RADIO-ELECTRONIC Engineering SECTION

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RADIO & TELEVISION NEWS

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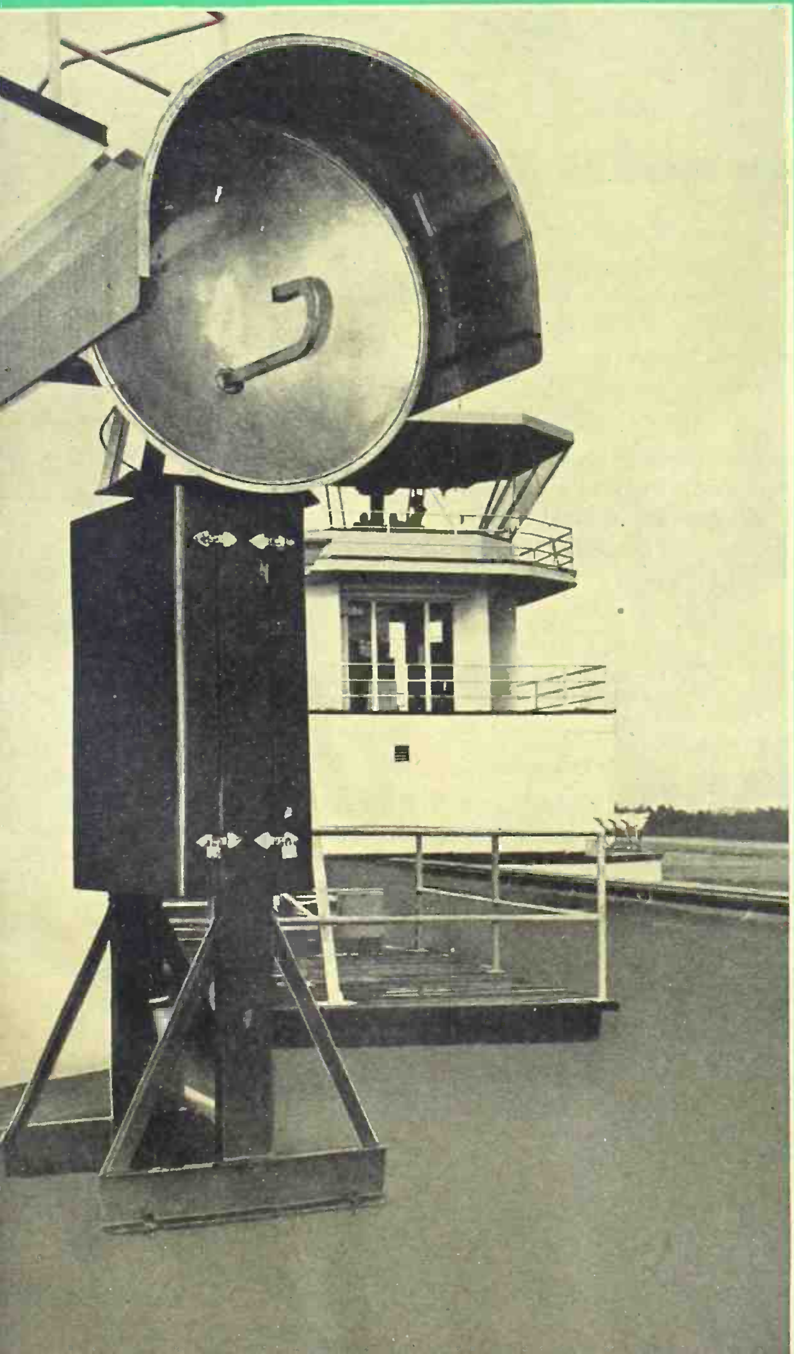

JANUARY, 1952

DEPARTMENTS

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← The antenna of a Motorola microwave relay system. Systems of this nature have been installed at airports by Aeronautical Radio, Inc. to transmit signals between airport control towers and air/ground radio control antenna arrays at points away from airfields.

COLOR TV STATUS

THE RECENT NPA order halting production of color TV receivers did not materially affect research and development work in this field. Successful large-screen theater demonstrations of color by *RCA* in this country, and demonstrations of the *Eidophor-CBS* system in Zurich, Switzerland, indicate that color TV for theaters, at least, is in an advanced state of development.

The National Television System Committee (NTSC) has accomplished a great deal with respect to recommending suitable standards for a compatible color television system. The chairman of this committee, Mr. W. R. G. Baker, outlined these proposed standards in a recent report.

According to this proposal, three different characteristics of the color picture are transmitted. These are the brightness, hue and saturation. The brightness information is transmitted in the usual fashion, as in a black-and-white picture. In addition, a "color carrier" is added, with a frequency which is an odd multiple of one-half of the line frequency. The sidebands containing the color or chromaticity information are thus interlaced with the brightness signal spectrum, utilizing more fully the available 4-mc. bandwidth. The two chromaticity signals, hue and saturation, modulate this color carrier in two different ways, for example, in amplitude and in phase, so that all of the color information is contained in the single color subcarrier. Thus, existing receivers could receive pictures in black-and-white from a color TV transmitter without any alterations by making use of the "brightness" signal, making the system completely compatible.

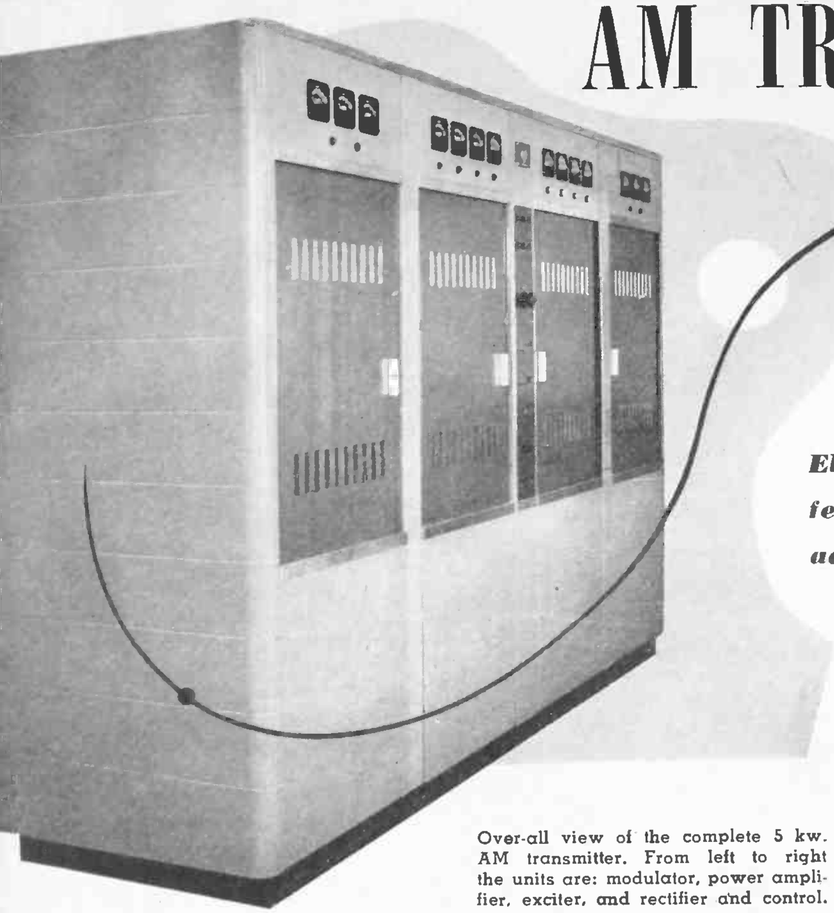
Most of the components of such a system have been tested extensively, and have been proved practicable. These tests are continuing, and further refinements are being worked out. One such refinement is the "oscillating color sequence" proposed and tested by *Hazeltine.* This technique greatly reduces adverse effects resulting from errors in the modulation of the color sub-carrier, and those due to interference of various kinds.

It appears very likely that a complete, compatible color television system, accepted by the industry, will be ready for presentation before the FCC within a reasonably short time. Work on this system cannot be considered to detract from our defense effort, since an acceptable color TV system would be very desirable to many branches of our military forces.

AM TRANSMITTER DESIGN

By M. H. HUTT
Engineering Products Dept., RCA

Electrical and mechanical design features of a unit which can be adapted to 5 or 10 kw. operation.



Over-all view of the complete 5 kw. AM transmitter. From left to right the units are: modulator, power amplifier, exciter, and rectifier and control.

FIRST CONSIDERATIONS in the design, planning, and mechanical layout of a new transmitter are the basic needs and operating requirements to be met in the broadcast field. Most of these technical requirements have been very well established by broadcasters with over thirty years of operating, or "on-air," experience.

Therefore, in the design of the *RCA* BTA-5G/10G (5/10 kw.) Transmitter, care was exercised to retain the many design features "proved-in" by its predecessors, as well as providing new and novel ideas. Listed here are some of the major factors which had to be taken into consideration in the final design.

1. Reduced cost, without any sacrifice in quality.
2. Reduced weight and size.
3. Simplified operation and maintenance.
4. Simple and easy installation.
5. Convenient and economical conversion to 10 kw. operation, plus addition of phasing equipment.
6. Accessibility to all components and tubes.

The 5 kw. transmitter consists of four major units; namely, the exciter, the power amplifier, the modulator, and the power rectifier units. With the addition of a few components, it can be converted into a 10 kw. unit without increasing cabinet and floor space. Cabinets of companion design and styling for phasing equipment may also be added where directional operation is required.

Each cubicle or cabinet measures approximately 27" x 30" x 84". Solid, rigidly formed panels of ⅛" thick aluminum are used to construct the cabinet enclosures. This fact alone accounts for a considerable saving in weight and increases the ease with which the units can be handled. Additional interior space is also gained by using the formed panel construction.

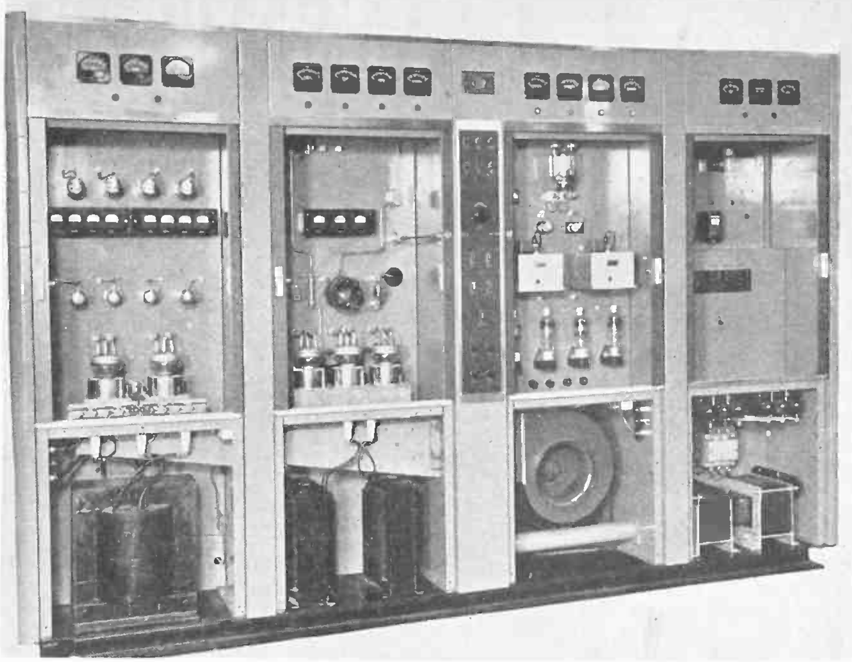
A sturdy steel base, used to support the vertical chassis and the two vertical side panels, has also been formed to allow the fork of a "pilot" jack (small hand or motor-powered lift truck) to reach under and through it for moving individual units during assembly and test. The four cabinets, completely assembled, require a total floor space of only 10 feet 10 inches in length, by 30 inches in depth. The sliding doors make it possible to conserve additional floor space because no clearance is needed to accommodate hinged doors.

Two wire ducts, one for the front and one for the rear, made of formed sheet steel, are long enough to reach the entire length of the four units comprising the complete transmitter. When the transmitter is installed, these wire ducts are first located, leveled, and secured to the floor. This provides two good rails on which the transmitter units can be set and finally located. The formed bases of each cabinet are notched to clear the wire ducts and also to align themselves up with the cable openings.

Another advantage of a wire duct of this type is the ease with which the interconnection cable and power connections can be installed. The wire duct is open along the entire front side, as are the "U" shaped notch openings for the cable connections of each unit. Thus, the interconnection cable may be simply laid in place, and the task of weaving the cable in and out of openings and holes is eliminated. As the cable is placed in the duct, each branching leg of wires automatically extends up through the notches provided in the base units to its appropriate terminal board.

On each base unit are assembled the vertical chassis and the two vertical side panels which are fastened together to form an "H" section. However, prior to assembling the cabinet unit, the vertical or center chassis may be assembled and wired as a sub-assembly item. In all units except the exciter, this vertical chassis divides the unit into two equal front and rear compartments. In order to provide additional space for a blower in the lower compartment, and to allow accessibility to the crystal oscillators and other components, the chassis in the exciter is forward of the center and does not extend into the lower compartment.

Two shelves, one front and one rear, located approximately 30 inches from the floor, further divide the units into upper and lower compartments. This



Front view with sliding doors opened and lower panels removed to show the interior arrangement. The mechanical layout is similar in all four units.

provides a means for mounting additional equipment which must be fixed in place. In the modulator and power amplifier units, the front shelves provide means for supporting the Type 5762 air-cooled power tubes. The air is piped from the blower mounted in the exciter through a duct system assembled directly to the under side of the shelves. The compartments below the shelves are used front and rear to house the heavier components which rarely require service. Removable panels below the door area provide easy access to these lower compartments. These lower panels are quickly removed by releasing two camlock fasteners just inside the lower edge of the door opening above the shelf. An interlock switch provides the protection against high voltage when these panels are removed. All large transformers, reactors, voltage regulators, capacitors, circuit breakers, etc., are housed in the lower compartments and the blower is situated in the lower compartment of the exciter. The lower rear panel of the exciter unit also contains an "intake" air filter. This filter is a dry type and can be cleaned with a vacuum cleaning attachment without removal from its mounting.

The upper front and rear sections of each unit contain the components which require occasional attention and service. This requirement is facilitated by the use of new, horizontal, sliding doors. Interlocking, extruded aluminum slats are used to make the doors. Small rubber caster assemblies, riding in an upper and lower track, guide the doors as they move from the front to the side of the cabinets. A four-inch separation between units provides the space into which the opened doors slide, with one door entering from the front and another from an adjacent cabinet entering from the rear. A series of openings in certain slats provide the windows necessary for observation of tubes and components. These openings are protected with plexi-glass held in place by small spring clips for easy removal. Each door is equipped with a latch assembly which locks the door in place while closed and is easily tripped while pushing the door open. The door also activates an interlock switch and a ground switch, which both operate at the desired position of the door to provide full protection. However, the front door of the rectifier and control unit is not interlocked and, therefore, provides access to main switches and circuit breakers.

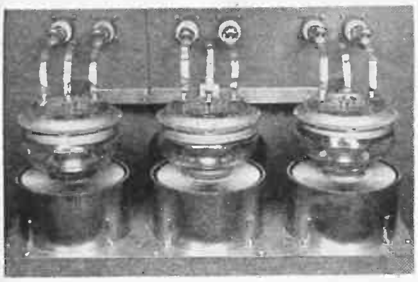
Above the sliding doors on the transmitter front are the meter panels for mounting meters and indicator lamps. Below the doors are the lower removable panels. Both panel areas are separated from the door area by trim strips. In general, over-all external appearance and styling matches other existing *RCA* transmitter equipment.

The four-inch spaces, provided between units for housing the open doors and door tracks, are covered with filler channels which are fitted into the over-all styling. The center filler channels are eight inches wide and the front center channel contains the external transmitter controls.

Both units adjacent to the center section have only their rear doors entering this area. This arrangement leaves the front section free for locating the necessary controls. There are only two units with components requiring external tuning controls: the power amplifier to the left of the control panel contains a variable vacuum capacitor, controlled manually by a vernier dial mounted on the door jamb adjacent to the control panel; and the exciter to the right of the control panel has a "slug-tuned" coil, controlled manually by a similar dial located on its door jamb. Therefore, these dials are in the vicinity of the control panel and may be grouped with the other controls to form a central control panel. No further mechanical mounting is required, since installation of these assemblies is part of the completed unit.

Internally, the mechanical layout and arrangement is similar for each of the four transmitter cabinets. As mentioned previously, each unit is made up of a vertical chassis and two vertical side panels fastened together to form an "H" section. The shelf level is just about even with the lower edge of the door. Except for the exciter unit, the vertical chassis extends from the base to the top cover. In addition to a more simplified assembly, all the smaller components assembled on these chassis are made extremely accessible. The small tube sockets are mounted vertically, and the tubes horizontally. This arrangement makes all wiring easily visible and accessible. The chassis is placed approximately fifteen inches from the door opening, so that all components on the chassis are within easy reach. All components such as capacitors, resistors, coils, etc., are, in most all cases, mounted on the rear side of the chassis. This results in a clean arrangement on the front of the chassis where only the necessary tubes, meters, crystal oscillators and associated components are mounted.

The modulator and power amplifier units are very similar in internal arrangement and follow the general "chassis and shelf" layout described above. The associated power-rectifier unit is divided similarly into compartments for housing the components which supply the voltage to the modulator and power amplifier. The front compartment behind the door of the power-rectifier is accessible at all times and is not interlocked, but fully protected to permit operation of control switches. The rear compartment of this unit, behind the door, contains a special thyratron control circuit, the components of which are arranged on a hinged insulated chassis. An insulated shelf is also used to support the thyra-



Mechanical assembly of the Type 5762 tubes used in the power amplifier unit.

tron tubes which are visible from windows located on front of the transmitter door. A set of arc-back indicator lamps is also mounted on the thyratron tube shelf and is visible through jewels mounted in the vertical chassis.

A single blower, located in the lower part of the exciter cabinet, supplies all the air required for cooling the power tubes in both the modulator and power amplifier. Additional cooling required for components is also piped and bled from this same source. The air is carried from this common source by a simple air duct system that is part of the individual cabinet assembly, as described previously. Smaller pipe ducts or openings leading off the main ducts direct the air to the required "hot-spots."

Directly above the air ducts on the shelves of the modulator and power amplifier are mounted the 5762 tubes on an insulated box type mounting. This box is made of mycalex stock of sufficient size to provide the support and insulation required. This assembly is divided in the modulator to provide two separate tube mountings for a push-pull connected arrangement. In the power amplifier, the assembly is combined to provide a parallel connected arrangement for two tubes when operating at 5 kw., or three tubes when operating at 10 kw.

The four thyratron tubes, located in the rear of the "power-rectifier" because of their function, are spot cooled by a small blower assembly mounted below the tube shelf. Except for this small unit blower, all cooling air is supplied by the one main blower driven by one motor. There is one air filter to service; maintenance, in general, is minimized.

The blower motor is coupled to the wheel through a variable pitch pulley and "V" belt. The drive thus provides for variations in air requirements due to differences in altitude locations or whether operating at 5 or 10 kw.

The cooling air is vented through perforated covers in the tops of the cabinets. If it is exhausted into the operating room, ventilating fans located near the ceiling may be used to discharge the heated air in the summer or, in the winter the exhaust air from the transmitter may be used to heat the room. If the operating room is air conditioned, the heated air from the transmitter may be exhausted outside by ducts leading from the tops of the cabinets.

The addition of two reactors, a power amplifier tube with its voltage regulated transformer, and a few minor components is all that is required to convert from a 5 kw. transmitter to a 10 kw. transmitter. The space and mounting facilities for this conversion are provided in the 5 kw. design without additional space or expense and kept within the limitations of the original size and design.

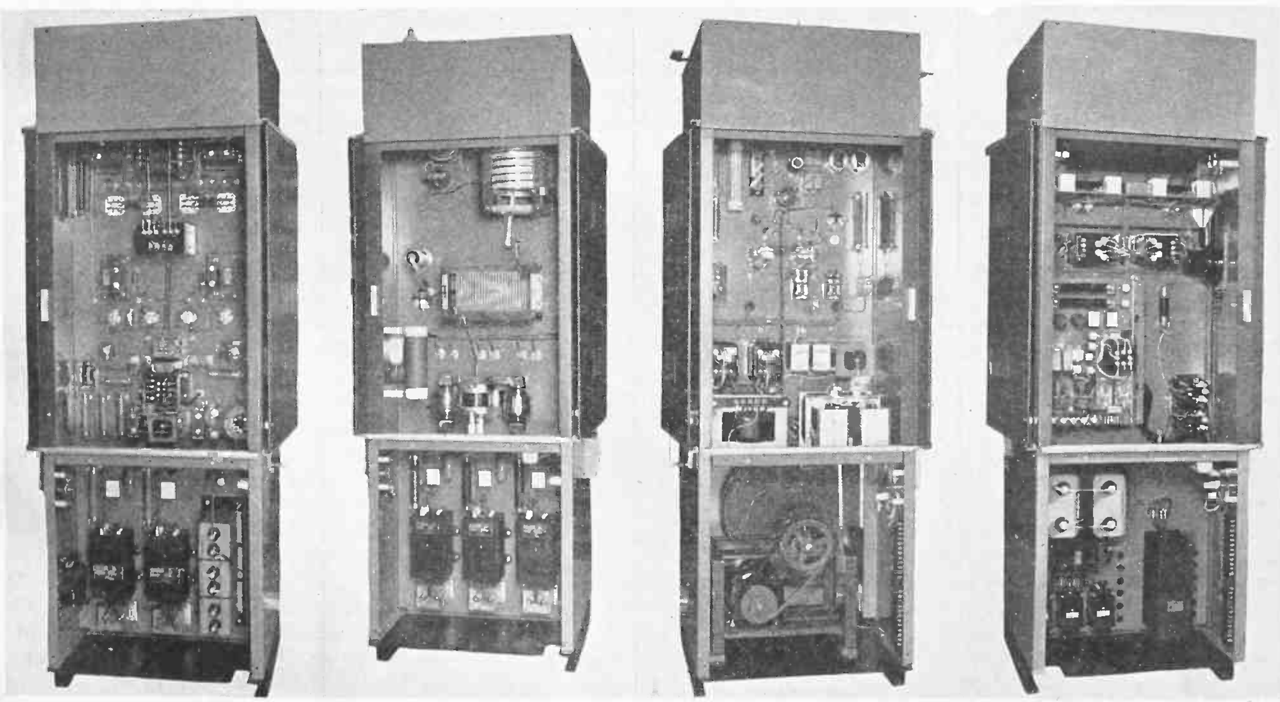
Provision has been made in the design for easy addition of cabinets for phasing or audio equipment. These cabinets are similar in design and are supplied as required by the individual radio station. By using a combination of wire ducts, filler channels and trim strips, these additional cabinets are easy to install and blend well with the over-all styling. The new BTA-1M Transmitter (a 1 kw. AM transmitter) has also been designed to be housed in a single unit of this same design. Therefore, it can be installed adjacent to the BTA-5G or 10G as a "stand-by" unit and still be in harmony with the over-all equipment.

