NOVEMBER, 1950

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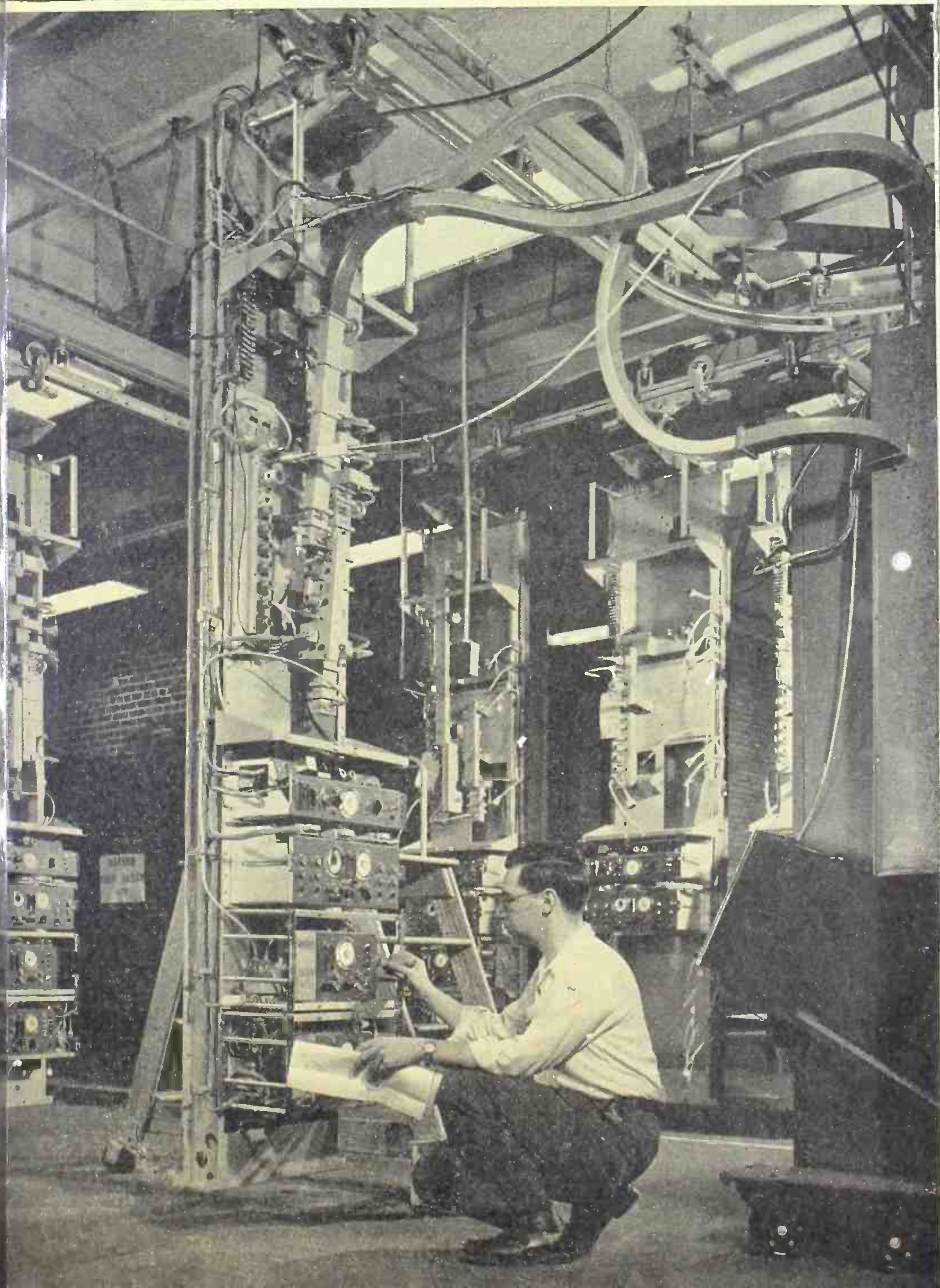
RADIO-ELECTRONIC Engineering



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COVER PHOTO — Courtesy of Western Electric

A Western Electric engineer is shown giving a final test to the equipment which receives the telephone and television signals from one tower and transmits them along to the next tower in the Bell System radio relay chain. The flexible wave guides seen at the top of the picture connect the radio relay equipment to the testing apparatus developed by Western Electric engineers.

NBC studio 8H in New York City, showing sound-diffusive construction of walls and ceilings.

SYNTHETIC REVERBERATION

By DAVID FIDELMAN

The persistence of sound due to multiple reflections gives rise to certain characteristics which may be produced synthetically.

WHEN sound is heard in a room or auditorium, one of the most important factors affecting its quality is the acoustical reflecting quality of the room. As the sound starts, its intensity does not immediately reach maximum, because it takes an appreciable time for some of the sound to reach the walls and undergo one or more reflections before reaching the listener. The intensity reaches its maximum when the steady-state condition is attained—the listener hearing both the direct and the reflected sounds at the same time. After the sound stops, it also takes an appreciable time for various reflections to be completely absorbed so that they can no longer be heard. If familiar sounds are heard without these reflections, as in a room with completely sound-absorbing walls, they sound unnatural.

This persistence of sound due to multiple reflections is called *reverberation*. It is different from an echo in that it consists of a large number of reflections which blend evenly with one another and with the original sound, whereas an echo is just the sound from a single reflection after a small time delay. The number of reflections, their time and amplitude distribution, their frequency distribution, and their distribution in space are functions of the room itself—and it is these reverberation characteristics which determine the acoustic properties of any room, auditorium or theater.

The *reverberation* time of a room has been defined as the time required for the intensity of a steady sound to decrease 60 db. after the source has been stopped. This time of decay, and the exact nature of the sound decrease, are determined by the geometry of the room, the position of the walls and other reflecting surfaces, and the amount of reflection from these surfaces.

The optimum reverberation time depends upon many factors—the most important being the volume of the room, and the type of program material which is being heard. There is no theoretical scientific basis for the choice of desirable reverberation times, but experience has shown what is most pleasing to the ear, and standards have thus been determined subjectively. Early experience with broadcast studios has shown that when there is no re-

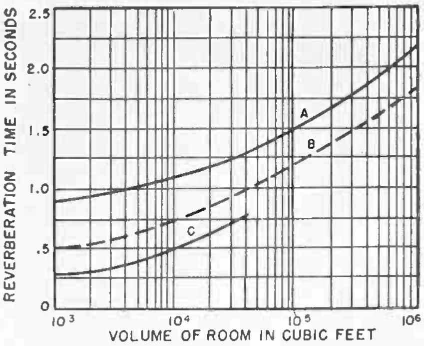


Fig. 1. Optimum reverberation times for rooms of various sizes. A—auditoriums and theaters; B—broadcast studios, music; C—broadcast studios, speech.

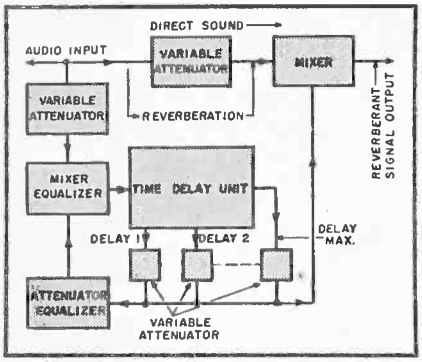


Fig. 2. Use of a time delay unit to give synthetic reverberation.

verberation the room gives a dull, lifeless effect to sounds. However, when there is too much reverberation, the energy from successive sounds tends to overlap and reduce intelligibility.

As a result of numerous listening tests, the optimum reverberation times of various size rooms, for frequencies from 500 to 1000 cycles per second, have been found to be those shown in the curves in Fig. 1. Curve A shows the values for auditoriums and theaters, where the sound is produced and listened to in the same room. Curves B and C are the desired reverberation times for broadcast and recording studios, where the sound is produced in the studio and heard in another room—Curve B giving the values for music, and Curve C for speech. The reverberation in the broadcasting studio should be less than in rooms and auditoriums where the sound is heard directly, since the reverberation of the listening room must also be considered.

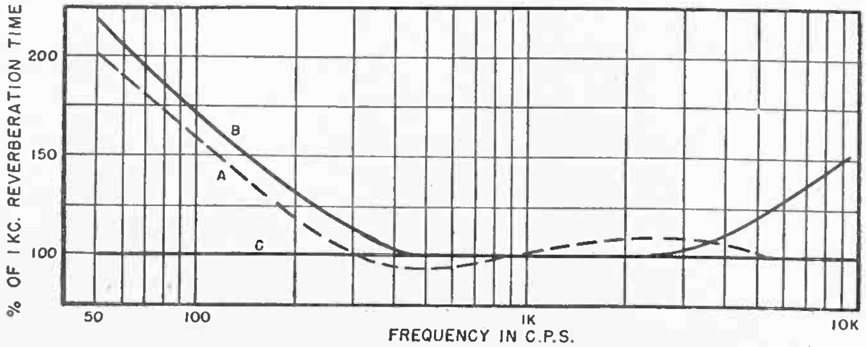
The optimum reverberation time as a function of frequency, relative to the 1000 cycle value, is shown in Fig. 3. Curves A and B show two different curves which have been recommended —curve A the result of the most recent investigations, and curve B the previously accepted standard. Curve C shows the desired curve for radio studios used for broadcasting speech, which represents a special case. Such a studio should have little reverberation and a flat frequency characteristic, as shown, since it should neither add nor detract from the speaker's voice, which on reproduction in the home should sound as though he were actually present in the room.

The problems of designing rooms and auditoriums for good acoustic properties increase when the rooms are to be used for a variety of different program materials, as in broadcast studios and in many auditoriums. A good solution to these difficulties is offered by the use of electronic synthetic reverberation systems. Synthetic reverberation consists of permitting the listener to hear the original sound exactly as it occurs, but to produce the reverberation synthetically in some device other than the room in which the sound originates. Ideally, by using a device in which any desired type of reverberation effect could be produced, the room in which the sound is produced would be treated to render it acoustically inert, so that it would produce no sound reflections or reverberation. All reverberation effects would then be created in the synthetic reverberation unit, and the listener would hear a combination of the direct sound originating in the room and the reverberation produced elsewhere synthetically. For example, in radio broadcasting the direct sound would be picked up by the microphone, reverberation added synthetically, the two signals mixed in the proper proportion, and the combined signal then broadcast. In an auditorium the entire room would be made sound absorbing so that the audience would hear only the original sound directly, and a microphone used as a pickup for reverberation production, which would then be transmitted from loudspeakers situated at various positions around the auditorium.

Such a system might have a number of important advantages. First, of course, would be the obvious saving in space and money which would otherwise be required for obtaining the proper acoustics architecturally. In recording and radio broadcasting it is often desirable to obtain the acoustics of a large auditorium or concert hall, which are not generally found in the average broadcast studio. Often, also, a single studio must be used for a variety of programs requiring widely different acoustic conditions—which cannot conveniently be achieved by architectural control. On the other hand, electronic synthetic reverberation systems are so versatile that they can produce synthetically a counterpart of practically any interior. In addition, they might even produce the equivalent of a space pattern more satisfying than might be produced architecturally.

Many different approaches have been made toward the design of synthetic reverberation systems, and many different types have been in use for various applications over a period of years. The different types of design all aim at one important factor — to achieve a time delay in transmission of the audio signal which will be sufficiently great to be used for reverberation purposes. Once this delay has been achieved, it can be used to give a reverberation effect as shown in Fig. 2. Part of the input (which is an audio signal containing no reverberation) is applied through a suitable equalizer to the time delay unit. As the diagram indicates, there should be available outputs from the delay unit having several different time delays. The simple introduction of a single small time delay does not produce reverberation, but a single echo. To give the effect of reverberation it is necessary to have the reflection repeated many times (perhaps as many as 40 or more) with decreasing amplitude, and the time between the successive reflections must be short enough so that the individual reflections will not be distinguishable. In the basic unit shown, the various outputs of the time delay unit should be separated by times of the order of 10 to 20 milliseconds. They can then be combined through suitable mixing networks, amplified if necessary, and sent through the time delay unit again to give further reflections. In this manner the desired

Fig. 3. Optimum reverberation time as a function of frequency: A—latest standard; B—previous standards; C—speech broadcast.



effect of many successive reflections of decreasing amplitude can be attained to any desired degree.

Many different methods have been used for obtaining the required time delay. These include acoustic, electrical and mechanical delay lines, and simple mechanical motions. Although all of these methods are more or less capable of giving the desired result, the most practical and widely applied are those using acoustic delay and simple mechanical motions for the required time delay.

Acoustic time delay

In the past the most widely used method of time delay for synthetic reverberation (especially in motion-picture recording and radio broadcasting studios) has been the type of acoustic time delay known as the *echo chamber*.

The echo chamber consists generally of a large empty room of 10,000 or more cubic feet in which loudspeakers are placed for introducing sound, and microphones for picking up the reverberation. The walls are generally covered with glazed hard-surface materials (such as sheet rock, or hard-surface masonite covered with a hard paint), the floors of painted wood or cement, and the reverberation time is between 2 and 5 seconds.

Reverberation control with such echo chambers is accomplished by sending any desired part of the signal through them before recording or broadcasting. A typical setup for performing this function is shown in Fig. 5. One bank of mixers and attenuators is used for the sound which is not to have reverberation added. The signal from bank 1 is then amplified and sent to the echo chamber, as well as directly — the premixing being done so that only one chamber is necessary. The output of the echo chamber is then amplified and combined with the direct signal to the desired amount.

With the use of good quality loudspeakers and microphones, quite good results are obtained with the use of echo chambers. However, they are not practical for very extensive use since they require considerable space, are expensive, and do not possess any great flexibility in variation of their characteristics.

Another type of acoustic time delay system, which has overcome the major disadvantages of the echo chambers, makes use of a long narrow pipe with a loudspeaker at one end and a microphone at the other. The essential units of this system are shown in simplified form in Fig. 8, and may be compared with the requirements of the basic system as shown in Fig. 2. Part of the input signal goes directly through a switch and a mixing coil to the output

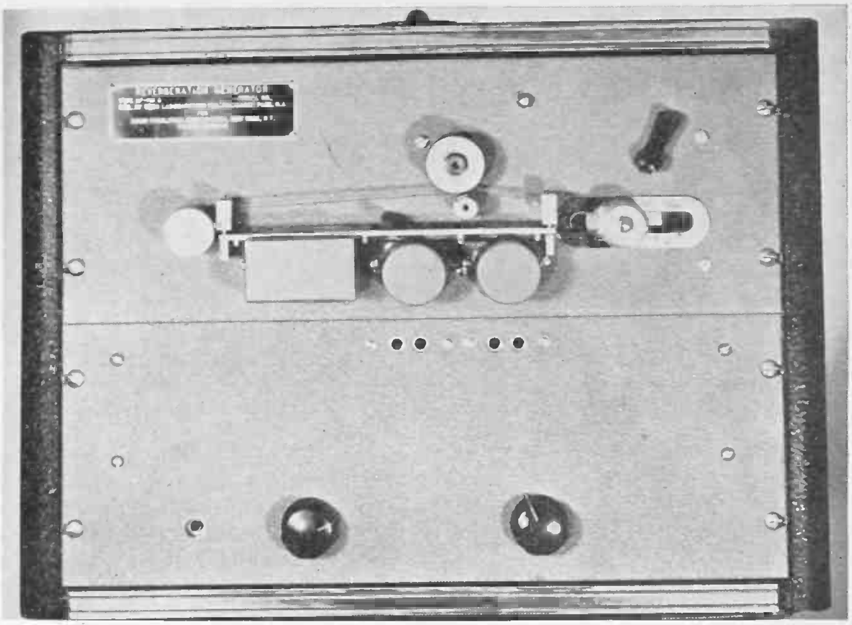


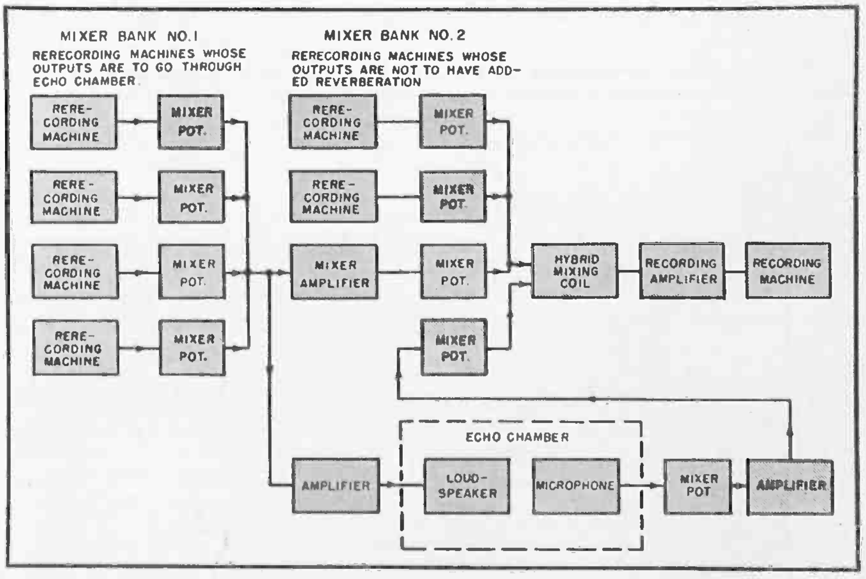
Fig. 4. Magnetic tape reverberation unit of the type described in Fig. 6.

of the channel, and part goes through an amplifier to the input of the time delay section. This time delay section consists of three lengths of pipe into which sound is applied by two loudspeaker units, with microphones so arranged that sound is picked up after it has traveled distances of 25, 50, 75 and 100 feet. Thus there are four separate time delays of approximately 0.023, 0.046, 0.069, and 0.092 second between the input sound and the signal received at the various microphones. The output signal from these microphones is then amplified and combined, then further amplified and equalized before being combined with the output.

In order to obtain greater time delay without the necessity of going to excessively long lengths of pipe, part of the delayed signal is fed back to the input and sent once again through the 100-foot length. This process can be repeated as many times as necessary to give the desired total reverberation. Each time the first four delayed signals traverse this circuit four new reflections appear at the channel output, resulting in successive groups of four reflections in each group. The setting of the attenuator in the feedback circuit determines the decay between each group of four reflections, and therefore the total reverberation time.

Considerable frequency - response equalization is necessary in order to compensate for the transmission deficiencies of the pipes, and there must be very careful acoustic impedance matching from the loudspeakers and

Fig. 5. Setup for using echo chamber to add synthetic reverberation in recording.



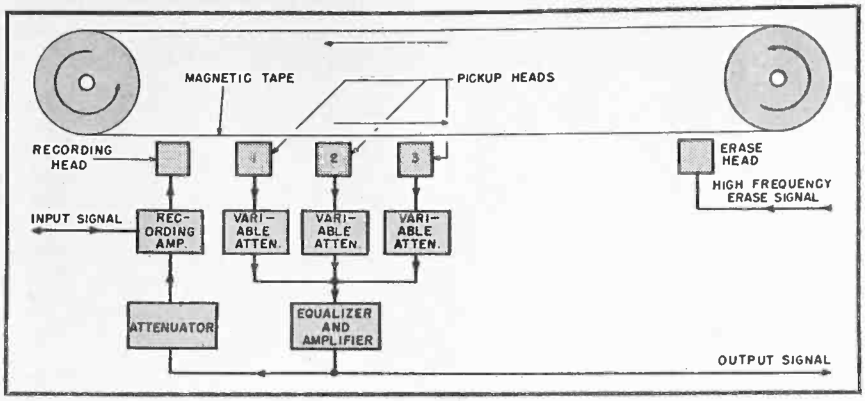


Fig. 6. Use of magnetic recording to give time delay for synthetic reverberation.

