RADIO-ELECTRONIC *Engineering* SECTION

RADIO & TELEVISION NEWS

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MARCH, 1952

DEPARTMENTS

RADIO-ELECTRONIC ENGINEERING is published each month as a special section in a limited number of copies of RADIO & TELEVISION NEWS, by the Ziff-Davis Publishing Company, 366 Madison Avenue, New York 17, N. Y.

← K. B. Boothe, Audio & Video Products Corp., N.Y.C., is demonstrating the Ampex Model 307 3-speed magnetic tape recorder which will record all RDB-approved subcarrier frequencies used in FM-FM telemetering. Top frequency response is 100 kc. at 60 inches per second.

Personals

PAUL BARON has joined the Instrumentation Division of *Audio & Video Products Corporation,* New York, N. Y., as field engineering representative. Mr. Baron's experience as an engineer includes work at the *Raymond Rosen Engineering Products Company* and the *Eckert Mauchly Computer Corporation.* He has done considerable original work with magnetic tape recording and electronic circuitry in analog computer type devices.

WILLIAM F. CASSEDY, JR. has been elected president of *Aircraft Radio Corporation,* Boonton, N. J., designer and manufacturer of radio and electronic equipment. He succeeds Lewis M. Hull, who will now serve as chairman of the board and treasurer. Mr. Cassedy, previously vice president and general manager of *Kearfott Manufacturing Company,* has had long experience in manufacturing electrical and mechanical instruments.

SAUL DECKER has been promoted from assistant to chief television engineer of *CBS-Columbia,* manufacturing subsidiary of *Columbia Broadcasting System.* In his new capacity, he will be responsible for design and development of all television and radio chassis. Prior to joining *CBS-Columbia,* Mr. Decker was associated with the *Garod Radio Corporation,* and was employed as a consultant by *Allen B. DuMont, General Television Corporation,* and others.

LEWIS GORDON, newly-appointed managing director of the International Division of *Sylvania Electric Products Inc.,* joined the organization in 1931 as the Lighting Division's New York City district manager. He served in various management capacities before being named to head *Sylvania's* international sales activities. Mr. Gordon is a member of the Export Committee of the Radio & Television Manufacturers Association.

ANTHONY H. LAMB has been appointed vice president in charge of manufacturing at *Weston Electrical Instrument Corporation,* Newark, N. J. Mr. Lamb, who started with Weston in 1924 as an instrument assembler, became a vice president in charge of their Tagliabue Instruments Division in 1950. A pioneer in the field of photoelectricity, he holds a Personal Achievement Award from the U. S. Navy for developing special instruments.

DR. L. C. MARSHALL, Professor of Electrical Engineering at the University of California and head of the Microwave Laboratory operated there, has now been appointed director of *Link-Belt Company's* new physical testing and research laboratory at Indianapolis. Active in radar research for many years, he collaborated with Dr. D. H. Sloan to develop the Resnatron microwave oscillator which holds the record for power output.

Magnetic Tape DATA-RECORDING SYSTEMS

By ROBERT ENDALL

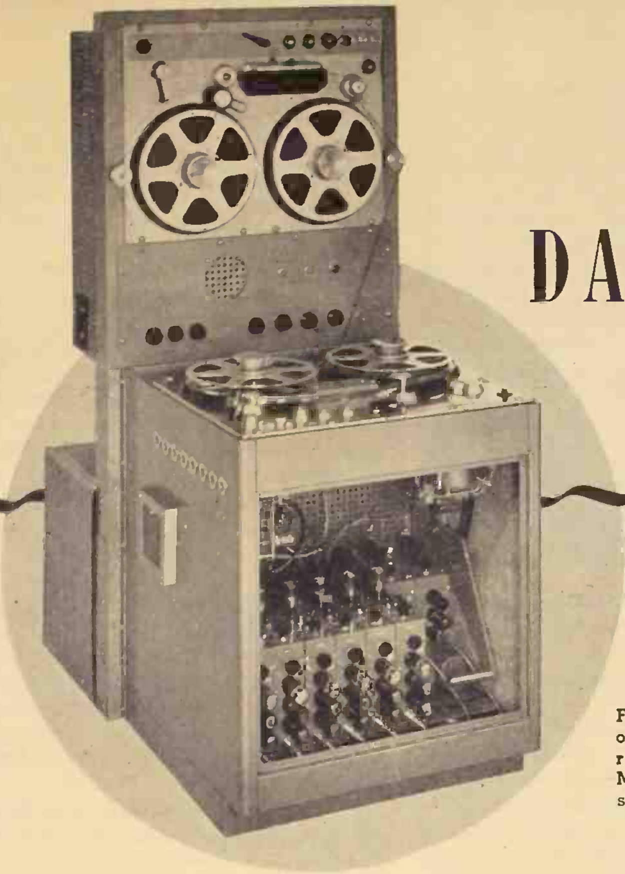


Fig. 1. Commercial laboratory signal-analysis reproducer, Ampex Model S-3037, has 3-speed drive, 8-track reproduction.

Information can be recorded and stored reliably and conveniently by means of magnetic tape.

MANY OF the most important applications of electronics in military, scientific, and industrial problems require a simple and effective method of recording the data which are the results of measurements. Such data may be obtained as measurements of industrial processes, as telemetering information from remote positions, as measured results of scientific and engineering experiments, or from any other of numerous applications of this type in which it is desirable to have a record of the measured data. Such records are useful not only for maintaining permanent records of the data, but also in that they allow detailed analyses of particular sections.

Many different methods have been used to record this type of information. These methods have included oscilloscope photography, disk recording, and ink-chart recording. However, none of these methods has been completely satisfactory from the viewpoints of convenience and simplicity of operation, reliability and reproducibility of results, and frequency response.

With the development of magnetic tape recording, a method became available for the recording of information and data which avoids the limitations and drawbacks of the previous methods. Magnetic tape makes available a simple, convenient and reliable method of recording information with the desired speed and frequency response on tape which can be easily stored, transported and played back at any later time.

Magnetic recording methods are extremely well suited to this type of service, and possess several important advantages over other methods of data recording:

(1) A large amount of information can be stored on a relatively small volume of tape.

(2) The recorder is compact and rugged; therefore, it can be used under adverse conditions and in locations where other types of recorders cannot be used.

(3) The cost of tape recording equipment is low—both initially and in operation. The major part of the analysis system need not be taken on location, and the tapes can be played back under laboratory conditions.

(4) The tapes can be played back indefinitely without loss of information.

(5) The fact that tape can be erased and re-used allows monitoring of processes which would otherwise not be economical. The recorder can be run almost indefinitely in order to obtain one good record.

(6) Simultaneous recordings can be made of several events on one tape, and these records analyzed individually so that only one set of recording and analyzing equipment is necessary.

These relative advantages make magnetic tape recording one of the most valuable techniques which exists for the recording of data.

Because of the wide variety of problems which involve the recording and storage of data for future study and analysis, a number of different magnetic tape data-recording systems have been developed to meet the different requirements of the various applications. For example, some applications require the recording of the results of a measurement at extremely high speed with very good high-frequency response, others might require recording the result of a single measurement for a long period of time with moderate frequency response, while a great many applications require the recording of several different sets of data simultaneously to maintain the exact time relationship between them. The design of the different recording systems will, of course, be quite different depending upon the type of data for which they are to be used. This article will illustrate some of the design principles of magnetic tape recording by describing the essential elements of several basic systems for recording on standard commercial magnetic tape a number of simultaneous sets of data.

The recording of single-channel information also has many important uses. However, multichannel systems may have all the features of single-channel systems and be at the same time much more versatile and general

Fig. 2. A mechanical switch, the ASCOP Model 1-30-30S high speed multichannel commutator.

in their application. Therefore, this article will particularly emphasize the multichannel systems and consider the single-channel systems as special applications.

There are several possible methods for recording several simultaneous information channels on the same magnetic tape. These methods fall within the general classifications of:

(a) *Time-division methods*, in which the various signals are recorded on a single channel by sampling the various channels in succession, using a sampling or switching device;

(b) *Frequency-division methods*, in which the various signals are recorded on a single channel by modulation of a number of different subcarriers in a multiplex system;

(c) *Space-division methods*, in which the various signals are recorded on a single magnetic tape in adjacent tracks by means of multiple-track recording systems.

Each of these methods may be employed in a number of different ways, depending largely upon the requirements of the specific applications and the manner in which the original data is derived. Considerable work has been done in developing and perfecting systems of recording by each of these methods.

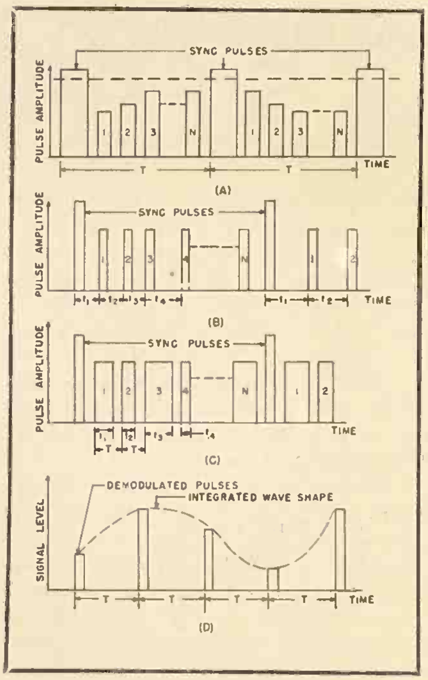


Fig. 3. Typical time-division pulse trains for different types of pulse modulation systems. (A) Pulse amplitude modulation, (B) Pulse time modulation, and (C) Pulse width modulation. (D) Signal in each channel after playback and demodulation in any time-division multiplex system, showing integration of pulse amplitudes to give original signal.

The basic time-division method of recording or transmitting information is that in which the information in the various channels is sampled in sequence by means of some sampling or switching device. This may be done by either a mechanical or an electronic switch. The signal which is to be recorded will, therefore, consist of a series of pulses, each of which represents the magnitude of a single channel at that particular instant of time. As in other fields of information transmission and communication, many different systems may be used for coding the pulses so that they contain the desired information. The most commonly used systems of pulse modulation are:

(1) *Pulse amplitude modulation*, in which the amplitude of the pulse is proportional to the magnitude of the signal being represented;

(2) *Pulse time modulation*, in which the time position of the pulse (relative to a fixed set of time reference pulses, or to the preceding pulse) is proportional to the magnitude of the desired signal;

(3) *Pulse width modulation*, in which the duration of the pulse is varied by the signal;

(4) *Pulse code modulation*, in which the magnitude of the data signal is converted into a sequential group of pulses representing a binary code.

The system of pulse amplitude modulation is the least complex, and requires the simplest circuit techniques.

A block diagram of the basic system of time-division multichannel recording is shown in Fig. 4. The various input signals are amplified (if necessary) and applied to the inputs of a commutation sampling device. The commutator may be either a mechanical or an electronic multichannel switch. The output signal from the commutator consists of a series of pulses of one of the types shown in Fig. 3. In pulse amplitude modulation systems the various pulses have essentially constant width and position, but vary in amplitude; in pulse time modulation systems all the pulses will have constant amplitude (except for the synchronizing or reference pulse), but their relative time position will vary; in pulse width modulation systems the amplitude and relative time position of the pulses remain constant, with the pulse duration varying. Pulse code modulation is essentially a specialized form of pulse amplitude modulation (or of any of the other systems).

The resulting series of pulses is now a single-channel signal which can be amplified by the recording amplifier and recorded by a standard commercial recorder upon magnetic tape. When the tape is played back at any later time,

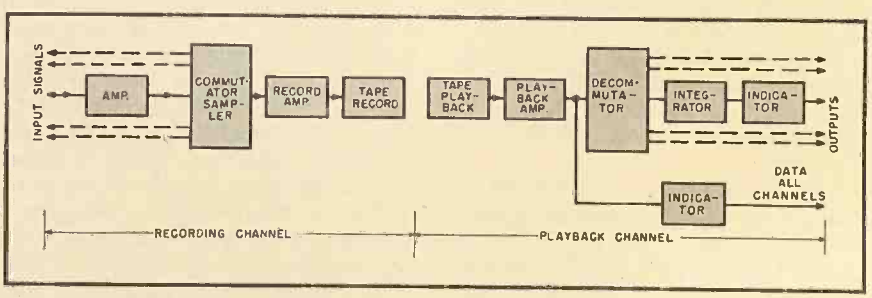
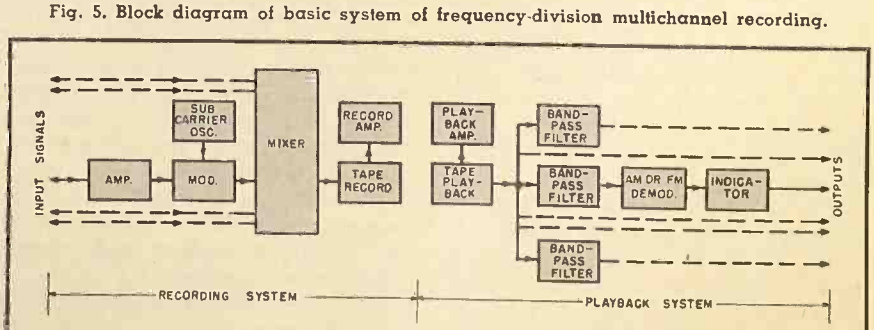


Fig. 4. Block diagram of the basic system of time-division multichannel recording.

Fig. 5. Block diagram of basic system of frequency-division multichannel recording.



this signal (after suitable amplification) must then have the pulses separated into the correct channels. The decommutator for performing this function will generally be an electronic switching circuit which can be properly synchronized, since a mechanical switch would have too much inertia for correct synchronization.

After the pulses have been demodulated, the information they contain is in the form of pulses as shown in Fig. 3 (D). These pulses must be integrated in order to deliver the original signal again as a continuous waveform. By the sampling theorem, if the time interval between pulses is T, then the highest frequency component which can be reproduced is $\frac{1}{2}T$ cycles per second (although a higher number of samples is, of course, preferable for high-accuracy systems). This limitation determines the requirements of the commutator switching system and of the tape recorder. Mechanical switches are generally commercially available which are capable of as many as 60 contacts at rates up to 60 rps—*i.e.*, 3600 contacts per second—and experimental switches have been able to sample as many as 12,000 contacts per second. Thus, assuming 3600 contacts per second with each alternate contact left blank to give break-before-make isolation between adjacent channels, and connecting the contacts in groups to give maximum frequency response in each channel, a ten-channel system would then be sampled ever 1/180 second per channel, while a five-channel system would be sampled every 1/360 second per channel. This would permit a frequency response up to 90 cps for the ten-channel system, and up to 180 cps for the five-channel system. When the required frequency range falls within the limits obtainable with such switches, it is often simplest and most convenient to use mechanical commutation, inasmuch as these switches are compact, reliable, quite versatile because of the many wiring combinations possible, and result in simpler circuits than electronic switching methods. A photograph of a standard commercial sampling switch designed to sample 60 contacts at rates up to 60 rps is shown in Fig. 2. When better high-frequency response is required, and for systems where this type of switching is not applicable, electronic switching circuits must be used. Practical electronic commutator systems have been developed which can provide 16 data channels with 6400 information samples per second in each channel.

The frequency response required from the magnetic tape recorder depends primarily upon the switching rates of the commutator. When mechanical switches are used, their output information can be recorded by standard commercial units with a frequency response up to 10 kc. When electronic commutators are used, higher frequency response is required. Fig. 6 shows a photograph of a commercial magnetic tape recorder having a frequency response of ± 3 db from 350-80,000 cps, which is sufficient to reproduce signals from high speed electronic commutators.

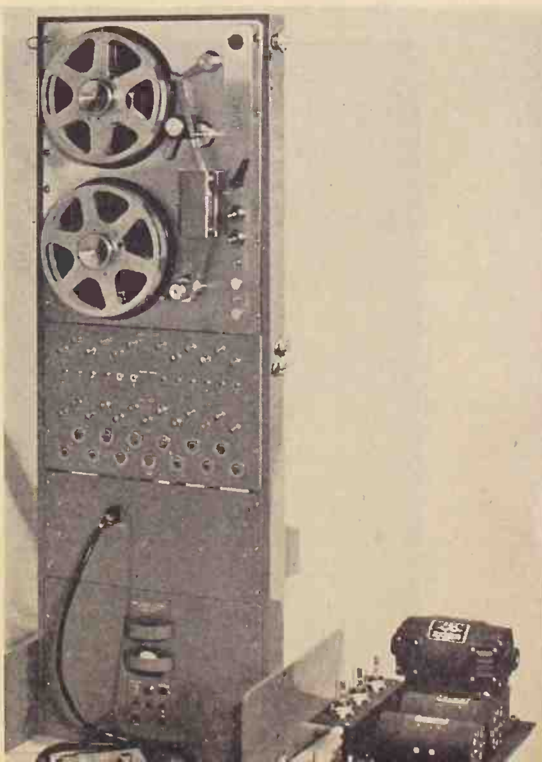
Fig. 6. The Ampex Model 302 single-channel recorder. This unit will cover all telemeter channels up through 40 kc. Frequency response ± 3 db from 350 to 80,000 cps.

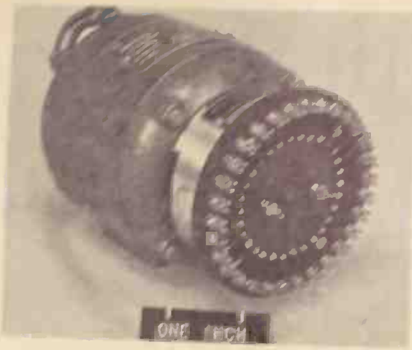
The basic frequency-division method makes use of a number of subcarrier oscillators of different frequencies which are modulated by the signals to be recorded, and the modulated subcarriers are then combined into one composite signal which can be recorded on a single recording channel. The modulation may be either AM or FM, depending upon the requirements of the system and the characteristics of the tape recorder. The basic block diagram for frequency-division multiplex systems is shown in Fig. 5. The various input signals are amplified (if necessary), and each is then applied to the modulation input terminal of the subcarrier oscillator. The most commonly used type of modulated oscillator circuit for this service is the multivibrator. The modulated subcarriers are then combined in a mixing circuit which may, in the simplest case, consist simply of a number of resistors properly connected to add the various signals together and give proper isolation between the different channels. The composite mixed signal is then applied to the input of the tape recorder amplifier and recorded on the magnetic tape.

When the composite multiplex signal is played back, the various signals are separated into the correct channels by bandpass filters. The carriers are then demodulated by the appropriate type of detectors, whose outputs can be read on an indicator, recorded or displayed in any desired manner.

The frequencies of the individual oscillators and the required over-all frequency response of the tape recorder will depend upon the highest frequency components which are of interest in the signals being recorded. In both AM and narrow-band FM the modulated bandwidth is on the order of twice the modulating frequency; therefore, the recorder shown in Fig. 6 could accommodate a 16-channel multiplex system with a frequency response which depends upon the subcarrier frequencies selected for each channel. The choice

Fig. 7. The Ampex Model S-3024, a 13-channel system for recording and reproducing signals obtained in petroleum and similar geophysical applications.





