BELL LABORATORIES RECORD

TELEPHOTOGRAPH SYSTEM

F. W. REYNOLDS

HIGH FREQUENCY VACUUM TUBES

F. B. LLEWELLYN

PROGRAM CIRCUIT TRIALS

H. S. HAMILTON

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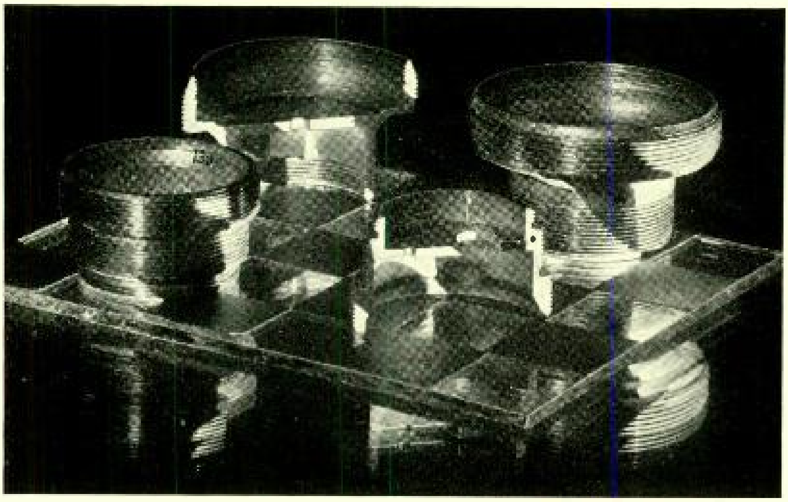
BELL LABORATORIES RECORD



Die castings for the handset

VOLUME THIRTEEN—NUMBER SIX

for

FEBRUARY

1935

Philander Norton, 1882-1935

PHILANDER NORTON

Philander Norton, Assistant to President, died on January 10 at Port Washington after a brief illness. Mr. Norton was graduated by Princeton University in 1907, and having received the degrees of A.M. and E.E. in subsequent years, entered the Engineering Department of the Western Electric Company in October, 1910. At first concerned with the investigation and design of ringing systems for party lines, his energy and initiative soon placed him at the head of a group of engineers. Among his responsibilities here was the development of protective devices for telephone lines; the carbon block held in a porcelain block by fusible cement, which is now the Bell System standard, was the outcome of this work.

During the World War Mr. Norton was engaged in production work on vacuum tubes, and later he was one of the engineering group stationed at Nahant for development of submarine detectors.

Returning to West Street early in 1919, Mr. Norton resumed his work on protective devices; a year later he was given supervision over analysis and testing of newly designed apparatus and also of investigations of new materials. In this and his outside activities he had demonstrated his ability to make and hold friends. When, therefore, in 1926 Col. Shreeve was appointed technical representative in Europe, Dr. Jewett selected Mr. Norton to succeed him as Assistant to President. In this position his analytical ability and his engineering background, combined with his gracious personality and unfailing desire to act cooperatively, enabled him to relieve Dr. Jewett of the details of contact with other organizations and with a large number of foreign and domestic visitors. In 1929 the editorship of the *Bell System Technical Journal* was added to his responsibilities.

Mr. Norton was a member of the American Institute of Electrical Engineers, and of the Princeton Engineering Association. He was an active alumnus of Manlius School, and in his home community was a past-Chairman of the Citizens Unemployment Committee.

Disturbances in Radio Transmission

By A. M. SKELLETT
Radio Research

ALL radio waves which traverse long distances over the earth's surface make use of the upper atmosphere. Indeed were it not for the electrical properties of these high regions*, by reason of which the waves are bent back toward the earth, radio transmission over distances greater than a thousand miles or so would be impossible. Short waves, at least, would simply pass out into space instead of following the curvature of the earth.

These electrical properties are due to the ionization of the gases; that is, the breaking up of the atoms and molecules into electrons and ions by ionizing agents. It is believed that the most important of these agencies is the ultra-violet light from the sun. Others which are believed to contribute to the ionization are the ultra-violet light from the stars, cosmic rays, meteors, and electrons, ions or neutral particles from the sun. None of these, except possibly cosmic rays, acts in a steady continuous manner, and in consequence the electrical state of the ionosphere varies continually. Some of these variations are fairly regular and cyclic while others are irregular and give rise to disturbances in long distance radio transmission.

*The atmosphere may be divided into four parts: (1) the troposphere, extending to a height of about 7 miles; (2) the stratosphere or "isothermal region" from 7 miles to about 25 miles; (2) the ozonosphere from about 25 to about 45 miles and (4) the ionosphere above about 45 miles. The ionosphere is the region which is important in radio transmission.

One type of such disturbance occurs at the time of a "magnetic storm," and is very detrimental to short waves travelling over high-latitude paths. In fact, radio pulse experiments have shown that the ionosphere in polar regions completely absorbs short waves at such times. Coincident with the magnetic and radio effects other phenomena are observed, the most prominent of which are the abnormal electric currents in the earth's crust and the appearance of the aurora in unusually low latitudes. Since the magnetic aspect of these disturbances has received by far the greatest amount of study, the term magnetic storm is used in the discussion of any of these phenomena.

Theoretical considerations indicate that the variations of the earth's magnetic field have only a minor effect on radio transmission in general, the changes in the ionization of the ionosphere being responsible for the major effects. The latter deviations appear to be of two kinds, a general increase in the amount of ionization and an increase in the turbulence. In the daytime the resultant effects on radio transmission vary greatly with the wave length: long distance transmission by long waves (5,000 meters or more) is better, but transmission by short waves (10 to 100 meters) may be severely disturbed or completely wiped out. During the night hours, the effect on the short waves is of the same kind as in the daytime, whereas the long waves experience a relatively mild depression in the strength of the received signals.

Apparently the general increase in ionization during disturbed periods enhances the "reflecting power" of the ionosphere for long waves during the day, while an opposite effect is produced on the short waves. It appears that the layer of ionization which is intensified by the disturbance acts both as reflector for the long waves and as absorber for the short, so that the increase in ionization affects the two ranges of frequency oppositely. These facts imply that the short waves are reflected at a higher level than the long, and such is known to be the case.

The study of magnetic storms has furnished strong evidence that the fundamental cause of these various phenomena is to be found in the sun. This is indicated by the appearance, in the magnetic records, of the two major solar periods: the eleven-year period of sun spots and most other forms of solar activity (Figure 1), and the approximate twenty-seven-day period of the sun's rotation. There are now also enough radio data to show this twenty-seven-day period. In Figure 4 the size of a dot on the radio chart corresponds, roughly, to the relative intensity from day to day of the disturbances of the short-wave telephone circuits between New York and London. The tendency for these to recur time after time at intervals of approximately twenty-seven days is apparent. There are also enough data on the long waves to show an eleven-year period of variation over more than one solar cycle.

At the time of each of the nineteen great magnetic storms that occurred from 1875 to 1903, E. W. Maunder, an English astronomer, found that there was a large sun spot on the visible side of the sun. For storms of lesser magnitude the relation did not always hold. Magnetic disturbances sometimes occur when no spots are visible on the sun, and large spots are at times observed when no disturbances occur. Evidently the cause of the terrestrial disturbances must be sought further.

An instrument which makes such a study possible is the spectrohelioscope, which discloses phenomena entirely invisible in the ordinary telescope. As its name implies, it enables one to observe the sun in the light of any particular wavelength in the

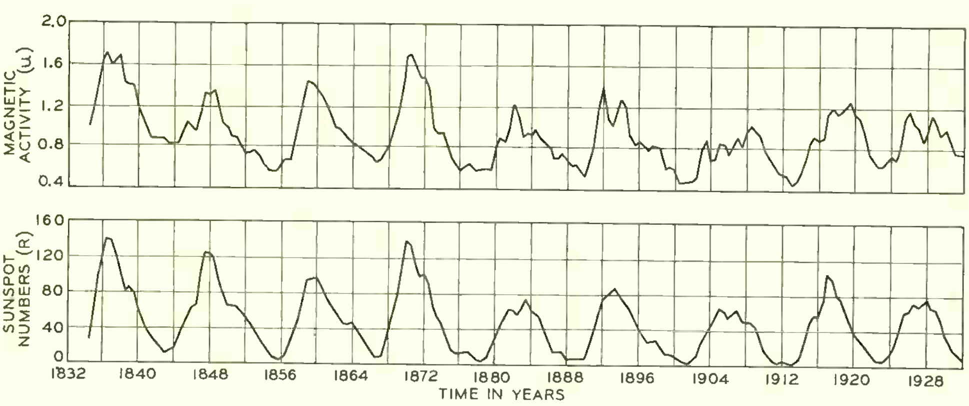


Fig. 1—Magnetic and sun spot data show an eleven-year period of variation. These data were compiled by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington

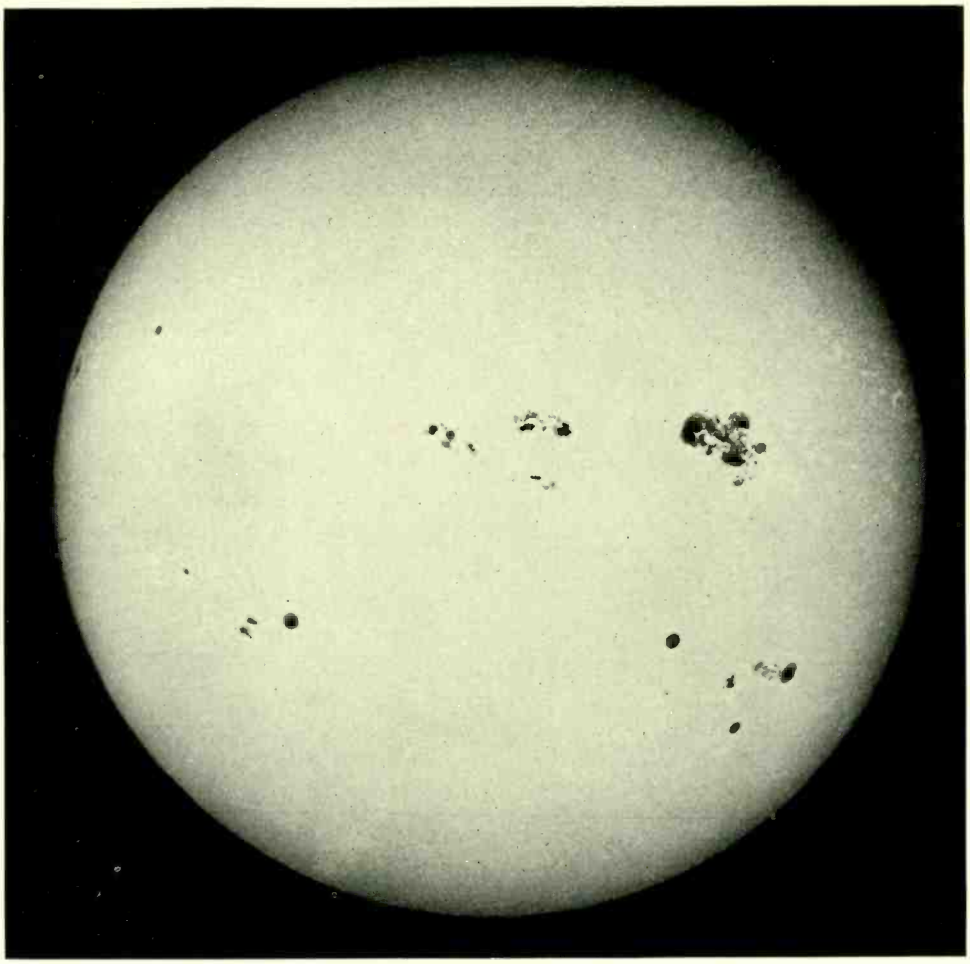


Fig. 2—This photoheliogram, taken by Ellerman at Mount Wilson Observatory, shows several sun spots

