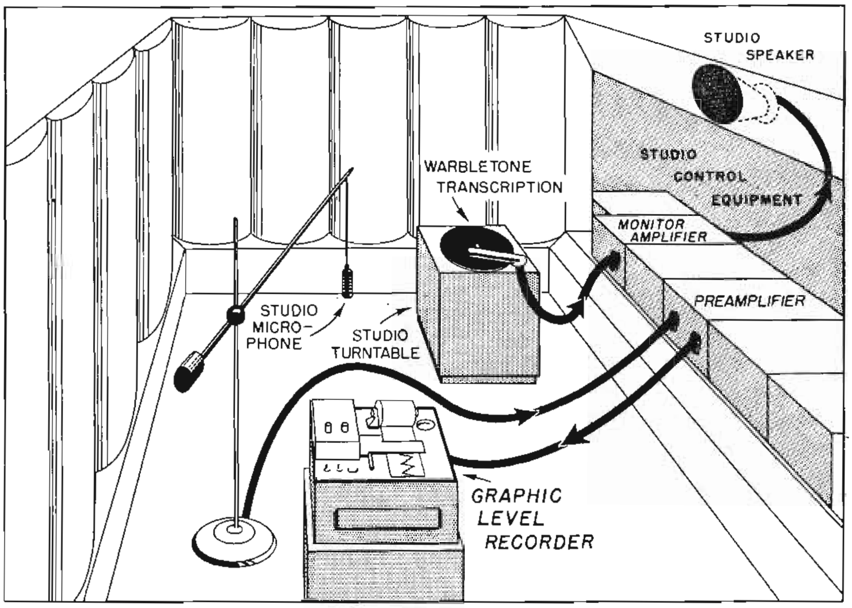


Fig. 4—Broadcast station may use already installed facilities in conjunction with level-recorder for reverberation tests. Measurement of frequency response, field intensity, etc., are further uses

The measuring range of the instrument is determined by the input potentiometer. Since these potentiometers are interchangeable, a narrow as well as wide range of intensities can be covered. The resistors are terminated in a contact train which is divided into 100 steps. In a potentiometer of 0-25 db, each step represents ¼ db; in one of 50 db, each step represents ½ db, etc. Potentiometers of 0-25, 0-50, and 0-75 db are available for the PL and PS models.

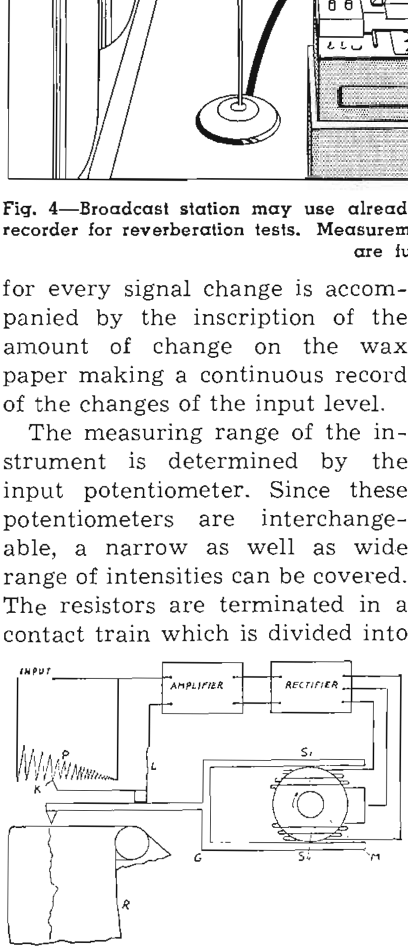


Fig. 3—Schematic of the high-speed level-recorder

**TABLE III
REVERBERATION TIME LIMITS FOR AUDITORIUMS**

Room Volume (Cubic Feet)	Optimum Limits of Reverberation Time in Seconds — Half Audience 200 cps	Half Audience 1000 cps	Full Audience 200 cps	Full Audience 1000 cps
10,000..	1.2	1.0	1.0	0.8
25,000..	1.4	1.2	1.2	1.0
50,000..	1.7	1.4	1.5	1.2
100,000..	2.0	1.7	1.7	1.4
200,000..	2.3	1.9	1.9	1.5
400,000..	2.5	2.1	2.1	1.7
600,000..	2.8	2.3	2.3	1.8
800,000..	3.1	2.5	2.5	2.0
1,000,000..	3.4	2.8	2.7	2.2

These values are for an auditorium where a universal application is sought, i.e., it is to accommodate music and speech with and without sound reinforcement. Where sound reinforcement is to be exclusively used, the above figures should be reduced by 20 percent.

For a test set-up the loudspeaker and microphone are preferably located in different parts of the room (Fig. 4). When the oscillator is turned off the sound decay is plotted on the recorder chart paper. The cause of echos shown in B and C of Fig. 1 can be located in the room by measuring the time from the shut-off point of the oscillator and the occurrence of the echo.

Decay Curve Slope

The reverberation time is determined by the average slope of the decay curve, and is measured conveniently by the Reverberation-time scale as shown in Fig. 2. The vertical line of the scale is fitted to the average slope of the decay line with the cross-line intersection coinciding with the bottom calibration line. Running along this calibration line we find that the reverberation time on the illustrated example is .9 seconds. For making noise level records, the oscillator is shut off and a running level of noise is recorded on the recorder in the various parts of the room.

In the process of making a field

plot of sound distribution, it is necessary to use the microphone as a roving probe throughout the room. Although the pre-amplifier in the oscillator can be used with long connecting cables, it becomes much more convenient to use a pre-amplifier which is in a small portable case with a low impedance output. The recorder can remain stationary, as the microphone and pre-amplifier are carried around the room and the sound level is plotted on the chart. The warble is used on the oscillator to prevent standing waves in the room and permits a smooth curve of the sound distribution.

The following is a list of some applications for highspeed, level recorders:

a. Maintenance of circuits and apparatus in broadcasting stations.
b. Recording of radio field intensities.
c. Measurement of studio characteristics.
d. Determination of the frequency characteristic of a portion of a broadcasting system during regular operation without interruption.
e. Reverberation time measurements.
f. Decay of sound.
g. Sound absorbing—and insulating properties of acoustic materials.
h. Acoustic impedance of commercial materials.
i. Sound intensity and loudness measurements in general.

The complete equipment comprising a reverberation analyzer kit consists of: (1) Model PL highspeed level recorder; (2) Model WO warble-tone oscillator.

**TABLE IV
REVERBERATION LIMITS FOR SOUND STUDIOS AND HOMES**

Room Volume (Cubic Feet)	Optimum Limits of Reverberation Time in Seconds 200 cps	1000 cps
10,000	0.7	0.6
25,000	0.9	0.8
50,000	1.1	0.9
100,000	1.3	1.0
200,000	1.5	1.1
400,000	1.6	1.2
600,000	1.7	1.3
800,000	1.8	1.4
1,000,000	1.9	1.5

The Model PL recorder equipment is normally furnished with a 50 db scale which is linearly calibrated in decibels on a 2-in. wide chart, and is capable of faithfully recording changes in sound level up to 400 db per second. Controls are provided for starting and stopping the chart paper and the writing mechanism. It is provided with a fast paper and writing speed for reverberation time measurements, and a slow paper and writing speed for the recording of noise and sound level measurements.

Reverberation Studies

The Model PS recorder has only one writing and paper speed, but can be used where only the reverberation studies are required. This instrument is a simplified form of the Model PL and as an economy measure is available to those not anticipating an overall survey of all acoustic conditions.

The Model WO warble-tone oscillator is an audio-oscillator with a main tuning dial calibrated logarithmically from 50 to 20,000 cps. The warble rate can be selected for 3, 6 and 10 times a second. The warble extent can be adjusted by means of a dial calibrated from 0 to 1000 cycles above and below the center frequency. Included in the oscillator case is a 10-watt amplifier, a crystal microphone, a pre-amplifier with a gain control for adjusting the sound level, and a 10-watt loudspeaker built into the removable lid of the case. Both units are constructed for portability with each housed in a leatherette case 9" x 12" x 16", and each weighing less than 35 pounds. Each instrument is operated on 115 volt 60 cycle current and comes equipped with a detachable line cord.

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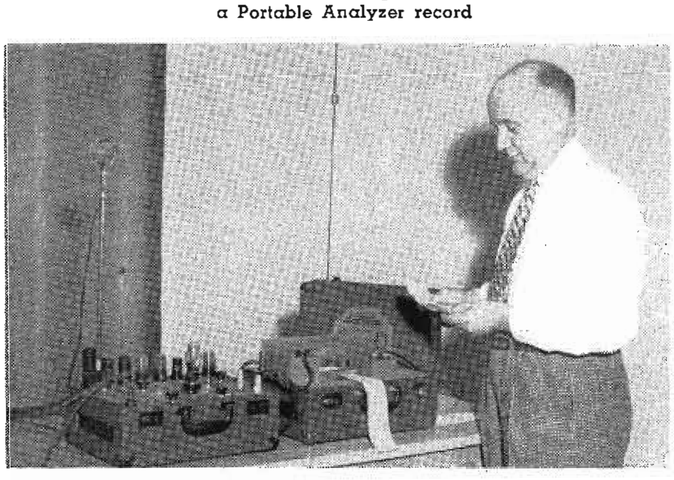
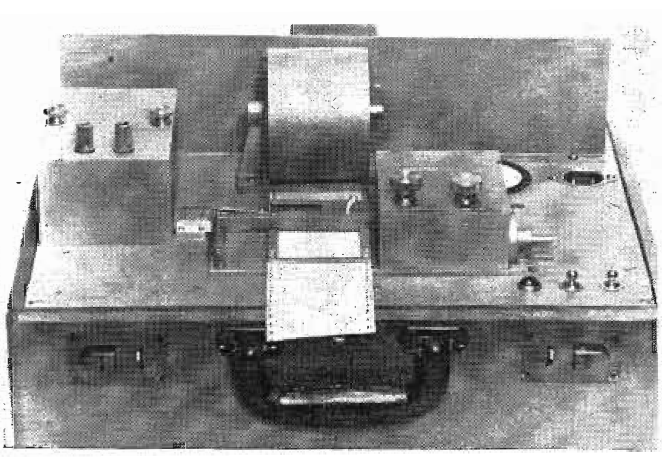
A. W. Niemann, founder of Sound Apparatus Co. in 1932 examines a Portable Analyzer record



Model PL recorder has a fast writing speed for reverberation tests and a slow one for noise and level measurements



Radar System for Airport Traffic and Navigation Control

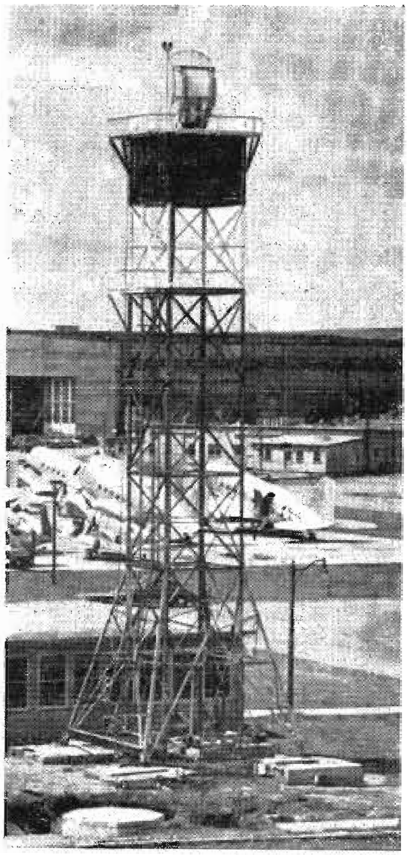
By FRED J. KITTY, Project Engineer
Bendix Radio Div., Bendix Aviation Corp.

Bendix-Navy GCA "Quonset Installation" combines advantages of many systems to provide for surveillance, height-finding and instrument approach — Part III

• The precision approach system of radar set AN/FPN—1 (XN2) consists of two X-band radar sets scanning a small angle of space in the direction of approaching aircraft. One radar set scans vertically to determine very accurately the angle of the aircraft above the horizontal to detect any deviation from a preselected glide path. This is called the elevation system. The other set scans horizontally to detect any deviation in course from that leading down the center line of the runway. This is called the azimuth system. Each set has its own indicator with a single range of six nautical miles. An approach indicator coordinates the elevation and azimuth deviations so that the approach controller can orally direct, with extreme accuracy, the pilots of incoming aircraft.

The azimuth, elevation and approach indicators and two video amplifiers are installed in racks in the indicator room housed in the control tower building (Fig. 1, August issue Tele-Tech). All other major units are mounted in the trailer (Fig. 15 and 16) which can be towed to either of two preselected sites. Cables from the indicator location have been laid underground to connect to identical terminal boxes at these sites. These and a connector panel at the rear of the trailer provide for quickly connecting the trailer to the rest of the system. The two sites are separated by 4500 and 2000 ft. of cable respectively from the indicator room.

The two synchronizers (elevation and azimuth) are identical in construction and function to the ones used in the search and height finder systems.‡ The master positive trigger from the search system controls the elevation synchronizer which in turn produces a trigger to control the azimuth synchronizer. Thus it may be seen that all four radar systems are synchronized.



The Search Tower containing the search transmitting and receiving equipment

There are two identical transmitter racks, one for each of the two systems. Each contains a receiver, synchroscope, transmitter and H. V. power supply. Except for the transmitted frequencies these components are identical with those used in the height finding system. The 2J51 magnetron in the azimuth transmitter is tuned to 9040 mc while the 2J51 in the elevation transmitter is tuned to 9010 mc.

Except for mechanical arrangement, length of waveguide and omission of the rotating joint, the plumbing used in each of the precision systems is identical with that of the height finder system. This includes the directional couplers and adjustable impedance transformers shown on the height finder block diagram.

The elevation antenna system occupies the left rear corner of the trailer and when erected projects above the roof. A house is provided to protect the antenna mechanism, the house being braced by struts to the trailer roof. The front of the house consists of a plastic sheet translucent to radio energy. The entire house is removable for travelling and a cover fits over the hole in the roof.

The elevation reflector is identical with that used in the height finder system, the lower half in this case being hinged to the trailer body. The antenna array consists of 165 probe fed dipoles mounted in a 14 ft. length of variable-width waveguide. Scanning is accomplished in a manner identical with that used for the height finder except that the scan range is from +1° to +8° with respect to the normal. The array produces a beam

‡See Tele-Tech for August and September.

0.6° wide in elevation at the half power points.

In order that scanning below the horizon may be obtained the entire trailer is tilted 2° into the ground so that the actual limits of scan are from 1° below the horizontal to 6° above. Angle data is obtained from the scanner in an identical manner to that used in the height finder; the angle coupler and coupling capacitors being identical. However, the voltages produced by the scan range from +2 volts to +102 volts in this case. The elevation antenna system is installed so that it may be rotated by means of a motor through an angle of 20 azimuth degrees.

The azimuth antenna system is mounted horizontally along the left side of the trailer, protected by a plastic sheet similar to the one used in the elevation system. For travelling a steel cover folds over the plastic sheet. The azimuth reflector resembles the height finder reflector except that it is in one piece and is 8 ft. in length. It is parabolic and mounted so that it may be turned 7° about its horizontal axis. The reflector controls the elevation thickness of the radiated beam which is approximately 2° at the half power points.

The antenna array consists of 114 probe fed dipoles mounted in an 8 ft. length of variable width waveguide. Scanning is accomplished in a manner similar to that used in the height finder, the limits of scan being −1° to −21° with respect to the normal. The trailer is parked at an angle of 84° to the runway so that the actual limits of scan are from 5° to the right of the runway to 15° to the left. The array produces a beam which is less than 1.2° in azimuth at the half power points. The azimuth antenna system uses angle data equipment identical with that used in the height finder system. However voltages produced by the scan range from +10 to +90 volts in this case.

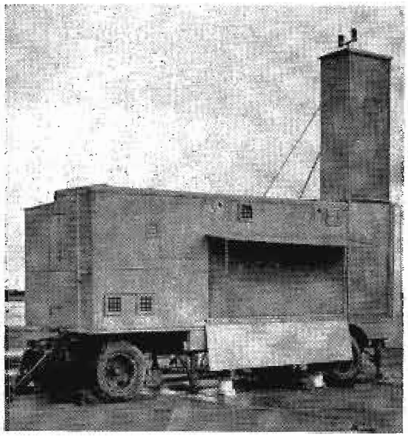


Fig. 15—The trailer housing the precision antennas, transmitters and receivers

The precision antennas (Fig. 17) have two scans, one electrical and one mechanical. The electrical scan is continuous and its rate is fixed. The electrical scan drive motor runs at approximately 1750 rpm and drives the two variable width waveguide scanners simultaneously through a mechanical linkage with an overall reduction ratio of 30:1. It can be easily shown that this results in one complete scan cycle per second or it may be said that each antenna makes two sweeps (1 up and 1 down) per second. The mechanical motion of the antennas is controlled through pedals at the elevation and azimuth indicators. (Figs. 18 and 19).

These are quite similar as far as circuitry and general features are concerned to the height finder indicator already described. The azimuth indicator has a single range of six nautical miles, with one mile range marks. It presents a picture in azimuth of a 20° arc in front of the precision system trailer, rotated so that the azimuth operator, who views the indicator, sees the same picture that the pilot sees approaching the field. Using 10 in. of the 12 in. cathode ray tube, with an EPI presentation, the horizontal component of the sweep is expanded three times for increased accuracy in azimuth.

A hand wheel on the front of

Fig. 16—General view inside the trailer, looking down the aisle from rear door

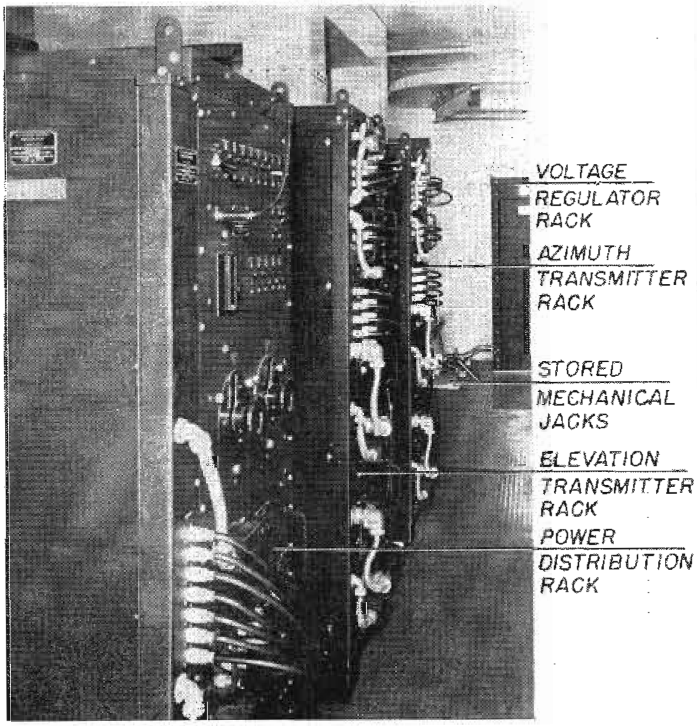
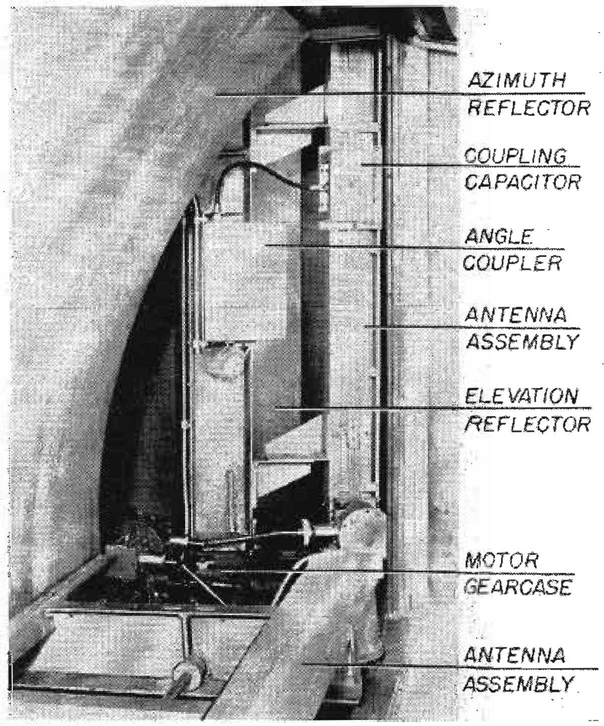


Fig. 17—Close-up view of the Precision antenna system, identifying its elements



the indicator actuates a cursor with which the tracker follows the signal of the incoming aircraft. A synchro generator driven by the same handwheel actuates the azimuth marker on the approach indicator. Since the radar equipment is mounted in the trailer, which may be as far as 5000 ft. distant, a video amplifier is provided in the bottom of the rack to amplify the signals transmitted over this long line. An identical amplifier is provided for the elevation indication. These amplifiers are not required in the search or height finding systems, whose radar equipment is located within 500 ft. of the indicators.

Pedals are provided at the bottom of the rack by means of which the azimuth tracker rotates the elevation antenna system in azimuth to keep it aimed on the target. An electronic follower circuit indicates the azimuth position of the elevation antenna. This electronic follower extinguishes the azimuth indicator range marks except in the space being scanned by the elevation antenna. The range marks appear as a fan, or wedge, with the point at the origin of the sweep. Operation of the pedals moves the wedge left or right in accordance with the rotation of the elevation antenna.

Fig. 18—The two operators sit back-to-back, operator for the Approach Indicator being in the foreground, with the Elevation operator in the background

Elevation Indicator

The elevation indicator has a single range of six nautical miles, with one mile range marks. It presents a picture in elevation of a 7° arc in front of the trailer, from 1° below the horizontal to 6° above. Using 10 in. of a 12 in. cathode ray tube, with an EPI presentation, the vertical component of the sweep is expanded ten times for increased accuracy in elevation. A hand wheel in front of the indicator actuates a cursor by means of which the elevation tracker follows the signal of the incoming aircraft. A synchro generator driven by the same handwheel actuates the elevation marker on the approach indicator.

Pedals are provided at the bottom of the rack, by means of which the elevation tracker tilts the azimuth antenna system in elevation to keep it aimed on the target. Electronic follower circuits like those in the azimuth indicator, allow the range marks to show only in the position covered by the azimuth antenna beam. The cursor used on the elevation indicator is adjustable for any desired glide path, depending upon the type of aircraft to be landed.

The approach indicator contains two synchro motors, one receiving deviation information from the azimuth indicator, the second from the elevation indicator. In the case of the elevation system the synchro motor swings a wire semicircle (through gears) behind a curved plastic disc on which are etched numbers representing feet of deviation above and below the glide path. Thus when the tracker moves his cursor he moves a wire marker in the approach indicator. Two dial lamps in the latter cast the wire marker's shadow on the "ground glass" surface of the plexiglass disc. The same process is used in the case of the azimuth deviations.

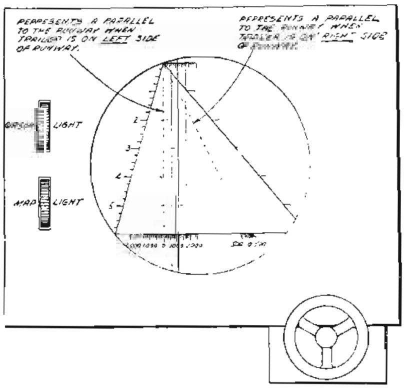


Fig. 19—Azimuth indicator presentation

Now, since the two wires are mounted at right angles under the same disc, the position of the aircraft with respect to the ideal can be read directly, in terms of rectangular coordinates at the point on the indicator where the two shadows intersect. The origin of the rectangular coordinate system used on this indicator, represents the ideal position for the aircraft. A full set of radio facilities are provided at the approach indicator position to afford complete communications with aircraft and the other radar operators.

Functions of Operators

The azimuth tracker sits in front of the azimuth indicator rack. He performs two major functions: he follows the signal on his indicator with a cursor which controls the azimuth deviation marker on the approach indicator; by means of pedals he aims the elevation antenna in azimuth.

The elevation tracker sits in front of the elevation indicator rack which faces the azimuth rack. Thus the two trackers are sitting with their backs to one another. The elevation tracker performs the same two functions with respect to elevation that the azimuth tracker

(*Continued on page 93*)

Mobile Radiophone for Taxicabs Proves Its Worth

Operators of many installations using low-power two-way FM in 152 mc band report business increases as much as 40%

• "We have learned that a car equipped with 2-way radio is three times as useful as one without." These words of L. L. Welsh, president of the Welsh Taxicab Co., Morristown, N. J., mark one significant reason why the advent of radio in the taxi service is accompanied by an average 40% increase in business. Two-way radio sets work like magic in putting to work the otherwise wasteful "empty returns."

With the automobile market in short-supply, cab-starved taxi companies across the nation are now trebling their fleet sizes in effect with 2-way radio units. Twenty-one of these taxi companies in the Greater New York area comprise a fast-growing organization called the Metropolitan 2-Way Radio Taxi Owner's Association. This group is pledged to the task of mutual negotiation for maximum efficiency and workable radio procedure. Welsh, who is also president of this organization, emphasized the value of mutual discussions which account for "remarkable cooperation between radio taxi companies operating on nearly the same wavelength in a crowded spectrum." The association imposes self-censorship on the various group members and employs an association censor who monitors for superfluous conversation and other abuses of the wavelengths. It is learned from experience that the average transmission requires a period of only 6 seconds, and any conversation much beyond this may be cause for a citation.

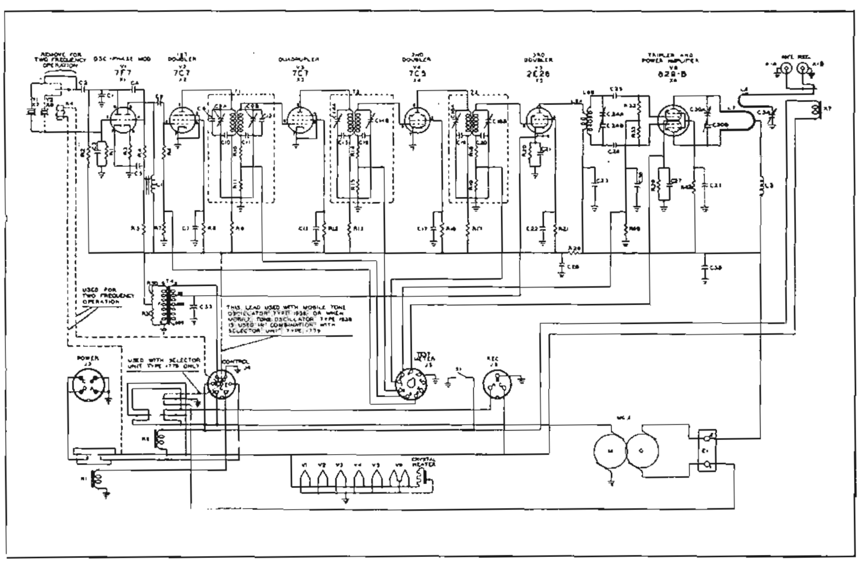
Welsh explained that each taxicab company is assigned a preliminary number which identifies the call. If a taxi of company A hears the transmission of a taxi of company B, there would be no possibility of error because of this numbering system. A Welsh radio call, for example, bears the prefix number 2 and each numbered car is assigned a call such as 2-10 or 2-15. The number 10 and 15 taxi's of another nearby company may be 4-10 or 4-15. In this way, transmissions are kept in the proper administrative channels.

