RADIO

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EDITORIAL

THE REACTIVATION OF AMATEUR RADIO

◀ In view of the restrictions on amateur radio activities, an OEM statement issued on June 11th proved of academic interest only. On that date the Defense Communications Board recommended to the War Production Board and the Federal Communications Commission that, with regard to the construction of certain radio facilities, there be immediately placed into effect the following policy:

1) No future authorizations involving the use of any materials shall be issued by the Federal Communications Commission nor shall further materials be allocated by the War Production Board, to construct or to change the transmitting facilities of any Amateur or Class 3 Experimental Station.

2) No future authorizations involving the use of any materials shall be issued by the Federal Communications Commission nor shall further materials be allocated by the War Production Board, to construct or to change the transmitting facilities of any Aeronautical Fixed (domestic) Station, Itinerant Aircraft Station, Flying School Station, or station operating in the *Emergency* and Miscellaneous Radio Services; provided, however, that upon proper showing that any such station serves as essential military need or a *vital public need*, which cannot otherwise be met, the Commission and the War Production Board will take action commensurate with the importance of the particular facility in question.

But the foregoing takes on practical interest in view of a joint release by the ODC and FCC on June 13th, with regard to war emergency radio service for civilian defense units. Under authority granted in Order No. 9 of the Defense Communications Board, the two agencies are collaborating their activities relative to proposed emergency civilian defense radio systems to be available in the event air raids damage or destroy other means of communication, the two-way radio systems to be operated by civilian radio technicians, including radio amateurs.

Thousands of compact radio stations to be constructed and operated under prescribed restrictions largely by persons who have had amateur radio experience are expected to augment the services of the OCD organizations throughout the nation. It is anticipated that the two-way stations will be constructed of parts amateurs and others now have on hand. The transmitters will use not more than 25 watts input power, and operate on assigned frequencies above 112 megacycles. Provision has been made for testing during blackouts and other mobilization trials. Printed manuals designed to facilitate administrative operation will be distributed by the OCD, through its regional offices.

Officials at the Communications Commission explained that blanket licenses for all civilian defense radio stations within a civil defense operations area would be granted to an "instrumentality of local government" when the equipment is in the possession or control of the local government. A "radio aide" for the local instrumentality must be certified and appointed in accordance with FCC rules. Separate operator licenses designated "War Emergency Service Operator Permits" will be issued to persons assigned to operate each radio station. However, it was emphasized at the FCC that no individual operator permit of this special class will be issued unless the applicant first holds a regular FCC operator license or permit, and only after the FCC has been satisfied in regard to the integrity and loyalty of each applicant for a War Emergency Service Operator Permit.

Thousands of amateurs have been waiting for just such an opportunity to be of service in such manner as they are able. The opportunity is now at hand, and we are sure the most will be made of it.

—M.L.M.
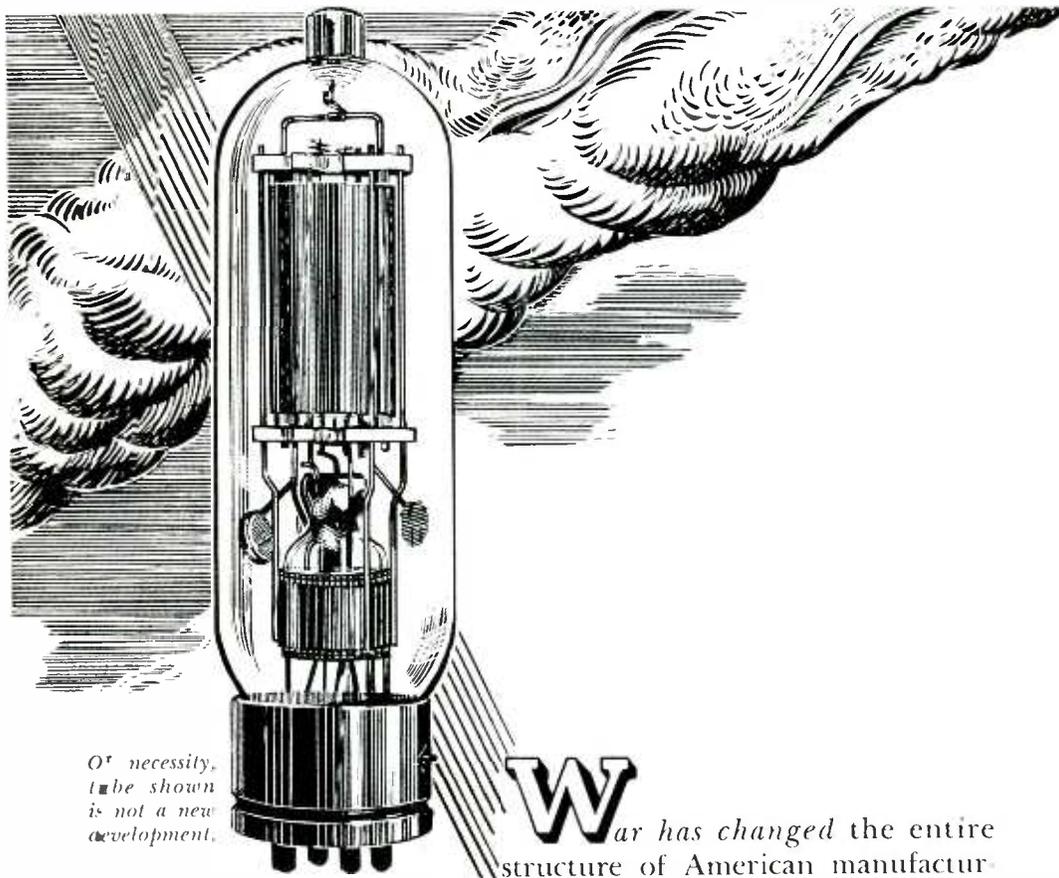
*Of necessity,
t■be shown
is not a new
development.*

War has changed the entire structure of American manufacturing with resultant shifting in engineering point of view. Electronic designers are conquering problems never before presented.

Many defense developments will — when presented to the post-war commercial market — make unheard of changes in electronic scope.

"Secret weapon" is a hackneyed phrase, but would be justified when applied to any number of new applications of electronics. "RADAR," the u.h.f. aviation locator, may, for instance, be standard equipment on commercial aircraft after the war. Yet it is only one phase of the new developments.

The Raytheon laboratories are well in the vanguard of those developing new devices and usages. When the war is brought to a successful conclusion the RAYTHEON name will mean more than ever before to the engineering world.

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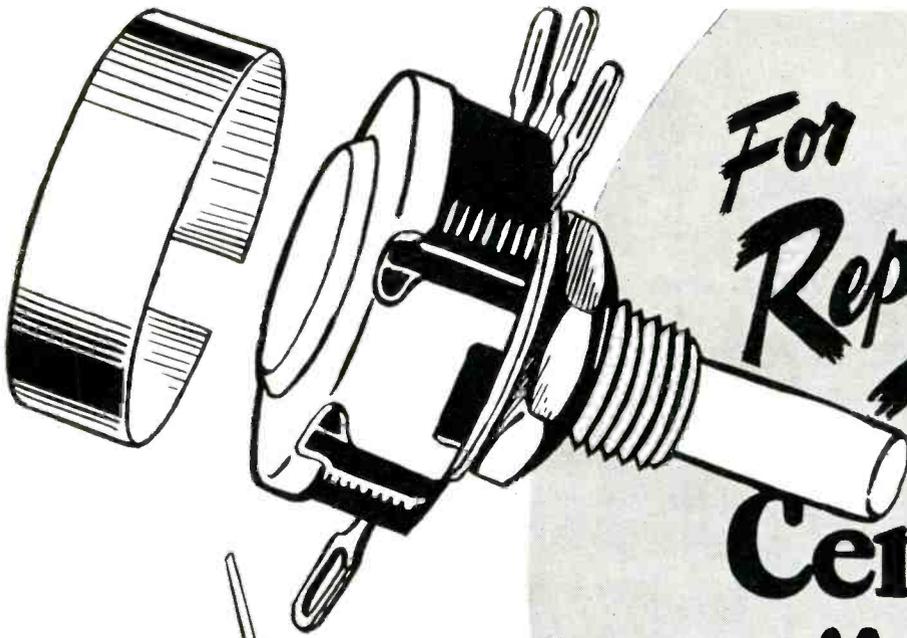
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COVER

Dynamic view of the tank coil in the output stage of WHN's new 50-kw. transmitter recently placed in operation.

ARTICLES

MISCELLANEOUS

CLOSE-UP OF THE FIVE-TOWER RADIO RANGE STATION.

RADIO IN AVIATION

GERALD O. CROWLEY

Senior Control Tower Operator (CAA)

◀ Introduced originally for communication purposes, aviation radio has outgrown its swaddling clothes and assumed new facets embracing a complexity of duties and uses of the utmost importance to the safe guidance of aircraft in flight. Perhaps
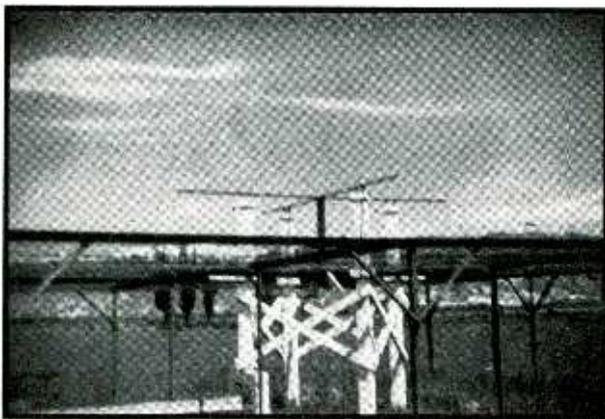
Close-up of the radiating system of the 75-megacycle "Z" marker station, with its four horizontal dipoles. See Fig. 2 for pattern.

no other single factor has contributed so greatly to the rapid progress of air transportation since the county fair curio stage of 1919. The modern airliner, in addition to its short-wave radio transmitter and receiver for communication with ground stations, carries radio equipment and devices performing lesser-known tasks with an uncanny degree of accuracy and dependability.

At the altitudes and speeds of which airplanes are now capable, much of the airliner's flight path is above clouds or overcast. Visual reference to landmarks which serve as check points for slower aircraft flying closer to the ground is only rarely possible. Governing the flight altitude of aircraft in this manner, therefore, has become a practice of the past. Now the airline pilot depends upon the modern system of navigation by the use of radio aids.

Radio Range Stations

The major radio aid to navigation is the vast network of radio range stations whose "on-course" signals mark out the country's transcontinental airways. Range stations serve also as voice communi-

cation stations of the Civil Aeronautics Administration, transmitting weather reports and traffic information to pilots en route. Contrary to popular belief, the range station does not—in a true sense—emit a "beam" for pilots to follow. *Fig. 1* shows a portion of the radiation pattern of a range station using Adcock, vertical radiators. It will be noted that the "on-course" signal actually results from the overlapping of the signals radiated from the corner towers. The center tower emits a non-directive, continuous-wave signal at the assigned frequency of the station in the 200-to 400-kc. band. The N and A towers radiate in the pattern shown an unmodulated signal 1,020 cycles higher than the assigned frequency. The beat note resulting from this frequency difference is heard in the receiver as an audio note of 1,020 cycles. The N and A signals are keyed alternately with their code letters so spaced that when heard together the result is an unbroken audio note. This is the on-course signal, and occurs in the shaded portions of the diagram where the N and A signals overlap.

For voice communication the modulation is applied to the signals radiated from the center tower, resulting in simultaneous voice and range transmissions. Separation of the two signals is accomplished

Fig. 1. Radiation pattern of radio range with Adcock vertical tower radiators. Center tower pattern, stippled; A towers, broken cross lines; N towers, full cross lines.

at the receiver through the use of band-pass and band-elimination filters. Where the range is intended for navigation purposes only, the center tower is omitted—the signal from the corner towers being directly modulated at 1,020 cycles. This also applies to the loop type stations, which, because of their undesirable night-time characteristics, are rapidly being replaced with the vertical tower type stations.

"Cone of Silence"

A pilot letting down through an overcast to land at an airport must first establish his position over the range station—this being the starting point for standard instrument letdown procedures. The radiation pattern of the range station provides him with one indication by an entire absence of range signals directly above the station. Called the "cone of silence," this is illustrated in *Fig. 2.* Supplementing this negative indication is the signal from the "Z" marker transmitter.

The "Z" type marker station transmits on a frequency of 75 mc. Its radiation pattern is cone-shaped and follows roughly the pattern of the cone of silence above the range station. This pattern is achieved by arranging four horizontal dipoles, as shown in the photograph, and feeding opposite pairs equal currents in phase. Antenna power is approximately five watts. The signal is modulated at 3,000 cycles and provides pilots with visual as well as aural indication when crossing the station.

Also transmitting on 75 mc. are the fan-marker, or "FM" type stations. These stations are located on one or more legs of important radio ranges at

One of the 120-foot vertical towers forming a part of the radio range station.

Cockpit of a Douglas DC-3 transport plane. At top of photo is the ADF tuning head. Frequency change switch at top right. In foreground is master radio panel and ADF Azimuth indicator.

distances of roughly twenty miles from the station. They serve as radio check points for the pilot making an instrument letdown and provide positive identification of range legs. The horizontal radiation pattern of this type station is elliptical in shape, with the major axis approximately four times the minor axis. Four horizontal dipoles arranged as shown in *Fig. 3*, give this pattern, the major axis being perpendicular to the line of the radiators. With an antenna power of 100 watts the usable signal area is three by twelve miles, and is effective to an altitude of 20,000 feet. The signal is modulated at 3,000 cycles and keyed in a series of from one to four dashes. Visual indication to the pilot when crossing the station is provided in the same manner as for the "Z" type marker station.

"M" Markers

Another type of marker station is located along the airways at points where a pilot would ordinarily change over from one range to another. Called the "M" type marker, its signals are non-directive and appear as interference on the frequency of the range station signal. The stations are low-powered and can be heard for a distance of about fifteen miles.

They remind pilots to change the tuning of their range receiver to the frequency of the next range station. They serve also as secondary CAA communication stations, providing voice facilities on 278 kc.

278 kc. is also the transmitting frequency assigned to airport control towers. The control towers contact aircraft approximately ten minutes flying time from the field and issue landing instructions, traffic information, etc. Tower transmitters are authorized to use a power output of 15 watts, although often the transmitters are capable of up to 100 watts output. Full power is utilized when a directive antenna system is available and the transmitter may do double duty as a runway localizer. In this service the transmitter performs as a miniature range station, its on-course signal projected directly down the runway to be used. Modern u.h.f. blind landing systems now undergoing extensive testing are expected to replace entirely the low-frequency runway localizers.

Plane Equipment

To make full use of these radio navigation aids, and to maintain two-way radio communication with CAA and company ground stations, the modern airliner is fitted with an imposing complement of radio
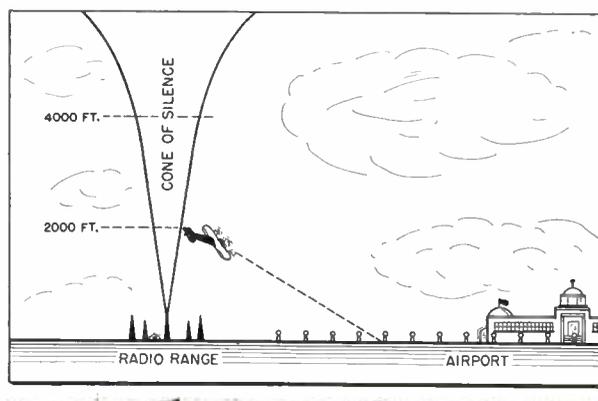

Fig. 2. Cone of silence above radio range station.
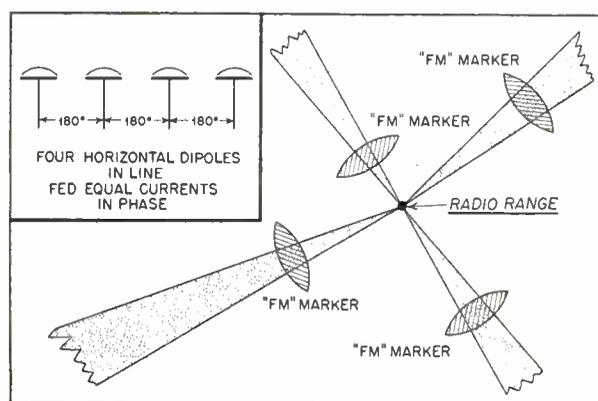
Fig. 3. Fan markers on legs of radio range. The antenna system is shown in box in upper left corner.

equipment. A typical setup in a Douglas DC-3 twenty-one passenger transport includes the following:

1—Range receiver.
2—U.h.f. marker receiver.
3—Automatic direction finder.
4—Multiple-channel transmitter-receiver.
5—Interphone amplifier.
6—Power source for above units.
7—Antennas—a total of six.
8—Static discharge cartridges.
9—Audio filters, jack boxes, control heads, master control panel, microphones, headsets.

Space and weight are, of course, primary consid erations in aircraft radio equipment—as are ruggedness and dependability. Units must be mounted to withstand severe jolts and be accessible in flight for minor adjustments. This condition is met in the DC-3 by mounting the first five items above in a rack directly behind the cockpit forward of the passenger cabin. Jack boxes and control heads and the master control panel are mounted in the cockpit within easy reach of the pilots, providing 100 percent remote control of all equipment. Units are individually fused, with the fuse panel readily accessible in flight. Dual frequency coverage is provided for all but the 75-mc. band, item -3- above covering both range and company communication frequencies and considered a stand-by receiver for these bands.

The range receiver is an eight-tube superheterodyne covering the band of frequencies from 200 to 400 kc. Remote tuning is accomplished by the use of "tach" shaft and control head; "coffee grinder," the pilots call it. The coffee grinder can be seen in the center of the accompanying photograph, mounted just above the windshield to the right of the center column. The range receiver is used for reception of radio ranges, "M" type marker stations and control towers. To provide quick change to tower frequency without disturbing the range tuning, a set of condensers within the receiver are pretuned to 278 kc. A toggle switch on the master control panel actuates a relay to select this frequency at will. Volume control, a.v.c. switch, beat oscilla-
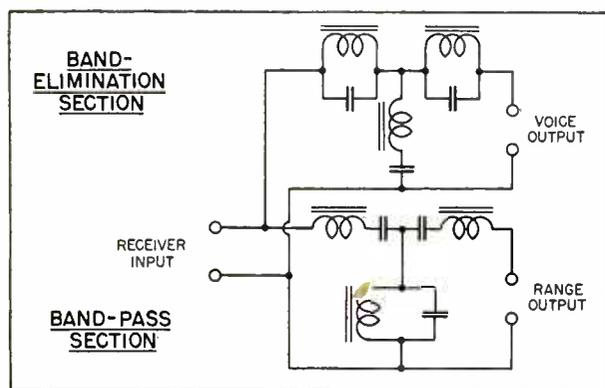
Open view of the 50-watt 10-channel aircraft transmitter-receiver. Frequency selection is by a motor-driven turret controlled from cockpit. Both transmitter and receiver channels are fixed-tuned and crystal-controlled.

tor switch and antenna selector switch are also located on the master panel. The antenna normally used is a balanced "T" located beneath the aircraft, but during static conditions a fixed one-turn loop may be switched in.

Band Filters

The switches to select range or voice broadcasts from the range station are incorporated in the pilot's individual jack boxes. The filter circuit is shown in *Fig. 4.* It consists of band-elimination and bandpass networks. For voice reception the band-elimination network is cut in, its components designed for maximum attenuation at 1,020 cycles. Cutoff frequencies are at approximately 830 and 1,250 cycles, sacrificing very little in speech quality. The band-pass filter for reception of range signals is designed for minimum attenuation at 1,020 cycles with cut off at approximately 900 and 1,100 cycles. Its use permits reception of range signals without the disturbing interference of the voice modulation.

The ultra-high-frequency marker receiver is used for reception of "FM" and "Z" type marker stations. Crystal control of frequency is obtained by utilizing a 6N7 tube as crystal oscillator and harmonic generator. The ninth harmonic is selected and beats with the incoming signal in a 6J7 modulator tube in the usual manner. Antenna used is a dipole mounted below the belly of the aircraft and coupled to the receiver by a low-impedance cable. Visual indication for the pilots is provided by rectifying a por-

Fig. 4. Audio filter for selection of voice or range signals.

Far view of a typical five-tower radio range station, with 120-foot vertical towers.

tion of the a.f. signal output and applying this voltage to the d.c. winding of a reactor of the saturable-core type. When the impedance is lowered by saturation, sufficient current flows in the a.c. winding of the reactor to operate an indicating lamp on the instrument panel. At the same time the pilots hear in their headphones the characteristic 3,000-cycle note of the u.h.f. marker stations.

Automatic Direction Finder

The automatic direction finder covers range and broadcast frequencies as well as the aircraft communication frequencies from 2,800 to 6,600 kc. In the space allotted, a technical description of the operation of the ADF's complicated circuits is hardly possible. Briefly, the phase relationship between current and voltage of an incoming signal as received simultaneously on a sense and a loop antenna is utilized to keep the loop automatically turned to the null position for the received signal. The loop is coupled by an autosyn system to an azimuth indicator in the cockpit whose needle then points directly to the station being received. The ADF azimuth indicator can be seen in the photograph just forward of the throttles on the control column. The ADF tuning head is in the extreme top center of the picture above the windshield. The meter fastened to the side of the head provides fine adjustments in tuning.

The importance of the aircraft communication equipment can be measured only by the importance of the complete CAA system of traffic control. Frequent position reports must be made by each aircraft in flight, that its course may be plotted on the flight progress boards in the airway traffic control centers. Traffic information and clearances must be received and acknowledged for. Frequent information on current and forecasted weather conditions must be made available to the pilots. These and other requirements denote the communications unit as perhaps the most valuable piece of radio equipment carried by the airliner. Constant development over

a period of years has evolved the present truly remarkable piece of apparatus.

A transmitter and receiver on one frequency was all that was once required for aircraft communication purposes. Heavier schedules and longer runs brought about the boosting of power in ground-station transmitters and consequent frequency congestion. It was found that a single frequency was not suitable for both day and night use. The aircraft band is now split at 4,000 kc., frequencies above that being used during the day and the lower end utilized after sunset. A coast-to-coast airline now splits radio communications into four sections, each using separate day and night frequencies. In addition to these eight channels required for company operations, 3,117.5 and 6,210 kc. are used by aircraft to communicate with CAA stations and airport control towers. The aircraft transmitter, then, must be able to select at will any one of ten operating frequencies.

Aircraft Transmitter-Receiver

The modern ten-channel aircraft transmitter-receiver shown in the accompanying photograph weighs 74.5 lbs. complete. It occupies a space in the radio rack slightly less than 23 by 16 by 8 inches. It provides 50 watts output, 100 percent modulated, on ten selected crystal-controlled frequencies between 2,500 and 13,000 kc. The ten receiving channels are also crystal controlled and utilize the transmitter tank inductances as r.f. coils in the "receive" position. Frequency selection is accomplished by a motor-driven turret remotely controlled from the cockpit.

In the transmit position a 6L6 tube acts as a Miller crystal oscillator on the lower frequencies and becomes a Pierce oscillator on the higher channels. The 6L6 drives two 807 tubes in parallel to an output of 50 watts. A zero-level carbon mike feeds a 6V6 speech amplifier tube which drives a pair of 807 modulator tubes in Class AB₂. The audio response from 500 to 3,000 cycles is flat to within plus or minus 3 db, and 100 percent modulation of the 50 watt carrier is easily accomplished. Power consumption in the transmit position during full modulation is 37 amps at 12.3 volts, plate power being furnished by the larger of the two dynamotors mounted at the rear of the chassis. The small box protuding from the front panel contains the motor which drives the band-switching turret. In the cockpit photograph the frequency change switch may be seen just above the windshield on the extreme right, while other control switches are incorporated in the master control panel. The antenna is stretched horizontally above the fuselage from just behind the cockpit to the rear fin. It is approximately 45 feet long and is tuned by rotating the tank coils at the front of the turret.

