A McGRAW-HILL PUBLICATION

electronics

CONTENTS—AUGUST, 1941

5-KW TRANSMITTER USING DIRECTIONAL ANTENNA, by L. C. Sigmon 18

Of interest to broadcast engineers is Mr. Sigmon's description of the completely modern 5-kw transmitter and directional antenna at KCMO

FREQUENCY RESPONSE CURVE TRACER, by S. F. Carlisle and A. B. Mundel 22

Cathode-ray tube is used to record logarithmic sweep voltage applied to one set of plates, while the other set of plates is fed by the output voltage of the device under test to obtain visual frequency-response curve

PHOTOGRAPHIC ANALYSIS OF TELEVISION IMAGES, by Donald G. Fink 24

Overall dynamic tone reproduction characteristics of television receiver can be analysed by photographic methods using miniature camera

SYNCHRONIZED VOLTAGES FOR BIOELECTRIC RESEARCH, by Harold Goldberg 30

An electric stimulus is applied to muscle tissue and a synchronized sweep voltage is fed to a cathode-ray oscilloscope to record potential impulses of short duration

FIVE YEARS OF INDUSTRIAL ELECTRONICS, II, by Ralph A. Powers 33

The second installment concludes the recital of experience in designing electronic control equipment for industrial use. Emphasis is given to the design and construction of phototube apparatus

NOISE AND INTERFERENCE IN FREQUENCY MODULATION, by Stanford Goldman 37

A mathematical and graphical analysis of the interference and noise encountered in f-m systems and a comparison between f-m and a-m systems is lucidly given

FREQUENCY RESPONSE OF PARALLEL L-C CIRCUIT, by Myril B. Reed 43

Complete analysis, in convenient reference form, shows the resonance and phase conditions of wave trap for different relative values of L, C, and R

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JAMES H. McGRAW
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Publication Office
99-129 North Broadway, Albany, N. Y.
U. S. A.

Editorial and Executive Offices
330 West 42nd St., New York, N. Y., U.S.A.

James H. McGraw, Jr., President
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MCGRAWHILL, New York
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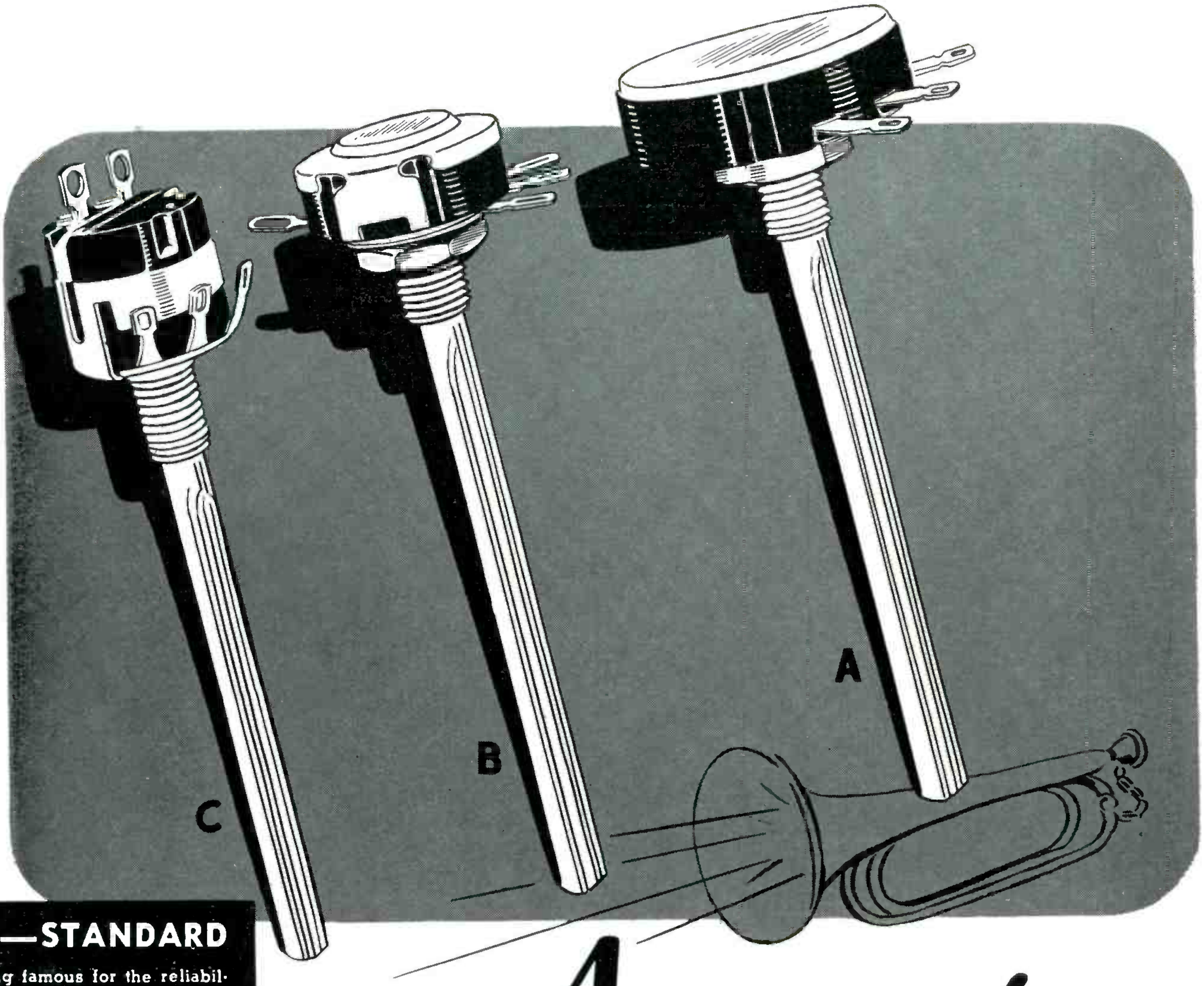

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Long famous for the reliability of Centralab's non-rubbing contact and long wall type resistor. Available plain, or with one, two, or three taps, and with SPST, DPST, or SPDT Underwriters Approved Switches.

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C—ELF

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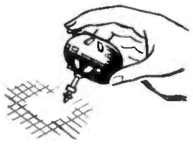

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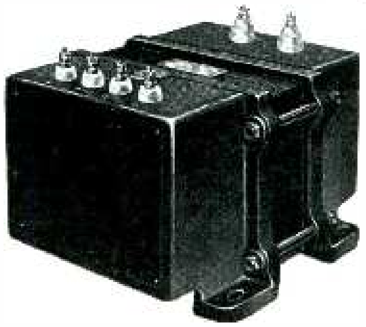
AmerTran modulation transformer, oil-immersed type, for large broadcast transmitters.



Type W plate transformers and reactors for all small and medium high-voltage rectifiers.

AmerTran audio transformers and reactors are available for all applications and meet exact requirements.

Type W filament transformer, air-insulated type, for tests up to 50 Kv.

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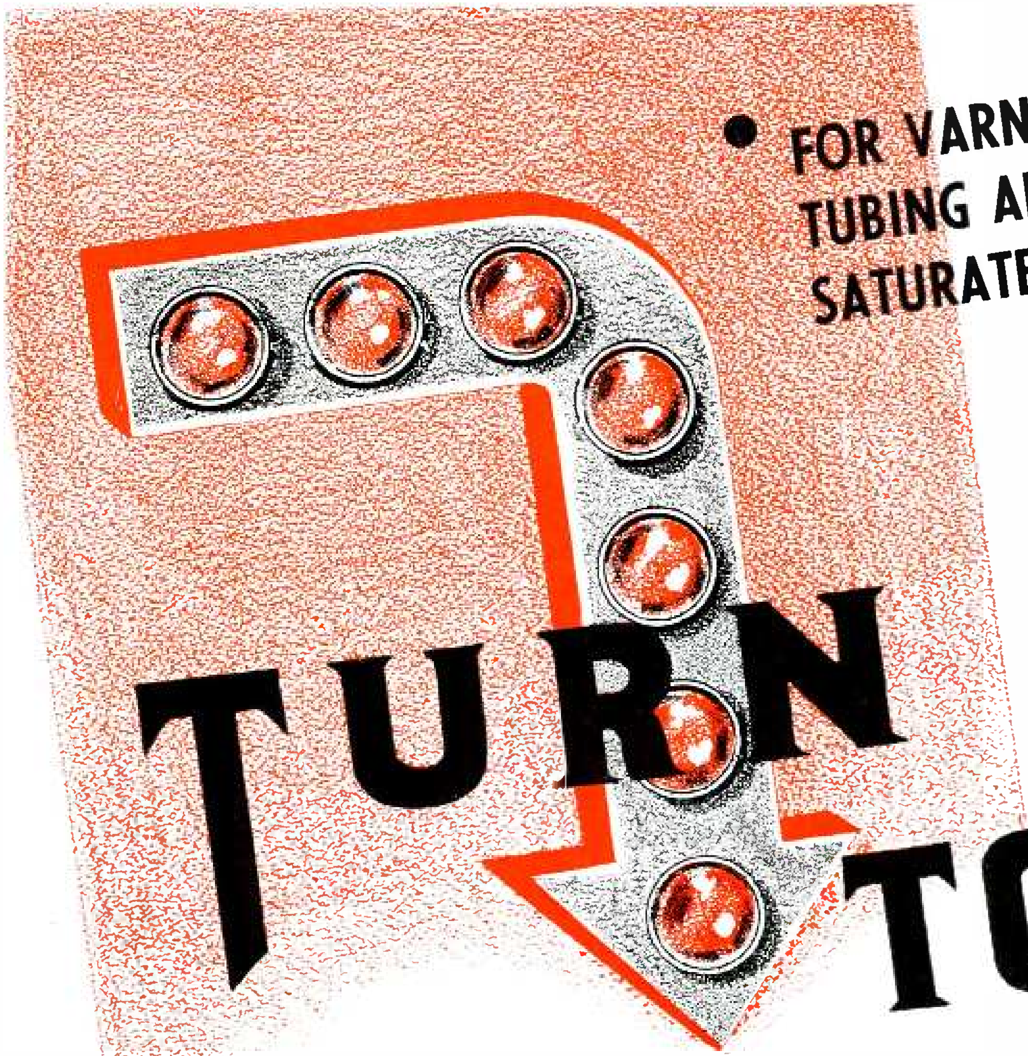
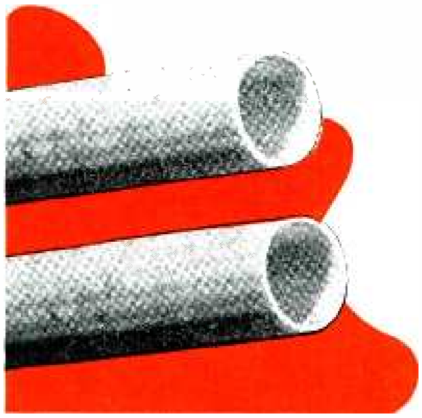


TURN TO TURBO



Turn out that old cracking—arcing—moisture-hungry—"bandaged" potential sleeve insulation. Turn to Turbo, precision-sized varnished tubing, thoroughly impregnated. Flexible—strong—smooth inside too for high speed snaking and fishing. An American Product, made in America. Write for sample board.

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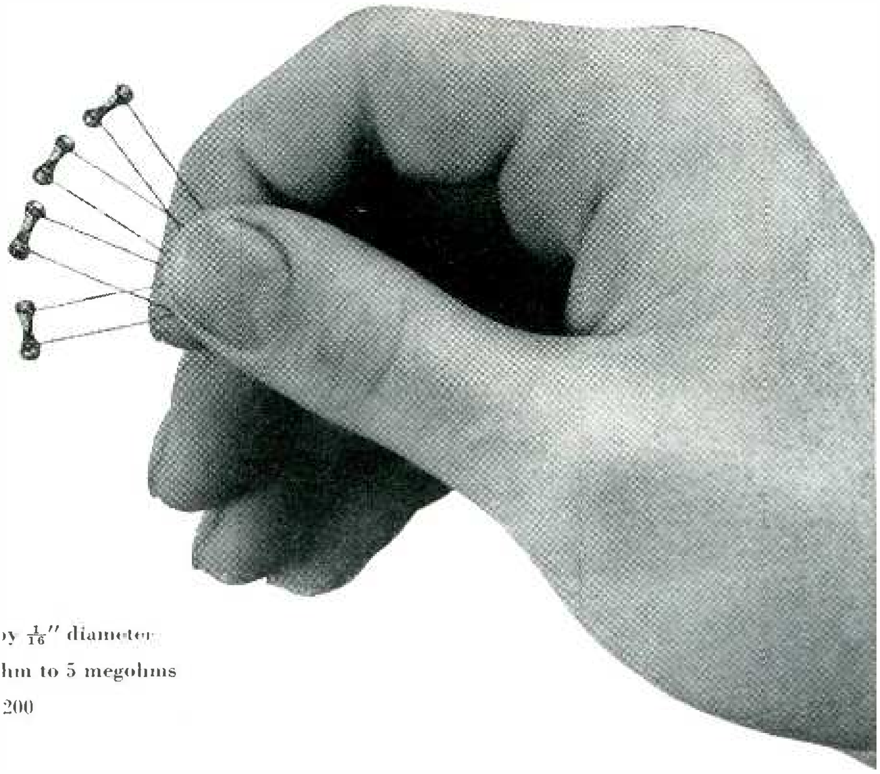

ACTUAL SIZE: 1/4″ long by $\frac{1}{16}$″ diameter

RESISTANCE RANGE: 1 ohm to 5 megohms

MAXIMUM RMS VOLTS: 200

● Globar Brand Resistors are of the ceramic type with excellent voltage-resistance and temperature-resistance characteristics. They are rugged; they are not affected by humid atmospheres; they retain their established resistance value under normal loading; they have a low noise level and the effect of radio frequency on the resistance is negligible up to 30 megacycles. Standard resistance tolerance: 5%—10%—20%. All resistors color coded according to R.M.A. standards. A trial in your circuits will verify these claims.

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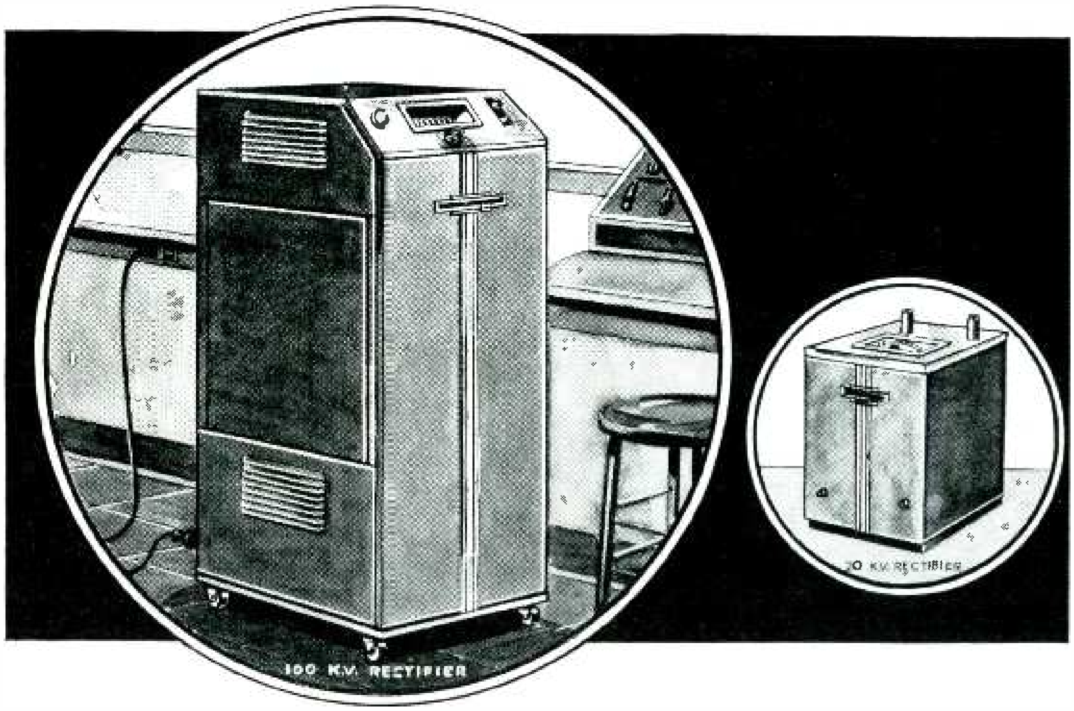

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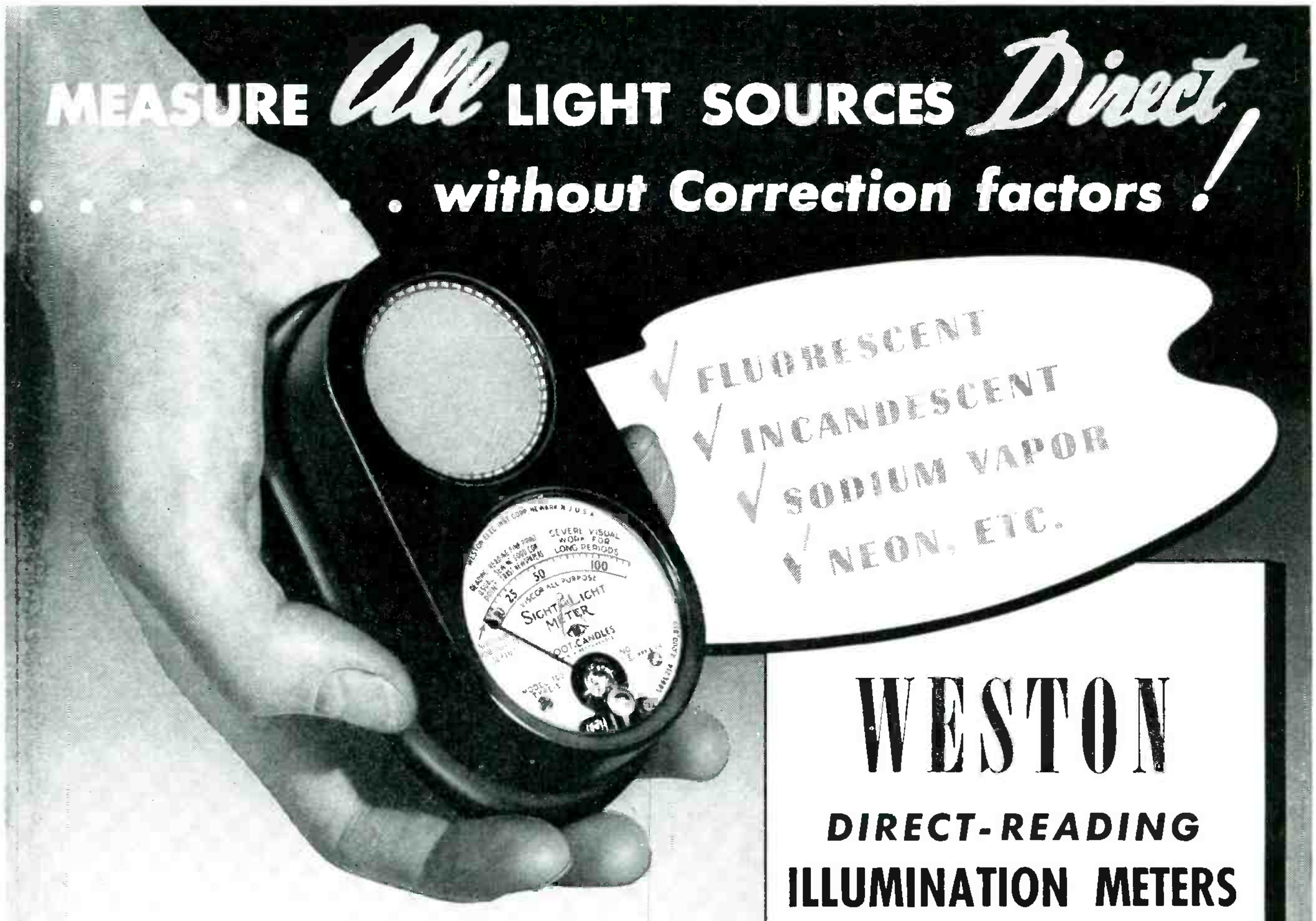

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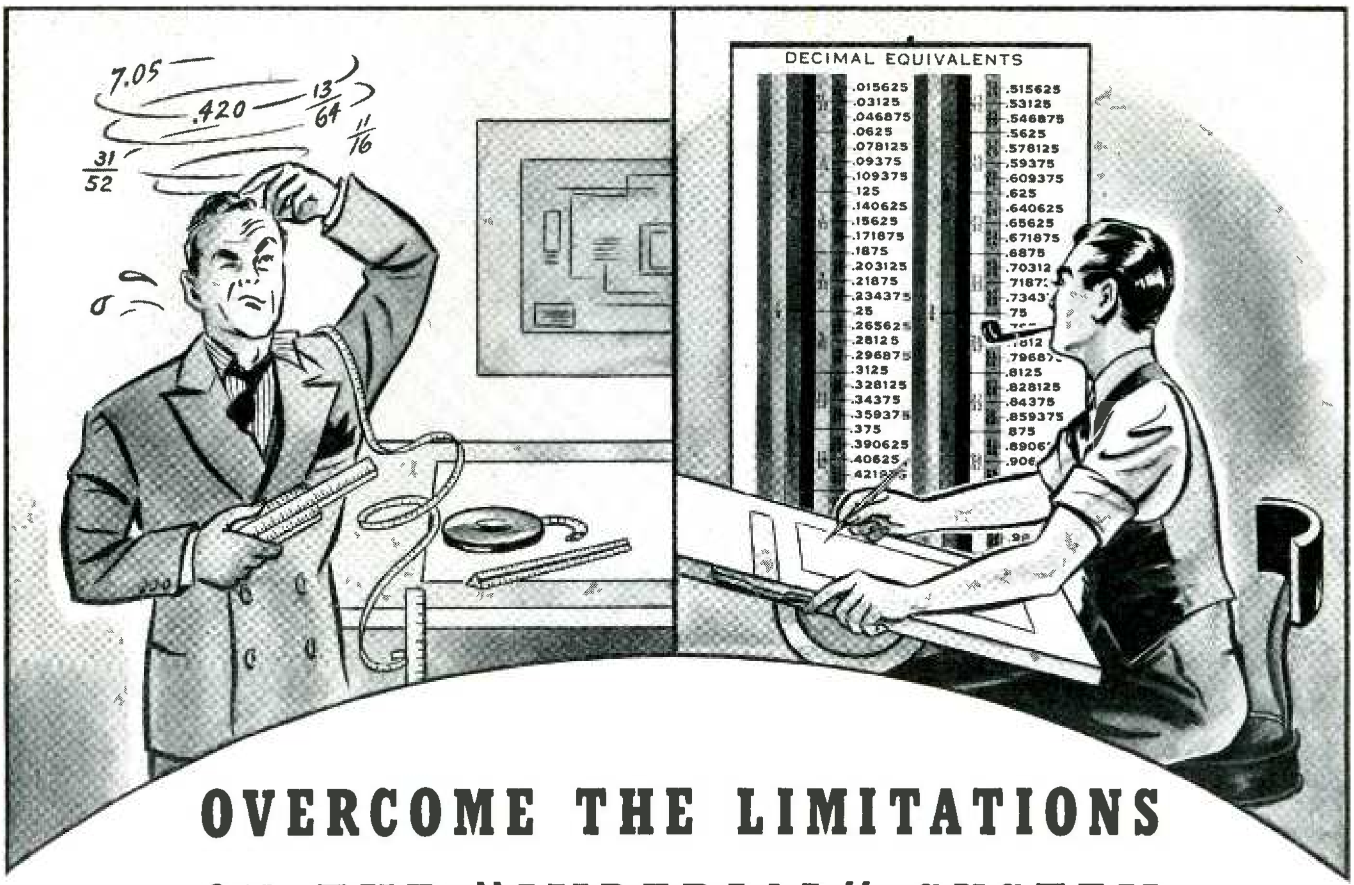

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- The "IMPERIAL" is the customary system of measurement used in the British Empire and in the U. S. A.

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- The "FOOT" . . . originated in Greece . . . became the standard unit of length in the early Olympic Games . . . reputed to be the length of Hercules' foot. Romans based their system upon the Greek method, and forced their Romanized code of measurement upon England. When Britain was again free, this Roman-Greek system was modified . . . and thus started the "IMPERIAL" system.
- The "YARD" . . . originally the circumference of a man's body, later the length of the first King Henry's arm . . . still later became a multiple of the foot.
- The "INCH" . . . the length of 3 barley corns . . . later became 1/12th of a foot.
- THE LIMITATIONS ARE THAT THESE UNITS ARE NOT MULTIPLES OR UNITS OF DECIMALS.

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A NEW PHASE-SHIFT MODULATOR

Used Exclusively in the New REL DL Line of FM Broadcast Transmitters

SIMPLER — MORE EFFICIENT

MAJOR E. H. ARMSTRONG — the inventor of FM — has recently developed a new phase-shift modulator circuit which REL has now incorporated in all of the new DL line of FM broadcast transmitters — now available for early delivery in five power ratings from 250 W. to 50 KW.

Remember — when you deal with REL — you deal with FM's Pioneer Manufacturer — with experience and knowledge gained from having built and put in operation — more FM broadcast transmitters than all other manufacturers combined.

The general overall characteristics of DL FM transmitters are:

★ OPERATING FREQUENCY: Available to operate on any predetermined frequency from 40 to 50 mc. The exact frequency must be specified when the order is placed.

★ FREQUENCY STABILITY: These transmitters are guaranteed to maintain their frequency within less than 200 cycles of the assigned frequency. The frequency is directly controlled by a single crystal, without the use of complicated mechanical or electronic devices.

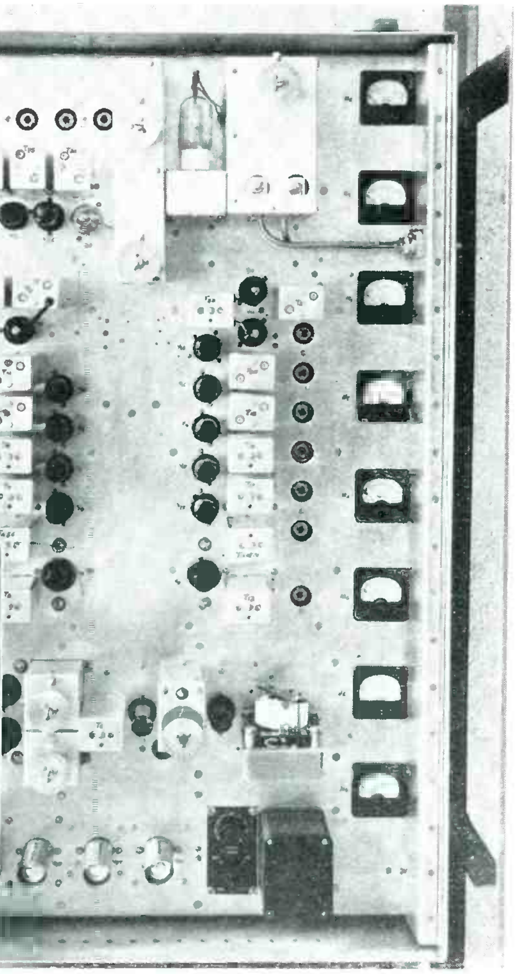
★ FIDELITY: The overall response is within plus or minus 1 db from 30 to 15,000 cycles.

★ DISTORTION: The measured r.m.s. harmonic distortion is less than 1% for all signal frequencies between 50 and 15,000 cycles at ± 75 kc. swing, (100% modulation) AND IS LESS THAN .2% FOR FREQUENCIES FROM 400 to 15,000 CYCLES.

★ NOISE LEVEL: The signal-to-noise ratio is better than 70 db, measured at the output of a monitor receiver. This is an unweighted measurement, with 150 kc. maximum swing, and includes hum.

★ INPUT: The audio input to the transmitters is zero level, 500 ohms, 6 milliwatts.

★ ECONOMY: New Type 558 Modulator employs only 28 small tubes from program input to operating frequency—affording lowest possible tube cost; for example, a complete set of tubes for the new catalog 518 DL 1000 W. transmitter including modulator is only $238.



The new Type 558 modulator — built directly into the 250 and 1000 watt basic transmitter units, which are used to drive amplifiers of all higher powers.

Illustrating a new, exclusive REL feature: Type 558 modulator panel hinged to swing out of its cabinet — making all parts quickly and easily accessible for adjustment and maintenance.

Write for booklet describing this new DL line of FM transmitters.

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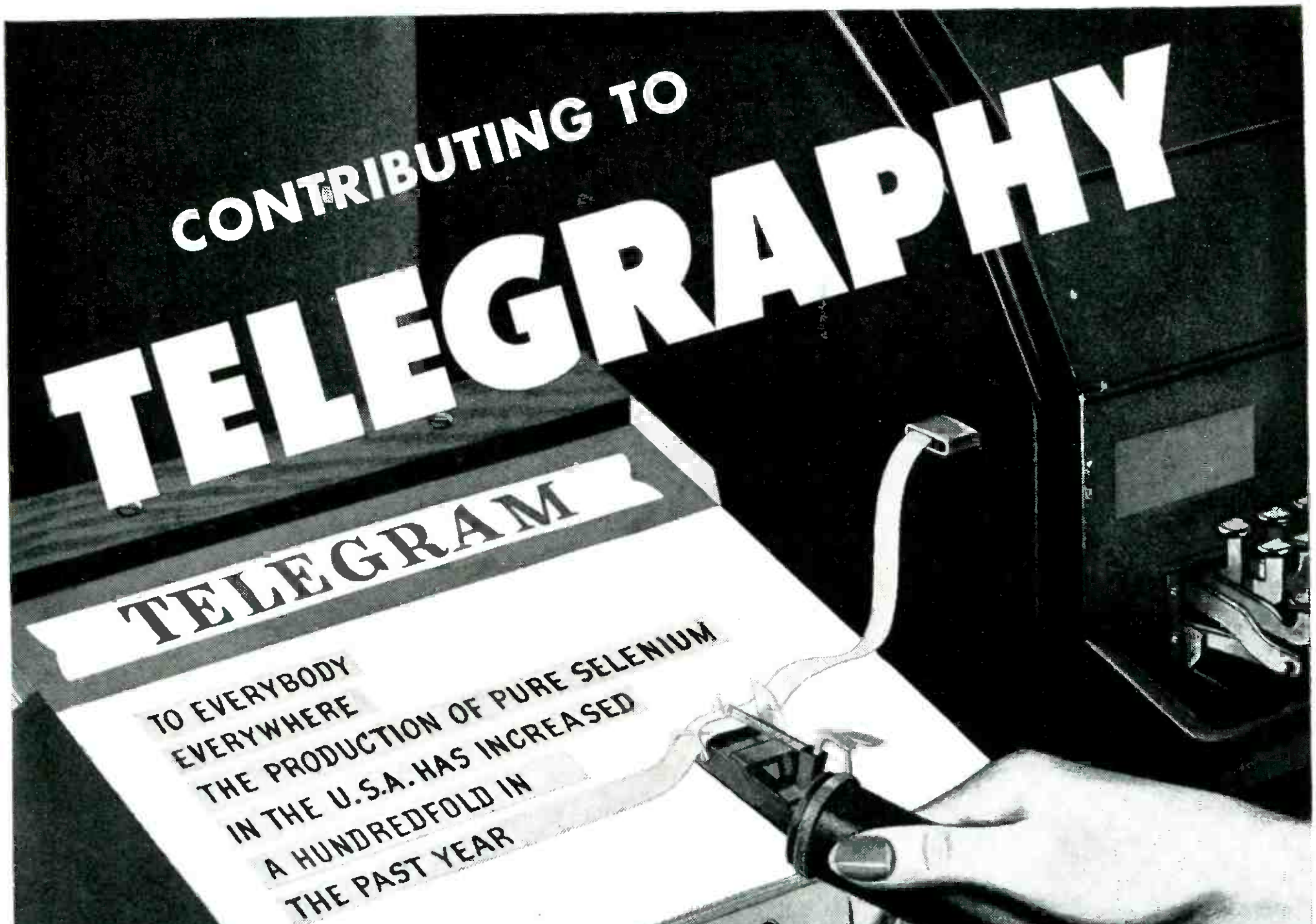

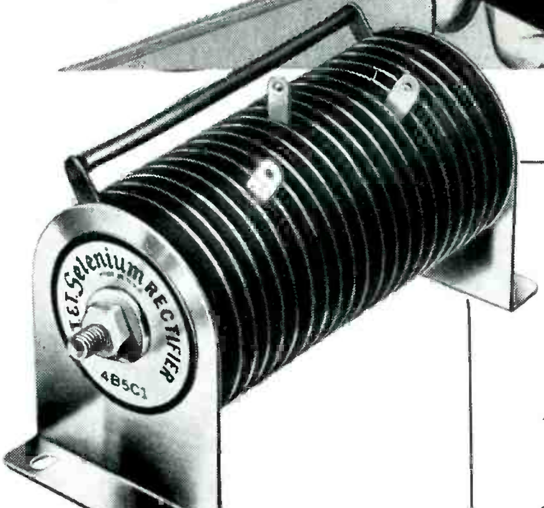

Telegraph engineers, extremely exacting in their requirements, have been quick to discover in the I. T. & T. Selenium Rectifier a ready adaptability to the many demands of Telegraphy, oldest of all the electrical communication arts, for direct current from alternating current sources.

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Our assembly line had to be twice as *fast!* Experts said: "Phillips Screws will cut fastening time in half." But how could *I* afford Phillips?

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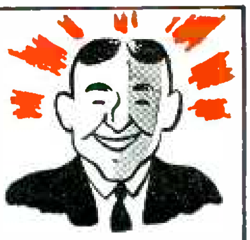
Went down to our assembly line . . . watched our screw-driving operations. Fumbled screws, slipping drivers, scarred work, slow hand-driving — were wasting time *and money!*

OLD-FASHIONED FASTENING?

Yes, slotted screws were costing me money through slow, wasteful screw-driving. And *I* had thought slotted screws cost less because their *price* is less — and I was wrong!

THEY WERE TELLING ME HOW TO RUN MY BUSINESS

. . . AND THEY WERE RIGHT ABOUT ASSEMBLY DELAYS!



MY ANSWER . . . PHILLIPS

So I began to buy Phillips Screws . . . the screws with the tapered recess that *clings* to the tapered driver and prevents driver slippage. They cut our assembly time 50% and went a long way toward solving our delivery-date problem. We now —

start *fast* with one hand	drive *fast* in awkward positions
drive *fast* with power drivers	keep going *fast* without slipping

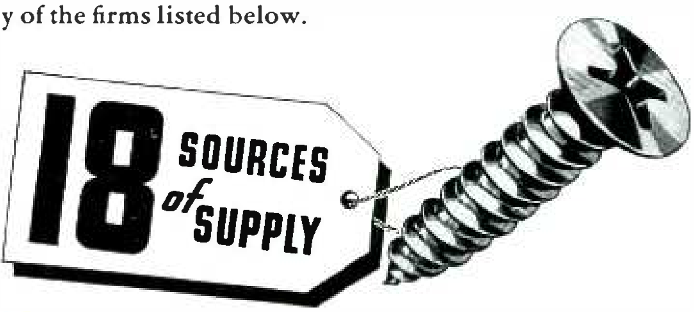
seat screws *fast* and tight.

PHILLIPS SCREWS MAY CUT YOUR ASSEMBLY TIME 50%

Look out for wasteful, slow-driving slotted screws — which, though they cost a few cents less than Phillips Screws, are much more costly in the long run. For further information on how *your* industry can speed product deliveries with Phillips Screws, write to any of the firms listed below.

PHILLIPS

RECESSED HEAD SCREWS



Speed Product Deliveries by Cutting Assembly Time

WOOD SCREWS · MACHINE SCREWS · SHEET METAL SCREWS · STOVE BOLTS · SPECIAL THREAD-CUTTING SCREWS · SCREWS WITH LOCK WASHERS

U. S. Patents on Product and Methods Nos. 2,046,343; 2,046,837; 2,046,839; 2,046,840; 2,082,085; 2,084,078; 2,084,079; 2,090,338. Other Domestic and Foreign Patents Allowed and Pending.

American Screw Co., Providence, R. I.
Central Screw Co., Chicago, Ill.
Chandler Products Corp., Cleveland, Ohio
Continental Screw Co., New Bedford, Mass.
The Corbin Screw Corp., New Britain, Conn.
International Screw Co., Detroit, Mich.
The Lamson & Sessions Co., Cleveland, Ohio
The National Screw & Mfg. Co., Cleveland, Ohio
New England Screw Co., Keene, N. H.
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Pheoll Manufacturing Co., Chicago, Ill.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N. Y.
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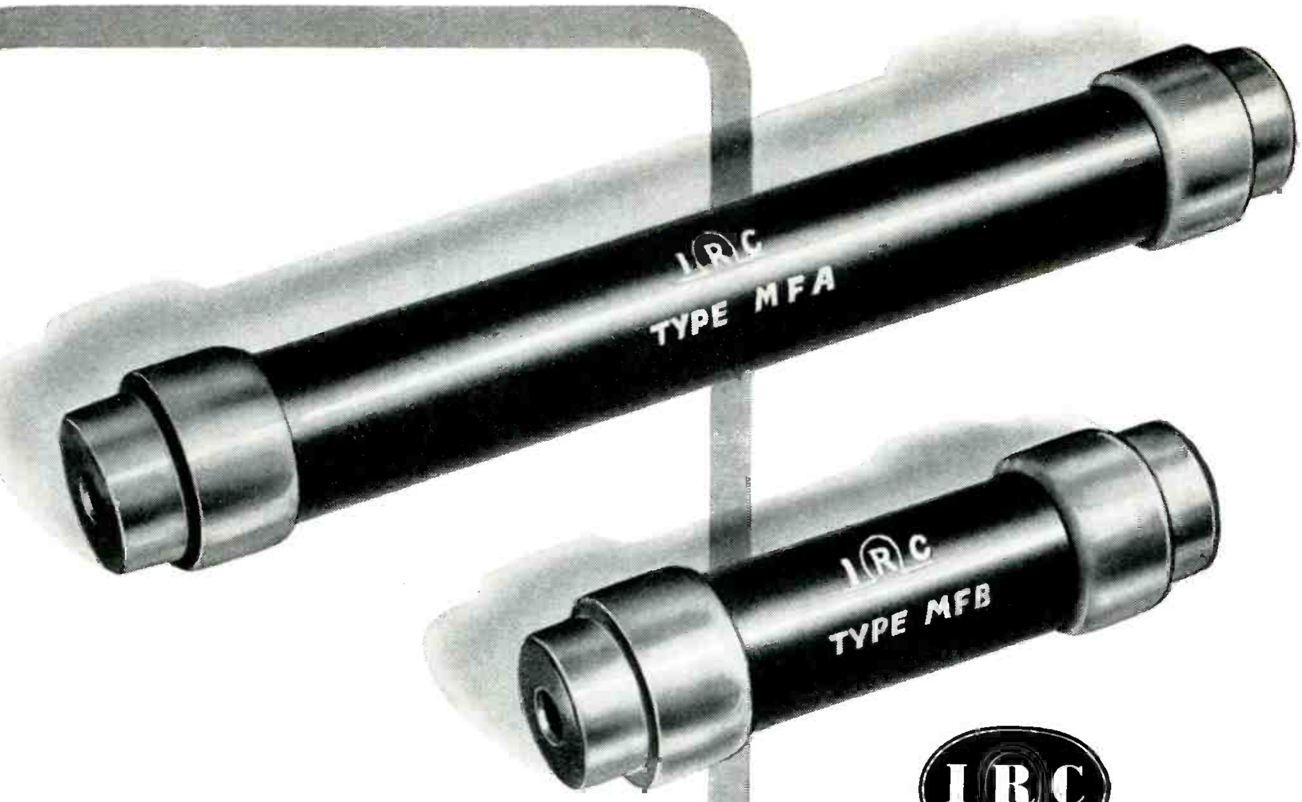
The Southington Hardware Mfg. Co., Southington, Conn.
Whitney Screw Corp., Nashua, N. H.



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IRC

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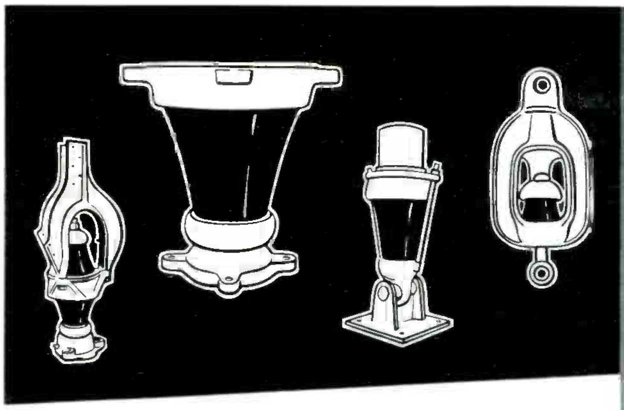

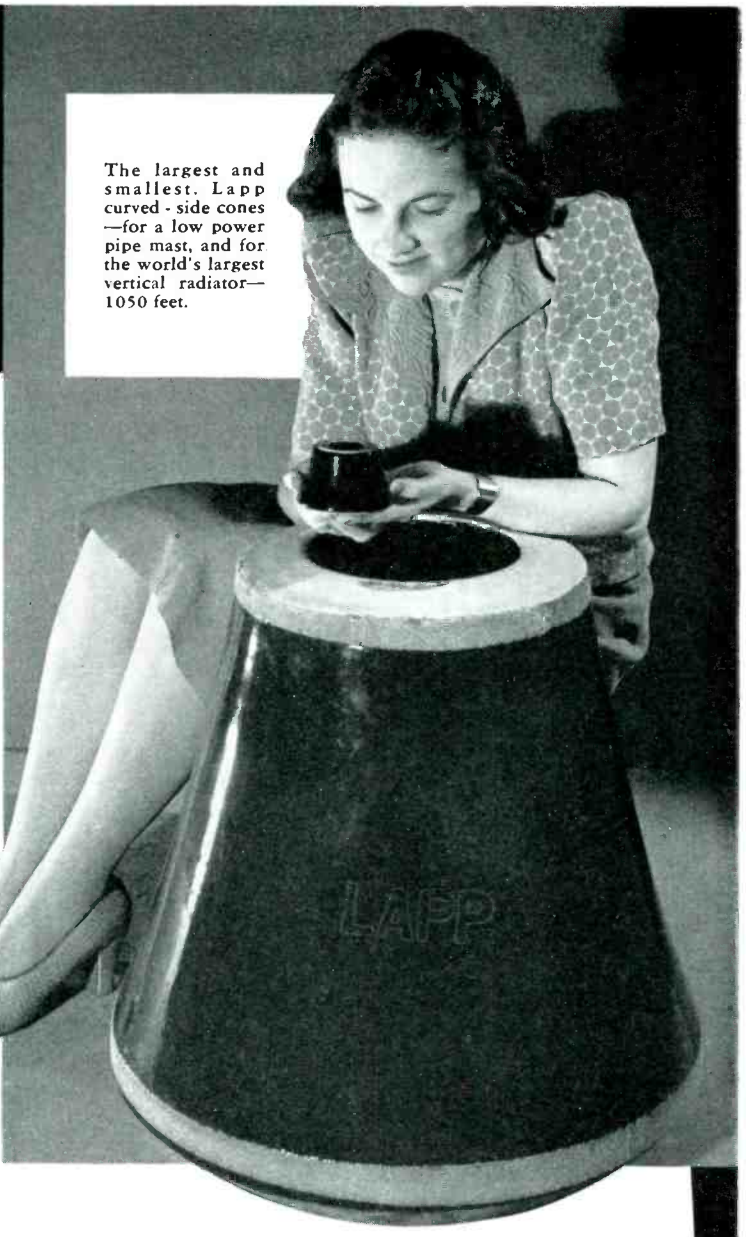

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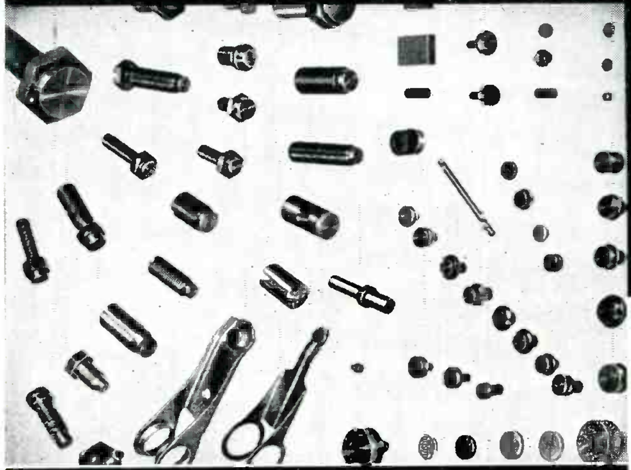
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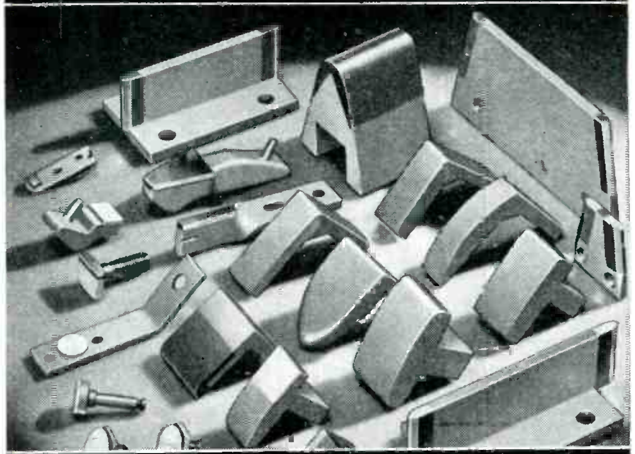
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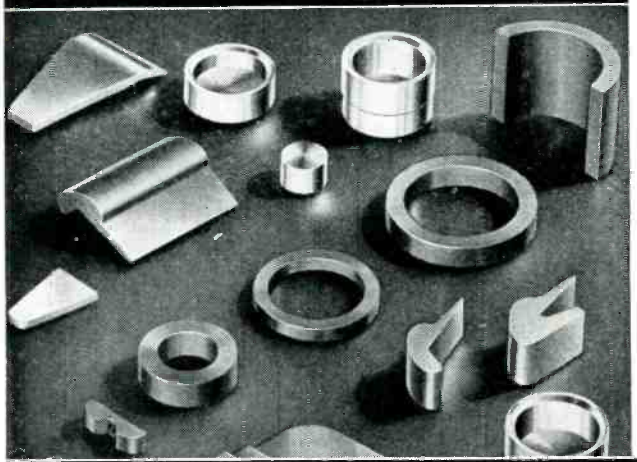
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ELECTRONICS....KEITH HENNEY *Editor*....AUGUST, 1941

CROSS TALK

▶ **CHEAT** . . . The radio industry has never been any rose when it came to telling the absolute and complete truth to prospective purchasers of receivers. There is no purpose, perhaps, in calling any one's attention to faults or disadvantages in one's product—but it is equally as dangerous to brag about advantages that do not exist. Frequency modulation is a case at point.