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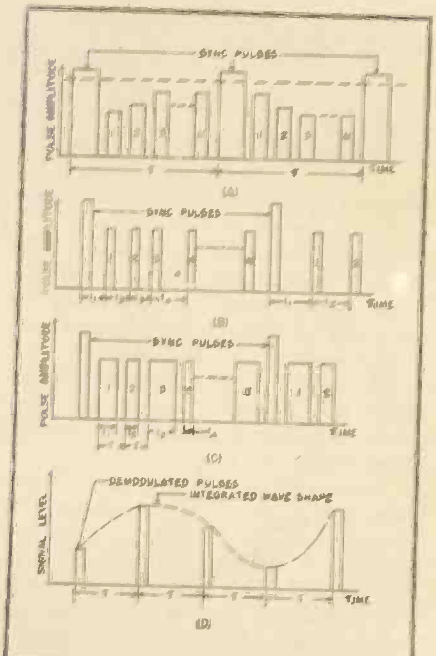

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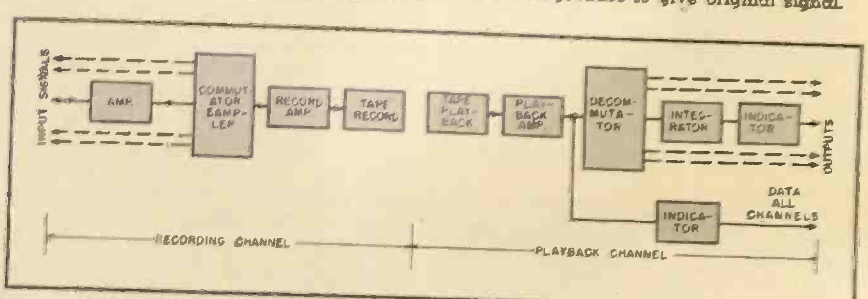

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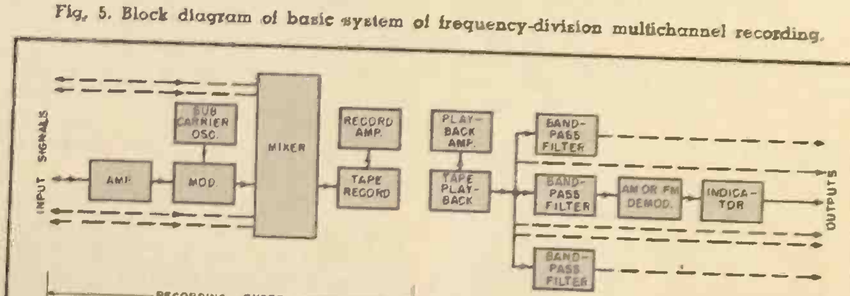

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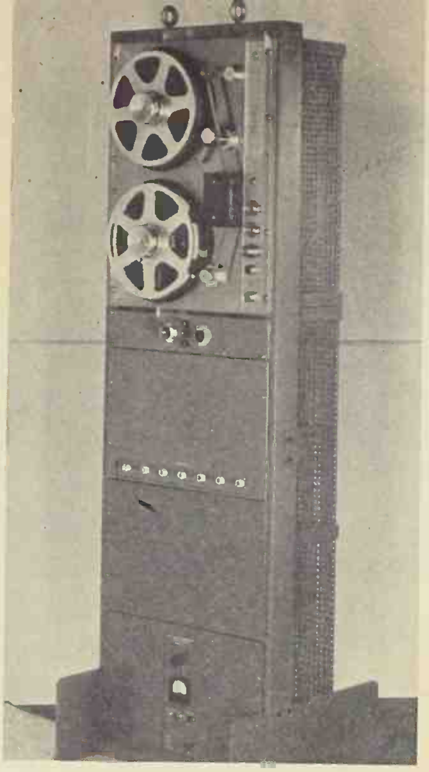


Fig. 8. The Ampex Model S-3041, a typical multitrack unit which records seven channels on a ½-inch magnetic tape.

between the use of AM or FM depends mostly upon the requirements of the particular application. Signals which vary at a slow rate (for example, up to 10 cps modulation) can be recorded with better than 0.5% accuracy on standard commercial tape recorders of the type used for radio broadcast recording.

However, the more common systems make use of frequency-modulated carriers, and the recording is then independent of tape and recording head characteristics. Particularly when high frequencies above about 15 kc. are being recorded, AM systems are not too useful for good accuracy, because high-frequency amplitude changes of as much as 50 or 60 per cent loss may be caused by inconsistencies in the magnetic tape coating material. FM systems avoid this difficulty, since amplitudes are limited to a fixed level.

Because the deviation used in most such systems is generally about ±7.5% of center frequency, the motional stability requirements on the tape drive are very severe, and only machines having very low flutter and wow can be used. Best results from frequency-modulated subcarriers are obtained by the use of electronic compensation for motional instabilities. Electronic compensation consists of recording one unmodulated carrier, and feeding the output of this channel to all the other channels, properly matched in amplitude and out of phase to cancel out the components generated by the flutter. The use of such compensation systems can reduce the flutter noise by a factor of four or greater. Because such compensation requires additional circuit complexity, considerable effort has been put into the design of tape recorders which are capable of better than 0.5% to 1% accuracy without the use of electronic flutter compensation. A commercial tape recorder, showing less than 0.04% peak-to-peak flutter on a typical test run and rated at 0.1% peak-to-peak flutter, is available.

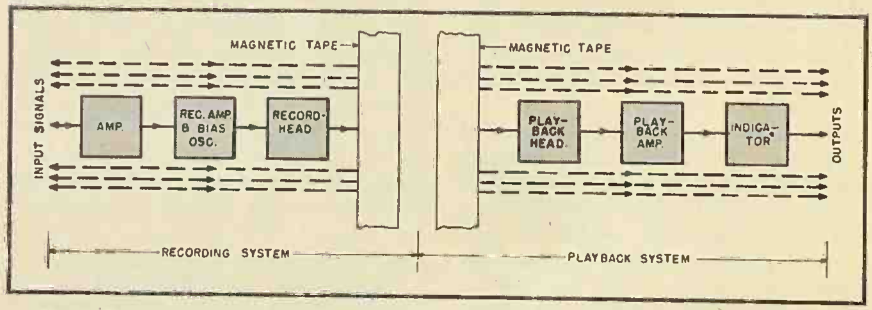
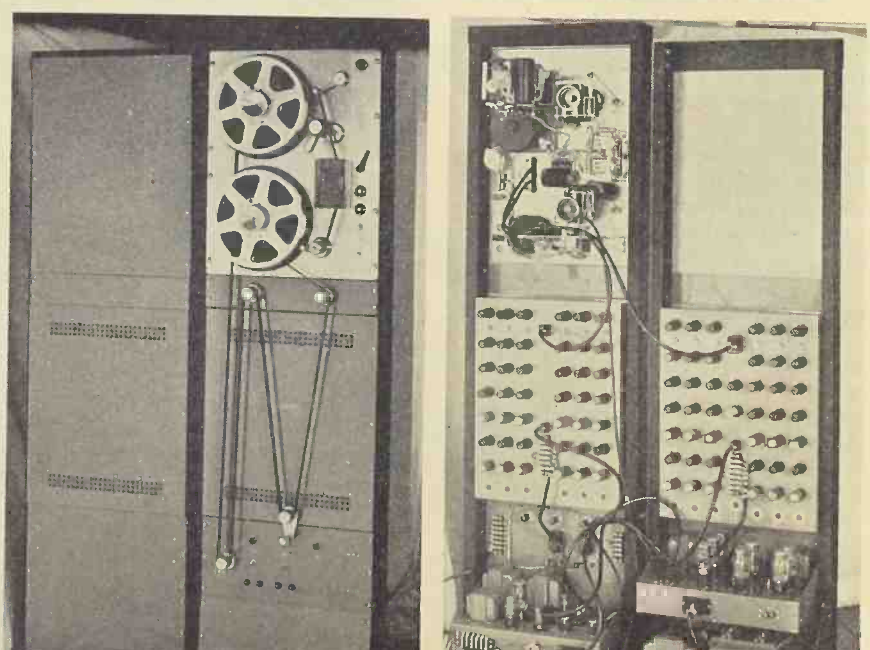


Fig. 9. Basic system for recording a number of independent channels on a single tape.

Fig. 10. Front and rear views of the Ampex Model S-3025, a 13-channel reproducer.



In space-division recording methods the various signals are recorded side-by-side in adjacent magnetic tracks on a single tape by means of multiple recording heads. When this system is used, each signal can be recorded with the maximum frequency range and signal-to-noise ratio of which the recorder is capable, since it is essentially a single-channel recording. Commercial units which have been designed for this type of service are capable of recording as many as seven tracks on ½-inch tape, and fourteen tracks on 1-inch tape, with crosstalk of −60 db or better between adjacent channels.

The basic multitrack recording system is shown in the block diagram, Fig. 9, and can be seen to consist essentially of a number of independent recording-reproducing channels, except that a common bias and erase generator may sometimes be used. Each channel contains a low-level amplifier (if one is necessary, depending upon the input signal level) and the recording amplifier. The playback channel contains a low-level amplifier and a high-level amplifier supplying sufficient signal power to drive the indicator or other units which display the signal in any desired manner. Since each recording channel is completely independent, the maximum frequency range and signal-to-noise ratio of such a channel can be attained in recording the required information. Systems are commercially available capable of recording multiple tracks with frequency response of ±3 db from 200 to 80,000 cps, signal-to-noise ratios of 40 db below 1% harmonic distortion, for 16-minute or 32-minute recording time.

Many applications require the recording of signals which contain frequency components down to zero cps. Such signals cannot be recorded directly

(*Continued on page* 30)

ETCHING - A GENERAL FABRICATION TECHNIQUE

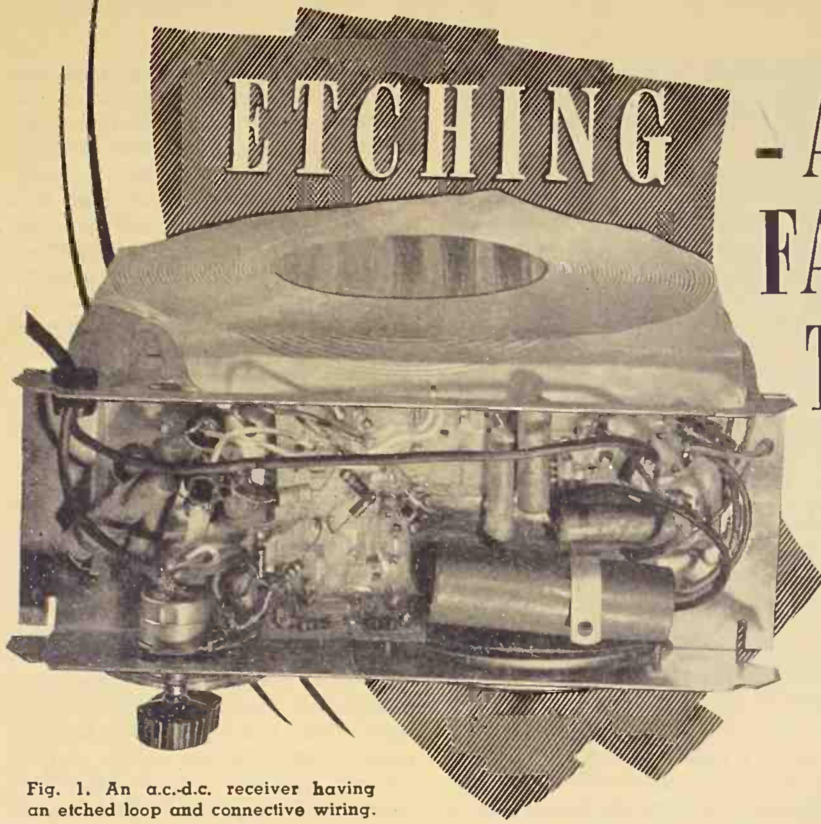


Fig. 1. An a.c.-d.c. receiver having an etched loop and connective wiring.

By
W. H. HANNAHS
and
J. A. CAFFIAUX

Physics Laboratories
Sylvania Electric Products Inc.

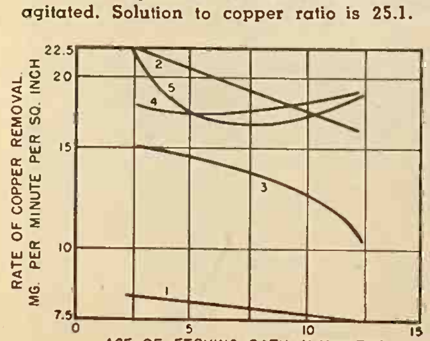
This technique permits saving many man-hours in the fabrication of circuit components and connectives.

IN MINIATURIZATION of electronic circuits and equipment, the reduction of man-hours needed to fabricate equipment is of extreme importance. A saving in skilled help is particularly urgent today in view of its scarcity and the growing demand caused by vastly extended application of electronics to new fields, both military and civilian.

The great demand for electronic equipment, both present and future, can best be met by the development of automatic assembly methods using miniaturized and standard components as desired. The efforts of Brunetti and Henry in devising methods for silk-screening of fuze amplifiers and i.f. strips have notably encouraged the introduction into industry of printed *R-C* assemblies for hearing aid and TV use. Abramson and Danko have shown also that simpler techniques, such as the solder pot dipping of pre-assembled components, may be more useful even though involving hand operations. In the latter technique, as in those reported here, the use of more conventional components is stressed with the emphasis placed on more convenient methods of assembling them into the end product. It is probable that total elimination of hand labor is still a far-off objective but a considerable saving may be had by product design, the use of printing techniques, and proper tooling without a complete dislocation of traditional manufacturing.

The possibility of improving on hand wiring was apparent at least as early as 1883 when H. W. Breckenridge invented a switchboard wiring panel involving a criss-crossed system of wires imbedded in a non-conductor. During the intervening years, many other schemes have been devised to provide a prefabricated system of connections for improving final assembly operations. In addition to conductive inks fired on steatites and the selective etching of copper-clad laminates, both of which methods are now well known, attention might be called to die-cut connections, the hot spraying of metal through stencils, and the blanking of wiring grids. The war-time exploitation of pre-laced and formed wire harness is in this category and has emphasized the fact that the more elementary techniques often have more extensive practical application when all requirements are considered.

Fig. 2. Curves showing effects of various control factors in copper etching with ferric chloride. 1. 41.5% concentration at 22°C not agitated; 2. 41.5% at 22°C agitated; 3. 41.5% at 42°C agitated; 4. 37.0% at 22°C agitated; 5. 43.7% at 22°C agitated. Solution to copper ratio is 25.1.



The complexity of electronic products requires that the design, the process, and the tooling be closely integrated to achieve an efficient method. However, if the three are too closely tied together, the resultant method often lacks flexibility of application. These primary considerations have entered into the development of printed circuit methods reported in this paper, which treats the laboratory development of etching techniques and test methods.

At the present time, considerable industrial attention is being given to a process for producing electrical connective harness and components by the selective etching of copper foils bonded to plastic laminates. U.h.f. coils, capacitors, and connective wiring can be produced on a surface which is substantially two-dimensional. Holes punched through the laminate permit the insertion of leads from standard components. These leads are thus presented for convenient hand soldering or, in some instances, they may be dip-soldered. The pattern which is acid-etched is determined by a resist of organic coating material put on the copper by a variety of graphic arts and methods such as pen drawing, silk screening, use of a rubber roller, or photography.

While the application of etching to the fabrication of electronic components

Fig. 3. Samples of etched broadcast loop antennas on plastic film.

and circuits has been reported in a number of journals, not much attention has been given to the process itself. The underlying idea of protecting a desired geometrical metal design with a resist or stop-off during a removal process was patented in 1888 and is an old technique in the fine arts and decorative fields. Since copper-clad laminates are of interest in etched-circuit fabrication, three methods of processing the laminates for use as electronic products have been worked out in the laboratory. In all of these the general procedure is to apply a protective coating of chemical resist to those areas of the copper which are to be retained.

In the first method, the resist is an ink and any of the regular means may be used to apply the circuit pattern directly to the copper.

In the second method, the copper surface is completely covered with a resist and a stylus is used to scribe those portions of the copper designated for removal.

In the third method, the resist is a photo-sensitized colloid to which the design is transferred photographically from a negative.

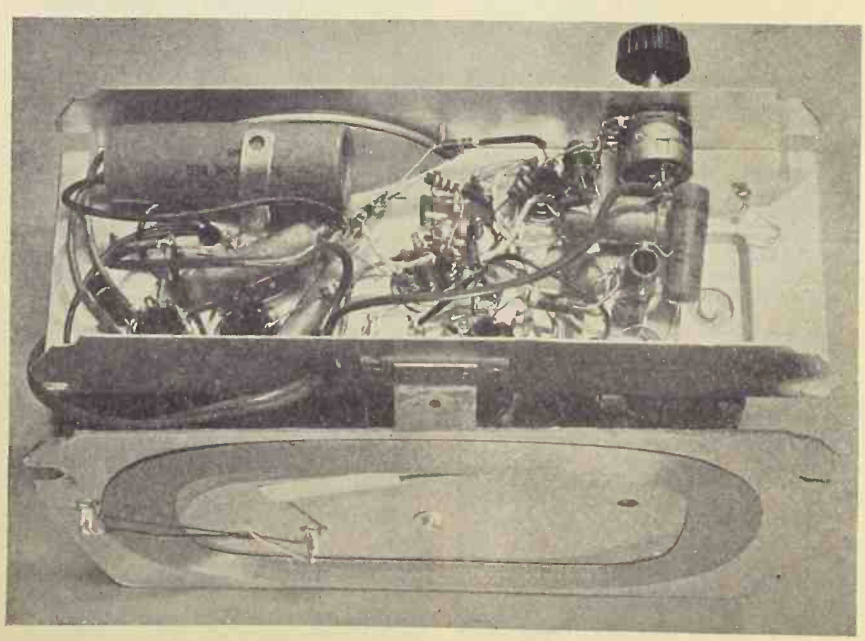
The first and third methods are generally used to manufacture electronic products today, particularly by concerns which have for many years used graphic arts etching for the production of signs, name plates and similar decorative items.

The etching of copper is, of course, a well established art in printing and engraving, and Method 3 is used daily for producing newspaper cuts and halftones in large volume. This photographic method offers great flexibilty in design and is capable of an ultimate definition of at least 1000 lines per inch when copper of one mil or under is used. However, it is somewhat slow, being intrinsically a batch process, and the cost of resist is rather high. With copper etching stock, a practical limit to line width may be assumed at about .015" due to variations encountered in etching a long, narrow strip. Larger quantities of etched products can undoubtedly be produced by utilizing an etch-resisting ink (Method 1) applied by means of a silk screen, printing press, or other graphic arts method, but there is no direct evidence that such a method is in use.

Preparation of Surface

In printing and lithography a great amount of attention is given to proper cleaning of the metal surface before any resist is applied. The purpose of this cleaning is two-fold: first, to prepare what will later be the printing surface for the proper retention of ink, and second, to promote adhesion of the resist. Only the second objective is of immediate concern for our purposes. While nitric acid etching has been tried for cleaning the copper surface, abrasive methods have been found more convenient and quite suitable. A satisfactory way of preparing the etching stock is to scrub it lightly with a moistened paste of calcium carbonate, or levigated alumina. The abrasive is washed away in running water and the cleanliness checked by observing whether or not a continuous film of liquid forms on the surface. Drying is accomplished by spinning at 78 rpm under a heat lamp.

Fig. 4. Under-chassis view of conventionally wired a.c.-d.c. receiver.



Application of Resist

While resists for the three different methods previously mentioned must have slightly different qualities, a common requirement is a resistance to "lifting" or porosity in the etching bath.

The resist used in the first method must behave properly with a ruling pen, dispose itself on the copper surface without running or contracting into drops, and otherwise conform to the requirements of an ink. For this purpose an opaquing ink has been found quite suitable.

In Method 2, and where the design is to consist of relatively wide copper areas separated by narrow spaces, it has been found convenient to use another type of resist in which the "spaces" may be scribed with a sharp, pointed tool. For this purpose the entire copper surface is rinsed with a quick-drying organic solvent after being cleaned, and then lacquered by spraying or brushing. Dykem steel blue, a layout lacquer, has proved satisfactory. If the coating is sprayed, it should be done in two thin layers, and if brushed on, by application of two coats at right angles in order to avoid pin holes. The design may be cut with a scriber or a narrow chisel-edge tool, using conventional drafting guides. After etching, the resist may be removed with alcohol.

In the third method, a very large amount of work has been done in the development of photo-sensitive stop-offs for the making of printing surfaces, and many variations of such material exist. The suspending media most frequently used for photo-sensitive bodies fall into categories which are typified by albumin, glue, shellac and, recently, polyvinyl alcohol. Evolution in the third class of coating has resulted in a group of materials, known to the trade as "cold top enamels," which have wide popularity in preference to the other materials because they require less caution and treatment to prevent undercutting during etching.