Installation has been further simplified by the fact that each unit is shipped completely assembled, except for the few components that are removed to prevent damage in transit. Except for the interconnection cable, one buss, three "boot," and three ground strap connections are all that are required during installation. Wire duct covers, end shields, filler channels and top trim strips are all assembled with a minimum of hardware, using the same size throughout.

The control panel on the front center filler channel is easily removed for servicing by removal of several screws and four cable plugs. Thus, the control

(*Continued on page* 29)

Rear view of the various units with interiors exposed. Left to right: modulator, power amplifier, exciter, and rectifier and control.



Comparison of several models of the Balitron with a conventional 6V6GT. Shown from left to right are a type 6V6GT, and the Balitron voltage amplifier, negative resistance amplifier, and power amplifier.

CIRCUITS of the BALITRON TUBE

By

NORMAN Z. BALLANTYNE

The stable negative resistance characteristic of the Balitron can be utilized in several useful circuits.

THE DISCUSSION of the new Balitron Tube, which appeared in the March and April, 1951, issues of this magazine, mentioned several new circuits which are applicable only to this type of tube. These strange circuits include a converter which has the stability of a crystal-controlled oscillator without heat compensation, but is a true v.f.o., a new type of electron coupled oscillator, a negative resistance amplifier which uses positive feedback to prevent oscillation, a zero plate resistance amplifier, and a direct-coupled amplifier circuit using a common power supply.

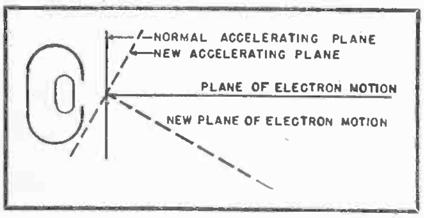
Perhaps the characteristic that contributes most to these unique circuits is the negative resistance characteristic which has been obtained with several test models of the Balitron. Negative resistance, where a decrease in applied voltage causes an increase in plate current, has been used before in the dynatron and transitron oscillator circuits, as well as others.

In the Balitron Tube, no critical biasing circuits are required to produce the negative resistance characteristic and it does not depend upon secondary emission. As a matter of fact, the negative resistance characteristic of the Balitron is developed by only slight changes in the tube element position from the normal positive resistance operation position. Negative resistance becomes, therefore, a characteristic of manufacture and a stable element at ordinary operating voltages.

Before we see how negative resistance is developed, it would be well to review the normal operation of the tube. In Fig. 2A we have a plan view of one model of the Balitron. In the normal operation of this tube, electrons are emitted from the cathode K and are formed into a beam whose major axis is at right angles to the plane of the paper. This beam-forming action is accomplished by the structure G_1, which is a solid metallic shield partially surrounding the cathode. Electrons in the beam are accelerated off the cathode wall by the field of attractive potential set up between the accelerating anode A on one side of the beam, and the positive deflection plate P_d on the other side. This attractive field accelerates electrons through the beam opening in G_1 and projects them through the plane of acceleration into the deflection area of the tube. The fields existing between P_d and the negative deflection plate N_d act upon the beam to bring it to a point of focus near the edge of the separator plate S_p. The beam is then split by the mutual electron repulsion, caused by the rapid increase in electron density per unit of space, and the repulsive field of the separator plate which is operated at ground potential. As a result of these forces, the beam is split so that under no signal conditions equal amounts of current flow to the target anode T_a and the target plate T_p.

Control is accomplished by changing the focal length of the beam so that it is deflected either into T_p or T_a. The beam is extremely sensitive to voltage changes upon N_d because, unlike ordinary deflection tubes, only a small part of the beam needs to be deflected to change the focal length.

Fig. 1. Comparison of normal plane of electron motion with new plane resulting from extension of electrode G_1.



With the essentials of the normal operation of this tube in mind, we can refer to Fig. 2B and see how negative resistance is developed in the Balitron. Basically, this is the same tube as shown in Fig. 2A. The major difference is the change in the G_1 structure near P_d, where a slight extension is made on G_1 in the direction of electron acceleration. This is coupled to the slight change in the P_d position to produce change in the plane of acceleration. In the normal tube, where the plane of acceleration is at right angles to the normal plane of electron motion, determined by erecting a line at right angles to the cathode wall and bisecting the G_1 opening, the new location of P_d and the extension of the G_1 structure shifts the plane of acceleration. This action causes the electrons to be accelerated in a direction which lies below the reference plane, as seen in Fig. 1.

Since the electrons are projected at a greater angle with respect to the surface of P_d than in the ordinary case, the voltage applied to P_d has much greater difficulty in deflecting the electron beam. As the voltage applied to P_d increases, the projection angle of the beam will be increased away from P_d, and the electron velocity will be increased.

Both of these characteristics make it more difficult for P_d to attract electrons and produce a reduction in the current drawn as the voltage is increased. Thus,

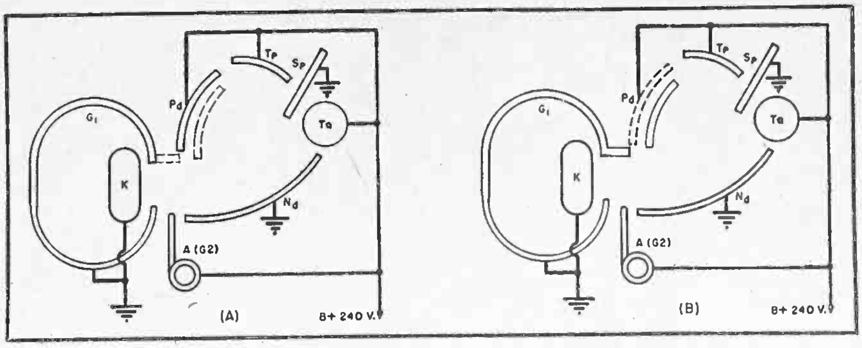


Fig. 2. (A) Plan view of one model of the Balitron. (B) Plan view of negative resistance version. Dotted lines in each case show the other version.

negative resistance for the P_d electrode is established.

As the T_p voltage is increased, it effectively builds up the field near P_d, since this is a relatively unipotential area. Thus, a negative resistance characteristic is established for T_p as well as P_d.

Of course, as either the P_d or T_p voltage decreases, the amount of angular shift produced in the electron beam is reduced and a greater number of electrons are received upon T_p and P_d, since they can be attracted more readily with a reduction in the energy level of the electrons. A reduction in voltage on either P_d or T_p below a critical level will reverse the resistance characteristic from negative to positive for the member concerned.

Relatively stable conditions of negative resistance operation have been obtained. Typical values are a slope yielding 13,000 ohms of negative resistance for P_d, and up to 40,000 ohms for the combined elements. These values were obtained with two hundred volts applied, and extend over an appreciable voltage range.

The negative resistance slopes obtained for the ordinary pentode and tetrode extend over relatively small values of voltage and current. As a result, the usable values of negative resistance are limited. In the negative resistance Balitron, however, the slope extends over much larger values of voltage and current, and the consequent usability of the negative resistance characteristic is extended. This can be seen from reference to Fig. 3 which shows a graph of the negative resistance slopes of P_d, T_p, and the combined curve of both.

In view of the much better negative resistance characteristic, it would be applicable to review the various circuits which use it. One of these circuits is the negative resistance oscillator. Despite the extreme stability of this oscillator, established as closely approaching the stability of the Pierce crystal, it is seldom, if ever, used outside the laboratory. One obvious reason is the extremely low efficiency and the resultant low power produced with the pentode tube. With an increase in power output, it would seem to be of extreme value.

The Balitron is adaptable to the operation of a negative resistance oscillator by simply inserting a tuned circuit having an impedance equal to, or greater than, the value of negative resistance in the circuit of P_d, T_p, or the combined elements, depending on which negative resistance slope is used. A typical circuit is shown in Fig. 6A where the combined elements are used. A more complex, but even more stable and powerful, circuit is the negative resistance electron-coupled oscillator which is shown in Fig. 6B.

In this circuit, the negative resistance of T_p and P_d causes oscillation to occur across the tank circuit composed of C_1, L_1. Since relatively high values of resistance are obtainable, the tank impedance can be relatively large without driving off the negative resistance curve as high impedance tanks will do where they greatly exceed the internal resistance of the tube.

As oscillation is developed within the tank by negative resistance action, sinusodial variations in the current flowing to T_a will result. This change in current appears upon T_a and is applied to the tank circuit L_2, C_2, which is tuned either to the same frequency as L_1, C_1, or to some multiple of that frequency. Thus, the negative resistance tank provides the frequency control of the circuit, with this frequency control electron coupled to the output tank through current variations. It is obvious that loading of the negative resistance tank is eliminated, and the output tank impedance is not necessarily held to the values required for negative resistance operation. The stability should thus be greatly improved.

Another possibility for increasing the effectiveness of this oscillator is the circuit shown in Fig. 6C. This is a negative resistance oscillator employing feedback to increase the effective power of the oscillator without decreasing the stability to any great extent. In this circuit, the negative resistance tank coil is center tapped. The coupling capacitor C_3 is inserted to couple the voltage present upon the lower end of the coil L_1 to N_d. Phase relationships must be such that the N_d voltage changes in phase with the T_p-P_d voltage. A study of the circuit will show that this condition is satisfied. In the ordinary circuit, this in-phase feedback would be degenerative but here, due to the strange characteristics of the tube, it operates as positive feedback since N_d and T_p-P_d are in phase in any case. It is well to note that the negative resistance tank circuit is in complete control of the operation of this circuit. The feedback does not produce oscillation (that occurs in the tank circuit itself) but increases the power output that it is possible to obtain. Exactly what effects will appear in regard to stability have

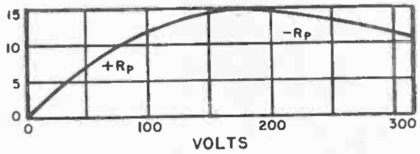
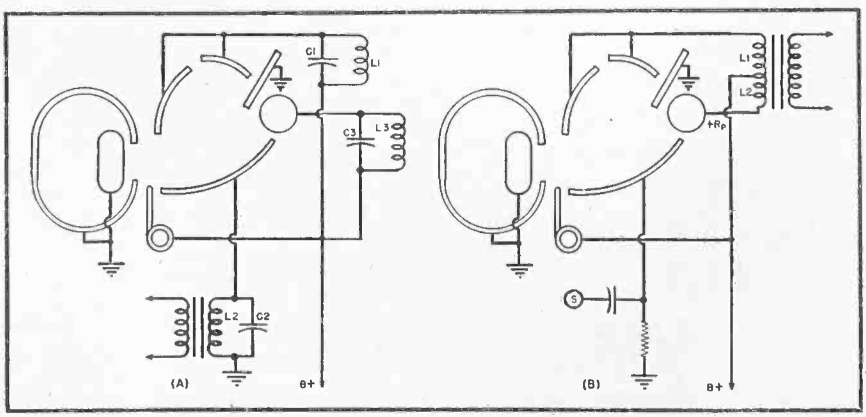


Fig. 3. Graph showing negative resistance slope of Pd and Tp.

Fig. 4. (A) The Balitron as a converter. (B) Amplifier circuit using the Balitron.



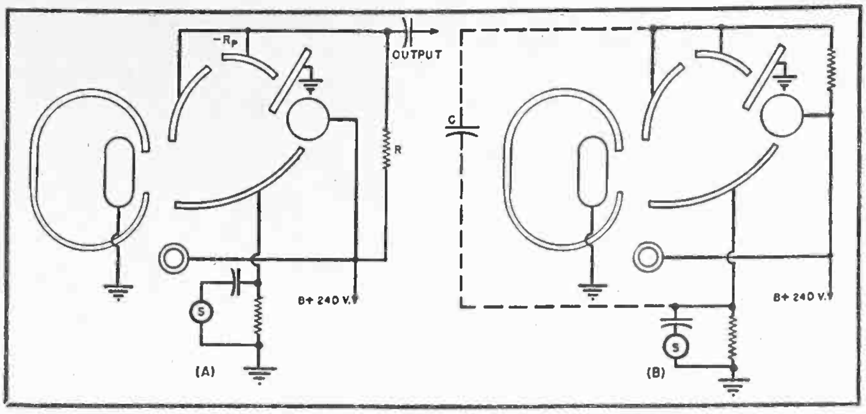


Fig. 5. (A) Negative resistance amplifier circuit. (B) Same as (A) with regenerative feedback provided by condenser C for the purpose of increasing gain.

not been established, but it is evident that stability will decline somewhat as the power output increases, due to the change in effective slope.

In these possible circuits, the startling frequency stability of the negative resistance oscillator is combined with an output tank to produce an oscillator having reasonable efficiency and power output. While no extensive tests have been made, it would seem that this oscillator would oscillate well into the v.h.f. region and provide a much wider basis for using this highly stable v.f.o.

While the negative resistance Balitron oscillator is still fresh, the possibility of using this tube as a converter must be considered. This circuit, shown in Fig. 4A, uses a tank circuit composed of C_1, L_1 tied to the negative resistance T_p-P_d. The variation in beam current thus produced is beating against the change in current produced by the signal voltage injected upon N_d by the signal tank circuit composed of L_2, C_2. The action of the signal voltage and the oscillator voltage will add when in phase, oppose when out of phase, and produce a resultant voltage when any phase difference exists. It is obvious that the output appearing upon T_a will be a heterodyne of the two frequencies. Converter action is thus accomplished with the highly stable negative resistance oscillator as a base.

Several advantages are inherent in this type of converter. The immense stability of the negative resistance oscillator is introduced with a no-drift tube to provide the extreme in tunable converter stability. The flow-back, or reverse current flow which takes place in an ordinary converter tube, is eliminated here since the modulating signals are applied simultaneously from opposite sides of the beam, not on consecutive control planes as in the ordinary case.

A third circuit using the negative resistance characteristics of the Balitron is the zero plate resistance amplifier. In this circuit, shown in Fig. 4B, the normal internal resistance of the tube is effectively cancelled out so that the total power is applied to the load. The concepts of this circuit involve not only the negative resistance T_p-P_d, but a positive resistance on T_a equal in magnitude to the negative resistance of T_p-P_d. In addition, the coefficient of coupling between L_1 and L_2 of the output transformer must approach unity.

In practice, the conditions of equal values of negative and positive resistance have been met with a negative resistance of 32,000 ohms on T_p-P_d, and the same value positive on T_a. Unity coupling was not, however, obtained.

In operation, the source (S) drives N_d throughout its cycle. On the positive swing, the I_{Ta} is decreased and the I_{Ta-Pd} is increased, with a resultant decrease in voltage on this member. The decrease in T_p-P_d voltage, because of the negative R_p, tends to increase the I_{Tp-Pd} but, at the same time, the increase in E_{Ta} tends to oppose this increase. The beam is then attracted equally by both plates and is free of the inherent resistance of either one. Since the internal R_p of the Balitron is the resistance of the beam to attraction by the plates and would normally damp the signal, it is clear that removing the damping action, by providing an equal attraction all over the voltage swing, is the same as removing the internal resistance.

The same action occurs on the negative swing, with the reduction in E_{Ta} caused by an increase in I_{Ta} being effectively cancelled by an increase in E_{Tp-Pd} and, because of the negative R_p, a reduction in I_{Tp-Pd}. It is then clear that the internal resistance is cancelled out on both sides.

In this manner, while the factors of internal resistance are all present within the tube, the effective resistances to beam movement are cancelled out by self-controlled feedback. The whole resistance presented to the flow of current within the tube is cancelled out and all the power is applied to the load.

Quantitative analysis of the power gain has not been accomplished, but the circuit has been tested for voltage gain. Where the maximum gain factor

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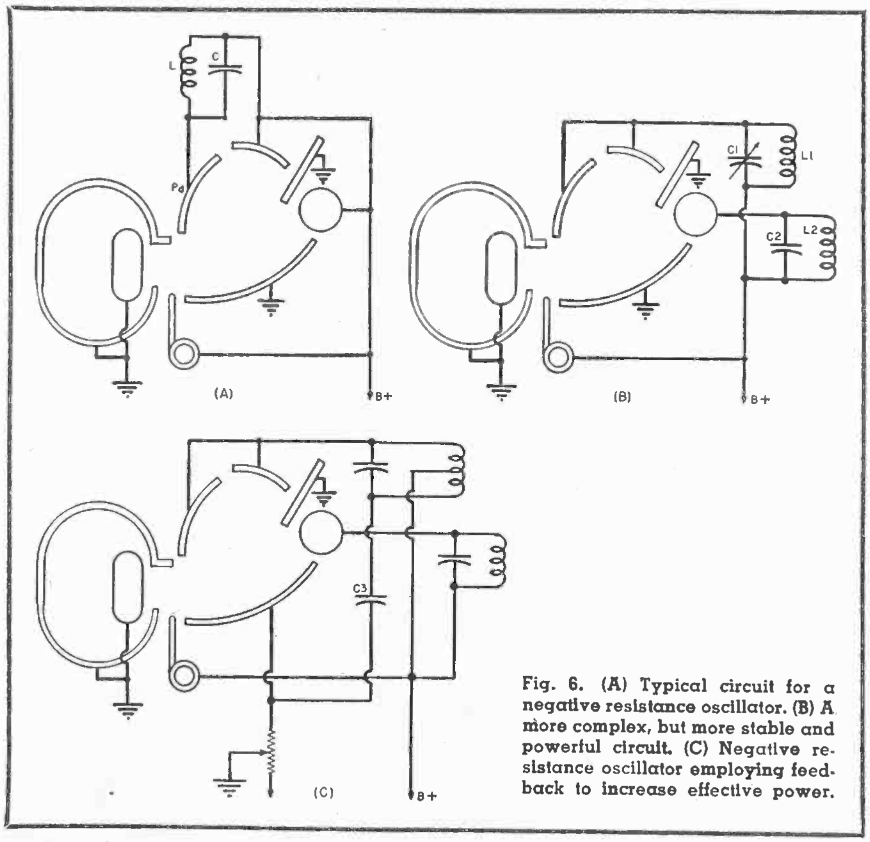

Fig. 6. (A) Typical circuit for a negative resistance oscillator. (B) A more complex, but more stable and powerful circuit. (C) Negative resistance oscillator employing feedback to increase effective power.

The Rectilinear AMPLIFIER

By

FRED JEWELL

Consulting Engineer
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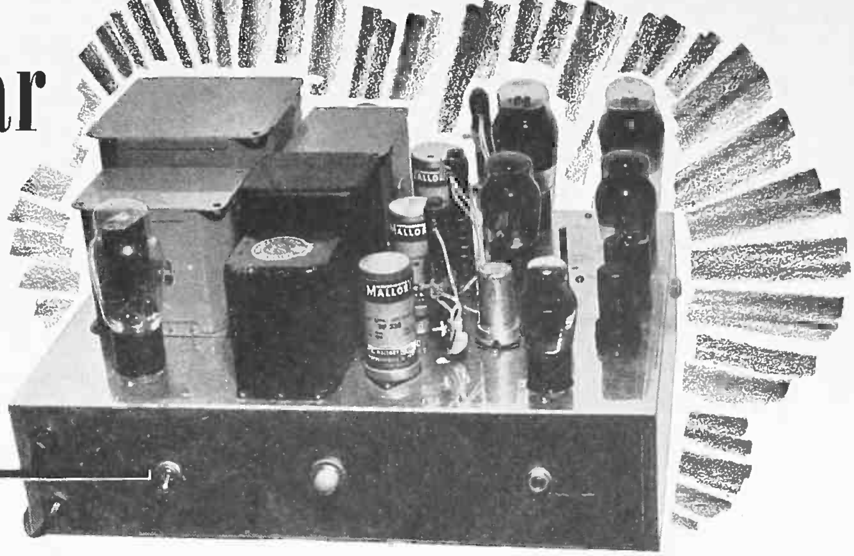


A completed version of the amplifier. It is used to amplify the output of a photocell in photoelectric engraving equipment.