A radio receiver into which an external f-m converter can be plugged will not receive f-m programs any more than a radio receiver with a phonojack will play records. Something else is necessary. Any claims, implied or explicit, to the contrary merely react upon the poor dealer who sold the poor customer the poor set.

Now, it is our idea that f.m. has the following advantages over a.m. It is wide band which means high tone fidelity. It is free from man-made and natural static. It is free from inter-station interference. The public has come to believe f.m. represents these advantages. Anything less than these advantages will come close to fraud in the minds of the public.

The transmitters and the allocations in the ether will provide these advantages—but it will be the receiver people who will throw them away, if they are lost. The wide-band feature requires a good amplifier and a good speaker. Anything less will debauch one advantage. Poor antenna installations naturally will ruin another advantage. No limiter or poor limiter will ruin still a third advantage—the ability to get interference-free signals from transmitters so spaced in the ether that the 2-1 ratio between desired and undesired signal strength may be utilized.

All of these advantages taken together mean f.m. to the public and the buyer of a set which does not possess all of them gets stuck.

Incidentally, signals from Zenith's Chicago f-m transmitter were heard with considerable amazement and much listening pleasure by one of ELECTRONICS' editors recently in New Jersey; and contrary to our recommendations an editor of *Business Week* took an f-m receiver to his summer-place way down in Pennsylvania. He is delighted—gets Paxton like a house afire, and Alpine like a ton of bricks. We, on Long Island, enjoy the Yankee Network news and weather bulletins from Paxton without a hitch. Who said f.m. was only good for short distances?

▶ **HELP** . . . In the first issue of ELECTRONICS, long ago, it was stated that the paper hoped to become a campfire for council and a meeting ground for a mutual exchange of helpful information among its readers. It seems to us that if ever our hope comes true, the time is at hand. Lack of materials, of man power, of time are going to work very severe hardships on many an electronics manufacturer unless engineers find ways to save these basic building blocks.

ELECTRONICS will be most happy to be the meeting ground in which one engineer can tell all the others how he has saved time, effort, materials, or money or has made an existing piece of equipment last longer, or has found a substitute for material now needed more urgently for national defense than for home or auto radios.

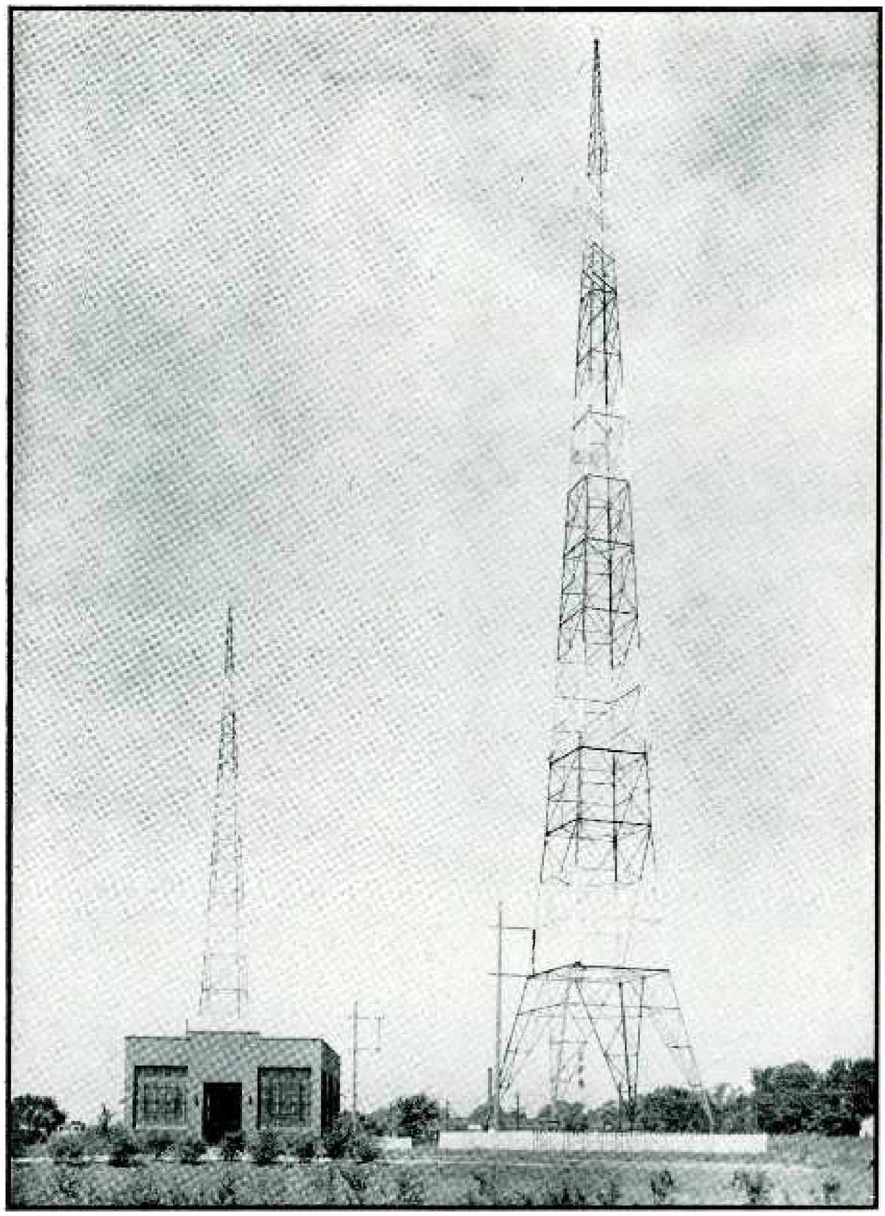
▶ **84** . . . We are happy to announce that Nikola Tesla has just celebrated quietly and happily his 84th birthday. According to the papers he is working on a new development; refuses to talk.

▶ **SQUEAL** . . . Announcement by Muzak, city-wide distributor of restaurant music by wire in New York City that a license had been secured to erect a 117 Mc 1000-watt transmitter at 5th Avenue and 42nd Street for purposes of broadcasting advertising-free music to renters of receivers is a most interesting invitation to watch an experiment. The signals will have a squeal on them so that the non-Muzak receivers cannot receive the music. This will probably excite a still-hunt for a method of circumventing the squeal—but anyhow the experiment is worth watching. Needless to say the transmitter will be frequency modulated.

KCMO's

By L. C. SIGMON

KCMO Broadcasting Co
Kansas City, Mo.



KCMO's 5-kw transmitter plant showing directional antenna array

THE widespread interest shown in 5-kw installations using directional antennas for increased power operation has prompted the following description of KCMO's transmitting plant and unique directional antenna array.

The first problem encountered was the selection of a suitable transmitter site which had to be located due east of downtown Kansas City, Mo., in order to give proper protection to four other stations operating on the same frequency. The transmitter site had to be located within narrow limits. It was necessary that at least seven acres be available, preferably on open, level ground to minimize the cost of grading and removing any old buildings. The site selected had to be sufficiently distant from Kansas City's metropolitan area so that the 250 mv/m contour would not contain more than 1 percent of the total metropolitan population and yet a signal greater than 25 mv/m was required in the downtown business district. A field intensity survey of a site near Kansas City's industrial district indicated satisfactory ground conductivity, and in addition it was near power and telephone facilities and clear of airlanes.

Installation

In the design of the complete installation the main purpose was to design as efficient an installation as possible within a reasonable cost. All plans for the construction of the transmitting plant, antenna, and ground system were designed and drawn by the KCMO Engineering Department, which also supervised the construction. The type of construction used, made it unnecessary to have a basement. Waterproof troughs in the flooring were used to carry the power wires, transmission lines, etc. These troughs were lined with No. 18 gauge copper which was also used for the main ground system in the transmitting building. The troughs were built in the reinforced concrete floor and covered over with removable steel plates. The floor of the entire transmitting building is covered with inlaid linoleum, so arranged that the steel plates can be removed without taking up the linoleum. The transmitting building is heated by gas steam radiators next to the side walls thereby simplifying the heating problem. The 5000-watt water-cooling system is arranged so that a certain amount of heat can be reflected into the transmitting plant when needed. This helps reduce the heating cost. Large windows completely enclose the main transmitting room giving excellent daytime lighting. Although the transmitting building measures only 30 feet by 20 feet, it is sufficiently large for convenient operation. Most of the furniture such as chairs, desks, etc., is of metal construction. Special precautions were taken to ground all metal objects in the transmitter building. A 3-inch, No. 22 gauge copper strip enclosed in the brick walls was used for grounding the metal objects, and all connections were welded.

The transmitter operating desk is directly in front of the transmitter with its speech and monitoring equipment. The monitoring loud speaker is mounted on the ceiling three feet in front of the operating

5-KW TRANSMITTER

Problems encountered in installing a modern broadcasting station. A three-element, directive antenna for operation on 5-kw which can be switched to a one-element, non-directional antenna working at 1-kw is discussed

desk. Mounted on the operating desk is the master control panel containing four remote r-f antenna meters, overmodulation lamps, gain controls, vu meter and other additional switches. Two relay cabinets containing speech equipment, frequency monitor, modulation monitor, distortion meter, audio oscillator, etc., are mounted one on either side of the transmitter.

Directional Antenna Design

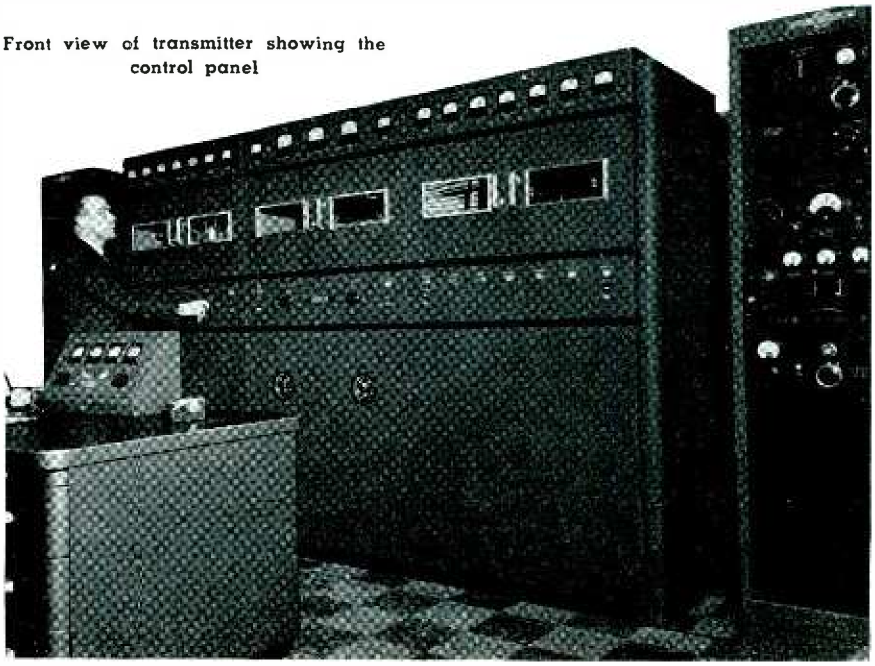
A great deal of consideration was given to the design of the antennas and their ground system for maximum radiation efficiency. Approximately twenty-four miles of No. 14 gauge copper wire was plowed into the ground at a depth of six to eight inches. The wire is spaced every two degrees and extends out 170 feet or one-quarter wavelength. The ground wires running between towers are spaced approximately one foot apart, and each wire is welded to a three-inch copper strip running down the center from tower to tower. This strip extends to the transmitting plant and is connected to its main ground system. The outer ends of all ground wires are connected together, and soldered to five-foot copper ground rods driven into the ground at regular intervals. Under each tower, is a 34-foot galvanized screen netting, placed on top of crushed rock, and connected to the main ground system. Galvanized netting is used instead of copper netting because it has nearly the same efficiency at the lower frequencies and affords a considerable saving in cost.

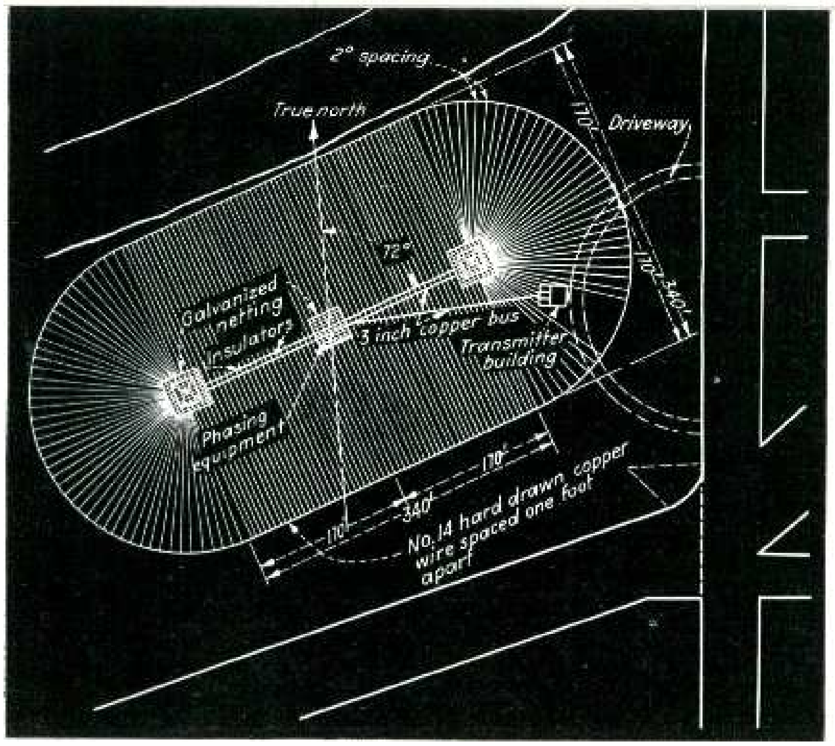
The line of towers for the directional array is 72 degrees clockwise from true north. The location of the line of towers was quite critical, and it was necessary to take a solar reading during the day on the sun. As a double check, a reading was taken on the North Star. It was rather interesting to find that these two readings checked within a half-inch in 300 feet.

The center antenna of the directional array is a copper cable suspended vertically halfway between the two towers. Insulators are inserted at frequent intervals in the messenger cable which is fastened permanently to the top of the west tower, and connected to counterweights at the east tower. Each element of the antenna system is spaced one-quarter of a wavelength apart. All three elements of the directional array are used after local sunset. During the daytime hours when operation is non-directional, power is fed to the center antenna only. It was first thought that it would be necessary to detune the two end antennas supporting the messenger cable to secure a non-directional pattern, but it was found that it was only necessary to ground the two end antennas. This simplified the circuit for switching from directional to non-directional operation. Under the center antenna two antenna tuning units are mounted. One houses the antenna coupling unit for non-directional operation. The other houses the directional antenna terminating and relay equipment. Only one terminating unit is necessary at each end antenna. All antenna units contain the necessary relays in making the change from directional to non-directional operation or vice versa.

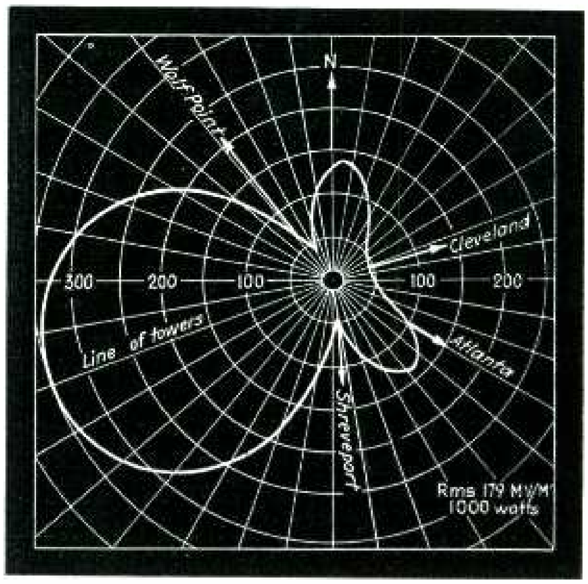
Transmission Lines

Two transmission lines feed the antenna system. One is a $\frac{7}{8}$-inch concentric line buried approximately $3\frac{1}{2}$ feet in the ground, which is below the frost level in this section of the country. It goes directly into the brick building located ten feet south of the center antenna. This building contains all power division and phasing units for the directional array. The transmission lines feeding the two end antennas and center antenna for directional operation are


Front view of transmitter showing the control panel



The ground system, consisting of 24 miles of No. 14 copper wire buried 8 inches in the ground



Field pattern of the directional antenna system indicating directions to protected stations

also ⅞-in concentric lines. These may be used either for feeding the center antenna power for directional or non-directional operation in case of emergency. The change-over is made by means of r-f relays. The transmission lines are filled with dry nitrogen gas at a pressure of 35 pounds per square inch to increase the breakdown safety factor as well as to prevent condensation forming within the lines. The ⅞-in transmission line running from the transmitting house to the center phasing house which is nearly 300 feet long has been buried over a year and so far it has not been necessary to add additional gas. It has been necessary to add some gas to the shorter lines.

Although the ⅞-inch transmission line is capable of handling 5000 watts, it was thought advisable as a safety measure to add a second line which is a 1¼-inch concentric line constructed above ground. This line is mounted on grooved posts and is anchored permanently between the transmitting plant and center antenna allowing expansion and contraction to occur from this point. A special anchor section was installed to prevent the inner-conductor from creeping with respect to the outer sleeve. The design of the line is such that it may expand or contract 1½ inches on either side of its anchor. Over the top of the transmission line a guard is mounted which serves three purposes. First, it offers protection from the direct heat rays of the sun; second, the line is protected from rain which in the case of a thunder shower on a hot day would cause the line to contract rapidly; and third, the guard serves to protect the line against objects that might accidentally come in contact with it. The transmission line is easily accessible, it being necessary only to remove the screws that hold the boards in place. This transmission line is also filled with dry nitrogen gas, but has not held the gas as well as the buried line apparently because the line was assembled in zero weather, and it was almost impossible to get a good sweated joint. The large concentric transmission line is being used to feed power from the 5000-watt or the 1000-watt amplifier in case of emergency by means of a relay to the non-directional antenna.

The safety factor of all transmission lines is such that presence of gas is not required for insulation. However, it does increase the safety factor. Every precaution has been taken in the design of the antenna system to protect it from lightning and static electricity. All r-f meters that are not read continuously are shorted out by means of a low resistance shunting switch. These switches have undoubtedly saved a number of meters during electrical storms.

A Western Electric 2A phase monitor was found to be most helpful in making the initial directional antenna adjustments. With this instrument it is possible by means of sampling loops mounted on each tower to read the current ratio and phase of any antenna combination. Where all phasing and power divided networks are centrally located, it is a simple matter to make directional antenna adjustments.

TABLE I—Operation of Directional Antenna

Transmitter amplifier load	490	ma
Line current at transmitter	4.0	amp
Feeder line current from transmitter	3.98	amp
1. Feeder line current to antenna (West)	4.18	amp
2. Feeder line current to antenna (Center)	1.44	amp
3. Feeder line current to antenna (East)	4.02	amp
1. Antenna base current (West)	1.01	amp
2. Antenna base current (Center)	2.32	amp
3. Antenna base current (East)	2.53	amp
1. Phase monitor loop current	150	ma
2. Phase monitor loop current	171	ma
3. Phase monitor loop current	150	ma
1. Antenna phase	0°	
2. Antenna phase	154½°	
3. Antenna phase	289°	

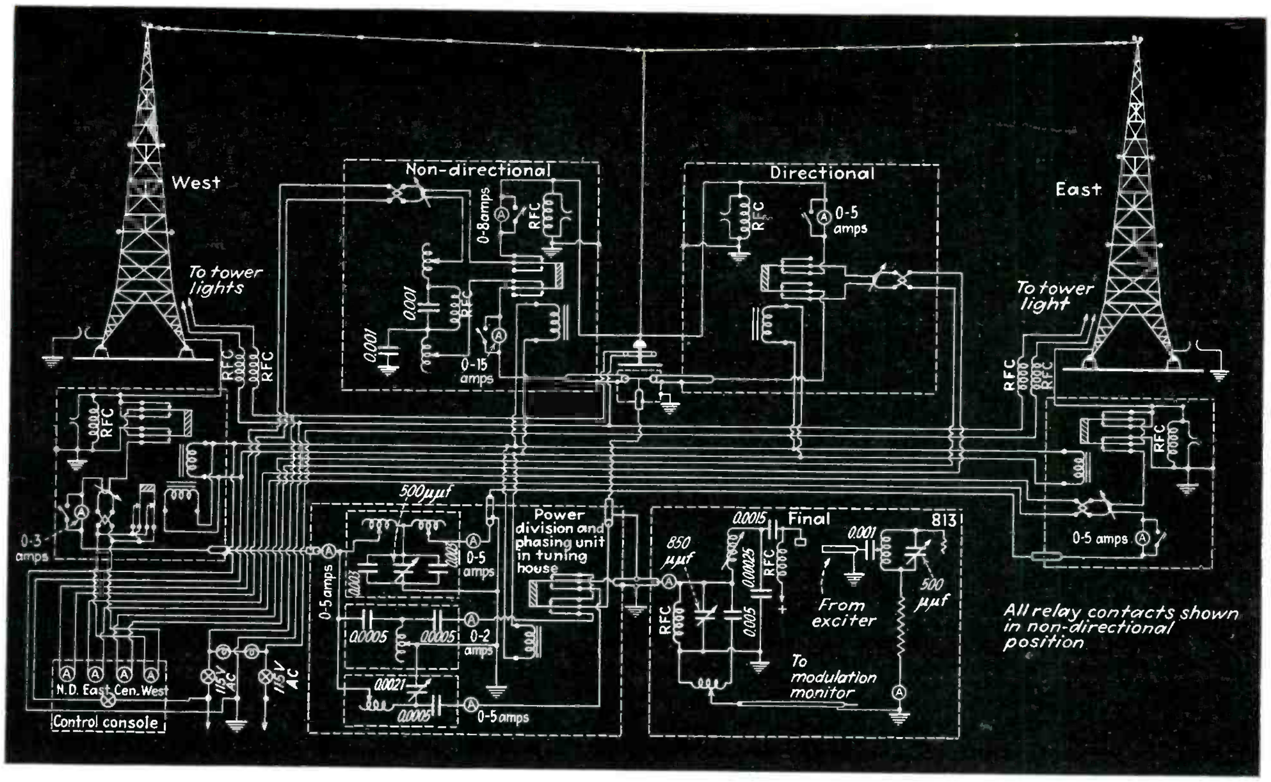
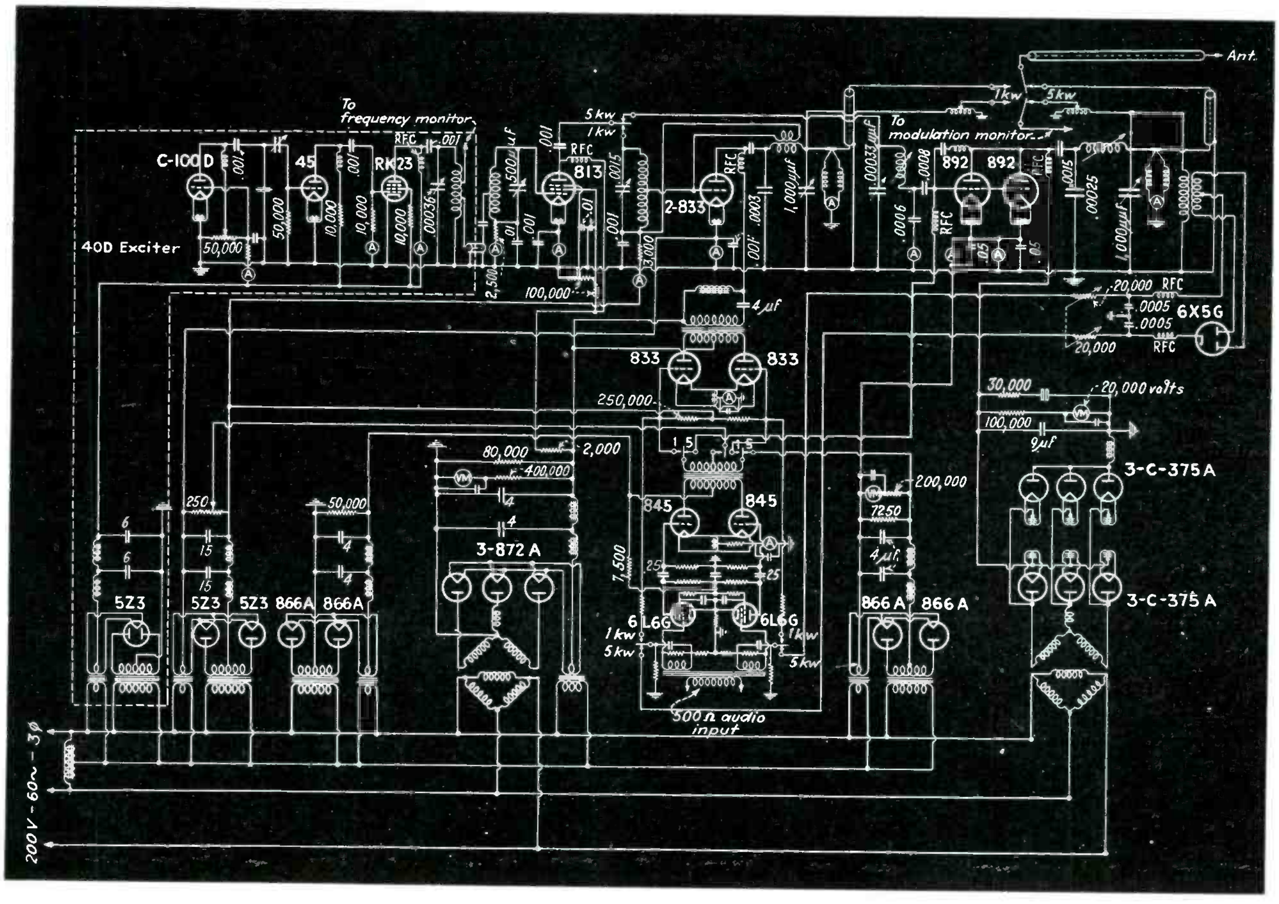


Diagram of the complete directional antenna system, including antenna phasing circuits

The Transmitter

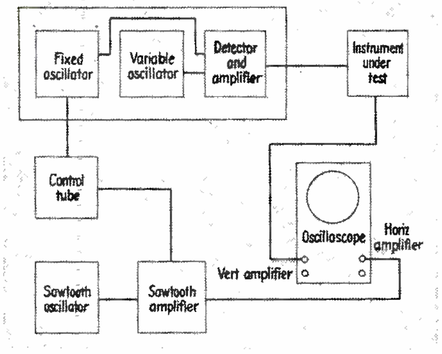
KCMO's transmitter is a Collins 21DA which is designed for either 1000- or 5000-watt operation. An interesting feature of this transmitter is the automatic return to 1000 watts in case of overloads in the 5000-watt amplifier. When the transmitter is operating in the 1000-watt position, the 5000-watt amplifier and 15,000-volt rectifier are completely idle making them accessible for maintenance. The 5000-watt amplifier is driven by the 813 r-f amplifier tube which also drives the two 833 r-f tubes for 1000-watt operation. The two 833 r-f tubes are high level modulated by two 833 tubes in Class B operation. The 892 water-cooled tubes in the 5000-watt amplifier are grid modulated by the 845 tubes that act as audio drivers to the 833 modulators when operating on 1000 watts. All power supplied to the transmitter is taken from a General Electric voltage regulator which maintains very close line voltage regulation. The transmitter also incorporates feedback circuits for both the 1000- and 5000-watt transmitter circuits, thereby reducing the distortion. The frequency response of both transmitters is within plus or minus 1½ db from 30 to 10,000 cps. This installation is in its second year of operation and has proven very satisfactory in every respect.

Circuit diagram of the transmitter showing switching arrangement for changing from 5-kw to 1-kw operation



Frequency Response Curve Tracer

The frequency of an audio generator is varied logarithmically from the lowest to the highest frequency and at the same time a logarithmic sweep voltage is applied to a cathode ray oscilloscope. The output of the generator is fed to the device under test and its frequency response curve appears on the screen of the oscilloscope



Block diagram of curve tracer used in obtaining the frequency response curves of audio equipment

By S. F. CARLISLE, Jr. and A. B. MUNDEL; *Sonotone Corp.*

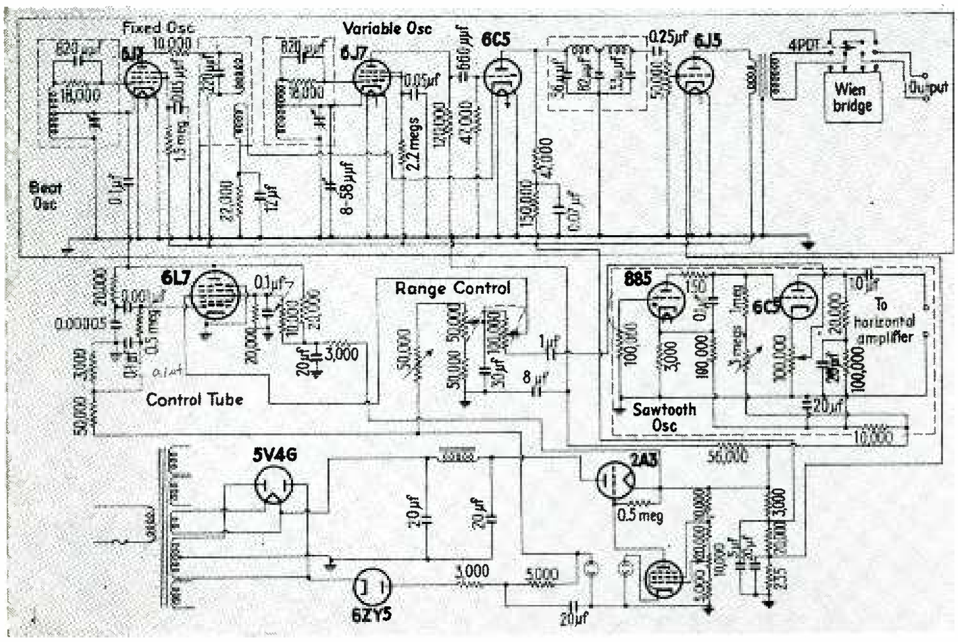
ONE of the most satisfactory methods of checking audio amplifiers and acoustical apparatus is that of measuring their gain throughout the frequency range for which they are designed. The instrument described in this article was designed primarily to facilitate this work in production, but has also been found very useful in laboratory work. A number of methods have been devised to examine and record the response characteristics of electrical and acoustical equipment. The simplest method is the point by point plotting of the output versus frequency. This, although accurate, is laborious. Another recording system uses a drum mechanically coupled to an audio oscillator with a recording stylus to record the output on coordinate paper carried on the drum. Systems have also been devised to slowly trace a frequency response on a special high-persistence cathode-ray tube screen.

In contrast to these methods, the instrument described here gives a continuous curve of the response characteristic on a standard cathode ray oscilloscope screen. By this means the output of devices having varying output over their frequency ranges can be continuously observed with greater rapidity than by other means.

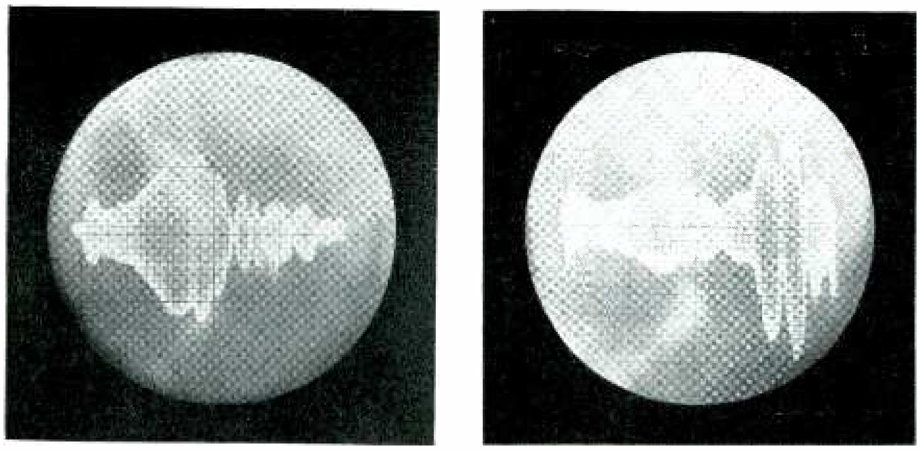
The main parts of this device are a saw-tooth oscillator and a beat frequency oscillator. The saw-tooth oscillator, used at a frequency of approximately thirty cps, supplies a linear sweep voltage to a frequency control tube and simultaneously moves the cathode ray beam across the horizontal axis. The beat frequency oscillator is arranged to have its variable oscillator (which is normally varied at the control of the operator) left unchanged and adaptable to its usual purpose. The fixed oscillator is frequency modulated at the frequency of the saw-tooth oscillator by the action of the control tubes. Thus, a variable audio frequency wave is generated.

The setting of the variable oscillator establishes the lowest frequency from which the audio output can sweep, and the sweep range is determined by the setting of the control tube and auxiliary circuits. Thus, the oscilloscope screen is not limited to a picture starting at zero frequency, but any portion of the audio range can be instantly segregated for examination.

This change of frequency of the fixed oscillator is accomplished in a manner analogous to that used in automatic frequency controlled superheterodyne receivers. The value of the received signal alters the grid potential of a control tube, which in turn is coupled to the oscillating circuit in such a manner as to change its frequency slightly and thereby tune the set more accurately to the



Circuit diagram of the curve tracer. The 6L7 control tube frequency modulates the fixed oscillator to provide a varying frequency



Typical frequency response patterns of hearing aid amplifiers. The pattern on the left indicates greater response at the low frequencies and the other indicates greater response at higher frequencies

signal being received. In both systems the control tube plate circuit is connected in parallel with the oscillator coil. The effective inductance of this coil is changed by altering the dynamic tube characteristic through the action of the control grid. The amount of control is established by the value of the bias potential applied to this grid.

The control tube in this system generates out of phase currents in its plate circuit by the action of a phase changing network connected between the plate and a grid. The amount of inductive control is varied by applying the discharges of the saw-tooth oscillator through suitable range control circuits. If these functions are all arranged for control by one grid, undesirable interaction occurs between the circuits having the different functions. A pentagrid tube (6L7) was therefore used. In this tube a screen separates the two control grids and thus eliminates interaction between them. The range of frequency change is controlled by varying the mutual conductance of the control tube. This is accomplished by varying the bias of the first grid, which has a remote cutoff characteristic. The instantaneous frequency is determined by the out of phase signal fed back from the oscillator tank circuit through the phase-shift network to the third grid. If the tube is biased to cutoff, it causes no change in the tank circuit inductance. Reducing the bias of the control tube's first grid increases its mutual conductance, thereby shunting the inductance of the coil with an apparent inductance and raising the frequency of the fixed oscillator.

It is usually desirable to have a logarithmic spread of the frequency spectrum on the cathode ray screen. This can be obtained by varying the bias of the control tube in linear saw-tooth fashion and using a tube whose mutual conductance changes substantially logarithmically with grid bias. The output frequency of the audio oscillator approximates a straight line function of the mutual conductance. The frequency will then vary logarithmically with time. By using the same saw-tooth wave as the oscilloscope sweep we obtain logarithmic spread of frequency on the oscilloscope screen.

The output of the signal generator will rise from a low frequency to a higher frequency if the first grid is biased to cutoff and the phase of the sweep voltage applied to the first grid of the control tube is so chosen that it rises from a negative to a positive value. By changing the tube parameters and circuit constants, the system can be varied from a logarithmic to a nearly linear frequency spread on the oscilloscope. In order to secure a good frequency range, a beat oscillator was chosen whose tank circuit frequency could be widely varied with only a small change in inductance. Uniform audio frequency response characteristics are also desirable.

The range of audio frequency sweep is controlled by varying the alternating voltage on the first grid. This voltage has a saw-tooth wave form going positive and negative about a biasing value equal to half of the peak value subtracted from the cut off voltage. This biasing potential must be varied in order to keep the minimum frequency of the fixed oscillator constant and occurring simultaneously with the peak of the saw-tooth wave. A multiple potentiometer system was developed, by which the bias of the first grid is varied in suitable proportion to the magnitude of saw-tooth potential applied. The range of sweep may be varied from very low values to fifteen thousand cps.

The frequency of the saw-tooth oscillator in the instrument described is approximately thirty cps. This frequency gives a good clean picture on the standard type medium persistence screen cathode ray tube. With this frequency, the low usable limit of the instrument is approximately a hundred cps. In order to examine frequencies of lower value, a slower sweep frequency can be provided for use with a long persistence cathode ray screen.

The calibration of the instrument, dynamically, can be accomplished easily by the use of a Wien Bridge connected between the output of the signal generator and the vertical plates of the cathode ray tube. The bridge can be calibrated at fixed frequencies, and when it is placed in the output circuit will show a sharp narrow V notch point at the frequency points to be determined. With the range control set to sweep from zero to 10,000 cps, the mid-point of the cathode ray screen was found to be 1,000 cps, indicating a very close approximation to a logarithmic frequency scale.

The modulator is provided with two output connections. One set of connections is made directly to the horizontal amplifier terminals of the oscilloscope. The other set of connections, provided with taps at various impedances, supplies the varying audio signal. This is connected to the amplifier under test, the output of which is connected to the vertical amplifier of the cathode ray oscilloscope.

This instrument has been found useful for testing all types of electrical and acoustical instruments, both in the laboratory and on the production test floor. The testing of microphones, receivers, filters, amplifiers, etc. is rapid and accurate. The instrument can be used for comparison of the product with a standard by a single switching system. One instrument has sufficient power to operate several test positions, each using a separate oscilloscope.

PHOTOGRAPHIC ANALYSIS OF TELEVISION IMAGES

MEASUREMENT techniques in television engineering have thus far been largely restricted to the electrical performance of the system. Comparatively little attention has been paid to measuring the visual qualities of the reproduced image, except as they are revealed in a standard test chart. The test chart, however, does not reveal the performance of the system when engaged in its primary function of reproducing a program. To study the changing scenes of a program some means of recording a single frame must be available. This article describes a photographic technique for studying the quality of television program images.

The Equipment Used

A miniature camera (Contax I) was chosen because lenses of the necessary high speed are available economically (comparatively) for such cameras and because many exposures may be made and processed conveniently under identical conditions. The basic lens used is a Zeiss Sonnar 5-cm, *f*/1.5, fitted with auxiliary lenses (Proxar 1 and Proxar 2) for reducing the lens-to-object distance to a minimum of 8 inches.

A rigid copying stand was constructed to fit directly over the picture tube of the television receiver.[1] A ground-glass focusing screen and auxiliary magnifier were used to bring the image into sharp focus on the film. For standardizing the density range when measuring contrast, a miniature step tablet (calibrated transparent gray scale) was employed within the camera, in direct contact with the film. A standard exposure meter (Weston 715) was used for direct measurement of the fluorescent light.

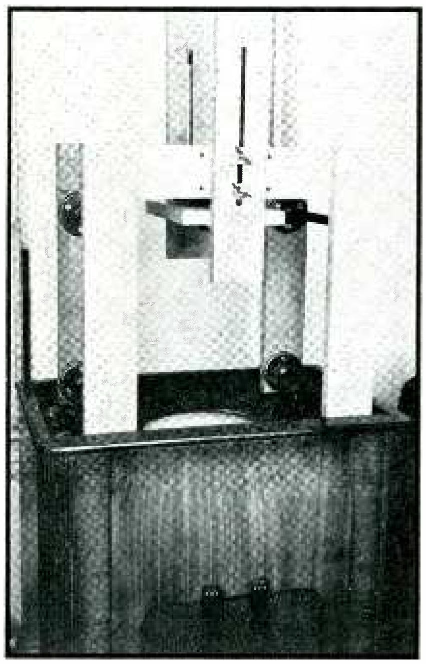


Fig. 1—The copying stand in place over the picture tube. The mirror has been removed and the connections to the vertical scanning coil reversed to simulate the reversing effect of the mirror

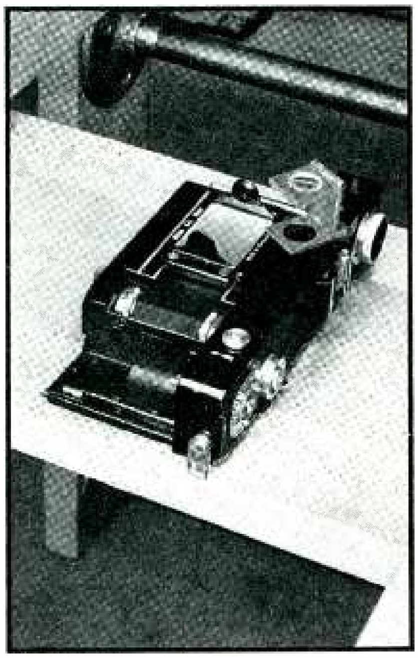


Fig. 2—The Contax in the focusing position with back removed

The electrical equipment consisted of a 0–100 μa microammeter for measuring the second anode current (beam current) of the picture tube and, with a calibrated resistance, for measuring the second anode voltage. A direct-coupled cathode-ray oscilloscope was used to measure the peak-to-peak values of the signal voltage applied to the picture tube grid.

For processing the film, tank development was used. In general the instructions of the film manufacturer[2] were closely followed as to temperature and time of development, agitation, etc. An Eastman Capstaff-Purdy densitometer was used in measuring the densities of the negatives.

All of the images photographed were broadcast by the National Broadcasting Company from Station W2XBS, New York, at 441 lines, 30 frames per second, on the 50–56 Mc channel during the period April 11 to May 11, 1941. More than 500 exposures were made during this period. Photographs of the equipment are shown in Figs. 1 and 2.

