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APRIL, 1950

DEPARTMENTS

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COVER PHOTO—Courtesy of General Electric

Dr. Albert W. Hull of the General Electric Research Laboratory, who has been credited with the invention of more types of electron tubes than any other man, has retired from his post as assistant director of the laboratory, but will continue to serve as a consultant. The cover photo is a recent portrait taken of Dr. Hull in his laboratory.

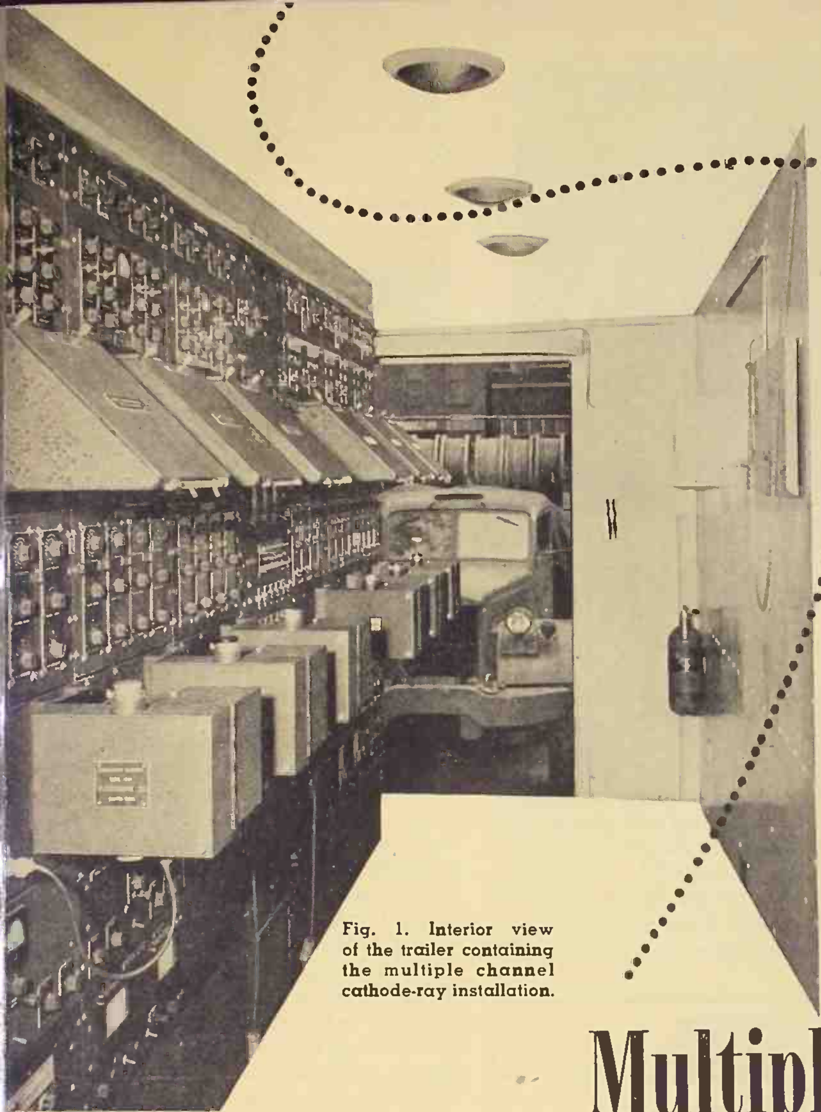


Fig. 1. Interior view of the trailer containing the multiple channel cathode-ray installation.

na is practically impossible, it is necessary to record the measurements in a form that will permit checking and evaluation on a vastly expanded time scale as well as permanence for repeated reference.

3. *Operation*—Manual control of more than two operations becomes difficult, and as the speed and number of operations is increased automatic control becomes necessary. This must be well timed and completely automatic to eliminate as far as possible the error element introduced by operators.
4. *Identification of Records*—Since many records are being taken at the same time, and often several in quick succession, with considerable time elapsing between recording and analysis, it is necessary to make provision for permanent positive identification of the records.
5. *Versatility*—Since the utility of the equipment generally depends on the number of applications to which it can be adapted it is necessary that the basic units be designed and constructed in such fashion that modification is simple.

There are two basic methods that may be used in multiple channel oscil-

Multiple Channel Cathode-Ray Instrumentation

24 channels are available for simultaneous recording of dynamic or transient phenomena.

By J. N. Van SCOYOC and G. F. WARNKE
Armour Research Foundation of Illinois Institute of Technology

MULTIPLE channel oscillography finds one of its greatest uses in the recording of dynamic and transient phenomena of a non-electrical nature. Many experiments can be repeated only to a statistical accuracy, if indeed they are repeatable at all. In such cases it becomes necessary to obtain the time "history" of the experiment by means of a number of simultaneous recordings; the number of data channels depending on the variable elements, cross checks required, or the size and shape of the object or field being investigated. Electrical measurements are usually reproducible enough not to fall into this category.

General

The design, construction, and use of multiple channel instrumentation is inherently more complicated than its single channel counterpart because of the following problems:

1. *Identification of Simultaneity*—When two or more measurements are taken some relative time reference must be supplied, with an accuracy required in the interpretation of the records.
2. *Recording of Data*—Since observation of non-repetitive phenome-

lographic recording. In the first, a still picture is taken, using commonly triggered horizontal sweeps on all cathode-ray tubes. Although all sweeps start at one time they may be of different durations so that expanded or contracted time records may be obtained. If the time scale is important, timing marks must be introduced in the form of x, y, or z axis markers.

In the second method a sweep is not used but a spot is photographed on continuously moving film. In this way the film provides the time axis, and variations in time scale are obtained by running the cameras at different speeds. An additional method of recording timing markers is available in this system, this being the use of pulsed glow tubes which can provide a common time scale for a group of traces.

For either of the above systems multiple beam tubes or nests of single beam tubes can be used. This reduces the number of cameras necessary and sim-

This article is based on a paper presented at the 1949 National Electronics Conference.

Fig. 2. Front view of the sequence timer control panel.

plifies processing and analysis of the records.

A recently completed 24 channel unit will be described to illustrate the functioning of a system which employs single beam tubes photographed by continuously moving film cameras. Some of the more specific technical problems such as elimination of cross-talk and hum, grounding circuits, etc., will not be discussed for lack of space.

In order to be able to conduct experiments in the field, remote from laboratory facilities, the twenty-four channels of oscillographic instrumentation, along with necessary auxiliary equipment and service and maintenance facilities, were mounted in an air conditioned semi-trailer. Fig. 1 shows an interior view of the installation. All units are relay rack mounted on a shock mounted frame. Space is provided behind the rack so that testing or maintenance can be accomplished without removal of the units. The twenty-four channels are arranged in six bays of four channels each, all identical. The center bay contains control equipment common to all channels. This figure will be referred to after a description of the operation of the system is given.

The functional block diagram shown in Fig. 3 illustrates the operation of a typical channel and the units common to all channels.

Resistance strain gauge or piezoelectric gauge input circuits are connected to the terminal unit which incorporates matching networks and acts as a junction point for input, calibration and amplifier circuits. In the case of strain gauge input, the bridge power supply is used to supply current to the strain gauge bridge circuits.

Input signals are fed to the amplifier, which operates from the amplifier power supply, and thence to the oscilloscope unit. The oscilloscope unit derives all its operating voltages from the oscilloscope power supply. The camera records the signals from four cathode-ray tubes of one oscilloscope unit on one 35 mm. continuously moving film. The controlling relay and power connections for the camera are located in the amplifier power supply unit.

Interval timer A derives its frequency from a secondary frequency standard and supplies timing pulses to one glow modulator tube in each of the six oscilloscope units.

Interval timer B supplies timing pulses derived from a tuning fork to all cathode-ray tubes and to one glow modulator tube in each four channel oscilloscope unit. It also provides a vertical sweep for test purposes and a zero time pulse for establishing a simultaneous point on all records.

Two glow tubes are provided for each oscilloscope unit (see Fig. 7), each of which records a timing trace along the outside edge of each film record as shown in Fig. 11. Two timing records of different frequencies are thus recorded which may be used to:

1. Interpolate time intervals or periods.
2. Facilitate counting of long time periods while maintaining short period accuracy.
3. Check one frequency source against the other.
4. Eliminate timing errors due to irregularities in film speed.
5. Provide baselines for amplitude measurements.

The accuracy of the frequency of the secondary frequency standard or the tuning fork may be checked by comparison with signals broadcast by WWV which are picked up in the receiver supplied.

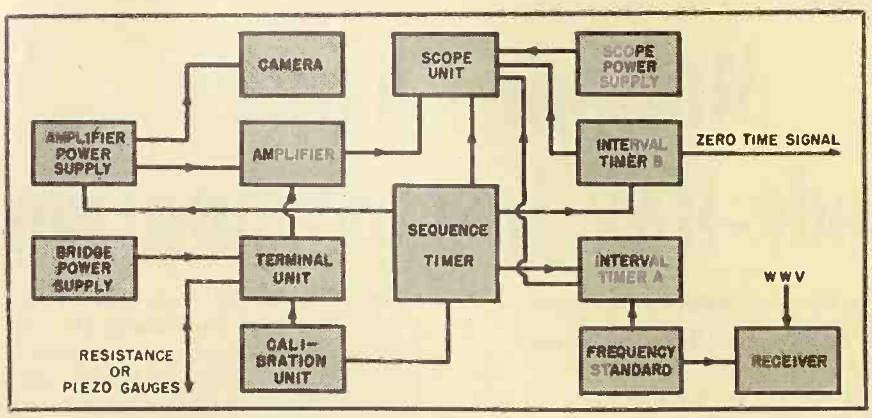
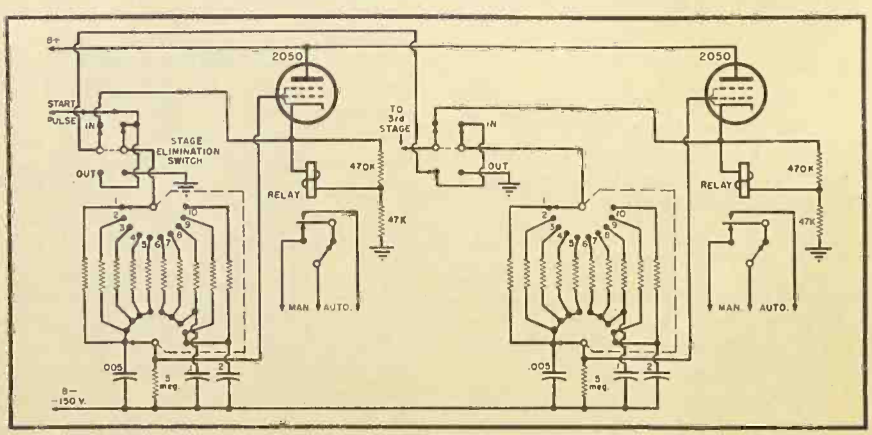


Fig. 3. Functional block diagram of a typical channel.

Fig. 4. Basic schematic diagram of the sequence timer.



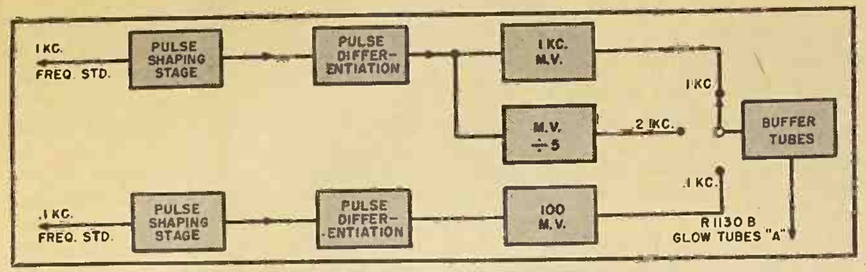


Fig. 5. Block diagram of interval timer A.

The sequence timer automatically controls all equipment operation during test, and since we have discussed the functional interdependence of all the instrumentation units, a description of the operation of this timer is in order.

Two of ten identical stages of thyratron delay circuits are shown in Fig. 4. Selection of ten time delays ranging from 10 milliseconds to 2 seconds is provided for each of the ten stages by means of *R-C* networks. Relays are used in the cathode circuits of the thyratrons, and the triggering voltage for the succeeding stage is derived from the thyratron cathode rather than from the relay. This prevents the relay time errors from being cumulative. Any stage may be bypassed by means of the stage elimination switch provided, and manual simulation of all automatic relay operations may be obtained by means of switches in the relay circuits.

The arrangement of these controls on the front panel of the unit is shown in Fig. 2. The top row of toggle switches controls the manual operation of each stage, while the bottom row of toggle switches is used to eliminate any stage which controls an operation unwanted for the particular test. The rotary switches are used to select appropriate time delays for each thyratron stage. Start and stop buttons are provided although the unit can be remotely controlled if it is so desired.

The arrangement for recording may best be described by reference to Fig. 7 which shows the front panel of the oscilloscope unit. Four 3 inch cathode-ray tubes are nested together to decrease the area of the field to be photographed. The vertical center lines of the tubes are two inches apart to provide one inch deflection on either side of center without overlap of traces. Two glow modulator tubes are mounted, one in either corner, on the horizontal center line of the two rows of tubes and a counter is mounted in the lower left corner. This counter is edge lighted by a concealed lamp for photographic identification of the record.

The cast aluminum frame supports a 45 degree front surface mirror. The camera is mounted on the front panel of the amplifier power supply below this unit with the lens vertical; the picture being taken by means of the 45 degree mirror. Tube face to film distance is such as to obtain a 9 to 1 reduction. The advantages of this system are its rigidity, freedom from differential vibration and saving of space.

Each channel is provided with individual intensity, focus and vertical positioning controls to take care of individual tube variations but all tubes are brightened simultaneously by one relay control. Three such units, twelve cathode-ray tubes, are supplied by one well regulated high voltage source which is capable of delivering 2000 volts + and — with respect to the second anode. The second anode of these tubes is not at ground potential but is designed to operate at approximately 320 volts above ground because of the direct coupling of the amplifiers.

The modulated glow tube in the upper right corner (Fig. 7) is the tube referred to as glow tube "A", being supplied by interval timer A, while the one in the lower left corner, "B", is supplied by interval timer B and is used for the zero time indication. A brief description of the timing unit operation will be facilitated by reference to Fig. 5 which shows a block schematic of interval timer A.

The 1000 and 100 cycle sine wave inputs, derived from a frequency standard, are amplified, clipped and differentiated. These pulses are used to trigger multivibrators which are of the single shot type. This prevents off-frequency pulses being generated and recorded if the frequency standard

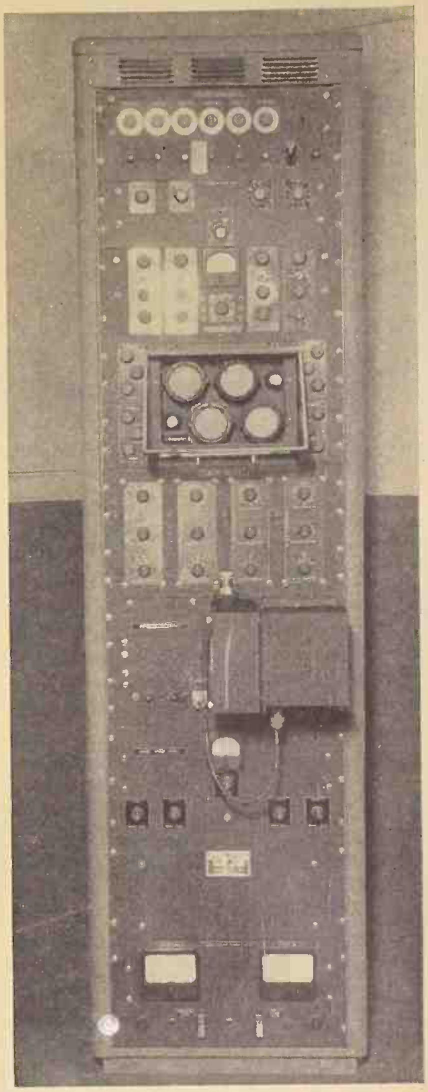
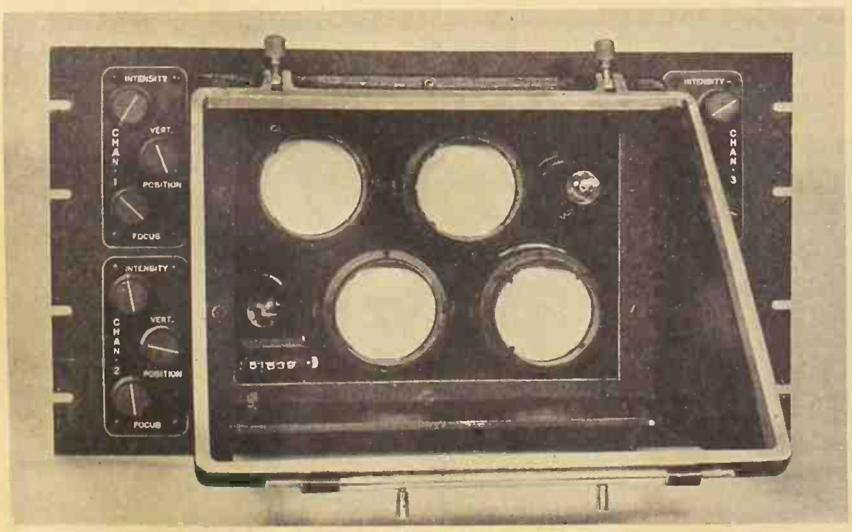


Fig. 6. Front view of a completely assembled 4-channel unit.

Fig. 7. Front view of an oscilloscope showing mirror mount (mirror removed).



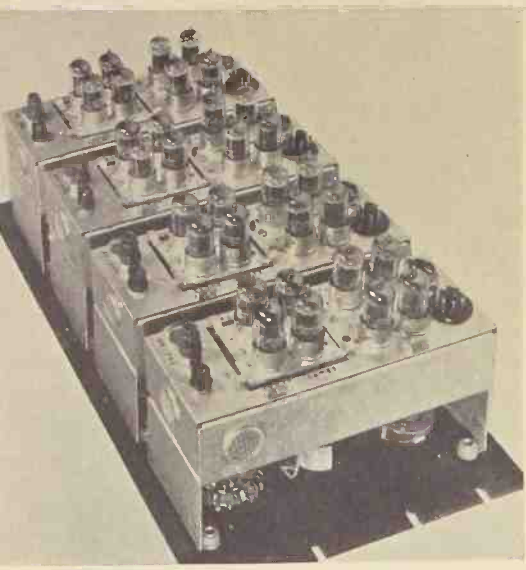


Fig. 8. The amplifiers which form the connecting link between the input circuits and the cathode-ray tubes are arranged in groups of four, as shown.

fails. A buffer tube is provided for each of the six glow tubes supplied from this timer. By six three position switches any one of three frequencies may be independently selected for each glow tube.

Fig. 9 shows a block diagram of interval timer B. Two sweep circuits are provided, one a conventional saw-tooth sweep and the other a multivibrator. This latter is used when high intensity traces are being focused to avoid possible burning of a line on the screen. The square wave produces a high velocity of spot travel across the usable portion of the tube face with the area of high intensity being off the face of the tube. Either of these signals is amplified and fed into push-pull cathode followers which provide low impedance output to the long interconnecting cables.

A 1000 cycle, temperature compensated tuning fork is used as a frequency source for the timing pulses in this unit. The sinusoidal output of the tuning fork is amplified, clipped, and differentiated, these differentiated pulses being used to trigger two multivibrators. The first multivibrator has a 1000 cycle repetition rate with adjustable pulse width and is connected to all the cathode-ray tube vertical plates at the same time the sweep is removed, by means of a sequence timer controlled relay. The effect of this is to produce small timing pips on all traces. The second multivibrator divides by two and has an output of 500 cycle pulses which are applied to the control grids of six buffer tubes supplying glow modulator tubes *B* in each oscilloscope unit.