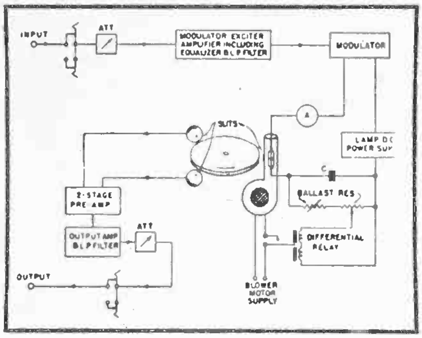


Fig. 7. Synthetic reverberation system using photoelectric recording of signal.

microphones to the pipe. Reverberation times of better than 3 or 4 seconds can readily be obtained with this unit, and it is quite flexible in operation. Since the pipes can be coiled up to save space, the entire unit is capable of being mounted in a single large relay rack.

Mechanical time delay

The most economical and most practical method of producing synthetic reverberation is by use of mechanical time delay, primarily because the times involved can so readily be attained by simple mechanical motions. For example a phonograph record turning at 78 r.p.m. makes 1⅓ revolutions in one second, therefore a sufficient number of pickups placed along the groove can give the time delay required for reverberation effects. A system of this type has actually been suggested, but has not been used to any extent because of the obvious difficulties and inconveniences of recording on discs and picking up the recorded signal by as many as four or five pickups.

However, several other units have been designed which make use of the principle of time delay by a simple mechanical motion, but use methods of signal injection and pickup which are simpler and more flexible in their applications. One method makes use of optical recording on a phosphor-coated disc, while a number of later ones use magnetic recording on wires and tapes.

The principles of operation of the electro-optical time delay system are shown in the diagram of Fig. 7. A rotating disc whose rim is coated with fluorescent material serves as the recording medium. The sound signal is recorded on the edge of this disc by means of a modulated light source and a simple optical system, and the signal is picked up at later points along the path of rotation by photocells through their associated optical systems. Since the light from a fluorescent material decays logarithmically an effect similar to reverberation is obtained—with the effective reverberation time depending upon both the speed of rotation of the disc and the decay characteristics of the phosphor.

The development of magnetic recording techniques has permitted a considerable simplification in mechanical time-delay reverberation units, since signals can be recorded and erased with great ease. By use of the latest design developments in magnetic recorders, a simple and compact mechanical time delay unit using magnetic tape as the recording and signal storage medium can be inserted directly as the time delay unit in the basic reverberation system shown in Fig. 2. Such a unit can be set up to perform all the functions of any of the other time delay systems which have been described, with a considerable saving in space, convenience and flexibility of operation.

The basic principle of the magnetic recording system as it is applied to the time delay function is shown in Fig. 6. The signal to be delayed is applied to the recording head, which records it upon the moving tape. At spaces along the path of motion of the tape are placed the pickup heads, the spacing being chosen according to the speed of the tape and the desired time delay between successive reflections. Since the desired time delay between reflections is of the order of 10 to 20 milliseconds and not greater than about 50 milliseconds if separate reflections are not to be heard instead of reverberation, the tape must move quite rapidly and the recording and pickup heads placed quite close together. (A typical time delay of about 25 milliseconds with a spacing of about one inch would require the tape to be moving at a speed of 40 inches per second.) One of the greatest advantages of the magnetic tape sytem is that the signal can be erased, which permits a considerable simplification in the equipment by the use of an endless belt of tape so that no recording material need be inserted or removed until the tape breaks. In early units of this type the click caused by the tape joint presented a problem, and switching methods were required to cut off the output during the time the joint passed through the pickup heads. However, at the present time the splicing of magnetic tape has become a simple procedure and this problem is no longer a very important one.

The rest of the magnetic reverberation unit is the same as the basic system of Fig. 2, with suitable attenuators and frequency-response equalizers to give the desired reverberation time

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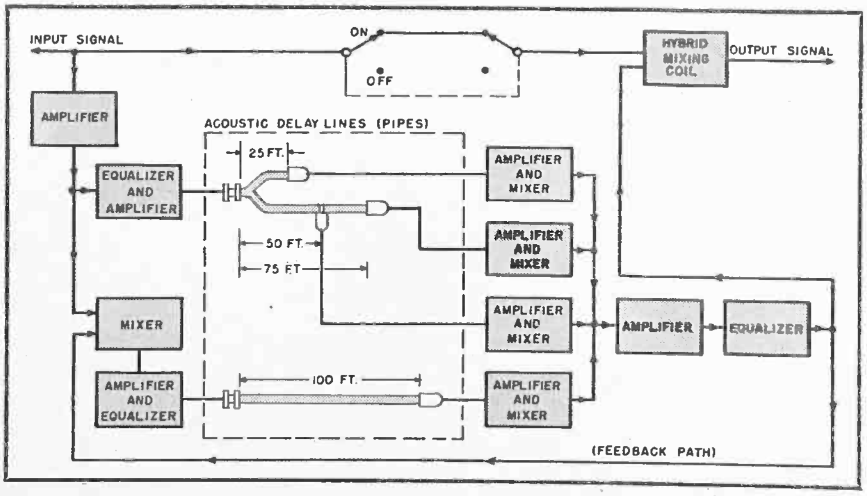
Fig. 8. Synthetic reverberation system using long pipes as acoustical delay lines.



An Improved AUDIO AMPLIFIER

Top chassis view showing controls and component location in the AB-5 amplifier and preamplifier driver.

By CURTIS W. FRITZE and JOHN D. GOODELL
Minnesota Electronics Corp.

Refinements in a basic amplifier are described, including a cross-coupled input circuit, balanced output, and improved preamplifier and equalizer.

SOMEWHAT more than a year ago a referenced article appeared in this publication describing an unusual audio amplifier.* The most unique characteristic of this circuit was its ability to operate with either beam power tetrodes or triodes as power output tubes. These tubes were directly interchangeable without circuit adjustments. Although this feature was interesting and may have served to settle some arguments, the remarkable frequency response range and extremely low distortion achieved were of more basic importance. Frequency response extended from below ten to over 200,000 c.p.s. within 1.5 decibels. Intermodulation distortion with either tube type was shown to be less than 1% at five watts using 100 and 7000 cycles per second mixed four to one as a signal source. At ten watts for the triodes and 16 watts for the beam power tetrodes intermodulation was less than five per-cent. At that time this amplifier was believed to approach ideal performance characteristics so closely that further design work on such circuits was discontinued.

Experience with a large number of these units in operation as laboratory standards, in radio and recording studios and high quality music systems proved these conclusions to be valid. In some applications it was found that greater flexibility with respect to input and output facilities would be advantageous. For example, it would be convenient for the amplifier to be capable of handling either a balanced push-pull input, a single ended input or input mixing of two signal sources. A balanced line output completely isolated from the balance of the circuits was desired in some instances. Many other circuit improvements were suggested and the entire amplifier was analyzed carefully stage by stage. The result is a new version that is actually superior in laboratory measurements. From the standpoint of listening tests under the most critical and rigorously controlled conditions with a variety of high quality associated equipment, it has not been possible to observe any improvement in music reproduction that could be recognized with sufficient consistency to warrant conviction of superiority in this design. It does provide greater flexibility for special applications, and for high quality music systems a suitable preamplifier driver has been designed.

Through correspondence with users of the original amplifiers and from field experience with a large number of installations it was determined that with a few isolated exceptions the amplifier was used exclusively with beam power tetrodes. It was decided that the interchangeability of the output tubes was not of sufficient practical value to warrant retention in the new design. This made possible the use of a special feedback loop from a push-pull secondary winding on the output transformer connected in the cathode circuit of the output power stage. Thus the previously used feedback loop from the loaded secondary could be eliminated. This increases the power handling capabilities at very high frequencies and permits isolation of the loaded secondary from the chassis ground. It is possible that the new design could be adapted to triodes, but no reason for doing so discourages design work along these lines.

As previously indicated, the initial consideration in the new design was to provide greater flexibility of input circuits. It was also desired to increase the gain so that an input of approximately one volt would drive the ampli-

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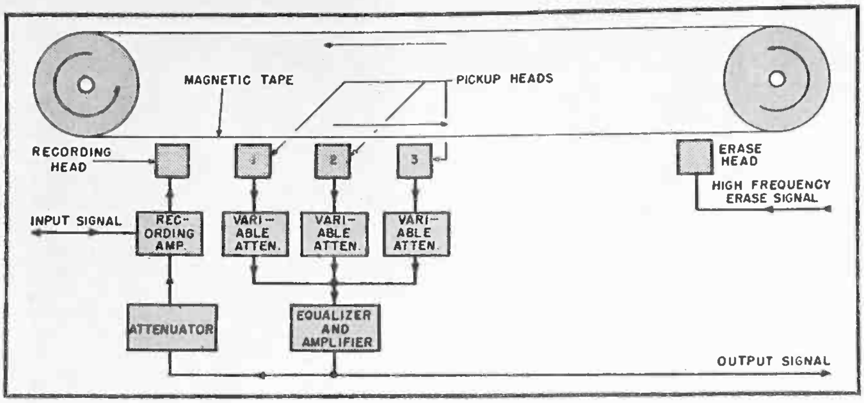

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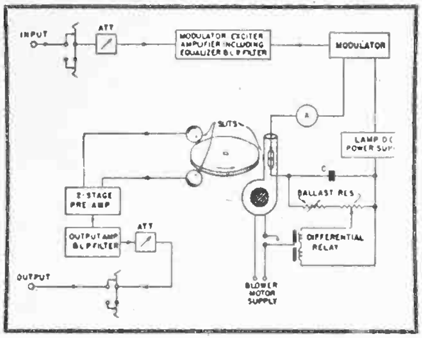

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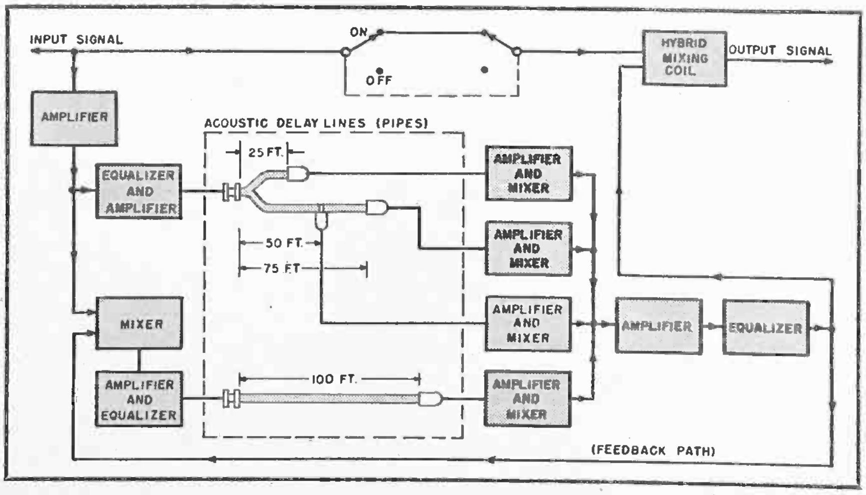

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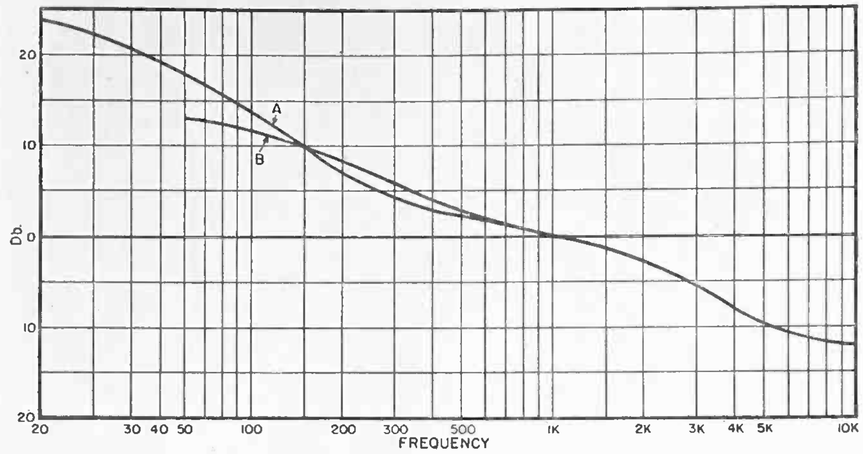


Fig. 1. (A) Standard equalization curve, and (B) LP equalization curve.

fier to full output. In the earlier design three volts of input signal was required. The cross coupled phase inverter originally described in RADIO-ELECTRONIC ENGINEERING, November, 1948, was investigated and incorporated with certain modifications of the values in terms of minimum intermodulation. It was also necessary to adjust the circuits in order to provide a suitable return point for the feedback loop from the output transformer. In this circuit V_1 and V_2 are cathode followers. The cathode of V_3 is connected through a suitable bias resistor to the cathode of V_1. The grid of V_3 is cross coupled to the cathode of V_2. Similarly the cathode of V_4 is connected through its cathode bias resistor to the cathode of V_2 and its grid is cross coupled to the cathode of V_1. Hence the signal appearing across the cathode loads of cathode followers V_1 and V_2 appears as the signal voltage for V_3, and the same voltage shifted 180 degrees is the signal voltage for V_4. Any signal appearing across the cathode load of V_1 or V_2 appears as a signal of suitable phase at the grids of V_3 and V_4. Any signal applied to the input of either cathode follower appears as an output of the phase inverter. This signal may be applied single ended to one of the follower grids, a push-pull balanced input applied to both grids simultaneously, or two signals from different sources applied one to each grid. The circuit has the advantage of an extremely high effective input impedance as a result of the cathode follower action, as well as relatively high gain from the second stage push-pull high mu triodes. The stage is direct coupled with low values of resistance and has no theoretical low frequency limitation as well as exceptionally good response at very high frequencies.

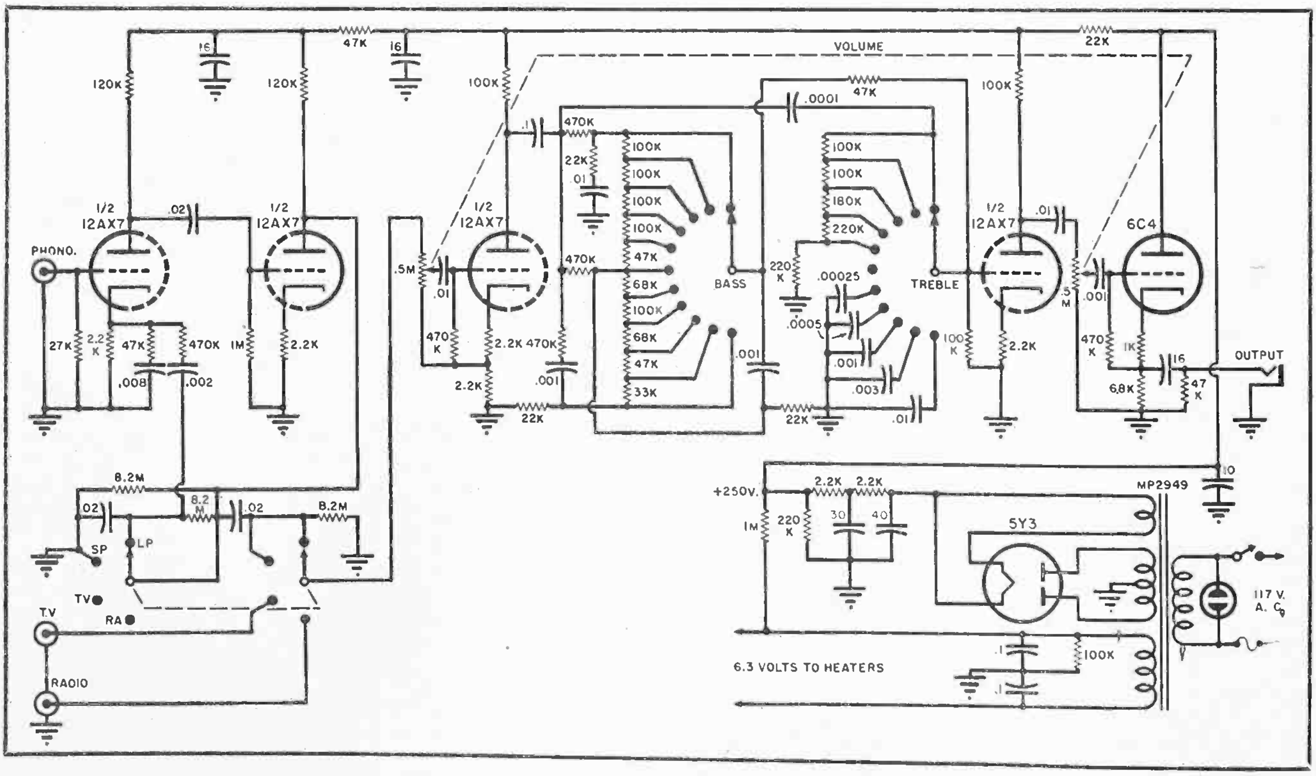
The third stage of the amplifier consists of two 6SJ7's pentode connected as high gain push-pull drivers. These tubes were chosen for their gain and high output voltage capabilities. A small portion of the load resistance is inserted in the cathode circuits. This increases the input impedance at high frequencies, provides current degeneration and a convenient tap for the direct coupled feedback loop from the plates of the output tubes. The next stage is a push-pull cathode follower stage used to provide a high input impedance for the power amplifier. The output impedance of the cathode follower circuit is approximately

$$Z = r_p/(1 + \mu),$$

very close to 500 ohms. Thus the reflected input impedance of the 6L6's has essentially no effect on the driver stages.

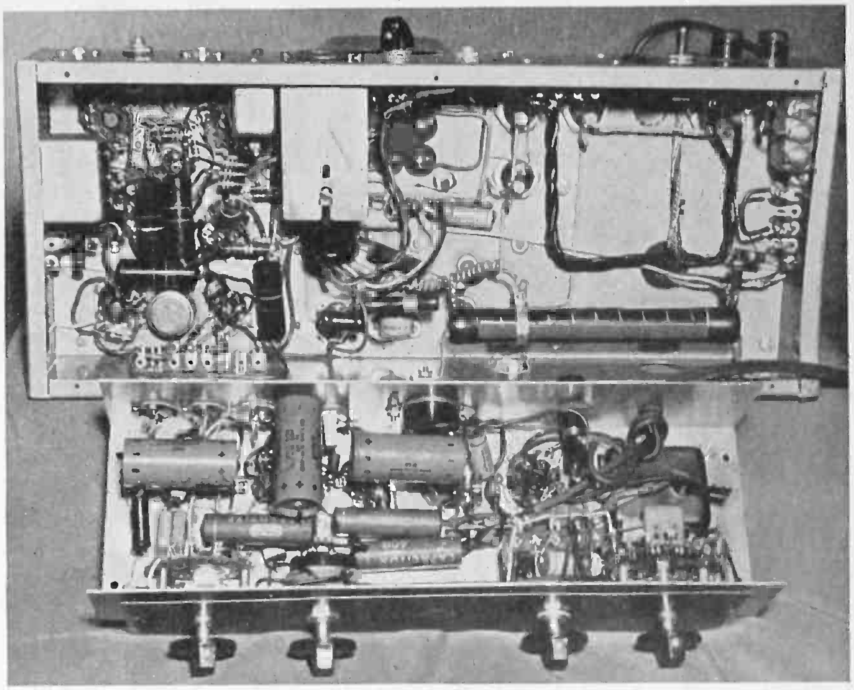
The output stage is a pair of 6L6 push-pull beam power tetrodes with direct coupled feedback from the 6L6 plates to the cathodes of the 6SJ7's. The 6L6 cathodes are connected to the feedback winding on the output transformer. Bias is obtained by means of a cathode bias resistor from the center

Fig. 2. Complete circuit diagram and component values for the AB-5 preamplifier-driver.



tap of the feedback winding. A third feedback loop including the entire circuit is taken from the output transformer feedback winding to the input cathode followers. All of the feedback loops are direct coupled so that frequency discrimination is minimized. A similar amplifier with no feedback would have a gain of approximately 40,000 to the plates of the output tubes. This amplifier has a gain of 400. The degenerative voltage feedback is thus calculated in the region of forty decibels. Ordinarily this large amount of feedback is difficult to obtain without tendencies toward oscillation. In this amplifier the fact that the feedback loops are direct coupled and balanced through the entire push-pull circuits eliminates this problem and no oscillation occurs at any frequency under any load conditions.

