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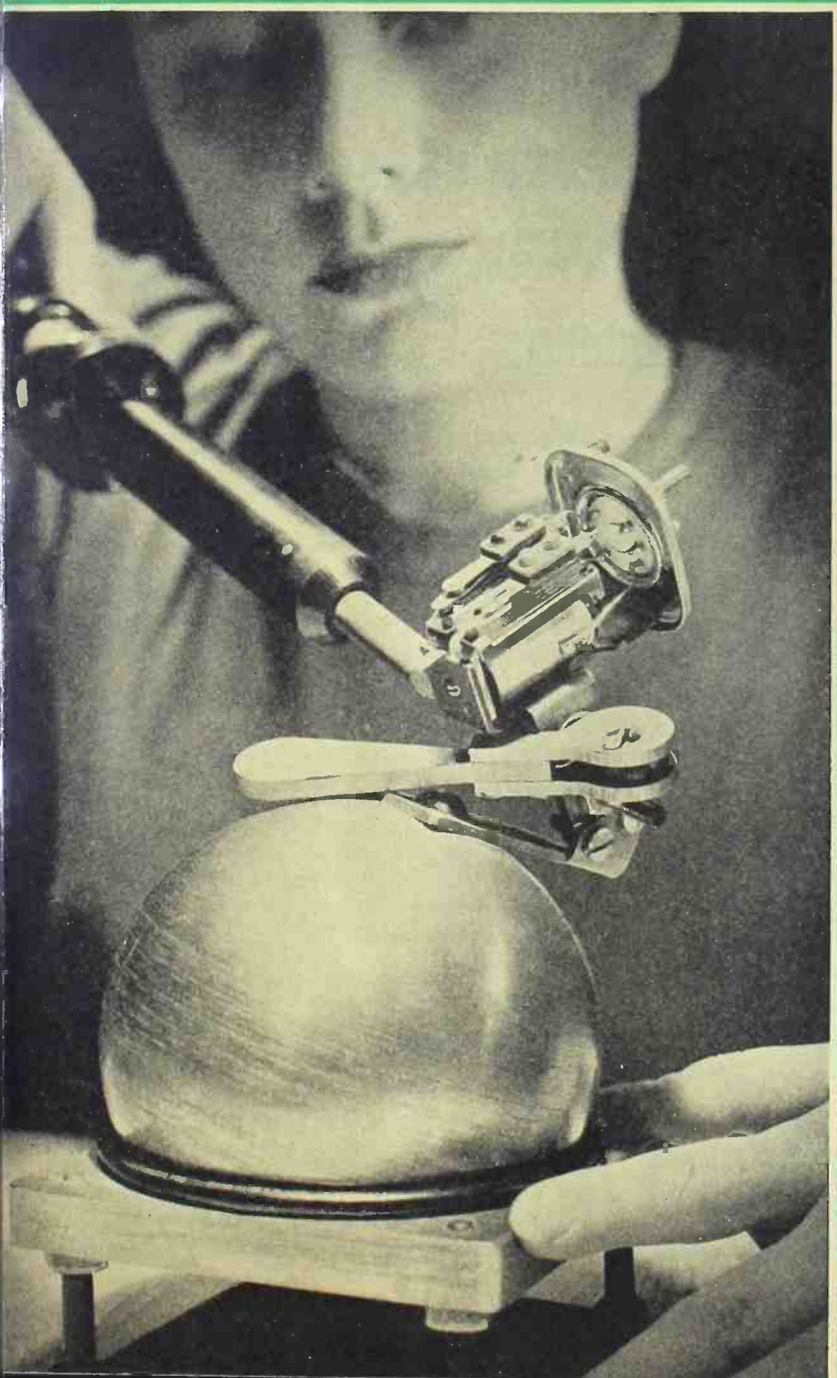

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Production men at Potter and Brumfield, Princeton, Indiana, have developed this unique ball-and-socket universal holding jig consisting of a small vise mounted on a 20 lb. steel ball. It is used in the manufacture of midget and subminiature relays.

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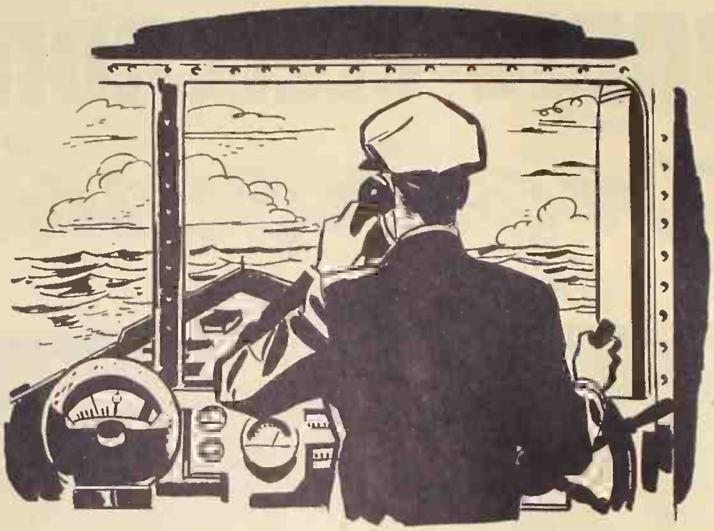

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SYLVANIA ELECTRIC

RADIO TUBES; TELEVISION PICTURE TUBES; ELECTRONIC PRODUCTS; ELECTRONIC TEST EQUIPMENT; FLUORESCENT TUBES, FIXTURES, SIGN TUBING, WIRING DEVICES; LIGHT BULBS; PHOTOLAMPS; TELEVISION SETS

SLOT ANTENNA DEVELOPMENTS

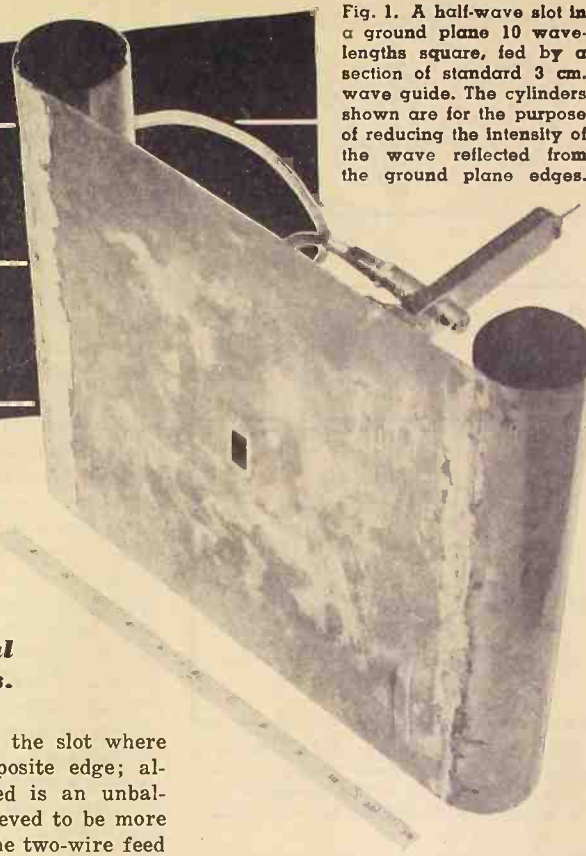


Fig. 1. A half-wave slot in a ground plane 10 wavelengths square, fed by a section of standard 3 cm. wave guide. The cylinders shown are for the purpose of reducing the intensity of the wave reflected from the ground plane edges.

By D. R. RHODES

Antenna Laboratory
Ohio State U. Research Foundation

Part I of a 2-part article presenting a general discussion of various types of slot antennas.

PERHAPS the most extensive research on antennas today is being conducted on various aspects of the so-called "slot" antenna. Several factors are responsible for the intense activity in this field, the most important being the fact that slot antennas, consisting simply of electrically excited holes in conducting surfaces, are inherently flush-mounted and hence are true zero-drag antennas. The property of zero-drag has always been held as an ultimate goal by designers of antennas for rapidly moving vehicles, and it was to this end that the more common types of antennas were streamlined as much as possible. There are practical limitations, however, and for many of the specialized requirements of today it would be virtually impossible to stay within the limits imposed by aerodynamic considerations. In addition to being flush-mounted, certain forms of slot antennas possess the important advantage of having controllable directions of radiation, beam widths, and side lobe levels, while still retaining the mechanical simplicity and ruggedness of construction necessary for successful operation and maintenance.

Rectangular Slot

The simplest type of slot antenna from the point of view of construction and ease of understanding is a narrow rectangular hole cut in a conducting plane surface and excited by a transmission line connected to opposite edges of the slot, usually at the center. Such an antenna is pictured in Fig. 4A. The feed system shown is a coaxial cable with the outer conductor grounded on one side of the slot and the inner conductor extended across the slot where it is joined to the opposite edge; although the coaxial feed is an unbalanced system, it is believed to be more practical in use than the two-wire feed system.

The radiation pattern produced on one side of the conducting plane in Fig. 4A is nearly the same as the radiation pattern of a dipole of the same size and shape, *i.e.*, a "complementary" dipole. This is a direct consequence of an old optical principle given by Babinet, when restated for general electromagnetic fields,[1] and has been confirmed by experiment. As an example, the measured pattern at 10 cm. wavelength of a slot 1.5 wavelengths long in a conducting plane 12 wavelengths square enclosed on one side by a circular cavity is shown in Fig. 2, and is compared with the theoretical pattern of the slot in an infinite conducting plane, or of the equivalent dipole in free space. The pattern in a plane perpendicular to the slot axis is essentially uniform on the radiating side of the slot. When the slot is half a wavelength long, the three dimensional pattern is nearly half of the familiar donut pattern of the half wave dipole, as shown in Fig. 4B. The impedance of a center fed rectangular slot is also determined from considerations based on the general form of Babinet's principle, the relationship between impedances of the slot and its complementary dipole being simply that their product is the square of half the impedance of space!

On the basis of the complementary relationship, the analogy between slots radiating in half-space and strip dipoles can be seen from Fig. 4C and D. For our purposes it will be convenient to assume that the slot and dipole are a very small fraction of a wavelength wide. Then, if the dipole is fed by a two-wire transmission line, the slot will also be fed by a two wire transmission line but at right angles to that of the dipole. A magnetic field exists in concentric circles around the dipole, while an electric field exists in concentric circles around the slot (on the radiating side of the slot). The analogy has been carried further in the literature by assuming that all slot radiation originates from equivalent "magnetic currents" in the slot itself, but since these are purely hypothetical and do not exist physically it is well to remember that all radiation must originate from actual electric currents flowing on the conducting plane in which the slot is cut. Nevertheless, the concept of equivalent magnetic currents are quite useful for obtaining the radiation pattern of complicated slots and slot arrays.

An important consequence of the slot-dipole analogy is the fact that *any wire antenna* (*e.g.*, dipole, loop, long wire) *or any array of wire antennas* (*e.g.*, bedspring, rhombic) *which lies entirely in a plane has the same radiation pattern as the slot or array of slots of exactly the same shape when cut in a large conducting plane (electrically shielded on one side) and when similarly excited.* It is this general comple-

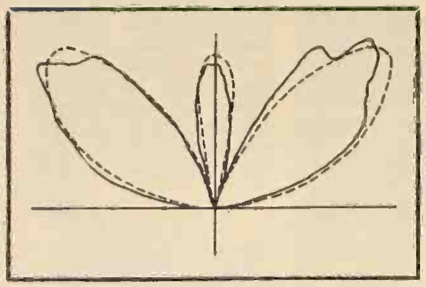


Fig. 2. Measured (solid) and calculated (dotted) radiation pattern in a plane containing a center-fed slot 1½ wavelengths long in a ground plane.

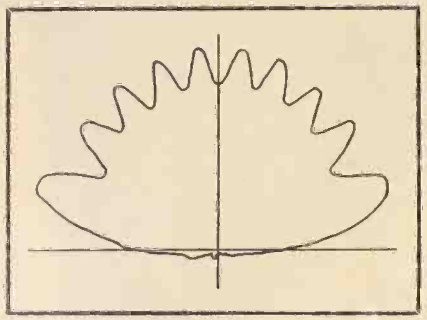


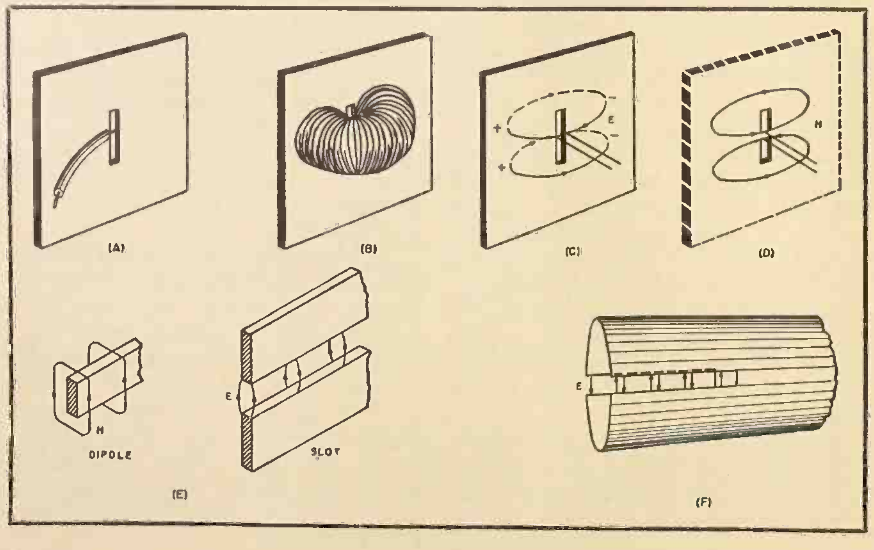
Fig. 3. Radiation pattern of a half wavelength slot in a square ground plane 10 wavelengths on a side measured in a plane perpendicular to slot axis.

mentary relationship which has made the slot analogy so useful to antenna design engineers. All that is known about the directive properties of wire antennas can either be applied directly or serve as a guide for designing flush mounted antennas. The complementary relationship is well illustrated for a number of slot antennas and other slot devices in a recent paper by C.E.G. Bailey.[2]

The necessity for restricting the slot-dipole analogy to slots radiating only on one side of a conducting plane becomes apparent when the fields about the slot and dipole are considered. Since the magnetic field about a dipole consists of closed loops, the analogy would require closed loops of electric field about the slot. The actual electric field about a slot in a plane, however, is as shown in Fig. 4E. Instead of forming closed, continuous loops, the electric field terminates on charges, with the result that the electric field is symmetrical rather than asymmetrical with respect to the plane of the slot. The pattern in a plane perpendicular to a slot in a conducting plane of practical size is quite different from the uniform pattern of a dipole if the slot is not shielded on one side. The most radical difference is in the plane of the slot, where a complete null due to out-of-phase radiation from the two sides of the slot is observed. A more accurate slot analog of the dipole is a pair of slots cut parallel to the axis on opposite faces of a thin elliptic cylinder and excited as shown in Fig. 4F. A very thin cylinder (small minor axis) closely approximates a conducting plane. The pattern about the axis of this antenna is nearly uniform. This method has been successfully applied to aircraft requiring a uniform horizontal pattern by considering the rudder as a cylinder of approximately elliptical cross-section;[3] two vertical slots on opposite faces of the rudder when fed in-phase produce the required pattern.

The electric field distribution in a rectangular slot is nearly sinusoidal. This is the field distribution one would expect on the basis of the slot-dipole analogy and is, in fact, found to be true experimentally. In addition to the similarity between the slot and a dipole, the resonant slot also strongly resembles a parallel wire transmission line short-circuited at both ends. The electric field distribution in a slot which is some multiple of a half wavelength long is nearly the same as the current distribution on a shorted transmission line. The flow of current on a transmission line is restricted to the narrow region defined by two parallel wires, and because of the close proximity of equal and oppositely flowing currents the total power radiated is negligible. The flow of current on a conducting sheet surrounding a slot, however, is spread out over a large area, with the result that a large part of the total available power is radiated into space. The radiation pattern for a slot is actually due to interference between currents flowing on all parts of the sheet, this is the same pattern as would be obtained from a "magnetic current" in the slot aperture.

Fig. 4. (A) Rectangular slot in a conducting plane. (B) Three dimensional radiation pattern of a half wavelength slot in a ground plane. (C) and (D) Electric and magnetic fields surrounding a slot and its complementary dipole. (E) Cross-section of a slot and complementary dipole. (F) Slotted elliptic cylinder as an analogue of the strip dipole.



It is rarely necessary, in practice, to let a slot radiate freely on both sides of a conducting surface. Usually the conducting surface is completely closed, with the slot enclosed on one side in a conducting cavity. This would certainly be necessary in aircraft, for instance, where equipment and personnel would otherwise be in the field of radiating currents. Experience has shown that the radiation pattern of a shielded resonant slot is affected very little by the type of shielding enclosure, but that the impedance properties can be vastly modified. Although a few scattered experiments have been reported, there as yet appears to have been no systematic study of the effect of cavity enclosures on the impedance of rectangular slots. Since the radiation patterns of straight wires (and hence of narrow rectangular slots in conducting planes) of various lengths and feed positions are well-known to electronic engineers,[4] they will not be considered any further here. Their general properties are obtained simply from considering interference between radiating current elements, whether they are true electric currents on the dipole or fictitious magnetic currents in the slot.

One significant modification of the slot-dipole analogy exists due to the necessarily finite size of the conducting plane in which the slot is cut. Instead of the uniform pattern expected when moving a probe in a plane perpendicular to the slot axis, it is found that the radiation field oscillates as a function of angle about a constant value and that it falls rapidly to zero in the direction of the plane. By way of illustration, the pattern of a center-fed half-wavelength slot in a square conducting plane 10 wavelengths on a side, measured at a wavelength of 3 cm., is shown in Fig. 3. These oscillatory scallops can be effectively reduced by curling the edges of the plane (see Fig. 1) thereby reducing the magnitude of the waves reflected from the edges of the plane and hence reducing that part of the power which is radiated by the partial standing wave of current on the sheet.

Slot Arrays

Rectangular slots can be arrayed in exactly the same manner as dipoles to produce a desired directional pattern. A planar array of slots fed in any way whatever will have the same pattern as a similar array of dipoles whose elements have the same relative phase and amplitude relationships. Rather than constructing slot arrays by grouping together individually shielded slots whose phase and amplitude are determined by adjusting feed cables, a method of wave guide excitation has been developed[5] that is used extensively at microwave frequencies. The array consists simply of half-wavelength slots cut in the walls of a wave guide. Radiation from a slotted wave guide depends on the position and orientation of the slots. When the slots are narrow in terms of wavelength, the field in each slot depends essentially on the component of current at right angles to the slot.

A broadside co-linear array of resonant, half-wavelength slots can be fed by a rectangular wave guide as indicated in Fig. 5A. To insure stability of the fields in the wave guide it is customary to allow only the dominant $TE_{0,1}$ mode in the guide by choosing a guide whose cross-section will not allow any higher order modes. Slots directed axially are excited only by transverse currents in the wall of the guide. About the center line the transverse currents have equal magnitude and opposite phase, the phase progressing uniformly along the guide according to the phase velocity in the guide. If the guide is a multiple of a half-wavelength long and short circuited at the ends, a standing wave of electric field is set up which has maxima one half of a guide wavelength apart, succeeding maxima being opposite in phase. Thus, staggered slots spaced at intervals of one half of a guide wavelength are excited all in-phase and, when radiation from each slot is small relative to the power in the guide, have nearly the same amplitude. The radiation pattern of such an array is highly directional in a plane through the slots, or rather through the center line of the guide, while remaining essentially omnidirectional in a plane perpendicular to the slots. The directional properties of this array are well illustrated by the pattern in Fig. 6 of an array of eight half-wavelength slots in the broad face of a section of standard X-band rectangular wave guide. This pattern was measured by Robert Krausz at a wavelength of 3.2 cm,; the pattern is typical for any similar array of uniformly excited slots or dipoles.

An array of slots such as as that in Fig. 5A can be mounted in a large conducting surface by electrically joining the slotted face of the wave guide to the surface of the conductor in some suitable manner. A practical method of constructing a wave guide fed array in a conducting surface is simply to remove one broad face of the wave guide and replace it by the slotted surface.