These glow modulator tubes do not operate until initiated by the zero time pulse circuit which operates as follows. A pulse provided by an external device such as a fuse or switch triggers a multivibrator which simultaneously applies a pulse to the buffer tube and fires a thyratron completing the ground circuit of the glow modulator tubes enabling them to fire. The duration of the zero time pulse is adjustable and, after it ends, the 500 cycle pulses are recorded. The effect of the timing pulses on the vertical plates is shown in Fig. 11. The timing traces along the edge of the film are those supplied by the glow tubes while the timing pips on the four traces are supplied by the 1 kc. multivibrator of interval timer B.

The recording cameras used were specially designed for the instrumentation. The motor and transmission are permanently mounted while the magazine is separately removable to facilitate handling. Film speeds of 0.6 ft./second to 10 ft./second are available and the lens has adjustable focus and aperture.

The amplifiers form the connecting link between input circuits and cathode-ray tubes and are also arranged in groups of four as shown in Fig. 8. Both d.c. and a.c. amplification are provided, the latter through the use of a preamplifier cascaded with the d.c. amplifier. The d.c. amplifier may be used by itself, having a maximum gain of 50,000 variable 40 db. in 2 db. steps and a frequency response from 0 to 50 kc., or the combination of preamplifier and d.c. amplifier having a maximum gain of 2,000,000 with a frequency response from 0.2 cycle to 50 kc. The preamplifier has 20 db. of attenuation in 5 db. steps. These amplifiers embody a new input stage which permits use

(*Continued on page* 26)

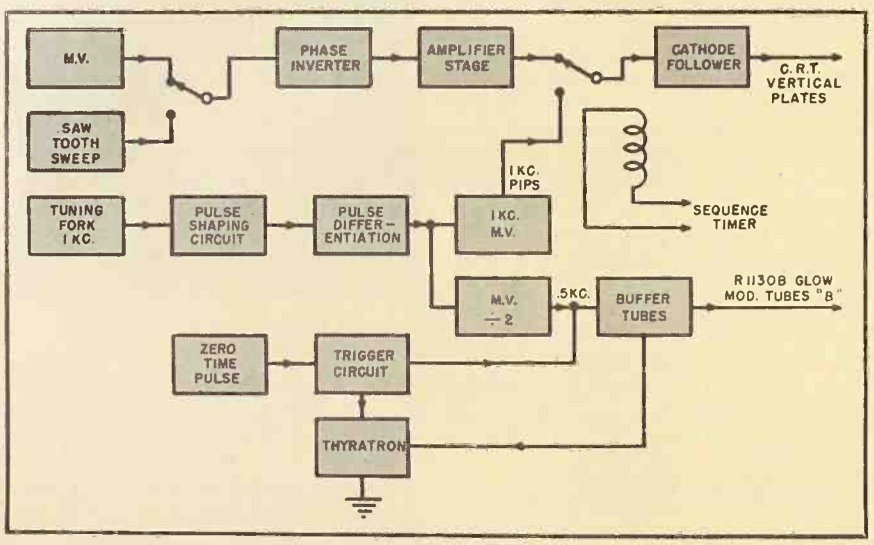


Fig. 9. Block diagram of interval timer B.

Fig. 10. Four channel record showing timing markers.

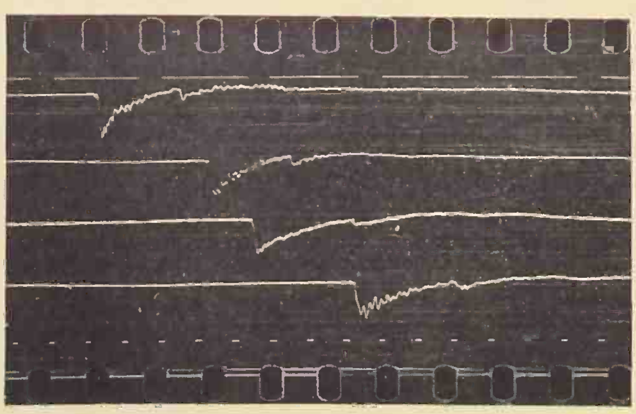
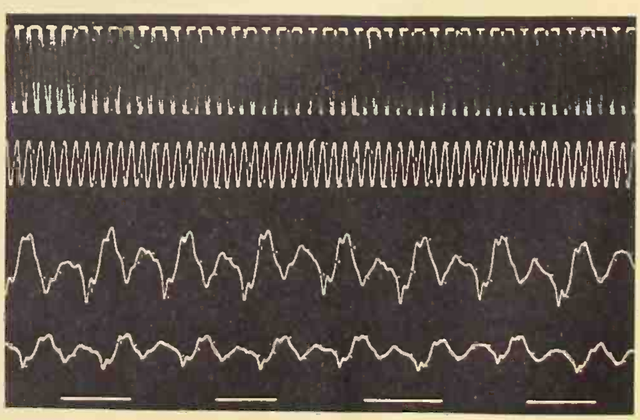
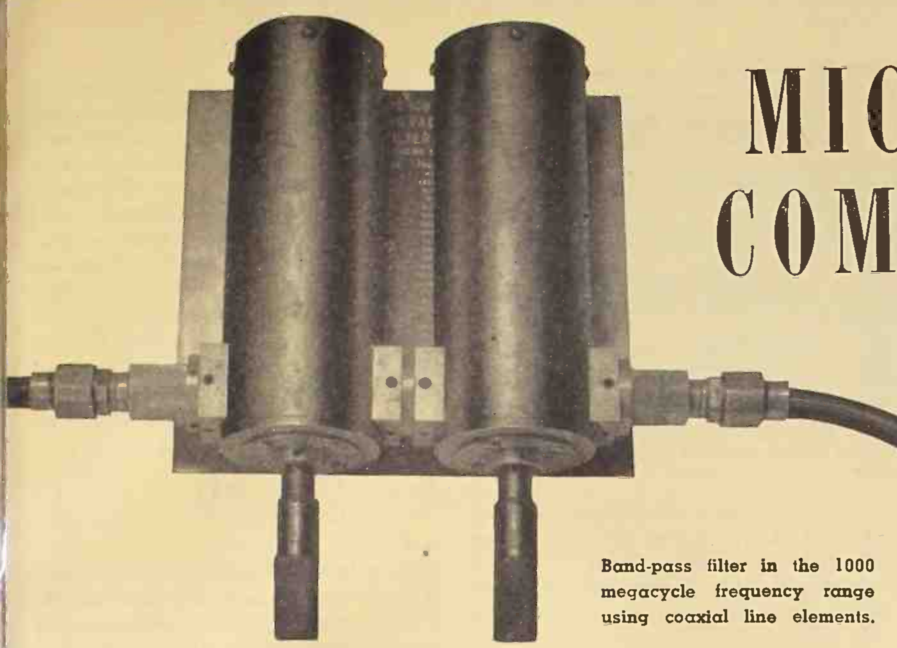


Fig. 11. The effect of timing pulses on vertical plates.





MICROWAVE COMPONENTS

By J. RACKER

Federal Telecommunication Laboratories

Band-pass filter in the 1000 megacycle frequency range using coaxial line elements.

A discussion of such coaxial line and wave guide components as quarter wave transformers, stub transformers, resonant lines and filters, etc.

IN the discussion given in the previous articles [1, 2] frequent reference has been made to the use of transmission lines as transformers, inductive and capacitive elements, filters, and other components. All of the general equations developed for transmission lines also apply when these lines are used as circuit elements. However, there is a major difference in approach between the use of transmission lines for the transfer of energy (as considered in the last article) and their use as components. This difference is: In the former case the problem is primarily one of selecting the best available manufactured line, while in the latter case the engineer must frequently actually design and build appropriate lines to meet his individual requirements. It is therefore necessary, in considering element design, to delve into the details of transmission line construction. Hence, a separate article on microwave components.

Coaxial Line Elements—Quarter Wave Transformer

This article, as the previous one, will be divided into two general sections; one considering the use of coaxial line elements for frequencies up to about 2000 mc. and the other, the utilization of wave guides for frequencies above 2000 mc. Coaxial line elements will be considered first, starting with quarter-wave transformers.

It has been shown that two purely resistive impedances can be matched to each other through the use of a quarter-wave transformer whose characteristic impedance is equal to:

$$Z_{0T} = \sqrt{R_0 R_L} \qquad (1)$$

where R_0 is impedance at sending end and R_L is load resistance. The characteristic impedance of a coaxial line is equal to:

$$Z_0 = \frac{138}{\sqrt{K}} \log_{10} \frac{D}{d} \qquad (2)$$

where D is outer conductor diameter, d is inner conductor diameter, and K is the dielectric constant. This equation is plotted on the nomograph on page 32.

Generally, the problem is to match a line with characteristic impedance, Z_0, to a load representing a complex impedance. In considering the input impedance of such a line versus distance from the load, it will be found that for each half wavelength of line traversed, two points of purely resistive impedance exist; one equal to $Z_0\eta_v$ (η_v voltage standing-wave ratio) located at maximum voltage points, and the other equal to Z_0/η_v located where voltage minimums occur.

It is usually more convenient to select a point of minimum resistance rather than the one of $Z_0\eta_v$, since in this case the characteristic impedance of the transformer required is less than that of the line. A line of lesser impedance can be obtained readily by utilizing a "sleeve" within the existing line as shown in Figs. 2A and B, while to increase the impedance involves increasing the outer diameter or decreasing the inner diameter, neither of which can be done simply.

The procedure for matching with a quarter-wave sleeve is as follows:

1. Measure the voltage standing-wave ratio at the input and determine the location of a minimum voltage point.

2. Design a sleeve which is a quarter of a wave long and whose diameters are equal to:

a) If sleeve is on inner conductor, its outer diameter d_1 should be:

$$d_1 = \frac{D}{\left(\frac{D}{d}\right)^{\eta_v - \frac{1}{2}}} \qquad (3)$$

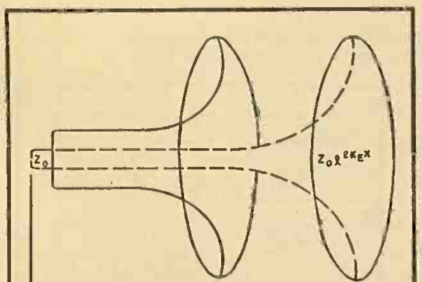
(derived from Eqts. (1) and (2) and the equation for voltage standing wave ratio[1]).

b) If sleeve is inside the outer conductor, its inner diameter should be:

$$D_1 = d\left(\frac{D}{d}\right)^{\eta_v - \frac{1}{2}} \qquad (4)$$

3. Insert this sleeve in the line at a position where the end of the sleeve facing the load is at the point previously determined to be a voltage minimum or an integral number of half waves from this position.

Fig. 1. Ideal exponential coaxial line.



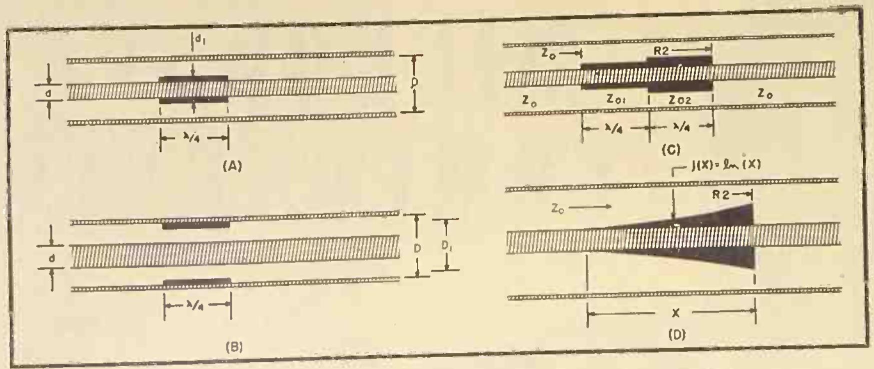


Fig. 2. (A) and (B) Quarter wave "sleeve" transformers. (C) Double sleeve transformer. (D) Tapered section matching Z_0 to R_2.

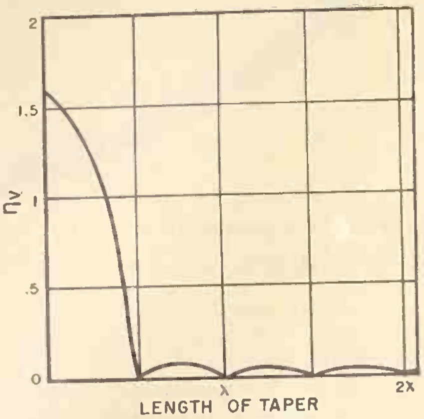


Fig. 3. Voltage standing wave ratio introduced by tapered section of coaxial line from 75 to 46 ohms.

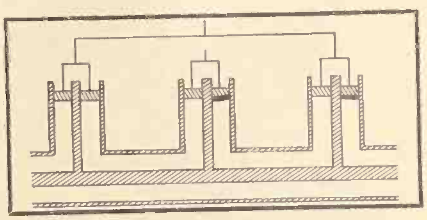


Fig. 4. Triple stub transformer.

A single quarter-wave sleeve used as a transformer has the disadvantage that it is resonant, i.e., it matches perfectly at one frequency only. The bandwidth over which the match is good can be extended by using two or more quarter-wave sleeves placed together and properly chosen in size.

A double-sleeve transformer such as the one shown in Fig. 2C should meet the following relationships:

$$\frac{Z_0}{R_2} = \frac{Z_{01}^2}{Z_{02}^2} \quad . \quad . \quad . \quad . \quad (5)$$

and

$$\left(\frac{Z_0}{Z_{01}}\right)^2 = \frac{Z_{01}}{Z_{02}} = \left(\frac{Z_{02}}{R_2}\right)^2 \quad . \quad . \quad . \quad (6)$$

For a three-sleeve network the relationships between successive sleeves should be:

$$Z_0 R_2 = \frac{(Z_{01})^2 (Z_{03})^2}{(Z_{02})^2} \quad . \quad . \quad . \quad . \quad (7)$$

$$\left(\frac{Z_0}{Z_{01}}\right)^3 = \frac{Z_{01}}{Z_{02}} = \frac{Z_{02}}{Z_{03}} = \left(\frac{Z_{03}}{R_2}\right)^3 \quad . \quad (8)$$

As more and more sleeves are used, the matching network is made less and less frequency sensitive, the limit being reached as the impedance variation approaches that of an exponential line. An exponential line, which effects reflectionless matching between two resistive impedances that is independent of frequency, is defined as a line whose characteristic impedance varies in accordance with the following equation:

$$Z_x = Z_0 e^{2K_0 x} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where Z_x is the characteristic impedance at point x, and Z_0 is the characteristic impedance of the line at the point $x = 0$. (K_0 constant of equation determines cutoff frequency f_c by $f_c^2 = K_0^2/L_0C_0$). Fig. 1 is a graphic presentation of a coaxial exponential line.

Since both inner and outer diameter of such a line must be varied, it would be mechanically difficult to connect such a line to two coaxial sections of equal diameter. However, by making a sleeve whose inner conductor diameter varies logarithmically starting with a characteristic impedance of Z_0 and ending with that of R_2, it is possible to achieve a very broad band matching network. Such a sleeve is shown in Fig. 2D, and this section is usually referred to as a tapered line.

The reflection introduced by a tapered line is given by:

$$\frac{V_2}{V_1} = \frac{\lambda(.434)\log_{10}}{j\,8\,\pi\,x}\,\frac{R_2}{Z_0}\left(1 - e^{-\frac{4\pi j x}{\lambda}}\right) \quad . \quad . \quad . \quad . \quad (10)$$

The variation of reflection with length of taper as calculated by this formula is illustrated in Fig. 3 for a taper from 46 ohms to 75 ohms.

Stub Transformers

Thus far we have considered matching two resistive impedances, assuming that no reactance exists. However, in many cases it may be simpler to choose a point along the line whose input impedance is equal to $Z_0 + jX$. Then by placing a reactance of equal magnitude to X, but opposite polarity at this point, the reactive component is tuned out and the input impedance becomes equal to Z_0. This is achieved through the use of stub transformers.

Shorted stub sections of line in shunt with the main transmission line, as shown in Fig. 6A, act as shunting reactances. Since this reactance varies in accordance with the following relation:

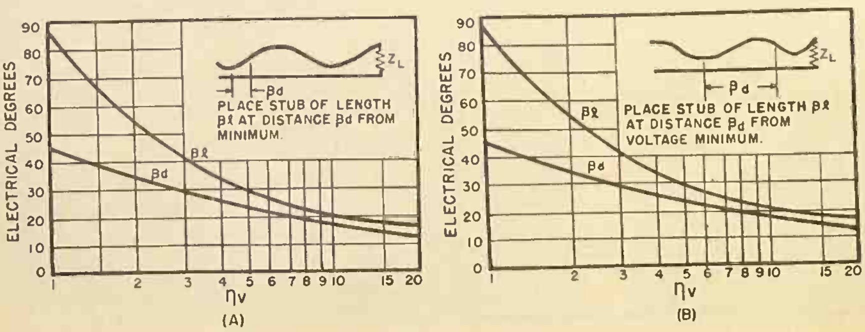
$$Z_{in} = j\,Z_0 \tan \beta l \quad . \quad . \quad . \quad . \quad . \quad (11)$$

The reactance may be either inductive or capacitive and have any value between zero and infinity (neglecting losses).

The points along the line whose input impedance has a resistive component equal to Z_0 can be determined from the *Smith* calculator (as described in previous article). For example, if the load Z_L were located at a point on the circle shown in Fig. 6B, the points corresponding to A and B represent a resistive component equal to Z_0. The stub for matching should be located at either A or B. If at point A, the input admittance of the stub should be capacitive and of magnitude X to balance out the inductive component of the input impedance of the line. Similarly, if the point B is chosen an inductive stub should be used.

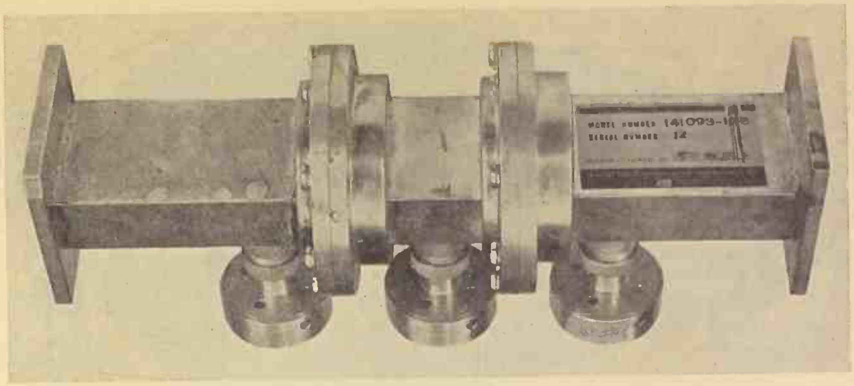
A correlation exists between standing-wave ratio, position of stub, and length of stub. Figs. 5A and B give the stub position and length in electrical degrees for any standing wave ratio η_v. As indicated on these curves,

Fig. 5. Impedance matching stub length (for distance Bd) for single stub transformer. (A) is for inductive and (B) a capacitive load.



should be measured from a minimum toward the load. The shorting bar in the stub can be made adjustable for fine tuning after stub is placed in position.

A transformer suitable for matching any two impedances can be constructed by placing three adjustable shorting stubs in shunt with the line, as shown in Fig. 4, spaced a quarter-wave apart and ganging the first and third adjustable stubs. This transformer has only two adjustments which are varied by the trial-and-error method until a minimum standing-wave ratio is achieved.



Typical band-pass filter using wave guide elements.

