WESTERN UNION
Technical Review

Power for Microwave Radio

•

A Precision Voltage Stabilizer

•

Properties of AM and FM Waves

•

Western Union
Switching Systems

•

Apparatus for
Reperforator Office

•

Magnetic Clutches
in Communications

VOL. 3 NO. 4
OCTOBER 1949

WESTERN UNION
Technical Review

VOLUME 3
NUMBER 4

Presenting Developments in Record Communications and Published Primarily for Western Union's Supervisory, Maintenance and Engineering Personnel.

OCTOBER
1949

CONTENTS

Published Quarterly by

THE WESTERN UNION TELEGRAPH COMPANY

Address all communications to THE WESTERN UNION TELEGRAPH CO., Committee on Technical Publication, 60 Hudson St., New York 13, N. Y.

SUBSCRIPTIONS $1.50 per year PRINTED IN U.S.A.

Power Supplies for Microwave Relay Systems

H. M. WARD

A paper presented before the Summer General Meeting of the American Institute of Electrical Engineers in Swampscott, Mass., June 1949.

MORE than a century ago, Samuel F. B. Morse transmitted the words "What Hath God Wrought!" from Washington to Baltimore, and thus became the first individual to make practical use of electrical energy in the communications field as a substitute for physical exertion. For many years thereafter, simple primary battery plants sufficed as the fundamental source of power, without which there would have been no telegraph industry. Subsequent improvements in the speed and efficiency of telegraph operations brought about greatly increased demands for power and have made the requirements as to stability and reliability much more exacting. It is the microwave radio relay system, however, with its inherent capacity for large numbers of communication channels on a single circuit, that has emphasized the necessity for power supplies of maximum continuity and dependability.

In a microwave radio beam system such as built by Western Union, the volume of traffic on a radio beam and hence the importance of the circuit far exceed that of anything previously used in the telegraph industry. Furthermore, completely automatic operation of all relay stations, except during prolonged operation on emergency power, was essential as a fundamental requirement. The relay stations are substantial in number and so widely scattered that the cost of providing attendants at each station on a 24-hour basis would have been prohibitive. Therefore the importance of maintaining continuous operation, and the fact that each relay station would have to function entirely without human aid at all times, in all kinds of weather, made extreme reliability one of the prime objectives in the design of the power plant equipment.

The Power Supply Problem

Radio beam "terminal" stations are located in cities where dependable power supplies already exist, but the "relay" stations, almost without exception, are located in remote country districts where the commercial power supplies are subject to frequent outages due to line breaks caused by ice and wind storms. The radio beam equipment was designed for operation on 115-volt, 60-cycle a-c commercial power. However, since a power interruption of even a fraction of a second would cause disturbance in the beam signals that would persist for an appreciable period of time, even after power is restored, it was essential to provide each relay station with auxiliary power equipment which would function so quickly and so dependably that any failure of the primary power sources would have no effect on the radio beam operation.

From previous experience it was known that automatic transfer switch operation could be achieved with an interruption of only about 0.05 second. It was also known that the addition of capacitors in the plate supply units of the radio equipment would make continuous operation possible during interruptions of more than twice that interval. The problem, therefore, was to provide an auxiliary source of 115-volt, 60-cycle alternating current which would function in less than 0.1 second after a fuse blew or a tree fell over the power supply line.

The Complete Power Plant

The major components of the power plants installed at all relay stations of the radio beam system are shown in Figure 1. Commercial 115-volt, 60-cycle a-c power