The original circuit design is laid out 2-5 times its size on glossy bristol board with India ink. This is reduced by photographing it to actual size on a high contrast "process negative" film, such as halftone film. The exposure of the sensitized plate under the negative may be made in an ordinary photo print frame, but is preferably done in a vacuum frame to insure close contact between the negative and the sensitized surface over which it is placed. The exposure varies somewhat with the environmental conditions as well as with the average density and contrast in the negative. The "development" of the cold top enamel consists of a drying and very slight hardening action of a weak dye-alcohol-water solution in which the exposed pattern is placed for a few minutes, followed by a complete washing out of the unexposed sensitized areas under cold running water. The developed pattern is then dried with forced air which may be warmed to approximately 100°F. The design is now ready for etching.

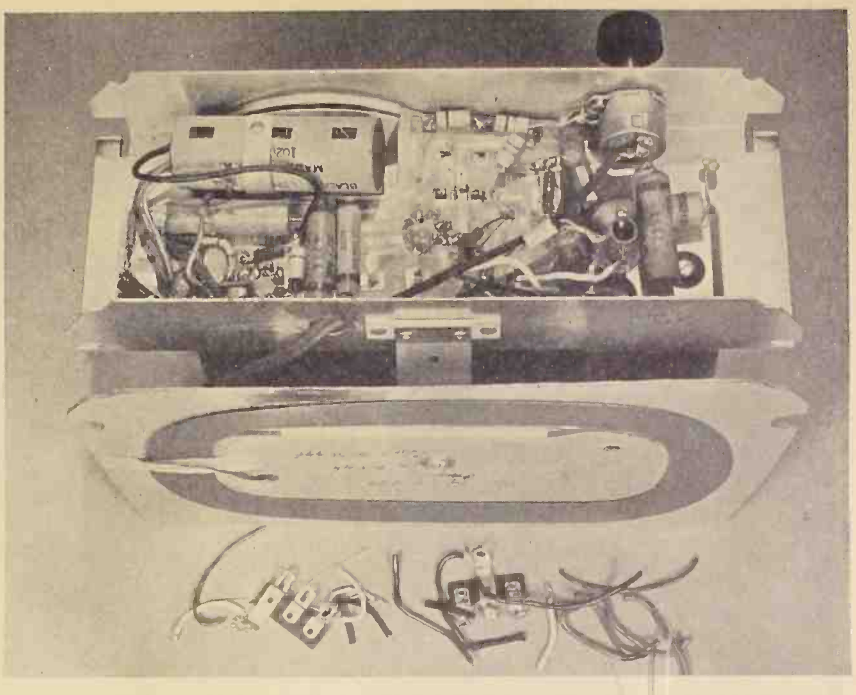


Fig. 5. Intermediate stage in simplification showing etched connective wiring.

Etching

One of the more easily controllable materials used in etching is ferric chloride solution. The plate maker alternately etches with nitric acid formulations or ferric chloride solution, but since the latter is easier to control and permits use of less critical resists, it has been the most common etchant applied to component fabrication. Ferric chloride is obtainable in 41.5% solution, ready for application, and some interesting parameters of its use in etching copper are expressed in Fig. 2. Curve 2 in comparison with Curve 1 shows the pronounced improvement with agitation. It is also significant to find that increasing (Curve 5) as well as decreasing (Curve 4) the solution concentration with agitation decreases the average rate, indicating an optimum concentration.

Greatly increasing the temperature of the etching bath (Curve 3) also results in a decreased rate, and in an observed formation of etching residues over the copper surface, together with a pitting of the surface. Fifteen to twenty minutes are generally adequate for etching patterns in one-ounce copper. The agitator consists of a shake table which has a two-inch excursion and is eccentrically driven by a motor at 56 rpm.

Electro-etching or deplating may be applied to hasten the removal of copper but cannot be used to carry the process to completion because the etching eventually detaches some of the areas to be removed from the circuit. The last traces of copper must in any case be removed by straight chemical etching. Electro-etching is five or ten times as fast as chemical etching and has less tendency to undercut the resist, making an attack upon the copper which is "V"-shaped when viewed in cross section rather than the "U" shape or inverted "V" shape cross section of attack experienced with chemical etching, according to some authorities. Some manufacturers of photographically etched products leave the residue permanently on the surface as a protective coating. If it is desired to remove this residue, a weak solution of ammonia is effective. If necessary this may be followed by abrasion with calcium carbonate to give a final brightening. In any case, there should be a rinsing wash in running water.

Work with stiff laminates has also been applied to etched circuits on flexible backing. As an example, these techniques have been applied to a highly competitive, large production item, namely an a.c.-d.c. five tube receiver.

Fig. 4 is an under-chassis view of a typical five tube a.c.-d.c. superheterodyne showing the familiar intricate pattern of point-to-point soldering. This set is in a highly competitive price bracket where the fact that "it costs as much to cut and solder in a wire as a resistor" is important. Typically also, this set has had its design intensively sifted and has gone through an assembly line shakedown for the maximum economy consistent with quality before consideration is given to printing techniques. This has the effect, of course, of requiring that revision of the design in terms of a printed circuit be compatible, at least in part, with existing design.

Fig. 5 is a picture of this set adapted to preformed connectives as the initial step in simplifying assembly. The wiring pattern is prefabricated by etching two-ounce copper foil supported on a flexible cloth backing. Holes punched at appropriate places in the layout are located over socket terminals, transformer lugs, etc., so that the circuit may be "buttoned" over these and the connections soldered without change in the original arrangement of the major components. Crossovers were eliminated, with a single exception, by using the resistors and capacitors for the required bridges. The displaced connections which previously were individually cut, stripped, and inserted are shown at the bottom of Fig. 5. The minor components are now in a fixed location to assist both installation and maintenance. Where attachment is necessary to component lugs out of the plane of the connective pattern, the cloth-backed copper has been slit to form tape-like conductors which are directed to the component.

In further evolution of this receiver into printed form, Fig. 1 shows the loop antenna also etched and integrated into the connective harness. The cloth backing does not extend into the loop, which is supported during processing solely by the impregnating lacquer film. This permits subsequent mounting of the coil on a low loss but inexpensive base for support without encountering problems of moisture absorption during the etching process. A photograph of the loop appears in Fig. 3. In this manner, antennas for broadcast frequencies have been achieved

(*Continued on page* 31)

WAVE GUIDE CALORIMETER

By
SAMUEL FREEDMAN

Electronics Division
Transport Products Corp.

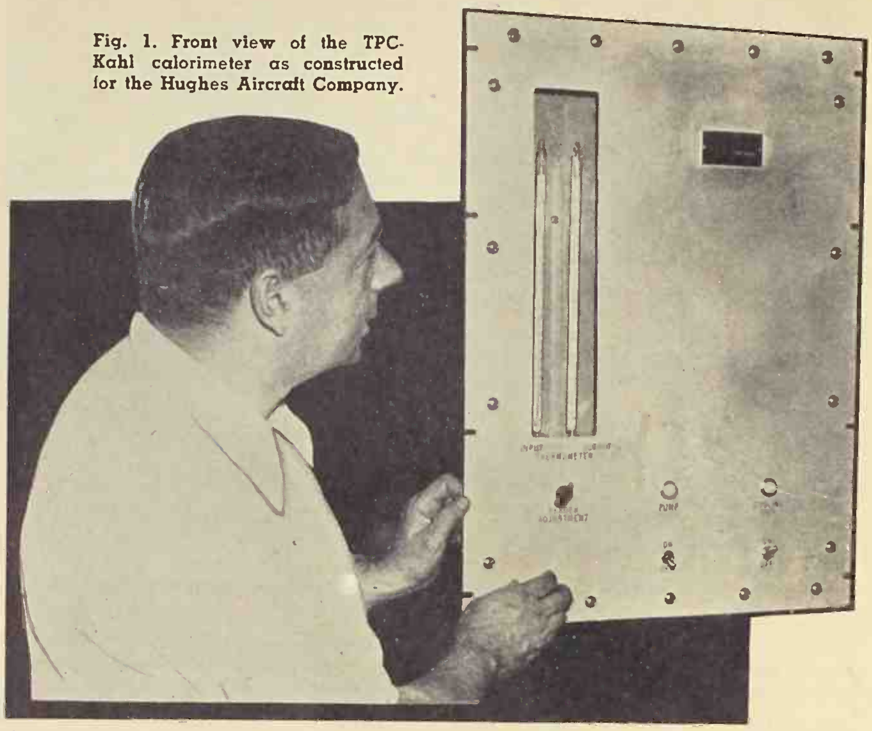


Fig. 1. Front view of the TPC-Kahl calorimeter as constructed for the Hughes Aircraft Company.

Accurate microwave power measurements, regardless of waveform or duty cycle, are possible with this unit.

THE MICROWAVE or wave guide type of calorimeter was introduced commercially in 1948 as a revolutionary method of measuring absolute or average power developed from a radar or magnetron output, and to serve as a primary standard in calibrating or checking any other apparatus used to measure microwave power directly or indirectly.

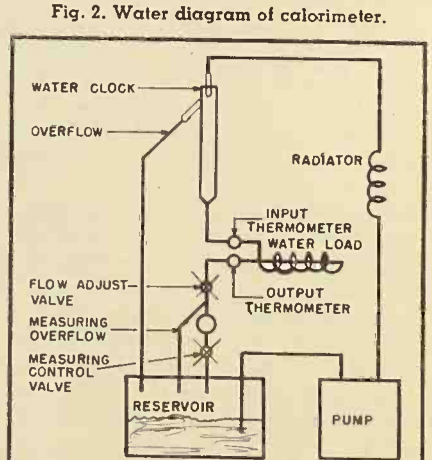
Physically, it is a device for circulating specific amounts of water through a glass water load in a wave guide, and for comparing the temperature difference between entering and returning water. The ability of water to absorb microwave power in a wave guide makes possible the direct or absolute measurement in actual watts of average power. This power is an average of whatever energy components are present, regardless of whether they are c.w. or pulsed. It is independent of the peak or fluctuating energy values existing in a system.

Absolute Power Measurement

In any radar or pulsed system, average power is still the final criterion of performance. The peak power, and the over-all capabilities of any radar, are tied in with average power. This power may be broken up into increments of a small number and of longer duration to provide low peak power, or many increments of short duration to provide high peak power. It is essential to have an accurate determination of average power, the foundation from which every other radar performance consideration has to be established. The microwave calorimeter is the most satisfactory device for the determination of average power.

Any commercial calorimeter includes a water load of a very elaborate and super-sensitive type, as illustrated at the top of Fig. 6. This fits into a wave guide terminating section. Since it absorbs all the power terminating into that wave guide section, it is immaterial whether the section terminates as an open or closed wave guide. This unit is the heart of the calorimeter. Water circulates through its tubulation at a certain flow rate; for example, at 180 cc. per minute. The incoming energy is completely absorbed by the water in this load.

Fig. 2. Water diagram of calorimeter.



The simplest water loads, including all those used prior to the development of the model illustrated in Fig. 6, comprise no more than a tapered, double-compartmented glass section. Water enters through the outer compartment and returns at the tapered tip through the inner compartment.

The water load in the upper part of Fig. 6 is much more elaborate, having about 460 cm. of developed glass path between input and output thermometer points. It is designed to fill the wave guide and intersect every energy mode several times in the X and Y planes along the Z axis. All the power is absorbed in the form of increased water temperature within the first third of the water load, the remaining two-thirds offering complete assurance of power absorption.

As illustrated, the unit has several water load sections all connected in series. At the left end is a tapered section of 1 to 2 wavelengths long for the lowest frequency to be measured. This is double-compartmented. Water comes in through the outer compartment and is returned through the inner compartment. There are also two glass coils of 3 mm. glass tubing, side by side, and a third larger oval glass tubulation of larger diameter encompassing the two smaller glass coils. At the beginning and at the end of this lengthy glass tubulation system are thermometer wells for input and output thermometers. In the new calorimeter, small "Dewar flask" units make up the wells, with the thermometers fitting into the "Dewar flasks." This minimizes the tendency of thermometers to be affected by local temperatures other than that of the water. Small glass extremities on the tip are for the purpose of balancing the water load in the wave guide.

Also illustrated in Fig. 6 is a single coil water load in which a vacuum exists between the coil section and the outer jacket so that the heated returning water will not be affected by the cold incoming water. Also, any infrared radiation from heated water will be jacketed by the outside colder water. The third item illustrated in Fig. 6 is a version of the Egyptian water clock type of flow meter. Water comes in at the top, fills the clock to the level of the overflow tube, and yields a steady pressure and flow through the free orifice at the bottom.

Any calorimeter must include a circulating system which produces a predetermined rate of flow through the water load. Provision must also be made to keep this flow constant during the time that measurements are to be made. A cooling system is provided to restore the water to room temperature before it is allowed to return to the water load for continuing power measurements.

Average Power

The heat transfer is equal to the weight of the circulating water multiplied by the temperature difference and multiplied also by the specific heat of the liquid which, in the case of water, is unity.

Since 1 cc. of water weighs 1 gram, the basic formulas for calorimetry may be reduced to the following simple relationship:

cc. per min. x temp. diff. (°C) = calories per min.

Since 1 watt = 14.334 calories per minute, the average power can be accurately calculated.

From the foregoing, it may be seen that variations in water flow cause a wide range of temperature difference for a given power. Actually, a calorimeter is calibrated by selecting a flow which will cause a desired temperature difference for a certain amount of power. There are practical maximum and minimum temperature limits to be used.

If the outlet temperature is permitted to exceed about 65°C, air bubbles may form in the liquid. The minimum temperature is that of the highest temperature likely to exist in the working space, such as 25°C. There is a usable over-all range of about 40°C. For example, if the calorimeter is to measure from 0 to 500 watts average power, a flow rate should be selected which will produce a temperature rise of 0.08°C for each watt of power. If the instrument needs only measure up to 50 watts, then a flow rate can be selected to produce a temperature rise of 0.8°C for each watt of power to be measured.

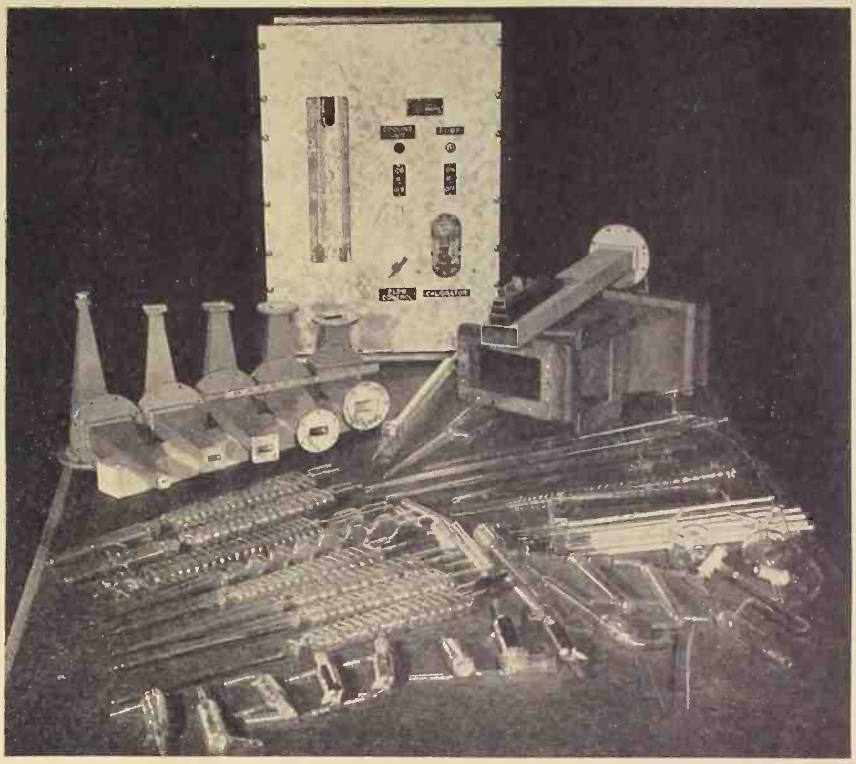
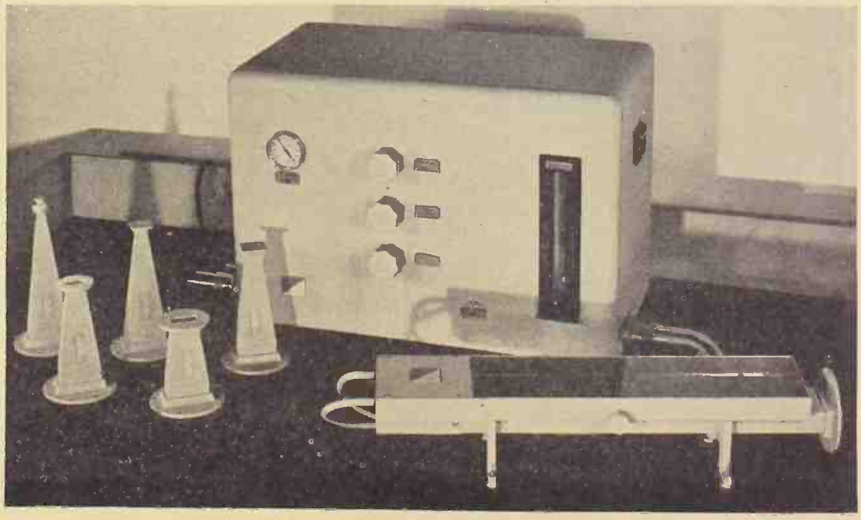


Fig. 3. Improved version of calorimeter in background, with various wave guide adapters and tubes immediately in front. In the foreground are many different types of water loads. The longer and narrower the load, the smaller the VSWR. At the left front are several silvered Dewar flasks for thermometers. At right front are several thermometers and three Egyptian water clock flow meters.

The first commercial calorimeters were developed at *DeMornay Budd Inc.*, as an offshoot of the company's wave guide program. That firm discontinued operations in August, 1949. During 1948 and the first half of 1949, a total of fourteen units such as the one illustrated in Fig. 4 were built.

These calorimeters comprised two separate units interconnected with rubber tubing. As shown in Fig. 4, the large cabinet contained the water reservoir, flow meter, water reservoir temperature and water control valves. The cooling system consisted of tap water entering one of the plumbing fittings shown at the left lower end of the cabinet and returning out of the other. The flow meter, calibrated in hundredths-of-a-gallon flow per minute, is the glass column at the right. The actual calorimeter is the unit in the front of the illustration comprising a wave guide (S-band or 3″ x 1½″ size) containing a tapered water load plus two thermometers supplied with a slide rule

Fig. 4. A commercial microwave calorimeter, developed by DeMornay Budd, Inc.



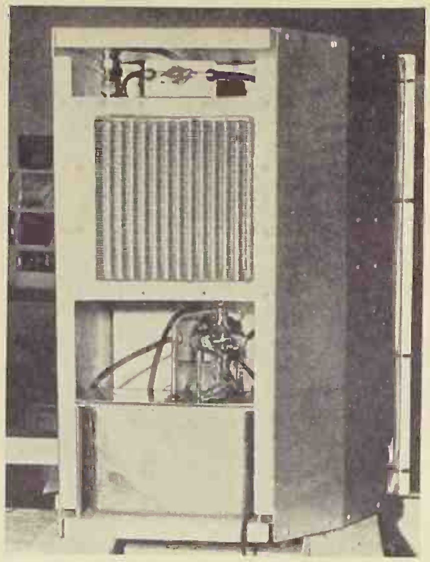


Fig. 5. Rear view of TPC-Kahl microwave calorimeter shown in Fig. 1.

scale. The reference point on the slide rule is set by a knob to the mercury level of the input (horizontal) thermometer. Then, in line with the mercury level of the output (horizontal) thermometer, the power is read directly in watts on the slide rule scale.

Also shown in the illustration are five wave guide transitions or adapters used to couple radar systems operating at higher frequencies. Although the mode of operation undergoes change by use of such a transition, the water load absorbs the energy of all the modes present in the calorimeter wave guide section. It will be noted that the length of the wave guide transitions increases with the magnitude of the transition to be made in terms of wavelength or frequency. They all have the same flare angle but their extension varies with the final dimension to be reached.