A novel circuit is used to provide essentially flat response from zero to several kilocycles.

FOR SOME time there has existed a need for a device that could accurately amplify minute electrical signals resulting from electrical, mechanical, temperature and optical variations, over a range of frequencies from d.c. to several kilocycles. Existing circuits performing applications of this nature have had their shortcomings—principally instability, feedback, cumulative high voltage, grid blocking, high grid bias, etc. The necessary essentials of an amplifier to meet these exacting requirements are:

1. Straight line amplification from zero to several kilocycles in frequency.
2. Freedom from distortion and harmonics.
3. Absolute stability and high gain.
4. A time rise factor reduced to an absolute minimum.

Numerous tests have proven that the Rectilinear Amplifier presented in this article meets the above standards.

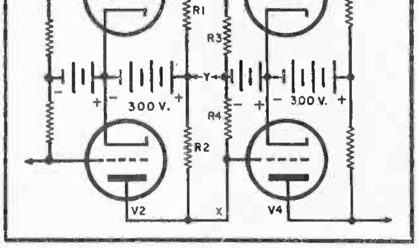
From a casual glance at the schematic diagram of Fig. 5, it may appear that this amplifier is nothing more or less than a push-pull, direct-coupled amplifier with a separate power supply for each stage. On closer inspection, however, it will be found that it is neither push-pull nor direct-coupled, unless a broad interpretation of a bridge-type amplifier could be called a push-pull amplifier. Although it is true that a bridge-type amplifier does automatically incorporate the push-pull principle, a push-pull type amplifier does not have the gain or stability of the bridge-type amplifier.

Granting the rectilinear amplifier does connect the plates of one stage of amplification to the grids of the following stage, it is not directly coupled; it is *directly connected.* By the use of a separate power supply for each stage, it is essentially an a.c. coupled amplifier. This new and unusual feature overcomes the inherent faults of a d.c. coupled amplifier and introduces advantages which will be outlined later.

Fig. 1 indicates the type of basic bridge circuit used, in which the output of one stage is directly connected to the input of the following stage. When all resistors are equal, the flow of current in R_3 and R_4 will be the same, and the potential across these resistors at points *XX* will be zero. Consequently, no potential will be impressed upon the grids of V_3 and V_4 other than the usual grid bias.

Consider V_1 and V_2 as electronic valves (shown in Fig. 2A), and KP_1 and KP_2 as the cathode-plate resistance of these tubes. If circuit KP_1 is closed and KP_2 is opened by a potential impressed upon the grids of these tubes, the bridge becomes unbalanced and the current will flow in the direction of the arrows. A potential difference of 200 volts will then be impressed between the grids of V_3 and V_4, the grid of V_3 becoming negative and the grid of V_4 positive. However, if a reverse potential is applied to the grids of V_1 and V_2, as indicated in Fig. 2B, it will also unbalance the bridge circuit and cause current to flow in the opposite direction. This will cause a potential difference of 200 volts to be impressed between the grids of V_3 and V_4, but the grid of V_3 will become positive and grid of V_4 will become negative. Therefore, the polarity is reversed across V_3 and V_4 by a change of polarity across the grids of V_1 and V_2. Tubes V_1 and V_2 cannot become completely closed or opened, but any variation of the cathode-plate resistance of these tubes, caused by a change of potential upon the grids, will cause a corresponding potential change across the resistors of the plate circuit of these tubes, within the limits of their characteristics. Actually this condition causes the circuit to become an electronic relay.

Fig. 1. The basic bridge circuit as it is used in the rectilinear amplifier.



It will be noted that if a physical connection is made at point *Y*, Fig. 1, the value of the bridge type of amplification is destroyed and it becomes a direct coupled amplifier. Also, a potential difference of 150 volts will exist between these two points, which would throw a high negative bias on the grids of V_3 and V_4. This would cause grid blocking and a consequent loss of stability and gain which would necessitate compensating measures to offset this problem, and thus tend to introduce other undesirable complications.

The primary objective of any amplifier is to convert a minute electrical signal pattern into an exact duplicate output power pattern which can be converted into mechanical and other forms of energy by a transducer. Consider Fig. 3, which could be a pattern of an input voltage variation, regardless of whether

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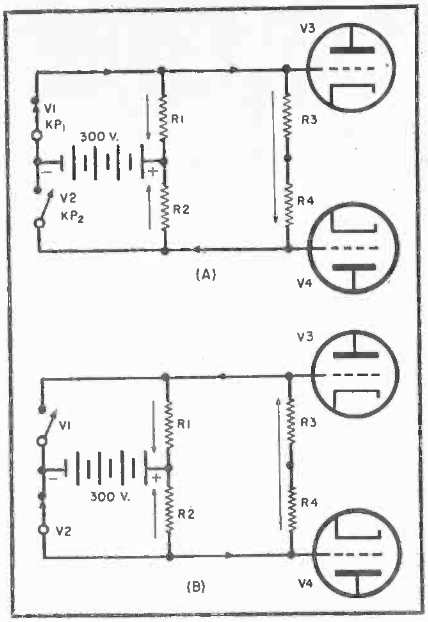


Fig. 2. Analogy of the theory of the circuit (A) with one polarity, and (B) with the polarity reversed.

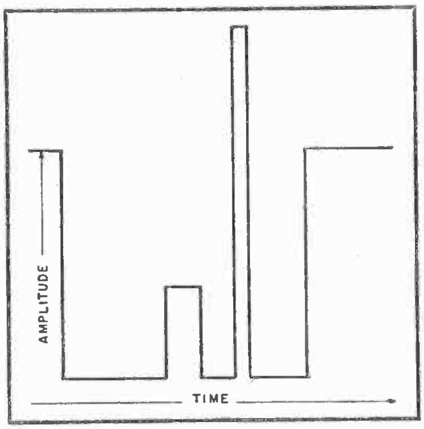


Fig. 3. Representative signal pattern.

or not this would be radio signal impulses, signals from a generator, variation of light density impinging upon a photoelectric cell, or a low frequency audio signal such as that appearing at a phonograph pickup from either wire, tape, or a mechanical recording.

An amplifier which would give an output which is an exact duplicate of this pattern, without any slopes or rounding of corners, could be considered an amplifier with suitable characteristics. It is limited only to the time required for the current to built up in the circuit. For most practical purposes, the time rise factor is very low when pentodes are used.

An amplifier which uses any method of impedance coupling from one stage to another in cascade amplification, such as condensers or transformers, could not reproduce this pattern as effectively, due to the finite time required for current to build up in inductance and capacity.

The first stage of the bridge-type amplifier (Fig. 1) provides the basic circuit requirements. It can measure illuminations corresponding to a phototube current of only 10^{-10} ampere. Although this circuit has little or no value as an a.c. amplifier, it will not float or drift and is very stable. In coupling this to another stage of amplification without a condenser or a transformer as a medium of coupling, we have an a.c. amplifier as well as a d.c. amplifier with the required characteristics.

This same circuit automatically incorporates the principle of push-pull amplification. The second and other even harmonic currents generated within the stage produce no effect on the output resistors and, hence, do not appear in the output circuit. Push-pull operation requires less filtering of the 60-cycle power and delivers more than twice the power of a single tube.

Interstage Coupling

The interstage coupling of cascade amplification in direct-coupled amplifiers presents the main problem. The fact that all the stages of the entire amplifier are in series, complicates this method considerably. This problem is best explained by considering Fig. 4, which shows two stages of intermediate coupling feeding an output power stage.

Assume the following:

1. V_1 is a low plate voltage tube of the order of 90 volts plate supply and 5 ma. current flowing in the plate-cathode circuit.
2. V_2 is a type of tube with characteristics of the order of 300 volts plate supply and current carrying capacity of 30 ma.
3. V_3 has a plate voltage of 450 volts and a current carrying capacity of approximately 100 ma.

This would mean that a total plate potential of 90+300+450 volts, or a total of 840 volts, would have to be applied to the amplifier. Therefore, there would be a potential difference of 840 volts between the input and output, involving all the difficulties of insulating and shielding, and the physical danger of this high voltage.

Now, as the plate of each preceding stage is directly coupled to the grid of the following stage, a high negative bias is applied to the grid of the next tube. This produces high negative bias at points X of Fig. 4. It may be overcome to a degree by means such as pointed out by Loftin-White in their direct-coupled amplifier but, here again, we introduce another complication to overcome the inherent objection of this type of an amplifier.

As pointed out previously, any change in the potential of the entire circuit affects the circuit as a whole. This especially applies to the grid-cathode circuit, as any change in potential of the grid-cathode circuit is amplified by the amplification factor of the tube itself, which will have a tendency to throw the amplifier into a state of oscillation. Once more, means may be introduced to overcome this difficulty to a certain extent, such as tube voltage regulators and line voltage regulators of the power supplied by an a.c. rectifier.

By considering the schematic diagram of Fig. 5, it becomes readily apparent how these objections are overcome and, in effect, this amplifier imbues all the characteristics of an a.c. amplifier. Yet, it is directly connected and auotmatically takes advantage of all the features of a direct-coupled amplifier.

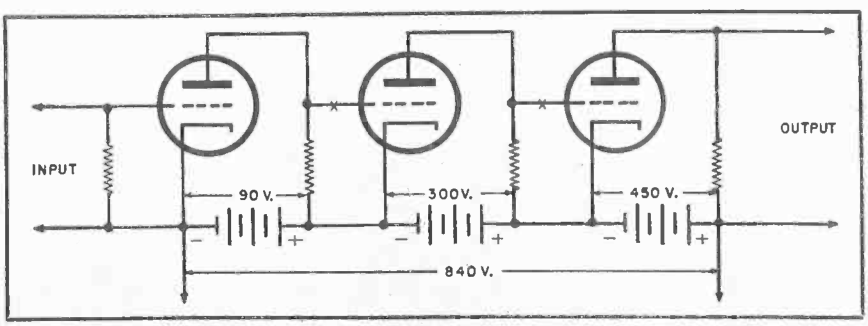
It is very important to understand that the B power supply for each stage is independent of the other supplies. This method of coupling eliminates the necessity of having to use a high positive grid bias on the grid of the following tube. Considered in another way, this circuit embodies the principles of resistance coupling without the use of condensers. It also incorporates the principles of the bridge-type amplifier with its advantages of high gain and stability.

Application and Characteristics

The schematic diagram of the complete, all-purpose amplifier, embodying all the principles covered in this article, is shown in Fig. 5. Under actual test, this amplifier will take the output of a

(*Continued on page* 31)

Fig. 4. Circuit diagram of a conventional direct coupled amplifier with two stages of intermediate coupling feeding an output power stage.



SLOT RADIATORS AND ARRAYS

The characteristics of slot arrays and the effects of slot position are detailed.

By R. J. STEGEN

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Hughes Aircraft Company**

> *Author's Note: The measurements recorded in this article are based on a slot width of 0.0625 inch in a 1.0 x 0.5 inch rectangular guide.*

ASSOCIATED WITH the electromagnetic field in a wave guide or other transmission line is the distribution of current over the boundary surfaces. The arrangement of current is such that a narrow slot may be cut into the transmission line parallel to the direction of current flow. This slot will not perturb the current distribution in the transmission line and will therefore not couple the internal field to space. Examples of this type of slot are the slots cut along the center lines of the broad sides of rectangular wave guides, those on coaxial lines which are parallel to the axis of the transmission line and those which are cut into the narrow side of rectangular wave guides normal to the guide axis. The first two examples cited offer a means of entry into the transmission system and are used to study the internal field configuration, usually connected with impedance measurements. The third example of a non-radiating slot has been used as a parasitic element in a Yagi array of slots.

If a narrow slot is oriented so that it is not parallel to the current lines, it will constitute a radiating element. The degree of coupling of the internal field to space depends on the current density intercepted by the slot and the component of the length of the slot transverse to the current lines. The type of circuit element that the radiating slot presents to the transmission-line representation of the wave guide is a function of the position and orientation of the slot on the wave guide.

Linear arrays of slots may have carefully controlled illumination over the aperture. Such arrays may be used as antennas where the optical approach is unsatisfactory due to limitations of space, weight or windage requirements. The design of such arrays requires a knowledge of both the power radiated by each slot and the relative phase of the fields from each slot. Available data were used to design shaped beams and low side lobe level arrays. The results were not up to expectations so that improved data were desired. In addition, the phase of the fields radiated by slots other than the resonant ones was not known.

A series of measurements was performed on slots having their longitudinal axis parallel to, but displaced from, the axis of the wave guide. This type of slot may be represented as a pure shunt element across the transmission-line representation of the wave guide. The measurements were conducted at X-band, but the results indicate that the necessary information for designing arrays at other frequencies may be obtained with very few checking measurements. Direct scaling of parameters obviously may be used.

The admittance measurements were conducted along two lines:

(a) Direct admittance measurements using a traveling probe in a slotted wave guide and

(b) Calculations of the admittance of slots from radiation pattern measurements.

Slots having a conductance greater than 0.1 can be measured very accurately by the direct measurement technique. Lower conductance slots are measured more accurately by comparing them to a known high conductance slot in method (b) above.

The power pattern of 2 isotropic elements is proportional to:

$$P = A_1^2 + A_2^2 + 2\,A_1 A_2 \cos\left(kd\cos\theta + \emptyset\right) \quad . \quad . \quad . \quad (1)$$

where A_1 and A_2 are magnitudes of the excitation coefficients, d is the spacing, and $\emptyset$ is the phase difference between the coefficients. The radiation pattern is maximum or minimum depending on whether $\cos(kd\cos\theta + \emptyset)$ is $+1$ or -1. Then the ratio:

$$\frac{A_2}{A_1} = \frac{\left(\frac{P_{max}}{P_{min}}\right)^{1/2} - 1}{\left(\frac{P_{max}}{P_{min}}\right)^{1/2} + 1} \quad . \quad . \quad . \quad . \quad (2)$$

is obtained and:

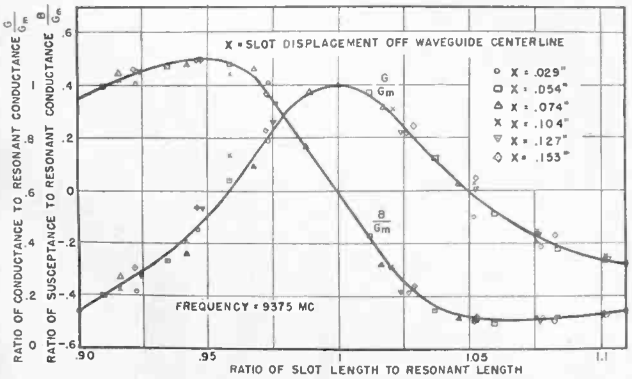


Fig. 1. Variation of the components of the admittance of a longitudinal shunt slot.

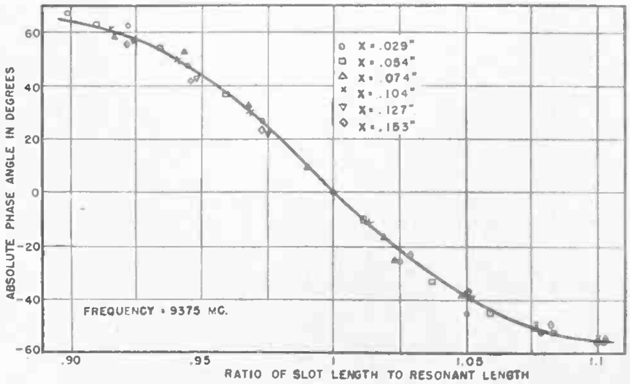


Fig. 2. Absolute phase angle of slot radiation versus the ratio of length to resonant length.

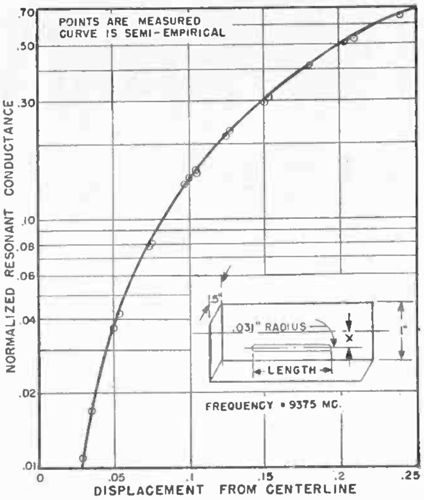


Fig. 3. Resonant conductance of longitudinal slot vs. slot displacement.

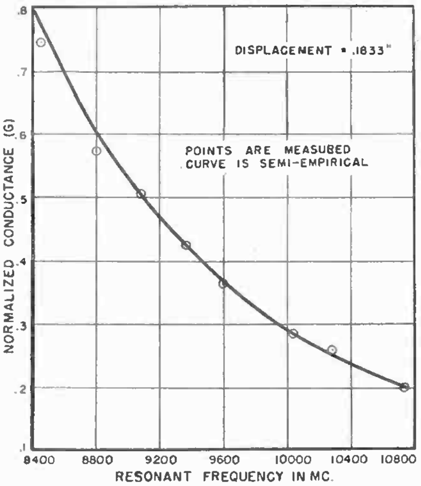


Fig. 4. Resonant conductance of longitudinal shunt slot vs. resonant frequency.

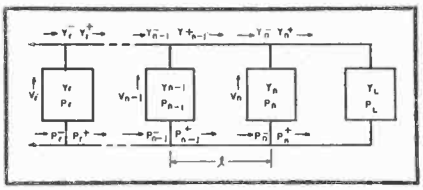


Fig. 5. Equivalent block circuit of an array of shunt elements.

$$\emptyset = (2n + 1)\,\pi - k\,d\cos\theta_{min}, \quad = 2n\,\pi - k\,d\cos\theta_{max} \quad . \quad . \quad . \quad . \quad (3)$$

where θ_{min} is the position of P_{min}.

For shunt slots spaced an integral number of guide wavelengths apart (neglecting guide attenuation):

$$P_i = |V|^2\,G_i = K\,A_i^2 \quad . \quad . \quad . \quad . \quad (4)$$

Since K may be arbitrarily made equal to V^2,

$$G_i = A_i^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

and therefore:

$$G_2 = G_1\left(\frac{A_2}{A_1}\right)^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

We know G_1 from slotted line measurements and A_2/A_1 from above.

Using an analysis based on Maxwell's equations, it can be shown that the ratio of the field across a longitudinal shunt slot to the total field in the wave guide is:

$$\frac{E_s}{E_t} = j\,K\,Y \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

where K is a positive real quantity. This equation shows that the field in the wave guide lags the radiated field of a resonant slot by 90°. If the wave guide field at the slot is taken as a reference, then the phase of the radiation is the phase of the admittance or:

$$\emptyset = \text{arc tan}\,\frac{B}{G} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Watson[1] has shown that the admittance of a slot traverses a circle on the rectangular coordinate admittance plane as the length of the slot is varied. This circle satisfies the expression:

$$G = G_m\cos^2\emptyset \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where G_m = the maximum value of the admittance and occurs at resonance. Tests were performed on six slots, each having different displacements from the wave guide center-line.

A polar plot of measured values of G and $\emptyset$ shows that the points lie on a circle which coincides with the circle defined by Eqt. (9). From these circles the maximum conductance of each slot is obtained. The points in Figs. 1 and 2 were also determined from the above measurements. It is interesting to note that the ratios G/G_m and B/G_m and the phase of the radiation are independent of the center-line displacement of the slots.

Stevenson's[2] expression for the conductance of a resonant longitudinal shunt slot in a rectangular wave guide is:

$$G_T = 2.09\,\frac{a\,\lambda_g}{b\,\lambda}\cos^2\left(\frac{\pi}{2}\frac{\lambda}{\lambda_g}\right)\sin^2\left(\frac{\pi\,x}{a}\right) \quad (10)$$

where x = slot displacement off the wave guide center line.

The measurements made on longitudinal shunt slots in 1.0 x 0.5 inch (outer dimension) wave guide at 9375 mc. differed from the value obtained from (10) by the factor 0.96. The semi-empirical expression for the conductance of a longitudinal shunt slot at 9375 mc.,

$$G = 0.96\,G_T = 1.19\sin^2\left(\frac{\pi\,x}{a}\right) \quad . \quad (11)$$

is plotted in Fig. 3. Radiation measurements with a large ground plane about the slots gave essentially the same results as direct admittance measurements without a ground plane. The difference must be attributed to finite slot width and finite wall thickness. The resonant frequencies of a shunt slot were determined as the slot length was increased.

A typical curve of the resonant frequencies of a shunt slot as a function of slot length is shown in Fig. 6. The empirical curve is directly proportional to free space wavelength.

Since slot resonant length is directly proportional to free-space wavelength, a single curve of slot length as a function of displacement from the wave guide center-line will be sufficient. Fig. 7 is a plot of the resonant lengths in free space wavelength of longitudinal shunt slots as a function of the displacement off the wave guide center-line. Watson[3] has shown that for small displacements the theoretical length of a longitudinal shunt slot increases parabolically with its displacement from the center of the broad face. This is experimentally verified by this curve. Fig.

Fig. 6. Shunt slot resonant frequency vs. length.