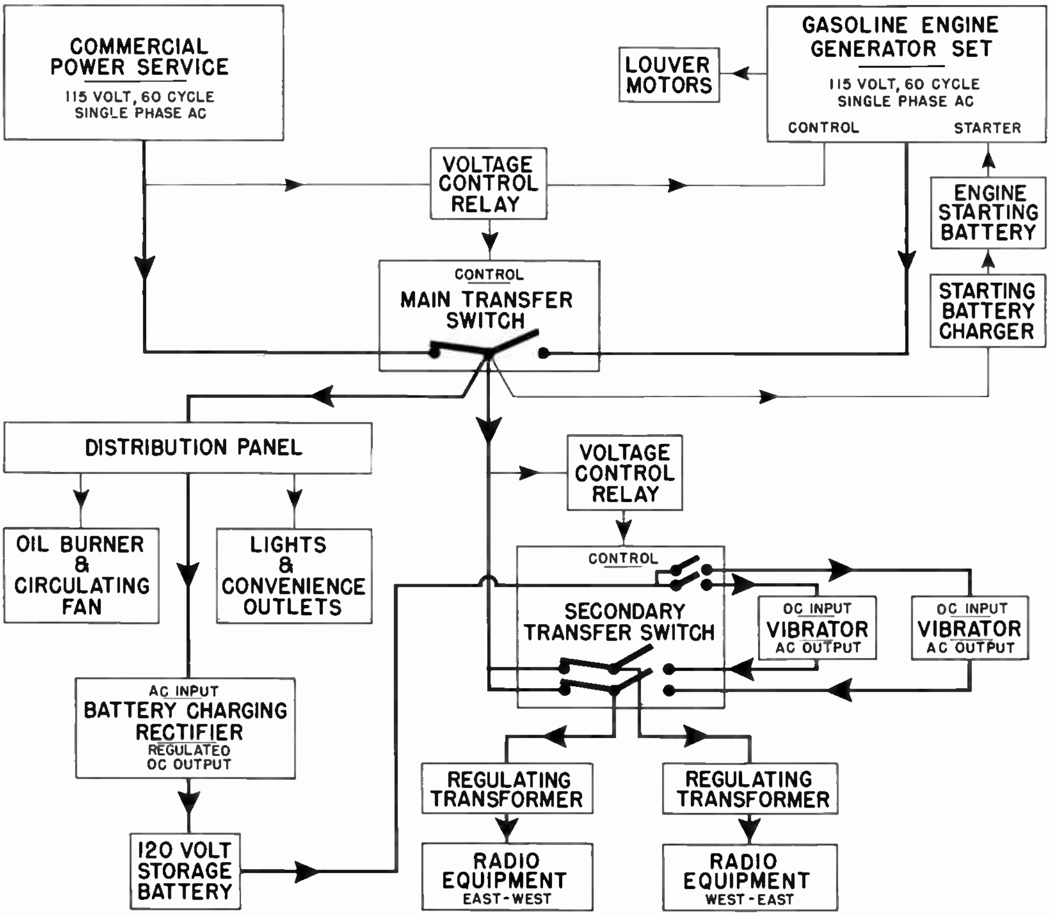

Figure 1. Block diagram of relay station power plant

service is used as the normal source of supply for operating radio equipment, battery charging rectifiers, station and tower lights, oil burner motors and other miscellaneous loads. An engine generator is provided as the prime emergency power supply for protection against prolonged power failures, and vibrator units, operated from a storage battery, are provided as the initial "instantaneous" reserve source of alternating current to maintain radio operation during the early stage of a power interruption, until the engine generator unit has started and reached a steady operating condition.

In the event of failure of the regular service, or a drop in voltage from the normal 115-120-volt level to below 102 volts, the "secondary" relay-controlled transfer switch almost instantaneously connects the storage battery to the input side of the two vibrator units and transfers the radio load to the vibrator units. Simultaneously, the "main" relay-controlled transfer switch is set to start the engine-driven generator, and to switch the load to it just as soon as the latter comes up to full speed and voltage, which may be 30 seconds or more after the initial operation. Actual starting of the engine is delayed for approximately 15 seconds in order to avoid unnecessary starting during extremely short power failures. If for any reason the engine should fail to start, the radio load would remain on the vibrators.

Simultaneously with these operations, special signals are automatically transmitted to each terminal to indicate that a power interruption has occurred and whether the load is being carried on the vibrator unit or the emergency engine. These fault tone signals are sent by a code keying unit, operating over the service channel of the radio beam circuit.

When regular power is restored, the load is automatically transferred back to that service, the engine unit shut down and the signals to the terminal stations restored to normal. Here again, however, actual return to regular power is delayed for about 5 seconds after the commercial service reaches a minimum value of 108 volts, in order to make sure that the restoration is reasonably permanent. It often happens that in the case of a power failure resulting from a short circuit or grounded transmission line, the power station attendant will make one or more attempts to reclose the circuit breaker feeding that line, only to have the breaker trip out again if the fault has not burned clear. The slight additional delay in transfer back to normal service almost entirely eliminates unnecessary switching operations and restarting the vibrators and engine unit under such conditions. Regulating transformers are interposed between the "secondary" transfer switch and the radio equipment in order to correct for variations in the commercial service, engine unit and vibrator voltages.

Each station is provided with a small oil burner for heating purposes, not only to provide comfortable working conditions during emergencies, but to prevent condensation on radio and power equipment which could interfere with normal operation. The heating plant is normally operated so as to prevent the inside temperature dropping below 40 degrees F. This has the added advantage of facilitating the starting of the engine unit and preventing loss of battery capacity at excessively low temperatures.

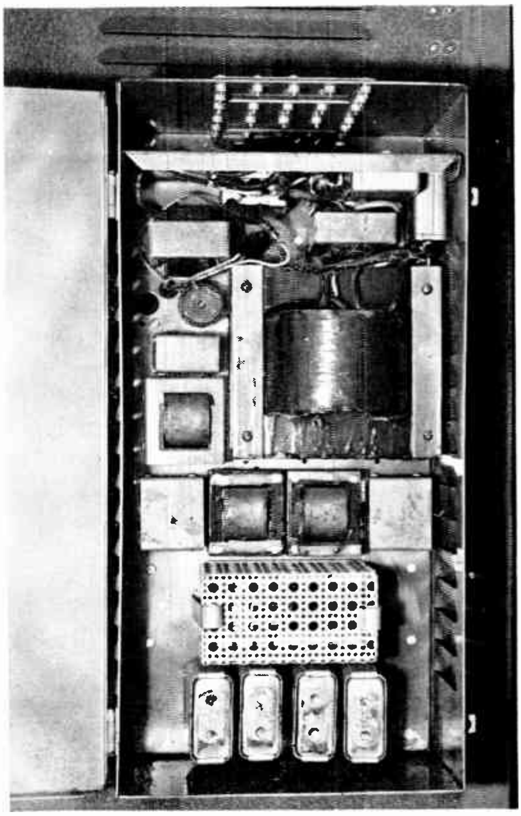

Figure 2. Vibrator unit

Vibrators

The vibrators, which are normally intended to carry the radio load only until the engine unit has started and attained a steady operating condition, are big brothers to the units used for automobile radio operation and are the largest size available which have been in use long enough to establish a satisfactory record of reliability. (Figure 2.) Each vibrator has an output rating of 750 volt-amperes at 115-volt, 60-cycle alternating current, and delivers its full capacity a-c output almost instantaneously after closing of the d-c input circuit. Inasmuch as the radio load for a relay station, sending and receiving in two directions, is slightly in excess of 1 kva, it was necessary to divide the load between two 750-va vibrator units. The units are supplied from the storage battery which is kept fully charged at all times.