Resonant Lines and Filters

It has been shown in the article "Microwave Techniques", that a quarter-wave shorted line is equivalent to a parallel resonant tuned circuit, while a quarter length open circuited line is equivalent to a series resonant circuit. Hence, it is seen that coaxial lines can be used as a tuned circuit or filter.

The expression derived in the first article assumed the existence of lossless lines. This is equivalent of considering a tuned circuit with no resistance. For many purposes it is possible to neglect the attenuation of the line; however, when designing a resonant line for use in an oscillator or filter, the losses in the line must be considered to obtain the actual impedance and bandwidth of the circuit.

The most convenient parameter to use for determining the bandwidth and impedance of resonant lines is the Q. The Q of any line is defined to be:

$$Q = 2\pi \frac{\text{Peak energy storage}}{\text{Energy dissipated per cycle}} \quad (12)$$

and in a coaxial line is:

$$Q = \frac{\omega\sqrt{LC}}{2\,\alpha_T} \quad (13)$$

where

$L = .46\, \mu_1 \log_{10} b/a \times 10^{-6}$ henries/meter

$C = \frac{.241\varepsilon_1}{\log_{10} b/a} \times 10^{-10}$ farad/ meter

α_T is line attenuation as given in previous article[2].

The parallel and series resonant impedances may be expressed in terms of Q by the following relationships:

$$Z = \frac{Z_0\,\beta l}{2\,Q} \text{(series)} \quad (14)$$

$$Z = \frac{2\,Z_0\,Q}{\beta l} \text{(parallel)} \quad (15)$$

Defining the bandwidth as $(\omega - \omega_0)$, with ω the angular frequency at which the input impedance is $\sqrt{2}$ times the series resonant impedance, and $1/\sqrt{2}$ of the parallel resonant frequency, the relation between bandwidth and Q is given by:

$$Q = \frac{\omega_0}{2(\omega - \omega_0)} = \frac{f_0}{2\,\Delta f} \quad (16)$$

In general, the Q of a line is increased by increasing either the size of the conductors or the spacing between conductors. Increasing the size of conductors decreases the skin effect, whereas increasing the spacing between conductors increases the inductance per unit length.

It can be shown that the attenuation constant of a coaxial line becomes a minimum when D/d is equal to 3.6. This corresponds to a characteristic impedance of 77 ohms. Since the factor $\omega\sqrt{LC}$ is independent of D and d, the maximum Q likewise occurs when D/d is 3.6. Fig. 7 plots the Q of air-dielectric copper coaxial lines as a function of frequency for various sizes of lines, all having the optimum value of $D/d = 3.6$.

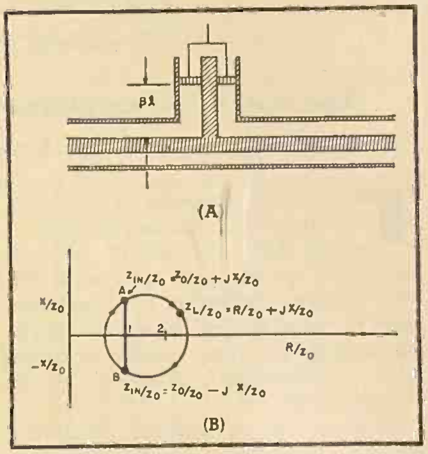
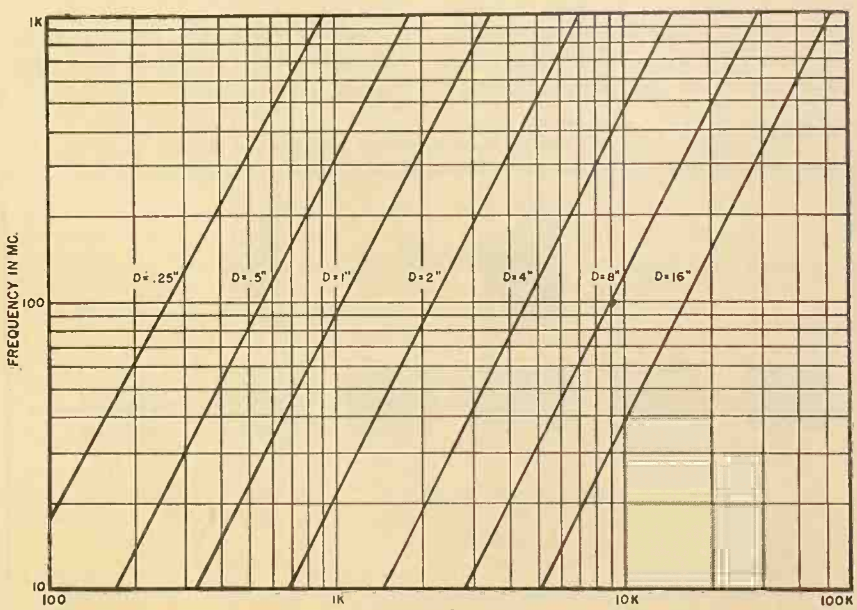


Fig. 6. (A) Single stub transformer. (B) Typical normalized impedance diagram showing location of points where resistance component is equal to Z_0.

Where a high degree of power must be handled by the coaxial resonant line, such as when it is used in a transmitter output stage, the dimensions of the line should also be selected on the basis of power handling capability. The theoretical power that can be handled by an air-dielectric line using the breakdown voltage as 15,000 v./cm. is equal to: (*Continued on page* 18)

Fig. 7. Q of copper coaxial lines with optimum D/d ratio of 3.6.



D.C. AMPLIFIER OF IMPROVED STABILITY

By
SAMUEL FREEDMAN

The d.c. to be amplified modulates an a.c. signal. This a.c. signal is then amplified and rectified.

THE MAIN purposes of this type of amplifier are to provide a more stable method of and an electronic system and apparatus for amplification, indication and measurement of direct current as well as slowly fluctuating d.c. not readily attained with conventional so-called direct current amplifiers.

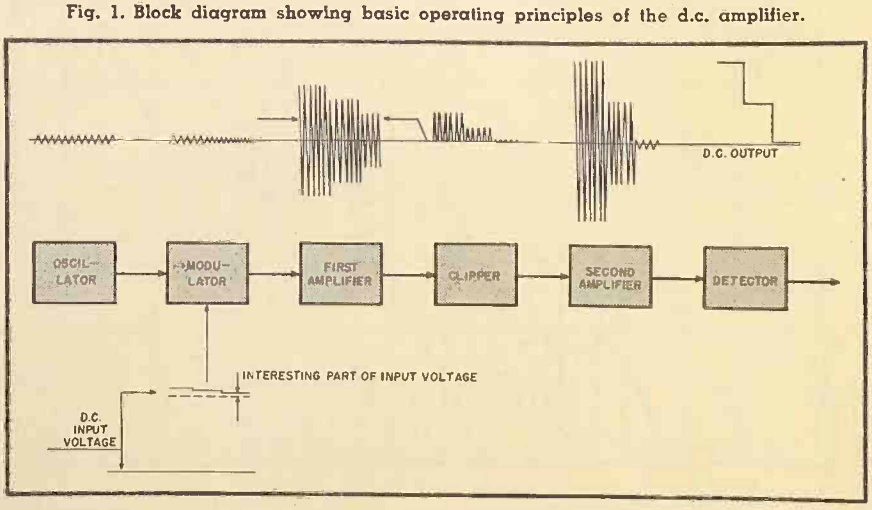
Ordinary direct current amplifiers depend upon direct coupling between the output of one vacuum tube stage and the input of the next stage, wherein the direct current or varying voltage under test is directly applied to the tubes. This often results in false and erratic indications due to the picking up of spurious currents and to small plate or filament voltage fluctuation occurring in the vacuum tube circuits themselves.

The d.c. amplifier described in this article is designed to have greater stability and dependability, as well as increased voltage amplification. It achieves this by incorporating certain conventional frequency techniques, such as the employment of the principles of intermediate frequency stages as used in radio receiving systems between the various amplifying sections. The amplification of direct current is obtained by generating an alternating current by means of a suitable oscillator and modulating this alternating current with the direct current where amplification is desired. The result is an amplitude modulated signal with the direct current as its envelope of modulation. This signal is then amplified by means of a suitable high gain alternating current amplifier, detected and translated.

Fig. 1 shows a block diagram of the major components of this amplifier. Fig. 2. shows a circuit diagram of the entire amplifier. A set of circuit values is indicated although the tuned circuits may be any value depending on the desired frequency of the oscillator.

Referring to the major block components in the sequence given in Fig. 1, operation can be described as follows:

Fig. 1. Block diagram showing basic operating principles of the d.c. amplifier.



Oscillator

The oscillator comprises a tube (V_1 Type 6SF5). The oscillation needs to be small but constant in amplitude. Any convenient frequency may be employed for interstage coupling by means of tuned circuits commonly used in i.f. or r.f. interstage coupling techniques. The amplitude stability is very important. In the figure, the circuit of the oscillator coil T_1 is a tuned grid circuit with a coupling coil to provide the necessary feedback in the plate circuit. The oscillator can, if desired, be any other convenient type of oscillating circuit. A proper amount of negative feedback is injected in the cathode by the 1000 ohm resistor. This negative feedback tends to keep the amplitude of the oscillation small and to increase the amplitude stability. "OSCILLATOR CONTROL" potentiometer in the plate circuit provides means of adjusting the amplitude of the output without affecting the stability of the oscillator. Switch B provides means to switch the coupling circuit on and off without changing the previous adjustments. The coupling circuit as shown in the figure is of the double-tuned type marked T_2. The coupling should be loose enough so as to prevent the small load changes due to adjustments in the following circuits from affecting the amplitude of the oscillations. The tuned circuits are the usual i.f. circuits tuned, trimmed, coupled and shielded as currently used in i.f. techniques. The filter section comprising a .05 μfd. condenser and 3000 ohm resistor in the plate circuit helps in keeping constant the amplitude of the oscillation.

Modulator

The modulator consists in Fig. 2 of a type 6SK7 tube (V_2) which has a remote cutoff characteristic that makes it possible to have the variations of output amplitude proportional to the variations of grid bias. This happens where the characteristic curve follows closely enough the square law (i.e. where the current is proportional to the square of the signal voltage). The average value of the grid bias should therefore be kept around that point. This means that the adjustment of the modulator must be always kept at the point of best linearity. This may not be the same as the point corresponding to the desired amplification of the small voltage fluctuations. This is possible by means of the "AMPLIFIER CONTROL" potentiometer which covers all values of d.c. input signals from 0 to 100 volts. A 2 meg. resistor in the input circuit provides a d.c. connection for the grid during the preliminary adjustments when no signal is present at the input terminals. The 10k resistor in the plate circuit in connection with the meter and Switch A in position #1 makes it possible to adjust the "AMPLIFIER CONTROL" until the operating point falls in the square law portion of the characteristic curve. In this particular circuit version, the meter is set to 50 which will show that the right current corresponding to the proper bias is flowing through the tube. Tube V_2 in addition to serving as modulator is also the first amplifier indicated in Fig. 1 by virtue of being connected to tuned circuit T_3.

Voltage Regulating Section

In this circuit version, two voltage regulating tubes of the VR105 type (V_3 and V_6) provide good regulation of the cathode voltage across the "AMPLIFIER CONTROL" potentiometer, as well as good regulation of the screen voltage of V_2. The 4000 ohm resistor in series with the tubes up to the B supply is the ballast resistor. This voltage regulating section is also connected with the following stage to provide a similar control of the cathode and screen voltages of the clipper tube V_4 (type 6SJ7).

Clipper

Since the best operating point of the modulator with respect to linearity does not correspond to the best operating point with respect to the gain of small fluctuations, a clipper tube is used to eliminate everything except the abnormal amplitude fluctuations that represent the desired signal. The use of a sharp cutoff pentode (6SJ7) V_4 provides a sharp clipping of the input oscillation if the grid bias is beyond cutoff. In this case only a part of the positive peak of each oscillation draws current to the plate. The tuned plate circuit T_4 functions as a class C amplifier thereby making V_4 also function as the second amplifier as shown in block diagram (Fig. 1). The grid bias is adjusted by means of the "CLIPPING CONTROL" potentiometer. The 10k ohm resistor in the plate circuit in connection with the meter and the switch A in position #2 helps in finding out the proper bias. In the circuit version shown it will be about 10 volts although the optimum value is determined by experimentation.

Detector

An ordinary biased detector using a pentode of the 6SJ7 type (V_5) may be used to reproduce the amplified d.c. signal on the meter when switch A is connected in position #3. "DETECTOR CONTROL" potentiometer is used to have zero current with zero signal. This is indicated on the meter when switch A is in the "READING" or #3 position. In the event greater sensitivity is desired, the meter may be arranged in a bridge circuit or in connection with other suitable modifications thereof, since a bridge circuit is more sensitive than a simple meter arrangement.

Alignment

Referring to Fig. 2, the unit may be aligned by adhering to the following sequence of instructions:

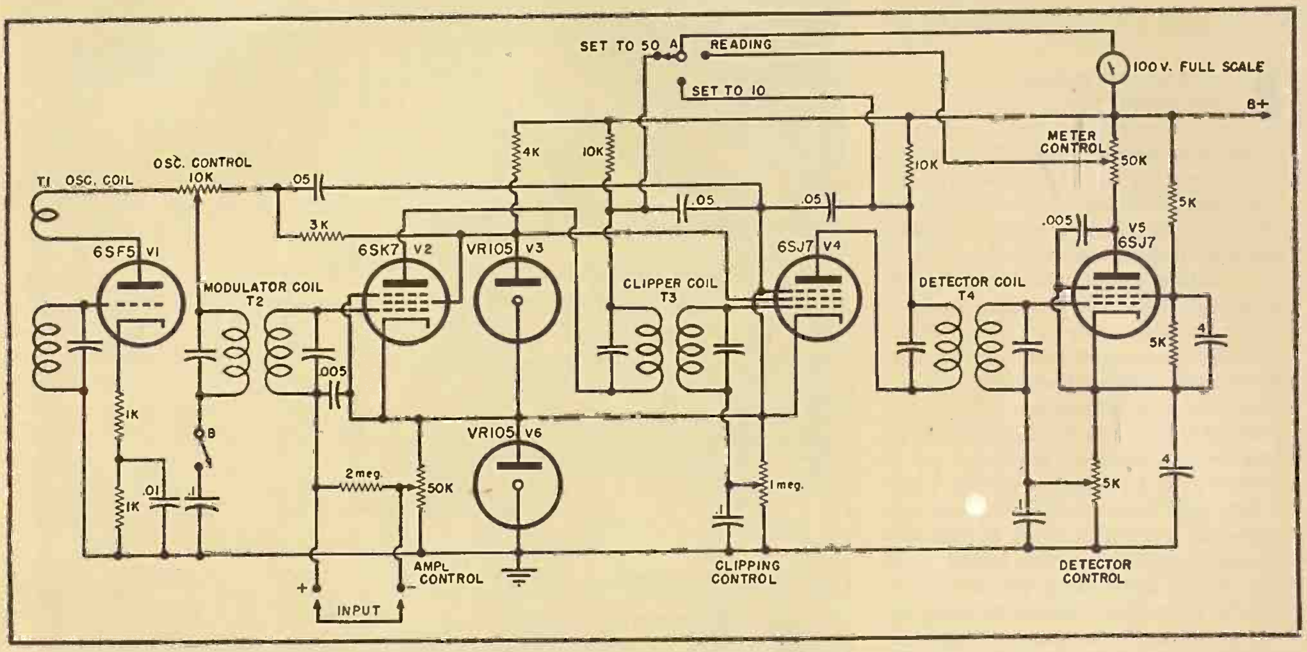


Fig. 2. Complete circuit diagram for the d.c. amplifier, including some component values.

1. Throw switch A in the "set to 50" position # 1 (to the left in Fig. 2).
2. Throw switch B "on".
3. Turn potentiometer "OSCILLATOR CONTROL" P1 all the way to the right and then bring slightly back.
4. Adjust "AMPLIFIER CONTROL" potentiometer to read 50 on the meter.
5. Throw switch B to the "off" position.
6. Throw switch A in the "set to 10" position #2.
7. Adjust "CLIPPING CONTROL" potentiometer to read ZERO. The adjustment should not be allowed to go below zero. It should be stopped when the meter reaches zero.
8. Throw switch B in the "on" position.
9. Adjust potentiometer "OSC. CONTROL" to read 10.
10. Throw switch A in the "READING" position #3.

(*Continued on page* 31)

Forced Air Cooling for ELECTRONIC EQUIPMENT

Basic principles and practical methods for the correct design of air cooling systems.

By B. E. PARKER
Engineering Head, FM dept., Gates Radio Co.

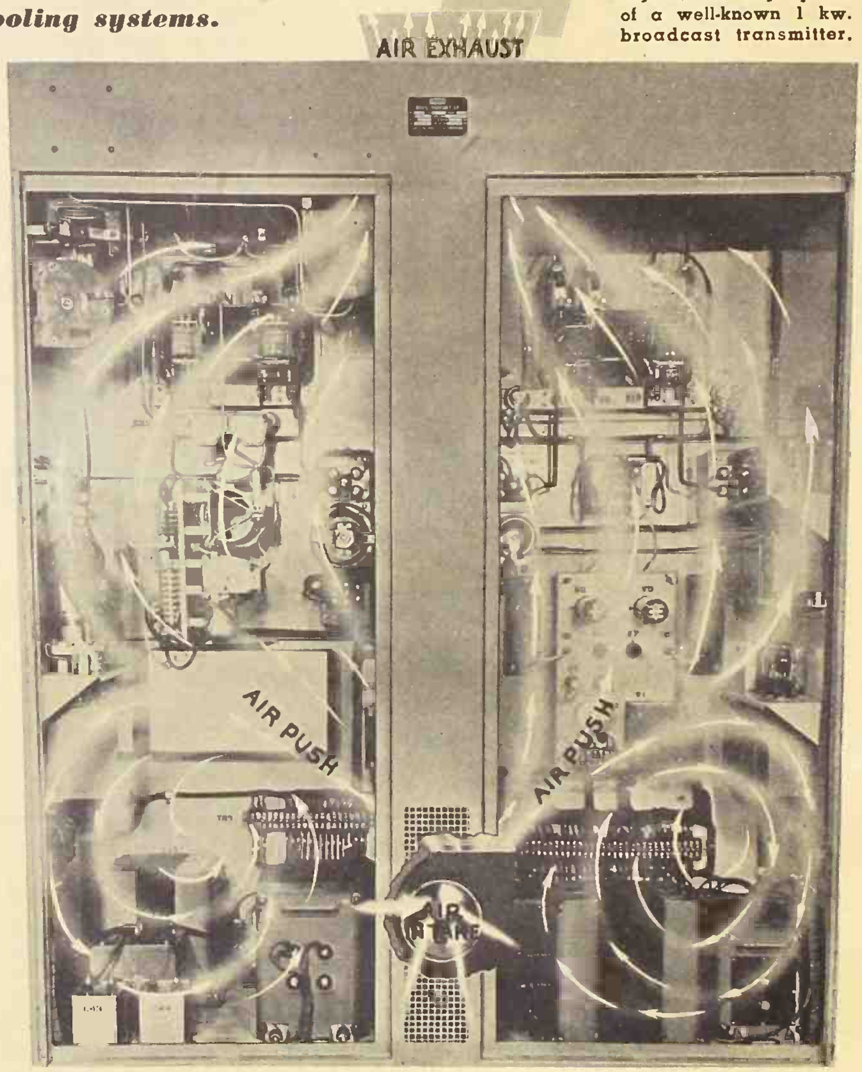


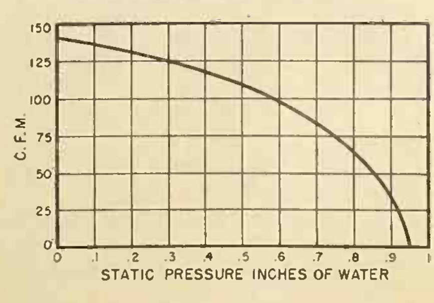
Fig. 1. Cooling system of a well-known 1 kw. broadcast transmitter.