The broadside array of uniformly excited slots is, in a sense, a special case of a general method for obtaining any desired radiation pattern. Although the broadside array is the simplest form of co-linear array, it is possible to obtain any radiation pattern by proper adjustment of phase and amplitude of a sufficiently large number of half wavelength slots.[6] To produce an arbitrary phase difference between slots it is sufficient to terminate the wave guide in a matched load, thereby establishing a continuous phase distribution in the guide. The required phasing of each slot is then obtained by properly choosing the position of each slot along the guide and the phase velocity in the guide, and the amplitude distribution is obtained by adjusting the distance of each slot from the center line. This method has met with considerable success in the design of arrays to produce specifically shaped beams.

Two dimensional arrays of slots can be constructed by assembling several of the above one dimensional wave guide slot arrays parallel to each other. The radiation pattern in a plane perpendicular to the parallel wave guides is then controlled by the spacing between wave guides and by the choice of the relative phase and amplitude of power fed into the wave guides. The over-all radiation pattern of a two dimensional square array of uniformly fed, equally spaced slots has the form of a pencil beam whose sharpness is determined by the number of slots in the array. This type of slot array is analogous to the "bed-spring" array of electric dipoles used in early low frequency radar sets.

Parallel as well as co-linear slot arrays can be cut in wave guide walls

(*Continued on page* 31A)

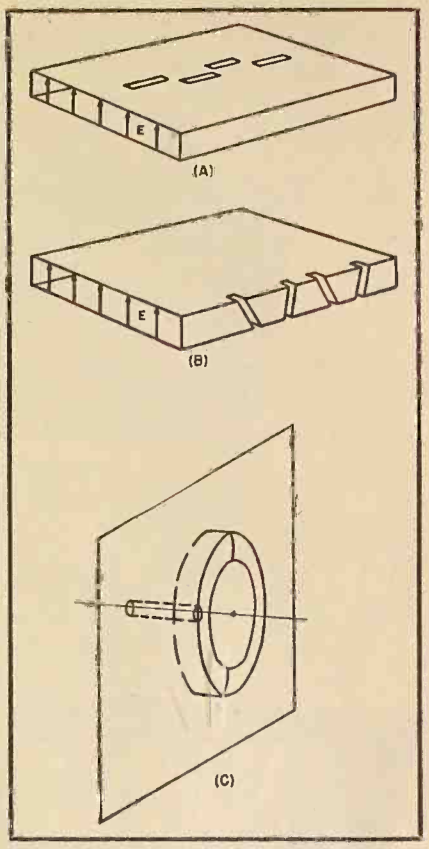


Fig. 5. (A) Co-linear array of resonant slots in a rectangular wave guide. (B) Array of resonant slots in edge of a rectangular wave guide. (C) Annular slot in a conducting surface.

Fig. 6. Radiation pattern of a broadside array of eight resonant co-linear slots in a rectangular wave guide measured in a plane through the slot axis.

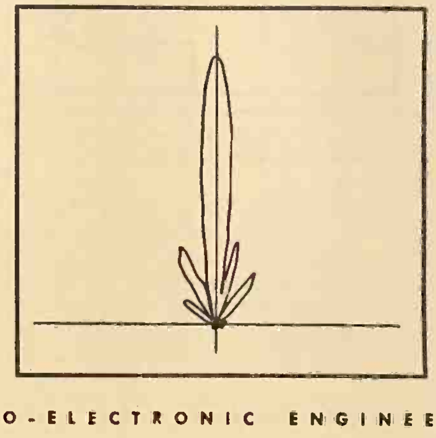
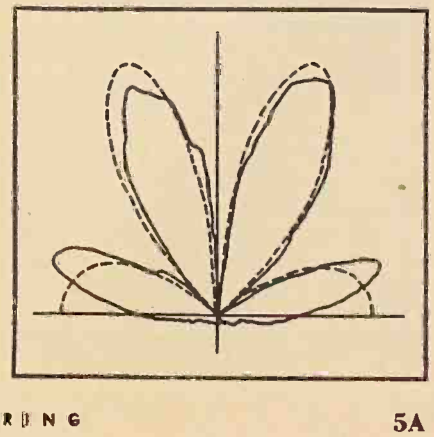


Fig. 7. Measured (solid) and calculated (dotted) pattern in a plane through axis of annular slot 1.62 wavelengths in dia. in a 12 wavelengths square ground plane.



Simple bench setup required to run calibration curve on a.v.c. meter. Typical curve is shown in Fig. 2.

METER A.V.C.

By ALVIN B. KAUFMAN

Useful circuits for causing meter sensitivity to be altered as the deflection is varied.

A METER with a.v.c. action is an extremely useful and interesting instrument to have around an engineering laboratory.

The meter or circuit to be described is completely electronic, using no tubes, and consisting of only three items, a micro or milliampere meter, a half-watt resistor, and a *Conant* Type BH or BHS instrument rectifier.

A meter with a.v.c. action is mainly useful as a galvanometer, but it may be calibrated to be useful as a voltmeter or milliammeter. In these latter uses the accuracy is approximately three to five per-cent when the basic meter movement is two per-cent and where the scale is hand calibrated.

This meter does not have a suppressed zero, or expensive non-linear D'Arsonval movement, but uses, as indicated, an ordinary meter whose case does not even have to be opened, unless it is desirable to put the two additional components inside the case, or a direct recalibration of the meter scale is required.

The a.v.c. meter may be used to advantage with capacity, inductance, and resistance bridges. It is desirable for bridge operation to have the null indicator extremely sensitive near null and very insensitive away from null. This allows the operator, when off of null, to observe if he is resetting the bridge in the proper direction, without the nuisance of changing the meter or bridge amplifier sensitivity by hand for each new balancing operation.

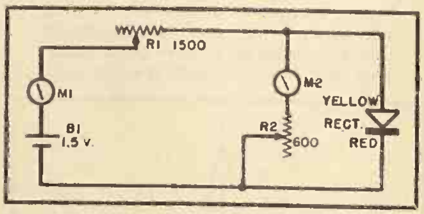


Fig. 1. Typical test setup and calibration using a 0-1 ma. meter.

Meter a.v.c. rather than amplifier a.v.c. to obtain this bridge characteristic results in sharper and easier to secure nulls. Maximum sensitivity exists with all bridge components acting at maximum sensitivity. With amplifier a.v.c. effectively the amplifier gain is reduced the instant the bridge is unbalanced off the null. This immediate reduction in gain causes the bridge to have a broad null, too much so, as to be a satisfactory method of achieving the desired results. Optimumly the bridge amplifier gain or meter sensitivity should vary as a two step proposition, with a square wave type of response. Here as the null is almost reached, the meter sensitivity suddenly increases and remains fairly constant over the lower ten per-cent of the dial. This meter a.v.c. does. Thus for the final setting of the null, the meter sensitivity remains constantly high *for a wide enough balance range* to secure an easy sharp null.

Galvanometers may be of the zero center type, used with d.c. bridges or a regular meter using a.c. bridge rectified a.c. amplifier output signal. Either of these bridges, a.c. or d.c., may employ meter a.v.c.

Six variations of circuitry are shown in Fig. 4, three for standard meters and three for zero center meters. In all cases the basic theory is essentially the same, so the three standard meter circuits will be discussed. The zero center meters require additional rectifiers because the direction of current flow changes.

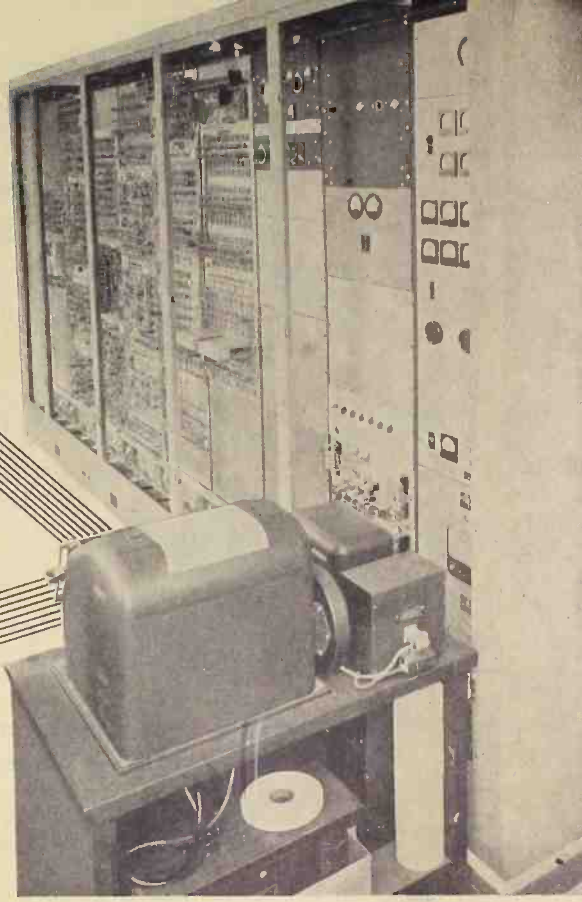
The operation of meter a.v.c. depends on the basic fact that copper or selenium instrument rectifiers have decidedly non-linear rectification curves.

(*Continued on page* 26A)

NBS COMPUTATION LABORATORY

Equipment and techniques available at the National Bureau of Standards for various kinds of computations.

By FRANZ L. ALT
NBS Computation Laboratory



View of SEAC with input-output equipment in foreground. Indirect operation is possible with punched tape.

WITH the completion of SEAC (the NBS Eastern Automatic Computer) and the acquisition of several new types of punched-card computers, the National Bureau of Standards Computation Laboratory is now provided with the most up-to-date equipment available for carrying out its function as a centralized national computational facility.

The functions of the NBS Computation Laboratory are quite broad. In addition to performing computations requested by Federal agencies, universities, and private industries, the laboratory works continuously to create a stock-pile of mathematical tables. At the same time, an effort is made to develop new or improved techniques for numerical computation, particularly those adaptable to automatic computing machines, and to train mathematicians in the application of numerical methods.

Once the SEAC, the Bureau's new high-speed automatically-sequenced electronic computer, has been supplied with coded instructions and numerical data, this general-purpose machine automatically performs all of the logical and arithmetical operations required to solve a particular problem. By combining a vast number of simple operations into a complex, high-speed sequence, it can calculate the answers to many difficult problems whose solutions otherwise would be impractical.

For those problems which are too large for manual computing methods and yet not large enough to make the use of SEAC practical, the four new punched-card machines are proving invaluable. In these machines, which were constructed by the IBM Corporation, numbers are represented by holes punched in cards. When a deck of cards is run through one of these machines, it reads several numbers from each card, performs a prescribed sequence of additions, subtractions, multiplications, or divisions, and punches one or more of the answers obtained into unused portions of the punched card.

In the newest machine of this type acquired by the Bureau, the Card-Programmed Calculator, "programming"—the giving of instructions to the machine—is accomplished by means of cards.

In addition, the Laboratory has new types of electronic sorters and typewriters, as well as a battery of standard auxiliary machines. A card-controlled typewriter specially designed for producing mathematical tables is being acquired. Thus, the Laboratory is equipped to solve a wide variety of computational problems in science, engineering, and administration.

The IBM Card-Programmed Calculator.

The Type 082 IBM Electronic Sorter.

RECORDING ANTENNA RADIATION PATTERNS

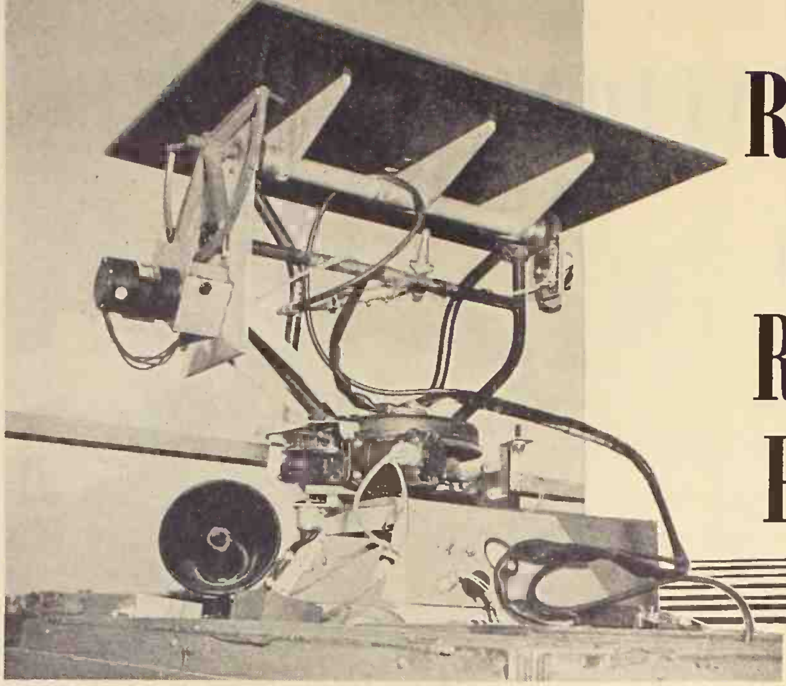


Fig. 1. The motor-driven antenna mount. Separate d.c. motors are installed for azimuth and elevation drives.

This device features a 1000 cycle amplifier, a logarithmic attenuator, and complete flexibility.

By CHARLES W. BRASSE, JR.
Bendix Radio Div., Bendix Aviation Corp.

AS MORE and more antenna research is conducted towards precision pattern requirements, the need arises for dependable but relatively inexpensive antenna pattern measuring equipment.

Experience in plotting patterns point-by-point has shown that: 1. The importance of peaks or nulls occurring between increments is not always evident until much time and money has been wasted. 2. Furthermore, a permanent record is desirable for direct comparison with later developments of similar equipment.

3. It is also quite necessary in most cases to be able to use the same measuring equipment over a wide band of frequencies without major changes. 4. The ability to continuously record inputs varying over 40 db. or more without changing scales is also in demand.

The *Bendix* Automatic Antenna Pattern Recorder is a device which continuously plots the strength of the signal, received by the antenna under study, versus its angular rotation. The position and output of the transmitter remain constant.

Received r.f. energy which is amplitude modulated with 1000 cycles is tuned at the antenna and detected by a bolometer in a suitable tuning assembly. The resultant audio signal is fed into a 1000 cycle tuned amplifier and logarithmic attenuator. The output of this actuates the pen-movement of a modified *Esterline-Angus* Recorder.

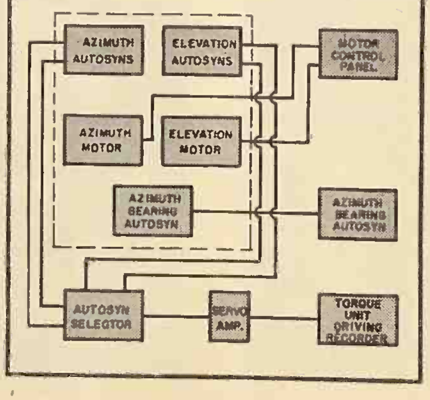
This pen draws a record of the signal strength from the antenna on a standard paper roll which is calibrated linearly over a range of 50 db. The roll of paper is driven by a torque unit which is synchronized with either azimuth rotation or elevation deviation of the motor driven antenna mount.

There is a choice of either 1:1 or 5:1 *Bendix* autosyns on both the azimuth and the elevation axis of the antenna mount, providing 10° or 2° of rotation to the ¾ inch respectively on the final recording. This allows "blow-up" of patterns for closer scrutiny when desirable.

Tuner and Bolometer

The bolometer was selected as the detector because its audio output voltage is directly proportional to r.f. input power. Another advantage of the bolometer over a crystal is that its resistance-power curve is linear over a wide range of power. In this equipment 1/200 ampere Littelfuses are used as bolometers with a d.c. current of 4.7 mils giving optimum performance. In most cases the bolometer holder and tuner have been combined into one unit, stub tuners being used for microwave work, and lumped constant tuners for v.h.f.

Fig. 2. Block diagram of controls for the antenna mount shown in Fig. 1.



Receiver

The heart of the installation is the 1000 cycle amplifier and *Bendix* Logarithmic Attenuator. (Refer to Figs. 4, 5, and 6.)

1000 cycle energy from the bolometer is amplified by two tuned triode stages and one pentode stage. Then, the five pentodes of the logarithmic section follow in cascade. These pentodes are operated in the logarithmic portion of their characteristic curves.

A slight bit of correction in the curve is established by the use of a different pentode in the first stage. After being further amplified, and stabilized with degenerative feedback, the 1000 cycle signal is detected, filtered, and sent back to the grids of the *Bendix* Logarithmic Attenuator section as a.v.c. voltage.

This a.v.c. voltage has the desired logarithmic characteristic. A vacuum-tube voltmeter circuit is necessary to transform this high impedance voltage into a current useful for operating the three meter movements required by the *Bendix* system. The meters are in series and are used as pen movement in the *Esterline-Angus* Recorder, for calibration and visual operation, and as an auxiliary meter at the antenna pedestal for tuning purposes.

A diode circuit operating from a negative supply is connected as a clamp on the a.v.c. line to prevent its voltage from dropping below the point where oscillations and motorboating occur, due to the tremendous inherent gain of the system.

Good regulation of plate and screen voltages is extremely important for proper response of the unit, and a unique circuit for accomplishing this has been incorporated in the unit.

This "receiver system", as described, is quite linear on a logarithmic scale over the required 50 db. It should be noted that the logarithmic attenuator section continues to be linear for at least 10 db. above the rest of the unit, but has not been utilized because of overloading of the first amplifier stages at that level.

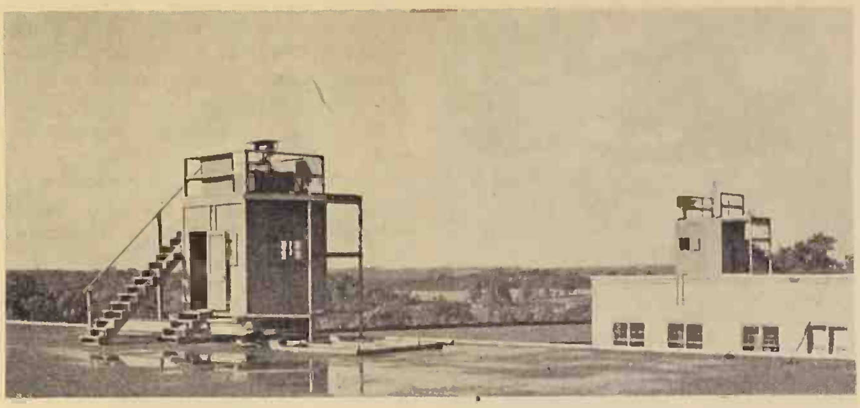


Fig. 3. Over-all view of transmitting (right) and receiving (left) locations.

Decade Calibrator and Modulation Source

Calibration of the receiver is accomplished by four simple controls on the front panel of the logarithmic attenuator which are used in conjunction with a decade 1000 cycle voltage source.

This is necessary to compensate for temperature variations, line voltage fluctuations, and differences due to tube replacements.

A source of 1000 cycle calibration voltage varying from one microvolt to 1/10 volt, with the required accuracy, proved to be difficult to obtain. The unit which evolved consists of a cathode follower, with a resistor decade in the grid circuit, which is fed 1000 cycles from an audio oscillator. The output of the cathode follower is monitored by an a.c. vacuum-tube voltmeter, to which decade checks may be made down to .001 volt.