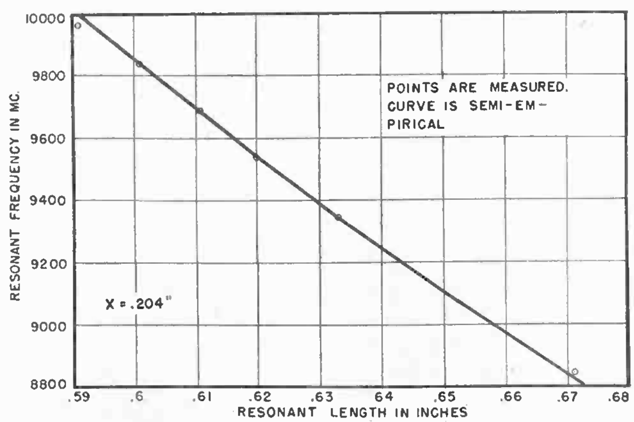
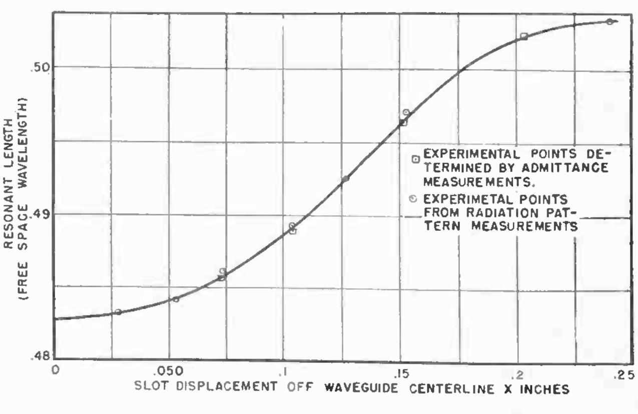


Fig. 7. Shunt slot resonant length versus displacement of the center line off the wave guide.



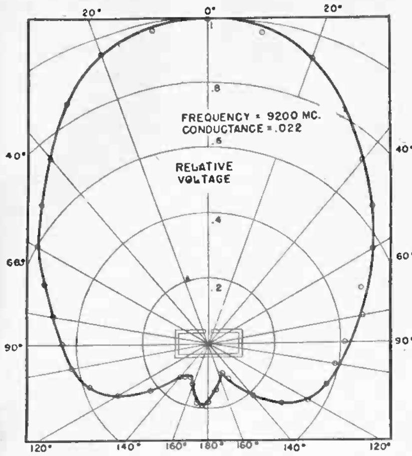


Fig. 8. E-plane radiation pattern of a low conductance longitudinal shunt slot.

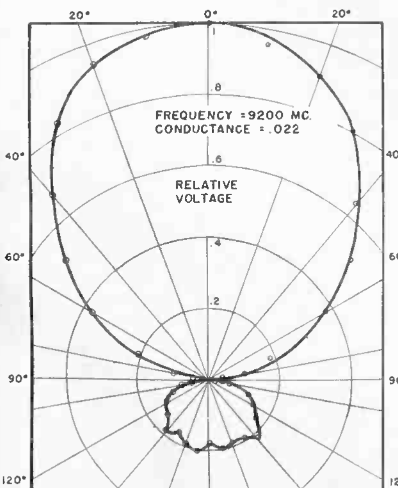
4 is the conductance of a resonant slot as a function of frequency. The points are measured and the curve satisfies the equation:

$$G = 1.61 \frac{\lambda_g}{\lambda} \cos^2\left(\frac{\pi}{2} \frac{\lambda}{\lambda_g}\right) . \quad . \quad . \quad . \quad (12)$$

Slot Radiation Patterns

The design of an array of shunt slots to give a specified radiation pattern requires that the radiation pattern of a single slot be known. For a shunt slot array in a straight wave guide the pattern of primary interest is the H-plane pattern. Fig. 11 is a typical H-plane pattern for a single slot. When a large ground plane was placed about the slot, the pattern was altered only by the elimination of the backward lobe. This pattern is the same as one-half of an E-plane pattern of a half wavelength wire dipole in free space. It is of interest to compare the E-plane patterns of a low conductance slot (Fig. 8), a high conductance slot (Fig. 9), and a slot with a large ground plane about it (Fig. 10). The asymmetry of the high conductance slot on the surface of the wave guide caused the radiation pattern to tilt off the normal. Symmetry in the pattern resulted when the slot was surrounded by the large ground plane. The amplitude variations in the radiation pattern are due to interference effects caused by reflections from the edges of the ground plane. The measured positions of the maximum and minimum values check very closely with those calculated from the expression:[4]

Fig. 11. H-plane radiation pattern of a longitudinal shunt slot.



$$\theta = \text{arc} \sin \frac{n\lambda}{2d} . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

which is obtained by assuming elements at the edges of the sheet having random amplitude and phase. The distance across the sheet is $2d$.

The change in the field patterns due to lateral displacement must be compensated for when designing an array using these slots in the surface of a plane wave guide. No compensation is necessary when the surface about the slot is a large ground plane.

An array of slots may be used to produce a shaped beam or a beam with the narrowest main lobe radiation pattern for a given side lobe level. Both of these types require arrays having carefully controlled aperture distributions. The relative magnitude and phase of the radiation fields required from each slot may be determined by several known methods. One may use the potential analogue method, or the equivalent analytical method discussed by T. T. Taylor and J. R. Whinnery[5], or methods such as Fourier analysis, which are less general but often adequate in particular cases. Having determined a particular set of excitation coefficients, the next parameters to decide upon are element spacing and transmission line termination. The latter usually depends on whether the elements are resonantly or non-resonantly spaced. An open circuit across the terminating slot is used with a resonantly spaced array. The spacing between elements is determined by the type of radiation pattern required and the input admittance characteristics desired. For example, to have high efficiency, a short array requires a non-dissipative termination, and for greatest bandwidth the spacing must be resonant. A long array will have a small bandwidth if resonantly spaced with either type of termination. Non-resonant spacing and matched termination give the long array very good bandwidth characteristics.

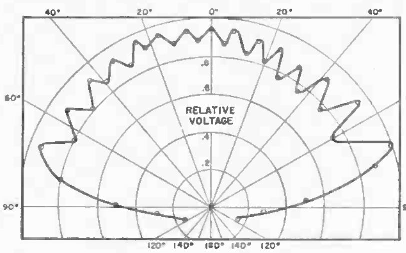


Fig. 10. E-plane radiation pattern of a slot in a 19-inch square ground plane at 9200 megacycles.

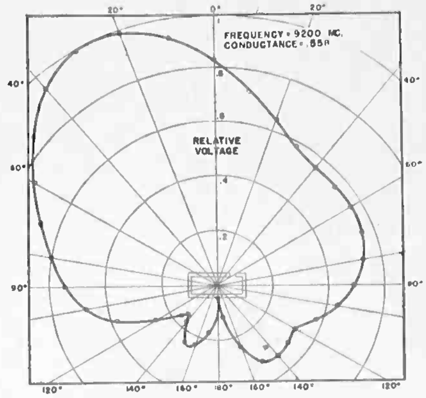


Fig. 9. E-plane radiation pattern of a high conductance longitudinal shunt slot.

Fig. 5 is the equivalent circuit of an array of shunt elements where mutual effects between the elements, except their coupling to the dominant mode, are neglected. This circuit applies very closely to longitudinal shunt slots. The array consists of n elements, the first being nearest the generator.

The exact transmission line equations are relatively complicated. However, in particular cases, these may be simplified considerably.

Resonant Spacing

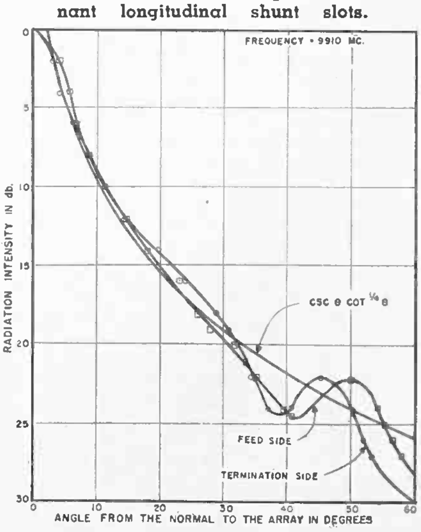
For arrays with half or full wavelength spacing:

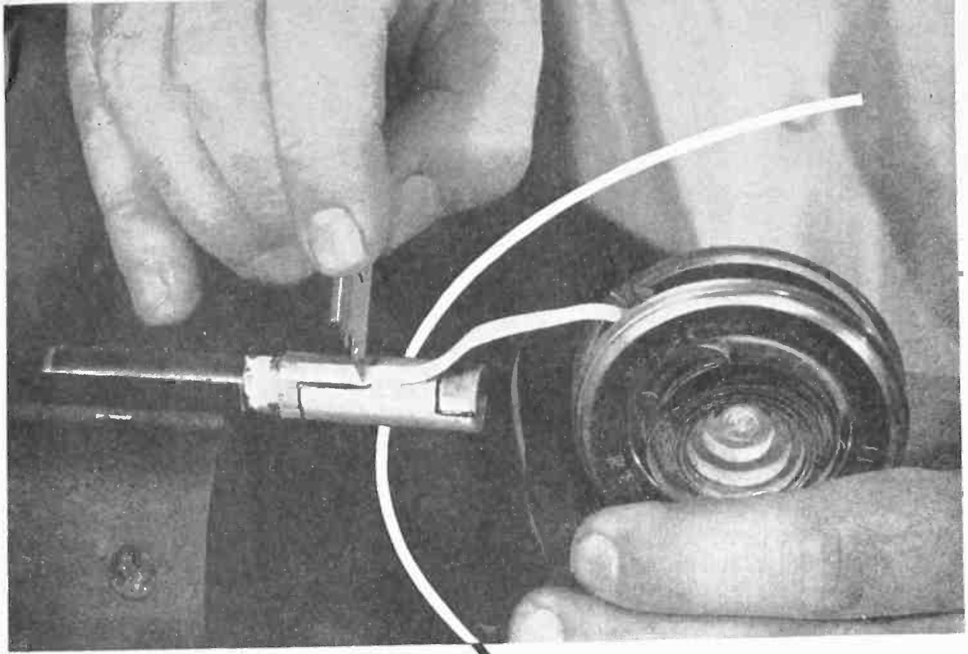
$$V_r = V_n \left[1 + \alpha l \sum_{s=1}^{n-r} s Y_{r+s} \right] \quad (14)$$

which reduces to $V_r = V_n$ for short arrays. Because:

(*Continued on page* 26)

Fig. 12. Radiation pattern of a seventeen-element array of resonant longitudinal shunt slots.





One of the new NBS resistors is set in place on a miniature cylindrical chassis. It is cured by baking.

HIGH-TEMPERATURE ADHESIVE TAPE RESISTOR

This NBS development permits better control of resistors in printed circuit techniques.

PRINTED electronic circuits, in which components and wiring are superimposed directly on insulating bases, are being used increasingly because of their adaptability to economical mass production and because they facilitate miniaturization of equipment. A major disadvantage of the printed circuit method, however, has been the difficulty of incorporating satisfactory resistors in the circuits. This difficulty has been largely overcome by an adhesive tape resistor method recently devised by B. L. Davis and associates of the National Bureau of Standards. The new resistor method was developed as part of a program of electronics research and development sponsored by the Navy Bureau of Aeronautics.

In this technique, circuits are first printed in narrow metallic bands on insulating bases, leaving a small gap at each point where a resistance is required; one of the self-adhesive resistors is then cut from a strip and pressed into position. Much better control of resistance values is possible than with previous printed resistor methods, and higher yields of acceptable assemblies are assured. The new method thus appears to combine the advantages of printed resistors and of separately manufactured resistors. The NBS tape resistor was developed to withstand the high temperatures of very compact equipment and operates satisfactorily at temperatures up to 200°C; in other electrical characteristics it is similar to present film-type carbon resistors.

In the past, the usual method of introducing resistances into printed circuits has been to paint or spray a strip of resistance material directly on the base plate. The desired value of resistance is obtained by varying the composition and dimensions of the resistance strip laid down. Production of individual resistors to close tolerances by this direct-coating method is difficult, and the reduced probability of producing a number of satisfactory resistors on the same base plate greatly decreases the yield of acceptable assemblies.

Compositions and techniques used in making and applying the new tape resistors are remarkable for their simplicity. The resistor consists of a mixture of graphite or carbon black, resin, and solvent, applied in a thin layer to a thin roll of asbestos paper tape.* The resistive coating is sufficiently adhesive to stick to an insulating base plate and to make satisfactory electrical contact with metallic terminals. When the resistor is in position, the resistance film is protected from abrasion and electrical shorts by its asbestos-tape backing. Resistor dimensions are kept constant. A variety of coating formulations gives a range of values from about 100 ohms to 10 megohms.

The resistor is manufactured by spraying the resistance mixture onto a moving belt of tape. A thin (0.002 inch) protective film of polyethylene is lightly pressed over the resistance coating for protection in handling and storage; it is easily removed when the resistor is used. An electrically-driven slitting machine quickly cuts the tapes into long strips of the desired width.

At present, the resistor tape, cut to width, is applied to printed circuitry by hand from a continuous spool. The tape is pressed into position and cut off with a razor blade. Plans call, however, for development of a device comparable to a wire stapler which will accept a roll of the resistor tape and apply and cut off a resistor of standard length each time a knob or handle is pressed.

Silicone resin** is used for the binder-adhesive because of its suitability for high-temperature operation. Since the curing temperature of the silicone resin formulations is high (300°C), and since curing is done after the resistors have been positioned in the circuit, the NBS tape resistor is, at present, applicable only to glass or ceramic base materials. However, enough work has been done with lower-curing resins to indicate definitely that they can be used in making tape resistors having cure temperatures low enough for application to some heat-resisting plastic materials. These resistors would be suitable for conventional operating temperatures.

The possibility of varying resistor dimensions to obtain a range of values

*"*Quinterra*" *tape* (Johns-Manville, *New York*) *has been found satisfactory.*

***DC* 996 *is the preferred resin of those investigated so far.*

was considered but rejected. This so-called "aspect ratio" system has the advantage of reducing the number of formulations needed for a complete resistor range, but it complicates equipment design and production. Resistor dimensions were therefore standardized at a length of 0.5 inch (0.3 inch interelectrode distance) and a width of 0.13 inch ± 0.02 inch. This slight leeway in width permits some adjustment of resistor value in the slitting operation. With constant dimensions, wattage ratings are substantially independent of resistance value, and different contact resistance values due to different contact areas of silver and resistor are eliminated.

Both natural and synthetic graphites, as well as various carbon blacks, are used in the resistor formulations. Values of the resistors are varied by changing the ratio of carbon to resin in the mixture and by using different carbons. The proportion of carbon to resin ranges from 10 to 50 per-cent; leaner mixtures have been found to give less favorable characteristics.

Tape resistors made from graphite mixtures have proved remarkably stable at ambient temperatures of 200°C. Another advantage of graphite formulations is that unusually low resistance values, down to about 100 ohms, can be obtained. Unfortunately, however, the useful upper limit of the graphite formulations seems to be about 5000 ohms. Carbon blacks, which are less desirable at high temperatures, give values from 5000 ohms to 10 megohms. Only a few carbon blacks have been found which yield tape resistors satisfactory for operation at 200°C. For most resistance ranges, however, carbon-black tapes have been made which are satisfactory at 170°C.

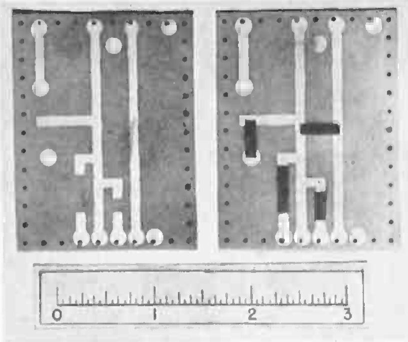
The coating formulation, carbon, resin, and solvent, is agitated with porcelain balls on a ball mill for at least 72 hours before it is sprayed on the tape. Spraying is done in a special cabinet. To secure a uniform coating, the tape, in the form of an endless belt 13 feet long and 1¼ inches wide, is moved rapidly past a spray gun many times as the spray mixture is slowly deposited. A number of infrared heat lamps, mounted within a few inches of the moving tape, hasten removal of solvent during spraying and dry the tape to the desired degree of stickiness after spraying is stopped.

The tape-slitting machine employs 12 disk knives mounted in pairs, slightly overlapping so as to give a scissors action and separated by accurately-ground spacers. A small sample of the tape may be tested for value before the entire tape is slit. Testing is done by cutting the sample into a series of strips varying in width by 0.01 inch over the range 0.11 to 0.15 inch and making up a test plate from these strips. On the basis of test results, the slitter can be set to cut the entire roll into strips of the width necessary to give the desired final resistance value. A single belt of resistance tape yields approximately 1500 resistors.

Proper curing of the resistors after application to the printed circuitry is extremely important. The curing process hardens the resistor, bonds it more firmly to the plate, and stabilizes its electrical characteristics. Although the optimum cure for different formulations differs considerably, a compromise cure of 4 hours at 300°C has proved satisfactory and has been adopted as standard. Curing is done in a temperature-controlled electric furnace to which an aluminum inner liner has been added to secure more uniform temperature distribution.

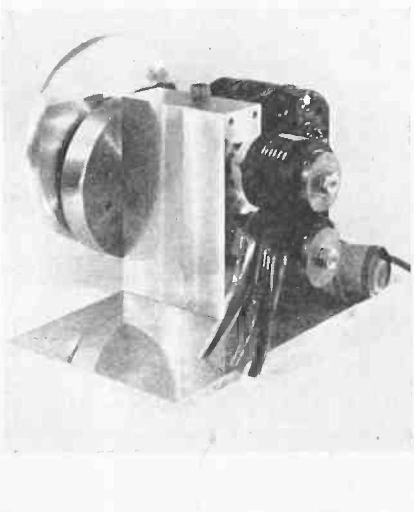
In using the resistors at 200°C, it has been found that those made from some formulations change sharply in value during the first 24 hours, then remain stable for several hundred hours. For this reason, there is some advantage in following the standard 4-hour cure at 300° with a 24-hour treatment at 200°C. As changes in the resistor film resin take place quite slowly at room temperature, the resistor tape may be stored for long periods. Its storage life may be further extended by refrigeration.

Testing and development of tape resistors are continuing at NBS. This work utilizes a test oven of special design which permits automatic recorded measurements to be made simultaneously on a large number of resistors without removal from the oven. Improved resistance formulations are being sought, particularly for certain ranges. Attempts are also being made to develop a satisfactory additional protective coating for application to the positioned resistor.

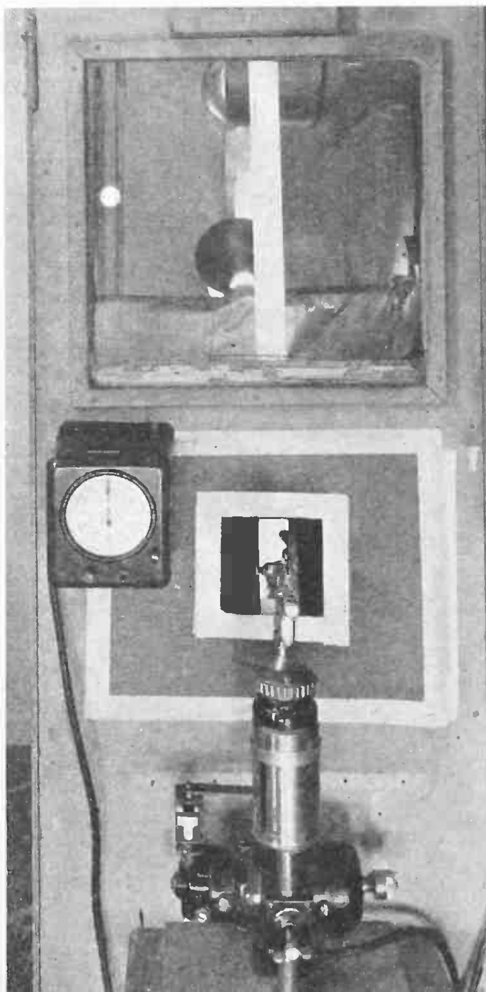


Typical printed circuit without (left) and with (right) the new NBS adhesive tape resistors in place. In printing the silver circuit pattern on the ceramic plate a gap of 0.3 inch is left at each point requiring a resistance. Resistors of appropriate values are then pressed into position and cured by baking the whole plate.

A specially designed electrically driven tape slitter cuts the tape resistor into strips of the desired width. Twelve disk knives, mounted in pairs and spaced by accurately ground spacers, overlap slightly to give a scissors action.



End view of spray cabinet in which the resistive coating is applied. A spray gun deposits the resistance formulation onto an endless belt of thin asbestos-paper tape. Infrared lamps accelerate drying. Many trips are made, assuring uniformity of coating.