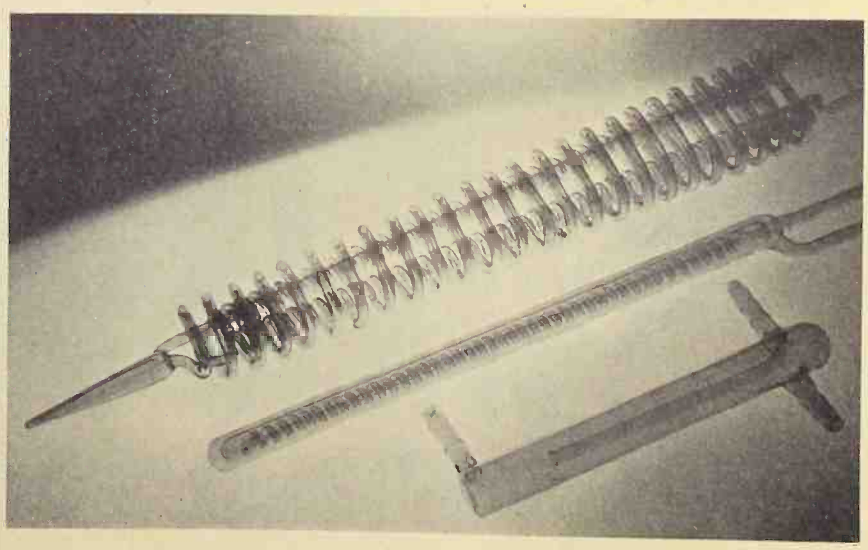
Although the *DeMornay Budd* calorimeter quickly became a useful instrument, superior to anything else previously available for measuring absolute power, it had certain design difficulties which were not fully overcome in succeeding designs of other firms. A survey of calorimeter users indicated the following design shortcomings:

1. There was a lack of portability and a tendency for errors to develop when the level, placement, and height of one unit were changed with respect to the other of the two-unit calorimeter apparatus.
2. The water load and thermometers underwent misalignment with respect to each other.
3. The slide rule scale developed errors when thermometers were changed or disturbed.
4. The units had a multiplicity of control valves.
5. The flow meter used a moving float which could stick or pick up sediment.
6. Air bubbles and sediment could develop in the system.
7. The water load did not completely intersect all the possible energy modes likely to exist in the X and Y planes along the Z axis within the wave guide section.

Improved Calorimeter

Fig. 2 shows the water circuit diagram of an improved calorimeter developed by *Technical Products and Services Company*, of Santee, Calif., operating as the Electronics Division of *Transport Products Corporation*, of Louisville, Ky. It utilizes new, improved glass techniques brought to the United States by German glass experts employed by the *Kahl Scientific Instrument Corporation*. The water load, illustrated in Fig. 6 and improved in later models, is designed to provide the maximum exposure of glass tubulation to r.f. energy, with the least feasible amount of water needed to fill the water load. It is designed to permit a water flow up to 300 cc. per minute when flowing by gravity alone.

Fig. 6. Top, super-sensitive water load. Center, simple water load with vacuum section between coil and outer compartment. Bottom, Egyptian water clock.



Constancy of the water flow must be maintained. This is accomplished by using an Egyptian water clock, previously described. The flow rate is adjusted by means of a flow adjustment valve and is maintained constant by means of the water clock device. Any small variation in the delivery of the circulating pump changes the amount of overflow but not the volume of water in the tube.

The circulatory system consists of a vibratory pump, radiator, blower motor and a stainless steel water reservoir. The pump operates on the jet principle, vibrating about 7200 times per minute. It requires little power and can be varied in output pumping rate by changing the input voltage. The radiator and circulating fan restore the water to room temperature before the flow is reintroduced to the wave guide water load. Short periods of use may not require the temperature-restorer cooling system, particularly for lower power measurements (below 50 watts average power), as it would take many circulations through the system before reservoir water would rise appreciably in temperature.

Although standard reference water has been used in study and experimentation, in practice any clean tap water suitable for drinking has been found satisfactory. The presence of impurities in water can cause it to have a higher specific heat, resulting in some positive error. Even distilled water, if used for a long time, will lead to the development of impurities in the system. Experiences to date with calorimeters used in areas such as Fort Wayne, Ind., Long Island, N. Y., and San Diego, Calif., have been satisfactory with clean drinking water.

Fig. 1 shows the entire calorimeter in a cabinet. The only controls on the front panel are the toggle switches for the pump and the radiator blower motor. Recessed behind the panel are two thermometers, specially built with expanded scales and with the mercury column color-coded by means of capillary, glass-colored reflectors adjacent to the column. One thermometer shows a thick mercury line of blue; the other is colored red. This, plus the fact that the thermometers are vertical at eye level, makes them easy to read. The bases of these thermometers recess in miniature thermos-bottle, double-compartmented units, with water circulat-

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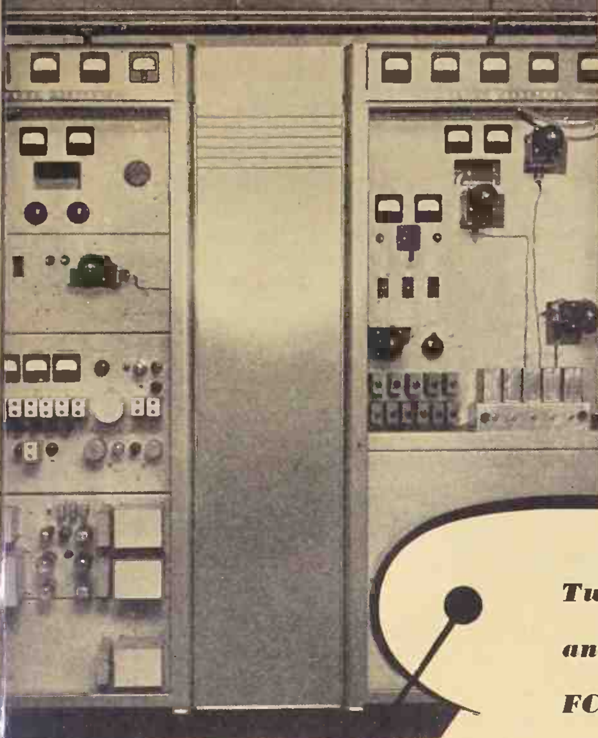


Remote Control for FM Broadcasting

Two pairs of telephone line for metering and for control are necessary with this FCC-approved transmitter control system.

Fig. 1. Front view of the G-E transmitter equipped for remote control at WHYN.

By
HAROLD SCHUMACHER
and
CHARLES TAMM
Engineering Staff, WHYN

WITHIN THE past year or so, a number of FM stations have returned either their construction permits or licenses to the FCC and have left the air. There have been various reasons given for these deletions but the most prevalent is that of economy. In many instances, remote control of the transmitter will prove to be an economical feature. Described below is a complete remote control system which is in experimental operation at this time by authority of the FCC.

There are, of course, other possible methods which may be used but the following seems to be most foolproof in operation.

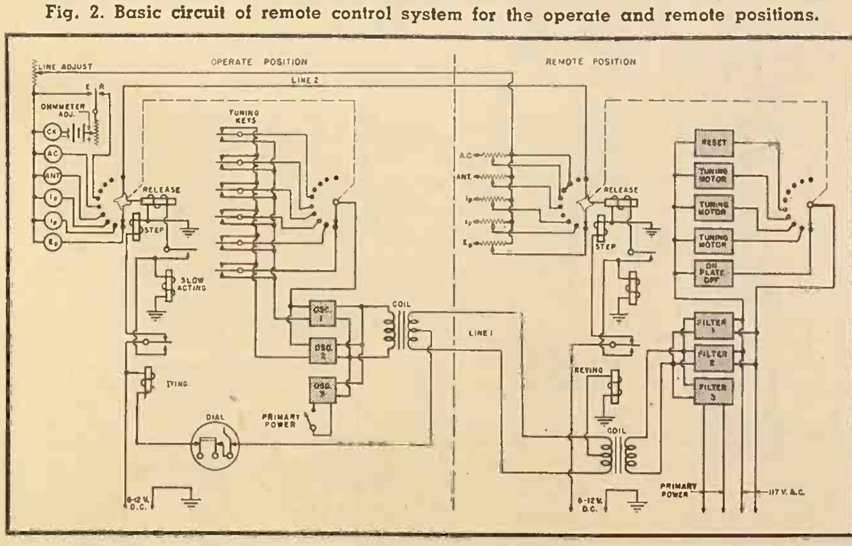
In the remote controlling of any transmitter, all FCC regulations and requirements pertaining to that type of service must be met by the remote control device so that the operator at the control point has complete control over the transmitter at all times while on the air.

In the case of FM broadcasting service, the following information must be available: final amplifier plate voltage and current readings, antenna transmission line r.f. output, center frequency deviation, percentage of modulation, and tower light operation, as well as continuous audio monitoring for quality control. It must be possible to control the final amplifier plate tuning and the antenna coupling load. In addition to the above requirements, it is possible, with this particular installation, to read final amplifier grid current, final screen voltage (and regulate same), tune the final grid circuit, adjust primary voltages, tune the antenna coupling load, turn on and off primary voltages (filaments, control circuits and blowers), and apply plate voltages.

The transmitter which is being used in this installation is a *General Electric* Type BF2A 3KW. The conversion can be accomplished without defacing the transmitter, as can be seen in Fig. 1. The control motors are mounted on angle brackets which, in turn, are mounted on the transmitter by means of the original dial panel mounting holes.

In this particular case, the remote control point is approximately six miles from the mountain top location of the FM transmitter. There are two pairs of telephone line required in addition to the regular program lines, one pair as metering line, and the other pair as control line. Provisions are incorporated at the control end for adjusting these lines daily to compensate for weather and resistive changes. At the remote end, each line is terminated through a ten-position stepping relay, the actuation of which is accomplished by a similar stepper and dialing system at the control point. In this way, it is only necessary to dial a single digit in order to perform any of the tuning operations and simultaneously receive the associated meter reading at the control panel. In the event of line failure,

Fig. 2. Basic circuit of remote control system for the operate and remote positions.



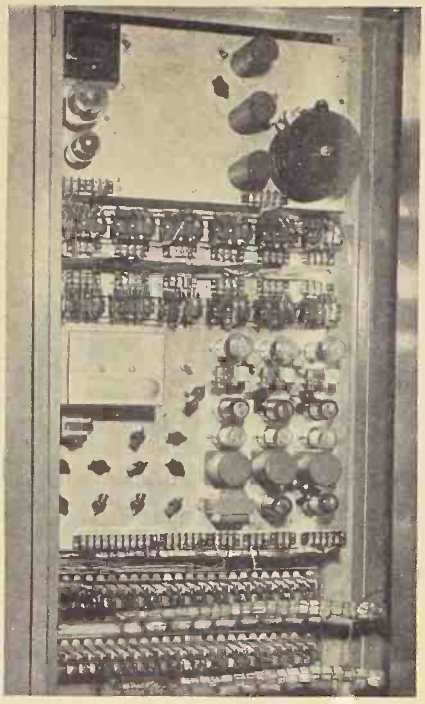


Fig. 3. Relay chassis and power supply at the transmitter location.

the transmitter is immediately thrown off the air, thereby assuring that the transmitter cannot continue on the air when it is out of control of the remote operator.

By referring to Fig. 4, a block diagram of the entire installation, and Fig. 2, a basic schematic diagram, it will be possible to trace the following operations.

At the remote transmitter location, time clock *A* applies primary control voltage to the remote relay chassis and its associated power supply one hour before air time. This power supply furnishes both six and twelve volts for relay operation as well as plate and filament voltages for the sharp bandpass tone amplifiers. There are three of these sharp bandpass amplifiers, one for primary transmitter power control, one for right hand tuning and one for left hand tuning. These tones are designated as primary, right, and left tone, respectively. They are in the audio frequency range and so chosen as not to be harmonically related. These tones actuate their respective sensitive plate relays in the tone amplifiers which, in turn, further actuate other relays, causing a right or left rotation of the tuning motors. These tuning motors operate at ¾ rpm and have been found to be satisfactory for delicate tuning.

After the time clock has turned on the relay chassis and its equipment at the remote point, the operator at the control point turns on the power to the control panel. When this equipment has warmed up, the primary power tone is applied to the control line. This tone, after passing through its bandpass amplifier, actuates proper relays which, in turn, apply primary power (filaments, blowers and starter circuit voltages) to the transmitter. This primary tone is constantly on the line during the time the transmitter is in operation. In the event of line failure or termination of this tone, the entire system collapses and the transmitter goes off the air.

After the above primary power is applied to the transmitter, the operator may dial #1 at the control point. Meter #1 on the control panel will give the primary voltage reading, and by actuating the anti-capacity type toggle switch below meter #1, the Variac controlling the transmitter line voltage can be adjusted.

Dialing #2 and throwing the toggle switch under meter #2 to the right will apply plate voltage to both the driver and final amplifier stages. Meter #2 will then read the final amplifier plate voltage. By throwing this same toggle to the left, the plate voltages will be removed, but the filaments and blowers will remain in operation until the primary tone is removed from the line.

Dialing #3 will allow meter #3 on the control panel to read total cathode current of the final amplifier, while by throwing the associated toggle, the plate tank capacitor will be tuned right or left to resonance.

Dialing #4 will again give total cathode current of the final amplifier and by throwing its associated toggle right or left, the antenna coupling may be varied.

Dialing #5 will give a reading of the relative antenna transmission line voltage, while operation of the toggle will control the Variac in the screen grid circuit. (Also note dialing #7.)

Dialing #6 will give the grid current of the final amplifier, and its toggle will tune the grid capacitor.

Dialing #7 will give the screen grid voltage, while throwing its toggle will also control the screen Variac, as in position #5.

Dialing #8 will short the metering line to ground at the remote end to enable the control operator to zero-adjust the line, thus compensating for day to day changes.

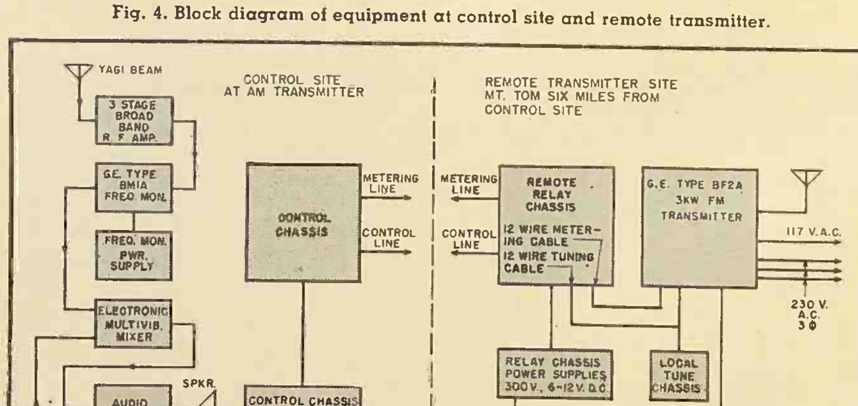
Dialing #9 will, by use of the toggle, allow the audio gain of the program amplifier at the remote location to be regulated. The metering at this position is, at present, unused, audio gain being apparent by percentage of modulation on the frequency meter.

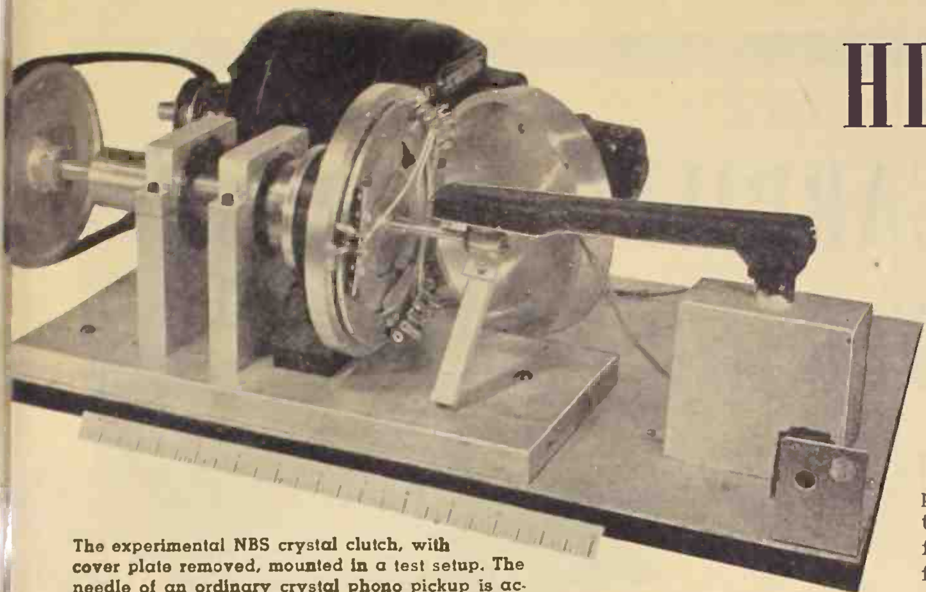
Dialing #10 will give an actual meter reading of the operation of all tower lights as well as the top flashing beacon. The toggle at this position is to be used for turning on and off the antenna de-icing equipment. A note of interest is the method of constant observation of tower light operation. The tower lighting consists of two pairs of 100-watt lamps at respective levels and a twin 500-watt flashing beacon. A sampling voltage is taken off a current-operated transformer, rectified and sent down the metering line when #10 is dialed. With just the four lamps burning on the tower, a given voltage is registered on the meter, and each time the top beacon flashes, this reading increases. It is, therefore, possible to determine if any of the four small lights have gone out or if the beacon is not functioning properly.

At the remote transmitter location, the equipment consists of the remote relay chassis and its associated power supply, seen in Fig. 3. The relay chas-

(*Continued on page* 27)

Fig. 4. Block diagram of equipment at control site and remote transmitter.





The experimental NBS crystal clutch, with cover plate removed, mounted in a test setup. The needle of an ordinary crystal phono pickup is actuated by the shaft to indicate when rotation starts.

HIGH SPEED CRYSTAL CLUTCH

Response speed of 0.2 millisecond is achieved by applying a voltage to suitable Bimorph crystals.

AN EXPERIMENTAL crystal clutch recently developed at the National Bureau of Standards is believed to be the first of its type. In the new clutch, application of a direct-current voltage to the electrodes of three "Bimorph" piezoelectric crystal elements causes bending of the elements. This bending presses the clutch output disk against the rotating input disk. The new experimental unit was devised by Ernest Codier of the NBS staff as part of a program for the development of fast-acting clutches suitable for use in high speed computers.

Distinguishing features of the crystal clutch are high speed of response and almost negligible current drain. No current flows, other than insulation leakage, after the applied voltage has charged the capacity of the crystals. The clutch therefore creates no magnetic field, an advantage in some applications.

In the only clutch model thus far constructed, the output shaft delivered useful torque in as little as 0.2 millisecond after voltage was applied. Output torque of the engaged clutch was approximately 16.5 ounce-inches at 400 volts excitation, or 21 ounce-inches for 500 volts. The no-voltage drag torque, however, was about 7.5 ounce-inches, a substantial fraction of the engaged torque.

Construction of the crystal clutch is essentially simple. The output disk is located between two rotating members: a thin, flexible crystal pressure plate and a heavier mounting plate or input disk. Three of the Bimorph crystal elements, which bend when opposite potentials are applied to different parts of the crystal surfaces, are spaced at 120-degree intervals. When the exciting voltage is applied, the crystals press against the pressure plate at a radius of 1.5 inches, pinching the output disk between the pressure plate and the input disk.

The clutch proper and its immediate mounting occupy a space about six inches in diameter and a little more than an inch long. The complete assembly includes, in addition, internal bearings for the output shaft, bearings and mounts for the entire assembly, a drive pulley, and slip rings for transmitting the exciting voltage to the rotating assembly.

The new clutch was tested for speed of response by placing the needle of an ordinary crystal phonograph pickup in a small dimple in the clutch output shaft. By connecting the pickup output to the vertical input of a cathode-ray oscilloscope, and connecting the clutch excitation voltage to the horizontal input, the time lag between the application of the exciting voltage and the resulting motion of the output shaft was observed. Alternatively, by connecting the Bimorph terminals to the vertical plates of the oscilloscope, it was possible to observe the voltage rise as the capacitance of the Bimorph crystals became charged.