Basic Exposure Data

Table I shows the results of a number of exposures made under standardized conditions with different film emulsions. The data were taken as follows: The fluorescent screen was uniformly illuminated by reducing the contrast control until no image was visible, and adjusting the brightness control so that beam currents of 1, 3, 9, 27, 81, and 243 μa were obtained in succession. Beam currents were taken in logarithmic progression, since the density is roughly proportional to the logarithm of the beam current.

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(1). The receiver is that described by the author in ELECTRONICS, September, 1939, page 16: "A Television Receiver for the Home." The receiver employs a nine-inch 9AP4 picture tube, has an effective video range of 3.5 Mc. and is capable of developing about 40 volts peak-to-peak on the picture tube grid.

(2.) "Kodak Films—A Data Book on Negative Materials" Eastman Kodak Company, Rochester, N. Y., 1939.

Improvements in television, within the newly established standards, depend largely on studies of the visual quality of the images. This paper describes a technique of using photography to study line structure, image contrast, brightness, and noise effects

By DONALD G. FINK

Managing Editor (On Leave), Electronics

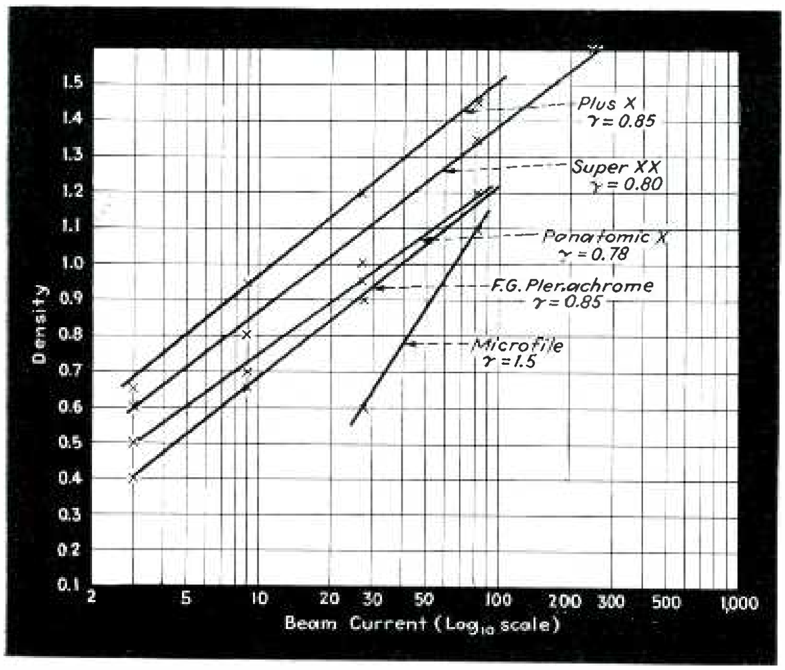


Fig. 3—Determination of the gamma of the film by plotting density against the logarithm of the beam current. Since the beam current per unit area is proportional to the exposure, this plot is similar to the usual *D*-log E characteristic for photographic materials

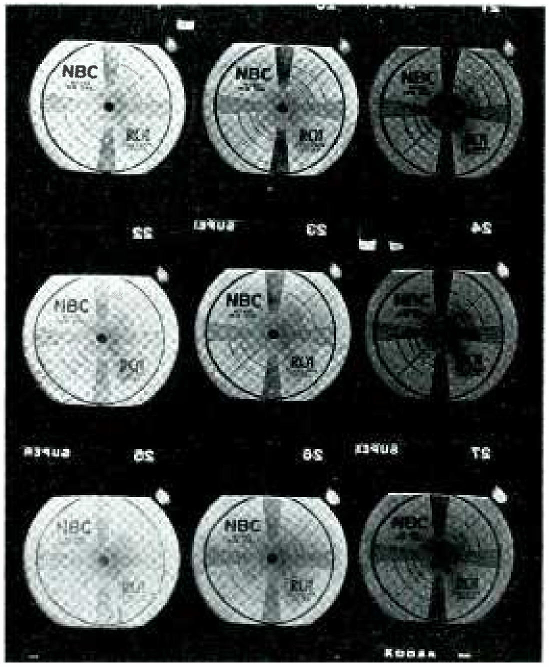


Fig. 4—Effect of brightness and contrast controls on image appearance. Brightness control varied from left to right with beam currents of 50, 25, and 12.5 microamperes, respectively. From top to bottom the video signal voltages (affecting contrast) are 28.3, 17.4 and 13.0 volts

In general the 1 μa setting gave a barely visible scanning pattern when viewed in total darkness, whereas the 243 μa setting was considerably brighter than the brightest highlights of the image as customarily used in viewing programs. The average brightness employed in viewing programs corresponds to the range between the 9 μa and the 27 μa settings.

The exposed film was developed in a tank under the conditions specified in Table I. The values of density on each negative were measured with the densitometer, taking care to measure the same portion of each frame, since the scanning pattern was not uniformly bright over the screen surface.

Table I is in no sense a general table of exposure-density information, since the values given are based on a particular sample of the P4 phosphor. Wide variations in the luminous conversion efficiency of this phosphor, as well as its spectral output, arises in processing the tube during manufacture, and these quantities also vary with the age of the tube. Moreover the table does not apply to other phosphors which generally have quite different luminous efficiencies and spectral outputs. Finally, the table is not based on a sufficient number of different observations to have general significance. Nevertheless it will serve as a guide in selecting initial test exposures in similar investigations.

The values of exposure given in the table for Super X, Panatomic X, and Plus X are those found satisfactory in this investigation for general photography of television program images. The highlight density with such exposures ranged from 1.2 to 1.4 corresponding to a beam current (at 6600 volts) of 75 to 100 μa. The shadow density was close to the base density of the film, corresponding to beam currents below 5 μa.

The table may be used as a guide when the beam current, second anode voltage, scanning pattern area, shutter speed or aperture have values other than those given in the table. The following relationships indicate the necessary conversions.

1. The photographic exposure (in say, meter-candle-seconds) is directly proportional to:
   - The shutter time.
   - The beam current, for a given second anode voltage.
   - The second anode voltage, for a given beam current.
2. The photographic exposure is inversely proportional to:
   - The square of the numerical lens aperture (*f*-number).
   - The area of the scanning pattern.
3. The negative density, over the straight portion of the H. and D. curve is a linear function of the logarithm of the exposure.

In summary:

$$\text{Negative Density} = K_1 \log_{10} \frac{t_s i_{b2} e_{b2}}{n^2 A_p} + K_2$$

where

t_s = shutter time
i_{b2} = beam current
e_{b2} = second anode voltage
n = numercial aperture of the lens (f—number)
A_p = area of the scanning pattern, and
K_1, K_2 are constants.

The maximum negative density, for a given exposure, may be increased by employing a more active developer, increasing the development time, and increasing the temperature of the developer, but graininess, fog, and danger of spotting are all thereby increased. Negative intensification may also be used to increase the density after processing.

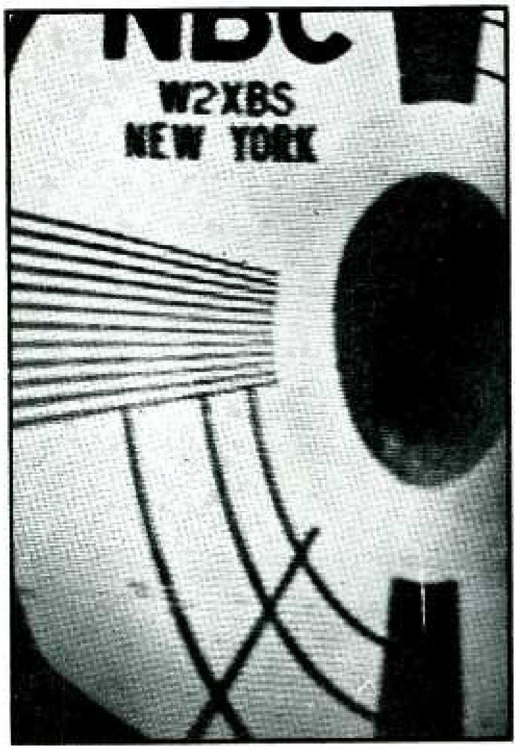


Fig. 5—Properly interlaced line structure. Note the appearance of the converging lines in the resolution wedge. Taken at 8 inches from end of picture tube

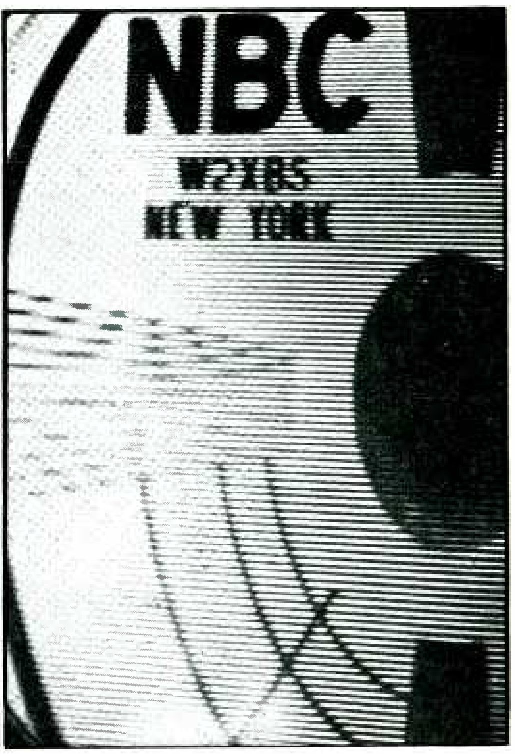


Fig. 6—Pairing of interlace, artificially induced by improper setting of vertical sync control. Note how loss of every other line impairs definition

Determination of Program-Image Brightness Ratios

The measurement of the contrast and gradation of program images, as distinguished from test charts, has been almost wholly neglected up to the present. The only means known to the author of measuring these quantities under program conditions is photography applied under standardized conditions. A major purpose of this study was to develop a technique of measuring such program-image contrast ranges. Two methods were investigated.

The first method, the one least subject to experimental error, involves the compilation of the information shown in Table I. The method consists in making five or six exposures to the uniformly-illuminated scanning pattern, each at a different value of beam current. The corresponding negative densities are measured with a densitometer, and a plot made between the logarithm of the beam current and the density. Since the logarithm of the photographic exposure is proportional to the logarithm of the beam current (assuming constant second anode voltage), this plot is a sensitometric plot (H. and D. curve) of the film characteristics. The slope of the straight-line portion of the curve is the gamma of the film. Figure 3 shows the determination of the gamma of the films shown in Table I. The films (except Microfile) were developed to an indicated gamma of 0.8, according to the manufacturer's instructions. The actual values of gamma, measured by the above method, range from 0.78 to 0.85.

Once the gamma has been determined for a given roll of film, it is possible to measure the contrast (or brightness ratio) present in any frame taken on the same roll of frame, since the emulsion and processing conditions are sensibly constant for that particular roll. The advantage of miniature photography in this method is apparent, since a 36-exposure roll permits taking about 30 program images, leaving the remaining 6 for calibration in accordance with the above procedure.

The contrast of a screen image

TABLE I

NEGATIVE DENSITIES RESULTING FROM EXPOSURE TO FLUORESCENT LIGHT

(White-light Phosphor "P4")

Film, exposure, and processing	Gamma	Densities						
		Base*	Beam Current, μa**					
			1	3	9	27	81	243
Super XX / Exp. 1/25th sec. at f 1.5. Dev. 18 min. in D-76 at 71°F. Agitated 10 sec. every 3 min.	0.8	0.4	0.45	0.60	0.80	1.10	1.35	1.60
Plus X / Exp. 1/10th sec. at f/1.5. Dev. 14 min. in D-76 at 70°F. Agitated 10 sec. every 3 min.	0.85	0.40	0.50	0.65	0.95	1.20	1.45	....
Panatomic X / Exp. 1/10th sec. at f 1.5. Dev. 11 min. in D-76 at 71°F. Agitation 10 sec. every 3 min.	0.78	0.35	0.40	0.50	0.70	0.95	1.20	....
F. G. Plenachrome / Exp. 1/10th sec. at f/1.5. Dev. 15 min. in D-76 at 70°F. Agitation 10 sec. every 3 min.	0.85	0.35	0.35	0.40	0.65	0.90	1.15	....
Microfile / Exp. 1/2 sec. at f/1.5. Dev. 5 min. in D-76 at 71°F. Agitation 5 sec. every 1.25 min.	1.5	0.35	0.35	0.35	0.40	0.60	1.10	....

* Density of the processed film in portions not exposed to light (density due to fog, anti-halation back, etc.).

** At a second anode voltage of 6600 volts, and a scanning pattern area of 42.5 sq inches ($W = 275$ sq cm).

may be expressed by the ratio of the brightness of the brightest portion of the image to the brightness of the darkest portion of the image, as it existed on the screen at the instant the photograph was made.

The brightness ratio of a program image is determined by measuring the density of the most dense portion of the photographic negative, D_m as well as that of the least dense portion, D_o. The difference between these density values is then divided by the gamma value, γ, determined from the calibration. The antilog of the result gives the brightness ratio,

$$\text{Brightness ratio} = \text{Antilog}_{10}\left[(D_m - D_0)/\gamma\right]$$

This method of measuring program-image brightness ratios takes into account all the factors influencing visual contrast, whether they arise from apparatus limitations, signal-to-noise limitations, or optical effects such as halation.

The second method of measuring program-image contrasts is simpler because it can be carried out without measuring the beam current, that is, without the use of electrical measuring equipment. A calibrated step-tablet (transparent gray scale) is used to determine the gamma of the film by taking one exposure of the screen, uniformly illuminated at maximum brilliance, through the gray scale. A simple means of so doing is to place the gray scale in optical contact with the film. The Eastman photographic step tablet No. 1, is suited to the purpose. It has ten steps with increments of approximately 0.15 density unit per step, covering a total density range of 1.5 or a brightness ratio of 31.6 times. This step tablet is of such size that it may be conveniently covered, in contact, by a single frame of miniature 35-mm film.

The method is as follows: The step tablet is inserted in the camera over the frame opening, held in place by a small piece of adhesive tape, and the film threaded into the camera in the usual way, over the tablet. The camera is then set up before the picture tube, which is operated with the contrast control off (no image, uniform illumination) and the brightness control at or near its maximum position. The film is then exposed in the usual way. The camera is then opened in a darkroom (or the film rewound so the camera may be opened in a lighted room) and the step tablet removed. The remaining frames of the roll are then exposed to program images.

After processing, the exposure taken through the step tablet shows gradations of density which are measured with the densitometer. These values of density are plotted against the density of the step-tablet sections. The slope of the straight portion of this curve is the gamma of the film. The scene brightness ratios represented by other frames on the same roll of film are determined, once the gamma value has been measured, by taking the antilog of the density range divided by the gamma.

The success of this second method of gamma calibration depends on the fluorescent screen being uniformly illuminated, at least over a region sufficiently large in area so that the density measurements can be made on the successive steps in the image. The surface of the tube may be explored with an exposure meter to give an approximate indi-

Fig. 7—Image, photographed at 1/100 second, showing the alternate lines of a single interlaced field. Note diamond shaped pattern superimposed on vertical resolution wedges

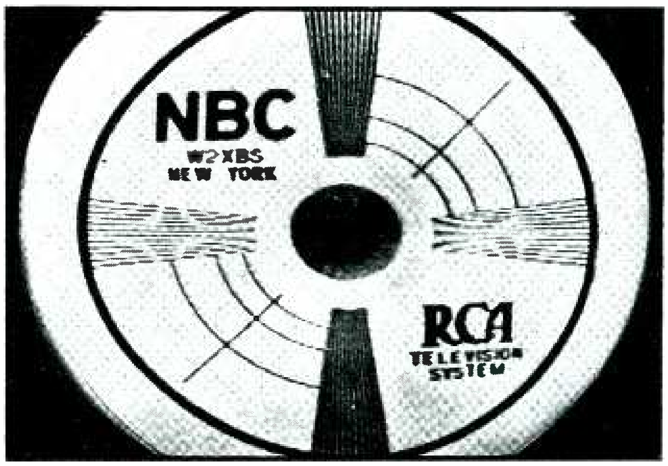


Fig. 9—Effect produced when slit of focal plane shutter moves across lines of the image for exposure times of approximately 1/100 second or less

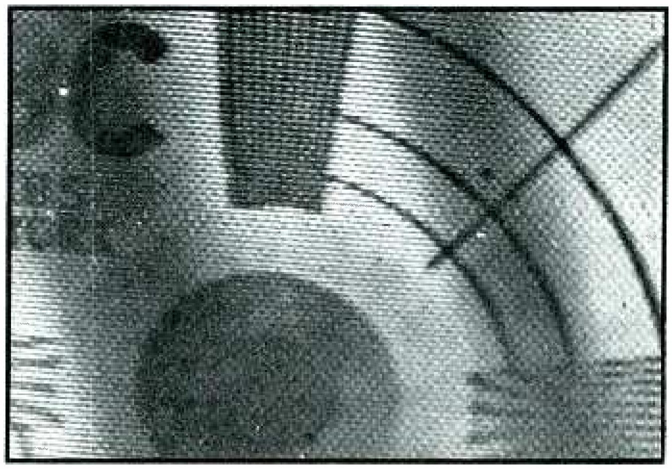


Fig. 8—Effect produced with short exposure time when slit of focal plane shutter moves opposite to progression of lines built up in formation of image

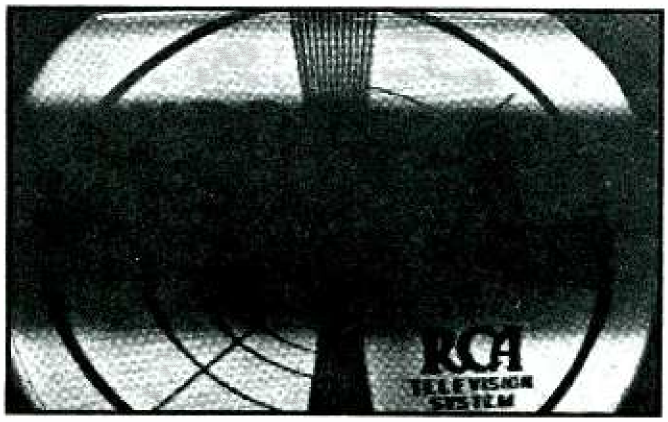


Fig. 10—Reduction of detail and contrast in image of boxer and referee, resulting from severe noise. Area shown is about one-third of the image

cation of the uniformity of illumination. If there is any doubt, the calibration should be carried out by the first method outlined, using successive exposures at known values of beam current.

An example of the measurement of program-image brightness ratios by the second method is shown in Table II. The gamma of this film (subject to error due to non-uniformity of illumination of the picture tube across its surface) was found to be 0.6. The corresponding density ranges, brightness ratios, and average brightnesses are tabulated for several values of average beam current and for several values of peak-to-peak signal voltage applied to the control grid of the picture tube. All of these exposures were taken with the standard test chart so that comparable densities could be found.

Inspection of Table II shows that the brightness ratio increases as the peak-to-peak video signal increases, as is to be expected. It shows also that as the average brightness (average beam current) is changed, a point of maximum contrast is found in each case at 25 μa, whereas lower contrast is found at low brightness (12.5 μa) and at high brightness (50 μa). The increase in the brightness ratio is most pronounced in the lower values of peak-to-peak grid signal voltage. This technique is a ready means of studying the proper operation of the picture tube to obtain maximum contrast. Figure 4 shows the test chart images on which Table II is based.

In a typical program image the brightness ratio between the announcer's brow and his hair, the highest value encountered in this study, was found to be about 15 times. It should be pointed out that the ratio of the corresponding beam currents in this case was considerably greater than 15 to 1, since part of the "electrical" contrast is lost due to halation in the picture tube screen.

Studies of the Fine Structure of the Image

Photographic technique is necessary whenever the fine structure of a program image is to be studied, since the scenes shift too rapidly to permit direct visual study. Even when a test chart is used, photographic study serves a purpose in revealing the structure of individual frames and fields.

In applying the miniature camera to this problem, it is necessary to employ auxiliary lenses to obtain an enlarged negative image, free from the effects of photographic graininess. A single auxiliary lens of 2 diopters power (Proxar 2) at an object distance of 12.5 inches was found to produce an image of the 9-inch screen which nearly filled a single frame of the film. The grain of Super XX film processed normally corresponds to about 1000-line definition. Thus when a television image fills the film frame, the film definition is sufficient to reveal the line structure clearly.

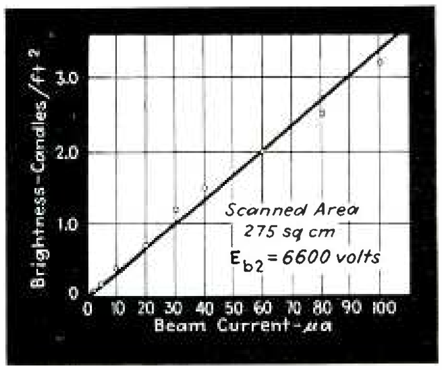


Fig. 11—Calibration of brightness against beam current of the 9AP4 tube used in this study

For accurate examination of the structure, however, the film frame should cover less than the full area of the television image. Two auxiliary lenses (Proxar 1, 1 diopter power and Proxar 2, 2 diopters power) were used, one on top of the other, to reduce the lens-object distance to 8 inches, when the camera was normally focused for 3 feet. Under these conditions the film frame covers about one-third of the television image and the grain does not obscure the content of the image.

Figures 5 and 6 show typical test-chart images photographed in the manner just described. The vertical scanning amplitude was exaggerated to show the line structure more clearly. Figure 5 shows a normal, properly interlaced pattern. Figure 6 shows an image with paired interlace, which displays the characteristic spurious pattern over the vertical-definition wedge. Other aspects of line structure may be studied conveniently in this manner.

The study of the structure of individual fields is possible if an exposure of 1/60 second or less is used. Figure 7 shows such an exposure made in 1/100 second at *f*/1.5 on Super XX film. The image, since it is composed of alternate lines, is very similar to the paired-interlace image, and it displays a similar spurious pattern on the vertical-definition wedge. The lines at the top of the image are the beginning of the next field.

The synchronism of this particular exposure with respect to the field scanning was a matter of chance. Synchronism can be assured if a square-wave generator is available. The output of this generator, operating at 30 cps and synchronized by the vertical sync signals, is applied to the grid circuit of the picture tube. The positive halves of the square waves permit the picture tube to assume normal brilliance during alternate fields, whereas the negative halves of the waves blank out the intervening fields. If a succession of exposures is made at random, however, with a shutter speed of about 1/100 second, one frame covering a single field almost always results.

In photographing images at these short exposure times, care must be taken in the orientation of the focal plane shutter with respect to the lines of the image. The lines are formed in succession from top to bottom of the picture when viewed upright. Accordingly the slit of the focal plane shutter should be parallel to the lines and should proceed from top to bottom of the image, as it falls on the film. In the Contax camera, this condition is met when the long axis of the camera is parallel with the long axis of the television image, and when the top edge of the camera is opposite the bottom edge of the image (i.e., the camera is held upside-down before the image). If these precautions are not observed, the effects shown in Figs. 8 and 9 may be obtained. In Fig. 8, the motion of the shutter slit is opposite to the progression of the lines and an exposure is obtained only in the narrow regions where the two motions coincide. If the motion of the shutter slit is across the image, the effect shown in Fig.

9 is obtained. This image, incidentally, offers an excellent means of calibrating the velocity-time curve of the shutter motion, since the interval between lines is known to be 1/13,230 second in this case (1/15,750 second for 525-line, 30-frame images).

In one experimental exposure of 1/500 second, made to determine the limiting usefulness of photographic lenses and films, a recognizable image was obtained during the blanking interval, that is, solely from the light of the phosphorescent afterglow. The density is too low to permit any quantitative measurements, however.

Another aspect of the fine structure of television images, the effect of noise, was also briefly studied. Figure 10 shows a frame (1/25 sec at $f/1.5$, Super XX) of a boxing match in which a large amount of noise was present, presumably in the camera preamplifier. The brightness ratio due to the noise components is difficult to measure, because the areas of the individual pulses are so small, but an approximate value may be found. The frequency content of the noise bursts also may be determined roughly. (The fundamental frequency of a particular noise impulse, in Mc, may be assumed to be the inverse of twice its duration in microseconds. The duration is about 1 microsecond for every 2 percent of the picture width occupied by the noise peak.) The photographic method is virtually the only approach to the study of noise effects in television images since the random nature of noise makes visual observation inconclusive.

Determining Average Brightness

The average density of a photographic image corresponds to the average logarithm of the brightnesses of the original scene. Hence if the average density can be determined from the negative, the relative average brightnesses of different exposures on the same roll of film can be compared. However, quantitative averaging of density values is almost impossible by direct visual observation. The averaging process may be carried out in a photoelectric photometer, by a substitution method, using a neutral gray film of the same area. But by far the simplest method of measuring the average brightness of a television image is by measuring the average beam current. This method has been used in Table II in comparing the average brightnesses of images made with different grid-signal voltages and correspondingly different contrast ratios.

To express the average brightness in photometric units, some form of calibrated photometer is necessary. A rough calibration may be made with a sensitive portable exposure meter (such as the Weston Model 715). Figure 11 **shows** such a calibration made with the tube used in this investigation, average screen brightness against average beam current. This curve reveals that the average brightness corresponding to the average beam current (30 μa) usually employed in viewing, is about 1 candle per square foot.

Tests with the Weston meter made in this work reveal that the speed ratings of the films when exposed to fluorescent white light are somewhat lower than the corresponding ratings for daylight, but higher than those for incandescent light. Typical approximate values are 80 (Weston) for Super XX and 24 (Weston) for Panatomic X. These speed ratings are derived from the exposures shown in Table I, on the assumption of an average brightness of 1.6 candles per square foot.

A valuable use of the photographic system here described is in recording images from programs having some particular significance. An example is shown in Fig. 12.

The author wishes to express appreciation to Prof. J. B. Russell of the Marcellus Hartley Research Laboratories of Columbia University under whose direction was conducted a study of television quality, of which this paper is a part. The reader is referred to "Brightness Distortion in Television" *Proceedings of the I.R.E.*, June 1941, for a discussion of some of the theoretical aspects of the visual quality of television image reproduction.

Fig. 12—British refugee child listening to parents via transatlantic telephone, in NBC studios. Typical image recorded for documentary purposes

TABLE II

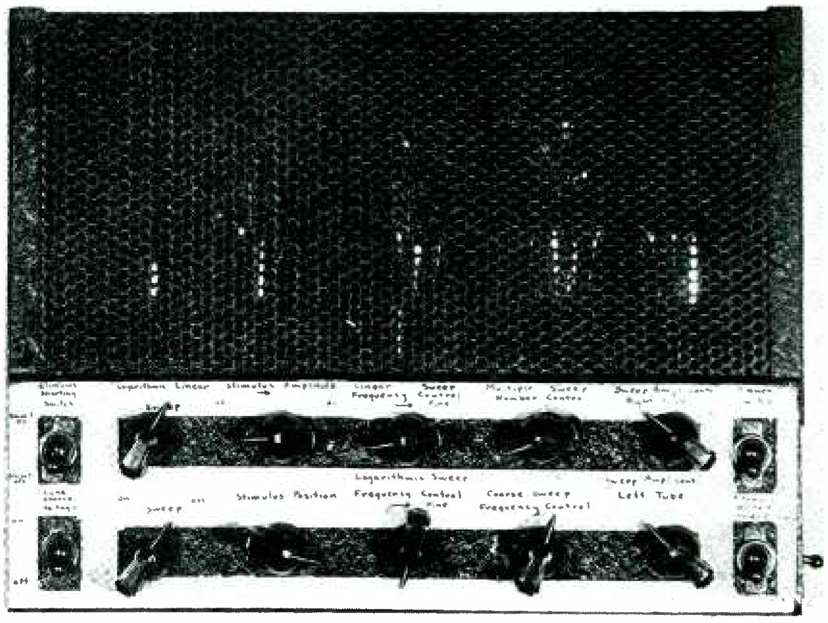
BRIGHTNESS RATIOS VS VIDEO SIGNAL AMPLITUDE AND AVERAGE BEAM CURRENT

Frame Number	Peak to-peak Video Volts*	Density** Range	Brightness Ratio***	Average Beam Current	Average Brightness (c/ft²)
19	28.3	0.60	10.0	50	1.70
20	28.3	0.61	10.5	25	0.85
21	28.3	0.52	7.4	12.5	0.43
22	17.4	0.46	5.9	50	1.70
23	17.4	0.57	8.9	25	0.85
24	17.4	0.46	6.0	12.5	0.43
25	13.0	0.43	5.3	50	1.70
26	13.0	0.53	7.6	25	0.85
27	13.0	0.48	6.3	12.5	0.43

* From black to maximum white, exclusive of sync signal amplitude.
** Difference between maximum and minimum densities.
***Antilog$_{10}$ (Density Range of Negative/0.60). Gamma = 0.60.

SYNCHRONIZED VOLTAGES

By HAROLD GOLDBERG
University of Wisconsin



The combined voltage sweep generator and simulator which is used to produce curves of biopotentials on an oscilloscope screen with the electric stimulus synchronized with the sweep voltage

IT is usual in biomedical research, in recording the action-potential-time curves from active muscle, such as the heart, to provide a time axis by means of a linear velocity of the recording film. This method is impractical, however, for use with skeletal muscle and nerve which have action potential impulses of much shorter duration. In addition to the fact that very high film velocities are required, it is sometimes necessary to repeat exposures to obtain sufficient line density on the film. These reasons preclude the use of moving film to provide a time axis. A more desirable method is the practice of taking still pictures of the phenomena with an electrical sweep. This applies only to recording with cathode ray tube technique. The time axis may be either linear or non-linear in this method; may be as fast as desired; and may be repeated for multiple exposures. In this procedure, however, the stimulus, which is generally electrical, must be synchronized with the sweep voltage in some manner.

The circuit used was designed for work which required the simultaneous recording of two action potentials. These are amplified by two identical d-c amplifiers[1] and impressed on two cathode ray tubes mounted side by side. It was necessary that the records allow time comparisons of events and this made the requirements for the stimulator and sweep circuit more exacting than for a system involving the recording of a single action potential alone. The arrangement can be extended for use with three channels and a three trace cathode ray tube for recording three events simultaneously.

The circuit was designed with a view towards satisfying the following requirements:

1. A condenser discharge type of stimulating voltage controllable as to amplitude, duration, and form and which can be made to occur at any desired point in the sweep.
2. Linear and logarithmic sweep of any desired speed and amplitude. Manual control of starting point of spot on screen in any sweep.
3. Single, multiple, and periodic sweep as desired.
4. Undistorted sweep voltage amplified output sufficient to cover from 1.5 to 2 times the screen diameter.
5. No condenser coupling arrangements giving rise to undesirable transients. Events and positions must be duplicated in any sweep for any given setting of controls.
6. Battery operation on a minimum of battery requirements.
7. Operation in conjunction with d-c amplifiers if desired.

Battery operation is necessary since shielding of specimens is difficult. All work at the University of Wisconsin is done in a shielded room from which alternating currents are excluded. Tubes with 6.3-volt filaments were chosen since they are conveniently operated directly from a 6-volt storage battery. The operation and features of the design are best described by a detailed consideration of the circuit.

The sweep voltage generator is of the usual type employing a type 884 gas triode using a condenser charge through a type 38 pentode for linear sweep and a variable resistor for logarithmic sweep. Coarse control of sweep speed is provided by a condenser bank. Fine control of linear sweep speed is effected by bias change on the pentode through P_1. P_2 allows fine control of logarithmic sweep speed. S_1 allows changeover from one mode to the other.

While a single sweep of the spot, and therefore the occurrence of a single action potential, is sufficient in most cases for adequate line density in the cathode ray tube screen, under some conditions it is necessary to make double or multiple exposures. Furthermore, periodic sweep is desirable for visual observation of nerve action potentials. The circuits involving tubes 884-1 and 884-2, with their attend-

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An instrument for generating simultaneously a sweep voltage for a cathode ray oscilloscope and another synchronized voltage which is used to induce a reaction to be observed on the cathode ray tube screen

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ant switching arrangements allow single sweeps, multiple sweeps automatically controlled, and periodic sweep.

The operation of the circuit (Fig. 1) is as follows. Tube 884-1 is biased to a continuously non-conducting state as long as 884-2 is non-conducting. Breakdown of 884-2 puts 884-1 into operating state for periodic sweep. With S_4 open and S_4P in the non-P position, 884-2 is non-conducting and closure of S_3 sweeps the spot across the screen and keeps it there. Return of S_3 to open position returns the spot to the initial starting point. This is the single sweep operation. Periodic sweep is initiated by closing S_3 with S_4 open and S_4P in the P position. Opening S_3 stops periodic sweep. If multiple sweep is desired, that is, periodic sweep which comes on and then automatically ceases after any predetermined period of time, S_4 is closed and S_4P thrown to the non-P position. Closure of S_3 now provides periodic sweep which terminates according to the time constant of the discharge circuit of P_3 and the 3 μf condenser. Opening S_3 resets the device. By proper adjustment of the time constant, the sweep can be made to occur any predetermined number of times and then automatically stop.

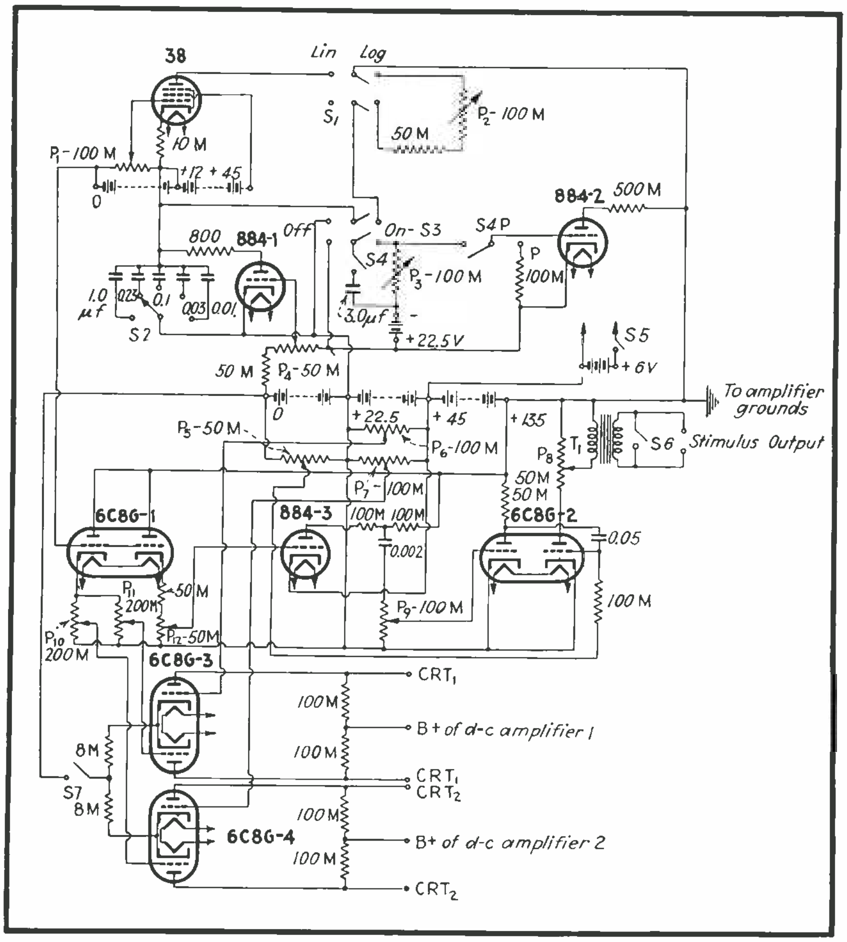

Fig. 1—The instrument which produces sweep voltages either in single, multiple, or periodic pulses with linear or logarithmic characteristics

The usual method of condenser-resistance coupling of the sweep voltage to the sweep voltage amplifiers is not used since it introduces a discharge path for the sweep voltage. This is objectionable because of the distortion introduced in slow sweeps (unless the time constant of the coupling circuit is impractically long) and because the spot will return slowly after single sweeps unless quickly returned by switching S_3 to "off". It is inconvenient to return the spot at once in some cases and the slow return would be undesirable. For this and for other reasons, a method of coupling is used which isolates the condenser voltage and does not provide a discharge path. This method of coupling makes use of a twin triode, 6C8G-1, both sections of which are operated as unity amplifiers. The sweep voltage is coupled directly from condenser to the grids of both sections which are biased to cutoff. The entire sweep voltage may be impressed without driving the grids positive. The amplifier, which is in reality a negative feed-back amplifier using 100 percent feed-back, has an output which is in phase with the input and an amplification which is very nearly unity. The entire load is in the cathode circuit in this application. This circuit has several interesting properties and uses other than that described here.

The sweep voltage output of one section is taken off by means of the two sweep amplitude controls, P_{10}

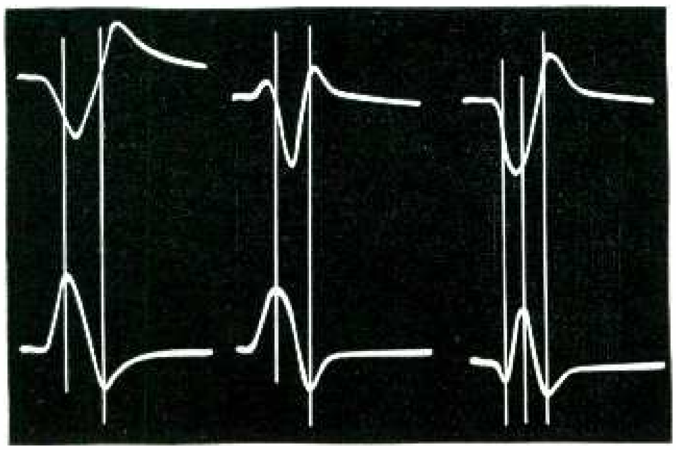

Fig. 3—Three sets of curves taken with two d-c amplifiers, two cathode ray tubes, and the sweep generator and stimulator. Upper curves with unipolar and lower with differential leads

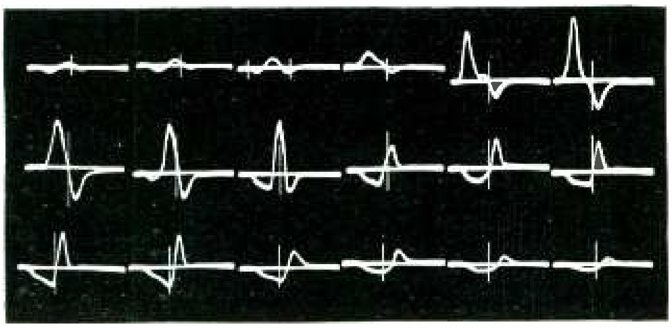

Fig. 2—A series of curves taken with electrodes equally spaced over the length of a frog's gastrocnemius muscle. The peak voltage is less than 25 millivolts, duration about 14 milliseconds

and P_{11}. Each provides independent control of the sweep output voltage amplitude of its corresponding amplifier. Two sweep voltage amplifiers (there may be more if desired) are provided, one for each cathode ray tube, using twin triodes (6C8G-3 and 6C8G-4). Each is a direct-current, phase-inverting, push-pull amplifier.[1, 2] Starting position of the spot is controlled by P_6 and P_7 which supply a variable bias to one grid of each amplifier. Therefore both starting position and amplitude of sweep may be independently controlled on each tube. This allows the sweep voltage supply to each cathode ray tube to be adjusted with the aid of a ruled, transparent screen so that the spot passes the same relative positions on the two tubes at the same instant of time. An initial warm-up of the cathode ray tubes is required to maintain this adjustment. The adjustment is independent of sweep speed or frequency and thus allows direct time comparisons between events in two action potentials recorded simultaneously.

The battery supply for the sweep voltage amplifiers as shown here is arranged for use with the d-c action potential amplifiers although it need not be. Supply voltage not shown in the circuit diagram is provided by the batteries of each d-c amplifier. The cathode ray tube power supplies float on the d-c amplifier supplies. This arrangement results in minimum battery requirements and automatically insures proper operation. The switch S_7 is kept open except when the sweep voltage is actually needed so as to minimize the drain on the action potential amplifier battery supply.

The stimulator portion of the circuit involves the second section of 6C8G-1, 884-3, 6C8G-2, and T_1. The stimulating voltage delivered is a modified condenser discharge voltage variable as to amplitude, duration, and time of occurrence during the sweep. This last feature allows advantageous placing of the action-potential-time curve on the screen since the action potential follows the stimulus by a short time interval. The operation is as follows.

With no input from P_{12}, 884-3 is non-conducting. If P_{12} is adjusted so that some fraction of the sweep voltage is impressed on the grid of 884-3, this gas triode will break down at some instant during the sweep. A larger input will cause breakdown to occur sooner. The tube remains in the conducting state until the return of the spot occurs. Thus, variation of P_{12} will cause breakdown to occur at any desired point in the sweep. Both breakdown and return to the non-conducting state give rise to condenser discharge voltages across P_9. The durations of these are determined by the time constant of the discharge or coupling circuit and are made some suitable value. The voltage due to the breakdown, modified in some detail, is used as the stimulating voltage; the other, due to the return to non-conduction, is in the opposite direction and is suppressed. It is evident that the voltage pulse due to breakdown may be made to occur at any position of the spot during its sweep and that the position is independent of sweep speed. Partial suppression of the undesired pulse and phase inversion of both pulses is accomplished by feeding the voltage from P_9 into one section of 6C8G-2 which has zero bias on its grid. Partial suppression results for the undesired pulse since it drives the grid positive; the desired pulse drives it negative. If desired, the peak of the desired pulse may be clipped by adjusting P_9 to drive the grid beyond cutoff on the peak. Final suppression of the undesired pulse and final modification of the desired pulse must now be carried out. This modification is a sharp cutoff of the desired pulse at some time during the discharge so that the remaining portion of the exponential discharge is suppressed. This allows variation in the duration of the pulse and also minimizes distortion of the action potential due to leakage of the stimulus into the input of the action potential amplifiers. This leakage, called "shock artifact" by workers in this field, is an ever present problem. It is due to the disparity in stimulating voltage, 10-15 volts peak, and action potential peak, less than 30 millivolts. The final modification is performed by the second section of 6C8G-2 which is operated at any desired point beyond cutoff by means of P_5. The undesired pulse is now negative and is completely suppressed because it only serves to drive the tube still farther beyond cutoff. The only portion of the desired pulse that is amplified is that driving the grid positively from cutoff. This accomplishes the abolition of the exponential discharge beyond the desired point. Increase in the negative bias causes cutoff of the pulse at an earlier time and shortens the duration of the pulse. The output is fed through T_1, a matching transformer, and the amplitude controlled by P_8.

It is essential that T_1 be well

(Continued on page 82)

INDUSTRIAL ELECTRONICS – II

The second and concluding part of a discussion of the outstanding problems in applying electronic instruments to industrial applications. Here several successful installations of phototube equipment to perform difficult production problems are described

By RALPH A. POWERS

Electronic Control Corp.