The 6U5 electron ray tube provides a unique method of observing conditions of overload or serious unbalance caused by tube failure. Under normal conditions of operation no voltage appears at the grid of the 6U5 except for unbalanced transients. The signal is controlled by balanced resistors from the plates of the output tubes, and unless there is unbalance the inputs cancel. An unbalanced condition will produce a strong signal to the grid of the 6U5 and the visible indication will flutter violently. This effect may be checked by removing one of the driver or output tubes and observing the indicator tube. Some motion of the indicator tube pattern may be expected as a result of slight unbalance inherent in the signal or from stray wiring capacitance during normal operation, but this is easily distinguished from a condition that indicates serious trouble. Operating at relatively low levels it is quite astonishing to observe how little difference there is in the audible result from removing one of a pair of push-pull output tubes in a well-designed circuit, and this indicator arrangement often saves a good deal of guesswork when the unbalance is audibly questionable.



Wiring and component placement for the AB-5 amplifier and preamplifier driver.

In all of the circuits it is necessary to pair the "mirrored" resistors within approximately 1%. If this is accomplished with care minor unbalances

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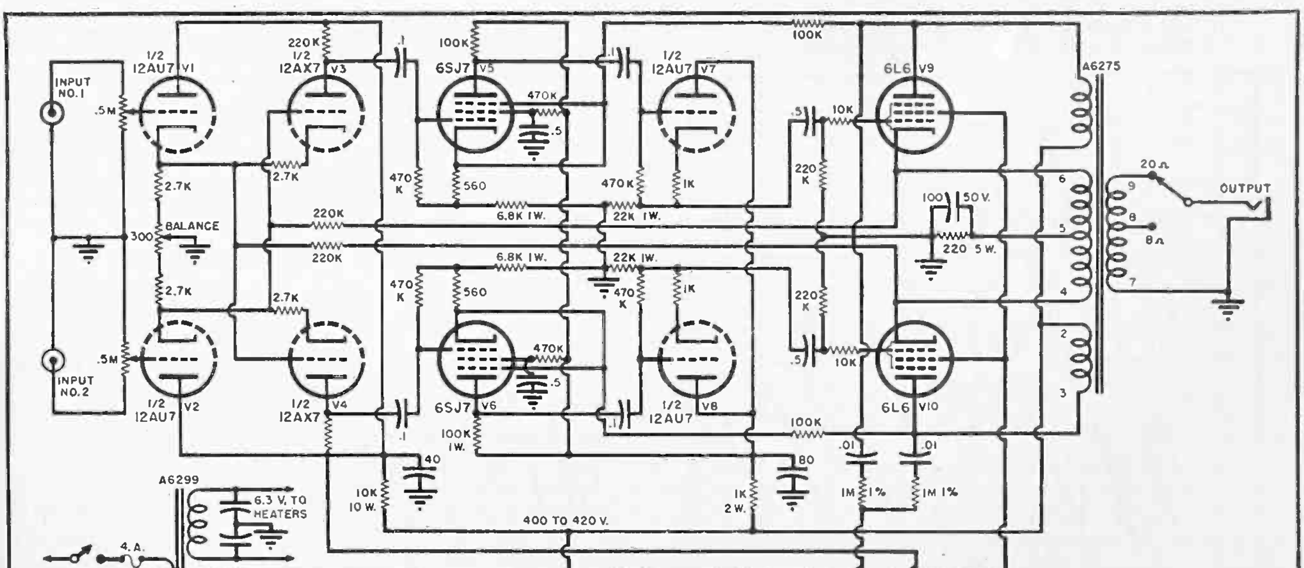
Fig. 3. Complete circuit diagram and component values for the AB-5 power amplifier.



Graphical Determination of Nonlinear Distortion

By A. K. CHATTERJEE and G. H. FETT
Dept. of Electrical Engineering, U. of Illinois

Specially constructed characteristic curves permit distortion analysis in the presence of either voltage or current feedback.

IT IS generally known that feedback in an amplifier can be used to decrease nonlinear distortion. It has been shown that under certain conditions the decrease in distortion is proportional to the magnitude of the quantity $1/(1-KB)$, where K is the amplifier gain without feedback and B is the feedback factor. However, the mere fact that the amplifier does have nonlinear distortion means that the method by which the improvement is calculated is questionable, for that calculation is based upon linear circuit theory. It is true that the error is small under most conditions because the amount of distortion is small in the first place. When the output approaches the overload point the error will be large. This fact suggests that a graphical analysis will prove helpful in solving the problem. In making this analysis some other interesting points will also be discussed.

A graphical analysis is possible if the feedback network can be conceived as a component of the tube, and the tube characteristics are altered to produce an equivalent tube. A set of modified plate characteristics of the vacuum tube will enable the engineer to not only determine graphically the equivalent tube characteristics but also to find the magnitude of the distortion.

Let the amplifier with feedback be represented by the simplified diagram of Fig. 3. The diagram leaves out the details of the network so that attention is focused on the general method. The plate diagram of the vacuum tube, the plot of i_b as a function of e_b for various values of grid voltage e_c, is shown by the solid lines of Fig. 1. Now the input voltage e_i and the grid voltage e_c differ because of the feedback voltage e_{fb}, and the bias voltage E_{cc}. It will be our problem to relate e_i and i_b.

(a) *Voltage feedback*

Suppose that the feedback voltage is given by:

$$e_{fb} = B\ e_b$$

where B is the feedback factor. The grid voltage e_c is a combination of all of the voltages of the grid circuit, or

$$e_c = E_{cc} + e_i + e_{fb} = E_{cc} + e_i + Be_b$$

The sign of B can be positive or negative depending upon the network con-

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Fig. 1. Plate diagram. Dotted lines are equivalent characteristics to account for voltage feedback.

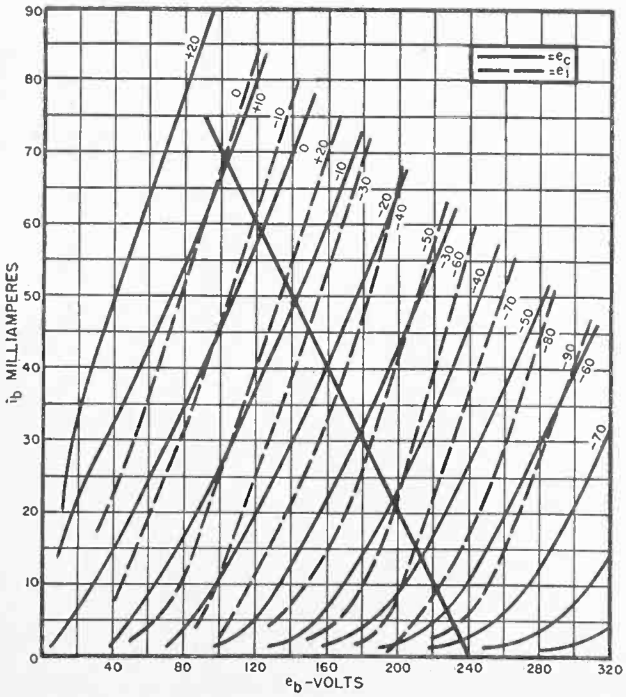
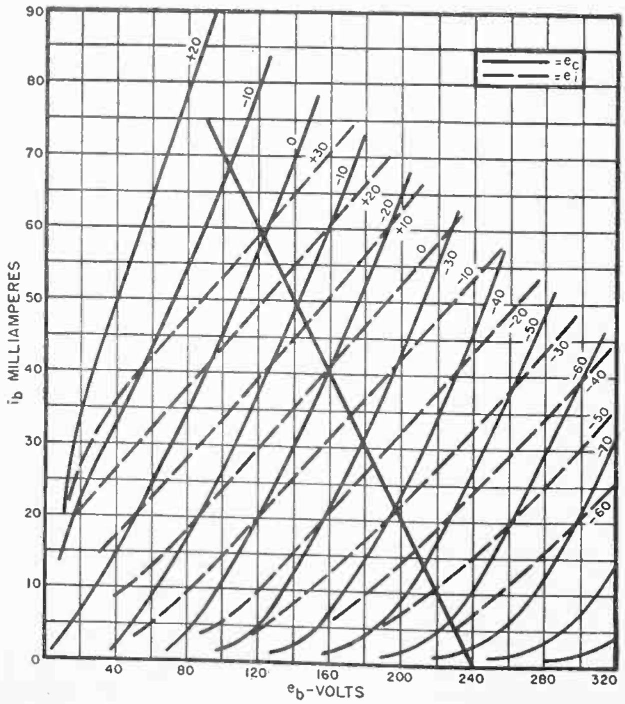
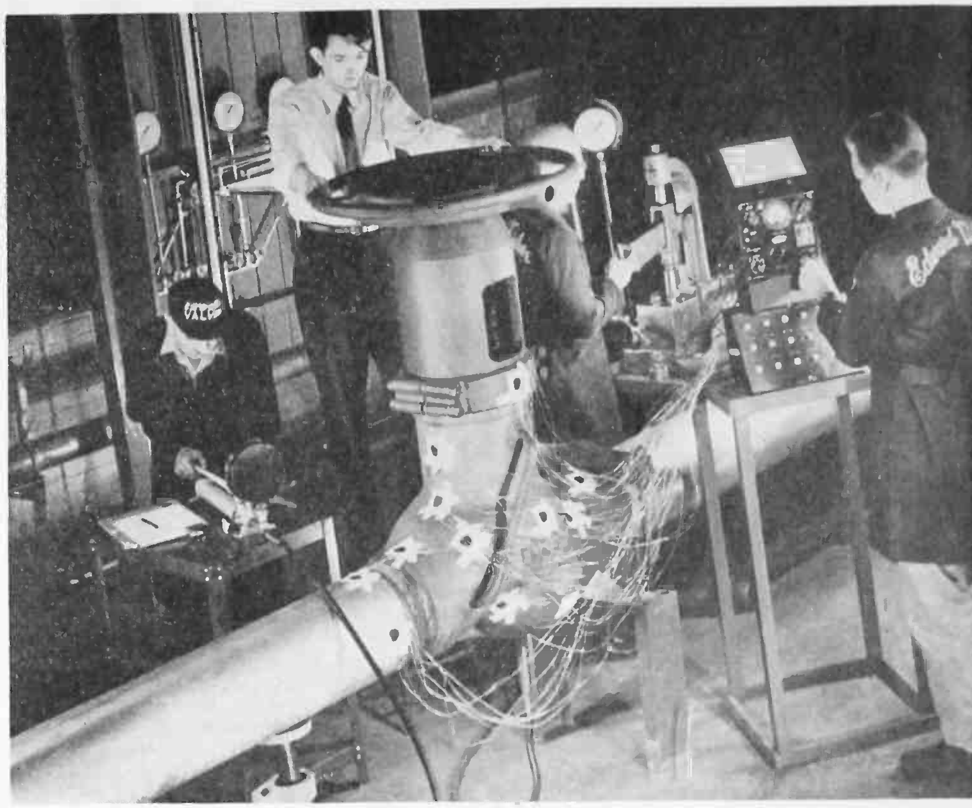


Fig. 2. Plate diagram. Dotted lines are equivalent characteristics to account for current feedback.





Instrumentation of a valve to determine stresses.

STRESS and STRAIN DETERMINATION

By ALVIN B. KAUFMAN

Installation and calculations required to determine stress or strain in a member.

THE application of strain gauges to numerous industries has been delayed through a lack of knowledge of where and how to apply strain gauge equipment for an economic solution to perplexing problems.

Strain gauges are not a cure-all, but in their place have proven a powerful aid to the engineer in his search for methods of determining load distribution in complex structures. It is a maxim that measuring equipment by its very nature must disturb the true condition surrounding any phenomenon, but the size and weight of the strain gauge is generally so small in comparison with the tested structures that its effect may safely be ignored. The strain gauge consists of a strand (or multi-strands) of resistance wire in intimate contact with the metal structure. It is cemented to the structure solidly enough so that any change in length of the structure material (*i. e.*, strain) will change the length and diameter of the gauge wire and consequently its resistance. This change of resistance is then interpreted and recorded in terms of strain (dS), stress (p.s.i.), bending or deflection (inches), total load in pounds, or any of a number of functions when employed with a transducer for measurements.

This article will endeavor to answer questions on the installation and the calculations required to determine strain or stress in a member; it will not be concerned with mathematical analysis of structure stresses, but rather the methods used to determine the strain in an element of a complex structure.

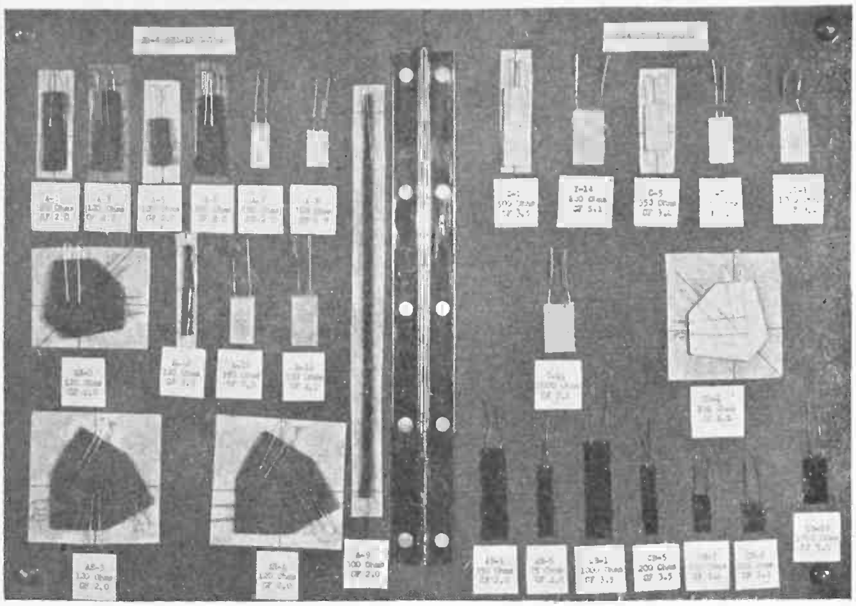
Where force rings or links may be employed, relatively simple equipment may be constructed to indicate load, either in compression or tension.[1,2] However, it is quite impractical to use this sort of equipment on a completed structure. Not only this, but it is usually impossible to "calibrate" a completed structure. Thus, when strain gauges are applied to the structure, it is necessary to be able to directly read strain without any preliminary calibration by test loading. This can be accomplished with fairly high accuracy, strain indications generally being within 2 to 5% of the true value.

The strain gauge should be applied to an element or structure before any load is applied or it cannot indicate true total load or strain, but only the change in any existing load, after the gauge has been cemented in place.

The cross section area of the element need not be known to determine how close it is to the failure point, as the strain itself will indicate this, but it is necessary to know the cross section where qualitative load values are required. The strain will indicate the p.s.i. loading, but not the total load in pounds. Even here, the cross section area may be ignored where, as in a building, the *H* beam and its gauges may be calibrated by machine or weights before installation in the building or structure.

Such structure elements may have from one to four gauges installed. On a beam two active and two dummy gauges may be installed (as with a link) or just two active gauges with a separate dummy plate, where it is desirable not to include Poisson's ratio in the required calculations. It may be desirable to install single gauges in some installations. On sheet metal where the direction of the forces might be quite unknown and bending may occur, it is necessary to employ three to six gauges in a rosette or delta wherein all three values, with their positive or negative signs, are measured and integrated to indicate the true direction of the load and its absolute value. Where the strain or stress magnitude only is required and direction of the force is unimportant, then a shear installation is made with from two to four gauges installed as a half or full bridge in a special configuration as discussed later.

Generally speaking, one or two

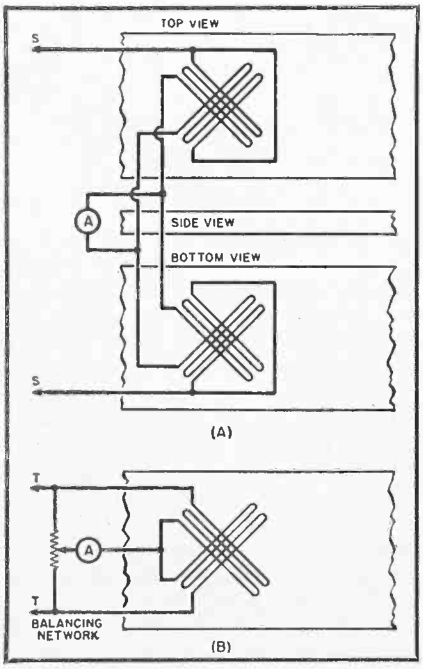


A few of the many types of strain gauges available.

gauge applications will suffice for most test setups. Here any dummy gauges are mounted on a flat metal plate of the same composition as that upon which the active gauges are mounted. This insures that the bridge will be adequately temperature compensated, as the dummy plate and gauges exposed to the same temperature conditions of the active gauge mounting will have the same coefficient of expansion and change of resistance with temperature and expansion as do the active gauges.

It is preferable normally to secure as much signal output as possible from the bridge for a given strain (dS).

Fig. 1 (A) Wheatstone bridge (balancing network not shown). (B) Half-bridge.



In a beam or normal tension and compression situation this allows two active gauges on the bridge, both having the same sign of dS. If these gauges are placed catacorner in the bridge, their outputs will add and result in a greater bridge output signal.

The output signal for a single active gauge is $dE_o = \frac{1}{2} R_g \; I \; K \; dS$ where dE_o is r.m.s. or d.c. volts, I is the gauge current (generally ½ total bridge current), K is the gauge factor, and dS is the strain on the metal element. K gives the ratio of the change of gauge resistance to the strain producing it. This change is sometimes twice the strain. The factor is supplied by the gauge maker. As all of these factors and voltages are known, then dS may be solved for.

Where more than one active gauge is employed, the formula is almost the same:

$$dS = \frac{dE_o}{R_g \, I \, K \, N/2}$$

where N is the number of active gauges.

With the strain known, the load in pounds may be easily calculated as $P = dS \cdot A \cdot E$, where P is the load in pounds, dS the strain, A the cross section area in inches, and E the modulus of elasticity.

The above formulas apply only when all the gauges under strain are mounted axially with the load or strain direction. Where dummy gauges are not on an auxiliary plate, but cemented on the stressed structure at right angles to the axial stress, the bridge output will be higher than indicated by the formulas by a factor of u or $2u$, where u is the designation for Poisson's ratio. This is the "shear" installation when used on metal sheet. Poisson's ratio indicates the ratio of lateral strain to a given axial strain. Simply stated, a bar loaded axially will have its diameter increase or decrease depending upon the sign of the axial load. The lateral strain, produced at right angles to the axial load (by that load) is approximately between 0.25 and 0.33 for steel and aluminum alloys and is a shear load. This produces an added signal from the dummy gauges. For a half bridge, with the dummy on the structure, the correct factor is $dE_o \; (1+u)$ while for the full mounted bridge, two active, two dummy, it is $dE_o \; (1+2u)$. As all materials, regardless of form, are responsive or obey Poisson's ratio, then these formulas are valid for bar, rod or sheet stock, singly or in structure.