Welsh mobile stations went on the air in June, 1946 using Link equipment. The FCC issued experimental class II licenses for 16 mobile stations and one fixed station. Eight taxis already are radio-equipped and the remainder under way. W2XIG, the fixed station, is a 250-watt Link, type 1908, FM radio set and is assigned a frequency of 152.27 mc. Each mobile station consists of a 15-watt FM transmitter and its companion receiver. The mobile units transmit on a frequency of 157.5 mc.

Phase Modulation

Link mobile and fixed station transmitting equipments use the phase deviation principle for generating the FM carrier. Three doublers, one tripler and one quadrupler are required to multiply the phase-deviated crystal-controlled frequency up to the 152-162 mc band. Both the fixed station and the mobile transmitters are essentially the same, except that the latter has a dynamotor plate power

Fig. 1—Wiring diagram of the Link crystal controlled FM mobile transmitter using dynamotor power supply



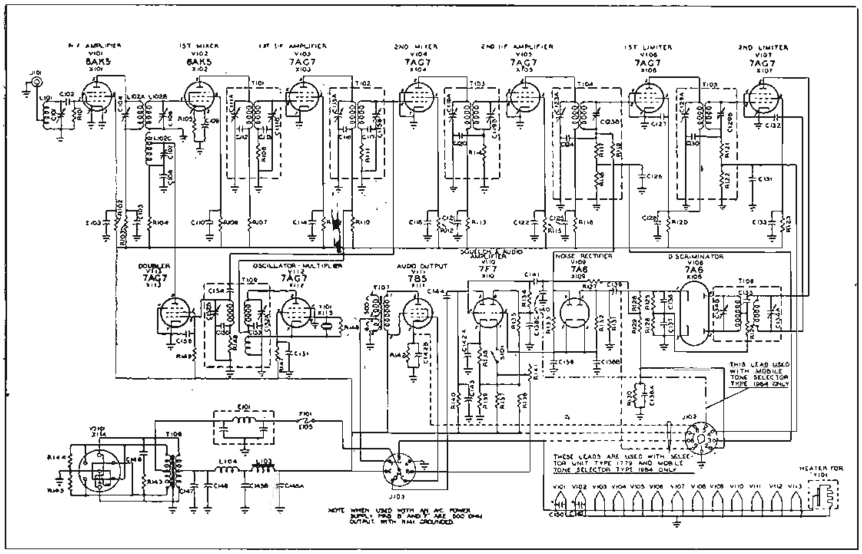


Fig. 2—Wiring diagram of the Link FM receiver for mobile installations

source—the former, a 115-volt ac source. A schematic of the mobile transmitter is shown in Fig. 1.

The receivers use the Foster-Seeley discriminator circuit preceded by a double limiter. The sets are designed for ±20 kc deviation and audio frequency range from 350 to 5000 cps within ±2.5 db. An undistorted receiver output of 1 watt across a 500-ohm line is available at the output terminals. A quartz crystal insures stable reception under conditions of temperature variation, humidity and vibrations generally encountered in mobile service, and a double heterodyne circuit provides excellent bandpass characteristics and security against spurious responses. A synchronous vibrator type power supply is used for the mobile receiver; a conventional ac power supply is used for the fixed station set. A schematic of the mobile receiver is shown in Fig. 2.

Few Tube Types

From the viewpoint of minimum maintenance, one main feature of the receivers is that a total of 13 tubes are used; yet only 5 different tube types are required to serve as rf amplifiers, mixers, IF amplifiers, limiters, oscillators, multipliers, discriminators, squelch, noise, and audio tubes. Because the mobile set is used mainly in vehicles, the Link FMTR-7C set is designed for sharp discrimination against motor noise and ignition interference. However, a distributor suppressor is supplied with the equipment in case it is necessary to reduce further any received interferences.

Power Supply

The heavy demands of the taxi service for 2-way radio telephone dictate the use of a power supply of greater capacity than the ordinary automobile generator. For this purpose, Leece-Neville three-phase, 60-ampere alternators operate into selenium rectifiers producing about 7 volts across the battery. A voltage regulator system consisting of a number of relays are connected in the field circuit of the alternator to vary the amount of charge into the battery

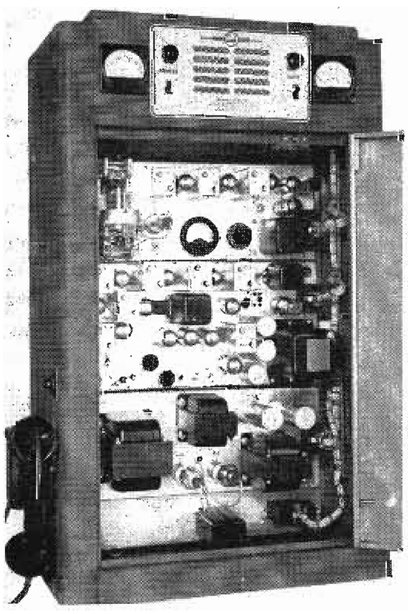


Fig. 3—Fixed station transmitter-receiver

depending on its state of charge. The use of alternators allows simple line voltage control by means of varying the field current and has lower brush outages. A more detailed description of the Leece-Neville mobile power source appears elsewhere in this issue. Refer to that article for the schematic of the complete power unit.

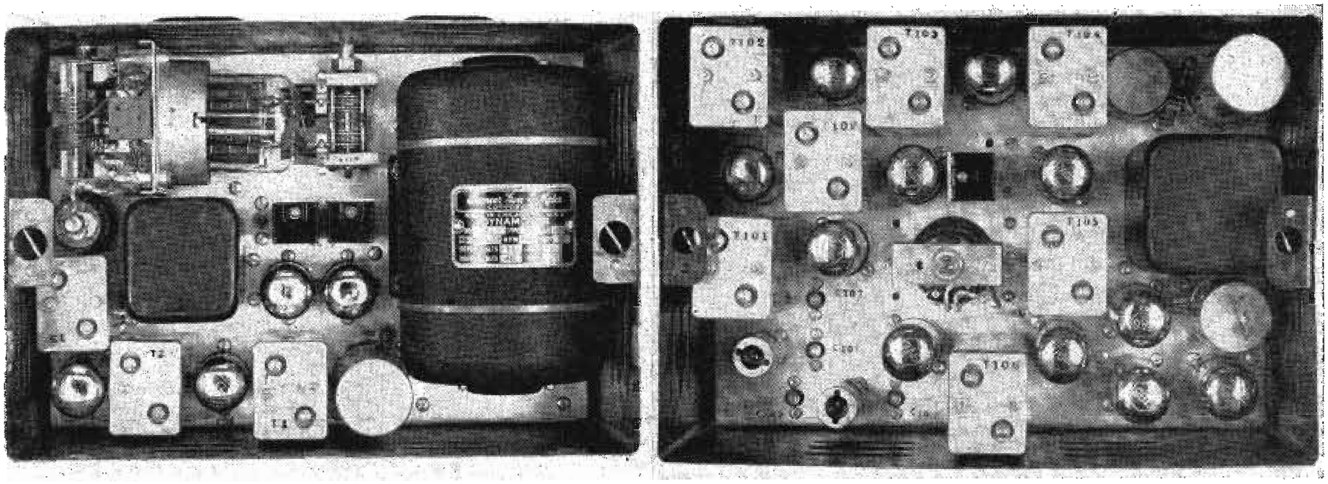
Morristown is a community of 15,000 nestled in a cradle of sharply rising hills. Owing to these hills a 15-watt fixed transmitter provided service, though inadequate, until the present 250-watt unit was installed. A Link high-efficiency, coaxial-type FM antenna on a favorably situated hilltop overlooks Morristown from an elevation of 375 feet and blankets an area encompassing approximately 150,000 people. Welsh cab drivers report no dead spots within the city limits. Transmissions average a distance of approximately 5 miles, but line-of-sight transmission is possible over distances up to 30 miles. Something of a transmission feat is performed daily by Welsh cabs operating right in the heart of New York City's skyscrapers without losing touch with their home station, 30 to 40 miles away.

Land Line Control

A special remote control unit designed by Link Radio enables the taxi dispatcher in the Morristown business district to modulate hilltop station via landline. The unit consists of the following main pieces of equipment: a push-to-talk handset, a loudspeaker, a receiver amplifier, a microphone amplifier, a self-contained power supply, a volume control, a signal strength meter and a VU meter. The fixed station has been in continuous day and night operation for over a year without any serious breakdown.

In the mobile units, a remote control head containing connections for a head set and loudspeaker are connected to the mobile unit in the rear of the automobile as shown on page opposite.

For repairs and maintenance, Welsh Taxi retains a radio repair service which maintains and repairs Link radio equipment ex-



Left—Top view of Link mobile radio transmitter; twin tetrode 829B in upper left serves as tripler and power amplifier. Right—Top view of receiver, which is a double superheterodyne, double limiter FM set

clusively over an area which includes Morristown. Worthington Knapp Radio Service of nearby Roselle Park, N. J., is responsible for the proper operation of mobile sets used by 24 different companies and departments including taxi, police and state installations. The cost of the service is scheduled at the rate of a few dollars per unit per month.

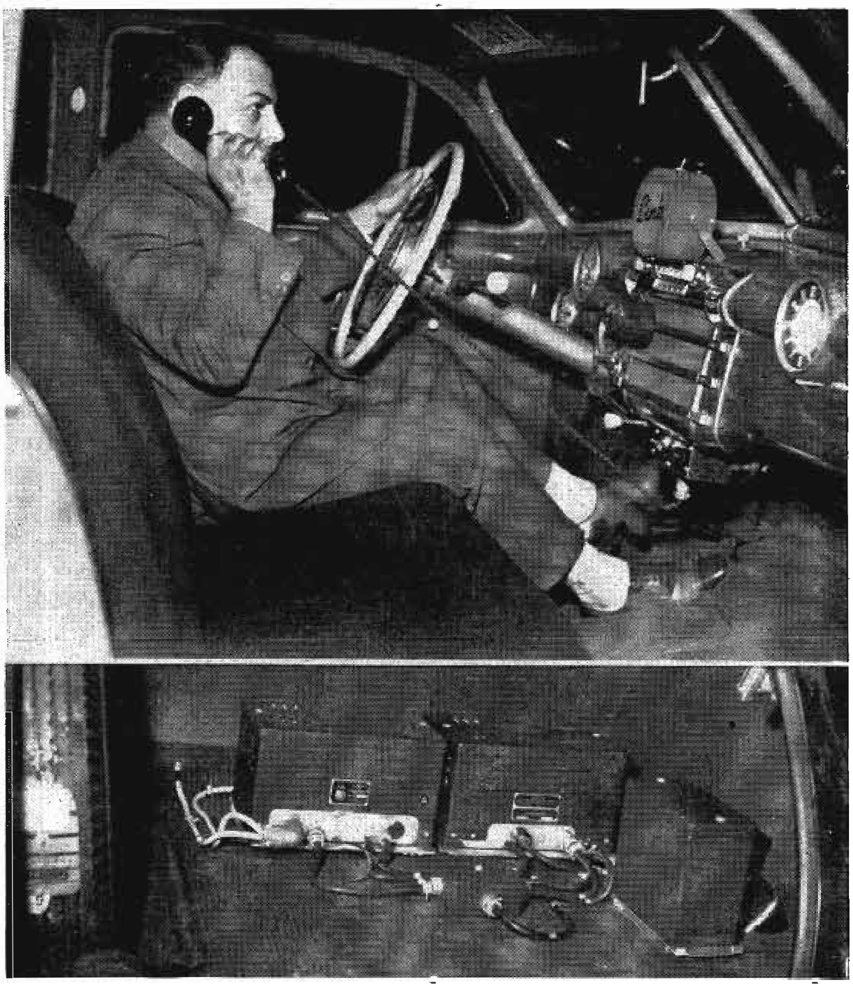
When a unit is returned to the repairshop it is first given a sensitivity test. If it does not measure up to standard, the tubes are checked and defective ones replaced. If the trouble is in the circuits, the vehicle is fitted with an entire working unit and returned to service. The defective set is then overhauled.

Amortization, 2-5 years

On the technical side, maintenance problems are at a minimum. Replacement of tubes is the chief reason for any servicing at all because of the jarring conditions to which radio tubes are subjected in vehicles. However, important advances in tube manufacture have shown up in fewer tube replacements. The 6AG7 tube, for example, is now being manufactured with such ruggedness that replacement is down to a minimum.

An afternoon spent behind the Welsh Taxi Company's dispatching board will provide first-hand evidence that 2-way radio is very seriously much more than a promotion stunt. During one busy session only three cabs were available—one with mobile radio and two without. The dispatcher assigned all three to calls. Meanwhile, other requests came in for immediate service. The dispatcher radioed Taxi No. 1 and reassigned him immediately. Taxis 2 and 3 were heard from sometime later when No. 1 had already handled all their fares as well as its own.

A period of 5 years operation with 2-way radio in the taxicabs is allowed to write off the expense of the installation. However, according to Welsh, that may be done as early as 2 years.



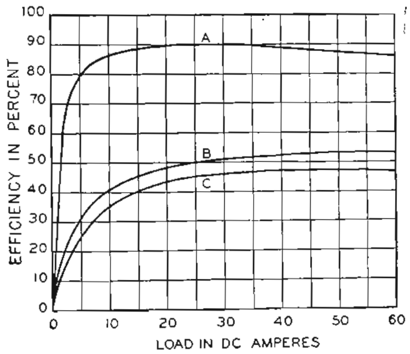
Typical taxicab installation showing location of speaker and handset bracket. Below is a view of the transmitter and receiver installed in the luggage compartment

AC Automotive Generator System for High Output

Simple equipment giving flat output curve with wide variations of engine speed uses dry disk rectifier and automatic voltage regulator

• To the growing load on the electrical system of motor vehicles has been added another current-consuming element—the radiotelephone. For some years automotive and electrical engineers have viewed with trepidation the ever-increasing load imposed, first by such strictly automotive gadgets as cigarette lighters, heaters, auxiliary lighting equipment and latterly by automobile radios — a load which now very closely approaches if it has not already reached, the limitations of thc universal dc generator-storage battery arrangement. It appears certain, now, that something must be done about it, and ac generators may be the answer.

Police communications engineers were the first to feel the need for greater electricity producing equipment. In consequence, dc generators capable of considerably greater output, even at the very much lower speeds represented by slowly cruising "squad" cars, became available and are quite widely used. But there still remain both physical and electrical limitations which it is difficult to overcome with dc generators due in no small measure to the tremendously wide variation in vehicle speeds, and hence in armature speeds, at which they must operate.



Efficiency curve of generator-rectifier system giving 60 amps at 7 volts, 1150 to 12,000 rpm—A, generator; B, rectifier; C, overall efficiency

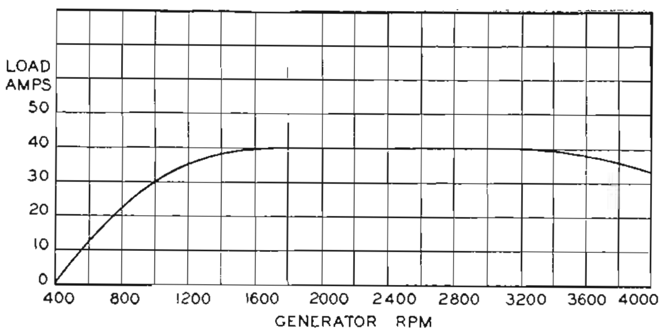
To overcome these limitations and at the same time provide the greatly increased output demanded by the additional load represented by a radiotelephone, the Leece-Neville Co., Cleveland, has developed a radically new and different automotive generator system. Its elements are a generator producing alternating instead of direct current, a dry-disc rectifier which converts the ac to the dc normally used in a vehicle system, and a voltage regulator unit.

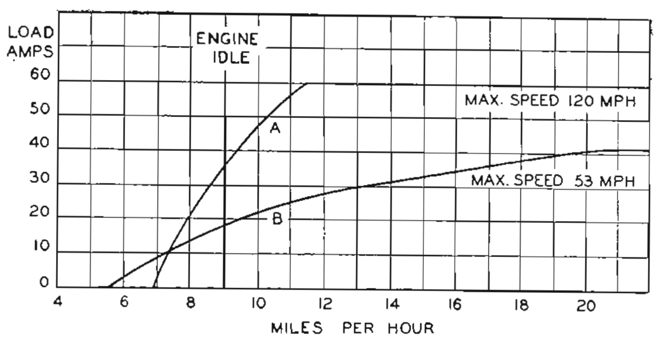
The use of direct current in automotive equipment has been the result of the simplest solution to the problem of a portable power supply—the storage battery. The conventional automobile, truck, or bus has a dc generator driven by the engine of the vehicle, and controlled by a three-element regulator.

As the current load is increased, the generator tends to develop greater heat at low engine speeds, which makes cooling a major problem. As the speed increases, the mechanical limitations of securing the armature windings becomes a major consideration. The life of the brushes imposes a limitation in high speed operation in a generator designed for low speed with high output.

In an effort to get away from the constant design compromise required in a direct current generator, and at the same time solve the problem of flat output curve for wide variations of engine speed, Leece-Neville turned to an alter-

Left—Performance curve of alternating current generator with a range of 7 volts, 40 amps at 1600 rpm. Right, Comparison of performance of AC generator (A) and DC generator (B), engine idle speed being 450 rpm



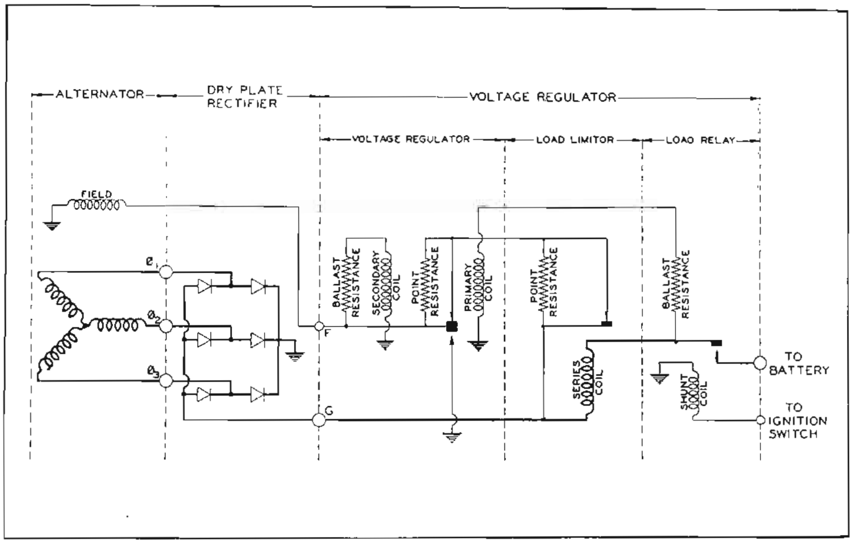


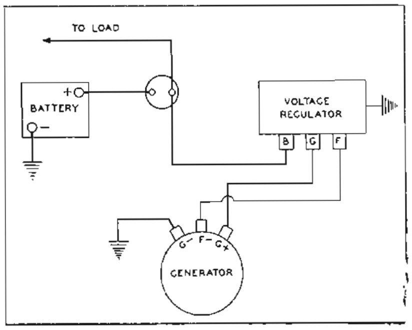
nator. This uses a rotating magnetic field formed from two six-legged forgings excited by a donut coil which increases the field strength to meet higher load demands. The mechanical strength of this design is at once apparent, and the problem of securing the field coil mechanically for high speed operation is slight.

Output of the alternator is taken from a three-phase stator (corresponding to the armature of a conventional generator) thus eliminating sparking and brush wear, the two major problems of commutation in a dc generator. The stator is "Y" connected (although a delta connection is possible) giving a voltage conversion factor of 1.732 times that of any single leg. This ac output is applied to the three-phase full-wave dry disc rectifier unit. This unit is composed of pre-aged, magnesium-copper-sulphide plates which in effect replace the commutator of a direct-current generator, since a dc output is obtained.

Either the positive or negative output of the rectifier can be applied to the common ground by a strap to the frame of the car, while the other tap is fed back through the series coil of the load limiter of the voltage regulator unit, and from there to the proper pole of the battery.

The control unit is composed of three sections: a voltage regulator; load limiter; and a load relay. The voltage regulator and load limiter are connected to control the field current of the rotor as a function





Schematic diagram of the complete Leece-Neville alternating current system showing relationship between alternator, rectifier and voltage regulator functions. Below, wiring diagram of dc system for negative ground

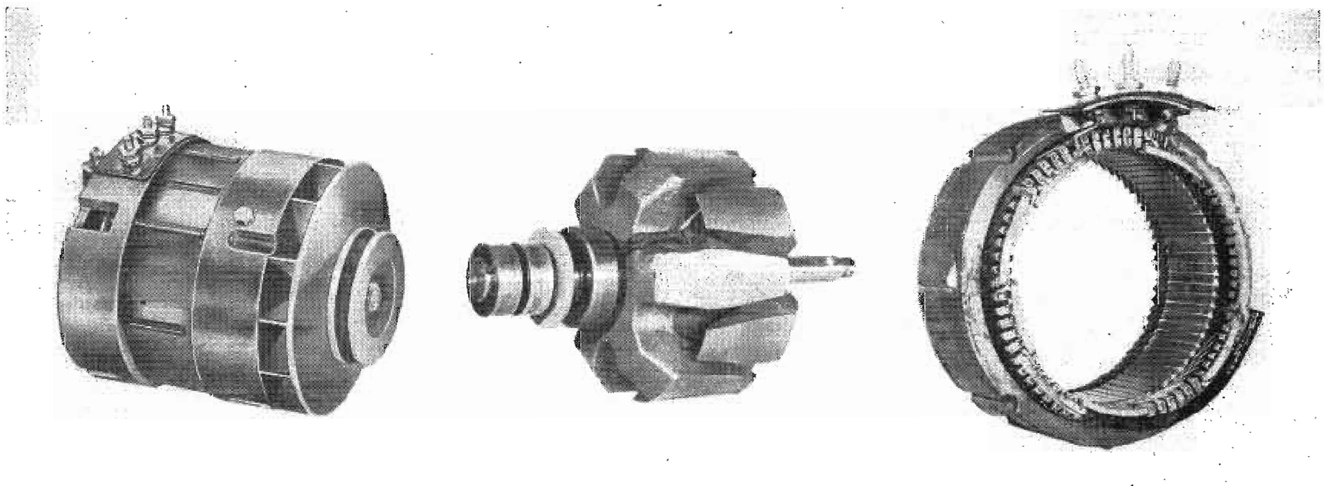
of load voltage or current, regardless of engine speeds above 575 rpm, and load demands within the capacity of the system, where the alternator ratio is 2:1.

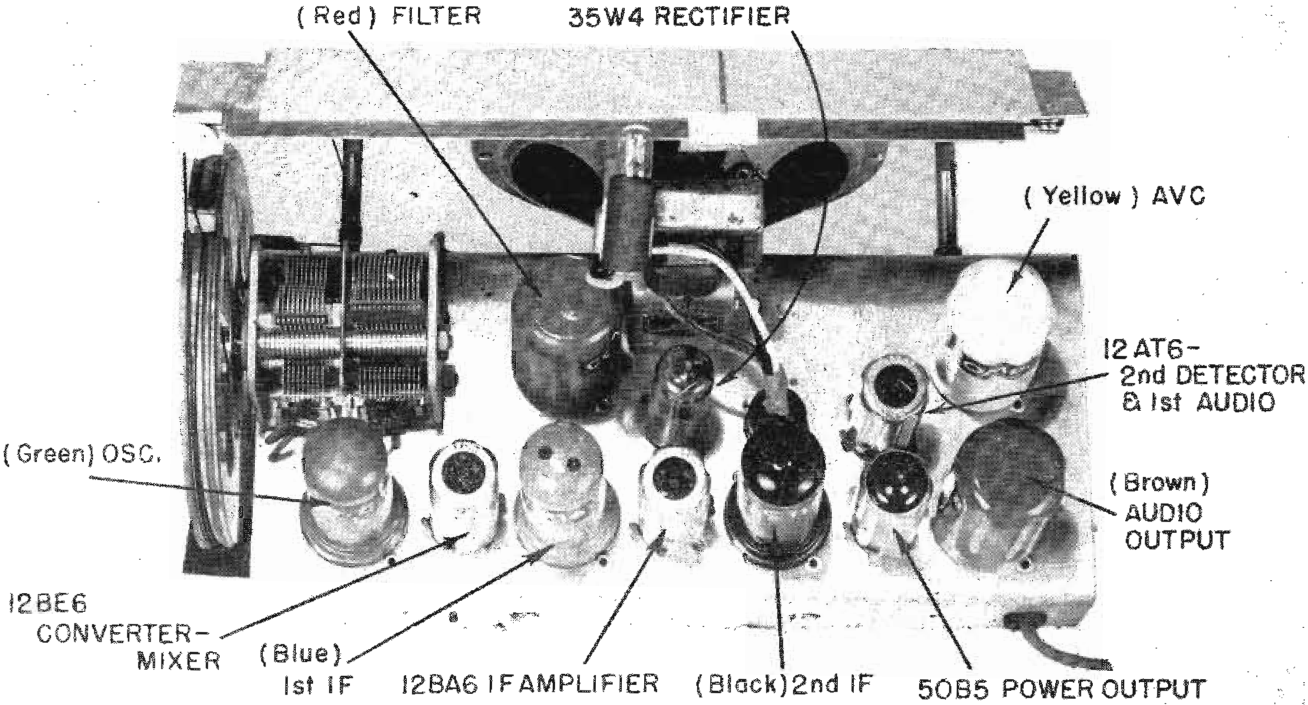
When the output of the rectifier is sufficient for the load, the field coil will be partially grounded out by any increase in voltage. The variations in field strength control the alternator output. The grounding out of the field coil does not eliminate the flow of dc through the rotor winding, however. A meter connected in series with it in this condition would show a definite flow of dc which would vary with the speed and load. This factor aids in assuring voltage control for the system. The load relay performs the function of the reverse current circuit breaker of the normal generator system, and is activated by the ignition switch.