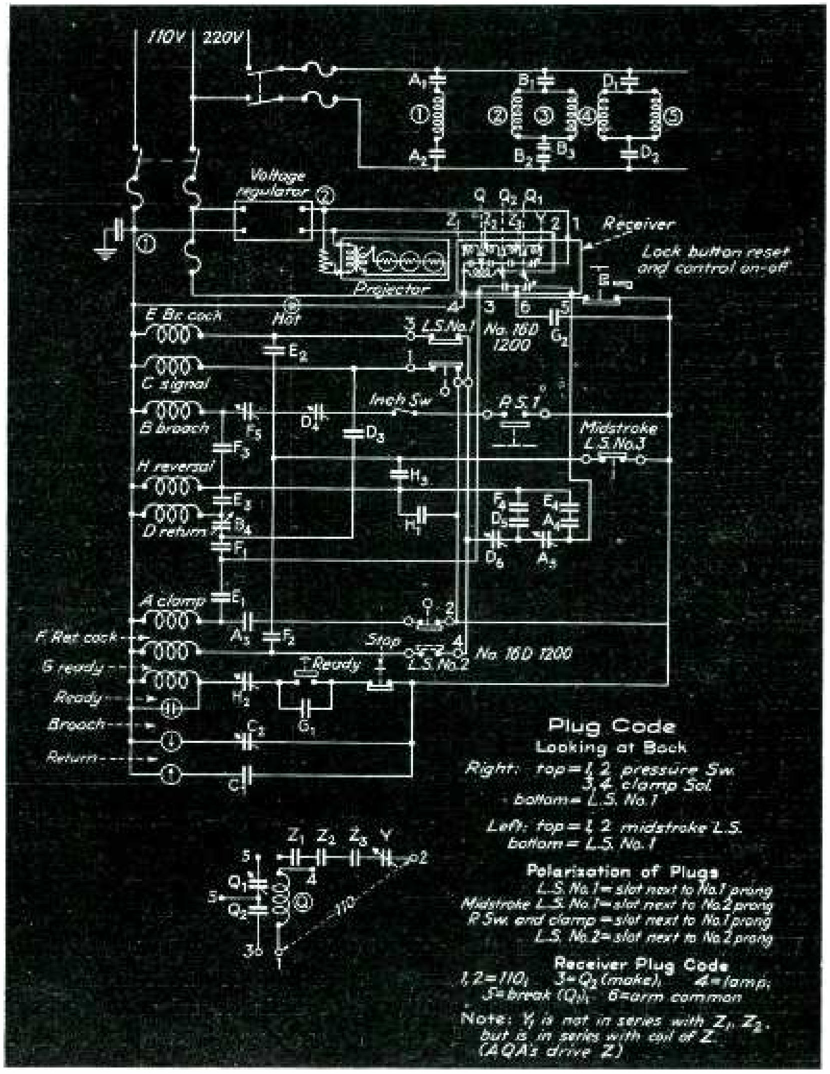

Fig. 1—Circuit diagram of an early light curtain control equipment for a bearing broaching machine. The large number of mechanically moving parts in an industrial application as complicated as this gives rise to service calls which can sometimes be eliminated by greater use of tubes

In 1935 it was largely a matter of education of the machine and tool designers concerning what electronics could do for them. They had read newspaper accounts of the wonders of the "electric eye", the electron tube, the cathode ray tube, but had little opportunity to know where they would help them. Consequently, when they were approached on the uses of electronics, what it might save them, they picked out the toughest problem they could find, probably because it had them stumped, and thought certainly the electric eye could do the job. So, during these first two years the toughest problems that were to be had were placed right in the lap of the electronic engineer. In order to obtain a second reception with the engineers in charge of purchasing, it was necessary in many instances to bring in a quotation, telling just how the finished electronic gadget would work, how much it would cost and when it could be delivered. In many of these cases the electronic engineer, who was having so many problems presented that he could not sleep nights, did not actually know which was the first plan of attack of the problem. Fortunately, some of the gadgets and devices worked exactly as they were desired, but there were many for which the cost of engineering alone was twice the selling price. Naturally, a time to halt this procedure had to come, so that those with the simple problems were not helping to pay for the engineering on the most difficult. The two-point plan found to be effective was briefly as follows:

1. During the past few years valuable experience has been gained in knowing how to combine solutions of past problems into an effective solution for the "run of the mine" problems. This is what might be termed experience with some records to back it up. These problems can be quoted on directly, giving the price of the finished article, the approximate delivery date, and a guarantee of operation.

2. The more difficult problems must be solved in a different way from the selling viewpoint. From past experience, it can be rather crudely estimated how much time will be necessary for one, two, or more men to develop various ideas which appear to meet the customer's requirements. Then the prospective customer must be willing to risk that amount of money for laboratory work before any concrete work is started. This system works out very

nicely, because if at the end of the experimental stage the engineer has some luck, the balance of estimated maximum expenditure (which is refunded to the customer) can be applied to the purchase price of one or two of the completely engineered units. No one loses on this system, unless the electronic engineer cannot invent practical applications. If this happened very many times, he undoubtedly would soon lose the fun of trying to lick difficult jobs.

Many of the special applications of electron discharge devices, briefly described below, fall into one or the other of the above classifications of procedure.

All Electronic Broaching Control

Several years ago the light curtain principle of machine control and operator safety was applied to a bearing broaching machine. After some troubles with limit switches, relays and other mechanical parts, the control functioned perfectly. There was a continual source of service, however, in magnetic switches or relays. The unit performs many million cycles of operation, and as a result contacts may fall off relays, return springs lose their elasticity, armature hinges wear out; in fact any mechanical device will show signs of wear under such continuous operation. When the relays have all been repaired, and the unit is not in need of service, the records of production with the light curtain have justified the development of all electronic control. Two all electronic control units are now being completed.

With the exceptions of the electronic light curtain, the relay circuit is shown in Fig. 1. From the circuit, some idea can be obtained of the number of moving parts of the various relays in order to insure complete operation of the machine for its various functions of broaching the bearing.

With the light curtain projector and receiver, as shown in the circuit, connected to this elaborate relay interlock cabinet, it was possible to obtain the necessary following sequence:

1. Equipment ready to start the cycle of operation.
2. The operator removes his hands from the opening of the machine, thereby allowing the light curtain to be completed.

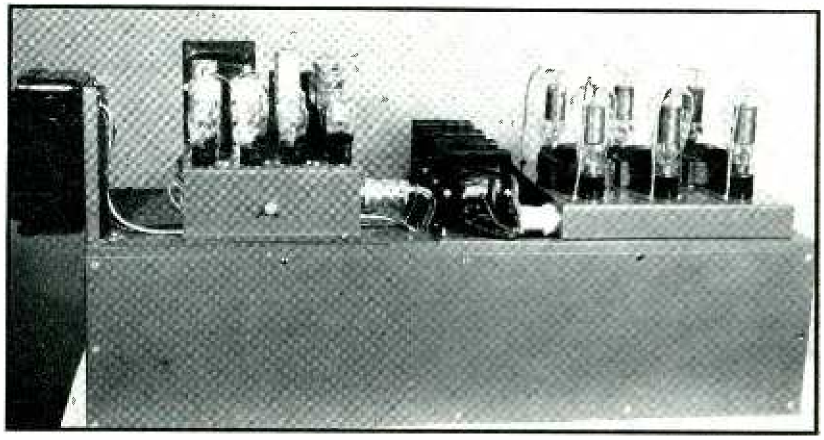

Fig. 2—Broaching machine control using electronic switching means instead of relays as shown in Fig. 1. The solenoid air valves are operated by the anode current of the gas tubes

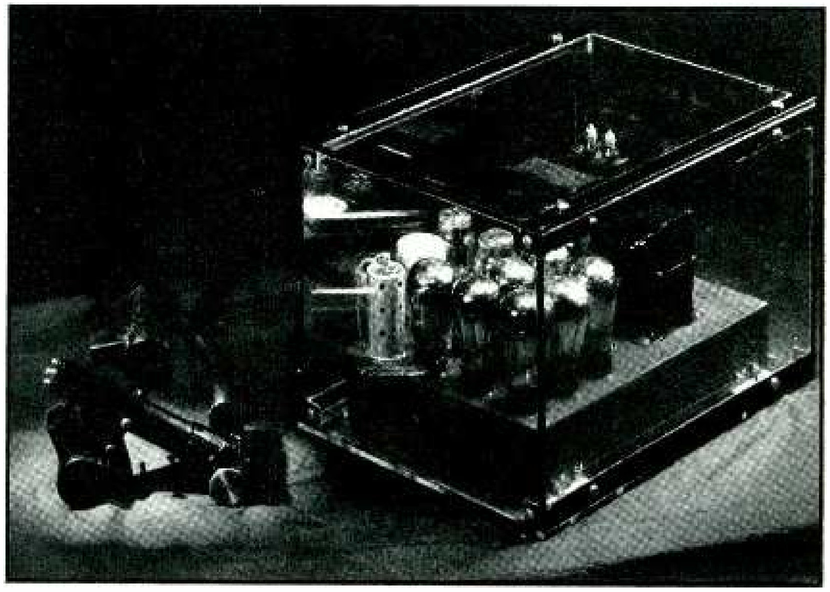

Fig. 3—Experimental unit for sorting rock salt. It is encased in glass to minimize corrosion from the salty atmosphere

3. The operator uses one hand (when necessary) to press the automatic "start" button.
4. This electrically latches a relay, thereby energizing, through its back contacts, a second relay.
5. The 3-way, ⅜-inch solenoid valve for the clamping cylinder responds from these contacts.
6. The clamping cylinder is now energized and as soon as pressure has been built up, the "make" contacts of this pressure switch will close.
7. These contacts in turn energize the solenoid 4-way valve for the broaching operation.
8. The broaching cylinder proceeds to its complete forward position and at that point operates contacts on a limit switch.
9. These contacts in turn actuate the relay, holding the solenoid air valve in a position with the broach forward.
10. The operator again intercepts the light curtain to remove the piece.
11. In so intercepting the light curtain, the solenoid air valve for the clamping cylinder is released, allowing clamping pressure to be exhausted and the operator to remove the piece. (A pilot light turns on when it is time for the operator to remove the piece.)
12. The operator now comes out of the light curtain in removing the piece of work; thus, the "make" contacts of the circuit at the end of the broaching stroke impulses the relay to its normal position.
13. However, if one relay was dropped out due to interception of a portion of the light curtain, the

broaching cylinder can now return to normal, or "back" position, awaiting a restart of the operation.

It can be appreciated from the above sequence of necessary operations, that the relays and limit switches are necessary to obtain increased production through the use of light curtain control and at the same time insure complete safety to the operator of the bearing broaching machine.

Incidentally, the use of the light curtain equipment with this sequence increased production from approximately 7,000 pieces to well over 11,000 pieces per eight hour day, with less operator fatigue than was experienced with normal push buttons or hand operated valves in order to complete the above outlined complicated sequence.

To contrast these large number of moving and wearing parts with the mechanics of the electronic circuit will prove the elimination of service difficulties and "time down" of the machine during service which is a most important problem in maintaining a factory at its peak of production. This is an application that should prove the value of all electronics, over the combination of electronics and electro-mechanical switching arrangements, in industrial service.

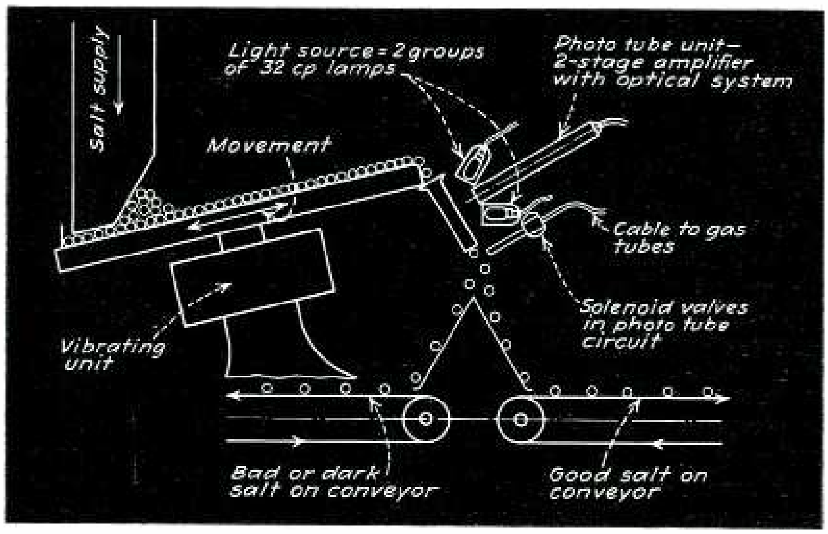

Fig. 4—Diagrammatic sketch showing method of operation of rock salt sorter. The pieces of salt drop one at a time past the photoelectric unit. The dark pieces reflect less light causing a blast of air to blow them off the path of the good pieces

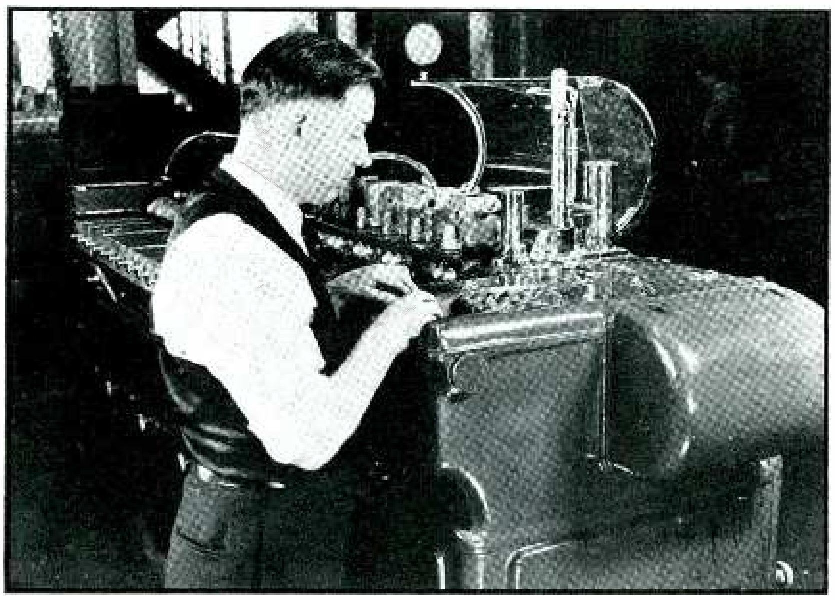

Fig. 5—This electronically controlled guage using trigger circuits measures wall thicknesses, diameter, out of square ends and many other measurements. The photoelectric scleroscope can be seen in the foreground

Several years ago, the first experimental photoelectric rock salt sorting single unit was produced. The amplifier was encased in a glass enclosure, much like a small aquarium, to prevent salt dust from entering. Glass is the material used to minimize corrosion of the case. The phototube was in a separate housing with two light sources, as shown in Fig. 3. This experimental unit was produced to determine the feasibility of picking out the dark pieces of salt and allowing the pure crystals, to pass. After completion of the photoelectric device, considerable time was spent in developing suitable mechanical means to line the individual crystals of salt into a single column, which would drop past the phototube. At this point the salt was illuminated, and the darkened or undesired particles would reflect less light to the phototube while the clear and white crystals would reflect more light, allowing their passage. After trying several rotary means, similar to that used in sorting beans and similar objects, this idea was abandoned and a vibration method was developed. The arrangement of the vibrating conveyor, which feeds the salt in ten individual rows, is shown in Fig. 4. At this point, the salt falls off, one crystal at a time, through the small directional chutes. Each of the ten chutes is arranged with a special phototube housing in the form of a 2-inch square stick measuring about 18-inches in length. Each phototube housing contains a two stage amplifier. The power supply and the thyratrons for operating the small air valves are mounted on a rack and panel assembly. If a darkened piece of salt appears before any one of the ten photoelectric units, a small fast acting solenoid valve opens for a predetermined period of time, only long enough to allow the squirt of air to move that darkened crystal of salt out of the normal axis of fall. As a result, it falls on one side of a 'camel back', while the good pieces fall on the other side. To make the machine practical, the solenoid air valves must open very rapidly. Special valves which operate directly in the anode circuits of the ten thyratrons were made. The thyratrons are arranged with automatic 'put out circuits', so that after the air blast of a fraction of a second, the valves will quickly close, eliminating the

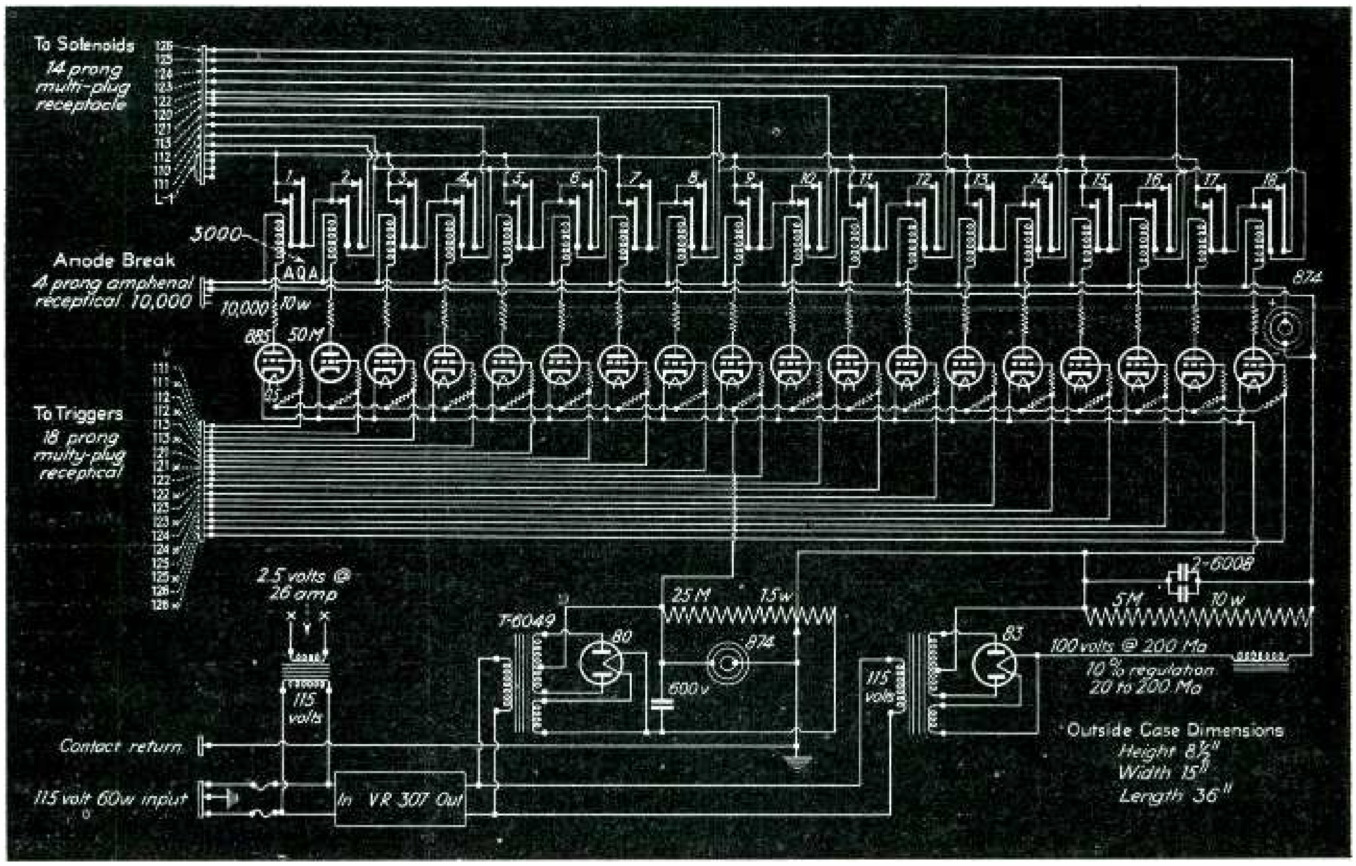

Fig. 6—Diagram of an 18-trigger circuit. This type of circuit is used for measuring, grading and sorting a variety of products. Note that the anode circuits can be opened during the time their operation is not required

possibility of rejection of good salt. The valves were made to open and close 20 times per sec. against an air pressure of 90 pounds per sq. inch. By adjustment of bias of the amplifiers and by adjustment of light source intensity, various grades of salt can be selected and reselected for various degrees of purity.

Experimental work is now being conducted on using the same unusual mechanical means of feed, in combination with the same fast means of rejection, for grading various ores, especially gold ores.

Trigger Gauging

With the increase in demand for high speed measuring, an increase in the necessity of electrical circuits to perform the functions quickly has been realized. After three or four years of experimental work, the trigger circuits were developed. Essentially, a trigger circuit is nothing more or less than the arrangement of a gas triode with either d.c. or a.c. applied to the plate and with the grid circuit arranged to operate directly from the measuring contacts.

The use of gas tubes allows storing of the impulses over a given period of time to allow automatic rejection or sorting of the pieces. With d.c. applied to the anode, after an over- or under-size piece has been inspected, gas tubes are fired and remain fired until a limit switch on the complete automatic machine opens after rejection of the undesirable piece in its correct position.

A typical machine operated by electronic means is illustrated in Fig. 5. Rejection and sorting, where all measurements are taken during rotation or movement of the object, are obtained through the use of trigger circuits. Rejection is occasioned by storing the impulse until the undesirable piece has reached the following station before rejection.

Figure 6 illustrates the principle of the use of gaseous tubes for measuring. The grids of each one of the tubes are connected through a suitable circuit so that in the event undesirable pieces reach the gauges, the grids of the tubes are made sufficiently positive in order to cause their firing, thereby storing the rejection selection because of the fired condition of the thyratron.

This same type of measuring and grading, through the use of trigger circuits, was introduced a number of years ago and has been closely followed by others interested in obtaining electronic business in measuring, grading and sorting.

These are but a few of the special photoelectric and electronic units. Others include a gauge to measure the thickness of babbit of metal backed bearings; measuring the outside diameter and wall thickness of permanent mold castings; checking the condition of butt welds, and porosity of castings; and automatic rejection of cracked iron or steel castings. Complete special machines have been built for the automatic rejection of soft tappets, soft tips of valve stems, and roll inspection from roller bearings as well as for many other applications.

In looking back over five and one-half years of electronics in the industrial field, one finds that ordinary units, ordinary machines, or the combination of the most simple electronics with the most simple machines very seldom offer the answer to the specific problem set forth by the engineer.

F-M Noise and Interference

This survey discusses the f-m principle in noise reduction, the extent to which frequency-modulation is effective in reducing various types of interference, compares a-m systems with f-m systems, and concludes that the distribution and phase relationships of sidebands largely explain success of "staticless" reception

By
STANFORD GOLDMAN
General Electric Co., Bridgeport, Conn.

PROBABLY the outstanding reason for the growing use of frequency modulation is its characteristically low noise and interference levels. It is the purpose of the present article to give elementary explanations of these effects, and to present simple formulas for practical use in the calculation of f-m noise and interference.

A few fundamental facts about modulation will not be out of place at this point. An audio signal consisting of a pure audio tone of frequency μ and intensity proportional to a^2, may be written as $a \cos 2\pi\mu t$. If this signal is used for amplitude modulation of the r-f carrier, $A \sin 2\pi ft$, the resulting amplitude modulated signal is

$$A(1 + k\,a \cos 2\pi\mu t) \sin 2\pi ft = A[\sin 2\pi ft + \frac{1}{2} ka \sin 2\pi(f + \mu)t + \frac{1}{2} ka \sin 2\pi(f - \mu)t] \quad (1)$$

where k is a constant, depending on the depth of modulation.

The result of amplitude modulation has thus been the generation of two sidebands in the frequency spectrum. These are displaced from the carrier on either side by the audio frequency μ and have a magnitude equal to $ka/2$ times the carrier magnitude. The quantity ka is called the modulation factor, and, in amplitude modulation, can never exceed 1.

If, on the other hand, the audio signal, $a \cos 2\pi\mu t$, is used for frequency modulation of the r-f carrier, $A \sin 2\pi ft$, the resulting frequency modulated signal* is

$$\begin{aligned} A \sin [2\pi ft + (D/\mu) \sin 2\pi\mu t] &= A\, J_0 (D/\mu) \sin 2\pi ft \\ &+ J_1(D/\mu) [\sin 2\pi(f + \mu)t - \sin 2\pi(f - \mu)t] \\ &+ J_2(D/\mu) [\sin 2\pi(f + 2\mu)t + \sin 2\pi(f - 2\mu)t] \\ &+ J_3(D/\mu) [\sin 2\pi(f + 3\mu)t \\ &- \sin 2\pi(f - 3\mu)t] + \ldots\ldots \quad (2) \end{aligned}$$

The result of frequency modulation has thus been the generation of sidebands displaced from the carrier frequency not only by the audio frequency, but by all harmonics† of the audio as well. The magnitudes of the sidebands are no longer simply proportional to the modulation factor divided by 2, as was the case in amplitude modulation, but are now proportional to the quantities $J_n(D/\mu)$. These quantities are called Bessel's functions, and vary somewhat like damped sine waves. A group of them is shown in Fig. 1.

The instantaneous frequency of the f-m signal, $A \sin[2\pi ft + (D/\mu) \sin 2\pi\mu t]$ is

$$\frac{1}{2\pi} \frac{d}{dt} [2\pi ft + (D/\mu) \sin 2\pi\mu t] = f + D \cos 2\pi\mu t \quad (3)$$

The maximum frequency deviation occurs at that point of the audio cycle when $\cos 2\pi\mu t = \pm 1$. At that instant, according to Eq. (3), the frequency deviation from the carrier is equal to D. The extent of frequency modulation is measured by this maximum frequency deviation. In amplitude modulation, there is a theoretical limit to the extent of modulation, namely when the depth of modulation is equal to the carrier magnitude. There is no corresponding theoretical limit (except zero frequency) to the extent of frequency modulation. In practice, the extent of modulation, in frequency modulation, is limited by the government's ruling on maximum frequency swing or by the modulation capabilities of the transmitter. The modulation factor in f-m is defined as the ratio of the frequency deviation to the maximum permitted frequency deviation.

In Fig. 2 are shown amplitude and frequency modulated waves and their sideband components.‡ In Fig. 3 are shown the differences in sideband composition for various modulating and maximum deviation frequencies.

The General Problem of Interference

In amplitude modulation, as is well known, the ratio of audio interference to audio signal is in general the same as the ratio of r-f interference to r-f signal arriving at the second detector. This is not true in frequency modulation. In frequency modulation, the stronger of the two r-f signals arriving at the limiter grid, tends to remove the audio effect of the weaker.

The reason for this is illustrated in Fig. 4, where the two r-f signals are represented by rotating vectors, as is customary in studies of modulation. Let us suppose that A is the desired signal and B is the interference. The resultant of the two is R, and the rate of change of the angle ϕ_R is the total effective frequency modulation.

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* In a uniform sine wave, such as $\sin \omega t$, the frequency is $1/(2\pi)$ times the rate of change of the argument of the sine function, or in other words

$$f = \frac{1}{2\pi} \frac{d}{dt} (\omega t) = \frac{\omega}{2\pi}$$

If the sine function is not uniform, it is customary to define its instantaneous frequency in an analogous manner as $1/(2\pi)$ times the rate of change of the argument of the sine function. In accordance with this definition, the f-m signal in Eq. (2).

$$A \sin \left[2\pi ft + \left(\frac{D}{\mu}\right) \sin \;\; 2\pi\mu t \right]$$

is shown by Eq. (3) to have a frequency ($f + D \cos 2\pi\mu t$). This is the justification for saying that the expression in Eq. (2) is frequency modulated with the audio signal $a \cos 2\pi\mu t$. The constant, D, represents the maximum frequency deviation of the signal from that of the unmodulated carrier, f. This maximum deviation occurs when $\cos 2\pi\mu t = \pm 1$. The constant, D, is proportional to the audio signal strength, a, as well as to the frequency sensitivity of the transmitter.

† The "harmonic" sidebands, if proportioned as in Eq. (2) produce no distortion in an f-m signal. On the other hand, absence of harmonics in these proportions will cause distortion.

‡ Note that amplitude modulation does not change the carrier energy, but it adds sideband energy. On the other hand, frequency modulation decreases the carrier energy and puts energy into the sidebands in such a way that the total (carrier + sideband) energy is independent of the extent of modulation.

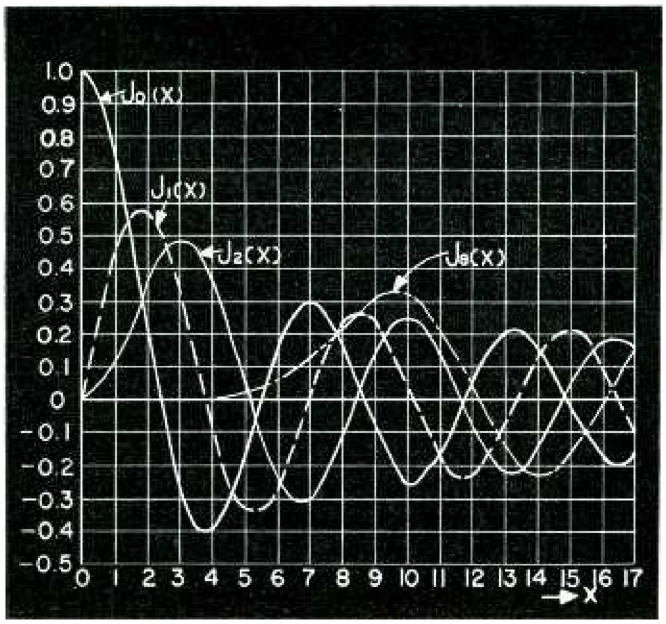

Fig. 1—A group of Bessel functions, plotted for order 0, 1, 2, and 8, and in which $x = D/\mu$. To use, we must determine x from known values of D and μ

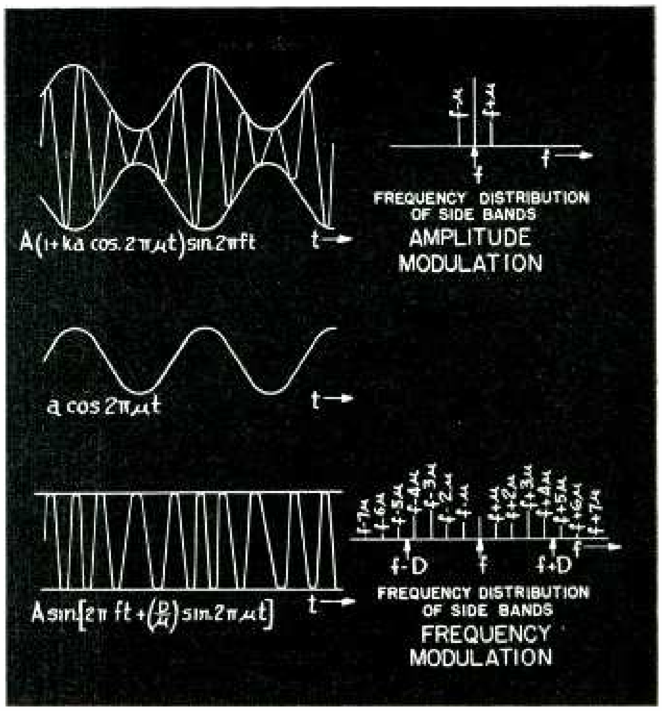

Fig. 2—Diagram of modulated waves and their sideband components for amplitude modulation (top) and frequency modulation. Modulating wave is sinusoidal

It is apparent from the figure that even if the angular variation of B is thousands of degrees, it will not cause much change in ϕ_R, for the maximum angle between R and A cannot exceed $\tan^{-1} B/A$. Therefore, if the modulation of A has a large deviation ratio (ratio of the maximum deviation frequency to the audio frequency which is the case in wide band frequency modulation so that A (and therefore R) has several complete revolutions in one audio cycle, the relative effect of B on the overall frequency modulation will be very small; considerably smaller than the value of B/A might lead one to expect from amplitude modulation experience. Furthermore the elimination of the effect of B becomes more complete as the maximum deviation frequency of A is increased.

If A is the desired f-m signal and B the interference, then the audio signal will be quite free from interference so long as A is greater than B during all portions of the audio cycle. If the relative value of B is then increased, there is a rapid rise in the amount of audio interference when B approaches the value of A, and by the time B exceeds A during all portions of an audio cycle, the interference has completely eliminated the signal. There is thus a sharp transition from good signal to poor signal as the relative value of A to B is decreased, such as would occur at a critical distance away from the A transmitter. Since the interference, B, is likely to have amplitude modulation as well as frequency modulation, the transition is not quite as sharp as it would otherwise be, but it is still very striking.

The foregoing discussion gives a general idea of the action of f-m in reducing interference. It is next desired to derive quantitative formulas for the action of f-m. This is quite involved mathematically in the general case. However, as will be seen in the following sections, in the most important practical case when the signal is considerably greater than the interference and a good limiter is used, the derivations become quite simple.

A different type of noise reduction exhibited by wide band f-m receivers, but which can also be achieved in a-m receivers, is described in footnote on page 42.

The Simplest Case of Interference

Probably the simplest type of interference in a radio receiver is that produced by a harmonic wave of fixed amplitude and frequency, such as an unmodulated carrier, $B \sin 2\pi gt$, whose intensity is small relative to that of the desired signal. Let us first find what interference this produces in an amplitude modulated signal receiver. Let the signal carrier be $A \sin 2\pi ft$. Then the resultant is

$$\begin{aligned} A\sin 2\pi ft + B\sin 2\pi gt &= A\sin 2\pi ft \\ &+ B\sin 2\pi ft\cos 2\pi(g-f)t \\ &+ B\cos 2\pi ft\sin 2\pi(g-f)t \\ &= [A + B\cos 2\pi(g-f)t]\sin 2\pi ft \\ &+ B\sin 2\pi(g-f)\cos 2\pi ft \end{aligned}$$

$$= \sqrt{A^2 + 2AB\cos 2\pi(g-f)t + B^2}\,\sin\left\{2\pi ft + \tan^{-1}\left[\frac{B\sin 2\pi(g-f)t}{A + B\cos 2\pi(g-f)t}\right]\right\} \tag{4}$$

As the result of a Taylor series expansion the amplitude of the resultant is then, approximately,

$$\sqrt{A^2 + 2AB\cos 2\pi(g-f)t + B^2} = A[1 + (B/A)\cos 2\pi(g-f)t] \tag{5}$$

provided that A is much larger than B. Comparison of the right side of Eq. (5) with the left side of Eq. (1) indicates that the interference causes an effective interference modulation factor of B/A. Furthermore, the interference modulation frequency is $(g-f)$.

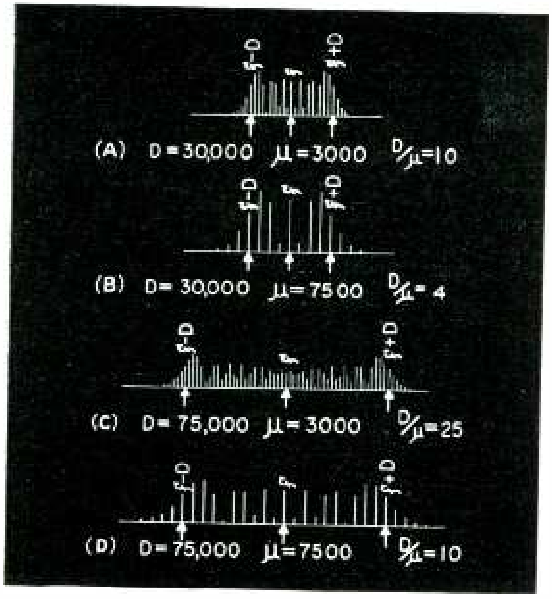

Fig. 3—Spectrum distribution in frequency-modulated system, for various deviation frequencies, *D*, and modulating frequencies, μ. Compare top and bottom curves for which $D/\mu = 10$ in both cases

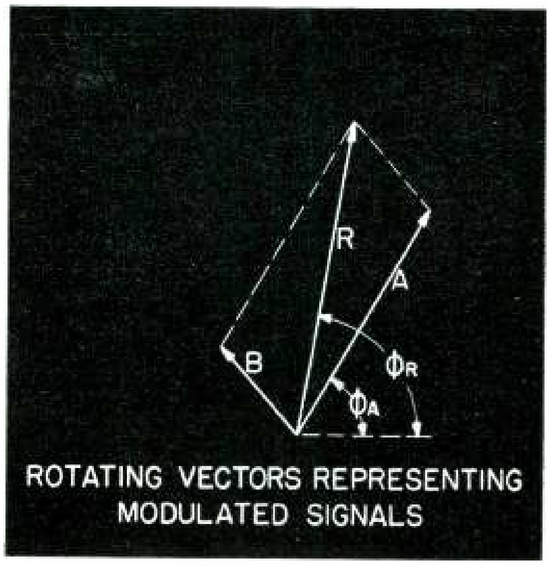

Fig. 4—Rotating vectors representing f-m signals. Vector *B* is the interfering signal, *A* is the desired signal, *R* is the resultant

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Let us next see what effective interference modulation, the same signal $B \sin 2\pi gt$ produces in a frequency-modulated signal receiver with the same signal carrier. To find this, we refer again to Eq. (4). If it is again assumed that A is much larger than B, then, approximately

$$\sin\left[2\pi ft + \tan^{-1}\left[\frac{B\ \sin\ 2\pi(g - f)t}{A + B\cos 2\pi(g - f)t}\right]\right. = \sin\left[2\pi ft + (B/A)\sin 2\pi(g - f)t\right] \quad (6)$$

Therefore, by comparison with the left side of Eq. (2), we see that the modulation factor is

$$\frac{B}{A}\cdot\left(\frac{g - f}{D}\right) \quad (7)$$

where D is the maximum frequency deviation of the f-m system. The modulation factor of the interference in frequency modulation is consequently less than in the corresponding a-m case by the ratio $(g-f)/D$. It is therefore clear that the interference is reduced in the same proportion as the maximum deviation of the f-m system is increased, as already indicated in our general discussion of interference in the preceeding section. Equation (6) shows that audio interference signal has the frequency $(g-f)$ just as in the a-m case. It also shows the further important fact that the modulation factor of the interference is directly proportional to the audio frequency $(g-f)$.

Common Channel Interference

Common channel interference is the interference between the desired signal and an interfering signal of approximately the same carrier frequency. The modulation produced on the desired carrier, by the interfering carrier and its sidebands is the measure of common channel interference.

For the sake of simplicity, we shall assume that both the interfering and the desired carriers are unmodulated. Then, in accordance with the analysis of the preceding section, the modulation factor of the interference is B/A in the amplitude-modulation case, and is $B\ (g-f/AD$ in the frequency-modulation case. Here, as before, B and A are the relative signal strengths of the interfering and signal carriers, $g-f$ is the difference frequency between the carriers, and D is the maximum frequency deviation of the f-m system. In the case of wide band frequency modulation, D is greater than the highest audio frequency passed by the receiver, so that common channel interference in f-m is necessarily less than it is in amplitude modulation. This is a distinct advantage of frequency modulation.

Present f-m transmission standards call for an accentuation of high audio tones at the transmitter, with an equalization of the system by a corresponding decrease in high frequency response at the receiver. This decrease in high frequency response at the receiver is approximately linear above 1500 cps. The f-m carrier difference-frequency interference is therefore limited to 1500 B/AD regardless of the pitch of the carrier difference-frequency. At the frequencies at which frequency modulation is now broadcast (42 Mc to 50 Mc), the pitch of the difference-frequency will vary rapidly throughout the audio range at all times due to frequency drift so that 1500 B/AD is a good approximation to the average common channel interference. By a more elaborate study*, it can be shown that this approximation for the average inter-

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* S. Goldman, IRE Convention, June, 1940.

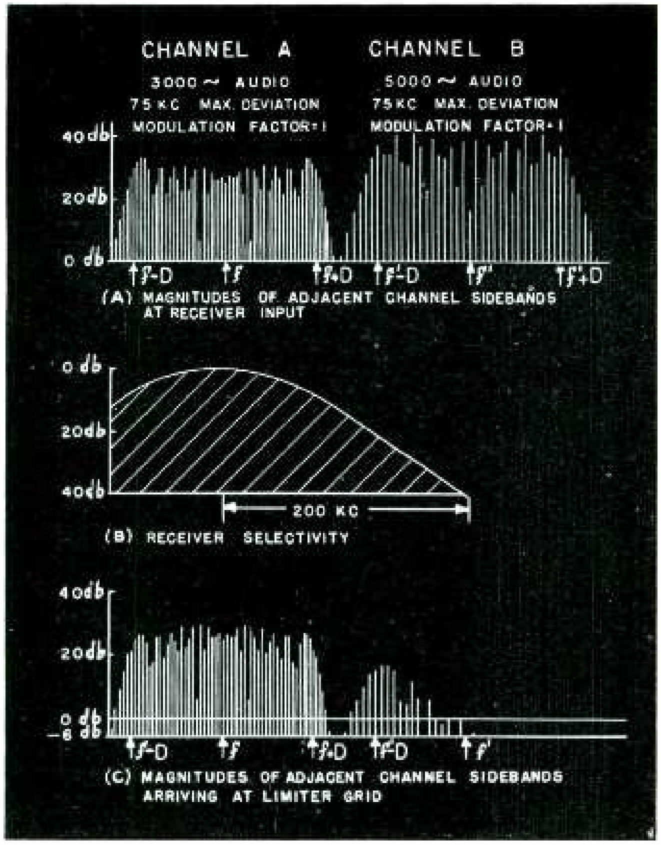

Fig. 6—Amplitude-frequency spectrum of frequency-modulated signals in two adjacent channels, for interfering signal in adjacent channel 6 db greater than desired signal

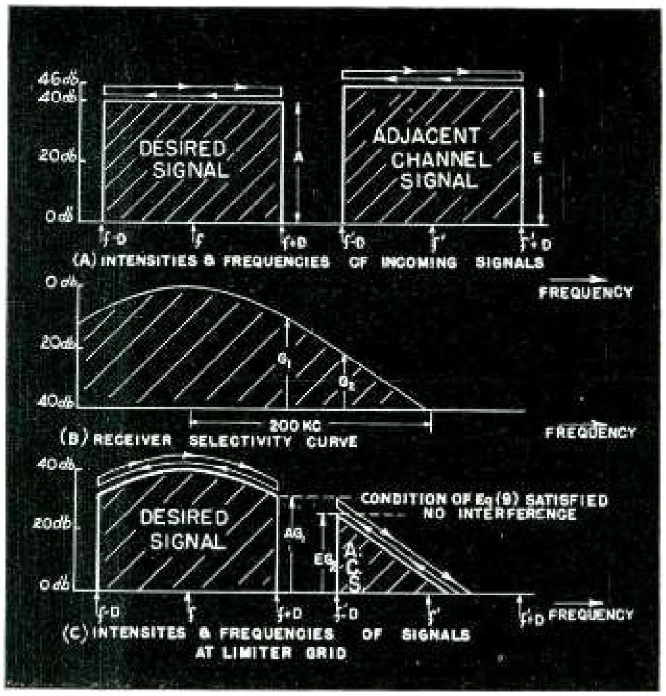

Fig. 5—Graphical study of adjacent channel sideband interference, for adjacent channel 6 db above desired channel signal. Shaded areas indicate desired and undesired signals

ference is still valid even when both carriers are modulated by a normal program.

With present f-m standards, D is normally 75,000 cps. Therefore f-m common channel interference is

$$\frac{1500}{75000} \cdot \frac{B}{A} = \frac{1}{50} \cdot \frac{B}{A} \qquad (8)$$

or about one fiftieth of what it would be for the corresponding case in amplitude modulation.

Adjacent Channel Interference

In the case of adjacent channel interference on present f-m channels, the carrier difference-frequency note is far above audibility, so that it no longer causes interference. However, the higher order sidebands in frequency modulation extend so far away from the carrier that interaction between sidebands may be of audible frequencies. The selectivity of the receiver also enters into the adjacent channel interference picture, so that all in all it is quite a different story from the common channel case.

There are two ways of treating f-m adjacent channel interference, one of which may be called static and the other dynamic. Both of these treatments must be used for a complete picture. In the static treatment we consider the carrier and sidebands as shown in Fig. 5A and the selectivity of the receiver. The magnitude of sidebands getting to the limiter grid as a result of the selectivity, is shown in Fig. 5C. If we know the magnitudes of these sidebands, we can calculate the interaction of audible frequencies. It is by no means obvious that the interaction of sidebands in frequency modulation will give rise to audio or how large this audio will be. However, it has been shown* that the interaction of two adjacent channel signals will give audio of the difference frequencies of the adjacent channels' sidebands and of amounts proportional to the products of the magnitudes of the sidebands multiplied by the factor audio difference frequency, divided by the maximum deviation frequency of larger signal carrier at limiter. This derivation is rather involved and will not be reproduced here.

In the dynamic treatment of f-m adjacent channel interference, we consider the carriers of constant intensity but varying in frequency as shown in Fig. 6. If now, during any appreciable portion of an audio cycle, the interfering carrier intensity arriving at the limiter grid exceeds that of the signal carrier, then, as shown previously in discussing the general problem of interference, the signal is ruined as a high quality signal. If, on the other hand, *the level of the desired signal exceeds that of the interfering signal at the limiter grid during all portions of the audio cycle* then it may be shown mathematically for all normal signals that the adjacent channel interference will be at least 60 db below the signal level. The condition indicated in italics thus is both necessary and sufficient for an f-m signal free from adjacent channel interference. This condition may be expressed by the following formula:

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* S. Goldman, IRE Convention, June, 1940.