A VIDEO PROBE

By
ROBERT R. RATHBONE
Servomechanisms Laboratory
Massachusetts Institute of Technology

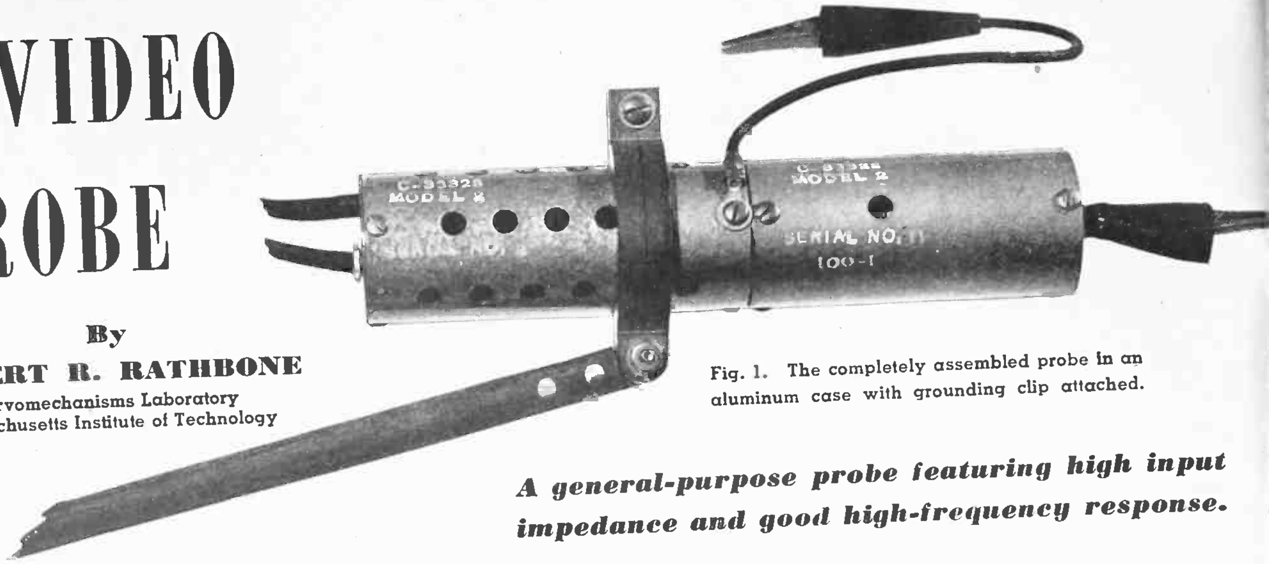


Fig. 1. The completely assembled probe in an aluminum case with grounding clip attached.

A general-purpose probe featuring high input impedance and good high-frequency response.

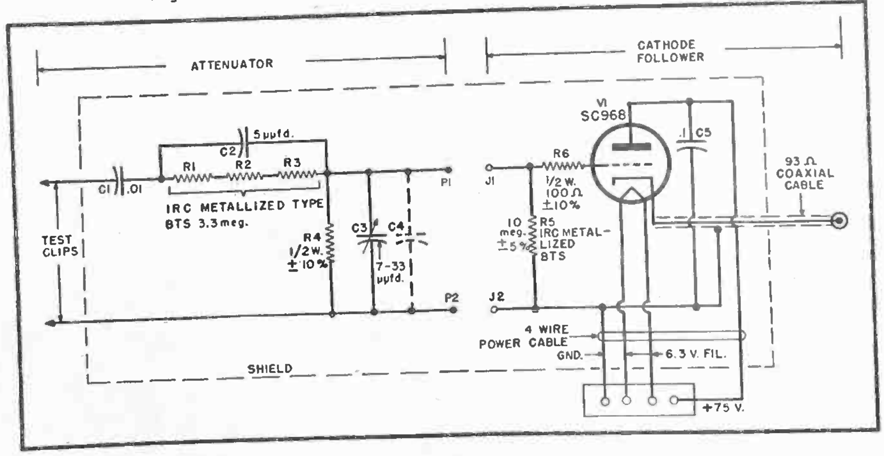
Editor's Note: This article is the sixth in a series describing the special pulsed-circuit test equipment recently developed at the Servomechanisms Laboratory, M.I.T., under the sponsorship of the Office of Naval Research. The equipment was built for the purpose of testing an electronic digital computer, but the units are sufficiently flexible in design to be valuable laboratory tools for general pulsed-circuit testing. The next article will describe the wide-band amplifier used with the video probe.

DURING THE early development and testing of the Whirlwind I electronic digital computer at the Servomechanisms Laboratory, Massachusetts Institute of Technology, trouble was encountered from stray capacitance and inductance in the cable used to connect a synchroscope to the circuit whose waveform was being observed. If the cable was unterminated, reflections and undesirable oscillations occurred, and any variation in the length of the cable during a series of observations produced inconsistent measurements; on the other hand, a terminated cable loaded the circuit under inspection.

To overcome these problems, several video probes of the cathode-follower type were constructed in the Laboratory. In general, cathode-follower probes employ an *R-C* compensated voltage divider which has a certain step-down ratio (usually 10:1 or 100:1) to provide a method of coupling from a test point to a synchroscope or video amplifier. Such probes utilize the capacitance of a coaxial cable as part of the *R-C* circuit, the cable also providing a flexible lead (of fixed length) from probe output to the input of the scope. This type of probe is useful for the observation of long pulses; however, when the pulses are about the same length as the delay time of the coaxial cable, reflections occur.

Model 2, the probe now in use, is the result of the combined efforts of many; in particular, Mr. John Ely and Mr. Harry Kenosian deserve special mention for their work on the original design. This model, shown in Fig. 1, feeds a terminated coaxial cable having a characteristic impedance of 93 ohms. The cable may be made any length up to 100 feet without introducing reflections. The cathode follower, designed to feed the cable, has low output impedance, good high-frequency response, and high input impedance. A type SC-968 triode, offering small size, high mutual conductance, and high dissipation ratings, was selected for the cathode follower, but since the tube overloads at voltages greater than one or two volts at the input, it was necessary to provide for plug-in attenuators so that a wide range of input voltages could be accommodated. The circuit schematic and parts values for both the cathode follower and the attenuator are given in Fig. 2.

Fig. 2. Circuit diagram of the attenuator and cathode follower.



It was found that the attenuators could not be sufficiently compensated when the top end of the voltage divider was shunted by a 2-μμfd. condenser, unless special precautions were taken. It was necessary to use three *IRC* metalized resistors (R_1, R_2, R_3, Fig. 2) in series, and to avoid overheating the pigtail leads on the resistors when soldering. These resistors, plus R_5, must be measured to within ± 1% of their rated values to insure an over-all probe accuracy of 1-2%. In all except the 1:1 and 3:1 attenuators, it was necessary to add capacitance on the lower end of the attenuator to get proper compensation (C_3, C_4, Fig. 2). One of the two condensers is variable and may be adjusted to give the proper compensation. An input capacitor of 0.01 μfd. (C_1) is connected to the attenuator to keep d.c. voltage out of the grid of the cathode follower. The value of the bottom end of the voltage divider (R_4) depends upon the values of R_1, R_2, R_3, and R_5.

The attenuator and the cathode follower are built into separate sections. Each section is encased in aluminum tubing which provides shielding against hand capacitance and pickup of stray voltages, particularly noticeable with high-impedance circuits such as exis

(Continued on page 29)

In this panel are illustrated standard models of HELIPOT multi-turn and single-turn precision potentiometers—available in a wide range of resistances and accuracies to fulfill the needs of nearly any potentiometer application. The Beckman DUODIAL is furnished in two designs and four turns-ratios, to add to the usefulness of the HELIPOT by permitting easy and rapid reading or adjustment.

A B C

MODELS A, B, & C HELIPOTS
A—10 turns, 46" coil, 1-13/16" dia., 5 watts—resistances from 10 to 300,000 ohms.
B—15 turns, 140" coil, 3-5/16" dia., 10 watts—resistances from 50 to 500,000 ohms.
C—3 turns, 13-1/2" coil, 1-13/16" dia., 3 watts—resistances from 5 to 50,000 ohms.

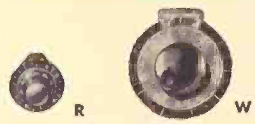
D E

MODELS D AND E HELIPOTS
Provide extreme accuracy of control and adjustment, with 9,000 and 14,400 degrees of shaft rotation.
D—25 turns, 234" coil, 3-5/16" dia., 15 watts—resistances from 100 to 750,000 ohms.
E—40 turns, 373" coil, 3-5/16" dia., 20 watts—resistances from 200 ohms to one megohm.

F G J

MODELS F, G AND J PRECISION SINGLE-TURN POTENTIOMETERS
Feature both continuous and limited mechanical rotation, with maximum effective electrical rotation. Versatility of designs permit a wide variety of special features.
F—3-5/16" dia., 5 watts, electrical rotation 359°—resistances 10 to 100,000 ohms.
G—1-5/16" dia., 2 watts, electrical rotation 356°—resistances 5 to 20,000 ohms.
J—2" dia., 5 watts, electrical rotation 357°—resistances 50 to 50,000 ohms.

LABORATORY MODEL HELIPOT
The ideal resistance unit for use in laboratory and experimental applications. Also helpful in calibrating and checking test equipment. Combines high accuracy and wide range of 10-turn HELIPOT with precision adjustability of DUODIAL. Available in eight stock resistance values from 100 to 100,000 ohms, and other values on special order.



R W

MODELS R AND W DUODIALS
Each model available in standard turns-ratios of 10, 15, 25 and 40 to 1. Inner scale indicates angular position of HELIPOT sliding contact, and outer scale the helical turn on which it is located. Can be driven from knob or shaft end.
R—2" diameter, exclusive of index.
W—4-3/4" diameter, exclusive of index. Features finger hole in knob to speed rotation.

FOR PRECISION POTENTIOMETERS come to Helipot

...world's largest manufacturer of such equipment!

For many years The Helipot Corporation has been a leader in the development of advanced types of potentiometers. It pioneered the *helical* potentiometer—the potentiometer now so widely used in computer circuits, radar equipment, aviation devices and other military and industrial applications. It pioneered the Duodial*—the turns-indicating dial that greatly simplifies the control of multiple-turn potentiometers and other similar devices. And it has also pioneered in the development of many other unique potentiometric advancements where highest skill coupled with ability to mass-produce to close tolerances have been imperative.

In order to meet rigid government specifications on these developments—and at the same time produce them economically—Helipot* has perfected unique manufacturing facilities, including high speed machines capable of winding extreme lengths of resistance elements employing wire even less than .001" diameter. These winding machines are further supplemented by special testing facilities and potentiometer "know-how" unsurpassed in the industry.

So if you have a problem requiring precision potentiometers your best bet is to bring it to The Helipot Corporation, world's largest manufacturer of such equipment. A call or letter outlining your problem will receive immediate attention!

**Trade Marks Registered*

The versatility of the potentiometer designs illustrated above permit a wide variety of modifications and features, including double shaft extensions, ganged assemblies, the addition of a multiplicity of taps, variation of both electrical and mechanical rotation, special shafts and mounting bushings, high and low temperature operation, and close tolerances on both resistance and linearity. Examples of potentiometers modified for unusual applications are pictured at right.

A C

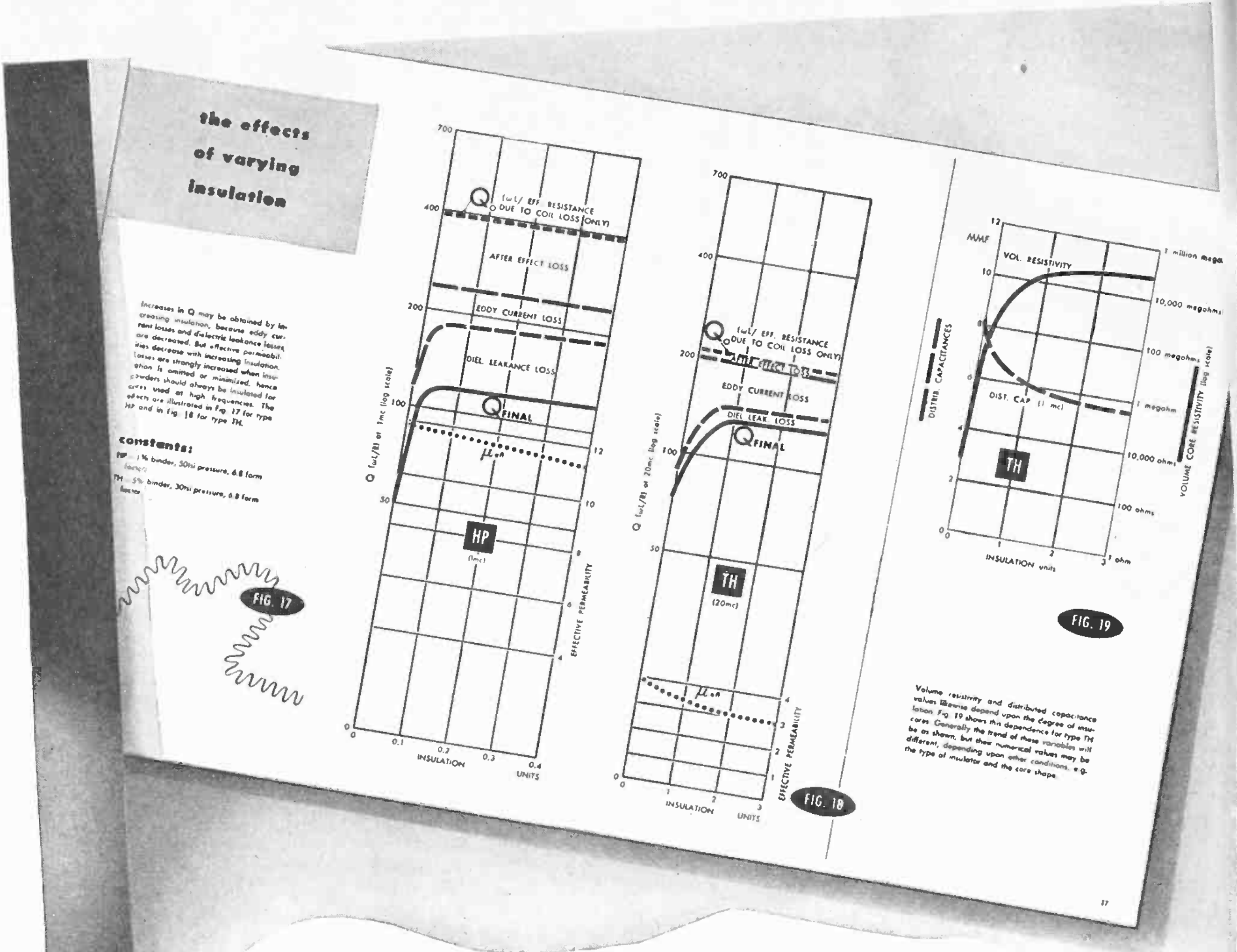
3-GANGED MODEL A HELIPOT AND DOUBLE SHAFT MODEL C HELIPOT
All HELIPOTS, and the Model F Potentiometer, can be furnished with shaft extensions and mounting bushings at each end to facilitate coupling to other equipment.
The Model F, and the A, B, and C HELIPOTS are available in multiple assemblies, ganged at the factory on common shafts, for the control of associated circuits.

B F

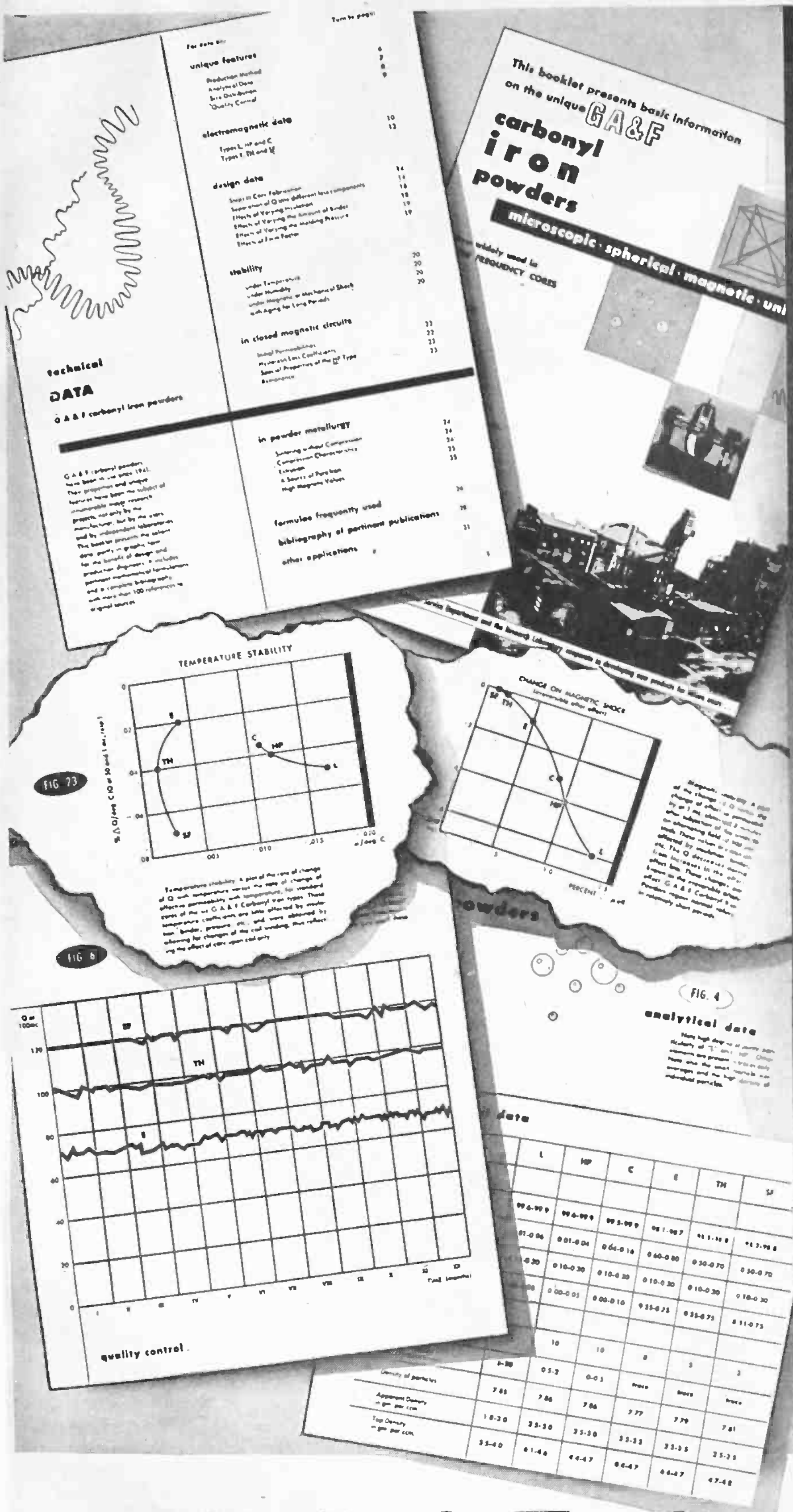
MULTITAPPED MODEL B HELIPOT AND 6-GANGED TAPPED MODEL F
This Model B Helipot contains 40 taps, placed as required at specified points on coil. The Six-Gang Model F Potentiometer contains 19 additional taps on the middle two sections. Such taps permit use of padding resistors to create desired non-linear potentiometer functions, with advantage of flexibility, in that curves can be altered as required.

THE Helipot CORPORATION, SOUTH PASADENA 4, CALIFORNIA

Field Offices: Boston, New York, Philadelphia, Rochester, Cleveland, Detroit, Chicago, St. Louis, Los Angeles and Fort Myers, Florida. Export Agents: Fratham Co., New York 18, N.Y.



the effects
of varying
insulation
constants:
AFTER EFFECT LOSS
EDDY CURRENT LOSS
DIEL. LEAKANCE LOSS
HP
FIG. 17
INSULATION
UNITS
EDDY CURRENT LOSS
DIEL. LEAK. LOSS
TH
FIG. 18
VOL. RESISTIVITY
DIST. CAP
TH
INSULATION units
FIG. 19



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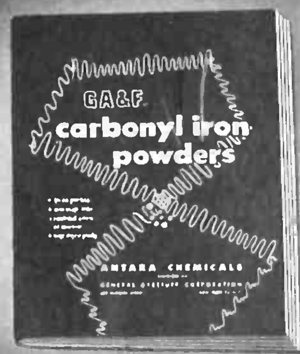
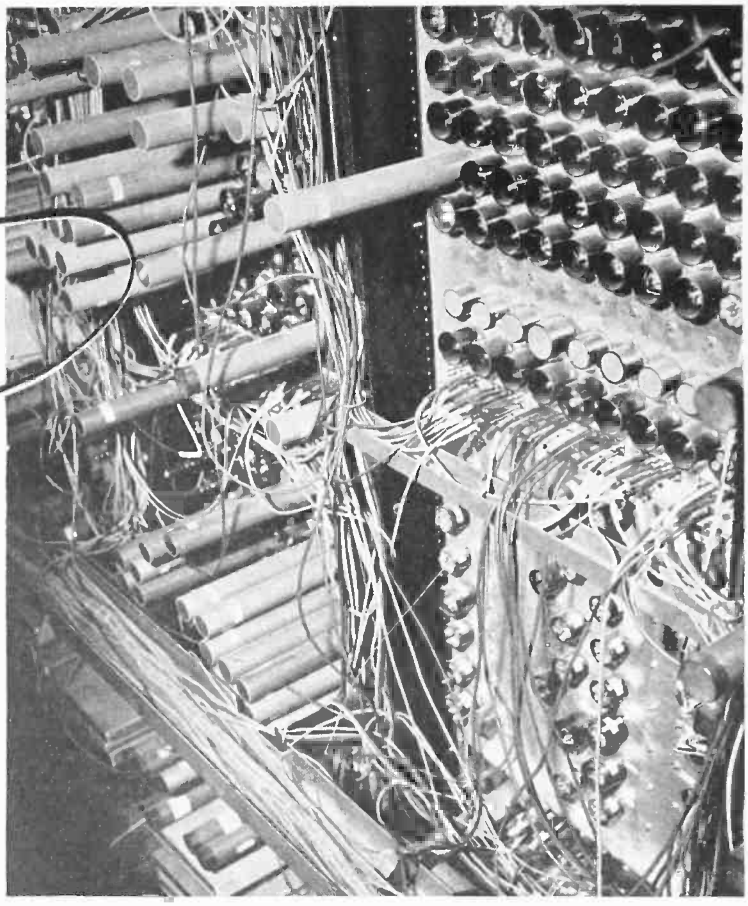


...the technical portrait of an unusual product

G A & F® Carbonyl

GERMANIUM DIODE EXPERIENCE

Performance of the 16,000 germanium diodes used in the NBS SEAC computer.