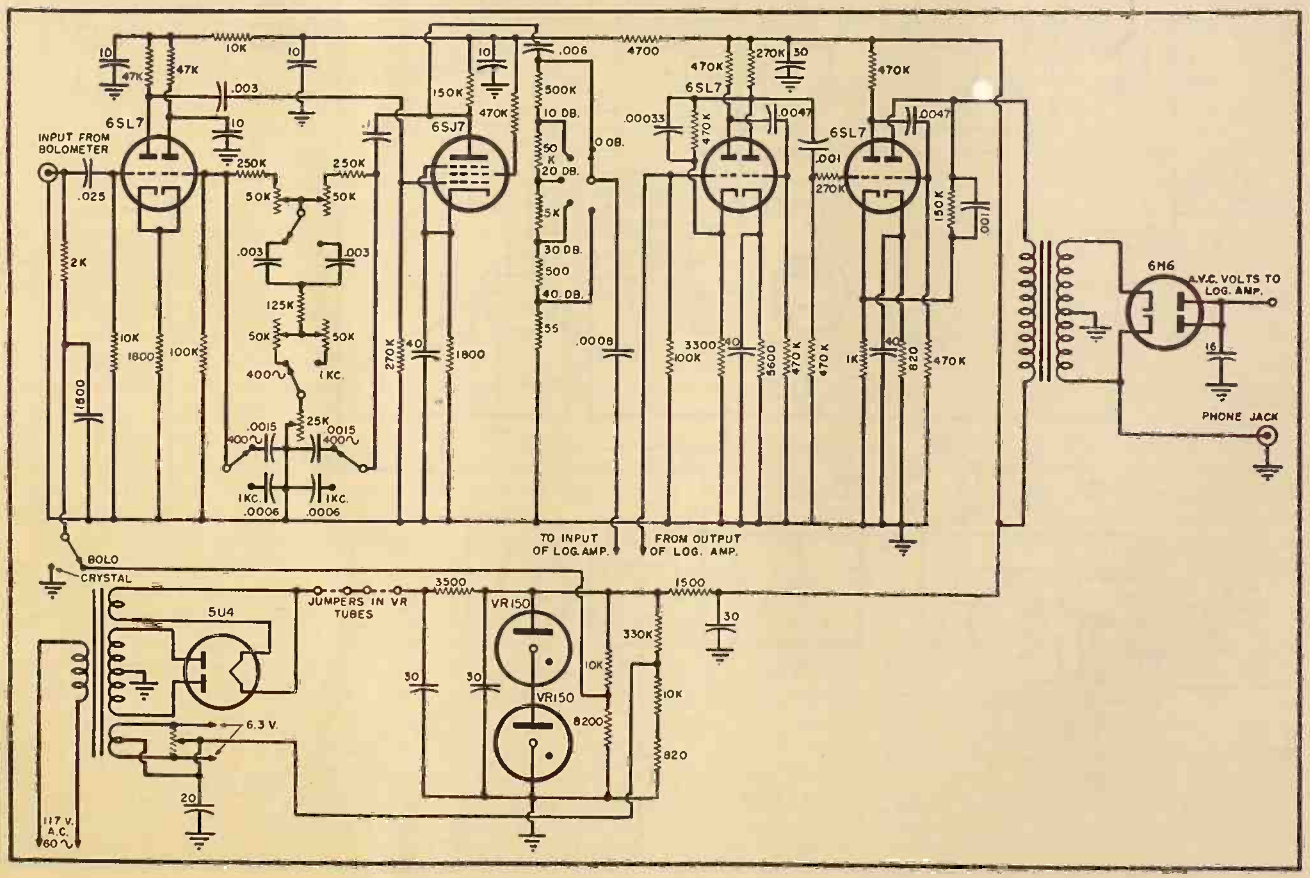
The same audio oscillator is switched from the calibrator to the remote transmitters as a modulation, or trigger source. This alleviates any question as to whether the modulation frequency is the same as the frequency of calibration. The importance of this same source cannot be stressed too much, since the amplifier is sharply tuned.

Servos

Synchronization of the paper in the recorder to the movements of the antenna mount is accomplished in a rather unconventional but reliable way.

A pair of *Bendix* autosyn transmitters geared together in a 5:1 ratio is

Fig. 4. Complete schematic diagram of the preamplifier and post amplifier portions of the system.



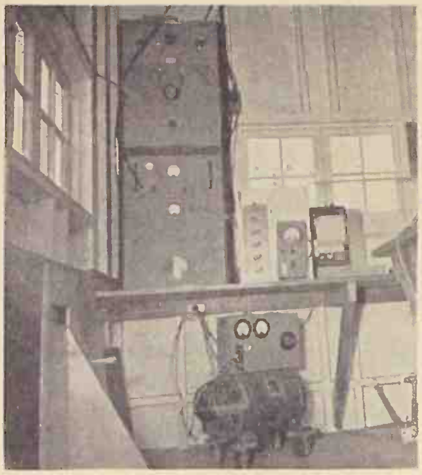


Fig. 5. Installation of the 1000 cycle amplifier and logarithmic attenuator.

mechanically connected to the azimuth drive of the antenna mount. A similar pair is connected to the elevation drive. Electrically, the rotors of all four autosyns are connected in parallel, and the stators go to the servo selector switch, previously mentioned. The selected autosyn transmitter is fed into a *Bendix* servo-amplifier unit which furnishes enough power to the torque unit to drive the paper roll dependably.

An autosyn transmitter on the azimuth movement which is directly connected to a *Bendix* Radio Compass Indicator serves as an azimuth bearing indicator for accurately monitoring antenna position at all times. This is extremely useful for manually locating peaks or nulls when no permanent record is required. A similar arrangement may be used to monitor elevation deviation but it was not found to be necessay in this installation.

Antenna Mount

A motor driven antenna mount was decided upon, both to unburden the operator, and to guarantee smoothness of recordings.

Separate d.c. motors are installed for azimuth and elevation drives. These are speed and direction controlled from either the main panel in the receiver house, or the auxiliary control panel at the base of the antenna mount. Azimuth and elevation motor stop switches are provided at the ends of travel in both directions so that mistakes in starting positions or mangled equipment due to carelessness may be avoided.

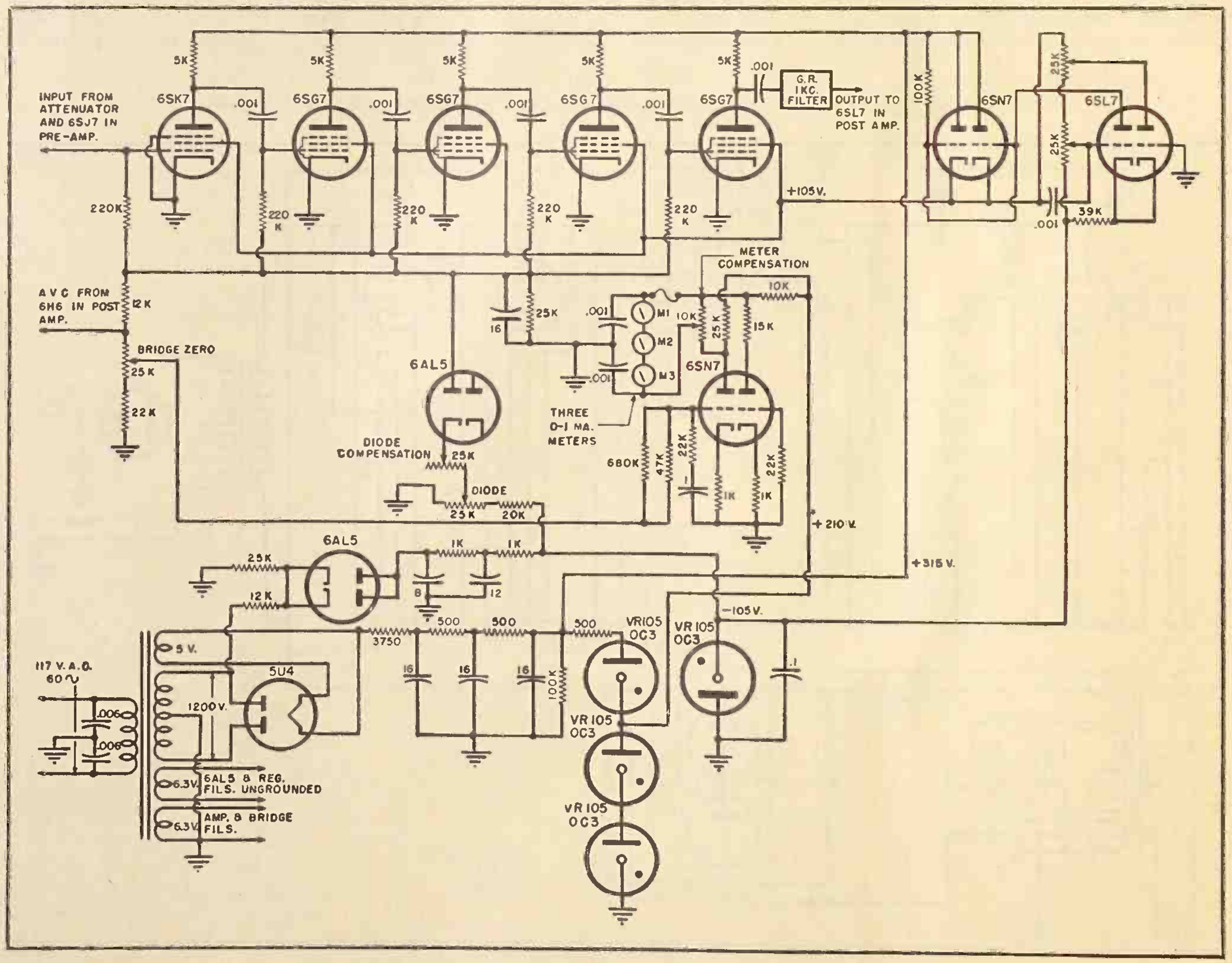
Summary

This antenna pattern measuring equipment has been successfully used more or less continuously for three years without much change from its original form.

Recordings of almost every type of antenna in the v.h.f., u.h.f., and most of the microwave spectrum have been filed with gratifying results. For demonstration purposes some patterns have been repeated on the same piece of recording paper and the equipment duplicated the originals with hairline accuracy.

A choice of a good site for antenna pattern recording is essential for satisfactory results and outstanding sources of reflection or changing conditions must be kept to a minimum. Figs. 1 and 3 show the actual installation of the equipment described above and indicate how the location minimizes unwanted reflections.

Fig. 6. Schematic diagram of the logarithmic attenuator portion of the receiver.



Past, Present and Future

RECORDING SYSTEMS

Fig. 1. Magnetic tape has invaded every field of recording from audio to industrial and computer applications. Shown is an installation of Magnecord magnetic tape equipment at station WISC.

By **JOHN D. GOODELL**

The Minnesota Electronics Corp.

Present limitations and future possibilities of some of better-known recording and reproducing systems.

IT IS THE purpose of this article to discuss the processes of thinking that may lead to the development of recording systems superior to those available at present, and to discuss the characteristics and limitations of known methods. The trend is strongly in the direction of finding means for recording information in the most compact possible form, in finding improved methods for recording television signals and other high frequency signal sources.

Although most readers are aware that the electrical transmission of intelligence in the form of pictures has been studied since the beginning of broadcasting, many may be astonished to know that the basic techniques of the art as it exists today were established more than a century ago. It was in 1842 that Alexander Bain designed a device that included methods of synchronization between transmitter and receiver, as well as the basic principles of scanning techniques. His drawings show two synchronized pendulums with means for maintaining synchronization and methods for periodic motion of the paper as the stylus in each pendulum swings across it. The transmitting pendulum makes electrical contact with raised type faces and the receiving pendulum transmits a current to the surface of a special paper chemically treated to produce discoloration at the points of discharge.

There are many methods of recording that have been used in the past and forgotten in the present, some of which may be revived with new interest as new techniques are developed to improve them. Certainly it is worthwhile to review the highlights of past efforts that may suggest new ideas in the light of recently acquired knowledge. Many engineers today would expect the term "Hot Air Recording" to be part of a cartoonist's gag line, although this was one of the more important research projects associated with facsimile transmission only two decades ago.

In considering various techniques that may be used for recording, it is well to define the problem in its most general terms in order to minimize the possibility of overlooking a worthwhile system because of a restricted initial concept. "Recording" implies the storage of intelligence. The limiting definition might be that "whenever an event occurs that makes a change of any kind, recording has taken place." The fact that the event occurred is stored in the change. Usually we are concerned only with changes that are uniquely related to the events that caused them and are sufficiently static to fit the time elements of the problem. To be valuable in practical applications it is necessary that the effects be reversible to the extent that they may be used to generate or indicate intelligence recognizably related to the origin. In general, the problem of reproduction is the limiting factor, for many recording methods are available that have ideal characteristics except for the difficulty involved in playback.

The earliest recording was in the form of drawings from which intelligence could be derived by virtue of the physical similarity to the original. Later this developed into writing, and arbitrary symbols were practical because of agreement concerning their meanings. Television essentially constitutes a reversion to the former, more primitive and direct method. With few exceptions audio signals are based on the latter. It should be noted that speech is a form of recording as defined above, for it constitutes the translation of intelligence contained in one person's mind into acoustic energy which is translated back into the original intelligence by the observer. In common with most recording systems, there are usually some losses involved in this process.

There are two basic purposes for recording systems. One is to introduce a time delay. This may be in an order of thousands of years or, in short term memory systems for computers, may involve only microseconds. The other purpose is to facilitate transmission.

Signals may be recorded in series, in parallel, or in series/parallel. Pure series systems, such as the dot-dash type of code, are relatively rare. Acoustic energy usually represents intelligence in series/parallel, the complex components of a waveform being contained in parallel while the sequence of waveforms is in series. Motion pictures are a form of series/parallel recording.

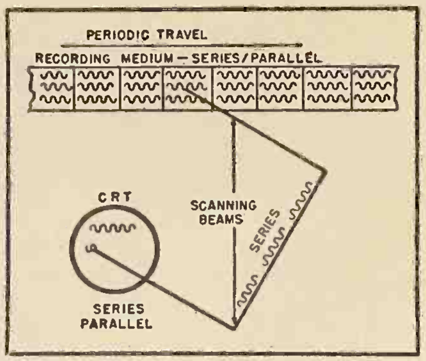


Fig. 2. System for converting signals from series to parallel orientations.

Television transmission is more closely related to series orientations while its presentation includes large parallel sections. The minimum wavelength that must be handled by any recording sysstem is inversely related to the percentage of series orientation in the intelligence. This statement implies that the individual channel bandwidth (the top frequency required) is decreased to the extent that the information is handled in parallel. Multiple channel (parallel) recording has been proposed as a means of decreasing the bandwidth required per channel for recording television signals. This is a perfectly sound theoretical concept and such methods will very likely be developed. At the time of writing no satisfactory process has been publicized.

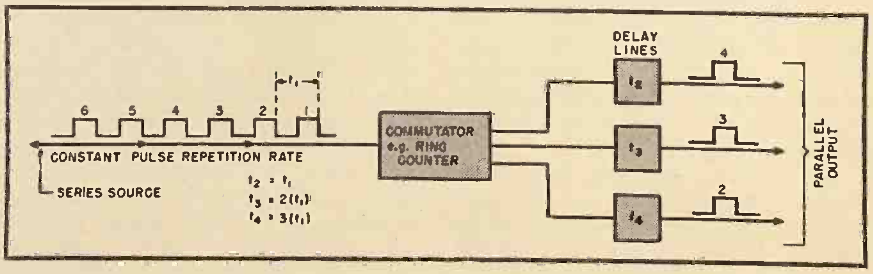
This problem resolves itself into changing the orientation of the signals with respect to time. It means that signals observed by a scanning mechanism in series time sequence must be rearranged in sections that are available instantaneously in parallel. The design of the reproducer determines whether translation back into series is necessary. A multiple beam cathode-ray tube, for example, might be able to accept and present several channels simultaneously. In current practice it is necessary to rearrange television information in series.

There are several possible methods of accomplishing these effects. One is by means of a scanning mechanism. A principal difficulty is involved with the losses that are sustained if synchronization between the recorded signal and the playback scanning mechanism is imperfect. The characteristics of known mediums are such that dimensional changes with temperature, humidity, and other factors seriously limit the accuracy of scanning synchronization between record and playback. Another method is to use intermediate storage systems such as multiple delay lines with varying time constants. Several computing devices have been designed using the procedure. The schematic drawings in Figs. 2 and 3 are illustrative. Note that parallel methods of handling digits in computers require a relatively large number of circuit elements and relatively few time elements. The inverse situation obtains with the series type of setup. Arbitrary coding is a method of representing information in parallel. An article describing a specific make and model of automobile in detail might require several thousand words while the few words involved in stating the make and model represent the same information.

A number of sine waves of different frequencies may be combined into a single complex waveform that may be later analyzed in order to re-observe the individual components. This constitutes parallel to series to parallel conversion in one sense. It should be noted in this connection that the bandwidth required for the transmission or recording of the complex waveform is in direct ratio to the number of its components and the spacing between them frequency-wise. From this is derived the concept that the amount of intelligence that can be handled in a single channel is directly related to the bandwidth. This principle does not apply if arbitrary codes are used.

One very interesting method of limiting the amount of information that must be handled in a recording channel is to remove all components that exist as constants and re-insert them in the reproduction process. For example, given suitable circuitry, it might be possible to filter out the harmonic components of a square wave four megacycle television signal, transmit it as a sine wave and re-insert the harmonic components at the receiver in order to produce the original square wave. Unfortunately, although the frequencies of the harmonic components may be constant, the relative amplitudes are not. The problem is to find a means of so triggering harmonic generators in the receiver as to produce components of suitable amplitude with respect to the amplitude of the individual waveforms in the signal.

Fig. 3. Suggested method for converting signals from series to parallel orientations.



Recording mediums and systems may be divided into at least four basic categories. Those to be discussed here are as follows: (1) physical, (2) chemical, (3) magnetic, and (4) electrostatic. Some systems are combinations of these. Playback systems may utilize entirely different principles from those involved in recording.

In the first group are such systems as sound on disc recording in which a groove is physically modulated, changed in shape either vertically or laterally, in accordance with the signal. This method is capable of extremely accurate representation of the signal content within a limited portion of the audio range. It is limited largely by the masses involved in both recording and playback, and finally by the structure of the medium used. This is a typical system in which the recording characteristics are appreciably superior to reproduction methods. It is possible to engrave signals in some materials with frequency content that cannot be reproduced by any means known in the present state of the art.

There are many other methods by means of which it is possible to make a gross physical change that constitutes a reproducible recording. One is represented by punched paper tape such as is used in player piano rolls, telegraph systems, some of the facsimile devices, and a number of business machines. These are limited in range and application by the structural characteristics of the materials, their stability and the masses of the devices generally used for recording and playback. However, it is possible to effect reproduction with light beams and photoelectric cells so that this group is usually limited on the recording end rather than in playback.

A very wide range of possibilities exists in the chemical category. The hot air recording system mentioned earlier was used for reproducing radio transmitted pictures. A stream of hot air was pulse modulated by means of an electrically operated valve, and when applied to a chemically treated paper produced discoloration. Heat sensitive mediums are used today for very low frequency recording, notably in electrocardiographic and similar medical equipment. In most of these a heated stylus contacts the paper. "Thermofax" is an office duplicating process operating on thermal principles recently announced by *Minnesota Mining and Manufactur-*

ing Company. It may have other applications.

Probably the earliest phenomenon to be used in connection with recording systems that pass an electric current to or through the medium was developed from the iodine test for starch. The paper is impregnated with potassium iodide and starch, and the passage of electric currents releases free iodine which discolors the starch. Combustible compounds that release oxygen locally when triggered by heat have been applied for purposes of increasing the writing speed. In some mediums the chemical action is contained entirely within the paper structure and impregnations. In others a bar shaped electrode is used, and the passage of current causes a metallic ion to pass into the paper, combine with chemical structures and produce a color change. The difference is of principal significance with regard to patent problems.

Papers and other bases have been coated with materials that burn off so as to leave a localized color variation. Still another method is to separate two chemical compounds by an inert binder that is heat sensitive. The local application of heat melts the binder and allows the active compounds to combine and produce a recorded trace. There are many dyes that are sensitive to heat, electrical currents, light, electron beams, and other sources of modulation.

One reason for seeking improved methods of this kind is to eliminate the developing procedures required in photography. This is not only a matter of minimizing time and expense, but also the handling problems involved in using materials that must be protected from light. There are many other disadvantages to photographic methods, such as the fact that they cannot be monitored under dynamic conditions and are not subject to re-use. Processing time has been reduced to a matter of four or five seconds with some techniques, but even this is often undesirable.

To date photographic methods have not been equalled in performance for many applications, among them the recording of television signals, but it is not unlikely that the near future will see a change to another type of recording in systems where photography is now used exclusively.