The Leece-Neville generator system provides a flat performance curve of 60 amperes from 11½ miles per hour up to a maximum speed of 120 mph, with 35 amperes capacity at engine idling speeds. This compares with the heavy duty generator system used in police cars having the following perform-

(*Continued on page 93*)

At left is shown the complete alternator, with the rotor in the center and the field assembly at the right





Top chassis view of the Cosmo-Compo receiver, identifying functions of its five tubes and six color-coded plug-in units

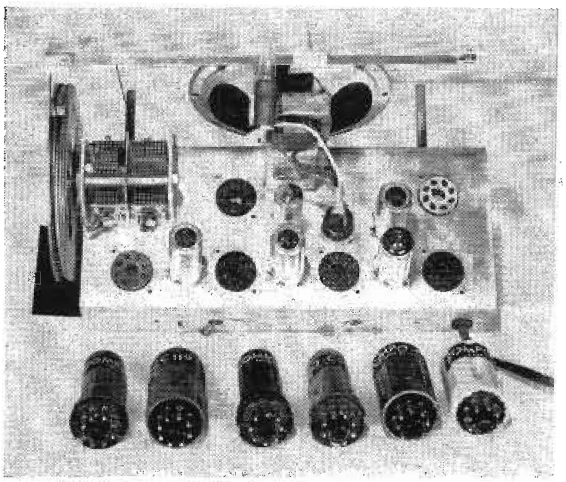
Here's the All Plug-In Receiver

AC-DC set for AM eliminates all chassis wiring except filaments by separately "canning" each circuit unit for quick replacement

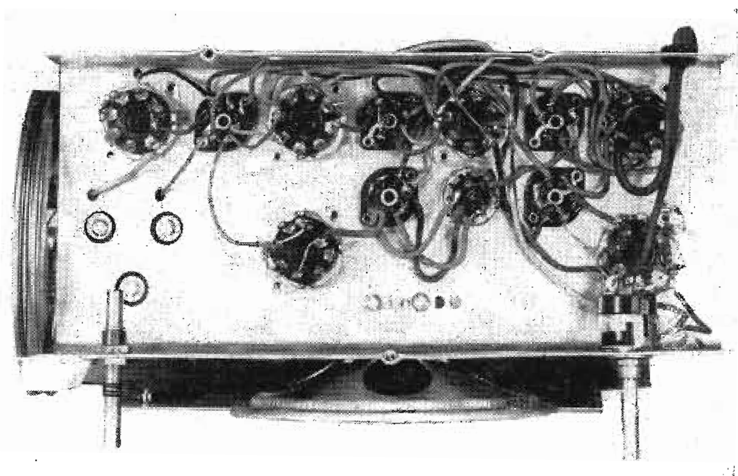
• Adapting principles worked out during the late war, and before, Cosmo Electronics Corp., 675 Hudson street, New York, has succeeded in developing a compact AM receiver in which all elements of the superhet circuit have been made plug-in.

Oscillator and IF units are pretuned and there is sufficient tolerance to make interchangeability of units practical. All normally under-chassis resistors and capacitors are included in their respective cans, leaving nothing underneath but the filament wiring. Volume control, too, eventually will be plug-in.

Top view of chassis with all plug-in units removed but with the five tubes in place



Below chassis view of the receiver showing standard sockets for plug-in units and tubes. All wiring except for filaments is eliminated



Survey of World-Wide Reading

Electronic news in the world's press. Review of engineering, scientific and industrial journals, here and abroad

Wave Propagation in Irregularly Shaped Guides

P. Krasnooshkin (Journal of Physics, Moscow, Russia, Vol. X, No. 5, pp. 434-445).

The propagation of electromagnetic waves and of sound waves in bent guides of varying rectangular cross-section (Fig. 1) is investigated. Base and top walls (A and B) are in parallel planes, the lateral walls, C and D, being generated by vertical, straight lines tracing base lines c and d, respectively. Guides where curves c and d are parabolas, ellipses, and circles are treated.

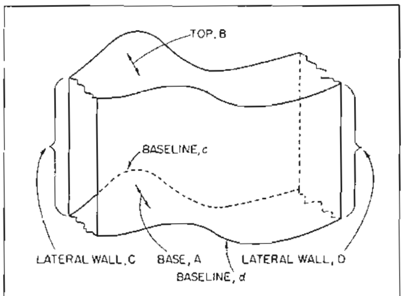


Fig. 1—Bent waveguide of varying rectangular cross-section

Mathematical equivalence is established between these guides of complicated shape and straight guides of constant cross-section filled with an unhomogeneous dielectric. Variation in cross-section without bending is equivalent to parallel layers of various dielectrics in successive cross-sections of the guide at right angles to the direction of wave propagation. Bending of the guide corresponds to different dielectric layers between the two lateral walls, C and D.

If the two curves c and d (Fig. 2) determining the shape of the lateral walls, are parabolas, the narrow passage symmetrical with respect to the narrowest point particularly attenuates the low-frequency components of the wave Part of the wave will be reflected, the remainder will pass; this phenomenon is termed tunnel effect. A formula for the attenuation is given.

Similar considerations lead to expressions describing the propagation and attenuation of waves in elliptical waveguides (Fig. 3, left) as a function of the wavelength and guide dimensions. These have the characteristics of a band-pass filter, passing an infinite number of bands, separated by absorption bands.

When studying a slightly spiraling waveguide with annular base, (Fig. 3, right) it becomes evident that bending, without variation in cross-section, has no effect on the cut-off frequency. However, the wavelength and phase velocity inside the guide increase with the radius; close to the outside wall they are larger than in a straight guide, while close to the inside wall they will be smaller than in a similar straight guide. Thus the wave front remains at right angles to the conducting walls of the guide. Further, the amplitude near the inside wall will be considerably smaller than that near the outside wall. In extreme cases, the wave will cling to the outside wall of the guide, simulating a clinging effect.

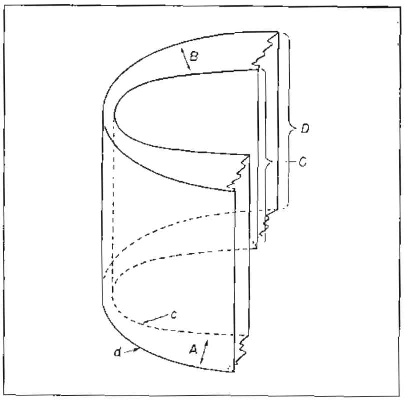


Fig. 2—Waveguide where the two base lines c and d are parabolas

In an experimental investigation, a 1710 ±10 mc wave was propagated between two bent, very wide metallic strips (radius of curvature of outer strip 100 cm and of inner strip very small). The wavelength in open space was 17.5 cm, while a wavelength of 19.0 ±1.1 cm was observed near the outside wall; the depth of the clinging effect was 15 ±2 cm.—JZ

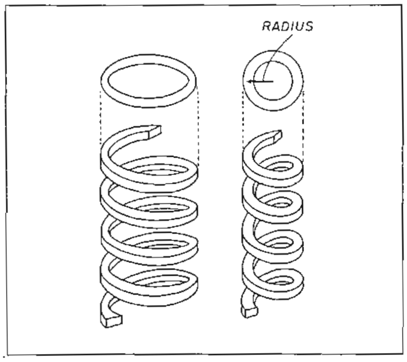


Fig. 3—Spiraling elliptical waveguide and spiraling waveguide with annular base

Rubber as Electro-Mechanical Transducer

(Electrical Manufacturing, June, 1947, pp. 122, 212).

The United States Rubber Co. has developed an electrically conducting rubber product by adding carbon black. The resistance of this rubber varies as the rubber expands or contracts; this makes it suitable as an electro-mechanical converter.

The Admiral Corp. availed itself of this possibility and designed a phonograph pick-up where the needle movements are made to contract or expand a rubber element. The resistance variations are then transformed into current variations. A flat frequency response from 50 to 10,000 cycles within three decibels is claimed. A minimum service of two years is predicted.—JZ

Cavity Accelerator for Electrons

H. L. Schultz, C. L. Clarke, J. A. Lockwood, R. L. McCarthy, C. G. Montgomery, P. J. Rice, and W. W. Watson (The Physical Review, August 15, 1947, pp. 346-347).

A linear electron accelerator incorporating a series of independent resonant cavities is under construction at the Sloane Physics Laboratory, Yale University; 580 Mc pulses are applied to the cavities by separate power amplifiers, all driven by the same master oscillator. The cavities are axially aligned circular cylinders operating in the TM_{010} mode which supplies an axial electric field. This field accelerates the electron beam injected with a 10kv velocity and traveling along the axis; the beam enters and leaves the resonators through small holes in the end plates.—JZ

B.B.C. Television Channels

H. T. Mitchell (Post Office Electrical Engineers' Journal, Epsom, Surrey, England, Vol. 40, Part 1, pp. 33-36).

The article describes the coaxial cable system provided by the General Post Office for the transmission of television signals in the London area. Coaxial cables, rather than screened balanced pair cables, were selected because of the lower losses introduced, because they are cheaper, and because the repeaters required are simpler and smaller. A 7 mc carrier is used; both sidebands are transmitted.

Transportable equalizing and amplifying equipment necessary for other video channels using telephone cable repairs has also been designed and constructed by the General Post Office.—JZ

Testing Magnetic Materials for Recording

L. C. Holmes (Journal of the Acoustical Society of America, Vol. 19, No. 3, pp. 395-403).

Definitions and specific measurement procedures for the important characteristics of magnetic recording media are proposed. Suggestions for performance requirements are made. Background noise, cross-talk, modulation noise, and frequency response are given particular attention. The ratio of intrinsic coercitivity to rententivity may be considered as a figure of merit for high frequency response; it should be at least 0.1 in c.g.s. system. However, other considerations limit this ratio to unity.—JZ

Transducer Sensitivity and Impedance

P. Vigoureux (Proceedings of the Physical Society, London, England, January 1, 1947, pp. 19-30).

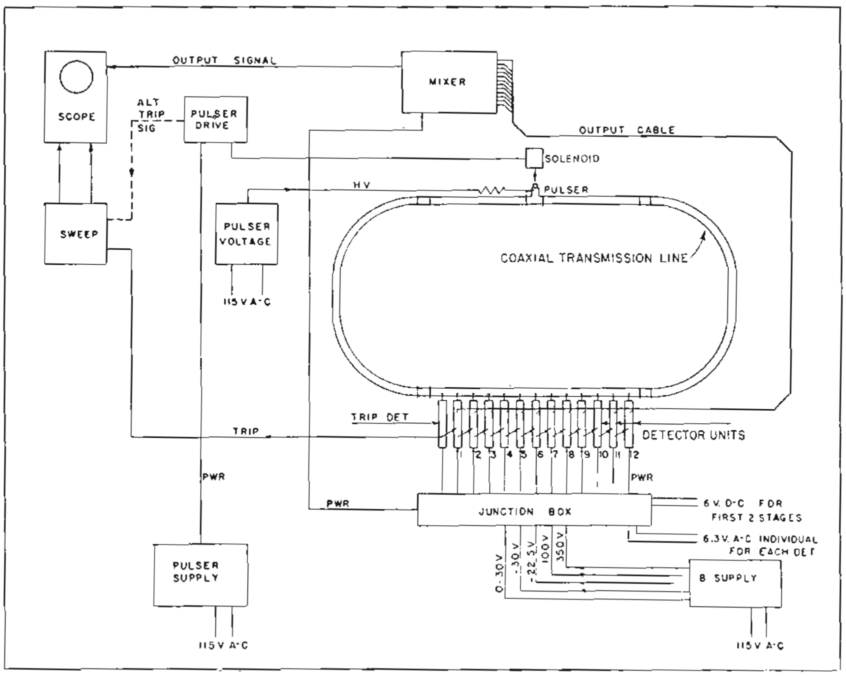
A method is proposed involving only electrical measurements for the determination of characteristics involving the mechanical properties, such as frequency of maximum acoustic output and radiation resistance, of piezoelectric crystals and magnetostriction materials. Measurements of the electric impedance in air and in water over a range of frequencies near resonance or at a few selected frequencies are requird. The method is based on consideration of equivalent electric circuits for these transducers and the plotting of admittance or impedance diagrams.—JZ

Measuring 10^{-8} to 10^{-10} Sec.

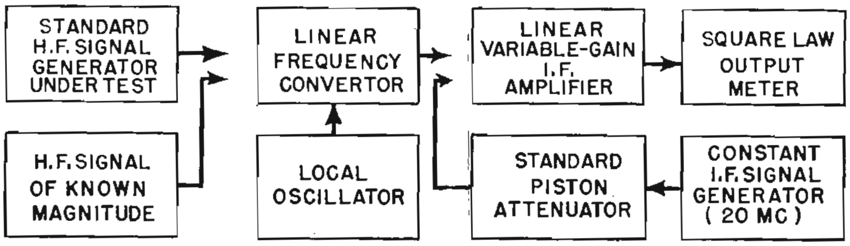
S. H. Neddermeyer, E. J. Althaus, W. Allison, and E. R. Schatz (Review of Scientific Instruments, July 1947, pp. 488-496).

In the chronotron a 10^{-8} to 10^{-10} sec. time interval can be measured with an accuracy of 10^{-10} to 10^{-11} sec. by determination of the superposition locus of two transient pulses, introduced into opposite ends of a transmission line. Assume the two pulses to start simultaneously, the superposition locus will be in the center of the line. Any deviation from the central location is a measure of the time interval, if the velocity inside the line is constant and known. In the superposition region, the voltage will be double the original pulse. Its position can, therefore, be established if the length of the line is explored either with a movable single detector or with a series of fixed detectors.

The chronotron may take the shape of a closed loop of coaxial line, see figure below; pulses are introduced at the center of one straight leg, a series of 12 fixed detectors is mounted in the opposite leg. All detector outputs are simultaneously recorded on an oscilloscope screen. Correct positioning of the pulses is assured by gate circuits synchronizing the detector outputs with the sweep circuit voltage. Each detector unit incorporates a three-stage, direct-coupled, negative-feedback amplifier, a cathode follower stage, a pulse lengthener, a restorer and the gate stage. The gate stages are triggered at 0.4 millisecond intervals by a series of interconnected univibrators. Pulse generator, coaxial line, detectors, amplifier, gate circuits, and trigger units are described in some detail.—JZ



The chronotron measures 10^{-8} to 10^{-10} sec time intervals between pulses



Instrument for calibrating standard signal generators and attenuators for 3 to 300 mc

Calibrating RF Signal Generators and Attenuators

G. F. Gainsborough (Journal of the Institution of Electrical Engineers, London, England, Part III, Vol. 94, No. 29, pp 203-210).

The essential features of the calibrating method for standard RF signal generators will be clear from an inspection of the block diagram. The output signals of the HF signal generator under test and of a known HF signal generator are alternately heterodyned with a local oscillator signal. Magnitudes of the resulting 20 mc beat frequencies are compared with signals from a standard IF generator of known performance. The standard IF signal generator comprises a 20 mc Hartley generator and an H_{11}-mode piston attenuator excited through a filter to eliminate other modes. A square-law output meter indicates equality between the amplified signals from the frequency converter and the attenuator.

A diode or crystal rectifier may be used as the linear frequency converter; care must be taken to assure that the locally generated signal is at least ten times as large as the HF signals. The IF amplifier gain can be varied by 0.5 db steps over a range of 92.5 db.

Performance of the piston attenuator—a waveguide with slidable piston, operated below cut-off—was investigated. The field is attenuated exponentially with distance along the tube to such accuracy that the position of the piston is an exact indication of the attenuation in the guide. Piston attenuators are therefore acceptable as primary standards, i.e., the attenuation may be computed from its dimensions and no calibration is required. A Faraday screen is inserted at the input side of the attenuator to prevent other disturbing modes from entering the wave-guide. With this expedient, the piston attenuator is applicable up to thousand megacycle frequencies.

With the present instrument, signal ratios up to 10 db can be measured with an accuracy of 0.02 db, while signal ratios between 10 db to 90 db can be measured to within 0.2%. Signals 16 db below the noise level are indicated to 0.5 db. A 3 to 300 Mc range has been covered, but the method is applicable to higher and lower frequencies. Details of the various elements incorporated in the instrument are given, operation studied, and errors determined.—JZ

French Tube Processes

M. Descarsin (Le Vide, Paris, France, Vol. 2, No. 8, pp. 217-227).

A historical account of the manufacturing processes of vacuum tubes in France is presented. Glass sealing technics and electrode mounting procedures are given particular attention. Development from electron tubes constructed similar to incandescent lamps to present day structures are traced. —JZ

Space-Charge Lens for Ion Beam

D. Gabor (Nature, London, England, July 19, 1947, pp. 89-90).

The electron space-charge lens is intended for focusing high-energy, positive ion beams. The electron cloud, which generates the field for the lens, is held in place by a magnetic field. For anode potential values below a given value, the magnetic field prevents almost all electrons from reaching the anode, while negatively biased guard electrodes prevent the electrons from escaping at either end. The electrons will rotate in equilibrium orbits; their distribution in the cloud is uniform.

The negative charges in the electron cloud are responsible for a radial electrostatic field. This electrostatic field, which increases proportional to the radius, acts as concentrating lens for the positive ions. The effect of the magnetic field on the heavy ions is comparatively negligible.

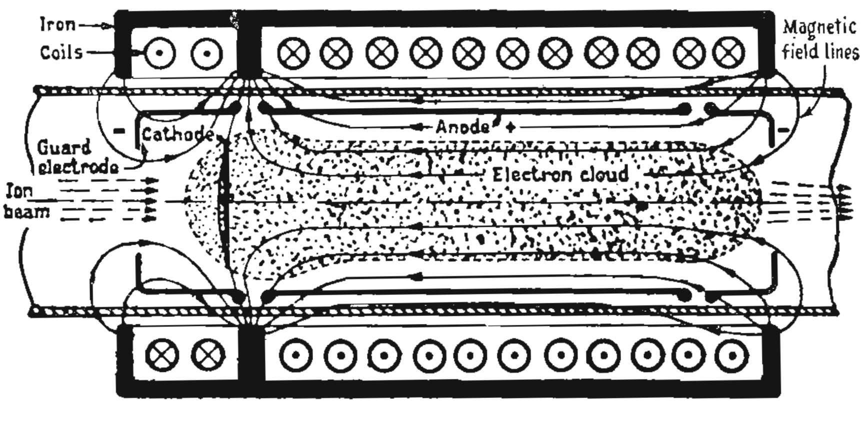
In a numerical example, the magnetic field may be 500 gauss, the length 20 cm, corresponding to about 8,000 amp. turns, the radius of the anode cylinder 2 cm, the anode voltage 15 kv. Then for 100 MeV protons, a focal length of 8.7 meters is obtained.—JZ

Frequency Range Preference Test

H. F. Olson (Journal of the Acoustical Society of America, July, 1947, pp. 549-555).

Previously reported tests indicate that listeners prefer a restricted frequency range in single-channel reproduced music and speech. To study the reason for this preference, all-acoustic tests with a six-piece orchestra and the listeners in the same room, similar to an average livingroom, have been carried out. All reproducing apparatus, such as radio or phonograph, is eliminated. An acoustical low pass filter, cutting off at 5000 cycles per second, is placed between the musicians and the

Electron space-charge lens for concentrating positive ion beams



listeners and arranged so that it could be switched in and out; the filter is hidden from view.

It is established that under these conditions, i.e., without any reproducing apparatus, the full frequency range is preferred. Similar results are obtained for speech. From these tests, it appears that the preference of the average listener for a restricted frequency range in reproduced sound is caused by the distortions and deviations from the original sound introduced by the reproducing apparatus; it is not to be interpreted as a preference for restricted frequency ranges in the original sound, but rather as an expedient to reduce objectionable distortions and deviations.

Further investigations involving stereophonic and single-channel reproduced sound and full and restricted frequency ranges are planned. The type of distortion introduced by a single-channel reproducing system, as opposed to stereophonic reproduction, is considered important.—JZ

Betatrons at National Bureau of Standards

(Bulletin of the American Society for Testing Materials, August 1947, pp. 92-93).

Plans for the installation of two betatrons at the National Bureau of Standards are reported. They are to operate up to 50 and 100 million volts, respectively. Standardization problems, particularly with regard to safety measures, will be studied. An extensive program of great importance to medicine, industry, and scientific research is contemplated.—JZ

Light Modulator for Sound Recording

G. L. Mimmick (Journal of the Society of Motion Picture Engineers, July, 1947, pp. 48-57).

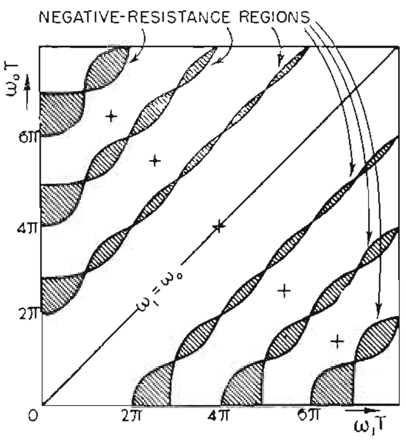
The construction of a sound recording galvanometer is described in some detail. Particular attention was given to reduction of distortion indicating a large air gap, wider armature, iron-cobalt alloy for the pole pieces, increased copper in the modulation coil, and a tungsten-loaded neoprene line as damping means. The power required for 100% modulation is 1.25 watts.—JZ

Electron-Plasma Oscillations

F. Borgnis (Helvetica Physica Acta, Basel, Switzerland, Vol. 20, No. 2, 1947, pp. 207-221).

The theory of high frequency electron oscillations in a gas discharge plasma is presented. The treatment of the plane problem by Langmuir and Tonks, which leads to the concept of the Langmuir frequency, is extended to describe the generation of sustained oscillations in a plasma. The frequency of such oscillations, which originate inside the discharge, is, in general, not identical with the Langmuir frequency.

Langmuir and Tonks assume a discharge space filled with a homogeneous plasma consisting of heavy positively charged ions and negative electrons. In the undisturbed plasma, positive and negative charge densities are



Negative resistance regions of plasma are indicated as functions of oscillating frequency times transit time and of Langmuir frequency times transit time

equal everywhere in the plasma. If an electric field is applied, the heavy positive ions stay in place, while the readily movable electrons are slightly displaced from their position of equilibrium. As a consequence of this small displacement, the positive and negative charge densities are no longer evenly distributed throughout the plasma and an electric field originates. This electric field will in turn exert a force on the electrons, pulling them toward their equilibrium position, which they will pass, etc. Thus each electron will oscillate with a Langmuir frequency ω_0 and with an amplitude equal to the original displacement caused by the external field. These oscillations are damped and will gradually subside. The Langmuir frequency is given by the equation

$$\omega_0^2 = e\rho_0 / m\varepsilon_0,$$

where e and m are electron charge and mass respectively, ρ_0 is the undisturbed electron charge density in coulomb/cm^3 and $\varepsilon_0 = 0.886 \times 10^{-13}$.

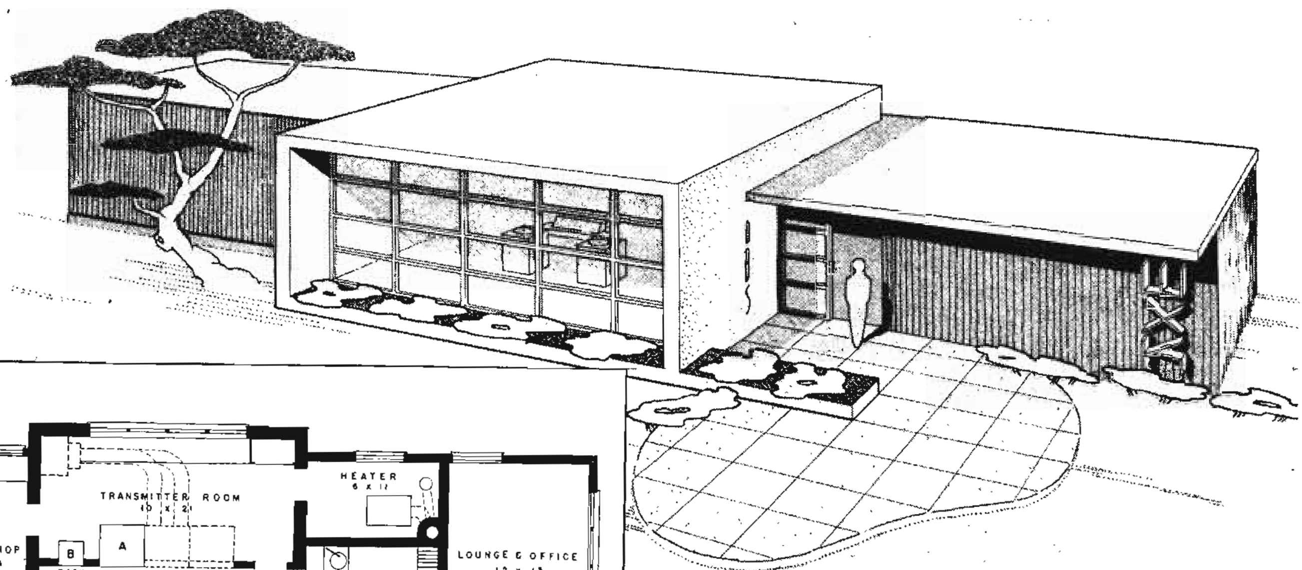
However, the various parts of the plasma do not oscillate independently of each other; interaction between different electrons takes place. To evaluate this interaction, the electrons are considered as a gas. It is shown that the pressure constitutes the connecting force. Under these conditions, each electron oscillates with a frequency equal to the Langmuir frequency or larger, while, when considering different electrons, their displacements from their equilibrium position, at a given instant, have a sinusoidal shape. These oscillations also cannot prevail. No measurable effect on the external circuit can be generated by this mechanism.