A group of base-mounted diodes and associated cabling, part of the 16,000 diodes used in the NBS Eastern Automatic Computer.

UNITED STATES production of germanium diodes for radio and electronic applications has expanded to something like 4 million a year. Yet because they are relatively new, germanium diodes have not received extensive service study, and few significant data on their characteristics in extended use have become available. Because it uses some 16,000 germanium diodes for computing and switching functions, with the requirement of very high reliability, the National Bureau of Standards Eastern Automatic Computer (SEAC) is a natural proving ground for the diodes. Of interest, therefore, is a recent preliminary study of experience with germanium diodes in the SEAC program. Conducted by J. H. Wright of the NBS electronic computer laboratory, the study is based on data compiled during the electronic computer's first six months of operation after its dedication in June 1950.

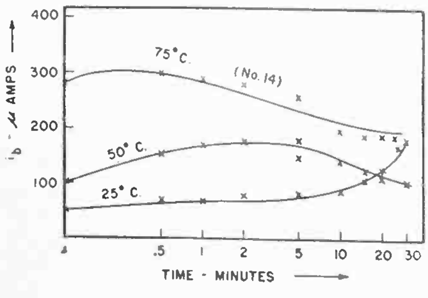
Reliability is the outstanding requirement of diodes in computer use. Even momentary failure of a single one of SEAC's diodes will cause computer misfunction.

In view of this severe requirement, germanium diode experience in the SEAC program has been gratifying. After some 2500 hours under voltage, only about 5.4 per-cent of the diodes initially in service had had to be replaced, rest of the replacements being because of back current drift, or "creep". The great majority of these replacements were made in the course of routine maintenance checks before the questionable diodes could cause computer misfunction. Also encouraging, the rejection rate for the several thousand diodes purchased in the last six months of 1950 was less than 2 per-cent. Moreover, diode quality has undoubtedly improved since SEAC's first diode purchases were made, and continued improvement seems likely.

SEAC circuitry was designed to use diodes of a single specification, the 50 volts (back) 50 milliamperes (forward) type. A design value of -40 volts was selected as being the absolute limit of back voltage that would be encountered, and 20 ma. was chosen arbitrarily as the peak forward current.

Each diode must be individually tested before use in SEAC; spot checking is inadequate, since all weak links must be excluded. Tests are made twice before a diode goes into service, once before soldering into position and once after. Equally important to reliable computer function are the preventive maintenance checks made at regular intervals on diodes already in service.

Back current drift with time of an individual "creeper" diode recorded at three different operating temperatures.



SEAC diodes are tested for back current at -40 volts and for forward voltage drop at 20 ma. forward current, the design maxima. For a "normal" diode, *i.e.*, one that does not "creep" appreciably, permissible back current at -40 volts is specified as 250 µa. before soldering, 300 µa. after soldering, and 500 µa. for units in service. For a "good creeper", corresponding rejection limits are 120, 200, and 300 µa. (A "good creeper" is defined as one that drifts less than 50 µa. and stabilizes markedly in the ½ minute observation period.) Rapid "wigglers" (rapidly-fluctuating creepers, with periods of less than a second) must not exceed plus or minus 10 µa. fluctuations. Maximum permissible forward voltage at 20 ma. is 2.0 volts before or after soldering and 2.3 volts for units in service. Fixed forward current was specified rather than fixed voltage, partly because SEAC's gate circuits are current operated, and partly because the fixed-current test circuit is short-circuit proof.

Deterioration of back characteristics has been the chief reason for SEAC diode replacements; and excessive creep has been a much more frequent reason for replacement than excessive back current. Excessive creepers are replaced because of their unpredictability, although creep of itself will not necessarily cause computer misfunction. Creep in back current was observed in a substantial percentage of the commercially available diodes tested for SEAC, including both the wax-imbedded types and the hermetically-sealed types without the wax embedding. The incidence of creep varied between makes, however, as well as from batch to batch. Forward characteristics, unlike back characteristics, deteriorated very little; and the number of complete failures such as shorts and opens was negligible.

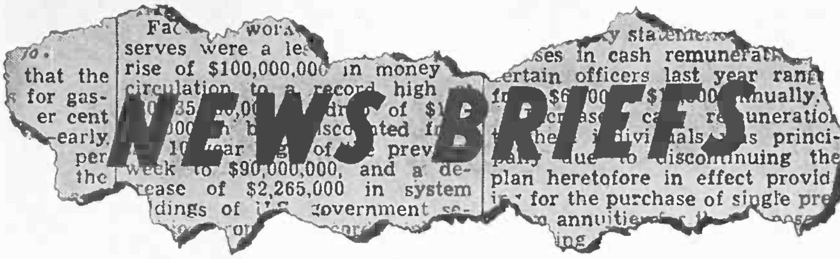
Creepers vary widely in their behaviour. Initial creep may be in the direction of either increased or decreased current, while the long-term trend may bear no relation to the initial trend. Initial downdrifters are at present considered as undesirable as updrifters, since either seems likely to rise to excessive currents in the course of time. Creep may be gradual and steady, perhaps ultimately leveling off. Or, as more often happens, it may be more or less periodic, the period varying widely from less than a second ("wigglers") to a number of minutes or even hours.

It now seems clear that diode creep is not caused to any appreciable extent by imperfect mechanical contact. Although moisture is suspected of playing some role, it appears unlikely that some of the observed creep phenomena could be caused by moisture alone.

In addition to the observations on diodes in regular service, a few experiments were made. To study the effect of operating temperature on creep, 29 creepers were tested at 25° and 75° C. Although individual units differed, these experiments indicate that drift is not notably aggravated by increase in temperature within the usual range.

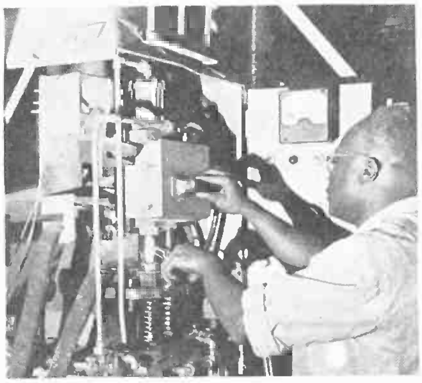
Another group of 18 creepers was studied for 210 hours at room temperature in an effort to determine whether an observation of one minute or less is sufficient to exclude long term creepers. These limited data indicate that one-minute or ½ minute observations, holding to a 300 μa. limit, satisfactorily exclude those units which would later drift beyond 500 μa.

The SEAC diode experience study indicates a definite need for more life data and better specifications for germanium diodes for computer applications. NBS investigators have outlined data-compilation and specification projects which they hope will be undertaken cooperatively by computer groups and other interested diode users.



HEAT-DETECTING MACHINE

An electric-eye unit that literally sees heat is helping in the production of electronic tubes in the *General Electric*



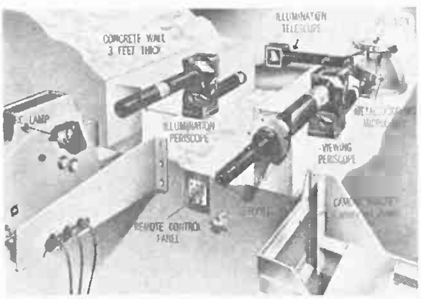
Company's Industrial and Transmitting Tube Plant, Schenectady, New York.

Controlling temperature of glowing graphite crucibles that give off a dazzling white light too intense for eye safety, the electric eye unit can be used to control temperatures ranging upward from 2000 degrees Fahrenheit, with only a 15-degree leeway in accuracy, by adjusting it to register gradations in color from a dull red right through the "hot-color" spectrum, to the brightest white.

The changes in color and intensity, from small tube parts that are fused in the crucible, react on the photoelectric tube in the electric eye, setting off a reaction that controls the crucible temperature at a critical point.

RADIOACTIVE DETECTION DEVICE

The first of its kind, a new instrument can now safely study and photo-



graph deadly radioactive materials, it was jointly announced by *American Optical Company's* Instrument Division, Buffalo, New York, who built the device, and the *General Electric Company*, Schenectady, New York.

The instrument is a special microscope for examining the structure of metals, combined with camera, periscopes, and an illuminating system, in such an arrangement that light can get in and out through the thick walls of the test chamber, but nuclear radiations from the radioactive specimens are completely blocked. Operating by remote control, the instrument permits atomic researchers to work in complete safety, and will make possible investigations never before accomplished on the effects of radiation damage to materials.

ELECTRONICS CENTER

In a plan revealed by the *General Electric Company*, Syracuse, N. Y., and Cornell University for the establish-

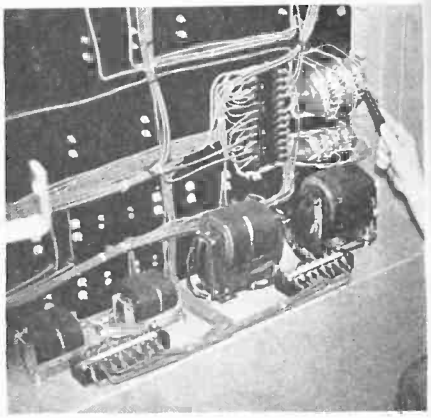
ment of an advanced electronics center at Ithaca, New York, projects may include development of such items as control systems for guided missiles, electronic countermeasures, and infrared systems.

The project will be known as the *General Electric* Advanced Electronics Center at Cornell University and its activities will be directed by a four-man management team—two from industry and two from science, representing fully with their combined skills and experience, the abilities required in scientific, industrial, military, and academic aspects of such a pioneer venture.

The over-all purpose of the project, as outlined by *GE* and Cornell officials, "is to carry out advanced study and development in the field of electronics, and at the same time provide scientists and engineers with teaching and educational opportunities."

MAGNETIC AMPLIFIER REGULATOR

Tested under simulated operating conditions by *Westinghouse Electric Corporation*, 306 Fourth Ave., Pittsburgh, Pa., a magnetic amplifier regulator has successfully controlled a 4000-hp double-armature motor that will be

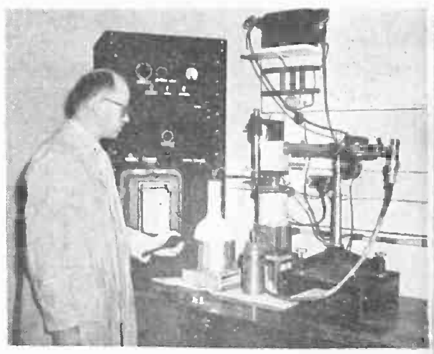


used on a 66-in. tandem cold reduction mill.

This amplifier is a static device, having no bearings, brushes, or moving parts, and can be mounted on panels in control cabinets. Its operation is analogous to that of the three-element vacuum tube, and consists of two sets of coils wound on a magnetic core. Obtaining wide ranges of speeds, it maintains the speed constant for any given control setting.

PHOTOELECTRIC INTERFEROMETER

A recording photoelectric interferometer, recently developed by Dr. R. N. Work of the National Bureau of Standards, greatly simplifies the determination of transition temperatures in natural and synthetic rubbers and high polymers, observing and plotting varying length of a polymeric sample against



temperature over the range from −185°C to +185°C.

The new interferometer was developed in connection with a program under way at NBS, which has as its object the design of new polymers having specified characteristics. An important phase of the program is being sponsored by the Office of Naval Research, relating to the development of low-temperature rubbers for use in the arctic or in high-altitude flight.

The NBS photoelectric interferometer is particularly well adapted to survey work where transitions must be located rapidly in a large number of materials. The data can be processed with a minimum of effort, and a precision of ±0.5°C or better in the location of transition points can be realized. Values of coefficient of expansion thus obtained for rubberlike materials are reproducible to at least ±5%.

MAJOR SMPTE AWARDS

Earl I. Sponable, Technical Director of *20th Century-Fox Film Corporation*, was signally honored by the Society of Motion Picture and Television Engineers at its 70th Semi-annual Convention in Hollywood, California.

Mr. Sponable, Past President of the SMPTE, received both the society's Progress Medal and the Samuel L. Warner Memorial Award, for his outstanding contributions to the technical advancement of the motion picture art, particularly in the fields of sound-on-film, color film, and large-screen television.

Joining the Fox Film Corporation in 1926, he designed and built the first sound motion picture studio, assisted in developing commercial sound motion pictures, participated in creation of the first sound newsreel and has become a leader in the pioneering development of equipment and techniques for large-screen theatre presentation of televised program material.

TELEVISION TEAMWORK

Speaking before a joint branch meeting of the AIEE and the IRE at Rensselaer Polytechnic Institute, Dr. W. R. G. Baker, *General Electric Company's* Vice President, said that television industry team work will provide the country with a compatible color television system.

He pointed out that work similar to that now being carried on by the National Television System Committee for color television, resulted in the development of standards for black and white television over a decade ago. Citing the committee's work as a prime example of teamwork needed from modern engineers, he further stated that greater-than-ever engineering opportunities are afforded today in the engineering field which has as its goal the improvement of man's standard of living.

THEATRE TV

Occupying a relatively small amount of space in the projection booth of the *RKO Fordham Theatre*, Bronx, New York, this compact control and monitoring rack is operated by the theatre's projectionist, and is used to present

full-sized TV images on the theatre's screen.

The *Radio Corporation of America*, Camden, N. J. instantaneous theatre television system is equipped with an optical unit which projects the television program, and is mounted on the front of the balcony.

ENGINEERING OPPORTUNITIES

The Rome Air Development Center has Civil Service openings for electronic engineers and scientists at salaries ranging from $3410 to $7040 per annum. Grades are determined by training and experience.

Occupants of these positions will be engaged in applied research, development and tests of electronic air-ground systems.

Send full details of your education, experience, age, and salary requirements to "Employee Utilization Section, Civilian Personnel Branch, Rome Air Development Center, Rome, New York."

TWO NBS APPOINTMENTS

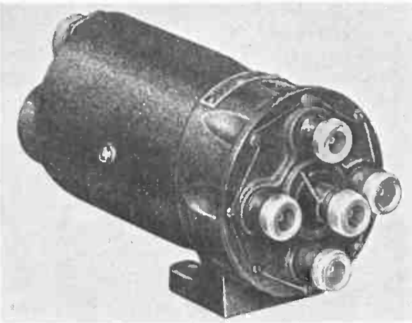
The National Bureau of Standards, Washington, D. C. has appointed Alan J. Hoffman, former member for the Institute for Advanced Study, Princeton, N. J., to its staff in the division of applied mathematics. Dr. Hoffman will work in the Computation Laboratory of the division, responsible for compiling mathematical tables and developing improved techniques for numerical com-

(*Continued on page* 29)

NEW PRODUCTS

R.F. SWITCH

A single-pole, 4-position coaxial r.f. switch, for applications at radar frequencies, is being offered by *Transco*



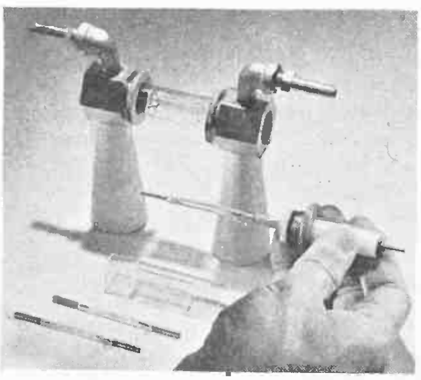
Products, Incorporated, along with various models for aircraft applications requiring performance under extreme temperature and shock conditions.

Performing at a frequency range up to 11,000 mc., a VSWR less than 1.5, and external features of compactness for easy installation, all r.f. switches have been built according to MIL specifications.

Further information may be obtained from *Transco Products, Inc.,* 12210 Nebraska Ave., Los Angeles 25, Calif.

HIGH-INTENSITY LIGHT

Mercury arc lamp and water-jacket components have been redesigned by the *Huggins Laboratories,* Hamilton Ave., Menlo Park, Calif., to provide arc widths of 1, 1¼, and 1½ mm. Having approximate power inputs ranging



between 1 and 2 kw., brilliances from 40,000 to 90,000 candles per square centimeter, and light outputs from 65,000 to 130,000 lumens, the high-intensity light can be operated from a.c., d.c., single-flash, or stroboscopic power supplies, and can be provided with all-quartz accessories where a powerful source of ultraviolet is needed.

High speed and stroboscope photographs, optical apparatus, photosynthesis, and photochemical processes, as well as specialized procedures requiring unusual brilliance in either the visible or ultraviolet light spectrum, are included in its applications.

VARIABLE DELAY LINE

The distributed-parameter, continuously variable delay line offered by *Advance Electronics Company,* P. O. Box 394, Passaic, N. J., is capable of providing a continuously variable time delay from zero to 0.6 microsecond.

It has complete freedom of time jitter, fast rise time, limitless repetition frequency, greater bandwidth, and good transient response. Type 302 includes among its applications accurate distance measurements in radar or loran systems, for establishing coincidence of sweep and input signal in high-speed oscilloscopes, and for measuring time intervals with accuracy better than a small fraction of a microsecond.

TOROIDAL CORES

Molded powdered-iron toroidals, produced by *Lenkurt Electric Company,* 1115 County Road, San Carlos, Calif., range in sizes of 0.800 to 3.375 inches outside diameters. Available in magnetic materials which accentuate high-Q, high inductance, low generation of harmonic distortion products, and high

magnetic and temperature stability, these cores are also supplied wound to individual specifications, cased, uncased, or hermetically sealed.

CURRENT STABILIZER

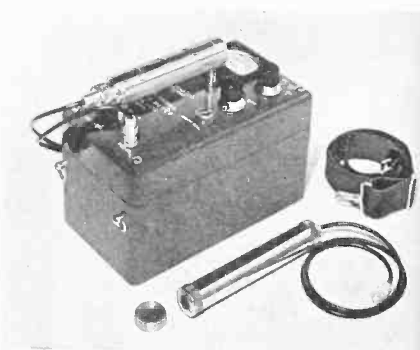
Designed to hold tube current constant at any given setting when used in conjunction with water-cooled x-ray diffraction equipment, the new *Norelco* MA Stabilizer has three ranges, 0.5 to 2 ma., 7 to 25 ma., and 25 to 50 ma.

The stabilizer developed by the *North American Philips Company, Inc.,* 750 S. Fulton Ave., Mt. Vernon, N. Y., selects the three stages by means of a three-positioned lever switch mounted on the end of the stabilizer chassis and is provided with safety circuits which protect the x-ray tube filament from excessive heating.

A mechanical stop is also provided on the variable auto-transformer to assure sufficient x-ray tube voltage.

SURVEY METER

A new Alpha Beta Gamma Survey Meter with an optional probe for alpha detection, has been developed for use as both a radiation dosage rate meter and a low-level contamination monitor. The SU-5A, manufactured by *Tracer-*



lab, Incorporated, 130 High St., Boston 10, Mass., can be used for checking glassware, benchtops, hands, coats and locating small amounts of spilled radiochemicals, in addition to locating radium, and measuring dosage rates from stored radioisotopes, to ascertain whether adequate shielding has been employed.

Waterproof, lightweight, battery operated and provided with two sets of scale ranges, it is equipped with a P-17 side window probe which permits the separate measurement of gamma radiation in the presence of beta radiation.

LABORATORY MONITOR

Known as the "Radiation Sentinel," a new laboratory monitor has been

announced by *Nuclear Instrument & Chemical Corporation,* 223-233 West Erie St., Chicago 10, Ill. Model 1615A is equipped with a four-inch meter and a selector switch which permits the meter to indicate either count rate or Geiger tube voltage.

Included in the Radiation Sentinel is a built-in power supply, a switch for a chart drive recorder, and a magnetically mounted probe which permits the thin mica window counter to be mounted on any iron or ferromagnetic object for monitoring vacuum lines, bench top surveying or clinical and therapeutic checking.

AIRBORNE AUDIO AMPLIFIERS

The production of airborne audio amplifiers, developed primarily for PA and entertainment use aboard aircraft, has been started by *Gertsch Products, Inc.,* Los Angeles, Calif.

The two Models AA-1A and AA-1B, identical in appearances and differing only in their input power requirements, include variable frequency response by means of a 4-position filter for noise suppression, remotely operated HI-LO level control, and dual input circuits.

MINIATURE COUNTER DECADES

The Potter Instrument Company, 115 Cutter Mill Road, Great Neck, N. Y., announces a new miniaturized, redesigned version of the four-tube Electronic Counter Decade, available in two models which differ only in the maximum counting capabilities.

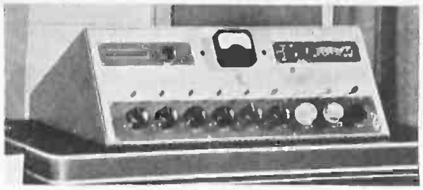
The Model 12 is designed for counting at rates up to 130,000 counts per-second, and the Model 13 for counting at rates up to 30,000 counts per-second. Equipped with a binary decimal coding system (1-2-4-8), it is easily adaptable to computer circuitry and recording devices using four styli.

The new decades are available with either a remote panel-mounted four-lamp readout or with a small plug-in neon cluster on the decade frame for applications in which the indicators serve only for tube servicing.

STUDIO CONSOLETTE

Providing a flexible speech input system for AM, FM and TV broadcast stations, an improved consolette (*RCA* Type BC-2B) has been announced by the *RCA Engineering Products Department,* Camden, N. J.