Magnetic recording uses principles that were known for several decades but applied spasmodically and experimentally. In the last few years it has developed with remarkable speed into one of the most important known methods. It has invaded practically every application of recording principles. A very high percentage of transcriptions for broadcast, practically all original recording in the motion picture field, and a good portion of the initial recordings for disc pressings are now done with magnetic recording tape. In the computing field magnetic recording drums and magnetic tapes are widely used for temporary and permanent storage. Intensive development work is going on in many laboratories in an effort to extend the range of useful applications to include television signals and other sources of densely packed intelligence.

One reason that photographic methods are so well adapted is that they lend themselves to parallel storage, and relatively simple methods of conversion from parallel to series and back to parallel. The principal reason that magnetic tape is more desirable is the matter of erasure and multiple use with the attendant reduction in cost.

No one knows the theoretical limitation with regard to the minimum wavelength that can be recorded in magnetic tape. The ultimate limit might be the particles in the structure of the magnetic coating, and these are in an order of a micron. No one factor can be considered at present as exclusively limiting but all of the various factors seem to converge to a limitation of about a thousandth of an inch. This limitation is imposed by the dimensions of the gap in the head, the use of high frequency bias, the thickness of the coating, etc.

It should be mentioned immediately that many of these problems are peculiar to existing conventional magnetic recording and playback systems. Unquestionably the near future will see the revelation of methods that are very different and that may eliminate many of the problems now encountered. Sound on film recording was developed through many stages involving techniques that used different basic charactestics of the film. Variable density, variable area and other systems will find their corollaries in magnetic recording. At the present time systems in wide use function in such a manner that the reading head sees the derivative of the magnetic signal. Playback is entirely in terms of the time rate of change. Thus the tape is required to be continuously in motion. With photographic presentation of picture information the motion is intermittent and the intelligence is presented in large parallel sections.

A magnetic storage system has been designed in which the signals are stored in static form and are read by heads in which an exterior current source is used to make observation possible. There are experimental head designs that are capable of producing an output signal that is directly representative in amplitude of the magnitude of magnetization and in phase of the direction of magnetization. It is possible to record extremely compact pulse signals by passing current directly through the tape but playback of such signals presents a number of problems.

One possible method of recording picture information and playing it back is to induce localized magnetic pulse recordings with multiple heads. The physical size of the heads can be eliminated as a problem because the orientation of the pulses need not be related to the visual pattern that they represent. In playback the tape is moved in periodic sections as with motion picture film. The multiple reading heads are designed to observe directly the degree and

(*Continued on page* 27A)

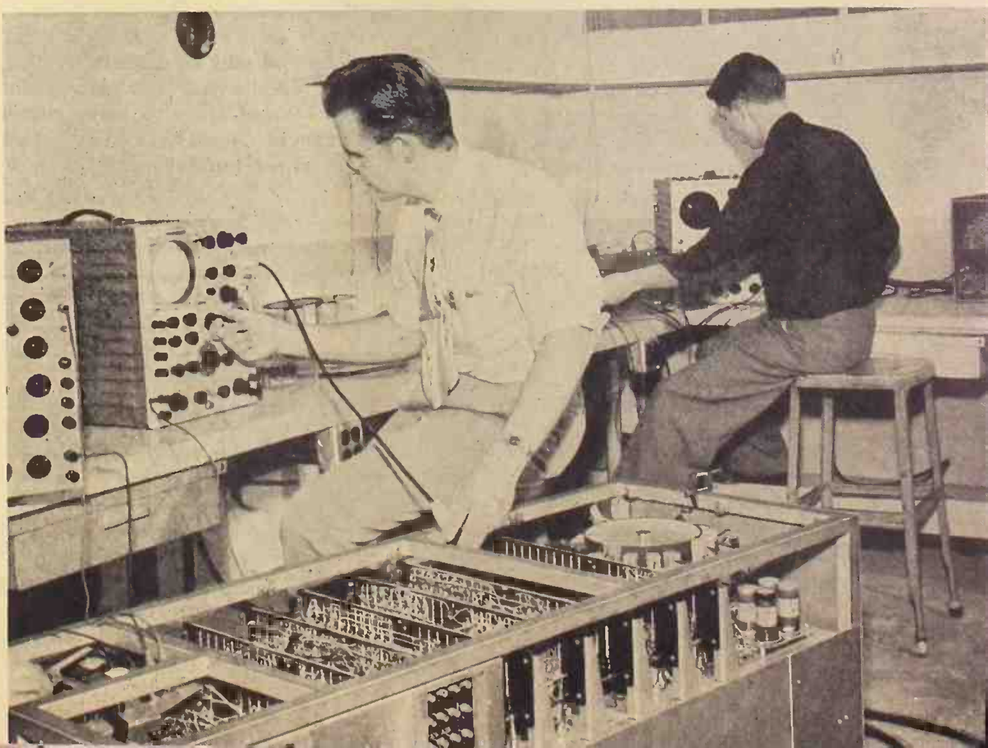


Fig. 4. Interior view of "Maddida" electronic computer showing the magnetic drum recorder. Computers require recording systems for short term memory and reference material.

Tube Applications In AMPLIFIER DESIGN

Fig. 1. Three of the tubes discussed in the text. Top, 6BL7GT; right center, 6AR6; far right, 3C33.

By HOWARD T. STERLING
Chief Eng., The Electronic Workshop, Inc.

Simplified graphical solutions for some tubes new in the audio field, and some new circuit developments.

IT IS the purpose of this paper to bring to light several new tubes heretofore relatively unknown to audio, notably the 3C33, the 6AR6, and the 6BL7, as well as to discuss the choice of optimum operating conditions for both these and more familiar types.

A simplified method of graphical solution will be described, and a number of interesting circuit developments, including Extended Class A operation, will be discussed.

In all the years that audio amplifier designs have appeared in the literature, there has been little that is basically new. The continued emphasis has been on more and more careful design utilizing already established principles.

Refinements have certainly been introduced—inverse feedback, resistance coupled amplifiers, various types of phase inverters and, more recently, such power amplifier developments as Extended Class A operation and the *McIntosh* output circuit. Fundamentally, however, amplifier design is dependent upon an ever more meticulous application of the principles and techniques with which we are already familiar.

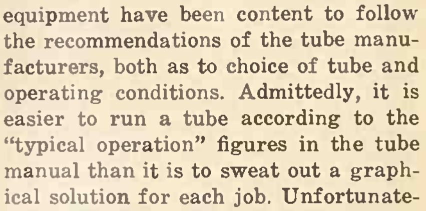
An outstanding example can be found in the so-called Williamson amplifier. There is nothing new or novel in this design; its immediate popularity was justified by the extreme care with which feedback was employed over an extremely wide range.

Up to now, most designers of audio equipment have been content to follow the recommendations of the tube manufacturers, both as to choice of tube and operating conditions. Admittedly, it is easier to run a tube according to the "typical operation" figures in the tube manual than it is to sweat out a graphical solution for each job. Unfortunately, audio design is reaching the point where it is just that little extra that makes the difference.

In almost every case, for a given tube, better results can be achieved by choosing operating conditions for the specific application. This need not be as difficult as it sounds. A highly simplified method will be described whereby almost all the necessary information can be obtained from the tube curves in a couple of minutes.

There are a number of tubes, however, for which no audio data is available, and where the curves provided may even be inadequate for a ready evaluation of audio performance. The 6AS7, whose use for audio was suggested by the author some years ago, and which has since become popular, is a case in point. It was rated in the tube manuals for booster scanning service, and any graphical solution within the limitations of its published characteristics will show a severely limited power capability. 6AS7 operation as described so far in the literature indicates a power capability of around ten watts. Proper choice of operating conditions make it possible for the 6AS7 to deliver *22 watts!* Since the 6AS7 is convenient for the purpose, it will be used to demonstrate the simplified method of graphical analysis.

Fig. 2. Triode curves for the 6AR6. A pair will deliver 20 watts.



Graphical Solution

Normally, with this method, it should be necessary to draw only one line. In the case of the 6AS7, however, it is necessary to extend the zero grid line, as shown in Fig 3. From this point on, the solution may proceed as follows:

1. Decide upon the plate voltage. This is the voltage appearing between the plate and cathode of the tube (where cathode bias is employed, the plate voltage will be less than the supply voltage by the amount of the bias). The plate voltage multiplied by the

plate current will give the plate dissipation; this should not exceed the maximum rating for a given tube. In the case of the 6AS7 solution the voltage was chosen as 200 volts. This, with a bias of 93 volts will give a plate current of 65 mils with a resulting dissipation of 13 watts.

2. Draw a load line from the plate voltage point on the zero current axis, so that it intersects the zero grid line. These two lines should form essentially an isosceles triangle. *i.e.*, the slope of the load line should be the same as that of the bias line, but negative. This load line is shown as the dashed line in Fig. 3.

3. Output power may now be computed. This will be equal to the r.m.s. value of the signal current times the r.m.s. value of the signal voltage. The peak current swing may be read from the curve sheet. For the 6AS7 the current swing is from zero to 457 ma. The r.m.s. value will then be $457/\sqrt{2}$ ma. The peak plate voltage swing is not quite as easy; the swing is from 200 volts down to 104 volts, or 96 volts. Its r.m.s. value will be $96/\sqrt{2}$. These multiplied together will give approximately 44/2 watts or 22 watts.

4. The plate-to-plate load resistance should be four times the plate resistance at the zero bias point, or four times the resistance represented graphically by the loadline we have drawn. This resistance will equal the plate voltage swing divided by the current swing. In this case it will be 96/457 or 215 ohms. This times four gives a plate-to-plate load of 860 ohms, much lower than any previously published figures for the 6AS7.

A tabulation of the 6AS7 data is given in Table 1.

Full power will be realized only if the d.c. plate voltage is not permitted to vary with signal.

3C33

Although the 3C33 was announced about five years ago, it has never been used in audio applications. This is due in part to the fact that it appears only in the transmitting tube manual, and is rated for "control amplifier" service. The curves for the 3C33, like those for the 6AS7, do not extend into the high current region.

The 3C33 is a dual triode, indirectly heated. Its appearance, as may be seen from Figs. 1 and 4, is unusual for low frequency applications. It will deliver 40 watts with 500 volts on the plates. This is *the* tube for the purist who wants high output with low idling current.

If we subject the 3C33 to the same analysis as we did the 6AS7, we come up with some extremely interesting re-

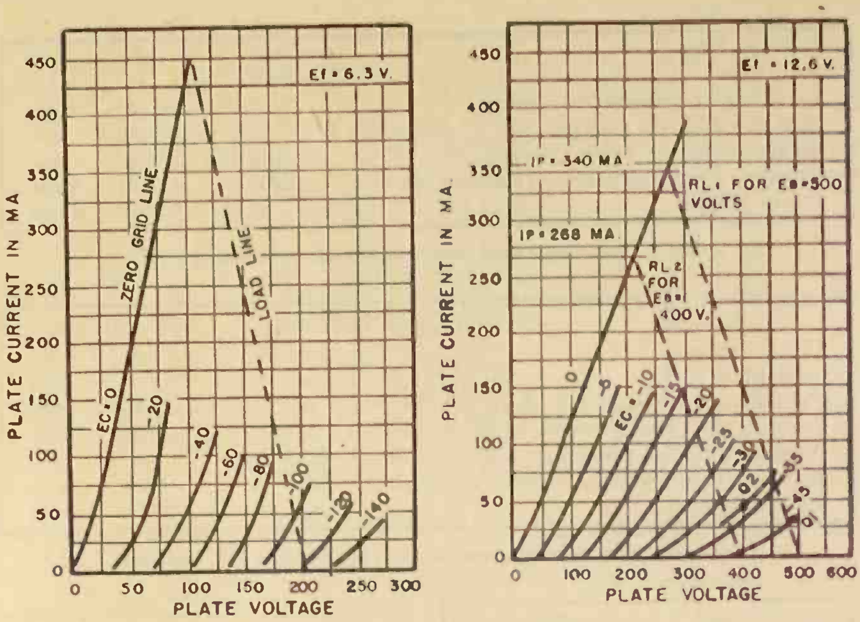


Fig. 3. Simplified graphical solutions for power amplifiers applied to the 6AS7 (left) and 3C33 (right). Procedure is outlined in text.

sults. Fig. 3 shows the graphical solution for operation at 400 and 500 volts. The optimum plate-to-plate load for each case is 2800 ohms; the usual 3000 ohm winding would be quite satisfactory. The points Q_1 and Q_2 represent the no-signal operating points, or "quiescent points" for either side. Typical operating conditions are given in Table 2.

For most applications the 25 watt operation indicated would be adequate, and no special precautions need be taken, other than those dictated by good design practice. Where maximum power is desired, and the tube is to be operated at 500 volts, it should be used

Plate Voltage	200 v.
Grid Bias	-93 v.
Peak Signal Voltage (per grid)	93 v.
Zero Signal Plate Current	130 ma.
Maximum Signal Plate Current	294 ma.
Effective Load Resistance (plate to plate)	860 ohms
Power Output	22 w.

Table 1. A tabulation of data for both sections of the type 6AS7-G tube.

Fig. 4. Deluxe amplifier using the 3C33. Driver tubes are 6P5's.

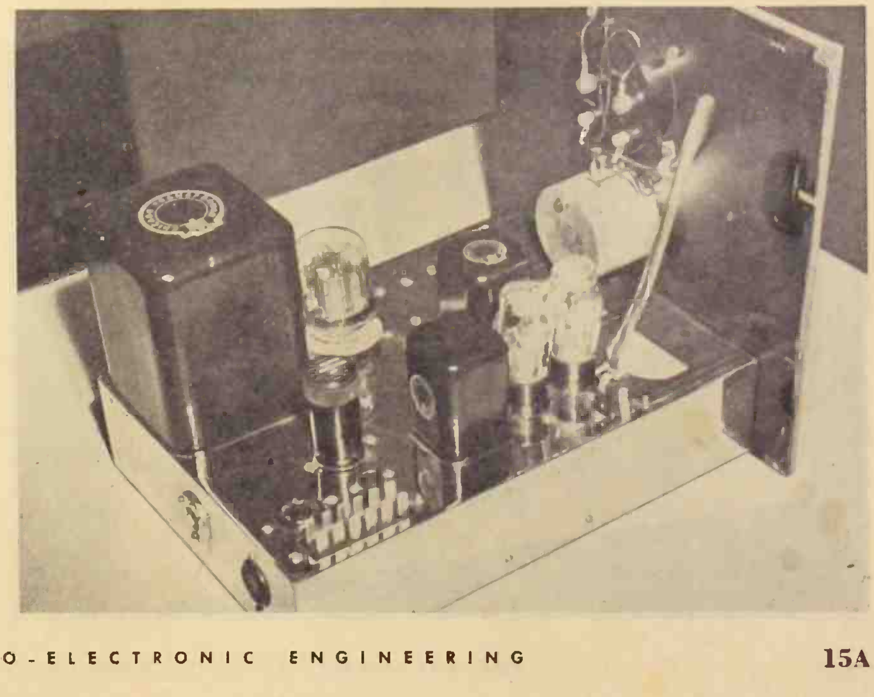


Plate Voltage	400	500	volts
Grid Bias	-33.5	-45	volts
Peak Signal Voltage (per grid)	33.5	45	volts
Zero Signal Plate Current	75	56	ma.
Maximum Signal Plate Current	172	198	ma.
Effective Load Resistance (plate to plate)	2800	2800	ohms
Power Output	25	40.5	watts

Table 2. Typical operating conditions for both sections of the 3C33.

	5881 (and 6L6)	807 (and 1614)	
Plate Voltage	400	400	volts
Grid Bias	-38	-39	volts
Peak Signal Voltage (per grid)	38	39	volts
Zero Signal Plate Current	95	100	ma.
Maximum Signal Plate Current	124	148	ma.
Effective Load Resistance (plate to plate)	4500	3300	ohms
Power Output	13.3	15.8	watts

Table 3. Typical operating conditions for the 5881 and 807 - two tubes.

Plate Voltage	400 v.
Grid Bias	-55 v.
Peak Signal Voltage (per grid)	55 v.
Zero Signal Plate Current	100 ma.
Maximum Signal Plate Current	175 ma.
Effective Load Resistance (plate to plate)	2500 ohms
Power Output	20 w.

Table 4. Typical operating conditions for the 6AR6 - two tubes.

only where plate current is metered, and the bias on the two halves readily adjustable. This is because the plate dissipation is only 15 watts per side, and at 500 volts the plate current is limited to 30 ma. Idling currents higher than this will endanger the tube; lower idling currents will move the operation down into the nonlinear region with a consequent increase in distortion.

This means, in effect, that 500 volt operation of the 3C33 is ideal for the experimenter or the technically minded, but is less suitable for installations where maintenance is sporadic. 400 volt operation is much less critical, and where 25 watts is sufficient it should be entirely satisfactory.

6AR6

The 6AR6 was developed during the war for radar applications, and for some reason was never adopted for audio. It was introduced by the author at the Audio Fair last fall, and is rapidly on the way to popularity. It is a beam power amplifier, roughly similar to the 6L6, but with considerably higher current handling capacity. It was the first commercial tube to use the stubby envelope which has recently become familiar with the 5881.

A pair of 6AR6's, triode connected, with 400 volts on the plates, will deliver 20 watts Class A. This is roughly twice the class A power usually obtained from 807's in Williamson-type amplifiers and three times the Class A power normally obtained from 2A3's.

A graphical solution is shown for the 6AR6 in Fig. 2. In this case no extension of published characteristics was necessary. The dashed line represents a plate-to-plate load of 2500 ohms. The dotted line indicates the path of operation for a single tube. It may be noted that plate current flows even at the most negative point of the grid swing, thereby fulfilling the requirement of Class A operation.

Table 4 gives the operating conditions which are recommended for the 6AR6.

5881 - - - 807

Triode operation of such tetrodes as the 616, 807, 1614 and 5881 has become quite popular since the introduction of the various "Williamson" circuits. For purpose of discussion these four types can be reduced effectively to two. The 5881 is electrically identical to the 6L6, and the 1614, within its maximum ratings, is the same as the 807. The 5881 (or 6L6), however, differs slightly from the 807. The 807 has somewhat greater current capability, with a resulting increase in power output.

In choosing between these types, it should be remembered that the 5881 is a specialized tube intended specifically for audio work, whereas the 807 (or 1614) is designed for Class C r.f. amplifier applications. This would suggest that 5881 characteristics are likely to be somewhat more consistent in the operating range used for audio.

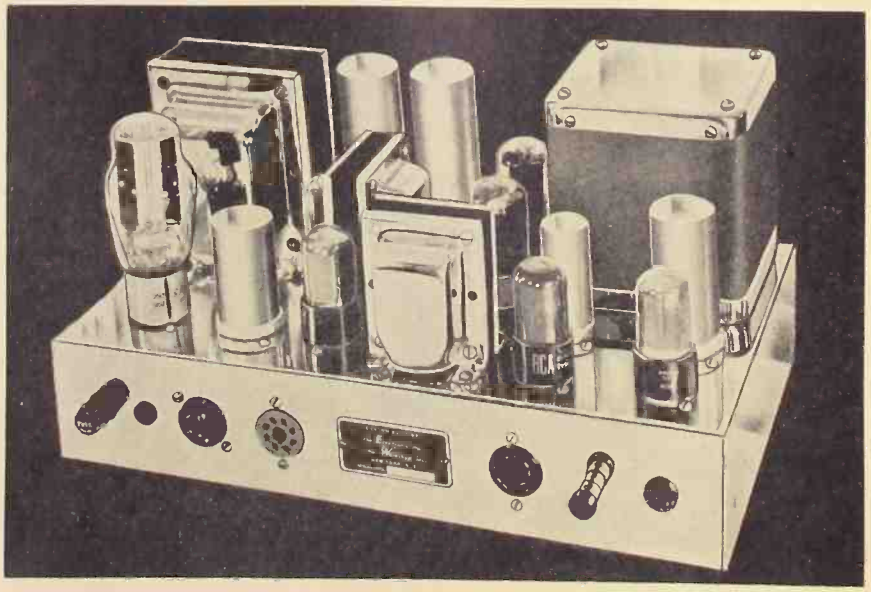
Comparative Class A operating conditions are shown in Table 3.