solar spectrum. If the instrument is set for one of the absorption lines of hydrogen, the distribution of this element over the solar surface may be seen. In this light the appearance of the sun is strikingly different from that given by white light (Figure 2). The granular structure is much coarser, and clouds of hydrogen are usually seen over the surface, while around the edge such clouds may often be observed as prominences or ruddily hued flames projecting out from the sun.

The prominences are sometimes seen to blow off into space with great velocities (Figure 5), and such observations strongly suggest a mechanism by which a disturbance may be transmitted from the sun to the earth. A number of bright eruptions have been observed to occur on the solar surface, usually near large spots, which were followed by magnetic storms on the earth after an average interval of about twenty-six hours. Theoretical considerations indicate that the speed of a particle ejected from the sun by

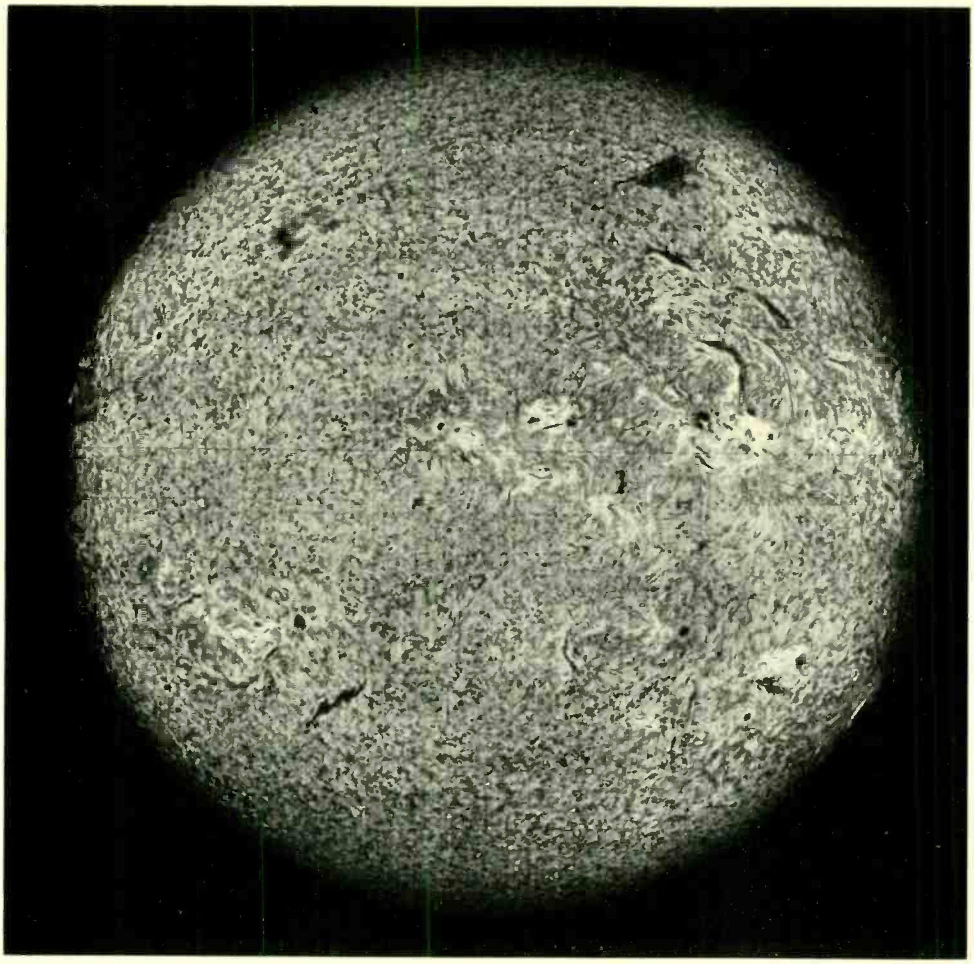


Fig. 3—This spectroheliogram (in the Hα line) showing flocculi was taken at Mount Wilson at about the same time as Figure 2

radiation pressure would be a thousand miles per second, at which velocity the particle would take twenty-six hours to traverse the 93,000,000 miles from the sun to the earth. The conditions are not as simple as this would imply, however, and recent studies of the motions of prominences cast some doubt on the generally accepted importance of the rôle which is played by radiation pressure in ejecting them.

Regarding the means by which the disturbance is transmitted between the sun and the earth, it appears likely that the actual carriers are electrons or ions or a combination of both. The fact that the disturbance on the sun can be seen before electrical effects are experienced on the earth, implies a carrier other than light. Moreover the form and position of the aurora produced at such times have been reproduced in the laboratory by bombarding a magnetized iron sphere with electrons.

One may picture the origin of a magnetic storm in this way. First a solar eruption emits a stream of electrons and possibly ions into space; then some time later these charged corpuscles arrive at the earth and are so guided by its magnetic field that most of them enter the atmosphere around the polar regions. As they strike the outer atmosphere they ionize and disturb it, and as a direct result radio transmission through these regions is poor and a brilliant aurora appears. It has been suggested that electric currents would be set up in these high regions which would give rise to the magnetic and electrical effects observed at the earth's surface.

The durations of these great solar eruptions are very brief, astronomically speaking, usually a matter of hours or less, and since the sun can be observed only intermittently, the record of their appearance is necessarily very incomplete. It is probably significant that almost all of those observed have been followed by intense magnetic storms.

At times long distance transmission is disturbed when there is no magnetic storm. The question naturally arises: are there other means by which the normal behavior of the ionosphere may be altered? Is it possible, for example, that the haphazard bombardment of the upper atmosphere by meteors is one such cause of disturbance?

The average shooting star has a velocity many times that of the fastest rifle bullet. When it strikes an atmospheric molecule, the energy of impact is great enough to break up the molecule into ions and electrons. Often a bright meteor will leave a glowing train which floats in the

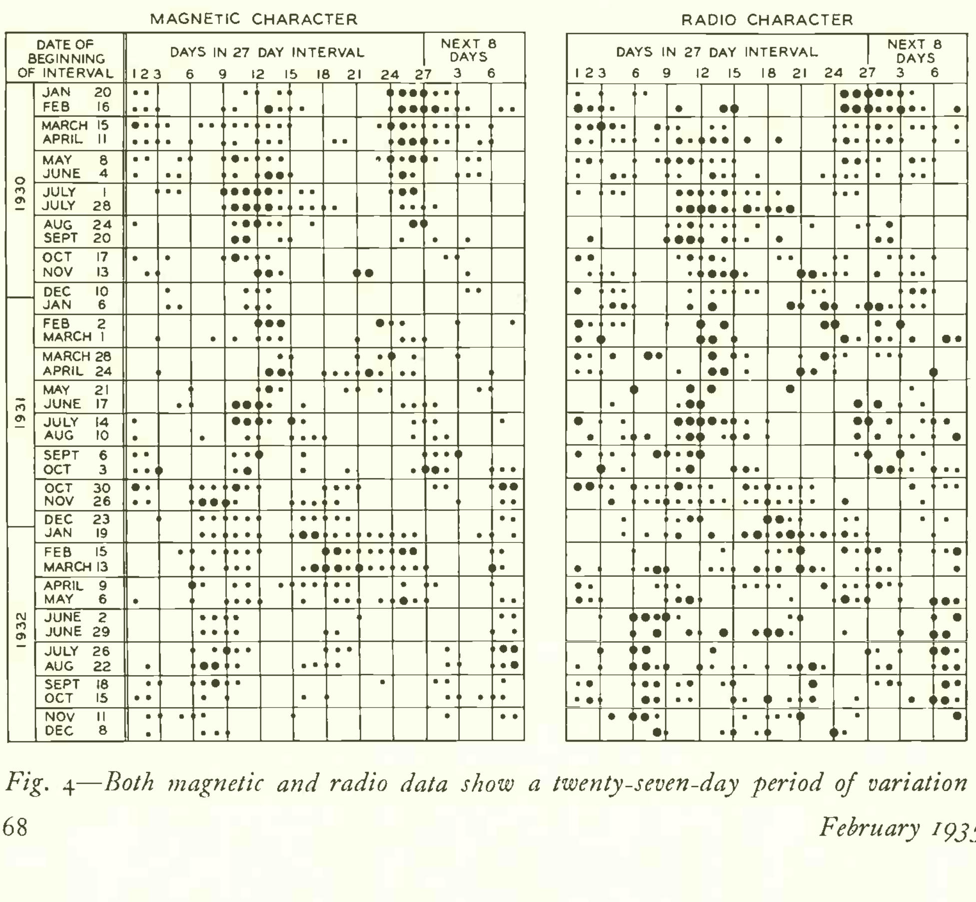


Fig. 4—Both magnetic and radio data show a twenty-seven-day period of variation

upper atmosphere for some time after the meteor has disappeared and which may be a mile or more in diameter. It seems likely that such nighttime trains are one of the phenomena accompanying ionization. They seem to occur exclusively in the lower layer of the ionosphere.

More direct proof of meteoric ionization was obtained at the Laboratories at Deal during the Leonid meteor shower of 1932. Measurements of ionization by the radio pulse method indicated increases in ionization directly overhead coincident with the passage of bright meteors through this region. For the brightest observed, the ionization increased by an amount in excess of that which is found at noon in summer. These observations, as well as others made by J. P. Schafer and W. M. Goodall during other meteor showers, furnish direct evidence of the ionizing effects of visible meteors in the lower layer of the ionosphere.