Engine Generator Units

Inasmuch as remote controlled automatic engine generator units had been used by thousands during the war in various branches of the armed services, there was considerable choice in the selection of such equipment. Various models produced by five of the larger manufacturers were inspected and compared, and a design worked out which incorporated the various features of the different makes that were considered essential for the radio beam service. Four-cylinder gasoline engine drive (Figure 3) was selected in preference to a single or two-cylinder Diesel engine for two major reasons. First and foremost was the conviction that more reliable starting under cold weather conditions would be assured, particularly with unattended operation. Secondly, it appeared probable that the operation, adjustment and emergency repair of gasoline engines would be more familiar to the average maintenance man, due to similarity to the ordinary automobile engine. Use of the individual manufacturer's standard arrangement of starting and protective controls was adhered to so far as practicable, since these had invariably been used on a sufficient number of units to insure that basic faults had been eliminated.

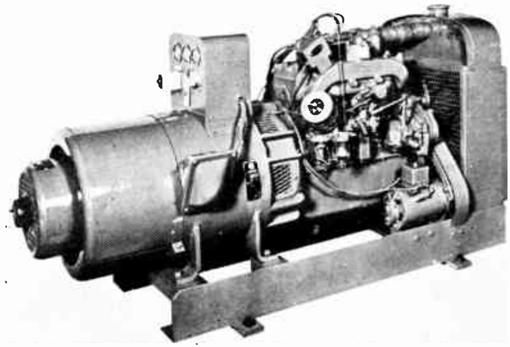

Figure 3. 10-kw engine alternator unit

The engines are radiator cooled and two motor-operated louver openings are provided in the building wall for venting the heated radiator air and admitting fresh cool air. The radiator air exhaust opening is located directly in front of the engine and a canvas duct is provided between the front of the radiator and the opening to direct the air flow and insure maximum discharge from the room, particularly during summer months. Protective hoods are provided on the outside to prevent drifting snow, ice or sleet from plugging the

Figure 4. Air intake hood and power service entrance meter cabinet, gasoline tank

opening or interfering with the operation of the louvers (Figure 4) and only a very coarse ½-inch mesh screen was specified to further reduce the possibility of restricting the air flow, either by the screen itself or as a result of snow or ice being deposited on the screen. Various protective devices to shut down the engine automatically in the event of overheating, improper lubrication or operation at excessive speed, are provided. The alternator is equipped with a special voltage regulator, developed by the Electric Machinery Company, which has no moving part or contacts and which consequently should reduce operating difficulties from such sources to a minimum. The engine governor is capable of maintaining a speed within limits of 1 percent maximum variation at any given constant load and 4 percent maximum change between no load and full load.

An underground gasoline storage tank of 120-gals. capacity is provided at each of the normal one-beam stations. This will provide for about five or six days continuous operation, which is considered adequate to allow time for replenishment, even under severe weather conditions. The quantity in storage is purposely limited in order to minimize the possibility of gum formation which will occur when gasoline is stored for periods in excess of one year. Such gum formations could easily clog up the carburetor or fuel pump and cause failure of the plant to function, without prior warning.

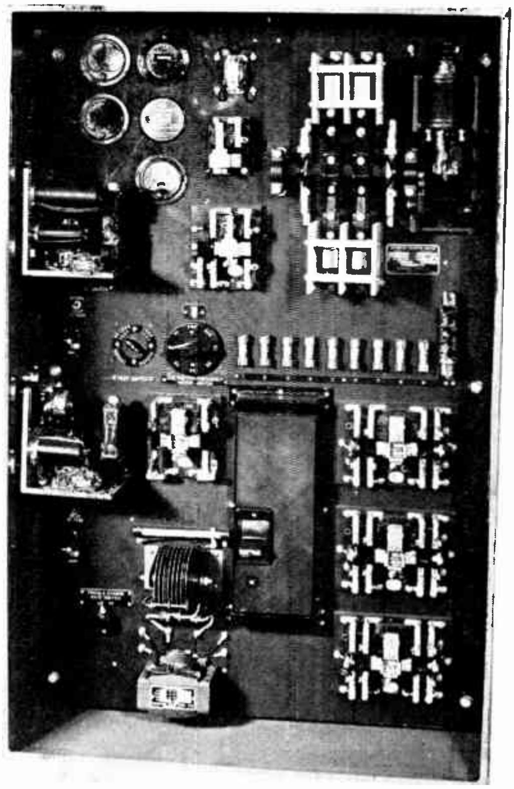

Figure 5. Main control panel, front

Battery and Charging Rectifiers

In the majority of relay stations where only one radio beam is involved, a 57-cell bank of 100-ampere-hour capacity storage battery is used to supply the d-c input to the vibrator units. A somewhat larger battery is provided at stations such as Neshanic where additional load is imposed by extra beam circuits. The battery is kept on trickle charge from a regulated output selenium rectifier, developed primarily for this project. This rectifier maintains a constant voltage on the battery regardless of supply voltage variations within limits of 90 to 130 volts, so that the battery is kept fully charged at a rate just sufficient to offset internal losses. When the battery is used during a power failure, the charging rate is automatically increased until the battery is restored to a fully charged condition, at which time the trickle rate again prevails. The rectifier is also designed with inherent characteristics which prevent over-loading and burning out of the rectifier stacks or transformer.