Type of Bias

A number of points will have become apparent in the course of this discussion. The values given for plate-to-plate load are consistently lower, and class A power output higher, than would be expected from the results obtained in current practice, and described in current literature. This will have been particularly noticeable in the discussion of the 6AS7, and of the 5881 and 807.

The explanation is very simple. Current practice is to operate these tubes with cathode bias. With cathode bias operation, the increase in plate current with signal causes a rise in the voltage across the bias resistor. This has the double effect of increasing the bias and reducing the effective plate voltage, with a consequent reduction in the peak plate current which can be obtained.

Fig. 5. Electronic Workshop's model A-18 amplifier using 6AR6 triodes.



By using higher values of load resistance, the plate current rise with signal will be much less, and a compromise can be reached which will result in best performance. The power to be expected under these compromise conditions, however, may be as little as one half that to be expected from normal fixed-bias operation.

All of the operating conditions described above assume the use of fixed bias, or at least of some method of bias that does not permit the operating point to change with signal.

One serious error which is often made in using cathode bias is the omission of adequate bypassing of the common bias resistor. This bypassing would be unnecessary if operation were truly linear, but in actual practice the upward swing in plate current in one tube is greater than the downward swing in the other. This produces a wave across the cathode resistor at twice the frequency of the applied signal, with resulting distortion in the output. When the cathode resistor is heavily bypassed, this of course does not occur.

The use of a common cathode bias resistor introduces another problem which is often overlooked. Any variation in the plate current of one tube will produce a corresponding variation in the opposite direction in the other. The result of this interaction is effectively to double any unbalance between the tubes. This can be a serious disadvantage in modern low distortion circuits.

Automatic Bias Controls

Ideally, there are two types of automatic bias controls. The first type is used to adjust the operating point of the amplifier in accordance with signal level applied. At low levels the bias would be adjusted to provide class A operation, and at high levels it would change so that operation would be class AB or B, with its higher output and better efficiency. Such a system has been used in at least one commercial amplifier for some years. It incorporates a two stage d.c. amplifier, with its resulting unreliability.

The second type of automatic bias control would serve the purpose of maintaining balance between the halves of the push-pull stage. So far, no practical circuit for this purpose has been introduced.

A new type of automatic bias control circuit which fulfills both these functions has been introduced in the *Electronic Workshop's* new amplifier model A-18. (Fig. 5) This system is completely reliable; no d.c. amplifiers or vacuum tube circuits of any kind are employed. The output stage of the A-18 is shown in Fig. 6. By careful proportioning of

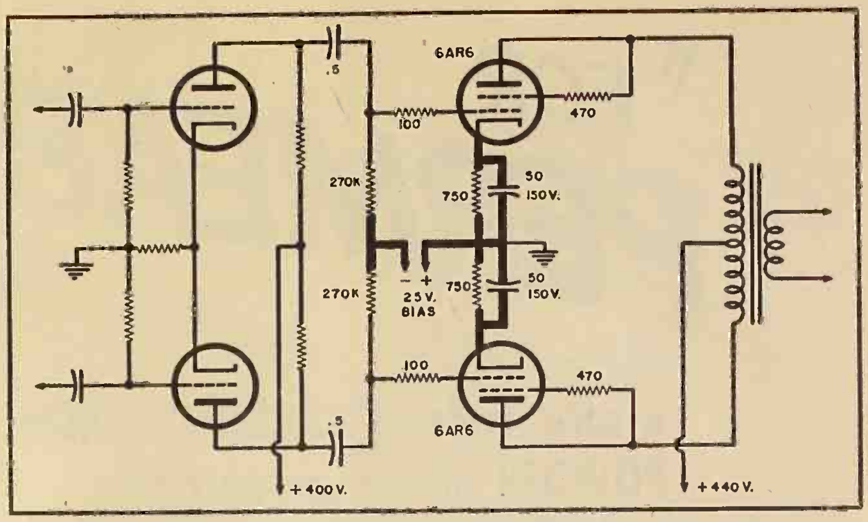


Fig. 6. Automatic bias control used in model A-18. Circuit provides for balance of push-pull tubes and for change in operating point at high levels.

fixed bias and cathode bias, the operating point shifts with increasing signal from class A at around 10 watts to class AB_1 at 18 watts, with a consequent improvement in low level distortion and high level efficiency.

At the same time, the resistance present in the individual cathode circuits provides a degree of d.c. degeneration that will greatly reduce the effect of any plate current unbalance. An unbalance between output tubes which with normal cathode bias systems would be 50% will be reduced by this method to well under 10%, which is quite acceptable.

Most commercial amplifiers, regardless of price range, have no provision for plate current balancing. Better quality amplifiers are usually shipped with selected tubes, but as these tubes age, and as unmatched replacements are made, the performance suffers.

With this new automatic bias control

Plate voltage	450 v.
Grid Bias	-45 v.
Peak Signal Voltage (per grid)	45 v.
Zero Signal Plate Current	110 ma.
Maximum Signal Plate Current	256 ma.
Effective Load Resistance (plate to plate)	2500 ohms
Power Output	47.5 w.

Table 5. Suggested operating conditions for 807's in extended Class A operation. Values are for four tubes.

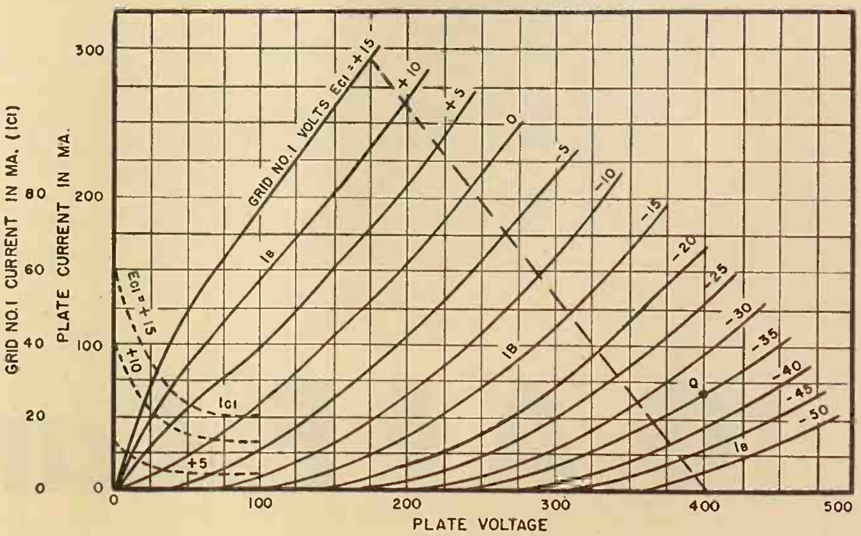
system the user is assured of optimum performance at all times, even with tubes chosen at random.

Extended Class A Operation

For many years, it has been necessary to make the choice between high

(*Continued on page* 30A)

Fig. 7. Graphical solution for Class A_2 for 807's to deliver over 30 watts.



"FOR PERMEABILITY

a core made of CARBONYL IRON POWDER means compact size and efficient performance....."

"**Permeability** plus **stability**—these two qualities determine the ability of a radio receiving set to select and hold clear reception on a particular wave band. In household, portable and automotive receivers, compact size and weight reduction also become important factors . . . . . In the making of both RF and IF coils we have come to rely upon cores made of Carbonyl Iron Powders. We can trust their uniform quality and uniform crystal structure to hold the permeability within plus or minus 1% over a period of years."

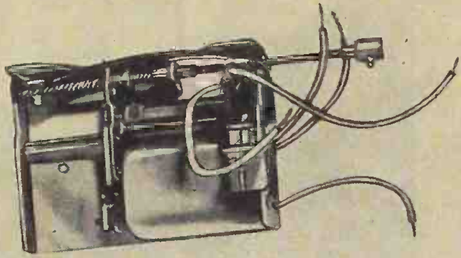
THE F. W. SICKLES COMPANY
CHICOPEE, MASSACHUSETTS

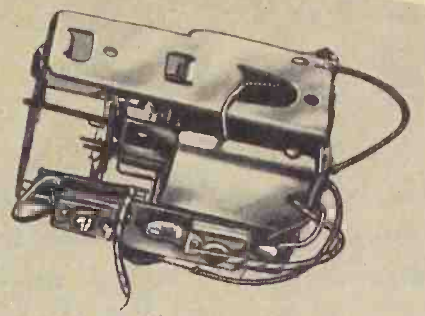
FOUNDED IN 1921—under the name of Radio Development Co.,—the F.W. Sickles Company are today the world's largest makers of radio coils. Several hundred different models of RF and IF coils—made by this firm—are now in daily use by manufacturers of electronic equipment, as well as by amateurs, experimenters, radio service men and government agencies, both here and abroad.

The Sickles endorsement of Carbonyl Iron Powders is extremely gratifying to us . . . It is also important evidence for the consideration of any receiver or equipment manufacturer. Let us send you the book described at the right. It will cost you nothing to get the facts . . . Ask your core maker, your coil winder, your industrial designer, how G A & F Carbonyl Iron Powders can improve the performance or reduce the size of the equipment you make. The possible gains and savings are far greater than here indicated.

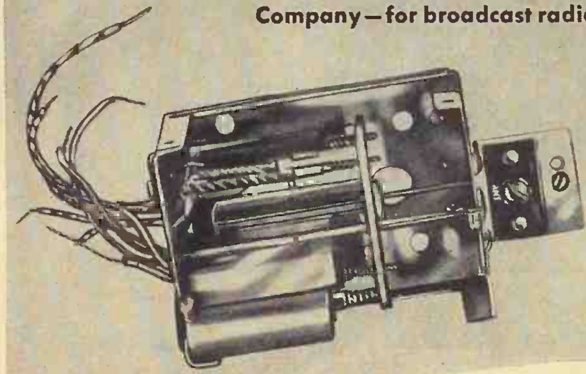
G A & F® Carbonyl

TUNING...





Precision tuning units—made by The F. W. Sickles Company—for broadcast radio receivers



THIS FREE BOOK – fully illustrated, with performance charts and application data – will help any radio engineer or electronics manufacturer to step up quality, while saving real money. Kindly address your request to Department 51.

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Iron Powders...

MEMBER mpa METAL POWDER ASSOCIATION

R.F. MICROPOTENTIOMETERS

This low impedance device, developed by NBS engineers, will provide accurate r.f. voltages from 1 to 10^5 microvolts.

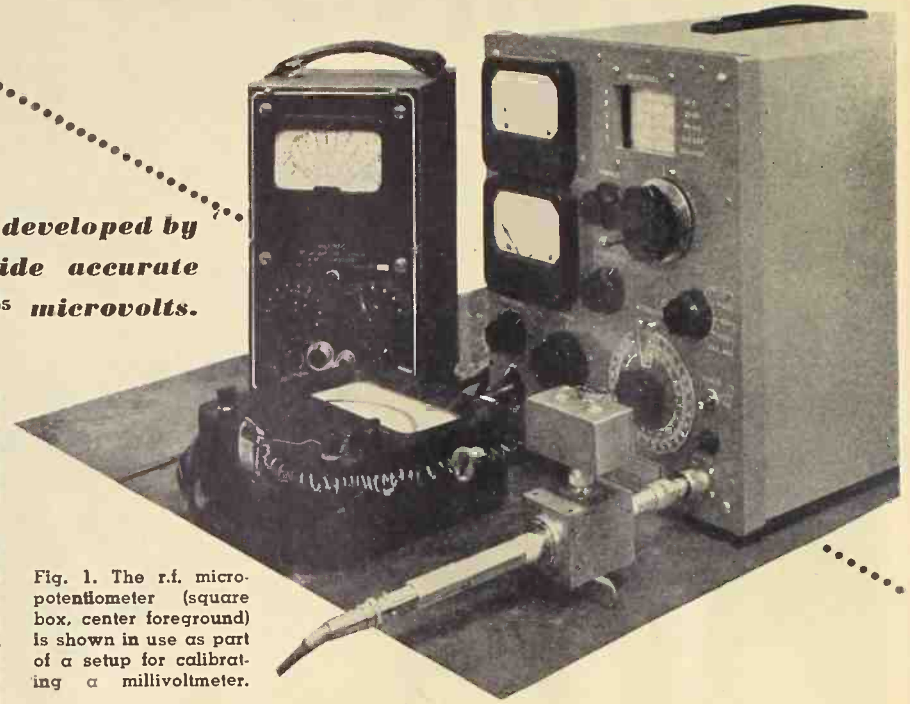


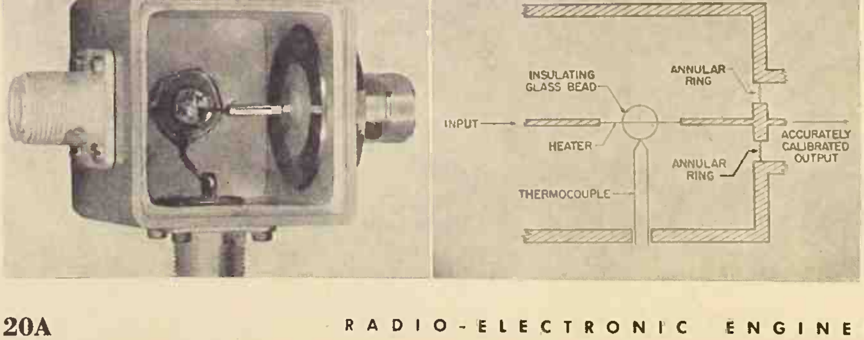
Fig. 1. The r.f. micropotentiometer (square box, center foreground) is shown in use as part of a setup for calibrating a millivoltmeter.

EXTREMELY simple devices which produce r.f. voltages at a very low impedance and at a wide range of frequencies have been conceived and developed by M.C. Selby of the National Bureau of Standards. Known as "R.F. Micropotentiometers," they provide accurate voltages from 1 to 10^5 microvolts without the use of attenuators at frequencies up to 300 megacycles and above. Thus, convenient standards of low voltages are made available which should greatly reduce equipment and shielding problems encountered in calibration of present-day commercial voltage generators, attenuators, voltmeters, and other radio-frequency equipment.

The micropotentiometers should prove especially useful in measurements of radio receiver sensitivity. Here the large disagreement between various standard voltage generators at high frequencies and low voltage levels has been due to three major causes. First, generator output impedance and receiver input impedance are not ordinarily known as functions of changing frequencies. Second, extreme care is necessary in using precision voltage-dropping attenuators. Finally, the long-time calibration stability of vacuum tube voltmeters is uncertain. For these reasons, manufacturers of voltage generators have not been able to guarantee the accuracy of their equipment at all frequencies. Development of the micropotentiometers now appears to have removed most of the obstacles to standardization of receiver sensitivity.

The new instruments consist essentially of appropriately housed and mounted current-carrying elements together with means for monitoring the currents they carry. Their electrical constants are simply determined by using known d.c. voltages and currents. The current-carrying elements are annular membranes, either metallic or nonmetallic, of various radii, thicknesses, and electrical resistivities. Monitoring may be accomplished by means of thermocouples, thermoelements, bolometers, stable vacuum tube voltmeters, or other devices whose indications are independent of frequency. Thermoelements have been used in measurements of 1 to 100,000 microvolts at frequencies from zero to 300 mc. and also for 100,000-microvolt measurements in the region of 1000 mc.

Fig. 2. Exposed view of one of the r.f. micropotentiometers recently developed by NBS. The drawing at the right is a functional diagram of the unit.



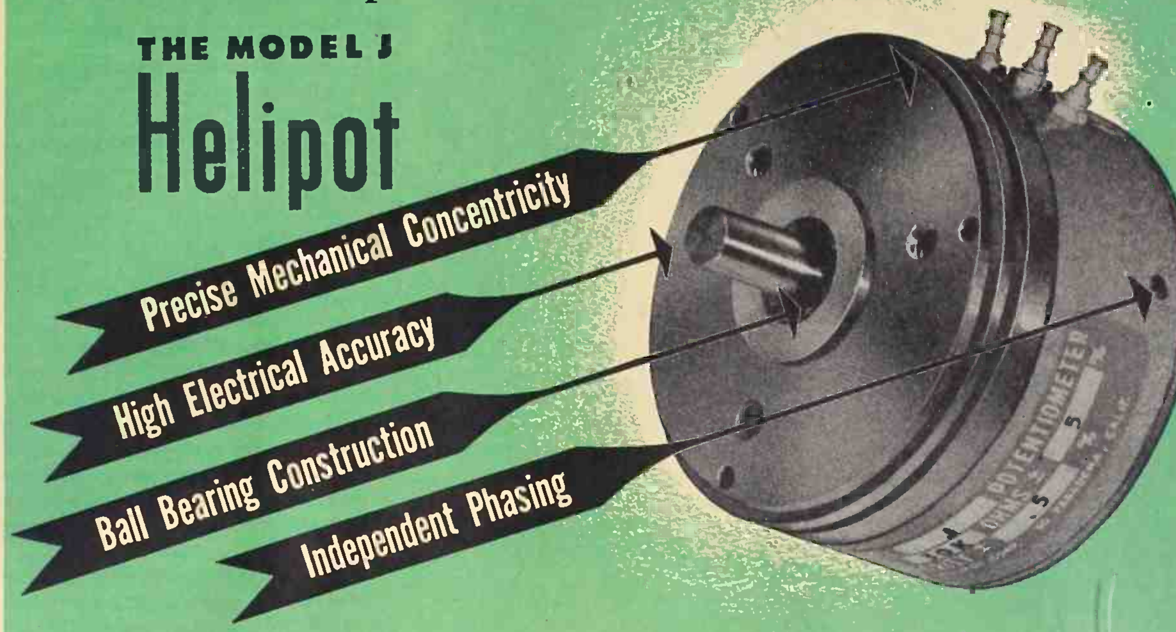
These micropotentiometers are the first low-impedance (of the order of milliohms) devices which provide r.f. voltages in the microvolt range and which make these low voltages available without the use of attenuators. They thus provide useful tools for many problems where constant voltage and low voltage sources are required. The devices are inherently frequency insensitive up to and above 300 mc. Extremely low and essentially nonreactive output impedance facilitates their use for checks and references with standard voltage generators.

In comparing the micropotentiometers with other sources, such as a voltage-measuring thermistor bridge, absolute reproducibility and agreement have been limited only by the relative complexity of the standards of comparison. Verification of the exact frequency and voltage ranges of the micropotentiometers in terms of other independent standards is still in progress at the Bureau, along with other phases of design and application. Probably the greatest single difficulty encountered in this work has been the lack of stable sensitive receivers which can indicate one microvolt (or lower voltages) at 100 mc. and higher frequencies with accuracies of 10 per-cent or better. However, available evidence appears sufficient to recognize in the "R.F. Micropotentiometers" reliable, economical, and critically needed instruments for standardization of both single-ended and balanced voltage circuitry.

A New Concept in Precision Potentiometers . . .

THE MODEL J

Helipot



. . . combined with mass-production economies!

TYPICAL 6 GANG MULTIPLE ASSEMBLY

***If it's a tough potentiometer problem, bring it to* Helipot**

—for Helipot has facilities and know-how unequalled in the industry for mass-producing precision potentiometers with advanced operating and electrical features.

This recently-developed 'Model J' Helipot, for example, combines several revolutionary advancements never before available in the potentiometer field . . .

Precise Mechanical Concentricity

Modern servo mechanisms and computer hook-ups require high mechanical precision to insure uniform accuracy when connected to servo motors through close-tolerance gears and couplings.

In the "Model J," close concentricity between mounting surface and shaft is assured by a unique mounting arrangement. The unit can be aligned on either of two wide-base flange registers and secured with three screws from the front of the panel . . . or it can be secured with adjustable clamps from the rear of the panel to permit angular phasing. Or if preferred, it can be equipped with the conventional single-hole bushing type of mounting.

In addition to accurate mounting alignment, exact rotational alignment is assured by the long-life, precision-type ball bearings upon which the shaft rotates. Precise initial alignment coupled with negligible wear mean high *sustained* accuracy.

High Electrical Accuracy

Helipot products have long been noted for their unusually high electrical accuracy and the "Model J" embodies the latest advancements of Helipot engineering in this field.

For example, tap connections are made by a new Helipot welding technique whereby the tap is connected to only ONE turn of the resistance winding. This unique process eliminates "shorted section" problems!