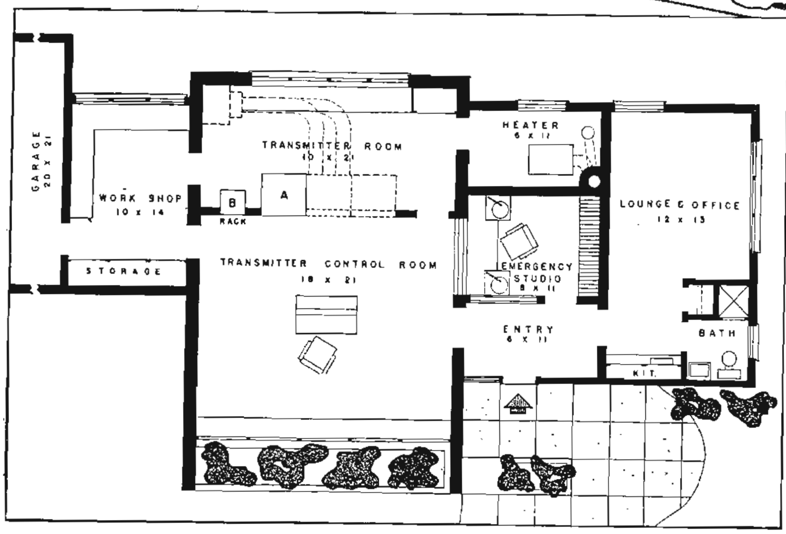
The energy of sustained plasma oscillations, which may supply oscillation energy to a circuit, is derived from the energy of the dc electron convection current, moving through the plasma. To study this case, which so far has not been considered, the behavior of electrons at great distance from their equilibrium positions is investigated. Any problem connected with the generation of sustained oscillations therefore, requires an external current; this current be composed of a direct current and a superposed alternating current of angular frequency ω_1.

It is shown that the resistance of a discharge space across a plasma with constant positive charges fixed in space, while the electrons move across the space, becomes negative for small applied voltages of certain frequencies. These are the frequencies where the plasma can supply high frequency energy to the external circuit. It happens for frequencies different from the Langmuir frequency. There is a cooperation of space charge forces which determine the Langmuir frequency and the transit time effects of the electron convection current in the discharge space.

Assuming constant external current, the plasma is to have the

(Continued on page 92)





Typical of presentations is this elevation and ground plan for a modern radio station which may house a transmitter of either 1-, 3- or 10-kw power, together with all necessary studio equipment. This is one of six designs especially prepared by the Washington "Communications Architects" firm of Deigert & Yerkes

Complete plans for layout, arrangement, construction and equipment of buildings

Modern Broadcast Station Design

• A great many broadcast stations, like Topsy, "just growed". Many, of course, have been carefully planned from the ground up—and down—with a view to capitalizing on every natural advantage and with due consideration given to possible future expansion. Their number, though is relatively small. But from now on there can be little excuse for lack of adequate planning in the light of all the years of experience that broadcasting has behind it. For the Western Electric Co. has just issued, through the September number of its "Oscillator" what for a long time will go as the very last word on this whole subject.

If there is any feature or factor of big and little broadcasting stations not covered by this 68-page encyclopedia of modern design and construction it can be put down as trivial—and even some of the things that might be considered trivial, but which really are not, are thoughtfully covered. The book represents a work that long has been waiting to be done. Now it has been done very well.

Altogether there are some 60 pages devoted to the architecture, design, layout and equipment of broadcasting stations, both AM and FM. Two-thirds of the book is a pictorial presentation of fronts and plans of broadcasting stations, some brand new to the point where they have not yet been built. These are six original designs from the boards of Deigert & Yerkes, well-known Washington "Communications Architects". Others are photographic layouts showing the outside and inside, as well as floor plans, of six existing stations that are considered by experts to

THE BOOK COVERS:

A—Preliminary Planning
- 1—Secure expert help in planning and construction
- 2—Specialists must work together from the beginning
- 3—Expert planning will save money

B—Choosing a Site
- 1—Basic formula for site selection
- 2—Factors in site selection
- 3—How much land does a broadcast station need
- 4—Marshy or over-water sites
- 5—The mid-city building
- 6—Transmitters on mountain tops

C—Layout of the Building
- 1—Combine or separate studios and transmitter?
- 2—Show-place, or just an enclosure?
- 3—Units of the building

D—Technical Accessories to Building
- 1—Heating the building—Waste transmitter heat
- 2—Cooling the building
- 3—Construction methods and materials
- 4—Landscaping

F—The Style of Your Building

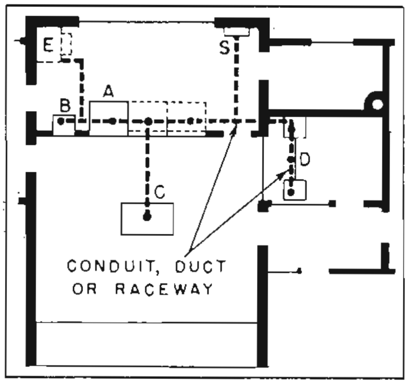
be the best there are. In addition there are four pages of exteriors of what may well be considered to be beautiful buildings.

Those six original designs by Deigert & Yerkes represent the accumulated experience of a great many years devoted to broadcast station design. By comparison with many existing buildings some of the designs may appear a bit on the extreme side, but every one of them is functional to a degree. The designs are for a 250-watt AM station, a 250-watt FM station, a 1-kw AM station, an expandable station that may serve for either 1;3-or 10-kw FM, a 5-kw AM station and a 50-kw FM station. The designs are complete with floor plans even to the point where proper locations for wiring ducts are indicated.

Beautiful Buildings

The section devoted to existing buildings which have been selected by experts as representing the best in use today covers half a dozen stations which might well serve as models for new installations. Supplementing floor plans, photographs show every essential feature of these installations: KGBS, Hartingen, Tex.; KSJO, San Jose, Cal.; KPFM, Portland, Ore.; KTAR, Phoenix, Ariz.; WIOD, Miami, Fla.; WTOP Washington. All these stations are Western Electric equipped throughout. On another four pages there are photographs of 24 additional station exteriors, not all of them WE equipped.

One of the most valuable features of the presentation is a tabulation prepared as the result of questionnaires returned by no less than 600 broadcast stations giving an extraordinarily complete statistical picture of everything having to do with station construction and physical operation. Each one of these 600 stations has given facts in answer to more than 30 specific questions covering, among other things, the size of their buildings, their cost, the materials of which they are built and a host of other things every broadcast station engineer and owner will want to know.



Indicative of the detail with which plans have been prepared, even such things as cable ducts are specified

On the whole, the book is intended to give practically encyclopedic information on station design and there won't be many to quarrel with the manner in which the objective has been achieved. Some idea of its contents may be gained from the appended, abbreviated table of contents. Under the general heading "Building the Home for Your Broadcast Transmitter", it is explained, first, that the material has been brought together "to help you in planning a building . . . that in every respect will really be a 'home' for your transmitter".

Consequently the experts who collaborated in the preparation of the book have started in the logical place, which is "Preliminary Planning", with a dissertation on the prime necessity for seeking the advice of experts long before a hole in the ground is started. From there on the book goes right on through Choosing a Site, Layout of the Building, Technical Accessories to the Building and the Style of Your Transmitter Building.

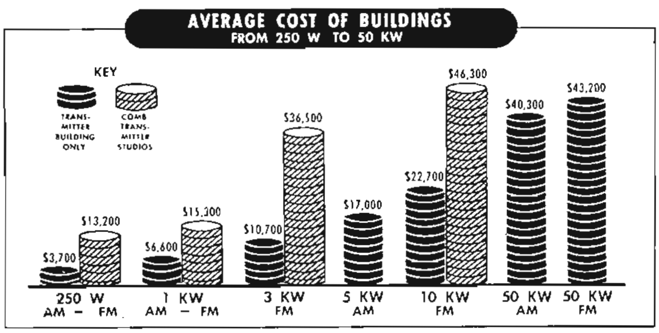
Designs are Functional

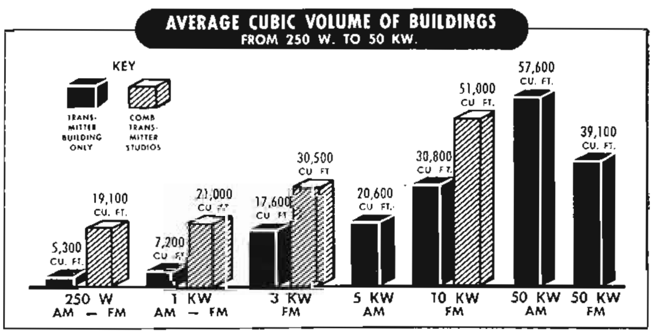
The photographs and plans that have been included provide for stations of any and every size from a tiny 250 watter to a full-grown 50 kilowatter. Transmitter buildings can be show places, and if they are out where they can be seen by a lot of people it is pointed out that they may well belong in that category. But in any case they must be true homes, and functional, and that is where the designers have placed the greatest emphasis—on usefulness.

In every case the authors have done all the thinking that any prospective station owner or engineer ever need do except insofar as local problems are concerned. But even here the answers that are given, or suggested, will go a long way toward eliminating the possibility of future troubles.

After all, the broadcasting business has grown to substantial structure. It is a business that is as susceptible to mistakes as is many another where experience is considerably longer. But into this 68-page book Western Electric engineers and designers have piled so much solid sense that there can be little excuse for anyone to make mistakes that might be attributed to lack of experience.

These two charts, based on a statistical survey that drew answers to more than 30 specific questions from some 600 broadcast stations, give essential data on existing stations, are valuable for estimate purposes or for comparison with current data





WASHINGTON

Latest Electronic News Developments Summarized by Tele-Tech's Washington Bureau

ALLOCATIONS-TECHNICAL DECISIONS COMING—With the summer-long International Telecommunications-Radio-High Frequency Broadcasting Conferences which kept Chairman Denny and Commissioners Jett and Webster, together with a number of key staff officials, at Atlantic City continuously, now ended, the FCC is slated to formulate a number of important decisions, allocations-wise and aimed at revised engineering standards, that will be highly important to television, FM broadcasting and the aviation-marine-mobile radio services. The Commission naturally had to postpone final determinations on many of the technical questions until the global spectrum master-plan was mapped out by the nations at the Atlantic City parleys.

ORGANIZATION OF FCC INTO DIVISIONS—Plan to restore the organization of FCC into divisions, which was used in Commission's first four years and now has been advocated by Senate Interstate Commerce Committee Chairman White in his FCC reorganization bill was not to become effective on October 1 as previously proposed. Because of the absence of three Commissioners at the Atlantic City conferences, the FCC membership feels more time should be given to the blueprinting of the three-division setup so its consideration will be a major topic during October. If the division structure should be approved, the creation of a Safety and Special Radio Services Division, which has been proposed, would be specially beneficial to the fields—aviation, marine, urban, highway, taxi, bus-truck mobile, police, fire, etc.—which are the new spheres of radio with huge equipment possibilities. It would mean greater specialized attention will be given to these fields by the Commission.

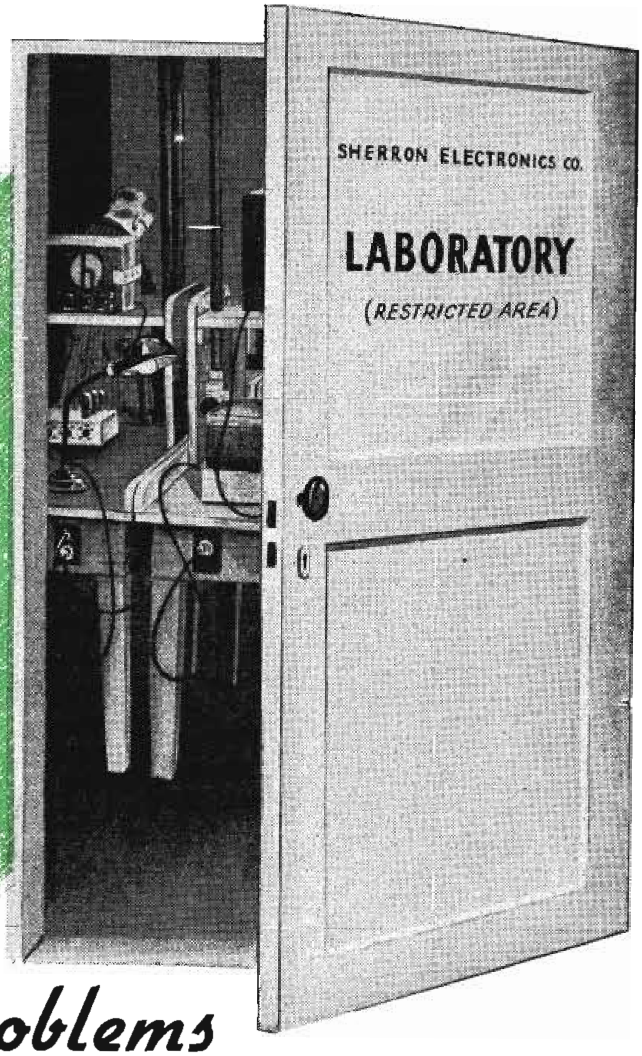
RESIGNATIONS OF DENNY AND DURR—Late in the fall or at least by the end of the year, Chairman Charles R. Denny and Commissioner Clifford J. Durr are expected to resign from the FCC. Even though both will neither confirm or deny reports about their retirement, it is believed certain that they will leave. Denny is slated to become vice-president and general counsel of the National Broadcasting Co. and Commissioner Durr is planning to enter teaching probably at his Alma Mater, the University of Alabama Law School, or possibly Yale Law School. Major reason for the retirement of Chairman Denny is the low salaries paid to Federal Government officials—for example, as head of the FCC and chairman of the three Atlantic City conferences and as chieftain of the U. S. delegations at those three parleys he gets a total salary of $10,000.

JETT FOR INTERNATIONAL RADIO POST—Able engineer-Commissioner E. K. Jett also had been rumored among those considering departing from the FCC with his selection as the U. S. member of the new International Frequency Registration Board. But, when the World Telecommunications Conference at Atlantic City decided to locate the IFRB at Geneva, Switzerland, instead of the UN headquarters in the United States, Commissioner Jett was said to have not been desirous of the appointment. Another important radio post, however, may offer a public service opportunity to Commissioner Jett, who is world-renowned in radio engineering and allocations, in the Atlantic City parley's decision to locate the Comite Consultatif International de Radiodiffusion (CCIR) in the United States either in New York or Washington. The CCIR, for the first time in his history, will have a permanent director and there would be no more capable selection. Another logical choice might be Dr. John H. Dellinger, chief of the Bureau of Standard's Radio Propagation Laboratory, who is ranked as one of the most expert radio scientists in the world.

FM NOISE ELIMINATION—The Bureau of Standards is carrying on experiments to eliminate cosmic noise from the fringes of the primary service areas of FM broadcast stations. The tests are aimed toward determining whether elimination of the cosmic noise in FM sets—the only natural interference reported in FM radio—is economically feasible, or whether such elimination would raise the costs of sets too much.

RADIO EXPORTS—Because of the barriers in foreign exchange against "dollar" imports which are being raised by foreign nations in all parts of the world, including Latin America, the U. S. Commerce Department is closely following the radio export operations of American manufacturers and is working in full cooperation with the Radio Manufacturers Association to break through such obstacles.

ROLAND C. DAVIES
Washington Editor



DOORWAY TO SOLUTIONS FOR *Electronics Problems*

America's destiny may well be determined by the vision, resourcefulness and researches of electronics scientists. The implications of the development of electronic applications are clear, even without definition. Speed, therefore, is a crucial factor in the evolution of electronics, whether as a tool or weapon . . . Keenly alert to this urgency, Sherron's scientists, physicists and mathematicians are massed in an ever-pressing assault on electronics problems. At their command is the most advanced equipment. Theirs is the experience of a host of different electronics enigmas clarified, of specialized electronics applications worked out to meet difficult and unusual operating conditions.

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3. THERMIONIC EMISSION
4. HIGH VACUUM ELECTRONIC TUBES TECHNIQUES
5. RADAR: — (DETECTION — NAVIGATION)
6. ELECTRONIC CONTROL FOR DRONE AND GUIDED MISSILES

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News of the Industry

Communications a Major Electronic Conference Topic

Complete program for the National Electronics Conference, which is to be held at the Edgewater Beach Hotel Chicago during the three days November 3, 4 and 5, reveals that as usual a large amount of time is to be devoted to communications and allied subjects. Following is the schedule of papers: (*see page* 89)

Million Dollar Cab Installation for Chicago

What is believed to be the largest private radiotelephone system in the country (operating as a limited common carrier) is to be installed by Chicago's Yellow Cab Co. The company is to equip 1600 of its cabs with mobile transmitter-receiver units, the installation to cost $1,001,283. The equipment manufacturer who wrote this large order is the Mobile Communications Co., Long Beach, Calif.

Tall Tower for WPTZ

Philco's television station WPTZ is getting a new antenna. The structure, to be one of the loftiest ever built for TV, will rise 552 ft, be topped by a three-bay turnstile. At the 250-ft. level there is to be a platform for Philco's continuing microwave research. It is estimated that the new radiator will permit WPTZ pictures to be seen by 4,000,000 people. The old tower, now in use, is less than one-third (165 ft.) as high as the new one now started.

Railroad Radio Gains

The use of radio by the railroads of the country is increasing rapidly. At present 35 of the 150 lines have installed radio equipment, mostly for yard and switching operations. FCC has revealed that all told the railroads have 122 fixed transmitters and 814 mobile units in use. The Atcheson, Topeka and Santa Fe line is the largest user with several land stations and 130 mobile units.

Dr. B. E. Shackelford

Shackelford, Smith-Rose Head IRE Slate

Dr. B. E. Shackelford, manager of the license department of RCA International Division, likely will be the next president of the Institute of Radio Engineers. The nominating committee has slated his name along with that of R. L. Smith-Rose, superintendent of the radio division of the National Physical Laboratory, England, as vice-president. At the same time, a number of new directors will be elected this month from the following list of names which has been placed in nomination:

Two directors-at-large will be elected for the period 1948-1950 from the following nominees :

B. deF. Bayly, Oshawa, Canada; consulting engineer at the University of Toronto.

A. B. Chamberlain, chief engineer of the Columbia Broadcasting System.

J. E. Shepherd, of Hempstead, L. I.: research engineer for the Sperry Gyroscope Co.

J. A. Stratton, professor of physies and director of the research laboratory of electronics, Massachusetts Institute of Technology.

One regional director will be elected for each designated region from the following nominees, for 1948:

(*Continued on page* 91)

Rochester Meet, Nov. 17-19

With some 15 engineering dissertations on the agenda, the Rochester Fall Meeting, sponsored by the RMA Engineering Department and IRE, will get under way on Monday, November 17. The sessions will wind up on Wednesday, November 19, as usual in the Sheraton hotel. Following is the tentative program: (*See page* 91)

Stringer Heads NAB-FM

Arthur C. Stringer has been appointed director of the FM Department of the National Association of Broadcasters; he has previously served as director of special services for NAB. Coincidentally, NAB has let it be known that as a result of the first meeting of its FM executive committee under the guidance of Leonard Asch (WBCA, Schenectady), the FM Department hereafter is to devote a major part of its efforts to the business and programming problems of members. FM engineering, it is believed, has reached a satisfactorily high standard of excellence and acceptance. At the forthcoming convention, slated for Atlantic City Sept. 15-18, Major Edwin H. Armstrong will be invited to demonstrate his relay network.

URSI-IRE Meeting

The American Section, International Scientific Radio Union, and the Washington Section, Institute of Radio Engineers, will hold a second meeting this year in Washington on Monday, Tuesday, and Wednesday, October 20 and 21, in the auditorium of the New Interior Department building, Washington.

CONVENTIONS AND MEETINGS AHEAD

October 1-11—National Radio Exhibition, Olympia, London, England.

Oct. 20, 21—Fall meeting of U.R.S.I. Auditorium, Interior Dept., Wash., D. C.

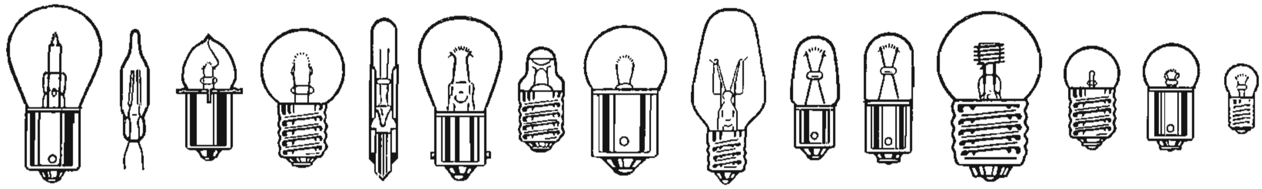
October 20-24—Society of Motion Picture Engineers, Theatre Engineering conference, Hotel Pennsylvania, New York.

November 3-5—National Electronics Conference, Edgewater Beach Hotel, Chicago.

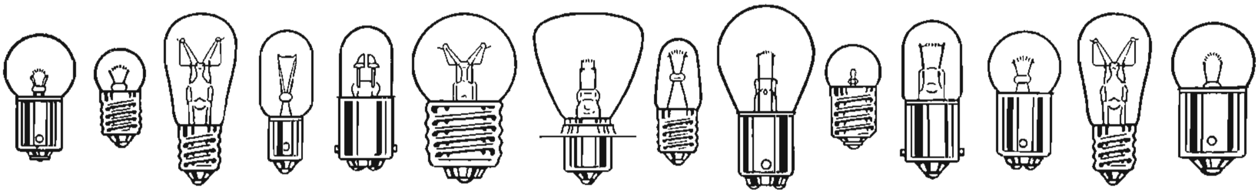
Nov. 17, 18, 19—Rochester Fall Meeting, RMA Engineering Dept. and IRE, Hotel Sheraton, Virgil M. Graham, Chairman, Sylvania Electric Products, 40-42 Lawrence street, Flushing, N. Y.

March 22-25—IRE convention and Radio Engineering show, Grand Central Palace and Hotel Commodore, New York.

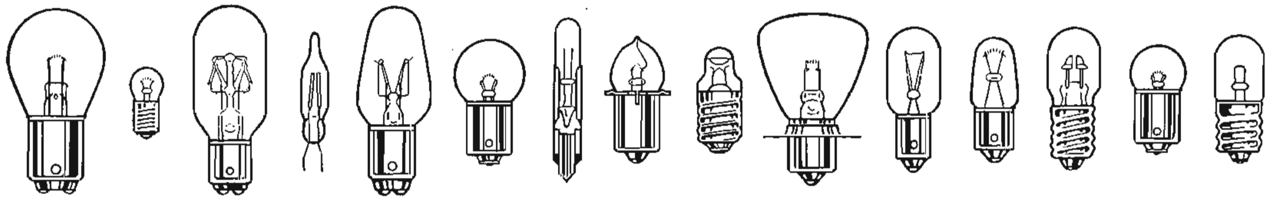
May 10-15—Radio Parts and Electronic Equipment Shows, Inc., Hotel Stevens, Chicago.



These little bulbs can make



a big difference in the success



# of your product

Whatever miniature lamps you need...incandescent or neon-glow...GENERAL ELECTRIC makes 'em all!

What can these little bulbs do for your product?

This brief check list of typical uses may suggest an idea to you:

Illuminated dials
Decorative light effects
Safety lighting
Pilot lights
Lighted toys
Inspection lights
Lighted signals
Numeral indicators
Night lights
Pinball games

WHAT progressive manufacturer doesn't ask himself almost daily—"How can I make my products more useful, more saleable, more profitable?" Many designers answer that problem by using inexpensive miniature G-E light bulbs to add safety, convenience and beauty to a wide variety of products.

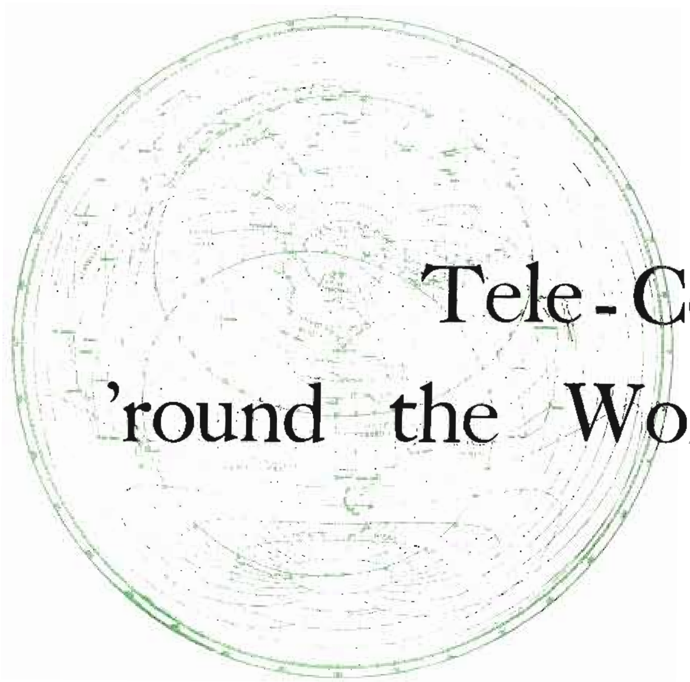
Whatever job you may have for miniature bulbs, there is a G-E lamp that will suit your purpose exactly. General Electric's line is complete—all sizes and types—all wattages and voltages — filament and neon-glow lamps—for delicate service or heavy duty. And the high quality of every bulb is backed by G-E Lamp Research.

To make sure you get the right lamp for your application, entrust the selection to specialists who know all kinds of miniature lamps intimately. G-E Lamp engineers have the experience and practical knowledge to assist you. Call your nearby G-E Lamp office for full information. Ask for your copy of "Big Jobs for Small Bulbs".

General Electric Co., Lamp Dept., Nela Park, Cleveland 12, Ohio.

G-E LAMPS

GENERAL ELECTRIC



Tele-Communications 'round the World

By ROLAND C. DAVIES,
Tele-Tech Washington Bureau

News of engineering matters of importance and of markets in various foreign fields

PHILIPS PRODUCTION OVER PREWAR LEVEL—Showing a remarkable recovery from the effects of the German invasion of the Netherlands during the war, the N. V. Philips Co., Eindhoven, one of the world's largest radio manufacturers. recently revealed in a report to stockholders that it has brought up production to 13% over prewar. The company is now exporting to more than 100 countries and the Philips' share of exports of the Netherlands is now said to be 19% as compared with 8% in 1938. Philips also is opening a branch assembly factory in the Dutch East Indies at Sourabaya, Java, later this year, which will concentrate on five-tube table models.