In the receive position the 6L6 tube is again utilized as crystal oscillator. In receiving, the Pierce circuit is used on all frequencies. Two r.f. stages

precede the first detector and give excellent image rejection. Two i.f. stages, combination second detector-a.v.c.-first audio and push-pull 12A6 audio tubes complete the tube complement. Sensitivity is better than 2 microvolts-per-meter at all frequencies. Plate power is supplied by the smaller dynamotor. Power consumption in receive position with transmitter tube filaments on is 7.2 amps at 14 volts.

The output of all receivers is fed through a master dual output interphone amplifier. This provides separate output for each pilot's jack box and permits interphone communication. The jack box selector switches are so arranged that one pilot may receive range signals while the other conducts two-way radio communication with ground stations. During an instrument letdown one pilot may listen to the range receiver while the other double-checks him by tuning in the range signals on the ADF receiver.

Anti-Static Cartridge

Not the least novel piece of radio equipment aboard the airliner is the anti-static cartridge. Flying through snow or dust storms the entire aircraft may become heavily charged with static electricity. The charge is often so heavy that sparks leap across windshields and radio antenna insulators. At such times radio reception even on the loop antennas is knocked out completely. Aeronautical radio engineers went to work on this knotty problem and devised the anti-static cartridge as a means of bleeding off this static charge. The DC-3 carries two of these cartridges in the extreme tail just below the rudder and stabilizers. Each consists of a dural tube about three inches in diameter and twelve inches long. About four feet of flexible steel wire connected to a similar length of rubber-covered resistance cord is coiled inside. By throwing a switch in the cockpit the pilot can release a spring gun mechanism in the cartridge which shoots the wire out into the slipstream. The static charge then discharges from the tip of the trailing wire, while the resistance cord damps the oscillation in the same manner as the resistance type automobile spark-plug suppressor.

Future in U.H.F.

The trend in aviation radio is toward the ultra-highs. The success of recent tests on u.h.f. radio ranges operating in the band of 123 to 127 mc. foretells abandonment of the low-frequency range stations. CAA airport towers are already installing u.h.f. transmitters which will operate in the frequency range of 129 to 132 mc. A blind landing system in use at Indianapolis, Ind., utilizes three u.h.f. transmitters in performance of its various functions. Thousands of successful experimental blind landings have been made using this system. There is no question but what this type equipment will soon replace the inadequate low-frequency runway localizers in use at some fields.

Radio altimeter equipment has been undergoing extensive service testing by the airlines and military and naval services. This device consists of a frequency-modulated transmitter operating in the neighborhood of 420 mc., a receiver at the same frequency and a cycle-counting device. In use the transmitted signal is radiated downward from the aircraft while a small portion of the signal is permitted to reach the receiving antenna. The signal reflected from the ground is then compared in the receiver with the direct signal received, the difference in frequency being directly proportional to the distance of the aircraft above the ground. The cycle-counting circuit applies this reading to a meter with its scale calibrated in "feet above ground." The advantage of this type of indication over that of the pressure-type altimeter, which indicates height above sea level, is immediately apparent.

The principal advantages expected to be gained from the swing to ultra-highs are: freedom from atmospheric interference; freedom from fading and skip effects; reduction in power and weight of equipment; smaller, but more efficient antenna systems; more frequencies available. Today the ultra-highs have the 200-to 400-kc. band on the run. Tomorrow they may assail the ramparts of the medium-wave communication band. And all towards the one objective: that aviation may continue its phenomenal rate of progress—ad finem. . . .

NEW CIRCULAR ANTENNA

◀ Radio engineers inspecting a new General Electric circular type radio antenna exhibited at the recent convention of the Institute of Radio Engineers at Cleveland. An outstanding feature of the antenna, simple in structure, and resembling a donut, is its ability to radiate substantially uniform energy in all directions without resorting to the complex and comparatively costly structures previously designed with phasing networks to secure this uniform pattern.

LOW-FREQUENCY R-F OSCILLATORS

Design of 10- to 500-kc. Generators for Carrier-Current and Remote-Control Applications

RUFUS P. TURNER

◄ Frequencies between 10 and 500 kc., which formerly were of no interest except for the appearance of superhet intermediate frequencies at four or five points in this range, are important now as channels for carrier-current and induction field communication, and remote control.

The generation of low radio frequencies is accomplished with oscillator or amplifier circuits basically identical with high-frequency units, except for the difference in tank circuit values. Inductances and capacitances for this work are larger in magnitude; while, generally speaking, stray capacitances (including tube interelectrode capacitances) are of less moment than in short-wave circuits.

Low power is employed in carrier current and induction field systems in order to keep down interference. Tank coils for such power levels need not be bulky, but may consist of the high-inductance choke coils, i.f. oscillator "transformers," old-time honeycomb coils, etc., from the spare parts shelf.

Most of us have some of these inductors lying around unused, and these may be pressed into service as low-frequency tank coils. If the inductance of a readily available coil is insufficient to resonate at the desired low frequency, the difference may be made up by padding the circuit with a silver mica fixed condenser of suitable capacitance. And while the presence of fixed capacitance in the circuit will limit the tuning range of the variable condenser, the circuit may still be peaked to the desired frequency by the latter.

Determining L and C

Fig. 1 gives a chart for finding either the inductance or capacitance which will resonate at any desired frequency between 10 and 500 kc. When either one of these quantities is known, one may readily find the other by lining up the known points with a straight edge. If both inductance and capacitance values are known, the frequency to which they will tune may be determined from the chart.

An example of the use of the chart is the determination of required condenser size: To find the total capacitance required to tune a 1-millihenry coil to 50 kc., lay a straight edge across the chart so that one end intersects the inductance scale at the 1-mh.

point and the other end rests upon the 50-kc. point on the frequency scale. The required capacitance— 0.01 μfd.—is then read at the point of intersection of the straight edge with the capacitance scale. Another example: To what frequency will a 2.5-mh. air-core choke coil and a 100-μμfd. condenser resonate? The 2.5-mh. point on the inductance scale is lined up by means of the straight edge with the 100-μμfd. point on the capacitance scale. The line established by the straight edge then intersects the frequency 320 kc. on the frequency scale.

Low-Frequency Coils

Air-core coils for low-frequency oscillators and amplifiers may take any one of several shapes. The principal configurations are (1) single-layer solenoid, (2) multi-layer solenoid, and (3) universal-wound type.

For frequencies between 400 and 500 kc., the single-layer solenoid type of construction may be employed without running into ungainly sizes for a given inductance, provided, of course, that the current-carrying requirement of the coil is low enough to allow small-sized wire to be used. The inductance of a single-layer coil may be determined by means of the equation:

$$L = \frac{200 \ A^2 \ N^2}{3A + 9B} \qquad (1)$$

Where L is the inductance in millihenries;
A, diameter of coil in inches;
B, length of winding in inches;
N, number of turns.

If a large value of current is to flow through the coil, the wire size must be increased proportionately and a single-layer type of inductor might become too bulky. In order to preserve the same coil length, it then becomes necessary to wind the inductor in more than one layer.

The second pattern—the multi-layer coil—is wound by placing one complete layer of winding upon another until the required number of turns have been wound. Spools or bobbins may be used as forms for this type of winding. While this type of construction materially reduces the girth of a high-current coil, it increases the distributed capacitance and attendant losses.

Equation (1) is altered slightly to give the inductance of a multi-layer coil:

$$L = \frac{200\,A^2\,N^3}{3A + 9B + 10C} \qquad (2)$$

Where the additional term, C, is the radial depth of the winding, in inches, and all other terms are the same as in Equation (1).

The third pattern—the universal winding—is difficult of duplication unless a coil-winding machine is available. Most i-f. transformers and r-f. chokes are of this type of construction, and may be readily employed. For low-power, low-frequency generation, receiver-type r-f. chokes are available in inductance values between 1 and 250 millihenries and with current-carrying capacities from 50 to 125 milliamperes. Superhet beat oscillator coils are likewise convenient for low-power work and are available for 175, 456, 465, and 500 kc. These operating frequencies may be still further lowered, when desired, by loading the circuit with fixed condensers. For higher-powered oscillators and amplifiers, transmitter-type r-f. chokes (also universal wound) are available in inductance values between 225 microhenries and 25 millihenries, and rated to carry from 250 to 500 milliamperes.

Circuits

Figs. 2 to *4* show well-known circuits which are finding use in low-power systems for low-frequency
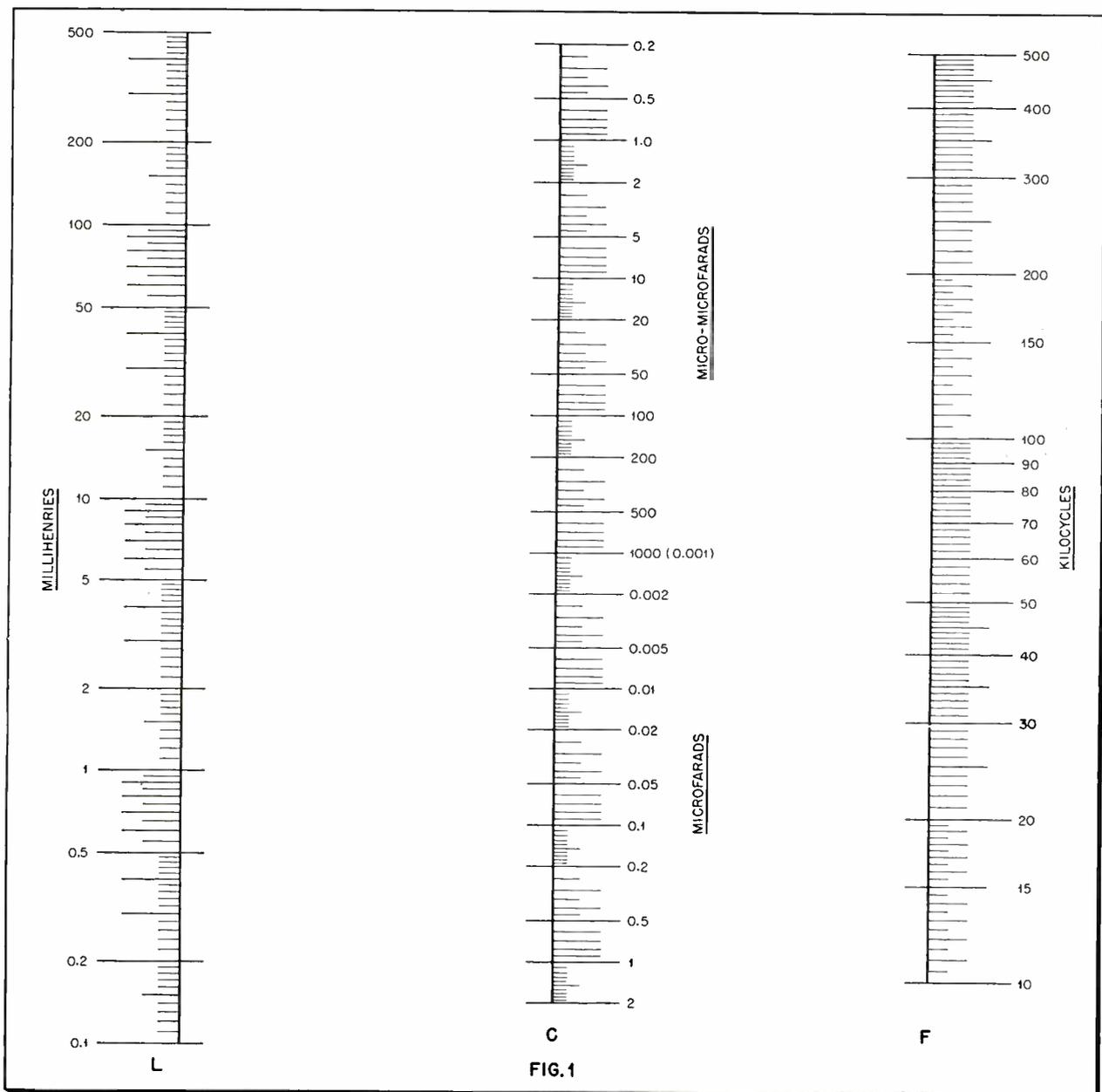

FIG. 1

Chart for finding either the inductance or capacitance which will resonate at any desired frequency between 10 and 500 kc.

emergency communications and for remote control.

Fig. 2 is an electron-coupled arrangement with constants shown for 100-kc. operation. The coil, L, is a 2.5-mh. pi-wound, receiver-type r-f. choke. The cathode tap is connected between the first and second pi's from the grounded end. *C1* is a 0.001-μfd. silver mica fixed condenser for tank-circuit loading, while *C2,* the variable section, is a 100-μμfd. midget tuning condenser.
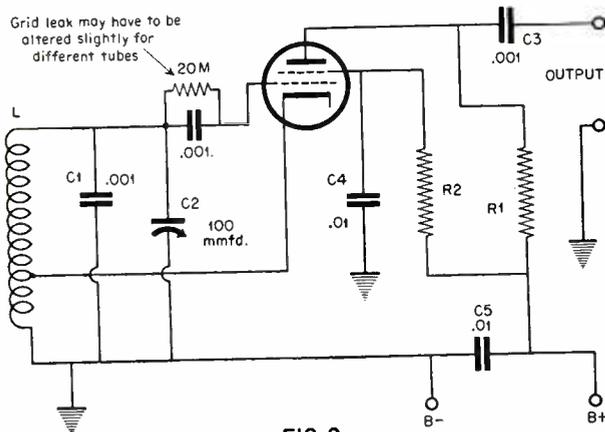

FIG. 2

Electron-coupled oscillator circuit with given constants for 100-kc. operation. Tube may be pentode or beam-power receiving type.

The tube may be any convenient receiving type pentode or beam-power tetrode of suitable power output. If a pentode is used, the suppressor must be connected to the cathode at the socket. The plate and screen resistors, *R1* and *R2,* will be those values specified in the characteristics for the tube used. The r-f. output is delivered through a fixed mica condenser, *C3. C4* and *C5* are respectively screen and plate bypass condensers of high capacitance.

The inductor for this oscillator might likewise be an internally-tuned superhet-type of beat oscillator coil.
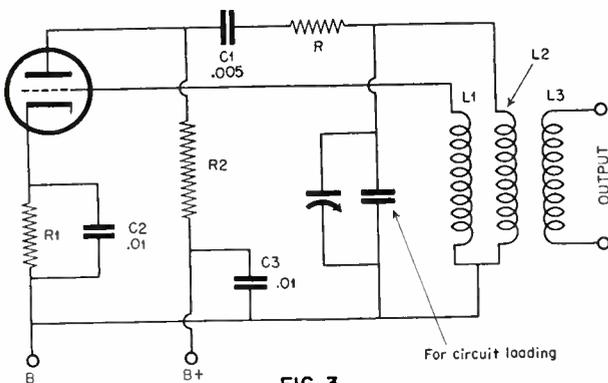

FIG. 3

Resistance-stabilized low-frequency oscillator circuit suitable for low-power carrier-current work.

Fig. 3 shows a resistance-stabilized low-frequency oscillator circuit which has been in use for some time in signal generators. This is a stable circuit well suited to low-power work where large drains are not to be made upon the oscillator, such as in driving a low-frequency output amplifier.

Peculiar to this circuit is the stabilizing resistor, *R,* which is connected in series with the plate coil, *L2.* The value of this resistor, which must not be less than 5 times the tube plate resistance, may be determined approximately from the equation:

$$R = R_L (\mu - 1) - R_p \qquad (3)$$

Where R is the value of the stabilizing resistor;
R_L, recommended load resistance for the tube;
μ, amplification factor of the tube;
R_p, plate resistance of tube.
(See tube characteristics sheet for R_L, μ, and R_p.)

With this approximate value in the circuit, the exact value may be arrived at experimentally by increasing the resistance to the point where oscillations are stopped, then decreasing the resistance to the point where the circuit goes into oscillation *quickly* as the plate voltage is rapidly switched on.

The resistance-stabilized circuit operates best with triodes with amplification factors between 5 and 10. The following tubes gave good performance in tests carried out by the writer: 1G4-G, 1H4-G, 2A3, 6A3, 6AD7-G, 6AE5, 6F6 (triode-connected), 6L6 (triode-connected), and 45.

The cathode resistor *R1* is of such value as to give slightly less bias than would be required for Class A
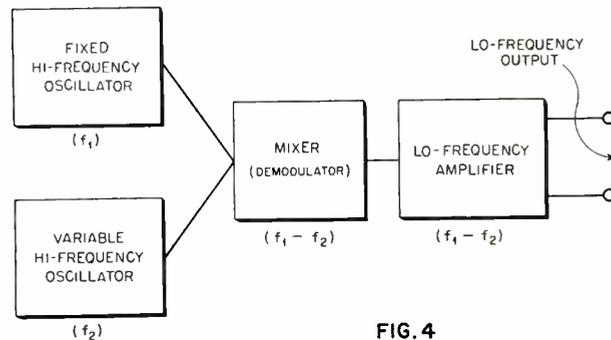

FIG. 4

Functional block diagram of beat-frequency oscillator.

amplifier service with the same tube, and the plate load resistor is of approximately the same value required for Class A. The coupling condenser, *C1,* and the bypass condensers, *C2* and *C3,* should be of mica construction for best results.

The grid, plate, and coupling coils—*L1, L2* and *L3* —are close-coupled, generally being wound upon the same form in such a manner that the grid coil is split, half of it lying on each end of the plate coil. The plate and grid coils are usually of the same inductance, and the size of the close-coupled coupling coil is adjusted to give the desired voltage output.

Fig. 4 shows a functional block diagram of a beat-

PORTABLE BOMB DETECTOR

FRANK A. BRAMLEY

Radio Technician, Connecticut State Police

The portable, battery-operated bomb detector. It is housed in a lady's overnight case with inside dimensions of 12½" x 9¼" x 4" deep. Any similar case will do.

◀ As preparations for National Defense increase in scope and intensity, local and state police departments are perfecting plans to safeguard life and property with every known scientific device. With this in mind the radio technicians of the Connecticut State Police Department were directed to design a device to minimize the danger to officers assigned to investigate suspicious packages, supposed bombs, etc. Recalling the death of several New York State detectives who tried to remove a bomb at the 1940 New York World's Fair, and the recent FBI round-up of Axis saboteurs, makes any device which would decrease the danger of investigating suspicious packages a welcome object to police officers.

The device described herewith has actually been used to test a supposed bomb. The officer who used the amplifying device was able to do so successfully although he had never been instructed in its use.

Most bombs of the homemade type, such as are likely to be found in public places or defense factories, use a timing mechanism which will usually consist of some simple clockwork to set off the bomb after the saboteur has made his getaway. Such a mechanism would make a ticking or clicking sound which could be heard if one were close enough. But getting close is the thing most unwise to do.

Essentials of Outfit

The complete outfit consists of three units, only one of which will be completely described here. They are:

1. A high-gain, battery-operated amplifier
2. A jointed boom with attached microphone
3. A metal shield to hold in front of the operator's body.

The so-called "Bomb Detector" is essentially a high-gain, battery-operated speech amplifier. The pickup device is a Shure "Stethophone" which is a special type of crystal microphone. The reproducer is a pair of crystal headphones fitted with earmuffs.

Since the purpose of the device is to pick up faint sounds originating within a box or package at any spot, the device must be small and easily portable—thus battery-operated. And also, since the persons operating it are almost certain to be excited or very nervous, it must be as nearly foolproof as possible.

For these reasons the device is completely shielded and the tubes are mechanically protected; an automatic switch is provided so that the batteries will be turned off when the cover is closed. The batteries are selected for their quality of long shelf life. The earphones have earmuffs attached permanently to them with Duco cement; thus extraneous noise will tend to be reduced and the operator may concentrate on the sounds picked up by the microphone. Likewise, the microphone is selected because of its characteristic of eliminating most of the incidental noises in or on the surface of the object with which it is in contact.

The Amplifier

The amplifier itself is a straightforward speech amplifier essentially flat in characteristic. It uses standard 1.5-volt tubes. The first two stages are self-biased by virtue of the 10-megohm grid leaks, while

the output stage has a bias resistor in the negative battery lead. An output transformer is provided which will match either low- or high-impedance earphones, and a coupling condenser is provided for matching to crystal phones. While any reliable phones may be used, the crystal type is suggested because of their wide response. In the case of the microphone, however, the Shure Stethophone was selected after trying many other types, and it is felt that very indifferent results will be had if a standard mike is used.

The Shure Stethophone is designed for this sort of work and has a response which begins to cut off at 1500 cycles, and at 2000 cycles it is 10 db. down, while at 8000 cycles it is 25 db. down. Frequencies below 100 cycles are unnecessary, and the amplifier is built taking this into consideration. Thus the microphone itself determines the frequency response of the whole device.

The automatic switch is mounted on a bracket at the rear of the case in such a manner that closing of the cover opens the "A" battery circuit in case the operator should forget to turn the power off.

The sub base has a tight fitting cover or bottom so that the wiring is completely shielded. This factor is very important to achieve stable operation of an ungrounded device such as this.

It was at first thought that the use of battery-type tubes in such a high-gain amplifier as this would cause trouble, but no trouble whatever from microphonics has occurred. The only precaution was to cushion-mount the tube sockets. They are suspended beneath the sub base about $\frac{1}{2}$ inch by means of 1-inch 8/32 bolts with three $\frac{1}{4}$-inch rubber grommets used as spacers between the socket and the sub base. This simple precaution is quite adequate.

No correction of frequency response is necessary, and the amplifier appears to be reasonably flat nearly up to 15,000 cycles, but cuts off rapidly below 150 cycles.

Jointed Boom

Inasmuch as any listening must be done at a distance, some means of placing the microphone in contact with the supposed bomb must be provided. For this purpose mechanics of the Connecticut State Police Department designed a jointed boom like a fish pole, but much heavier. For this purpose 3-foot sections of brass tubing were obtained from a local fish pole manufactory. These sections were of gradually decreasing sizes about $\frac{3}{4}''$ od. on the big end to about $\frac{5}{8}''$ od. at the small end. The sections were made to fit smoothly into each other in fish-pole fashion by means known to a good mechanic. The boom may then be quickly assembled from a convenient carrying form.

The microphone was attached to the small end, and the cable run down inside the tubing. Sufficient slack must be provided so that the sections may be folded up without injuring the cable. Since the boom will be seldom used, it is felt that the cable will last a great many years.