High linearity is also assured by Helipot's advanced production methods. Standard "Model J" linearity accuracies are guaranteed within ±0.5%. On special order, accuracies to ±0.15% (capacities of 5000 ohms and up) have been obtained.

Ball Bearing Construction

The shaft of each "Model J" is carefully mounted on precision-type ball bearings that not only assure sustained rotational accuracy, but also provide the constant low-torque operation so essential for servo and computer applications. Starting torque is only ¾ of an inch-ounce (±.25 in.-oz.)—running torque, of course, is even less.

Independent Phasing

When using the "Model J" in ganged multiple assemblies, each section can be independently phased electrically or mechanically—even after installation on the panel—by means of hidden internal clamps controlled from outside the housing. Phasing is simple, quick, accurate!

Mass-Production Economies

In addition to its many other unique features, Helipot engineers have developed unusual techniques that permit mass-production economies in manufacturing the "Model J". Actual price depends upon the number of taps required, special features, etc. . . . but with all its unique features, you will find the "Model J" very moderate in cost.*

Wide Choice of Designs

The "Model J" Helipot is available in a wide selection of standard resistance ranges—50, 100, 1,000, 5,000, 10,000, 20,000, 30,000 and 50,000 ohms . . . in single- or double-shaft designs . . . with choice of many special features to meet virtually any requirement within its operating field.

***Write for Bulletin 107 which gives complete data and price information on the versatile "Model J" Helipot!**

THE Helipot CORPORATION

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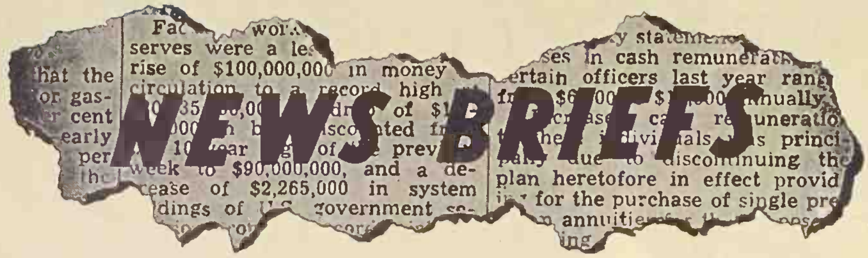
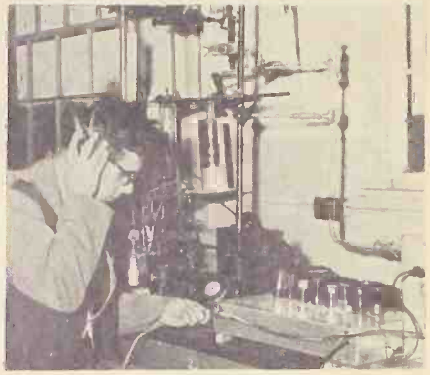
Field Offices: Boston, New York, Philadelphia, Rochester, Cleveland, Detroit, Chicago, St. Louis, Los Angeles and Fort Myers, Florida. Export Agents: Fratham Co., New York 18, New York



CHECKING EINSTEIN THEORY

The New York University College of Engineering is now using special ap-



paratus to measure the effect of speed on the mass of an electron in order to check the Einstein theory of relativity.

Earphones register clicks from a Geiger counter every time an electron is emitted from the Radium D in a specially evacuated chamber. The pulse frequency is checked with a stop watch shown at the left hand of the operator.

NATIONAL ELECTRONICS CONFERENCE

Dr. E. H. Schulz, chairman of the electrical engineering department at Armour Research Foundation of Illinois Institute of Technology, has been named 1951 president of the National Electronics Conference, Inc. Dr. W. G. Dow of the University of Michigan was named chairman of the board.

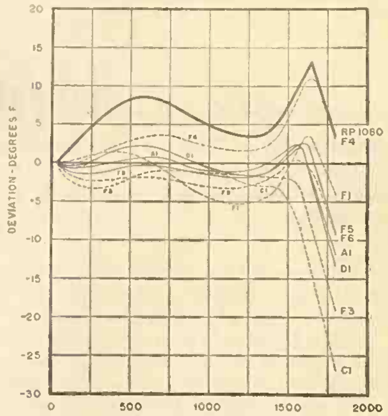
The seventh annual conference will be held October 22, 23, and 24 at the Edgewater Beach Hotel in Chicago.

Other officers who will plan and present the 1951 conference are: Executive vice president, J. A. M. Lyon of the Northwestern Technological Institute; Executive secretary, Karl Kramer of *Jensen Mfg. Company;* Recording Secretary, H. J. McCreary of *Automatic Electric Company;* Treasurer, C. E. Skroder of the University of Illinois; Arrangements committee chairman, S. R. Collis of *Illinois Bell Telephone Company;* Exhibits committee chairman, R. M. Soria of *American Phenolic Corporation;* Housing committee chairman, R. R. Jenness of Northwestern Technological Institute; Proceedings committee chairman, C. E. Barthel, Jr. of Armour Research Foundation; Program committee chairman, J. D. Ryder of the University of Illinois; and Publicity committee chairman, J. W. Armsey of Illinois Institute of Technology.

IRON-CONSTANTAN THERMOCOUPLE TABLES

Recently, at the request of the Scientific Apparatus Makers of America, the National Bureau of Standards has undertaken to derive a temperature-e.m.f. reference table for iron-constantan thermocouples which will be suitable for adoption as a standard.

Deviations observed at NBS between readings of sample iron-constantan thermocouples and the 1913 (L and N) temperature-e.m.f. table are shown by the dashed and fine continuous lines. The heavy line indicates differences be-



tween the RP 108 and the 1913 tables. Present preference is to base the new SAMA table upon the temperature-e.m.f. relation of thermocouple A-1.

As a prerequisite to the adoption of this table, the Bureau has requested that interested parties should consider the following questions: Is Industry-wide standardization on a single reference table for iron-constantan desirable? Is the 1913 table, or a close approximation to it, acceptable for this purpose? What degree of hardship will be occasioned by abandonment of the RP 1080 table?

The reaction of producers and users of pyrometers is a matter of interest to the Bureau, and replies to the above questions as well as related comments can be addressed to the National Bureau of Standards, Temperature Measurements Section, Washington 25, D. C.

STANFORD TO BUILD NEW LABS.

Two new electronics laboratories, one for applied research and the other for student electrical engineering activities, are to be constructed at Stanford University in California.

Construction of the student electrical engineering laboratory, which will be in the form of a wing adjoining the applied research center, was made possible through a gift from *Hewlett-Packard Company* of Palo Alto, electronics equipment manufacturing firm headed by two Stanford graduates, William Hewlett and David Packard, both of the Class of 1934. This wing will include classrooms, laboratories, workshops where students can work with radios and try out their own ideas in unsponsored research, a library, and student lounge.

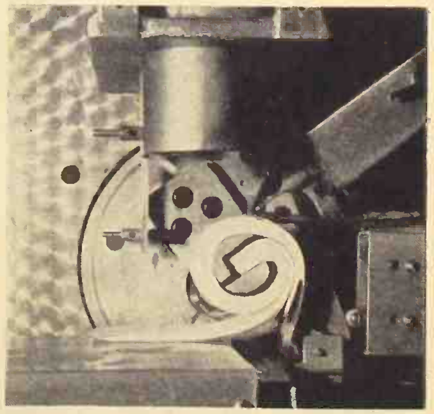
It was also announced that the university has received an Office of Naval Research contract for a research program in applied electronics. The grant supplements existing basic research contracts held by the university with ONR, the Air Force, Signal Corps, and the National Bureau of Standards.

ELECTRONIC COUNTING MACHINE

A fully automatic electronic machine for counting worn-out paper money has been designed and developed by H. M. Joseph and Carroll Stansbury of the National Bureau of Standards for the Department of the Treasury.

Although new paper money has been machine-counted for many years, mechanical handling of worn-out notes has until now been a perplexing problem. About 8 tons of currency are turned in daily for redemption. The notes are limp, wrinkled, and difficult to handle and require tedious counting by hand.

Shown is the NBS Electronic Cur-



rency Counter which counts 30,000 notes per hour. A package of "half-notes" has been firmly locked into the jaws of the spindle (center). As it rotates, the combined action of the friction band (curled around outer contour of packet) and of a jet of air (air hose, center) causes each note to break the light beam of a phototube (left). Two small mirrors reflect the light to the phototube through the path of the ruffled sheets.

Twenty-five of these machines will be placed in service soon, replacing the present hand-count system and saving about $250,000 annually.

COLOR TUBE PROCESS

Zetka Television Tubes, Inc., of Clifton, New Jersey has acquired the right to purchase an interest in *Sightmaster Corporation's* patents and patent applications affecting the improved construction of color cathode-ray tubes. According to reports, *Zetka* has already made a substantial payment on account.

This improvement in cathode-ray tube construction for color applies to either the *CBS* or *RCA* system. With the use of these patents, *Zetka* will be the first manufacturer to market a cathode-ray tube built for color specifications.

EXPAND STEVENS INSTITUTE LAB.

As part of a program to provide a modern and effective curriculum on the subject of industrial engineering, Stevens Institute of Technology has increased the facilities of its industrial engineering laboratory. The laboratory will be used chiefly by the Graduate School and the Industries Training School, and is designed to give students practical experience in the use of time and motion study and other industrial engineering techniques.

A unique feature of the laboratory will be the application of modern statistical procedures for treating time and motion study problems formulated by Dr. A. Abruzzi of the Graduate School staff. These include random sampling for estimating production rates and delay percentages, and for establishing standard time values for operation elements and motions.

Instruction in the laboratory will be under the general supervision of the Department of Management. Planning and scheduling will be directed by Prof. Joel E. Crouch. Among the instructors are A. Abruzzi, consultant, who will teach production management techniques and statistical appraisal of time study; Thomas A. Sawyer, industrial engineer at the *Western Electric Company*, teaching motion study; John Feltman, assembly section manager, *Allen B. DuMont Laboratories*, teaching time study; and Milton Morrison of the Stevens faculty, teaching statistical quality control.

TECHNICAL BOOKS

"INTRODUCTION TO INDUSTRIAL ELECTRONICS" by R. Ralph Benedict, Prof. Electrical Engineering, University of Wisconsin. Published by *Prentice-Hall, Inc.*, 70 Fifth Avenue, New York 11, N. Y. 436 pages. $6.35.

This volume provides an introductory and fundamental survey of the subject of industrial electronics, covering a description of the basic tubes and their behavior through a treatment of elementary circuits and typical applications.

Because of their importance in the field of industrial electronics, a great deal of emphasis is placed on gaseous tubes, phototubes, and the cathode-ray oscilloscope. The theory of amplifiers, oscillators, detectors, and modulators is rather briefly treated as many previous texts have included detailed theory on these subjects. The remainder of the book deals with circuits and electronic systems useful in industrial and power fields.

Some elementary calculus is employed and the reader is assumed to have an elementary knowledge of d.c. circuits and apparatus and of a.c. circuits.

"APPLIED ELECTRONICS ANNUAL 1951," edited by R. E. Blaise. Published by *British-Continental Trade Press Ltd.*, 222, Strand, London, England. Available from J. D. Griffiths, 2 Clarke Court, Rutherford, New Jersey. 264 pages. $8.00.

The first edition of this year book and directory for radio and electronics consists of two sections: editorial material and a world directory.

The editorial section contains material written by men wellknown in the field on every aspect of the use of radio and electronics. There are chapters on receivers, transmitters, sound recording, television, radar, telecommunications, testing, and measuring.

The world directory contains several sections, namely: (1) Manufacturers of Radio and Electronic Equipment, (2) Suppliers of Component Parts and Materials, (3) Wholesalers and Importers, (4) List of Trade-marks and Names, and (5) Classified Buyers' Guide. A listing of specialized journals published in the various countries is also included as well as radio and electronic associations and institutes throughout the world.

NEW PRODUCTS

ELECTRONIC STANDARD CELL

Hastings Instrument Co. Inc., Super Highway at Pine Ave., Hampton 10, Va., is introducing an Electronic Stand-

ard Cell for industrial and laboratory use. This unit provides a d.c. reference voltage stable to 0.25%. Output ripple on the low current models is less than 0.01%.

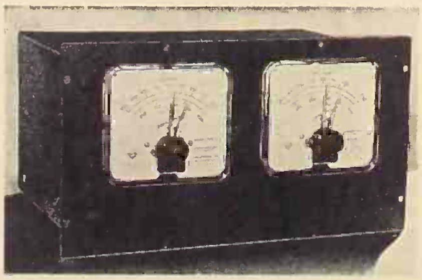
This unit is for use with self-balancing potentiometers, wire strain gauges, recording oscillographs, resistance thermometers, and other applications which require a stable d.c. source. It operates from an a.c. source; 90 to 130 volts, 50 to 500 cycles.

Electronic Standard Cells for precise output voltages of 1.00, 10.00, 100.00 and the electrochemical standard cell voltage of 1.018 are available for immediate delivery. Units for any voltage in the 0 to 100 volt range with current drains from 0 to 30 milliamperes are available upon request.

CONTROL FOR DIMPLING DIES

An Automatic Pyrometer Control designed for controlling the temperature of dimpling dies used on aircraft structures is announced by *Assembly Products, Inc.*, Chagrin Falls, Ohio.

The unit includes two Simplytrol



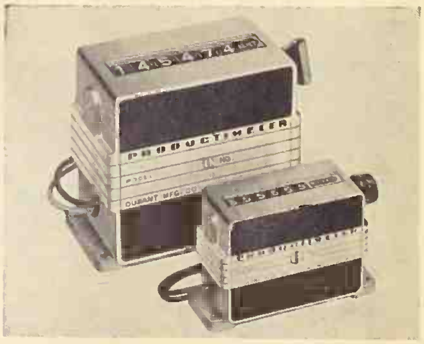
double contact meter-relays, one for each section of the die. Each meter has an on and off contact for regulating the heat of the die and a low limit contact for safety shut-off. Temperature range is from 350° to 750°F. Other ranges can be supplied for temperatures from minus 75° to plus 3000°F.

Simplytrol Pyrometer Controls are made in single units for individual control and in Polypoints for independent control of any number of units. Bulletins SP-12 and CMR-9 giving complete details are available upon request.

ELECTRIC COUNTERS

The *Durant Manufacturing Company*, 1919 No. Buffum St., Milwaukee 1, Wisconsin, has added two new electric units to its line of Productimeter counting and measuring machines.

The smaller, identified as the "Y" Electric, is for light applications where reading is done at close range. It will operate at speeds up to 1000 counts per



minute. The second unit is the "CS" Electric for heavy industrial applications, and features larger figures for distant reading. Its speed is up to 800 counts per minute. Standard voltage for both is 110 v. 60 cycles a.c. These two counters are available in six figures capacity and are resettable.

Bulletin No. 55 "New Electric Counters" is available upon request.

DECIMAL SCALERS

Two nuclear instruments recently developed by the *Berkeley Scientific Corporation* of Richmond, California offer potential users a choice of either a Basic Geiger-Muller Scaler devoid of nonessential features at an absolute minimum cost (Model 100) or a Universal Scaler suitable for both Geiger-Muller and scintillation work (Model 110).

Single continuous control is provided from 0-2500 volts, and maximum continuous counting rate is 1000 c.p.s. Resolution of random pulse pairs is better than 7 microseconds. Accessory outlets are provided for external time clock, timer, loudspeaker, or output pulse per count to drive count rate meter or Counting Rate Computer and Recorder.

Model 110 includes a positive or negative high voltage supply selectable by a simple internal switch. This model also includes a built-in predetermined counter with presettable scaling factors of 100, 200, 400, 1000, 2000, 4000, 10,000, and 20,000.

METAL

Transport Products Corporation, 120 South Campbell St., Louisville 6, Ky., has announced a new metal called Chemalloy for radio-electronic applications.

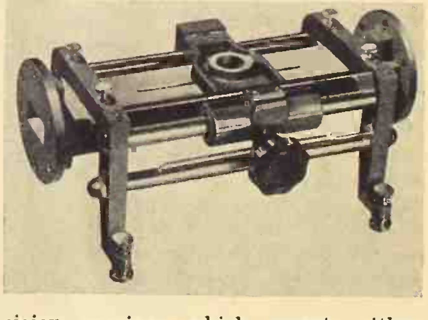
According to reports, this metal can be used as a dry bearing without any lubrication, as a bearing that can carry on when lubrication is ineffective such as during initial startup or in cold temperatures, as a fluxless welding rod for aluminum, and as a precision casting metal. It does not rust or corrode, nor does it heat up when sawed or machined or when in frictional contact with the same type of metal.

Developed by *Chemalloy Associates* of Santee, California, Chemalloy is being tried for casting wave guides to high precision, increasing the rating of motors and generators, dissipating heat of hermetically sealed components, etc. Further information may be obtained by writing *Transport Products Corporation.*

WAVE GUIDE TEST INSTRUMENTS

The *Hewlett-Packard Company* of Palo Alto, California, is introducing a line of 100 new wave guide test instruments. The line provides full frequency coverage from 2.6 kmc. to 18.0 kmc. in six most-needed wave guide sizes.

One of the most important new instruments of the line is the -hp-809/810 series slotted sections and precision carriage. Model 809B has a single pre-



cision carriage which accepts either slotted wave guide sections or coaxial sections covering frequencies from 4.0 to 12.4 kmc. Model 810B wave guide slotted sections for the 809B carriage are available in sizes 2" x 1", 1½" x ¾", 1¼" x ⅝", 1" x ½". Also offered is the Model 806A coaxial slotted section for frequencies 3.0 kmc. to 12.0 kmc.

In addition to slotted section equipment, this line includes fixed attenuators, calibrated variable attenuators, variable flap attenuators, wave guide to coaxial adaptors, adjustable shorts, hybrid tees, wave guide tees, detector mounts, frequency meters, slide screw tuners, E-H tuners, coaxial detectors, broad-band probes, low-power terminations, high-power terminations, klystron power supplies, and a broad line of basic coaxial equipment including u.h.f. and s.h.f. signal generators, coaxial slotted lines, microwave power meters, and standing wave indicators.

ACCELEROMETER

A self-generating accelerometer using Glennite piezoelectric ceramics and designed for use in the measurement of

high frequency shock and vibration is announced by the *Gulton Manufacturing Corporation* of Metuchen, New Jersey.

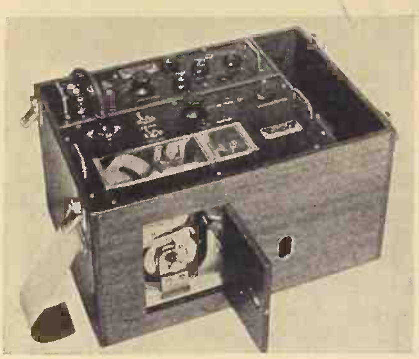
Model A403 utilizes a compressionally sensitive system. The pickup has a resonance of approximately 8000 cycles and when used with a low pass measuring system it will produce signals up to 4000 cycles. Output is linear with acceleration up to the rated value of 600g making it possible for the engineer to use a single pickup from approximately 0.1g to 600g.

This accelerometer can be operated over a wide range of temperatures, namely from −60°C to + 90°C. Calibration is normally furnished with 4 ft. of shielded cable supplied with the unit.

STRAIN RECORDER

The Testing Equipment Department of *The Baldwin Locomotive Works*, Philadelphia 42, Pa., has announced a recording SR-4 strain amplifier which reproduces both static and rapidly changing measurements of strains, forces, fluid pressures, displacements, vibrations, acceleration, etc., on a strip chart with rectangular coordinates.

Known as the *Baldwin-Sanborn* recorder, the instrument is a direct-writing, inkless, vacuum-tube voltmeter



consisting of an a.c. powered strain gauge amplifier of the conventional modulated carrier type in which the bridge is excited at 2500 cycles per second by a built-in oscillator, a D'Arsonval moving coil recording galvanometer in which a current of 10 milliamperes produces a writing arm torque of 200,000 dyne cms. and 1 cm. deflection, and a paper drive mechanism which is simple and rugged in operation.

In addition to use with strain gauges, the instrument can be used with temperature sensitive elements such as the *Baldwin* Type T-14 and can reproduce any electrical phenomena ranging from a few millivolts to more than 200 volts.