Amplification may be used with the strain gauge bridge and oscillographic recordings made, or a *Brown*, *Bristol* or *L & N* potentiometer may be used and any d.c. bridge output voltages measured. Amplification may be of the d.c. variety or an a.c. signal may be applied to the bridge and any a.c. unbalance amplified and rectified into a strain signal by the carrier or phase sensitive system.

In some cases it may be possible to use a galvanometer and take direct readings. Usually structure loadings are too light to give sufficient dS for this purpose. However, this may be determined from $I_g = dE_o/Z_o$ where dE_o is as calculated previously and Z_o is equal to R (one leg of the bridge) plus the internal resistance of the galvanometer, *i.e.*, $Z_o = R_g + R_{gal}$ .... I_g is given in amperes.[3]

The above formulas will give accurate results if the gauges are cemented properly to the structure with the technique described in *Baldwin-Southwark* literature and in particular Bulletin 279B. With accurate testing equipment, over-all results of plus or minus several percentage are possible. The ultimate accuracy depends on a number of conditions.

One of the major problems associated with the strain gauge bridge, particularly when used with an amplifier, is its calibration when it is impossible to test load the structure, at the strain gauge point, with a known load. Even where the bridge output voltage is read directly on a potentiometer, a variation of bridge supply potential will cause error. For these reasons it is deemed important to make a "bridge" calibration.

This may be accomplished a number of ways as outlined below:

a) Using a mechanical calibrator, which is connected in the bridge in place of the measuring gauges. This may consist of two or more gauges mounted on a calibrated cantilever beam (deflection vs. dS known).

b) By the electrical calibration of the amplifying equipment with a known dE_o possessing the same generator impedance.

c) By applying a known unbalance to the bridge, causing the recording meter or galvanometer to deflect a measurable quantity.

Of all these systems, the last one is most commonly used, being suitable for instant calibration of any number of channels and requiring no special set-up.

If it is possible to make one arm of the bridge vary by a known resistance, a simulated stress will have been produced and calibration of associated equipment will have been accomplished as outlined above.

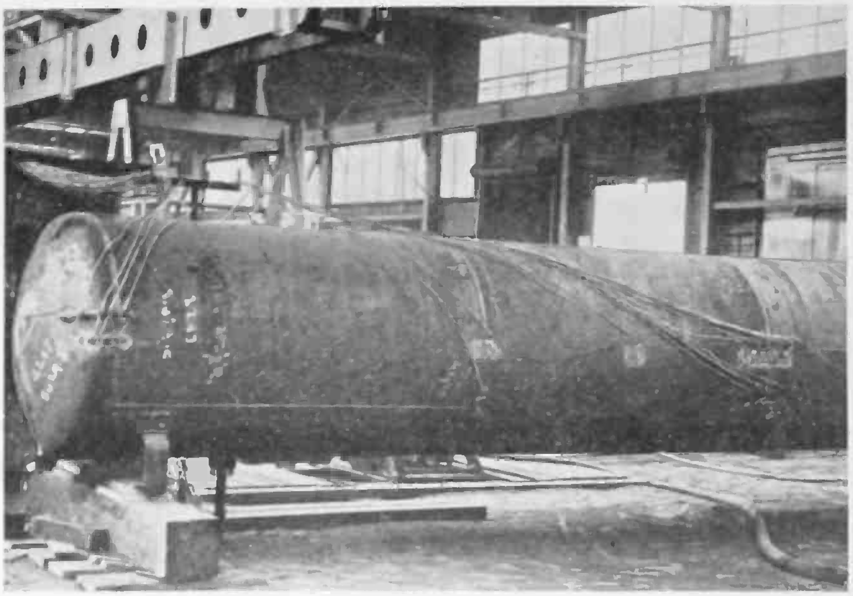
Generally speaking a precision calibration resistor of 100,000 ohms is used, but this may vary widely upon the recording sensitivity. The higher this value of resistance, the less simulated strain and calibration error. The error from calibration by this method is generally between ¼ and ½%.

Balancing is necessary to cancel out any normal variation of resistance between strain gauges. This can affect calibration accuracy. The gauge resistance is normally held to ±.0015% in manufacture in order to insure easy initial balancing. Its exact resistance is not critical as the dR_g change is of the same percentage regardless of gauge value (where K is constant), and the dE_o is the same regardless of gauge resistance for a given strain.

The calibration always should be accomplished *across the active gauge*, which is usually in an arm of the bridge with the balancing resistors included, where one-half of the bridge is a transformer or other center-tapped power source. In this event any calibration error will be small. However, this is only feasible for a bridge with one or two active legs. Calibration in other legs may result in large errors.

In the shear installation, calibration is made across either gauge, the "u" factor being taken care of in the calibration formula. With a half-bridge there will be no error; with the full bridge, one-half is shunted by the balancing resistors and a calibration error will occur. This error may be high or low depending on where the calibration is made, gauge resistance, balancing resistance, and size of the calibrating resistor. This error may be as high as 2%.

Numerous factors influence the accuracy of the strain gauge. These are the change in resistance of the strain gauge with temperature, the coefficient of expansion and contraction of the wire in comparison with the material



Typical strain gauge installation on a boiler to determine stresses.

it is mounted upon, thermal e.m.f. between leads and gauge wire, and the cross sensitivity of the gauge.

Considering temperature resistance change of the strain gauge first, it becomes apparent that where a single strain gauge is used its change of resistance with temperature would cause an error in the absolute value of strain indicated. Where static strain indication is not important, this will result in a shift of zero reference but no inaccuracy of the dynamic strain indication. Normally a minimum of two gauges is used in an installation. One may be a dummy mounted on a similar alloy as the active gauge, or possibly mounted on the same structure. In this case, with two or four gauges in the circuit and mounted adjacent to each other, all the gauges will assume the same resistance at a specific temperature and no fraudulent signal will be produced. With the gauges not mounted on the same structure, although adjacent, it is possible, in some circumstances, that wide temperature gradiations exist which could cause error.

Copel, Constantan, or Advance wire

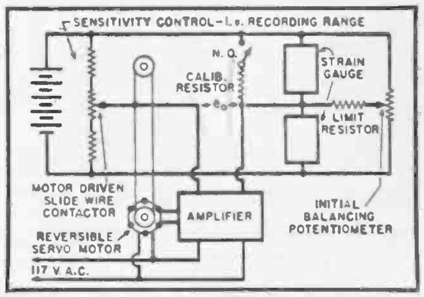
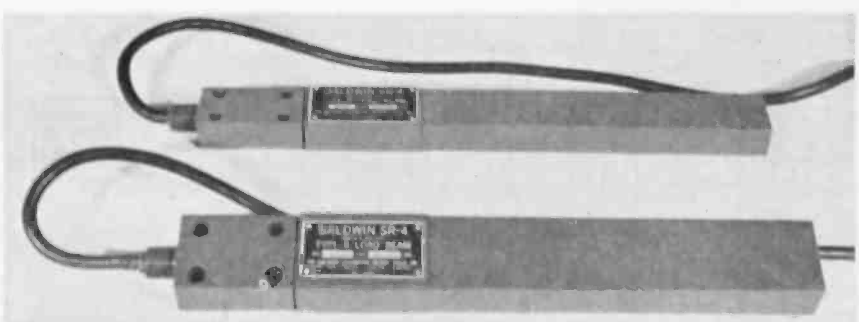


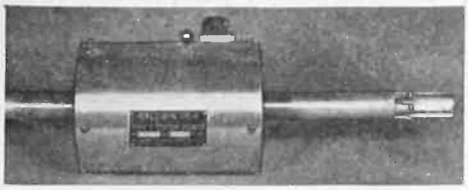
Fig. 2. Diagram of an automatic recorder for static strains.

of about one mil diameter are generally used for strain gauges because they display the smallest value of temperature coefficient of resistance.

The only indication error which may be missed is the result of a strain in the wire set up due to a difference between the thermal expansion of the wire and the material on which it is placed. Here again, this error will cancel where the dummy gauge is placed on the same material, at the same temperature. The same cancellation will occur with two or four active gauges mounted on the structure.

Strain gauged beams for the determination of torque or load without backlash or "give" in the system.





Typical torque tube assembly.

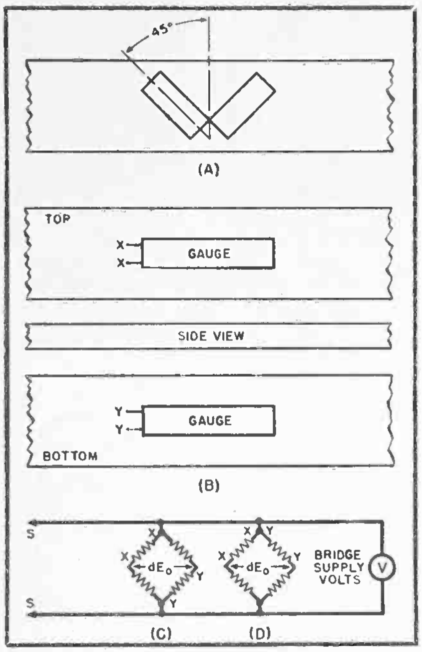


Fig. 3. (A) and (B) Torque tube installation. (C) and (D) Bridge wiring for axial load (left) and bending load (right).

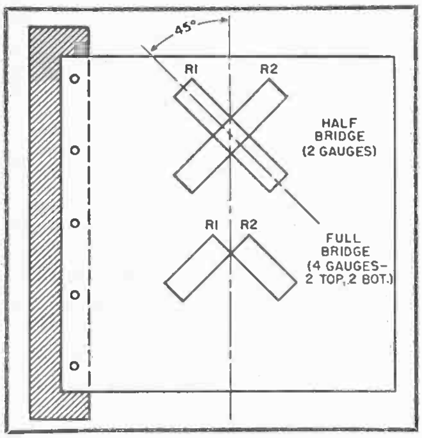


Fig. 4. Shear installation.

The next two factors are presented for interest only, having no appreciable effect on the strain gauge signal, but of sufficient value to raise a question were they not discussed.

All wire strain gauges consisting of a single strand wound back and forth to produce a high resistance gauge in a small space (as *Baldwin* SR4 gauges) are in some degree sensitive to strain transverse to the gauge axis. This will be seen clearly, with the gauge examined, when it is realized that there is an appreciable length of wire running laterally across the gauge (at the bends). For this reason the single value of sensitivity (or gauge factor, *K*) quoted by the manufacturer is valid only when there is a fixed ratio between the longitudinal and lateral strains to the gauge axis, as in simple compression or tension. Accordingly, in a complex stress, field corrections are necessary for extreme accuracy. Clearly the cross sensitivity will vary with the geometry of the gauge grids, which are made in numerous fashions. This cross sensitivity effect with the SR-4 gauge may amount to 3% of the total axial sensitivity.[4]

The thermal e.m.f. effect would appear at first glance to be a very serious one. The dissimilar metals, where the gauge wire contacts the lead wire, can generate high thermoelectric potentials. Copper to advance, for instance, will develop 44 microvolts per degree centigrade. However, there are two leads leaving the gauge. There are *two* thermoelectric potentials. These potentials are equal and opposite when these two contacts are at the same absolute temperature. The same situation exists throughout the electrical system, where brass, nickel, etc. terminal studs or feed throughs may be used. That these thermoelectric potentials cancel may be seen by examining the mechanism of thermoelectricity.

The installation of strain gauges on a structure, torque tube, or other miscellaneous device involves numerous items: allowable gauge current, number of gauges to use, preparation of surface where gauge is to be cemented, effects of bending upon axial installation, and corrections of formulas for various effects. Many of these items have been discussed, but a few notes are necessary in concluding this article.

Ignoring the type of installation, the actual gauge installation on the structure is quite simple and the cementing technique described fully on each package of SR-4 strain gauges. An important note, however, is that the gauge should never be installed on a plated or anodized surface. These types of surfaces cause the material to have both a primary and secondary modulus. The gauge must be cemented to the structure's primary metal if accurate results are to be obtained. Any surface coating may be removed by file or paper, but should be finished off to a smooth surface.

When it is desirable to have long term high accuracy, the use of bakelite gauges is recommended, otherwise the nitrocellulose type are quite satisfactory. The use of bakelite gauges is not enough where static strains are to be read over a very long period. It is necessary then to completely waterproof the gauge with suitable compounds. In this case the drift with age is of small magnitude.

The gauge current and its wattage dissipation depend mainly upon the material the gauge is mounted upon. A safe value is 25 milliamperes gauge current for normal installations. It is this factor which limits the bridge from having unlimited output. With this gauge current bridge output voltages of from one to 30 millivolts are not uncommon. Light structural loads may produce considerably less output.

An idea of the equipment required to measure the strain gauge load is thus indicated. Commercially a *Baldwin* SR-4 Strain Indicator may be used to read strain directly. This unit indicates directly in microinches and has Gauge Factor compensation. It is suitable only for static indications. Amplification systems are beyond the scope of this article and will not be discussed.

The six types of installations are as follows:

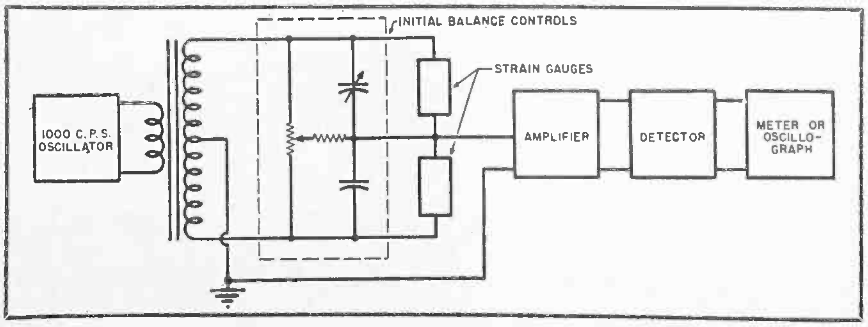
1. The shear installation is used on sheet metal to determine the maximum strain in the metal, where direction of the force is unknown. The gauges are mounted at 90° to each other as indicated in the drawings. A full or half bridge may be used. Special correction for Poisson's ratio has already been discussed. Fig. 5 indicates the installation configurations.

2. The axial installation for tension or compression loads is simple and has been discussed fully.

3. The bending installation is the

(*Continued on page* 29A)

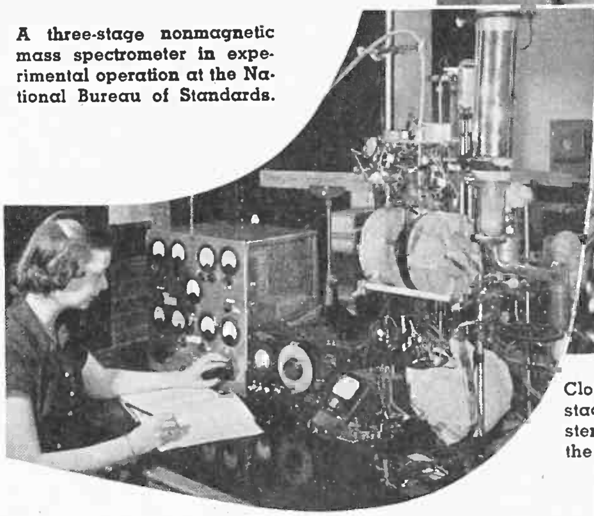
Fig. 5. Single channel standard recording configuration.



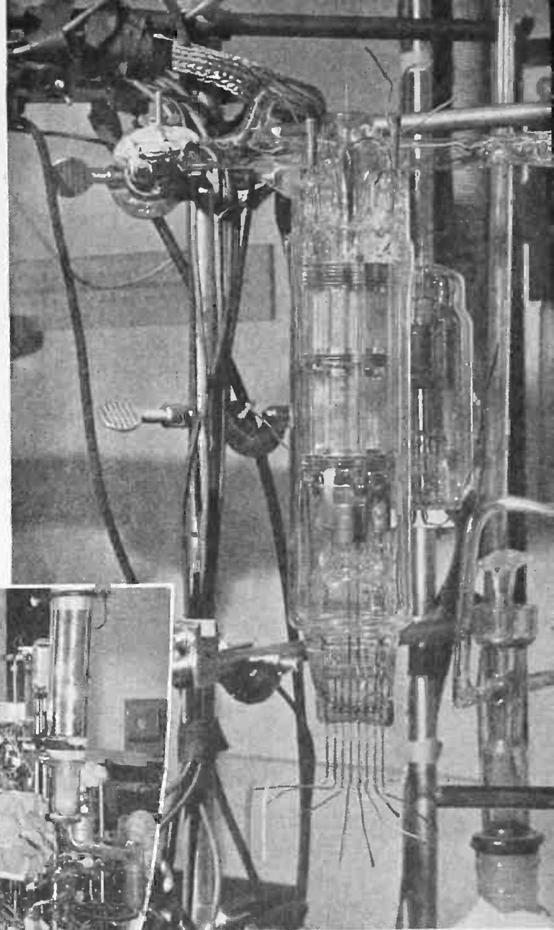
NONMAGNETIC MASS SPECTROMETER

This mass spectrometer, developed at NBS, uses the principle of velocity selection. A radio-frequency field replaces the magnetic field ordinarily used.

A THREE-STAGE nonmagnetic mass spectrometer, employing the principle of velocity selection, has been developed by Dr. Willard H. Bennett of the National Bureau of Standards. In the new spectrometer a radio-frequency field replaces the usual magnetic field. Combining unusually simple operation with small size, light weight, and high sensitivity, the instrument has promising applications in several fields of science and industry.



A three-stage nonmagnetic mass spectrometer in experimental operation at the National Bureau of Standards.



Close-up of a completed three-stage tube. Three sets of tungsten-wire grids are spaced along the tube to form the three stages.

In ordinary mass spectrometers a high intensity beam of ions is bent in the field of a large iron magnet, passed through a narrow slit, and then focused accurately on a narrow receiving slit. The nonmagnetic mass spectrometer uses neither bending nor focusing. Ions produced in the ionization chamber travel in parallel paths through the tube, a glass cylinder 8 inches long and 2 inches in diameter. Three sets of three tungsten-wire grids are spaced along the tube to form the three stages. A radio-frequency potential is applied to the middle grid in each stage. An additional grid, with a negative potential applied, follows the final stage and in the absence of r.f. potential turns back any electrons that may have arisen anywhere along the tube. Following the final grid is a collector plate whose potential is sufficiently positive to repel all but the desired positive ions.

The distances between grids and between stages are selected very accurately so that for any particular ion mass there will be a single definite frequency of the radio-frequency potential which can speed up ions of that mass as they pass through each stage. The increased speed of these ions enables them to overcome the opposing potential on the collector while all other kinds of positive ions are turned back. Successive distances between stages must be chosen so that the r.f. potential will complete an exactly integral number of cycles during the time it takes for an ion of the desired mass to travel between stages, picking up maximum energy in each stage. The best combination of these integral numbers for a three-stage tube turns out to be 7 and 5, and in actual operation the seven-and-five cycle tube has completely separated the isotopes of chlorine. From this observation it is estimated that a four-stage tube, using integral numbers 13, 11, and 7 should resolve masses differing by only one per-cent.

The spectrometer can make use of all the ions that can be made to emerge through a grid several centimeters in diameter, and a new kind of positive ion source has been developed to take advantage of this. A spiral filament delivers an ionizing electron current of 100 milliamperes through a double grid attached at one end of a hollow metal cylinder 3 centimeters deep. The far end is closed by a grid and near it is another grid at a negative potential which turns back all electrons and draws positive ions out from the cylindrical enclosure. At a pressure of 4 x 10^{-5} millimeters of mercury the source delivers a positive ion current of 100 microamperes.