In practice the operator stands behind an iron shield or a heap of sandbags and manipulates the boom until the microphone comes into contact with the object to be examined. The microphone must be in contact because the design of the Stethophone is such that it does not respond efficiently to air-borne sounds but is very sensitive to contact sounds. For instance, a very quiet wrist watch lying on a table several feet from the microphone will produce loud sounds in the earphones, if the mike is also on the table, but the same watch would not be heard if held only a few inches from the mike suspended in air. The use of a contact type mike and of headphones is necessary to reduce extraneous noise and feed-back. With a standard mike, a typewriter 50 feet away or an auto horn two blocks away produce deafening sounds if the gain is up high.
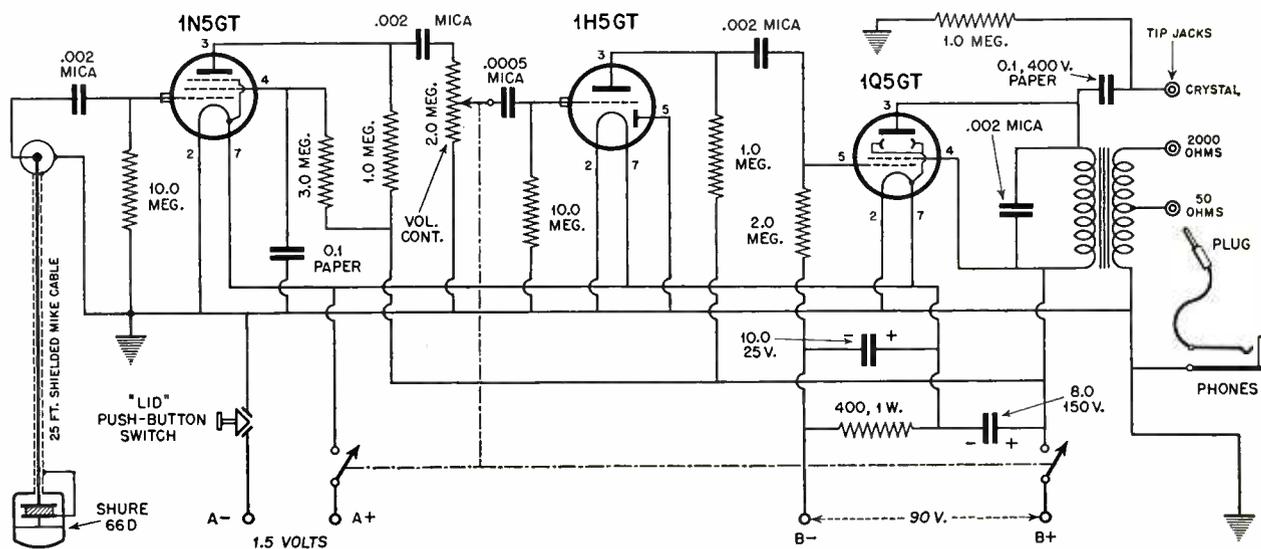
Schematic of high-gain, battery-operated a-f. bomb detector amplifier, designed for use with Shure Stethophone.

THE COMPLETED CONSOLE. THE 78 TURNTABLES ARE IN FRONT, THE 33 TABLE AT LEFT REAR.

A Versatile

SPEECH CONSOLE

CORTLANDT VAN RENSSELAER

◄ The Speech Console herein described was constructed to make possible a maximum number of relaying, sound reproduction and recording functions.

The primary objectives in working out the design were economy, reliability, fidelity, and completeness. Since the first of these was a major factor, care was taken in the selection of the apparatus to secure types which would give a maximum of quality for a minimum of cost. That this aim was realized is amply demonstrated by the fact that the frequency and distortion characteristics compare most favorably with those of commercial equipment designed for broadcast applications. Besides the recording turntable, two others were added for dubbing; a 78 r.p.m. and a 33-1/3 r.p.m. table. In order that the space be used with the utmost efficiency, a speaker resonant chamber and a record file were included in the construction of the desk.

Mechanical Design

A study of the various possible schemes for de-

signing the desk revealed that a speech amplifier console on a table, of which the turntables were an integral part, would be the most logical arrangement. The recess in the front of the desk top makes all apparatus more accessible to the operator. The top shelf of the record files on the side of the desk accommodates 250 ten-inch commercial pressings. The lower shelf holds 200 twelve-inch records or a number of the now popular albums. The speaker cavity on the right hand side is of the base-reflex type and will give, with a reasonably good speaker, excellent listening quality. The dimensions for placing the rear baffle are such that the area of the enclosure causes it to resonate at approximately 100 cycles, but to obtain the best possible response certain measurements should be made.

Baffle Adjustment

It might be well to theorize on the design principles of speaker cavities in order that this procedure may be better understood. All loudspeakers have such

frequency characteristics that their lower register drops off at some specific frequency. The lowest note which most reasonably-priced speakers will reproduce with normal volume is about 150 cycles. The ideal frequency response curve of such a speaker would be similar to that in *Fig. 1-A*. To make this
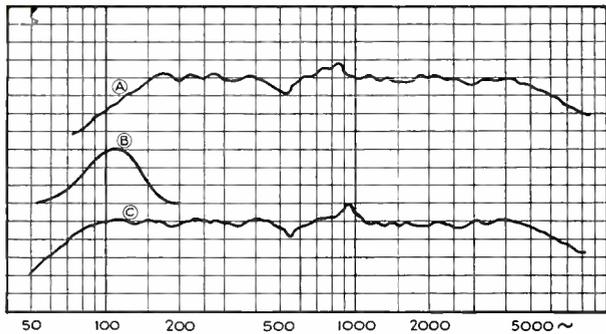
FIG. 1

A—Ideal response curve; B—peak provided by baffle; C—curve of combined speaker and bass-boost baffle.

speaker reproduce lower notes with normal volume, it is necessary to build its baffle in such a fashion that it will resonate about 50 cycles lower than the lowest frequency of the speaker. The resonance curve for such a baffle is shown in *Fig. 1-B*. Adjusting the baffle so that it matches the speaker requires some patience, but it can be done with normal laboratory equipment. The curve of the combination of the speaker and baffle is shown in *Fig. 1-C*.

The suggested procedure is as follows: Connect an audio oscillator to the input of the amplifier to which the speaker is connected. Put a volume-indicator meter across the output of this amplifier and maintain the output over the tested range of frequencies at a constant level. To measure the characteristics of the speaker, a microphone with its calibration curve must be used. This calibration curve is usually supplied with a microphone and can be considered a good enough criterion of the microphone's characteristics to be used for this purpose. It is suggested that the microphone be connected to an amplifier, the output of which is read on a db. meter. Then a curve should be drawn of the decibel indications over speaker frequencies of from 50 to 200 or 300 cycles. In order that there be as little error as possible from side radiation of the speaker cone, the microphone should be placed directly in front of the speaker and some distance from it. At any specific frequency, the microphone output will be a certain number of db. below a reference level. This number of db. must be added to the speaker frequency response curve at various points in order to correct it for the error caused by the microphone.

From observation the speaker cutoff point and the baffle resonant frequency can be determined. The rear board of the speaker cavity in the desk should

be moved back and forth, and the characteristics should be measured for various positions. When the response curve appears similar to that of *Fig. 1-C*, the baffle can be considered properly placed.

Construction of Desk

The desk is constructed of three-quarter inch five-ply and is held together with wood screws. The lumber was purchased in the exact sizes needed, and sanding and assembling the pieces required only a few hours. The irregular shapes were cut out by the lumber company. The desk is mounted on two-by-three bases which leave foot room around the edges and add a touch of smartness to the appearance. Eight flat steel casters are placed on the bottoms of the two-by-three's to prevent marring of the floor. It is finished with clear shellac.

The speech amplifier case originally contained a Philco radio, which was transferred to another cabinet. An interesting feature is the tilt back chassis which makes the sub-deck wiring, the tubes, and the panel connections instantly available for servicing. As can be seen in *Fig. 2*, the chassis is in a vertical position with the underdeck wiring facing outward and the transformers and tubes in a horizontal plane inside. It is mounted on small hinges which are attached to the rear of the cabinet with wood screws.

Electrical Considerations

For a clearer understanding of the possible operations which can be performed with the amplifier, a
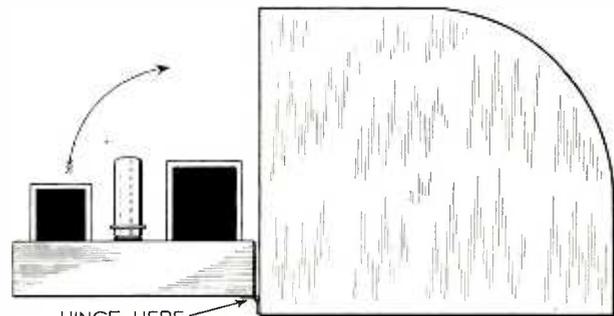
FIG. 2

Details of tilt-back chassis, for easy servicing.

self-explanatory block diagram is shown in *Fig. 3*. The mixing circuit of the amplifier consists of eight channels which are connected through four two-position key switches and four potentiometers to the four grids of two 6N7's. As the block diagram indicates, the respective connections are as follows: 1) Microphone, 2) Remote line, 3) Microphone, 4) 33-1/3 r.p.m. turntable, 5) Recording turntable, 6) 33-1/3 r.p.m. turntable, 7) 78 r.p.m. turntable, 8) Receiver.

The reason for having two separate inputs for

MIKE — 6SJ7 — 0.1, 400 V. — 1 MEG. 1/2 W. — 1 MEG. 1/2 W. — ELECTRONIC MIXERS — 6N7 — TONE CONTROL CIRCUIT — 6C5 — 0.1, 400 V.

KEY 5 — 1 MEG. POT. — 250 M 1/2 W. — 1M 1W. — .05 400 V. — 10.0 25 V. — 5 MEG. 1/2 W.

KEY 6 — 1 MEG. POT. — 0.1, 400 V. — 250 M 1/2 W. — 1M, 1W. — 35 M 1W. — THORDARSON AUDIO CHOKE T-14C70

6SJ7 — 250 M 1/2 W. — 0.1 400 V. — 1 MEG. 1/2 W. — 1.0 200 V. — 20 M 1W. — .04 400 V.

MIKE — 5 MEG. 1/2 W. — .05 400 V. — 10.0 25 V. — 1M 1W. — 1 MEG. 1/2 W. — 8.0 450 V. — 50M 1W. — KEY 7 — 6N7 — 1 MEG. POT. — .01 400 V. — TONE CONT. POT. THORDARSON R-1068

KEY 8 — 1 MEG. POT. — 50 M 1W. — 1250 1 W. — 10.0 25 V. — 8.0 450 V. — 25 M, 1 W.

78 R.P.M. T.T. — MOTOR — REL. — TO ACCOMODATE RELAYS USED — 5000 Ω TO 500,15,8 AND 4 Ω 40 W. OUTPUT TRANSF. — VOLUME INDICATOR — 6F8G — 50 M, 1W.

78 R.P.M. T.T. — MOTOR — REL. — 500 M — 0-1 MA. — 50 M POT. — 500 TO 100,000 TRANSF. — 250M POT.

33 1/3 R.P.M. T.T. — MOTOR — REL. — LOW-CURRENT D.C. RELAYS — 10 MEG. 1/2 W. — .01 400 V. — 7500 1 W.

RECEIVER — KEY 1 — 3:1 AUDIO TRANSF. — MASTER AMPLIFIER — 2A3 — 0.1 400 V. — 100M, 1/2 W. — 6N7 — 1 MEG. POT.

REMOTE — PHONES — KEY 2 — 100 M 1/2 W. — 0.1 400 V. — 100 M 1/2 W.

RECORDER — 15 Ω OUT. — 100 M 1/2 W. — 400 M 1/2 W.

8 Ω OUT. — 4 Ω OUT. — KEY 3 — 2A3 — 0.1 400 V. — 100 M 1/2 W. — 3M, 1/2 W.

SPEAKER — KEY 4 — 2A3 — MONITOR AMPLIFIER — 0.1, 400 V. — 100M, 1/2 W. — 6N7 — 1 MEG. POT.

400 V., 200 MILS 5 V., 3 AMP. 6.3 V., 5 AMP. 2.5 V., 5 AMP. POWER TRANSF. — 100 M 1/2 W. — 0.1 400 V. — 3 M 1/2 W. — 25.0

83 — 6.3 V. — 2A3's — 0.1 400 V. — 100 M, 1/2 W. — 100 M 1/2 W. — 1250 1 W.

50.0 — 500 Ω WIRE WOUND ADJUST FOR PROPER BIAS — 200 MIL SWINGING CHOKE — 200 MIL CHOKE — 40 MIL CHOKE — 8.0 450 V. — 20 M 15 W.

8.0 450 V. — 8.0 450 V. — 8.0 450 V.

FIG. 3

A block diagram of the complete speech console, showing operations that may be performed with the equipment.

the 33-1/3 r.p.m. turntable is that the simultaneous use of either two microphones or both 78 r.p.m. tables would make impossible the use of the slower speed one. The receiver in use here is a Hallicrafters communication type, the headphone high-impedance output of which has excellent quality on broadcast
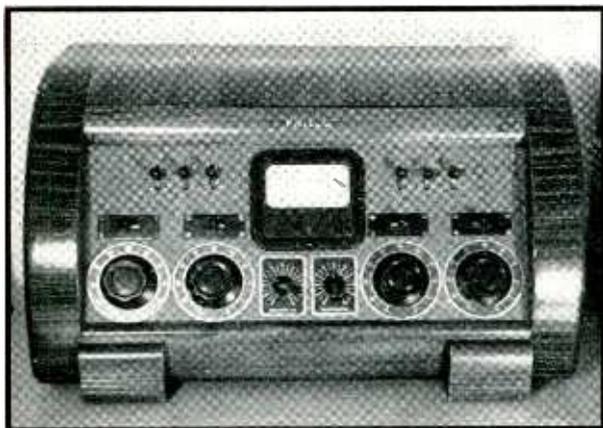
The amplifier console. The Thordarson tone control potentiometers, which were added later, were placed in the upper left corner. One of the key switches was moved to the right side to provide the necessary room. Note convenient position of volume-indicator meter and gain controls.

reception. Aside from switching the inputs, the four main keys also perform other important functions. The first two are so connected that switching on the microphones automatically turns off the monitor speaker, thereby preventing feedback. Each turntable switch is connected to a relay which automatically sets the motor running when it is closed.

Electronic mixing with 6N7's is particularly well suited to this type of amplifier, since constant output characteristics are maintained over long periods of time, and the advantages of cross-mixing are obtained without appreciable power loss. The over-all voltage gain from any of the inputs to the output of either 6N7 mixing stage is 19. Conventional 6SJ7 microphone amplifiers are used. Their voltage gain is approximately 100.

Tone Control Stage

A standard Thordarson tone control with a 6C5 tube is used. Its advantage in recording is enormous. The characteristics of the amplifier can be adjusted to suit those of the recording head so that the resultant recording will have any desired characteristics. With the Thordarson tone control it is possible to increase or decrease the response of an amplifier at 10,000 or 100 cycles about 15 db.

The tone control potentiometers are mounted on the upper left hand corner of the speech console face.

Power Amplifiers

Both the master amplifier and monitor amplifier consist of 6N7 phase inverters driving push-pull 2A3's. The specific advantages of this arrangement are: 1) There are no coupling transformers; therefore, the frequency characteristics are limited only by the output transformers. 2) Low plate resistance tubes such as 2A3's are preferable for high-quality

The record files at left end of desk. The upper shelf holds 10-inch discs; the lower 12-inch ones.

reproduction through low-impedance speakers and recorders. 3) The lack of coupling transformers reduces the cost of the console considerably.

Through the use of an especially designed phase-inverter circuit, it has been possible to reduce distortion at full output to practically an unmeasureable degree, and, at the same time, to obtain the essential 60-volt grid drive necessary for the 2A3's.

Needless to say, it is exceedingly important that the phase-inverter circuits be balanced by actual voltage measurements, for a poorly balanced phase inverter can cause very serious distortion. One thing to remember is that the plate emission of no two 2A3's is exactly alike; therefore, once these calibrations have been made, the tubes must not be changed unless the amplifier is rebalanced.

Connections between the potentiometers and keys on the front panel and the sub-deck wiring are made with shielded wires. The key switches are Western Electric built. The chassis lacks about one inch of being as wide as the opening in the back of the cabinet. Along the side of the cabinet in this opening are placed a series of terminals to which the low-impedance inputs and outputs of the amplifier are connected. Since the amplifier is permanently placed on the desk, the high-impedance lines are connected directly from the pickups and the receiver to the keys.

Outputs

The plates of the monitor amplifier 2A3's are connected directly to the speaker which is, in this case, an electro-dynamic type with a self-contained output transformer. The plates of the master ampli-

Cueing in a record. This view shows details of the bass reflex speaker inclosure, with lower port. Speaker cavity adjustment is covered in text.

The speaker end of desk, made of ¾" plywood. Note heavy 2 by 3 base which leaves foot room around edges.

fier 2A3's are connected to a tapped impedance output transformer which is connected to several key switches. These output switches are mounted in the upper right hand corner of the speech console face. The first of them operates the remote line input, mentioned briefly before in regard to the input circuits. This line has an impedance of 500 ohms. It enters a two-position key in such a fashion that it may either go through a step-up ratio transformer and to the input circuit, or be switched directly to the 500-ohm termination of the master amplifier. This circuit makes possible the recording of programs originating at a remote point or the playing of programs at a remote point which are originating at the console.

The purpose of the second key is to switch a pair of monitoring earphones from the output of the master amplifier to the remote line input. In this fashion, a program which is being recorded can be heard without the use of the monitoring speaker, and the remote pickup can be monitored without the use of the amplifier. The 15-ohm output of the master amplifier is connected to the third key. This key makes connections with the recorder which has a 15-ohm impedance, or with a lug termination, included for convenience in case such an output should be needed. The fourth key similarly connects the 4- and 8-ohm outputs of the master amplifier to lug connections.

The Cathode-Ray

OSCILLOSCOPE

JAY BOYD

PART IV—SEEING PATTERNS ON THE SCREEN

◀ Having covered the theory and design of cathode-ray oscilloscopes in preceding issues, we can hook up that instrument to some of our pet apparatus, and watch it work. But first, let's make a few checks on the oscilloscope, itself.

Checking 'Scope Operation

Turn on the heaters, but allow them to warm up a minute with the brilliance control turned low. Then set the focus control near its middle position and turn up the brilliance control until a spot appears on the screen. Turn the focus control to the right or left until this spot becomes as small and sharp as possible, and at the same time keeping the brilliance fairly low. Place the spot in the center of the screen by adjustment of the beam centering controls.

The spot should never be allowed to remain in one position any longer than necessary, as this may soon burn a dead spot in the fluorescent material coating the screen. So be careful to always keep the beam in motion or reduce the brilliance below that required for visibility.

Having learned the operation of the four knobs controlling the beam; that is, brilliance, focus, vertical and horizontal centering, we are now ready to try the saw-tooth oscillator.

Switch the free horizontal deflection plate to the horizontal amplifier and its grid to the saw-tooth oscillator—its normal position. Advance the horizontal gain control and the spot should become a horizontal line as the beam is swept back and forth across the screen. The synchronization control should be turned to the left.

Since the electron stream must now cover a much greater screen area than when not deflected, it will be necessary to advance the brilliance control to maintain a visible line. The rough and fine frequency controls may be manipulated, but won't show much effect on the horizontal line until the frequency is reduced to 15 cycles per second or less, or until a signal is applied to the vertical plates.

Before placing an a.c. signal on the vertical plates,

we may check vertical deflection of the beam by application of any convenient d. c. voltage of 20 to 70 volts. Connect the positive to the unamplified vertical binding post and negative to ground. Switch the free vertical plate to this binding post and the beam should shift upward. If the d.c. voltage is known, we can ascertain the deflection sensitivity of the instrument, which will be useful in future testing.

And while about it, we might also test the vertical amplifier. Switch the free vertical plate to this amplifier and apply a small signal to the vertical amplifier binding post. A positive d.c. signal will cause the beam to flick *downward* momentarily, after which it returns to the center of the screen. An a.c. voltage shifts the beam both upwards and downwards.

The reason a positive voltage causes a downward flick when using the amplifier is that the amplifier's output voltage is always opposite in sign (or 180° out of phase) to the signal applied on its grid. Also, a d.c. signal displaces the beam only momentarily because the amplifier is capacity coupled, being intended for amplification of d.c. signals. If it were intended to amplify a d.c. signal, or a.c. of very low frequencies, a direct-coupled amplifier would be necessary, and that's another headache.

Formation of Patterns

After having ascertained that the oscilloscope is functioning properly, we are ready to put it to work. When the instrument is properly connected to any type of electrical apparatus various types of patterns will be formed on the fluorescent screen. The shapes of these patterns show just how the apparatus is functioning.

The great variety of patterns produced are without number. We can show and explain only a limited number of the more frequent ones in this limited space. Every user will discover patterns that are "not in the book." So if he is to benefit most he must carefully study the way in which these patterns are formed, so the interpretation of unfamiliar patterns will be easy.

Tracing a Sine Wave

Let's begin by playing around with a common 60-cycle sine wave. Connect the vertical deflection plates to any convenient 60-cycle supply, either direct or through the vertical amplifier. If the particular 'scope is equipped with a "60-cycle test" binding post, wire this over to the vertical amplifier post and work through that amplifier.

With this signal on the vertical plates, and with the horizontal amplifier gain turned to zero, a thin, vertical line will be formed, extending an equal distance above and below the center of the screen.

With the horizontal plates connected to the saw-tooth oscillator (through the horizontal amplifier, of course) we may get any number of patterns, depending upon the *frequency* of the saw-tooth oscillator. But to make it easy, first adjust this oscillator to a frequency of *nearly* 60 cycles per second.

A pattern like that in *Fig. 1* will appear, but it will wriggle like a worm as it changes its shape upon the screen. With the synchronous selector switch turned to the "internal" position, advance the synchronization potentiometer slowly until this wriggling suddenly stops.

Now the saw-tooth oscillator frequency is locked to the 60-cycle signal being observed. And if the frequency of the test signal should vary several cycles per second, the saw-tooth oscillator will follow it and remain locked to the frequency under test.

But let's study this simple pattern more closely and see how it is formed. Remember, the beam is being acted upon by *two voltages;* that from the signal and that of the saw-tooth oscillator.

The latter is frequently called the "timing" oscillator because it furnishes the "time" bases of the "graphs" we make on the c.r. screen. In the case given, its frequency is 60 cycles per second. Therefore, the time required for one cycle is 1-60th of a second.

Being saw-tooth in form, the voltage increases at a uniform time rate in one direction, drawing the electron beam across the screen. Then this voltage collapses instantly, returning the beam to the opposite side of screen and the cycle begins anew.

The beam, then, will move uniformly from one side of the screen to the other, this direction being from left to right in most oscilloscopes.

But at the same time, the beam is also shifted *up and down* by the signal voltage applied to the vertical plates. It is the combination of these two forces upon the beam, and their timing relationship, which causes the formation of patterns upon the screen.

At this point the reader may wonder why we see only *one* sine curve, knowing that 60 of these cycles occur each second. Yes, 60 traces really are made on the screen each second but the saw-tooth oscillator begins its cycle in synchronism with the signal on the vertical plates, so each trace lies exactly on top of the preceding one. Due to the persistence time of the screen and also our own eyes (the latter re-taining an image for about a twelfth of a second), we see the pattern as a single trace.

Other Patterns from Same Signal

Now change the sweep frequency to 30 c.p.s. and you will find two cycles on the screen, as shown in *Fig. 2.* The sweep time is slower and the signal goes through two complete cycles for every one of the saw-tooth oscillator.

Set the s.t.o. at 120 c.p.s. and the pattern may look like *Fig. 3* or *Fig. 4,* depending on just what part of the signal cycle the trace begins. Since the time is just one-half that required for a complete cycle, *two* horizontal sweeps are necessary to record a single cycle.

Next, set the s.t.o. for 180 c.p.s. and make the "pattern" shown in *Fig. 5.* If the foregoing pattern formation is not quite clear, repeat all the experiments until they are thoroughly understood, before going to more complex patterns.

As the s.t.o. frequency is varied, a number of other patterns are produced, many of these being pretty but having little practical value.