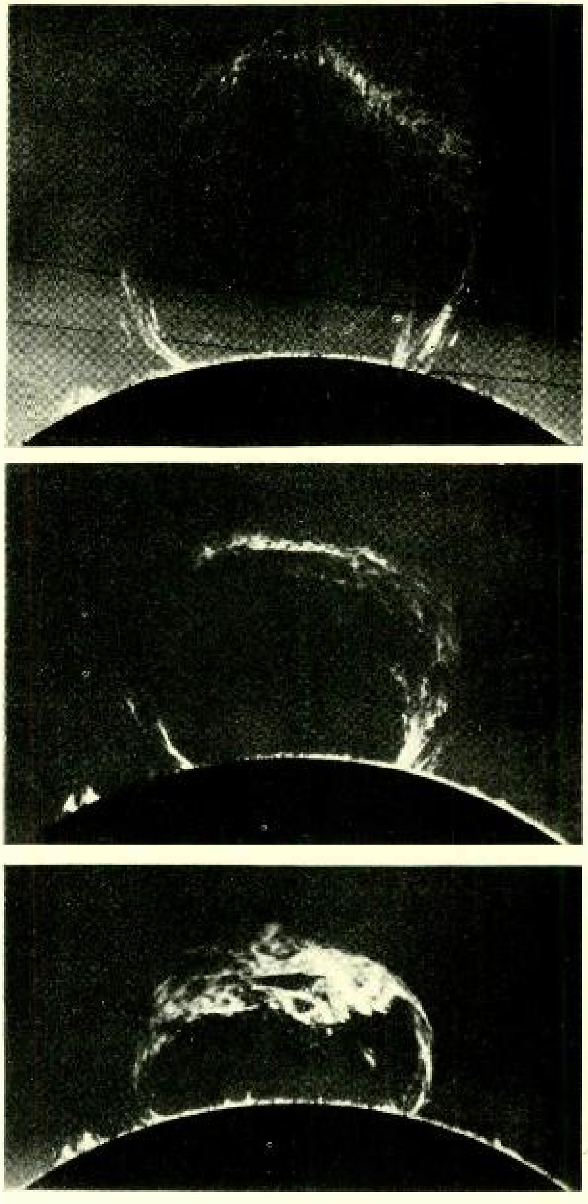


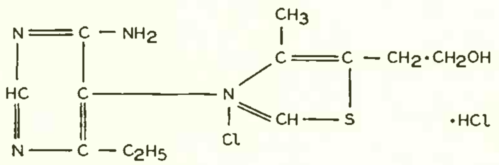
Fig. 5—These spectroheliograms show three successive stages of a prominence blowing off the sun. The time interval between 1 and 2 is about forty-four minutes, and between 2 and 3 about fifteen minutes. The pictures were taken by Pettit at the Yerkes Observatory

A conservative estimate of the number of meteors which hit the atmosphere each day is one billion, averaging about five per square mile of the earth's surface. If each meteor spreads ionization around its path to a distance of a fraction of a mile, a radio beam which travels a long distance through the ionosphere will be subjected at normal times to a continuous bombardment. This brings up a question which has not as yet been answered: does this bombardment produce sufficient turbulence to cause fading?

It is in the general region of the lower layer, fifty to seventy-five miles above the earth, and in that neighboring to it, that most of the shooting stars observed by the naked eye are seen. The telescope, however, reveals many more whose paths apparently lie in or near the region of the upper layer (175 to 190 miles high). These are much more difficult to observe since they are much fainter and traverse the field of the telescope in a very small fraction of a second. It is not unlikely, therefore, that the upper layer may experience meteor showers which are never seen. Whether or not they are the cause of unexplained interruptions of long distance transmission cannot be determined from present data, but that they constitute a possible source of such disturbances as these is evident.

Last Spring R. R. Williams, Chemical Director, announced a method of preparing Vitamin B_1*. The work has now reached another milestone: the proposal of a formula for the Vitamin* B_1 *molecule, showing how its atoms are linked together. The organic chemist uses such a formula to suggest methods for synthesizing the substance in the laboratory. It may also suggest how the substance works in the body. The formula shown is that proposed for Vitamin Hydrochloride.*

Mr. Williams has pursued this work as an outside interest with the coöperation of several associates. Among them two members of the Chemical Laboratories have spent their spare time on the project: Robert E. Waterman, who has been engaged in the enterprise for the past ten years, and A. E. Ruehle who, in recent months, has done very effective work on the ultra-violet absorption of the vitamin and its cleavage products.



The New Telephotograph System

By F. W. REYNOLDS
Telephotograph Engineer

TELEPHOTOGRAPHY was relatively an early development in the field of electrical communication but its practical application on a commercial scale awaited improvements in terminal equipment as well as in communication channels. The past decade, however, has witnessed its commercial use both in this and other countries. During this period the Bell System operated a telephotograph network between several of our larger cities, and from the experience obtained, development work was undertaken culminating in the new 70B1 system.

The general method employed in picture transmission consists of analyzing or scanning in successive elements an area containing the graphic information and converting such information into some characteristic of an electrical current as a function of time. The resulting current is then transmitted to the receiving equipment where a process inverse to that employed for sending is used to reproduce the information in substantially the original form.

In the new 70B1 equipment shown schematically in Figure 2, the photographic print or other information on paper is wrapped about the cylinder of the sending machine which is connected through a clutch to a constant speed motor. The latter not only ro-

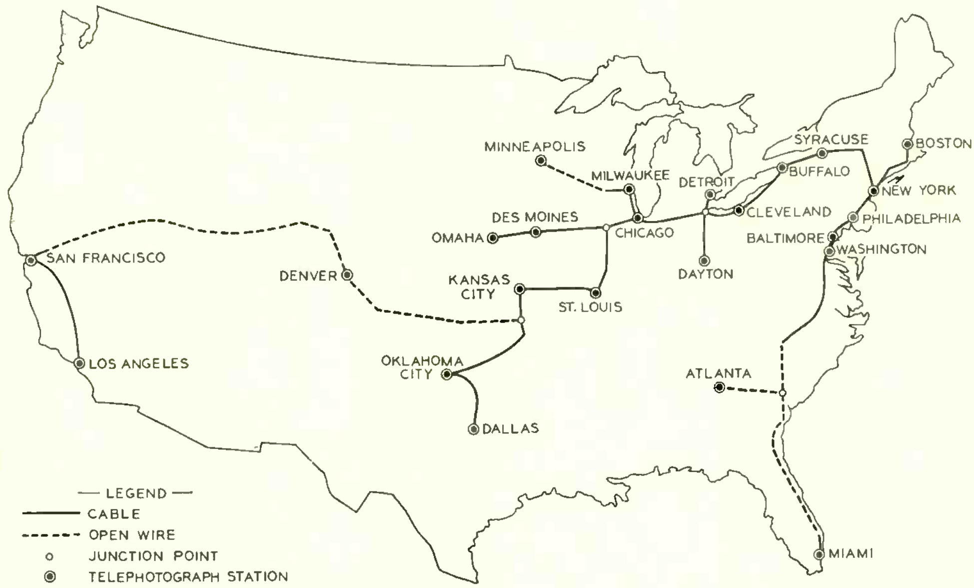


Fig. 1—A recently established telephotograph network

tates the cylinder but, through mechanical coupling arrangements, causes an optical system to advance parallel to the axis of the cylinder one-hundredth of an inch for each revolution of the cylinder. A pulsating beam of light, rectangular in cross section and one-hundredth of an inch wide, scans the complete picture area in successive parallel paths. This pulsating light, modulated by reflection from the picture, is directed to a photoelectric cell. The electrical output of the latter, after amplification, is filtered so that the frequencies used for transmission are approximately from 1200 to 2600 cycles and are only those essential for single side-band transmission.* The cylinder will accommodate pictures of various sizes up to and including 11 x 17 inches, the longer dimension being the useful length of the cylinder. The speed of scanning, 20 inches per second, results in the transmission of one inch of picture per minute, measured along the axis of the cylinder. An 8 x 11 inch picture, for example, requires eight minutes for transmission.

The receiving equipment employs mechanical arrangements similar to those for sending, except that the receiving cylinder is enclosed in a housing to exclude light other than that from the receiving optical system. This design permits operation of the equipment in ordinary room illumination. A photographic film (or paper) is wrapped about the receiving cylinder and as the latter rotates an optical system advances (in phase with the scanning at the sending machine) and exposes each elementary area in succession. The exposure at any instant is determined by the opening of a ribbon light valve actu-

*This is the first commercial use of single side-band transmission in telephotography.

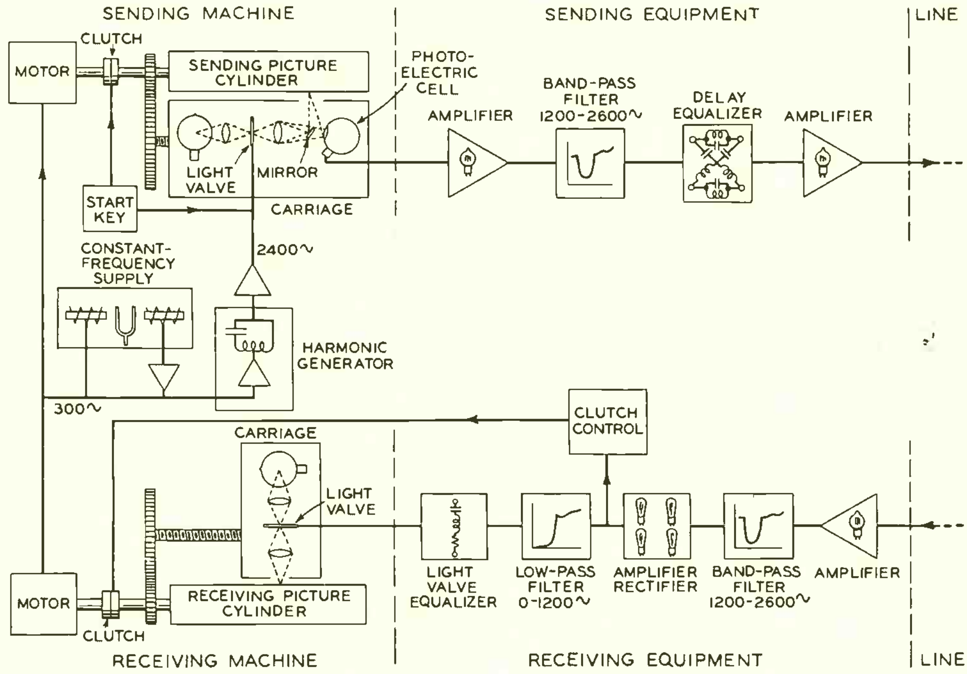


Fig. 2—Schematic of sending and receiving equipment for one station

ated by the rectified picture current.