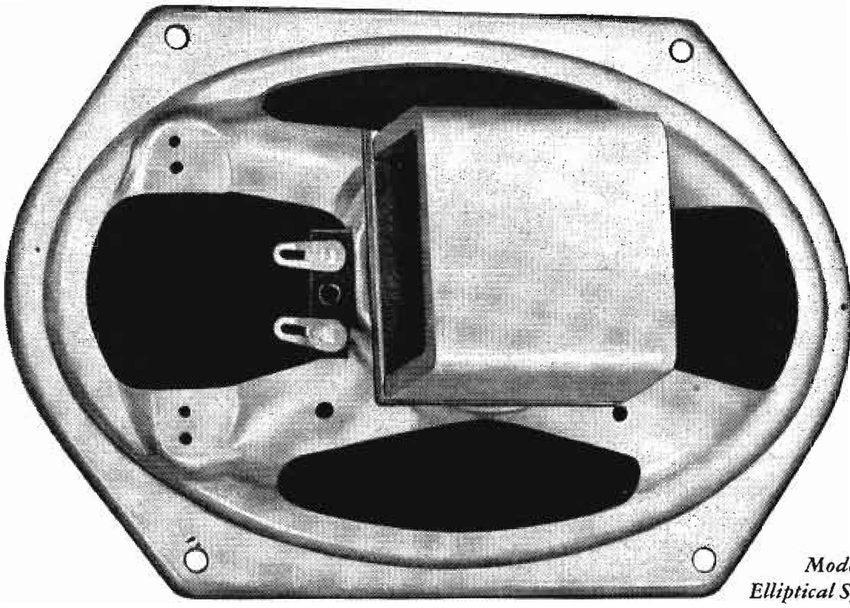
YUGOSLAVIA'S FIVE-YEAR PLAN—Stimulated building of radio broadcasting stations, both medium and short-wave, and intensification of manufacturing of radio receivers so that the nation will be self-sufficient domestically in home sets feature the Yugoslav five-year radio plan. The equipment, which is imported, has mainly come from Soviet Russia and it is most difficult — almost impossible — for American manufacturers to ship their products into Belgrade and other Yugoslav outlets. The station construction for which the Soviet furnished the transmitters include a 150 kw medium-wave station at Belgrade, seven stations in smaller cities with power ranging from 10 to 25 kw, and a short-wave station with a contemplated 210 kw power for the capital city of Belgrade. By the end of 1951 Yugoslavia plans total broadcasting power of 850 kw, an increase of 35 times the 1939 strength. Starting with 10,000 sets produced by the end of this year, Yugoslavia is aiming toward an annual production mark of 150,000 receivers.

JAMAICA AND TRINIDAD MAY GET BROADCASTERS — The Colonial Governments of the Islands of Jamaica and Trinidad have announced that they will consider applications from private firms to operate broadcasting stations on the islands. Heavy capital investment and recurrent costs involved are stated by the administrations as motivating them away from the government ownership trend of other parts of the Empire.

1000-LINE TELEVISION FOR FRANCE — The Radio-diffusion Francaise, according to reports in the Journal Official, has adopted for its national television network, construction plans for which are now being drawn up, a definition of 1000 lines, although some sources indicated this is not yet definite and the exact definition may vary between 800 and 1100 lines. The Eiffel Tower transmitter, presently serving Paris, is scheduled to continue on its present definition of 450 lines for some years.

ARGENTINE MARINE TRAFFIC—Following recent issuance of an Executive Decree, all public radiotelegraph messages sent direct to ships at sea from Argentina, or direct to Argentina from vessels, must now be sent or received exclusively through the stations of the Posts and Telecommunications Office of that country. The preamble to the decree stated that the law existing to the present time gave the government a monopoly only on messages covering a distance up to 1000 kilometers but that, since the date of the original law, the radio art and the government's radio facilities have progressed to such an extent that messages can now be exchanged with ships in any part of the world and adequate provision made for the safety of life at sea.

GREEK MARKET FOR U. S. RADIO — A recent survey of the Greek market for radio receiving sets indicates an increased demand may be expected beginning with the fall months of 1947, with the set



Model 57B2226, 5" x 7" Elliptical Speaker shown above

Magnavox presents...

a new 5" x 7" Elliptical Speaker

NOW The Magnavox Company, pioneer in the production of elliptical speakers, offers you another important new addition to its family of famous component parts—Model 57B2226, 5" x 7" Elliptical Speaker.

This model is immediately available in electrodynamic or permanent magnet design, in various field and magnet sizes to meet any requirement. Your inquiries are invited.

The Elliptical Speaker offers decided advantages in design and performance for a wide variety of applications. Where space is at a premium (especially height), or when a certain sound pattern is desired, the popular oval speaker has proven itself to be the answer.

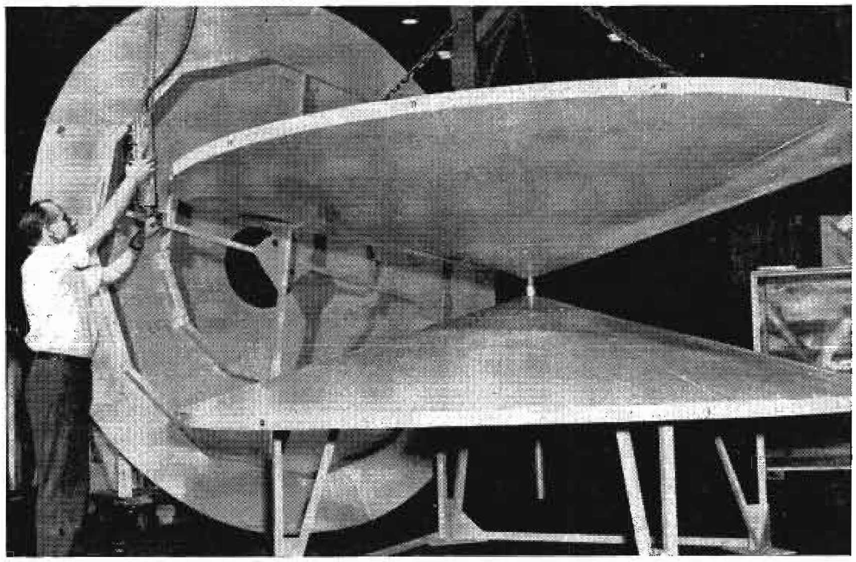
Over 100 different speaker models are made to supply every production need. Capacitors and other component parts are "tailor-made" to the individual manufacturer's requirements. In your planning, be sure to consult with loud speaker headquarters. The Magnavox Company, Components Division, Fort Wayne 4, Indiana.

Magnavox

has served the radio industry for over 32 years

SPEAKERS · CAPACITORS · SOLENOIDS · ELECTRONIC EQUIPMENT

WMAL'S "Chicken Brooder" Antenna for TV



A television antenna of a new type—it doesn't have to be "aimed" at mobile transmitters—has been designed by the engineers of General Electric Co., and radio station WMAL, Washington. Termed a biconical antenna, and styled "chicken brooder" because of its physical resemblance to such a device, the unit is to operate in the 1295-1425 mc range, will be mounted 220 ft. up a 320 ft. tower which will carry WMAL's TV and FM antennas. It is to be used for pick-ups from a roving transmitter for spot coverage.

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most in demand being a five-tube table model equipped with standard and shortwave bands. Also expected to increase is the demand in rural areas for battery sets. During the years 1936-39, the United States supplied 65.8% of the Greek imports of radio receiving sets and this percentage has jumped to 80% during the postwar period. However, as radio receiving sets have always been regarded by the Greek import and exchange control authorities as "luxury" items, their importation is subject to stiff exchange restrictions with the result that American products cost the importers an extra 40 to 60%.

PANAMA PERMITS DUTY-FREE IMPORT—Two new broadcasting stations are scheduled to start operation in the Republic of Panama in the near future, equipment for which will be supplied by Hallicrafters and the Radio Corporation of America. The Hallicrafters station is being installed for Cia. De Mena Herrara, Ltd., to operate on 1250 kc with 400 watts power. Call letters assigned to the station are HOQ. The RCA transmitter, on which delivery has been promised in early winter, is to be installed for Norberto Zurita. It will operate on 1170 kc with 250 watts power. Call letters will be HONZ. A contract between the station owners and the Panamanian Government permits duty-free importation of all equipment needed in the installation and also for replacements as needed from time to time.

RADIO CONGO BELGE TO BECOME RELAY STATION—Radio Congo Belge, which during the war and up to the present time has performed an important function for the Belgian Government with its worldwide beamed broadcasts in French, Flemish, English and Portuguese, will be reduced to the status of a relay station when the home government completes construction of a new station which is planned for Belgium. However, the Congo station will not be reduced from its present 50,000 watts power and a European staff of around 12 persons will be maintained there for station operation and emergencies arising from disruption of service from Belgium.

TURKISH RADIO RECEIVING SET SURVEY—Almost half of the total of around 188,000 radio receiving sets in Turkey are located in Istanbul, according to a survey made available last month. More than 100,000 sets are concentrated in the areas of Istanbul, Ankara and Izmir.

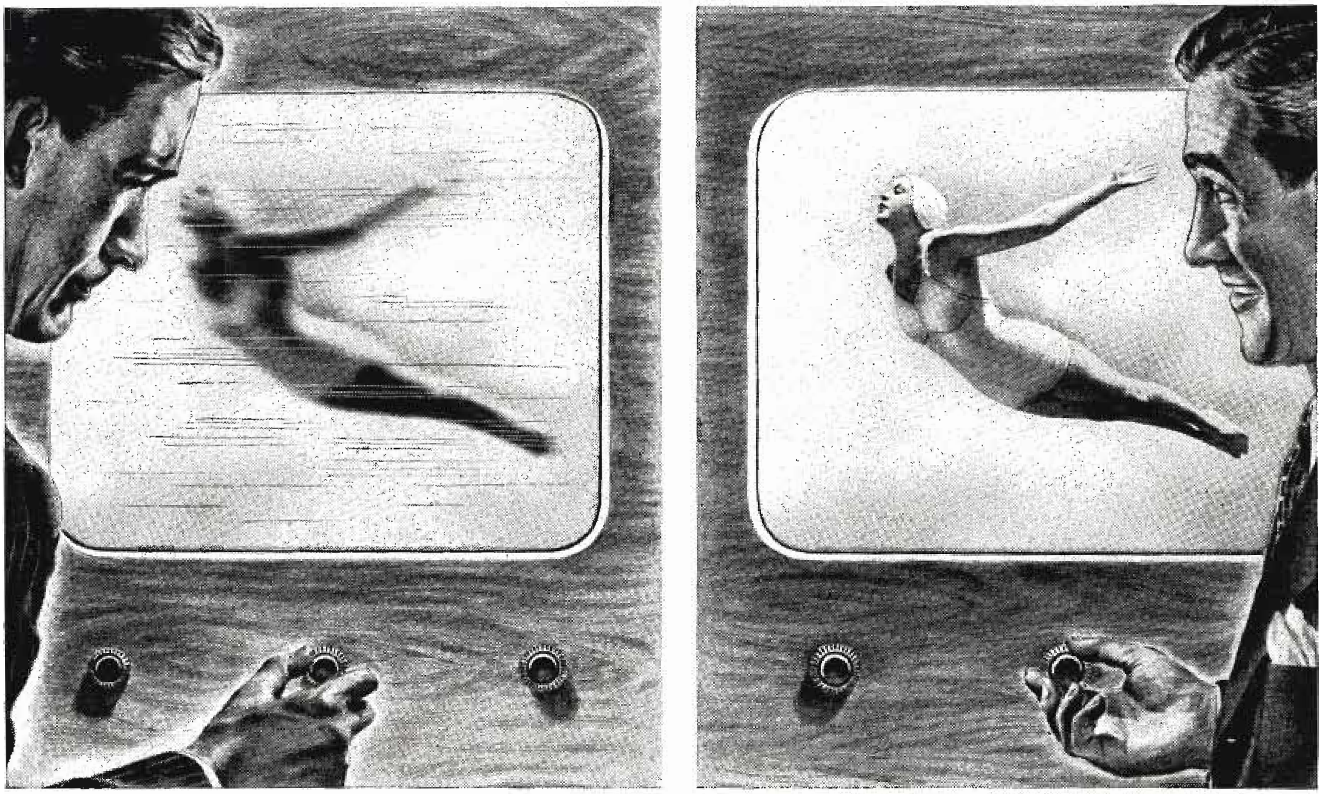
NBC Shatters TV Transmission Record

Shattering all previous television records, the National Broadcasting Co., presented more than 83 hours of television programs during the 11-day period from Friday, Aug. 22, through Monday (Labor Day), Sept. 1. A record number of television cameras and crew members was used to make these pickups possible. Eight field cameras — including one two-camera chain flown up from NBC's Washington television station—were used during the 11-day period.

High point of the coverage of the American Legion's activities came Saturday, Aug. 30, when the station was on the air 13 consecutive hours, most of which were devoted to the day-long parade up Fifth Avenue. Several hours of this day were accounted for by the opening of the Davis Cup tennis matches. On most of the important programs televised during the period, the NBC Television network brought the proceedings to viewers in four cities along the eastern seaboard. These were NBC's own New York station WNBT and Washington station WNBW, as well as Philadelphia's station WPTZ and Schenectady's station WRGB.

Difficult engineering handicaps were overcome to make these pickups possible, since on several of the days four different mobile unit programs were telecast. In addition, the regularly-scheduled studio television programs were presented all during this period without interruption.

Nerves? OR Curves!

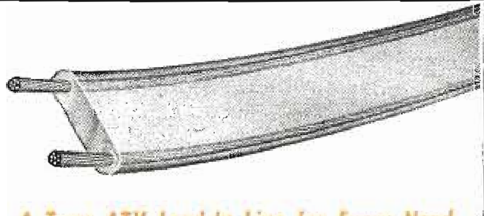


A Type ATV* Television Lead-In Line Can Make All the Difference

ANACONDA Type ATV lead-in lines are playing an important part in helping to give television buyers the kind of reception they want.

The well balanced design of conductors and dielectric in ATV lead-in lines minimizes the effects of attenuation and impedance mismatch. Satin-smooth polyethylene insulation sheds water readily — thus avoiding subsequent impedance discontinuities.

ATV line fulfills the most exacting requirements of wide-band reception — providing maximum freedom from distortion. Television buyers expect a lot. See that an ATV lead-in line helps your set to deliver! 47402



A Type ATV Lead-In Line for Every Need

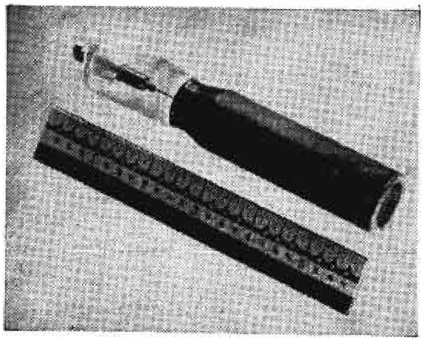
Anaconda offers a complete selection of Type ATV lead-in lines for 75, 125, 150 and 300 ohms impedance unshielded and 150 ohms shielded. For an electrical and physical characteristics bulletin, write to Anaconda Wire and Cable Company, 25 Broadway, New York 4, New York. Also, write for the characteristics of the complete line of Anaconda coaxial cables.

ANACONDA from mine to consumer

ANACONDA WIRE AND CABLE COMPANY

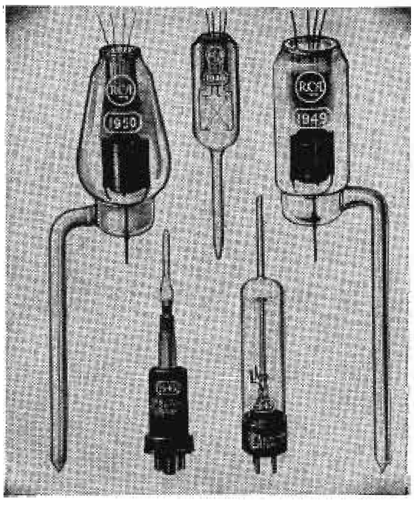
*An Anaconda Trade-Mark

New Types of Electron Tubes



SELF-QUENCHING GEIGER TUBE

Designed for use with beta, gamma and soft X-radiations, this multi-purpose, self-quenching Geiger tube is capable of handling in excess of 3000 discrete counts per second. Especially suited to tracer, survey and X-ray spectrometer work, the tube is rugged and utilizes an extremely thin mica window, vitreous-sealed to the main tube body. Construction consists essentially of a tubular chrome iron cathode having a mica window of high transmissibility at one end and a glass section for supporting the anode at the other end. Threshold voltage is 1350 and the plateau exceeds 300 volts in length. Normal operating potential is 1450 V. The tube has a quantum efficiency for soft X-rays in the order of 70 — 80%. Overall length is 6 in., diameter 1 in.—*North American Philips Co., 100 East 42 St., New York.*



VACUUM-GAGE TUBES

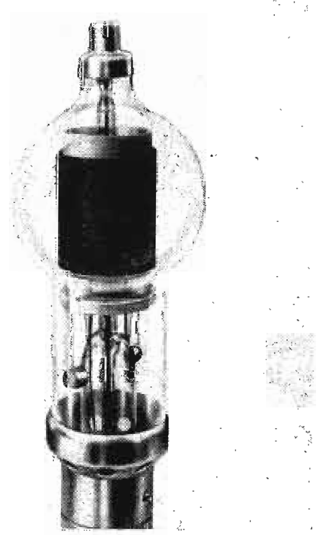
RCA-1945 is a highly evacuated, ionization gage tube sensitive to hydrogen, and particularly useful in detecting and locating leaks in vacuum enclosures. The tube is constructed with a palladium plate, which acts, when cold, as a vacuum-tight barrier to the vacuum system and permits exhaustion to a high degree. When heated, the palladium plate serves as a permeable membrane, permitting hydrogen introduced in the vacuum system to flow into the tube. An increase in hydrogen pressure of less than .0001 micron can be detected with the 1945 on systems using rotary pumps.

RCA-1949 is an ionization type vacuum-gauge tube for measuring gas pressures in the range below 0.1 micron. When operated with a grid voltage of +110 V. and a plate voltage of —22.5 V., it has a sensitivity of 110 microamps. per micron.

RCA-1950 is similar to the 1949 in application, but is constructed with soft glass and has different dimensions.

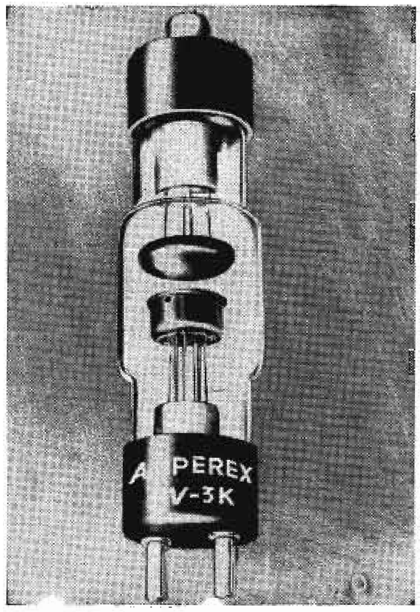
RCA-1946, a thermocouple type, is useful in measuring gas pressures from 1 mm to .0001 mm of mercury. It may be used as a protective device in vacuum systems, to assure maintenance of a desired vacuum.

RCA-1947 is a Pirani type of soft-glass, vacuum-gage tube for measuring presssures in the range from approximately 0.5 mm to 0.01 mm of mercury, but it can be used with reduced sensitivity to measure pressures above and below this range.—*Tube Dept., RCA Victor Radio Corp. of America, Div., Harrison, N. J.*



HEAVY-DUTY THYRATRON

Type F-5563 is a 15,000 volt, heavy-duty, mercury-vapor thyratron which operates both as a rectifier and as an instantaneous electrical circuit breaker under heavy temporary overloads. The grid design allows normal rated current flow yet blocks sudden destructive overloads without damage to tube or circuit. Of the negative-control, triode type, the tube operates on a filament voltage of 5 at 10 amps. A typical grid voltage is approximately minus 70 V. With 15,000 volts peak forward and inverse anode voltage, the tube is rated at 1.6 amps. average anode current with a peak of 6.4 amps.—*Federal Telephone and Radio Corp., Clifton, N. J.*



X-RAY RECTIFIERS

The Types AV-3E and AV-3K rectifier tubes for X-ray equipment are identical except that the AV-3E makes filament connection through an Edison screw base, while the AV-3K utilizes two pin terminals. Maximum peak voltage rating for either continuous or intermittent operation is 125 kv. Maximum load current is 50 ma for continuous operation and 200 ma for intermittent operation. Overall length is 10½ in. for type AV-3E and 10¾ in. for type AV-3K. Maximum diameter is 2½ in. Envelope is Pyrex, cathode consists of a loop-type tungsten filament. Both are designed for oil-immersed cooling systems—*Amperex Electronic Corp., 25 Washington St., Bklyn., New York.*

GAS PHOTO-TUBES

A complete line of gas phototubes with blue-sensitive response (S-4) is made available with the addition of four new types,—the 5581, 5582, 5583 and 5584. These tubes have high sensitivity to light sources predominating in blue radiation, no response to infrared radiation and a high signal-to-noise ratio. They are especially useful in sound reproduction from a dye-image sound track utilizing an incandescent light source, since there is no "masking" of the dye-image modulation by infra-red transmission. These same features are of importance in industrial phototube applications, when response to infrared radiation is not desired. Each of the tubes is comparable in luminous sensitivity, anode characteristics and structure to an older type having S-1 response, to permit replacement with minor circuit modifications. The 5581 compares with type 930, type 5582 with type 921, type 5583 with type 927, and type 5584 with type 920.—*Tube Dept. Radio Corp. of America, Harrison, N. J.*

BIG CAPACITY

COMPLETE FABRICATING EQUIPMENT

GOOD SERVICE

LARGE additions to equipment during the war, and especially since VJ Day, have provided Formica with by far the largest capacity in the industry for manufacturing insulating sheets, tubes and rods, and for fabricating them to your blue prints.

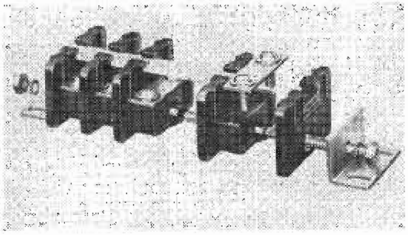
The tremendous backlog built up during the post war order boom has been whittled down and service and deliveries are now normal on electrical material. And that means good service, with a uniform high quality material, accurately machined where machining is required.

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

THE FORMICA INSULATION COMPANY

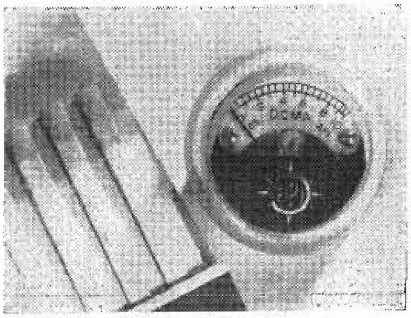
4657 Spring Grove Avenue, Cincinnati 32, Ohio

Parts for Design Engineers



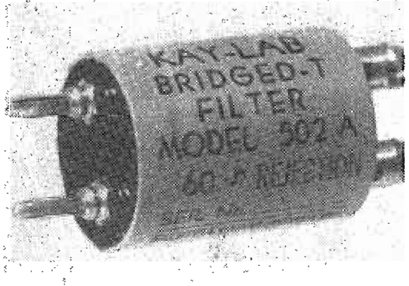
Terminal Block Kits

Designed for experimental work and maintenance operations, the Type 33 terminal block kit permits quick assembly of any number of terminals to it. Kit No. 200 contains necessary molded sections, terminals and screw assemblies; Kit No. 201 has a supply of end brackets, partitions, threaded rods, screws, nuts, and washers. The blocks are recommended for installations where the temperature does not exceed 400° F.—**Terminals Sales Office, Curtis Development & Mfg. Co., 1 North Crawford Ave., Chicago 24, Ill**



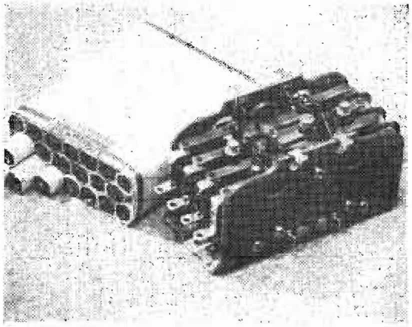
Midget Meters

Among the smallest D'Arsonval type instruments commercially available, this series of midget meters has a barrel diameter of one inch and a depth behind the mounting panel of one inch. Maximum overall dimensions including studs and mounting flanges are 1-3/16 x 1-3/16 in. The movement, mounted on polished pivots in Vee jewels, will stand rough usage. Voltmeters, milliammeters, ammeters, millivoltmeters, microammeters, rectifier type ac and thermocouple instruments are available, the maximum self-contained voltage range being 500 v. Alnico V magnets with machined soft iron poles provide low response time and good damping. Cases are clear plastic, either Lucite, polystyrene, Lumarith or other materials. Hermetic sealing is possible, when required.—**Assembly Products Inc., Chagrin Falls, Ohio.**



Hum Filter

Designed for high impedance instruments such as oscillographs, the Kay-Lab bridged-T hum filter, when inserted at the input terminals cancels 60 cycle stray hum pickup, even when open leads are used. No matching transformers are required for the units which have a common ground from input to output. The filter is 1½ in. in diameter by 2 in. in length (excluding terminals). It is also available for 120 cycles and other frequencies. **Kalbfell Laboratories, Inc., 1076 Morena Blvd., San Diego 10, Cal.**



3-Position Relay

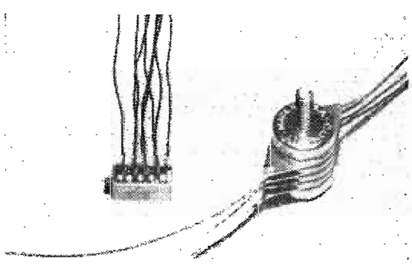
This null indicating polarizid relay for control circuits and servo-mechanisms combines high sensitivity and speed with flexible contact structure of up to 4 normally open circuits for each polarity. When the coil is provided with opposed windings for use in a push-pull circuit approximately .005 watts per contact pole is required, while with a single-wound coil about .0025 watt is needed. Contacts, which may be ganged in double break or parallel pair arrangement, are rated at 5 amps., 110 V. ac. A balanced armature makes for high resistance to shock and vibration.—**Sigma Instruments, Inc., 70 Ceylon St., Boston 21, Mass.**