One of these, where the s.t.o. frequency is neither an exact multiple nor sub-multiple of the signal frequency, is shown in *Fig. 6.* Here the sweep time is one-and-a-half times that of the signal (or two-thirds
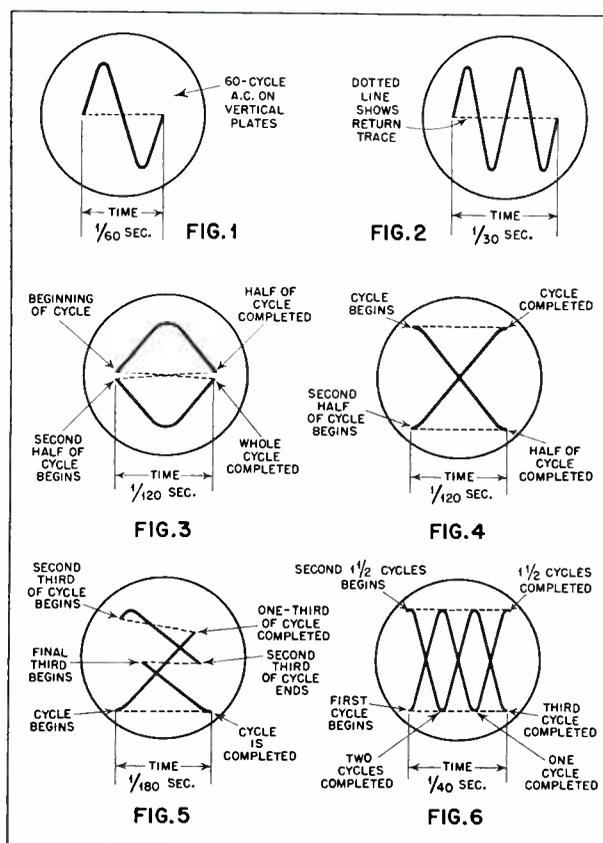
Six sketches, explained in text, showing how various patterns are developed on the 'scope screen. Fig. 1 is a 60-cycle sine wave.

signal frequency—40 c.p.s. in this case), so we get three cycles on the screen for every two horizontal sweeps.

Patterns Not Requiring S.T.O.

In all foregoing examples, the graphs were drawn by plotting the test signal against a linear time base, the latter furnished by the saw-tooth oscillator. While the s.t.o. is necessary for about ninety percent of the work you will do, there are a number of applications which make its use unnecessary.

Trapezoidal patterns, so useful in transmitter checking, and Lissajous figures, from which frequency comparisons may be made, are produced by applying a.c. signals to both vertical and horizontal plates simultaneously. Receiver alignment is another special case, wherein the horizontal deflection is controlled by a frequency wobbulator. But since we have just shown how a.c. wave forms are plotted against a linear time base, it is perhaps most logical to next consider audio amplifier checking by this method.

Checking Audio Amplifiers

Audio amplifiers may be checked on the oscilloscope by several methods but the set-up sketched in *Fig. 7* allows us to see most easily what we wish to know. The audio oscillator may be simple or elaborate, so long as it will produce sine waves of good form. Its output does not have to be "flat" in respect to frequency.
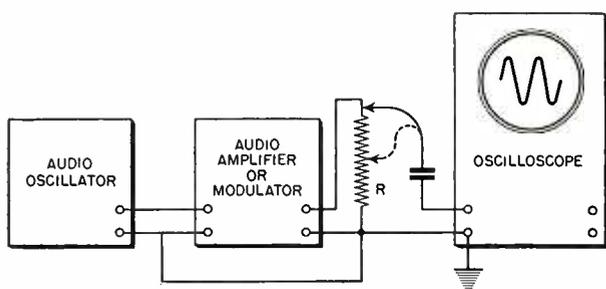
FIG. 7

Simple set-up, with audio oscillator, for checking the frequency response of audio amplifiers.

The amplifier feeds into a load having an impedance similar to that for which it was designed. The output may be fed either to the vertical plates or through the vertical amplifier. A coupling condenser of .25 μfd. should be used when not working through the vertical amplifier. If a modulator is being checked it will be necessary to reduce the voltage to 50 or 75 volts by tapping the 'scope down on the load resistor R.

Horizontal deflection is obtained by using the s.t.o. for the "time" base, its frequency being adjusted to that of the audio amplifier. Using "internal" syn-

chronization, the pattern produced should be a perfect sine wave similar to that shown in *Fig. 1*. Halving the s.t.o. frequency will place two waves upon the screen. It is somewhat optional whether we see one, two, or three cycles, although the former is better when really going after "bugs."

Overloading an amplifier stage can be expected to produce flattened peaks, which may look like *Fig. 8*. But this overloading usually produces harmonics in the amplifier's output which may alter its waveform to appear something like *Fig. 9*.

FIG. 8   **FIG. 9**   **FIG. 10**
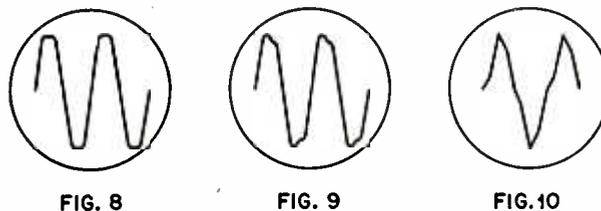
Fig. 8—Flattened peaks due to overloading. Fig. 9—Distortion due to presence of harmonics. Fig. 10—Distortion caused by harmonics and phase shift.

The exact appearance depends on several factors such as degree of overloading, percentage and relative amplitudes of all major harmonics, presence of regeneration, amplifier phase shift, adjustment of grid operating point, grid drawing current, saturation of audio transformers or other undesirables.

If the waveform is composed of fairly straight lines bending at well-defined angles like that of *Fig. 10,* use larger coupling condensers and check up plate and grid resistor networks; phase shift is occurring somewhere.

Correct analysis of distorted waves unquestionably requires a great deal of skill. But this does not detract from the oscilloscope's usefulness. If any distortion is found, the observer should next check the amplifier stage by stage until the fault is localized. It should then be easy to remedy the fault by substitution of any parts suspected, rechecking each change for improvement of pattern.

Balancing Phase Inverters

Whenever phase-inverter circuits are used it is essential that both sides of the circuit be perfectly balanced. To check circuits similar to *Fig. 11,* connect oscilloscope ground post at *A* and run *B* or *C* into the vertical amplifier. If resistor *R* is of correct value the signals taken from *B* and *C* will be of equal amplitude. Swinging the vertical amplifier to *D* and *E* should also show equal signals.

Similar signals will be found at *F* and *G* but this is misleading, since the voltage at one end of the transformer primary will be found at the opposite end of the winding, whether the tubes feeding this winding balance or not. Therefore, the overall output should be checked between *H* and *I*.

Single-ended Stages

Single-ended Class A stages produce very little distortion if operated with correct bias and are not over-driven. If correctly biased but overloaded, both peaks will be flattened as in *Fig. 8*. If improperly biased, flattening will occur on either the top or bottom peak, depending on whether the bias is too little or too much, and will produce patterns similar to *Fig. 13*.
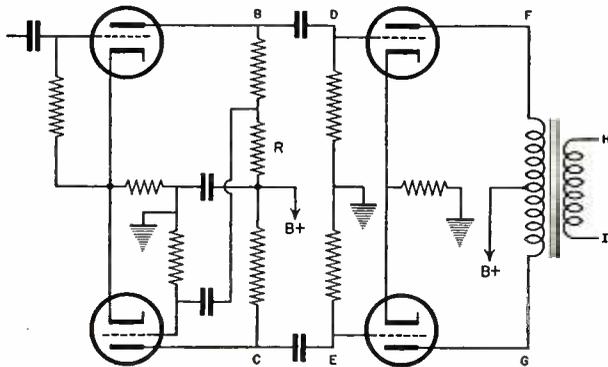
FIG. 11

Typical phase-inverter circuit, easily balanced by means of the oscilloscope. See text.

Another excellent test of linearity may be obtained from the set-up sketched in *Fig. 12*. A signal from the audio oscillator feeds the vertical plates through the oscilloscope's vertical amplifier, while the same signal deflects the beam horizontally, working through the audio amplifier under test, and not using the 'scopes horizontal amplifier.

If the amplifier being tested is operating linearly the pattern will appear as a straight diagonal line like *Fig. 14*. A pattern such as *Fig. 15* indicates slight overloading at the bottom, while the upper bend shows very bad overloading on the upper peak.

This test presupposes, of course, that the oscilloscope's amplifier is linear. Incidentally, the two amplifiers within the oscilloscope may be checked in a similar manner, which should be done before making the above test.

Checking for Hum Pickup

The oscilloscope is also useful for checking hum in amplifiers or other apparatus, where it is frequently difficult to distinguish between a.c. field pickup and power-supply ripple. With the equipment set up as in *Fig. 7*, but with the oscillator output turned down, an a.c. ripple may appear on the screen.

Remember that inductive field pickup will show up as a 60-cycle wave, while power-supply ripple will have a frequency twice that of the power line, or 120 c.p.s. So with the s.t.o. set for 60 c.p.s., if this ripple shows up as a single cycle the trouble is hum pickup in

an input transformer or wiring pickup in one of the first stages. But if two cycles are found, a need for more power supply filtering is indicated.

Another method is to run a 60-cycle a.c. signal on the horizontal plates with the audio amplifier running into the vertical amplifier. Sixty-cycle hum pickup produces a narrow oval, while power supply ripple shows a "figure 8" lying on its side.

Transmitter Testing

For checking the performance of radiophone transmitters the cathode-ray oscilloscope has no equal. Besides checking the speech and modulator stages as described, the overall output can be conveniently observed. *Fig. 16* shows a typical set-up which allows observation of either the r.f. envelope or formation of trapezoidal patterns, simply by flipping the usual horizontal selector switch, *SW1*, to either position.

Unless the transmitter is a broadcast job running after hours, a suitable dummy antenna should be substituted for the usual sky-wire. A two- or three-turn pickup loop placed near the final amplifier tank feeds the r.f. signal directly to the vertical plates *without* the amplifier.

A non-inductive voltage divider[1] from the modula-

---

[1] A total resistance of around one megohm seems best in practice. Larger values produce phase shift, making meaningless patterns. If the voltage on the final amplifier runs around 1,000 volts, R1 may be made up of two half-megohm, one-watt resistors, with about 50,000 ohms for R2. R1 should consist of eight or ten 100,000-ohm, one-watt resistors for 2000-volt rigs. And keep those resistors off the operating table; they carry dangerous voltages!
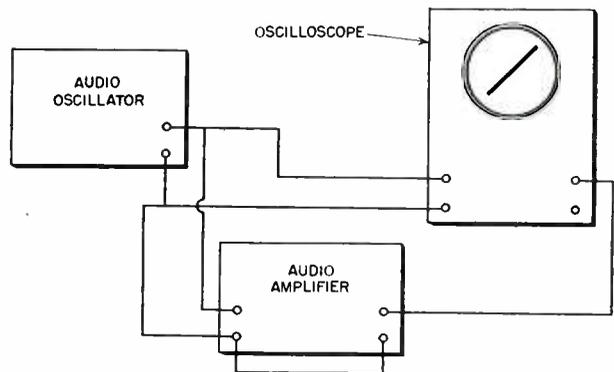
FIG. 12

Test set-up for checking linearity of audio amplifier.
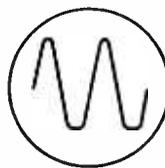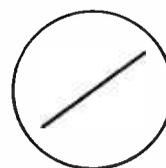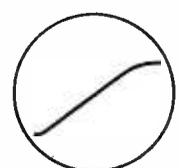
FIG. 13   **FIG. 14**   **FIG. 15**

First pattern indicates improper biasing; second, perfect linearity; third, overloading at both ends.

tion transformer to ground and a tenth- or quarter-mike coupling condenser taps off the audio signal, furnishing horizontal deflection for trapezoidal patterns.

Throw the horizontal selector switch to the s.t.o. and turn on the transmitter. With no audio signal adjust the pickup loop until a ribbon of color shows across the screen. This pattern should look like *Fig. 17*, except in practice the individual r.f. cycles are so close together as to be indistinguishable. These individual cycles are shown in all sketches to make pattern formation more easily understood.
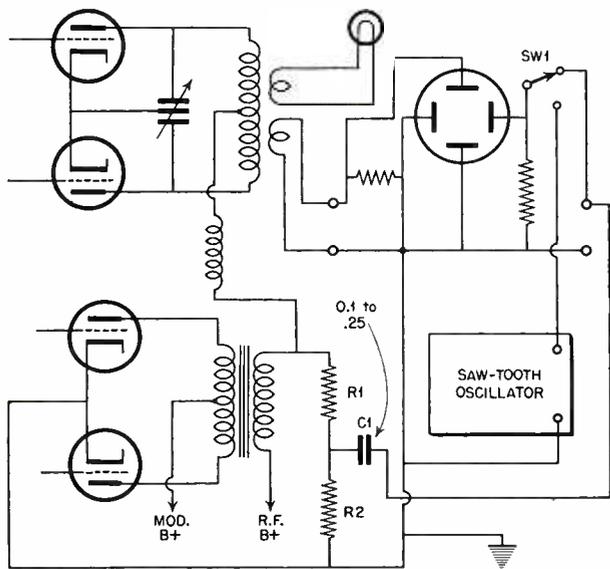
FIG. 16

Set-up for observing r-f. envelope at output of transmitter.

If the ribbon is bulged in spots like *Fig. 18,* there is hum on the carrier. This may be in either the speech or r.f., but if the former it should have been removed before testing the whole rig.

Now turn on the audio oscillator and watch the pattern change to the shape of *Fig. 19,* which shows a good, 100% modulated envelope. Use internal synchronization to make the "bumps" stand still.

Crank up the gain and notice narrowing of these individual "bumps," *(Fig. 20)* which seem tied to-gether like link sausage. Those bright horizontal lines have no vertical deflection, telling us quite definitely that no carrier is being transmitted at these points. If the modulator is working beyond its capability, the peaks will also be found flattened.

Fig. 21 shows flattening of the peaks only, although the carrier is not over-modulated. This may indicate lack of sufficient grid excitation or incorrect grid bias on the final amplifier. Or it may mean that the modulator or one of the speech stages is being overtaxed.

Trapezoids and Triangles

The r.f. performance of 'phone rigs should also be checked by trapezoidal patterns which, generally speaking, indicate their performance more clearly than the envelope method. Their formation is brought about by deflecting the beam vertically by the r.f. and horizontally by the audio signal. This latter must be taken from the modulation transformer; if taken from a low-level stage, phase shift will be present and the patterns meaningless.

The way in which these patterns are formed should be apparent from a study of *Fig. 22*. A minute faction of the audio power which modulates the carrier is used to swing the beam horizontally. Positive audio peaks increase the carrier amplitude to twice its unmodulated value, while negative audio peaks reduce the carrier to zero.

Positive audio peaks swing the beam to the left, negative to the right in most 'scopes. The opposite occurs in certain makes, reversing the pattern, but this is of no importance. If modulation is 100% the left side of the pattern will be twice the unmodulated value, while the vertical deflection is reduced to zero at the right. The increased brightness on this side of the triangle is due to the beam covering less area and does not indicate faulty adjustment.

When modulation is linear the sides of this triangle will be perfectly straight, although the height of the left (perpendicular) side does not have to be equal to the length of the other two.

Fig. 23 shows linear modulation of less than 100%, the pattern being a trapezoid rather than a triangle. This pattern is very useful for measuring modulation percentage. Carefully measure the maximum and
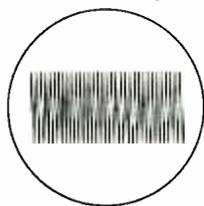
| FIG.17 | FIG.18 | FIG.19 | FIG.20 | FIG.21 |
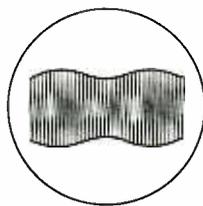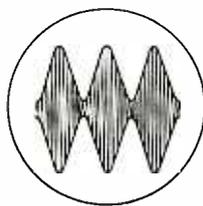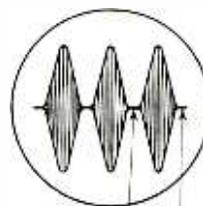
NOTE ABSENCE OF CARRIER
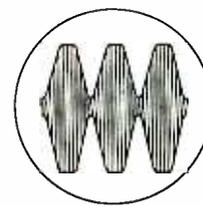
From left to right: Pattern of carrier; hum on r-f. carrier; carrier 100% modulated; overmodulated carrier. In Fig. 21, the carrier is not overmodulated, but the flattened peaks indicate insufficient excitation.
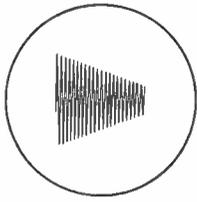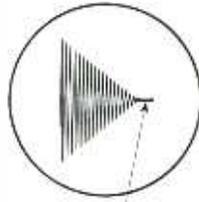
FIG. 23   FIG. 24   FIG. 25   FIG. 26   FIG. 27

NOTE LACK OF CARRIER
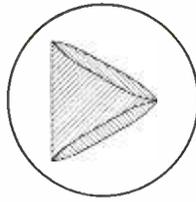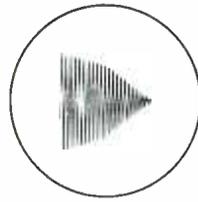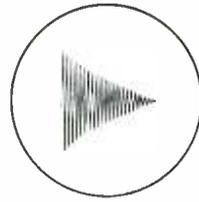
Trapezoidal patterns provide an easy means of checking the r-f. performance of phone rigs.

minimum height of the trapezoid and apply the following formula:

$$\text{Percentage modulation} = \frac{\text{E max.} - \text{E min.}}{\text{E max.} + \text{E min.}} \times 100$$

Fig. 24 shows a familiar pattern. The modulation is very good—but there's entirely too much of it! The bright "handle" shows the beam being dragged along by the audio signal but no vertical deflection, the carrier being completely cut off. Turning the audio gain knob to the left cures this sort of trouble.

Patterns such as *Fig. 25* show improper phase relations between the audio and r.f. signals on the deflection plates; not a transmitter fault. If such occurs, increase *C1* and reduce *R1* and *R2* in *Fig. 16* and check ground connections.

Incorrect R.F. Amplifier Adjustment

In all foregoing examples there was no fault with the final r.f. amplifier; the trouble was over-modulation, overloaded speech or modulator stage, or faulty oscilloscope connection. But now let's take a look at some r.f. amplifiers that are ailing.

One common fault, lack of final grid driving power, shows up as *Fig. 26*. Note that modulation is linear

R.F. ENVELOPE

AUDIO SIGNAL

NEGATIVE AUDIO PEAK

POSITIVE AUDIO PEAK

NOTE THAT SCREEN IS COVERED HORIZONTALLY ONCE FOR EACH HALF AUDIO CYCLE.
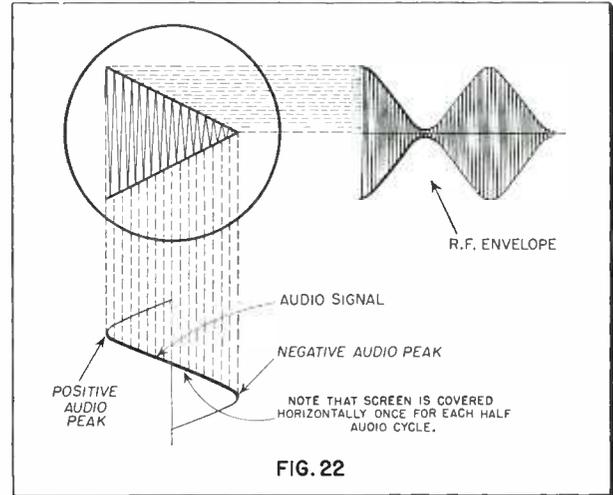
FIG. 22

Illustrating the manner in which a trapezoidal pattern is formed on the screen of an oscilloscope. See text.

up to about 60%, after which the r.f. peaks do not continue to rise in proportion to the audio voltage increase.

Sometimes we find a pattern like *Fig. 27,* in which

A   B   C   D   E   F

G   H   I   J   K   L
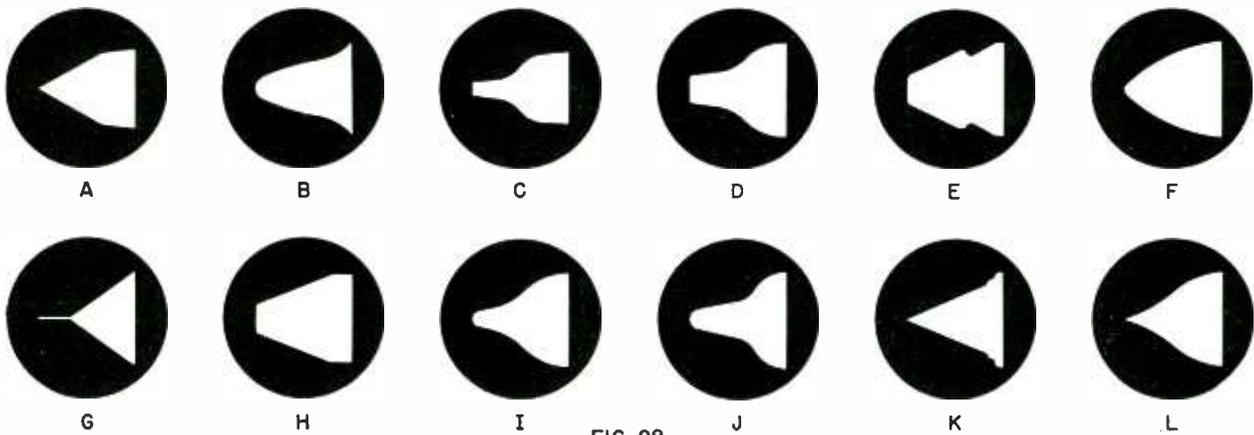
FIG. 28

Trapezoidal patterns. A: Insufficient Class C excitation. B: Improper neutralization. C: Distortion of negative peaks. D: Mismatched modulator. E: Regeneration in modulated stage. F: Insufficient excitation and bias. G: Overmodulation, with clipping of negative peaks. H: Plate modulation of s-g tube. I: Approximately 100% suppressor modulated. J: Suppressor modulated, with xtal in grid circuit. K: Whiskers (parasitics) on positive peaks. L: Well-adjusted grid or cathode modulation.

ELECTRONIC VOLTMETERS

Design and Application

JOHN H. POTTS

◀ Within the past few years the electronic voltmeter has become widely accepted as one of the most simple, accurate and convenient instruments for measuring d-c. voltages in high-impedance circuits. Because of their wide use in the war effort, it is felt that a discussion of their design and applications will be of particular interest at this time.

Essentially, the electronic voltmeter differs from other vacuum-tube voltmeters in that it is designed to measure d-c. voltages only, rather than a.c., or both a.c. and d.c. By limiting its application to d-c. measurements, greater stability, accuracy and simplicity are readily obtained. These advantages are extended to a-c. measurements when the electronic voltmeter is employed in conjunction with a suitable rectifier. In addition, such instruments may be designed to serve as ohmmeters, as well as voltmeters, and in such applications enable measurement of extremely high resistances.

Fundamental Circuit

The fundamental circuit of one of the simplest types of electronic voltmeters is shown in *Fig. 1*. The meter in the cathode circuit of the triode indicates the cathode current. When a negative d-c. voltage is applied to the grid, the current decreases; when the grid terminal connects to the positive pole of the voltage source, the cathode current increases. Thus the meter may be calibrated to indicate both the *polarity* and the *magnitude* of the d-c. voltage under measurement.

Now let us see what design considerations are involved in this simple circuit. First, to complete the grid circuit when the voltmeter is disconnected from the circuit under test, the resistor R must be used. A high resistance, of the order of 10 megohms, is desirable, since the amount of circuit loading and the ohms-per-volt rating depend upon the value of resistance chosen. Thus, if R is 10 megohms and the meter is calibrated to read up to 5 volts, negative or positive, the sensitivity is equal to 2,000,000 ohms-per-volt. To duplicate this sensitivity using a microammeter and series multiplier, without the vacuum tube, would require a center-zero meter designed to deflect to full scale in either direction for a current of 2.5 microamperes. While such meters are available, they are costly and require considerable care in handling. By using the electronic voltmeter circuit, a relatively insensitive meter—full scale deflection for 1 ma.—may be employed to provide equal sensitivity.