Several factors enter into the design of a clutch of this type. Speed of response, the principal design goal, is related to the inertia and loading of the output system, the available torque, the distance the crystal pressure point must move before it begins to pinch the output disk, and the resonant frequency of the crystal itself. It is the resonant frequency that sets the ultimate limit for speed of response.

The dimensions of the Bimorph crystal determine not only its resonant frequency but also its sensitivity. The resonant frequency, in kilocycles, of a Rochelle-salt crystal Bimorph is given by 26 T/LW, and the sensitivity in mils per kilovolt is approximately 0.08 LW/T^2, where L, W, and T are crystal length, width, and thickness, in inches. Since increased crystal thickness is favorable to high resonant frequency but unfavorable to high sensitivity, design dimensions must be matters of compromise and judgment.

If resistance is present in the excitation circuit, the voltage appearing across the crystals will rise exponentially while the crystal capacity (about 0.0065 μfd) is charged. If the voltage rise is excessively slow, speed of response will of course be impaired. It might be thought that if resistance were eliminated, so as to give very fast voltage rise, speed of response would be a maximum. This does not prove to be the case, however. Instead, an irregular output motion appears, while response time shows no significant improvement.

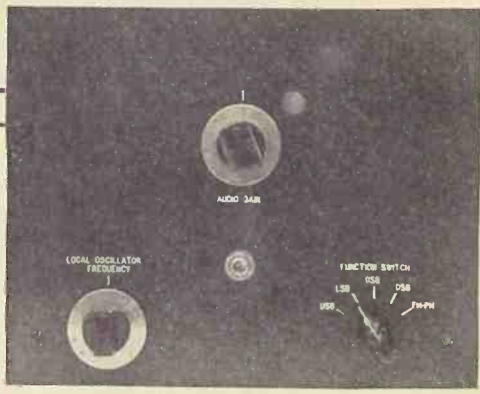
Rochelle-salt crystal elements are used in the present clutch because they are readily available and highly sensitive. Rochelle salt has several disadvantages, however: it is easily fractured, melts at 55°C, and will deliquesce unless protected from humidity. Barium titanate crystals, a logical alternative, should provide a mechanically rugged clutch usable at temperatures up to 100° C.

Obviously, the crystal clutch developed at NBS does not have wide applicability. Yet its high speed and negligible current drain could be very valuable in a few highly specialized but nevertheless important instrumentation functions. The experimental clutch model could undoubtedly be improved upon; in fact, several desirable modifications have already become apparent.

EXALTED-CARRIER SINGLE-SIDEBAND RECEPTION

Top-rear view of adapter removed from the cabinet.

By ROBERT C. MOSES



Front panel view of the converter, showing the various controls which are used.

Theory of operation and fundamental circuit design of an adapter for exalted-carrier SSSC reception.

SINGLE-SIDEBAND suppressed carrier (SSSC) offers advantages over certain other methods of transmission, particularly in point-to-point radiophone systems where readability under adverse conditions is of primary importance. Among these advantages are reduced bandwidth requirements, elimination of heterodyning resulting from co-channel interference, improved over-all signal-to-noise ratio, and substantially higher operating efficiency. Reception of SSSC does, however, impose certain special requirements upon the communications receiver if the above advantages are to be fully realized. It has been found that these requirements are effectively fulfilled with an adapter unit of the type to be described in this article. Making use of synchronous detection with exalted-carrier reception, this unit provides additional functions necessary for reception of SSSC transmissions. Also, selection of either or both sidebands of a conventional AM signal, as well as detection of FM and PM, is made available.

The principle of exalted-carrier reception with phase rotation of the demodulated audio components to select either sideband independently is not new. Work along these lines was carried on as far back as 1945 by M. G. Crosby and others[1], and more recently by D. E. Norgaard of *General Electric Company*.[2] The unit to be described is patterned in part after Mr. Norgaard's original design, but incorporates certain features which make for an over-all simplification of the receiving system.

Demodulation of signals in which the carrier and one sideband are partially or completely suppressed involves, in addition to the usual r.f. and i.f. amplification, the following provisions in the receiver:

1. Generation and insertion of a synthetic local carrier of the proper frequency and phase to permit substantially distortionless demodulation of the single-sideband suppressed-carrier signal.
2. Combination of separate audio components corresponding to the desired and any residual undesired sideband components in such a manner that the latter are discriminated against.
3. Means of selecting either the upper or lower sideband signals for further amplification.
4. If the receiver is intended to respond also to double-sideband plus carrier transmissions, suitable means of maintaining phase synchronism between the received carrier and the locally generated carrier must be provided.

The above requirements are fulfilled in the dual exalted-carrier demodulation system to be described.

Theory of Operation

Single frequency sine wave modulation on a single-sideband suppressed-carrier signal produces a pure r.f. component of frequency, corresponding to that of the original carrier plus or minus the modulation frequency, and an amplitude proportional to that of the modulating signal. Thus, if a 50-volt, 4000-kc. carrier were amplitude modulated by a 5-volt, 1000-cycle sine tone, and the carrier and upper sideband were subsequently eliminated, the result would be a single radio frequency signal at 3999 kc. having an amplitude of approximately 5 volts. If the modulating signal were a complex speech waveform occupying a band of frequencies from 100 cycles to 3000 cycles, the resulting single-sideband output would be a band of r.f. components ranging from 3999.9 kc. to 3997.0 kc. The spectrum of such a single-sideband suppressed-carrier signal would occupy the band of frequencies from 3997.0 kc. to 3999.9 kc., with no components present above 4000 kc.

In order to recover intelligence from an SSSC transmission in a substantially distortionless manner, it is necessary to demodulate the received single sideband against a locally generated carrier having a frequency exactly the same as that of the original carrier.[3] This is essential in order that the demodulation audio components lie in the correct frequency relationship both to the original carrier and to each other. By the same token, the amplitude of the locally generated carrier should be very much greater than the peak amplitude of the received signal, in order to insure minimum distortion in the demodulation process.

Dual Exalted-Carrier Demodulation

If a locally generated carrier of 150 volts peak amplitude, at a frequency of 4000 kc., was combined with a two-volt signal at 3999 kc. in a suitable demodulator, the resulting audio output would be a 1000-cycle signal having an amplitude of about two volts. If this same 3999-kc. signal were introduced simultaneously into two similar demodulators, and the 150-volt local carrier applied to one of them were shifted in phase by 90° with respect to the carrier applied to the other, the audio output from each demodulator would still be a two-volt signal at 1000 cycles. The two audio voltages would, however, be in phase quadrature, and this relationship would hold regardless of the r.f. frequency of the two-volt signal. The important aspect of this otherwise commonplace effect is that the phase relationship between the two audio voltages reverses if the two-volt r.f. signal producing the 1000-cycle beat lies on the opposite side of the local oscillator frequency. For example, if a +90° phase difference between the audio voltages exists when the two-volt r.f. signal is at 3999 kc., then a −90° phase relation would result if the frequency of the latter were shifted to 4001 kc. The phase relationship between the demodulator output voltages thus gives an indication of whether the r.f. signal is on the high or low frequency side of the local oscillator.

In practical demodulation of an r.f. carrier having sideband components above and below the local oscillator frequency simultaneously, a double-sideband AM signal, for example, these effects occur separately and independently in each demodulator. Thus, the individual sideband components of the double-sideband signal are resolved into discrete groups of +90° and −90° voltages of equal amplitude and identical waveform. If the individual demodulator outputs are fed to a pair of audio-phasing networks having the property of introducing constant +45° and −45° differential phase shifts over the useful audio frequency range, the resulting output voltages will be in-phase for one set of sideband components, and 180° out-of-phase for the other. Suitable means may be employed for combining these voltages differentially, thus discriminating against one or the other of the two sidebands.

A block diagram of such a dual exalted-carrier demodulation system is shown in Fig. 2, while Fig. 1 illustrates the phase relationships existing at the several significant points.

Selection of Sideband

By reference to the vector diagrams, it can be seen that the direction in which the phase of the 90° audio voltage at the output of each demodulator is rotated will determine which one of the two sideband components will appear at the output of the combining amplifier. In order, then, to select either the upper or lower sideband independently, it is only necessary to interchange the positions of the 45° lead-lag networks with a suitable reversing switch. It is possible also to pass both sideband components of a double-sideband signal by simply disconnecting one of the demodulator outputs from the audio-phasing network. In addition, amplitude demodulation of an FM or PM signal may be accomplished by combining its sidebands with a local carrier shifted 90° in phase with respect to the carrier of the received signal. Since the required r.f. phase shift is already provided, it is only necessary to bridge around the audio-phasing network, and connect the appropriate demodulator directly to the combining amplifier.

Synchronizing of Local Oscillator

The output voltage of either demodulator in the presence of a small unmodulated carrier is determined by the strength of the small carrier and its phase relationship to the local oscillator signal at any particular instant. The absolute value of this voltage is proportional to (E_c cos θ), where E_c is the peak carrier voltage and θ is the phase angle between the two r.f. signals. The local oscillator is applied to each demodulator in quadrature; therefore, when the two r.f. signals are in phase synchronism, the d.c. output of one demodulator will be essentially zero while the output of the other will be a d.c. voltage approximating the peak of the applied carrier. Use is made of one of these d.c. components for local oscillator phase control by applying it to a reactance tube connected across the tank circuit of the latter. The local oscillator is thus caused to lock into synchronism with a receiver carrier, and the sidebands of the received signal are demodulated against a large synthetic carrier acting in place of the real carrier.

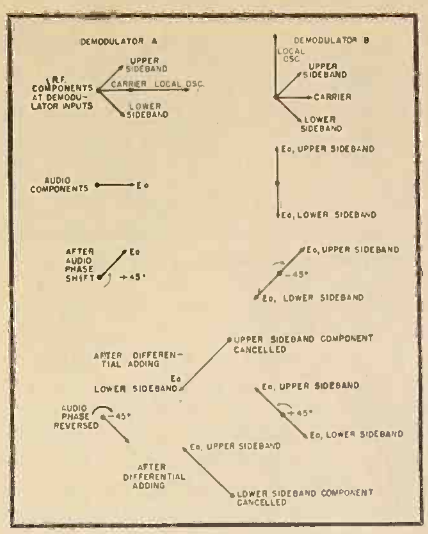
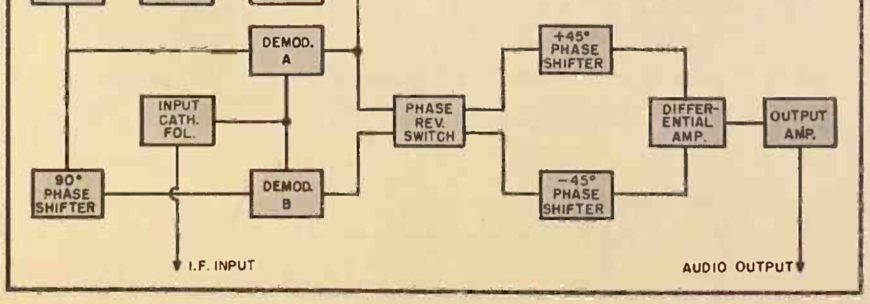


Fig. 1. Phase relationships in adapter.

Circuit Details

Fig. 4 shows a complete schematic diagram of the dual exalted-carrier demodulator and its associated audio circuits. Because the adapter unit is intended to operate out of a communications receiver having an i.f. on the order of 465 kc., the operations outlined above are carried out at this frequency. The local oscillator V_2 uses a small power pentode, type 6AK6, in an electron-coupled circuit with a high in-

Fig. 2. Functional block diagram of the complete adapter unit.



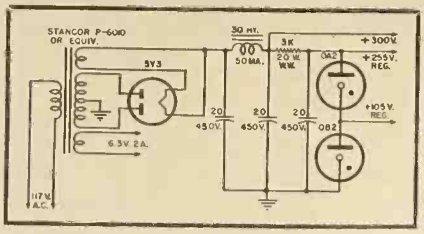


Fig. 3. Circuit of the power supply.

ductance grid tank. The tuning capacitance for the oscillator is supplied in part by a small trimmer capacitor, C_{10}, in parallel with a panel vernier control, and in part by the equivalent capacitive reactance of the oscillator control tube V_1, a type 6BH6. The plate of the oscillator is capacitively coupled to one of the demodulators, and inductively coupled to the other by means of the double-tuned i.f. transformer T_1. This i.f. transformer provides the required 90° r.f. phase shift between the two local oscillator components which are applied to the demodulators. The coupling between the transformer windings is variable to permit equalizing of the amplitudes of these components.

Because the demodulators are somewhat unorthodox, they may deserve some special consideration. Fig. 5 shows a functional schematic of one demodulator, in which generators E_1 and E_2 represent the local oscillator and signal voltages respectively, and D_1 and D_2 are the demodulator diodes. R_1 and R_2 are the diode load resistors, capacitor C_2 is the diode load capacitor, and R_3, C_3 are the usual r.f. filter elements. For purposes of explanation, it will be assumed that the diodes have matched characteristics, and that the resistors R_1 and R_2 are equal in value.

Consider for the moment that no signal voltage is applied at E_2, and that E_1 is a 150 volt peak signal at the i.f. frequency. Consider also that the equivalent impedance of generator E_2 is negligible compared to that of E_1 and the load resistors, R_1 and R_2. Voltage E_1 is applied to diode D_1 through capacitor C_1 and generator E_2. E_1 is also applied to diode D_2 through capacitors C_1 and C_2. At the instant when E_1 is positive at the anodes of the diodes, a rectified current, I_{d1}, flows through D_1, generator E_2, and load resistor R_1 in such a direction as to make the common anode connection of the diodes negative by approximately the peak of voltage E_1. At the same time, an equal current, I_{d2}, is flowing through diode D_2 and resistor R_2 so that the cathode end of R_2 becomes positive by the same amount. The cathode of D_2 and the output terminal are, therefore, at the same potential as the ground end of R_1. Consequently, the circuit as a whole is balanced for any value of E_1.

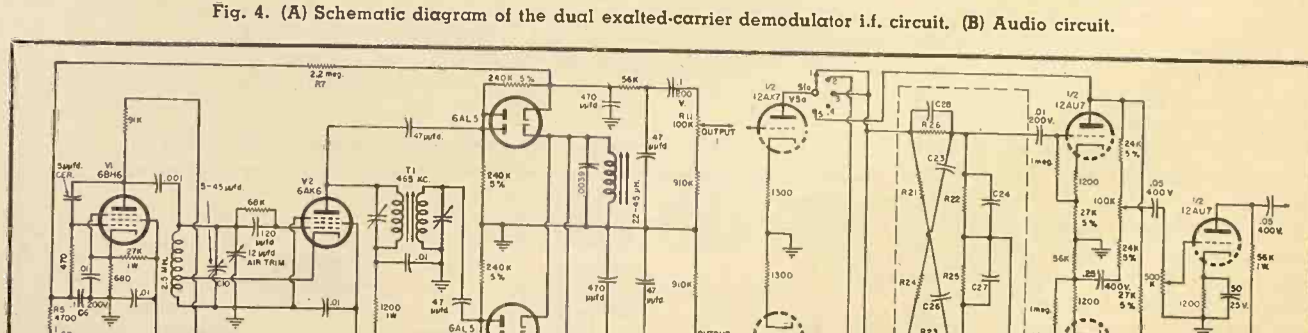
Now let a small voltage be applied at E_2, and assume for the moment that E_1 and E_2 are of the same frequency and phase. Because E_2 is impressed only across diode D_1, this diode is acted upon by the voltage $E_1 + E_2$, and therefore will produce a proportionally greater current through its load resistor R_1. The circuit is unbalanced by this small voltage, the cathode of D_2 becoming negative by an amount approximately equal to the peak value of E_2. If, on the other hand, the two voltages are 180° out-of-phase, diode D_2 will be subjected to the effective voltage $E_1 - E_2$, and the circuit will become unbalanced in the opposite direction. The cathode of D_2 will go positive, again by an amount equal to the peak value of the small voltage E_2. It can also be shown that if the relative phases of E_1 and E_2 lie between zero and 180°, the cathode potential of D_2 will vary between $-E_2$ peak and $+E_2$ peak, and will become zero when the phase relationship between the two voltages is 90°. The demodulator is thus phase- as well as amplitude-sensitive, and the output voltage at any instant is proportional to the peak value of E_2 multiplied by the cosine of the phase angle between the applied r.f. voltages E_1 and E_2.

Like any conventional diode detector, the output of each demodulator contains a d.c. component. However, in this case, the d.c. component is fundamentally phase-sensitive as mentioned above. The d.c. component at the output of one demodulator is filtered by means of the resistance-capacitance elements $R_7 - C_6$ and $R_5 - C_7$ (Fig. 4), and applied to the grid of V_1 as a control voltage for local oscillator phase correction. The control circuit is associated with the demodulators in such a way that the phase of the local oscillator signal is inherently 90° displaced from that of the received carrier when the frequencies of the two are synchronized. This latter point is important inasmuch as it determines the relative phasing of the locally generated carrier and the sidebands of the received signal when FM and PM transmissions are demodulated by the phase rotation method.

The audio components at the output of each demodulator are in quadrature, having undergone a ±90° phase displacement during the demodulation process. These audio components are amplified individually in the two sections of a 12AX7 dual high-mu triode, V_5. One side of the amplifier incorporates an audio gain control, R_{11}, to facilitate equalizing of the output voltages. Because it is essential that the audio components retain their original 90° phase relationship up to and including the plate circuits of V_5, each half of the stage operates with negative feedback developed across individual unbypassed cathode resistors. This feedback improves the phase response of the amplifier, and minimizes the generation of spurious harmonic components which would impair the sideband discrimination properties of the system.

The audio phase shift networks are

Fig. 4. (A) Schematic diagram of the dual exalted-carrier demodulator i.f. circuit. (B) Audio circuit.



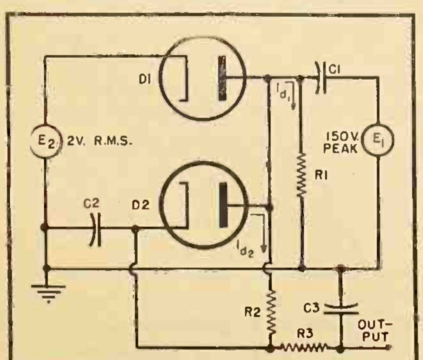
Audio Phase Shift Network	
Part No.	*Required Value*
C_{23}	6300 $\mu\mu$fd.
C_{24}	2100 $\mu\mu$fd.
C_{25}	4750 $\mu\mu$fd.
C_{26}	28500 $\mu\mu$fd.
C_{27}	9500 $\mu\mu$fd.
C_{28}	1050 $\mu\mu$fd.
R_{21}, R_{24}	15,000 ohms
R_{22}, R_{25}	50,000 ohms
R_{23}, R_{26}	100,000 ohms

Table 1. Components for the audio phase shift network of Fig. 4B.

complementary 45° lead-lag circuits which provide a constant 90° differential phase shift over a band of frequencies from 200 to 2600 cycles. These networks have a lattice configuration employing six resistive and six capacitive elements, and introduce an insertion loss of approximately 9½ db at 1000 cps. The design of such phase-shifting circuits has been discussed in detail elsewhere.[4,5] In this particular arrangement, two input voltages having a quadrature phase relationship will provide two output voltages having either a 0° or 180° phase difference. The output phase relationship depends upon whether the input components were initially shifted by +90° or −90°. Because the direction of phase rotation will determine which of the two sideband components are rejected in the following circuits, selection of sideband sense is accomplished by interchanging the positions of the 45° lead and 45° lag circuits with respect to the demodulator outputs. The in-phase and out-of-phase audio voltages corresponding to the two demodulated sideband components are applied to a differential combining amplifier designed to respond to 180° phased signals and reject in-phase signals.

The combining amplifier, V_6, a dual triode type 12AU7, is made up of two individual parallel channels, each of which is 100% degenerative. One chan-

Fig. 5. Equivalent circuit of balanced demodulator. D_1 and D_2 are matched, and $R_1 = R_2$. E_1 represents local oscillator signal; E_2 represents i.f. signal.