A separate battery with rectifier charger is provided for starting the engine generator unit.

Control Equipment

The major portion of the transfer switching and control equipment is incorporated on the main control panel, Figures 5 and 6, mounted immediately adjacent to the engine unit. This panel is enclosed in a metal cabinet with hinged double doors, front and back, to facilitate access. The two voltage control relays, which constitute the "brain" of the plant, are mounted on rubber supports fastened to the side of the cabinet, to prevent vibration or jars from affecting their operation. Connections from the voltage control relays to the panel are made through multiple conductor plugs and receptacles to facilitate testing, removal and replacement of the units. The upper control relay, shown on the left side of the cabinet in Figure 5, provides the signals required for starting and stopping the unit and operation of the main transfer switch. The lower unit controls transfer of the radio load to and from vibrator operation.

The voltage control relays were designed especially for this project since nothing was commercially available which would provide the degree of sensitivity and other characteristics desired. The a-c voltage to be monitored is applied to a small bridge-type selenium rectifier with a 75-microfarad capacitor across the d-c output of this rectifier as a filter. Variations in the a-c voltage are directly reflected in the d-c output voltage of this small rectifier. A Western Union 41-C relay, standard except for armature air-

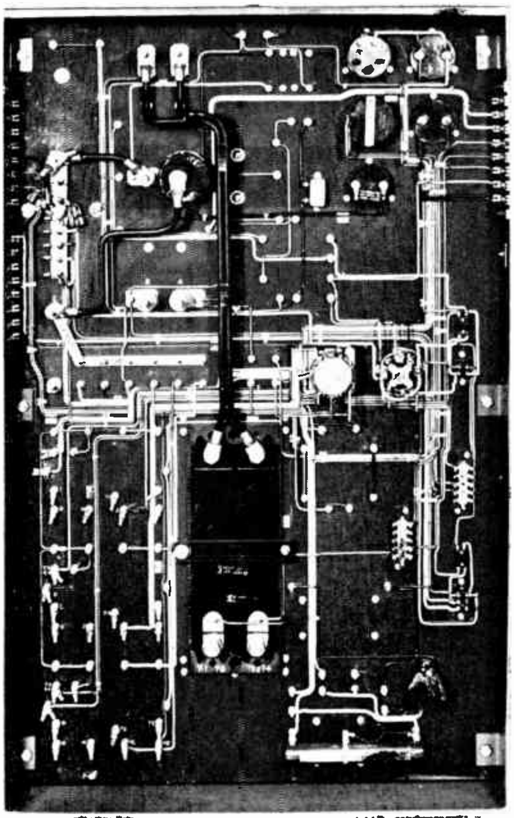

Figure 6. Main control panel, rear

gap and contact spring adjustments, is used to detect these variations. The two voltage control relays are essentially identical except for the method used for obtaining the different time delay desired on the reclosing operation. In one, charging of a capacitor through a fixed resistor provides the desired 5-second delay; the other, shown in Figure 7, utilizes a small synchronous motor-driven cam to provide a 1-minute delay, to give time for the engine unit to attain stable operation. Toggle switches are provided to by-pass the control relays so that they may be tested and adjusted without unnecessary transfer of load to the engine unit or vibrators. A pilot light at the top of the control cabinet indicates whenever any of the special test switches are not in normal position for full automatic control, to guard against the maintenance man inadvertently leaving the station without protection.

A special portable test set was designed for checking the adjustment of the voltage control relays. Because of normal manufacturing variations in the small selenium rectifier stacks, resistors and other components, it is essential that each 41-C relay be checked and adjusted in conjunction with the actual unit in which it is to be used. The relay test set provides a variable a-c voltage and meter, together with cord and plug connectors and indicator lights so that the 41-C relays may be conveniently checked in the required manner, without interference with operation of the radio circuit.

Meters on the main control panel show station load, voltage and frequency of outside power, engine and vibrator units, and provide ready means for checking operation of the plant. An elapsed time meter maintains a continuous record of hours of engine operation and shows whether any failures of regular power have occurred between inspections. A control switch is provided which permits testing of the engine unit either at no load or under load, simulating an actual power failure.

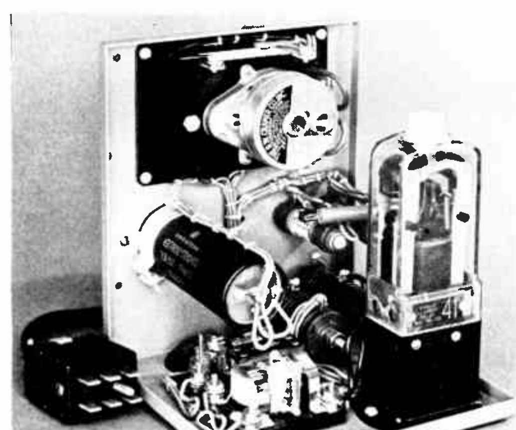

Figure 7. Voltage control relay for secondary transfer switch control

Also included on the main control panel are fuses for protection of load and control circuits, engine unit circuit breaker, auxiliary protective relays, and a selenium rectifier for charging the engine starting battery. This battery is normally kept on a slow "trickle" charge in order to maintain it at full capacity. A higher charging rate is available from the rectifier for use if required.