Damage due to accidental overload of the meter may be guarded against in the design. $R2$ serves as a limiting resistor which prevents the plate current—and cathode current—from rising to extreme values should the applied positive grid voltage exceed the range of the meter. When the applied grid voltage is negative, the cathode current decreases, so the only effect of excessive voltage of negative polarity is to reduce the meter current to zero, so no damage can possibly result.
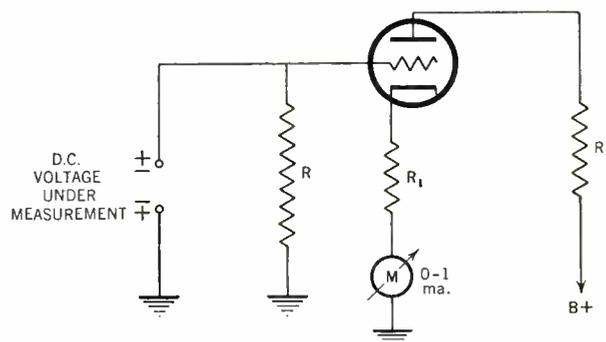
Fig. 1. Fundamental circuit of electronic voltmeter. Meter in cathode circuit indicates cathode current.

The use of the cathode resistor $R1$ provides degeneration so that greater stability is secured. Minor variations in tube characteristics then have negligible effect upon the calibration of the meter. However, $R1$ must not be too high in value, otherwise the tube will function as a detector and alternating voltages in the circuit under test will produce a rectified voltage which will register on the meter. To avoid this, the cathode resistor is so chosen that the bias applied enables the tube to operate as a Class A amplifier; and the plate voltage is selected to meet the range of the meter chosen.

Operating Point

A grid-voltage, plate-current characteristic of a typical triode is shown in *Fig. 2*. Note that the operating point is chosen at a grid bias which produces

a plate current of 0.5 ma. The voltages and resistances in the circuit are so chosen that this value of plate current occurs in approximately the middle of the straight portion of the Eg-Ip curve. Thus a 1-ma.
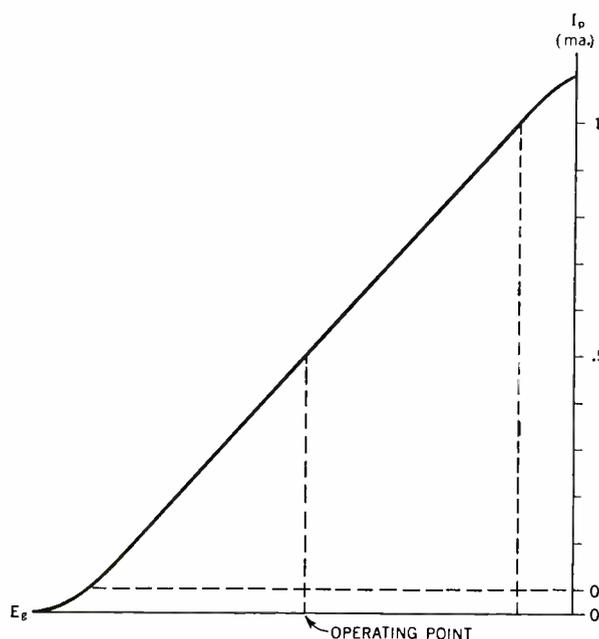
Fig. 2. Grid-voltage, plate-current characteristic of typical triode. Point is chosen which produces a plate current of 0.5 ma.

meter will read half scale when the electronic voltmeter is operating, but with no test voltage applied. If this point on the voltmeter scale is calibrated as zero, then a 5-volt change in a positive direction will cause the meter pointer to deflect full scale to the right, while a 5-volt change in a negative direction will cause a similar deflection in the opposite direction. Since operation is chosen over a straight portion of the curve, the scale is substantially linear. Further, it should be noted that, though changes in tube-operating voltages will cause an increase or decrease in the meter current, they will not affect the calibration, provided means are employed to readjust the plate current to 0.5 ma.

Preventing Rectification

Since the operating point chosen is such that the deflection in a positive direction is substantially the same as that in a negative direction for equal applied voltages of opposite polarity, it follows that a-c. voltages within the operating range of the voltmeter will not be rectified provided they are of pure waveform. If, however, the alternating voltage applied is unsymmetrical in form, or of sufficient magnitude to drive the bias beyond cutoff, rectification will result unless special precautions are taken. This is done by employing a simple resistance-capacity filter in the grid circuit, as shown in *Fig. 3*. In some commercial

instruments, the resistance is placed in the probe end of a shielded cable which plugs into the input terminals of the electronic voltmeter, as shown in *Fig. 4*. A small capacitance, of the order of .001 μfd. is placed across the input circuit. The grounded shield forms the balance of the capacitive section of the filter circuit. Sufficient attenuation is thus secured to render negligible the effect of a strong a-c. component in the d-c. reading of the circuit under test. It is, of course, not entirely essential that the cable be shielded, but this is an advantage in guarding against stray pickup, due to the high impedance of the input circuit. By placing the resistor *R1* in the probe, the shielded cable capacitance is effectively isolated from the circuit under test and it becomes possible to measure d-c. voltages in tuned circuits without introducing any more loading than would result if the isolating resistor alone were shunted across the circuit under test. Since it is possible to make *R1* 1 megohm or more, measurements of d.c. in radio-frequency circuits are thus made possible without appreciable detuning effect.

Commercial Design

The complete circuit of a typical commercial design of electronic voltmeter, as employed in signal-tracing instruments of various types, is shown in *Fig. 5*. This circuit represents the design originally used in the RCA Rider Chanalyst. When used with the special cable and probe shown in *Fig. 4*, the ranges covered are as shown on the diagram. The filter condenser *C1* is limited to a capacity of .001 μfd. While a larger capacitance would provide greater attenuation of a-c. voltages arriving at the grid, it would also increase the time constant of the input circuit to the
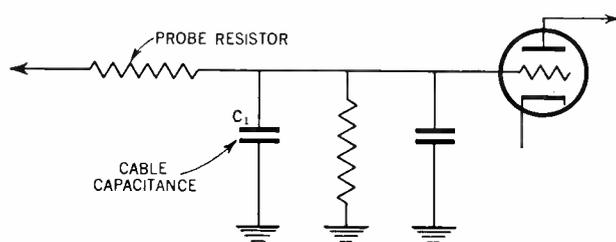
Fig. 3. Grid-circuit resistance-capacitance filter used to prevent rectification of a-c. voltages.
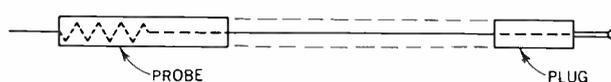
Fig. 4. In some designs the filter resistor is placed in the probe end of the shielded cable.

extent that the interval required for the charge accumulated on the condenser to leak off would become appreciable. During the period over which this charge is held, the voltage applied to the grid remains effective, so the meter pointer does not return to zero

until this charge is dissipated. This results in sluggish action which interferes with the utility of the device. There is no appreciable time lag of this sort when the values shown in the diagram are maintained.

The 5000-ohm rheostat shown in the cathode circuit is adjusted to give the required sensitivity for the particular tube chosen. When properly adjusted, the meter pointer will rise to half-scale deflection as soon as the tube has reached operating temperature, and will deflect to full scale for an input voltage of 5 volts (applied through the 1-megohm probe) in either a positive or negative direction. In the latter direction, the deflection is not quite full scale, since the tube bias does not reach cutoff. Once adjusted, this rheostat seldom requires change when replacement tubes are substituted, except when the replacement differs widely in characteristics from that for which the original calibration was made. Changes in power-supply voltage will affect the zero setting; compensation for these changes is made by readjusting the 10,000-ohm zero adjustment. The normal applied plate voltage (at the tube plate) is 70 volts.

This design of electronic voltmeter has outstanding advantages in that it permits measurements of either positive or negative voltages without regard to the polarity of connection of the voltmeter. The ground connection of the electronic voltmeter is simply connected to the corresponding ground connection of the apparatus under test and the probe may be moved from circuit to circuit, without the operator needing to know the polarity of the voltage under test. Further, the magnitude of the voltage is likewise of small concern. For, if the voltmeter is switched to the 5-volt scale and the voltage across the circuit under test is as much as 500, no damage to the meter will result. The maximum current which will be produced in the cathode circuit of the tube, and which passes through the meter, is approximately 8 ma., which does not overload a 1-mil. meter enough to bend the pointer. And, when overvoltage of any magnitude in a negative direction is applied, the result is simply to reduce the meter current to zero.

Laboratory Design

These advantages are obtained at a sacrifice of

Fig. 5. Circuit of typical commercial design of electronic voltmeter, as used in signal tracing.

the accuracy and readability which would result were the full scale of the meter to be used, and means were employed for reversing the polarity. While the advantages greatly outweigh the disadvantages when an electronic voltmeter of this design is employed for trouble-shooting in maintenance work, for laboratory applications a design utilizing the full range of the meter is undoubtedly preferable. Although the polarity of the voltage must be known, a reversing switch enables such adjustment with minimum effort.

A fundamental circuit of a laboratory type electronic voltmeter is shown in $Fig. 6$. This is a bridge arrangement in which $V1$ and $V2$ form two arms of a bridge and the sections of the potentiometer $R3$ supply the other two arms. When $R3$ is properly adjusted, the current flowing in the plate circuit of

Fig. 6. Fundamental circuit of laboratory type electronic voltmeter of the bridge type, with VI and V2 the two arms.

$V1$ is balanced out by that flowing in the plate circuit of $V2$. Thus no current flows through the meter circuit and the meter reads zero. If the plate voltage increases due to a change in line voltage, the plate current of each tube should increase in like degree (provided their characteristics are identical) and therefore the bridge remains balanced and the meter indication is unaffected. For the same reason, changes in heater voltage should likewise produce no unbalance in the circuit. Practically, however, it is impossible to obtain conveniently tubes which match precisely, so some slight degree of unbalance due to changes in operating voltages must be expected. It is customary, in the more elaborate designs, to use some form of voltage regulator in the power-supply circuit, such as an Amperite or a special voltage-regulating transformer. An exceptional degree of stability is then secured.

It will be noted that $V2$ serves solely as a means of balancing out the normal quiescent plate current in the measuring tube, $V1$, when no external voltage is applied to the grid of $V1$. However, when the test probe of $V1$ is connected to a d-c voltage source and a positive voltage is applied to its grid, the current in the plate circuit of $V1$ is increased and consequently the cathode voltage is likewise increased. The increase in plate current upsets the balanced state due to the bridge arrangement, causing a meter indication. This reading is further increased because the unbal-

ance due to the increase in the plate current of $V1$ is further augmented by a decrease in the plate current of $V2$ (due to an increase in cathode voltage). Thus the action is somewhat regenerative and greater sensitivity is thus obtained.

It might be pointed out that the need for the reversing switch to change the meter polarity might be avoided by interchanging the input leads and re-adjusting the meter to read full scale and deflect in reverse direction for negative voltages. While this could be done, it would be necessary to isolate all circuits from grounds, otherwise in measuring high negative potentials the case of the instrument would be "up in the air" and a severe shock might be thus obtained. Such contingencies are avoided when the case is grounded and the reversing switch is employed in the manner shown.

Resistance Measurement

The application of this device to the measurement of resistances is obtained in the manner illustrated in *Fig. 7.* A voltage E, sufficient to produce full-scale deflection of the electronic voltmeter, is applied through the calibrating resistor R to the input circuit of the electronic voltmeter. Since the input circuit resistance is extremely high in comparison with that of the calibrating resistor R, no appreciable voltage drop occurs. But when an unknown resistor, Rx, is shunted across the input circuit, as shown, the voltage applied to the electronic voltmeter input is reduced so that the input voltage Ei, resulting, is determined by the formula

$$Ei = E \left(\frac{Rx}{Rx+R} \right)$$

whence the value of unknown resistance producing any measured input voltage may be readily calculated.

It has been stated that the input resistance of the electronic voltmeter is extremely high in comparison with the calibrating resistor R of *Fig. 7.* In order to obtain such a condition, it is necessary to operate $V1$ and $V2$ far below their rated voltages. When the heater voltage is reduced to approximately 5 volts and the plate voltage is limited to 60 volts, and is further reduced by the cathode bias, lowering of input resistance due to ionization of gas particles is reduced to such degree that an input resistance of the order of thousands of megohms is readily realized. Thus it becomes possible to measure resistances of the order of hundreds of megohms in the manner shown in *Fig. 7.*

In multi-range ohmmeters, one annoying characteristic of most conventional designs has been the need to readjust the zero setting when switching from a high range to a low range, and vice versa. This is due to the change in current drain on the test battery, causing a varying voltage drop across the internal resistance of the battery. By using an electronic voltmeter in the resistance-measuring circuit diagrammed in *Fig. 7,* the zero setting does not require readjustment when switching from range to range.

This is due to the fact that the drain on the battery is practically nil, except when the unknown resistor is under test, because the input circuit of the voltmeter presents a constant high impedance termination
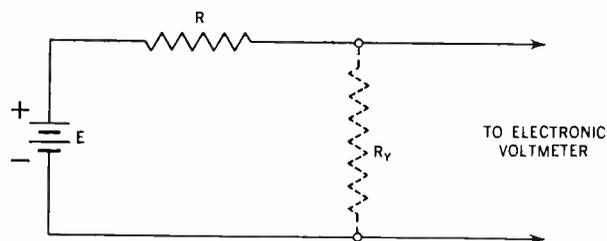
Fig. 7. Additional circuit employed with electronic voltmeter for making resistance measurements.

to the measuring circuit. However, it must be pointed out that some inaccuracy will result if a run-down battery is used in the circuit. Though the open-circuit voltage remains substantially unaffected by the increase in the internal resistance of the battery, this resistance is added to that of the resistor under test and may cause serious errors when very low values of resistance are measured. For higher resistance ranges, of course, no trouble results. It is convenient to avoid this trouble by checking the condition of the battery by noting the reading obtained from a low value resistor of known resistance, say 10 ohms or less, and to replace the battery when the reading obtained deviates appreciably from the known value.

VoltOhmyst Jr.

One of the most widely known types of electronic volt-ohmmeters, incorporating most of the features described above, is the RCA VoltOhmyst Jr., the schematic of which is given in *Fig. 8.* This instrument measures d-c. voltages in six ranges, from 3 to 1000 volts, full scale, with a constant input resistance of 10 megohms (this becomes 11 megohms when the 1-megohm resistance in the probe is added); a-c. volts (at 1000 ohms-per-volt) in 5 ranges from 10 to 1000 volts, full scale; and ohms in 6 ranges, from 10 ohms to 10 megohms, center scale. This means that the effective range as an ohmmeter covers from 0.1 to 1000 megohms.

The meter used has a 200-microampere movement. This sensitivity is required because of the low operating voltages employed. Note that the heater voltage for the 6K6GT's is only 5.7 volts and the total output voltage of the high-voltage section of the power supply is only 60 volts. The effective plate voltage is less than this value, since the cathodes are "up in the air" 30 volts. These low operating potentials make for the high input resistance required in the ohmmeter circuit.

A polarity reversing switch, $S2B$ and $S2C$, enables the input circuit to remain grounded regardless of the polarity of the voltage in the circuit under test.

Note that additional filtration of alternating voltages present in the circuit under test is furnished by the resistance-capacity network composed of the 3-meg-ohm resistor $R3$ and the .003 $\mu\mu$fd. bypass condenser $C1$. This network, in effect, forms the second section of a two-section filter, of which the first section is formed by the shielded cable capacity and the 1-meg-ohm resistance in the test probe, which is used for all d-c. measurements. For a-c. measurements, the copper-oxide rectifier is employed in a conventional design. Since the tubes are not required for a-c. measurements, the instrument need not be plugged into the power line when testing a-c. circuits.

Radio-Frequency Measurements

While the copper-oxide rectifier is convenient for low-frequency measurements, the utility of the instrument is increased if some means for making r-f. measurements is made available. A simple vacuum-tube rectifier which will serve the purpose is diagrammed in *Fig. 9.* A unit such as this may be built up in a shielded can, which may be made quite small if the tube chosen is of the acorn variety, such as the 955. The leads to the electronic voltmeter from the rectifier carry only d.c. and may therefore be quite long without causing difficulties. The a-c. component is filtered out by the resistance-capacity network, $R2$-$C1$.

It should be particularly emphasized that the input resistor of the electronic voltmeter must be open-circuited when this rectifier is employed, otherwise the sensitivity of the instrument will be appreciably reduced. The "contact" potential of the rectifier will

produce a reading on the electronic voltmeter, even when no a-c. voltage is being measured, but this may be taken into account when calibrating the instru-
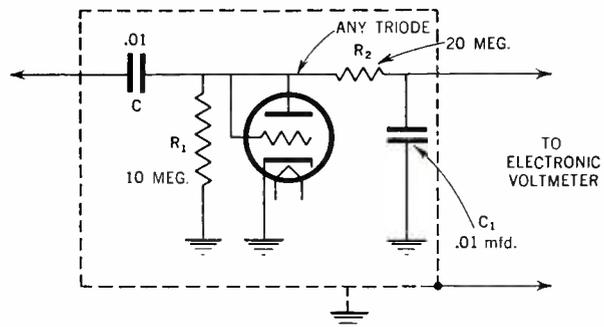
Fig. 9. Simple vacuum-tube rectifier circuit which may be added for the purpose of making r-f. measurements.

ment for a.c., which must be done in any event. The scale will be fairly linear and the readings will be proportional to the positive peak of the voltage being tested. This will cause no error in measuring sine waves, but inaccuracies will result if complex waves are being measured. For higher voltage ranges, where the sensitivity must be reduced, the input circuit of the electronic voltmeter may be used in the normal manner, using the range switch and voltage divider resistors just as for measuring d-c. voltages. For the higher voltages, the increase in output voltage of the rectifier will be essentially proportional to the magnitude of the voltage being measured, so the readings will follow a linear scale.
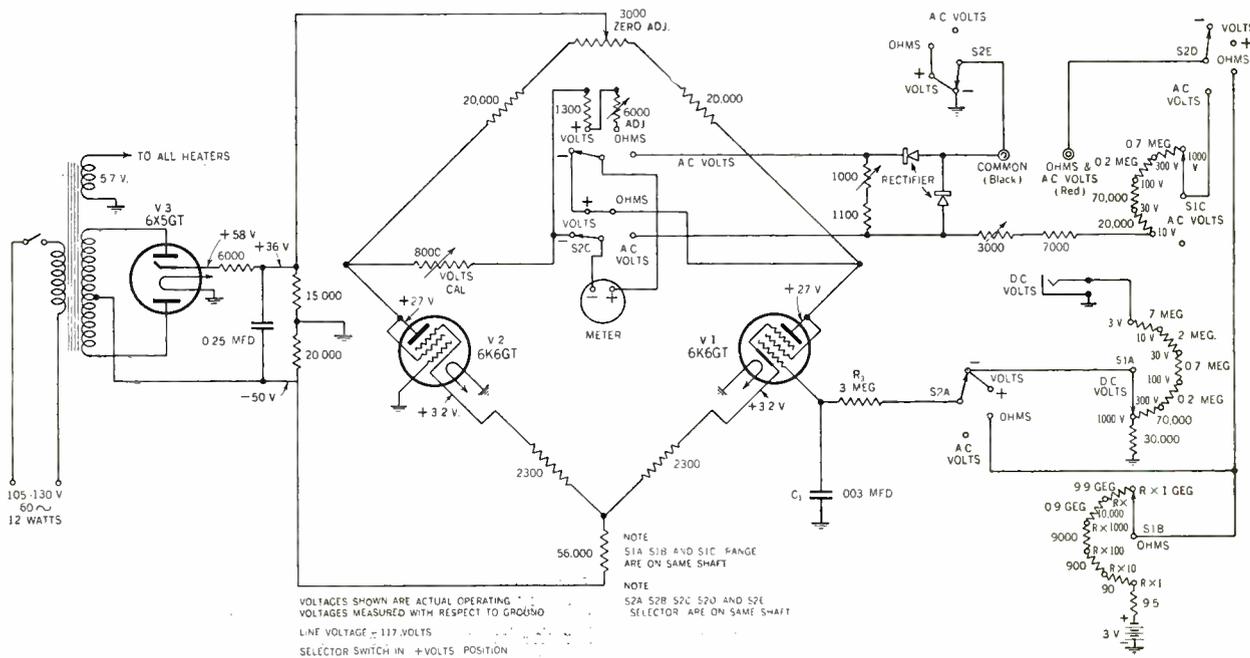
Fig. 8. Schematic of the RCA VoltOhmyst Jr. electronic volt-ohmmeter. It measures d-c. voltages in six ranges, a-c. volts in five ranges, and ohms in six ranges, as indicated in the diagram. Its effective range as an ohmmeter is from 0.1 to 1000 megohms. Note that the cathodes of V1 and V2 are up in the air to the extent of 30 volts.

RADIO DESIGN WORKSHEET

No. 3—TUNED R-F CIRCUITS

SIMPLE TUNED CIRCUIT

Problem 1:—*To explore some of the characteristics of a simple tuned circuit. The accompanying figure illustrates a simple series tuned circuit.*
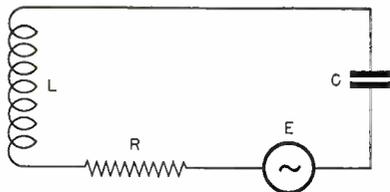
Solution:—The reactance of the circuit is:

$$X = 2\pi fL - \frac{1}{2\pi fC}$$

And the impedance is: $Z = \sqrt{R^2 + X^2}$

At resonance $2\pi fL = \frac{1}{2\pi fC}$ and $X = O$

Hence $Z = R$

In television and other applications the phase of the current flowing in the circuit is of considerable interest. To determine the relation between phase and current amplitude for a constant applied or induced voltage, let I_o be current at resonance and I the current at any other frequency. Then:

$$I_o = \frac{E}{R}$$

At any other frequency, f, $I = \dfrac{E}{\sqrt{R^2 + X^2}}$

Let $K = \dfrac{I}{I_o} = \dfrac{R}{\sqrt{R^2 + X^2}} = \dfrac{1}{\sqrt{1 + \tan^2\theta}}$

where θ = phase angle between I and I_o

Then $\theta = \pm\tan^{-1}\dfrac{\sqrt{1-K^2}}{K}$ (1)
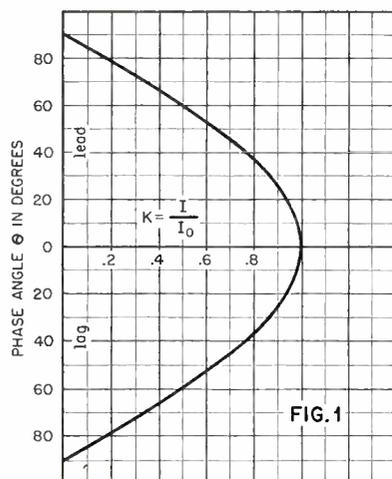
FIG. 1

Fig. 1 illustrates the relation between phase and amplitude of current I as percent of I_o as found from equation (1)

PASSBAND TUNED CIRCUIT

Problem 2:—*To determine conditions for constant passband of tuned circuit as frequency is varied.*

Solution:—Define passband as frequency difference between points of 0.7 maximum response (i.e., 3-db.
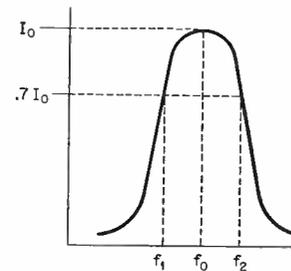
loss). From *Fig. 1*, referred to in *Problem 1*, it will be noticed that at 70% of maximum response the phase angle is 45° and the resistance and reactance components of the tuned circuit impedance are equal.

$$\Delta f = f_2 - f_1$$

Now the shape of the resonance curve is due to the ratio $\dfrac{R}{2f_oL}$ instead of R alone. This quantity is often called the *decrement* of the circuit. To derive this relation, we know that at $.7 I_o$:

$$2\pi f_1 L - \frac{1}{2\pi f_1 C} = -R$$

$$2\pi f_2 L - \frac{1}{2\pi f_2 C} = R$$

Multiply these equations by $2\pi f_1 C$ and $2\pi f_2 C$ to obtain:

$4\pi^2 f_1^2 LC - 1 = -2\pi f_1 CR$ or $C(4\pi^2 f_1^2 L + 2\pi f_1 R) = 1$

$4\pi^2 f_2^2 LC - 1 = 2\pi f_2 CR$ or $C(4\pi^2 f_2^2 L - 2\pi f_2 R) = 1$

Whence $4\pi^2 f_1^2 L + 2\pi f_1 R = 4\pi^2 f_2^2 L - 2\pi f_2 R$

$$R(2\pi f_2 + 2\pi f_1) = 2L(2\pi^2 f_2^2 - 2\pi^2 f_1^2)$$

$$\frac{R}{2L} = \frac{2\pi^2 f_2^2 - 2\pi^2 f_1^2}{2\pi f_2 + 2\pi f_1} = \pi\frac{(f_2^2 - f_1^2)}{(f_2 + f_1)} = \pi(f_2 - f_1)$$

$$\frac{R}{2f_oL} = \pi\frac{(f_2 - f_1)}{f_o}$$

$\therefore$ Decrement $\delta = \dfrac{R}{2f_oL} = \dfrac{\pi\Delta f}{f_o} = \pi R\sqrt{\dfrac{C}{L}}$

$$\frac{R}{2L} = \pi\Delta f$$

$$\Delta f = \frac{Rf}{2\pi fL} = \frac{f}{Q} \text{ where } Q = \frac{2\pi fL}{R}$$

If $Q = Kf$ where K is a constant, then Δf is constant with varying frequency.