POWER SUPPLY

Either d.c. or single-flash operation of AH-6 or BH-6 mercury-vapor arc lamps can be obtained from 115 volts 60 c.p.s. power with the Model 1-BC power supply announced by *Huggins Laboratories*, 738 Hamilton Avenue, Menlo Park, California.

With d.c. setting, the power supply delivers one kilowatt—1.2 amp. at 800 volts. Open-circuit voltage of 1700 volts is supplied for starting the lamp. Standard d.c. ripple is about 5 per-cent, but lower values can be supplied in special units.

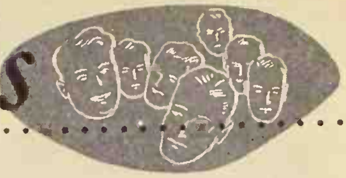
With flash operation, the 10 μsec. pulse at a power of approximately 2.5 watt-sec. is provided by a power capacitor discharging through the lamp by means of a thyratron controlled spark gap. Maximum repetition rate is 6 pulses per minute.

INDUCTION REGULATORS

General Electric's Transformer and Allied Product Divisions at Schenectady, New York, has announced a line of three-phase, dry-type induction voltage regulators. The new line includes both self-cooled and forced-air-cooled regu-

(*Continued on page* 29A)

Personals



GEORGE A. BAIRD has been appointed an Associate Research Engineer of *Burroughs Adding Machine Company's* Research Division at Philadelphia. Prior to joining *Burroughs*, Mr. Baird was a research assistant at the University of Pennsylvania, Moore School of Electrical Engineering. A member of the AIEE and the IRE, he received the degree of B.E.E. from Villanova College and the degree of M.S. from the University of Pennsylvania.

W. L. BUDGE of the *Westinghouse Electric Corporation* has been appointed manager of the Atomic Power Division facilities near Idaho Falls, Idaho, where the "Mark I" naval reactor will be assembled and tested. A graduate from the University of Colorado in 1941 with the degree of Bachelor of Science in mechanical engineering, Mr. Budge joined the *Westinghouse* Graduate Student Training Course at East Pittsburgh.

ROBERT V. D. CAMPBELL has joined the staff of the Research Division of *Burroughs Adding Machine Company* as Supervisor of the Planning Department. Mr. Campbell served in the U. S. Navy during World War II, and was stationed at the Computation Laboratory of Harvard University where he later received the appointment of Research Associate. Prior to joining *Burroughs*, Mr. Campbell was a member of the engineering staff of *Raytheon Mfg. Co.*

DR. MARTIN A. EDWARDS, formerly associate engineer in charge of *General Electric's* General Engineering Laboratory's technical divisions, has been appointed engineering manager. Dr. Edwards will be responsible for all engineering activities of the laboratory. During his 22 years with *G-E*, Dr. Edwards has been a three-time winner of the Coffin award, the first of which was presented for his work on synchronous torque amplifiers for marine applications.

GEORGE S. EVANS has succeeded the late Ralph R. Brady as manager of commercial engineering for the Lamp Division of *Westinghouse Electric Corporation.* Mr. Evans has been in the company's research, engineering, and production departments, working with gaseous discharge devices such as lamps and electronic tubes, since he joined *Westinghouse* fifteen years ago as a member of its graduate student course in Pittsburgh.

CAPT. GEORGE F. SHECKLEN, USNR, Executive Vice President of the *Radiomarine Corporation of America*, has received the Marconi Memorial Medal Achievement. Capt. Shecklen set up the now-famous Radio Central at Shanghai and served in several capacities with *RCA*. Upon his return to inactive duty status in 1945, Capt. Shecklen became Vice President and General Manager of *Radiomarine* and was later appointed to his present position and elected a Director.

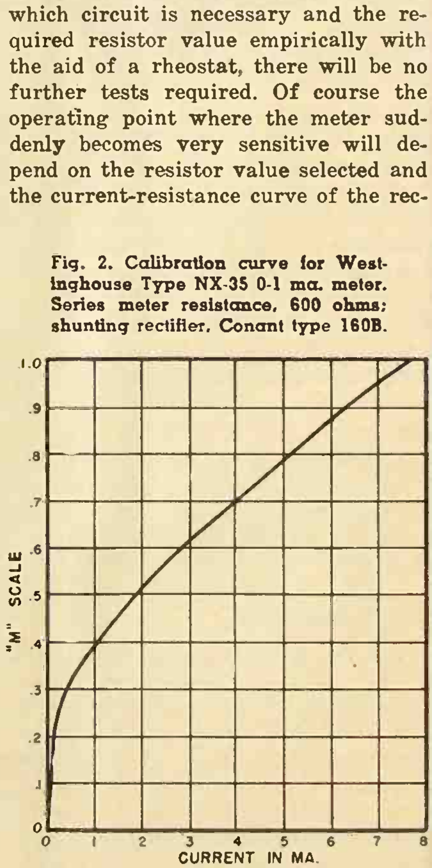
Meter A. V. C.

(Continued from page 6A)

The radical change in resistance of this type of rectifier, Fig. 3, is utilized to produce the a.v.c. effect. Considering Fig. 4B, a half-wave rectifier is connected across a meter winding. As current flows through the meter armature, an *IR* voltage drop is developed across it. Depending upon the internal resistance of the meter, at some point a voltage will be developed across the meter to suddenly and quite sharply cause the rectifier to lose its high no-current resistance and fall to a low resistive value. From this moment on, the meter movement no longer has a high resistance shunt, the shunt now taking the majority of the supplied current and effectively making the meter very insensitive. The point at which this critical voltage develops makes necessary the use of alternate circuits A and C. If this voltage develops too soon a series rectifier resistance must be used (Fig. 4A) to regulate the operating point, or conversely if the critical voltage develops too late (or not at all) then a series meter resistance (Fig. 4C) must be used.

In determining which configuration is required, circuit B should be used first. The operation of the meter will then indicate which alternate circuit will be required, if at all necessary. Basically it can be seen that the circuit is very simple, and after determining which circuit is necessary and the required resistor value empirically with the aid of a rheostat, there will be no further tests required. Of course the operating point where the meter suddenly becomes very sensitive will depend on the resistor value selected and the current-resistance curve of the rec-

Fig. 2. Calibration curve for Westinghouse Type NX-35 0-1 ma. meter. Series meter resistance, 600 ohms; shunting rectifier, Conant type 160B.



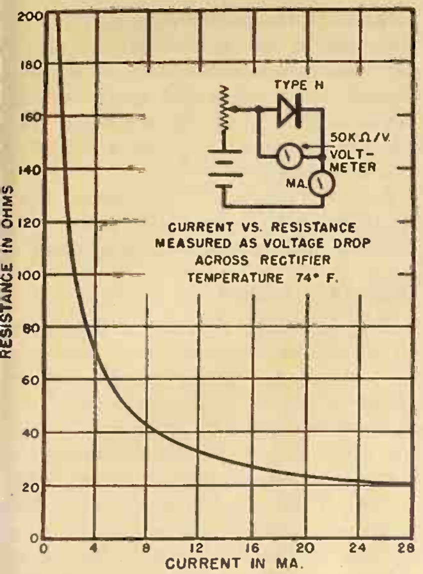


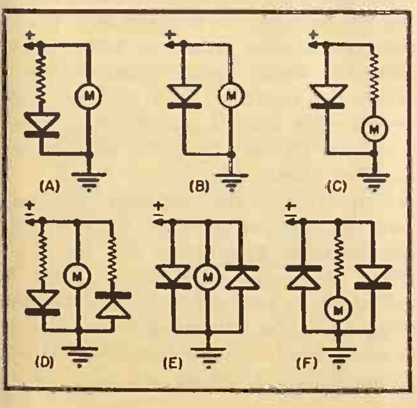
Fig. 3. Current vs. resistance measured as voltage drop across rectifier.

tifier chosen. A typical high current instrument rectifier is indicated by Fig. 3. A type BH rectifier should be used with a microampere or one milliampere meter, while the type H rectifier should be used with a meter of much higher current range. This is to allow the meter shunt to start taking a high percentage of the supplied current before exceeding the rating of the meter.

The meter readings will not be completely stable due to slight erracticness in the non-linear resistance operation of the rectifier. For this reason, and the fact that these rectifiers change characteristics with temperature, the best use is not for a voltmeter or milliammeter. These slight changes in characteristics are not particularly important in a null indicator and for these reasons it is recommended for galvanometer use.

In securing a null, the ultimate indication may vary by several per-cent (of full scale) at different times, but is sufficiently stable for short periods of time that accurate, on the head, nulls may be secured one after the other. In the case of the d.c. bridge where the output signal actually falls to zero level, this effect will not be noticeable.

Fig. 4. Several possible circuits. Only the meter armature winding is shown with its relation to the rectifier and resistor.



The thought may occur that this meter's operation may approach a logarithmic curve and that it may be used as such. This is not the case, however. With the addition of other rectifiers and resistor a logarithmic curve can be approached with fair accuracy, but only with fair over-all accuracy due to the stability of the rectifiers. It is not recommended for accurate testing involving this application.

Recording Systems

(*Continued from page* 13A)

direction of magnetization. They may be connected to individual light sources representative of units of picture information, or they may be scanned by circuitry such as ring counters to rearrange the signals in series form. There are many other systems under development.

Electrostatic principles have been widely investigated and are used in a number of existing practical systems. In computers electrostatic charges stored on the face plates of cathode-ray tubes are used for temporary memory. Xerography is used for printing of type faces, pictures, and for office duplicating machines. This process depends on the electrostatic attraction and repulsion of charged particles and areas. The fact that charged particles may be microscopically small, and smaller, indicates that this might represent the ultimate in methods for densely packing intelligence. Electrostatic storage and memory is not necessarily as temporary as might be thought upon initial consideration. New materials and combinations of old materials indicate that storage time may certainly be provided that is quite adequate for television program transcription. An electron beam consists of charged particles and it is capable of modulation at frequencies higher than are required by current problems.

This is by no means a complete review of recording systems that have already been explored, nor is it a complete survey of existing investigations. It is entirely possible that a radically new medium and method will be developed that will have advantages over all of those now known. It is equally possible that an old method, explored briefly and then dropped into obscurity because of a limitation that existed then and perhaps does not exist now, will be recovered to the advantage of the future. Certainly there is a wealth of opportunity for ingenuity in the entire field of recording, and the potential rewards are well worth seeking.

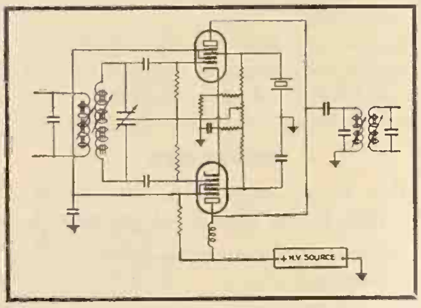
PATENT REVIEW

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.

SELECTIVE AMPLIFIER

The object of this invention is to provide an amplifier circuit which is highly selective at a frequency determined by a local crystal or tuned circuit.

The circuit consists essentially of two mixer tubes connected with their control grids in push-pull with respect to the incoming signal, and the plates in parallel. A crystal is connected in the injector grid circuit of one of the tubes. The operation is such that when the incoming signal is the same frequency as the crystal, that tube is disabled and the other tube amplifies this specific



frequency in the normal manner. At other frequencies, the signals at the plates of the two tubes are essentially equal and opposite in phase so they cancel each other. Thus the output is highly selective at the crystal frequency.

A modification consists of replacing the crystal with a high Q resonant circuit.

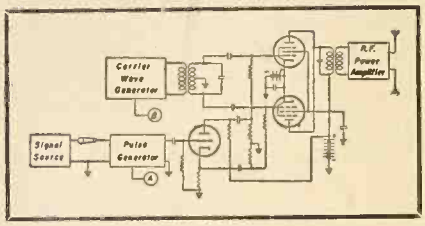
Patent No. 2,533,802 was issued Dec. 12, 1950, in the name of D. L. Hings.

INTELLIGENCE TRANSMISSION SYSTEM

This invention describes a communication system utilizing intermittent pulses, with some characteristic of the pulses being modified to provide intelligence. The purpose of this system is to provide an arrangement for reducing to a large extent the effect of random noise and static on such systems.

An r. f. stage is provided in which the grids of two tubes are excited in push-pull and the plates are connected in parallel. The grids are normally biased beyond cut-off, and are connected to an electron discharge device. This device is capable of producing two separate pulse voltages in push-pull, connections being such that the two tubes of the push-pull arrangement are alternately rendered conducting. The output thus consists of bursts of oscillation at the carrier frequency.

At the receiver, these bursts are combined with a local oscillator output of



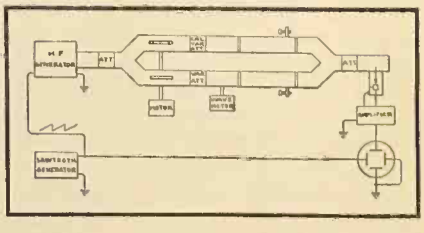
essentially the same frequency, and these two signals tend to alternately reinforce or cancel each other, as alternate bursts differ in phase by 180°. This combined signal goes through a filter, or integrating circuit, which gives the desired pulse output without appreciable effect from extraneous noise or static.

Patent No. 2,533,146 was issued Dec. 5, 1950, in the name of Walter A. Schwalm.

MICROWAVE ABSORPTION

This is essentially a dual microwave spectrometer for comparing the microwave absorption of an unknown gas with that of a known standard gas. The ultra-high frequency input, which is being swept over the desired band, is split and fed through the two wave guides, one containing the unknown, and the other the standard. The input is rapidly switched from one channel to the other, and the output later combined, detected, amplified, and fed to the plates of a cathode-ray tube.

By properly synchronizing the cathode-ray sweep frequency with the



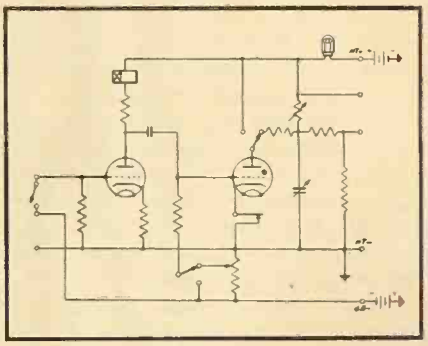
switching frequency, a dual display will appear on the C-R tube, one due to absorption in the known channel and the other due to that in the unknown channel. Frequency calibration is accomplished by a calibrated cavity which absorbs energy at its resonant frequency, producing a sharp dip in the C-R tube trace.

Patent No. 2,532,817 was issued Dec. 5, 1950 in the names of James M. Lafferty and Amandus H. Sharbaugh.

TIME BASE CIRCUIT

This invention provides a time base circuit for a cathode-ray oscillograph with means for producing the conventional saw-tooth time base to give deflections in a given direction, and means for producing single non-recurrent deflections in the opposite direction.

The circuit consists essentially of a condenser which is charged slowly from a high-voltage source and then discharged rapidly through a gaseous discharge tube to give the conventional saw-tooth output voltage. A suitable switching arrangement is provided so that if desired, a non-periodic input pulse will discharge the condenser, thus causing the electron beam to move in the opposite direction for a single sweep.



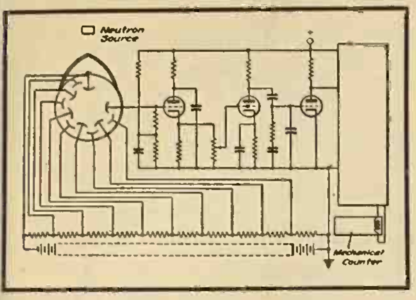
A suitable relay may be provided for resetting the circuit after a single pulse so that it will be ready for the next pulse.

Patent No. 2,533,251 was issued on Dec. 12, 1950, in the name of S. S. Hill.

NEUTRON DETECTOR

This device is basically a scintillation counter so arranged that it will count neutrons. This is made possible by causing the neutrons to impinge on a phosphor containing boron or some other material which emits protons when struck by neutrons. The protons then produce the desired scintillations. Protons may be kept from the counter by suitable filters.

Calculations are included showing that the layer of material for converting neutrons to protons can be relatively thin, of the order of 1 to 5 millimeters, and still absorb all the neutrons. Thus the physical size of the counter need not be excessive. It is claimed that the device will count slow and fast neutrons impinging at either a rapid or slow rate.



Patent No. 2,534,932 was issued Dec. 19, 1950 in the name of Kuan-Han Sun.

New Products

(Continued from page 25A)

lators in standard 10 per-cent and 20 per-cent ranges of regulation.

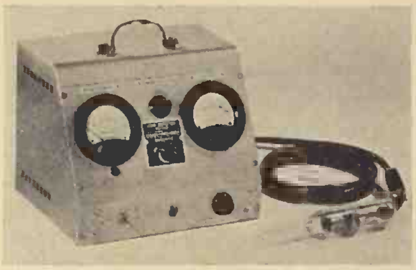
The standard line is being offered in ratings from 120 to 660 volts and from 12 to 85 kva. Three-phase, dry-type ratings have been available in these sizes in the "Triplex" assembly.

The manufacturer has emphasized that the new design is not intended to entirely replace the "Triplex" assemblies. Certain applications and some ratings, especially the smaller sizes, lend themselves more readily to the "Triplex" than to the new "conventional" design.

LEAK DETECTOR

Distillation Products Industries, Division of *Eastman Kodak Company*, Rochester, New York, is announcing a leak detector for use in vacuum systems down to one micron Hg. Known as the Leak Detector, Model LD-01, this instrument detects even minute leaks in high vacuum systems by capitalizing on the tendency of halogens and their compounds to enormously stimulate the emission of positive ions by a hot platinum anode.

The circuit of Model LD-01 is a simple one, employing only three standard radio tubes and housed in a cabinet on a dolly for convenience in working around large systems. The sensitive tube is 5" long, 1 5/16" in diameter,



and has a 3" tubulation, 7/16" outside diameter. This may be connected to a system under test with a fitting of the stuffing box type.

Further information may be obtained on request.

POWER AMPLIFIER

General Radio Company, 275 Massachusetts Ave., Cambridge 39, Mass., has announced availability of a wide frequency range aperiodic amplifier providing a maximum of 15 watts output with less than 0.2 volt input.

Type 1233-A Power Amplifier, in addition to its use as a general laboratory or testing amplifier, has specific applications in the driving of supersonic generators, the exciting of broadcast antennas for measurements with deflection-type instruments, and for use

as an oscilloscope deflection amplifier. When used with an antenna and tuned input, this unit can drive a Type 1931-A Modulation Monitor to monitor remote transmitters.

Three output combinations are available with a maximum frequency range from 20 cycles to 3 megacycles. Output transformers furnish low-impedance output up to 1.5 megacycles. Noise and distortion are low on all ranges, and readings of output voltage are given on a 3-range panel vacuum tube voltmeter.

CALENDAR
of Coming Events

APRIL 30-MAY 4—SMPTE Convention Hotel Statler, New York.

MAY 9-11—1951 Annual Meeting of the Engineering Institute of Canada, Mount Royal Hotel, Montreal.

MAY 10-12—41st Meeting of Acoustical Society of America, National Bureau of Standards, Washington, D. C.

MAY 21-23—1951 Parts Distributors Show, Stevens Hotel, Chicago.

MAY 23-25—1951 IRE Technical Conference on Airborne Electronics, Biltmore Hotel, Dayton, Ohio.

JUNE 20-22—IRE Seventh Regional Conference, Seattle, Washington.

JUNE 25-29—1951 Summer General Meeting of AIEE, Royal York Hotel, Toronto, Canada.

AUG. 22-24—7th Annual Pacific Electronic Exhibit, San Francisco Civic Auditorium, San Francisco, Calif.

OCT. 22-24—7th Annual National Electronics Conference, Edgewater Beach Hotel, Chicago.

Tube Applications

(*Continued from page* 17A)

fidelity operation of Class A triodes, with their familiar limitations as to efficiency and output power, and the use of beam tetrodes with their high peak power capability and relatively high distortion. The "triode *vs.* pentode" argument has raged for years. The dilemma has finally been resolved by the introduction of a new mode of operation, known as "Extended Class A".[1] By operating triodes and tetrodes together in the push-pull parallel arrangement shown in Fig. 9, the full advantages of both types of operation may be realized.