The housing containing the cylinder is removed from the machine at the end of the transmission and taken to a photographic dark room where the exposed film is detached and the image developed. The equipment is designed primarily to transmit from a positive print and receive a negative image, consequently a geometrical reversal is necessary in order that the positive print made from the received negative shall not be reversed left to right compared with the original. This reversal is accomplished by advancing the sending and receiving optical systems in opposite directions.

It is essential that sending and receiving picture machines operate in phase. This condition is obtained in the 70B1 equipment automatically without sharing the channel or the use of line time. Each picture station is equipped with a tuning fork oscillator which supplies the frequency of 300 cycles for accurately controlling the speed of the driving motor within a few parts in a million. The motors are allowed to run continuously during an operating period and are connected and disconnected from the picture cylinders by a magnetically operated clutch. At the start of a picture transmission the closing of a key at the sending machine causes the operation of the sending clutch and a signal is sent out to operate the clutches of all receiving machines which may be connected to the network. Both sending and receiving machines may be set to stop automatically at the end of any desired length of transmission up to the maximum of 17 minutes, and can be quickly reset manually to the starting position.

Provisions have been made in a recently established network whereby any one of 24 stations can send to or receive from the others on a broadcast basis. The network can also be split, and various parts worked independently when desired. Loud speakers are provided for the continuous monitoring of the circuit as well as telephone sets to talk over the network for coördination purposes between picture transmissions. During a picture transmission the circuit is automatically held to operate one way only from the sending station, wherever it may be, to all the receiving stations using a special d-c. control circuit. The same control circuit may also be operated at any station where it is desired to broadcast operating or other information to the network and prevent interruption.

An Editorial Comment

As to the success of the telephotograph system, the following editorial quotation from the magazine EDITOR AND PUBLISHER *is evidence:*

"*The copy, in general, is rated by consuming editors as splendid engraving material—a removal from the original so slight that it makes little or no difference in the printed result.*"

Vacuum Tubes at Very High Frequencies

By F. B. LLEWELLYN
Radio Research

RECENT growth in the use of high-frequency electrical oscillations has been accompanied by considerable extensions in many applied branches of electrical theory. Nowhere is this more true than in the field of vacuum-tube electronics, dealing with the distribution and motion of electrons within a thermionic vacuum tube and with their influence on its properties. Certain simplifying assumptions which gave valuable results in earlier practice are not approximated in the operation of vacuum tubes at very high frequencies, and it has been necessary to abandon some of these assumptions to develop more widely applicable theories.

When the original investigation of vacuum tube electronics was attacked by early workers, such as Van der Bijl and Nichols in these Laboratories, it was not necessary to consider the fact that an electron emitted at the cathode does not reach the anode instantaneously but requires a certain length of time to cross from one electrode to the other. The time of transit could be neglected because it was always very short when compared with a cycle of any of the alternating currents in use at that time. With this assumption there was developed the familiar concept of the equivalent internal circuit of the vacuum tube, consisting of a resistance in series with a generator whose emf is μ times the alternating component of the grid potential.

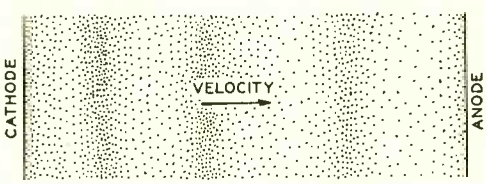


Fig. 1—The distribution of electrons between the cathode and anode of a two-element vacuum tube, operating at a frequency whose period is shorter than the transit time of the electrons, is somewhat similar to that of the molecules of air in a sound wave

When the frequency is very high, the electron transit time may become comparable with or even greater than a period of the alternating current. For example, it would require 25×10^{-10} seconds for an electron to cross a space half a centimeter long under the influence of a potential difference of 100 volts, provided that the cathode emitted a sufficient number of electrons to maintain space charge. This time is the period of a four-hundred megacycle oscillation. In such a case the behavior of the vacuum tube departs widely from that which would be predicted from the simple equivalent circuit. Even at much lower frequencies, in fact, the effect of the transit time becomes of importance.

A rough representation of the complicating conditions can most easily be pictured for a case in which the transit time is supposed to be fairly long when compared with a period of the alternating current. The electron stream may then be thought of as a moving system of alternating rarefactions and condensations of electron density, in some respects like the molecular system into which sound waves can be analyzed. Thus the distribution of the charge density at a particular instant inside a two-element tube may be as shown in Figures 1 and 2. At the same instant, the values of the electron velocity at

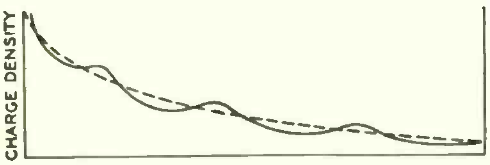


Fig. 2—A graph of the electron densities pictured in Figure 1 shows them falling off in passing from the cathode to the anode

different points across the tube will be as shown in Figure 3.

It is well known that the product of charge density times charge velocity is equal to the "conduction current." Hence curve A, in Figure 4, obtained by multiplying together the ordinates of the curves in Figures 2 and 3, gives the distribution of the conduction current across the tube.

The conduction current, however, forms only a part of the total current in any electron system, the "displacement current" forming the remaining part. Between the plates of a condenser containing no free electrons, the current is all displacement current; in an ideal metal, the current is all conduction current. Moreover, the displacement and conduction currents are always related to each other in such a manner that at any given instant, the total current is the same at all points along the direction in which the current is flowing, although it may have a different value at a later instant.

Thus in Figure 4 the conduction current A plus the displacement current B must give a total current C which at the given instant is the same at all points between the two electrodes of the tube. At a later instant, that total current will have changed its value, thus giving rise to the effective high frequency current emitted by the vacuum tube. What successive values the total current will take is influenced by the successive distributions of conduction and displacement currents. A tube may be expected to behave quite differently at high frequencies, when these two components are not uniformly distributed between the elements, from the way it behaves at low frequencies when at any instant the distribution of these components is substantially uniform.

This pictorial view is suited to give only a very rough idea of electronic conditions within the tube. Actually transit times which are of the order of a fraction of a cycle up to one or two cycles are usually of more concern. To describe events under these conditions, mathematics must be used, but some of the results of the mathematical analysis may be stated fairly simply.

A two-element vacuum tube, for instance, appears at low frequencies to act like a resistance having a value

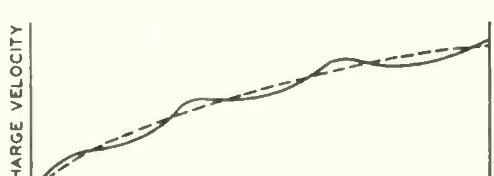


Fig. 3—Accompanying the decreasing electron densities graphed in Figure 2 are increasing electron velocities. The analogous sound wave would be one taking place in a wind whose velocity increased as it passed from cathode to anode

given by the slope of the static characteristic of the tube. As the frequency is gradually increased so that the transit time comes into prominence, the impedance changes from a pure resistance to a combination of resistance and capacitance, and the resistive component actually becomes slightly negative at certain frequencies. It can be shown that os-

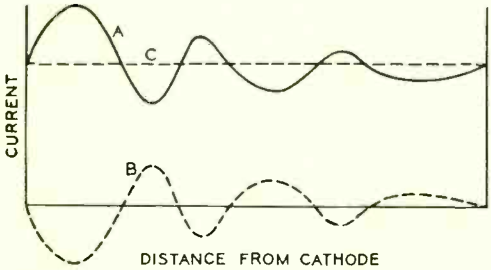
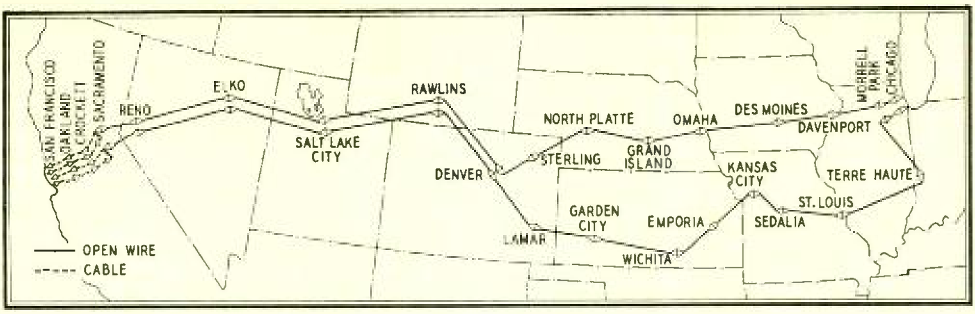


Fig. 4—The conduction current (A) is the product of the velocity and density of the charge (Figures 2 and 3). Accompanying it is the displacement current (B), and the sum of these two currents is the same at any one instant at all points of the tube (C)

cillations would occur in such systems if the loss in the external circuits could be made sufficiently small. Practically this method of producing ultra-high frequency oscillations has not been very successful because of the difficulty of procuring circuits whose losses are sufficiently low at the high frequencies in question.

In the case of a negative-grid triode, the cathode-plate path consists at low frequencies of a resistance in series with an effective generator. The high-frequency circuit changes into a resistance-capacity combination in series with a generator. The voltage of the generator is no longer opposite in phase to the excitation applied to the grid, but varies continuously in phase as the frequency is increased. The cathode-grid path, which at low frequencies can be represented with sufficient accuracy by a capacity, changes into a capacity-resistance combination in which the resistance becomes the predominating element. At very high frequencies, the loss in this resistance is so large as greatly to diminish the efficiency of oscillatory circuits containing such tubes. Even at frequencies as low as twenty megacycles, measurements made by J. G. Chaffee have shown that the resistance in the cathode-grid path of present standard tubes plays an important part in the determination of operating conditions.

Another system for generating oscillations of ultra-high frequency utilizes a vacuum tube triode in which the grid is operated at a high positive potential compared with both the cathode and the plate. Although the operating efficiencies of this system are at present decidedly lower than those obtainable with the more usual low-frequency circuits, it nevertheless forms one of the most effective means available for producing oscillations with frequencies measured in thousands of megacycles. The answer to the question which will prove to be the better decimeter oscillator ultimately hinges on whether the efficiencies of the positive grid triode can be pushed upward, or the losses between the grid and cathode of the negative grid triode can be pushed downward, sufficiently to give one type or the other a decided advantage.