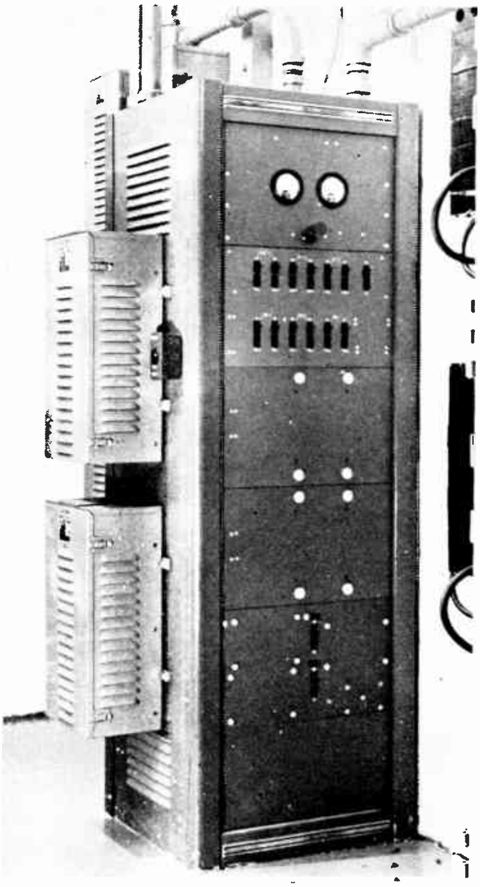

Figure 8. Relay station rectifier and power equipment cabinet

The rectifier and its control components are housed in a rack cabinet, Figure 8, which is also used for mounting circuit breakers in the d-c input circuits to the vibrator units and the a-c input to the regulating transformers. The two vibrators and two regulating transformers required at the average one-beam station are housed in this same cabinet, to simplify the installation of equipment. The main control cabinet associated with the engine unit and the rectifier cabinet were completely assembled, wired and tested before shipment to the station. It was then necessary only to put these two units in place and provide interconnections between them and to the radio equipment, power service entrance switch, engine unit and lighting cabinet to complete the installation. Since many of the relay stations were in isolated locations, material savings in installation costs were thus effected.

Terminal Station Power

Because the terminal stations are manned 24 hours a day, the radio system power facilities at these points are of a more usual type than described in the foregoing. Existing emergency supplies were utilized where available and vibrators were installed to serve as an instantaneous source of alternating current where an existing battery reserve was available. The same type of voltage control relay as used in the relay stations was utilized at the terminal stations to control transfer of the radio load from regular to vibrator power. The regulating transformers and vibrators, voltage control relays, transfer switches and associated protective circuit breakers and alarm equipment for a two-beam terminal are housed in a rack cabinet such as shown in Figures 9 and 10.

Operating Experiences

The preceding general description of the radio beam power plants and some of the considerations which affected their design necessarily lacks considerable detail regarding such items as the engine starting control and protective devices, generator voltage regulators, radio shielding, power distribution to radio equipment on the tower, and actual circuit diagrams. Rather than attempt to describe these various details, it would seem more desirable to present a brief resume of the operating results experienced to date with the power equipment of the radio beam system.

The New York-Philadelphia circuit was put into actual traffic operation late in 1947. The New York-Washington installation was completed and put into traffic operation on a trial basis during February

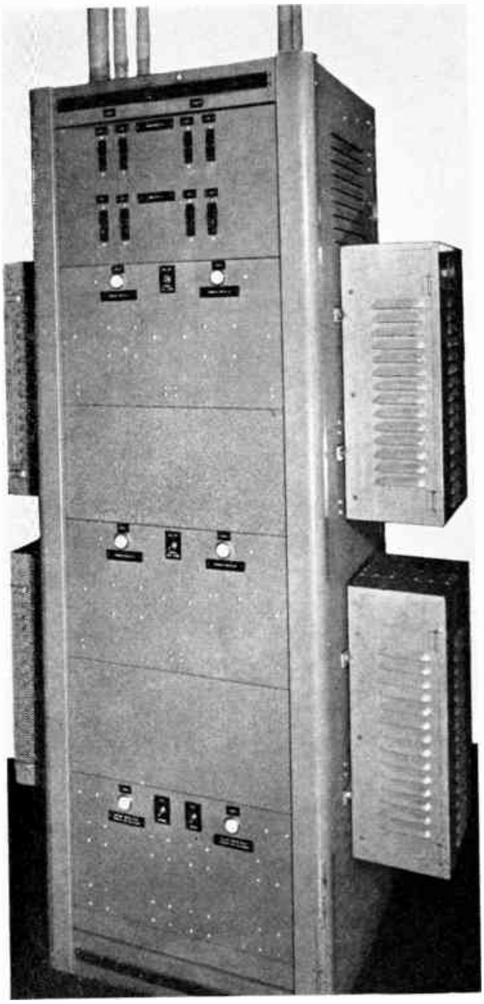

Figure 9. Terminal station power equipment cabinet, front view

1948. The New York-Pittsburgh and Washington-Pittsburgh circuits were completed and operated under test conditions a few months later. Operation was continued until late August 1948, when regular operation was temporarily discontinued to permit changes in tower construction incidental to the installation of additional television channels between New York and Philadelphia, and to make adjustments in radio equipment which operating experience had proven desirable. This in effect constituted the initial "field trial" of the power plants.