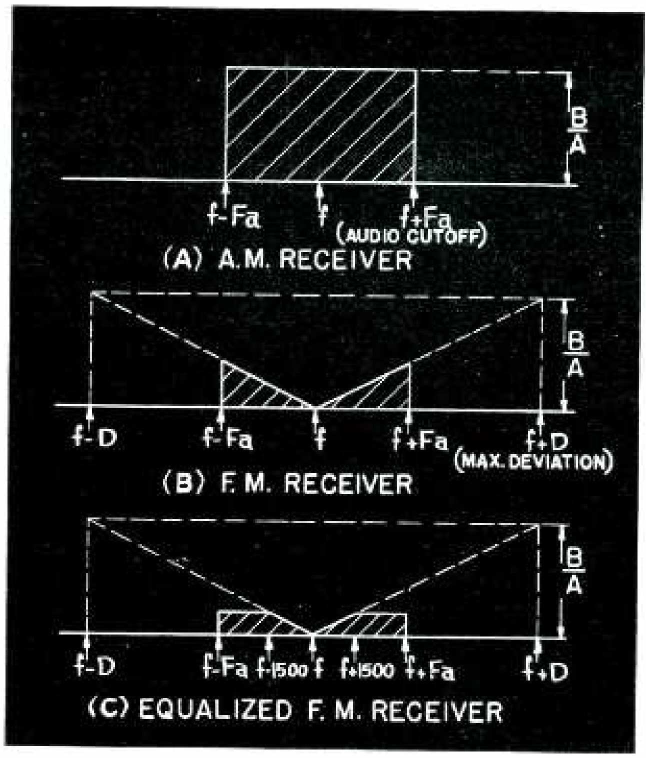

Fig. 7—Shaded areas are proportional to the effective values of sideband noise for three different types of receivers

$$AG_1 > EG_2 \qquad (9)$$

where A is the level of the desired signal at the input of the receiver,

G_1 is the gain of the receiver at the frequency of maximum deviation of the signal toward the adjacent channel,

E is the level of the adjacent channel interfering signal at the input of the receiver, and

G_2 is the gain of the receiver at the frequency of maximum deviation of the adjacent channel toward the signal channel.

According to Eq. (9), there must be enough receiver selectivity in the frequency range between the frequencies of maximum deviation of the signals toward each other, to take care of the difference in level of the desired and adjacent channel signals at the input of the receiver.

Random and Impulse Noise

While any undesired response of a radio receiver, such as hum, adjacent channel interference, etc., may be called noise, we wish to consider here particularly the two kinds of noise‡ usually called random noise and impulse noise. Random noise is a general type of noise such as the interchannel noise of a very sensitive radio receiver. This noise is due to a continuous distribution of nondescript radio frequency signals of unrelated phases. Interaction between these radio frequency noise signals and a strong signal carrier gives rise to audible noise. Interaction between the r-f noise signals themselves, also gives rise to audible noise, but this is of much smaller amount in amplitude modulation, and is negligible in frequency modulation, if a carrier is present.

The audio noise consists of terms of the type described by Eq. (5) and (B/A), in amplitude modulation and terms described by Eqs. (6) and (7) in frequency modulation. The shaded areas in Fig. 7 show the magnitudes of the audio effects of these sidebands in accordance with (B/A) and Eq. (7).

Since the phases of the r-f signals in random noise are unrelated, the total noise modulation factor is equal to the square root of the sum of the squares of all these terms. Thus the noise in amplitude modulation is proportional to the square root of the band-width. This may be expressed by the formula

$$\text{Noise} = K\sqrt{F_a} \qquad (10)$$

where K is a constant, and F_a is the highest audio frequency reproduced by the receiver. It then follows from Fig. 7 that in frequency modulation,

$$\text{Noise} = K\sqrt{\int_0^{F_a}\left(\frac{g-f}{D}\right)^2 d(g-f)}$$

$$= \frac{K\ F_a}{\sqrt{3}\ D}\sqrt{F_a} \qquad (11)$$

Consequently for random noise, frequency modulation is superior to amplitude modulation by a (voltage) factor of $\sqrt{3}\ D/F_a$ in case there is no receiver equalization. For the equalized receiver, the improvement ratio of frequency modulation over amplitude modulation is approximately $D/1500=50$ for random noise, if $D=75{,}000$ cps.

Let us next consider impulse noise, for those cases in which the signal exceeds the noise peaks. This is noise characterized by high peaks of short duration, such as are generated by automobile ignition systems, and by many important natural and man-made sources. The components of impulse noise are essentially spread uniformly over the transmission band of a receiver in a way similar to the frequency spread of random noise. However, the phases of impulse noise components are not spread at random.† It is clear physically and may be demonstrated by Fourier analysis that when an impulse is at its peak, its frequency components must be in phase. Therefore the total noise modulation factor of *impulse noise* components is the sum of that of the individual components, and is not an r-m-s value. Consequently, in amplitude modulation systems, the peak voltage of the resultant of the frequency components, the peak voltage of the transmitted impulse noise, is directly proportional to the bandwidth of the transmission system of the receiver. This is quite different from the case of random noise, in which the peak voltage is proportional to the square root of the bandwidth of the transmission system. Wide band reception makes impulse peaks higher and therefore makes it more likely that they will

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‡ The principal formulas of this section were originally derived by Crosby, *Proc. I.R.E.*, April, 1937.

† V. D. Landon, *Proc. I.R.E.*, Nov. 1936, p. 1514.

exceed the signal level and thus cause serious interference. Consequently, in weak signal areas, ignition noise may be more disturbing in wide band frequency modulation than in narrow band frequency modulation or in amplitude modulation.

It may readily be shown mathematically that the peak frequency deviation caused by impulse noise, or, in other words, the peak f-m impulse noise, is likewise proportional to the sum of the effects of the components in the band width of the transmission system. This band width is the audio frequency transmission band of the receiver, since any higher frequency noise components are lost in the audio amplifier and speaker. In the case of any single impulse, both the frequency modulation and amplitude modulation effects of the impulse depend upon the phase of the r-f signal carrier at the instant that the impulse occurs. These phase effects will, however, average out in any overall picture.

The relative values of impulse noise are therefore.

$$\text{Impulse noise} = k\,F_a \tag{12}$$

for amplitude modulation and

$$\text{Impulse noise} = k\int_0^{F_a}\left(\frac{g-f}{D}\right)d\,(g-f)$$

$$= k\,\frac{F_a^{\,2}}{2D} \tag{13}$$

for frequency modulation. Consequently frequency modulation is superior to amplitude modulation for impulse noise by a (voltage) factor, $2D/F_a$ in case there is no receiver equalization. For the equalized receiver, the improvement ratio of frequency modulation over amplitude modulation is approximately $D/1500 = 75{,}000/1500 = 50$ for impulse noise. This is the same ratio as for random noise.

Discussion

In the foregoing treatment, formulas were derived to show the amount of interference and noise reduction in frequency modulation systems. These formulas were derived on the assumption that the r-f signal reaching the limiter tube was considerably greater than the interference. This is quite a justifiable assumption in deriving the interference reduction obtained in frequency modulation systems, for if the condition is not satisfied and the interference at the limiter tube is greater than the signal, then as was pointed out, there is, except in special cases,* no reduction in interference at all, but rather an increase in it. The derivations also assumed that only frequency modulation gave rise to audio in the f-m receiver. In other words, a perfect limiter was assumed. The formulas derived thus show to what extent frequency modulation reduces interference under conditions when it does so best.

The real explanation of frequency modulation's effectiveness is to be found in the distribution and phase relations of the f-m sidebands. To understand this, suppose that an audio signal *amplitude modulates* an r-f carrier of say two megacycles and that this modulated carrier is amplified by a high gain amplifier which has uniform amplification in the entire frequency range from zero to four megacycles. If the output of this amplifier is observed on an oscilloscope, the noise will be tremendous and will mask the signal unless the latter is very large. If, however, the amplifier is tuned and only passes a signal in the region within ±10 kc of the carrier, the noise will be greatly reduced while the signal will be practically unaffected, so that a tremendous improvement in the signal to noise ratio will be observed. This shows how frequency selectivity reduces noise. On the other hand, mistuning of an i-f amplifier will demonstrate very quickly how frequency selectivity reduces adjacent channel interference.

The next question which naturally arises is why frequency modulation reduces interference. Prior to an investigation, it might be supposed that the limiter tube, by cutting off noise peaks, was the important factor in noise reduction. This, however, is not the answer; because noise peaks which exceed the signal will be just about as noisy in f-m as in a-m receivers and it is only when the signal reaching the limiter exceeds the interference that frequency modulation is effective. The real and very important increase of the limiter is that it strips the signal of amplitude modulation and allows f-m to do its work.

In the case of an f-m signal there is a combined system of amplitude, frequency, and phase selectivity. The selective circuit in this case is the discriminator or slope detector in combination with the audio amplifier of restricted band width. If a signal comes to this detector with amplitude, frequency, and phase relations of its components such as shown on the right side of Eq. (2), these components will combine in such a way as to give maximum frequency shift at an audio frequency rate and consequently maximum audio output. If on the other hand the amplitude, frequency, and phase relations of the components are not those shown on the right side of Eq. (2), they will not combine efficiently to give frequency shift at an audio frequency rate. The combination of carrier and sidebands on the right side of Eq. (2) has the property that it will produce extremely large frequency shifts at a low audio frequency rate as compared with what would be produced by a random distribution of carrier and sideband components of the same energy. Thus the slope detector in combination with the audio amplifier effectively selects those signals with amplitude, frequency, and phase relations of their components similar to those shown on the right side of Eq. (2).

The explanation of the effectiveness of frequency modulation in reducing noise and interference may therefore be considered as a generalized type of selectivity. It would be interesting to consider possible uses of other types of selective circuits. A different type of combined amplitude, phase and frequency selectivity already used in radio receivers is the demodulation of a weak carrier by a strong one at the second detector.

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* In the case of impulse noise of very high peaks of very short duration, there is another effect which works to the advantage of wide band f-m systems, which in effect, however, is not peculiar to frequency modulation.

Short duration impulses are always spread out in the i-f amplifier of a receiver, the amount of spread being inversely proportioned to the band width of the i-f amplifier. This is a well-known property of tuned circuits. Now a sharp impulse will cause a tremendous frequency shift in the f-m signal, corresponding with, although not necessarily proportional to, the high amplitude peak. However, the band widths of most i-f amplifiers and the outputs of most slope detectors in use are limited to very little more than that produced by a 75 kc. frequency shift. A band width of ± 75 kc from the carrier is nevertheless still sufficiently wide to reduce the duration of the impulse to a very short time. The maximum audio output produced by an impulse is thus limited, whereas its duration is kept short. The overall effect of highly peaked, very short duration impulses is therefore greatly reduced in wide band f-m receivers.

This phenomenon is of considerable practical importance, but as already mentioned, it is not peculiar to frequency modulation. Wide band a-m receivers with amplitude limiting, would show the same property.

Frequency Response of Parallel Resonant Circuit

By **MYRIL B. REED**

Illinois Institute of Technology, Chicago, Ill.

THE two-branch parallel circuit, commonly called a wave trap, Fig. 1, is very widely used in both communication and power net-works, power factor and voltage control in power systems, and tuning and filtering in communication systems.

This paper gives in a readily usable form the results of a complete mathematical study of the current versus frequency response of the wave trap.

A mathematical analysis of the total current as a function of frequency may be carried out, for constant generator voltage, E, by studying the admittance expression:

$$Y = \sqrt{\left(\frac{R_L}{R_L^2 + 4\pi^2f^2L^2} + \frac{R_C}{R_C^2 + \frac{1}{4\pi^2f^2C^2}}\right)^2 + \left(\frac{2\pi fL}{R_L^2 + 4\pi^2f^2L^2} - \frac{\frac{1}{2\pi fC}}{R_C^2 + \frac{1}{4\pi^2f^2C^2}}\right)^2}$$

Also of interest is the phase angle between the generator voltage and the current flowing into the parallel circuit. This angle, given by

$$\theta = \tan^{-1} \frac{X_C Z_L^2 - X_L Z_C^2}{R_C Z_L^2 + R_L Z_C^2},$$

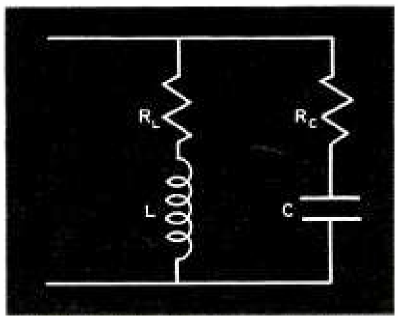


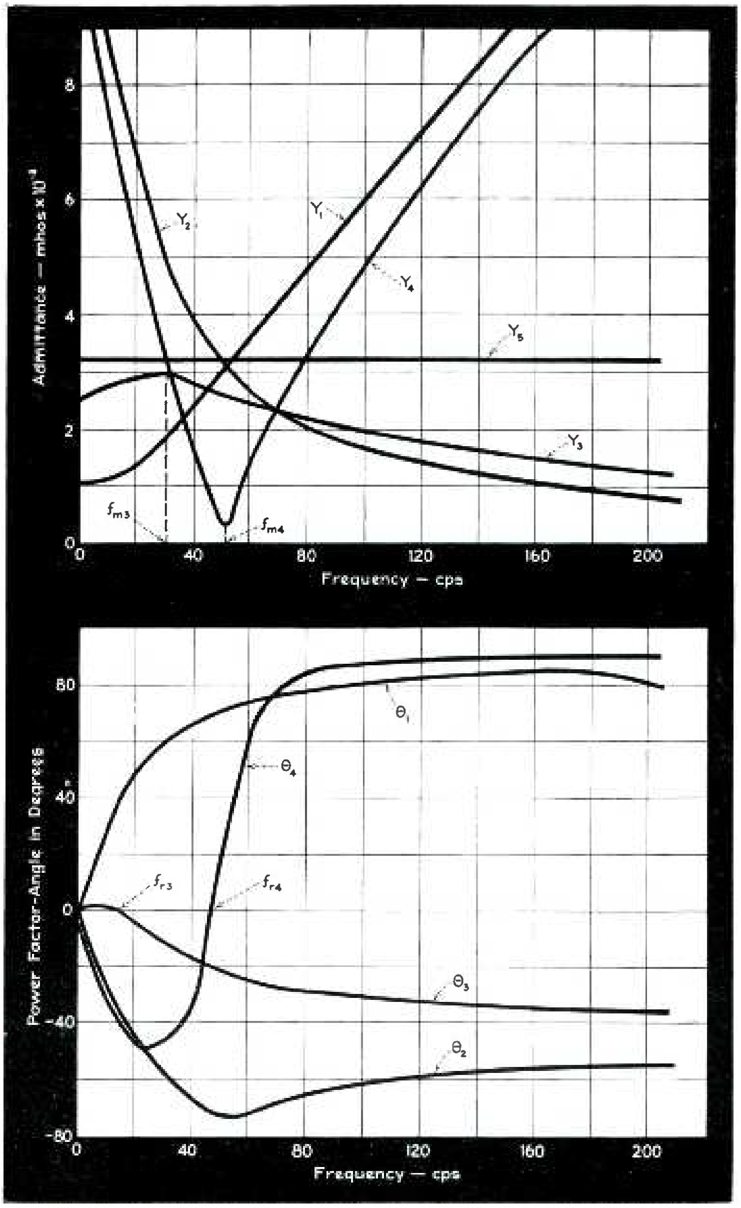
Fig. 1 (Above)—Circuit diagram of parallel resonant circuit, with resistance in both arms, and for which analysis applies

Fig. 2 (Right)—Admittance and phase angle curves used in example, but typical of all possible operating conditions of *LC* circuit. For all frequencies, $\theta_5 = 0$

is positive if current leads voltage.

A graphical representation of the behavior of the wave trap is shown in Fig. 2. As shown, there are five general forms of the admittance or current versus frequency relation. In addition to the well known constant and minimum value relations (curves Y_5 and Y_4 and the corresponding θ_5 and θ_4 curves) there are the *maximum* value (Y_3), decreasing (Y_2), and increasing (Y_1) admittance functions with the corresponding phase functions θ_3, θ_2, and θ_1. As may be shown mathematically, these five pairs of curves constitute all possibilities. The relative frequencies at which the maximum or minimum values of Y and unity power factor resonance occur are shown on the curves and in the tabulation below.

The determination of which one of the five admittance-frequency responses a particular wave trap will have is ordinarily difficult. However, by means of the following system of inequalities, it is easy to determine such features of a wave trap as:



whether it will resonate, whether resonant frequency, if it exists, is at a higher or lower frequency than that at maximum or minimum admittance, whether the admittance function has a miximum or minimum, and whether the angle θ is lead or lag.

In the following table, let

f_r be the resonant frequency, (current and voltage in phase),

f_m be the frequency at which minimum current occurs,

f_M be the frequency at which maximum current occurs.

L be the inductance in the inductive brance,

C be the capacitance in the capacitive brance,

R_L be the resistance of the inductive arm, and

R_C be the resistance of the capacitive arm.

Then, depending upon the relative magnitude of R_CR_L with respect to that of L/C, there are three possible cases to be analyzed, as shown in the table. By proper selection of the appropriate circuit conditions, the table may be used to determine the circuit response for any possible physical condition which may be encountered.

The use of this system of relations can best be illustrated by an example. Assume $R_C = 2000$ ohms, $R_L = 100$ ohms, $L = 1$ henry, and $C = 10^{-5}$ farad. Then

$$R_CR_L = 2 \times 10^5 > 10^5 = L/C$$

$$R_C^2 = 4 \times 10^6 > L/C, \text{ and } R_L^2 = 10^4 < L/C$$

$$R_L^2 + L/C)^2 = 121 \times 10^8 > 42 \times 10^8$$

$$= 2R_L^2(R_L^2 + R_CR_L).$$

From the third from the last row of case III the admittance equation is a decreasing function (see Y_2 of Fig. 2) which will never be resonant, and, since $R_C > R_L$, from case III, $\theta < 0$, or the circuit power factor is lagging for all frequencies as shown in curve θ_2 of Fig. 2.

If $R_C = 1$ ohm, $R_L = 100$ ohms, $C = 10^{-5}$ farad, and $L = 1$ henry

$$R_CR_L < L/C; R_C^2 < L/C; \text{ and } R_L^2 < L/C$$

hence from case I the admittance has a minimum, f_m at 50.2 cps as shown by curve Y_4 of Fig. 2. Also, since $R_C < R_L$, the minimum admittance is at higher frequency than resonance, $f_r = 45.3$ cps. Also, from case I, $\theta > 0$ or leading for frequencies above resonance and $\theta < 0$ or lagging for frequencies below resonance.

ADMITTANCE, RESONANCE AND PHASE RELATIONS FOR PARALLEL CIRCUIT

Circuit Element Relations	Response-Frequency Relation	Resonance and Phase Relations
Case I — $R_CR_L < L/C$		
$R_L^2 < L/C$, $R_C^2 < L/C$ $\begin{cases} R_L > R_C; f_m > f_r \\ R_L = R_C; f_m = f_r = \dfrac{1}{2\pi\sqrt{LC}} \\ R_L < R_C; f_m < f_r \end{cases}$	Curve has a minimum at f_m	Circuit is resonant. $f < f_r;\ \theta < 0$ $f = f_r;\ \theta = 0$ $f > f_r;\ \theta > 0$
$R_L^2 = L/C;\quad R_C^2 < L/C$		
$R_L^2 < L/C;\quad R_C^2 = L/C$		Circuit is not resonant
$R_L^2 < L/C$, $R_C^2 > L/C$: $(R_C^2 + L/C)^2 > 2R_C^2(R_C^2 + R_CR_L)$		
$R_L^2 < L/C$, $R_C^2 > L/C$: $(R_C^2 + L/C)^2 \leqq 2R_C^2(R_C^2 + R_CR_L)$	Y decreases; curve has no maximum or minimum.	$R_L > R_C;\ \theta > 0$
$R_L^2 > L/C$, $R_C^2 < L/C$: $(R_L^2 + L/C)^2 \leqq 2R_L^2(R_L^2 + R_CR_L)$	Y increases; curve has no maximum or minimum	$R_L < R_C;\ \theta < 0$
$R_L^2 > L/C$, $R_C^2 < L/C$: $(R_L^2 + L/C)^2 > 2R_L^2(R_L^2 + R_CR_L)$	Curve has a minimum at f_m	
Case II — $R_CR_L = L/C$		
$R_L^2 < L/C$ $R_C^2 > L/C$	Y decreases; curve has no maximum or minimum	Circuit is not resonant
$R_L^2 > L/C$ $R_C^2 < L/C$	Y increases; curve has no maximum or minimum	$R_L < R_C;\ \theta < 0$ $R_L > R_C;\ \theta > 0$
$R_L^2 = R_C^2 = L/C$	$Y = \sqrt{C/L}$, and curve is constant for every frequency	Circuit is resonant at every frequency $\theta = 0$ always
Case III — $R_CR_L > L/C$		Circuit is resonant
$R_L^2 > L/C$, $R_C^2 > L/C$ $\begin{cases} R_L > R_C; f_m > f_r \\ R_L = R_C; f_m = f_r = \dfrac{1}{2\pi\sqrt{LC}} \\ R_L < R_C; f_m > f_r \end{cases}$	Curve has a maximum at f_m	$f = f_r;\ \theta = 0$ $f > f_r;\ \theta < 0$ $f < f_r;\ \theta > 0$
$R_L^2 = L/C;\quad R_C^2 > L/C$		
$R_L^2 > L/C;\quad R_C^2 = L/C$		
$R_L^2 < L/C$, $R_C^2 > L/C$: $(R_L^2 + L/C)^2 < 2R_L^2(R_L^2 + R_CR_L)$		Circuit is not resonant
$R_L^2 < L/C$, $R_C^2 > L/C$: $(R_L^2 + L/C)^2 \geqq 2R_L^2(R_L^2 + R_CR_L)$	Y decreases; curve has no maximum or minimum	$R_L > R_C;\ \theta > 0$
$R_L^2 > L/C$, $R_C^2 < L/C$: $(R_C^2 + L/C)^2 \geqq 2R_C^2(R_C^2 + R_CR_L)$	Y increases; curve has no maximum or minimum	$R_L < R_C;\ \theta < 0$
$R_L^2 > L/C$, $R_C^2 < L/C$: $(R_C^2 + L/C)^2 < 2R_C^2(R_C^2 + R_CR_L)$	Curve has a maximum at f_m	

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TUBES AT WORK

An integrated remote amplifier, studio input circuit, a half-cycle electronic switch, and a flexible rectifier unit, and keyless telegraphy are discussed

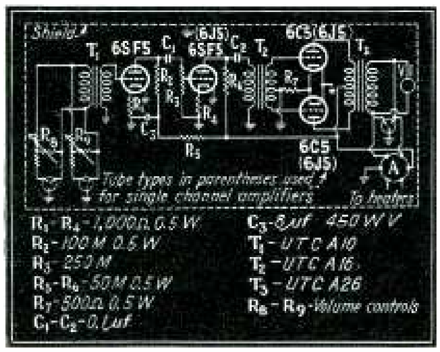


Fig. 1—Basic circuit of the amplifiers using two microphones for remote pick-up at station WILL

Integrated Remote Amplifier System

By A. JAMES EBEL

University of Illinois
Station WILL

THE PICK-UP AMPLIFIERS described represents a solution to a problem which confronts many stations, especially those that have many remote programs to handle and little funds with which to handle them. The non-commercial station for which this equipment was designed operates on a rather limited yearly budget, yet the character of its broadcasts requires an average of eight remote pickups a day involving a total time of approximately five hours. It is station practice to have one man set up and check all the remotes for the broadcast day before the day gets under way. While this requires more equipment, it saves on labor, transportation, and program failures since the equipment is all checked far enough in advance of the program to allow time for replacement.

In designing equipment for an integrated setup it is necessary to examine the program content of the average day to determine how many of the remotes require only a single channel, how many can be operated with dual channel equipment and how many require more channels. It is, of course, poor management to use three-channel amplifiers on programs that require only a single channel. An analysis of the above situation showed that roughly 75 per cent of all programs require only a single channel amplifier. This figure is probably higher than the average. It indicates, however, that the station in question should have at least six single channel amplifiers and two multi-channel amplifiers with their associated power supplies. A further analysis will indicate that if battery supplies are used, the drain on the battery for five hours operation each day will be rather heavy. Therefore, the use of alternating current is indicated wherever possible with battery standby if the a-c supply is uncertain. Maximum flexibility dictates that the power supplies be interchangeable and therefore separate. This also eliminates the vexing inductive hum problem when alternating current is used, but it does require that the same type tubes be used both for a-c and battery operation, a factor which tends to shorten battery life. However, since alternating current can be used in most cases this is not generally an important item. Should it become important a solution lies in the small portable storage battery.

The electrical characteristics of the amplifiers must, of course, be at least as good as those set forth in the "Standards of Good Engineering Practice." However, since the amplifiers are to be used as part of an integrated system of remote amplifying equipment, their characteristics must be better than those dictated by the state of the art so that they will not become quickly obsolescent and leave a weak link in the system. The electrical specifications of the amplifiers are as follows:

Frequency response	Flat within 1 vu from 40 to 10,000 cps
Amplitude distortion	Less than 1% at +10 vu
Noise Level	—50 vu
Gain	85 vu

The entire remote system is built around a basic circuit. This circuit for

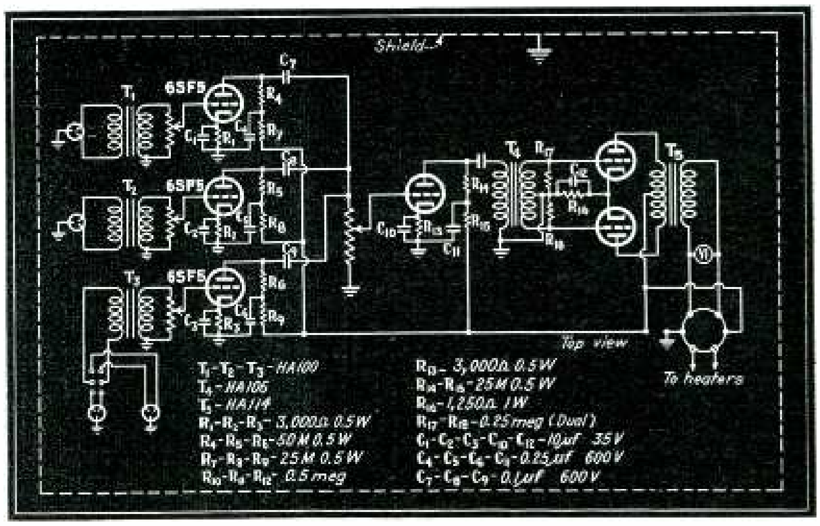
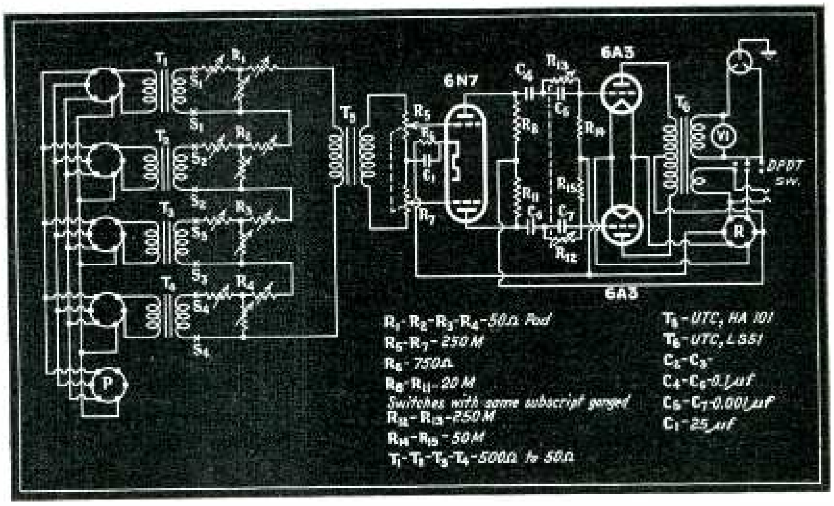


Fig. 2—Above, schematic wiring diagram of three channel pick-up amplifier. Note similarity to Fig. 1

Fig. 3—Below, circuit of recording amplifier designed by Mr. Ebel of station WILL



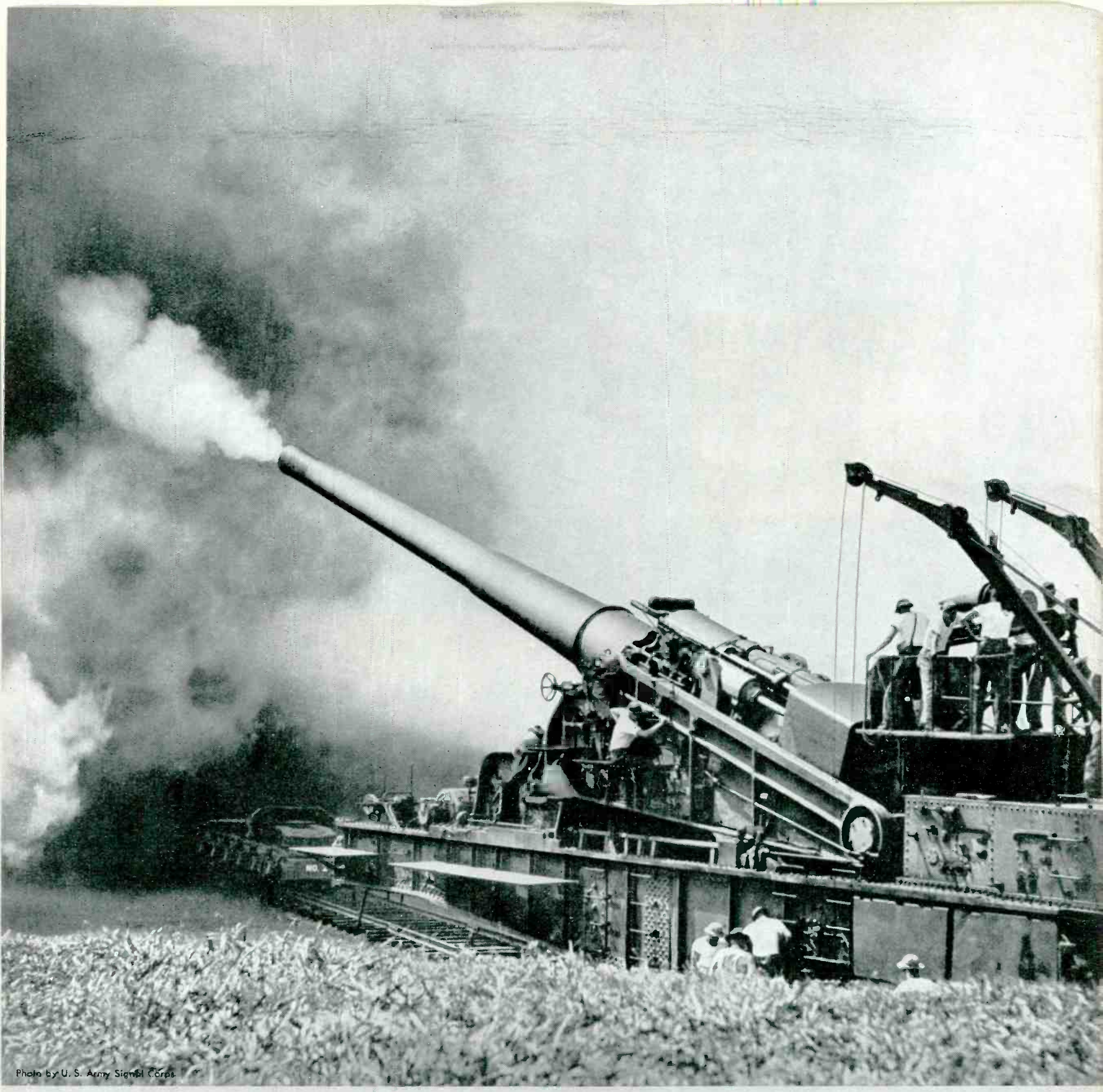
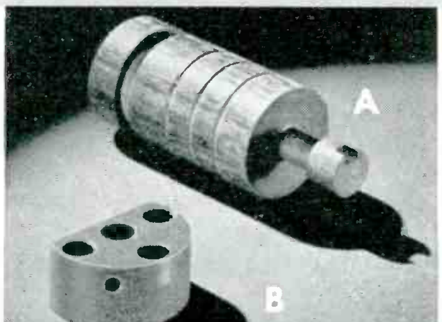


Photo by U. S. Army Signal Corps

RADIO CALLS ITS SHOTS



A — Airbrake piston — drilled, turned and grooved on lathe, milled.
B — Insulator—bandsawed, turned, drilled, and counterbored.

Army and Signal Corps engineers see to it that there are no weak links in the chain of communications controlling gunfire or troop movement. • Bakelite-laminated insulates many important circuits, here as in other less spectacular, but no less essential, operations. SYNTHANE CORPORATION, OAKS, PENNA.

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a double-channel amplifier is shown in Fig. 1. The single channel circuit is identical with that of Fig. 1 except for the omission of one microphone, and substitution of the 6J5 tubes for the 6SF5 and 6C5 triodes. It might be pointed out at this point that no originality whatsoever is claimed for the circuits used. They are circuits that have been successfully used in audio work, adapted to the requirements of the system. Examination of the two circuits will show their similarity. The diagrams of each of the amplifiers are self-explanatory and need no further comment.

All amplifiers use identical circuit components wherever possible and are wired in exactly the same manner. The advantages of this arrangement are twofold. First, only a limited number of spare parts need be kept on hand for all the amplifiers, and second, it is very easy to maintain amplifiers since when the operating personnel knows one amplifier they know all of them. Because these amplifiers have to take much punishment all components are securely mounted with a liberal use of tie points. We were somewhat dubious about the volume controls used in the amplifiers but after one year's service we have yet to experience a noisy control. When one does become noisy it is but a matter of five or ten minutes to replace it with a new one already on hand.

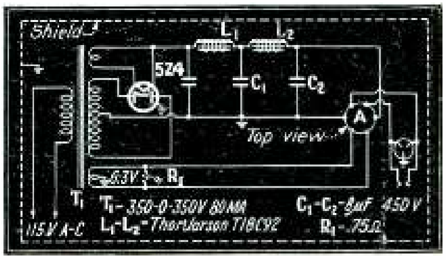
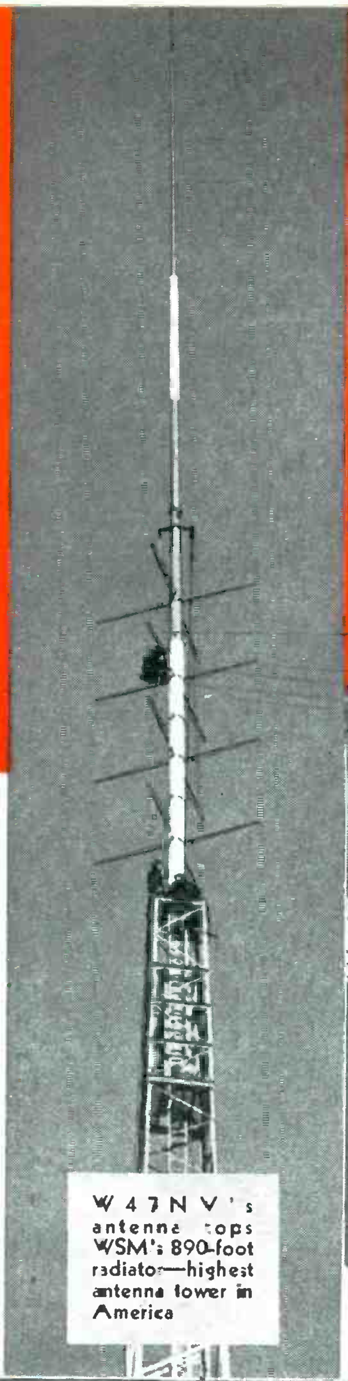


Fig. 4—Circuit diagram of the power supply for the preamplifiers

The amplifier cases for single channel units were made up by a metal worker in lots of four and the chassis were punched according to a template furnished by us. The chasses and cases of the multichannel units will be standardized so that all future units will be similar to those now on hand. The dual-channel amplifier is somewhat of an orphan to the system since it was constructed before the type of case was decided upon. While its circuit is standard, it is built in an aluminum box and the plug mountings are not conventional. It is hoped to rebuild this into a standard sheet metal case in the near future.

The a-c power supplies are wired according to the circuit in Fig. 4 and mounted in sheet metal boxes. Six wire connecting cables are used throughout for connections between amplifier and power supply. Three wire polarized Hubbell connectors for audio circuits is also standard with all our equipment. The three wire output plug for the amplifiers is mounted in the cover of the power supply box as is the head-

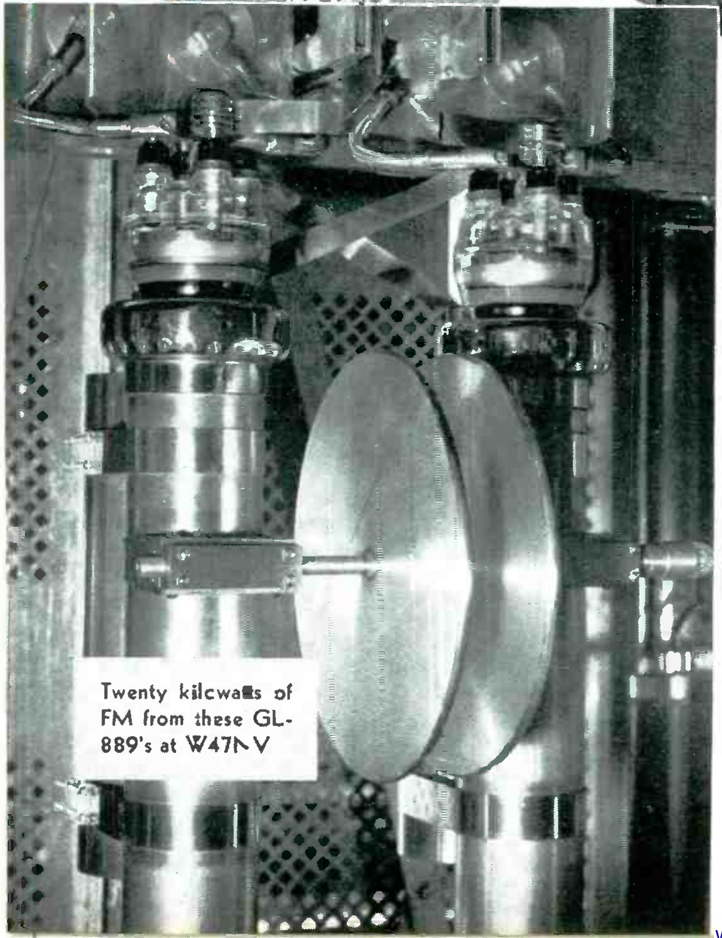
FM's First
COMMERCIAL STATION
Packs a 20-kw Wallop with GL-889's



W47NV's antenna tops WSM's 890-foot radiator—highest antenna tower in America

Mr. DeWitt, left, chief engineer of W47NV, and W. Crockett of the G-E Nashville Office talk over FM

"Tube Performance Highly Satisfactory," Reports Chief Engineer Jack DeWitt of Nashville's W47NV



Twenty kilowatts of FM from these GL-889's at W47NV

W47NV, operated by the National Life and Accident Insurance Company of Nashville, went on the air as the first commercial FM station March 1, and in June was granted full commercial status by the FCC. Read Mr. DeWitt's comments . . .

"We are operating at 20-kw output on a 10-hour-a-day schedule," he writes. "We have found the GL-889's to have excellent stability; they are easy to drive and to neutralize.

"We have tested both the regular and spare sets of tubes under operation conditions, and we find that the balance obtained with either pair is unusually good. All of the tubes have uniform characteristics, which, of course, is very important at FM frequencies.

"We have every reason to expect highly dependable service from them."

General Electric has transmitting tubes and a complete line of FM equipment to meet your needs. Get both through the nearest of the 80 G-E offices. General Electric, Schenectady, N. Y.

GENERAL ELECTRIC

161-21-8850

phone jack. The microphone input plugs are located on the amplifiers thereby providing isolation for the low level circuits.

Carrying cases to house the various units were designed and constructed by one of the staff members. These are also uniform and are made of three-ply oak with heavy brass angle strippings. Cases have been made to house amplifiers with battery supplies and to house amplifiers with a-c supplies. A compartment for carrying accessories is also provided. These cases have stood up very well under the roughest handling for more than a year.

A recent addition to the system of amplifiers is the recording amplifier. It too is standardized to fit the integrated system. It consists of a four channel amplifiers or any other zero level source. The input plugs on the recording amplifier are arranged so that power is furnished to each of the single channel amplifiers through the six wire cord connection to the amplifier. The power is obtained from the recording amplifier power supply so that no separate power supplies are necessary to operate the various single channel amplifiers. This recording amplifier can also be used for a small public address amplifier or as an audition amplifier in conjunction with the portable recording turntable. The circuit diagram of the recording amplifier is shown in Fig. 3, and of the power supply in Fig. 5.

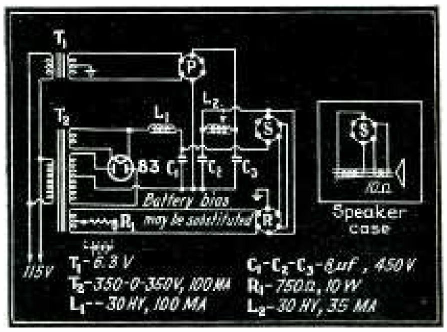


Fig. 5—Connections for power supply unit for recording amplifier

In conclusion the writer again wants to stress that the object of the above described amplifiers was to provide a standardized amplifier setup at a minimum of expense without sacrifice of quality. There have been times when other circuits have been tried but they were all discarded in favor of the standardized circuit even though the other circuits might offer some advantages not present in the standard circuit. It has been possible to standardize all the associated equipment and connecting plugs making for maximum flexibility and requiring a minimum of equipment.

The author wishes to acknowledge the valuable assistance of G. Edward Hamilton who made the lay-outs and did most of the construction work on the amplifiers, and fine workmanship of Robert Schmidt who designed and constructed the amplifier cases.

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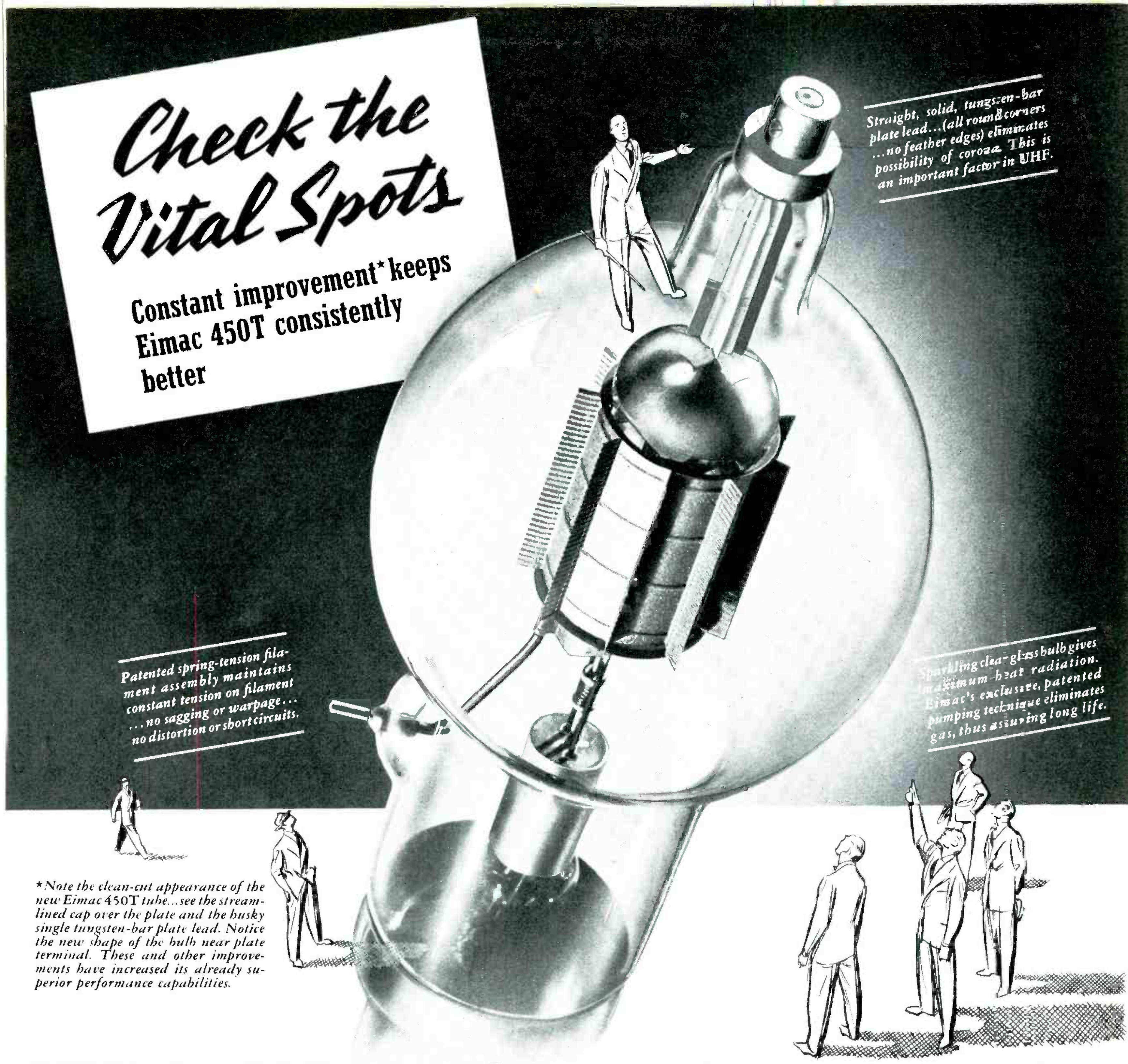
Constant improvement* keeps Eimac 450T consistently better



Straight, solid, tungsten-bar plate lead...(all round corners ...no feather edges) eliminates possibility of corona. This is an important factor in UHF.