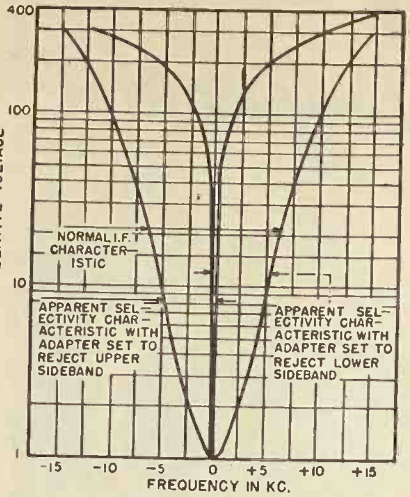


Fig. 6. Normal selectivity curve and apparent selectivity with adapter set to reject upper and lower sidebands.

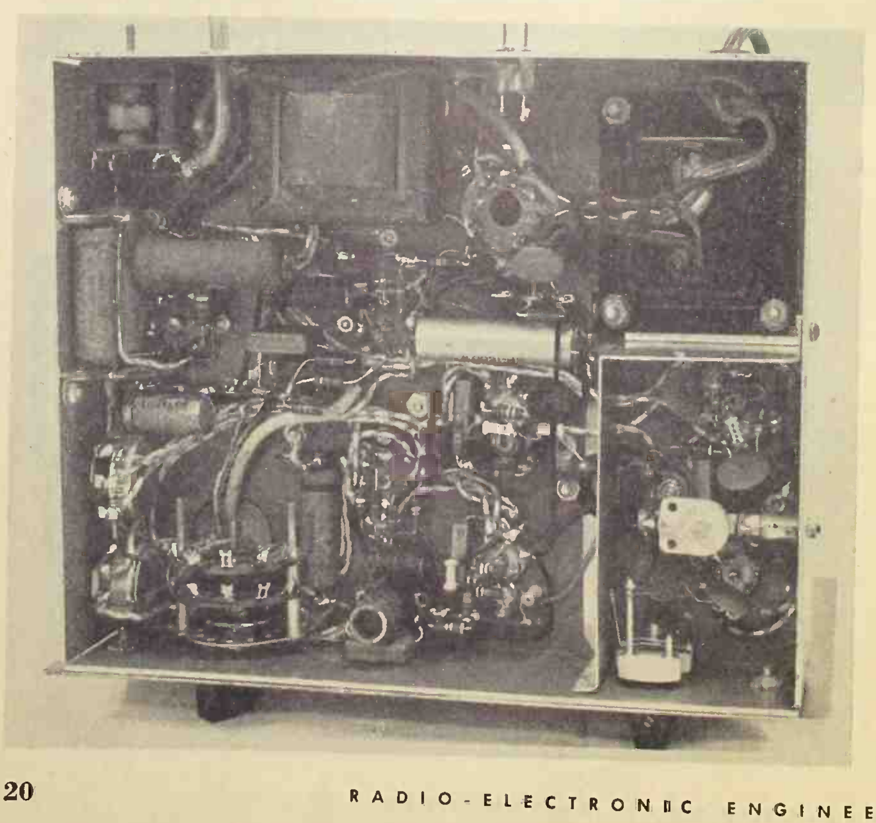
nel consists of a cathode follower with a relatively large cathode load resistor, while the other includes both plate and cathode loads, the values of which are equal. The plate signal from the latter channel is combined with the cathode signal from the former across a potentiometer, R_{32}, which serves as a balancing control. In practice, this potentiometer is adjusted for maximum suppression of the undesired sideband. A combined output signal, proportional to the sum of the two 180° phased input voltages, appears at the center of R_{32}, while in-phase components across it are effectively cancelled. The resulting single-ended voltage is then amplified in a conventional output stage consisting of one section of a 12AU7, V_{7a}.

Because the equivalent impedance of the source supplying the i.f. signal to the demodulators must be negligible compared with the diode load resistances and the impedance of the local oscillator source, the demodulators are driven from a cathode follower. This consists of the other triode section of V_7, the cathode load for which is the low-impedance *L-C* circuit, L_2-C_{16}, tuned to the i.f. frequency. Coupling from the receiver is effected through a four-foot length of RG71/U coaxial cable. The capacitance of this cable (54 μμfd.) is of the correct value to resonate the grid circuit of the input cathode follower to the i.f. frequency. The i.f. signal is extracted from the receiver through a very small coupling capacitor, C_{22}, at the plate of the last i.f. amplifier stage. The over-all voltage transfer from the last i.f. amplifier to the demodulators provides a gain of about three, due to the moderately high *Q* of the tuned input circuit. The optimum operating level at the grid of the cathode follower is approximately two to four volts r.m.s., although effective local oscillator synchronization is obtained at levels as low as 0.5 volts. Use of the receiver a.v.c. has been found to be neither desirable nor necessary.

The five-position function switch, S_1, permits reception of the upper or lower sideband independently, both sidebands together, or FM-PM signals. In each of the two double-sideband positions, one or the other of the demodulator outputs is disconnected from the audio phase shift networks. In the FM-PM position, the sidebands of the received signal are combined with a large local oscillator voltage, shifted in phase by 90°, and the appropriate demodulator output connected directly to the grid of the output amplifier. Under these conditions, the audio-phasing networks and the combining amplifier stage are unused.

The power supply is included as an integral part of the adapter, since the requirements of the unit are quite modest. The total plate supply drain is on the order of 38 ma. at 300 volts, and the heaters require 6.3 volts at 1.8 amperes. To insure stability of the local oscillator under variable line voltage conditions, the plate and screen supplies of both the local oscillator and reactance tubes are regulated by means of miniature VR tubes. These have the further purpose of reducing the effective impedance of the plate supply to the first audio amplifier, V_5. Low plate supply impedance minimizes phase shifts which may destroy the audio phase relationships at the input of the audio-phasing networks.

Under-chassis view of adapter, showing location of component parts.



Operating Characteristics

In receiving single-sideband suppressed-carrier signals which are transmitted with substantially no carrier, there is no automatic lock-in action of the local oscillator. The latter is set to the i.f. peak frequency, and the receiver tuned slightly in order to establish the correct frequency relationship to the transmitted single sideband. In practice, it has been found that the receiver tuning is not nearly so critical as at first might be expected. SSSC reception using the exalted-carrier technique is far less difficult than that obtained with usual methods involving the receiver beat oscillator. This is because the often-encountered restrictions imposed by limited b.f.o. injection are removed, thus permitting substantially distortionless demodulation of the single-sideband signal.

When receiving normal double sideband plus carrier transmissions in the absence of interference, either of the DSB or SSB positions may be used, and will yield about the same audio output. If interference is present on one or the other of the sidebands, selection of the appropriate SSB position will reject heterodynes and spurious interference components lying in the audio band between 80 and 3500 cycles. The absolute degree of rejection will depend to some extent upon the particular audio frequency or band of frequencies to which these components correspond, but will be not less than 23 db anywhere within this range. At frequencies between 200

(*Continued on page 29*)

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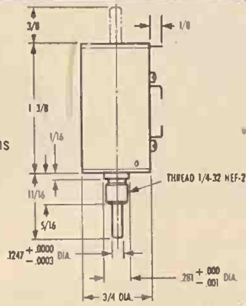
CONDENSED SPECIFICATIONS

Number of turns	10
Power rating	2 watts
Coil length	18"
Mechanical rotation	3600° + 12° − 0°
Electrical rotation	3600° + 12° − 0°
Resistance ranges	100 ohms to 50,000 ohms
Resistance tolerance	± 5.0%
Linearity tolerances:	
All values	± 5% (standard)
5000 ohms and above	± .1%
Below 5000 ohms	± .25%
Starting torque	0.75 oz. in.
Net weight	1.0 oz.



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Helipot—world's largest manufacturer of precision potentiometers—has built an enviable reputation for highest standards in all its products, and the Model AJ is no exception.

The resistance elements themselves are made of precision-drawn alloys, accurately wound by special machines on a copper core that assures rapid dissipation of heat.

Each coil is individually tested to rigid standards, then is permanently anchored in grooves that are precision-machined into the case. Slider contacts are of long-lived Paliney alloy for low contact resistance and low thermal e.m.f. . . . and precious-metal contact rings are used to minimize resistance and electrical noise. All terminals are silver plated and insulated from ground to pass 1,000 volt breakdown test.

LONG LIFE: Although Unusually compact, the AJ is built throughout for rugged service. Potentiometer life varies with each application, of course, depending upon speed of rotation, temperature, atmospheric dust, etc. But laboratory tests show that, under proper conditions, the AJ has a life expectancy in excess of one million cycles!

Helipot representatives in all major cities will gladly supply complete details on the AJ—or write direct!

THE Helipot CORPORATION

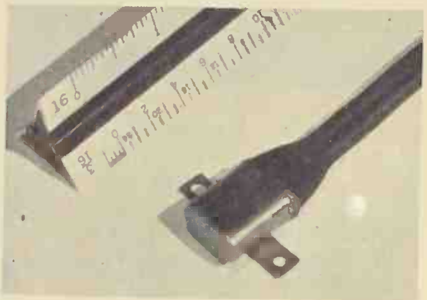
South Pasadena 4, California

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

NEW PRODUCTS

THERMOSTATS

Stevens Manufacturing Company, Inc., announces an addition to its line of positive-operating Type C bimetallic strip thermostats. Especially designed for applications in which moisture beads or other severe conditions preclude the use of ordinary thermostats, Type CH100 features an electrically independent bimetallic thermal element.

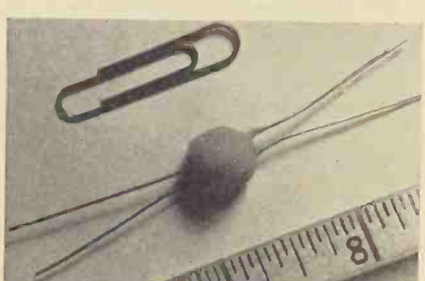


Type CH100 units are for use in low-wattage circuits where precise thermal control is mandatory, as in electronic and communication equipment, control apparatus and appliances where moisture beads are a problem. They can also be made as a so-called "alarm thermostat," a double unit precalibrated to close the circuit at both a minimum and a maximum temperature.

Dimensions, performance curves and engineering data are available on request from the *Stevens Manufacturing Company, Inc.*, 69 South Walnut Street, Mansfield, Ohio.

MINIATURE PULSE TRANSFORMER

For use where space is at a premium, *P C A Electronics Incorporated* has designed a miniature pulse transformer for low power application. The small size and weight of the unit permit direct mounting with its leads to the chassis.

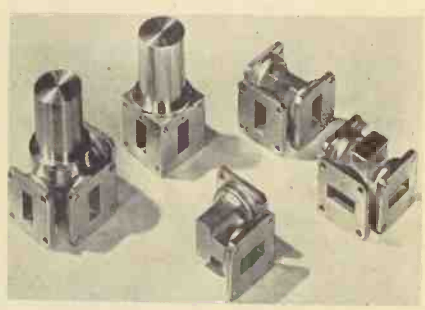


Special features of the *P C A* pulse transformer are fast rise time, with a minimum decay providing a good waveform for specific pulse techniques. Product applications include airborne radar, guided missiles, electronic computers and other coded pulse sources.

A brochure describing detailed engineering data is obtainable upon written request to *P C A Electronics Incorporated*, 6368 DeLongpre Avenue, Hollywood 28, Calif.

MICROWAVE COMPONENTS

A line of specialized microwave components for use in radar, telecommunications, microwave experimentation and similar fields, has been announced by *General Precision Laboratory, Inc.* Typical units are a lightweight, high efficiency switch, supplied in either wave guide or solid block construction; a compact "twist and turn" elbow; and improved broadband shunt and series tees. Facilities are available for development of components to fill specific systems requirements.



Units embody design principles which afford unusually low absorption and reflection losses over a 10% bandwidth. The aluminum construction minimizes weight, and all units can be used in pressurized systems.

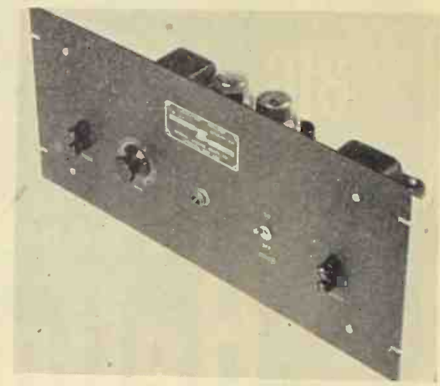
Further information may be obtained by writing to *General Precision Laboratory*, 63 Bedford Road, Pleasantville, N. Y.

INDUSTRIAL RECORDERS

A new industrial recorder, announced by *Offner Electronics Inc.*, 5320 N. Kedzie Ave., Chicago 25, Ill., and known as the Dynograph, offers a high speed, direct writing oscillograph and a special chopper-type amplifier which makes the machine completely drift-free. The Dynograph, used for simultaneous recording of rapid transients, operates at 100 times the speed of other recorders and has a pen deflection linearity of 1 per cent with pen response of 1/120th of a second.

LABORATORY AMPLIFIER

A versatile electronic tool, the relay-rack Type 221-A laboratory amplifier, has been announced by *Hermon Hosmer Scott, Inc.*, for industrial and scientific laboratories. This amplifier features extended frequency response, high power output, and negligible hum and distortion.



Free bulletin may be obtained on request from *Hermon Hosmer Scott, Inc.*, 385 Putnam Avenue, Cambridge 39, Mass.

FAST-RISE PULSE GENERATOR

Designed for testing the transient response of wide-band systems, the Model 503 fast-rise pulse generator recently announced by *Spencer-Kennedy Laboratories, Inc.*, can also be used for the generation of impulse or "continuous spectrum" noise for signal-to-noise ratio testing, and for narrow-band receiver alignment.

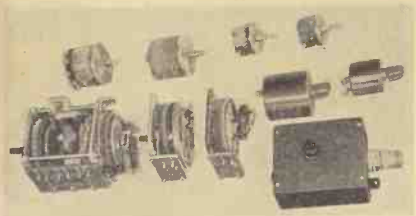
Model 503 produces a rectangular pulse having a rise time of less than 10^{-9} seconds. The width of the pulse is controlled by the external "width" cable, and may be as short as 2×10^{-9} seconds.

Further information can be obtained

from the *Spencer-Kennedy Laboratories, Inc.*, Dept. RT, 186 Massachusetts Avenue, Cambridge 39, Mass.

VARIABLE TRANSFORMERS

Much of the new electrical equipment, in order to conserve space and to keep weight to a minimum, is designed for



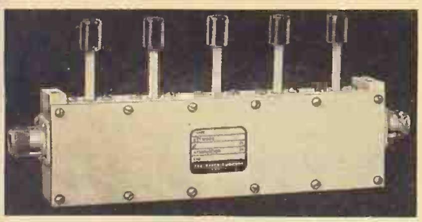
operation at frequencies of 400 cycles and higher. For use with this high frequency equipment, the *Superior Electric Company* offers a line of Powerstat variable transformers. The units are available in a multitude of voltage and current ratings in single and polyphase models.

If further information is desired, write to R. F. Greene, Advertising Manager, *The Superior Electric Company*, Bristol, Conn.

ATTENUATOR

The *Daven Company* announces the availability of its new radio frequency attentuator, Series RF-550. With two units connected in series, these attenuators are available with losses up to 100 db in one db steps. These units have a zero insertion loss and a frequency range from d.c. to 225 megacycles.

Standard impedances are 50 and 73 ohms, but special impedances are avail-



able on request. Resistor accuracy is within ±2% at d.c.

For complete information, write to the *Daven Company*, 191 Central Avenue, Newark, N. J.

MINIATURE MAGNETIC HEAD

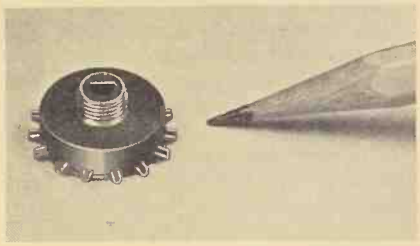
The CRC miniature magnetic head, Model HA 102, was developed by *Computer Research Corporation*, 3348 W. El Segundo Blvd., Hawthorne, Calif., to provide higher component density in magnetic memory storage systems.

Its small size, ⅜" in diameter and 1" long, increases the number of heads that can be positioned around a magnetic drum, and permits shorter registers. The non-abrasive core, made from hard ferrite, will not injure magnetic drum coatings, nor will occasional scrapings damage the head. The unit operates at frequencies up to 120 kc., has 13.8 mh. total inductance, 11 ohms of d.c. resistance, and is stable over wide temperature ranges.

MINIATURE ROTARY SWITCH

A new miniature rotary switch, developed to meet the requirements of miniaturization in airborne electronic equipment, has been announced by the *Electro Development Corp.*, 6014 W. Washington Blvd., Culver City, Calif.

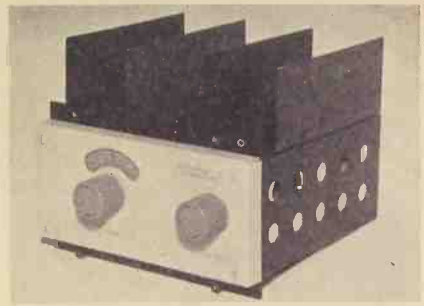
The Edco rotary switch has plastic, compression-molded parts for greater resistance to arcs than the commonly used phenolics. It is less than 1/10 the size of conventional switches, having a di-



ameter of ⅝" and thickness of 3/16". Contacts are of pure silver and the contact arm is silverplated beryllium copper, treated for maximum strength.

AIRBORNE RECEIVER

Gertsch Products, Inc., Los Angeles, Calif., has started to produce its new

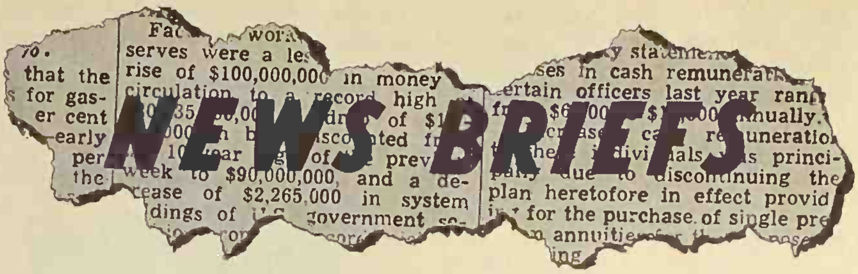


Model AR-1 receiver, a five-tube, miniaturized, superheterodyne broadcast receiver designed especially for airborne use where light weight, small size, high sensitivity and good signal-to-noise ratio are needed.

RESISTORS

Printed resistors and resistance films of the carbon composition type, which range in value from 25 ohms per square to one megohm per square, are now

(*Continued on page* 28)



CRYSTAL ANALYSIS UNITS

This photograph shows electrical connections being made on the main chassis of a crystal analysis unit at the Mount Vernon, N. Y., plant of *North American Philips Company, Inc.* Such x-ray diffraction equipment finds important application in the orientation of quartz

for piezoelectric oscillator plates used in communication systems, especially in aircraft and tanks, and on naval vessels.

COMPUTING LABORATORY

The Board of Education has announced the acceptance of grants totalling $200,000 from *General Motors Corporation* and *Ford Motor Company* for expansion and maintenance of the large-scale computing laboratory at Wayne University.

Wayne, which now has two large-scale computing machines, a "differential analyzer" and a "cinema integraph," will acquire a third one—a digital computer to be built by the *Burroughs Adding Machine Company*—with the $150,000 grant from *General Motors.* Wayne officials stated that the new machine would make possible a complete instructional program in large-scale computation.

The $50,000 grant from the *Ford Motor Company* will be used for operating expenses of the expanded laboratory.

NEW CORPORATION

Mr. Frederick T. Budelman and Mr. William Fingerle, Jr., in association with *French-Van Breems, Incorporated,* exporter of electronic equipment, have formed a manufacturing and engineering corporation for radio and electronic equipment. To be known as the *Budelman Radio Corporation,* the new corporation will engage in carrying out development contracts in the FM communications and multi-channel relay fields.