The emergency engine at Neshanic carried the station for a continuous period of over nine days, following the great ice storm of January 1-2, 1948. During this period, all power lines in the vicinity were down due to the storm, as were also all open wire telegraph circuits between New York and Philadelphia. However, the radio system continued to function throughout the emergency and to provide reliable circuits for traffic service. Later, while the New York-Washington circuit was carrying traffic on a fairly regular

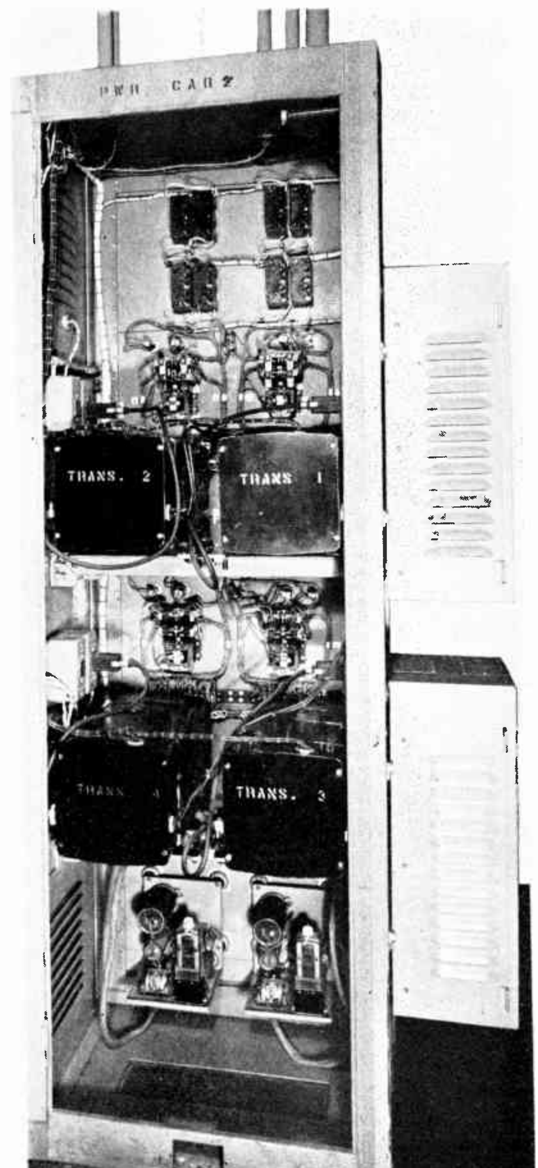

Figure 10. Terminal station power equipment cabinet, interior view

basis, accurate records of operation were kept and the following tabulation shows the number and duration of power supply failures occurring at each of the terminal and relay stations on that one circuit during the three months' period between May 1 and August 1, 1948. could be determined from the log and subsequent detailed reports submitted by the maintainers. It will be noted that the outages of the commercial power supply add up to the rather astonishing total of approximately 150 hours.

Operation of the power plant equipment

Station	*Number of Failures of Commercial Power Supply*	*Total Duration of Failures*
Neshanic	12	31 hours 43 min.
Mt. Laurel	4	15 " 3 "
Brandywine	0	
Elk Neck	2	6 " 1 "
Cub Hill	2	7 " 10 "
Severn	3	1 " 10 "
Washington Terminal	6	(All momentary)
New York Terminal	0	
Total all stations	29	61 hours 7 min.

There was no interruption of the radio beam circuit during that period and no failure of the power equipment to function, indicating a high degree of reliability.

Subsequently, during a widespread snow, ice and rain storm on December 15-16, 1948, at least 16 separate power failures occurred, affecting 10 of the 18 relay stations on the three beam circuits comprising the New York-Washington-Pittsburgh triangle. As many as six of these stations were operating on emergency power at a time, making it difficult for terminal station attendants to correctly interpret and accurately log the multitude of alarm signals being transmitted. The following tabulation indicates the number and duration of failures, as accurately as was not perfect in all these instances, as there were two rather serious outages of the beam circuit due to loss of power. One of these was caused by a regulating transformer circuit breaker opening at the instant the load was transferred back to regular power, apparently because of faulty breaker operation or because there was a current surge larger than had been designed for. In two other instances, these breakers failed to function properly, but in these cases the maintainer was present and closed the breaker immediately. Higher capacity circuit breakers have subsequently been substituted at all stations.

In the other beam interruption, actual failure occurred due to a combination of circumstances. Here, the engine unit failed

Station	*Number of Failures of Commercial Power Supply*	*Total Duration of Failures*
Brandywine	3	3 hours 23 min.
Honeybrook	1	4 " 38 "
Red Lion	1	0 " 45 "
Blue Mountain	5	17 " 10 "
Allegheny	1	3 " 15 "
Bakersville	2	25 " 22 "
Jennerstown	1	0 " 38 "
Little Savage	1	81 " 8 "
Sideling Hill	2	7 " 55 "
Gambril Park	1	7 " 20 "
Total all stations	18	151 hours 34 min.

to start and at the same time the keying unit associated with the radio fault tone alarm system failed to function, so that no one knew the power had failed until actual interruption of the beam occurred. Subsequent investigation showed that the station operated satisfactorily on battery power for at least nine hours after the regular power failed. Failure of the engine to start was apparently due to the exhaust pipe opening being completely clogged with ice, in spite of the precautions which had been taken to prevent such an occurrence. This constituted the only major interruption of the beam caused by lack of power, during this entire interval.