Patented spring-tension filament assembly maintains constant tension on filament ...no sagging or warpage... no distortion or short circuits.

Sparkling clear-glass bulb gives maximum heat radiation. Eimac's exclusive, patented pumping technique eliminates gas, thus assuring long life.

**Note the clean-cut appearance of the new Eimac 450T tube...see the streamlined cap over the plate and the husky single tungsten-bar plate lead. Notice the new shape of the bulb near plate terminal. These and other improvements have increased its already superior performance capabilities.*

EIMAC 450T sets the pace in modern radio

The adoption of Eimac 450T's for use in aircraft ground stations marked the beginning of a long series of sensational successes for these radically designed but soundly conceived vacuum tubes. Today they occupy the key sockets of many of the most important radio transmitters in the world. In fact many of these transmitters are built specifically around the unusual capabilities of the Eimac 450T. Contained in this fact is proof that Eimac 450T tubes are setting the pace in modern radio. Further proof is to be found in that Eimac tubes are the most copied tubes on the market today... their once radical shape is now almost a standard, although their performance has yet to be exactly duplicated. These obvious truths should mean much to you in the selection of vacuum tubes for your application. Get in touch with the nearest Eimac representative for complete information about the Eimac 450T... or any of twenty odd tube types available.

You'll get greater economy in first cost and in operation from these, the only tubes unconditionally guaranteed against premature failures caused by gas released internally.

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Studio Input Modifications

By Earle Travis, KVEC.

After purchasing a limiting type line amplifier, many operators set their old line amplifier aside to gather dust as a spare or standby. I have found that a line amplifier such as a RCA 55-A can be put to many uses around the station, as, for example, a bridging amplifier for network reversals or to talk back on remote lines, a substitute for the studio line amplifier, to allow the regular amplifier to be worked on, or in conjunction with an a-c meter as a very sensitive level meter.

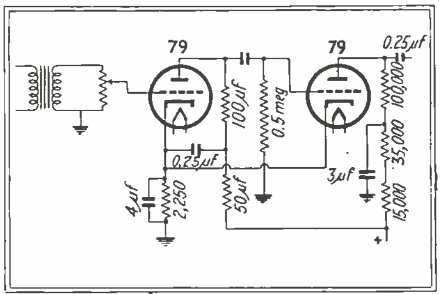


Fig. 1—Circuit of preamplifier using a double triode in single envelope

In order to use the 55-A as a substitute for a line amplifier such as the RCA 40-C its gain should be increased. A good way to do this is to substitute a 79 for the 6C6 input tube. The 79 is a double triode with the same base as the 6C6. Figure 1 shows the input circuit using a 79. Parts with indicated values are added parts. With this altered input the gain of the amplifier should be around 75 db.

The switching arrangement for the whole setup is shown in Fig. 2. It will be seen that the input may be switched either to an air program or an audition program. We have only one audition circuit. In studios with several audition circuits it might be well to use a multiple point rotary switch so any audition program could be selected. The output is brought out to two switches which allow it to be

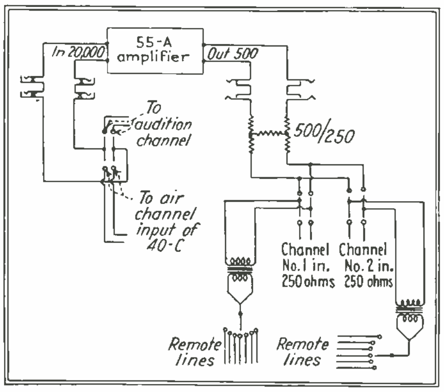
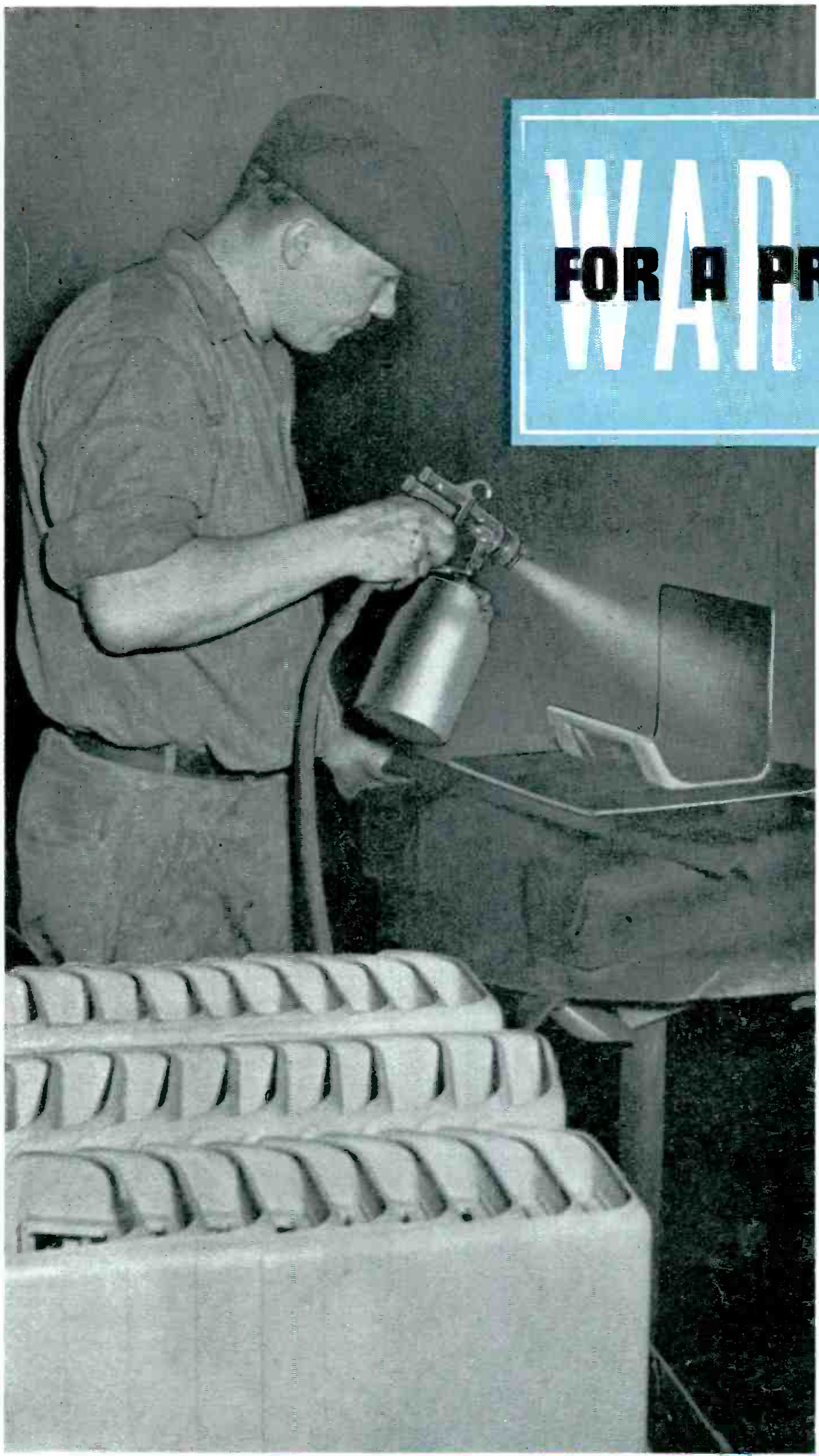


Fig. 2—Suggested arrangement of using line amplifier in broadcast work. The pairs of remote lines are indicated as single wires



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The manufacturers of TelAutograph Telescribers turned to Lewyt. Instead of using complicated dies Lewyt contrived some inexpensive tooling, formed and shaped sheet steel into nine different pieces. These were welded, ground, and assembled with extreme precision to make the chassis and casing. Then the finishing touches, one step of which you see illustrated here, to give this product an attractive and enduring complexion upon which incidental surface scratches would forever remain inconspicuous.

This product engineering achievement is typical of what the name Lewyt stands for today. Many of the most notable firms in the country are having Lewyt fabricate their products—or highly specialized parts of their products.

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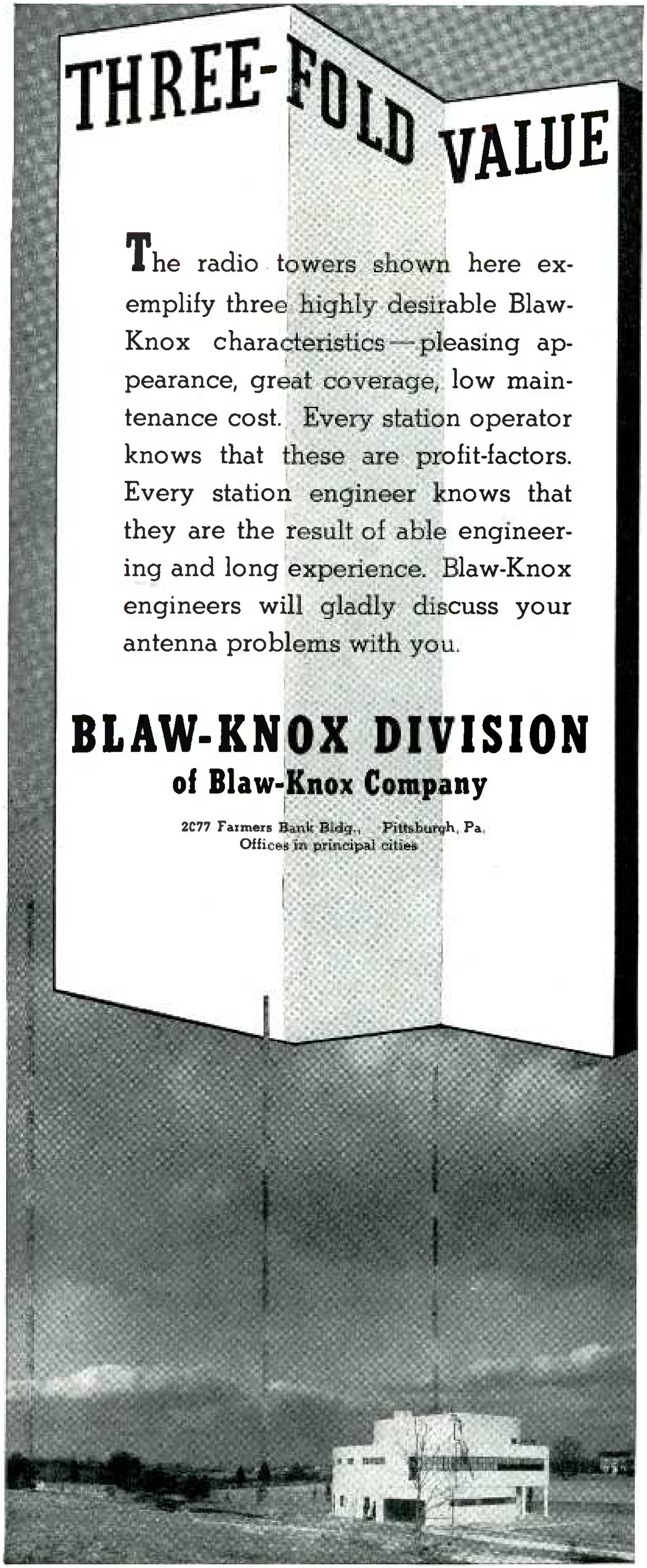


switched to either of our two incoming channels.

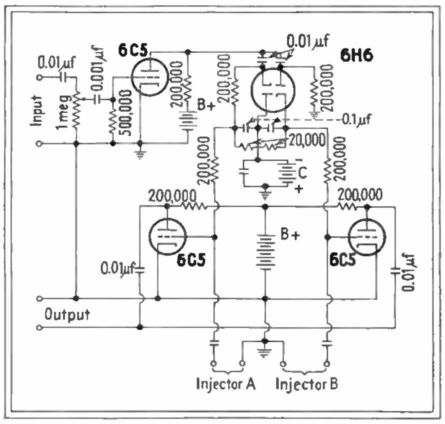
In order to use the amplifier for measurement work it is only necessary to terminate it with a 500-ohm resister and then connect the meter across the resister. This can best be done at the patch board. The input is then either switched or patched to whatever circuit you are interested in. Before many measurements are attempted a curve should be run with instruments of known accuracy as some dry disk meters have unusual characteristics.

• • •

Half-Cycle Electronic Switch

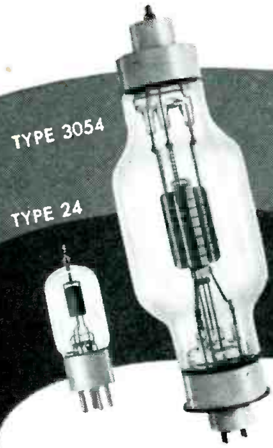
By Esten Moen

A different kind of wave-switch is sketched in the figure herewith; the usual wave-switch depends upon locking a circuit with the inflection-points of a wave, but this one instead just traces out the maximum-minimum. The first tube of the circuit, a 6C5, is a repeater-amplifier which will avoid unnecessary damping of the source, which may be a single-tube oscillator. The amplified waves then enter the 6H6 "clipper" tube, in which positive crests enter one channel and negative crests the other channel. A *C* battery and bypass condenser are inserted to bias grids of the following 6C5's to or beyond cut-off until the appropriate voltage from each wave-crest is delivered by the 6H6. Then during the half-cycle in which the grid of one of the last two 6C5's is made sufficiently positive for the tube to be conducting, any signal voltage injected at *A* or *B*, will be superimposed upon the input voltage. Both *A* and *B* may be injected independently of each other, the resultant being recombined into a single pair of output terminals.



Double rectifier and three triodes are used in this half-cycle switch which differentiates positive and negative peaks

This final resultant voltage can then be scanned on a cathode ray tube if the scanning wave is made linear and synchronized with the original input. Of course, the final wave shape can be made "square" if the plate voltage of the last two 6C5's is reduced and two more triodes are added as amplifiers.



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The summary below shows GAMMATRON radiation-cooled transmitting triodes with a power range of 50 to 5000 watts for every purpose. Variations of these types are available to meet special requirements, such as: increased filament power or special connector arrangements. Also available is a complete line of tantalum high vacuum rectifier tubes for high voltage operation.

Write for data on all standard GAMMATRON types and request our engineering department for assistance on your special problems.

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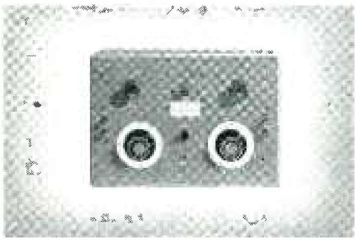
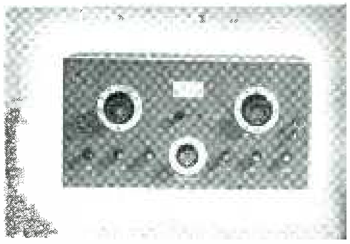
TYPE NO.	24	54	152L	158	254	257*	304L	354C	354E	454L	454H	654	854L	854H	1054L	1554	2054A	3054
MAX. POWER OUTPUT: Class 'C' R.F.	90	250	610	200	500	230	1220	615	615	900	900	1400	1800	1820	3000	3600	2000	5300
PLATE DISSIPATION: Watts	25	50	150	50	100	75	300	150	150	250	250	300	450	450	750	1000	1200	1500
AVERAGE AMPLIFICATION FACTOR	25	27	10	25	25	...	10	14	35	14	30	22	14	30	13.5	14.5	10	20
MAX. RATINGS:																		
Plate Volts	2000	3000	3000	2000	4000	4000	3000	4000	4000	5000	5000	4000	6000	6000	6000	5000	3000	5000
Plate M.A.	75	150	500	200	225	150	1000	300	300	375	375	600	600	600	1000	1000	800	2000
Grid M.A.	25	30	75	40	40	25	150	60	70	60	85	100	80	110	125	250	200	500
MAX. FREQUENCY, Mc.: Power Amplifier	200	200	175	100	175	150	175	50	50	150	150	50	125	125	100	30	20	30
INTERELECTRODE CAP:																		
C g—p u.u.f.	1.7	1.8	5	4.6	3.6	0.04	9	3.8	3.8	3.4	3.4	5.5	5	4	5	11	18	15
C g—f u.u.f.	2.5	2.1	7	4.7	3.3	13.8 In.	12	4.5	4.5	4.6	4.6	6.2	6	8	8	15.5	15	25
C p—f u.u.f.	0.4	0.5	0.4	1.0	1.0	6.7 Out.	0.8	1.1	1.1	1.4	1.4	1.5	0.5	0.5	0.8	1.2	7	2.5
FILAMENT:																		
Volts	6.3	5.0	5-10	12.6	5.0	5.0	5-10	5	5	5	5	7.5	7.5	7.5	7.5	11	10	14
Amperes	3	5	13-6.5	2.5	7.5	7.5	13-26	10	10	11	11	15	12	12	21	17.5	22	45
PHYSICAL:																		
Length, Inches	4¼	5 7/16	7¾	4¾	7	6¾	7¾	9	9	10	10	10⅜	12½	12½	16½	18	21¼	30¾
Diameter, Inches	1⅜	2	2½	2	2⅝	2⅝	3½	3⅜	3⅜	3¾	3¾	3¾	5	5	7	6	6	9
Weight, Oz.	1½	2½	8	4	6½	6	9	6½	6½	7	7	14	14	14	42	56	66	200
Base	Small UX	Std. UX	Johnson #213	Std. UX	Std. 50 Watt	Giant 7 Pin	Johnson #213	Std. 50 Watt	Std. 50 Watt	Std. 50 Watt	Std. 50 Watt	Std. 50 Watt	Std. 50 Watt	Std. 50 Watt	Johnson #214	HK 255	W.E. Co.	HK 255
*Beam Pentode.																		
NET PRICE	4.75	8.00	30.00	18.50	13.50	27.50	65.00	24.50	24.50	27.50	27.50	75.00	75.00	75.00	175.00	225.00	300.00	395.00

GAMMATRONS of course!





A Flexible Rectifier Unit for College Laboratories

By F. V. Schultz

In the laboratory courses in electronics, and alternating current machinery courses for non-electrical students at Michigan State College, it was thought desirable to include experiments on rectifiers. Single phase rectifiers have been tested frequently in the electronics laboratory, but polyphase rectifiers have been largely avoided due to the amount of time required to assemble the apparatus and make the necessary connections. With these facts in mind it was decided to build portable units containing all the required apparatus and having all the educationally unimportant connections permanently made. These units were to be built so that by making a minimum number of connections practically any rectifier circuit employing not more than six tubes could be quickly set up.

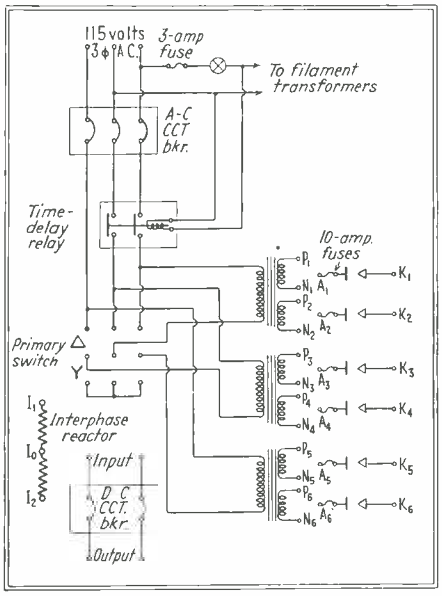


Diagram of rectifier which may be connected in various ways; as half-wave or full-wave, single or three-phase power supply

In deciding the ratings of the units several factors were considered. In running tests on them it would be desirable to be able to use meters which are standard in our laboratories. It was thought that occasionally it might be desirable to use one of the rectifiers for the field exciter of a synchronous machine and this requirement would dictate that the output rating of one of the standard circuits should be about 125 volts at about 15 amperes. An investigation showed that if the double-wye circuit were designed to have these characteristics the characteristics of the other circuits would be such that they could be easily measured by the meters which are available.

It was decided that the input should be at 115 volts since this is the most readily available in our laboratories. The circuit diagram is shown.

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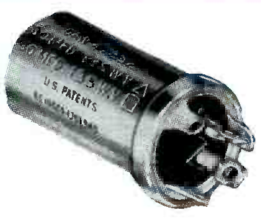
This experience in construction is hidden to the eye, but in capacitor performance tests, Cornell-Dubilier's extra dependability is easily recognized, and its value plainly proven by the fact that C-Ds are standard equipment today for the leading air lines in the United States.

CAPACITORS MAY LOOK ALIKE BUT . . . *There is extra long life, extra uniformity and dependability built into C-Ds. Next time you specify capacitors look for the Cornell-Dubilier seal of experienced engineering. And get the* hidden extras *at no extra cost. Send for Catalog. Cornell-Dubilier Electric Corporation, 1006 Hamilton Blvd., South Plainfield, New Jersey.*



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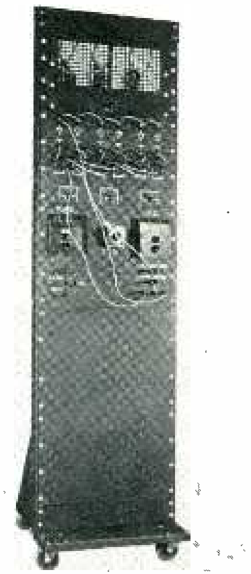
vapor tube was chosen since it has characteristics which match well the output requirements mentioned above when the double-wye circuit is used. A separate filament transformer was used for each tube so that it is possible to have the various cathodes at different potentials. The primary of the filament transformers is controlled by a mercury tumbler switch and is fused. The cathodes of the tubes must heat for five minutes before the plate voltage is applied so, in order to make sure that this precaution is always observed, a time-delay relay was placed in the primary of the anode transformers. This relay is controlled by the filament circuit.

With the above specifications in mind the anode transformers and the interphase reactor were designed. They had to be built special to our order. The primaries of the anode transformers were permanently connected, but, by means of a plug-type switch, it is possible to connect the primaries in either wye or delta.



Front panel of the flexible rectifier connected up by students

For overload protection in the primary of the anode transformers a circuit breaker is provided. This breaker is also used as a switch. The primary line current for most of the circuits considered does not exceed 15 amperes and the anode transformers were designed on this basis. However, at full load the three-phase, half-wave circuit has an input current of 25 amperes. To meet these requirements a circuit breaker was chosen with a rating of 15 amperes in order to protect the transformers but with a time-delay feature so that the overload of 25 amperes can be carried for one minute before the breaker opens.

A circuit breaker was provided to be

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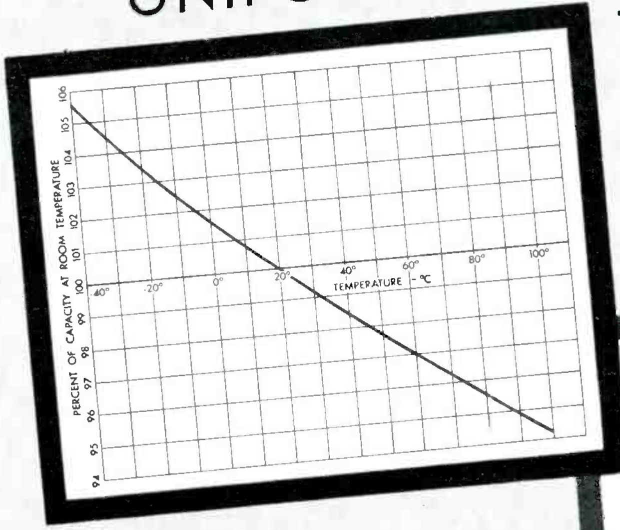
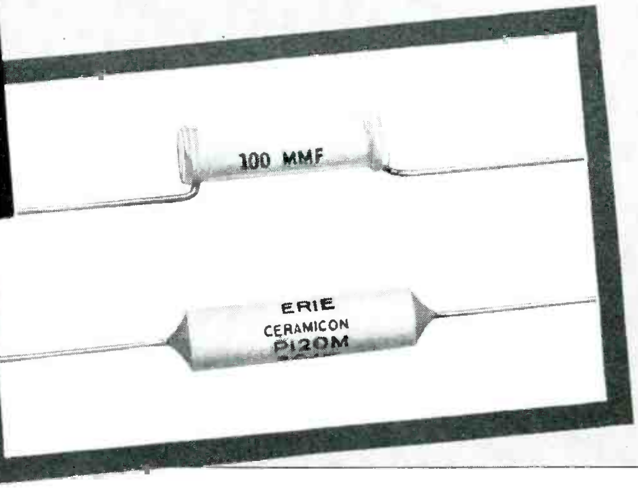




Erie Ceramicons

REG. U.S. PAT. OFF.

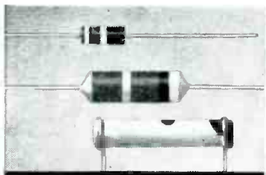
Above illustration shows special radio frequency oscillators and recording equipment used for determining temperature characteristics of Erie Ceramicons over a range from −40°C to +100°C.

LABORATORY test equipment designed and constructed by the Erie Resistor Engineering Department now makes it possible to reproduce in chart form the actual behavior of Erie Ceramicons under continuous pre-determined changes in temperature. This equipment, shown at the left, records the percent change in capacity of a Ceramicon that occurs as the temperature of the oven, in which it is placed, is automatically raised from −40°C to +100°C.

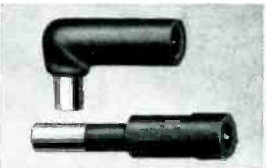
Results of these tests bear out the findings of radio engineers who have used Erie Ceramicons under varying temperature conditions. These fixed capacitors, properly used as compensators, have a very uniform capacity change over a wide range of temperature. This is illustrated in the above chart of a type N680 non-insulated Ceramicon. Note the uniform capacity curve as the temperature is increased from −40°C to +100°C. (−40°F to +212°F)

Erie Ceramicons are made in insulated and non-insulated styles for compensating for any reactance change from −.00068 to +.00012/°C due to temperature change. Maximum available capacity is 1100 mmf. Complete details of characteristics and specifications will be sent on request.

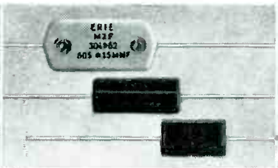
ERIE RESISTOR CORP., ERIE, PA. LONDON, ENGLAND · TORONTO, CANADA.



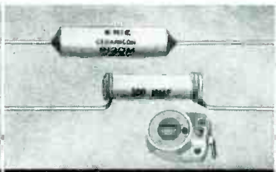
RESISTORS



SUPPRESSORS



SILVER MICAS



CERAMICONS
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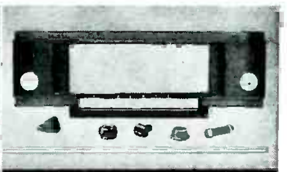


PLASTICS

used in the output circuit. The maximum current provided by any of the circuits is 15 amperes so this breaker has that rating. However, many of the circuits available have permissible output currents of less than 15 amperes so this breaker cannot be depended upon for protection in many of the circuits. To afford protection in all cases a fuse was placed in series with the anode of each tube.

For single phase circuits the input power must be connected to the two upper input jacks in order to provide power to the filaments. The plug of the anode transformer switch must either be placed in the delta position or removed and a jumper used to connect the center left jack to the center jack of the nine jacks used in this primary switch.

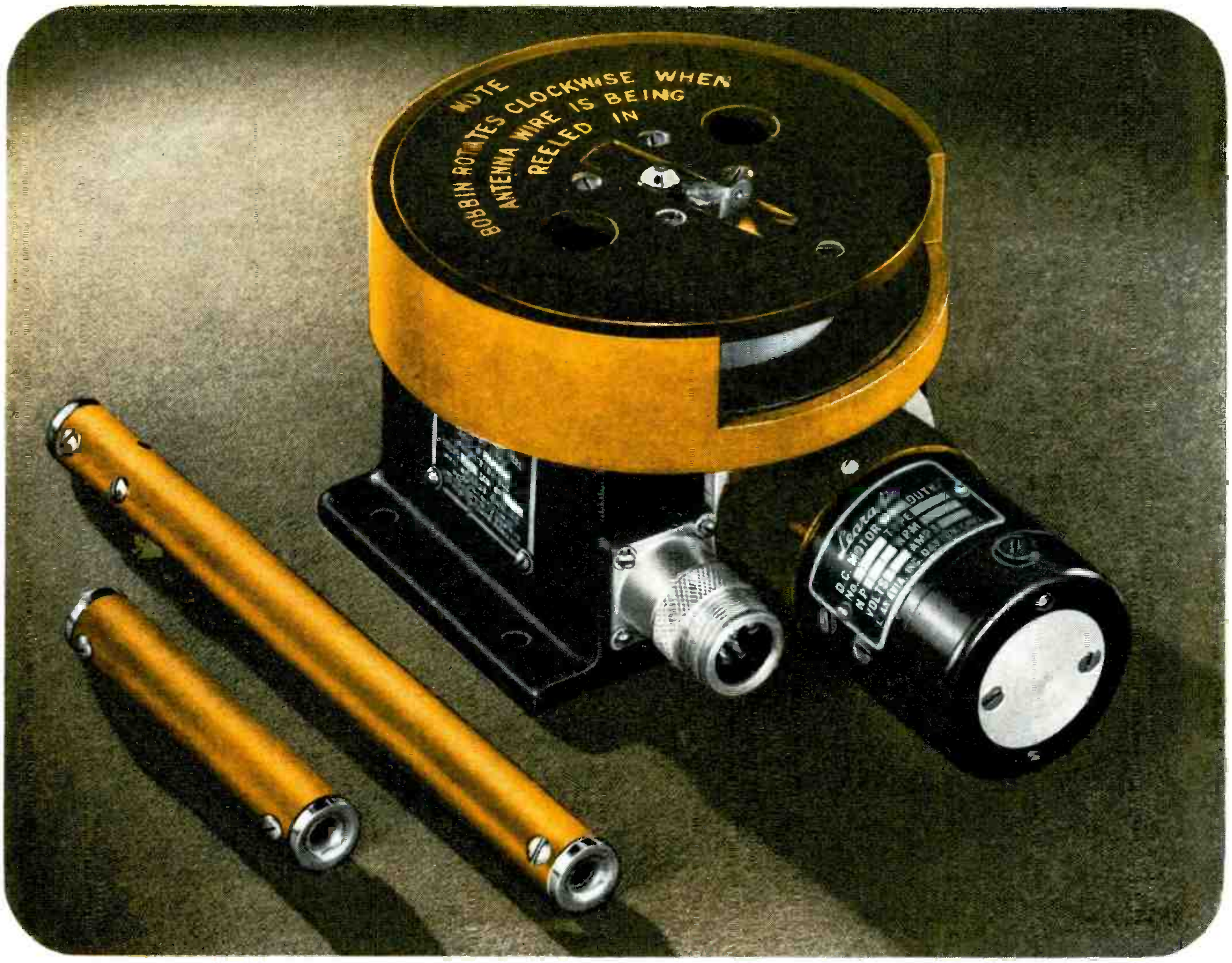
Rear view of flexible rectifier unit. Note neat appearance and ready accessibility of the parts

Pilot lights are placed across the primaries of both the filament and anode transformers.

To make the units absolutely flexible as regards possible circuits, the anode and cathode of each tube and both terminals of all transformer secondaries are brought out to separate connections on a panel. These panel connectors, as well as most others, are banana jacks. By using jumpers having banana plugs circuits are easily set up.

For the input and output connections there are placed, in parallel with the customary banana jacks, binding posts, so that any type of connection can be made, depending upon the facilities of the laboratory in which the unit is being used.

The positions of the various components are shown in the photographs. For the most part the reasons for the placements shown are obvious.



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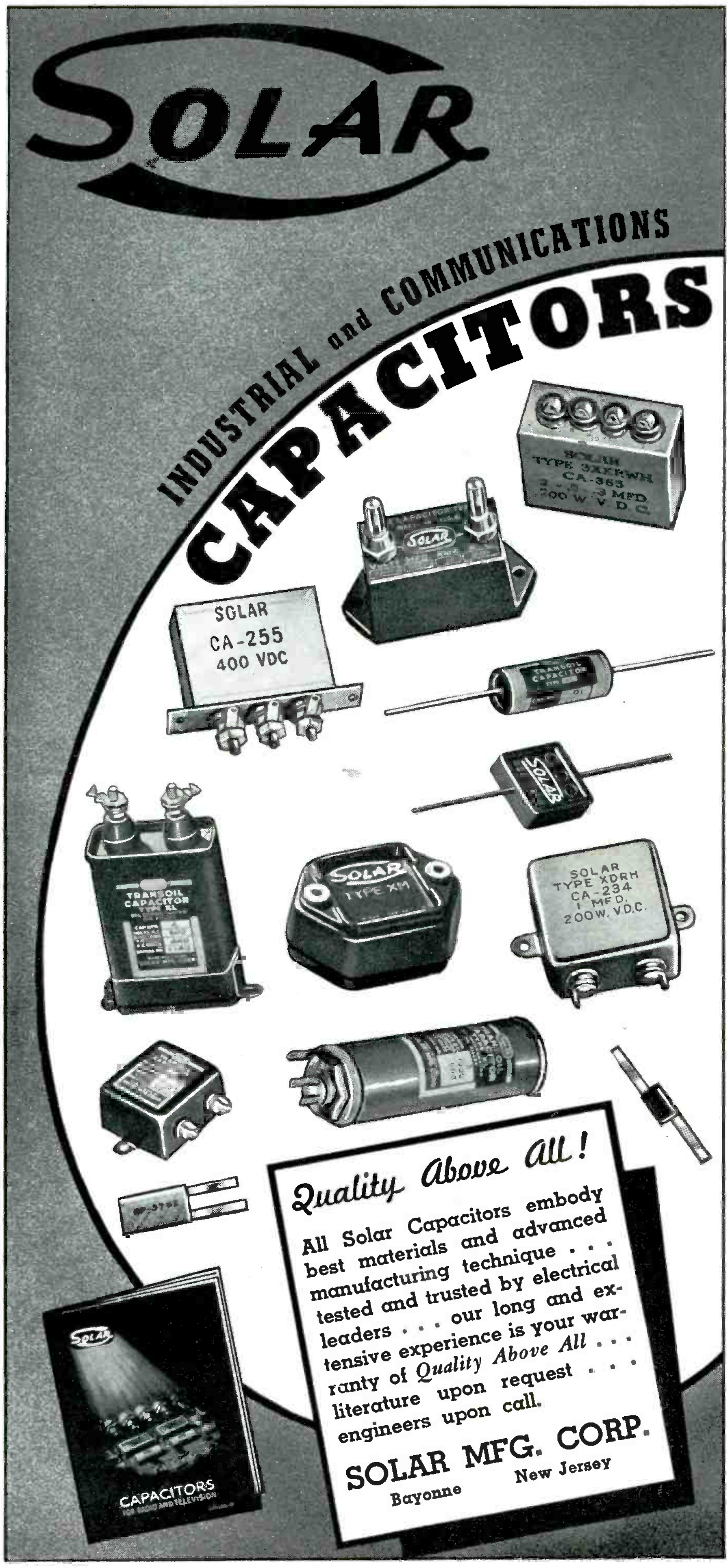


Keyless Telegraphy.

By David P. Boder
Illinois Institute of Technology

THE VARIETY OF TELEGRAPH KEYS for the transmission of the Morse code indicates that a problem of discomfort and fatigue undoubtedly exists in the procedure of sending of Morse signals. The length of time required to train a good sender also indicates that there is room for improvement in procedure of teaching as well as in the methods of operation. The method appears especially useful during training and for incidental message transmission where top speed appears unessential or possibly undesirable. The following suggestions represent an outgrowth of the author's psychological research on speed and character of human motility.

Any simple relay circuit (Fig. 1) seems to work satisfactorily. The relay will open (or close, depending on arrangements of the circuit) when grid voltage is changed by bringing leads A_1 and B_1 into contact. Moreover, this contact can be accomplished indirectly by interposing the human body or any region of it between the two leads. Should a mild shock be experienced at all, a resistor up to 0.5 megohm may be interposed along one of the leads. By arranging the circuit in the manner described below, no such resistor was necessary. *A* and *B* are sheets or strips of black paper used by the Eastman Kodak Company for wrapping and interleaving of x-ray film. This paper possesses good conductivity for high frequencies while acting nearly as insulator for ordinary power frequencies. If the operator rests one hand on *A*, the contact with *B* of one or more fingers of the other hand will actuate the relay.

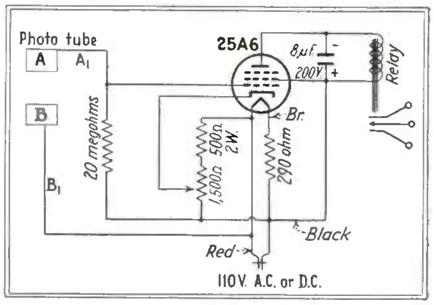


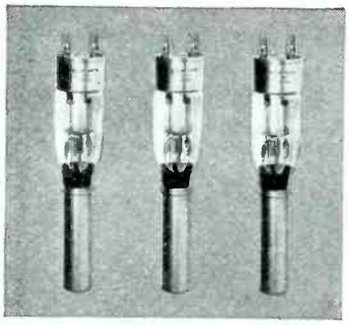
Fig. 1—Relay circuit which is useful in psychological studies and in learning the Morse code

One of the features of the circuit appears specially attractive from the standpoint of training. If *B* is replaced by a sheet of Teledeltos paper, manufactured by Western Union for facsimile recording, and a metal covered graphite pencil is used instead of the bare hand, the operator may actually *write* on the white side of the paper, listening simultaneously to the "dots and dashes" of the oscillator. Such learning, in addition to proprioceptive (muscle sense) and auditory components, will be helped by definite visual components. It seems psycho-

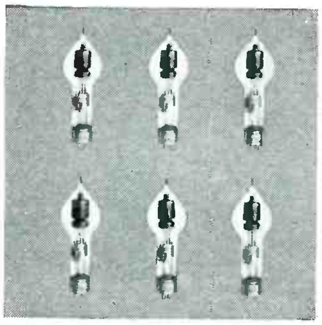
LOOK WHAT'S HAPPENED TO RECTIFIERS

Tube-hour cost slashed 80—90% in 10 years!

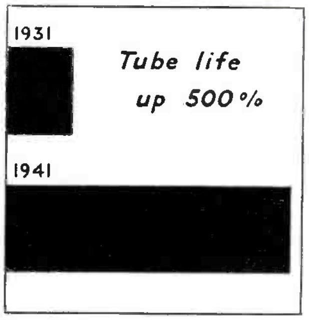
SAVINGS FOR 5 KW TRANSMITTERS



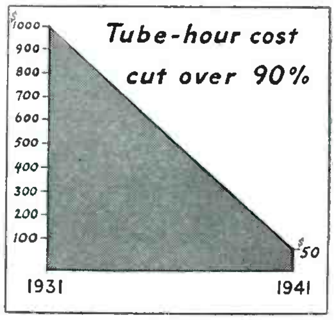
1931: Ten years ago 5 KW transmitters used three 222A high vacuum, water cooled Rectifier tubes . . . at a cost of $220 each—$660 for a set.



1941: Today 5 KW's use six 315A mercury vapor tubes in a three phase, full wave Rectifier . . . at a cost of $35 apiece—or $210 for a set of six.

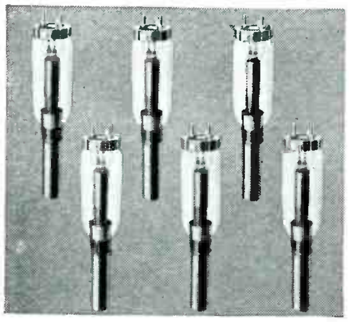


The old 222A's averaged approximately eight to nine months operation. The 315A's average life is from 3 to 4 years—an increase of about 500%.

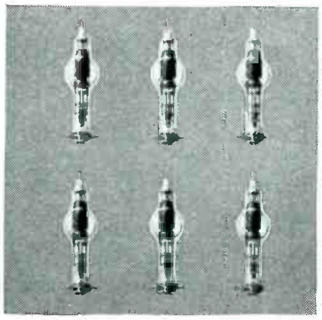


In 1931, Rectifier tube cost for a 5 KW transmitter was around $1000 per year. Today, with 315A's, the average cost is from $50 to $70 a year. *Over 90% saving!*

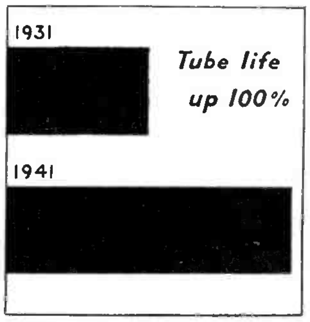
SAVINGS FOR 50 KW TRANSMITTERS



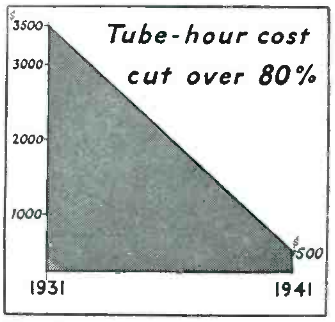
1931: Six 237A high vacuum, water cooled Rectifiers did the job in the old 50 KW's. They cost $435 apiece—more than $2600 for a set of six.



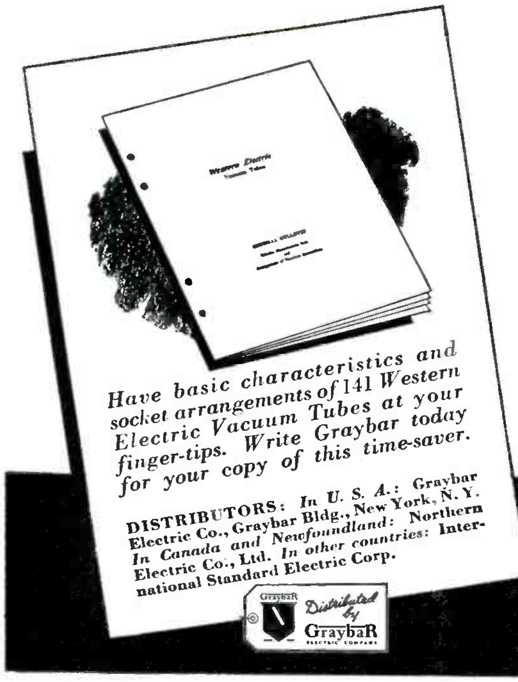
1941: Today's 50 KW's use six 255B mercury vapor Rectifiers. Costing only $125 apiece, the entire set means an outlay of but $750.



237A's had an average life of about nine months. Compare that with low-cost 255B mercury vapor Rectifiers' life of about a year and a half.