Now: $Q = \dfrac{2\pi fL}{R} \quad \dfrac{K'f}{R}$

If R is constant for all frequencies involved, and L likewise, then $Q = K''f$ and $\Delta f = K'''$.

Therefore, for a capacitatively tuned circuit, the passband will remain constant if R is constant.

One means of approximating this condition is to add to a high Q circuit additional resistance, the value of which is large compared to the variation of resistance with frequency.

Q. & A. STUDY GUIDE

—Theory and Practice

CONTINUED FROM MARCH ISSUE

181. Under what load conditions will a vacuum tube have the highest ratio of power output to plate circuit d.c. input?

The voltage and current must be in phase. Maximum instantaneous power is delivered when the product of the maximum values of E and I is maximum; maximum average power is equal to one-half the value of the maximum product of E and I.

182. Under what load conditions will a vacuum tube produce its greatest output?

When the external load resistance is equal to the internal resistance of the tube.

183. What is the chemical composition of the active material composing the negative plate of a lead-acid type storage cell?

A lead oxide paste pressed in a lead-antimony alloy frame or grid; when the battery is charged with direct current the oxide is changed to pure lead, of a spongy consistency.

184. What is the chemical composition of the active material composing the negative plate of an Edison type storage cell?

Finely divided iron powder placed in thin rectangular pockets of steel frames or grids.

185. What is the chemical composition of the active material composing the positive plate of a lead-acid type storage cell?

A lead oxide paste which is changed, on charging the battery with direct current, to lead peroxide assuming the oxygen freed from the negative plates on charging.

186. How does a primary cell differ from a secondary cell?

A primary cell (i.e. dry cell) cannot be recharged once it becomes exhausted (unless provided with new electrodes and new electrolyte) whereas in a secondary cell (i.e. storage battery) the process of changing chemical energy into electrical energy with a resultant flow of current is reversible. The storage cell, when exhausted may be charged by an external current in reverse polarity to the current delivered from the cell.

187. What is the chemical composition of the active material composing the positive plate of an Edison type storage cell?

Nickel oxide in the form of round tubes.

188. What is the chemical composition of the electrolyte used in an Edison type storage cell?

A solution of potassium hydroxide.

189. What is the chemical composition of the electrolyte of a lead-acid storage cell?

A dilute solution of sulphuric acid.

190. Why is a 45 volt, dry cell "B" battery generally considered unsatisfactory for use when the terminal voltage has fallen to approximately 36 volts?

When the terminal voltage of a 45-volt dry cell "B" battery has fallen to approximately 36 volts, normal "local action" or deterioration, together with polarization will have taken place and increased the internal resistance of the battery, reducing the current available to an unsatisfactory value for general purposes.

191. What is "polarization" as applied to a primary cell and how may its effect be counteracted?

Polarization is the formation of hydrogen gas bubbles around the positive electrode of the primary cell. These bubbles decrease the electrode's surface in contact with the electrolyte, increasing the cell's resistance. In addition, a minute voltage is set up between the hydrogen gas and the electrode opposite to the useful voltage of the cell, thereby reducing the output voltage. Polarization cannot be permanently overcome, but may be temporarily remedied by placing chemicals in the cell to supply oxygen (i.e. manganese dioxide) which react with the hydrogen to form water. Also, idleness will diffuse the gas somewhat.

192. Describe three causes of a decrease in capacity of an Edison type storage cell.

(1). Local deterioration upon standing idle for any length of time. (2). Temperature: a nickel-iron cell has a critical temperature which varies with the discharge rate. At a normal rate of discharge this is slightly above the freezing point of water. Lower temperatures reduce the capacity. (3). Gradual reduction of the density of the electrolyte with use.

193. What is the cause of the heat developed within a storage cell under charge or discharge condition?

The flow of electric current through the electrolyte generates heat.

194. How should sulphuric acid and water be mixed, if it becomes necessary to do so in order to replace lost electrolyte?

The acid should be poured slowly into the water and stirred constantly. *Never pour water into acid.*

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Addenda

A grouping of principally foreign references on Crystallography from the German book *Piezoelektrizitat des Quarzes*, by Adolf Scheibe, is published as a supplement to the foregoing Bibliography, and will be found on page 61.

PORTABLE BOMB DETECTOR

This amplifier obviously has other uses. The one that is most obvious is eavesdropping on suspects with a hidden microphone. For this purpose a standard lapel microphone is good and the cartridge only out of a regular crystal microphone may also be used. The Stethophone mike is not satisfactory for picking up voices since it was not designed for such a purpose. If the amplifier is connected to a vibration pickup type of mike, it may be used to listen to heartbeats, but if used for this purpose, it would be better to increase the size of the coupling condensers in the amplifier to increase the low-frequency response, because heartbeat sounds are mainly in the low-frequency region.

A 15-foot extension cord for the microphone may also be found convenient. The jack for the earphones should be wired to the proper tap for the type of earphones it is expected will be used.

The case in which the equipment is installed may be purchased at any department or luggage store which carries low priced luggage. Mirrors and pockets not desired are easily torn out.

Q. & A. STUDY GUIDE

195. How may a dry cell be tested to determine its condition?

By placing an ammeter across the terminals of the cell to determine the current.

196. What will be the result of discharging a lead-acid storage cell at an excessively high current rate?

The battery may be damaged physically as well as greatly reducing its ampere-hour capacity.

(To Be Continued)

CATHODE-RAY OSCILLOSCOPE

the r.f. voltage rises in greater proportion than the audio, causing the outward curvature of the triangle's sides. This comes from regeneration when the final amplifier is not properly neutralized.

Checking Other Modulation Methods

Grid, screen, suppressor or cathode-modulated rigs are checked by the same apparatus set-up, the only difference being the requirement of less resistance in *R1 (Fig. 16)*. Adjustment of all these methods of modulation are less tolerant than plate modulation and their frequent checking is especially recommended.

Space does not permit a detailed description of all patterns, so a number of sketches are grouped together and briefly explained in *Fig. 28*, most of these being shown in the new *Radio Handbook*. Other patterns may be found in various articles. A very unusual case was described in the June, 1939, issue of RADIO[2] but is too long to repeat here.

Bear in mind that the oscilloscope may be connected to any stage suspected of faulty operation, so don't be afraid to experiment. And when new patterns are found think out the cause before trying haphazard cures. The results will be very much worth while.

Visual alignment of receivers, frequency comparisons by Lissajous figures, and numerous other oscilloscope applications will be discussed in the next installment.—Editor.

[2]The Pursuit and Capture of Parasitic "X."

SPEECH CONSOLE

One very important part of every satisfactory recording amplifier is a volume indicator. On the console face is a 0 to 1 milliammeter of the quick acting type, in a three-inch square case. The circuit, as shown in the master diagram, consists of a single 6F8G, the first section of which acts as a diode rectifier, while the second section serves as a current-varying tube for the meter. Since this circuit is resistance coupled, the meter has very good frequency characteristics. The input potentiometer makes possible the setting of the standard volume at any desired level. This potentiometer is mounted on the chassis of the amplifier and is adjusted with a screwdriver. It is suggested that a standardized volume-indicator meter be connected in parallel with this one to determine its range. Then a constant-amplitude signal can be run through the amplifier, and reference points of standard volume can be noted for positions of the potentiometer.

The two 78 r.p.m. turntables are General Industries models. The 33-1/3 r.p.m. unit is a General Electric dual-speed model with a twelve inch table. The recorder was built by Universal. The power supply, which is placed inside the speaker cabinet in the desk, is a standard swinging choke-input type employing an 83 rectifier. It supplies 360 volts at 200 milliamperes.

LOW FREQUENCY R-F. OSCILLATORS

frequency l.f. oscillator circuit strongly recommended for the generation of frequencies between 10 and 300 kc.

In this arrangement, the low-frequency beat note between two higher-frequency oscillators, one fixed and the other variable, is utilized. The two oscillators are coupled into a suitable mixer (demodulator) stage, the difference frequency being fed from this stage into an amplifier whose output tank is resonated at the beat frequency. In some instances (notably when frequencies between 10 and 50 kc. are amplified) the output amplifier may have resistance coupling in its plate circuit in lieu of a coil and condenser.

Any two convenient oscillators may be employed in this arrangement as long as it is possible to separate their frequencies of operation by the amount of the desired low frequency. For example: A fixed-frequency 6SK7 oscillator might be operated at 1000 kc. and a variable 6SK7 oscillator of the same electrical and mechanical construction operated between 1010 and 1050 kc. The beat note between the two might thus be adjusted to any value between 10 and 50 kc. This difference frequency would then be delivered by the mixer (which might be built around a 6L7 tube) to the 10-50-kc. output amplifier.

Another possibility often overlooked in the search for a low-frequency r-f. source is the 100-kc. crystal frequency standard in many station inventories. These instruments deliver an unusually stable signal at 100 kc. which may be amplified with a simple low-powered, capacity-coupled amplifier stage. Modulation may be applied to the amplifier.

CATHODE-RAY OSCILLOSCOPE

JAY BOYD

At the request of many radio instructors, and for the benefit of students and technicians now or soon to be allied with the war effort, we are reprinting the first part of Mr. Boyd's excellent series of articles on the Cathode-Ray Oscilloscope.

◀ Of all the apparatus at our disposal there is none so versatile as the cathode-ray oscilloscope. By its use we may observe, compare or record any instantaneous changes or conditions taking place in any of our radio, sound or other electrical circuits.

The oscilloscope is to the radio engineer what the X-ray or fluoroscope is to the medical profession. By its use we can look at its fluorescent screen and see just what electrical effects are occurring in any part of the circuit to which it is connected. *(Figs. 1 & 2)*

FIGURE 1
THE X-RAY SHOWS PICTURE LIKE THIS
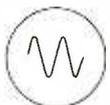
FIGURE 2
THE CATHODE-RAY OSCILLOSCOPE PRODUCES GRAPHS OF ELECTRICAL PHENOMENA

What Is the Oscilloscope?

The heart of the instrument is the cathode-ray tube. This is a special type of high-vacuum tube, shaped like a funnel, containing an electron gun, usually two pairs of deflecting plates, and a coated screen at the front of the tube where the image or pattern is viewed.

In operation, the heated cathode releases a cloud of free electrons. These are drawn through the electron gun which accelerates their velocity and focuses them into a tiny stream. As these electrons strike the coated surface of the viewing screen, a fluorescent glow is produced, lasting for a fraction of a second.

It is a property of emitted electrons that they will be attracted or repelled by any positively or negatively charged bodies in their proximity. Located between the electron gun and viewing screen will be found two sets of flat deflecting plates, arranged so the electron stream must pass between them.

Placing an electrical charge on these plates will cause the beam to move up or down, or to either side, making visible a graph of whatever action is taking place within the circuit under inspection.

In addition to the cathode-ray tube there is a special type of "saw-tooth" timing oscillator for providing the horizontal deflection, as required by

the majority of applications. But this is quite simple! In most commercial oscilloscopes we will find two amplifiers, labeled "vertical" and "horizontal," along with their respective gain controls, and switches for cutting them in or out of the circuit as desired. And then there is a power supply—usually a dual sort of affair. And that's about all there is to the instrument.

Put these five units—cathode-ray tube, saw-tooth oscillator, horizontal and vertical amplifiers and power supply into a suitable cabinet and there you have a complete, self-contained cathode-ray oscilloscope. A block diagram of this assembly will be found in *Fig. 3*.

Applications Are Many

It would be impossible to list all the applications for which the cathode-ray oscilloscope may be used to advantage. Its users are always finding new roles for it to play.

But before telling some of its more popular uses, let's consider its workings in a little more detail. We mentioned that the "movable element" is the electron stream. The mass of these electrons is so infinitesimally small that, for all our practical purposes, their weight and mass may be entirely ignored. The diversion of this stream, or beam, from its normal course may be effected at the highest radio frequencies without the sluggishness which would be the case if a mechanical vibrating element were used, however small it might be. Therefore, the beam will faithfully follow excitation of any frequency and pro-

Fig. 3. Block diagram of a typical cathode-ray oscilloscope.

duce a true graph upon the viewing screen.

Now let's consider some of the cathode-ray oscilloscope's more popular uses.

Audio amplifier checking—We may observe and correct waveforms, tube overloads and consequent distortion, feedback, unwanted oscillations of audio or radio frequencies, power supply hum, inductive pickup, check and measure gain per stage, frequency response, match phase-inversion circuits or load impedances.

The effect of any changes may be observed when "cleaning up" or "flattening out" a newly-built amplifier which, to the critical ear, will sound only as good as it looks on the oscilloscope.

Transmitter checking—The oscilloscope is the most satisfactory instrument known for checking the performance of radiophone transmitters. Besides checking the entire audio system from microphone to modulation transformer, we can also adjust the transmitter for the much desired hundred per cent modulation, check neutralization, lack or excess of grid drive, over- or under-biasing of amplifier, linearity of modulation, overloaded speech or modulator tubes. Modulation transformers may be properly matched to the r.f. load. The source of hum modulation or r.f. feedback may be more easily found and corrected.

Or, in short, if the phone transmitter is "ailing," the 'scope will certainly show up its faults. These checks are made by observing either the modulation envelope, audio waveform, or trapezoidal patterns, and sometimes by the eliptic or cat's eye pattern.

Receiver checking and alignment—Besides being useful for stage by stage checking of receiver circuits, the cathode-ray oscilloscope offers the most accurate means known for correctly aligning tuned circuits, and particularly the intermediate frequency channels of superheterodynes. Performance of demodulator and audio systems of the receiver may also be easily checked.

Study of power circuits—Alternating current waveforms are shown as a "graph" upon the screen and their various relations may be studied, measured and analyzed. Transients and surges
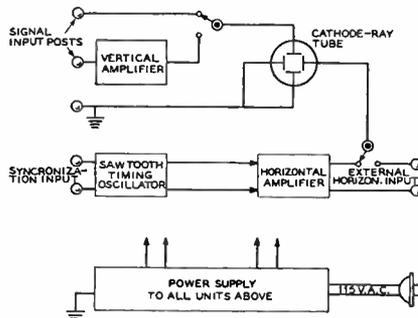
may be inspected, as well as operation of relays, circuit breakers, fuses, etc.

Large-screen oscilloscopes are ideal for class-room demonstrations of all sorts of electrical and radio phenomena.

The automotive and aviation industries have made frequent use of oscilloscopes in their studies of vibration, noise, combustion pressures, ignition systems, etc.

One special type of cathode-ray oscilloscope, the cardiagraph (or 'scope) is used by doctors and hospitals for the study of heart conditions.

Another special type of instrument is used by orchestra directors for the exact tuning of musical instruments.

The Story of Cathode Rays

Now that we have covered a rough outline of the instrument and its many uses, let's turn back the pages of history for a brief look at its forbears. Not that it is necessary in order to understand the 'scope. But because its history is so interesting, and because we will more greatly appreciate the instrument when we remember the earlier apparatus.

The production of electron streams, which he named "cathode rays," was first discovered by Sir William Crookes about 1874, while experimenting with Geissler tubes *(Fig. 4)*. These are simply vacuum tubes having electrodes in either end and containing small amounts of rarefied gases, which glow, something like our present-day neon tubes, when high voltages are applied to the electrodes.

He noticed that if these were pumped to a very high vacuum, the gaseous glow would disappear and then the inside walls of the glass tube would show brilliant fluorescent effects.

It was also found that these free electrons always left the cathode at right angles to its flat surface, and that if this cathode were made concave they could be focused into a highly concentrated beam, having enough energy to fuse platinum foil inserted at this focal point within the tube. There was much controversy over the question of whether the cathode ray was an ether wave, an invisible light, or a stream of material particles flowing between the cathode and anode.

Sir J. J. Thomson, about 1892, determined that these cathode rays were, in reality, a stream of free electrons and proved that they might be deflected by a magnetic or electrostatic field *(Fig. 5)*. In his experiment he placed a strip of mica, coated with zinc sulphide, within the tube, parallel to the electron stream. Placing a magnet near the tube deflected the beam. As the electrons ricocheted along the screen, their path was made visible by the fluorescent glow thus produced. This experiment laid the foundation for our modern cathode-ray tubes.

Here we may diverge a moment to be reminded of another important discovery, for which the cathode ray was directly responsible. A German physicist,

Wilhelm Konrad Röntgen, in 1895, made the discovery that whenever cathode rays fell upon the walls of the tube or any obstacle within, and especially the platinum anode, a form of invisible radiation, capable of passing through many opaque objects, was produced. He had discovered the X-ray!

It should be noted here that the cathode ray differs from the X-ray in that the former is simply a stream of free electrons, while the latter is similar to our radio and light waves, only much, much shorter.

And now back to our story. About 1894 a Frenchman, Hess, suggested using the cathode ray as the writing stylus for tracing curves of electrical phenomena. Then K. F. Braun of Germany designed and applied a cathode-ray oscillograph for this purpose as early as 1897 *(Fig. 6)*.
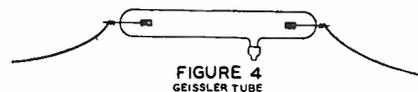
FIGURE 4
GEISSLER TUBE
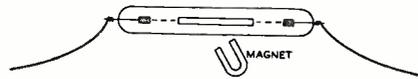
FIGURE 5
CROOKES' EXPERIMENT, PROVING
DEFLECTION OF CATHODE-RAYS
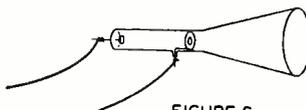
FIGURE 6
A SIMPLE BRAUN TUBE

This and all former tubes used a cold cathode, electron emission being effected by means of high vacuum and potentials of anywhere up to 100,000 volts. With such high potentials, the electrons attained velocities of about one-half the speed of light.

A few years later, Dufour in France and Sir J. J. Thomson and A. B. Wood in England built oscillographs of this pattern. They stood several feet in height, being made of iron and shaped like an upturned funnel, with the cathode at the top. They were equipped with a door for insertion of the six photographic plates and two fluorescent screens which were carried on a revolving drum. A glass window permitted viewing as well as photographing the phenomena under study.
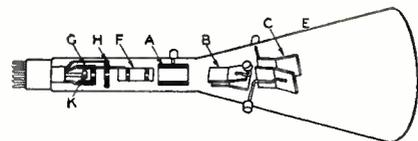
Fig. 7. A typical cathode-ray tube.

After loading the plate-holders and pumping the vacuum for awhile, these pioneer physicists were ready to photograph a few patterns, which usually consisted of a single trace across the screen. But in spite of this laborious method,

some very fine oscillograms were produced, particularly of radio wave trains.

So just remember that, the next time you think it is a little trouble to hook up your modern and highly developed oscilloscope!

Modern Cathode-Ray Tubes

In 1905 Wehnelt found that by using a hot cathode operation at very low voltages was practical but the filament life of the tube was a short one. Western Electric brought out their type 224, hot-cathode tube about 1921. This tube contained a small amount of argon gas, which, along with a critical adjustment of filament temperature, caused the electrons to gather into a concentrated stream. An improved cathode structure increased the filament life to several hundred hours.

In the earlier 1930's, Manfred von Ardenne in Europe and R.C.A., Dumont, Farnsworth and others in America began experimenting with cathode-ray tubes for television. This resulted in development of the excellent series of hot-cathode, high-vacuum tubes now available for either oscilloscopic or television use.

These tubes all focus by adjustment of voltages on certain elements of the electron gun, and, containing no gas, have a very long life.

Theory of the Tube

Having covered a rough outline of cathode-ray tubes and oscilloscopes, let us now examine the individual components in greater detail.

The "innards" of a typical cathode-ray tube are shown in *Fig. 7*. These comprise the cathode K which releases free electrons when heated by the filament within the cathode sleeve. This cathode is surrounded by a cylinder G, which has a small hole in its front for the passage of the electron stream. Although this element is not a wire screen as our usual grid, it is known by that name because its action is similar; that is, the purpose of controlling the cathode stream by a variation of its negative potential.

Next in line is found the first accelerating anode, H, being simply a disk having another small hole in its center. In some tubes this element is connected within the tube to a second cylindrical accelerating anode, A, both these elements operating at the full potential of the tube. In the tube sketched the first accelerating electrode connects to a base pin and operates at reduced voltage.

Between these elements is found a sleeve, F, containing two more small disks, these also having small holes in their centers. This is known as the focusing electrode.

The electrodes just described comprise the electron gun, which produces free electrons and focuses them into a slender, concentrated stream, for projection onto the viewing screen.

A comprehensive explanation of the electron action in this process of focusing involves a study of what is known

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as "electron optics," so called because the electron stream obeys many common optical laws.[1]

We will simply state here that when the focusing electrode voltage is adjusted to approximately one-fifth that of the accelerating electrodes, a very fine beam of electrons will find a focal point on the viewing screen.

Since the tube manufacturers have designed their tubes so as to focus properly, all we have to worry about is the inclusion of a potentiometer in our circuit for making this adjustment, and another potentiometer for adjusting the grid voltage to the value necessary for producing the desired brilliance of pattern.

Deflecting the Beam

Up to this point we have covered only the production and focusing of the beam. This, of course, must be deflected from its normal course so as to strike any part of the viewing screen if a pattern is to be produced. As previously stated, either a magnetic or electrostatic field will attract or repel the beam from its normal course.

Some tubes, particularly a few of the larger ones meant for television use, are designed for magnetic deflection and do not contain the electrostatic deflection plates found in all the smaller tubes used in cathode-ray oscilloscopes. Beam deflection in tubes of the former type is accomplished by means of electromagnets, usually made in the form of a yoke, which slip over the neck of the tube.