In another case, the radio load remained on battery for two hours before being picked up by the engine unit, which then operated satisfactorily until the end of the power failure, five hours later. There was no interruption to the radio beam and what happened to the power unit can only be surmised from the fact that there were ice and carbon deposits around the exhaust pipe and muffler joints, quite similar to what were found in the previously described failure.

The operation of the power plants at the various radio relay stations has been very gratifying. The reliability already demonstrated gives ample assurance that lack of power will not destroy the advantages of microwave radio beams for operation through fog, sleet, ice storms and lightning, at times when these same elements may completely paralyze commercial power supplies.

THE AUTHOR: H. M. Ward joined the staff of the Central Office Engineer after graduating in Electrical Engineering from Ohio State University in July 1921. He engaged in power engineering and the development of special power equipment for central offices, and designed most of the telegraph power plant at 60 Hudson St., New York. Subsequently he was closely associated with the original development of rectifiers for telegraph power supply, and was responsible for the design of rectifier installations at the Hammel and North Sydney cable stations which constituted the first satisfactory substitute for storage battery plants in ocean cable service. More recently, in addition to the radio beam power plants, Mr. Ward has directed the design of power installations for reperforator switching centers at such offices as Cincinnati, Kansas City, Minneapolis, Syracuse and New Orleans. He is a licensed professional engineer, a member of Eta Kappa Nu, honorary electrical engineering fraternity, and Sigma Xi. He is now on the staff of the Director of Installation, in charge of the engineering and installation of power equipment.

A Precision Voltage Stabilizer for Direct Current Power Supply

A. A. STEINMETZ

PUBLIC POWER facilities in the remote geographical locations of some of the ocean cable stations are more than ordinarily liable to interruption and to wide variations of potential and frequency. Accordingly, to protect movement of traffic through these stations, it has been regular practice to use storage batteries to supply current to the various circuits. Duplicate batteries are necessary so that one set may be on charge while the other is being used.

The message capacity of ocean cable equipment has in recent years been increased considerably by employing electronic amplifiers at the terminal of the cables. These amplifiers, of a high gain characteristic, are generally of a direct current type and for stability require very close control of current supply potentials. For example, the difference in terminal voltage which occurs when the working and spare battery banks are interchanged is sufficient to require amplifier readjustment.

To meet these extraordinary stability requirements, a rectifier power supply has been developed which will maintain its output voltage constant within 1/200 percent while the input voltage varies plus or minus 10 percent from normal. The rectifier operating potentials can now be obtained directly from the service mains; the storage battery plant, in conjunction with a vibrator converter, is needed only in the event of failure of the public power supply. This installation has contributed to more reliable operation of the cable apparatus and has also permitted a substantial saving in storage batteries.

At the outset of the development of a voltage regulating arrangement suitable for cable station use, a popular electronic voltage regulator of somewhat fundamental type was examined and was found to hold the rectified output potential constant within 1/2 volt as the applied potential was varied over a considerable range. This device employed a control tube of the pentode type with an indirectly heated cathode, and it was found that variations in cathode emission were partly responsible for the remaining variation in output voltage. This fault was overcome by the substitution of a filament type pentode which required only 0.050 ampere for heating purposes and so could be energized from the regulated output of the regulator. The original regulator, thus modified, is shown in Figure 1; its operation is as follows:

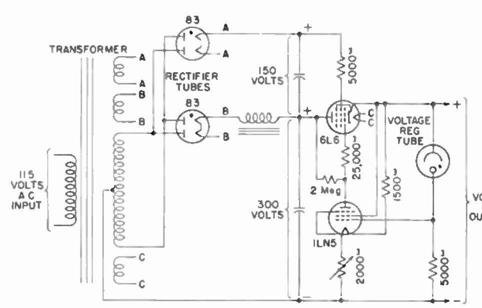

Figure 1. Conventional type regulator. Cathode of control tube energized from regulated output

In the regulator of Figure 1, the rectified output from the smoothing filter traverses the anode-cathode path of a 6L6 regulating tube. The potential of the control grid of this tube, which is normally negative with respect to its cathode, is determined by a potentiometer arrangement which comprises the anode-cathode path of a pentode control tube in series with a 2-megohm resistor, the combination being connected across the rectified output in advance of the regulating tube. The impedance of the anode-cathode path of the pentode is in turn controlled by the regulated output voltage as reflected by the IR drop occurring across a 5000-ohm resistance which, in series with a voltage regulator tube (VR-75), is connected across the final output terminals. A normal negative grid-cathode potential difference for the pentode is established by means of an adjustable filament resistor also connected in shunt to the output terminals. A second rectifier tube with a condenser filter is provided to furnish the positive potential for the screen grid of the regulator tube, which must be substantial in order to maintain the necessary low impedance for this tube.

The voltage regulating function of the system occurs as follows. The voltage drop across the VR tube remains substantially constant at 75 volts so that any departures of the output voltage from normal are reflected 100 percent across the 5000-ohm resistor in series with it. Assume now, for example, that the output voltage increases to render the grid of the pentode less negative with respect to its cathode. The impedance of the anode-cathode path of the pentode is thus reduced and the grid of the regulating tube is in turn made more negative so to increase the impedance of this tube and hence limit the output current, or voltage. A similar but reversed action takes place should the output voltage decrease, so that output voltage variations are reduced to a fraction of what they would be in the absence of the regulating arrangement. This correction function is substantially independent of frequency so that it is effective also to suppress any ripple voltage not fully removed by the filter.