Besides offering control facilities for one or two studios, it serves an announce booth, a control room microphone, two turntables, a network, and five remote lines. The frequency response from any input to the line output is within plus or minus 1.5 db from 30 to 15,000 cps. The total rms harmonic distortion is less than .5 per-cent from 50 to 15,000 cps at a line-output level of 18 dbm. The new consolette has a total power input requirement of 150 watts, 50 to 60 cps a.c., and 105 to



125 volts. It weighs approximately 114 pounds and has over-all dimensions of 11¼ inches high, 33 inches wide, and 21½ inches deep.

Further information may be obtained from the *RCA Engineering Products Department,* Camden, N. J.

A.C. VOLTAGE REGULATOR

With an accuracy of 0.01%, the Model 1001 A.C. Line Voltage Regulator is of importance to techniques demanding a.c. line regulation of unusual accuracy.

This new unit, manufactured by *Sorensen & Co., Inc.,* Stamford, Conn., also offers a combination twist-lock and double-T receptacle; three-function output switch for (1) normal regulator functioning, (2) operation with integral semi-fixed resistance in place of poten-

(*Continued on page* 29)

Personals

NICHOLAS E. GOLOVIN has been named Assistant Director for Administration of the National Bureau of Standards, which will include planning and management functions for technical programs. Mr. Golovin, who received his M.A. in mathematical physics from Columbia University, previously was head of the Management Division at the Naval Ordnance Test Station, California, and Associate Superintendent at the Naval Research Laboratory.

DR. VICTOR S. HICKS, newly appointed Chief Physicist of *Tracerlab, Incorporated*, will direct many research and development projects. He received his A.B. from Williamett University in 1925; his M.S. from the University of Washington in 1927; and his Ph.D. from the University of California in 1930. Dr. Hicks is a member of many scientific societies, among them the American Physical Society and is the author of many technical papers in the field of physics.

JAMES C. P. LONG has joined the engineering staff of the *Sprague Electric Company*, it was announced by Julian K. Sprague, Vice President. Formerly head of the Material Coordination Section of the Bureau of Aeronautics, U. S. Navy Department, he also served as a member of the RDB's Panel on Components. Mr. Long is a graduate of Grove City College, Grove City, Pennsylvania and served in the Navy as a Lieutenant from 1943 to 1946.

C. J. LUTEN was appointed Editor of the Service Dealer magazine for *Sylvania Electric Products Incorporated*. He previously served as a director of educational advertising, an assistant editor to an employee magazine, and a reporter for the Dallas Times Herald. Mr. Luten graduated from Southern Methodist University and was the recipient of the 1944 Sigma Delta Chi Award, naming him outstanding journalism graduate of his class.

DR. LOUIS N. RIDENOUR has been appointed Director of Engineering for the *International Telemeter Corporation*. A graduate of the University of Chicago and California Institute of Technology, he served with Massachusetts Institute of Technology during the war and played an important part in the development of microwave radar, helping its introduction into airforce operations. His new duties will be connected with technical developments of the Telemeter System.

OTTO H. SCHADE, nationally-known scientist of the *Radio Corporation of America* Tube Department, became the first recipient of the David Sarnoff Gold Medal Award, conferred on him at the 70th Semi-Annual Convention of the Society of Motion Picture and Television Engineers. The award was given in recognition of his development of rating methods for measuring the picture-reproducing quality of 35mm film and television systems mathematically.

Slot Radiators

(*Continued from page 13*)

$$P_r = |V|^2 G_r \quad (15)$$

$$G_r = G_n \frac{P_r}{P_n} = P_r \frac{\sum_{r=1}^{n} G_r}{\sum_{r=1}^{n} P_r} \quad (16)$$

The input admittance to this array is:

$$Y_{in} = \sum_{r=1}^{n} G_r + j \sum_{r=1}^{n} B_r \quad (17)$$

In general, the input admittance is designed to be either unity or a large real value (overloading). These and other values are easily attained; other values may be more desirable in certain cases.

A radiation pattern of a resonantly spaced array of 17 resonant slots is shown in Fig. 12. The theoretical curve of csc θ cot$^{1/4}\theta$ was designed from 3° to 45°. The measured pattern and the theoretical curve show less than 3 db deviation from 2° to 55°. Machining tolerances can easily explain the departure of the radiation pattern from the theoretical curve, especially with the large (1860:1) range of radiated powers required.

Fig. 13 is the radiation pattern of a 15 element array of non-resonant slots. The theoretical curve of csc^2 θ cot$^{1/2}$ θ was to be duplicated by the array for 6° to 60°. The results of the pattern measurements indicate a variation of less than 3 db from 1.5° to 61°.

Non-resonant Spacing

Interelement spacing, other than resonant, has the advantage that with a matched termination and elements having small admittances, the input admittance to the array will be near unity at all frequencies except in the vicinity of the resonant spacing frequencies. The reason for this matched condition is that the reflected waves from the elements are small and add together with effectively random amplitude and phase (because of the non-resonant spacing) at the input to the array. The voltages for a lossless transmission line are:

$$V_{n-1} = V_n \left(\cos \beta l + j \overline{Y_n} \sin \beta l\right) \quad (18)$$

$$V_r = V_{r+1}(2 \cos \beta l + j Y_{r+1} \sin \beta l) - V_{r+2} \quad (19)$$

These expressions show that the magnitude and phase of the voltage at the rth element are functions of both the distance between elements and the admittance introduced at the $(r + 1)$ element. For the usual case of slots spaced about a half guide wavelength apart and the reflection coefficients small we have:

$$P_r^+ = P_{r+1} (1 + 2 \alpha l) \quad (20)$$

$$Y_r^+ = \frac{\overline{Y_{r+1}} \cos \beta l + j \sin \beta l}{\cos \beta l + j \overline{Y_{r+1}} \sin \beta l} \quad (21)$$

This admittance equation may be solved very quickly by use of the Smith Admittance Chart. The reflection coefficient at the rth slot is:

$$\Gamma_r^+ = \Gamma_{r+1}^- \, e^{-2\alpha l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

This shows that only the amplitude of the reflection coefficient is altered by transmission line attenuation. If it is necessary to take attenuation into account, this expression may be used.

From the equivalent circuit it follows that:

$$G_r = G_r^+ \frac{P_r}{P_r^+} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (23)$$

so that all the G_r may be readily determined. The phase of the admittance of each slot is determined by the required phase and the phase error in the voltages due to transmission line loading. If the admittances of the slots are small, the phase error in the voltages will be small and, in some cases, may be neglected.

A 24 element array of slots was calculated to give a Tchebyscheff aperture distribution. The side lobe level was to be 30 db below the main beam. The excitation coefficients are all real for a Tchebyscheff array so that by using low conductance slots the phase error in the voltages could be neglected. The array was therefore designed with resonant slots. The spacing was greater than a half wavelength to improve the impedance characteristics. A matched termination was used. The VSWR characteristics are shown in Fig. 14. The half power beam width at the design frequency of 9375 mc. was the same as the calculated value. The beam width varied from 4.2° to 3.4° over the band from 8500 mc. to over 10,100 mc. The beam width is inversely proportional to the aperture in wavelengths. The main beam scanned 12.4° over this same band, being 2° from the normal at the design frequency. Over this same frequency range, the side lobe levels in the plane of the axis of the array normal to the surface of the wave guide were below 26 db. Four off-axis, secondary beams occurred which were 19 to 22 db below the main beam. A restrictive horn along the length of the array removed the secondary lobes, raising the side lobe level about 1 db. In a two dimensional array of these slots, the secondary lobes would not appear.

The author wishes to acknowledge the influence of discussions with R. H. Reed, the theoretical work of J. R. Miller and the non-resonant slot experimental results of T. T. Taylor, W. G. Sterns, and R. A. Henschke.

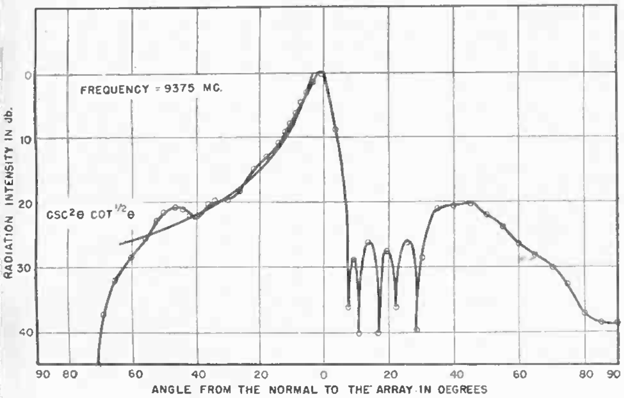
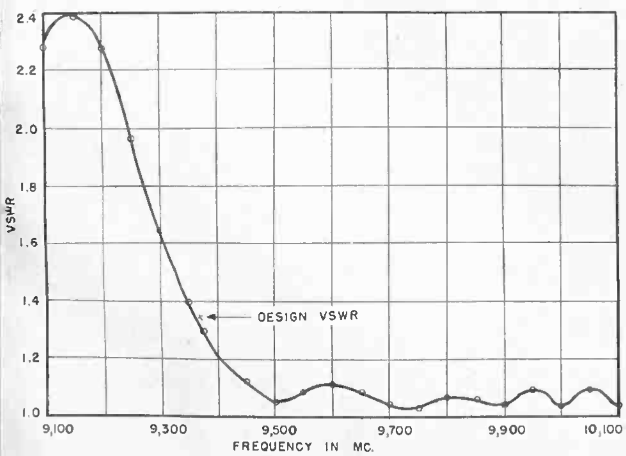


Fig. 13. Radiation pattern of 15 element array of non-resonant longitudinal shunt slots.

Fig. 14. Input VSWR of 24 element array of resonant longitudinal shunt slots.



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1. *Watson, W. H., "The Physical Principles of Waveguide Transmission and Antenna Systems," Oxford University Press, London, 1947. p. 95.*

2. *Stevenson, A. F., "Theory of Slots in Rectangular Wave Guides," Journal of Applied Physics, Vol. 19, 1948, pp. 24-38.*

3. *Watson, W. H., op. cit., p. 200.*

4. *Reich, H. J., "Very High Frequency Techniques", Vol. I, Harvard RRL Series, McGraw-Hill Book Company, Inc., New York, 1947, p. 174.*

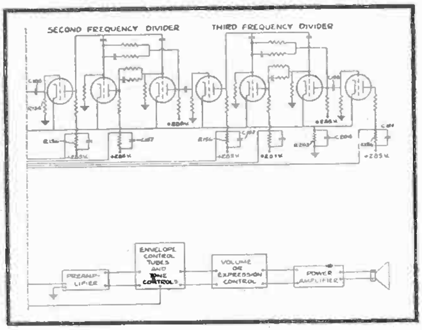
5. *Taylor, T. T. and Whinnery, J. R., "Applications of Potential Theory to the Design of Linear Arrays," Jounral of Applied Physics, Vol. 22, 1951, pp. 19-29.*

PATENT REVIEW

Printed copies of these or any other patents may be obtained from the U. S. Patent Office for 25c each. Address the Commissioner of Patents, Washington 25, D. C.

ELECTRICAL MUSICAL INSTRUMENT

Improving tone quality produced by electrical musical instruments, and means for producing electrical signals corresponding to musical tones of a de-



sirable quality, are the objects of this invention.

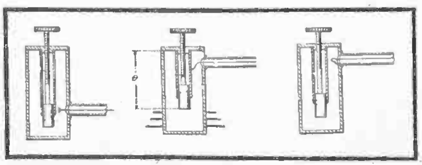
With the apparatus of this device, the rectangular wave output of the frequency divider is rectified to a very narrow pulse whose width is small in comparison with its period. All of the low order harmonics are then present in substantially equal amplitude, with this equality continuing to higher harmonics if the pulse is sufficiently narrow.

The solo oscillator is comprised of triodes having a resonant tuning circuit, and is keyed by connecting a suitable inductance into the circuit to give the correct frequency.

Patent No. 2,562,908 was issued on August 7, 1951 in the name of J. M. Hanert.

UHF LOAD DEVICE

The principal object of this invention is to provide an improved tunable load device for high frequency systems, en-



abling the device to dissipate large amounts of power, and eliminating the disadvantages of "burn-outs" and ceramic insulation cracking which occurs in some systems in present use.

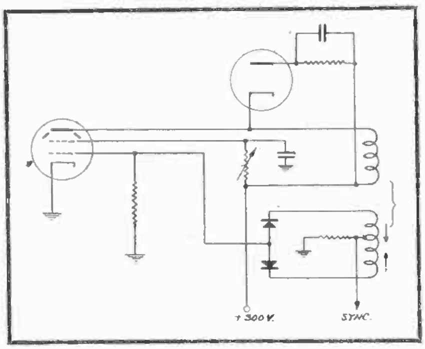
The device consists of a tunable ultra-frequency resonant cavity which is connected to a highly resonant transmission unit, the cavity being so designed and adjusted that r.f. power from the line is transmitted into the cavity and is dissipated therein in the form of heat. This is accomplished by tuning the cavity to resonance and coupling the line to a part having an impedance characteristic equal to the surge impedance of the transmission line.

Patent No. 2,562,921 was issued on August 7, 1951 in the name of A. G. Kandoian.

SWEEP GENERATOR

Relating to coil circuits, saw-tooth wave generating devices used to excite them, and to cathode-ray tube deflection circuits, this invention discloses a method for maintaining linearity in magnetic deflection systems.

The sweep generator introduces an automatic controlling voltage which either retards or accelerates devia-



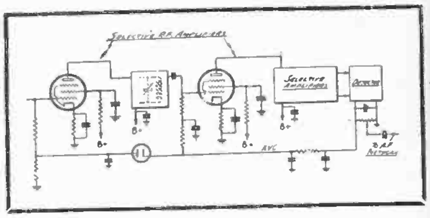
tions from given rates of change in the deflection voltage, and provides a deflection circuit containing fewer components than before believed necessary. It also initiates a self-oscillating saw-tooth type deflection voltage generator, the output of which is directly applied to the deflection coils of a cathode ray oscilloscope.

Patent No. 2,562,941 was issued on August 7, 1951, in the name of L. W. Parker.

AVC CIRCUIT

This invention presents an improved arrangement for protecting the automatic volume control (AVC) circuit of a receiving system subject to strong signal reception, without preventing AVC action on the first tube during normal operating conditions.

The AVC circuit provides a uni-directional conductive device in the AVC line between the control grid of the first tube and the control grid of each of the following tubes, the device being conductive when the AVC line is more negative than the control grid of the first tube and being non-conductive



when the control grid is more negative than the AVC line.

The schematic diagram shows an aircraft receiver incorporating this arrangement by application of a vacuum tube diode.

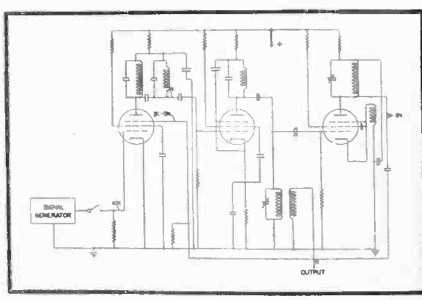
Patent No. 2,563,052 was issued on August 7, 1951 in the name of Olin L. Mac Sorley.

FREQUENCY DIVIDER

This invention presents a frequency division system of improved stability which is insensitive to amplitude changes in the incoming signal. Both input and output are sinusoidal and no output is produced in the absence of an input signal. Furthermore, the system is very stable over a band of frequencies.

Its basic principles involve beating an input signal of high frequency KN, where K is a whole number constant greater than unity, with a lower frequency signal $(K\text{-}1)\ N$ to obtain a still lower frequency signal N. Signals of approximately the frequency $(K\text{-}1)\ N$ exist in the system in small amplitude during the absence of the input signal, but immediately upon application of the input signal, a beat signal of approximately the desired frequency N is produced.

Patent No. 2,562,952 was issued August 7, 1951, in the names of Carl M.



Russell, Keith R. Symon and Robert C. Padesky.

AM Transmitter

(*Continued from page* 5)

panel may be placed on a bench or table for any service work that may be required.

The present day manufacturing problems, which involve high costs for fabricated parts and assemblies, together with the difficulties of procuring materials, have been held to a minimum. However, the BTA-5G/10G design has provided the many additional features that have been described, plus the removal of the unnecessary parts, and ofttime cumbersome items, that made it possible to accomplish this present improved design.

Video Probe

(*Continued from page* 16)

at the input of the attenuator. The top or front section of the probe is the attenuator; the bottom section is the cathode follower. The attenuator may be unplugged after two screws are loosened. Components for each section are mounted on a phenolic strip which rests on two shelves attached to the end pieces, with sufficient clearance for air cooling around the triode. The over-all dimensions of the assembled outer shell are 7 x 1½ inches.

A single leg, or "unipod", was devised to overcome the difficulty of using the probe to test a vertical panel. The leg is a ¼-inch bakelite rod, about 12 inches long. One end is mounted pivotally toward the back of the probe, permitting the free end to rest against the chassis of the subassembly for support.

Specifications

Attenuators

Attenuators include 1:1, 3:1, 10:1, 30:1, and 100:1 types. All have an input impedance representable by a resistance of 10 megohms shunted by a capacitance of 2 to 8 $\mu\mu$fd.

Cathode Follower

Input signal amplitude ± 1.8 volts maximum; ± 0.15 volt minimum. (Both determined by the amplifier used with the probe.) The circuit has a high-frequency response impedance level of 10 megohms within the usable range. Gain is approximately ⅓; output impedance, 93 ohms. The tube used is a subminiature triode, SC968.

Power Supply

If the probe is used near its video amplifier and synchroscope, power is obtained from a supply mounted on the synchroscope chassis. If it is used at a remote distance, the same power supply is available in a portable case. Voltages used are + 75 v. d.c. and 6.3 v. a.c.

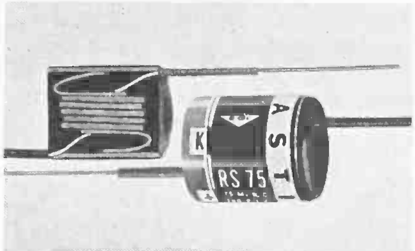
New Products

(*Continued from page* 25)

tiometer, (3) direct load connection with the control diode for regulations of voltages; four vacuum tubes and no relays; and tube filament voltages regulated for long life.

ELECTRONIC SELENIUM RECTIFIERS

An improved design of molded-in electronic selenium rectifiers has been announced by *Electronic Devices Inc.*,



Precision Rectifier Div., 429—12th St., Brooklyn, N. Y. Manufactured with bar or insulated tin-copper leads, the rectifiers have an outer case of spiral-wound phenolic wax which is rock hard at 100°C and whose thermal conductivity and low loss plates compensate adequately for the loss of cooling due to molding in.

In ratings from 250 ma. d.c. to 500 ma. d.c. the standard open plate construction is used. However, the high-efficiency plates lead to cooler operation and longer life.

CONTACT-OPERATING SWITCH

Developed for industrial use, the Type A-C-O Switch permits unusually fast switching by the return-action design of the operating plunger mechanism, which is insulated from the contacts. The *General Control Company*, Boston 34, Mass., announces that its typical applications are on machine tools, circuit transfer of timers and recording equipment; in safety circuits, and as a limit switch. The operation is such that the first press transfers the contacts, and the second press restores them, with single-pole, double-throw contacts permitting adaptation of the A-C-O switch to either normally closed or normally open circuits.

MULTIPLE PRECISION CONTROL

The Series 42A potentiometer, manufactured by the *Clarostat Manufacturing Company, Inc.*, Dover, N. H., accomplishes simultaneous control of 2 to 20 circuits or functions in electronic computing equipment.

Encased in a mineral-filled bakelite housing, designed to lock together with similar units forming a single tandem assembly that is held together by metal end-plates and threaded tie rods, the potentiometer has a resistance range of 100 to 100,000 ohms for linear windings. The contact arm of each unit can be readily adjusted on the common shaft that slips through the tandem sections, synchronizing with the common shaft or with the contact arms of other units.

News Briefs

(*Continued from page* 23)

putation. Having been granted a Ph.D in 1950, Dr. Hoffman was the recipient of a Pulitzer scholarship, a New York State scholarship and a Columbia University fellowship.

Appointed to the consulting staff of the National Bureau of Standards is Dr. Frank Wenner, consulting physicist in the development of electrical instruments for the *Rubicon Company.*

NEW LITERATURE

Wire Wound Potentiometers

The *DeJur-Amsco Corporation* has issued a new four-page catalogue covering its line of series L-400 precision wire-wound potentiometers.

The catalogue No. RE-L is available by writing to *DeJur-Amsco Corporation*, Industrial Division, 45-01 Northern Blvd., Long Island City, N. Y.

Balitron Circuits

(*Continued from page* 8)

of the tube was 17 per section, the total voltage gain was found to be 82. Oscilloscope patterns showed no noticeable distortion.

A circuit which is of doubtful value at the present time, but interesting, nevertheless, is the negative resistance amplifier circuit shown in Fig. 5. The *R-C* circuit, shown in Fig. 5A, looks like an ordinary *R-C* amplifier, but the factor of negative R_p on P_d-T_p changes the whole concept.

When the source (*S*) drives N_d negative, the current to T_p-P_d is increased. This increase in current lowers the T_p-P_d voltage, and the negative R_p condition tends to increase the current to this member above the change produced by N_d. The current to T_p-P_d will continue to increase until either the source changes the value of voltage applied to N_d in the opposite direction, or the lower limit of negative R_p is reached.