Since the same bias is applied to both triodes and tetrodes, the tetrodes will normally be cut off. For small signal voltages the circuit behaves as a normal triode amplifier. As the signal approaches maximum, however, the tetrodes conduct and supply the large peak currents required for high power output. Fig. 8 shows the typical composite characteristics for this type of operation. These particular curves are plotted for 807's, but various types of tubes may be used. 6AR6's are particularly suitable.

The dashed lines in this drawing are the composite grid lines. The most important point of interest is the path of operation for one side (Line c-d in the figure). Even when maximum grid swing operation is class A, the path of operation is still nowhere near the zero axis. The plate-to-plate loadline is drawn for 2500 ohms. Suggested operating conditions for 807's are given in Table 5.

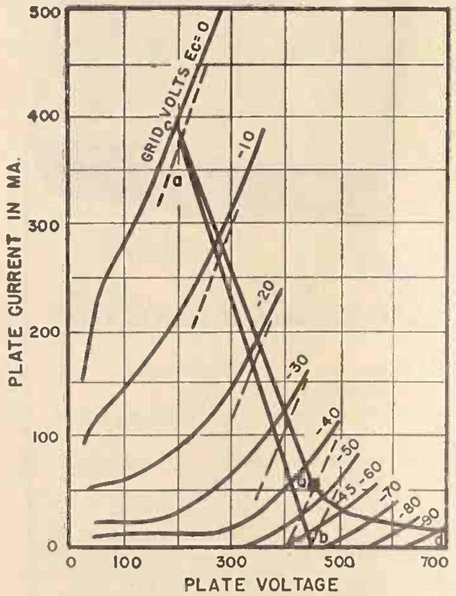
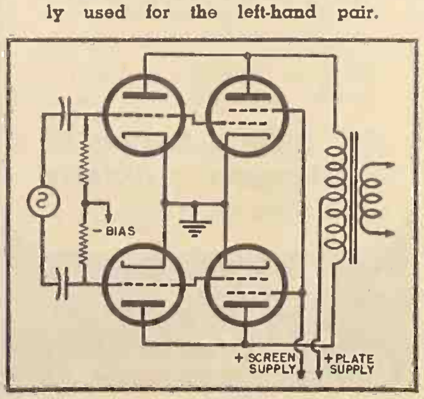


Fig. 8. Composite characteristics for Extended Class A operation of 807's. Other tetrodes may be used.

Fig. 9. Extended Class A circuit. Triode-connected tetrodes are usually used for the left-hand pair.



Screen Voltage Supply

With the Extended Class A circuit, as with any operation of tetrodes where the screen is to be operated at a lower voltage than the plate, we have the problem of screen supply regulation. This is a serious problem, because poor regulation of the screen voltage will seriously limit peak power capability.

A novel and extremely simple solution to this problem is shown in Fig. 10. A VR tube of appropriate voltage rating is used as a screen dropping resistor from the high voltage supply. If normal screen current is inadequate to keep the VR tube properly lit, a resistance may be used to draw an additional 5 ma. or so. With this system the screen regulation will be as good as the high-voltage-supply regulation, for all practical purposes.

This simple screen voltage arrangement may be used with the Extended Class A circuit of Fig. 9 (with a VR-105), or it may be applied to any tetrode amplifier system.

Class A_2 Operation

There is still another way to get high peak power capability from triodes. By operating up into the grid current region, provided the driver system is linear, it is possible to realize as much as twice the normal Class A power.

It is by means of this that some commercial amplifiers are able to get peak power of the order of thirty watts from 2A3's. Unfortunately, by virtue of the 15 watt dissipation rating of the 2A3, operation at this level is necessarily in the AB_2 region, with the tubes driven to cut-off during the negative cycle.

Fig. 10. Screen supply circuit for use with Extended Class A or with normal pentode amplifiers.

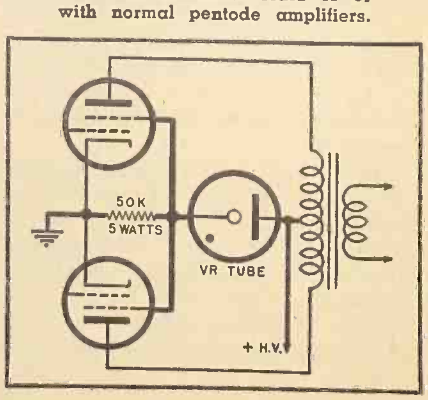


Plate Voltage	400 v.
Grid Bias	35 v.
Peak Signal Voltage (per grid)	50 v.
Maximum Instantaneous Grid Current	20 ma.
Zero Signal Plate Current	140 ma.
Maximum Signal Plate Current	
Effective Load Resistance	215 ma.
(plate to plate)	3000 Ohms
Power Output	32.5 w.

Table 6. Typical operating conditions for Class A_2 807's, two tubes.

By careful choice of tubes and operating conditions, however, entirely satisfactory A_2 operation is possible. It is necessary to select an operating point such that the dissipation rating of the tube will not be exceeded, and which will at the same time permit the full negative grid swing without cutting the tube off.

Such a solution is shown in Fig. 7 for the 807. The 30 watt dissipation rating permits operation at 75 ma. per plate. By driving the grids to 15 volts, a power output of 30 watts Class A can be obtained.

Typical operating conditions are given in Table 6.

The published curves do not extend into the region of maximum negative grid swing, but experimental work has shown this operation to be within the limitations of Class A.

This type of A_2 operation may also be used with the Extended Class A system, with corresponding improvement in power capability.

The design of drivers for A_2 operation represents a number of problems which must be taken up separately. Suffice it to say that tubes such as the 6SN7, or the new 6BL7, when used in any one of a number of cathode follower configurations, serve the purpose admirably.

Older Tube Types

For a number of reasons, the older and more familiar output triodes have been omitted from this discussion. The different versions of the 2A3, the 6A3, 6B4G, 6A5G, etc. are all extremely familiar. Other tubes, like the 300B and the 845 are less familiar, but are for a number of reasons of less interest than the types which have been discussed.

One major disadvantage of these older types lies in the fact that they are directly heated (the 6A5G has a direct connection from cathode to heater). This results in the necessity for elaborate precautions against hum, and frequently makes biasing less convenient. The higher-power types also have power supply requirements which are not as conveniently met as in the more modern types which have been described. Let's face it; high quality audio is an up-and-coming business, and it is essential to get the very most out of any tube that's used. The time is long past for the conventional "old standby" designs which are still cluttering the audio literature.

REFERENCE

1. *Sterling, H. T., "A New Power Amplifier Circuit Incorporating 'Extended Class A' Operation,"* Electronics, *in press.*

Slot Antenna

(*Continued from page* 5A)

to increase the radiation directivity. The method most commonly used is to cut the slots in the narrow face of the wave guide as in Fig. 5B. Since current flow in the narrow faces is all transverse, it is necessary to slightly incline the slots in order that they intercept flow lines of current. The radiation amplitude from each slot depends on the angular orientation of that slot, varying from zero when the slot is strictly transverse to a maximum when the slot is longitudinal. For small inclination angles the phase of each slot can be reversed by changing the sign of the slope of the slot. Thus, by spacing the slots half a guide wavelength apart and short circuiting the wave guide a quarter wavelength away from the first and last slot, the slots in Fig. 5B will be excited all with the same phase and amplitude and will produce a broadside pattern similar to that for the co-linear array. Because of the fact that the narrow side of a wave guide is always less than half a wavelength it is necessary to extend the slot into the broad faces in order that the slots be resonant. For this reason parallel slot arrays are not readily flush mounted in large conducting surfaces. One other serious disadvantage of the parallel slot array is the mutual interaction between slots; parallel slots radiate strongly along the axis of the array, while co-linear slots have negligible radiation along the array axis. Because of this high interaction, the phase and amplitude of radiation from each slot cannot be obtained simply.

One other type of slot antenna which has found extensive application is the annular slot shown in Fig. 5C. This is the slot analog of the circular loop antenna. When the annular slot is enclosed on one side by a circular cavity and fed by means of a coaxial cable whose center conductor extends through the cavity to be connected to the center of the circular disc, the electric field is directed radially across the annulus and is uniform if the slot is sufficiently narrow. An annulus whose diameter is small in terms of wavelength is simply an elementary electric dipole perpendicular to the surface, since its analog, the small loop, is an elementary magnetic dipole perpendicular to the surface. The measured pattern of a small annular slot in a plane and of a short stub above a plane readily bears out the analogy.[7] The radiation field is uniform about the slot, reaching its maximum value at the surface of the plane and progressing continuously to zero directly above the slot (a donut pattern). When the diameter of the annulus is increased beyond a wavelength, radiation from opposite sides of the annulus interfere to produce zeros in other directions. The pattern of a narrow annulus 1.62 wavelengths in diameter, when mounted in a 12 wavelength square ground plane and measured at a wavelength of 10 cm., is shown in Fig. 7 along with its calculated pattern. It is seen that the calculated pattern agrees well with the measured pattern except at the surface of the conducting plane. This discrepancy is again due to the finite size of the conducting plane, an effect observed previously in Fig. 3 for the pattern of a rectangular slot. A rather interesting observation in both cases is the fact that the field was reduced to half of its calculated value. This phenomenon is observed whenever an abrupt discontinuity exists, the value of the function at the discontinuity being simply the average value of the function.

Annular slots can be arrayed concentrically to give any desired pattern in a plane perpendicular to the conducting plane while still retaining a uniform pattern in cones about the slot axis, if a sufficiently large number of slots are used. The required directional pattern is obtained by properly choosing the radius of each annulus and the phase and amplitude of fields in the annuli.[8]

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3. *Carter, Martin, Thorne, "Slot Antennas in Elliptic Cylinders and Airplane Vertical Stabilizer", RCA Laboratories Report No. CM*-45-15, *April*, 1948.
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6. *Woodard, P. M., "A Method of Calculating the Field over a Plane Aperture Required To Produce A Given Polar Diagram", Jour. I.E.E., vol* 93, *part IIIA, No.* 10, *p.* 1554, 1946.
7. *Rhodes, D. R., "Flush Mounted Antenna for Mobile Application", Electronics, p.* 115. *March* 1949.
8. *Pistolkors, A. A., "Theory of the Circular Diffraction Antenna". Proc. I.R.E., p.* 58, *January* 1948.

(To be continued)

Editor's Note:

Mr. G. B. Devey, author of the article entitled "Antenna Systems Design" which appeared in the March, 1951 issue, has requested that the following statement be published to supplement the article: "This work was done while the author was in the employ of the U. S. Navy Underwater Sound Laboratory, New London, Conn."

PHOTO CREDITS

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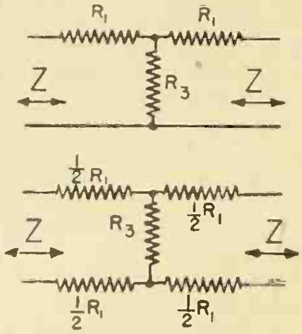
SYMMETRICAL T AND H ATTENUATORS

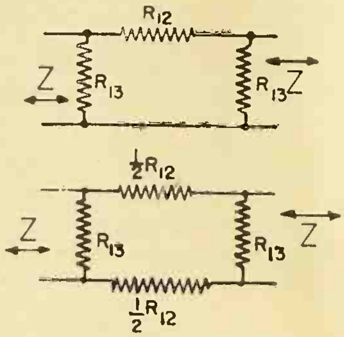
A nomograph for designing symmetrical attenuators when the terminal impedance and required loss are known.

A STRAIGHT line through "Decibels for R_1" and "Impedance" gives value of R_1. Another line through "Decibels for R_3" and "Impedance" gives value of R_3 for T and H attenuators. Example shows design of a 500 ohm attenuator with a 5 db. loss. The value of R_1 is 140 ohms and that of R_3 is 822 ohms.

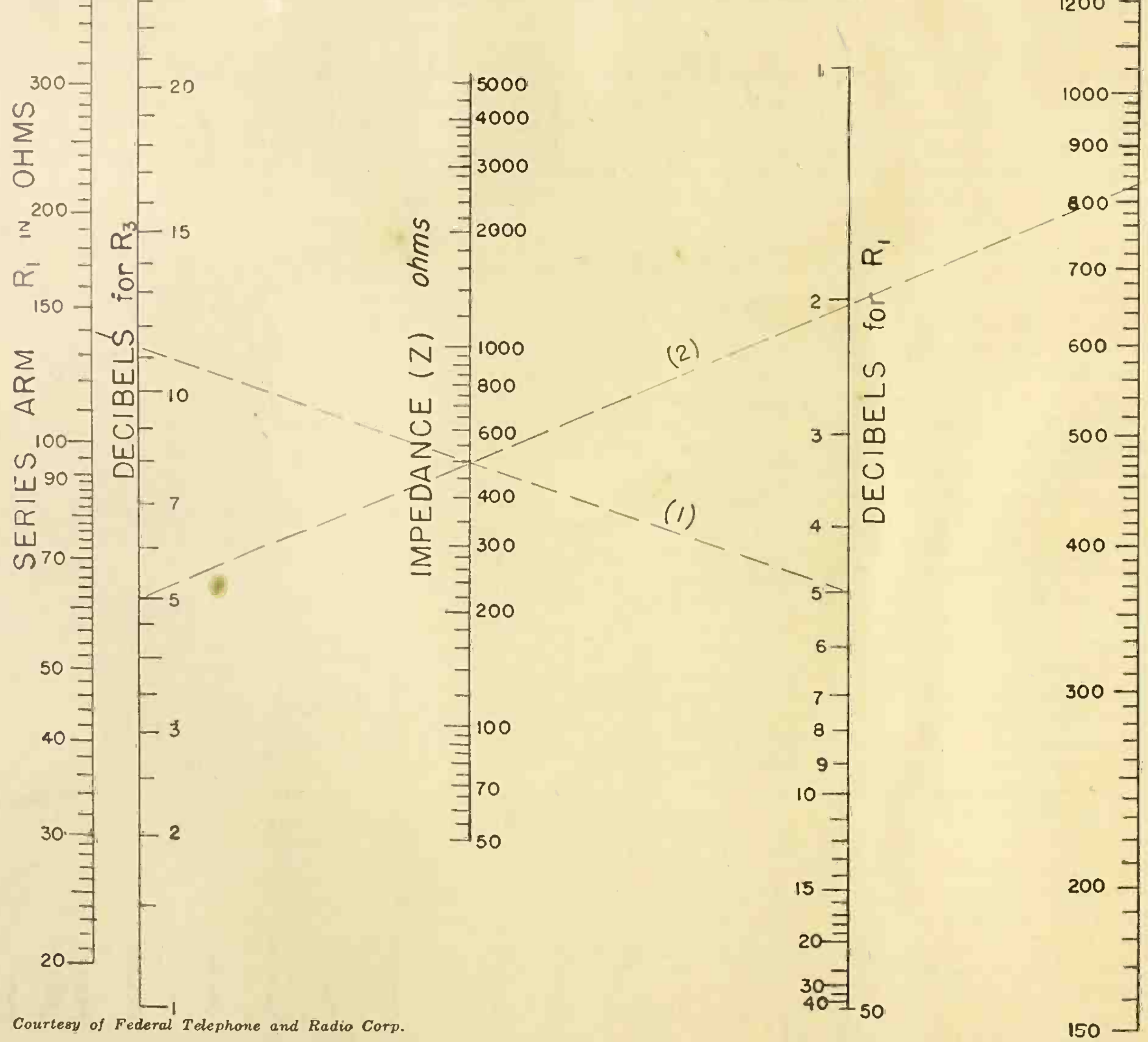
For symmetrical π and 0 attenuators, the nomograph is used to determine values of R_1 and R_3. The values of R_{12} and R_{13} are then given by the following equations: $R_{12} = Z^2/R_3$ $\quad R_{13} = Z^2/R_1$



T AND H ATTENUATORS



π AND O ATTENUATORS



Courtesy of Federal Telephone and Radio Corp.

SYMMETRICAL T AND H ATTENUATORS

A nomograph for designing symmetrical attenuators when the terminal impedance and required loss are known.

A STRAIGHT line through "Decibels for R_1" and "Impedance" gives value of R_1. Another line through "Decibels for R_3" and "Impedance" gives value of R_3 for T and H attenuators. Example shows design of a 500 ohm attenuator with a 5 db. loss. The value of R_1 is 140 ohms and that of R_3 is 822 ohms.

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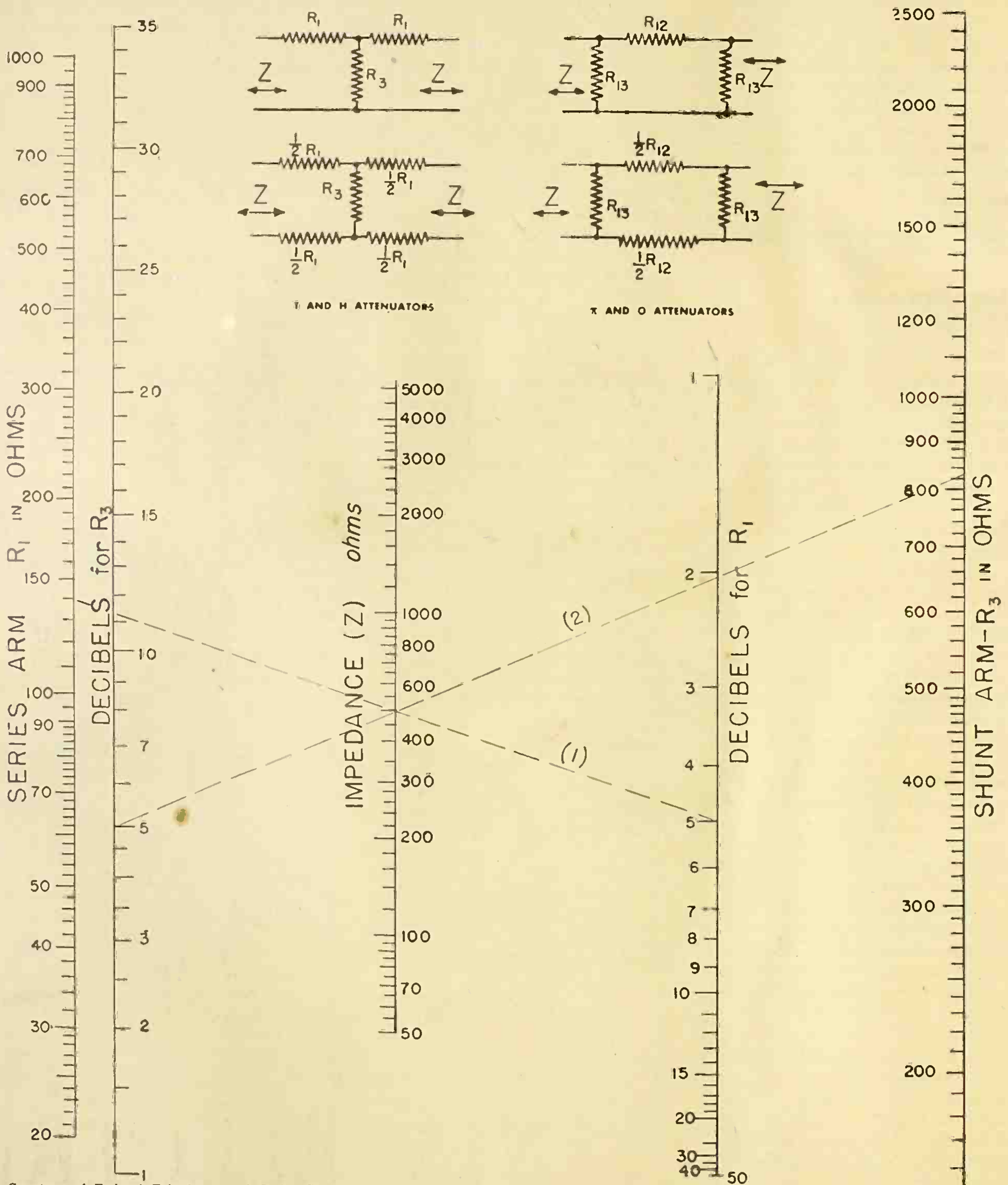

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