By an appropriate change in ion source and reversal of potentials, the spectrometer works well for the study of negative ions, an important feature of the new instrument. Since negative ions are in general much less abundant, when they exist at all, the unusual sensitivity of the Bennett spectrometer is a great advantage in the study of negative ions.

In the development of vacuum tubes, as for example, power transmitting tubes, such a spectrometer can be very helpful in analyzing gases and vapors that are evolved from the heated electrodes.

Surface reactions are another group of processes for which the new spectrometer can be used, separately analyzing the positively or negatively charged components. In gaseous discharges, the instrument can be used for direct analysis of the ions without magnetically disturbing the discharge.

One of the urgent needs of the U. S. Bureau of Mines is an instrument which can be used in the field for the analysis of small percentages of hydrogen in the manufacture of helium. The new spectrometer has already demonstrated adequate sensitivity and resolution for this

(Continued on page 25A)

MICROWAVE PROPAGATION And Site Planning

Such factors as path attenuation, line-of-sight, fading, and repeater stations must be considered when planning microwave installations.

By J. RACKER
Federal Telecommunication Laboratories

PROPAGATION of microwaves is limited by the well-known line of sight principles. However, this does not limit application of microwave links to short distance communication since repeater installations can be used to extend the range of properly designed equipment up to several thousand miles. This article will cover the major considerations, both electrical and economic, involved in the selection of sites for point-to-point microwave link systems.

In system design it is necessary to secure a reasonable compromise between cost and performance. Because of the large fixed costs incurred for each repeater installation, it is essential to select the minimum number of sites that will give the required performance. On the other hand the selection of repeater sites at too great a separation may require excessively high and costly towers, or may degrade system performance, either in signal-to-noise ratio or in reliability.

Once the number of repeater points to be used for a given path is determined based on the requirements of the system, the actual selection of sites is not only dependent upon the propagation conditions, but also involves such problems as the availability of the site selected at a reasonable price, accessibility to site under adverse weather conditions, source of primary power, and possibility of using existing structures to support antennas. Frequently the sites that appear most suitable on the basis of line of sight charts and topographical conditions will not prove acceptable because of the other factors mentioned above. It is therefore advisable to choose two or three alternate sites for each primary one selected.

Maximum Attenuation of Each Hop

As a result of the relatively large amount of noise introduced in microwave receivers as discussed in previous articles[1,2], the signal-to-noise ratio of a given system is frequently considered the most critical factor. Hence, as a starting point, the number of repeater points and the characteristics of each hop are calculated on the basis of a given signal to noise ratio.

The noise introduced by each receiver in the system can be expressed by the following relationship:

$$P_n = P_0 F G \quad (1)$$

where $P_0 = KTB$ is the noise present at the input to the first stage, F is the noise factor of the receiver, and G is the gain of the receiver.

The total noise introduced by n identical receivers would therefore be:

Typical two-way microwave repeater installation with side "drop channel" link installed by Keystone Pipeline Company.

$$P_{nn} = P_0 \, F \, G_n \quad . \; . \; . \; . \; . \; . \; . \quad (2)$$

The power P_{rn} required at the nth receiver to attain the necessary signal to noise ratio is obtained by:

$$S/N = 10 \log \frac{P_{rn}}{P_{nn}}$$

$$= 10 \log \frac{P_{21}}{P_n} \text{ for one hop.} \quad (3)$$

where S/N is expressed in db.

For the case where all hops are equal, and the signal-to-noise ratio at the output of the last receiver is proportional to the signal-to-noise carrier ratio at its input, an increase of received power of 10 log n over the power, P_{r1} required for one hop, must be provided at each repeater. This result can be expressed in terms of path attenuation A. For a single hop the maximum attenuation that can be tolerated is equal to:

$$A_{m1} = \frac{P_t}{P_{r1}} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (4)$$

where P_t is the transmitter power delivered to the antenna. If there are n-1 repeaters (or n receivers), then the maximum path attenuation for each hop (all hops assumed to be equal) will be:

$$A_{mn} = \frac{P_t}{P_{r1} \; (10 \log n)} \quad . \; . \; . \; . \quad (5)$$

This equation can be expressed in db. by the following equation:

$$A_{mn} = A_{m1} - 10 \log n \; . \; . \; . \; . \; . \quad (6)$$

The total path attenuation, A, of the signal between transmitter and receiver is given by the following expression:

$$A = A_1 \times A_2 \times A_3 \times A_4 \quad . \; . \; . \quad (7)$$

where A_1 is the absorption factor, A_2 is the atmospheric factor, A_3 is the topographical factor, and A_4 is the free space factor.

(It should be noted that the attenuation of transmission lines, covered in previous articles[2,3], must also be considered since the lower the line attenuation the higher P_t will be, increasing maximum allowable path attenuation.) The absorption factor, A_1, is almost equal to 1 for frequencies less than 10,000 mc. and can therefore be neglected for microwave links operating in this range. Even under the most adverse conditions—heavy snow or rain—at the highest frequency, this effect will be small compared to the normally available margin for fading.

The variation in total path attenuation giving rise to unfavorable propagation conditions, or fadings, are due to changes in the atmospheric factor A_2. This factor represents variations in propagation due to stratification of the atmosphere. This effect will usually be most pronounced in the summer months over water rather than over land circuits.

Even with a favorable topography, fadings of the order of 20 db. are occasionally observed at all frequencies. The exact cause of these fadings is not completely clear. For the communication engineer the essential question is to know how often fadings of a certain amplitude, measured in db. deviation with respect to free-space conditions, are likely to occur and how long fades are likely to last.

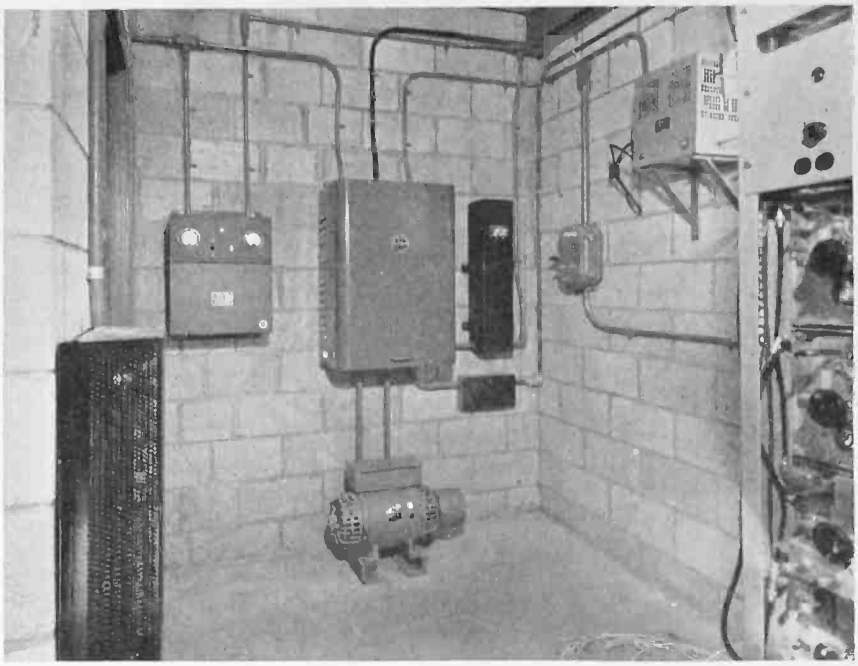


Fig. 1. Automatic battery charger, voltage regulating unit, and control unit for switching in emergency power when needed at the relay station.

The available information to date is based on statistical measurements at only a few specific locations. It is difficult to correlate measurements in different locations and it is especially hazardous to estimate how the frequency of fadings of a given amplitude will vary with changes in distance between transmitter and receiver. So far, it has been found that in temperate climates over distances not exceeding 40 miles, the fading does not exceed 20 db. for more than 0.1 per-cent of the time. For longer distances it is only known that fadings of 20 db. will occur more often but no specific information is available as to the exact percentage. For this reason it is recommended that the maximum range of each hop should be limited to 40 miles unless a prolonged period (about 1 year) is available to study fading conditions of a particular path.

The Topographical Factor

Reliable communications can be obtained at microwave frequencies only when line of sight, shown in Fig. 2, is obtained. However, due to atmospheric conditions, radio waves are refracted slightly towards the earth. It is found that if the real earth is replaced by a fictitious earth having an enlarged radius 4/3 times that of the earth radius, a straight line on a profile map can be drawn. The true prime radius of the earth, a, is approximately 3960 miles so that the fictitious radius, a', is 5260 miles.

The maximum distance, d, for which radio line of sight is obtained for given heights, h_1 and h_2, is given by the equation:

$$d = \sqrt{a'} \, (\sqrt{2h_1} + \sqrt{2h_2}) \quad . \; . \; . \quad (8)$$

By a convenient mathematical coincidence, when d is expressed in miles and h_1 and h_2 in feet, Eqt. (8) reduces to the following simple form:

$$d = \sqrt{2h_1} + \sqrt{2h_2} \quad . \; . \; . \; . \; . \quad (9)$$

See nomograph of Fig. 7.

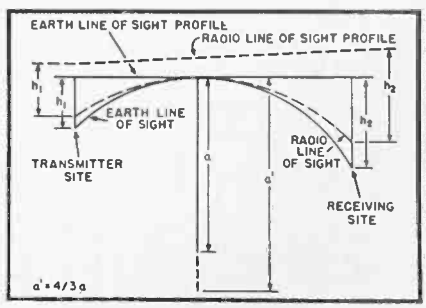
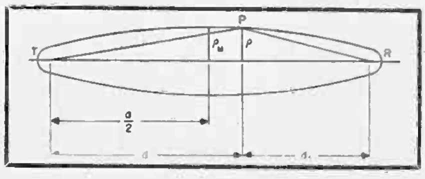


Fig. 2. Line of sight diagram for the earth and for microwave signals.

Fig. 3. First Fresnel zone clearance.



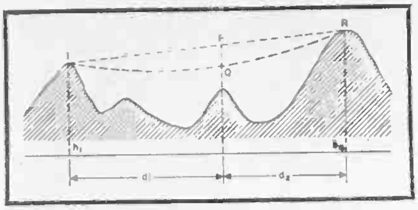


Fig. 4. Flat earth diagram.

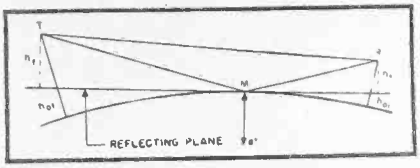


Fig. 5. Interference between direct and reflected rays.

A simple method of checking whether radio line of sight is obtained between two sites is to plot the profile on a plane earth diagram as shown in Fig. 4. The radio ray will appear curved on such a diagram. The vertical deviation from the straight line between transmitter and receiver at any point P is given by:

$$PQ = \frac{d_1\, d_2}{2a'} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

where d_1 and d_2 are as shown in Fig. 4.

When distance is expressed in miles and dip in feet, this equation simplifies to:

$$PQ = \frac{d_1\, d_2}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

The maximum dip will of course occur at the mid-distance point, at which point the dip is $d^2/8$ feet (d in miles).

Another more direct method would be to plot the profile on a form in which the 4/3 earth's curvature is included as shown in Fig. 6. In this case the radio line of sight is indicated by a straight line. This type of chart usually plots distance in miles versus height in feet and it is possible to read the clearance, if any, of the line of sight path over the profile directly in feet. The importance of this factor will become evident.

In the discussion thus far the radio ray has been depicted as a line with very small area. Actually the ray travels as a plane wave of finite area and the line joining transmitter to receiver should be sufficiently above the ground at the radio horizon to permit the complete wavefront to pass. A criterion to determine whether the earth is sufficiently removed from the radio line of sight is to have the first Fresnel zone clear all obstacles in the path of the direct ray. The first Fresnel zone is bounded by points on the wavefront for which the transmission path is greater than the straight path by one half wavelength.

Assimilating the problem to the case of a point source, at the transmitter site T, directing energy to the receiver point R, at a distance d, as shown in Fig. 3, all points P that exceed the straight path TR by one-half wavelength are situated on an ellipsoid. The radius of the first Fresnel zone at any point P_1 (located d_1 from T and d_2 from R) is given by:

$$\rho = \sqrt{\lambda \frac{d_1\, d_2}{d}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

The maximum occurs when d_1 equal to d_2 and is:

$$\rho_m = \tfrac{1}{2} \sqrt{\lambda d} \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

Expressing d in miles and F in megacycles, the maximum radius is given in feet by:

$$\rho_m = 1{,}140 \sqrt{\frac{a}{F}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

When the sites chosen are of sufficient height to clear the first Fresnel zone at all points in the path including trees and buildings, then the received field strength due to the direct ray is nearly equal to the free space attenuation and A_3, the topographical factor, is nearly equal to zero. For this reason the first Fresnel zone height is added to the profile, shown in Fig. 6, so that clearance available can be seen directly on line of sight chart. Usually the procedure is to add the height of the first Fresnel to the points closest to line of sight path and then select towers of appropriate height to clear the most critical point. It is important to note that the tower height selected must be sufficient to adequately clear all trees in the immediate surroundings. Trees are frequently overlooked in line of sight calculations and experiences thus far indicate that they can be very bothersome, unless adequately cleared, even though an apparent clear-cut line of sight is available.

Another factor that should be considered is the possible interference between the direct and reflected rays. The simplest case is for transmission over

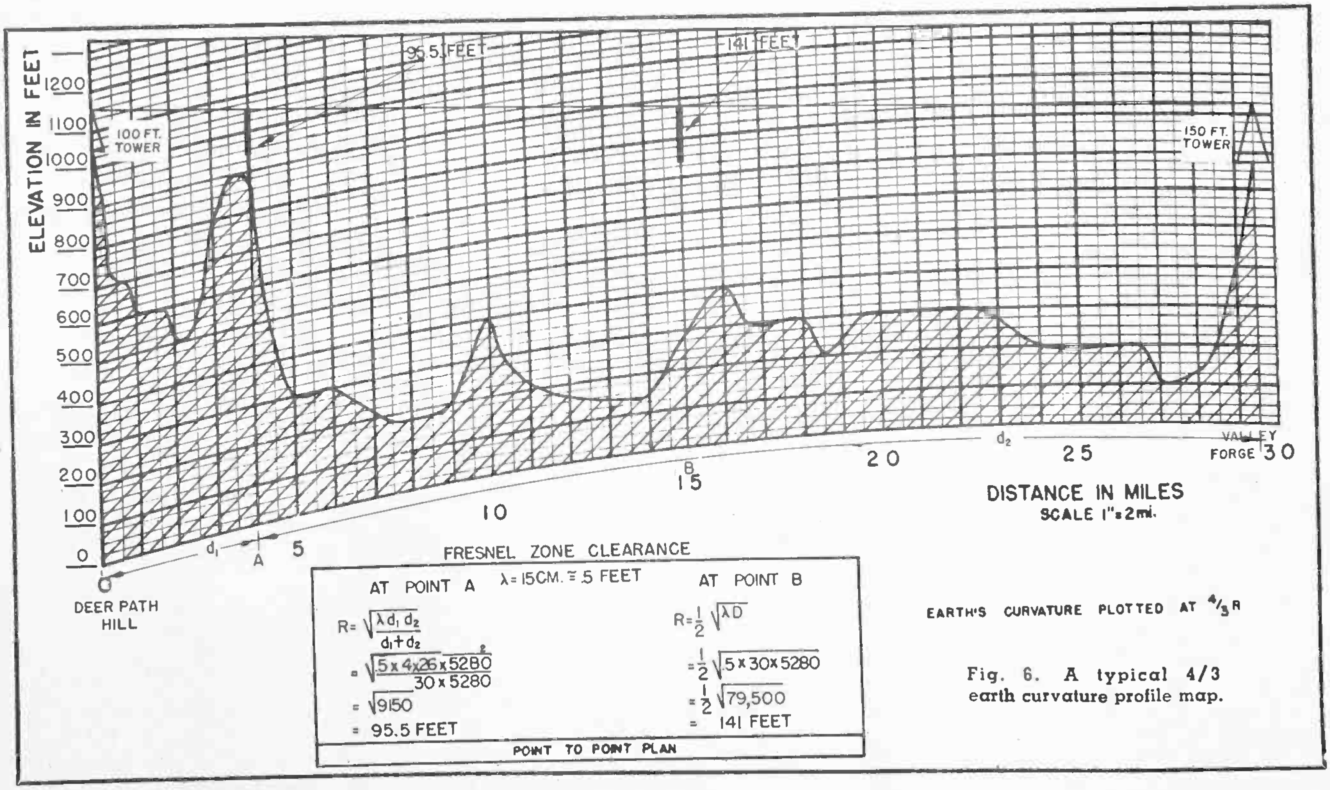
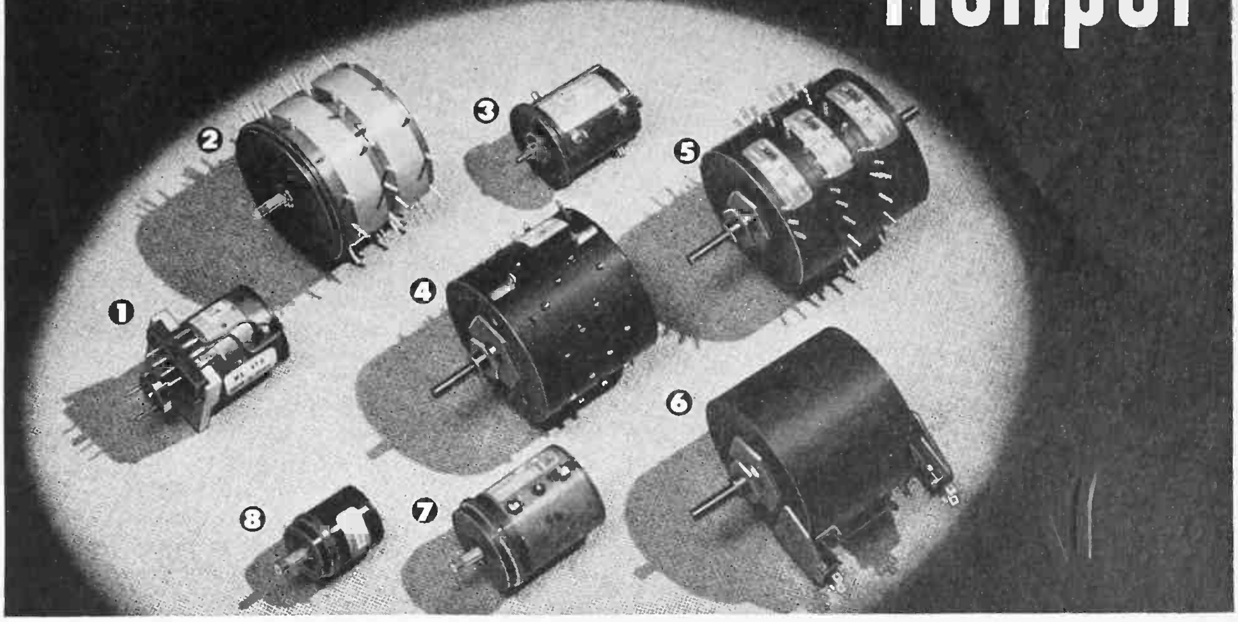


Fig. 6. A typical 4/3 earth curvature profile map.

Typical of the TOUGH POTENTIOMETER JOBS solved by Helipot



Precise Accuracy + Maximum Versatility + Space-saving Compactness

The potentiometers illustrated above are typical examples of the tough problems HELIPOT engineers are solving every day for modern electronic applications. If you have a problem calling for utmost precision in the design, construction and operation of potentiometer units—coupled with minimum space requirements and maximum adaptability to installation and operating limitations—bring your problems to HELIPOT. Here you will find advanced "know-how," coupled with manufacturing facilities unequaled in the industry!