Yes, Rectifiers have changed! A decade ago, cost per year was near $3500 . . . today—using 255B's—it's about $500. That's a cut in tube-hour cost of *over 80%.*



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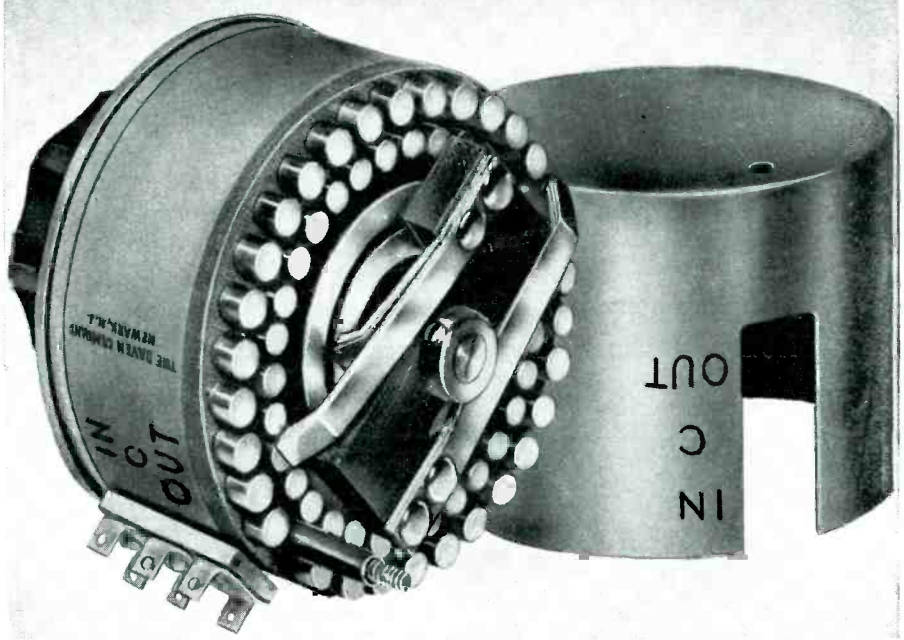

logically sound to expect an improvement in the rate and facility of learning due to such an additional cue. Moreover, the student of telegraphy who outside of class hours "dots-and-dashes" with his finger on the table, or transcribes words in code with pencil and paper, will be performing actually the same operations as in the class room or even in the actual sending room if the method should prove satisfactory.

The circuit has a number of other uses. The relay may easily activate or itself be converted into a magnetic pen for all forms of recording on running paper. The layout may also be used as a hold-up or burglar alarm.

In connection with the latter purpose one specific procedure may be suggested. The visible section of A_1 and B_1 on the surface of a bank teller's or cashier's counter may be made as inconspicuous as possible; two thin wires, two narrow strips of x-ray paper or two thin smears of shaving cream or green soap are sufficient. If a coin is placed across these two leads, the contact will close and the relay will keep the alarm circuit in "off" position. The removal of the coin will cause the alarm to sound. It may appear more advisable to use instead of the coin, a few dollar bills in a conventional money wrapper paper strip. To one side of the wrapper is then pasted a narrow strip of x-ray paper; or the wrapper is treated with a smear of green soap. If placed across the two leads, the package, like the coin, will act to keep the alarm "off". The removal of the package by the intruder or by the cashier in handing over the loot will throw the alarm into action.

The apparatus is easily built for battery operation as well, and may be used outdoors to prevent tampering with or removal of objects.

• • •

Aircraft Test Unit

Several radio test units have been combined into a single unit by Ralph Core, radio shop foreman for the American Airlines, Inc. The new tester is designed to service all receivers used in the Flagship Fleet. Power to operate the receiver on test is furnished by the power supply in the tester

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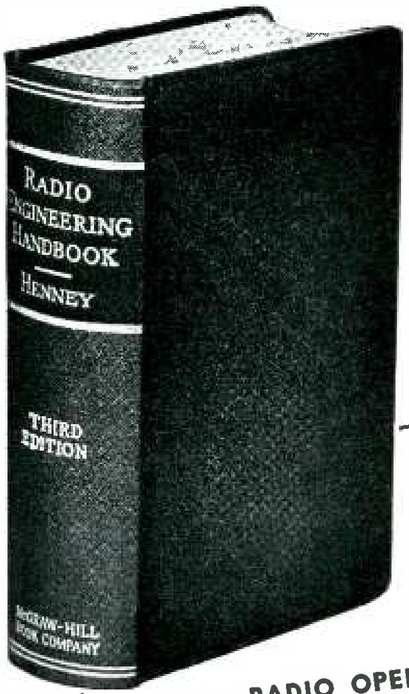

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THE ELECTRON ART

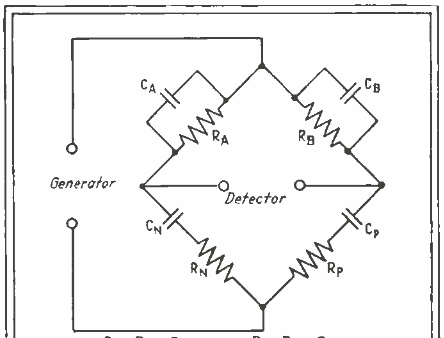
Impedance bridges, hyperfrequency waves, the use of a cathode-ray oscilloscope for dynamic balancing, electrostatic photo-multipliers, and p-v diagrams on a cathode-ray tube are reviewed

Impedance Bridges

ACCURATE IMPEDANCE MEASUREMENTS are often necessary when the purchase of a commercial bridge is not economically justified. The July 1941 issue of the *General Radio Experimenter* describes a method of setting up bridge circuits using standard components usually on hand in a laboratory. At audio frequencies, these circuits will realize accuracies approaching those of commercial bridges over a wide range of impedances. The parts used in these schemes are of precision quality.

A generalized capacitance bridge circuit which may represent several types of bridges by changing the relative magnitude of the impedances is shown in Fig. 1. If C_A and C_B are zero, the circuit becomes a series-resistance type of capacitance bridge where the losses in the *P* arm are balanced by the resistance *N* in the standard arm. If C_N and C_P are made infinite, the network becomes a parallel-resistance type capacitance bridge where the effective parallel resistance of the unknown capacitance is balanced by the resistance R_A, in parallel with the standard capacitance C_A. If D_N and Q_B are small compared to D_P and Q_A the result is a Schering bridge. Here, the dissipation factor of the *P* arm is balanced by the parallel capacitance in the *A* arm.

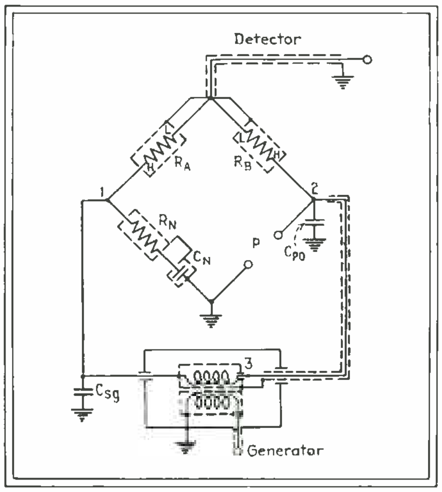
The author uses the symbol *D* for the ratio of series resistance to series reactance. This value is equal to $R\omega C$ for a condenser in series with a resistance. The ratio of series reactance to series resistance, frequently called storage factor, is designated by *Q*. A capacitance in parallel with a resistance has a *Q* equal to $R\omega C$. The equations shown are written in terms of the dissipation and storage factors of the arms, and they hold for the reduced circuits mentioned. For accurate results the complete expressions should be retained and examined for the effect of stray capacitances and other residual impedances in the bridge arms. concerned, it does not matter whether the generator and detector are connected as shown or interchanged.



$$Q_A = R_A\omega C_A \qquad D_P = R_P\omega C_P$$
$$Q_B = R_B\omega C_B \qquad D_N = R_N\omega C_N$$
$$C_P = C_N\left(\frac{A}{B}\right)\frac{1+Q_B^2}{1+D_N(Q_B-Q_A)+Q_AQ_B}$$
$$D_P = \frac{D_N+Q_A-Q_B(1-Q_AD_N)}{1+D_N(Q_B-Q_A)+Q_AQ_B}$$

Fig. 1—Above, generalized capacitance bridge with equations of balance

Fig. 2—Below, series-resistance bridge made from standard components



Inasmuch as high-input-impedance amplifiers preceding the null detector are almost universally used in a-c bridge measurements the sensitivity problem is best discussed on the basis of the use of a detector of infinite impedance. For a given unbalance of the bridge, the ratio of open-circuit output voltage to input voltage (with the generator across resistive arms) is

$$\frac{E_o}{E_i} = \frac{\frac{A}{B}}{\left(1+\frac{A}{B}\right)^2}d \tag{1}$$

where *A* and *B* are the resistance of the arms across which the generator is connected, and *d* is the fractional change in the unknown from the condition of true balance.

If the generator is connected across unlike arms (one resistive, and the other reactive) E. (1) becomes

$$\frac{E_o}{E_i} = \frac{\frac{A}{B}}{1+\left(\frac{A}{B}\right)^2}d \tag{2}$$

where either *A* or *B* is a reactance.

GROUND STATION OF R.A.F. BOMBER COMMAND

Interior of radio station in which radio operator maintains communication with aircraft during R.A.F. flights

The simplest type of bridge mentioned is the series-resistance bridge which uses variable ratio arms to balance the unknown capacitance against a fixed standard, and a variable resistance in series with the standard condenser to balance the losses in the unknown arm. Accurate results may be obtained from this bridge which is shown in Fig. 2, if the various circuit and circuit-element residuals are measured and their effects on the capacitive and resistive balances computed. The approximate equations of balance are

$$C_p = C_N \frac{A}{B}$$

$$D_p = D_N + Q_A - Q_B$$

The capacitance C_{sg}, consisting of inter-shield capacitances of the transformer winding and the capacitance, or point (1) to ground causes an error depending directly on the ratio of its magnitude to that of the standard. C_{po} is the capacitance of point (2) to ground. The magnitudes of these two capacitances can be measured quite accurately by balancing the bridge with C_{sg} connected alternately across the N and P arms. With the connections shown, C_{po} is measured directly (if the standard condenser is large compared to C_{sg}). With the leads from the transformer reversed at the bridge, a value for C_{sg} is obtained that will be in error by the amount of capacitance contributed by point (1) to ground. Careful wiring arrangement will keep this value low. The error in measurement does not exceed 1 μμf for C_{po}, and 5 μμf for C_{sg}. Typical values are 10 μμf for C_{po}, and 100 μμf for C_{sg}.

The article also covers briefly the terminal-to-shield capacitances of decade resistance boxes which make up the internal residuals in standards, and the dissipation-factor balance. In Fig. 2, the terminal connected to the highest resistance decade is labeled H, and the terminal connected to the lowest resistance decade is designated as L. R_A, R_B, and R_X are decade boxes.

• • •

Hyperfrequency Waves

OF MORE THAN PASSING INTEREST is an article called "Hyperfrequency Waves and Their Practical Use" by Leon Brillouin which appeared in *Electrical Communication* (Vol. 19, No. 4). This paper deals with waves whose wavelengths are of the order of centimeters. It covers briefly the characteristics of hyperfrequency waves, early experiments in this field, a commercial transmitter and receiver, and the propagation of these waves along conducting hollow tubes.

Hyperfrequency waves behave like optical waves in that they travel in straight lines, and are affected by optical lenses, mirrors, and parabolic reflectors. Recently it has been found that these short waves also behave somewhat like acoustic waves. Hollow pipes, resonators, and dielectric cables, all showing a marked similarity to the pipes used in acoustics are incorporated in electrical apparatus associated with the production and propagation of these waves. Hollow tank resonators have been suggested by physicists because of their very high Q factors. For short radio waves, ordinary inductance-capacity circuits can not be used, and the technical practice is to use parallel lines or coaxial lines as resonators. These lines will work if the distance between lines is small compared to the wavelength. For hyperfrequency work these lines cannot be built, so tank resonators are used.

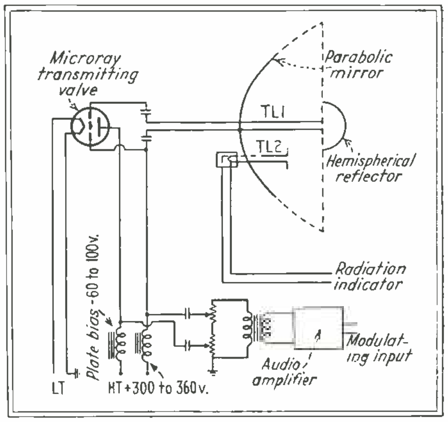


Fig. 1—Simplified circuit of Microray transmitter. TL1 and TL2 are coaxial feeders

The 'Laboratories L.M.T.', laboratories of Le Matériel Téléphonique in Paris had been active in the hyperfrequency field for some time. Clavier, Darbord, and various co-workers conducted researches which resulted in radio transmission across the English Channel using a wavelength of 18 centimeters. The system has been in commercial use since 1934, and is used for two-way teleprinter messages as well as duplex telephony. Simplified circuit diagrams of the transmitter and receiver are shown in Figs. 1 and 2.

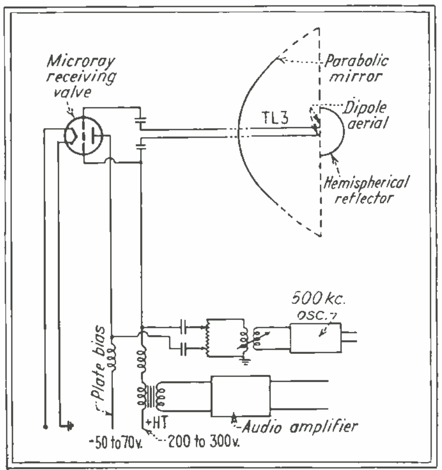


Fig. 2—Simplified diagram of Microray receiver. TL3 is a coaxial feeder

The oscillations are generated in the tube and are conducted by a coaxial feeder to a small antenna at the focus of a parabolic reflector. The reflector produces a narrow linear beam which is aimed at the receiver's parabolic mirror which reflects the waves to a dipole antenna situated at its focus. From the antenna the waves are fed to a receiving tube and its amplifier. It is interesting to note that both the transmitter and the receiver use positive grid tubes. The reflectors are in direct sight of each other.

An interesting property of these waves is their ability to be propagated along hollow conducting tubes which are known as dielectric cables. These hollow conductors act as high-pass filters for electromagnetic waves since only frequencies above a certain cut-off frequency can be transmitted through them; the higher the frequency the smaller the attenuation. This small attenuation property may prove to have important practical applications.

The article also discusses the theory of dielectric cables mathematically analyzing the propagation characteristics of various shaped cross-sections of hollow conductors.

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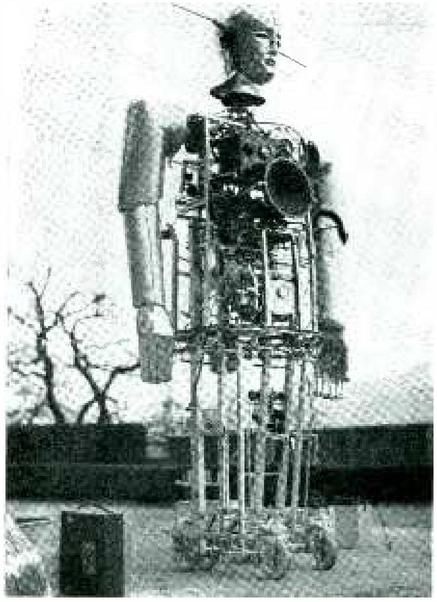
SWISS ROBOT



August Huber, an electrician at Niderteufen, Switzerland, has developed this artificial soldier as an aid to the defense of his mountainous country. Named Sabor, this robot is 7 feet 5 inches tall and weighs 450 pounds, and can be controlled from a remote point by short wave signals which are picked up by the antenna on the head. Microphones instead of ears, and a loudspeaker in Sabor's chest, enable this robot, through the control operator, to carry on conversations

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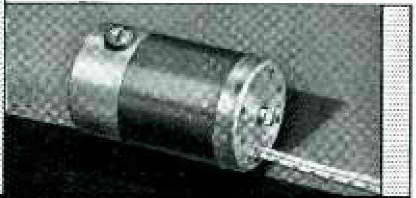

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Oscillographic Determination of Dynamic Balancing

"Dynamic Balancing of Small Rotors By Means of the Cathode-Ray Oscillograph," by August Raspet and Robert A. McConnell, appears in the April-May 1941 issue of the DuMont *Oscillographer*, published by Allen B. DuMont Laboratories. It can be demonstrated mathematically that a rotor can be brought to perfect balance by two weight adjustments made at any radial distance in any two non-coincident planes which are perpendicular to the axis of rotation. When convenient circles have been chosen as the correction loci, the practical problem remaining is to determine the amount and location around the periphery, of the masses which must be added or subtracted. In order to achieve a balance with a minimum change of mass, it is customary in the case of rigid rotors to choose the correction planes to be near opposite ends of the rotation axis and to choose the correction radii as large as possible.

The rotor to be balanced is mounted in cantilever bearings and rotated at controlled speeds. It may be driven by electrical means, by belt, or air jets. The cantilevers should be sufficiently stiff so that the associated natural frequencies lie within the range of the cathode-ray oscillograph. The needle of a rochelle salt phonograph pickup engages the side of each bearing cantilever so that the bending of each cantilever generates a corresponding voltage.

A rotor mounted in this manner will have two modes of vibration. In one the two bearing cantilevers will bend in phase, that is, they will move up and down together. In the second case the cantilevers will move out of phase, so that the rotor executes a torsional motion about an axis parallel to the cantilevers. In usual shaped rotors, where the radius of gyration about the

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ANTARCTIC RADIO STAFF

The Navy radio staff at West Base in the Antarctic. Left to right: Chief Radioman Clay W. Bailey of Belmont, Mass.; radioman 1st class J. A. Reese of Deport, Texas; and Naval Aviation Pilot R. Giles of Conyers, Georgia

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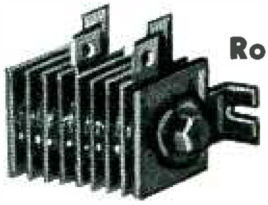

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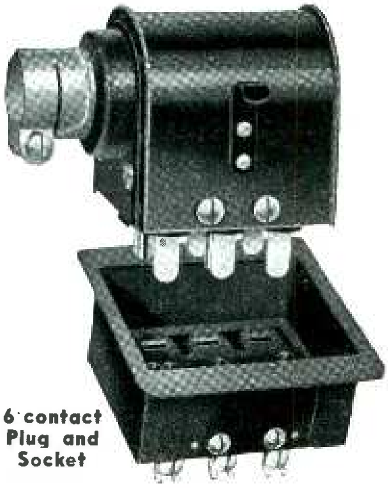

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rotor axis is not too large compared to the inter-bearing distance, the resonant frequency of in-phase motion will be considerably below that for out-of phase motion. These two modes of vibration form a basis of a method of balancing described here.

The procedure is to connect the phonograph pickups to the horizontal and vertical deflection of a cathode-ray oscillograph. When the rotor is turned at a speed below the out-of-phase resonant frequency and above the in-phase frequency, the in-phase motion of the bearings resulting from static unbalance will appear on the screen as a narrow loop whose slope to the left or to the right can be checked as corresponding to in-phase bearing motion. The amplitude of motion resulting from a mass unbalance is independent of frequency for frequencies well above resonance. Hence, the deflection of the cathode ray beam will be constant and proportional to unbalance over a range of speeds. To determine the angular position at which the mass should be applied to achieve static balance, the rotor is marked with numbers around its circumference. The cathode-ray screen is covered with a mask so that only the extreme deflection appears and the intensity control is turned up. In a darkened room and with a fairly large cathode-ray tube a number on the rotor is stroboscopically stopped. This indicates the point at which the weight must be added or subtracted.

Dynamic balance is achieved by increasing the rotor speed above the out-of-phase resonant frequency. The slope of the deflection line on the oscillograph will reverse in sign, showing the change of relative phase for the bearings. The mass adjustment for dynamic balance is accomplished as for the static case except that mass must be added or subtracted at two diagonally opposite joints in the stroboscopically determined point through the rotor axis. Mass adjustment is carried out until the voltage output of both pickups is at a minimum.

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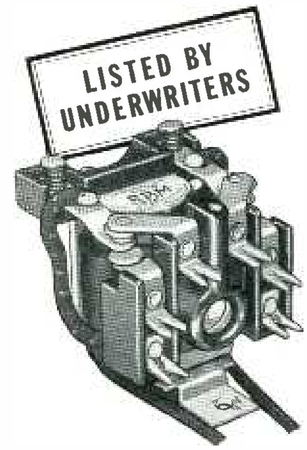
Tubes with Two Control Grids

A QUITE THOROUGH investigation of the properties of the type 6L7G tube is discussed by Alexander H. Wing in "On the Theory of Tubes with Two Control Grids," in the March 1941 issue of the *Proceedings of the I.R.E.* The author states that the purpose of this paper is to describe certain characteristics of two control grid tubes, which previously had not been discussed in any great detail, and to set forth a method of evaluating the performance of these grids by methods which are not so time-consuming as to prevent their use in practice. Numerous charts and tables are presented to show the characteristics of the 6L7G under varying conditions. It should be well worth while for any engineer using the 6L7G in design work to study this article.



Electrostatic Photo-Multipliers

THE OPERATION and characteristics of photo-multipliers are covered in an article called "Operation of Electrostatic Photo-Multipliers" by R. C. Winans and J. R. Pierce. The story appears in the May 1941 issue of *The Review of Scientific Instruments*. The characteristics of the Western Electric D-159076 photo-multiplier are used to illustrate various points covered in the text. This tube incorporates a caesium-oxygen-silver type photocathode and a six-stage electrostatic type electron multiplier.

The tube works in a circuit as is shown in Fig. 1. The photocathode emits electrons at a rate proportional to the amount of light falling on it. The emitted electrons are attracted to the next more positive electrode in the series and strike it with an energy corresponding to the potential difference between the two electrodes. Part of this energy is utilized in the liberation of secondary electrons from the second electrode. The ratio of secondary electrons to incident electrons is the secondary emission ratio, or the current amplification per stage. The emission from the second electrode strikes the third where a similar amplification takes place, and so on through the series. If X secondary electrons are emitted by one electron striking the plate, and there are n stages, then the over all current gain of the tube is X^n. To keep the electrons in the correct paths, electrostatic or magnetic fields are used. The tube discussed

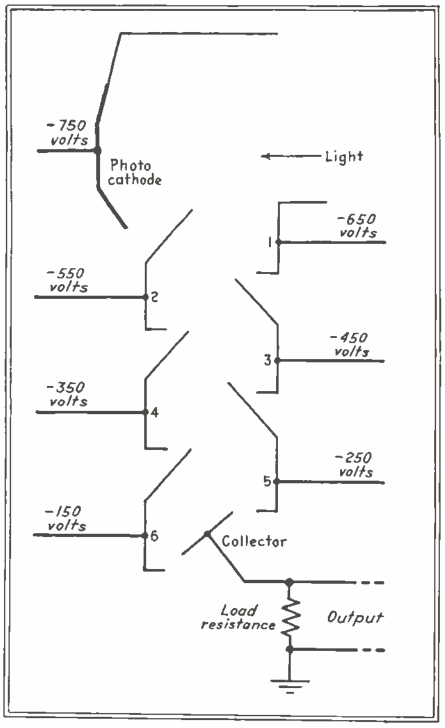


Fig. 1—The electrostatic photo-multiplier. The voltage developed across the load resistance is sufficient to drive a power amplifier

uses electrostatic fields and only needs the application of suitable potentials to the tube terminals. The photomultiplier is really a vacuum phototube plus a high quality amplifier. The D-159076 for instance, has a gain of 70 db which is about 60 db more sensitive than the normal gas-filled phototube. The allowable voltage swing of the output is high enough to drive a power amplifier directly. It is suitable for frequencies up to several megacycles.

Tests show that the accuracy of the voltage division may vary plus or minus 5 percent, without changing the sensitivity of the device. Curves of output current versus collector voltage are flat from 75 to 150 volts for this tube. This means that the tube will deliver a peak voltage swing of 75 volts without distortion. The load impedance in the collector circuit should be so chosen that the collector voltage will always be within the 75 to 150 volt range. For example, a multiplier with a sensitivity of 40 milliamperes per lumen at 100 volts per stage, operating under conditions where the light varies from zero to 0.05 lumen, will have its collector current varying from zero to 2 milliamperes. At zero light and zero current the voltage should be 150 volts, and at full light and 2 milliamperes the voltage should be 75 volts. Thus the load impedance should be a 37,500 ohm resistor.

The article also discusses the fluctuation noises in phototube circuits and multipliers.

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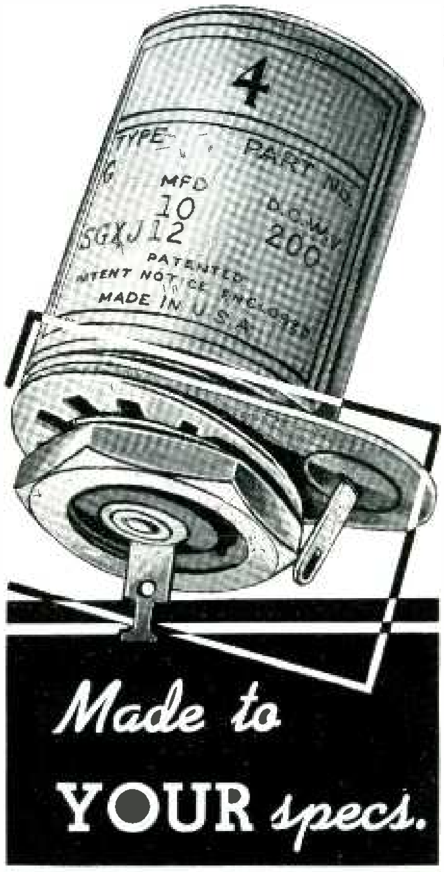
SCIENTISTS ATTEND MEETING

Dr. Arthur H. Compton, professor of physics in the University of Chicago; Dr. W. F. G. Swann, director of the Bartol research Laboratory of the Franklin Institute at Swarthmore, Pa.; Dr. William Wright, director of the Lick Laboratory at Mt. Hamilton, Cal.; and Dr. Ladislaus Marton, physicist of RCA Manufacturing Co. at Camden, attending the general meeting of the American Philosophical Society in Philadelphia



Cathode-Ray Tube For P-V Diagrams

MODERN HIGH-SPEED ENGINES make it impossible to use the conventional indicator such as is used in the steam engine to get a pressure-volume diagram for the determination of the machine's performance. The cathode-ray tube has been used quite successfully in this application. The beam is weightless, and responds readily to rapid variations in pressure which have been translated to voltage fluctuations thus making possible accurate diagrams.

"An Electrical Pressure Indicator For Internal Combustion Engines" by P. J. Hagendoorn and M. F. Reynst (*Philips Technical Review*, December, 1940), is an article which describes a pressure indicator using a cathode-ray tube. A metallic membrane is set into the cylinder wall, and serves as one electrode of a condenser, comprising part of a bridge connection to which is fed a high frequency voltage. Variations in pressure inside the cylinder, as the piston goes through its cycle, cause the membrane to vibrate and vary the capacity of the condenser. This action causes a modulation of the high frequency voltage which is amplified, detected, and then impressed on the vertical deflecting plates of the cathode-ray tube. The horizontal deflecting voltage which must be proportional to the displacement of the piston is obtained in a similar manner. A fixed plate and a metallic cylinder comprise the electrodes of a condenser. The cylinder is fastened to the crankshaft of the engine so that one revolution, (which produces a cycle of variation in capacitance), is equivalent to a complete cycle of the piston stroke. This variable condenser is also included in the bridge connection, and as before, is fed the high frequency voltage which is modu-

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SPEAK — DON'T WRITE

These members of the 33rd Division, Illinois National Guard, tell all about Army life. Instead of writing letters, they record their messages on discs and mail them home

lated by the change in capacitance with each revolution of the crankshaft. The modulated voltage is amplified, detected, and then fed into the horizontal plates of the cathode-ray tube.

Any undesired initial voltage which may be introduced by stray capacities and losses in the condensers in the bridge is compensated for by a special network. It consists of two bridge circuits so arranged that the phase of part of the oscillator voltage can be varied from 0 to 360 degrees, and is used to "wipe out" the undesired voltage. The relation between the deviation on the screen and the cylinder pressure must be linear if the indicated cylinder power is to be obtained directly by planimetry. Such a condition would exist only if the movements of the membrane were small compared to the width of the air gap, a condition which is far from satisfied. An ordinary linear amplifier would only reproduce the distortion, so an amplifier is used whose amplification decreases with increasing amplitude of the input voltage (increasing capacity variation) in such a way that the deviation from linearity is just corrected. This is accomplished by rectifying part of the output voltage and feeding it back into the input so that the operating point and the slope of the characteristic is changed according to the magnitude of the input voltage.

The article also calls attention to another application of the principle used in the device described. If the membrane were removed and the fixed electrode were placed near a vibrating body, the capacitance betwen the electrode and the ground would vary, and the vibration would become visible on the cathode-ray tube's screen. By choosing suitable dimensions for the electrode, vibrations with amplitudes from several microns to several centimeters can be measured.

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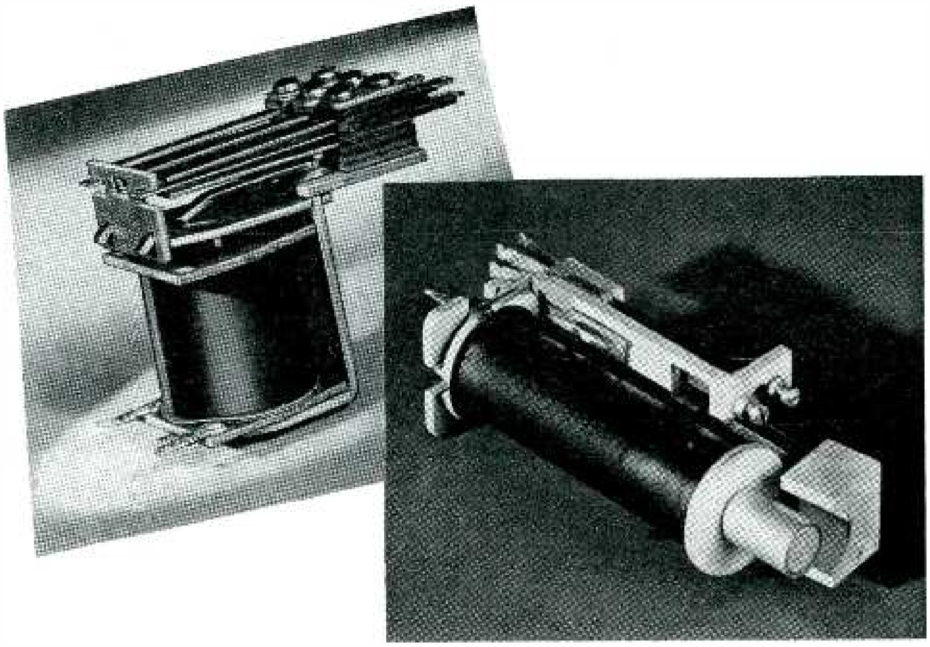
WOMEN IN DEFENSE

Betty Norton and Dorris Pattison, students of Adelphi College operate a one-half watt portable two way police radio transmitter as part of the Women's Defense Day program. The unit can communicate with cars within a mile



TUBES

Characteristics of phototubes are presented in addition to the data on receiving tubes registered by the R.M.A. Data Bureau during June

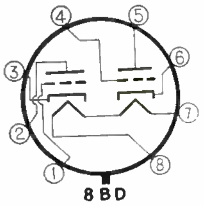
Tube Registry

Tube Types registered by R.M.A. Data Bureau During June 1941

Type 12SL7GT

Double triode amplifier, high mu, heater type, T-9 glass envelope, seated height 2$\frac{3}{4}$ inches (max), intermediate shell 8-pin octal base.

RATINGS
E_h = 12.6 v
I_h = 0.15 amp
E_b = 250 v (max)
E_c = 0 v (min)
TYPICAL OPERATION
Each triode unit
E_b = 250 v
E_c = −2 v
I_b = 2.3 ma
g_m = 1600 μmhos
μ = 70
rs = 44,000 ohms
Basing 8BD-0-0



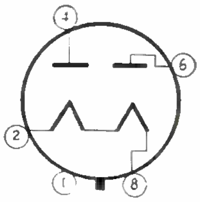
Type 5Y3GT/5Y3G

Full-wave rectifier, filament type, T-9 glass envelope, seated height 2$\frac{13}{16}$ inches (max), intermediate shell 5-pin octal base.

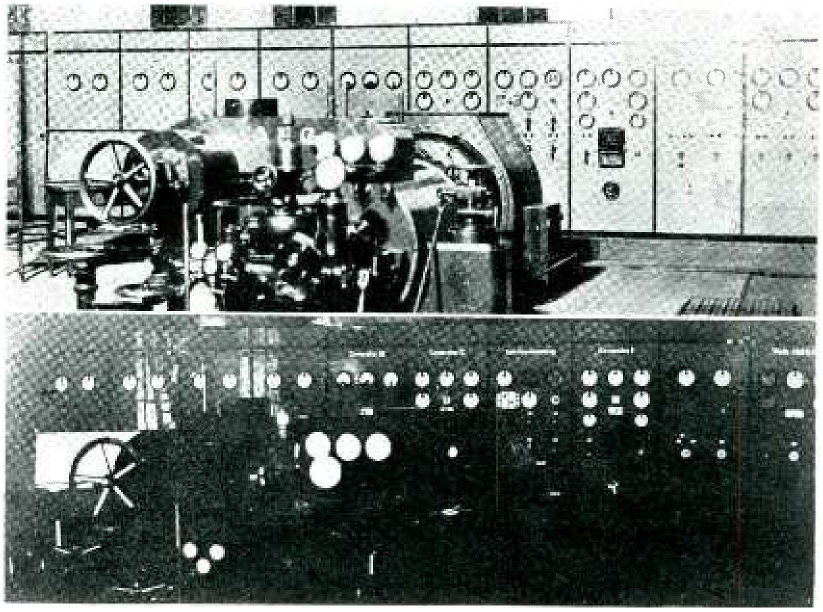
RATINGS
E_f = 5.0 v
I_f = 2.0 amps
E(inverse) = 1400 v
I_p(peak per plate) = 375 ma

WITH CONDENSER-INPUT FILTER
E_{ac}(rms, per plate) = 350 v (max)
I_{dc} = 125 ma (max)
Total Effective Plate Supply Impedance per Plate = 50 ohms (min)

WITH CHOKE-INPUT FILTER
E_{ac}(rms, per plate) = 500 v (max)
I_{dc} = 125 ma (max)
Input Choke Inductance = 5 h (min)
Basing 5T-0-0



TO CARRY ON DURING BLACKOUTS



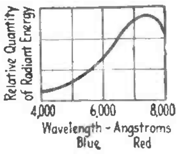
Here are two identical views of a power station, "somewhere in Germany". One photograph, made with normal artificial illumination shows the usual conditions of operation. In the event of a blackout, luminous meter dials and panel lettering guide the operating personnel in the proper discharge of their duties even though they must work in complete darkness

Phototubes

Type CE-5WB

Continental Electric Co.

PHOTOTUBE (vacuum or gas-filled), cathode area 0.56 sq inch, seated height to center line of cathode 1¼ inch, overall seated height 2½ inches (max), diameter ⅝ inch (max). This type is sometimes used in cartridges.

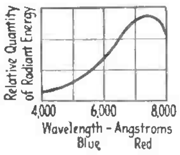


Sensitivity
 Gas-filled phototubes are available with sensitivities ranging from 10 to 400 μa/lumen.
 Vacuum phototubes are available with sensitivities ranging from 5 to 50 μa/lumen.
Operating voltage = 90 v
Ionization voltage (gas-filled tubes) = 115 v

Type CE-5AB

Continental Electric Co.

PHOTOTUBE (vacuum or gas-filled), cathode area 0.56 sq inch, seated height to center line of cathode 1⅝ inches, overall seated height 2¾ inches (max), diameter ⅝ inch (max). Based in a single contact auto lamp, anode to center contact.



Sensitivity
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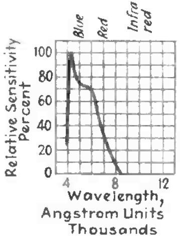
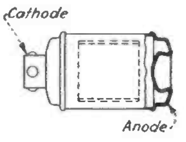
 Vacuum phototubes are available with sensitivities ranging from 5 to 50 μa/lumen.
Operating voltage = 90 v
Ionization voltage (gas-filled tubes) = 115 v

Type 926

R.C.A.

VACUUM phototube, cartridge type, window area 0.4 square inch, distance from base of cathode cap to center line of cathode 11/16 inch, overall length 1 21/32 inch, overall diameter 0.890 inch (max).





Luminous Sensitivity
 0 cps (dc) = 6.5 μa/lumen
 1000 cps = 6.5
 5000 cps = 6.5
C(cathode-anode) = 0.5 μμf
Max Ambient Temp = 100° C
Max Anode Supply Voltage = 500 v
Max Anode Current = 20 μa
Sensitivity = 0.0020 μa/μwatt radiant flux at 4400 A. See curve.

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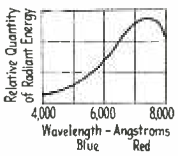
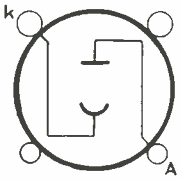


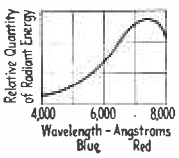


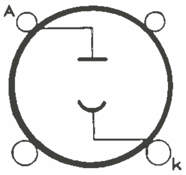
Sensitivity
Gas-filled phototubes are available with sensitivities ranging from 10 to 400 μa/lumen.
Vacuum phototubes are available with sensitivities ranging from 5 to 50 μa/lumen.
Operating voltage = 90 v
Ionization voltage (gas-filled tubes) = 115 v

Type CE-1S

Continental Electric Co.

PHOTOTUBE (vacuum or gas-filled), cathode area 0.94 sq inch, seated height to center line of cathode 2 inches, overall seated height $3\frac{1}{2}$ inches (max), diameter 1 inch (max), 4-pin base.





Sensitivity
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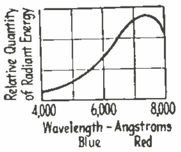
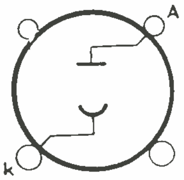
Vacuum phototubes are available with sensitivities ranging from 5 to 50 μa/lumen.
Operating voltage = 90 v
Ionization voltage (gas-filled tubes) = 115 v

Type CE-1RBS

Continental Electric Co.

PHOTOTUBE (vacuum or gas-filled), cathode area 0.94 sq inch, seated height to center line of cathode 2 inches, overall seated height $2\frac{3}{4}$ inches (max), diameter 1 inch (max), 4-pin base.





Sensitivity
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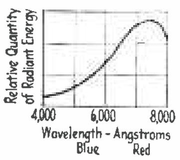
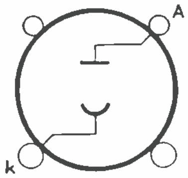
Vacuum phototubes are available with sensitivities ranging from 5 to 50 μa/lumen.
Operating voltage = 90 v
Ionization voltage (gas-filled tubes) = 115 v

Type CE-2

Continental Electric Co.

PHOTOTUBE (vacuum or gas-filled). cathode area 1.33 sq inch, seated height to center line of cathode 1⅞ inch, overall seated height 3 inches (max), diameter 1½ inch (max), 4-pin base.





Sensitivity
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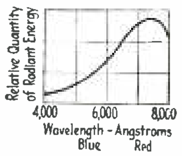
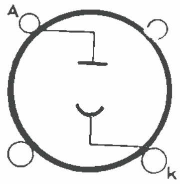
Vacuum phototubes are available with sensitivities ranging from 5 to 50 μa/lumen.
Operating voltage = 90 v
Ionization voltage (gas-filled tubes) = 115 v

Type CE-2RBS

Continental Electric Co.

PHOTOTUBE (vacuum or gas-filled), cathode area 1.33 sq inch, seated height to center line of cathode 1⅞ inch, overall seated height 3 inches (max), diameter 1½ inch (max), 4-pin base.





Sensitivity
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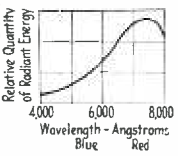
Vacuum phototubes are available with sensitivities ranging from 5 to 50 μa/lumen.
Operating voltage = 90 v
Ionization voltage (gas-filled tubes) = 115 v

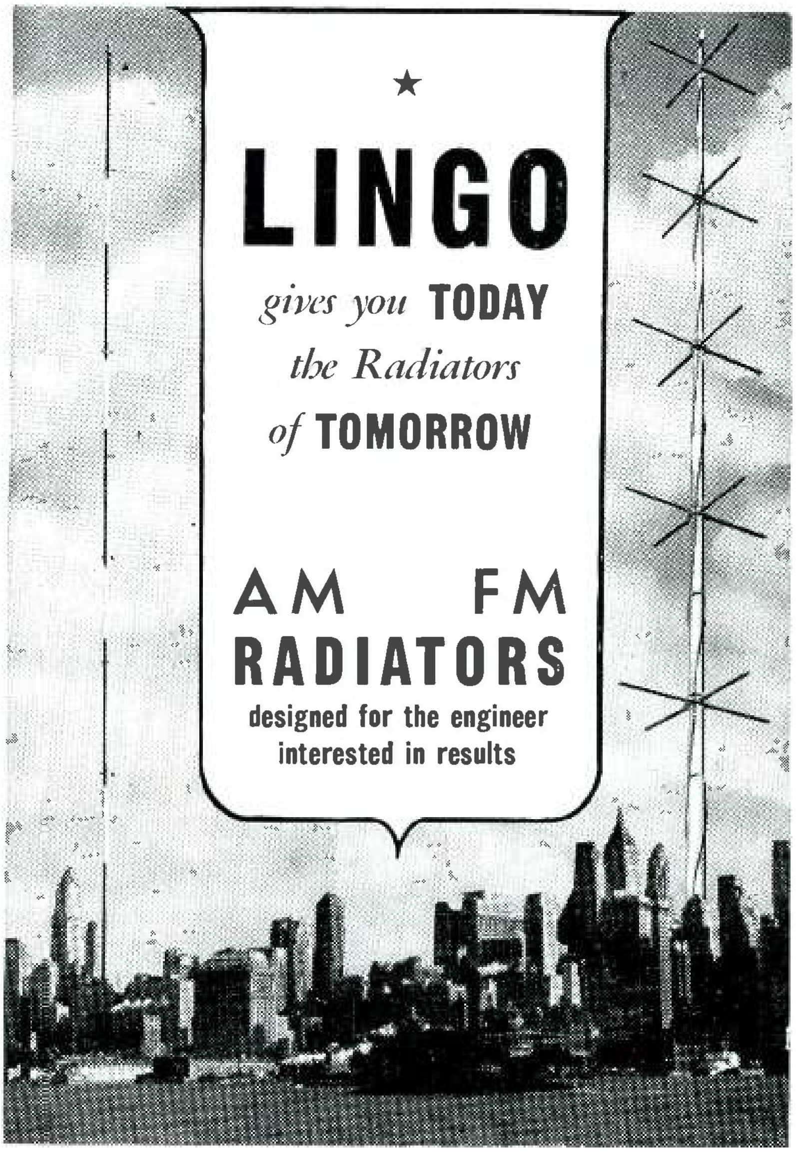
Type CE-3

Continental Electric Co.

PHOTOTUBE (vacuum or gas-filled). cathode area 1.73 sq inches, seated height to center line of cathode 3¼ inches, overall seated height 4½ inches (max), diameter 2¼ inches (max), flexible leads.

Sensitivity
Gas-filled phototubes are available with sensitivities ranging from 10 to 400 μa/lumen.
Vacuum phototubes are available with sensitivities ranging from 5 to 50 μa/lumen.
Operating voltage = 90 v
Ionization voltage (gas-filled tubes) = 115 v





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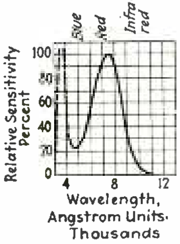
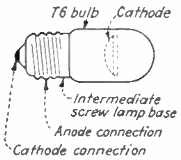
Type 924

R.C.A.

GAS phototube, end type, window-area 0.2 square inch, overall length 2 3/16 inches (max), overall diameter 13/16 inch (max), intermediate screw lamp base.





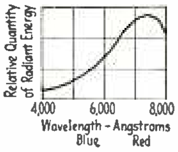
Gas Amplification Factor—Not over 8.5.

Luminous Sensitivity
  0 cps (dc) = 55 μa/lumen
  1000 cps = Less than 55
  5000 cps = Less than 55
C(cathode-anode) = 2.5 μμf
Max Ambient Temp = 100° C
Max Anode Supply Voltage = 90 v
Max Anode Current = 15 μa
Sensitivity (E anode supply = 90 v and R_l = 1 megohm) = 0.0050 μa/μwatt radiant flux at 7500 A. See curve.