Trials of New Wide-Band Program Circuits

By H. S. HAMILTON
Transmission Development

EARLY program circuits provided frequency bands about 5,000 cycles wide. These were in line with the capabilities of the radio broadcasting art and proved very satisfactory. Tests have shown, however, that better results could be obtained by transmitting wider bands, so that it seemed desirable to make improved facilities available. As a result the Laboratories, during the last few years, have developed program circuits capable of transmitting from 40 to 8,000 cycles. The circuits and apparatus made available for open-wire lines have recently been described in the RECORD.* A field trial of this system was recently made on lines between Chicago and San Francisco along the routes shown in the headpiece.

One circuit, referred to as circuit No. 1, was routed over the central transcontinental route. The facilities making up this circuit were largely those normally assigned to the coast network of the National Broadcasting Company. This circuit was 2,395 miles long with 16 repeater points. The second circuit, No. 2, was made up of facilities largely assigned to the coast network of the Columbia Broadcasting System. This circuit was routed through St. Louis and Kansas City to Denver and thence over the central transcontinental route to San Francisco, being 2,689 miles long with 19 repeater points. The open-wire conductors were mostly 165- and 128-mil copper conductors although some 104-mil facilities were involved. Both 8-inch and 12-inch spaced wires occurred in various parts of the line. Non-loaded cable facilities were included at both ends of the circuits.

To equip two circuits of these lengths a large amount of apparatus is required, and because of this as well as of the distances covered, the installation plans were necessarily quite complicated. For the most part the circuits were used in commercial service for the regular 16-hour service period daily. The testing of the equipment and particularly the cutting of the new apparatus into commercial service, thus required careful planning and execution of schedules to avoid interference with the regular service.

The manufacture and installation

*RECORD, *February*, 1934, *pp.* 162 *and* 167.

schedules were set up so that the majority of equipment was delivered and installed between May and August of 1931. Equipment at three stations, Wichita, Garden City, and Lamar, was delivered and installed in April to permit preliminary tests to be made, since the section of line from Wichita to Lamar was not then required for commercial service.

The field trial may be considered to have covered three stages. In the first period the necessary changes were made in the regular carrier systems. The second period covered testing the program equipment and cutting it into commercial service. In the last stage the overall tests were conducted.

As this new program system occupied a frequency range up to 8,000 cycles, it was necessary to drop one of the type-C carrier channels which were assigned to the program pairs involved. The carrier conversion was handled generally in the following manner: The normal carrier systems operating on the program pairs were first transferred to some other pairs or temporarily taken out of service. The new 8,000-cycle line filters were then cut in in place of the existing 5,000-cycle carrier line filters. After this was done the carrier systems were returned to the program pairs and readjusted to operate on a two-channel basis. Six carrier systems were involved on the two program circuits. The carrier conversion was accomplished between August 1 and October 17.

Because of the close coördination required between the carrier and program phases of the trial, and because of the number of stations and distances involved, detailed schedules for both the carrier and program work had to be made out and carefully followed. Ten engineers were sent out to the field to make the various tests and to supervise the cutting in of the program apparatus. The testing schedule was so laid out that the engineers would be located not only at the repeater point where the program equipment station was to be cut in service, but also at adjacent repeater stations to coöperate in the repeater section test. In general, an engineer remained at a particular

WIDE BAND PROGRAM CIRCUIT TRIAL
FORM (L)
RECORD OF SECTION LINEUP
(Cut over Data)

STATION Gr. Island
CCT. NO. Red
SHEET NO. 14
DATE 9/10/31
OBS. J.A.K.

From	Omaha				North Platte			
Date	9/10/31				9/10/31			
Time	12:45 A.M.				2:40 A.M.			
Temp.	80°				80°			
Weather	Clear				Clear			
Measured At	Line E-Jks		Rep. Out		Line W-Jks		Rep. Out	
	LOSS	DEV.	LOSS	DEV.	LOSS	DEV.	LOSS	DEV.
1000	7.2		-.04		6.55		-.12	
35	5.34	+1.86	-.02	+.02	4.80	+1.75	-.26	-.14
50	5.45	+1.75	+.05	+.09	4.95	+1.60	-.20	-.08
100	5.75	+1.45	-.04	0	5.10	+1.40	-.26	-.14
200	6.37	+.83	-.10	-.06	5.60	+.95	-.28	-.16
500	7.03	+.17	-.12	-.08	6.25	+.30	-.25	-.13
1000	7.2		0		6.55		-.12	
2000	7.57	-.37	+.03	+.03	6.85	-.30	-.02	+.10
3000	8.0	-.80	+.03	+.03	7.23	-.68	+.08	+.20
4000	8.52	-1.32	+.03	+.03	7.85	-1.3	+.02	+.14
5000	9.08	-1.88	-.08	-.08	8.48	-1.93	+.05	+.17
6000	9.65	-2.45	-.08	-.08	9.0	-2.45	-.09	+.03
7000	10.13	-2.93	-.04	-.04	9.6	-3.05	-.02	+.10
8000	11.52	-4.32	-.77	-.77	10.9	-4.35	-.85	-.73
1000	7.2		0		6.55		.05	
Final Equal. Setting	L 2		H 2		L 1-2		H 2	
Atten. Setting	16.5				15.0			
Rep. Used	14-A		~~11-E~~		14-A		~~11-E~~	

Fig. 1—Record of section lineup—Omaha-Grand Island-North Platte

station a day or so after the apparatus was cut into service. This was required to assure that everything was functioning properly and to allow observations to be made on commercial service with the new equipment in operation.

Fig. 2—Photograph of special equipment provided at San Francisco for overall tests

A great deal of information was prepared for this trial, which was furnished to the field engineers and to the various Associated Companies involved in this project. The most important was a preliminary bulletin which described the new program system and its performance characteristics, and included instructions for testing and lining up. The other information consisted of memoranda describing special tests, plans for carrying out the trial, instructions regarding data to be recorded, etc. Fourteen different forms were provided for tabulating the results of the various tests.

Armed with the information mentioned above, a lot of enthusiasm, some experience, and a great deal of determination, the field engineers after the close of a three-day conference held in Chicago sallied forth on June 20 to the repeater stations which had been assigned to them. On arrival at a station the engineer's first duty was to make a quick check of the complete layout to find out whether any equipment was missing. The results of this inspection were reported back to the control office at Chicago. Detailed measurements were then made on each piece of apparatus installed. These measurements included transmission-frequency runs on each unit, performance tests on the amplifiers, and performance and operating tests on the complete station layout.

In addition to these tests it was necessary for the engineers to make attenuation-frequency measurements of the line sections on each side of the station. From these measurements were determined the initial equalizer and attenuator adjustments. Where the weather made it possible, these

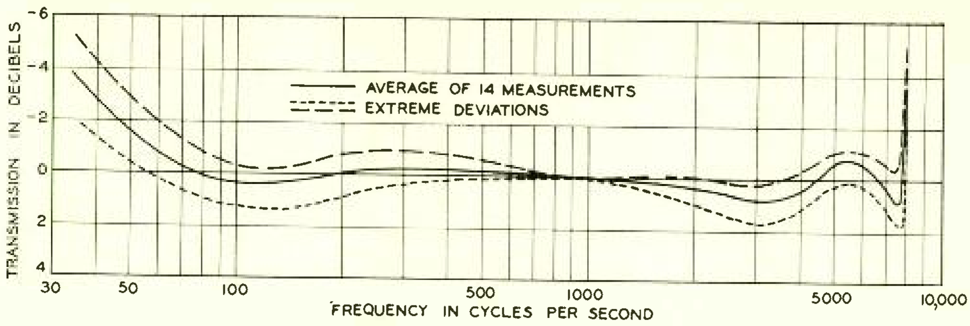


Fig. 3—Transmission frequency characteristics of circuit No. 2—San Francisco to Chicago

line measurements were repeated under different conditions so as to provide further information on the adjustments required due to varying weather conditions. Since most of the circuits were used for commercial service, it was necessary to make the measurements on the lines after the program networks were "good night."

When this work was completed, Chicago was notified, and arrangements were made to cut the station into service. It was generally possible to have our field engineers at the adjacent points, but the actual equipment was cut into the line wires by the plant forces. Our men made the necessary measurements and tests before and after the equipment was cut in.

Measurements made on the line sections during the cutover period were the most important of the field tests and were called "repeater section tests." From the measurements of attenuation of the line plus its line filters, the station equalizer settings were determined in accordance with a chart given in the bulletin. The settings thus determined were then applied to the station apparatus connected to the circuit and an overall repeater section measurement then made. In all cases it was found that the equalizer settings as indicated by the chart in the bulletin were the correct ones to use. The results of a typical section lineup are given on Figure 1. The first four columns apply to the Omaha to Grand Island repeater section, the receiving end of the circuit being at Grand Island. The first column gives the characteristic of the line and its associated filters. The second column is the deviation referred to 1,000-cycle zero. The third column gives the results of the overall repeater section measurements after the line equalizers and station attenuator had been adjusted in accordance with the data obtained from the line measurements. In other words it is the characteristic from the output side of the repeater at Omaha to the output of the repeater at Grand Island. The fourth column is the deviation of this characteristic referred to 1,000 cycles. The four following columns give corresponding information for the section from North Platte to Grand Island with Grand Island as the receiving end of the section. The equalizer and attenuator settings required for these sections are indicated at the bottom of the form.

The individual station measurements, repeater section tests, and station cutovers, constituting the second phase of the trial, were completed with the cutover of the last stations on October 19. The engineers were then located at strategic stations between San Francisco and Chicago to coöperate in the overall tests which comprised the third phase of the field trial and which were completed by November 30.

The overall tests were conducted from San Francisco rather than Chicago for a number of reasons, but chiefly because the circuits could be obtained at about 11:00 P.M., Pacific time, corresponding to 1:00 A.M. Central standard time. This was early enough in the evening so that outside program sources could be obtained at San Francisco, whereas more difficulty would have been experienced in Chicago in obtaining suitable program sources after one or two o'clock in the morning.

A listening studio was set up in the Grant Avenue office of the Pacific Telephone and Telegraph Company at San Francisco. The room was of fair size and acoustically treated so as to obtain the proper reverberation time. A two-unit loud speaker was placed at one end of the room, and was operated from a powerful amplifier—the combined system having practically flat frequency characteristics from below 40 to above 8,000 cycles. Other special equipment provided at San Francisco included a phonograph outfit for vertical cut records, attenuators, switching arrangements, and filters of different cut-offs. The photograph of Figure 2 shows the special equipment placed in the Grant Avenue office, and also the new program equipment provided on the two program circuits under discussion. The three right-hand bays accommodated the special equipment while the new program equipment was mounted in the bays to the left of these.