The only point in mentioning electromagnetic deflection here is to impress upon the reader that the beam is easily deflected by magnetic fields, since this may be the source of much annoyance if the tube is not kept clear of all power transformer and filter choke fields.

Electrostatic Deflection

Referring back to *Fig. 7,* we will find, between the electron gun and viewing screen, two pairs of flat electrodes which we know as deflector plates. An outside connection, similar to a grid cap on receiving tubes, is brought out from each plate in the tube sketched. However, in the case of smaller tubes for oscilloscopic use, these terminals are connected to pins in the tube's base. Also, it should be mentioned, one plate of each pair is tied together inside the tubes and then connected to the accelerating electrodes, A and H, making actually four electrodes tied to this common pin. These electrodes are operated at ground potential, which is the *positive* terminal of the high-voltage power supply in oscilloscope practice. The two remaining free plates, then, are used for application of the voltages under test.

It will be noted that each pair of plates is mounted at right angles to the other set. Placing a positive voltage on either free plate will divert the beam toward that plate and a negative charge will like-

[1]"Electron Optics in Television," by I. G. Maloff and D. W. Epstein.

wise repel the beam, as shown in *Fig. 8.*

If the top plate of the set nearest the electron gun is made alternately positive and negative, as by connection to an alternating current potential, the beam will move up and down. As the electrons strike the screen a momentary fluorescent glow is produced.

Cathode-Ray Tube Characteristics

As with other types of vacuum tubes, cathode-ray tubes are designed to operate with certain specified voltages, although they are quite tolerant in this respect. The 902, for instance, is rated for 400- to 600-volt anode potential, but will focus with good brilliance at considerably less voltage.

In changing the anode voltage, however, the deflection sensitivity, spot diameter or line width, and maximum brilliance will be affected.

The higher the anode voltage, the smaller is the spot diameter or line width, the greater is the brilliance of trace, and the *lower* is the tube sensitivity.

Deflection Sensitivity

The user of an oscilloscope should know the deflection sensitivity of his instrument, whether with or without use of any amplifiers. The potential required to move the beam from its center position to outer edge of the screen varies from about 100 to 150 volts, depending on the particular tube used and its anode potential.
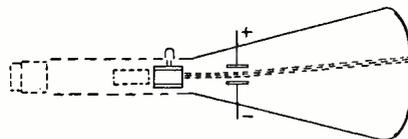
Fig. 8. A positive charge attracts the electron beam, deflecting it toward the charge.

In order to make the oscilloscope useful for testing voltages of such magnitude as encountered in receivers and amplifiers, a vertical amplifier is provided to boost the voltage under test to the value needed for beam deflection.

Changing the anode potential affects the sensitivity, this change being inversely proportional to the change in anode voltage. Or in other words, reduce the anode voltage to one-half and the tube is *twice* as sensitive. This is due to the simple fact that the velocity of electrons in their journey from the gun to the screen is in proportion to the anode voltage, and, therefore, a greater voltage charge is required on the deflector plates to divert a faster-moving stream.

The Fluorescent Screen

Cathode-ray tubes are made with several types of screen material, depending upon the purpose for which the particular type of tube is intended.

Their chief characteristic is known as "persistence," which refers to the period

of time the screen will glow after being bombarded by an electron shower.

Tubes intended for visual observation use screens of medium or long persistence; that is, the pattern remains on the screen for a fraction of a second, which eliminates any flickering at all but the very lowest frequencies. Screens of this type are well suited for "still" photography, whenever the pattern is of such character that it will remain stationary upon the screen.
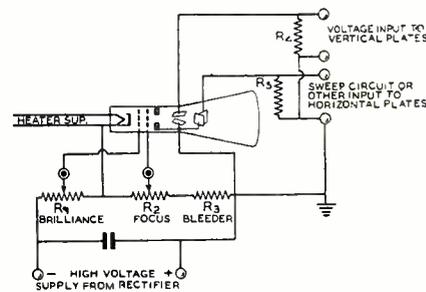
Fig. 9. Typical cathode-ray tube circuit.

There is also a short-persistence type of screen, which retains its glow for less than thirty microseconds, making it useful for oscillographic recording by means of moving-film photography. In this type of work the signal being recorded is connected to only one set of deflecting plates, the movement of the film furnishing the element of "time."

Medium or long-persistence screens glow with a greenish hue which is quite pleasant to the eye, especially when watching the screen for long periods of time. Short-persistence screens produce a blue line which is highly actinic, photographically.

In answer to the demands of television a screen giving a white line can be had in certain tube types. These make possible black-and-white pictures for the television audience.

Cathode-Ray Tube Circuits

Having covered the various elements inside the tube, as well as their functions, let us now consider a typical circuit in which they are used, as shown in *Fig. 9*.

The tube is shown schematically, with both the control grid and focusing electrodes shown by the usual grid symbols, as is customary in cathode-ray tube circuits. The potentiometers, *R1* and *R2*, control the intensity (brilliance) and focusing of the beam, *R3* simply completes the bleeder circuit.

Mention has been made of the two "free" deflector plates where test voltages are connected. Actually, they are connected to ground through resistors of from one to ten megohms. These resistors would not be needed if all circuits under test provided a ground return path. But with such high values, the input signals will not be affected. If allowed to "float" entirely free, these plates would soon accumulate enough electrons to give them a negative charge

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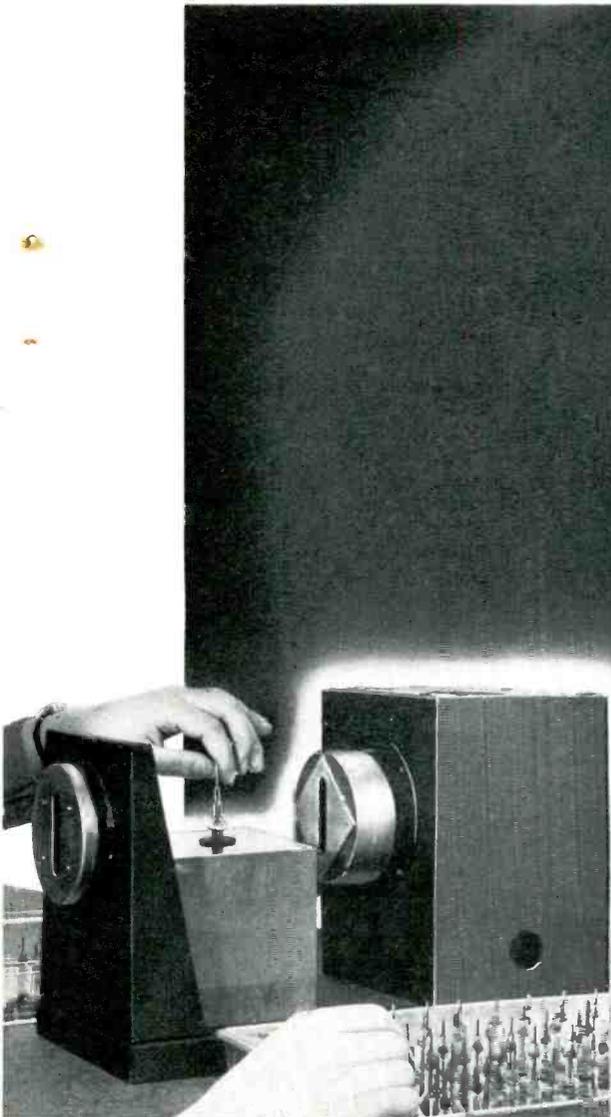
Observation of the stress points on glass bead seals around vacuum tube leads is made with this device. Close-up photo above shows the actual view of a faulty lead. Note the change in polarized light creating distorted shadows which show up stress and strain in beads. Such strain sometimes occurs where metal and glass are sealed together.
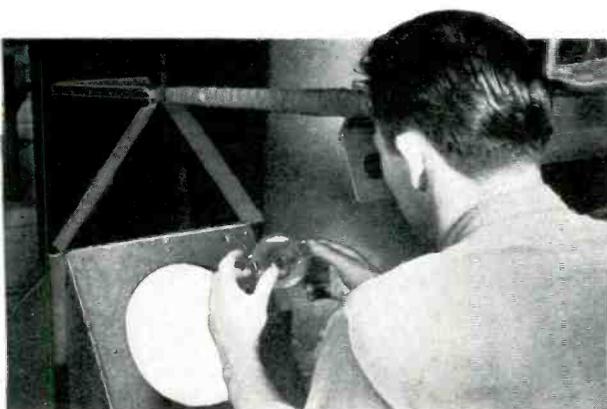
Inspecting the entire glass bulb with the help of a polarized light. This device shows up stress and strain on the glass which might be created during the shaping operations.

Mfg. by Eitel-McCullough, Inc., San Bruno, California, U. S. A.
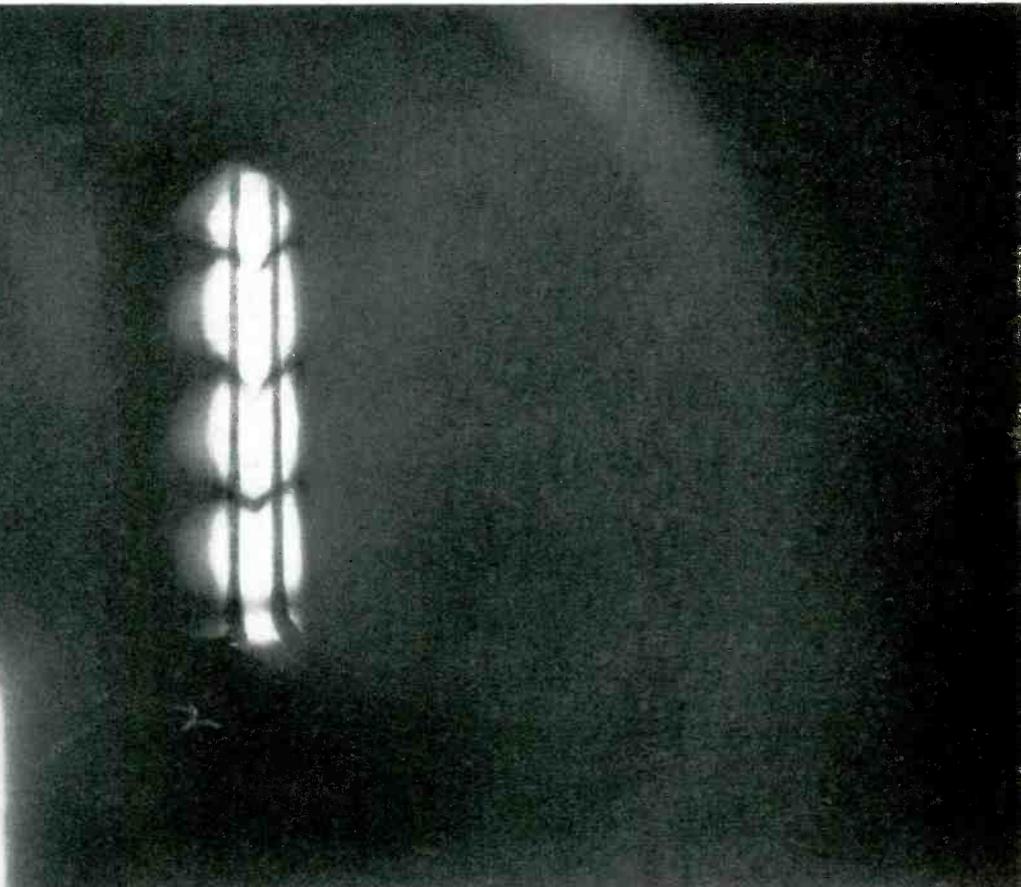
Casual observation of a vacuum tube does not reveal its flaws. That's why Eimac engineers have developed many devices for the purpose of exposing even slight weaknesses in construction. The above is not a dungeon window, but a close-up photo of a faulty bead on a filament stem as viewed through a special bead testing device. Needless to say, this stem will never reach final assembly . . . better "death before dishonor" to the Eimac tradition of dependability.

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Export Agents:
FRAZAR & CO., LTD., 301 Clay St.
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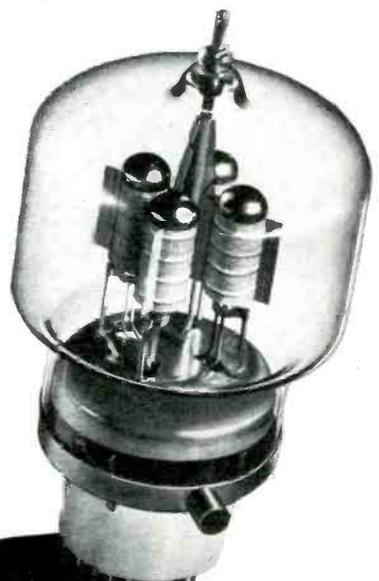
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TUBES

New Products

WORNER BLACKOUT WARDENS

Designed for the automatic blackout of signs, store windows, etc., these units have a range of 50 to 100 feet, depending on intensity of street light used as operating source.

Model 3001 is a single unit, with amplifier, relays, sensitivity regulators and photoelectric cell, all in one housing.
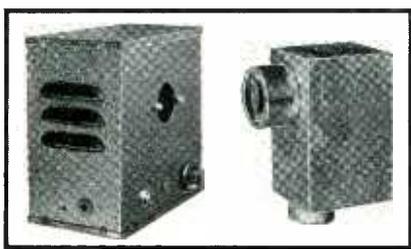
Model 3002 consists of two units; one being the Operating Unit and the other the Electric Eye Unit. No. 3002 is the same as No. 3001 in all other respects.

The Electric Eye Unit is weatherproof so that it may be located sufficiently close to a street light. Coaxial cable is used to connect the Electric Eye Unit to the Operating Unit. This may be up to 100 feet in length.

Relay contacts in both models are single pole, double throw, with capacity of 6 amps a.c. noninductive load and 2 amps inductive. Relay 3003 is provided for loads above 600 watts, and will handle up to 2000 watts.

Additional data may be obtained from the Worner Products Corp., 1019 West Lake St., Chicago.

★

A.A.I. ALARM SYSTEMS

Automatic Alarm Systems are designed for use in connection with steel wire fence. These alarm systems, although employing a new and improved method of protection, combine two tried and proven principles: the detection and
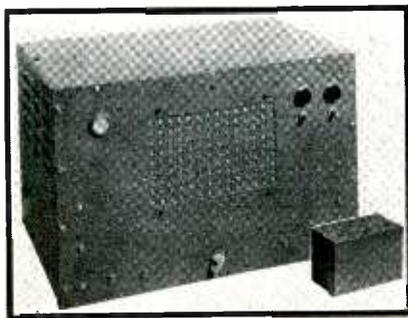
amplification of sound. The Detector is an inertia type, vibration instrument to be mounted on the guard fence at pre-determined intervals. The Indicator, located at a strategic point, is connected with the Detector unit and is designed to supply both an audible and visible warning of any attempt by saboteurs to scale, cut through or tunnel under the guard fence. The Indicator is built to operate on 110-120 volts, 60 cycles, and conforms with government requirements of uninterrupted operation at temperatures varying from 40 degrees below zero to 130 degrees above.

Illustrated is Model No. 11. This system is designed with a dual channel arrangement combined in a single unit, where the segregation of two sections of fence for separate alarms is advisable. It is supplied with six Detector units—three for each channel or section of fence—and will accommodate up to 12 Detector units.

A folder covering the complete details of the various models may be obtained from Automatic Alarms, Inc., Youngstown, Ohio.

★

"PLUG TYPE" SOLDERLESS TERMINAL

A "plug type" terminal designed specifically for use on panel boards and rotary switches, on shipboard—or wherever plug-in wire connections are de-

manded—assures a durable, solderless connection. These terminals are available in straight and right angle shapes for wire sizes 16 and 14.
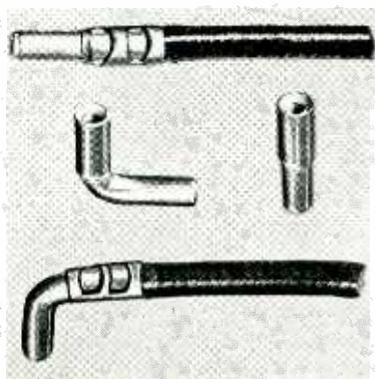
Easily installed—no special skill is required to crimp the terminal onto the wire end with the simple hand, bench or floor type crimping tools. The "plug type" solderless wire terminal is made of dead soft copper, annealed after fab-

rication to resist bending and breaking, and hot electro-tinned for corrosion resistance. For detailed information write for Bulletin No. 14 to Aircraft-Marine Products, Inc., 286 North Broad Street, Elizabeth, New Jersey.

★

SOLDERLESS TERMINAL WITH INSULATION SUPPORT

A new terminal with insulation support, designed to meet demands for insulation protection in the lower wire gauges. Short and compact, the insulation support is designed to grip the insulation firmly without puncturing. This

new type terminal is available now for wire sizes 18, 20 and 22 and it will accommodate insulation diameters of A. N. specification.

The "Diamond Grip" insulation support sleeve is notched and folded in at the end to form a strong lip and a toothed grip, to prevent sliding. Only one operation is required with bench or floor type crimping tool for both wire and insulation crimp. Hand tools also are available. Eliminates taping, speeds up production.

Write for Bulletin No. 13 for full details to Aircraft-Marine Products, Inc., 286 North Broad Street, Elizabeth, New Jersey.

★

NEW R.C.P. INSTRUMENTS

New RCP instruments for laboratory and production use are described in the latest Radio City Products bulletin No. 126, slanted directly at America's wartime industry.

Typical of these new RCP models is

a sensitive Electronic Limit Bridge for precision resistance testing, and a highly versatile multitester for quick and accurate production line tests.
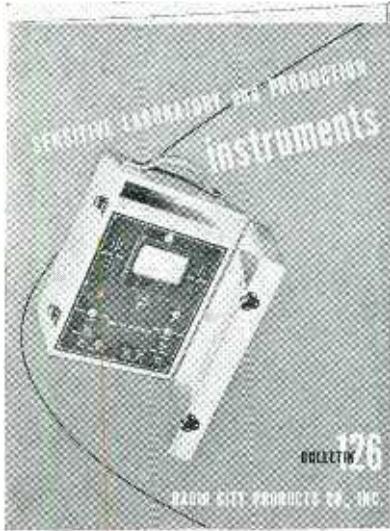
Copy of catalog will be sent on request. Inquiries should be addressed to the Engineering Department, Radio City Products Co., Inc., 127 West 26th St., New York City.

★

LIMIT SWITCH FOR AIRCRAFT SERVICE

A new lightweight limit switch designed especially for aircraft applications has been introduced by the General Electric Company.

The contact mechanism used is the G-E switchette. Snap action and double-break operation give the switch a high current rating. The switch is designed to meet all U.S. Army Air Force stipulations. The plunger operates with a 7/32 in. overtravel, which increases the number of applications for which the switch can be used.
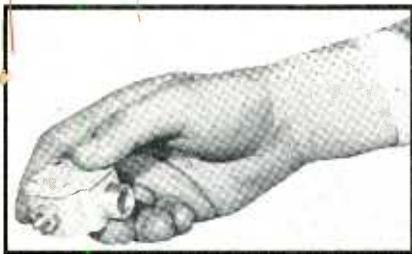
The aluminum housing is made dust-proof by the use of a gasketed cover. There is adequate space inside the housing for easy wiring. The switch is available in three contact arrangements: single-circuit, normally open or normally closed; and single-pole, double-throw.

Each form can be furnished with a contact air gap of .010, .020, or .030 in. The switch weighs .13 lb.

NEW METHOD OF PACKING RADIO TUBES

SAVES TIME, SPACE AND MATERIALS IN WAR EFFORT

◄ A revolutionary new principle of packing radio tubes which, if utilized by the tube industry, will result in major contributions to the war effort in shipping space, material, handling and warehousing savings, has been developed by the manufacturers of RCA radio tubes.

By adopting the new method, RCA alone is saving some 120 tons of packing material a year, and is able to ship approximately twice as many tubes in a boxcar or truck, thus halving the need for critical shipping space. The new method supplants packing, handling, storing and shipping practices which have been common for many years.

To extend the value of the new packing principle more quickly, RCA has granted patent rights to the new type cartons to other tube manufacturers. In addition, other tube manufacturers have been shown factory routines that have been developed to make the most efficient use of the new process.

The American Standards Association is studying the possibilities of setting up an American War Standard covering the packaging of electronic tubes as a result of RCA's pioneering effort. Far reaching effects are expected of the new packaging principle in many fields.

The new packing ideas were developed by Charles I. Elliott, a 27-year-old packing engineer who was employed by the RCA tube division to study the Company's methods of handling tubes during the manufacturing process, and preparing them for warehousing and shipping.

Old Systems Scrapped

Mr. Elliott found that existing packing methods required the use of 210 separate pieces of packing material per 1000 tubes. Improvised handling methods were used in the factory where tubes travel from one assembly operation to another. A packing box of 22 parts, some of them no longer obtainable, was used to store and ship glass tubes.

When he had finished re-designing packing cases, Mr. Elliott found that he had reduced the 210 pieces of packing per 1000 tubes to 24 pieces. He discovered that a single one-piece, tray-like container, planned to hold the tubes safe within shipping cases, could also be used to save time in the manufacturing processes.

Standardization Important

Standardization of tube packages is
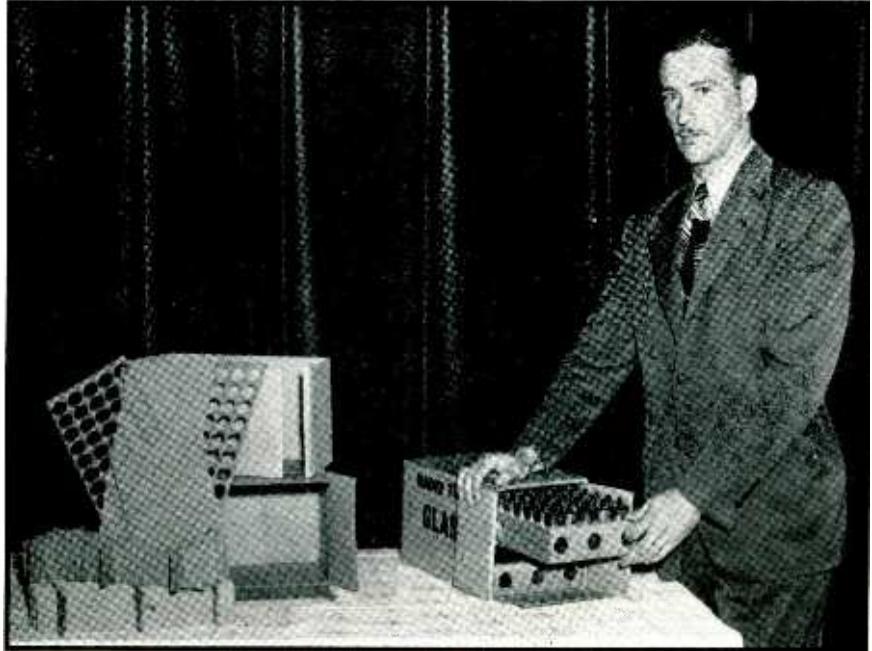
Charles I. Elliott, RCA packing engineer who developed the new method of packing radio tubes, demonstrates how 100 tubes may be packed in a sturdy carton for shipment while protected in two single piece heavy cardboard trays. To the left is shown the many pieces of packing material formerly required to pack the same number of tubes, indicating the savings in material made possible by the new method.

vitally important in wartime for many reasons. Spare radio tubes can be made to fit into spaces designed for them by the builders of planes, tanks, mobile units, ships and other fighting equipment. And the tube packages will fit the spaces, no matter from which factory they originated. This is a vital consideration with U. S. fighting equipment in action in many parts of the world.