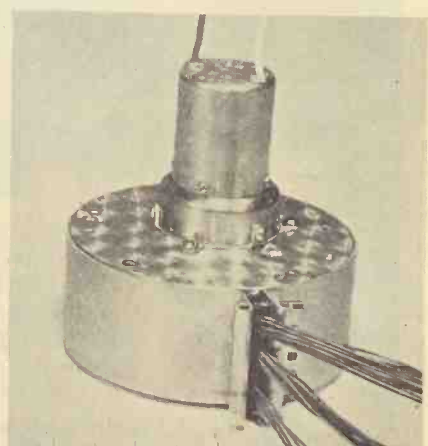
Messrs. Budelman and Fingerle, Jr., have previously been associated with the *Link Radio Corporation,* where they pioneered the development of FM communication equipment for the land mobile services and military applications.

The new corporation has established offices at 375 Fairfield Avenue, Stamford, Conn.

IN-FLIGHT CALIBRATOR

Designed to identify telemetered information from a guided missile in flight, the ten-channel in-flight calibrator recently developed by the National Bureau of Standards utilizes a system of cam-operated switches that eliminates many of the difficulties encountered in calibrators of comparable size and scope.

This device supplies four step-calibrating signals to the telemetering



record so that each received signal may be assigned finite values. Slow speed and fast speed cams sequentially activate switches that interrupt the normal channeling of telemetered information and pass calibration signals to the transmitter.

The initial model, which was designed by Messrs. L. L. Parker and W. A. Hereth of NBC, is now being manufactured by the *J. P. Seeburg Company.*

SMALL, LIGHTWEIGHT RADAR

The first radar ever to be produced on an assembly line basis, and the most widely used radar in the world today,

according to the *General Electric Company,* is the small, lightweight device now being manufactured at Syracuse, N. Y.

This *G-E* radar, which is credited with giving American jet pilots a decided shooting edge over enemy planes in Korea, eliminates guesswork on the part of the pilot. If the pilot keeps his enemy on the crosshairs of the computing gunsight, into which the radar feeds information, he is assured of a hit.

Conceived by *G-E* scientists shortly after the last war, the device is now being installed in Air Force, Navy and Marine Corps fighters throughout the world. Its use in Korea represents the first combat application of precision radar techniques to direct the firing of weapons from jet fighter planes.

NEW QUARTERS

Confronted with constantly increasing demand for research and manufacture in electronic and nuclear physics, the *Multi-Tron Laboratory* has moved to greatly enlarged quarters at 4624 West Washington Boulevard, Chicago, Ill. *Multi-Tron,* in addition to designing and manufacturing special purpose tubes, electron gun mounts and precision assemblies for vacuum tubes, is engaged in tool and die fabrication.

ENLARGED FACILITIES

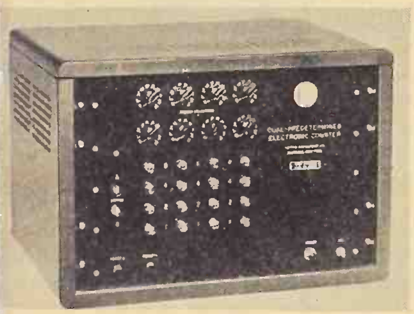
Technical Associates, Inc., has just moved into a new, modern building at 140 West Providencia Avenue, Burbank, Calif., which provides more than three times the space of their original location. This company, a pioneer manufacturer of instruments for nuclear research, has long been a supplier to the Atomic Energy Commission and the Armed Forces. The enlarged facilities were made necessary by the expansion of production for government defense.

In February, 1951, *Technical Associates* purchased a substantial interest in the *Landsverk Electrometer Company*, and along with this affiliation, added research facilities and a new isotope department.

ELECTRONIC COUNTER

Greatly increased usage of predetermined electronic counters is announced by the *Potter Instrument Company, Inc.*, 115 Cutter Mill Road, Great Neck, N. Y., for applications where the rate of material flow is extremely rapid. The dual predetermining feature facilitates slowing down in the final stage of a cycle to obtain satisfactory operation of gates, shears and other devices.

The Model 243 dual predetermined counter will continuously recycle, accepting counts up to 1000 per second,



and reset instantaneously after each output operation without missing a count. Ease in pre-setting makes this counter readily adaptable to any production line.

NEW RECORDING STUDIO

A new, fully equipped, air-conditioned studio, with convoluted walls and blanketed ceiling for commercial recording and personal transcription, has been opened by *Magno Recording Studios*, 37 West 57th St., New York, N. Y.

The new studio, headed by Mr. A. J. Dash as manager, and Messrs. Ralph Friedman and Howard Warren, in charge of engineering, is a departure from conventional construction, and offers sound synchronization work in its sound-proofed, acoustically engineered studio.

RADIOACTIVITY INSTRUMENT

Eliminating the expensive and fragile moving-pointer microammeter generally used to indicate radioactivity levels, the National Bureau of Standards has developed a radioactivity instrument in which radiation levels are read directly from a potentiometer dial.

To read an unknown value of radiation on this instrument, which was developed for the Navy Bureau of Ships

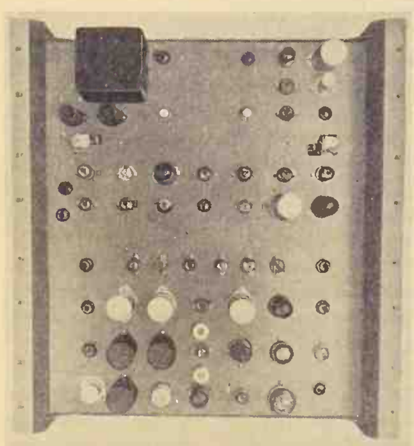
by Messrs. S. R. Gilford and S. Saito, the operator, wearing a small earphone, turns the dial to the point at which an audio oscillation begins. This indicating method is more convenient than a microammeter for plotting contours of equal radiation; leaving the dial set, the operator can locate a series of equally radioactive points as he walks along.

ELECTRONIC "MAGICIAN"

An electronic "magician" which can perform a number of video tricks and illusions has been created by the *RCA Engineering Products Department*, Camden, N. J. The new equipment, a special effects amplifier, can electrically accomplish fades, dissolves, superpositions, wipes, insertions, and other dramatic picture combinations at microsecond speed.

In the past, such programming effects have been achieved by systems of mirrors, sliding shutters, and various other elaborate contraptions. The new amplifier is expected to displace these optical and mechanical techniques.

RCA's special effects system consists of a single rack-mounted unit which



accepts the two video or picture signals to be mixed, together with a masking signal, and delivers the desired composite signal.

NEW LITERATURE

PRECISION POTENTIOMETERS

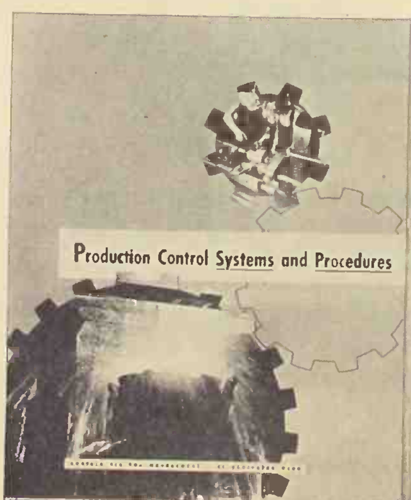
Two new product bulletins have been issued by the *Helipot Corporation*, South Pasadena, Calif. Bulletin No. 109 covers the new Model T—"The Tinytork"—small-sized precision potentiometer which combines minimum operating torque with reduction in cubic space and weight; Bulletin No. 115 describes the Model F single-turn potentiometer, featuring continuous mechanical rotation, minimum deadspot between the ends of electrical rotation, and versatile design.

THE "LINK" STORY

Link Radio Corporation, designer and manufacturer of electronic communications equipment, has prepared a 24-page brochure entitled "The Story of Link Radio and Its Engineers," which gives a brief pictorial story of the background of the organization and its engineering personnel. Shown in this booklet are photographs of the *Link* laboratories and technical facilities at 125 West 17th Street, New York 11, N. Y., as well as illustrations of several new products.

PRODUCTION CONTROL

Publication of a new 56-page book entitled "Production Control Systems and Procedures" has been announced



by *Remington Rand Inc.* Free to interested executives, this book details a method of materials control that results in a shorter production planning cycle while speeding production by eliminating the causes of varied delays on the production line.

Fully illustrated with typical forms and procedure charts, the book outlines complete procedures for engineering, production planning and progress, machine load, material and tool procurement and control. Included is a typical case history.

Interested executives can receive their copies by directing requests for publication X-1268 to *Remington Rand Inc.*, 315 Fourth Avenue, New York 10, N. Y.

PICKUPS

The pickups described in a new bulletin recently issued by *Consolidated Engineering Corporation* are widely used as primary sensing units in vibration and acceleration studies. Adequately designed to serve in such special cases as the testing of rocket or submarine equipment, they are equally adaptable for the more usual vibration checking in machinery, motors, vehicles or construction.

Bulletin CEC 1503 contains the answers to application questions regarding amplitude and accelerations, frequencies, nature of motion and range of temperature. A copy may be obtained from *Consolidated Engineering Corporation*, 300 North Sierra Madre Villa, Pasadena 8, Calif.

RCA PUBLICATIONS

The following technical publications have been released by *RCA's* Tube Department, Harrison, N. J.:

"RCA Kinescopes," (Form No. KB-1022), a new 20-page booklet covering *RCA's* complete line of picture tubes and including a replacement directory, a picture conversion chart and notes on tube conversions.

"TV Servicing," (Form No. TVS-1030), a new 48-page book on television trouble-shooting, tuner alignment, and circuit analysis.

"RCA Preferred Tube Types for New Equipment Design," a 4-page folder revised to include changes resulting from technological advances in tube design and application.

The first two booklets may be obtained from *RCA* tube distributors, or by sending 25 cents for *"RCA* Kinescopes" and 35 cents for "TV Servicing" to Commercial Engineering, *RCA* Tube Department, Harrison, N. J. The revised tube folder may be obtained on request from Commercial Engineering at Harrison.

ELECTROMETER SHUNT

A two-page bulletin describing the Model 2001 electrometer shunt has been released by *Keithley Instruments*, 3868 Carnegie Avenue, Cleveland 15,

Ohio. Available in any of seven standard resistance values, the new shunt permits quick conversion of the company's Model 200 electrometer to a micromicroammeter.

This bulletin lists specifications and includes connection diagrams for measurements of current, such as insulation leakage, in ion chambers, and in photoelectric cells.

POWER SOURCES

Sorensen & Co., Inc., now has available a new catalog giving full descriptions and up-to-the-minute ratings and specifications on its entire line of standard "Nobatrons"—electronically regulated d.c. power sources. Also included in the catalog is a comprehensive discussion of circuit theory and a description, with diagrams, of some of the many ways in which Nobatrons can be used.

Copies of the catalog may be obtained by writing to *Sorensen & Co., Inc.*, 375 Fairfield Avenue, Stamford, Conn.

ROTARY SOLENOIDS

A few of the many applications for Ledex rotary solenoids in remote control problems are described in a 4-page bulletin recently published by *G. H. Leland, Inc.*, Dayton 2, Ohio. Six models are manufactured which range in diameter from 1⅛ to 3⅜ inches. Applications vary from snap-action tripping of airborne bomb releases to the actuation of rugged, hydraulic valves in heavy duty materials handling equipment.

Remote Control

(*Continued from page* 14)

sis comprises a two-stage amplifier which amplifies the tones from the control line. The output of this amplifier feeds into the three separate sharp bandpass tone amplifiers previously described. There is also incorporated on this chassis a ten-position stepper relay and its associated slow release relays in a typical telephone dialing system which is actuated by a similar system at the control point. There are two sets of contacts on these steppers, ten in each set, which select both the tuning operation and metering circuit and apply each to its respective control line. Metering is accomplished by suitable shunts placed in the grounded side of the circuits to be metered. The resulting sampling voltages fed down the metering line are on the order of 50 volts. Meters at the control point are of the 0—500 microampere movement type with scales corresponding to those in the transmitter. Line adjustment and compensation is accomplished by employing an ohmmeter type circuit, shunted at the remote end.

At the remote transmitter location, there is also a local tune chassis which allows all motor tuning to be carried out right at the transmitter during maintenance routine.

At the control point location, the equipment comprises the control panel. This panel, shown in Fig. 5, consists of ten meters with their associated toggle switches below each, the operation dialing system and its relays, three tone oscillators, a two-stage tone amplifier, and a power supply furnishing voltages for relays, oscillators and amplifiers. A rear view of this panel is shown in Fig. 6.

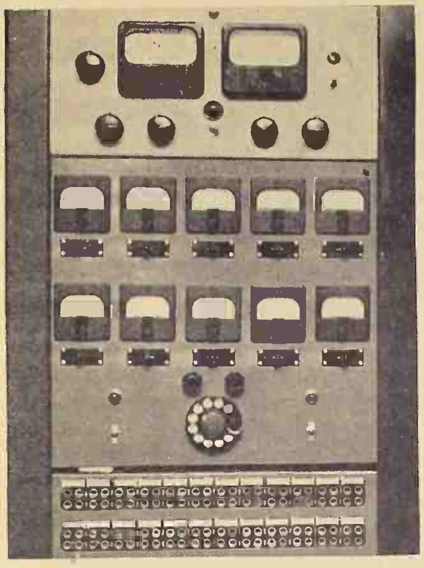


Fig. 5. Control panel with remote meters.

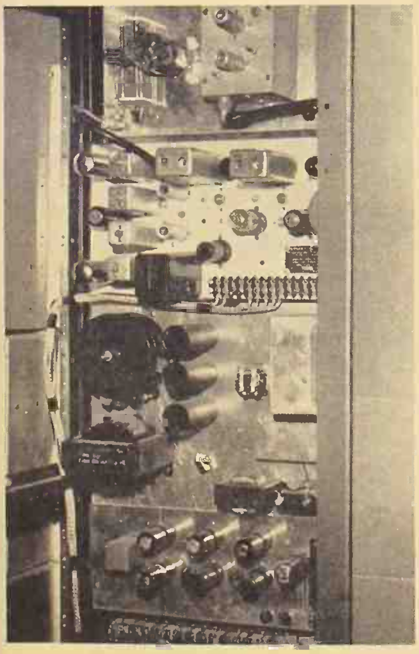


Fig. 6. Rear view of control panel.

At the control location, the approved frequency monitor is installed. The type used is a *General Electric* Type BM 1 A. This particular frequency monitor requires approximately 3 volts r.f. input for proper operation. To obtain this level of r.f. at the control location, a Yagi beam cut to operating frequency was erected and fed to a specially constructed three-stage broadband r.f. amplifier which, in turn, feeds the frequency meter. Center frequency deviation and percentage of modulation, as well as audio monitoring, are obtained through the normal operation of the frequency meter.

In order to monitor continuously both the AM and the FM transmitters which are duplicating the program, an electronic multivibrator mixing system is being constructed which will alternately feed the output of both the AM and FM frequency monitors to a single monitoring speaker. The timing of this mixer will be approximately three seconds on each alternation.

The above summary of operations shows the versatility of this system. Although there would be some variation on different types of transmitters, it would be possible to duplicate these operations on practically any of the present commercial FM transmitters.

Such a remote setup must be situated so that it is inaccessible to unauthorized persons, a requirement of FCC regulations concerning remote-controlled installations.

It is hoped that this article will call attention to the possibilities that remote control may have as a means of continuing FM broadcast service in cases where possible shutdowns have been contemplated.

TECHNICAL BOOKS

"ELECTRICAL ENGINEERING" —The Theory and Characteristics of Electrical Circuits and Machinery, by Clarence V. Christie, Professor of Electrical Engineering, McGill University. Sixth Edition. Published by *McGraw-Hill Book Company, Inc.*, New York, Toronto and London. 675 pages. $7.00.

While the latest revision of this book maintains the elementary approach of former editions, it is directed toward preparing and encouraging the student to extend his studies into more advanced phases of the subject. The emphasis is on the power field, but it is also intended for the student whose main interest lies in the field of communication engineering. All the material included in the previous edition has been retained, but a considerable amount of new descriptive material has been added and a number of additional problems have been worked out.

The treatment of a.c. circuits has been extended to cover some of the more important circuit theorems, and special types of d.c. machines are discussed. Treatment of the polyphase induction motor has been extended to include the main systems of speed control. The material on the mercury-arc rectifier has been brought up to date, and the study of system faults and stability has been made of more practical value by the inclusion of numerical examples.

"ALTERNATING-CURRENT MACHINES" by George V. Mueller, Professor of Electrical Engineering, Purdue University. Published by *McGraw-Hill Book Company, Inc.*, New York, Toronto and London. 502 pages. $7.50.

Designed for an undergraduate course in a.c. machines or for use by one who is beginning a study of the subject, this text presents an analysis of the construction and operating principles of transformers, polyphase induction machines, synchronous machines, single phase motors and rectifiers. Recent applications of high-frequency induction motors are covered.

The treatment is practical with a design viewpoint, and standard symbols and abbreviations are used throughout. The material on synchronous machines is based on the latest AIEE and ASA standards.

A large number of problems are included, each of which illustrates one or more principles. Oscillograms help to explain certain relations and to confirm results derived by mathematical methods.

New Products

(*Continued from page* 23)

being produced at *Glass Products Company*, 6911 S. South Chicago Avenue, Chicago 37, Ill. Wattage dissipation ratings are from one to five watts per square inch. Good aging properties are a characteristic of these printed resistors, and JAN specifications, as applied to the conventional carbon composition resistor, are readily met.

A precision film type resistor designed to operate at an ambient of 200°C at rated wattage has also been developed at *Glass Products Company*. This resistor is now being produced on a laboratory scale in one-half to five watt sizes.

SHUNTS

Three new shunts are offered by *Assembly Products, Inc.*, suitable for use with all types and makes of 50-millivolt meters and with Simplytrol contact meter relays, also manufactured by this company.

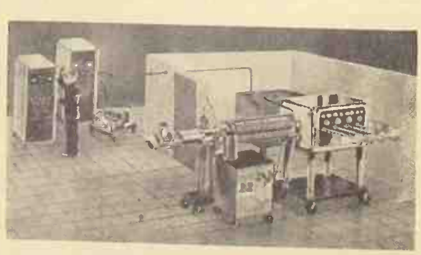
The three sizes, MSA, MSB and MSC, range from 30 amperes to 1200 amperes. They are mounted on bakelite blocks for insulation to 1500 volts. Terminals are of ample size with large flat surfaces for good heat dissipation.

Catalog Sheet S-1 will be mailed on request by *Assembly Products, Inc.*, Chagrin Falls, Ohio.

PARTICLE ACCELERATOR

Operating at voltages up to 250 kv. and producing an intense beam of charged particles for neutron production, nuclear reactions and scattering experiments, the new Cockroft-Walton type particle accelerator has been announced by the *American Instrument Company, Inc.*

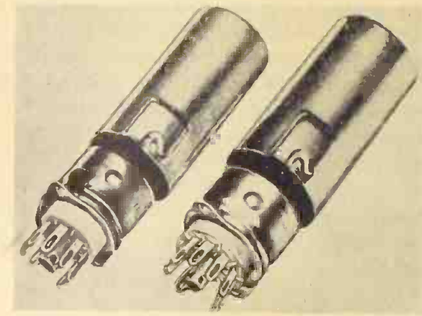
The machine operates effectively at any voltage from 20 to 250 kv. and delivers a focused beam of charged particles concentrated in a circle smaller than one millimeter in diameter. Beams of a larger area with uniform current cross section may be obtained.



Additional information may be obtained from *American Instrument Company*, Publicity Department, Silver Spring, Md.

MILITARY TUBE SOCKETS

Military tube sockets are now being made available by the *Methode Manufacturing Corporation*, manufacturers of electronic equipment for both military and civilian use. All *Methode* sockets meet applicable JAN specifications.



For further information, write to the *Methode Manufacturing Corporation*, 2265 West St. Paul Avenue, Chicago 47, Ill.

BW RESISTORS

The addition of BW resistors to the *Cinema Engineering Company's* resistor line has been announced. This new series is provided with solder lugs, and includes range sizes from single sec-

CALENDAR *of Coming Events*

MARCH 3-6—IRE National Convention, Waldorf-Astoria Hotel and Grand Central Palace, New York, N.Y.

MAR. 22-APR. 6—International Trade Fair, Navy Pier, Chicago, Ill.