Dual Metal Wire

A new type of electroplated and drawn wire that can be bent, swaged, hammered, woven or twisted is now being produced in commercial quantities. "Fernicklon" wire has a wide range of manufacturing applications in radio tubes, incandescent and fluorescent lamps, and electrical devices and appliances. In this new process metal rods of ¼ in. diameter are first electroplated, then cold-drawn down to diameters as fine as .0038 in. Initial production includes steel wire with nickel and copper wire with nickel or silver for radio tubes and lamps and other wire products. The wire can be subjected to severe climactic conditions and can be welded without destroying the coating at the point of weld.—**Kenmore Metals Corp., Warren, Pa.**

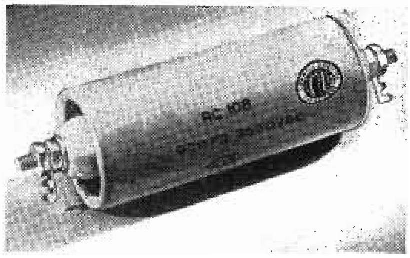
Plastic Radio Parts

Escutcheons and name pieces, injection molded of multi-colored plastic materials and other radio parts of mottled Lumarith, colored and clear Lucite have been made available to the radio industry. Push-buttons can also be supplied in plastic materials, the bases being injection molded of colored Lucite, while the top sections and inserts are of clear Lucite. The pieces are assembled and joined together with Lucite cement.—**G. Felesenthal & Sons, Inc., 4108 Grand St., Chicago 51, Ill.**



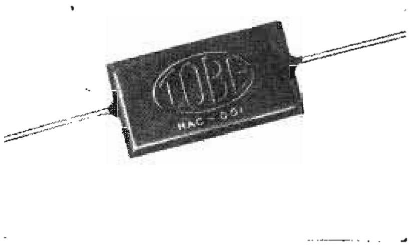
Rectifier Assembly

A new four disc instrument rectifier assembly designed for experimental use is available in .5 in. diameter, 30 mil discs, as type X, or .165 in. diameter, 5 mil discs, as type BX-C. Each of the four discs is insulated from the others and is provided with its own pair of leads. This construction permits connection of the four discs into any combination.—**Conant Electrical Laboratories, 6500 "O" Street, Lincoln 5, Nebr.**



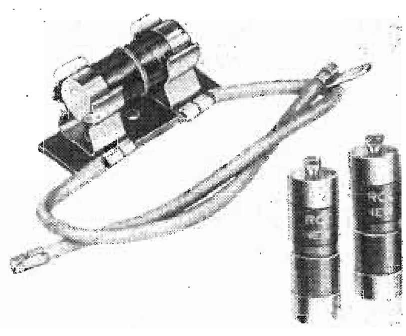
Television Capacitor

Type RC-108 capacitor with a rating of .05 mfd., 3500 V. dc is made with high safety factor. This latest addition to a line of high voltage and television capacitors is built in a cylindrical metal container 1-½ in. in diameter, 3 in. long with screw type terminals mounted on ceramic insulators protruding ¾ in. from each end of the case. Dykanol C impregnation and metal hermetical seal assure efficient operation under all atmospheric conditions.—**Cornell-Dubilier Electric Corp., South Plainfield, N. J.**



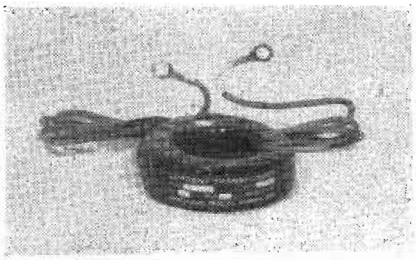
Miniature Capacitors

Molded in flat, mica-filled phenolic cases these miniature capacitors are for use in hearing aids, pocket radio receivers and other compact electronic equipment. Working voltage of the rectangalar-shaped units is 75 volts dc. Available are ratings of .001 and .005 mfd. with dimensions of 9/16 in. x 5/16 in. x 3/32 in., and .05 mfd. measuring 11/16 in. x 29/64 in. x 7/32 in. The units are case-sealed against 80% relative humidity. Operating temperatures are from -55 to +65° C.—**Tobe Deutschmann Corp., Canton, Mass.**



Mercury Switches

Hermetically sealed, these small 5, 10, 15 and 20 ampere mercury switches are especially adapted to explosionproof areas, since the metal enclosure provides hazard-free operation in atmospheres where switch sparking constitutes a danger. The units will operate at 110 and 220 volts ac or dc in an ambient temperature of 100°C without arcing, pitting or burning; they can stand an overload of 400% for a short period of time. Only 1-½ in. long x ½ in. in diameter, the switches may be installed in standard cartridge-fuse holders.—**Mercontrol Inc., 278 Pearl St., New York 7.**

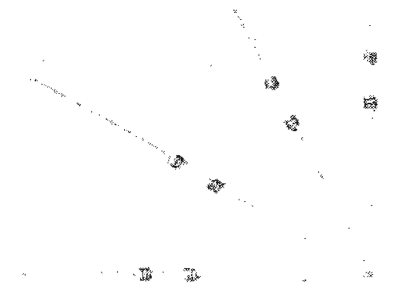


Ring Type Transformers

Available in ratios of 50/5 to 500/5, this ring type transformer is 3¼ in. in diameter and has a 1¾ in. window, with units having a ratio of 400/5 or more being slightly larger in diameter. Laminated electrical steel forms the core of the unit. Windings and 24 in. lead wires, with polarity identification, are taped and tied in place. The coil is encased in varnished cambric tape, impregnated with moisture-resistant insulating varnish. Each transformer is tested to an accuracy of 1% at full scale reading with a burden current of 2 volt-amperes.—**Midwest Electric Products Co., Mankato, Minn.**

Temperature Compensating Capacitor

To compensate for drift in the isolating circuit of FM receivers, where 6SB7 or similar tubes are used, this compensating ceramic capacitor can be produced with any temperature coefficient or capacity required. For example, the unit may consist of a Steatite capacitor of 5 mmfd with a 15-ohm resistor element as an inherent part of the unit. The curve of compensation can be controlled by the amount of resistance wire placed around the Steatite base tube. If a fast heating unit is required, a low resistance element is used.—**Electrical Reactance Corp., Franklinville, N. Y.**



Fuse Resistors

A new wire wound resistor has been developed that doubles as a resistor and a fuse at different power levels. At a relatively low power level the unit functions as an ordinary resistor while at higher levels it acts as a fuse and opens circuits when the wire burns out. Designated as type OWA, this new resistor is available in RMA values from 15 to 150 ohms and has a power rating of one watt.—**International Resistance Co., Philadelphia.**

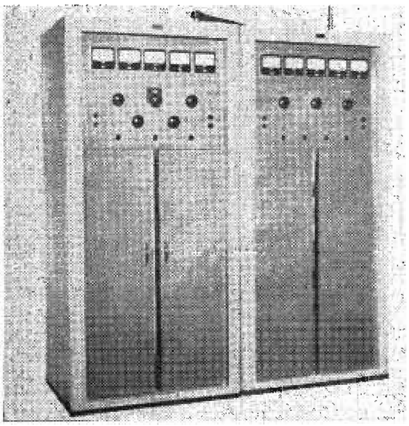
Resonant Relays

Previously available only in the range of 153 to 442 cps. type 182 resonant relays for remote control purposes are now offered with an extended range to 1000 cps. The units use a vibrating reed mechanism adjusted to respond to a narrow band of frequencies and to reject all others. By connecting an auxiliary relay or a thyratron to the resonant relay, almost any switching operation can be accomplished at a remote point.—**Stevens-Arnold Co., 22 Elkins St., South Boston 27, Mass.**

Connector

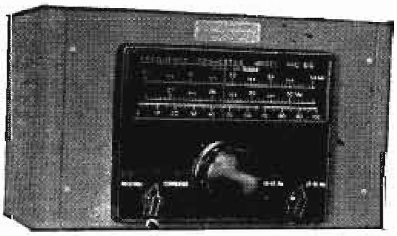
An efficient method of mechanically fastening solid or stranded wires and cables of small diameter uses AMP "solistrand" solderless wire connectors to make eye or straight splices, and to attach wire ends to screws, studs, hooks etc. Parallel connectors and ring tongue connectors are available. Spices are made by inserting wire ends into the barrel of the connector and "crimping" it by means of an AMP installation tool.—**Aircraft-Marine Products, Inc., 1616 North 4th St., Harrisburg, Pa.**

Communications Components



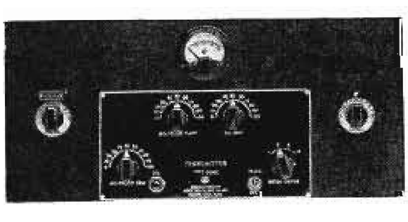
Broadcast Transmitter

This 3 kw FM transmitter, model BF-3A, uses phase shift modulation and direct crystal frequency control. The output of a 250 watt exciter, the BF-250A, supplied in a separate cabinet, is fed to the grils of four 4x500F power amplifier tubes, operated in push-pull parallel. The power amplifier is complete with self-contained power supply and control circuits. Each cabinet is 78 in. high by 36 in. wide by 26 in. deep. Frequency response is within 1½ db of standard 75 microsecond preemphasis curve. Power input is approximately 6250 watts from 220/110 volts, 60 cycle, single phase, ac. The same company will also have 1 kw and 10 kw FM transmitters available shortly.—**Gates Radio Co., Quincy, Ill.**



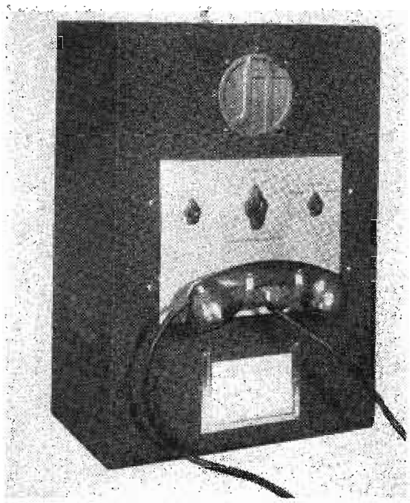
HF Converters

Model HFC 610 high frequency converter is available in two ranges; from 27 to 30 mc and from 50 to 54 mc. The units consist of a 6AK5 high gain rf amplifier stage, a 6AK5 mixer, and a 6C4 stable oscillator. Good selectivity and separation between stations, low internal noise, and image-free reception are characteristic. The dial is directly calibrated. A self-contained, regulated power supply is provided.—**Columbus Electronics Inc., 229 So. Waverly St., Yonkers, N. Y.**



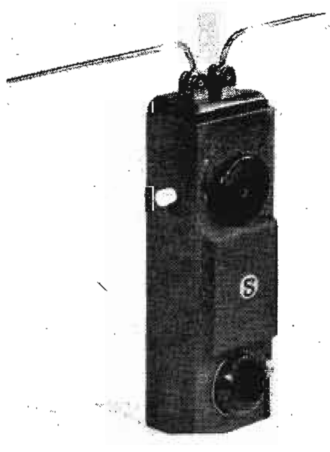
Amateur Transmitter

Having outputs in the 10-11, 6, and 2 meter amateur bands, this uhf transmitter uses an 829 B tube in the final PA stage, with plate input up to 100 watts. Crystal control utilizes the newly-developed Bliley overtone crystal-oscillator unit. Tube line-up consists of a 6AG7 crystal oscillator, a 2E26 tripler, and an 829B final stage. For 10 and 6 meter operation, the crystal output is used directly to drive the 829B, while for 2-meter operation the output from the overtone crystal is fed through the tripler. The 4800 series plug-in coils are designed to provide correct link selection in the grid circuit for various combinations. A multi-purpose meter, connected into the grid and plate circuits of the tripler and power amplifier, permits operational checks.—**James Millen Mfg. Co., Malden 48, Mass.**



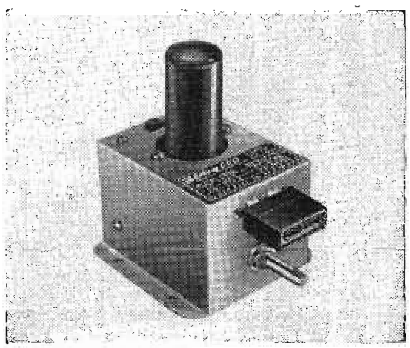
Radiotelephone

Model 351 marine radiotelephone, designed for 12 or 32 volt dc operation, covers the 2 to 3 megacycle marine band in five crystal-controlled channels (both transmitter and receiver) and has an output of over 35 watts. An internal power supply reduces standby drain to a minimum to conserve battery life. Twelve tubes are used for receiver, transmitter and power supply. Model 351 is housed in a steel cabinet measuring 21 in. high x 15¼ in. wide x 10 in. deep.—**Jefferson-Travis, Inc., Mfd. by Emerson Radio & Phonograph Corp., 111 Eighth Ave., New York 11.**



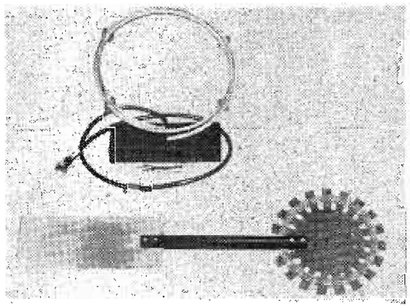
Two Way Radio

Half the size of the Army "Handie-Talkie", this transmitter-receiver combination weighs only 3½ lb., complete with batteries. The unit, which has adjustable tuning on both transmitter and receiver, operates in the 144-148 mc. amateur band, and has a range from 3 to 12 miles. Tube lineup comprises a 3A4 and a 958, both with instant-starting filaments. The circuit consists of a superregenerative detector and one stage of amplification, which are switched to oscillator and modulator on transmit. RF input is 2 watts. A folding half-wave dipole antenna is inductively coupled. The tuning arrangement involves a sliding split-stator capacitor with trimmer adjustment. Tuning range is 3 megacycles. Frequency shift from transmit to receive is negligible. Two Eveready 467 batteries provide 135 V. B-supply.—**Sperti Inc., Norwood Station, Cincinnati 12, Ohio.**



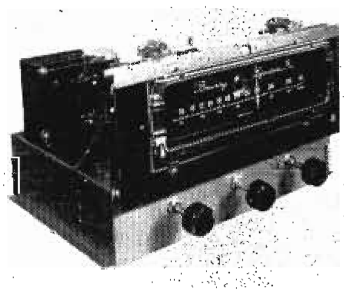
Crystal Controlled Oscillator

A complete packaged nucleus for new construction or conversion of existing equipment is provided in the new crystal controlled oscillator model CCO-2A. Designed for 2-6-10-11 meters the CCO-2A has direct output on 6-10-11 meters and ample output to drive a tripler stage for 2 meters. It has a 6AG7 tube, single mounting control, and a bandswitch and crystal socket are mounted on the outside of the subchassis with power and output terminals at back. Uses Bliley AX2 20-meter crystals for output on 10 and 11 meters, and the new Bliley AX3 crystals for 6 and 2-meter operation. —**Bliley Electric Co., Erie, Penn.**



Radiation Loop

Useful for checking loop-oscillator tracking, gain measurements, alignment etc., this radiation loop and alignment want may be used on any signal generator. The low-priced accessories find many uses during receiver design.—**Approved Trading Corp., 142 Liberty St., New York 6.**



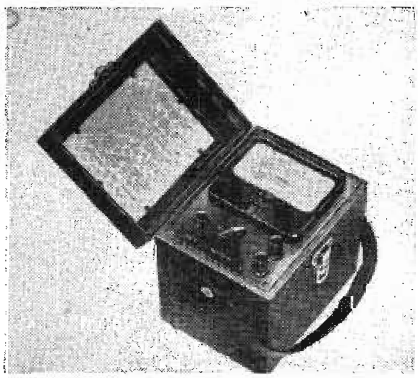
FM Tuner

Covering the 88 to 108 megacycle FM band, model RV-10 FM tuner utilizes the Armstrong circuit with dual limiters. A sensitivity of 10 microvolts produces good reception even outside of the accepted service area of FM transmitters. The antenna input is designed for 300 ohm standard down-lead. The unit is equipped with built-in power supply, large slide-rule dial with vernier drive, and a tuning indicator. It is practical for "built-in" installations, having dimensions of 6½ in. height, 9 in. depth, and 11 in. width. Weight is 10½ lbs.—**Browning Laboratories, Inc., Winchester, Mass.**

NEW LAB AND TEST EQUIPMENT

Vacuum Tube Voltmeter

Model 730 vacuum tube voltmeter is a low-cost instrument, utilizing miniature tubes conservatively operated to extend their life, and having a power consumption of less than 1 watt. The unit has six ranges of 2.5, 10, 50, 250, 500, and 1000 volts with an accuracy of ±3% ac and dc. A switch permits positive or negative readings on dc. An rf probe is provided having a flat response to 120 mc. The attenuator utilizes 1% accuracy stabilized-film resistors to guarantee calibration over long periods of time. The meter is a rugged 1 milliamp. type— **Allied Laboratory Instrnment, Inc., 355 West 26 St., New York 1.**



Precision Ohmmeter

Equipped with a long lasting power supply, ruggedly built, and easy to handle, Model 246 precision ohmmeter has a measuring range from 1 ohm to 100,000 ohms in four overlapping scales. Features of the instrument are: precision wire wound resistors, individual calibration, 4½ in. hand stepped scale. Power supply consists of two No. 6 dry cells. Ranges are provided from 0-100, 0-1000, 0-10,000, and 0-100,000 ohms. Overall dimensions of Model 246 are 7¾ in. x 6 in. x 7-13/16 in.—**Associated Research. Inc., 231 South Green St., Chicago 7, Ill.**

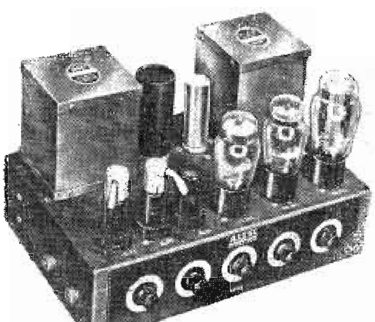
AC Power Supply

Model AC1135 ac power supply is designed to supply a continuously variable output voltage from 0-135 V., at 7.5 amps. maximum. Input is 115 volts, 50-60 cycles, and is fused and provided with main on-off switch. An output meter is provided for the two output circuits, each of which has an individual on-off switch and closed circuit ammeter jack.—**Tuck Electronic Corp., 76 Montgomery Street, Jersey City 2, N. J.**

Sound and Recording Equipment

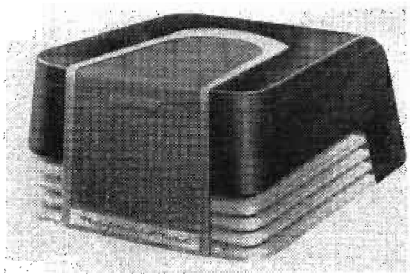
Studio Recorder

Designed to meet requirements of commercial studios the Fairchild console type studio recorder accommodates all sizes of acetates as well as 18-in. flowed wax masters. Direct worm and gear drive at 33 1/3 rpm. guarantees absolute timing through the synchronous motor. Speed can be changed to 78 rpm. without shutting off the motor. A No. 541 magnetic cutting head in combination with a precision lead screw mechanism assures uniform cutting at any continuously adjustable pitch from 80 to 160 lines, in-out or out-in. The 523 recorder is provided with a microscope, tangentially mounted to the record grooves, and it may be moved to any part of the surface. Height of the table above the floor is 41 in.; top is 32 in. wide by 24 in. deep.—**Fairchild Camera & Instrument Corp., 88-06 Van Wyck Blvd., Jamaica 1, N. Y.**



Audio Amplifier

Provided with two high impedance inputs, one for phonograph pickup and the other for radio, the Altec-Lansing A-323B amplifier has a nominal rating of 15 watts and will deliver rated power within 1 db from 35 cycles to 12,000 cycles. Its frequency response is flat from 20 to 20,000 cycles. Intended for use in conjunction with FM tuners and in high quality music reproducing systems, the amplifier has built-in equalization to operate directly from the GE variable reluctance or the Pickering magnetic pickup cartridges. A treble control, consisting of an adjustable low-pass filter, permits sharp cut-off of noise frequencies. A hum-balancing potentiometer eliminates necessity for selecting special tubes for noise-free operation. Tube line-up consists of a 5U4G rectifier, two 6J7's, a 6J5, and two 6L6G's—**Altec Lansing Corp., 250 West 57 St., New York 19.**

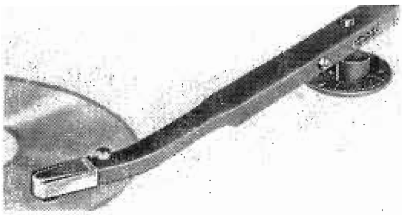


Tape Recorder

Accommodating up to one hour of recording, the Magnesonic tape recorder is useful for factory, office and home. New programs may be recorded continuously on the same tape by automatically erasing as new material is recorded. A simplified control panel permits operation by non-technical personnel. The recorder is supplied in a black ebony-finished, wooden cabinet.—**Sound Recorder & Reproducer Corp., 5501 Wayne Ave., Philadelphia, Pa.**

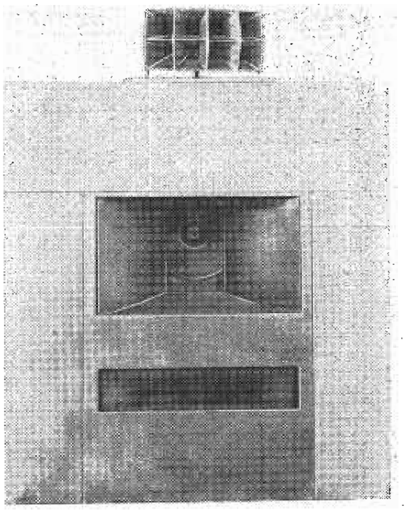
Portable Electric Megaphone

Capable of projecting voice over large distances the Taybern Type TPM-2 "Power-Voice" electric megaphone is a self-contained portable public-address system comprising a horn assembly and a battery-operated amplifier. The equipment is rugged and capable of operating under severe conditions; the amplifier case is ribbed-steel and the chassis is shock-mounted. A molded cover-gasket provides a water-tight seal. The amplifier, complete with batteries and miniature tubes, weighs 10 lbs. The megaphone section includes a spun-aluminum horn, at the small end of which is mounted a sturdy type of "sound power" microphone. Within the horn is a high-efficiency loudspeaker, which is not affected by wide temperature variations, humidity or moist salt air. The megaphone assembly weighs about 4½ lbs.- **Taybern Equipment Co., 120 Greenwich St., New York 6.**



Reproducer

Model 74-A, one of the new Audak tuned-ribbon reproducers, has adequate output without pre-amplification, and has a jewel stylus which can easily be replaced by the user. Dynamic mass of the unit is near zero, response is linear to 10 kc. Needle-point pressure is 24 grams. No torsional action is utilized.- **Audak Co., 500 Fifth Ave., New York City.**

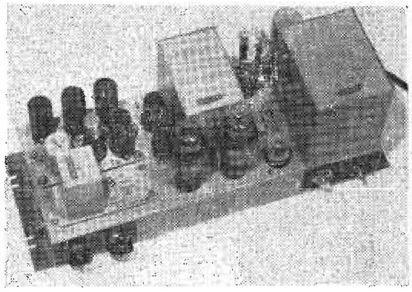


Theater Speaker System

Intended for small auditoriums up to 1000 seats the 800 "Voice of the Theatre" speaker system has an overall depth of only 23 in., making possible its installation in small houses with limited space between screen and backwall. The 15-in. low-frequency horn of the directly-radiating type, covers the range from 50 to 800 cycles and is equipped with Alnico 5 permanent magnet field. The high-frequency unit, designed to operate from 800 to 15,000 cycles, is a multi-cellular 2 x 4 horn. The resistance dividing network with a crossover frequency of 800 cycles is equipped with four 1 db attenuation steps in the hf output to meet specific acoustic requirements. Vertical distributing angle is 40°, horizontal angle 90°. Required amplifier output impedance is from 6 to 12 ohms. The system is rated at 20 watts.—**Altec Lansing Corp., 250 West 57 St., New York 19.**

Studio Microphone

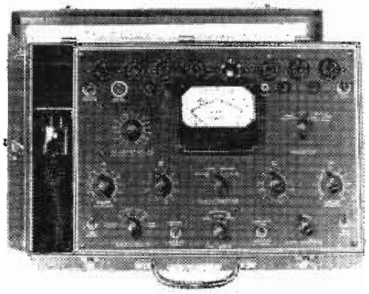
Designed to give high quality studio reproduction the Amperite ribbon microphone has a frequency range from 40 to 14000 cps within 3 db and an output of —56 db. In spite of pick-up angle of 120° front and back, feedback is very low. Standard equipment includes a switch, 25 ft. cable and a cable connector.—**Amperite Co., 561 Broadway, New York 12.**



Wired Music Amplifier

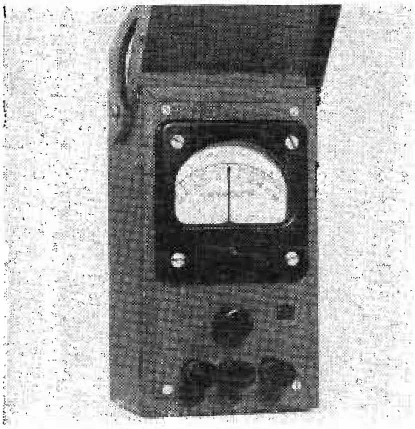
Suitable for wired music installations the Langevin 610 amplifier provides 20 watts of audio power with less than 5% distortion and a frequency response from 30 to 15,000 cycles within +1.5 db. A shielded balanced input transformer permits connection directly to the line. Maximum amplifier gain (up to 61 db) can be set by a gain limiting control, functioning independently of the volume control. Two input channels are provided: a line level channel for wired music and a microphone channel for plant paging. Input transformer will match 150 or 600 ohms or may be used for bridging 0 to 600 ohms. Operation is from 105 to 125 volts, 60 cycle, ac.—**The Langevin Co., 37 W. 65 St., New York 23.**

NEW LAB AND TEST EQUIPMENT



Mutual Conductance Tubechecker

Providing proportional mutual conductance readings under conditions closely resembling actual operation Model 798 Type 5 tubechecker not only tests all types of receiving tubes, but also is capable of handling voltage regulator tubes and low power thyratrons. Sixty-cycle ac potentials are used on tube elements, thereby approaching zero plate load conditions. A separate 5-Kc signal is applied to the control grid, and the resulting plate component of the high-frequency signal is measured on a rectifier meter. Three signal voltages of .75/1.5/3 volts provide mutual conductance ranges of 12,000, 6,000, and 3,000 micromhos. A hot neon test is provided for checking leakage between tube elements. The instrument operates on 105/125 volts, 50/60-cycle current. A rapid reference chart lists test values of all commonly-used tubes.—**Weston Electrical Instrument Corp., 617 Frelinghuysen Ave., Newark 5, N. J.**