THE primary purpose of any air-cooling system is either to remove heat or to prevent heat concentration at some specific point. This may be done by making use of natural thermal circulation or by forced air. Amplifiers and small transmitters are usually cooled by the natural thermal circulation resulting from the draft created by the rising of the hot air. Louvres and ventilator holes at the bottom and top of the enclosure permit the air to circulate through the cabinet, over the hot components and thence out. This is satisfactory only where the amount of heat dissipated is relatively small.

Where a large amount of heat must be removed, some form of forced air circulation is used. Fig. 1 is an example of an efficient system of the forced draft type. In this particular system turbulence is purposely created in order to flush all parts of the cabinet. This system is most effective when the heat radiating components (mostly plate and filament dissipation of the various tubes) are well separated. It has the advantage of removing relatively large amounts of air at comparatively low velocity, which produces little noise. In this particular example the cabinet tends to serve as a quieting chamber, and a baffle plate at the top further serves in muffling the air noise.

In this, as in all air cooling systems, the hot air must be expelled from the cabinet and replaced with cool air, otherwise the heat will be merely distributed throughout the cabinet by the blower or fan.

Fig. 2. Performance curve of the Fasco model 50749 blower.



While a blower or fan placed at the air outlet would be equally as effective, the air noise level would be much higher and the effectiveness of the dust filter at the air intake would be largely defeated. When the blower is located at the air intake, the cabinet is pressurized, preventing entry of dust and dirt through the small cracks due to doors and other necessary openings.

The tube handbook or manual usually makes a specific recommendation for cooling the tube used. In general it is unwise to depart radically from these recommendations unless the tube manufacturer is consulted regarding the intended change. Tube data sheets are usually available from the manufacturer or supplier which give the amount of air, the pressure drop, and maximum seal temperature for the tube. Most companies have tube application engineers who will gladly supply the above information since all this is available from the tests made at the time of tube design.

Where the cooling required is merely

a blast of air directed at the seals, the cooling system is relatively simple as a blower giving the required c.f.m. (cubic feet per minute) is sufficient.

Fig. 4 shows a 1 kw. FM transmitter using a pair of 4-400A tubes in which the cooling system is somewhat complicated due to seal cooling at both the base and anode. The manufacturer's bulletin shows that 14 c.f.m. per tube passing through the base, up over the plate seal is required. This amount of air will result in a pressure drop of .25 inches water column when used with the recommended socket and air chimney assembly. Fig. 6 illustrates graphically this cooling system as developed in the *Eimac* laboratories especially for this series of internal anode tubes.

The pressurized lower chamber serves to equalize the pressure for both tubes and to muffle the blower noise to a negligible amount. The air passes up through holes in the base of each tube, across filament and grid seals, out through the side of the base flange, up between the pyrex chimney and the tube envelope, at which point it is deflected across the anode seal.

The blower used in the transmitter shown in Fig. 4 has air volume and pressure capabilities several times in excess of the recommended tube requirements. The extra air is used in flushing the upper chamber and quickly forcing the hot air out through the top of the cabinet. This was easily accomplished by placing "bleeder" holes in the deck between the chimney and the tube base.

The measured pressure at the bottom of the tubes was .625 inches water column. This represents a safety factor of 150% above the tube manufacturer's rating, which was found by later tests to be most conservative. In fact the air inlet to the blower was obstructed until the pressure dropped to .15 inches water column. This pressure resulted in an anode seal temperature of 150°C with grid and filament seals 10 to 20 degrees cooler. The blower used has the performance curve shown in Fig. 2. From the curve it will be seen that with a pressure of .625 inches the blower will deliver 90 c.f.m. of air.

With the widespread use of external anode tubes, a pressurized system providing a steady stream through the anode fins has become popular in FM, television, and high power broadcast transmitters. Fig. 5 is a typical example of this type of cooling used in a recently announced 5 kw. broadcast transmitter.

Three *Eimac* type 3X2500F3 triodes are employed. Two tubes serve as the class B modulator, shown on the right. One tube, extreme left, is used as the modulated Class C r.f. power amplifier. The blank socket to the right of it is used for an additional r.f. tube to increase the power output to 10 kw. when desired by the station operator.

The tube manufacturer's bulletin specifies an airflow of 120 c.f.m. through the anode cooler. This will result in a pressure drop of 1.6 inches water column. In addition a minimum of 3 c.f.m. must be directed toward the filament stem structure, between the inner and outer filament conductors. Referring to Fig. 5 it will be seen how this is accomplished with a single blower cooling all three anodes as well as the filament seals. By means of a large blower in the lower right hand corner, just out of sight, the air is conducted by the heavy canvas duct up to the pressurized chamber which serves as the deck. The air is distributed by this chamber to the bottoms of the ceramic bowls which support the anode socket connections. The air passes up through the cooling fins of the tubes and on out through the top of the cabinet expelling the heated air. For 5 kw. operation, the unused tube socket is blocked off to prevent the escape of air and a consequent loss of air pressure.

Air for the filament seal requirements is provided by half inch tubing serving as air ducts. Referring to Fig. 5 it will be seen that these ducts extend up from the pressurized chamber and terminate in nozzles which force the air down into

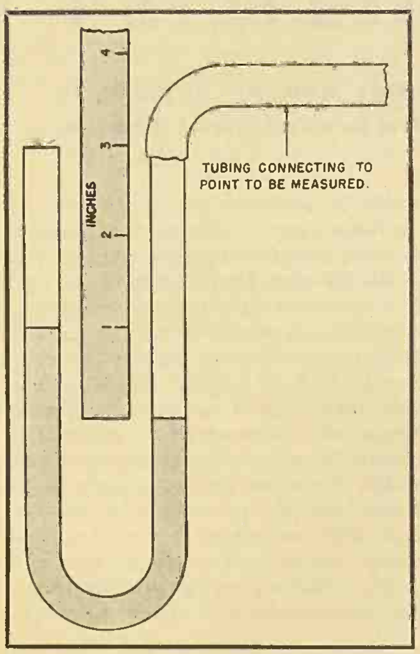


Fig. 3. Simple manometer construction.

the space between the inner and outer filament conductors.

Final measurements showed a pressure of 1.7 inches water column at the base of the tubes. In actuality, this was adjusted to this pressure value by bleeding off considerable air from one end of the pressurized chamber for flushing an adjacent cabinet. Temperature of the tube seals and anode coolers was

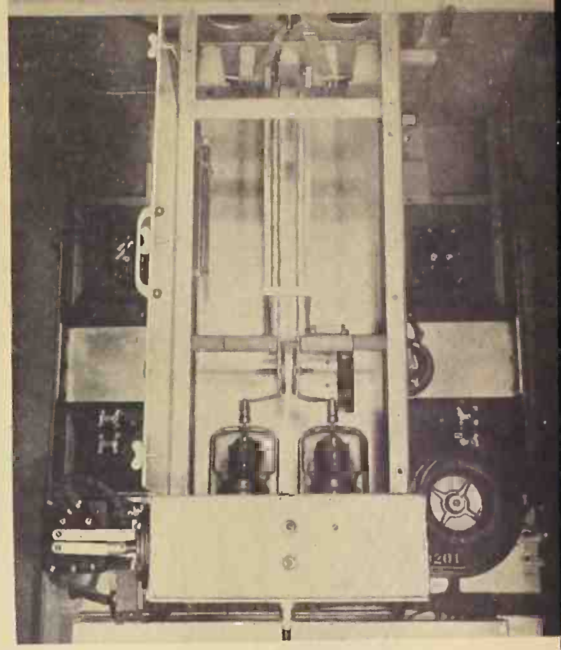


Fig. 4. Typical air cooling system used with internal anode tubes.

well under 150°C for continuous operation at full output.

The blower used for this system has a certified rating of 1.75 inches pressure at 800 c.f.m. This provides better than 400 c.f.m. for other purposes.

The selection of the blower depends largely on two factors, the air volume required in cubic feet per minute, and the air pressure at which it must work. Fig. 2 is the performance curve of a *Fasco* model 50749 blower. It is plotted as air volume in c.f.m. against air pressure in inches water column. Working into a static pressure of .625 inches, it will deliver a guaranteed volume of 90 c.f.m. This is the operating point for the blower used in the *Gates* 1 kw. FM transmitter shown in Fig. 4. If this blower is used in some other application where the pressure is only .3 inches, it will deliver 125 c.f.m.; or should it be allowed to exhaust in free space, the air

(*Continued on page* 27)

Fig. 5. Cooling system of 5 kw. transmitter using external anode tubes.

By WALTER V. TYMINSKI
Spencer-Kennedy Laboratories, Inc.

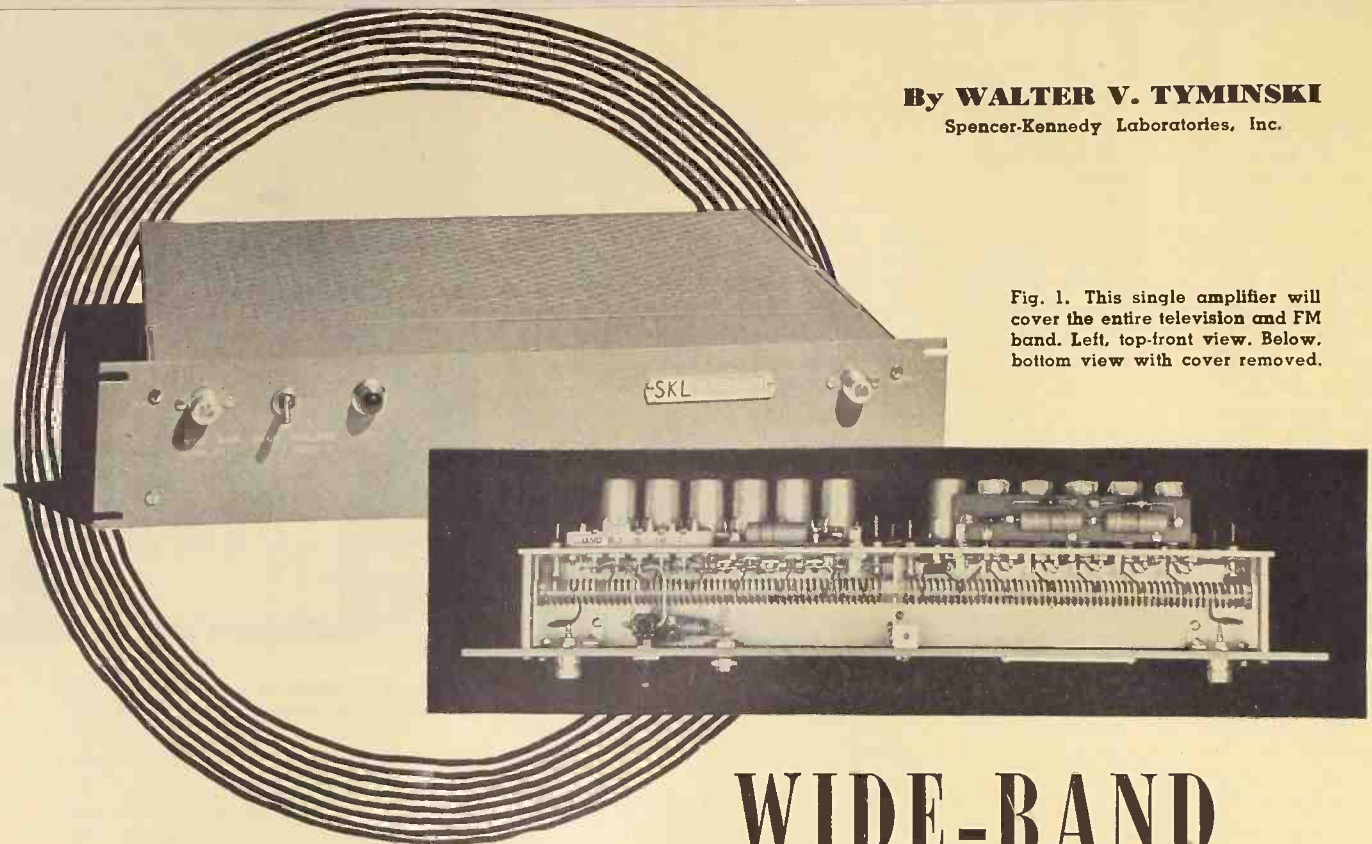


Fig. 1. This single amplifier will cover the entire television and FM band. Left, top-front view. Below, bottom view with cover removed.

WIDE-BAND CHAIN AMPLIFIER FOR TV

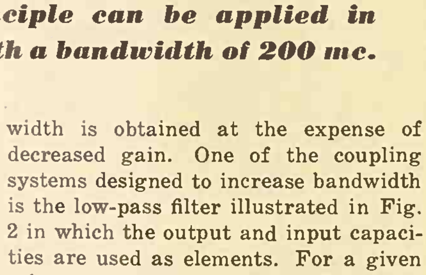
The chain amplifier principle can be applied in producing an amplifier with a bandwidth of 200 mc.

In many applications it is necessary to amplify a television signal before the picture quality is acceptable. Using conventional amplifier design a booster amplifier can be built to cover the bandwidth of an individual channel and a switching arrangement can be provided to cover the television spectrum. This solution is considered satisfactory by most individual users even though there is an additional control to manipulate. But many other uses require that the booster be placed at a remote position, such as directly at the antenna, and this necessitates the use of a non-tunable system. Individual channel amplifiers can be used with a means of combining the outputs into a common transmission line, but in some metropolitan areas where as many as seven television amplifiers and an additional one for FM would be needed, this method becomes complex and expensive. Another solution is the use of one amplifier to cover the entire television and FM band, and such an amplifier will be described in this paper. (See Fig. 1).

Experience with conventional amplifiers has shown that increased bandwidth is obtained at the expense of decreased gain. One of the coupling systems designed to increase bandwidth is the low-pass filter illustrated in Fig. 2 in which the output and input capacities are used as elements. For a given tube, the gain can be increased by raising the value of the line impedance, but this results in a smaller bandwidth. Conversely, decreasing the plate load reduces the gain, but increases the bandwidth. There is a theoretical gain-bandwidth product which cannot be exceeded no matter how complex a coupling system is devised for cascading stages.

The solution is to increase the transconductance without increasing the tube capacities. In conventional tubes this is difficult because once the cathode emission has been made as large as practical, further increases in transconductance are usually obtained by placing the grid closer to the cathode. But this smaller physical separation results in a higher value of input capacitance. Placing tubes in parallel does not help because while the transconductance is doubled the input and output capacities are also doubled. One solution is the use of a new type of tube construction such as a secondary emission type tube, but these tubes are still relatively expensive and a method of using conventional tubes is to be preferred. Percival, in his British patent, suggested that more than one tube be used per stage with the tube capacities arranged in filter sections as shown in Fig. 3. This effectively adds the transconductance without increasing the tube capacities.

Fig. 2. Filter type coupling using tube input and output capacities.



An analogy can be drawn between the filter containing the input capacities and a regular transmission line. When a wave enters the input terminals (AA of Fig. 3) it travels down the line and excites each grid in turn. Since the line is terminated in its characteristic impedance the entire wave is absorbed in the termination and there is no reflection. The individual tube then amplifies its grid voltage and a plate current of G_mE_g is available at the plates, where E_g is the grid voltage. While it is convenient to consider the grid line from a voltage standpoint, a current analysis is preferable for the plate line. Each of the tubes can be considered a constant current generator which feeds a current to the junction of the output capacity and the two inductances. (Fig. 6). A portion of the current flows through the capacity to ground, but the remainder splits, half going toward each termination. If the plate and grid filters are designed to have the same cut-off frequency the phase shift per section will be the same in both lines. The portions of the currents moving toward the load will add in phase because the signal has traversed the same number of filter sections regardless of the path considered. Thus, the total current in the load is n times the contribution of each tube, where n is the number of tubes used. The currents moving toward the reverse termination (CC in Fig. 3) are not in phase because of the different number of sections encountered in the parallel paths, and no useful output is available at this point. But, to avoid reflections the output must be matched at both ends and thus the reverse termination cannot be omitted.

The gain per tube is $G_mZ_p/2$ and the gain per stage is $nG_mZ_p/2$ where n is the number of tubes in the stage. In this type of amplifier there is an additive effect and thus an individual tube can have a gain of less than unity while the combination of tubes have any desired gain. This feature makes the chain type of amplifier especially attractive. From the standpoint of economy the tubes should be arranged such that a "stage" or "chain" has a gain of e(2.72). For additional gain the stages should then be cascaded. The essential difference between chain amplifiers and the conventional amplifier is that in the former more than one tube is used per stage while in the latter, individual tubes are cascaded. Stagger-tuned amplifiers are not in reality distributed amplifiers in the sense that a number of different responses are multiplied, while in the chain amplifier each tube amplifies the entire bandwidth in the same manner and the individual responses are added in the load.

Design Parameters

There are a number of filter section arrangements that can be used but the low-pass constant k type filter was chosen because of the simplicity of construction and the rising gain that is obtained with increasing frequency. In television applications the transmission lines and associated system usually have a rising loss characteristic with frequency and the amplifier compensates in part for this loss to make the over-all response flatter. The theoretical gain of this arrangement is:

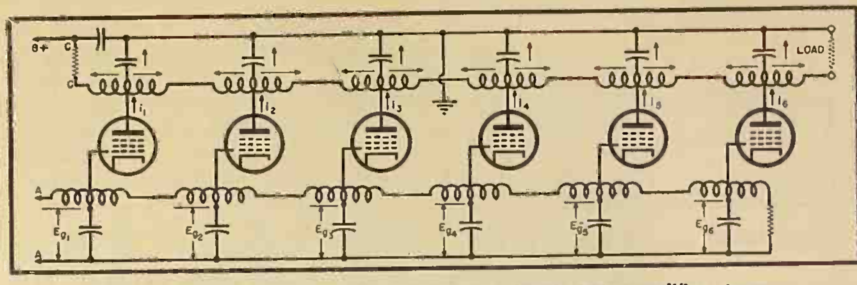


Fig. 3. Schematic diagram of a typical wide band chain amplifier stage.

$$\frac{nG_mR_p}{2\sqrt{1-x^2}} \quad \ldots \ldots \quad (1)$$

where n = no. of tubes

G_m = tube transconductance

$R_p = \sqrt{L_p/C_p}$

L_p = inductance element of plate line filter

C_p = capacitance element of plate line filter

$x = f/f_c$

f = actual frequency

f_c = cut-off freq. of filter

This function is plotted in Fig. 4. But in practice, it will be found that the gain will not rise as much as shown. The resistive component of the input impedance of a tube decreases with frequency and the loading produced on the line decreases the over-all gain. Other effects that reduce the gain in practice are such things as skin effect, transit time, and lead inductance.

The design equations for a low-pass constant k filter are shown in Fig. 7. A study of these equations shows that the greatest bandwidth and gain can be obtained by making the capacitance as small as possible. In the grid line the lowest value of capacitance possible is the combination of the input capacity together with the associated strays. It can be used directly as a filter element. A choice of the cut-off frequency determines the value of the inductance and thus the characteristic resistance of the line. Previously it was mentioned that plate and grid lines must have the same cut-off frequency but not necessarily the same characteristic impedance. But when amplifier stages are cascaded it is more convenient to have the same value of impedance for each line. The plate line should then have the same value of inductance and capacitance as the grid line. Since the output capacity of pentodes is lower than the input capacity a padding capacitor must be added in the plate line whose value is the difference between the tube input and output capacity.