For program sources two outside pickup points were used, one at the studios of the National Broadcasting Company at San Francisco and the other at the Mark Hopkins Hotel—a Columbia Broadcasting System pickup point. At both these places moving-coil type of microphones and the latest type of high quality speech input amplifiers were used. These program sources were supplemented

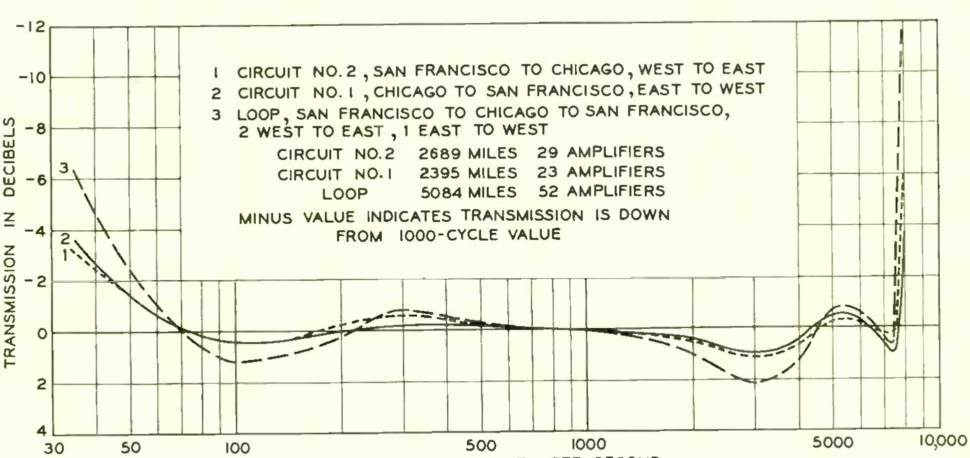


Fig. 4—Average transmission-frequency characteristic of Chicago-San Francisco program circuits

by a number of vertical cut records, which included recordings of the Roxy Theatre orchestra as well as various solo and instrumental recordings.

The tests each night, planned as a rule after the previous day's data had been analyzed, were generally made between the hours of 10:00 or 11:00 P.M. and 4:30 A.M., Pacific time. This allowed one to retire at about 5:30 A.M., but all concerned managed to get enough sleep to carry on in good shape and also to get a considerable amount of testing done.

The nightly tests started with the station routine, i.e., check-up of repeaters, setting them to specified gains, etc. This was followed by section lineups; the circuits were divided in sections in accordance with the location of the engineers, and transmission measurements made at four frequencies, namely, 40, 100, 1,000 and 7,000 cycles. If the results were not within required limits the attenuators and equalizers were adjusted as required. The various sections were then connected together, and the overall circuit measured at several frequencies. The results of some of these overall frequency measurements are shown on Figures 3 and 4. Figure 3 shows the average characteristics and extreme deviations of one of the circuits from San Francisco to Chicago. Figure 4 shows the average characteristic of the two circuits and also the characteristic of the two looped together making a circuit over 5,000 miles long.

Various other kinds of measurements were made, such as load measurements, and measurements to determine whether the circuit had any undesirable non-linear effects. Very critical listening tests were made in addition, in which the quality of a program after it had been transmitted over various length circuits was compared with the same program transmitted over a reference circuit, which was distortionless over the frequency range for which the circuits were designed. Figure 5 shows schematically

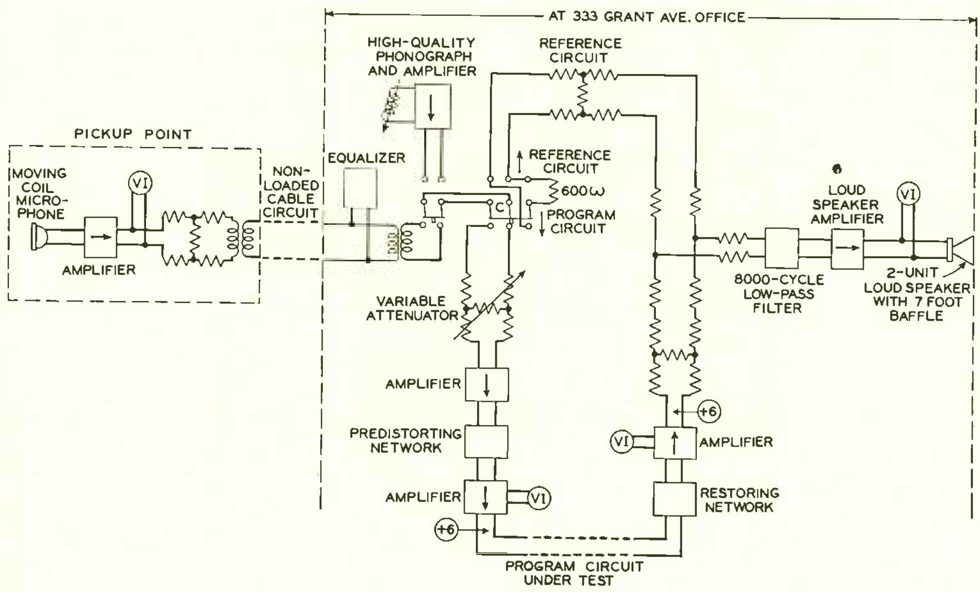
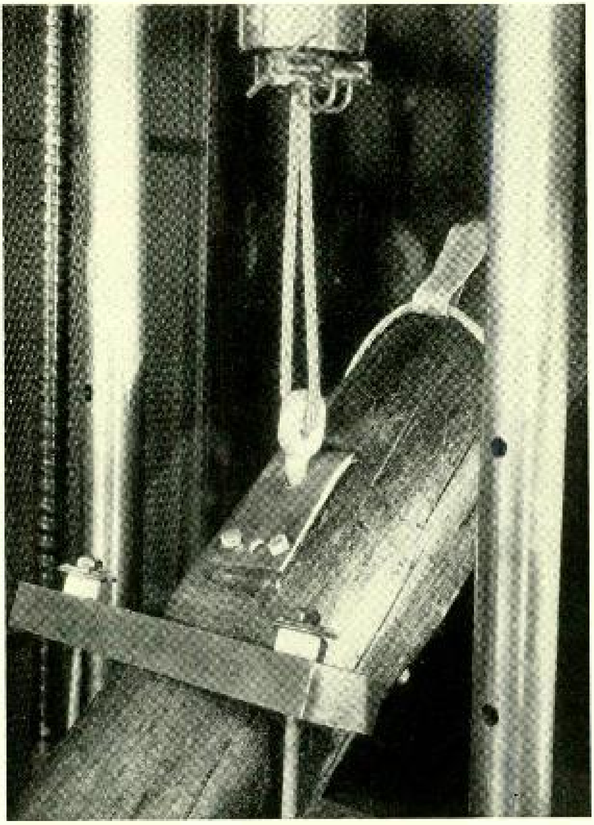


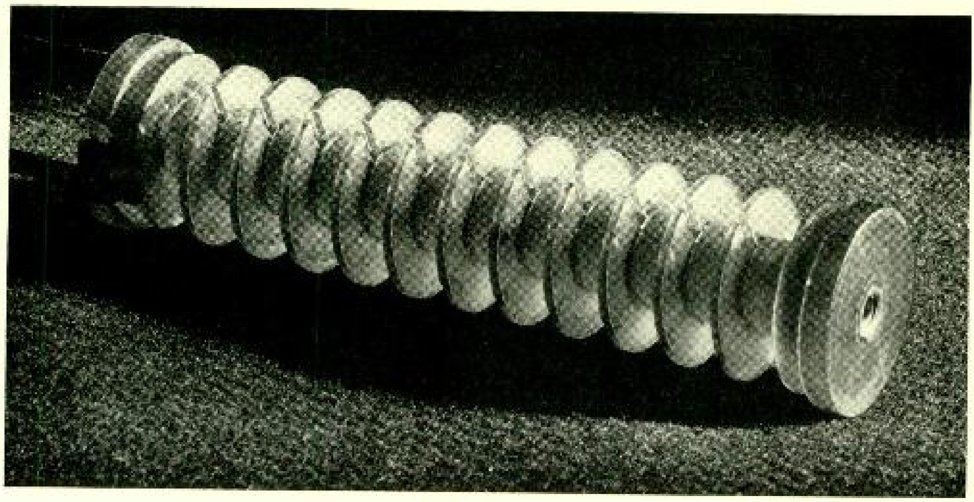
Fig. 5—Terminal arrangements at San Francisco for comparison tests

the terminal arrangements employed at San Francisco for these comparisons.

Various types of programs were used, such as speech, vocal and instrumental selections, and orchestral compositions—both classical and jazz. Quite a number of observers were used, some of whom were present on several tests and a few on all tests. On tests made on a San Francisco-Denver-San Francisco loop involving 2,600 miles of circuit, no observer was able consistently to differentiate between the quality over the reference circuit and that over the program circuit. On tests made on the San Francisco-Chicago-San Francisco loop certain of the more experienced observers were able to differentiate between the circuits somewhat more than 50 per cent of the time, but this, it should be remembered, was on a direct comparison test. None of the observers could tell with any assurance which was the program circuit and which was the reference circuit if a few minutes were allowed to elapse between switches.



The Amsler Hydraulic Testing Machine is a convenient means for testing the fixture used to attach heavy guy strands to telephone poles. This picture shows the conditions existing when the load is in excess of that which would break the heaviest guy strands used in the field



A Wire-Wound Grid Resistance

By R. A. OGG
Telephone Apparatus Development

FOR use in the grid and plate circuits of vacuum-tube repeaters, and other places where high resistances are required, a new unit has recently been developed by the Laboratories. The objective has been to provide inexpensive resistance units, ranging in value from 50,000 to 500,000 ohms, which would be small in size and yet stable over long periods of time. Although these units will dissipate two watts continuously, power capacity is generally not a consideration in grid type resistances.

The unit developed is shown in Figure 2. It is a wire resistance wound on a core of moulded cellulose acetate. The core is divided into twelve sections by separating washers that are an integral part of the core structure. A double-silk-insulated nickel-chromium resistance wire is used which, with the smallest diameter practicable, permits resistance values up to 500,000 ohms to be obtained. Over the completed winding is applied a covering of soluble cellulose-acetate-silk fiber and the whole unit is then dipped in acetone, which coalesces the serving and forms a tough moisture-proof skin. This surface layer is also sealed to the core structure at the two ends where a small tapered shoulder is provided, which effectively retards the entrance of moisture. Threaded inserts are moulded in both ends of the spool to permit it to be mounted on a panel by either end. Terminal lugs, also moulded in the structure, are provided at one end only. When mounted from the terminal end, these lugs project through the panel to the opposite side which is convenient when apparatus is mounted on the front of the panel.