Impedance Matching Bridge

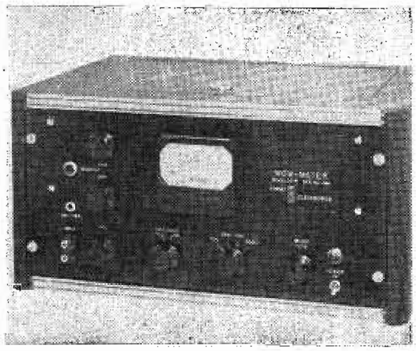
Designed to provide rapid and accurate means for checking quantities of identical components against standards, this simplified, inexpensive bridge instrument is adaptable to any test set-up, where impedance can be used as an indication. The bridge permits rapid grading of capacitors, resistors or reactors, detects shorted turns in coils or insulation, leakage in transformers, chokes, motors, etc. Sixty cycle current serves for most tests, but frequencies as high as 75 mc may be utilized, if necessary. The instrument contains a plug-in Balac rectifier unit, but no tubes. It is available as Model 70 for low sensitivity, Model 71 having medium sensitivity, and Model 72 for use with high-sensitivity galvanometers. — **Conant Electrical Laboratories, 6500 "O" Street, Lincoln 5, Nebr.**

Heat Transfer Unit

Model 20 heat transfer unit is used for cooling radio, television and other communication equipment, high frequency power tubes, induction heating units and laboratory testing apparatus. Heat generated by the equipment is taken up by a circulating cooling liquid, which dis-

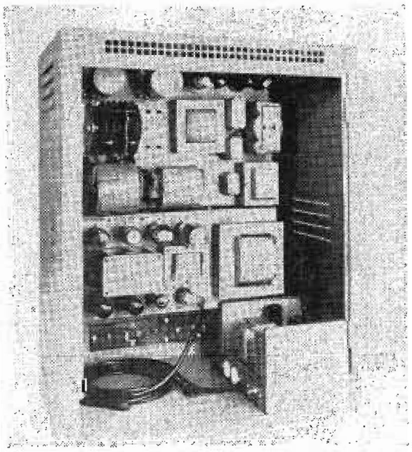
NEW LAB AND TEST EQUIPMENT

charges the heat into the air by means of a radiator and fan. Capable of dissipating up to 20,000 watts the unit is equipped with a six bank reverse flow radiator, two cooling fans, two centrifugal pumps, a large reservoir, thermostat, pressure switch and fittings. It is powered with two ½ HP. 3450 rpm. heavy duty induction-type motors. Overall size is approximately 30 in. x 27 in. x 26 in. high.—**Eastern Industries, Inc., New Haven 6, Conn.**



WOW-Meter

Measurements of variations and fluctuations of speed in phonograph turntables or other mechanical, optical and magnetic recording and reproducing equipment are made possible with the direct-reading Model 115 WOW-Meter, which consists essentially of an electronic frequency meter. A 1000 cycle test record is required for checking turntables. The varying component in the output of the frequency meter is amplified and measured by a peak-to-peak VTVM calibrated directly in per cent variation from the average frequency of the input signal. Frequency range is .2 to 120 cps; accuracy is 5% of full-scale value. A range switch permits full-scale readings of 3% and 1% wow on an essentially linear scale. Model 115-R provides up to 25 volt rms output for connection to a high-speed direct-inking oscillograph. The instrument operates on 105-125 volt, 60 cycles.—**Furst Electronics, 800 W. North Ave., Chicago 22, Ill.**



Voltage Regulator

Designed to provide a highly stable, precisely regulated scource of dc voltage and current, Model E-3006 voltage regulator is especially useful for instrument testing. The upper half of the unit is a modified Nobatron with an input voltage range from 95 to 125 volt ac and an output voltage of 6 V. dc. Regulation accuracy is 0.1% over a load range from 7½ to 15 amps. Maximum ripple voltage is ½%. recovery time 0.2 seconds. The lower half contains a regulated dc power supply with an input voltage range from 90 to 135 V. ac and a continuously adjustable output voltage from 0 to 300 V. dc. Load capacity is 100 ma. regulation accuracy being 1/10 of 1%.—**Sorenson & Co., Inc., Stamford, Conn.**

PERSONNEL

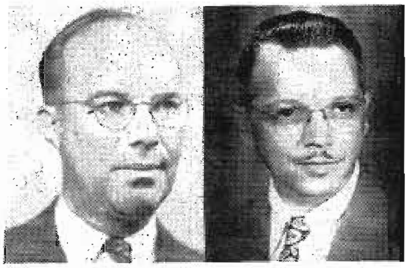
Rudolph Feldt has been placed at the head of the CR tube oscillograph manufacturing department of the Allen B. DuMont Laboratories, Inc. He will headquarter in the Clifton, N. J. plant.

Ralph B. Austrian who has been president of RKO Television Corp., left that post on Sept. 10 to join Foote, Cone and Belding, New York advertising agency.

Major-General Harry C. Ingles (retired) has been elected president of RCA Communications, Inc. He is a director of that corporation and also of Radio Corp. of America.

Dr. C. B. Jolliffe has been added to the board of directors of RCA. He joined RCA in 1935, is now executive vice-president in charge of RCA Laboratories Div.

Dr. W. L. Barrow has been appointed chief engineer of the Sperry Gyroscope Co., Inc. He joined Sperry in 1943 as director of armament engineering, was formerly on the staff of the electrical engineering department MIT.



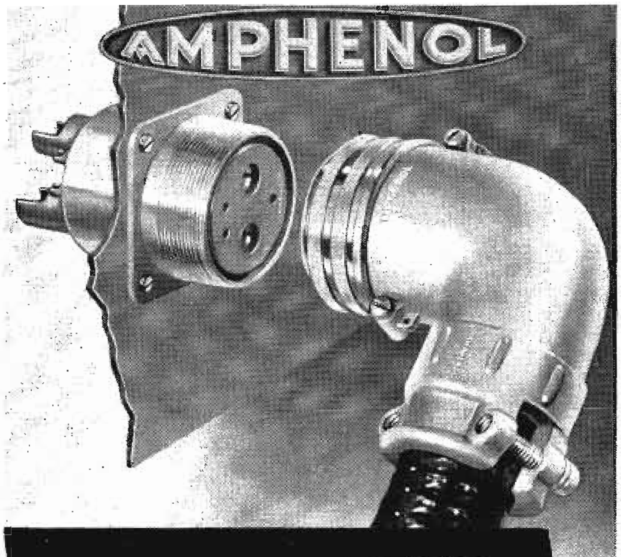
Dr. W. L. Barrow James F. Rinke

James F. Rinke has been appointed chief engineer by Potter & Brumfield Mfg. Co., Princeton, Ind. He goes to P&B from Electronic Laboratories, Inc., Indianapolis..

Rodolfo M. Soria has become associated with the American Phenolic Corp., Chicago as project engineer in charge of special development work on antennas and rf transmission lines. He was formerly instructor in electrical engineering at Illinois Institute of Technology.

H. C. Carroll has been appointed engineer in charge of General Elec-

AMPHENOL



"AN" CONNECTORS
Widen the Horizon of Industrial Electronics

Wherever industrial electronic equipment is sectionalized, Amphenol AN connectors serve with efficiency and economy to provide quick connection and easy disconnect for servicing or movement.

They save money by permitting associated wiring for one or many circuits to be prefabricated, thus electronic devices may be tested at the factory and instantly connected for use on arrival. This greatly simplifies installation and servicing procedures.

Available in five major shell designs, each of which accommodates over 200 styles of contact inserts, Amphenol AN connectors handle voltages up to 22,000, amperages up to 200. Types with pressure-proof, explosion-proof or moisture-proof housings also are available, as are standard elements for thermocouples.

Amphenol, long the leader in mass-producing AN connectors for the armed forces, remains completely tooled for large-scale production for industry at costs far below those in effect pre-war. Write for full data now.

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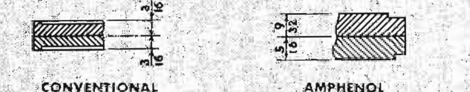
AMPHENOL

THICKER AMPHENOL AN INSERTS INCREASE BREAKAGE RESISTANCE



Here's another example of the "safety insurance" supplied by alert Amphenol engineering: On all sizes, from 20 up, Amphenol inserts are thicker, offering greater resistance to breakage. This is particularly important where larger diameters are employed, and a greater number of contacts accommodated.

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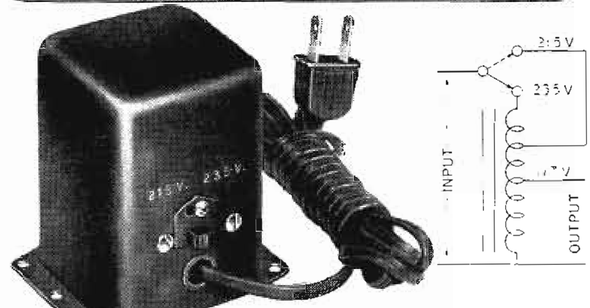
CHICAGO Step-Down TRANSFORMERS

Designed for simple conversion of domestic radios and electrical appliances to the 220 or 230-volt power supplies common in many foreign countries. Locking slide switch adjusts to whichever of two primary voltages provides best output at local voltage variations. Insulated 7-foot cord and plug on input side, standard female receptacle on output side. *"Sealed in Steel"* construction assures lasting efficiency in tropical and other adverse climates. Incorporates vacuum-impregnated core and coil in compound-filled, drawn steel case. Three sizes: 50, 100, and 150 load watts.

Write for further details and prices



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Division of Essex Wire Corporation

CHICAGO TRANSFORMER CTC TRADE MARK REG.

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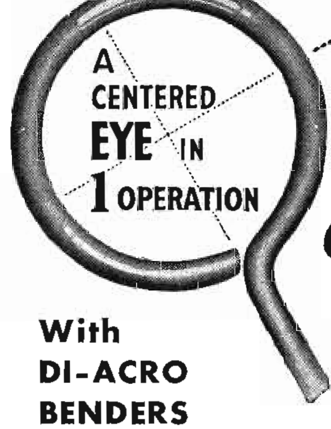

Precision CENTERED EYE Bending

The DI-ACRO Bender makes perfectly centered eyes from rod or strip stock at high hourly production rates. Both eye and centering bend are formed with one operation. Any size eye may be formed within capacity of bender and ductile limits of material.

With DI-ACRO BENDERS

DI-ACRO Precision Bending is accurate to .001" for duplicated parts. DI-ACRO Benders bend angle, channel, rod, tubing, wire, moulding, strip stock, etc. Machines are easily adjustable for simple, compound and reverse bends of varying radii.

DI-ACRO Bender No. 1

Forming radius 2" approx. Capacity 1/32" round cold rolled steel bar or equivalent. Also Benders No. 2 and 3 with larger capacities.

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"DIE-LESS" DUPLICATING showing many kinds of "Die-less" duplicating produced with DI-ACRO Benders, Brakes and Shears.

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DI-ACRO PRECISION MACHINES DIE-LESS DUPLICATING

O'NEIL-IRWIN MFG. CO.

321 8th Ave. So. Lake City, Minn.

tric's marine and aeronautics engineering division. He replaces Ray Stearns who has retired after 45 years service. Carroll has been assistant engineer of the division.

Frederick E. Hanson, in charge of Western Electric Co's. shops in New York and Allentown, Pa. has been appointed manager of the shops. He joined the company's Hawthorne works in 1918.

Dr. Fred C. Lindvall has been made a member of the board of directors of Consolidated Engineering Corp., Pasadena, Cal.

Carl P. Rapp who became associated with International Telephone and Telegraph Corp. in 1929 as plant operation engineer of the system, has been elected second vice-president of the company.

Carroll G. Killen has joined the field engineering staff of the Sprague Electric Co., North Adams, Mass. He was formerly connected with the Army's Watson laboratories, Red Bank, N. J.

Dr. Bernard Kopelman has rejoined Sylvania Electric Products, Inc., as section head of the metallurgical research group. His headquarters will be in the Bayside, N. Y. laboratories.

H. Hugh Willis has been appointed director of research and development of the Kellex Corp., atomic energy subsidiary of the M. W. Kellogg Co. He was formerly chief research director and vice-president of the Sperry Gyroscope Co., Inc.

M. W. Scheldorf has joined the engineering staff of Andrew Co., Chicago, as head of the engineering research department. During the past five years he has been a specialist in antenna designs for the electronics department of the General Electric Co.

Faraday to Sperti

Sperti, Inc., Cincinnati, has taken over the Faraday Electric Corp., Adrian, Michigan, which hereafter will be known as Sperti-Faraday. The consolidation combines the research and engineering departments of both companies and will permit considerable expansion and production increase.

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Also publishers of ELECTRONIC INDUSTRIES & ELECTRONIC INSTRUMENTATION

Langevin Joins Maxson

Carl C. Langevin has become a member of the board of directors of the W. L. Maxson Corp., New York. The Maxson corporation has recently acquired all of the common stock of a newly organized Langevin Mfg. Corp., also of New York, of which Carl C. Langevin is president. The new company has taken over all of the property and business, including good will, of the Langevin Co., Inc., with the exception of the latter's West Coast offices which will act as distributors in a sales and engineering service for Langevin products. The new Langevin Mfg. Corp., which retains the Langevin management and personnel, will continue the manufacture and sale of audio amplifiers, transformers and other apparatus used in recording studios, broadcasting, public address and other sound systems and industrial control equipment.

Gray Heads Electronic

The Electronic Tube Corp., 1200 East Mermaid Avenue, Philadelphia, has been reorganized with Edward D. Gray as president. Associated with him are Henry S. Bamford, vice-president and director, George B. Howell, chairman of the board. Gray was formerly with the New York Telephone Co., and was director of communications of the 8th Bomber Command during the war. Bamford was formerly chief engineer of the company. The corporation will continue to specialize in the production of multi-gun cathode ray tubes and multi-channel oscilloscopes.

Powder Metallurgists

Sintercast Corp. of America has been formed in New York with headquarters at 570 Lexington Avenue, as a consulting and development organization in the field of powder metallurgy. President of the new company is Erwin Loewy, presently connected with Hydropress, Inc. Associated with him are Dr. Claus G. Goetzel and John Ellis. Dr. Goetzel is vice-president and director of research; Ellis is chief engineer.

NEW ALLOCATIONS
See Page 29

NEW BOOKS

Elements of Electrical Engineering

(Fifth Edition) by A. L. Cook and C. C. Carr. Published 1947 by John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y., 662 pages; $5.

This text is primarily devoted to presenting fundamentals of the electrical branch of engineering as background for those specializing in other fields, or as the basis for further study in the subject.. Coverage includes electric and magnetic circuits; direct-current machinery; alternating currents; alternating-current machinery; instruments, electronics, and special applications. Previous editions of this book have been widely used as collegiate texts. In this edition the author assisted by C. C. Carr, has made a number of revisions: the latest types of machines are considered, and the material on electronics now includes industrial applications as well as fundamentals. Complex quantities are now discussed directly in connection with the ac circuit text material. The problems cited are entirely new, as are many of the illustrations.

Cycles—Science of Prediction

By Edward R. Dewey and Edwin F. Dakin, published by Henry Holt & Co., New York. 255 pages; $3.

As all communications engineers know, radio frequency propagation varies in cycles with the seasons and very largely in accordance with the cycle of sunspots. The present book has nothing whatever to do with radio or electronics, but nevertheless may be of considerable interest to executives charged with shaping the destiny of corporations. The authors have attempted to show, with the aid of much logic and many graphs and charts, that there are definite cycles governing the underlying growth of industry, that, if properly interpreted, may be used to predict such growth, or decay. Thus there are many sequential recurrences of ups and downs which appear to be timed to represent cycles of lengths varying from 41 months to as much as 54 years. Examples are explained as they apply not only to business enterprises, but to biology, medicine, geology and various other sciences.

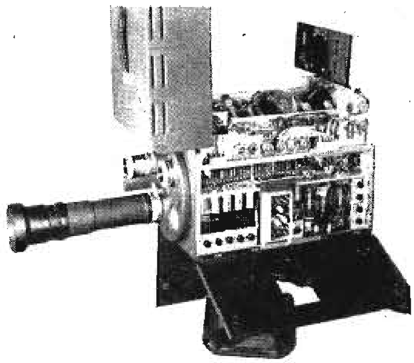
A-B Elects Loock

Fred F. Loock, formerly vice president and general manager of the company, has been elected president of the Allen-Bradley Co., Milwaukee, Wisc. Coincidentally, Harry L. Bradley was named chairman of the board, R. W. Whitmore was re-elected vice president, Louis Quarles, secretary, and A. F. North, treasurer.

IMAGE ORTHICON CAMERA WITH ELECTRONIC VIEWFINDER

• Built around the image-orthicon tube, DuMont's new television camera incorporates a number of unusual features which simplify operation. The unit is part of the complete camera chain equipments developed by Allen B. DuMont Laboratories, Inc., Passaic, N. J. In this new camera design, all essential controls have been concentrated at the rear of the camera. Hinged and removable panels permit immediate adjustments and replacements with minimum loss of time. The lens turret, operated by a rotatable handle at the back, accommodates four lenses, diaphragm and focus also being adjusted from the rear. To avoid parallax difficulties the camera retains the DuMont electronic viewfinder which is mounted on top of the camera by means of plug-in connections.

The electrical flexibility of this camera matches its mechanical convenience. Voltage control is provided for a wide variation in pickup tubes. There are knob adjustments for all internal controls. The video pre-amplifier is essentially non-microphonic so that image pickup is virtually unaffected by vibration or jarring of the camera in operation. Tubes and sockets are arranged for immediate and convenient accessibility. Controls at the rear of the camera, made available by opening panel doors, regulate the heater or the blower for the operation of the image-orthicon tube at the proper temperature; centering of the electronic image; adjustment of the pre-amplifier gain and alignment coil current.



Side and top panels on the new DuMont Image-Orthicon camera open exposing the whole insides for servicing

The camera takes a plug-in headset and microphone for use with the intercommunicating system of the studio or outside crew, and includes video pre-amplifier, blanking multivibrator, and horizontal and vertical deflection circuits.

Development and production of the new camera complements technical and operating advantages of the complete Image-Orthicon camera chain, which includes the Pickup Auxiliary, Low-Voltage Supplies, Synchronizing Pulse Generator, Camera Control and Monitor, Distribution Amplifier and Low-Voltage Supply, and the Mixer Amplifier and Monitor, which is adapted to two, three or four camera operation. The Mixer Amplifier and Monitor permits automatic lap dissolve and fade control.

Electronics Conference

(*Continued from page 66*)

MONDAY, NOVEMBER 3

Keynote address by President G. D. Stoddard of the University of Illinois
"Electronics Comes of Age", Dr. L. V. Berkner of the Joint Research And Development Board
Luncheon Speaker, W. Evans, vice-president of Westinghouse Electric Co.

1. NOISE SUPPRESSION

"Dynamic Noise Suppressor", H. H. Scott. Technology Instrument Corp.
"Intermodulation Method of Distortion Measurement", W. J. Warren, and W. R. Howlett, Hewlett-Packard Co.
"S/N Ratio in AM Receivers", E. C. Fubini and D. C. Johnson, Airborne Instruments Lab., Inc.
"Corona Discharge at High Altitude and Low Temperature", H. J. Dana, State College of Washington

2. ELECTRONIC INSTRUMENTATION

"Self-Balancing Thermistor Bridge", A. C. Bath, Bendix Radio Corp.
"Variable Ratio Inductance Bridges and Networks", Paul Glass and Sylvia May Dushkes, Askania Regulator Co.
"A Miniature Gastro-manometer for Electrical Recording", H. C. Roberts, University of Illinois
"Short-Time Oscillography", Jean V. Lebacqz, John Hopkins University

3. MICROWAVES

"Bead Supported Coaxial Attenuator (4000 to 10,000 mc.)", John W. E. Griemsmann and Herbert J. Carlin, Microwave Research Institute, Polytechnic Institute of Brooklyn.
"Wave Propagation in Beaded Lines", R. E. Beam, Northwestern University
"Coaxial Elements and Connectors", W. R. Thurston, General Radio Co.
"Broadband Matching of Impedances", R. M. Fano, MIT.
"Broadband Bolometer Type UHF Power Meters", M. J. DiToro, Polytechnic Institute of Brooklyn.

4. ELECTRONIC RESEARCH

"Organization and Operation of Electronic Research", R. M. Bowie, Sylvania Electric Co.
"Electronic Research in the University", L. T. DeVore, University of Illinois
"Electronic Research in the Research Institute", C. E. Zeigler, Midwest Research Institute
"Electronic Research in the Government Service", Archibald S. Brown, Wright Field
Banquet and Floor Show—Marine Dining Room

TUESDAY, NOVEMBER 4

5. MICROWAVES

"Higher Mode Technic for Wave Guides", M. W. Goodhue, Polytechnic Research and Development Co.
"Multiplex Transmission Through Waveguides Using Higher Modes", R. N. Buss, W. A. Hughes, H. D. Ross and A. B. Bronwell, Northwestern University
"Microwave Spectroscopy", D. K. Coles and W. E. Good, Westinghouse Electric Corp.
"Noise Reduction in Radar and Communication", S. Goldman, MIT
6. Joint session of National Electronics Conference and AIEE, program arranged by AIEE

7. COMPUTERS

"Electronic Computers", J. W. Mauckly and J. P. Eckert Jr., Electronic Control Co.
"Storage of Numbers on Magnetic Tape", J. A. Coombs, Engineering Research Associates
"Computers for Aeronautical Navigation", Hugo Schuck, Minneapolis-Honeywell Co.

8. ELECTRONIC CIRCUIT ANALYSIS

"Cathode Tap, Cathode Follower Amplifiers", Bradford B. Underhill, Penn State College
Luncheon: "An American Engineering Association". B. D. Hull, Chief Engineer, Southern Bell and President AIEE

9. NEW DEVELOPMENTS

"Ultrasonic Guidance of the Blind", Frank H. Slaymaker and W. F. Meeker, Stromberg-Carlson Co.
"Dynamic Properties of the Infrared Cesium Arc" J. M. Frank and W. S. Huxford, Northwestern University
"Heatless Preservation with Penetrating Electrons from the Capacitron", W. Huber, Electronized Chemicals Corp.
"Citizen's Radio Service", R. E. Samuelson, Hallicrafters Co.
"General Trends in Foreign Electronic Developments", A. H. Sullivan Jr., Wright Field

10. INDUSTRIAL ELECTRONICS

"Electronic Half-Tone Engraver", John Boyajean, Fairchild Camera and Instrument Corp.
"Electronic Servomechanism Testing Machine", H. W. Katz, University of Illinois
"Sealed Ignitrons for Radio Transmitter Power Supplies", H. E. Zuvers, General Electric Co.
"Single Phase Controlled Rectifier and Inverter Circuits", C. M. Wallis, University of Missouri

11. ANTENNAS

"High Gain with Discone Antennas", A. C. Kandoian, W. Sichak and R. A. Felsenheld, Federal Telecommunieation Lab. Inc.
"Slot Antennas", N. E. Lindenblad, Radio Corporation of America
"Measurement of Aircraft Patterns in Flight", J. S. Prichard Airborne Instruments Lab. Inc.
"Transmission Frequencies for Line of Sight Systems", L. S. Schwartz, Naval Research Lab.

12. NUCLEONICS

"Mass Spectrometer Type Detector", Robert F. Wall, Texas A. and M. College
"Scintillation Counter", J. W. Coltman, Westinghouse Electric Corp.

WEDNESDAY, NOVEMBER 5

13. MILITARY APPLICATIONS OF ELECTRONICS

"Guided Missiles", Walter N. Brown Jr., Haller, Raymond and Brown
"Telemetry System for Guided Missles", L. J. Neclands and Walter Hausz, General Electric Co.
"Foreign Developments in Infrared", E. A. Underhill, Wright Field
"Foreign Vacuum Tubes and High Frequency Technics", B. L. Griffing, Wright Field.

14. COMMUNICATIONS

"Teleran, A Technical Progress Report", R. W. K. Smith, D. H. Ewing and H. J. Schrader, Radio Corporation of America
"Crystal Saver", W. R. Hedeman Jr., Bendix Radio Corp.
"Pulse Count Modulation", D. D. Grieg and S. Metzger, International Telephone and Telegraph Corp.
"Air Traffic Control", W. D. White, Airborne Instruments Lab., Inc.

15. BASIC SCIENCE

"Semi-Conductors", K. Lark-Horovitz, Purdue University
"Supersonic Detection of Infrared Modulation", W. Fry and Fry, University of Illinois
"Microwave Scattering", R. T. Gabler, Westinghouse Electric Corp.

16. INDUSTRIAL APPLICATIONS

"High Frequency Operation of Fluorescent Lamps", J. H. Campbell and B. D. Bedford, General Electric Co.
"Magnetostriction Torquemeter", E. H. Schulz, Armour Research Foundation.
"Saturable Core Magnetometer Applications", W. E. Tolles, Airborne Instruments Lab., Inc.

17. TELEVISION

"The Chromoscope, A New Color Television Viewing Tube", A. B. Bronwell
"Color in Television Cathode Ray Tubes", E. B. Fehr, General Electric Co.
"A Modern Television Transmitter", C. D. Kentner, Radio Corporation of America
"Monitoring Equipment for Television Broadcast", M. Silver, Federal Telecommunieation Lab. Inc.
"Luminescent Screens For Cathode-Ray Oscillography", Carl Feldt, A. B. FuMont Labs. Inc.

18. ELECTRONIC INSTRUMENTATION II

"High Resolving Power Infrared Recording Spectrometer", R. D. Nelson and W. R. Wilson, Northwestern University
"The Phase Meter", W. O. Vandeven, General Electric Co.
"Accurate Measurement of Relative Phase", R. Glaser, MIT
"A Null Method for Determination of Impedance in the 100-400 mc. Rrange", J. F. Byrne, Airborne Instruments Lab.