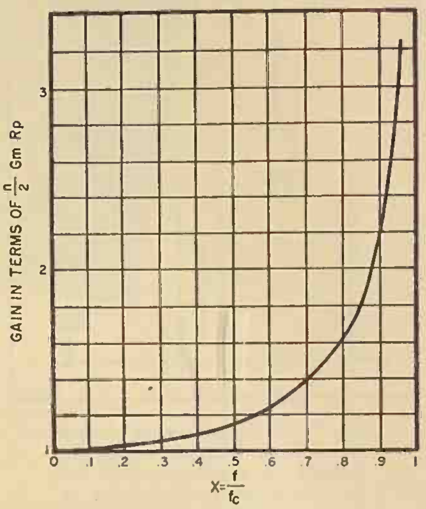
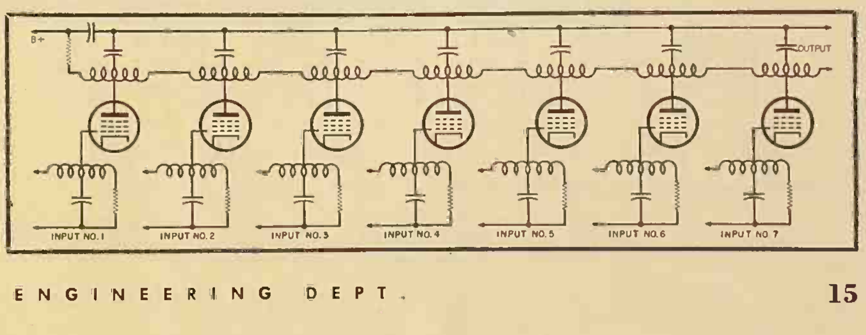


Fig. 4. Plot of theoretical gain frequency response of chain amplifier using constant K low pass filter sections.

Filter theory requires that the load be matched to the line so that there are no reflected signals from the terminations. The necessary value of impedance is determined from an analysis of a single section terminated in Z_c, with the input impedance also being equal to Z_c. For the filter section used in this amplifier the value of impedance is $Z_c = R_c\sqrt{1-x^2}$. This impedance is purely resistive in the pass band, starting out at $Z_c = R$ for zero frequency and decreasing to zero at cut-off. In the stop band the impedance is a pure inductive reactance which increases with

Fig. 5. Combining several inputs into common output for use as an antenna coupler.



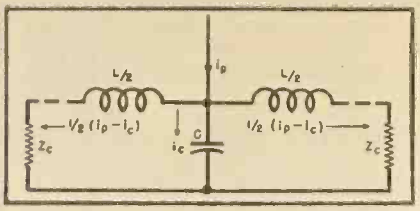


Fig. 6. Method of plate current division.

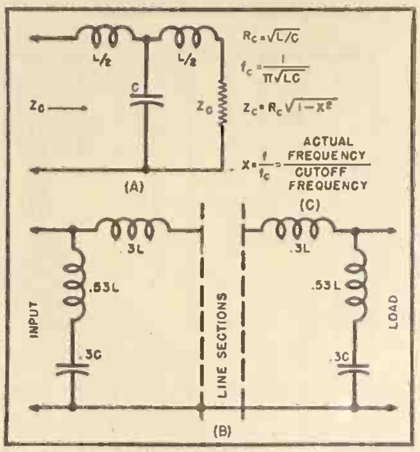


Fig. 7. (A) Typical series section filter. (B) M derived terminating sections to match constant resistance generator and load to the filter. (C) Design equations for the end and intermediate sections.

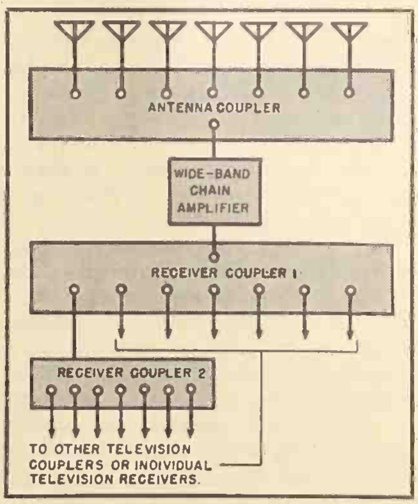


Fig. 8. Multiple television installation with as many receiver couplers and multipliers as necessary in the particular installation.

frequency. Since the impedance is not constant with frequency a constant resistance is not a good match, and if used, will result in reflected signals the magnitude of which will rise with frequency. This reflection in the grid line would cause a portion of the current propagated towards the load to be reflected. The effect of mismatches is to cause a standing wave in the gain frequency response of the amplifier. Thus the line termination must be made to look like a falling resistance with frequency. This can be done by using conventional half section filters as shown in Fig. 7 together with the design equations. The input, which is usually applied to a generator of constant impedance with frequency, is matched to the line in the same way.

An amplifier using the principles described was constructed and is shown in Fig. 1. The cut-off frequency is 250 mc., and a line impedance of 180 ohms was used so as to obtain a nominal voltage gain of 9 db. for a stage using six tubes. In the model shown, two stages were cascaded so as to provide a total gain of 18 db. Since 180 ohms is not a common television impedance, transformers were provided to bring the input and output of the amplifier to an impedance level of 72 ohms. Since the input transformer is used in the step-up position while the output transformer is used in the step-down position, with both transformers having the same turns ratio, the over-all gain of the transformers is unity. Almost any impedance can be obtained by the use of transformers and this is particularly simple in the case of unbalanced impedances because a simple autotransformer winding will suffice.

Uses

The wide-band chain amplifier has several advantages over conventional amplifiers, some of which are:

(1) One chain amplifier can amplify the twelve television channels, both old and new FM bands, the short wave frequencies, and even the broadcast band if desired. Using conventional amplifiers a large number of individual amplifiers would be needed to accomplish the same purpose.

(2) Tube failure in a chain amplifier is not fatal to the system, but merely results in a slightly reduced gain without appreciably affecting the form of the gain frequency response. In a conventional amplifier, tube failure means complete loss of the signal.

(3) The chain is extremely stable and will not drift appreciably even under wide temperature conditions.

(4) When individual channel amplifiers are used, amplification of a television signal through any of the other channel amplifiers will produce multiple images such as ghosts, because of the different time delays of the ampliers. This cannot happen in a chain amplifier.

(5) Unlike the chain amplifier, the use of several channel amplifiers increases the possibility of cross-modulation. Weak signals of other stations may produce an objectionable amount of cross-modulation in the output of the individual amplifier and the picture quality is impaired.

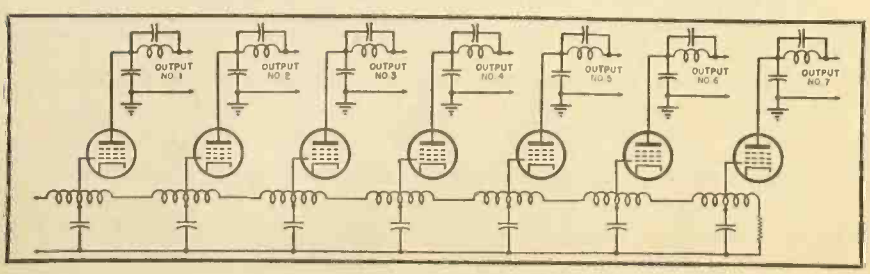
An amplifier of the wide-band type finds extensive applications in radar, oscillography, nuclear physics, television testing and distribution systems, and general laboratory measurements. Pulses, transients and low-level antenna signals can be amplified to useful levels by cascading several stages. The sensitivity of vacuum tube voltmeters and oscilloscopes can be made greater by the amount of gain provided in the amplifier. The output voltage of wide-band oscillators, signal, sweep and pulse generators can be increased with a convenience and stability no tuned amplifier can provide.

In many television installations it is found that a simple antenna system consisting of a separate low and high band antenna connected by a divider network is satisfactory. In these applications the amplifier can be inserted in the single transmission line. Other installations require a more elaborate antenna system and in the ideal case an individual channel antenna would be provided. This antenna could be cut for the desired frequency and then oriented for best signal reception. When more than one antenna is used the outputs must be combined before being applied to the amplifier. The other alternative is to run an individual line from each antenna and then switch the receiver input to the desired antenna. If amplification is desired the amplifier can be placed between the switch and the receiver. But this system requires a large amount of cable plus the nuisance of another control. Thus, the more convenient arrangement would be to combine the antenna outputs and run only one transmission line to the receiver.

There are a number of methods of

(*Continued on page* 29)

Fig. 9. Plate line altered to provide a number of outputs from a single input.



Do you have This Helpful Helipot *and* Duodial *Catalog?*

Do you have complete data on the revolutionary new *HELIPOT*—the helical potentiometer-rheostat that provides many times greater control accuracy *at no increase in panel space?*... or on the equally unique *DUODIAL* that greatly simplifies turns-indicating applications? If you are designing or manufacturing any type of precision electronic equipment, you should have this helpful catalog in your reference files...

It Explains **—** the unique helical principle of the HELIPOT that compacts almost *four feet* of precision slide wire into a case only 1¾ *inches* in diameter—over *thirty*-one *feet* of precision slide wire into a case only 3⅓ *inches* in diameter!

It Details **—** the precision construction features found in the HELIPOT... the centerless ground and polished stainless steel shafts—the *double* bearings that maintain rigid shaft alignment—the positive sliding contact assembly—and many other unique features.

It Illustrates **—** describes and gives full dimensional and electrical data on the many types of HELIPOTS that are available... from 3 turn, 1½" diameter sizes to 40 turn, 3" diameter sizes... 5 ohms to 500,000 ohms... 3 watts to 20 watts. Also Dual and Drum Potentiometers.

It Describes **—** and illustrates the various special HELIPOT designs available—double shaft extensions, multiple assemblies, integral dual units, etc.

It Gives **—** full details on the DUODIAL—the new type turns-indicating dial that is ideal for use with the HELIPOT as well as with many other multiple-turn devices, both electrical and mechanical.

If you use precision electronic components in your equipment and do not have a copy of this helpful Helipot Bulletin in your files, write today for your free copy.

THE Helipot CORPORATION, 1011 MISSION ST. SOUTH PASADENA 4, CALIF.

ENGINEERING DEPT.

Microwave Comp.

(*Continued from page* 9)

$$P_{max} = 4.05 \times 10^5 d^2 \log_{10} D/d \quad . \quad . \quad (17)$$

In practice, it is necessary to limit maximum power to considerably less than maximum limit due to higher gradients at stub supports and terminating joints.

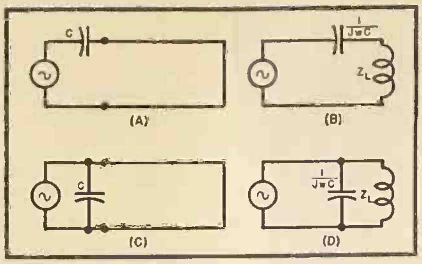


Fig. 8. Resonant lines (A) and (C) with capacitive inputs. Equivalent circuits are shown in (B) and (D).

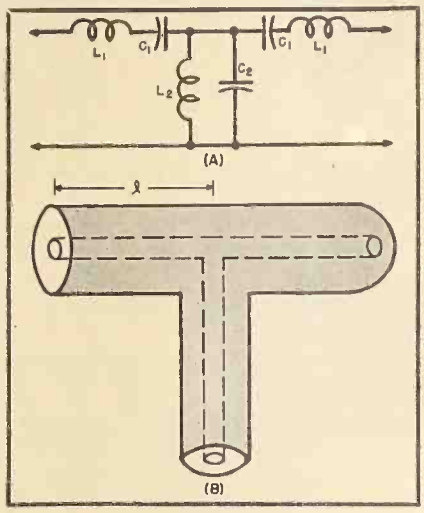


Fig. 9. (A) Coaxial line equivalent of simple "T" filter (B).

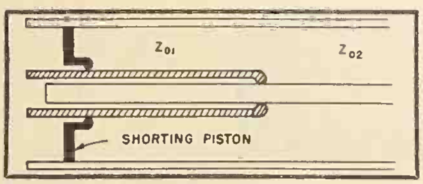


Fig. 10. Dual impedance line.

In many practical applications, the input to the line will have a capacitive reactance, as shown in Fig. 8, in which case the line must be foreshortened to cancel out this reactance. This is done by making the reactance of the line equal and opposite to that of the capacity, or:

$$\tan \beta l = -\frac{1}{Z_0 \omega_0 C} \text{(shorted)} \quad . \quad . \quad (18)$$

$$\tan \beta l = Z_0 \omega_0 C \text{ (open)} \quad . \quad . \quad . \quad . \quad (19)$$

Filter Networks Using Transmission-Line Elements

Resonant lines are used in a microwave system as narrow band filters. Many of the expressions that have been derived for tuned circuits at ordinary radio frequencies can be applied with equal accuracy to resonant lines at microwave frequencies. In fact, the general procedure in the design of any type of filter usually begins with determining the filter parameters on the basis of lumped constant elements in the conventional manner, and then calculating the coaxial line elements that will duplicate the filter configuration desired.

The simplest filter is, of course, the resonant line. The loss in such a line is given by the following expression:

$$\text{Db. loss} = 10 \log_{10} \frac{Q_u}{Q_u - Q_L} \quad . \quad . \quad (20)$$

where Q_u is the unloaded Q of the line and Q_L is the loaded Q.

Another simple filter is the band pass "*T*" filter shown in Fig. 9A. An equivalent coaxial line circuit is shown in Fig. 9B. The length, l, of the series arm is chosen so that the circuit will resonate at the frequency $f_0 = 1/2\pi\sqrt{L_1 C_1}$. The parameters of the line are chosen so that its equivalent inductance and capacitance at f_0 is equal to L_1 and C_1 respectively. The shunt arm is similarly designed to resonate at $f_0 = 1/2\pi\sqrt{L_2 C_2}$, and have equivalent inductance and capacitance to L_2 and C_2 at this frequency.

It should be noted that the off-resonance impedance of Fig. 9A is not exactly equal to that of Fig. 9B. The reason for this is that the impedance variation of a coaxial line is a tangential function, while that of a lumped constant element is linear. This difference, shown in Fig. 11A for an *LC* circuit, may or may not be important depending upon the individual application.

There are a number of methods that can be used to minimize this effect. Again the one used will be primarily a function of the results desired. For example, it is possible to minimize the impedance variation near the resonant frequency by using a dual impedance line such as the one shown in Fig. 10. The impedance variation of this line compared to that of a lumped constant circuit is shown in Fig. 11B.

Wave Guide Elements—Inductive and Capacitive Windows

If a wave guide contains a non-uniform discontinuity such as the step discontinuity of Fig. 12, a certain portion of the energy will be reflected and cause standing waves. Such a discontinuity corresponds to a reactance. Normally the discontinuities are made symmetrical to the parallel walls and are called windows. For a $TE_{1,0}$ mode, a window parallel to the "*b*" side of the guide[2] represents an inductance; a window parallel to the "*a*" side a capacity, as shown in Fig. 13.

A window is used in much the same manner as a stub in coaxial lines. In the article on "Microwave Transmission Lines", the method of matching a wave guide to any load was discussed, and as indicated in this article, normalized susceptance is the most convenient parameter to employ. The theoretical normalized susceptance of an inductive window is:

$$B = -\frac{\lambda_g}{a} \cot^2 \frac{\pi r}{2a} \quad . \quad . \quad . \quad . \quad . \quad (21)$$

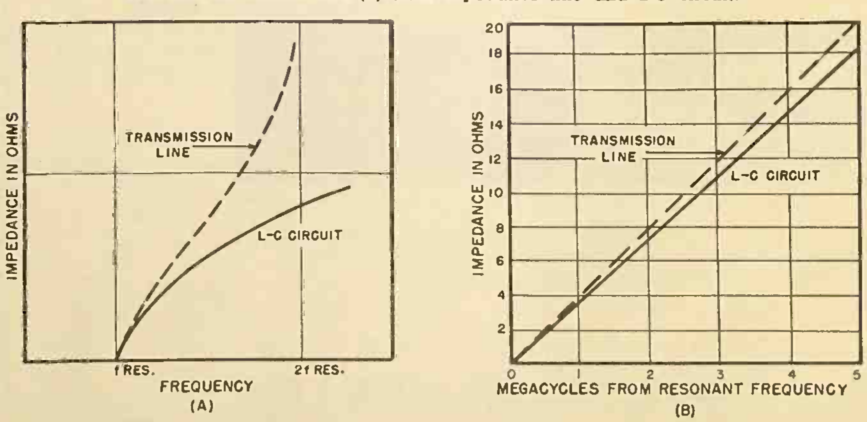
λ_g is the guide wavelength, and r the opening of the window. The actual susceptance obtained from a window is somewhat greater than the theoretical value. This is because of the finite thickness of the window which is not included in the simple theory and effectively increases the susceptance of the window.

The normalized susceptance of a capacitive window, assuming a window of zero thickness, is:

$$B_c = \frac{1.7\, b}{\lambda_g} \log_{10} \operatorname{cosec} \frac{\pi r}{2b} \quad . \quad . \quad (22)$$

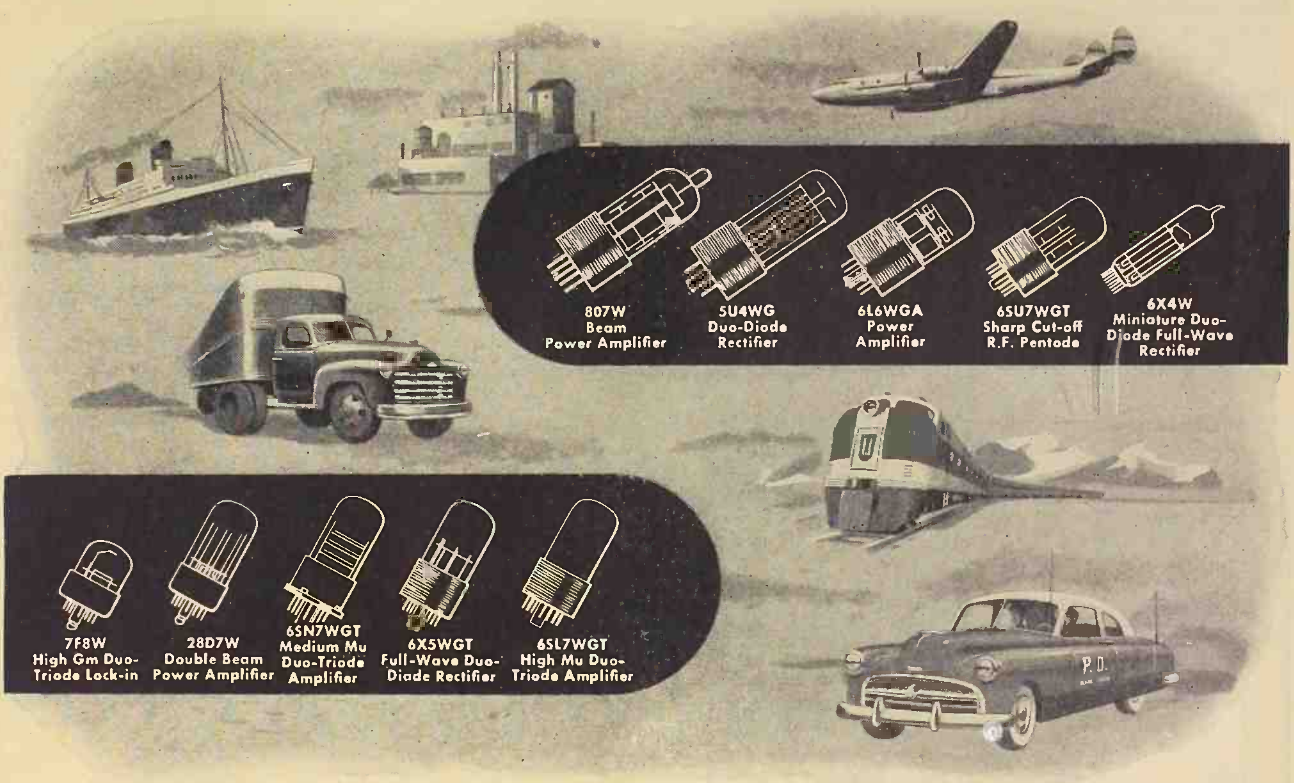
The thickness of the window has an appreciable effect in this case. An ex-

Fig. 11. Impedance vs. frequency for (A) single impedance resonant line and L-C circuit and (B) dual impedance line and L-C circuit.