The division of the spool into twelve sections makes it easier to wind and at the same time reduces the capacitance and inductance, both of which are usually undesirable in a resistance. To wind an undivided core of this size with the small-gauge wire employed, paper would have to be laid between consecutive layers of wire to keep the winding smooth. This would naturally slow down the winding operation and make it more expensive. With the narrow sections provided in the new unit, however, the winding in each section may be applied hit or miss, thereby greatly speeding up the operation. Moreover, if the core did not have partitions, the capacitance between layers would act more or less as a single shunt capacitance across the core. With the sectional winding, on the other hand, there is the effect of twelve capacitances in series, and the resultant overall capacitance is therefore much less. The reduction in capacitance is proportional to the square of the number of sections, and thus the new unit has far better characteristics than a continuously wound coil.

To reduce the inductance of the coil, adjacent sections are wound in the opposite direction, an arrangement which tends to balance out the overall inductance. Another advantage of the sectional winding is that it reduces the possible potential between adjacent turns. The only place where a high potential can exist with the sectionalized construction is where the lead from the last section is brought back over the entire length of the spool to the terminal at the other end. A thin sheet of cellulose acetate insulation is placed between the winding and this longitudinal lead to provide protection against breakdown and electrolytic corrosion along this wire.

Another convenience of the sectionalized winding is the readiness with which taps may be taken off between sections. It also permits a number of separate windings to be placed on a single core, and these windings may be connected to form resistance networks with very little panel space. A bracket has been provided for the core on which the spring pile-up of a regular R type relay may be mounted, thus providing the large number of terminals required for these purposes. Such a mounting is shown at the right of Figure 1. The small size of the new units is indicated by Figure 1, where one of them, of 500,000 ohms resistance, is shown mounted above five of the 38 type resistances, each of which has a resistance of 100,000 ohms. Until the new unit became available, the 38 type was usually employed where a high resistance was needed.

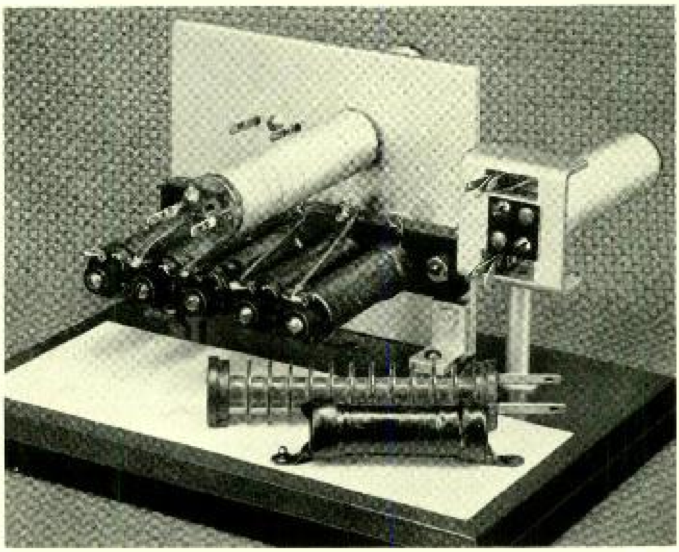


Fig. 1—With the new unit, the resistance of five of the older type may be placed on a single spool

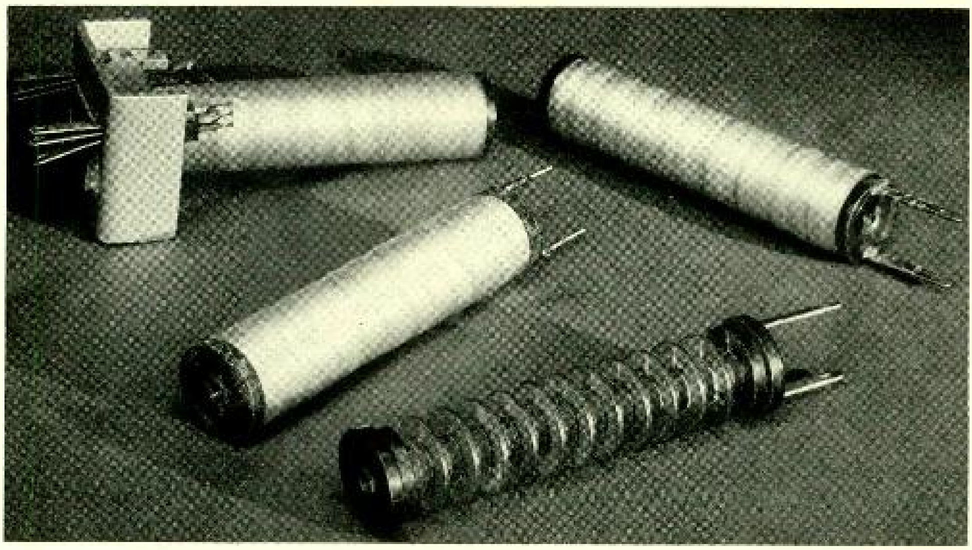


Fig. 2—The new unit may be provided with a multiple terminal bracket which is convenient for some purposes

Previous to the development of the new resistance unit, the requirements of small size, stability, and low cost have been for the most part incompatible for large values of resistance. Where carbon in some form is employed, to secure high resistance with small size, the result is almost never completely satisfactory because carbon resistances are inherently unstable, and also because they are usually noisy. If wire wound resistances were used, with the previous types of construction, they would either be excessively large, or if this were avoided by using extremely small sizes of wire, the resistances would be likely to open due to corrosion in a relatively short time.

In the new design this corrosive action is reduced by the moisture sealed construction, and by the use of cellulose acetate for the spool, insulation, and cover, since cellulose acetate is particularly free from corrosive elements. Combined with the other improvements made, this construction results in a unit superior to other types available.

This new resistance unit fills a need that has been steadily becoming more acute. Its major advantages arise from the use of a sectionalized cellulose acetate core together with the sealing cover formed by the acetone-dipped cellulose-acetate serving. This complete sealing reduces the likelihood of electrolytic corrosion to such an extent that No. 46 gauge wire may be employed instead of No. 42 gauge which has been the smallest size practicable heretofore, and the smaller wire allows a much smaller unit than would otherwise be possible. The improved construction has not only permitted the unit to be wound to within 1 per cent of the nominal value but has reduced the aging effect to less than 1 per cent—a decided improvement over previous constructions.

A High Precision Speed Regulator

By D. E. TRUCKSESS
Equipment Development

VOICE frequency carrier telegraph systems require twelve carriers at fixed frequencies 170 cycles apart, ranging from 425 to 2,295 cycles inclusive. At the receiving end of the line, band-pass filters are employed to separate the twelve channels. The characteristics of these filters are fixed, of course, and the mid-points of their pass bands are separated 170 cycles. If there were a variation in the frequency of one of the carriers, therefore, undesirable attenuation would reduce the higher or lower frequencies of the channel because of the rapidly rising attenuation characteristics at the sides of the pass band. To insure that the carriers are always exactly 170 cycles apart, the twelve inductor-type generators supplying them are mounted on a common shaft, which is also common to the driving motor. Although this arrangement maintains the proper separation between carriers so long as the motor is operating at the desired speed, a too high or too low speed of the driving motor would shift all the carriers above or below the mid-point of the pass bands of the filters,

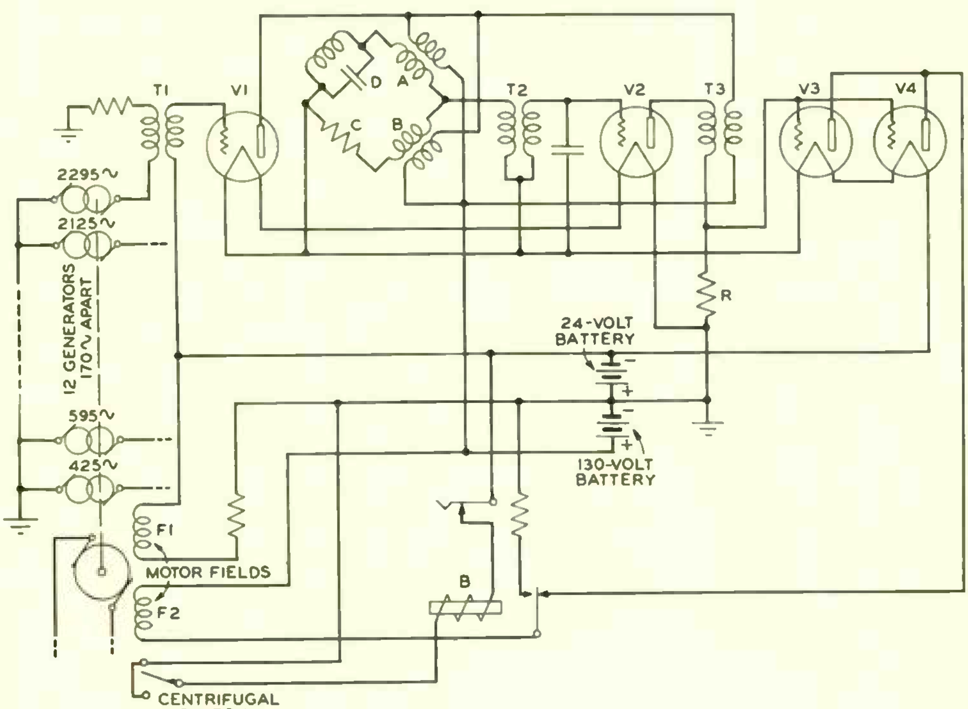


Fig. 1—Simplified schematic of high precision regulator circuit

and undesirable attenuation would occur in all the channels. To prevent this, some form of speed regulator is required for the motor.

A centrifugal governor of the center contact type is being used for this purpose, and with careful maintenance, the speed of the generator is controlled so that the variations are less than 1 per cent. Even with careful maintenance, the speed occasionally departs from the prescribed limits; this operates an alarm and calls for additional maintenance. Since the generator is usually common to many telegraph systems and the maintenance of the present governors is difficult and costly, it appeared that regulation of a distinctly higher order was warranted.