19. FM BROADCAST DEVELOPMENT

"A 50 kw. FM Broadcast Transmitter", C. J. Starner, Radio Corporation of America
"A Pulse-Counter Type FM Station Monitor", David Packard and Norman B. Schrock, Hewlett-Packard Co.
"Transatlantic FM Transmission", L. B. Arguimbau and J. Granlund, MIT
"Phase Modulation Circuit", S. M. Beleskas,

Radio Corporation of America

20. ELECTRONIC CIRCUIT ANALYSIS II

"Aanlysis of Oscillator Frequency Instability", F. P. Fischer, University of Connecticut
"Transient Behavior in Non-Linear Systems", Carl S. Roys, Syracuse University
"Calculation of Operating Characteristics of Electromagnetic Devices", R. M. Soria, American Phenolic Co. and T. J. Higgins, Illinois Institute of Technology

Rochester Meet

(Continued from page 66)

MONDAY, NOVEMBER 17

"Conductivity of Ionized Gas in the Microve Region", Ladislas Goldstein, International Tel. & Tel. Co.
"IF Selectivity Considerations in FM Receivers, R. B. Dome, General Electric Co.
"The Organization of the Work of the I.R.E. Technical Committees", L. G. Cumming, Institute of Radio Engineers
"Use of Miniature Tubes in AC/DC Receivers for AM and FM", R. F. Dunn, Radio Corporation of America
"Two Signal Performance of Some FM Receiver Systems", B. D. Loughlin, Hazeltine Electronics Corp.
"Engineering Responsibilities in Today's Economy", E. F. Carter, Sylvania Electric Products Inc.

TUESDAY, NOVEMBER 18

"Avenues of Improvement in Present Day Television", Donald G. Fink, McGraw-Hill Publishing Co., Inc.
"Standardization of Transient Response of Television Transmitters and Receivers", R. D. Kell and G. L. Fredendall, RCA Laboratories
"Spectral Energy Distribution of Cathode Ray Phosphors", R. M. Bowie and A. E. Martin, Sylvania Electric Products Inc.
"Quality Control in Receiving Tube Manufacture", J. A. Davies, General Electric Co.
Fall Meeting Dinner—6:30 p. m.; Toastmaster, R. A. Hackbusch; Speaker, F. S. Barton.

WEDNESDAY, NOVEMBER 19

"RF Inductance Meter with Direct Reading Linear Scale", Harold A. Wheeler, Wheeler Laboratories Inc.
"VHF Bridge for Impedance Measurements Between 20 and 140 MC," Robert A. Soderman, General Radio Co.
"Metallized Film Coaxial Attenuators", John W. E. Griemsmann, Polytechnic Institute of Brooklyn
"Airborne Beacon Receivers," Frederick Mitchell and Ken L. Henderson, Stromberg-Carlson Co.

PHOTOGRAPHIC SESSION — 8:15 P.M.

"The Problem of Amateur Color Photography", Ralph M. Evans, Eastman Kodak Co.

Head Ire Slate

(Continued from page 66)

North Central Atlantic:

J. V. L. Hogan, president of Faximile, Inc., New York.
F. A. Polkinghorn, Bell Telephone Laboratories, Inc.
H. P. Westman, associate editor of "Electrical Communication."

East Central:

W. A. Dickinson, Sylvania Products, Inc.
P. L. Hoover, professor of electrical engineering, Case School of Applied Science.
J. A. Hutcheson, associate director of research, Westinghouse Electric Corp.

Southern:

Ben Akerman, chief engineer of radio station WGST, Atlanta.
A. E. Cullum, Jr., consulting radio engineer, Dallas.

Canadian:

F. S. Howes, associate professor of electrical engineering at McGill University.
F. H. R. Pounsett, chief engineer of Stromberg Carlson, Ltd., Toronto.
One regional director will be elected for each designated Region from the following nominees, for 1948 and 1949:

North Atlantic:

L. E. Packard, treasurer of Technology Instrument Corp., Waltham, Mass.
H. J. Reich, professor of electrical engineering at Dunham Laboratory, Yale University.

Central Atlantic:

J. B. Coleman, assistant director of engineering, R.C.A. Victor Division.

Central:

T. A. Hunter, president, Hunter Mfg Co., Iowa, City.

W. O. Swinyard, chief engineer, Hazeltine Research, Inc., Chicago.

Pacific:

F. E. Terman, dean of the school of engineering, Stanford University.

Reverberation Tests

(*Continued from Page* 48)

16. Application of Sound Absorption to Factory Noise Problems. Hale J. Sabine & R. Wilson—Jrl. of Ac. Soc., July 1943.
17. Effects of Position on the Acoustical Absorption by a Patch of Material in a Room. C. M. Harris—Jrl. of Ac. Soc., January 1946.
18. Absorption & Scattering by Sound Absorbent Cylinders. R. Cook & Peter Chrzanowski—Jrl. of Ac. Soc., April 1946.
19. The Modulation of Sound Decay Curves. R. Watson—Jrl. of Ac. Soc., July 1946.
20. Acoustic Design Charts, by Frank Massa The Blakiston Co., New York.
21. Advances in Acoustical Treatment at new NBC Studios. "Electronics", March 1942
22. Practical Acoustics and Planning Against Noise, by Hope Bagenal Chemical Publishing Co., Brooklyn, N. Y.
23. Acoustical Planning for the Motion-Picture Theater Auditorium, by Potwin & Schlanger Arch. Rev., July 1944.
24. Acoustical Design and Treatment for Speech Broadcast Studios, by Content & Green I.R.E. Proceedings, February 1944.
25. Noise Reduction, Acoustical Materials, Their Selection and Use, by Sleeper Arch. Rev., March 1944.
26. The Theory of Sound, by Lord Rayleigh Dover Publications, New York-1945.
27. Studio Acoustics, Basic Principle and Recent Developments, by Richard H. Bolt Radio News, January 1946.
28. Some Common Acoustical Troubles, by Chadbourne International Projectionist, March 1946.
29. Improved Acoustics in New NBC Studios Radio Age, January 1946.
30. Irregular Room Surfaces in Studios, by K. C. Morrical Communications, April 1946.
31. Frequency Characteristics of Reverberation, by Col. Univ. of War Research P. B. 33402, November 1944.
32. Acoustics, by A. Wood Interscience Publishers, New York
33. Acoustics—A Handbook for Architects & Engineers, by P. L. Marks Chemical Publishing Co., New York.
34. Development and Current uses of the Acoustic Envelope, by Burris-Meyer Jrl. Soc. Mot. Pic. Eng., July 1941
35. Acoustics of Buildings, by Watson John Wiley & Sons, New York.
36. Factors Affecting Sound Quality in Theaters by A. Goodman Jrl. Soc. Mot. Pic. Eng. November 1941
37. Standards For Sound Control Architectural Record, March 1940.
38. Sound Insulation, by Keron C. Morrical Architectural Record, January 1940.
39. Elements of Acoustical Engineering, by Olson D. Van Nostrand.
40. Community Theaters: Acoustic Requirements by Burris-Meyr and Cole Architectural Record, 1939.
41. Structural Requirements of Houses: Insulation, Thermal and Acoustical, by W. Hayes Architectural Record 1939.
42. Applied Architectural Acoustics by Michael Rettinger Chemical Publishing Co., 1947
43. Electrical Engineers Handbook, by Pender, McIlwain, John Wiley & Sons, Inc., 1936.
44. Architects' Visual Equipment Handbook Bell & Howell Co., Chicago, Illinois.

Electron-Plasma

(*Continued from Page* 61)

same positive charge density throughout, and all variables to be functions of one space coordinate only, the electrons will traverse the plasma with a velocity oscillating around their average velocity with the Langmuir frequency.

In a homogeneous plasma a discharge space of length, d, may be considered. The electron current enters the discharge space with zero velocity in a region of zero field intensity. This corresponds to a virtual cathode. Then the figure indicates the frequency regions for which the resistance of the discharge assumes negative values. The abscissa and coordinate are the external angular frequency, ω_1, times the average electron transit time, T, through the plasma and the Langmuir frequency ω_0, times the transit time, T, through the plasma, respectively. Similar effects for the case of electrons moving in one direction only are obtained if the positive space charge is replaced by a homogeneous magnetic field at right angles to the direction of electron movement.—JZ

AC Generator

(*Continued from page* 56)

ance: maximum output of 40 amperes from 19½ miles per hour to 53 mph, and 18 amperes output while idling at 450 rpm.

From the above comparisons the advantages of the alternator system, on the basis of performance at wide variations in engine speeds, can be readily seen. With the present-day high loads imposed on the automotive generator system at wide ranges of engine speed, the Leece-Neville development should solve many of the problems now confronting engineers of the motor car industry.

Its use on cars equipped with radiotelephone is by no means its only application. It is suitable for use on fishing boats, which are used for hours trolling at slow speeds, boats equipped with two-way ship-to-shore radio equipment, equipment with electrically-operated air conditioning, heaters, and flasher lights—any equipment whether gasoline or diesel powered that operates at slow speeds, or where a heavy load is imposed by accessories.

Radar System

(*Continued from Page* 51)

does with respect to azimuth.

The approach conroller sits in front of two indicators mounted in a single rack, placed at right angles to each of the other two precision racks. The two indicators at the approach controller's disposal are the remoted search indicator and the approach indicator. He can thus watch aircraft being guided by the search operator and in emergency can guide them himself, until they are within range of the precision system. At that time the aircraft's position is indicated on the approach indicator as lateral and vertical deviations from the glide path, in feet. The approach controller transmits this information to the pilot in terms of correction instructions, by means of the radio communications equipment provided for him, thus guiding the pilot to a point over the runway from which the plane may be touched down visually in the usual manner.

Intercarrier Sound

(Continued from page 28)

synchronizing signal, according to FCC standards. The average kinescope requires about 30 volts of video signal for modulation; therefore, the sound signal would be 1% of this, or 0.3 volts peak-to-peak. However, it is possible to get much more than this with the circuit shown on Fig. 5.

For more exact explanation of this, let us refer to Fig. 6. This is the approximate equivalent circuit for the 6AG7 video amplifier shown on Fig. 5. The ac voltage introduced in the circuit is equal to the applied grid voltage times the amplification constant or MU of the tube. This MU is over 1000, but the real gain is limited by the fact that 130,000 ohms of tube plate resistance is in series with the load. The load resistance is determined by the highest frequency passed and the circuit capacities. Usually the highest load resistance that can be used is 4000 ohms. Both of these resistances are shown in series with the ac generator representing the available EMF in the tube. There is also a parallel resonant circuit in series with these resistances, which represents the sound pick-up system of Fig. 5.

The apparent resistance of such a parallel resonant circuit is equal to $Q\omega L$ which worked out in one practical case to be about 40,000 ohms. The voltage across this 40,000 ohms is nearly ten times as much as across the plate load resistor. Therefore, the voltage of the FM signal coming from the video tube is not 0.3 volts peak-to-peak, but about 3 volts. This much voltage is adequate to use on the diode discriminator without further amplification. A limiter also could be operated from this voltage, but for reasons explained before it was not used in an inexpensive set as shown on Fig. 5.

A ratio discriminator may be used to advantage, but for simplicity, the well-known detuned balanced discriminator is shown in the figure. This operates by tuning the pick-up coil of one diode higher, the other lower than 4.5 mc.

The output of the discriminator is entirely sufficient to overload the 6V6 output tube after one stage of voltage amplification. It is to be noted that this result is obtained without leaving the sound signal at higher than 1% amplitude ahead of the first detector. For simplicity the absorption trap may be tuned right on the sound signal and not slightly towards the picture carrier as was described. Tuning the sound trap so as to reduce the slope of the selectivity curve near the sound FM carrier, is a refinement useful for expensive sets where the greater signal obtained in connection with its use is fed into a limiter. The limiter operates better with this greater signal.

It is also noteworthy that while the common IF channel is amplifying a 4.5 mc bandwidth instead of the usual 4 mc, the gain and noise factors are not worse than for conventional bandwidths. The reason is that the usual 4 mc IF amplifier will also amplify the 4.5 mc signal, but at lower gain. This lower gain is not a disadvantage in the present case, but a necessity. As was described, the sound FM signal must be considerably lower than the picture IF signal is at its lowest point of modulation. This results in a substantially constant amplitude 4.5 mc FM signal. It is also necessary to reduce the sound FM amplitude in order to reduce the effect of sound on the picture.

The sound signal can affect the picture two ways: an audio frequency, or a 4.5 mc oscillation. It was described how the demodulation of the 4.5 mc signal may be prevented by lowering the slope of the resonance curve. In case this is not done and the method of tuning the sound traps right on the sound is used, some demodulation will take place. However, the FM signal is reduced in the IF to about 1% or 40 DB. If the FM is 10% demodulated, due to the slope of the resonance curve, the AF signal will be 20 DB below that. Consequently, the interference due to audio frequencies is about 60 DB below the useful signal, and so it is not noticeable.

The 4.5 mc signal appearing on the kinescope is also attenuated 40 DB in the IF before it reaches the detector. It is further attenuated by the parallel resonant circuit in the plate of the video amplifier. It was found, however, that because this frequency can only make dots that are smaller than one picture element, as much as one volt peak on the grid of the kinescope is tolerable. Actually, the 4.5 mc is less than 1/10 of this amplitude.

It is interesting to speculate on the effect of this new sound system on the use of tuned radio frequency receivers for picture reception. Such receivers are widely used in Europe and they have many valuable qualities, such as no radiation, no tuning images, wide bandwidth, etc. In this country we expect to use more television broadcasting stations and prefer to use the superheterodyne for greater selectivity, fewer tuning units, and because the sound receiver can be combined with the picture receiver. This was not the case when using the TRF circuit where an almost independent sound receiver must be used. The use of this new method practically eliminates the sound receiver from the TRF television set. The saving is therefore very much greater than in the superheterodyne and this may make the TRF a healthy competitor to the superheterodyne not only in Europe, but in this country as well.

At present the use of the new sound system is not expected to spread quickly to commercial receivers because of the difficulty encountered in the 200 mc television channel. This difficulty is, that the picture carrier cannot yet be kept constant enough for beating with an FM carrier. A slight frequency modulation of the picture carrier at present will cause a sound resembling a 60 cycle hum to interfere with the audio reception. This trouble is not present below about 100 mc. Since so far all television transmitters operate below or near 100 mc, a receiver using this sound system works satisfactorily.

Work is being carried on to stabilize the carrier of the 200 mc band television transmitters. When this is successfully accomplished, there is good reason to believe that all television sets will use the Parker sound system.

Loudspeaker Design

(*Continued from page 43*)

attenuate the sound at a lower frequency than the other type. It has a transverse resonance at a wavelength equal to about 1.1 times the diameter of the diaphragm, resulting in inefficient coupling at this frequency. If the diameter is kept to 2 in., this frequency occurs at approximately 6000 cycles, which is outside the specification limits. Hence, a diaphragm with a 2-in. clamping diameter, and a single opening sound chamber are suitable. This diameter can be seen to be not too far off for the power requirement, as 20 to 25 watt speakers of a similar type use diameters of about 2¾ in.

The suitability of this size for the power required can now be checked. We can make use of electro-mechanical analogy to get an expression involving power, deflection, diameter, etc., as follows:

The electrical expression for resistive power is

$$W = i^2R \qquad (19)$$

The average value of i can be shown to be

$$i = \omega Q \qquad (20)$$

Then $W = \omega^2Q^2R$ (21)

The mechanical counterpart of Q is X, the deflection. The mechanical power may be expressed as

$$W = \omega^2X^2R \qquad (22)$$

As $R = R_{mh}$, the mechanical resistance of the air load on the diaphragm and from equation (17) $R_{mh} = T_{sc}^2(\rho cA)$, the mechanical power which the diaphragm transfers to the air load is

$$W = \omega^2X^2T_{sc}^2(\rho c)'A \cdot 10^{-7} \text{ watts} \qquad (23)$$

From the values given above—throat diameter, ½ in.; f_c, 250 cycles, W, about 4 watts for the efficiency given—the deflection can be found if $(\rho c)'$ is known. As indicated previously, a value of $\rho c = 41$ cannot be used at 250 cycles, as it is theoretically zero at f_c, but in a finite horn such as this, the cut-off is not sharp so that $(\rho c)'$ still has a small, real value. This value is smaller in a finite exponential horn than in a conical horn of the same dimensions, as the latter has no definite cut-off frequency. Thus, by modifying the shape of the exponential horn somewhat, to impart the influence of a conical horn characteristic, a value for $(\rho c)'$ of the order of $\rho c/5$ to $\rho c/4$ can be safely approximated for a horn of these overall dimensions. The value of X can then be determined from equation (23); and for the other constants given, is about .03 in. As this deflection is not excessive for such a diaphragm (which is made of molded phenolic material because of its ruggedness), the value of 2 in. for the working diameter is satisfactory.

Referring now to Fig. 6., (showing the type of electrical band pass filter network to which this vibrating system is analagous) one of the characteristics of this type filter is that it attenuates very gradually outside of the theoretical cut-off frequencies. This is particularly true when the terminating impedances are of the nature available in an electro-mechanical-acoustical device like a loudspeaker. Hence, if we set 600 cycles as the design value for the resonant frequency of the series arm of the filter—$Z_1/2$—fair transmission can be expected to one octave below, or 300 cycles, the lower specification limit, with a gradual tapering off below this frequency.

The decreasing average value of $(\rho c)'$ with decreasing frequency in the short modified horn will still afford sufficient radiation resistance to permit some power to be transmitted to the air below 300 cycles. The distortion content increases in this range, however, and it would appear advisable actually to attenuate the input power at these lower frequencies. It seems though, that the average commercial user prefers to have some lower frequency output even with high distortion, in preference to having these lower frequencies entirely cut off—at least to the point where the distortion seriously interferes with intelligibility.

The computed throat diameter of ½ in. is just about large enough so that second harmonic acoustic distortion due to overloading of the air in the throat is not too serious. High intensities of power per unit area will introduce such distortion because of the non-linearity of the P-V characteristic of the gas. Several investigators have studied this effect, one group finding that the following relation checks quite well in practice:

$$R = \frac{(\gamma + 1) f^2 W \times 10^7}{4 \rho c^3 f_c^2 A} \qquad (24)$$

Where

R = Maximum intensity of second harmonic distortion

γ = 1.4 or ratio of specific heat of gases

W = Power transmitted through horn throat, in watts

f = Any frequency in the pass band

f_c = Cut-off frequency of exponential horn

A = Area of horn throat

ρ = Density of air

c = Velocity of sound in air

(The constants are in c.g.s. units.)

For the horn calculated above, this equation gives a second harmonic distortion about 20 db down from the fundamental, when f = 800 cycles. The above relation indicates it will increase as f increases, unless W decreases, which is often the case.

Having the size of the horn throat, and of the diaphragm, the terminating impedance of the mechanical filter is now computed. This can be taken, to a first approximation, as R_{mh}, which equals, from equations (16) and (17):

$$R_{mh} = \rho c \, (A_d)^2 / A \qquad (25)$$

This comes out close to 15,000 mechanical ohms for the dimensions given.

To compute the half-section band pass filter which the mechanical elements represent, we may proceed as follows:

Taking f_r = 600 cycles as the resonant frequency of the series arm, $Z_1/2$, from filter theory the total diaphragm mass and edge stiffness (Fig. 6) are related by

$$f_r = \frac{1}{2\pi}\sqrt{\frac{S_d}{M_t}} \qquad (26)$$

The spacing of the diaphragm to the sound chamber provides the shunt compliance, $1/S_c$, of the filter, and the theoretical upper cut-off frequency f_2 is given by

$$f_2 = \frac{1}{2\pi}\sqrt{\frac{S_d + S_c}{M_t}} \qquad (27)$$

and may be set at 4000 cycles, as the upper cut-off will be quite gradual in this filter. The value of S_c can be computed from equation (5) or its equivalent form, inasmuch as $\rho c^2 = \gamma p_o$:

$$S_c = \frac{A_d \gamma p_o}{X} \qquad (28)$$

Where

X = Spacing to sound chamber, in cms.

$p_o = 10^6$ dynes/sq. cm.

γ = Ratio of specific heat of gases, 1.4

from which S_c is found to be 372×10^6 dynes/cm. With $f_1 = f_r = 600$ cycles, and $f_2 = 4000$ cycles, the total allowable mass of the diaphragm is found from these equations, which give a value for M_t of .6 gram. Now as the lightest practicable molded phenolic diaphragm with a 2 in. working diameter that can be made to-day, will have a mass of between .25 and .3 gram, and using this figure as the basis of computations, the above value of M_t requires that the voice coil be not much over .3 gram. This is a fairly good ratio of voice coil mass to total mass for maintaining efficiency at the higher frequencies. With this value of M_t, the value of S_d required is found from equation (26) to be 855×10^4 dynes/cm.

It is somewhat difficult to determine the size of the voice coil, as it depends on many interrelated factors. The method used below for finding the required voice coil radius, r_{vc} to obtain a given stiffness with a diaphragm of a specified size and material, has worked out satisfactorily in practice. This is based on a derivation made to determine the relation between the stiffness of a clamped disc driven on a circle concentric with the center, and its stiffness when driven at the center. This indicates that the radius of the concentric circle, e.g. the voice coil radius, is expressed by

$$r_{vc} = r_d\,(1 - S_o/S_d) \qquad (29)$$

Where r_{vc} = Voice coil radius.

r_d = Diaph. Clamping radius.

S_o = Stiffness at center.

As the stiffness S_o is

$$S_o = 4\pi^2 f_p^2 M_d \qquad (30)$$

Where

M_d = Mass of disc only

f_p = Fundamental frequency of clamped circular disc.

And using the relation

$$f_p = .475\, hc/(r_d)^2 \qquad (31)$$

Where

h = Thickness of disc

c = Velocity of sound in the disc

there is found for $M_d = .3$ gram, $h = .005$ in., $c = 4.8 \times 10^5$ cms./sec., and $r_d = 2.54$ cms., that $f_p = 450$ cycles, and $S_o = 2.41 \times 10^6$ dynes/cm. Using eq. (29), r_{vc} is found to be .718 in.

The values of the elements in $Z_1/2$ and $2Z_2$ (Fig. 9) are now established. Next, it is necessary to find if the values of the terminating impedances will be sufficiently close to those of the respective iterative impedances Z_1 and Z_1' so that the network will behave as a half-section band pass filter when properly terminated.

In this type filter, Z_1 at any frequency in the pass band is

$$Z_1 = R\sqrt{1 - \frac{(f/f_m - f_m/f)^2}{(f_2/f_m - f_m/f_2)^2}} \quad (32)$$

Where

$f_m = \sqrt{f_1 f_2}$ and $R = \pi L_1(f_2 - f_1)$

As $L_1 = 2M_t$, and with the other values as given before, the maximum value of R at mid-band is about 12,000 mechanical ohms. The value of Z_1 decreases above and below f_m.

The magnitude of Z_1' can be obtained from

$$Z_1' = Z_1 Z_2 / Z_1 \quad (33)$$

giving an impedance of approximately 14,000 mechanical ohms. This is very close to the value of terminating mechanical resistance computed for the horn previously which was $R_{mh} = 15{,}000$ mechanical ohms. (Horn resistance is not considered herein.)

The input terminating impedance is a function of the interrelated factors mentioned above. It is usually necessary to arrive at the most satisfactory values of the various factors by successive approximations until all the constants are physically realizable and fulfill the overall requirements.

This mechanical impedance due to damping in the electrical circuit was given, Eq. (18), as

$$Z_{me} = B^2 l^2 \times 10^{-9}/Z_e \quad (34)$$

If the speaker is operated from a 4 ohm amplifier output, and disregarding reactances, with a gap flux density of 18,000 gauses, a value of almost 5000 mechanical ohms can be obtained for Z_{me}, providing the voice coil constants are proper. Although this value of Z_{me} does not match that of Z_1 at mid-band, it is sufficiently close considering the variation of R over the pass band. If there were no practical limitations on what constants could be obtained for mass, stiffness etc., of the diaphragm, maximum value of B, amplifier impedance, and the like, determination of the gauge and amount of wire for the voice coil could be calculated directly. These limitations make a compromise necessary however.

The volume and length of wire, and radius of the voice coil affect the value of B. The dc resistance, hence Z_e, depends on these factors and the amplifier impedance, so all are interrelated. The cross-section of the wire and its exposed area are functions of the power dissipated, if temperature rise is to be kept within allowable limits. These are familiar electrical engineering problems and will not be labored here.

In this loudspeaker, No. 37 enamel copper wire was finally chosen as being the best compromise. As the value of dc. resistance for an efficiency of approximately 35% is 6½ ohms, the corresponding length of wire is 380 cms. The mass is a little over .3 gram. With a voice coil diameter of approximately 1½ in., this results in a two layer coil of 16 turns per layer, with a coil height of 5/64 in. Making the air gap height somewhat less—about 1/16 in.; a theoretical flux density of close to 18,000 gauss can be obtained, using a standard

3 in. dia. x 1¼ in. high, Alnico V ring magnet, providing that high grade magnetic iron is used in the poles, and loss due to saturation and leakage is kept low by the design.

With 8 watts dissipation in the coil, the current density in the wire is quite high, but this is peak value and the average power with speech input is far lower, of the order of 6 to 10 db less. The inner and outer surfaces of the coil afford sufficient radiating area to keep the temperature rise within acceptable limits. It is necessary, however, to avoid the use of thermo-plastic materials in the construction, to prevent failure due to heating under continued operation.

A functional diagram of a driver unit built in accordance with these results, is shown in Fig. 10. The domed diaphragm center and corrugated suspension edge are examples of some of the refinements incorporated in actual design. These features, for instance, give better performance than the flat disc for which the calculations were made, as they impart plunger-like action up to a higher frequency than with a flat disc, the cut-off frequency theoretically being almost twice as high. Break-up into nodal patterns is also minimized, or at least controlled more favorably.

In spite of the departures from ideal values which practical limitations make necessary, this method permits sufficiently close prediction of performance for practical purposes. This is shown by the results. In Fig. 11, an amplitude-frequency response curve of the combined horn and driver unit measured at 4 ft. on the axis of the horn, is shown. Note that 300 cycles is down about 12 db, but that there is still some response (including harmonics) in the 150 cycle region. The irregularity from 400 to 800 cycles is due chiefly to the effect of the short finite horn with its relatively small mouth. On the high frequency end, the response extends well to 5000 cycles and averages only about 5 db down in the neighborhood of 6000 cycles, then tapers off as expected.

The measured efficiency from

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the electrical side, in a warble band from 750-1250 cycles, based on the usual ratio of motional impedance to free impedance, was found to be:

Efficiency = [(10 - 6.7)/10] x 100, or 33%.

There are of course some additional losses due to mechanical resistance and so forth, between the electrical circuit and the horn acoustic output.

From these typical results of an actual design, it can thus be seen that the required specifications of an electro-acoustic device are approached quite closely by following the principles of electro-mechanical analogy.

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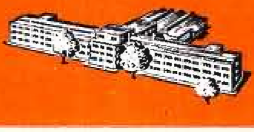

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