In handling receiving tubes alone, savings of 30 per cent in material were found to have been achieved by the new methods. Factory handling efficiency has been stepped up 20 per cent, loss by breakage has been materially reduced, as has the need for storage space. It is now possible to pack 647,500 tubes of a given type into a single boxcar, an increase of nearly 100 per cent in capacity.

A further improvement in the handling of the smaller types of receiving tubes has been made in the form of a "clip" of cardboard which holds 10 tubes. During testing, warehousing and branding operations, the "clip" of ten tubes is handled as a unit. However, when the time comes for the tubes to be packed into individual cartons for shipment, the "clip" is torn into 10 pieces along perforated

lines, to become the interior support for each tube in its individual carton. Further, the old 31-piece glass tube carton had resolved itself into a smaller, eleven-piece box.

Every Tube Type Aided

Tremendous advantages have been found in the new system in the handling of every type tube. In the case of a certain type power tube, a wooden box used to transfer small quantities about the factory and to the warehouse has given way to a more compact cardboard box in which the tubes are transported with greater protection from breakage.

One universal box has been designed for packing all types of power tubes of the same size, supplanting a large number of various sized special boxes. Ingeniously designed inner supports do away with the layers of wadding once used, while the application of simple laws of physics provides greater safety for the tubes when the box is subjected to unusual stress.

In the case of cathode ray tubes, the empty glass bulbs are now received at the RCA factory from the glass works in the same packing cases in which they are transported [Continued on page 53]

throughout the manufacturing, testing, warehousing and shipping processes. So much has been saved in the cost of the packing cases that the glass company has agreed to furnish them to RCA without cost.

Mr. Elliott's work has been carried on under the direction of L. E. Mitchell, Manager of the Industrial Engineering Department devoted to the development of better methods through work simplification.

"Kit" Packing

Perhaps most ingenious of all the new packing methods is that designed for "kit" packing of tubes, used to provide in one package the several types of tubes required for factory assembly of radio equipment and the tubes needed as replacement parts. It was formerly necessary to keep a stock of all sizes of kit packages. Now one single size box is provided for all types of kits. It is changed in size and shape by being torn the proper way along carefully designed perforated lines. Larger packing cases in which the kits are shipped are made to telescope, so that they can be made larger or smaller as needed.

"All the new containers are fabricated so that they can be laid out flat," Mr. Mitchell explained. "None of them is stitched or glued. The result is that empty cartons can be stored in one tenth the space formerly required. Further, we are able to have the empty cartons returned from our customers time and time again at nominal expense, still further increasing savings in strategic materials, facilities and manpower."

Theory of 'Scope

[*Continued from Page* 48]

and shift the beam completely off the screen.

The heater supply is connected to a transformer which furnishes 2.5 or 6.3 volts to the filament, depending on tube type. In the smaller tubes the cathode is connected to one side of the filament, within the tube.

The high-voltage leads are connected to the rectifier output of the power supply. It should be noted, though, that the *positive* lead is grounded, which is contrary to receiver practice.

Sweep Circuits

What is the "sweep circuit" and how does it function? This is one of the first puzzling questions of those to whom the oscilloscope is new. We are all familiar with those graphs which engineers use to show the relation of one function to another. Take the old familiar sine wave, for example, a graph of which appears in *Fig. 10*.

To the left we find a vertical line representing instantaneous voltage values. At the bottom is found a notation of the time in which these changes

take place, being 1/60 of a second in this case.

Now we will see how this same curve would be plotted on the cathode-ray screen. Facing the front of the tube
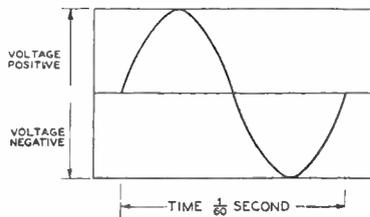
Fig. 10. Graph of a single sinusoidal wave.

would be seen the four deflecting plates if the screen were removed, and we would see the electron stream as a tiny dot if it were visible. (*Fig. 11.*)

The secondary of a transformer is here connected to the vertical plates so the beam will be moved up and down in accordance with the voltage. The voltmeter will read the r.m.s. voltage across the secondary, but the beam will follow the *instantaneous* potential. With no voltage on the horizontal plates, a fine vertical line will appear on the screen. Since this line represents the voltage changes from minimum to maximum, it is possible to measure the peak voltage directly with a ruler placed on the screen, provided the oscilloscope's sensi-

tivity has been previously determined.

Examining the remaining apparatus we find a battery with its center cell grounded and its positive and negative terminals connected across a potentiometer P, the slider arm A of which goes to the free horizontal plate. It is plain, then, that the beam will be moved to the right or left, depending upon the arm position.

This latter member is connected to a lever which follows the contour of a cam, C, being turned by a synchronous motor operating from the line under test.
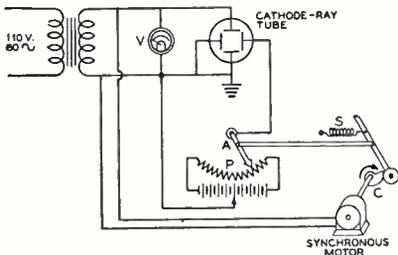
Fig. 11. Mechanical sweep circuit.

As the cam revolves, the slider arm will be drawn from left to right at a uniform rate and the electron beam will follow simultaneously. As the maximum lobe on the cam turns by its follower, the lever L and slider A are instantly snapped back to the left position by the spring S, and the sweep cycle starts all over again.

It will be apparent that during this cycle the beam has been deflected vertically by the voltage under inspection, and horizontally by the sweep circuit mechanism. If the cam is geared to the synchronous motor so as to revolve 60 times per second the beam will trace a pattern upon the screen similar to *Fig. 10.*

In one second's time the beam will traverse the screen 60 times, making a trace each time. But since the sweep mechanism moves in perfect synchronism, each trace will cover the exact position on the screen as did all preceding traces. Instead of seeing a moving pattern, then, the electrical wave appears to be "stopped in its tracks," permitting study as long as desired.

The above applies, of course, only if the phenomena is recurrent (and the sweep synchronized) but this condition holds true for most electrical phenomena in which we are interested.

Any transient surges occurring during this study will register as a deviation from the normal waveform, and appear as a fine line, diverting from the true waveform. They will glow for an instant, and then disappear.

While such a mechanism as above described might work at very low frequencies, it is quite evident that a better means must be found for sweeping the beam at frequencies varying from 15 to 10,000 cycles per second, or more.

The Relaxation Oscillator

While there are several types of electronic oscillators that will perform the function of producing a linear sweep, the relaxation oscillator is the simplest and most adaptable to our work. This type oscillator is used in all present-day commercial oscilloscopes.

It is also known as the "saw-tooth" oscillator, linear timing axis, grid-glow or thyratron oscillator, and perhaps another name or two. Its action is quite simple, but because it may be unfamiliar to some, it will be described in detail.

Evolution of Linear Timing Circuit

We have seen from the mechanical arrangement just described that a sweep oscillator must move the beam *at a uniform rate in one direction* and return to its starting point instantaneously. It is quite apparent, then, that our usual sine-wave oscillators are not suitable for this particular job.

The problem is to develop a suitable voltage for horizontally deflecting the beam and then to provide a means for instantly reducing this voltage to zero.

A simple neon oscillator is shown in *Fig. 12.* Current from the d.c. input circuit, flowing through resistor R, charges condenser C. The neon bulb N, has no effect until its flashing voltage (50 or

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60 volts) is reached. At this point, gas within the bulb ionizes, rendering the bulb a conductor, and instantly discharges condenser C as if it were a short circuit.

When the voltage across condenser C becomes reduced to almost zero, the neon gas de-ionizes, suddenly restoring the bulb to its former status of an insulator. Here another cycle of operation begins as condenser C begins "filling up" with another charge.

The frequency of operation is determined by the time required for charging condenser C. By selection of proper capacity values, and by making R variable, oscillation of any frequency from a few cycles up to many thousands may be obtained.

While extremely simple, this oscillator has three major faults which must be corrected before it can be used in a first-class oscilloscope.

First; its output, which will be slightly less than the neon bulb's flashing potential, is not sufficient to swing the electron beam completely across the screen.

Second; its frequency is not easily synchronized to the signal frequency. And third; as the condenser becomes more and more charged, its charging rate decreases, hence the output voltage does not increase linearly with respect to time.

Now, what to do about it! The first fault, insufficient output, is overcome simply by hooking on a stage of amplification.

Fault number two is remedied by changing to a thyratron tube, this being a more or less glorified version of the neon bulb. It looks just like a 76 but behaves differently.

A simple thyratron oscillator circuit is shown in *Fig. 13*. Instead of the neon bulb is a type 884 or 885 gas-triode (thyratron), which has a heater, cathode and plate—but has a little inert gas mixed with its vacuum content. Its action is quite similar to the neon bulb, except that its flashing voltage may be set to any predetermined value by application of proper grid bias potential Ec.

Two more resistors, $R1$ and $R2$, have been added to the circuit. The former simply limits the maximum charging rate, while the latter prevents $C1$ from discharging more rapidly than the little tube will stand.

It is a characteristic of type 884 and 885 tubes, that discharge will occur whenever the plate potential reaches about seven times the negative grid bias value. Since we will amplify the output voltage anyway, we can fix the flashing voltage at about 20 volts by biasing the grid to about—3 volts. This gives plentiful output and makes the saw-tooth wave linear in the bargain, the explanation of which will follow.

We have already mentioned that a condenser takes its charge in exponential fashion. The curved and dotted line in *Fig. 14* shows this charging character-

istic. The condenser starts charging fast but slows down as its potential approaches that of the charging voltage.
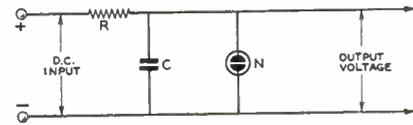
Fig. 12. Simple neon oscillator.

If such tank condenser is "flashed" when about half full its charging curve will be "rounded" like the solid line. Such a curve will make the pretty patterns on our cathode-ray screen rather distorted.

However, if the thyratron is set for a low flashing voltage—that is, only five or ten per cent of the d.c. charging voltage, this charging curve will be essentially linear, as shown in *Fig. 15*. Here we flash the condenser before its curve starts bending to any appreciable extent.[2]
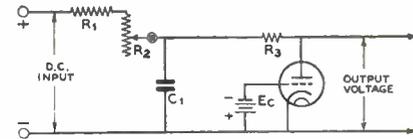
Fig. 13. Simple gas-triode (thyratron) oscillator circuit.

Synchronization

And now, about synchronization. We stated that the flashing voltage was determined by the thyratron's grid bias. If a small potential—less than a volt being required—is fed back from the signal under inspection to this thyratron grid, the tube will flash, always at the instant a certain signal voltage is reached.
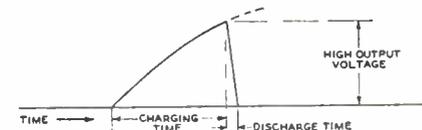
Fig. 14. Effect of operating at a high flashing voltage.

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[2]Another method of obtaining a linear output voltage is frequently found in television receiver designs, and in some of the older oscilloscopes. Instead of flashing the thyratron at a low potential, this method flashes at a much higher value; that is, two or three hundred volts, thereby eliminating the amplifier. By substituting a pentode tube for the current limiting resistor R, current flow to the tank condenser is limited to a constant rate. This method, however, is just as complicated as the low-flash-and-amplify method and is not nearly so flexible. Also, with the low-flashing circuit, the amplifier is also available for amplification of external signals, if desired, making it much more suitable for oscilloscopic use.

A potentiometer, *R4* in *Fig. 16,* provides control of the synchronizing potential. This voltage is usually taken from the signal voltage on the free vertical deflection plate, but in some cases from the signal, itself and occasionally from

Fig. 16. Complete sweep circuit, consisting of sawtooth oscillator and horizontal amplifier.
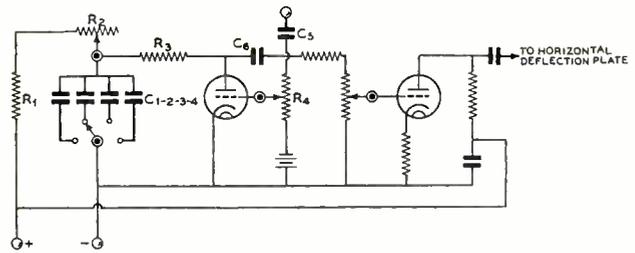
the 60-cycle a-c power source.

Something should be said of the polarity of output, both from the tank condenser *C*, and the complete sweep circuit, with amplifier. Referring to the first portion of *Fig. 17* will be found the "saw-tooth" waveform across the tank condenser. This voltage varies from a few volts above ground to the flashing potential of the thyratron. Note that this voltage is *always positive*. The waveform is a saw-tooth pulse, rather than an alternating current wave, at this point. However, the oscillator is coupled to the horizontal amplifier grid through a coupling condenser *C6, Fig. 16.* Here on the amplifier grid we will find the same saw-tooth characteristic. But the amplitude is now divided half above and half below our ground line of zero potential.

Now after amplifying this wave, we find that the amplifier has shifted its phase 180 degrees, as will be seen in the last portion of *Fig. 17.* This phase reversal is of no real importance, though. If the cathode-ray tube is mounted so the free horizontal plate is at one's left, the sweep cycle will begin at that side, travel to the right, and then snap back to start the cycle all over again. Our cathode-ray screen graphs will be correctly plotted from left to right, in relation to time.

About Amplifiers

In small commercial oscilloscopes one usually finds one vertical and one horizontal amplifier. The larger models, using five-inch tubes or larger, are usually equipped with two vertical amplifiers.

The vertical amplifier simply builds up the signal under test to sufficient amplitude to deflect the electron beam to the desired degree.

The chief purpose of the horizontal amplifier is to amplify the saw-tooth timing wave, as previously described, largely in the interest of linearity.

There is nothing unusual about either of these amplifiers, except that they should operate with as little distortion and have as flat

Fig. 15. Obtaining sweep-circuit linearity by means of a low flashing voltage.

Fig. 17. Pulsating oscillator output becomes a.c. on output side of coupling condenser.
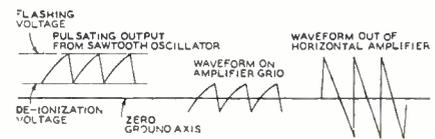
a frequency characteristic as can be obtained.

A flexible switching arrangement is always provided to make the oscilloscope as versatile as possible.

News

SIGNAL CORPS NEEDS INSTRUCTORS

The Board of Education is about to embark upon a new venture of training men for the Signal Corps.

They are interested in securing instructors for this program which will be conducted by the Public Vocational Schools for the various states. Those interested should contact the nearest U. S. Employment Service Office.

★

JEFFERSON-TRAVIS OPENS WASHINGTON OFFICE

The Jefferson-Travis Radio Mfg. Corp. announces the opening of a branch office in Washington, D. C., for the purpose of assisting U.S. Government Departments with respect to radio communication equipment being manufactured by the Company under government contracts.

Mr. F. Lee Hardesty will be in charge of the new office which is conveniently located at 1026 17th Street, N.W. Mr. Hardesty has resigned his position in the radio procurement division of the British Air Commission to accept this new post.

To assist in this work a member of the Jefferson-Travis engineering staff will be permanently stationed at the Washington office, so that the Company's production methods and facilities will be readily available to the U.S. Government Departments.

G. E. SHIPS TRANSMITTER FOR W75NY

General Electric has shipped an f-m. broadcast transmitter and associated equipment to New York City's newest f-m. station, W75NY, to be operated by Metropolitan Television, Inc. The station is the seventh in the New York area and is owned jointly by Bloomingdale's and Abraham & Straus department stores.

Construction of the station, atop the Hotel Pierre, was begun in mid-March under the direction of Louis Thompson, who has been placed in charge of the station.

The FCC assigned a Class B f-m. permit for the use of 47.5 mc. to Metropolitan Television, Inc., last year.

★

REQUIREMENTS FOR AERONAUTICAL STATION OPERATORS RELAXED

The Federal Communications Commission on June 16, through its Order No. 102, upon recommendation of the Defense Communications Board, modified certain of its rules for a period of five years or until further order of the Commission, to provide a relaxation of its operator requirements for aeronautical stations utilizing telegraph transmission. (These are ground stations used in connection with aeronautical operations.) This action permits operation of an aeronautical or an aeronautical fixed station by the holder of a radiotelephone permit or radiotelephone license bearing an endorsement attesting to the holder's ability to transmit and receive at least 16 code groups, International Morse Code, per minute.

This action is designed to relieve the rapidly growing shortage of skilled operators being caused by war-time conditions and the requirements of the military forces for radio operators. It specifically looks forward to the possibility of training women to assume these duties by providing for such operation without the detailed technical qualifications necessary for the more technical grades of licenses.

It will be necessary, however, at each station where holders of the restricted radiotelephone operator permits are employed as operators, that at least one first or second class radiotelegraph or radiotelephone operator, or, in lieu thereof, in a station using type A-1 or A-2 emission only a holder of a restricted radiotelegraph operator permit, be assigned to the station at all times for the purpose of making proper adjustments to the equipment and who shall be responsible for the proper operation of the station. This provision, however, will not relieve the station licensee of his responsibility for operation of the station in accordance with the Rules and Regulations of the Commission.

Holders of radiotelephone operator permits or licenses may obtain the required radiotelegraph endorsement by appearing at any of the Commission's District Field Offices or at the Washington, D. C., office and demonstrating their ability to transmit and receive at least 16 code groups per minute in International Morse Code. The endorsement will then be written on the face of the permit by the examining officer.

★

WARTIME CONDENSER CATALOG

This is war. That is the keynote of the new 1942 Aerovox Catalog just off the press. Starting out with a cover that reflects the stern atmosphere of the huge plant working day and night on the radio fighting and home fronts, the catalog lists those essential condensers, resistors and test instruments in popular demand and therefore still produced, stocked and available for prompt delivery. A further wartime note is the inclusion of several pages of motor-starting replacement capacitor listings, in acknowledgment of widespread and growing demand for refrigerator maintenance. A copy of this catalog may be had by addressing Aerovox Corporation, New Bedford, Mass., or through the local Aerovox jobber.

★

SYLVANIA ORGANIZATION CHANGE

M. F. Balcom, Vice President and General Manager of the Radio Tube Division of the Hygrade Sylvania Corporation, announces two top executive organization changes. This, at the same time, effects a rearrangement of duties down the line which streamlines

radio tube manufacturing and engineering activities in order to continue to meet the growing demands of war production.

H. Ward Zimmer, General Manufacturing Manager, is appointed General Manager of Operations of the Receiving Tube Division, which includes three plants in Pennsylvania, and one in New England. In continuing his general manufacturing managership, he will be in charge of equipment design and production, and general division purchasing.

R. M. Wise, Chief Radio Tube Engineer, is named General Manager of Operations, Special and Large Tube Division, which includes three other Pennsylvania plants. Continuing his general engineering responsibility as General Engineering Manager, Mr. Wise will be responsible for radio tube research and development engineering, commercial engineering and production development.

★

V. H. FRAENCKEL APPOINTED TO G-E RADIO, TELEVISION AND ELECTRONICS DEPT.

V. H. Fraenckel will have charge of the co-ordination of commercial engineering of all product lines of the General Electric Radio, Television and Electronics Department, according to a recent announcement by Dr. W. R. G. Baker, Vice President. G. F. Metcalf, formerly in charge of this work, has entered the U. S. Army with the rank of Lieutenant Colonel, Signal Corps. Mr. Fraenckel will report to G. W. Henyan, Manager of the Transmitter and Tube Divisions of the Department.

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W P. SAUNDERS COMMISSIONED

W. P. Saunders, Senior Business Specialist in the Office of Price Administration in Washington, has been granted leave of absence to assume active duty as a Captain with the U.S. Army Signal Corps.

Captain Saunders has been identified with the radio industry since 1918.

In October of 1941, at the request of Merle Fainsod, now Director of the Retail Trade and Services Division of the Office of Price Administration, he assumed duties with the Radio Unit of the Durable Goods Section, where he has assisted in the administration of prices of radios.

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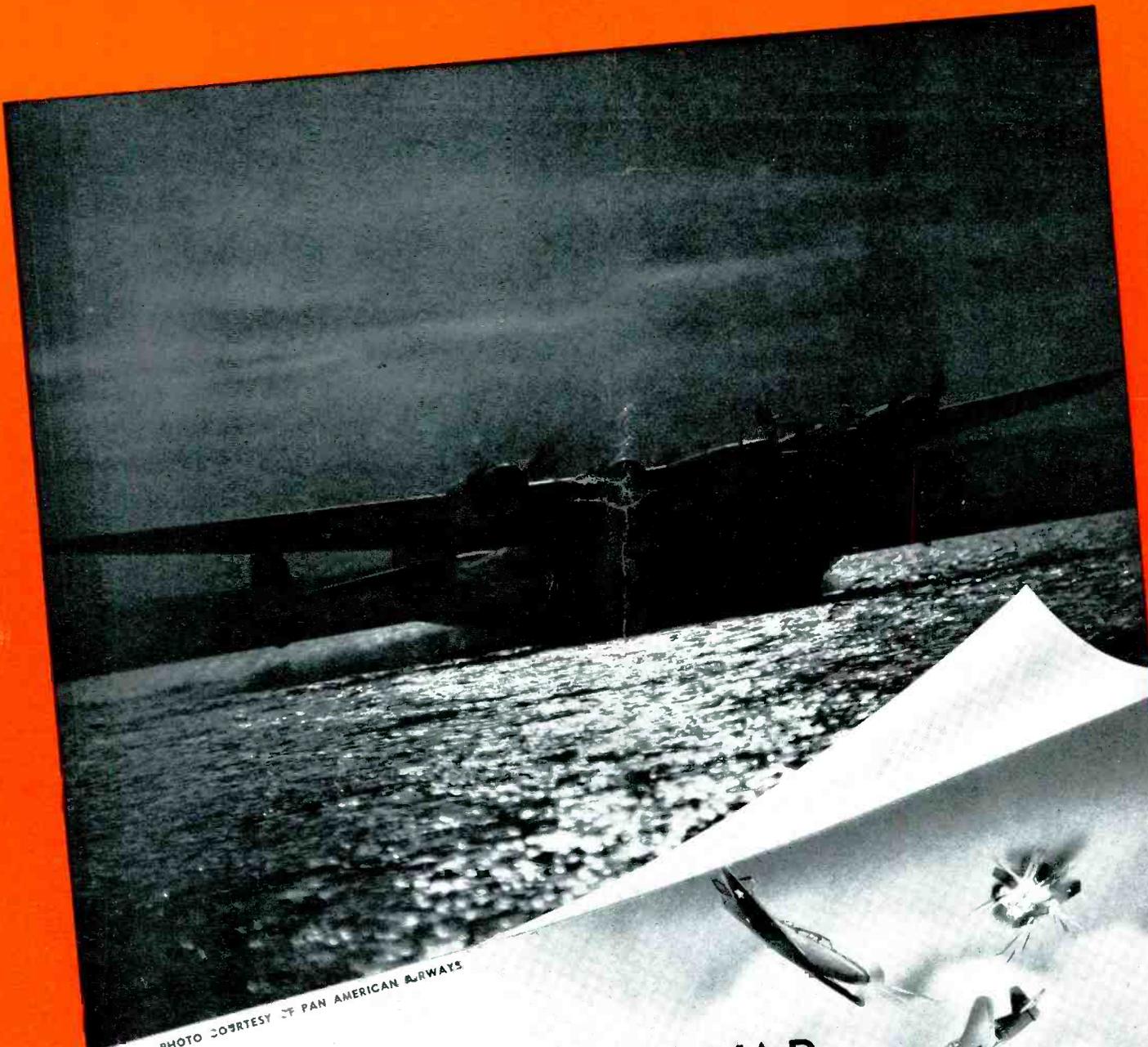
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