10 Times More Rugged–

New Sylvania shock-tested tubes withstand shocks greater than 400 G's



Ideal for industrial radio applications... for aircraft...buses...trains...police cars... or wherever shock and vibration are problems

Troublesome problems of tube failure resulting from shock or heavy vibration are now being solved... for keeps... by these new Sylvania "Ruggedized" or "W" tubes.

Originally designed to government specifications to withstand shock and vibration caused by artillery action, these tubes keep operating under vibration up to 2-½ G's... withstand shocks more than 400 times the force of gravity.

A dozen new design techniques have gone into the perfection of these tubes. More than that, they are *precision*-built from precision parts. Exhaustive lab and field tests have definitely proved them as much as 10 times more rugged than ordinary tubes. Electrical characteristics are similar to those of standard types.

Note too, their reduced overall length and their straight glass bulbs... features which make possible smaller and more compact equipment design.

Maximum ratings and other characteristics of these new "Ruggedized" types are available from Sylvania Electric Products Inc., Dept. R2304, Emporium, Pa.

CHECK THESE 10 "RUGGEDIZED" FEATURES for longer life and better performance

1. Double thickness micas
2. Heavier side-rod supports
3. Shorter leads
4. Straight glass bulb
5. Flat, circular header
6. Fewer internal connectors
7. Shorter elements
8. Reduced overall height
9. Additional mount supports
10. Low-loss phenolic base

SYLVANIA ELECTRIC

RADIO TUBES; CATHODE RAY TUBES; ELECTRONIC DEVICES; FLUORESCENT LAMPS, FIXTURES, SIGN TUBING, WIRING DEVICES; LIGHT BULBS; PHOTOLAMPS

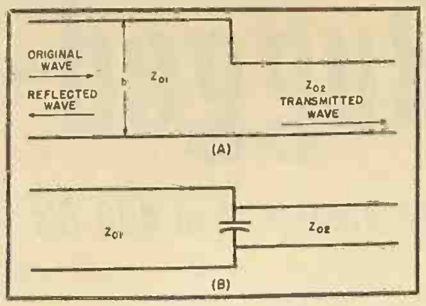


Fig. 12. (A) Wave guide with step discontinuity. (B) Equivalent circuit.

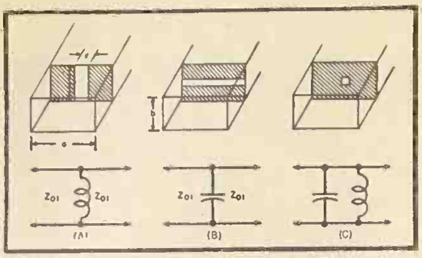


Fig. 13. Three types of wave guide windows and their equivalent circuits.

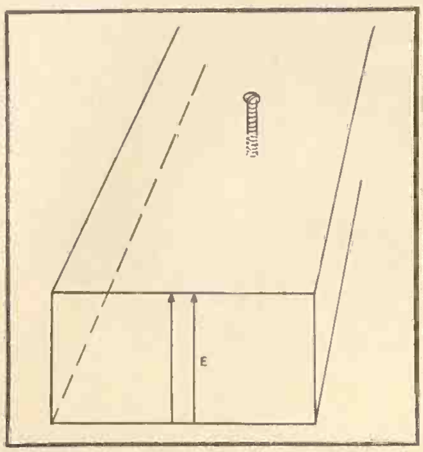


Fig. 14. Tuning screw in wave guide.

pression which provides results that are much closer to actual values is the following:

$$B = B_0 + \frac{2\pi w}{\lambda_g}\left(\frac{b}{r} - \frac{r}{b}\right) \quad . \quad . \quad (23)$$

where w is the window thickness, and B_0 the normalized susceptance for $w=0$.

The capacitive window is limited in application to low power systems because it greatly enhances the possibilities of breakdown.

Tuning Screws

A tuning screw is a cylindrical probe extending into the wave guide parallel to the electric field as shown in Fig. 14. The screw acts essentially as a shunting reactance in the guide. The magnitude of susceptance varies with depth into the guide. Short lengths of probe are equivalent to shunting capacities, the susceptance increasing with depth until a length of approximately a quarter-wave is reached in which case the resonance occurs and substantially all of the incident wave is reflected. For still greater lengths the screw becomes inductive. In most applications it is used in the capacitive region. The sharpness of resonance is a function of the diameter of the screw and higher Q's are found with smaller diameters. Typical measured susceptance of this screw as a function of r is shown in Fig. 16.

Three tuning screws separated from each other by one-quarter of a wavelength is a commonly used combination for broad tuning. To match a load to a line, the center screw and only one of the outer screws are varied.

Quarter-Wave Transformer

A quarter-wave transformer in a wave guide can be achieved by reducing the dimensions of the wave guide by a quarter-wave section whose dimensions are calculated from the following expression:

$$\frac{Z_{0T}}{Z_0} = \frac{b_T\, a\, \lambda_{gT}}{b\, a_T\, \lambda_g} \quad . \quad . \quad . \quad . \quad . \quad (24)$$

In addition to the change in characteristic impedance, a shunt susceptance is introduced at each junction, which may be calculated from Eqts. (23) and (22). These susceptances must then be tuned out by methods indicated previously.

A more practical method of achieving a quarter-wave transformer is through use of the asymmetrical capacitive transformer shown in Fig. 17. The input admittance seen at the generator side when the load end is matched is given by:

$$\frac{Y}{Y_0} \approx \left(\frac{b}{b_T}\right)^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (25)$$

This type of transformer has the advantage that it can be slipped into the guide, just as a sleeve, and adjusted for minimum standing-wave ratio by drilling a small hole in the center of the guide and positioning transformer with a dielectric rod.

Wave Guide Cavity Resonators

As in the case of the resonant coaxial line, it is possible to design a wave guide so that it will act as a tuned circuit, or resonate, at the desired frequency. Such a wave guide, which usually takes the form of an enclosed box, shown in Fig. 15A, is called a cavity. (Resonant coaxial lines are also sometimes referred to as cavities but usually a "cavity" implies an enclosed wave guide.)

Much of the material given for coaxial line resonators holds true for the guide cavity with the exception that all three dimensions of the guide must be properly designed to propagate the mode desired with maximum efficiency. The a and b dimensions are governed to a large degree by the same factors, i.e., cut-off frequency and attenuation for mode desired, that were described in the last article for transmission of energy. The z dimension determines the frequency of resonance. The expression for the resonant wavelength of a rectangular cavity is given by:

$$\lambda = \frac{2}{\sqrt{\left(\frac{l}{z}\right)^2 + \left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}} \qquad (26)$$

where l is the number of half wavelengths down the guide in "z" direction. For a $TE_{1,0,1}$ (last subscript representing half wavelengths in the z direction) $l = m = 1$, and $z = a$,

$$\lambda = \sqrt{2}\, a \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

The Q of a wave guide must be worked out individually for each type of mode used, starting with the definition given by Eqt. (12). In general, the Q will be proportional to:

$$Q \approx \frac{1}{\delta}\frac{V_{0L}}{S} \quad . \quad . \quad . \quad . \quad . \quad . \quad (28)$$

where V_{0L} is volume of guide and S is its surface, and δ is the r.f. resistance of guide conductor.

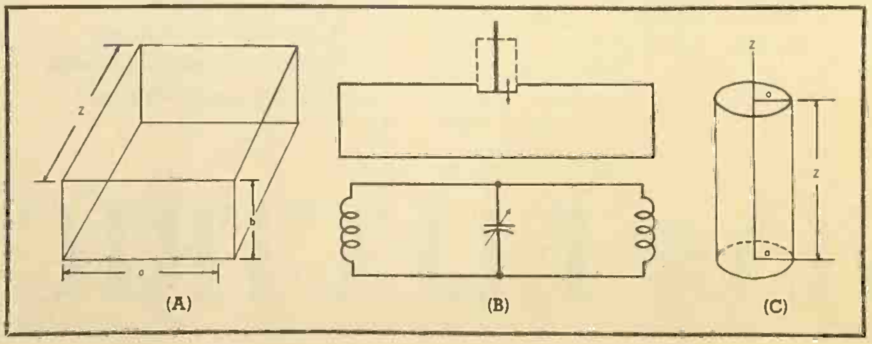
The Q of the cavity defined by equation (27) is:

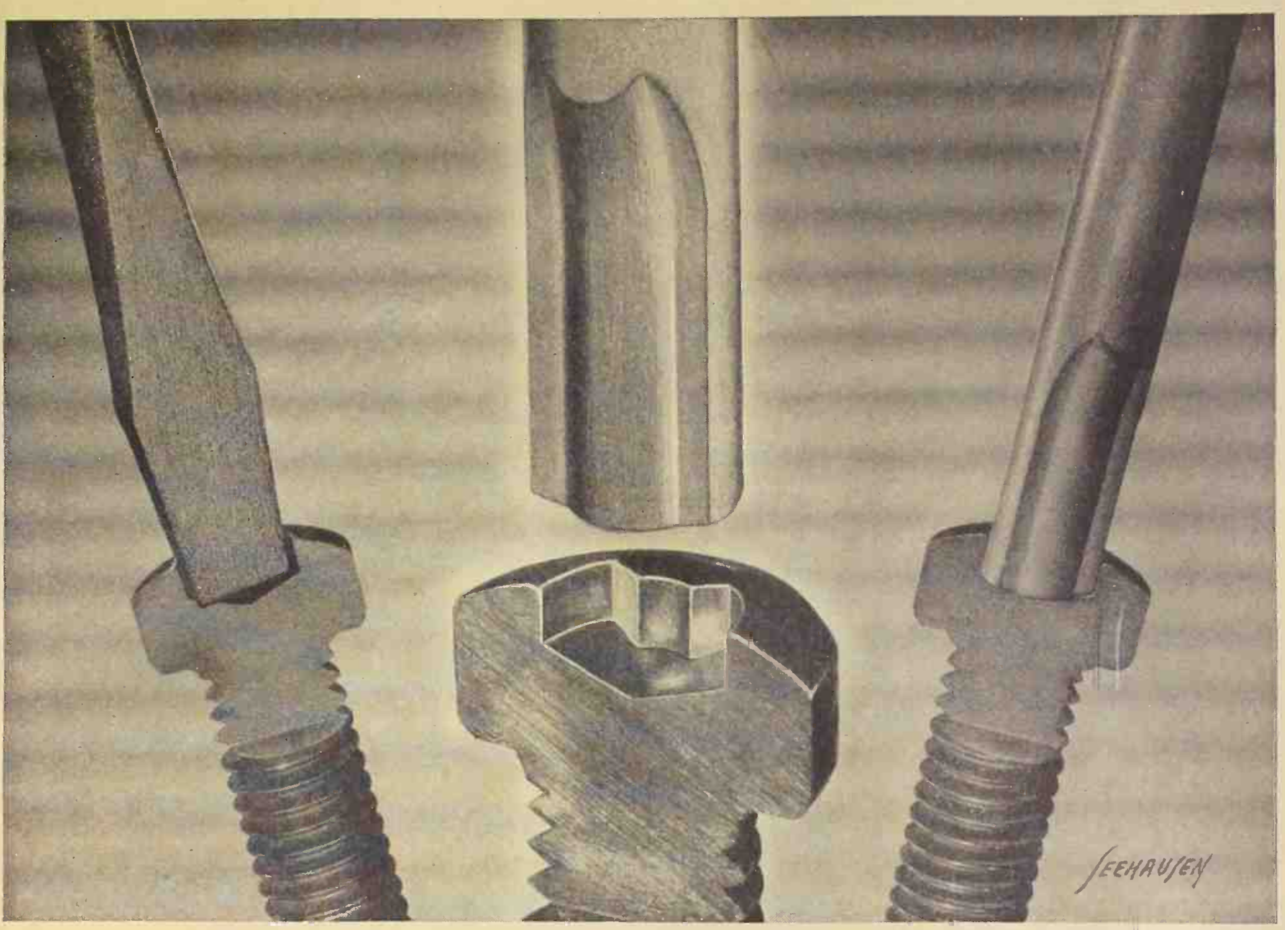
$$Q = .353\, \frac{\lambda}{\delta}\, \frac{1}{1 + \frac{a}{2b}} \quad . \quad . \quad . \quad (29$$

The shunt impedance of this cavity at resonance is given by:

(*Continued on page* 30)

Fig. 15. (A) Rectangular wave guide cavity. (B) Reentrant cavity and equivalent circuit. (C) Cylindrical wave guide cavity.





Here's How CLUTCH HEAD *Brings*

New Safety, New Speed in Line Assembly

Q. What is the main cause of driver skidding?	**A.** *"Ride-out" as set up by tapered driving.*
Q. How does CLUTCH HEAD overcome this "ride-out"?	**A.** *By elimination of the tapered recess.*
Q. How does the CLUTCH HEAD engagement differ?	**A.** *With straight sides of driver matching straight recess walls.*
Q. What safety benefit results from this engagement?	**A.** *No slippage, so no damage to operators or work.*
Q. Does this eliminate need for end pressure?	**A.** *Yes. No "ride-out" to combat; no end pressure; no skids.*
Q. Do CLUTCH HEAD users support this skid-free claim?	**A.** *Many. Norge says "Cabinet damage eliminated."*
Q. What of this feature as a fatigue factor?	**A.** *Effortless driving means more screws driven per day.*
Q. How does the Center Pivot Column add to safer driving?	**A.** *It prevents canting by guiding bit into dead-center entry.*
Q. Why is CLUTCH HEAD "America's Most Modern Screw"?	**A.** *Because it has features unmatched by any other screw.*

Q. What are these features?

A. *They include a recess engagement to match the ruggedness of the Type "A" Bit construction for driving up to 214,000 screws . . . non-stop; simple 60-second bit reconditioning; the Lock-On for easy one-handed driving, and basic design for common screwdriver operation.*

CLUTCH HEAD SCREWS

Q. And how may we check them?

A. *You may check all of these features by sending for package assortment of screws, sample Type "A" Bit, and illustrated Brochure. These will come to you by mail and will give you an understanding why CLUTCH HEAD users report 15% to 50% increases in assembly production.*

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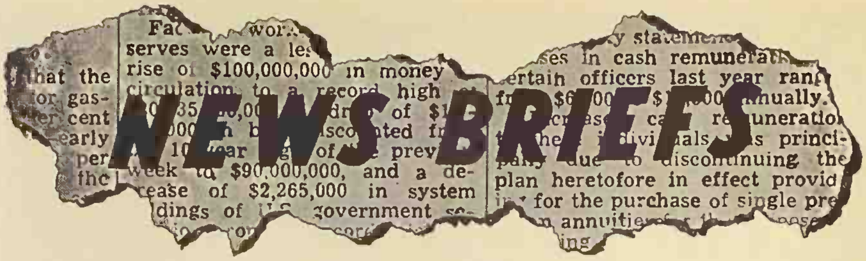
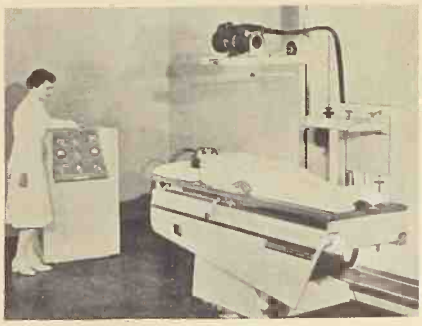


ELECTRONIC DEVELOPMENT

In a recent article on "Electrical and Allied Developments of 1949" published by *General Electric Company* was included the outstanding design of an x-



ray machine based on the building-block principle which will permit the physician's x-ray facilities to grow as his practice grows.

The complete unit shown actually consists of 15 subassemblies, which can be added to one another according to the scope of the physician's x-ray work and practice. The basic unit is composed of table top, table frame, legs, and Bucky diaphragm. When used with a mobile or portable type of x-ray tube-transformer assembly, it comprises the simplest unit for radiography. As his practice grows, the physician may add a special higher-powered tube and transformer, together with floor rail on which the tube can be moved alongside the table.

The same building-block system applies to fluoroscopy. The fluoroscopic carriage containing shutters and screen may be incorporated. Later a spot-film device for making radiographs of views as seen with the fluoroscope may be added.

LAUD ENGINEERING SCIENTISTS

In a recent address to the Machine Design Division of The American Society of Mechanical Engineers, Joseph B. Armitage, a director-at-large of the society and vice president of *Kearney & Trecker Corp.*, Milwaukee, Wisc., pointed out the tremendous advance in electronics during the war and its application to peacetime uses.

According to Mr. Armitage, although the great majority of our research men and scientists are still at work devising instruments of war, the relatively small portion of technical men available to apply the results of the engineering progress of the last ten years to peacetime uses have done a marvelous job.

EFFECT OF SHOCK ON ELECTRON TUBES

Members of the American Institute of Electrical Engineers learned at their recent Winter General Meeting of exhaustive scientific studies of electrical noise produced in electron tubes as a result of shock and vibration.

Lester Feinstein of the Product Development Laboratories, *Sylvania Electric Products Inc.*, Kew Gardens, New York, who revealed the study, said that structural causes of microphonism in electron tubes stem principally from rattle of elements, motion of the mount

as a unit and resonance of tube elements. Laboratory studies which he revealed were carried on for the development of new types of subminiature tubes.

Experimental procedures used in which methods and equipments have been developed to impart controlled motion to tubes and for measurement of electrical response were outlined. Included in methods which Mr. Feinstein reported were electromagnetic vibration tests run at either constant velocity or constant acceleration throughout a range between 25 and 10,000 cycles.

RADIO DISTURBANCE WARNINGS

The radio disturbance warning notices broadcast regularly from radio station WWV of the National Bureau of Standards are based on comprehensive observations of radio, ionospheric, solar, and geomagnetic phenomena at stations throughout the world.

Warnings are given in code following the time announcements at 19 and 49

minutes past each hour. A series of N's signifies that radio propagation conditions are normal, a series of U's that they are unstable, and a series of W's that they are disturbed or are expected to become so within 12 hours.

The direction of arrival of radio waves from transatlantic stations is measured with the instrument shown.

SYLVANIA ABSORBS COLONIAL

Sylvania Electric Products Inc., has absorbed its wholly-owned subsidiary, *Colonial Radio Corporation*, manufacturers of radio and television sets. The operations will be continued in Buffalo, New York, as the Colonial Radio and Television Division.

E. E. Lewis, formerly president of *Colonial*, has been elected vice-president of *Sylvania* in charge of the Colonial Radio and Television Division, and the personnel and policies will continue unchanged.

X-RAY MICROSCOPE

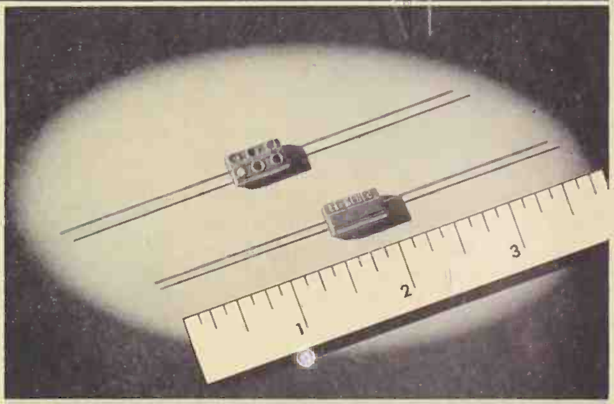
A microscope which makes it possible to examine directly minute details of internal structure in materials through

which light cannot pass has been announced by *General Electric's* Research Laboratory.