MAR. 31-APR. 2—Sixth Annual NARTB Broadcast Engineering Conference, Conrad Hilton (Stevens) Hotel, Chicago, Ill.

APRIL 15-17—AIEE South West District Meeting, Jefferson Hotel, St. Louis, Mo.

APRIL 19—IRE Cincinnati Spring Conference, Engineering Societies Bldg., Cincinnati, Ohio.

MAY 5-7—RTMA, AIEE, and IRE sponsored government—industry conference on Quality Electronic Components, Washington, D. C.

MAY 10—IRE New England Radio Engineering Meeting, Copley Plaza Hotel, Boston, Mass.

MAY 12-14—IRE National Conference on Airborne Electronics, Hotel Biltmore, Dayton, Ohio.

MAY 16-17—Fourth Southwestern IRE Conference and Radio Engineering Show, Rice Hotel, Houston, Texas.

MAY 19-22—Radio Parts and Electronic Equipment Show, Conrad Hilton Hotel, Chicago.

tion chapron-wound, to a 4-section resistor and multi-pi winding in the larger BW/1 type.

With resistance values of 1 ohm to 1 megohm, and wattage ratings varying from ¼ to 1 watt, the BW resistor is available in a variety of resistance wire alloys and impregnation treatments.

Further information may be obtained from the *Cinema Engineering Co.*, Burbank, Calif.

KLYSTRON POWER SUPPLY

Model KX, designed to power high-power klystron tubes, is being introduced by the *Polarad Electronics Corporation*, 100 Metropolitan Avenue, Brooklyn 11, N. Y. According to the manufacturer, it will be particularly useful with *Raytheon's* wide-band klystrons, such as the RK-5721.

The Model KX is mounted on a dish-pan type chassis provided for ease of access. The manufacturer will provide further details on request.

Exalted-Carrier

(*Continued from page* 20)

and 3000 cycles, the discrimination ratio approaches 36 db. The receiver thus behaves as though it had an equivalent selectivity characteristic similar to that of Fig. 6. This figure also shows the normal selectivity curve without the adapter. It can be seen that the apparent bandwidth of the receiving system has been effectively halved, yet because either sideband is accepted in its entirety (subject to the usual attenuation due to i.f. selectivity), the audio response has not been materially affected. Therefore, no loss of intelligibility results.

C.w. signals may be received in true single-signal fashion since the audio image is suppressed. The receiver b.f.o. is not used; instead the local oscillator in the adapter is detuned slightly from the i.f. peak frequency, and the receiver r.f. gain control backed down to the point where the local oscillator a.f.c. circuits are inoperative. Depending upon interference conditions, the DSB or either of the SSB positions may be used. In the latter case, the equivalent selectivity characteristics of Fig. 6 will be obtained.

Detection of phase- or frequency-modulated signals by the phase rotation method does not provide the high degree of suppression of random noise and spurious AM which characterizes limiter-discriminator and ratio detector systems. The audio recovery from an FM or PM signal in which the modulation index is not too large is, however, very much more satisfactory than that obtained with off-tune amplitude detection. Furthermore, because all i.f. circuits are synchronous-tuned to the mean carrier frequency, the effective signal-noise ratio is improved by at least 3 db.

The writer wishes to express his appreciation to Mr. Don Norgaard of the *General Electric Company* for permission to reproduce certain portions of the circuit design described herein.

REFERENCES

1. *Crosby, M. G., "Exalted Carrier Amplitude and Phase Modulation Reception," Proc. IRE, September, 1945.*
2. *Norgaard, D. E., "Practical Single Sideband Reception," QST, July, 1948.*
3. *Experience has indicated that a frequency difference of 10 to 20 cycles between the two carriers will not seriously impair quality of reception, provided the carrier suppression at the transmitter is 23 db or more.*
4. *Dome, R. B., "Wide Band Phase Shift Networks," Electronics, December, 1946.*
5. *A.R.R.L. Handbook, 1950, Chapter 9.*

Calorimeter

(*Continued from page* 12)

ing around the thermometer mercury bulb. Each thermometer base consists of finely ground glass which makes a very close and liquid-tight fit. Thermometers may be interchanged or others, with different scale divisioning, may be used at will.

Fig. 5 shows the rear view of the calorimeter developed by *Transport Products Corporation*, of Louisville, Ky., with the cooperation of the *Kahl Scientific Instrument Corporation.* At the top is a glass valve which is preset or changed at will to provide any amount of water flow rate in the system. Below the valve is the elaborate radiator for restoring heated water out of the water load to room temperature. Below this, in turn, may be seen a bulbous glass calibrating unit with a glass valve fitting at its bottom. In back of the calibrating unit can be seen the jet type version of water pump. The rectangular stainless steel case, on which is mounted the calibration and calibrating valve components, is the reservoir which holds the water needed for the over-all system. Normally, water is pumped out of the reservoir as per the flow diagram. Water is returned to the reservoir by allowing it to flow through the calibrating unit with the glass valve open. Whenever the flow rate is to be checked and the system calibrated, the glass valve is closed so that the water will fill up to the calibrating glass and overflow at its top into the reservoir. A stop-watch is used to measure the time it takes for water to fill up to the 100 cc. reference mark inscribed on the calibrating glass. A reference mark is also provided from which to commence the reading. For 500 watts power to be measured by a temperature rise of 40°C, 100 cc. of water should flow into the calibrating glass in 33½ seconds. The rate of flow may be increased or decreased by adjusting the glass valve at the top of the unit. This gives the calorimeter any desired degree of sensitivity and response to suit the wishes of the operator.

Fig. 1 shows all the controls normally needed to use the instrument. The thermometer at left is the "cold" thermometer, normally at room or reservoir temperature. The one at the right is the "hot" thermometer which reads the temperature of the water returning out of water load. Optionally, a reader control may be provided for moving a reference line along the thermometer to set cold temperature as zero reference on the hot thermometer, in order to facilitate computation of temperature rise. Pilot lights and toggle switches shown are for the circulating water pump and for the circulating fan to cool water in the radiator back to room temperature. In practice, the hot thermometer increases in reading with respect to the cold thermometer in a few seconds, and stabilizes at maximum temperature differential in three minutes or less for a flow rate of 179.15 cc. per minute against power measurements on the order of 50 to 100 watts average power. The thermometers shown are the most sensitive ever used in commercial calorimeters.

Operation

Operation is normally very simple. The pump is started by turning on the front panel toggle switch, which circulates water through the water load and around the bases of the input and output thermometers. After sufficient time has elapsed for water to travel completely through the water load and around the thermometers, a temperature differential develops between the two thermometers which otherwise would read the same. When this differential has stabilized, the temperature difference is read or determined, and reference is made to a calculated graph to determine the average power absorbed by the calorimeter, and thus the average power output rating of the device under test.

Future

Two of the interesting offshoot developments in the postwar wave guide art are "Microwave Calorimetry" and "Microwave Spectroscopy." When the two are combined, they become research tools which may point the way to the precipitation of matter suspended in liquids or gases. Already some interest is developing in such an approach for the freshening of sea water, leaving in certain elements and removing or modifying others, so that the result might be a product superior to ordinary fresh water. It may afford a more economical and superior method of removing superfluous matter in liquids by the use of molecular resonance rather than by high cost distilling or evaporation systems. Engineers at the laboratories of the *Technical Products and Services Company*, who are studying the effect on liquids circulated through water loads exposed to microwave energy in wave guides, have given these possibilities serious attention.

Another field of promise is the use of these water loads as r.f. power loads. Such loads minimize the limitations of present wave guide loads where absorbing materials, such as carbon-impregnated bakelite in the case of very low power, or concrete-graphite compositions in the case of medium power loads, develop excessive heat.

Modifications of this technique can also be used to measure electrical power regardless of frequency, such as in coaxial cables for lower frequencies.

Today, inasmuch as radars, microwave tubes, and nucleonic devices involve measurement of higher average power than was necessary in the past, the r.f. circulating water load as used in calorimeters affords the most convenient and economical solution to the problem of coping with the high heats involved.

Magnetic Tape

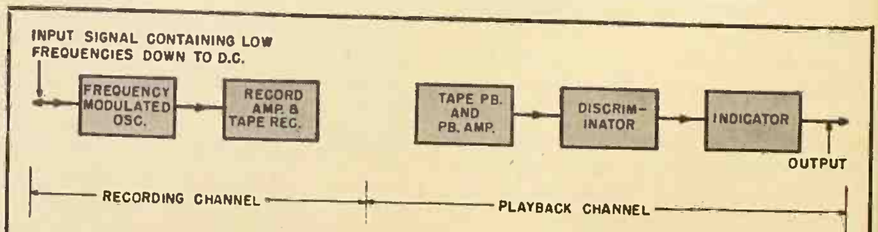
(*Continued from page* 6)

by audio-frequency recorders, which are not capable of reproducing low-frequency signals down to d.c. However, the use of frequency-modulated carrier techniques provides a method of recording such signals in multitrack systems, as shown in the block diagram, Fig. 11. A local oscillator in the recording channel is frequency-modulated by the input signal, and the modulated carrier recorded on the tape through the standard recording channel. In the playback channel, the carrier is demodulated by a discriminator so that the original signal is reproduced with frequency response down to zero cps. Since the entire recording channel is available for the frequency-modulated signal, the carrier frequency and the frequency deviation can be selected to take best advantage of the recorder bandwidth, using wide-band modulation to minimize the effects of speed variation of the tape, and a wide frequency range to give good high-frequency reproduction of the recorded signal. Such systems are capable of recording signal frequencies of 0 to 7500 cps with a signal-to-noise ratio of over 45 db below 3% harmonic distortion, and can give better signal-to-noise ratios for narrower-band signals.

Commercial units have been designed and are available for the multitrack recording systems which have been described. Photographs of some of these units are shown in Figs. 1, 7, 8 and 10. Fig. 8 shows a typical multitrack unit which records seven channels on ½-inch tape. As this unit was designed for field operation, it contains a tuning-fork oscillator and a power amplifier to provide accurate 60 cps driving power which may not always be available in the field. This supply also can serve to isolate the tape drive mechanism from any variations in commercial 60 cps power which might affect the accuracy of the data. Fig. 7 shows a photograph of a 13-channel recorder which has been used for the recording and reproduction of signals obtained in petroleum exploration and similar geophysical applications; these units use the frequency-modulated carrier system to give recorded frequency response to d.c. with an upper frequency limit which can be made as high as 20% of the carrier frequency. Fig. 1 shows a photograph of a laboratory signal-analysis reproducer which has a three-speed drive with eight-track reproduction on the horizontal table, while the vertical table permits rerecording of any two of the eight tracks with facilities for loop operation.

The various magnetic tape data-recording systems described in this article represent the different methods which have been found useful in a wide variety of applications. The specific system which is used in any single application depends upon the individual requirements, although in many cases the commercial availability of a recording unit may be the most important consideration. The methods and techniques which have been described should serve as a useful introduction to some of the techniques involved in the design and application of such data-recording systems.

Fig. 11. Block diagram showing use of frequency-modulated carrier techniques to provide a method of recording signals containing low-frequency components down to d.c. A single channel is shown.



Etching

(*Continued from page* 9)

with unloaded Q of 150 whereas a similar 220 microhenry coil etched from commercial copper-clad plastic laminate has a Q of about 50.

The advantages of the coil-lacquer-cloth circuiting process as compared to other printing techniques may be summarized as follows:

1. Connections may be designed for three dimensions.
2. Printing and etching may be done while the harness is in flat sheet form.
3. The raw stock is inexpensive.
4. Soldering may be done directly as with wire.
5. Ordinary maintenance may be practiced.
6. Mounting of the circuit after etching permits the use of various inexpensive and low-loss bases.
7. Processing is more conveniently done independent of a rigid base.

Of most importance is the fact that the circuit may be fabricated flat, permitting the use of a variety of graphic arts processes (all essentially two-dimensional), but may be folded into the three-dimensional forms required in the bulk of most electronic equipment. The standard components with lugs dispersed on several sides may be utilized with the prefabricated harness.

Many of the properties of this particular method derive from the flexibility of the thin backing which, of course, may be achieved by other means than the selective etching of metal foil. For example, some of the conductive silver paints can be printed and fired on asbestos cloth or papers.

A question often asked in the printed circuit field concerns the strength of the metal to laminate bond. Much effort has been expended in the field of adhesives since 1905, when F. C. Burgess developed a testing device to measure the adhesion of electroplated metals. Deposits on plastics have received less consideration. A review of existing literature coupled with a knowledge of the particular problem at hand suggested that two tests would be needed to obtain usable information. These tests were essentially (a) a straight pull perpendicular to the surface, and (b) a straight peel or rip perpendicular to the surface.

After studying test methods used in the field of adhesives, a method was selected which enables tests to be performed by applying an adaptive structure to commonly available equipment.

In ASTM Specification 429-39, such an adapter is described for addition to a standard tensile testing machine for the specific purpose of making adhesion tests of vulcanized rubber bonds to metal surfaces. Such an approach is indicated unless the amount of testing to be done is large enough to justify the construction of a complete lever-action machine.

An adapter was devised for use in connection with a standard laboratory press. This adapter merely reverses the direction of the force applied by the press so that a pull, instead of a press action, is provided as the platens are brought together. The adapter and press are shown in Fig. 6. The applied negative pressure may be deduced from the regular pressure gauge by an arithmetical relationship.

Two brass plugs in the technique here described are used interchangeably; one has an area of ½ square inch and the other an area of 1 square inch in order to cover roughly the range of forces to be measured without the necessity of changing the gauge on the press. A perforated piece is used to clamp the test piece face up in the apparatus. The plugs are secured to the metallized or metal-clad surface of the plastic by means of solder with a low melting point, to avoid damaging the bond between copper and laminate.

After placing the plug on the test piece, all of the metal cladding, except that under the plug, is removed by cutting around the circumference of the plug with a sharp scalpel and peeling off the excess copper. This stripping is necessary only for clad laminate and not for paint-type metallizations which are friable enough to break free in the plug area without precutting.

With the test piece in place, the adapter is placed in the press and pressure applied slowly enough for the reading on the gauge to be observed accurately just before the time of adhesion failure. (The addition of a maximum reading hand to the press gauge would increase the accuracy.)

It has also been considered necessary to develop a test for peeling or ripping the metal surfaces from the plastic laminate, which is started by release at some point on the surface. Both tests are necessary to gain enough information to establish controls on the materials and processes used to form circuits from these materials. A straight pull test is perhaps most appropriate for determining the relative performance of the materials put out by the various manufacturers, and for checking on the quality of such incoming raw material. While this test might also be applied to the material during processing, or to a finished product, it would not be representative of the most frequent type of destruction which is apt to occur to an etched circuit; namely, the pulling of a strip (connective wire) of copper from the surface after one end has been loosened by a ripping motion, such as might be applied by a component soldered to said strip.

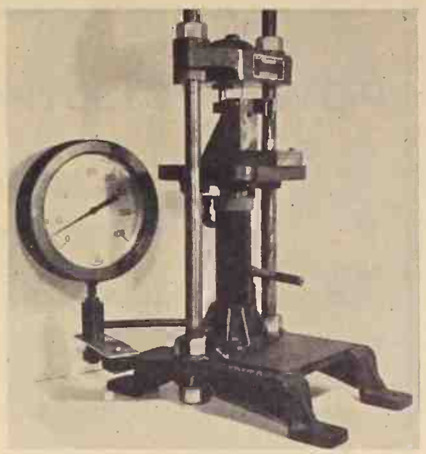


Fig. 6. Pull test adhesion adapter fitted to a laboratory press.

The general method used for peel testing is to measure the force required to strip a given width of cladding at a given rate.

In conclusion, it may be stated that a practical laboratory procedure has been developed for the production of electronic products from commercial etching stock. This procedure may have to be modified to adapt it to commercial production.

Two tests have been developed for the testing of etching stock, for quality control and for establishment of new production processes. These tests may be used to check the product as it arrives, or after any phase of the processing. Typical bond strengths are 200 lbs. per square inch pull and 11 lbs. per inch width of peel.

Of the two tests, the peel test might be preferable because it more nearly approximates the damage that might occur to the circuit; the preparation necessary for sampling is simple, and the time per test is greatly reduced. Several commercial etching stocks have been tested and found to have sufficient strength for many practical applications.

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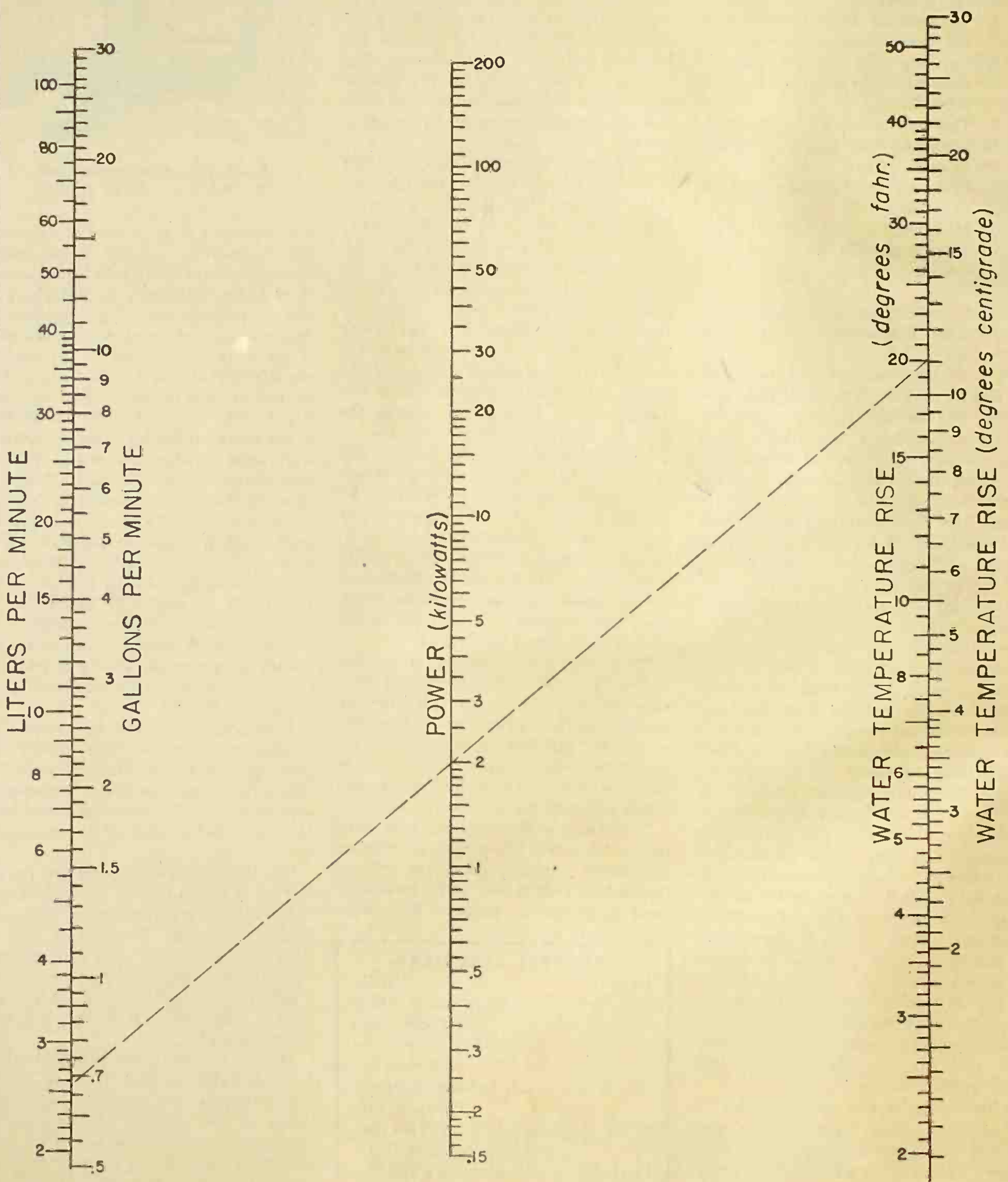
POWER DISSIPATED IN WATER-COOLED DEVICES

Nomograph for determining power dissipation in kw. based on water temperature rise and rate of flow.



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