The HELIPOTS above—now in production for various military and industrial applications—include the following unique features . . .

❶ This 10-turn HELIPOT combines highest electrical accuracies with extremes in mechanical precision. It features zero electrical and mechanical blacklash...a precision-supported shaft running on ball bearings at each end of the housing for low torque and long life . . . materials selected for greatest possible stability under aging and temperature extremes . . . special mounting and coupling for "plug-in" convenience . . . mechanical and electrical rotation held to a tolerance of ½° . . . resistance and linearity accuracies, ±1% and ±0.025%, or better, respectively.

❷ *This four-gang assembly of Model F single-turn potentiometers has a special machined aluminum front end for servo-type panel mounting, with shaft supported by precision ball bearings and having a splined and threaded front extension. Each of the four resistance elements contains 10 equi-spaced tap connections with terminals, and all parts are machined for greatest possible stability and accuracy.*

❸ This standard Model A, 10-turn HELIPOT has been modified to incorporate ball bearings on the shaft and a special flange (or ring-type) mounting surface in place of the customary threaded bushing. This HELIPOT also contains additional taps and terminals at the ¼- and 9¾-turn positions.

❹ *This standard Model B, 15-turn HELIPOT has a total of 40 special tap connections which are located in accordance with a schedule of positions required by the user to permit external resistance padding which changes the normally-linear resistance vs. rotation curve to one having predetermined non-linear characteristics. All taps are permanently spot-welded and short out only one or two turns on the resistance element—a unique HELIPOT feature!*

❺ This six-gang assembly of standard Model F single-turn potentiometers has the customary threaded bushing mountings, and has shaft extensions at each end. The two center potentiometers each have 19 equi-spaced, spot-welded tap connections brought out to terminals. *Each tap shorts only two turns of .009" diameter wire on the resistance element.*

❻ *This Model B, 15-turn HELIPOT has been modified to incorporate, at the extreme ends of mechanical and electrical rotation, switches which control circuits entirely separate from the HELIPOT coil or its slider contact.*

❼ This 10-turn HELIPOT has many design features similar to those described for unit No. 1, plus the following additional features . . . a servo-type front end mounting . . . splined and threaded shaft extension . . . and a center tap on the coil. All components are machined to the highest accuracy, with concentricities and alignments held in some places to a few *ten-thousandths* of an inch to conform to the precision of the mechanical systems in which this HELIPOT is used. *Linearity accuracies frequently run as high as ±0.010%!*

❽ *This single-turn Model G Potentiometer has been modified to incorporate a ball bearing shaft and a servo-type front end mounting. Special attention is given to contact designs and pressures to insure that starting torque does not exceed 0.2 inch-ounces under all conditions of temperature.*

The above precision potentiometers are only typical of the hundreds of specialized designs which have been developed and produced by HELIPOT to meet rigid customer specifications. *For the utmost in accuracy, dependability and adaptability, bring your potentiometer problems to HELIPOT!*

THE **Helipot** CORPORATION, SOUTH PASADENA 4, CALIFORNIA

Representatives in all major areas of the United States. Export agents: Frathom Co., 55 W. 42nd St., New York 18.

smooth ground as shown in Fig. 5. It is assumed that the reflection is complete, i.e. earth conductivity infinite, and the angle between the two rays is small. For these conditions, the resultant electric field at the receiver is equal to:

$$E = 2E_0 \sin\frac{2\pi}{\lambda}\frac{\delta}{2} \quad (15)$$

where E_0 is the free-space value of the field and δ the geometric length difference between the direct and reflected rays. The path difference is approximately equal to $2h_r h_t/d$, where h_t and h_r are the heights of the antennas above the reflecting plane.

When h_r is varied, the field strength goes through a series of maxima and minima. Similarly, changing meteorological conditions, which vary the electrical path difference, will vary the field strength at a given height. This effect can be minimized by using two antennas at different heights, known as space diversity reception, and selecting the stronger signal of the two. The vertical spacing of these antennas should approximately give a half wavelength variation between their geometric path differences. The spacing in feet for h_t in feet and λ in cm. should be approximately equal to:

$$\Delta h_r = 43.4\frac{\lambda\, d}{h_t} \quad (16)$$

Free Space Attenuation

The radio waves propagated from an antenna are attenuated in free space in accordance with familiar radiation formulas. For an isotropic antenna the free space attenuation is given by:

$$A_4 = \frac{16\,\pi^2\, d^2}{\lambda^2} \quad (17)$$

This equation can be expressed in terms of frequency and, with d in miles, by:

$$A_4 = 4.56 \times 10^3 f^2 d^2$$
$$A_4(\text{db.}) = 37 + 20 \log f + 20 \log d \quad (18)$$

where f is in megacycles.

The free space attenuation can be considered to be decreased when directive antennas are used since for a given transmitter output a much higher receiver input will be obtained. As described in a previous article[4] the directive characteristics of an antenna can be expressed in terms of effective area, A, or power gain G. Eqt. (18) can be modified to include antenna characteristics by the following expressions:

$$A_4 = \frac{16\,\pi^2\, d^2}{\lambda^2} \times \frac{1}{G_t\, G_r} \quad (19)$$

$$A_4 = \frac{\lambda^2\, d^2}{A_t\, A_r} \quad (20)$$

where G is the antenna gain; G_t—transmitter, G_r—receiver, and A is the antenna effective area.

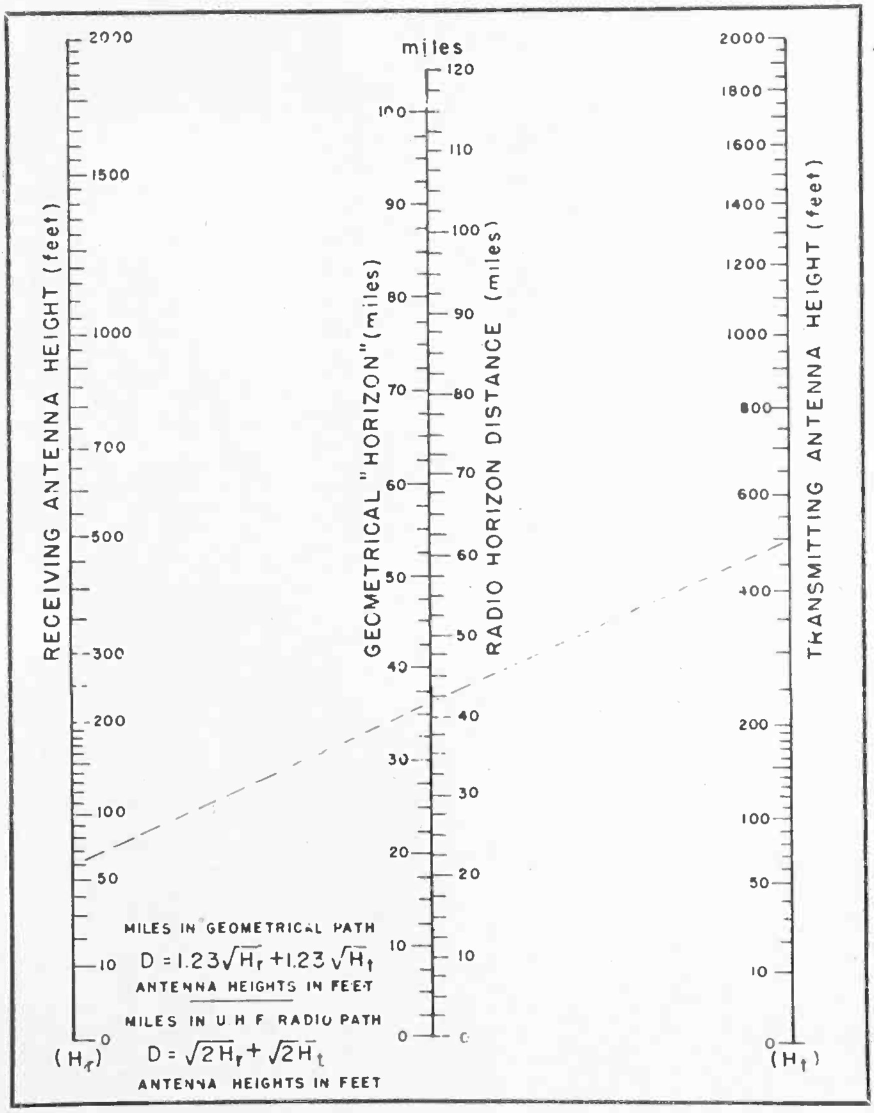
The parabolic antenna is frequently used in present day microwave links, and assuming the use of equal radius antennas for both transmitter and receiver, the free space attenuation of this type of antenna is given by:

$$A_4 = 6.6 \times 10^{12} \frac{d^2}{r^4 f^2} \quad (21)$$

where r is the radius of the antenna in feet, d is the distance in miles, and f the frequency in megacycles.

The free space attenuation of other types of antennas can be determined through the use of Eqts. (19) and (20). The effective area and gain of some common types have been given in a previous article[4].

Fig. 7. Nomograph for determining geometrical and radio horizons.



Signal to Noise Ratio

In Eqt. (2) earlier in this article, the noise power of a microwave link system with n repeaters was developed. In this equation the factor G, representing the gain of the repeater, was included. Since the transmitter output at each repeater is the same, the gain of the repeater must be equal to the attenuation of the path. Assuming favorable propagation conditions, *i.e.*, $A_1.A_2.A_3$ almost equal to one, Eqt. (2) can be expressed in terms of free space attenuation (parabolic antennas) by:

$$P_n = P_0\, Fn \times 6.6 \times 10^{12} \frac{d^2}{r^4 f^2} \quad (22)$$

Since the total distance $D = n\,d$, this formula may be written as:

$$P_n = \frac{6.6 \times 10^{12}\, P_0\, F\, D^2}{n\, r^4\, f^2} \quad (23)$$

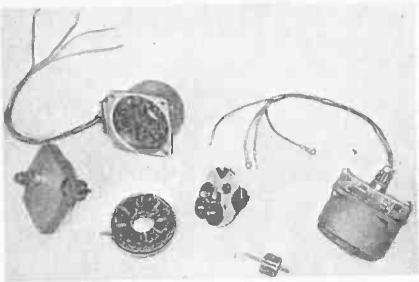
Thus if the total distance is kept constant, the output noise—and hence signal to noise ratio—may be decreased by using a larger number of repeaters. On the other hand, in order to reduce costs, the number of repeaters should be decreased and hence the compromise between cost and performance mentioned earlier in this article.

(*Continued on page 25A*)

NEW PRODUCTS

60-CYCLE MOTORS

The Brown Instruments Division of *Minneapolis-Honeywell Regulator Co.*, Wayne & Roberts Ave., Philadelphia 44, Pa., is now producing fractional



horse power, two-phase, reversible 60-cycle motors for applications requiring a low inertia drive motor with power requirements low enough to permit field excitation from an electronic amplifier.

In further description, the company pointed out that the motor can be used in servo-type mechanisms as remote positioners, for auto-bridge and auto-potentiometric circuits, and similar arrangements. Power requirements are: line field power, approximately 9.5 watts; amplifier field power, approximately 4.0 watts. Motor load impedance will vary from 6000 to 15,000 ohms with an average impedance of 12,000 ohms.

The motor is designed to have a tapered curve of speed versus voltage and at the same time maintain a relatively high torque at the lower speeds. The actual free rotor speed is 1620 r.p.m. and gear reduction trains are available to provide motors with speeds of 27, 54, and 162 r.p.m.

BEACON ANTENNA

Model 2HW high gain beacon antenna for the aircraft frequencies has been announced by *The Workshop Associates, Inc.*, 135 Crescent Road, Needham, Mass.

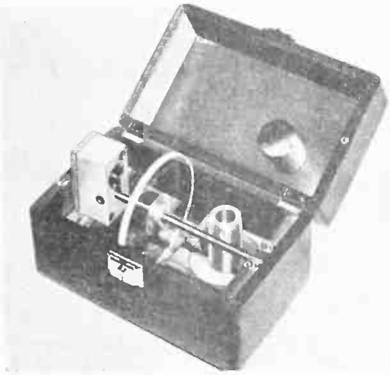
This model has a gain of approximately 3 db. and communication in all directions is possible due to its omni-directional radiation pattern, and a specially designed side lobe enables communication with aircraft while aloft. Model 2HW is designed for all aeronautical ground communications such as between local airports, control tower and ground aircraft, various airline offices, and other applications where its high gain will enable utilization of low cost equipment.

Full specifications plus studies of various applications are available at no charge from the manufacturer.

STRONTIUM MEDICAL APPLICATOR

Tracerlab, Inc., 130 High St., Boston 10, Mass., now has available for physicians an applicator containing a radioactive isotope for use in the treatment of certain surface conditions, particularly in reference to the eye.

The activity of the RA-1 Strontium Medical Applicator consists of a source of about twenty-five millicuries of Strontium-90 which has a half life of



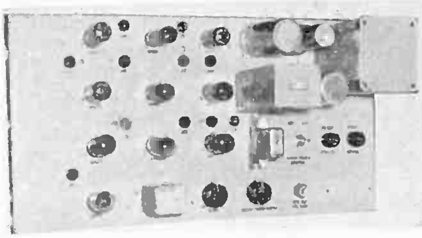
thirty years, resulting in a dosage rate of approximately twenty roentgens-beta equivalent at the aluminum surface of the applicator. The radiation emitted by the source consists of 0.65 Mev beta rays through which Strontium-90 decays to Yttrium-90, and 2.16 Mev beta rays through which Yttrium-90 decays to stable Zirconium.

With each instrument *Tracerlab* supplies a radioautograph showing the uniformity of the activity of the source, a chart which shows the percentage reduction of the surface dosage rate as a function of the depth of lucite, and a chart which shows percentage reduction of surface dosage rate versus time to allow correction for decay.

TV SYNC LOCK

General Electric Co., Electronics Park, Syracuse, N. Y., has announced a television sync lock unit which allows remote picture signals to be treated and handled like local studio productions.

Through the use of this unit, TV-30-A, local commercials, special effects or other local program material can be inserted into the remote picture



without disturbance by means of automatic synchronization of the local sync generator with the remote sync signals. This new unit provides adequate synchronizing control for the new *GE* sync generators, PG-2-A, PG-2-B, and PG-2-C.

Further details are available from the Commercial Equipment Division.

POWER GENERATOR

A deluxe electronic power generator for medium-power dielectric heating applications has been designed by the *RCA* Engineering Products Department to meet a variety of specialized industrial heating needs in such fields as plastics, wood-working, rubber, textiles, and food, and in experimental laboratories.

The 15-CH power generator is a completely self-contained unit capable of developing a power output of 18 to 21.8 kilowatts at frequencies of 5.5 to 41 megacycles. The high-frequency output is obtained from a stabilized, self-excited oscillator employing two *RCA* air-cooled 889R-A power tubes, which are supplied with high-voltage d.c. by a three-phase, full-wave rectifier. The power tubes have a rated anode input of 32 kilowatts.

This generator is now available through the Industrial Equipment Section of the *RCA* Engineering Products Dept., Camden, N. J.

FREQUENCY GENERATOR

A frequency generator which operates from conventional 28 volt d.c. air-

craft power supply and delivers a 1[illegible] volt sinusoidal voltage to a 1 megohm load has been announced by *Varo Manufacturing Company, Inc.*, Box 638, Garland, Texas.

Model 622B is hermetically sealed and its frequency is 400 c.p.s. ± 1/10% from −55° C to +110° C. Features of this unit include exceptional frequency stability over large ranges of temperature, altitude and input voltage. It is 3-1/16″ high, 1-11/16″ wide, 3⅜″ long, and weighs only 11 ounces.

IONIZATION GAUGE

Westinghouse Electric Corporation has developed a new ionization vacuum gauge that can be used to measure pressures as low as 5 x 10^{-10} mm. Hg.

Resembling a triode vacuum tube structurally, the new gauge has the usual three elements; filament, grid,

and ion collector, but these are inverted from the conventional arrangement. The filament, of which there are two, one being a spare, is outside the cylindrical grid while the ion collector, consisting of a fine wire, is suspended within the grid.

This new gauge can be operated on standard power supplies and will be furnished with special tubulation for direct connection to various types of glass systems. Further information on delivery and price may be obtained by writing Electronic Tube Sales, *Westinghouse Lamp Division*, Bloomfield, N. J.

SPECTRUM ANALYZER

A Vectron Spectrum Analyzer covering the S and X bands and featuring provisions for rapid interchange of r.f. heads that will provide coverage of the microwave spectrum to 30,000 mc. is announced by *Robert A. Waters, Inc.*, 4 Gordon St., Waltham, Mass.

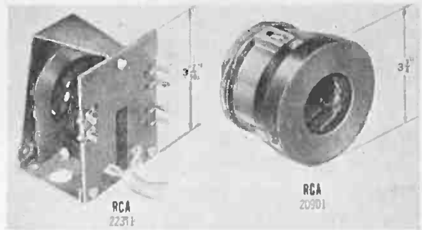
The unit features a functionally designed housing incorporating a 5″ cathode-ray tube indicator with a mounting that permits convenient use of a 35-mm. camera for recording information from the cathode-ray tube.

More detailed information on this unit may be obtained by writing Dept. SA of the company.

TV COMPONENTS

The Tube Department of *RCA*, Harrison, N. J., is offering a high voltage transformer and deflecting yoke for use with the 16GP4 and similar picture tubes having a deflection angle of about 70° and operating at an anode potential up to 14 kilovolts.

The Horizontal-Deflection-Output and High-Voltage Transformer, *RCA*-223T1, is designed for use with a single horizontal-deflection amplifier tube such as the 6AU5-GT, and a single high-voltage rectifier tube 1B3-GT. Because of its ferrite core, the 223T1 makes possible the design of a horizontal deflection



system which operates efficiently with a d.c. power supply of only 300 to 320

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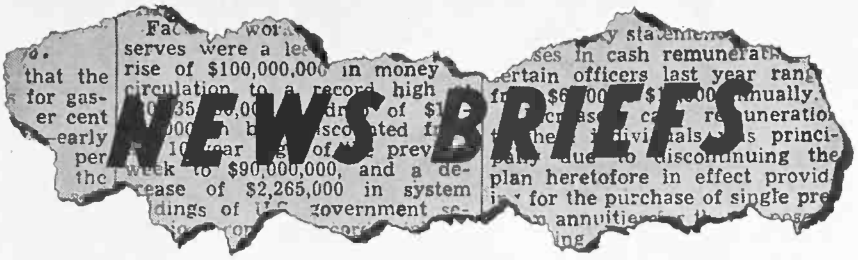


RECEIVE AWARD FOR KLYSTRON

For their development of the klystron which played a major role in World War II, two brothers, Russell H. and

Sigurd F. Varian of California, have received the John Price Wetherill Medals awarded by The Franklin Institute, Philadelphia.

According to Dr. Henry B. Allen, executive vice president of the Institute, microwave radar development during wartime would have been quite different and much slower if the klystron had not been invented. The klystron was conceived and developed at Stanford University, where the two scientists had obtained permission for the use of the university's laboratory and model shop.