When the signal voltage from the source (*S*) approaches its maximum negative value, the negative R_p will continue to act on the beam until the signal voltage has changed sufficiently towards the positive to counteract the effect of this action. When this occurs, it causes a reversal of the negative resistance action and $I_{Pd\text{-}Tp}$ is decreased, both by the signal voltage acting upon N_d and the negative R_p which is now trying to increase the voltage and decrease the current to that member. This action continues as the source goes through zero and climbs to the positive peak of the input signal. Here again, the N_d voltage must be changed sufficiently to overcome the negative R_P condition before another reversal of operation can take place.

Obviously, regeneration is taking place within the tube due to the negative resistance characteristic. This regeneration is not, however, that which is ordinarily conceived. This negative resistance regeneration differs from the normal regeneration in that no actual feedback of ordinary resistance, capacity, or inductive origin takes place. In addition, the actual value of the input signal is in no way altered as in ordinary regeneration.

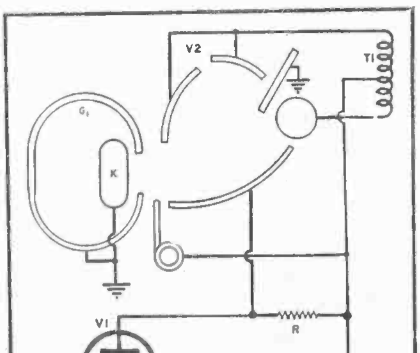
The gain of this amplifier is extremely large and the ordinary values of gain are vastly exceeded. One model of this tube had a maximum theoretical gain of 17.4 but produced a total gain of 196.

To reduce the negative R_p regeneration and increase the fidelity without sacrificing the vast gain of this tube entirely, actual regenerative feedback can be utilized. This condition is shown in Fig. 5B where the capacitor *C* is coupled directly from T_p-P_d to N_d. In this circuit, when the T_p-P_d voltage tends to swing positive or negative, voltage is fed back to N_d out of phase with the signal voltage on N_d, and the swing upon T_p-P_d is reduced. Thus, a normal regenerative circuit (capacity between grid and plate) is used to provide degenerative feedback. If *C* is made variable, it could be used as a gain control. But the fact that capacity is deliberately inserted between the input and output elements of the tube is of tremendous importance, since it illustrates most fully the freedom from normal capacity coupling.

A problem that has been the subject of considerable study has been the development of a means of directly coupling the plate of the first amplifier of a series to the control element of the next amplifier. Many of the direct-coupled circuits are well known, such as the Loftin-White circuit and the various d.c. amplifier circuits. Most of these circuits require a tapped power supply.

The Balitron offers a new solution to this problem. Previously, the limiting factor on direct coupling has been the necessity of operating the control element of the following tube at, or near, the cathode potential of that tube. In the Balitron, changes in tube design have produced a tube which requires a positive bias of up to 90 volts to reach cross-over (the point where the currents flowing to T_a and T_p are equal.) Under these circumstances, coupling from a previous amplifier plate to the control element of a Balitron amplifier can be accomplished as shown in Fig. 7.

Fig. 7. Direct-coupled amplifier circuit which overcomes many disadvantages of conventional circuits.



Here, V_1 is any type of low voltage amplifier, such as a 6SQ7, where the load resistance *R* is acting as the plate load and dropping the plate voltage to the operating value. Signal voltage is applied to the grid of V_1 and normal amplification takes place. The plate of V_1 is tied directly to N_d of the Balitron tube, V_2. Changes in the plate voltage of V_1 change the voltage on N_d, and the current through the Balitron is swung to produce an output in the transformer T_1.

It would be supposed that the positive N_d would draw large amounts of current from the cathode of V_2 and produce damping action upon the signal voltage. But such is not the case. Due to constructional design, N_d does not draw current until the N_d voltage rises to approximately 95 volts. For this reason, no power is drawn by the input, and the signal voltage is not damped.

The elimination of tube-introduced noise is one of the major problems of radio engineering. Hum, various phenomena introduced by the electron energy quantum, and variations produced by changes in value of applied potentials, all combine to produce output voltages which are not introduced by the input signal. In the Balitron, a new approach is offered to the problem. Since this tube operates normally as a single-ended input, push-pull output amplifier, it is quite obvious that it has all the hum suppressing characteristics of any push-pull circuit. Thus, power supply variations are not such a source of trouble.

Changes in cathode emission of either a periodic or random nature, such as shot effect, are then introduced into a push-pull circuit. Since these effects produce changes in the number of electrons in the beam, and since the variation splits into two substantially equal parts flowing in opposite directions in the plate circuit, it is clear that the effective noise voltage produced in the secondary will be zero. Changes in the accelerating anode voltage produce the same effect as a change in electron emission, and the resultant noise voltage is again zero.

Thermal agitation in the input is not, of course, affected by these conditions. Partition noise is reduced because the receiving elements are on nearly the same concentric plane and not dispersed in a series of concentric attractive planes.

Part of the problem would then seem to be solved by the use of the Balitron. The fidelity of response should be exceptionally good. The use of the Balitron as an r.f. preamplifier should increase the available signal-to-noise ratio values.

An effort has been made here to show some of the more important circuits and applications of the Balitron that have been discovered which differ markedly from the ordinary tube. These are special applications of the Balitron and should not be thought to be limitative of its field of application.

It must be emphasized that the full possibilities of these circuits have not been made by the author. The main interest of the author has been the development of the Balitron into an effective tube. However, the research problems presented various aspects of design which were recognized as sources for additional investigation. Insofar as possible, preliminary tests have been made on these circuits with positive results. Research facilities and time limitations have forced these tests to be modest. Qualitative analysis has not, therefore, been undertaken.

Without full investigation into all the aspects of these circuits, these can only be construed as suggestions with some supporting evidence to indicate their workability. Additional research must be undertaken to establish their true value.

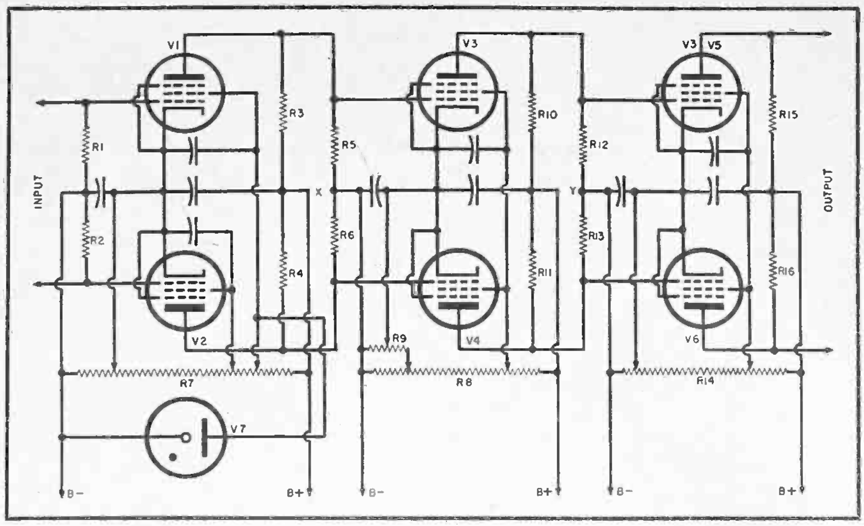


Fig. 5. Circuit diagram of a complete, three-stage amplifier using the principles outlined in this article. The amplifier is pictured on page 9.

Rectilinear Amp.

(*Continued from page* 10)

photoelectric cell which is measured in fractions of a microampere, and deliver over 150 mils at 300 volts in the output of each power tube, which is equivalent to approximately 45 watts of power.

Freq. cps	Input Volts	Output Volts
Zero	.0100	182.
30	.0100	190
50	.0105	200
100	.0107½	215
250	.0100	220
500	.0100	200
1000	.0100	200
2500	.0102	204
4000	.0102	204
7500	.0102½	205
10,000	.0105	208
15,000	.0110	210
20,000	.0125	212
30,000	.0150	216

Table 1. Frequency response of the complete amplifier from zero to 30 kc. It can be seen that the average gain is about 20,000, and that this value is closely approached throughout the total range of 0 to 30 kc.

Table I indicates the frequency range of the amplifier, with its related input and output voltage differential. With a square wave signal pattern of up to 30 kc. applied to the input terminals, essentially an exact duplicate of this pattern is produced in the output circuit, as pictured on an oscilloscope, indicating that the time rise factor is very low.

The stability of this amplifier is such that it can not be made to oscillate under any normal operating conditions. A variation of over 25% can take place in the power supply with no appreciable change in the output circuit. The a.c. hum is less than one tenth of one percent of the output signal, although a relatively small amount of filtering is used in the a.c. power supply units.

The values of the resistors of the circuit will depend upon the characteristics of the tubes. The condensers used are merely for bypass purposes of the filtered power supply. Tubes V_1 and V_2 are in a bridge-type circuit arrangement with a potentiometer across part of the B power supply of the screen grid circuit. This layout provides for an automatic biasing control in the input of the next stage so that zero potential is applied to the grids of the following two tubes at zero signal. Thus, when a signal is impressed upon the input terminals, the circuit of one tube is 180 degrees out of phase with the other tube, with a resultant push-pull action.

The plates of V_1 and V_2 are directly connected to V_3 and V_4, respectively. However, the B supply of V_1 and V_2 is independent of the B supply of V_3 and V_4. The output plate circuit of the power stage is coupled through two resistors. Due to the potential difference across these two resistors, only the a.c. component is impressed upon the output circuit. The heater current for these various tubes is applied in the conventional manner.

Although this amplifier was developed primarily to be used in conjunction with the photoelectric engraver with all its exacting requirements, it is by no means limited to this use only. Its predominant use would be in the extreme low frequency field where it may take minutes, hours, or even days for a significant change to take place, and then this change may occur quite suddenly, in as much as a thousandth part of a second or less. Considering the circuit characteristics, it has a wide adaptation in practically the entire field of electronics.

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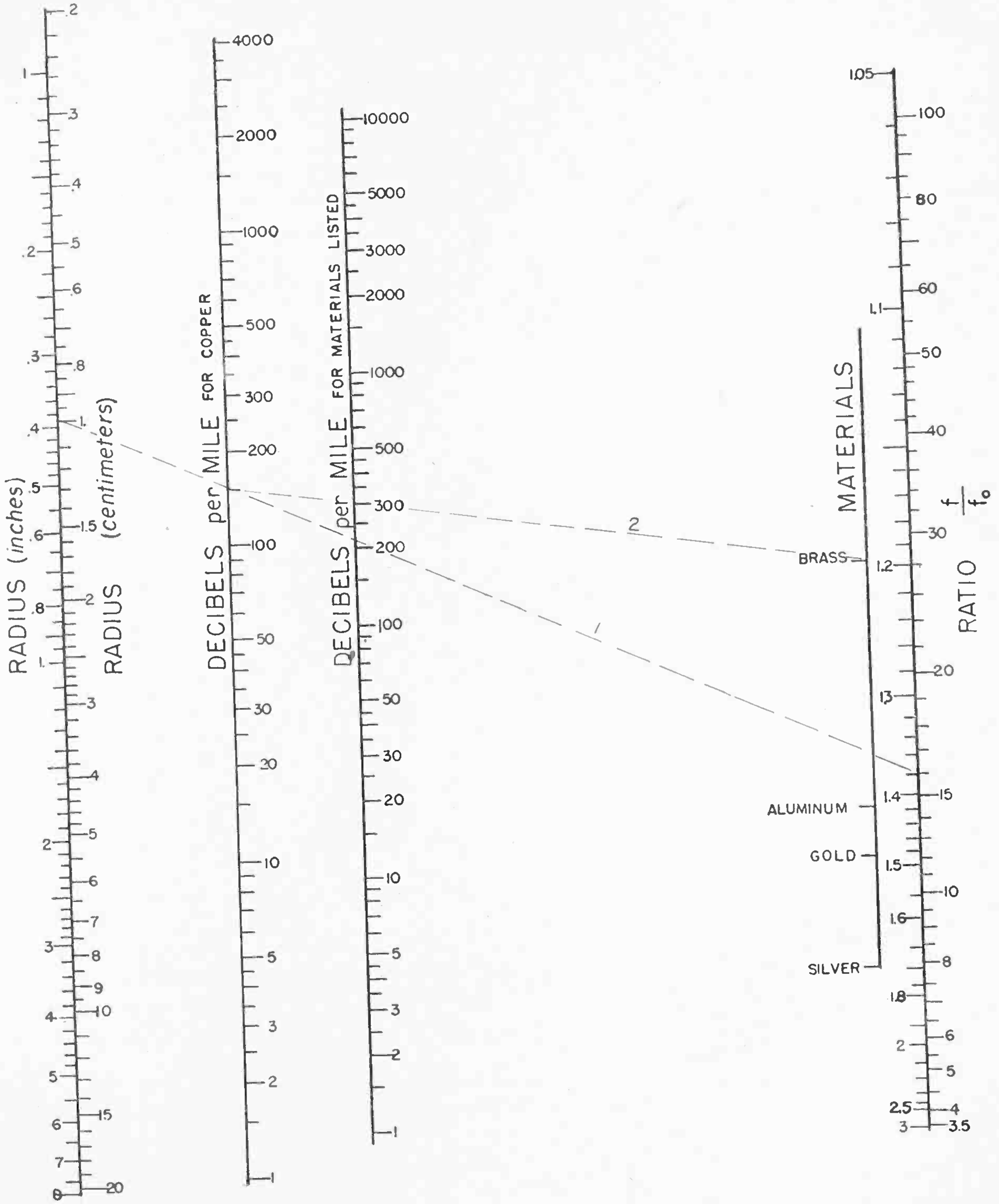
CIRCULAR WAVE GUIDE ATTENUATION

Nomograph for determining the attenuation of the $TE_{1,1}$ (H_o) mode in a circular air-dielectric wave guide.



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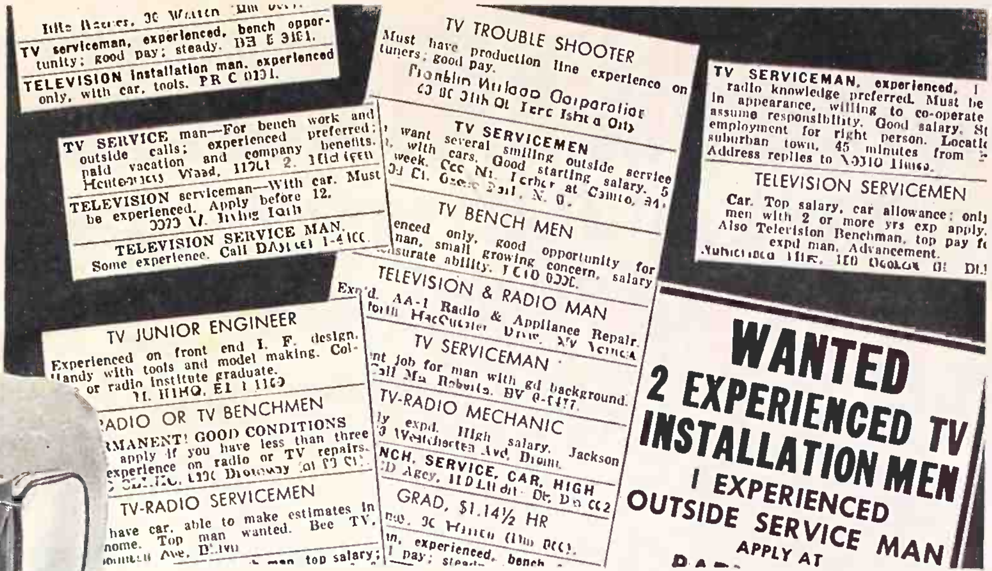

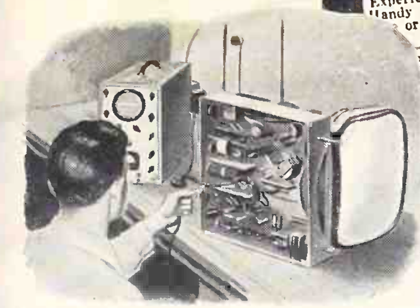

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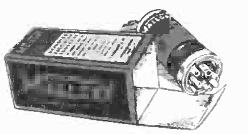

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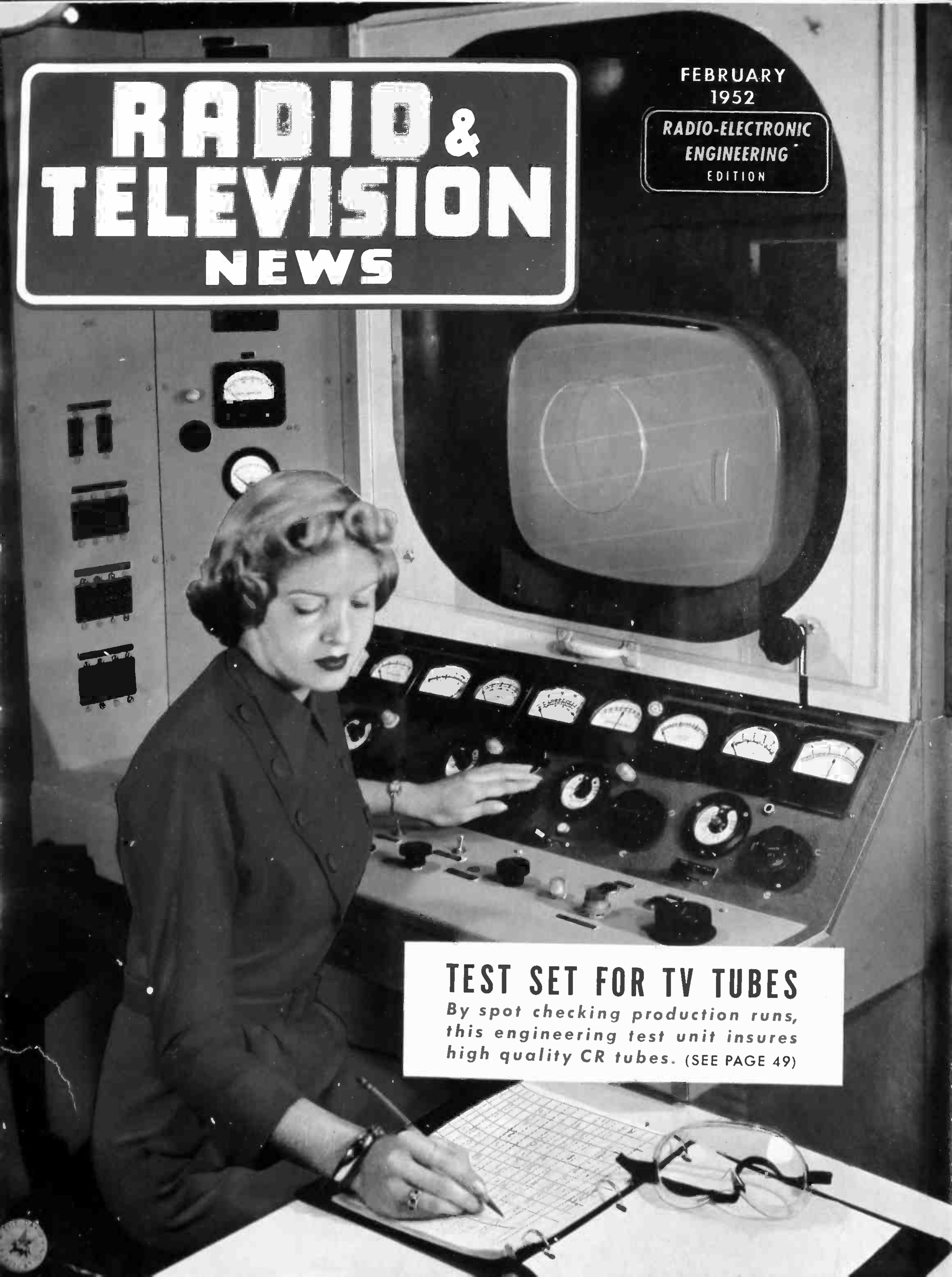

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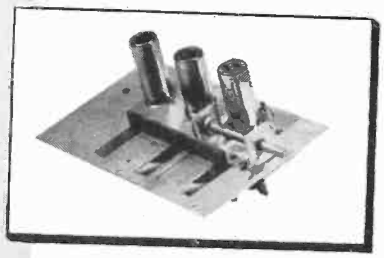
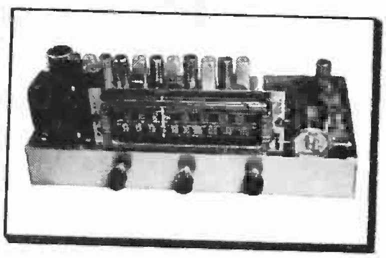
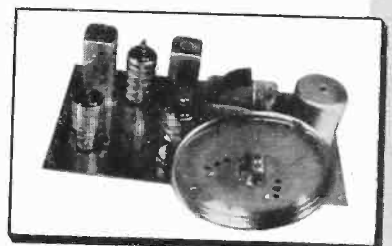


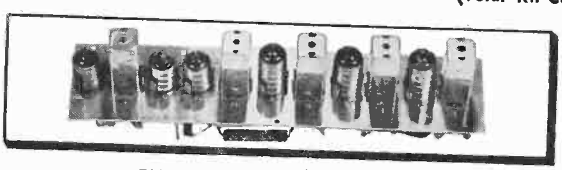
FM Tuning Unit $15.25



The Collins FM-AM Pre-Fab Tuner Assembled (Total Kit Cost $69.00)



AM Tuning Unit (Includes IF and Audio Amplifier) $19.25



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