Miss Charlys M. Lucht, who developed the x-ray microscope in collaboration with other *GE* scientists, is shown

(*Continued on page* 30)

In capacitors performance depends on dielectric strength to withstand strain. Before *El-Menco* capacitors leave the factory they must pass severe tests for dielectric strength — at *double the working voltage*, insulation resistance and for capacity value. El-Menco fixed mica condensers meet and beat strict Army-Navy standards. That's why you can rely on El-Menco performance in *your* product.



CM 15 MINIATURE CAPACITOR

Actual Size 9/32" x 1/2" x 3/16". For Radio, Television and Other Electronic Applications.

2 to 420 mmf. capacity at 500v DCw.

2 to 525 mmf. capacity at 300v DCw.

Temp. Co-efficient ±50 parts per million per degree C for most capacity values.

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NEW PRODUCTS

AIR METER

Hastings Instrument Company of Hampton, Virginia has announced that its Model G Air-Meter is the first elec-

trical anemometer to be free of the effects of rate of change of temperature.

This instrument provides instantaneous, direct, accurate readings of air velocities from 5 to 6000 feet per minute with an expanded scale in the low velocity ranges, and is now available with built-in temperature compensation to prevent momentary error in velocity reading when the probe is subjected to sudden changes of temperature.

A group of practical accessories is available, including a carrying case with battery operated power pack for use when 110 volt a.c. power supply is not available. For those now using *Hastings* Air-Meters, special probes which compensate for rate of change of temperature are available.

ELECTRONIC RELAY

Servo-Tek Products Co., 4 Godwin Ave., Peterson 1, N. J., has developed an electronic relay system to provide

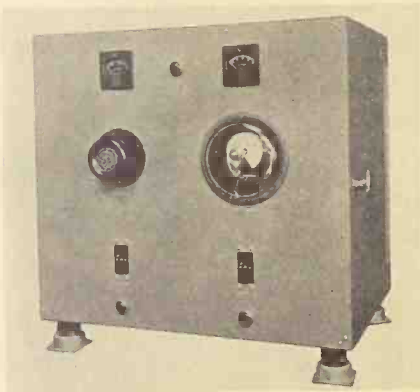
super sensitivity in industrial control applications. This miniature unit, which mounts on a standard 4" electrical connection box, incorporates simplicity of design and a minimum number of components.

The unit operates from the 115 volt 50-60 cycle line and uses no filament to draw standby power with the relay circuit energized. The load relay contacts are arranged to permit a choice of either opening or closing a circuit, or simultaneously to open one circuit and close another.

Additional data is available on request and the manufacturer will assist in application problems.

TV POWER CONTROL

RCA Engineering Products Department, Camden, N. J., has added to their TV equipment line a power control unit for mobile television pickup equipment



which provides power consumption readings and permits regulation of both input and output voltages from a central point in the mobile unit.

The control unit, consisting of transformers, circuit breakers, and other control apparatus for manually regulating both input and output voltages, is housed in a shock-mounted cabinet designed for mounting in the television truck.

Shown is the front view of the power control unit capable of operating from any two-wire system providing input voltages between 100 and 120 volts, or between 200 and 220 volts, 60 cycles at 5 kva.

AIR-COOLED TRANSFORMER

Larger-sized, air-cooled transformers, identified as *AmerTran* Type GS, are now being manufactured by the *American Transformer Company*, Newark, N. J. They are manufactured in standard ratings from 15 to 200 kva., single-phase, 60 cycles, and with either 240/480- or 600-volt, high-voltage windings. Low-voltage windings which are rated 120/240 volts are suitable for supplying lighting, motor and distribution loads.

According to the manufacturer, *AmerTran* Type GS provides adequate and

convenient accommodations for wiring connections in all types of installations without the need of specially fabricated fittings. In installing transformers for single-phase service, ample space for all required wiring is available in a large built-in wiring compartment located at the top of the transformer directly above a terminal board to which coil leads are connected.

MINIATURE POTENTIOMETERS

High precision miniature potentiometers are now being offered by *Technology Instrument Corporation*, 1058 Main Street, Waltham 54, Mass. Only ⅞" in diameter, and ⅜" in depth, these miniature potentiometers are available in resistance ranges of 100 to 25,000 ohms.

The accuracy of total resistance may be specified as close as ± 1%, and linearity to ± 0.8% of total resistance as required. These units may be ganged together with adjusting clamp ring to permit individual phasing.

Additional information may be obtained by writing direct to the company.

BETA GAMMA MONITOR

Model 2610A, beta-gamma portable count-rate meter, is being offered by the *Nuclear Instrument and Chemical Corp.*,

223 West Erie St., Chicago, Illinois. This model is housed in a water-tight

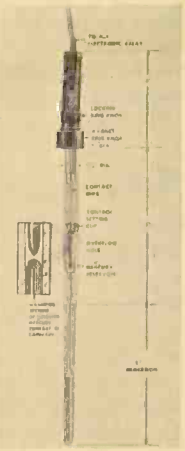
case and incorporates a proven electrical circuit which has been manufactured by the company for several years.

The interior is tropicalized to eliminate effects of humidity or other adverse atmospheric conditions. The probe is also water-tight and contains a plug-in type Geiger tube to facilitate servicing. Internal parts are arranged for ease in servicing and circuit components are mounted in the cover. The easy-to-read meter is calibrated in both milliroentgens per hour and in counts per minute.

The instrument is supplied complete with an attached radioactive source for checking calibration, batteries and crystal earphones.

THERMO-REGULATOR

The H-B Instrument Co., 2633 Trenton Ave., Philadelphia 25, Pa., has announced their Quick-Set Thermo-regulator on which the control setting can be varied over a wide range in a matter of seconds. Once set within 10°F. of the control temperature, adjustments of several degrees down to 0.01 and even smaller under favorable conditions, are made by merely turning a ring knob.



The compact, self-controlled Quick-Set Regulator fits into the medium to be controlled and, through an *H-B* Electronic Relay, can handle up to 30 amperes at 110 volts a.c. One model covers a range from approximately plus 30° to 600° F. or higher. Another model covers a range from minus 38°F. to about 50°F.

Full particulars may be obtained by writing to Dept. T-65.

DEMONSTRATION UNIT

A demonstration magnetic amplifier for educational purposes in schools and industry is being introduced by *Vickers Electric Division*, of *Vickers Incorporated*, 1815 Locust St., St. Louis 3, Missouri.

This unit is arranged so that all basic single-phase self-saturating circuits may be studied. By arrangement of the external connections either d.c. or a.c. output is available and either d.c. or a.c. control power may be used. Aside from the basic purpose to show the principle of the high-performance self-saturating magnetic amplifier, the new demonstration unit may be used in operating control circuits.

Reference material and bulletins included with each unit give the wiring diagrams of several control circuits, as well as a series of laboratory experiments arranged to help the student

determine magnetic amplifier static characteristics, internal impedance and optimum load, dynamic characteristics, and types of control circuits.

All colleges, universities, laboratories and other groups who are interested in the *Vickers* Demonstration Magnetic Amplifier are invited to write for complete details.

MAGNETIC CORE MATERIAL

Westinghouse Electric Corp., P. O. Box 2099, Pittsburgh 30, Pa., has developed two magnetic core materials for transductor application. These materials, Hipersil and Hipernik V, have rectangular, very narrow hysterisis loops, and are especially suited for electronic applications such as magnetic amplifiers, saturable reactors, and the new type of contact rectifiers.

Available in several thicknesses of lamination for various frequency and response requirements, the materials can be supplied in continuous toroidal or rectangular and butt-joint cores.

For further information, write direct to *Westinghouse*.

FREQUENCY-DEVIATION MONITOR

Motorola Inc., 4545 Augusta Blvd., Chicago 51, Illinois, is now offering to operators of 2-way FM radio systems a highly sensitive frequency-deviation monitor to measure the relative strength

of signals being transmitted, the magnitude of frequency modulation, and the error displacement of the signal from its assigned center frequency.

Designed for 117 volt, 60 cycle oper-

(*Continued on page* 31)

Personals

GABRIEL V. BUREAU has been appointed field engineer for the equipment sales department of the Radio Tube Division, *Sylvania Electric Products Inc.*, New York, N. Y. Mr. Bureau was formerly technical commercial manager for the *North American Philips* Co., and assistant sales manager for the *Amperex Electronics Corp.* He received his B.S. in electrical engineering from the University of Southern California and is a member of the IRE and AIEE.

LAWRENCE L. FERGUSON, assistant executive engineer at *General Electric Company*, has been appointed to take charge of the West Milton Area Project at West Milton, N. Y., where an experimental atomic power plant is under construction as part of the *GE* laboratory facilities. Mr. Ferguson, who is a graduate of the California Institute of Technology, will be responsible for coordinating all phases of design and construction.

B. K. V. FRENCH has been appointed application engineer of the Electronic Parts Division of *Allen B. Du Mont Labs., Inc.*, with headquarters in the East Paterson plant. Mr. French began his active radio career in 1923 with *Federal Telegraph & Telephone* as development engineer and has been associated with *American Bosch, RCA, Case Electric*, and *P. R. Mallory Co.* He is a Senior Member of IRE and a member of The Radio Club of America.

RALPH E. GOULD, chief of the time section at the National Bureau of Standards, has retired after over thirty-one years of service. Mr. Gould is the author of many articles in Bureau of Standards' and other publications concerning the technical aspects of time computation and the construction and testing of timepieces. Mr. Gould will devote his time to duties as Secretary of the Horological Institute of America.

R. L. GROVE has been appointed chief engineer of *Cornell-Dubilier's* Ceramic Division in New Bedford, Mass. Mr. Grove, a graduate of Ceramic Engineering from the University of Illinois, was previously with *Westinghouse Electric Corporation* as Ceramic Engineer in the company's electrical porcelain plant at Derry, Pa., and more recently with the *Centralab Division* of *Globe Union, Inc.*, Milwaukee, Wisconsin.

DR. JOHN McELHINNEY recently joined the staff of the Radiation Physics Laboratory of the National Bureau of Standards where he will use the Bureau's new 50-million volt betatron for research in nuclear reactions and high-energy x-rays. Dr. McElhinney is co-author of several articles concerning the thresholds of photo-nuclear reactions and is a member of the American Physical Society, Sigma Xi, and Phi Kappa Phi.

Instrumentation

(*Continued from page 6*)

of single ended, push-pull, or differential input.

Various types of input circuits may be used with the amplifiers and the recording system considered here. However, the present equipment was constructed specifically to use strain gauge and piezoelectric transducers. Strain gauges are normally employed in Wheatstone bridge circuits which are often referred to as full, half, or quarter bridges to designate the number of strain gauges employed, the remainder of the circuit being composed of fixed precision resistors.

Since the effect of strain on the gauges is to increase or reduce their resistance the same effect may be obtained by inserting resistance in series or in shunt with one of the gauges. The shunt method was adopted in this instrumentation as a means of calibration. The calibration steps are recorded immediately before the test record is taken and form a reference for analyzing the record that eliminates calculation of:

1. Amplifier gain.
2. Oscilloscope sensitivity.
3. Bridge current.

A piezo gauge input is normally single ended and requires extremely high input impedance, the input impedance of the amplifiers being 100 megohms and the remainder of the input cables, condensers, switches, etc., exhibiting an input shunt resistance in excess of 1000 megohms. A charge calibration is imposed on the circuit immediately before firing. This makes possible computation of blast pressures without necessity of determining cable shunt capacitances, signal attenuation, amplifier gain, etc.

Immediately after this calibration is applied the blast is fired and Fig. 10 shows a sample four channel record taken during recent tests. The outside timing markers are provided by the pulsed glow tubes. The pressure peaks occur at different times due to the varied positions of the input transducers, which were in this case Tourmaline crystal gauges.

The basic operation of the units has been traced from recording system to input networks, but the preliminary discussion of the physical layout was rather sketchy. Let us take another look at Fig. 1. Each of six bays of instrument units consists of the following, from top to bottom:

1. Calibration Unit.
2. Terminal Unit.
3. Oscilloscope Unit.
4. Amplifier Unit.
5. Amplifier Power Supply.
6. Bridge Power Supply.

Bays 2 and 6 contain oscilloscope power supplies. The central bay contains all the control equipment, or units whose function is common to all operations. A truck, used for transporting and reeling necessary cables, is shown in the background.

Each of these bays may be used separately as a four channel unit, with the addition of control units if desired.

Conclusion

The equipment described above fulfills in design and practice the necessary requisites for a versatile, smoothly operating, multichannel cathode-ray oscillographic unit. The complete versatility of the basic unit has not been discussed at length, but suffice it to say that with minor redesign a great number of uses can be accommodated.

The twenty-four channel mobile oscillographic measuring unit was designed and constructed for the Ballistic Research Laboratories of Aberdeen Proving Ground. The authors wish to acknowledge the aid and assistance rendered by Dr. C. W. Lampson and Messrs. C. L. Adams and W. E. Curtis of that organization.

Forced Air Cooling

(*Continued from page* 13)

volume would increase to 140 c.f.m. Most blower manufacturers include curves of this nature in their catalogues or bulletins. Where they are not included, they are almost always obtainable from their engineering or sales departments.

Since most radio laboratories do not have facilities for readily measuring the actual performance curves of the blower, it is wise to choose a blower manufactured and measured under NAFM or made by a reputable manufacturer who will guarantee the performance curve. A rough check may be made by checking the pressure at the point where the blower ceases to deliver air. For the blower of Fig. 4 this will be approximately .95 inches water column. The output of the blower should be exhausted into a cardboard box sealed sufficiently tight to prevent air leakage at the cracks or at the blower outlet connection. The pressure developed inside the box should then be measured by means of a manometer. If there is excessive leakage past the air rotor or the motor speed is too low resulting in low tip velocity, then it will be impossible to build up pressure to this point.

Noise is another factor which must often be considered. This is especially true in locations such as studios where the noise level must be relatively low at all times. In general, it will be found that high pressure cooling systems will result in higher noise levels. This is due to the high tip velocity necessary in generating the required air pressure. Low pressure systems, such as Fig. 1, have relatively low tip velocity and consequent low noise. This particular example has a pressure drop of only .125 inches water column at the rated volume flow of 400 c.f.m. In low pressure systems the air rotor turns at relatively low speeds, seldom more than 1800 r.p.m. and delivers a volume which is dependent on the physical size of the blower. High pressure blowers operate at high tip velocity or high peripheral speed and have less space between the air rotor and the housing resulting in the higher noise level.

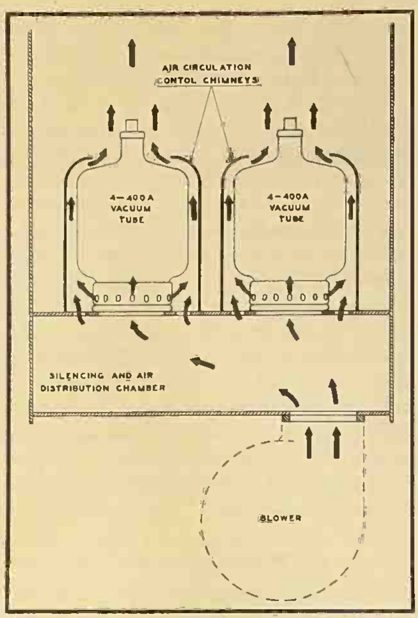


Fig. 6. Air path of system using internal anode tubes shown in Fig. 2.

Upon completion of the initial model, it is mandatory that the cooling system be checked as to its actual performance. This is not as difficult as it might seem and can be accomplished readily with quantitative results.

Obviously the first step is to measure the static pressure at the point specified by the tube manufacturer. A simple "U" tube manometer is sufficient for this measurement. A suitable unit may be purchased or may be made on the spot. A manometer sufficiently good for the static pressure measurements may be made by bending a short length of uniform cross-sectional area glass tubing into a "U" shape. Fig. 3 illustrates such a unit. Inside diameter should be on the order of one-fourth inch to minimize errors due to surface tension. Glass tubing of the required type is readily available from chemical supply houses or neon sign companies.

The measurement is essentially a wa-

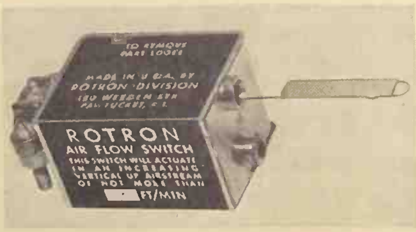
Fig. 7. Pressure type air interlock sw.

ter displacement process. One end of the tubing is left open, the other end is fastened by means of an air tight hose connection to the pressure point to be measured. The air pressure difference between the outside air and the pressurized chamber displaces the water. The difference between the water level of both legs of the tube represents the static pressure in inches water column and is measured directly in inches. In making the measurements it should be borne in mind that the tubing must be held in a vertical position for accurate results, and that the pressure is measured between the levels in the legs. For example, a static pressure of 1 inch would push the level of one leg up a half inch and that of the other leg down a half inch.

If the static pressure measured is equal to or greater than the tube manufacturer recommends, it may be safely assumed that the tube is being sufficiently cooled providing there are no obstructions past the tube which could introduce a pressure drop.

A further check is often desirable, however, and most conservative engineers or manufacturers do so as a matter of policy. This may be accomplished effectively by measuring the actual seal temperature and temperature of the anode coolers. This is difficult to do even at low frequencies due to inability to establish good heat conductivity between the seal under measurement and the thermometer bulb. In fact, such measurements may be so unreliable as to make them useless. At v.h.f. it is next to impossible to use bulb type thermometers due to the electrical conductivity of the mercury column or chemical used in the indicator column.

Fig. 8. Vane type air interlock switch.



Chemicals have been developed which can be smeared directly on the spot to be measured and which will change color or crystallize when a given temperature is reached. One of these which has found ready acceptance in the tube industry is *Tempilac*. It may be purchased in a wide variety of temperature ranges. A small brush may be used to dab it on the spot to be checked. When the temperature reaches the melting point of the *Tempilac*, say 150°C, it may be observed melting and crystallizing. The crystals remain as mute evidence that the temperature of that particular spot has at some time reached or exceeded 150°C.

Safety Or Protection Devices

Where forced air cooling is required it is mandatory that some kind of safety protection be provided to prevent damage to the tubes or equipment should some part of the cooling system fail.

In the past, air velocity type switches have been popular as an air interlock. These are usually of the vane type. The air blowing past and against the vane actuates a switch which removes the high voltage to the tubes. Upon failure of this air stream the air pressure against the vane will drop actuating the switch. These types of air interlock switches are operated by the movement of the air stream only. Fig. 8 illustrates a modern example of a positive air interlock switch of this nature.

Interlocks of this type are used in cooling systems having relatively large air volume with low pressure. They can not afford protection should air leakage occur after the point where the switch is placed. They do have the advantage of affording protection should an obstruction occur any place in the air stream sufficient to reduce the air flow to a predetermined value.

Pressure actuated air switches have become popular with the increasing use of external anode tube cooling systems. Fig. 7 illustrates a pressure interlock developed by *Coral Designs* which has proved popular in electronic applications having air pressure from .2 inches up. It is essentially a diaphragm instrument having a large cross-sectional area diaphragm which actuates a snap-action switch at a predetermined pressure. The large cross-sectional area of the diaphragm makes possible positive action at low pressure. The transmitter shown in Fig. 4 employs a switch of this type. It may be seen mounted on the left side of the lower pressure chamber. The *Gates* BC-5B shown in Fig. 5 also uses an interlock of this type mounted in the center of the rear side of the pressurized chamber.

TECHNICAL BOOKS

"COMMUNICATION CIRCUIT FUNDAMENTALS" by Carl E. Smith. Published by *McGraw-Hill Book Company*, 330 W. 42nd St., New York, N. Y. 401 pages. $5.00.