Russell H. Varian graduated from Stanford University and holds an honorable D.Eng. from Brooklyn Polytechnic Institute. He is a Stanford Research Associate, and is also president of *Varian Associates*, organized in 1948. Dr. Varian's brother, Sigurd, specialized in aviation and became a Pan American pilot. He was granted a leave of absence to carry on development work with Dr. Varjan. He is director of Development Laboratory of *Varian Associates.*

REVISE ELECTRICAL UNITS

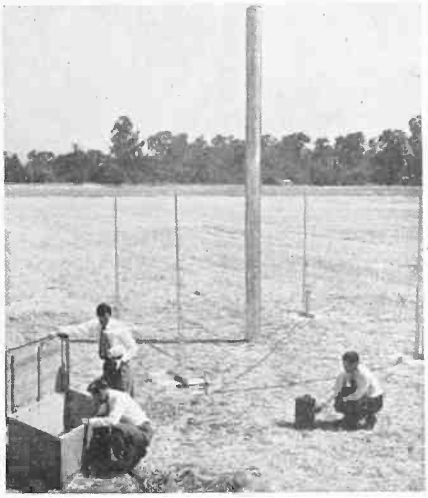
By an act approved July 21, 1950 (Public Law 617), the 81st Congress has given formal statutory sanction to a revision of the practical system of electrical units. In large part, the values adopted for these units resulted from research by the National Bureau of Standards, and the present legislation was proposed by the Bureau.

The changes in magnitude of the units are small, in no case larger than 1/20 of one per-cent, but the new law puts the values on a clear and unambiguous basis which assures the closest practical agreement between electrical and mechanical units.

The new Act is similar to the old law in defining the fundamental practical units as multiples of the units of the centimeter-gram-second electromagnetic system. Two sections of the Act define the basic photometric units, the candle and the lumen, which were not previously defined by law.

ELECTRONICS AIDS IN MEASURING WIND

A team of Stanford University scientists in Stanford, California have disclosed an electronic method for measuring winds 55 to 80 miles above the



earth. Their report, published in the Proceedings of the IRE, described a radio technique of analyzing the drift of meteor trails to measure wind speeds and directions in the ionosphere at altitudes twice as high as can be reached by sounding balloons.

The scientists, L. A. Manning, O. G. Villard Jr., and A.M. Peterson, utilized the electrical disturbances created by the passage of meteors through the outer atmosphere to make their measurements. The research, financed by the Office of Naval Research, is based on the fact that the electrical disturbances caused by the heat of a meteor's passage are efficient reflectors of radio waves and may be detected by a radar-like technique. This method is expected to have useful applications in the design of long-range guided missiles and in long-range weather forecasting.

Professor O. G. Villard Jr. (right) adjusts a test transmitter for checking alignment of meteor direction finder antennas seen in the background. Scientists L. A. Manning and A. M. Peterson are shown checking over some of the additional equipment used in studying the winds.

PSYCHOLOGIST USES PHOTOELECTRIC RECORDER

Psychologist Bernard R. Higley, of the Alfred L. Willson Children's Center in Columbus, Ohio, uses a *General Electric* photoelectric recorder to probe for hidden causes for the misbehavior of problem children. With this sensitive recorder a standard lie detector is used to determine the emotional response of subjects to various stimuli.

Through electrodes taped to the fingers, the recorder detects and makes a permanent record of minute changes in the electric conductivity of the palmar skin. The equipment notes the reaction of the subjects to pictures which Higley flashes on a screen. The recorder, developed by the *GE* General Engineering and Consulting Laboratory in Schenectady, detects current in microamps. By means of an optical system, changes in the tiny current being measured are relayed to the recording element, and the graphic patterns of the changes are automatically recorded on paper for study and comparison.

Dr. Higley believes the completed graph to be invaluable as an aid in discovering the causes of behavior problems of children.

KMTV CELEBRATES ANNIVERSARY

From a small beginning last September when Omaha claimed less than 2500 television receivers, KMTV has reached the conclusion of its first year with a market containing more than 28,000 television receivers. Responsible for KMTV's rapid growth has been Edward

May, President of the *May Broadcasting Company*, Owen Saddler, General Manager and Howard Peterson, General Sales Manager.

KMTV's expansion program will in-

(*Continued on page* 29A)

Microwave System

(*Continued from page* 20A)

Equation (23) makes no allowance for A_2 fading. However, as previously indicated, it is safe practice to allow for fades up to 20 db. This means that the maximum free space attenuation should be about 20 db. less that the maximum path attenuation given in Eqt. (5). Protection against fades will mean that the typical signal-to-noise ratio in the absence of fades will be much greater than the minimum satisfactory value.

Provision for 20 db. fading also provides a safety factor for losses in transmission lines and antenna systems during adverse weather. By a fortunate circumstance, the probability of fading during weather that adversely affects antenna systems is very slight. Under icing conditions, for example, there are a number of factors that introduce losses in the antenna system. However, under these conditions, propagation at microwave frequencies is usually excellent. Hence unless antenna icing introduces losses of the order of 20 db., high quality communications are maintained. Experience thus far indicates that this order of antenna icing loss is never reached. Consequently a transmission break would occur only if adverse icing conditions were combined with severe fading. Again this is a condition that has never been encountered.

Conclusion

In conclusion the author would like to point out that the factors particularly related to microwave propagation have been emphasized in this article. There are other problems to be met which include providing emergency power in the event that primary power fails. This involves the use of engine generators, battery storage, and voltage regulating equipment as shown in Fig. 1. Where a high degree of reliability is required, spare equipment to replace a unit that has failed must be provided together with necessary control apparatus to effect switchover and forward an alarm signal to the link terminals.

The author is grateful to Mr. A. G. Clavier, *Federal Telecommunication Laboratories*, for his permission to use nomogram presented in this article.

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Spectrometer

(*Continued from page* 15A)

task, and it can be readily adapted to automatic operation. Similarly, the new instrument could be used for continuous observation of the air in an enclosed space, giving warning of the presence of dangerous components such as hydrogen or chlorine. In addition, an active project is now under way at the National Bureau of Standards to adapt this instrument for use as an extremely sensitive carbon monoxide detector. Applications for detecting other types of gases are numerous.

The lightness and compactness of the nonmagnetic spectrometer offers a way to settle the question of the chemical composition of the upper atmosphere. This is a problem which is directly related to work in radio propagation and stratospheric flight. Arrangements have been made with the Applied Physics Laboratory of the Johns Hopkins University to send one of the new spectrometers aloft in a rocket. Before it is mounted in the rocket, the spectrometer tube will be evacuated and sealed; when the rocket has reached maximum altitude, an arm of the tube will be broken open to the rarefied air. The relative densities of atmospheric components will then be telemetered back to the ground for recording.

The nonmagnetic mass spectrometer is now being adapted to the rapid scanning of mass spectra. Present methods permit sweeping twice a second through the mass range from 10 to 50, displaying the measured mass components directly on the screen of a cathode-ray oscilloscope. The scanning is accomplished by sweeping the ion accelerating voltage from 50 to 250 volts while modulating the radio-frequency potential with a 1000-cycle signal.

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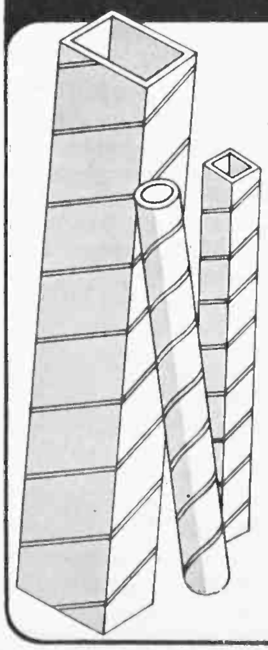
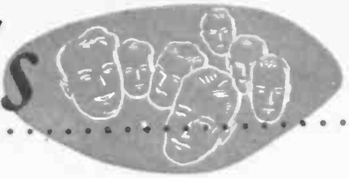


Personals



REAR ADMIRAL ROY M. W. GRAHAM, USN (Ret.) has been appointed special assistant to the manager of the Equipment Sales Division of *Raytheon Manufacturing Co.*, New York. During World War II, Admiral Graham was responsible for all naval communications facilities and services for the Hawaiian Sea Frontier and in February 1944 was put in command of the then newest type of amphibious flagship, the USS Mount McKinley.

DR. WALTER J. HAMER has succeeded Dr. George W. Vinal as chief of the Electrochemistry Section of NBS. Widely known for his work in the field of electrochemistry, Dr. Hamer was formerly research associate at MIT and from 1932 to 1934 held a U. S. Navy Post-doctorate Research Fellowship at Yale University. During World War II Dr. Hamer was active in work for the National Defense Research Council and the Manhattan Project.

MAX L. LIBMAN has been appointed patent advisor to the National Bureau of Standards and as such will be responsible for reviewing inventions made by members of the staff. Mr. Libman was formerly a patent attorney in the Legal Division of the Office of the Chief of Ordnance in the Department of the Army, specializing in electronic equipment. He is a member of the Bar of the District of Columbia and is a registered patent attorney.

JOHN A. P. OHMAN has been appointed a senior research engineer in the Physics Department of Southwest Research Institute. Formerly a vice president of *Geovision, Inc.*, and chief engineer for the *Rieber Research Laboratory*, Mr. Ohman is the author of various reports on petroleum exploration methods and has applied for several patents on geophysical exploration apparatus. He is a member of the IRE and the Society of Exploration Geophysicists.

PAUL ROSENBERG, President of *Paul Rosenberg Associates*, New York firm of consulting physicists, has been elected President of the Institute of Navigation for 1950-1951. Dr. Rosenberg was General Chairman of the meeting on Electronics and Navigation recently held in New York under the joint sponsorship of the ION, the Radio Technical Commission for Aeronautics, and the Radio Technical Commission for Marine Services.

W. A. WILDHACK, formerly Chief of the Missile Instrumentation Section of the National Bureau of Standards, will head the Office of Basic Instrumentation just established at the Bureau. Mr. Wildhack has been with NBS since 1935, working in the fields of aeronautical, mechanical and electronic instruments. The new office will coordinate a program of evaluation and improvement of instruments for measuring basic physical qualities.

Reverberation

(*Continued from page 6A*)

decay and frequency response. The number of pickup heads can vary, and some units of this type have been built with a great number of pickups so that no reverberation feedback is necessary, while others have been built with as few as one head so that the feedback path gives the entire decay envelope. The best compromise might be the use of two to five pickups — few enough so that simplicity of the circuit is maintained, and enough so that the gain of the feedback path can be kept low enough to give good stability with long reverberation times.

In the future the magnetic tape reverberation system will probably become the most widely used because of its compactness, simplicity of design, and ease of flexibility of operation. (A complete magnetic unit can be mounted in a standard relay rack using only 14 inches of panel space.) It is the least expensive of the various systems, foolproof, and has low maintenance costs. Many such units have been tested extensively and are in widespread use.

The Hammond Instrument Co. has developed an electromechanical reverberation control unit which has proved very satisfactory for use with the Hammond organ. In this unit, sound waves are caused to pass through a number of helical steel springs of varying lengths. The sound waves are converted back to electrical waves by crystal pickups at the ends of the springs. These delayed sound waves, when properly controlled and recombined with the original sound, produce the desired amount of reverberation.

Because of the improvements in design of synthetic reverberation systems, resulting in greater convenience and flexibility of operation, synthetic reverberation is coming into much more general use than in the past. Experimental studies of acoustical patterns and sound decay can be considerably simplified with the use of synthetic reverberation units, and the possibility that such devices may even yield space patterns more satisfying than have yet been achieved architecturally may result in great improvement in our system of sound reproduction.

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New Products

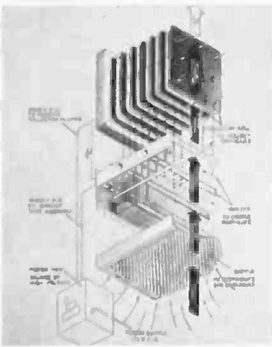
(*Continued from page 23A*)

volts, and which provides full deflection of a 16GP4 kinescope.

The *RCA*-209D1 Deflecting Yoke is coordinated in design to operate efficiently with the 223T1.

ELECTRONIC AIR CLEANER

Westinghouse Electric Corporation has announced a Precipitron electronic air cleaner designed to remove dust, dirt, smoke, soot, and other air-borne solids from normal air. It is constructed for upward or downward air flow to



conserve floor space and simplify maintenance. With a frame height of only 34½ inches, unused space above and below is used for inspection and servicing access.

This Precipitron charges the solid particles positively, then passes the air through a set of alternately charged collector plates where the solids are removed by electrostatic attraction. It is available in the following ratings: capacity, 1200 c.f.m. and up; efficiency, removes 90% of all air-borne particles traveling at 333 f.p.m., and 85% of those traveling at 400 f.p.m.; power supply, 115 volts, single phase, 50 or 60 cycles.

Further information may be obtained from *Westinghouse's* Sturtevant Division, 200 Readville St., Hyde Park, Boston 36, Mass.

TIME SWITCH

Coral Designs, a division of *The Henry G. Deitz Co.*, Box 248, Forest

Hills, New York, has added to its new series of electronic controls the Cat. 110 Electronic Time Switch. Automatic repeat, interval, delayed action, and programming are all incorporated in this unit and all of these plus variations are available by merely changing external connections to the terminal board.

Standard units are supplied for operation on either 115 volts or 230 volts, 50-60 cycles. All relay contacts are rated at 10 amperes to 115 volts a.c., 5 amperes to 230 volts a.c., non-inductive load.

DECADE AMPLIFIER

Technology Instrument Corporation, 1058 Main St., Waltham, Mass., has developed a wide band decade amplifier for general laboratory use and for special applications requiring zero phase shift and high stability of gain. Compact construction, cabinet or rack mounting, and a.c. operation from a self-contained power supply have been incorporated in the design to increase the general utility of the amplifier.

Type 500-A features input impedance high enough to permit measurements in most circuits without upsetting normal conditions. Output impedance is low enough to permit operation into a wide range of loads without causing a variation from the indicated gain of 10,000 or 1000 times. Zero phase shift from 20 c.p.s. to 100 kc. makes possible the extension of phase measurements to 5 mv. levels, when used with TIC type 329 phase meter. All instruments are adjusted as close as practical to zero.

SLOW SPEED TIMING MOTOR

The *Haydon Manufacturing Co., Inc.*, of Torrington, Connecticut, has announced production of its 4400 Series Timing Motor to replace the *Haydon* 4100 Series. The 4400 is an extra slow speed motor, available in standard speeds of 6, 8, 12 hours, 1 day and 1 week per revolution.

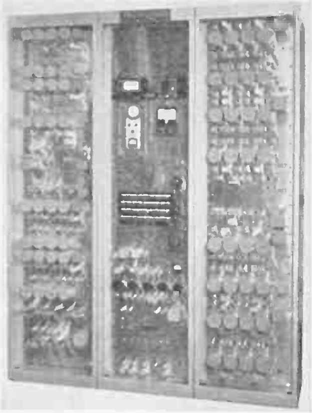
Non-standard speeds are available on quantity orders in the ranges of 5, 9, 10, 15, 16, 30, 32 and 36 hours, and 2, 4, 10 and 30 days per revolution. Typical applications suggested are: day-night thermostats, daily program timers, and refrigerator defrosting mechanisms.

Complete information on the 4400 Series is given in Catalog No. 322 available from the manufacturer.

MULTIPLEX TERMINALS

Philco Corporation, Philadelphia, Pa., is manufacturing communications channelizing of the time-division type for use with microwave radio relay systems. Employing pulse-amplitude modulation, the CMT-4 series is available in various models to provide 4, 8, 12, 16, 24, or 32 voice channels.

According to the manufacturer, these multiplex terminals have both the freedom from crosstalk of time-division sys-

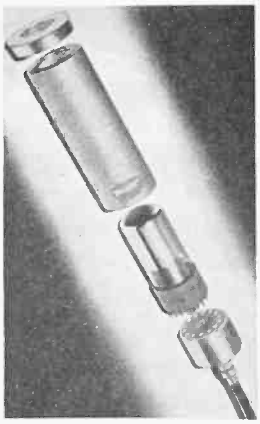


tems, and the spectrum economy normally associated with commercial telephone carrier systems. The composite output of a 32-channel Philco P.A.M. multiplex terminal is less than 300 kc. wide. Another feature is the ability to drop out one or more channels at repeater stations.

ALPHA SCINTILLATION PROBE

Tracerlab, Inc., 130 High Street, Boston 10, Mass., is introducing the P-12 Alpha Scintillation Probe designed for use with commercially available scalers and counting rate meters for the selective detection and measurement of alpha particles. The phosphor light pulse generated by alpha bombardment has a decay time of about ten microseconds.

The background count of the alpha probe is only about five counts per hour so that maximum statistical ac-



curacy can be achieved and weak alpha samples can be measured. It may also be used as a monitor in conjunction with either a scaler or a counting rate meter, depending on the desired accuracy.

If this scintillation counter is used for radioassay work, it can be mounted in the SC-24 Sample Holder and Probe Mount to assure complete geometric reproducibility. The same holder will also adapt it for use with the *Tracerlab* SC-6A Automatic Sample Changer.

ELECTRONIC TIMER

General Electric's Control Division has announced a compact electronic timer which provides automatic control of operation, limit, and sequence timing for literally thousands of industrial processes.

Available in three time ranges of .06-1.2 seconds, .6-12 seconds, and 6-120 seconds, this timer features a detachable back plate which mounts directly on a rigid conduit or any flat surface. The *GE*6J5 electronic tube in the timer is a standard model readily obtainable at most radio stores. Tests conducted indicate that the timer can perform a million or more operations at these controlled load requirements: inrush—15 amps., carry—10 amps., and break—5 amps.

Some applications of the device are: operation timing to control duration of such processes as paint spraying; limit timing to stop conveyor belts if material piles up; and sequence timing to control duration of operations on bearing-grinding machines, etc.

Additional information on the timer is contained in bulletin GEA-5255 which may be obtained from the *General Electric Co.*, Schenectady 5, N. Y.

HAND STAMPING DEVICE

The *M. E. Cunningham Company*, 192 East Carson St., Pittsburgh 19, Pa., has developed a hand stamping fixture for marking metal name plates. Designated Model SF-100, this tool is made from the company's special Mecco Safety Steel to prevent spalling, mushrooming, and injury to personnel.

This tool can be fabricated to order for processing one or a group of name plates, checks, and other flat metal objects. The chase section in the bottom of the holder has adjustable horizontal and vertical gauges to facilitate stamping on any required panel. These gauges are locked and adjusted by standard screws or set screws, and can be made in a variety of styles to suit round, square, rectangular, and special shape plates.

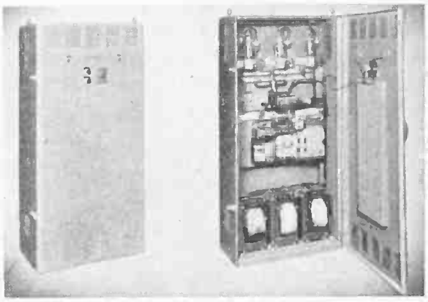
Data sheets and additional information may be obtained by writing the company direct.

ELECTRONIC RECTIFIERS

Floor- or wall-mounted electronic rectifier units to convert a.c. to d.c. for general purpose industrial and commercial applications are available from *Westinghouse Electric Corporation.*

Standard units can be supplied with constant or adjustable d.c. output voltages, in ratings as high as 230 volts, 87 amperes. The adjustable voltage units provide a range of from 60 to 100 percent of the rated output voltage. All components, including the anode transformers, are mounted in factory assembled enclosures to simplify installation, and to facilitate inspection and maintenance.

These electronic rectifier units are designed for operation on 115/230 or



230/460 volts, single phase or three phase. Further information may be obtained by writing *Westinghouse* at Box 2099, Pittsburgh 30, Pa.

LAMINATING MATERIAL

Flexfirm Products of El Monte, California, is introducing a ready-to-form laminating material with a high tensile and flexural strength, trade-marked Dryply.