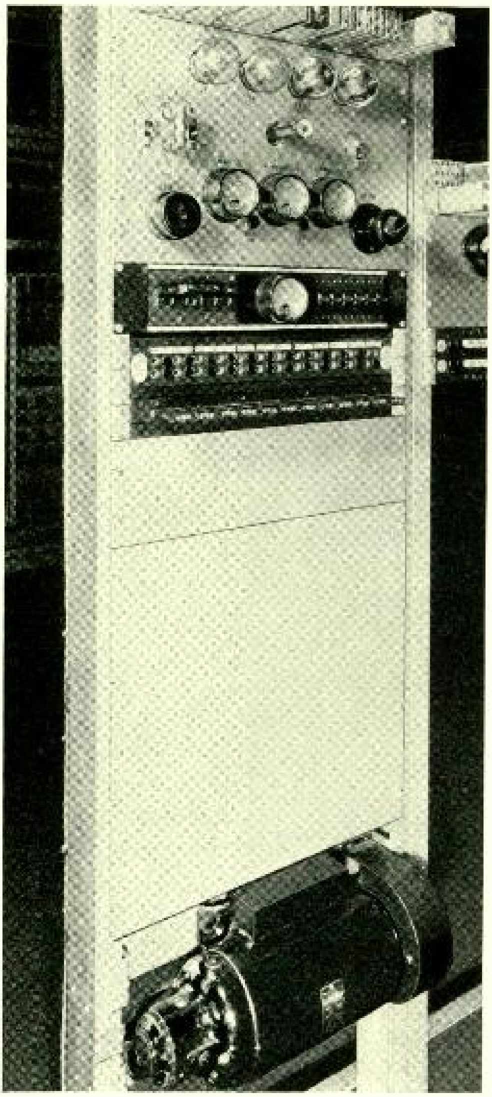


Fig. 2—All control equipment, together with the motor generator, is mounted on a single 19-inch bay

Recently, therefore, new speed control equipment has been provided which maintains a constant speed to within five-hundredths of one per cent. The new equipment incorporates the speed regulator developed by E. R. Morton of these Laboratories and described in the RECORD* in connection with a somewhat different use. It is essentially an electrical rather than a mechanical regulator, and provides a very large restoring force at very small variations from normal.

In this regulator advantage is taken of the characteristics of a circuit containing an inductance and a capacitance connected in parallel. At some one frequency, depending on the relative values of inductance and capacitance, such a circuit is resonant and its impedance is a pure resistance. At any frequency above this one value, however, the circuit has the characteristics of a capacitance and at any frequency below, it has the characteristics of an inductance. There is thus a change from leading to lagging current or vice versa as the frequency applied passes through the resonance value.

This is taken advantage of in two ways as shown in the simplified schematic of Figure 1. The resonant circuit forms one arm of a bridge circuit and the opposite arm is a pure resistance equal to that of the reso-

*RECORD, *November*, 1928, *p.* 101.

nant circuit at the resonance frequency. The other two arms are formed by the two equal secondary windings of a transformer whose primary is supplied at the frequency (2,295 cycles) of the highest of the carrier generators. The vertices of the bridge are connected to the grid of a vacuum tube through the transformer T2, and the plate of this tube is supplied through transformer T3 by the input frequency of the bridge, which is the high carrier frequency amplified by V1.

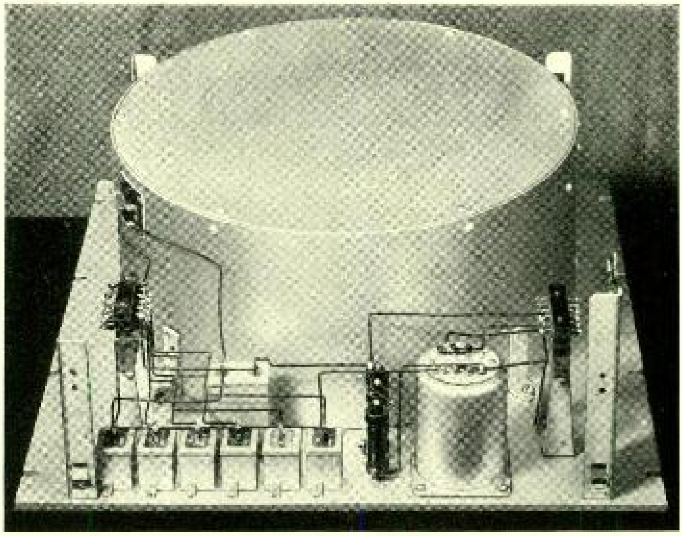


Fig. 3—The filter, as the bridge circuit is called, includes: a resonant circuit consisting of a large air core inductance, a condenser and six small adjusting condensers; a resistance for one arm of the bridge; and a transformer comprising the other two arms

At exactly 2,295 cycles, the bridge is balanced and as a result the voltage applied to the grid of V2 is too small to affect the plate current, which is a half wave rectified direct current. When the frequency becomes greater than 2,295 cycles, however, the bridge becomes unbalanced, and a relatively large voltage is applied to the grid of V2. This grid voltage, moreover, because the resonant circuit is a capacitance under these conditions, opposes the plate voltage, and as a result the plate current is decreased. When the frequency drops below 2,295 cycles, on the other hand, there is the same unbalancing of the bridge and the same increase in grid voltage, but under these conditions the grid voltage assists the plate potential, and the plate current increases.

The plate current of V2 flows through a fixed resistance R and the drop across this resistance is impressed on the grids of amplifier tubes V3 and V4. The output of these tubes is passed through field winding F2 of the motor driving the alternators. The normal potential of the grids of V3 and V4 is negative so that an increase in the plate current of V2 results in a higher negative voltage on the grids of V3 and V4 and a decrease in the plate current of these tubes, which flows through the motor field. A decreased current in the plate circuit of V2, on the other hand, results in an increase of field current to the motor. These changes in the field current, due to the change in phase angle of the current through the resonant circuit as the frequency passes through 2,295 cycles, are large compared to the change in frequency that causes them. As a result a very slight change in frequency will result in a comparatively large change in field current to the motor, and thus tend to bring the frequency back to the normal value very quickly.

The regulating field, F2, of the motor supplies about one-half of the ampere-turns needed for operation at the desired speed. The rest is supplied by the field F1 which has a fixed resistance in its circuit and is not adjustable. Any failure of the vacuum tube circuit might result, therefore, in the loss of half the motor field, thus causing the motor to run at a very high speed. To avoid such a possibility a centrifugal switch is provided on the motor shaft which closes when the motor speed changes from normal by as much as two per cent. The closure of the centrifugal switch operates a relay B, which transfers the regulating field from the vacuum tube circuit to a fixed resistance of a value that will operate the motor at its normal speed. At the same time an alarm is sounded so that an attendant may transfer the carrier load to a spare.

All the control equipment together with the motor-generator is mounted on a single nineteen-inch bay and wired as a unit, as shown in Figure 2. The bridge circuit, which is referred to as the filter, mounts on the rear of the panel immediately above the motor-generator. Figure 3 shows this panel with its outer cover removed. The large can encloses and forms a shield for the air core inductance which with a condenser forms the resonant circuit. The resistance forming arm C of the bridge and the transformer forming arms A and B are in the right foreground. The six small condensers are employed to adjust the resonant circuit for manufacturing variations.

Just above the filter on the regulator panel are keys and jacks for measuring the voltage of the twelve generators and for switching the load from the generators on this panel to those on the other panels. Just above these is the panel mounting the regulator circuit. Here are the vacuum tubes and meters, also the fuses and control for starting the set, and the generator field rheostat for adjusting the generator voltages.

The speed of action of this new regulator is so great that it is practically impossible to measure the deviation from normal. The slight variations that do occur, not over 0.05 per cent, arise from variations in the voltages of the power supply. By use of this apparatus, the maintenance effort required to keep the carrier frequencies at their proper value will be reduced and probably some improvement in the stability of the voice frequency carrier telegraph systems will also result.

Contributors to This Issue

After receiving the degree of Doctor of Philosophy from Cornell in 1924, F. W. Reynolds entered the Department of Development and Research in 1924. The initial public demonstrations of telephotography were then being made, and Dr. Reynolds took up this line of work. He has seen it pass through all its stages, and as a member of the Telegraph Facilities group has assisted in coördinating the work in many groups which has produced the present system which he describes in this issue.

During the World War, Dr. Reynolds was a member of the Signal Corps. Later he received the B.S. degree from Union College.

H. S. Hamilton received a B.S. degree in Electrical Engineering from Tufts College in 1916, and at once joined the Engineering Department of the American Telephone and Telegraph Company. With the division of this department in 1918, Mr. Hamilton became a member of the Development and Research Department, and with the later consolidation with Bell Laboratories, became a member of our Technical Staff. Mr. Hamilton has been engaged exclusively in developments pertaining to toll transmission, including telephone repeaters, program transmission, and carrier systems.

R. A. Ogg graduated in Mechanical Engineering at Pratt Institute in 1911. After a few years in tool and apparatus design and in plant engineering, he joined the Naval Transport Service where he received a commission as Ensign, Engineering. In 1919 he joined the Western Electric Company as a member of the Apparatus Drafting Division. He later transferred to the Specifications Division, where he engaged in the preparation of specifications on a variety of apparatus. For the past six years he has been a member of the design group engaged in the development of resistances for use in the telephone plant and in other development work at the Laboratories.

D. E. Trucksess received a B.S. degree from Pennsylvania State College in 1926, and joined the Technical Staff of the Laboratories in the same year. With

F. W. Reynolds

H. S. Hamilton

R. A. Ogg

D. E. Trucksess

A. C. Walker

A. M. Skellett

the Systems Development Department he has been chiefly engaged in the development of power apparatus. Recently he has given particular attention to the development of copper-oxide and hot cathode rectifiers.

After two years at the University of Colorado, A. C. Walker went to Massachusetts Institute of Technology, where he received the B. S. degree in Chemical Engineering in 1918. After a year in the chemical warfare service, and two in chemical research for a paper mill and a firearms plant, he went to Yale University for graduate study in physical chemistry, and received the Ph.D. degree in 1923. Coming to these Laboratories in that year, he has since been concerned with research on paper and textiles, first with the Chemical Laboratories, and since 1929 with the telephone apparatus development group. He has had a large part in developing and applying methods of purifying textile insulation, and methods for the inspection control of commercially purified textiles for telephone apparatus.

After receiving the A.B. degree from Washington University, A. M. Skellett continued his studies there and spent a summer as physicist with the Westinghouse Company. In 1927 he received the M.S. degree and joined the teaching staff of the University of Florida, spending the next two years there, first as instructor in electrical engineering and then as assistant professor of physics, and acting during the latter of these years as chief engineer of Station WRUF. On joining the radio research group of these Laboratories in 1929, he engaged in the design of long-wave radio antennas, and the following year he embarked on the investigation of general problems of radio transmission. Mr. Skellett has especially contributed to our knowledge of the relationship between astronomical phenomena and radio transmission. Last year he received the Ph.D. degree from Princeton University. In October he transferred to the physical research group where he is now engaged in developing applications of atomic and electronic devices to the telephone art.