Type CE-4WB

Continental Electric Co.

PHOTOTUBE (vacuum or gas-filled), cathode area 0.63 sq inch, seated height to center line of cathode 1⅜ inch, overall seated height 2½ inches (max), diameter 1 inch (max), no base. This type is sometimes used in cartridges.

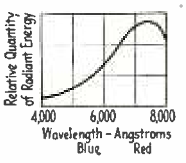


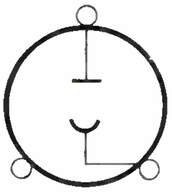
Sensitivity
  Gas-filled phototubes are available with sensitivities ranging from 10 to 400 μa/lumen.
  Vacuum phototubes are available with sensitivities ranging tom 5 to 50 μa/lumen.
Operating voltage = 90 v
Ionization voltage (gas-filled tubes) = 115 v

Type CE-5BB

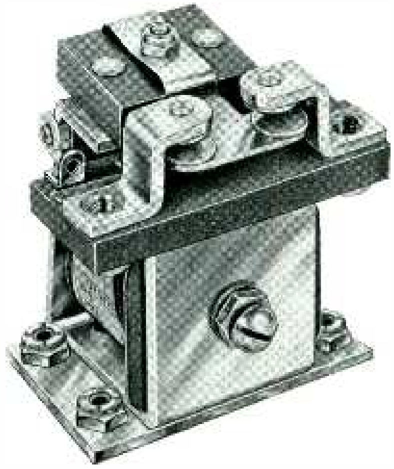
Continental Electric Co.

PHOTOTUBE (vacuum or gas-filled), cathode area 0.56 sq inch, seated height to center line of cathode 1½ inch, overall seated height 2½ inches (max), diameter ⅝ inch (max), 3-pin base.





Sensitivity
  Gas-filled phototubes are available with sensitivities ranging from 10 to 400 μa/lumen.
  Vacuum phototubes are available with sensitivities ranging from 5 to 50 μa/lumen.
Operating voltage = 90 v
Ionization voltage (gas-filled tubes) = 115 v



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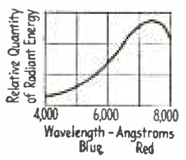
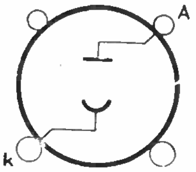
Type CE-4RBS

Continental Electric Co.

PHOTOTUBE (vacuum or gas-filled), cathode area 0.63 sq inch, seated height to center line of cathode $1\frac{3}{4}$ inch, overall seated height $3\frac{1}{2}$ inches (max), diameter 1 inch (max), 4-pin base.



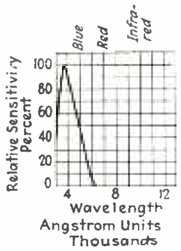


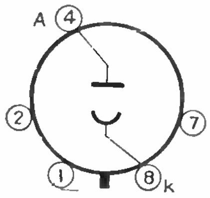
Sensitivity
Gas-filled phototubes are available with sensitivities ranging from 10 to 400 μa/lumen.
Vacuum phototubes are available with sensitivities ranging from 5 to 50 μa/lumen.
Operating voltage = 90 v
Ionization voltage (gas-filled tubes) = 115 v

Type 929

R.C.A.

VACUUM phototube, window area 0.6 square inch, seated height to center line of cathode $1\frac{5}{8}$ inch, overall length 3 1/16 inches (max), overall diameter 1.275 inch (max), 5-pin octal base.





Luminous Sensitivity
0 cps (dc) = 45 μa/lumen
1000 cps = 45
5000 cps = 45
C(cathode-anode) = 2.5 μμf
Max Ambient Temp = 50° C
Max Anode Supply Voltage (dc or peak ac) = 250 v
Max Anode Current = 20 μa
Sensitivity = 0.0400 μa/μwatt radiant flux at 3750 A. See curve.

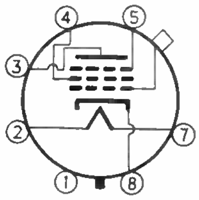
A Correction

THE incorrect basing diagram for the type 1851 tube was published in the June issue of ELECTRONICS. The correct data is presented below.

Type 1851

TRIPLE-GRID amplifier, heater type, metal envelope, seated height $2\frac{13}{16}$ inches (max), 8-pin base.

E_h = 6.3 v
I_h = 0.45 amp
E_b = 300 v
E_{c2} = 150 v
Cathode-bias resistor 160 ohms (min)
I_b = 10.0 ma
I_{c2} = 2.5 ma
g_m = 9000 μmhos
r_p = 0.75 megohm
Basing 7R



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★ *Absolutely Water tight . . . because of Kenyon's exclusive construction and manufacturing process!*
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Synchronized Voltages

(*Continued from page* 32)

shielded electrostatically between primary and secondary so that the capacitative coupling between them is reduced to a minimum. Any such coupling feeds the stimulating voltage directly into the input of the action potential amplifiers and increases the "shock artifact".

Experimental Results

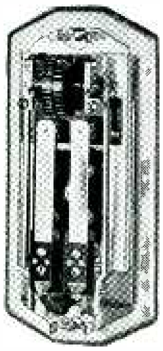
Figure 2 shows a series of action potential time curves taken with unipolar leads from a set of points equally distributed over the length of a frog's gastrocnemius muscle stimulated through its motor nerve. The duration of any one of these action potentials is about 14 milliseconds. The largest shown does not reach a peak voltage greater than 25 millivolts. The action potentials were amplified by a d-c amplifier and impressed on a 3-inch cathode ray tube with a blue, short persistence screen and separate deflecting plates. Records were taken with 35 mm Superpan Supreme film and an 8.5 cm f/1.8 lens.

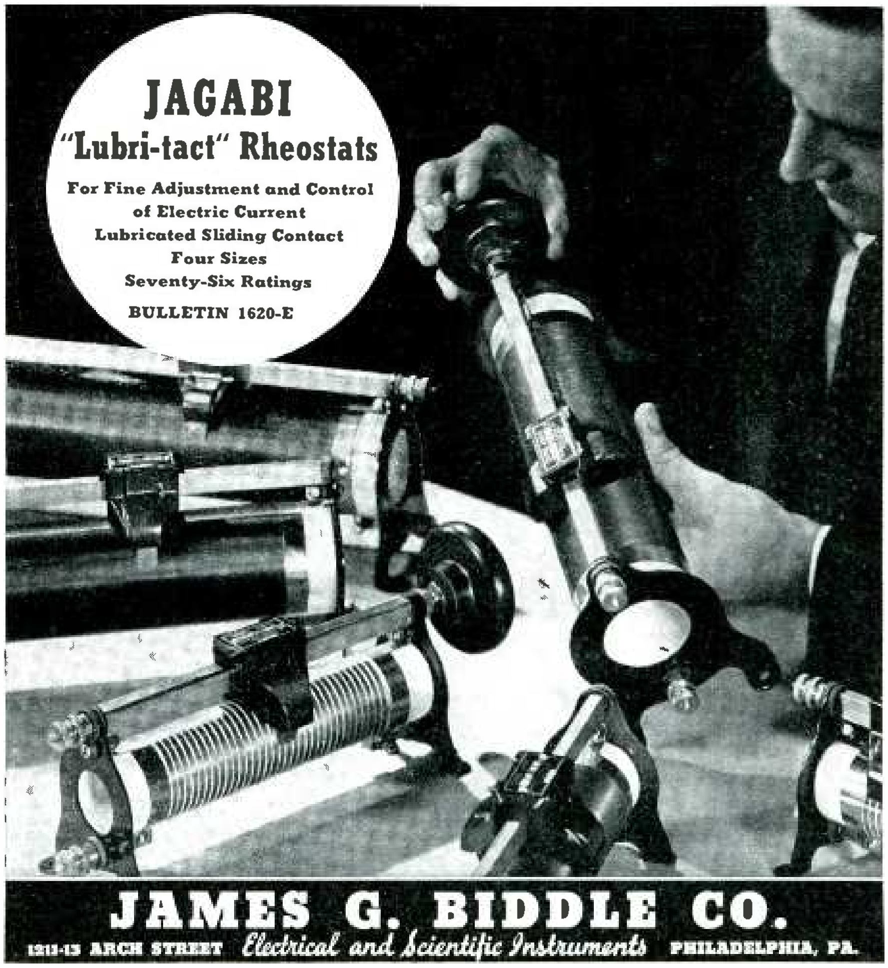
Figure 3 shows three sets of records taken with the double channel arrangement using two d-c amplifiers, two cathode ray tubes, and the sweep generator and stimulator. Each set is a simultaneous recording of the action potential time curve led off by two different types of electrodes from some point on a frog's gastrocnemius muscle stimulated through its motor nerve. The upper curve in each case is the electrical record obtained from unipolar leads and the lower is the corresponding record taken with differential leads. The lines were ruled in later for time comparison purposes. Maximum potential difference is not greater than 25 millivolts in any case and duration is about 14 milliseconds.

REFERENCES

(1.) A High Gain D-C Amplifier for Bio-electric Recording Harold Goldberg *Electrical Engineering, Transactions,* page 60, January, 1940.

(2.) "Direct-Coupled Amplifiers" M. S. Thesis, Harold Goldberg, University of Wisconsin Library, Madison, Wis.





THE INDUSTRY IN REVIEW

News

✦ An Alfred P. Sloan Foundation Fellowship for a year of advanced study of industrial problems at Massachusetts Institute of Technology has been awarded to W. Endres Bahls. One of eleven engineers chosen from all U. S. industry to receive this honor, Mr. Bahls, who is in charge of development and design work in connection with special radio tubes at the Harrison, N. J., laboratories of the RCA Manufacturing Co., will spend a year attending the Business and Engineering Administration School. The purpose of the Fellowship is to permit men actively engaged in industry to study subjects stressing the sociological aspects of modern industry . . . The Delta Star Electric Company of Chicago is now being represented in Detroit by the Wise Equipment Company located in the General Motors Building . . . Dr. Karl B. McEachron, high voltage engineer of the General Electric Company of Pittsfield, Mass., is the recipient of an honorary degree of Doctor of Science from Purdue University . . . Members of the Theater Sound Standardization Committee of the Research Council of the Academy of Motion Picture Arts and Sciences will attend the Pacific Coast Conference of Independent Theater Owners. The men who will attend are: John K. Hilliard (chairman), John Aalberg, Lawrence Aicholtz, Daniel J. Bloomberg, J. P. Corcoran, Lloyd Goldsmith, Russel O. Hanson, Elmer Raguse, William Thayer, and S. J. Twining. These men will be available for consultation on technical problems of theater and sound projection.

✦ Major E. H. Armstrong has been awarded the Franklin Medal by the Franklin Institute in Philadelphia . . . General Electric's short-wave stations, WGEA (Schenectady), and KGEI (San Francisco). are increasing their power to 50 kw. WGEO (Schenectady), another G.E. short-wave station is scheduled to go into operation late in August at 100 kw. . . . The American Network, Inc., has signed its first contract for commercial newscasting on f-m stations with the Socony-Vacuum Oil Company . . . The Paragon Electric Company has moved its manufacturing facilities to Two Rivers, Wisconsin. The new plant will be twice the size of the former plant . . . Several organization changes have been made at the Delta-Star Company of Chicago, Ill., following the death of Elias S. Cornell, chief Engineer. R. E. Anderson is now Vice-President; C. S. Beattie, Manager of Engineering; W. O. Hampton, Chief Design Engineer; S. C. Killian, Development and Research Engineer; and W. H. Boyce is now Manager of Industrial Sales . . . Dr. Karl T. Compton, president of the Massachusetts Institute of Technology has been elected to membership on the Advisory Council of the National Broadcasting Company. This group guides N.B.C. in matters of public policy . . . The Alden Products Company has moved into larger quarters at 117 Main Street in Brockton, Mass. . . . The Rauland Corporation has purchased the Sound Division of the Webster-Chicago Corporation. The new trade name is "Webster-Rauland" . . . E. I. duPont de Nemours & Co., is building a new neoprene synthetic rubber plant at Louisville, Kentucky, whose capacity will be 10,000 long tons a year . . .

✦ The only high voltage surge generator in the metropolitan area of New York City has been constructed at New York University's College of Engineering. Capable of generating 350,000 volts, it was built by Ralph Armington, a graduate student, under the supervision of Professor Harold Torgersen of the electrical engineering department. . . The 56th Annual Volume of the Engineering Index, containing 26,000 annotations of important articles that have appeared in domestic and foreign technical journals, 40,000 cross-references to these annotations, and an author and contributor's index of about 19,000 names is now ready for delivery. All branches of engineering are included, and the price is $50.00 per copy. . . NBC is constructing two new audience-type studios in Radio City. The latest developments in acoustical research and broadcast studio design are incorporated in their design. Studio A, largest of the NBC Chicago audience studios, is being renovated this summer. . . Radio Engineering Laboratories Inc. of Long Island City are being represented by Norman B. Neely Enterprises, 420 Market Street, San Francisco, Cal. in the sale of f-m broadcasting equipment on the Pacific coast. . . Emerson Radio and Phonograph Corp., New York City are contemplating a reduction of over 90 percent in the amount of aluminum normally used in the fabrication of its radio receivers. Their engineers have found that this can be done without sacrificing performance or efficiency. . . James S. Knowlson, president and board chairman of Stewart-Warner Corp. has been re-elected president of the Radio Manufacturers Association. . . Many soldiers in training camps are corresponding by means of phonograph records instead of letters. . . L'Tatro Manufacturing Co., pioneer in the 32-volt and 6-volt radio fields, was recently purchased by Eckstein Radio and Television Co. The offices and factory have been moved to Le Roy, Minnesota. . . E.. H. Alexander has been appointed engineer of the Industrial Control Division of General Electric's Industrial Department. . . Albert Danziger of Danziger Radio Labs. who was a pioneer in the high fidelity receiver field has accepted an engineering position in the Signal corps.

✦ The effectiveness of blackout lighting was recently demonstrated by General Electric engineers at Lynn, Mass. Twelve specially designed blackout luminaires spaced 100 feet apart were lit when the regular 4,000-candlepower street lights were turned off. These luminaires use a 2½-watt argon lamp, and the light they gave off could not be seen more than a few hundred feet above the ground. Objects or persons on the ground were visible at a distance of 25 feet. Since the argon lamp gives off ultra-violet rays, fence posts covered with fluorescent paint glowed when activated by the rays, indicating a method of increasing ground visibility under blackout lighting . . . Dr. Joseph Slepian, associate director of the Westinghouse Research Laboratories has been elected to the National Academy of Sciences. His research at Westinghouse helped make possible high-speed methods of extinguishing electric arcs, the modern lightning arrestor for power lines, and the ignitron . . . The battleship U.S.S. North Carolina is the first to have an electric organ, a product of the Hammond Instrument Company, as part of its equipment. The U. S. War Department has contracted with this company for the installation of 555 Hammond electric organs in all the regimental chapels now being built throughout the country . . . Marshall H. Ensor, radio amateur of Olathe, Kansas, won the fourth annual William S. Paley Radio Award for outstanding service to the nation. He has trained thousands in the radio code and radio fundamentals during the last ten years. The award has been given each year since 1936 to the radio amateur in the United States and Canada who has contributed most usefully to the American people . . . The Ferrocart Corporation of America announces the appointment of George H. Timmings as manager of its Chicago Laboratory . . . DuMont engineers have installed twenty-four fluorescent lamps in their New York television station W2XWV to replace incandescent lamps. By mounting the new lamps in horizontal rows on heavy framework, in two banks, placed on either side of the television camera facing the performers, objectionable flicker of individual fluorescent lamps has been cancelled out . . . J. Albert Stobbe, formerly General Manager of Arcturus Radio Tube Co., is now engaged in practice as attorney and consultant for industrial, communications, electronic and management matters. His office is located at 63 Wall St., New York City.

Literature

Standards. Two emergency defense standards, developed upon request of the War Department to help speed up production and inspection of products have been announced by the American Standards Association, 29 West 39th Street, New York City. They are called Guide for Quality Control (Z1.1-1941) and Control Chart Method of Analyzing Data (Z1.2-1941). The two standards have been published together in a single pamphlet which costs $0.75 per copy.

Plastics. The Plastics Department of the General Electric Co. of Pittsfield, Mass., has issued a folder called "The Change to Plastics". Twelve case histories in which plastics have been used to make items formerly made of other materials are cited.

Manual. Complete specifications, descriptions, and price information on radio communicating systems are given in a manual published by Air Associates, Inc., Bendix, N. J. The publication is available without charge to manufacturers affiliated with the airplane industry, recognized airport operators, and government department heads.

Insulating Materials. The complete line of General Electric insulating materials is covered in the new 1941 catalogue. Copies may be had by writing to the Appliance and Merchandise Department, Bridgeport, Conn.

Alloy Manual. A new handbook on molybdenum and tungsten products manufactured by American Electro Metal Corp., 300 Yonkers Ave., Yonkers, N. Y. is now available. It contains valuable information for engineers in the form of technical data on the chemical, physical, and electrical properties of molybdenum, tungsten, and other alloys.

Radio Products Catalogue. The J. W. Miller Co., 5917 South Main Street, Los Angeles, Cal. has just issued general catalogue No. 42 covering its line of radio coils and allied products. Included are several circuit diagrams and a price list.

Lathes. A catalogue covering 28 South Bend 9-inch lathes has recently been issued by the manufacturer. Copies of this book, No. 50-B may be had from South Bend Lathe Works, 398 East Madison Street, South Bend, Indiana.

Electric Motor Controls. A new catalogue describing the complete line of electric motor controls made by the Square D Co. has just been published. It is made up in loose-leaf form so that additional sheets may be inserted as they are issued. Copies may be obtained by writing to the Square D Co., Industrial Controller Division, 4041 N. Richards Street, Milwaukee, Wisconsin.

Instrument Catalogues. Products of Weston Electrical Instrument Corp., are covered in four new bulletins. Catalogue T-11-C describes Weston temperature gauges; No. B-19-A covers relays and photronic equipment; No. R-9-B shows the new panel instruments; and No. R-24-A deals with Weston test instruments.

Fuse Catalogue. Fuses, including aircraft antivibration, high voltage, instrument, radio, video, and vacuum types are listed in catalogue No. 8 of Littlefuse Inc., 4757 Ravenswood Ave., Chicago, Ill.

Aluminum Information. A series of articles called "The Cold Working of Aluminum" which originally appeared in *American Machinist* have been compiled into a booklet entitled "Forming Aluminum" by the Aluminum Company of America, Pittsburgh, Pa. Some of the items covered are: available alloys, blanking, piercing, drawn shapes, spun shapes, shape forming, embossing, coining, and stamping.

Welding Machine Bulletin. The Taylor-Winfield Hi-Wave welding machine which uses a stored energy welding process is briefly described in bulletin 1405 of the Taylor-Winfield Corp., Warren, Ohio.

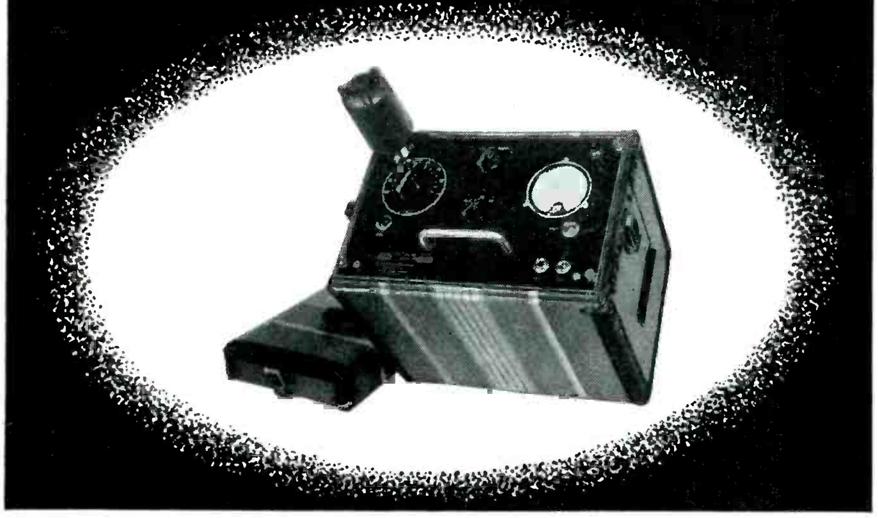
Condensers. The Solar Mfg. Corp., Bayonne, N. J., has issued catalogue No. 11 which covers its line of condensers. A folder entitled "Defense and You" listing recommended condenser types which will be readily available may be had with the catalogue if desired.

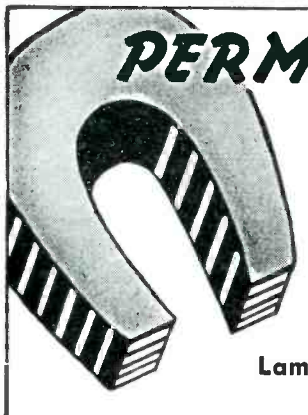
Tube Data. Technical features of 128 new types of tubes have been added to the new edition of the Ken-Rad Essential Characteristics booklet which may be secured from Ken-Rad Tube and Lamp Corp., Owensboro, Ky.

House Organ. A method of checking r-f power and tuning to peak efficiency using dummy antenna resistors is described in bulletin 111B of the Ohmite Manufacturing Co., 4835 Flournoy Street, Chicago, Ill.

Non-Metallic Materials. "What Material?" is the title of a new folder issued by the Continental Diamond Fibre Co., Newark, Delaware. It describes the applications of various kinds of non-metallic materials such as dilecto, diamond vulcanized fibre, micabond, celoron, and vulcoid which are made by the company. A large wall chart designed to help engineers select the proper type of material for a specific job is also available on request.

Bulletin. Aircraft voltmeters and ammeters are described in bulletin 43-347 issued by Dept. 7-N-20, Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa. The instruments mentioned are designed and rated in full accordance with government and commercial specifications.





New Products

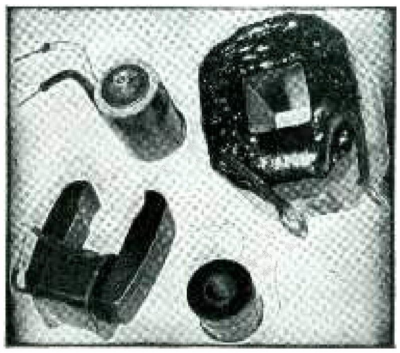
Receiving Station

THE RSC-1, a complete radio receiving station is the latest addition to the Hallicrafter (Chicago, Ill.), line of receivers. The unit tunes continuously from 1.8 to 2730 meters (110 kc to 165 Mc). A monitoring speaker connects to any one of the three units though separate speakers may be connected if desired.

Rotary Drive Rheostat

THE TRIPLEX ROTARY DRIVE RHEOSTAT, in which the resistances of three rheostats are simultaneously varied, is being marketed by the Rex Rheostat Company, 37 West 20th Street, New York City. Each rheostat may be varied separately if desired. These rheostats are for switchboard or table mounting. They are equipped with a dial having an angle of rotation of 330 degrees showing the position of the slider.

COILS
Electrical Windings



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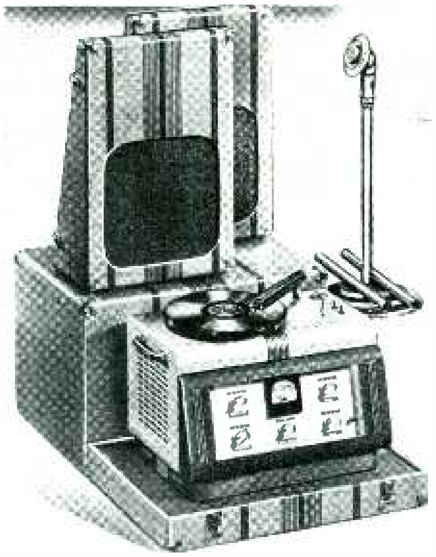
Mobile Sound System

ILLUMINATED SLOPING CONTROL PANEL, stand-by switch to conserve power, a jack for headphone monitoring, 30 watts of power output, and a speaker selector switch to permit adding or dropping speakers without affecting the tone quality are among the features of the new Knight mobile sound system currently featured by the Allied Radio Corporation, 833 W. Jackson Blvd., Chicago. The equipment, which includes a 30-watt amplifier with a phonograph turntable, two 12-inch dynamic speakers with 30-foot cables, a dynamic microphone with a 25-foot cable, and a collapsible floor stand, is housed in two portable cases. The amplifier, which may be operated from a 6-volt storage battery or the 110-volt a-c line has four input channels; two for high impedance microphones with individual volume controls, and two for phono on a single fader control. The output impedance may be varied to 2, 4, 6, 8, 250, and 500 ohms by means of a selector switch. The gain, on the microphone, is 135 db and on phono, 80 db. Hum is 60 db below rated output. Eight tubes are used: two 6SJ7's, one 6SA7, one 6SC7, two 6L6G's, and two 6X5G's.



A-C Power Plants

THREE LOW SPEED, 1200 rpm, a-c plants have been added to the line of Katolight Plants manufactured by Kato Engineering Co., Mankato, Minn. The new sizes will deliver 5, 7.5, and 10 kw, and are available with two or three wire service, or three phase, all at 60 cps. The prime movers are LeRoi, 4-cylinder, 4-cycle watercooled engines. The engine and generator assembly is mounted on rubber which permits installation of plant without bolting down on foundation. Voltage regulation ranges from 6 to 8 percent. The generators are filtered, and ignition systems are shielded for radio operation.

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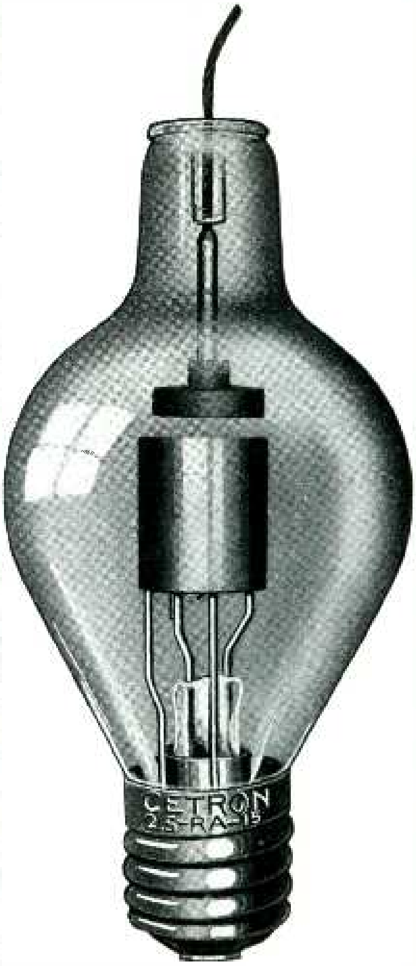
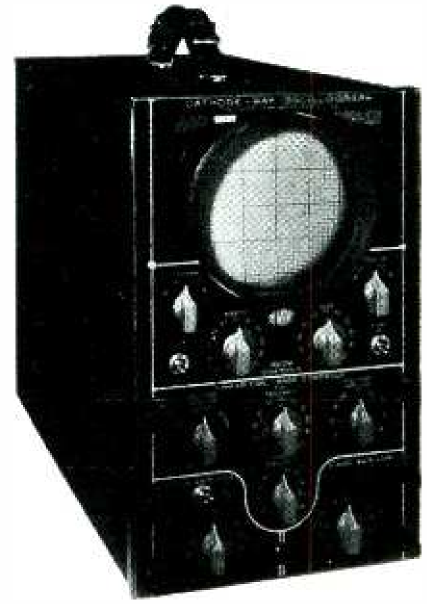


Storage Battery

A NEW TYPE OF STORAGE BATTERY for use in portable sets is being sold by the Willard Storage Battery Company, 241 E. 131st St., Cleveland, Ohio. This battery is 4 inches long, 3 inches wide, and 5½ inches high. The case is made of a strong, acid-proof transparent plastic. A spill-proof cover is provided to prevent loss of electrolyte. This makes it possible to operate a receiver in a tilted position, on its side, or even upside down. A charge indicator is built into the battery. A green ball sinks when the battery is 10 per cent discharged, a white ball when 50 per cent discharged, and the red ball when completely discharged. The balls float as the battery takes charge. A new type of electrolyte-retaining insulation soaks up the electrolyte like a sponge, keeps the solution in contact with the plates, and greatly reduces the quantity of free solution required. The plates used are of heavy construction, specially designed to withstand cycling service and overcharging. The cost is about that of two sets of batteries for the old type of portable receiver.

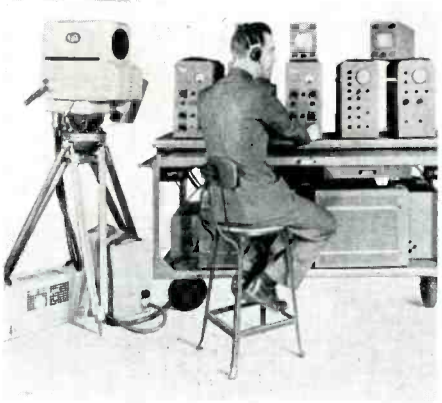
Smoke Control Robots

Two PHOTOELECTRIC smoke indication and elimination control robots for operation on 115 volts, a.c., or d.c. have been put on the market by Rehtron Corp., 2159 Magnolia Avenue, Chicago, Ill. Model SC-301, the indicator-signal type, has an illuminated density meter which continuously indicates smoke density in breeching or stack and provides for a bell or light signal when the smoke exceeds the maximum allowable density. The robot and light projector list for $40.00. Model SC-302 incorporates all the features of model SC-301 plus full automatic control for magnetic solenoid valve or blower motor supplying steam or air to over-fire jets. Adjustable time-delay on load circuit insures correct amount of steam or air to mix with unburned gases and supply oxygen deficiency which causes smoke to burn in the firebox. This robot and light projector list at $65.00.



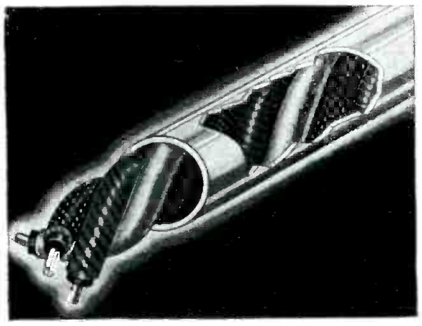
Television Equipment in Units

TELEVISION PICKUP EQUIPMENT is now being built in individual units which connect and work together to form a chain for given video broadcasting requirements by Allen B. DuMont Labs., Inc., 2 Main Avenue, Passaic, N. J. This makes it possible to obtain just the units required for certain video program work, while the flexibility of the chain permits addition or substitution of units as changing conditions may dictate. Part of a typical group of units is shown in the illustration. It is a dual camera chain which is made up of two cameras, each with its power supply, electronic view finder, and view finder units, working in conjunction with their individual camera control and power supply, camera monitor and monitor supply units. Both chains work directly with line amplifier and power supply, line monitor and supply, and a synchronizing generator. One of the cameras and its associated equipment is not shown.



Metal Shielded Wire

THIS NEW PRODUCT consists of shielding any type of insulated wire or wires with either seamless aluminum or copper tubing, tinned or untinned. This affords protection against moisture, corrosion, mechanical damage, and fire hazards. Metal shielded wire is manufactured by Precision Tube Co., 3824 Terrace Street, Philadelphia, Pa. It is available in lengths up to 50 feet, and comes in a variety of sizes from a single conductor with an outside diameter of 0.018 inch to multi-cable types of one inch outside diameter.



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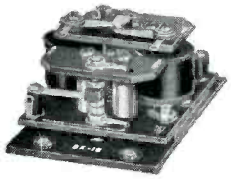

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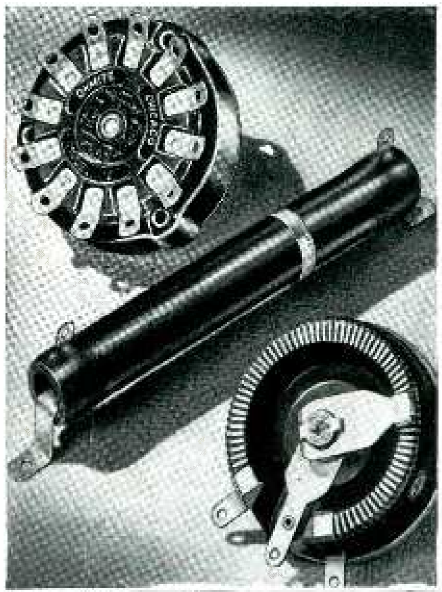

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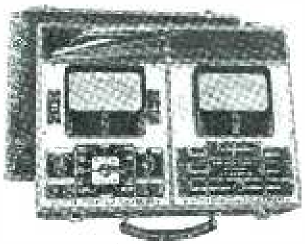

• 6 AC and 6 DC voltage ranges to 6000 volts at 1000 ohms/volt. • 6 DC current ranges from 0 to 1.2 MA to 0-12 AMPERES. • 4 internally powered resistance ranges to 10 MEGOHMS. • 6 DB ranges from —12 to 70 DB. • 6 output ranges to 6000 volts. • 8 AC Ammeter ranges from 0-300 MA to 0-60 AMPERES. Series 844-J (illustrated) in hardwood portable case with dual tool compartment and removable hinged cover—complete with batteries and extra high voltage test leads. Net Price......$48.95

WRITE FOR "PRECISION" CATALOG 42-E describing more than 40 radio and electrical test equipment models . . . Tube Testers, Combination Tube and Set Testers, AC-DC Multi-range Testers, Vacuum Tube Multi-Range Testers, Signal Generators, Industrial Circuit Testers, etc.

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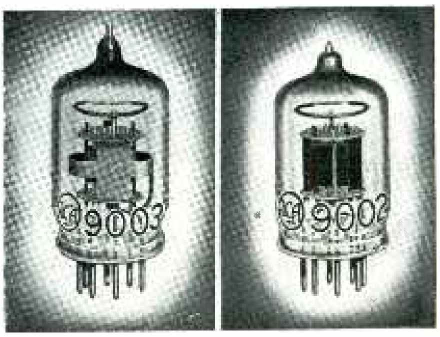
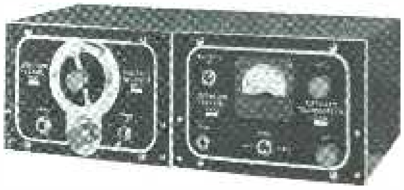
UHF Tubes

THE RCA MANUFACTURING CO., Harrison, N. J. are making available a new series of vacuum tubes designed for ultrahigh frequency use. RCA-9001 is a sharp cut-off pentode intended for use as an r-f amplifier. RCA-9002 is a triode which has two cathode and two plate leads. It has a moderately high amplification factor, and is useful as a detector, amplifier, and oscillator. RCA-9003 is a remote cut-off pentode designed for mixer and i-f or r-f amplifier applications. These midget tubes are of single-ended design, and have two cathode leads which permit completion of the plate and screen r-f circuits with minimum circuit inductance. This makes possible increased gain at ultrahigh frequencies.



Aircraft Communication Units

THE JEFFERSON-TRAVIS RADIO MFG. CORP., 380 Second Ave., New York, is introducing a new line of aircraft communication equipment. Among the models featured is model TR-5, a two way communication unit. The crystal controlled transmitter has a range of 2.8 to 6.5 Mc, and a power output of 5 watts with 100 per cent voice modulation. The transmitter is housed in a small cabinet which can be mounted on the panel of the plane. The receiver covers the 200 to 400 kc band, and is in a case matching that of the transmitter. A vibrapack, or a dynamotor power supply may be had with the Model TR-5. Another unit in this line is the Model PR-5, a portable receiver whose range is 200 to 400 kc, with a marking on the dial for the control tower frequency of 287 kc. The batteries and the receiver are mounted in a fabric covered case, and the total weight of the equipment is less than 10 lbs.



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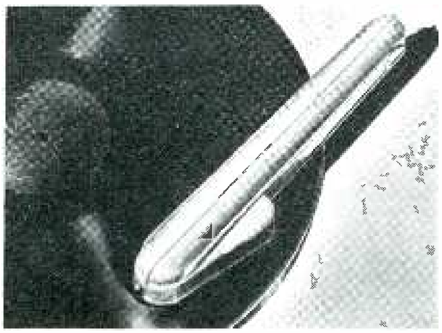
Portable Potential Transformer

A NEW PORTABLE potential transformer, model PV-130, for use with portable instruments and recorders is announced by Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. The instrument can be had for input voltages between 230 and 2300 volts with 115 volts output on 60-cps lines. The accuracy is plus or minus ¼ per cent both on ratio and phase angle up to 200 per cent of rated value. All terminals are of polished nickel, and terminal markings and polarities are clearly marked. The device is housed in an aluminum case designed to withstand wear and to insure lightness for portability.

Crystal Pickup

LIGHT WEIGHT, an offset head, low cost, and an output of 1.4 volt at 1000 cps, are some of the features of a new crystal pickup made by Shure Brothers, 225 W. Huron Street, Chicago, Ill. The unit weighs one ounce which improves reproduction and practically eliminates record wear. New type cartridge bearing seats permit easy up and down motion of moving system to overcome "pinch" effect and follow record grooves correctly. Model 97AN "Hi-Lo" pickup, complete with permanent sapphire point needle lists at $6.50. Model 97A which is the same as 97AN without the needle lists at $5.50.



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JACK PANELS

★ PATCH CORDS — PLUGS

These cords and plugs are built to take abuse. Cords are heavy, reenforced at ends. Unique construction of plugs not only makes cords easily replaceable, but provides for the ruggedness which is so necessary. They will fit any standard jack panels. Standard color, black.

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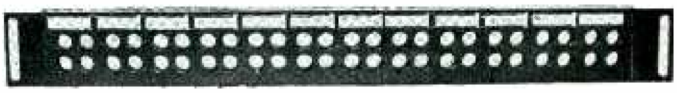
PJ-11	1 ft.	List $5.40 ea.	PJ-15	5 ft.	List $6.00 ea.
PJ-12	2 ft.	List 5.50 ea.	PJ-10	10 ft.	List 6.75 ea.
PJ-13	3 ft.	List 5.65 ea.	PJ-1	Plug only	List 2.25 ea.



PANELS

These panels have standard jack spacing for use with any double plug. Mounting holes fit all standard jacks. Pairs are so spaced that plug cannot be inserted incorrectly. Panels are of solid laminated Phenolic. Slotted brackets for mounting. Fit standard 19" relay rack. Improved designation strip included. Panel width: double row (48 jacks) 2⅛"; Single row (24 jacks) 1¾".

PJ-31, as illustrated—$5.45 PJ-33, single row—$4.75

PJ-31 panel with 48 PJ-118 jacks (normal contact) assembled—$29.20

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Hearing Aid Battery

A NEW LIQUID TYPE, rechargeable battery for hearing aid users is being featured by the Koehler Manufacturing Co., Marlboro, Mass. The case, a light weight (acid resisting, transparent Monsanto Lustron plastic is molded by the American Insulator Co., New Freedom, Pa.

Record Preservative

"SLIK", A LIQUID PREPARATION for preserving professional and home recording discs is being sold by the National Recording Supply Co., Hollywood, Cal. It minimizes surface noise on acetate or nitro cellulose blanks by reducing the cutting point friction thus lengthening the life of needles.

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Compact Converter

A NEW CONVERTER, built for high efficiency, quiet operation and long life is announced by the Eicor Co., 1060 W. Adams St., Chicago. This unit converts direct current to alternating current for use with amplifiers, projectors, phonographs, medical equipment, musical instruments, and similar applications. Available for 6, 12, 32, 115, 230 volts or other standard d-c input, the converter has a standard a-c output. All the units are equipped with ball bearings and may be had with or without a filter.

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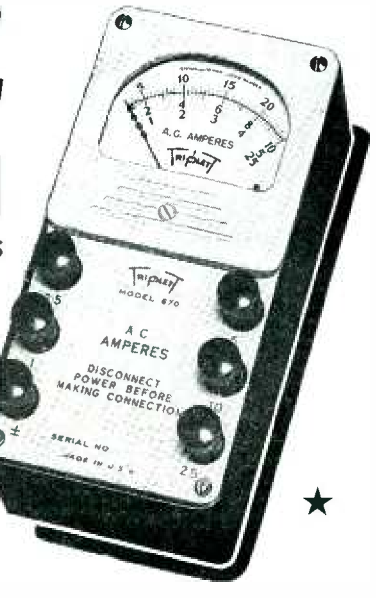
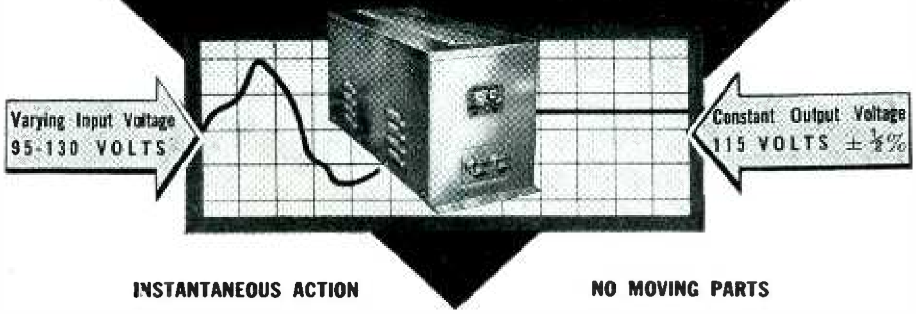
THE RV AUTOVALVE ARRESTOR is an improved single pole unit designed for protecting low voltage, low energy systems against insulation breakdown and apparatus failures. The internal elements consist of a porous block with a series gap formed by a mica spacer separating two metal electrodes.

The 60 cps arrestor breakdown is 800 volts rms, permitting signal circuits to be tested with a 500-volt megger. The impulse breakdown is 2200 volts peak. A discharge capacity of more than 10,000 amperes affords protection from lightning surge currents. Repeated discharges do not impair the arrestor's characteristics.

Glass Base Recording Disc

THE PRESTO RECORDING CORP., 242 West 55th Street, New York, announces a new high quality sound recording blank using a plate glass base. The disc is 0.104 inch thick, and has two center holes, one for the turntable shaft and the other for the cutting mechanism drive pin. Each hole is bushed with a brass eyelet to insure a snug fit over the turntable shaft and to prevent chipping due to careless handling. The glass base discs come in 12-inch and 16-inch sizes only. The same firm also announces an aluminum disc recoating service to radio stations and recording studios that have used aluminum base discs on hand. This service takes about ten days, and the charges for recoating are considerably less than the prices formerly charged for new aluminum discs.





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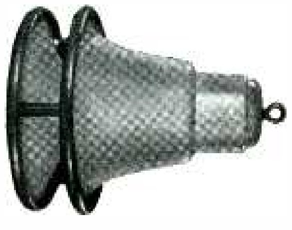
Cardioid Microphone

THE DESIRABLE FEATURES of the dynamic and the velocity microphones are combined in an instrument recently announced by the Turner Company, Cedar Rapids, Iowa. Two elements are used; one has a response pattern shaped like a figure eight, and the other is in the form of a circle. The combination of the two gives a response pattern shaped like a cardioid. This makes the instrument very sensitive to sounds originating in front of it, and insensitive to sounds originating to the rear of the microphone.

Model IBR, a radial intercommunicator booster speaker, designed for use where a radial speaker of high efficiency and compact size is required, is another product of the same company. Complete with built in pm sealed driver unit, the IBR is waterproof for outdoor installations. The bell diameter is 8 inches, the height is 9 inches, the impedance is 8 ohms, and the power capacity is 10 watts.



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E.

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LARGE MIDWESTERN radio receiver manufacturer has openings for experienced automotive and household radio receiver design engineers. Applicants should state education, experience and give references. Our own employees know of this ad. P-270, Electronics, 520 N. Michigan Ave., Chicago, Ill.

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New Weston model 151's, 0-125V AC flush type. $10.00 each

New Weston 456's, two meters in one flush type case, each meter has two differential coils on bobbin 5-0-5 ma. Res. 9 ohms. $15.00

Write for list of other meters and laboratory parts.

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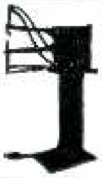

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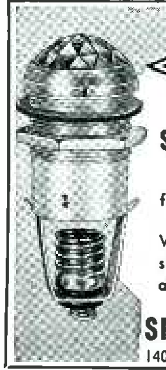

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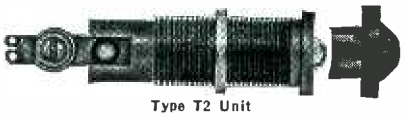

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