Dryply consists of glass cloth or mat impregnated with a complete polyester compound, including catalyst, which comes to the manufacturer in a dry state, ready to use. The material comes

in rolls and in use is simply trimmed, laid up for forming and heat cured by conventional methods.

It is reported that the material is dimensionally stable, will withstand all chemical and weather elements, and can be stored with a promised shelf life of 6 months or longer under normal room temperatures. Illustration shows finished Dryply parts formerly made of metal.

News Briefs

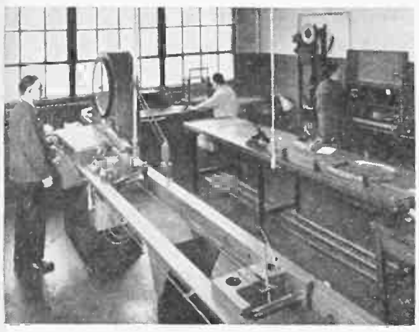
(*Continued from page* 24A)

clude top network presentations from *ABC* and *CBS*; these programs to reach Omaha through the nearly completed microwave relay directed from primary network stations in the East. Local improvements include a direct connection with *Northwestern Bell Telephone Company* by coaxial cable, and a new, sound proofed modernistic audition room. Completely linked with the master controls, this audition room contains the latest technical improvements and incorporates 16 mm. sound projection equipment, and a special TV monitor for the presentation of auditions through the transmitter system, all of which may be operated from a master control within the room itself.

WIRE TESTING MACHINE

Western Electric Company's Hawthorne works in Chicago is now using a 10,000 lb. wire testing machine for tensile tests on samples of all copper line wire produced at the plant.

The testing machine was especially designed by *Baldwin Locomotive Works* to apply test loads to wire ranging in length from 2 in. to 60 in. between the Templin grips. Loads are applied hydraulically by a ram with a 36-inch stroke. Loading speed may be varied



up to a maximum of 25 inches per minute by means of a hydraulic control valve. Maximum return speed is 20 inches per minute.

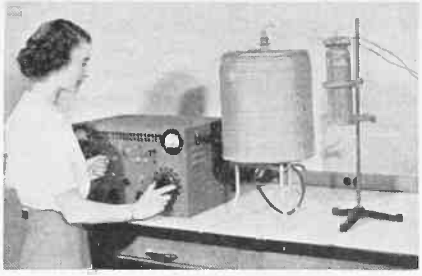
Accuracy of this system is within 0.5 per-cent of load or one scale division.

PRECISION THERMOSTAT

Dr. Wm. R. Eubank of the National Bureau of Standards has developed a precision thermostat which provides smooth, continuous control of an electric furnace within a very small range at temperatures between 1000° and 1550°C.

The device is of the type in which the furnace winding itself serves as the sensitive element, forming part of a bridge circuit for control of a thyratron tube. The thyratron circuit then acts as a continuously variable valve, allowing just enough current to reach the furnace to compensate for a given temperature fluctuation.

An advantage in the use of the phase-controlled thyratron is gradual or proportional control as contrasted to on-off control. It is expected that



the control circuit developed at the Bureau will find application in the regulation of other furnaces and in baths and heaters operating at lower temperatures. Heater elements, such as pure nickel or certain nickel-chromium alloys which have sufficient change of resistance with temperature in the lower temperature ranges would be required in the latter applications.

Stress and Strain

(*Continued from page* 14A)

same as the axial installation except that instead of the two active gauges being connected catacorner in the bridge, they are connected adjacent. Thus any axial loads cancel and only bending loads produce a signal.

4. Transverse installation gets its name from the gauge being mounted transverse to the axial strain so that its response is a function of Poisson's ratio.

5. Rosette or delta installations were discussed briefly at the start of the article and are too involved for a complete analysis here.

6. Torque installations are used when it is desirable to measure the torque in a drive shaft. The gauges are mounted at 45° to the tube axis as this is the direction of maximum strain. Usually full bridges are employed so that the slip ring resistances are a negligible amount of the power and galvanometer circuit resistances and accurate results are obtainable. As the dummy gauges are actually in shear, the shear formulas are used for these calculations.

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TECHNICAL BOOKS

"RADIO ENGINEERING HANDBOOK" 4th Edition, by Keith Henney. Published by *McGraw-Hill Book Company*, 330 West 42nd St., New York 18, N. Y. 1197 pages. $10.00.

Designers, engineers, and radio technicians will find in this volume principles, standards, and procedures that mean quick answers to routine and special assignments in communications, broadcasting, aircraft radio, television, and related fields.

This 4th edition is fully revised and enlarged to include several new chapters covering wave guides, inductance and magnetic materials, electron tubes, antennas, receiving systems, wave propagation, and radio aids to navigation. An entirely new section takes up in detail the physical, mathematical, psychological, and acoustical base on which all electrical communication exists.

This compilation of carefully selected design data, charts, tables, circuits, diagrams, and formulas will be of great aid in solving radio engineering problems more quickly, easily, and accurately.

"ELECTRICAL COMMUNICATION" Third Edition, by Arthur L. Albert. Published by *John Wiley & Sons, Inc.*, 440 Fourth Ave., New York 16, N. Y. 593 pages. $6.50.

The third edition of this text has been extensively revised, and as in preceding editions, covers the entire field of electrical communication including the transmission of code, speech and music by both wire and radio.

The basic subjects of acoustics, electroacoustic devices, networks, lines, cables, wave guides, and electronics have been grouped in the first part of the book, with telegraph, telephone, and radio systems in the last portion. Included in the expansion and modernization of the book is the emphasis and extended material on dial telephony; illustrations and problems have been completely revised and increased; and the standards of AIEE and IRE are closely followed. A special feature is the addition of review questions at chapter endings.

Although the book contains higher mathematics, the material is so arranged that continuity is not affected without the use of the mathematics. An extensive list of references is also included to assist those interested in locating additional information.

Audio Amplifier

(Continued from page 9A)

from changes in tube transconductance and other uncontrollable factors will be balanced out within very large limits by the feedback circuits. A balance potentiometer is shown in the cathode circuits of the input tubes for purposes of balancing the phase inverter in initial adjustment. This was deemed desirable because any direct current unbalance at this point is amplified by the following direct coupled stage. As a practical matter the adjustment need be made only during initial testing with a d.c. voltmeter connected from plate to plate, the balanced condition being indicated by zero voltage.

The secondary winding of the output transformer is shown with one side grounded in the diagram but this winding may be either floated or balanced to ground. The winding is completely isolated from the balance of the circuits as far as d.c. is concerned and the effect of reflections caused by the load is negligible. The effective internal generator impedance of the amplifier is extremely low, which provides both excellent damping and isolation of the load. The dynamic impedance of loudspeakers, recording heads and similar devices varies widely and abruptly in operation and this feature has considerable importance. Any tendency toward continued motion of the load device after sharp fundamental transients is effectively damped out. The internal generator impedance of the output circuits of the amplifier is in an order of magnitude approximating 1/20 of the rated tap impedance on the output transformer secondary.

The total noise level, including hum, is measured at approximately 78 decibels below maximum output with no shielded wire used anywhere in the amplifier circuits. Audio frequency square waves are reproduced without visible distortion and transient pulse signals without observable deformation.

AB-5 Preamplifier Driver

The circuit diagram for the preamplifier driver designed especially for this power amplifier is shown in Fig. 2. A single 12AX7 is used for the two cascaded preamplifier stages. Equalization is obtained by means of a selective frequency degenerative feedback loop from the plate of the second stage to the cathode of the first stage. The curves for both standard and LP equalization are shown in Fig. 1. The input resistance was chosen for flat response from a standard Pickering cartridge. High frequency "roll-off" for British *Decca* and *London* recordings can be obtained by adjusting the treble control to the first position of attenuation. The Long Playing equalization follows the *Columbia* TL-1 test recording within one decibel. 12 db. of attenuation for this characteristic is obtained by bypassing the plate to ground.

The input selector switch permits selection of the phono preamplifier with equalization for either Standard or LP and selection of either TV or Radio. High values of resistance are placed across the switch contacts of the preamp to keep the coupling and equalization capacitors charged so that snaps and clicks from changing the selector switch are minimized. A shorting type switch was also used in this circuit as an additional precaution against snaps and clicks. Each stage should have a common ground point with heavy buss connections between points to prevent hum pickup in the ground connections. Connections should be kept as short as possible to eliminate the necessity of shielding wiring, since the stray capacitance may cause high frequency loss. Gain from this preamplifier is sufficient for any of the standard variable reluctance pickups.

The third stage of the circuit is a stage of voltage amplification to provide a high level input to the tone control circuits. Part of the load resistance is placed in the cathode circuit to provide current degeneration for the stage. Degeneration is desirable in order to decrease the input capacitance of the stage and to increase signal handling capabilities of the stage. A blocking capacitor is required between the volume control and the grid to prevent the bias voltage from being upset. A high signal level to the tone control circuit is desirable to keep the signal to hum ratio high. Thus, careful shielding of the tone controls is necessary.

The tone controls are resistance-capacitance networks. Eleven position shorting type switches are used for the controls with the center as the flat position and varying degrees of accentuation either side of center. These switch type controls have been used in production for some time and have proven very satisfactory. The great advantage of the switch type is that once a desirable setting for a given input signal has been found, that exact setting can be precisely repeated at a later date. It may be found desirable to loosen the detent springs on the controls so that they may be rotated more easily.

The next stage in the driver is another stage of amplification to overcome the loss in the tone control circuits. This stage feeds a cathode follower through the second section of a dual potentiometer used as a volume control. One section of the control serves to limit the input to the third stage to prevent over-driving and the second section limits the input to the cathode follower and eliminates any hum or tube noise picked up in the tone control circuit when the control is set toward minimum. Balancing the signal by means of this control provides optimum signal to noise ratios as well as ideal control of the driver output level.

The cathode follower output stage is unique in that it provides an almost universal output combination. The output impedance is 500 ohms. With the large blocking capacitor this output may be used directly into the 500 ohm winding of a 500 ohm line to grid transformer for use with other equipment, or it may be fed directly into the grid circuit of an amplifier such as the AB-5 for which it was designed. The coupling capacitor used is a 16 mfd. 450 volt electrolytic. A low value of resistance across the output terminals keeps the capacitor polarized and maintains the d.c. voltage due to leakage across the output terminals at a negligible value. The output of this unit may be run as far as 500 feet through suitable shielded cable without audio frequency loss of consequence. The maximum output voltage of the entire unit with less than 2% intermodulation distortion is 6 volts. Distortion at the one volt level required to drive the AB-5 amplifier is ½%.

Where space is not at a premium and minimum hum is of great importance the power supply for this unit should be separated from the signal chassis. The frequency response is flat within one decibel over the entire audio range. For use with the AB-5 amplifier it may be found desirable to limit the very low frequency response by using smaller coupling capacitators. This is especially true for use with phono equipment with a large amount of turntable rumble. It was found that the response of the entire system was such that rumble on the order of two to four cycles per second caused the speaker cone to flutter violently.

When these units are constructed carefully with high quality components and properly adjusted using adequate laboratory instrumentation, their performance is appreciably superior to even the finest associated components available. They fall short of perfection only in the sense that perfection cannot, by definition, be obtained.

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(*Continued from page* 10A)

nections for the feedback circuit. It might be that for a plate voltage e_b of 100 volts the feedback voltage is —10 volts, or B is —0.10. Then when e_b is 200 volts, e_{fb} is —20 volts and so on. Let e'_i represent $e_i + E_{cc}$ and plot e'_i as the parameter on the plate characteristic of the vacuum tube. This can be done by assuming a constant value of e'_i and calculating the values of e_b and i_b. For example, if B is —0.10, the curve of constant e'_i of —40 volts will go thru the points corresponding to $e_c = -30$ volts, $e_b = 100$ volts; $e_c = -20$ volts, $e_b = 200$ volts; $e_c = -10$ volts, $e_b = 300$ volts and so on. Similarly the curve for e'_i of 0 volts would coincide with $e_c = 10$ volts, $e_b = 100$ volts; $e_c = 20$ volts, $e_b = 200$ volts and so on.

These curves of constant e'_i are shown in the dotted lines in Fig. 2. To be noted particularly are the facts that the

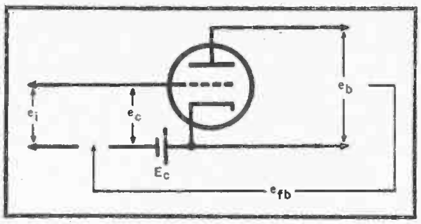


Fig. 3. Simplified diagram of feedback amplifier circuit.

characteristics appear much straighter, steeper and more nearly parallel. These facts indicate that the feedback has reduced distortion.

The dotted equivalent tube characteristics can now be used to determine the operation of the amplifier. For example, the load line may be drawn in the usual manner, with the x intercept at E_{bb}, a slope corresponding to the reciprocal of the load resistance, and going through the operating point. The distortion can now be obtained from the formulas which are available. For example, the second harmonic distortion is given by

$$\frac{I_{b\,max} + I_{b\,min} - 2I_{ba}}{2I_{ba}}$$

where $I_{b\,max}$, $I_{b\,min}$, and I_{ba} are the maximum, minimum and operating values of the plate current for the specified grid swing.

In Fig. 1 the load line is drawn for a load resistance of 1250 ohms. For a grid swing of 0 to —60 volts the second harmonic distortion is 4%, without feedback. A grid swing from 0 to —80 volts gives 2.5% distortion with feedback. The distortion has been decreased materially at the expense of gain, since the gain drops from 1.7 to 1.4. However, use of the formula $1/(1 - KB)$ shows that the distortion should have been decreased $1/(1 + 1.7x.1)$ or about 17%. The difference in answers is not due to the error in the formula as much as it is to errors in readings of the curves, but the difference of a 37% reduction and a 17% reduction is of interest.

The reader will be interested in the evaluation of the equivalent tube parameters g'_m, r'_p and μ' from the equivalent tube characteristics of Fig. 2. If g_m, r_p and μ are the actual tube characteristics, then:

$$r'_p = r_p/(1 - \mu B)$$
$$\mu' = \mu\,/(1 - \mu B)$$
$$g'_m = g_m$$

The equivalent plate resistance and amplification factor have both been reduced by the voltage feedback, while the transconductance was unchanged. The curves of Fig. 2 verify these statements.

(b) *Current feedback*

If current feedback is assumed, the feedback voltage is a function of the load current, so that:

$$e_{fb} = G\, i_b$$

then the equivalent plate characteristic diagram can be made similarly to that described above. Suppose that the G factor gives a voltage of —10 volts when i_b is 20 ma., or G is —500. The curve for $e'_i = 0$ is thus coincident with the points $i_b = 20$ ma., $e_c = -10$ volts; $i_b = 40$ ma., $e_c = -20$ volts; $i_b = 60$ ma., $e_c = -30$ volts and so on. The equivalent plate diagram is shown dotted in Fig. 2. It is seen again that current feedback straightens out the plate characteristics, reduces their slopes, and spaces them more evenly.

The distortion will evidently be reduced by the use of feedback. It is also interesting to note the values of the equivalent tube characteristics in terms of the actual tube parameters. These are:

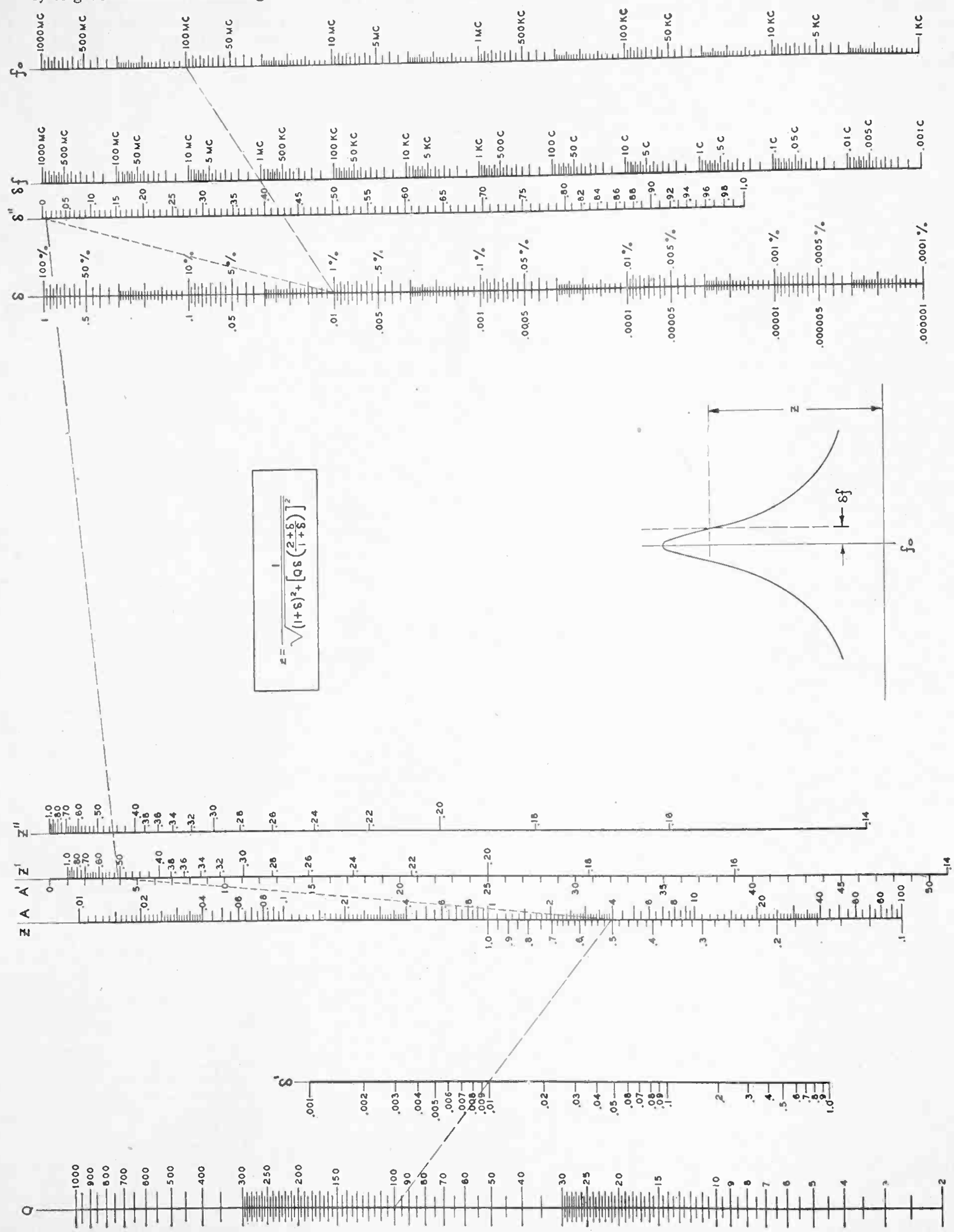
$$r'_p = r_p(1 - Gg_m)$$
$$\mu' = \mu$$
$$g'm = g_m/(1 - Gg_m)$$

Hence the equivalent plate resistance was increased with current feedback, which is verified from circuit considerations. The amplification factor does not change, while the transconductance of course goes down.

OFF-RESONANCE RESPONSE—SMALL DEVIATION

CHESTER W. YOUNG, Senior Electronic Eng., Consolidated Vultee Aircraft Corp.

ALIGN resonant frequency f_0 and frequency deviation δf to give fractional detuning δ. Transfer to δ' scale and align with Q to give Z. Transfer to Z', align with δ on δ'' scale to give exact response on Z'' scale.



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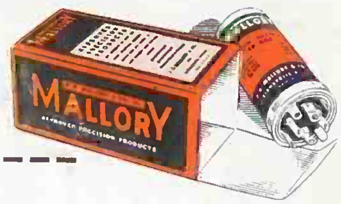

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