This book is the second of four books designed for a complete course in radio and communication engineering prepared by the author for home study. The first book of the series was Applied Mathematics for Radio and Communication Engineers, which contained material prerequisite for a complete understanding of this text.

This is an important new text in circuit fundamentals for students, operators, technicians, and engineers. It covers the physics of circuit elements, including vacuum tubes, and presents the fundamentals of a.c. and d.c. circuits. Circuit constants are discussed first and then used in a treatment of d.c. circuits. After a study of magnetism, inductance, and capacitance, the principles of alternating currents are treated.

Although the text was planned to serve as a study of fundamentals in residence or correspondence courses, it should also prove of value for reading or reference for those who do not have the time to undertake a complete course.

"ELECTRON-TUBE CIRCUITS" by Samuel Seely, Prof. Electrical Engineering, Syracuse University. Published by *McGraw-Hill Book Company*, 330 W. 42nd St., New York 18, N. Y. 529 pages. $6.00.

This college text is the outgrowth of several courses organized by the author on electron-tube circuits and applications that covered many of the important circuits in use during the second world war. It seeks to give a clear analytical method in the study of electron-tube circuits, and presents for study the various classes of circuits which find widespread application.

Examples indicating the procedure for combining circuits of various types to achieve either one or a multiplicity of operations is an important feature of this book. A discussion of tube circuits for performing mathematical operations and of those developed in connection with radar applications is found to be considerably more in detail than found in most textbooks of today.

The student should have completed his basic studies in a.c. circuit theory and basic electronics before undertaking a study of this material. The instructor will find that sufficient diversity exists to allow a choice of topics to satisfy almost any course requirements.

Wide-Band Amplifier

(*Continued from page 16*)

combining antenna outputs such as transformers, cathode followers, filter networks and stub arrangements. The wide-band amplifier can also be modified to provide a number of inputs with a common output. This can be accomplished by keeping the same arrangement in the plate line but changing the grid line. The simplest change is to enter the grid line after each filter section, and terminate the filter in its characteristic impedance, such as shown in Fig. 5. Thus each tube can be used for a separate input. The operation is similar to that previously described except that each tube has a different input. The signal applied to input No. 1 of Fig. 5 will excite the grid of the first tube and a current carrying this signal will travel toward the line and appear as a voltage at the receiver. Similarly, a signal applied to the input of the other tubes will also appear at the load and in this manner the output of the separate generators, in this case receiving antennas, are combined into a single transmission line. The use of this system provides nearly infinite attenuation between generators, thus eliminating interaction between antennas through the coupling unit. The receiving antenna's bandwidth can be sharpened in the stop band by using *m*-derived band pass sections in the grid line while using the conventional low-pass filter section in the plate. Thus any undesired frequencies received on the individual antennas will be further discriminated against. For further flexibility a method of gain control for each input can be added to the antenna coupler. This can be accomplished by use of resistance pads, variation of grid bias, or a variation of plate and screen voltages.

Many apartment house owners will not allow individual tenants to install antenna systems because of the large numbers of antennas that would have to be accommodated. This not only provides an unsightly appearance but breeds discontent because all of the positions on the roof do not provide good television reception. Also, interaction between antennas and receivers is likely to take place, all to the detriment of the picture quality of the reproduced signal.

But many of these same owners will agree to the installation of a master antenna system to which the individual sets can be connected. The problem then becomes one of splitting the single output into a number of loads. Additional amplification will usually be found necessary even in metropolitan areas because of the considerable loss found in long transmission line runs. The individual receivers must also be isolated from one another so as to minimize interaction between receivers. Numerous multiple installations have been engineered and the problem has been solved in a number of ways. Some installers have used resistance pads (of about 30 db.) in each outlet so that the path between receivers would have a total of twice that amount. Others have used transformers, cathode followers, filter arrangements, and the like. The wide-band amplifier can also be used in this application by what amounts to the inverse solution of the antenna coupling problem.

In providing a receiver coupler the grid line remains as in the amplifier but the plate line is altered to provide a number of outputs from a single input as shown in Fig. 9. The input signal produces the same grid voltage at each tube and a current appears in the plate line. The currents now, instead of being combined in a single output, each go into their individual load, thus providing a number of outputs from the single input. The outputs are isolated from one another and from the input by an almost infinite impedance and thus no interaction can take place through the coupler.

Thus the wide-band amplifier technique can be used to combine a number of inputs into a common line, amplify the entire spectrum, and then to split the output into a number of loads. This problem is exactly the one encountered in the multiple television installations (See Fig. 8) and is also applicable to the testing and repairing of television receivers with a minimum of equipment. A number of signal generators can be located at a central point and the outputs can be combined, amplified to the desired level, and then distributed to the test positions. The tester has available several channel signals at the one outlet, without the necessity of providing individual generators at each outlet and without switching. Each set can be aligned at one position without signal generator switching or the necessity of having different test positions for each channel. This is a similar problem to the multiple installation of television receivers and Fig. 8 applies with signal generators substituted for receiving antennas, and test positions for TV outlets.

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News Briefs

(*Continued from page* 22)

demonstrating an experimental machine. On the far right, contained in a cylinder, is the x-ray source. The x-rays come from the aperture in the cylinder, pass through the sample, and are then magnified by two mirrors contained in the unit on which Miss Lucht's fingers rest. The magnified x-ray image is finally cast on a photographic film mounted behind the optical system to the right.

GE scientists believe that x-ray microscopes may someday compete with electron microscopes and make possible examination of live specimens at much higher magnifications than ever before.

ELECTRONIC TORCH

Dr. J. D. Cobine, scientist of the *General Electric* Research Laboratory, has developed an electronic torch which can melt firebrick and even tungsten which melts at 3370 degrees centigrade. The flame consists of nitrogen being passed through a high-frequency arc.

The arc is formed by radio waves at the extremely high frequency of one thousand megacycles, generated by a magnetron tube. Dr. Cobine, shown melting a quartz rod in the flame, explained that the radio waves break up

nitrogen molecules which consist of two atoms into individual atoms. When these atoms reunite to form molecules again, heat is released.

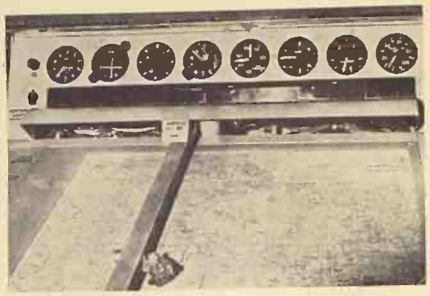
No uses have been found as yet for the extremely hot torch which is still at the laboratory stage of development.

JET PILOT TRAINER

From Wright-Patterson Air Force Base, Dayton, Ohio, comes the announcement of the new "Linktronic" trainer which is the latest device in training equipment for jet pilots providing indoctrination in the use of radio navigation systems.

The compartment of this new trainer looks exactly like the cockpit of a modern, single-engine, jet fighter. The gauges and indicators operate and register just as they would in a real plane.

The eight instruments across the trainer's panel shown are synchronized to those in the cockpit so that the instructor is at all times able to follow the student's performance. The lights below the instruments flash to indicate error, result of error, and operating



condition of the plane, while the flight recorder pen, mounted on a traveling arm, records simulated cross-country flights up to 1000 miles.

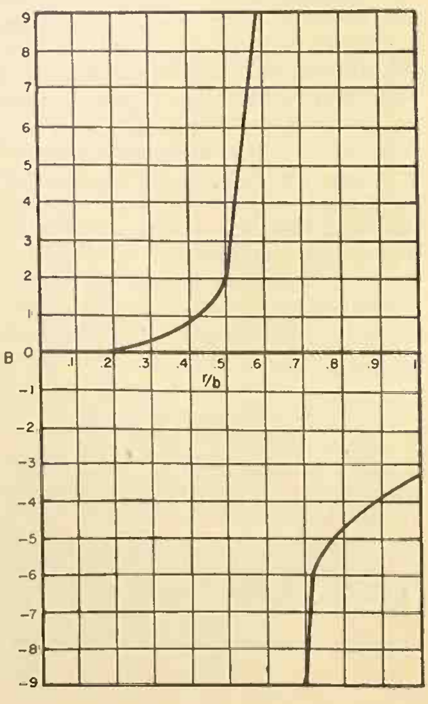
Microwave Comp.

(*Continued from page* 20)

$$R = 120\frac{\lambda}{\delta}\,\frac{b}{a}\,\frac{1}{1+\dfrac{a}{2b}} \qquad (30)$$

In practice it has been found that finer tuning and stabler performances can in some cases be obtained using a reentrant cavity such as the one shown in Fig. 15B. In this case the center discontinuity acts as a capacitance and the two side arms act as inductances. By varying the depth of the discontinuity,

Fig. 16. Typical normalized susceptance vs. screw length curve (x = 5.5 cm., b = .872", a = 1.872", and screw diameter = .126").



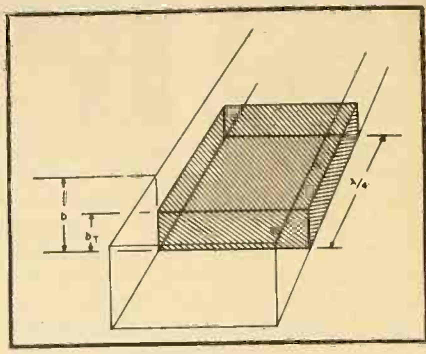


Fig. 17. Asymmetrical capacitive quarter-wave transformer.

the cavity can be made to resonate over a relatively wide range of frequencies.

Cylindrical cavities, such as the one shown in Fig. 15C, are employed in many applications. The characteristics of these cavities, which in many cases depend upon roots of Bessel Functions, are summarized below:

$$\lambda = \frac{1}{\sqrt{\left(\dfrac{1}{3.42}\right)^2 + \left(\dfrac{1}{2z}\right)^2}}$$

for $H_{1,1,1}$ mode . . . . . . (31)

$$\lambda = \frac{1}{\sqrt{\left(\dfrac{1}{2.61\,a}\right)^2 + \left(\dfrac{1}{2z}\right)^2}}$$

for $E_{1,0,1}$ mode . . . . . . (32)

$$\lambda = \frac{1}{\sqrt{\left(\dfrac{1}{1.64\,a}\right)^2 + \left(\dfrac{1}{2z}\right)^2}}$$

for $H_{1,0,1}$ and $E_{1,1,1}$ modes . . . (33)

$$Q \text{ (for TE modes half-wave long)} = \frac{Z_0}{\delta} \times$$

$$\frac{\left(u^1_{n,m} + \dfrac{\pi a}{2z}\right)^2 \left(1 - \dfrac{n}{u^1_{n,m}}\right)}{\left(\dfrac{z}{a}u^1_{n,m} + \dfrac{a^2\pi^2}{4z^2} + \dfrac{a(2-a)\pi^2 n^2}{4z^2 u^1_{n,m}}\right)} \qquad (34)$$

$$Q = \frac{a}{\lambda}\,\frac{1}{1+\dfrac{a}{z}} \text{ for TM modes, } n \neq 0 \qquad (35)$$

If $n = 0$, Q is given by:

$$Q = \frac{a}{\lambda}\,\frac{1}{1+\dfrac{a}{2z}} \text{ (TM mode, } n = 0) \qquad (36)$$

The use of many of the components described in this article will be clarified as the design of microwave equipment is covered.

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New Products

(*Continued from page* 25)

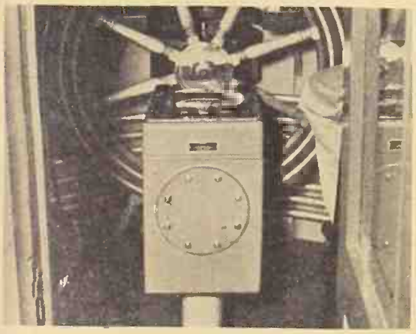
ation, the unit monitors up to five carrier frequencies in either the 25-50 mc. band or the 152-174 mc. band. Additional frequencies may be monitored by the simple exchange of control crystals.

An important part of the *Motorola* monitor is an AM receiver pre-tuned to Washington, D. C. station WWV, by which the monitor may be accurately checked and calibrated.

MARINE RADAR

Raytheon Manufacturing Co., Waltham, Mass., has introduced the newest in its series of commercial marine radar equipments, the Mariners Pathfinder Jr., designed to meet the demands of operators of tugs, ferries, fishing vessels, yachts and other smaller craft for a compact, low-power drain and lower cost radar.

The system, comprised of an antenna, transmitter-receiver and indicator, operates on a wavelength of 3.2 centimeters. The Mariners Pathfinder Jr. has a minimum range of 75 yards and a maximum of 20 miles. Range accuracy is within 2 per-cent and bearing accuracy is within 2 degrees. This unit is available for vessels equipped with 32-volt d.c., 110-volt d.c., 220-volt d.c. or 115-volt a.c. power systems. Power consumption in all cases is less than 750 watts.

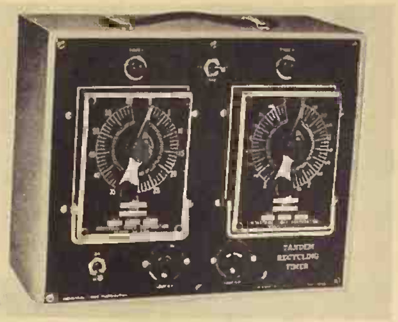


Photograph showing the indicator of Mariners Pathfinder Jr. radar installed in wheelhouse of the tug "Eileen Ross" illustrates compactness of the equipment.

DUAL TIMING DEVICE

Two individual timing elements, each able to control a specific operation, accommodated in a single housing is the Tandem Recycling Timer manufactured by *Industrial Timer Corporation*, Newark, N. J.

When the timer dials are set to the respective time intervals required, each cycle of operation will follow the other continuously in regular sequence. ON and OFF Toggle Switch, Load Control Switch and Pilot Lamp are integrated with other components to give a compact, clean-cut, portable assembly. The complete control cabinet measures 11½ x 9 x 7 inches and contains two sockets into which the timing elements are plugged so that they control a single-pole, double-throw load relay. The contact circuit of this relay is unpowered, permitting application of the particular voltage and current necessary for test or production.



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14 . . . Spencer-Kennedy Laboratories

D. C. Amplifier

(*Continued from page* 11)

11. Throw switch B in the "off" position.

12. Adjust "DETECTOR CONTROL" potentiometer to read ZERO. Do not allow to go below zero.

13. Throw switch B in the "on" position.

Now the d.c. amplifier is ready to function. Operations (1) to (13) are made before the amplifier is used and represents the basic alignment of the amplifier. They do not need to be repeated every time. They are made with no d.c. signal at the input terminals. The potentiometers involved in operation 7, 9 and 12 must never be touched again except for checking the alignment periodically by repeating all of the above operations.

Operating Instructions

To operate the d.c. amplifier after once aligned in accordance with the alignment instructions above, the following are the sequences:

(1). Throw switch "A" in the "set to 50" position No. 1.

(2). Turn the "AMPLIFIER CONTROL" potentiometer all the way down.

(3) Connect the terminals "input". The right polarity must be used. No reading is possible with wrong polarity.

(4) Turn the "AMPLIFIER CONTROL" potentiometer up to read 50 again. This position will be reached sooner than 4 of the alignment procedure. It should therefore be done carefully.

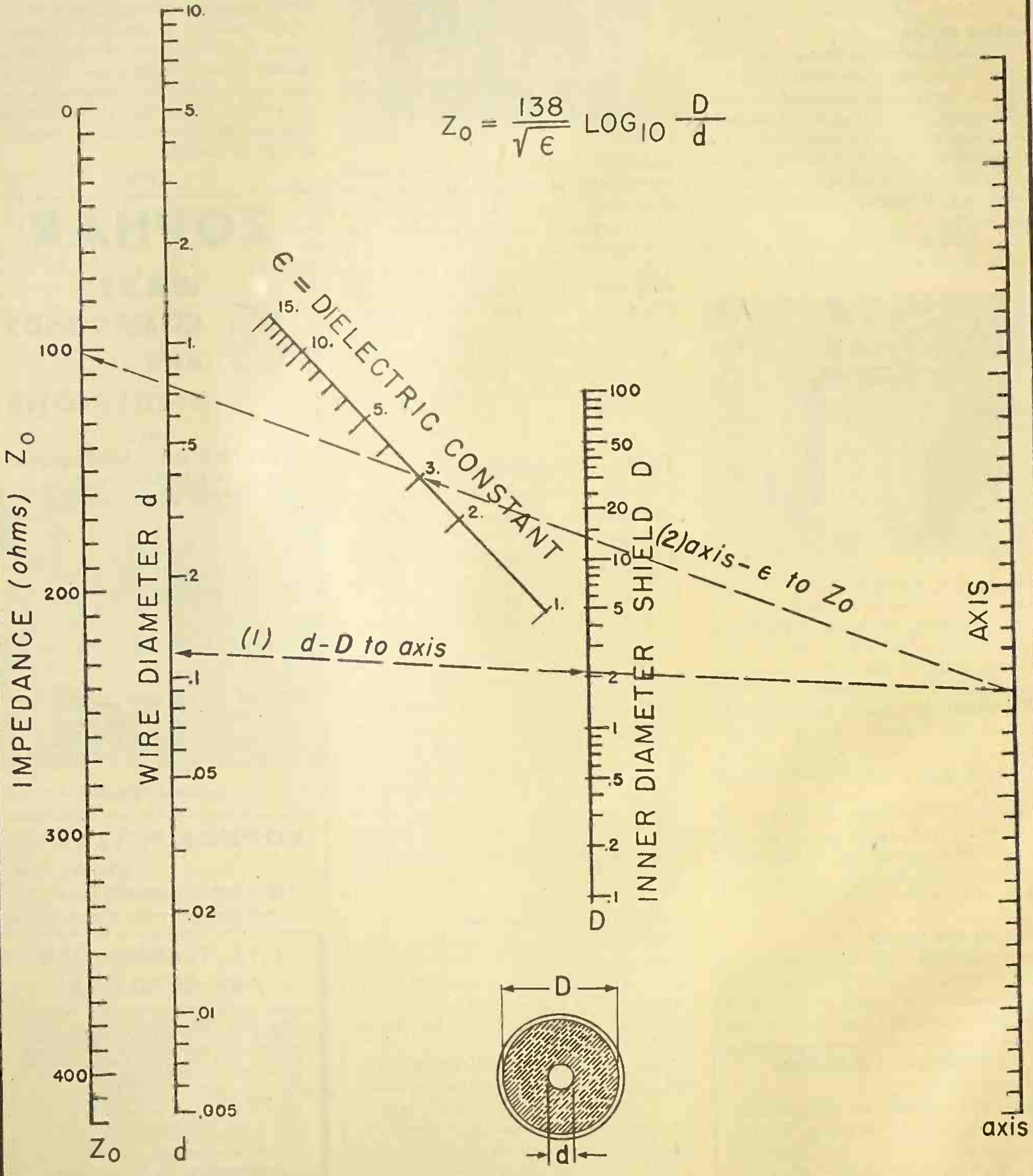
(5). Throw the switch "A" in the "Reading" position No. 3.

(6). Adjust the "METER CONTROL" potentiometer to read 50. Now any increase of the d.c. signal will increase the reading while any decrease will decrease the reading a proportional amount.

The meter may be calibrated by checking with known signals in case an actual measure is required instead of only an indication of d.c. voltage change. The maximum d.c. input voltage is 100 volts. The meter is a voltmeter with 100 volts full scale deflection and having an internal resistance as high as possible.

CHARACTERISTIC IMPEDANCE OF LINES

This chart gives theoretically exact values for solid dielectric concentric lines for any scale of dimensions if lossless dielectric (completely filling space between conductors) and perfect conductors are assumed.



Courtesy of Federal Telephone and Radio Corporation.