It can be seen that the regulator is essentially a negative feedback device in which output voltage variations are amplified and fed back to the grid of the regulator tube in reversed relation so as to reduce progressively the departure of the output voltage from normal. Perfect regulation would reduce the departures to zero, but that would require infinite gain in the amplifier, and the operation would be unstable. The output of the regulator of Figure 1 is subject to a voltage variation of 0.34 volt as the a-c input voltage varies over the range from 100 to 130 volts. To reduce this further, the amplifier must be provided either with more gain, or with a larger grid voltage swing. It has been observed that on the input (anode) side of the regulator tube the voltage variations may reach 80 volts or more while remaining approximately centered at 300 volts. Therefore, it was proposed to augment the grid voltage swing by introducing a limited amount of control voltage from the input circuit by means of a resistor placed in shunt to the regulating tube and then connecting the VR tube to an intermediate point thereon. The two parts of the resistor are designated R_1 and R_2 in Figure 2.

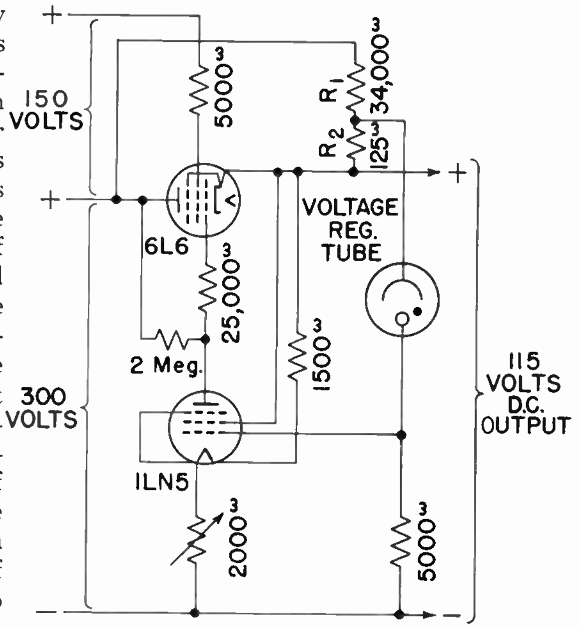

Figure 2. Regulator with compensation of control tube grid bias by input potential

Trial values for R_1 and R_2 may be calculated as follows: Let it be assumed that a voltage variation of 0.3 volt developed across the 5000-ohm resistor and applied to the grid of the pentode will be sufficient to provide ample correction.

Adopting somewhat hypothetical conditions, it can be seen that at one end of the regulating range the impedance of the regulator tube will approach infinity and the voltage (E_p) across the tube will be a maximum, while at the other end of the range the impedance will approach zero and the voltage across the tube will be a minimum. For the high impedance condition most of the VR tube current of 0.008 ampere will be furnished through R_1, and if 272 volts has been found to be a probable maximum E_p, then $R_1 = 272/0.008 = 34{,}000$ ohms. If an 80-volt regulating range is desired, the lower value for E_p will be 192 volts and the current in R_1 will be $192/34{,}000 = 0.0056$ ampere and the current in R_2 will be $0.008 - 0.0056 = 0.0024$ ampere. At the same time, the 0.3-volt variation developed across the 5000-ohm resistor is reflected entirely across R_2 since the voltage across the VR tube remains constant. Therefore $0.3/0.0024 = 125$ ohms for R_2.

The foregoing resistor computations were based upon somewhat hypothetical assumptions as to regulating ranges and also neglect the fact that the normal 0.008-ampere VR tube current varies continuously over a narrow range in accordance with the output voltage variations. To produce a 0.3-volt variation across the 5000-ohm resistor, this range would be 0.00006 ampere. In practice, the resistor values are adjusted experimentally to fit the particular VR and other tubes employed, and the regulating range encountered in particular applications. In Figure 3 the final column indicates that the voltage variation for the regulator of Figure 2 is reduced to 0.01 volt for an a-c supply voltage range of 100 to 130 volts.

Figure 4 is included to indicate the complementary current contributions from

I	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*
	6L6 Tube					*Output Voltage*	
Supply Voltage	*Ep*	*Esg*	*I34000-Ohms*	*I125-Ohms**	*E125-Ohms*	*Without Compensation*	*With Compensation*
100	140	278	0.00412	0.00388	0.485	115.62	115.50
110	168	315	0.00495	0.00305	0.38	115.73	115.510
120	196	360	0.00575	0.00225	0.282	115.83	115.505
130	220	405	0.0065	0.0015	0.187	115.96	115.502
Change in Voltage					0.298	0.34	0.01

*$I_{125\text{-Ohms}} = I_{VR75} - I_{34000\text{-Ohms}}$

I_{VR75} assumed to be 0.008 ampere for normal value.

Ep — Voltage from plate to cathode of 6L6 tube.

Esg — Screen grid voltage for 6L6 tube.

Figure 3. Regulator potential and current data as input potential varies. Output potential shown with and without compensation

the unregulated input via R_1 and from the regulated output via R_2, which together provide the regulating potential across the 5000-ohm resistor. The 80-volt regulating range in E_p shown in this figure occurs at 140-220 volts, somewhat different from that cited in the foregoing sample calculations.

Changing the output to 125 volts increases the VR-75 tube current to 0.010 ampere. The broken line included on Figure 4 shows that the slope of the line which represents the voltage drop across R_2 remains the same.

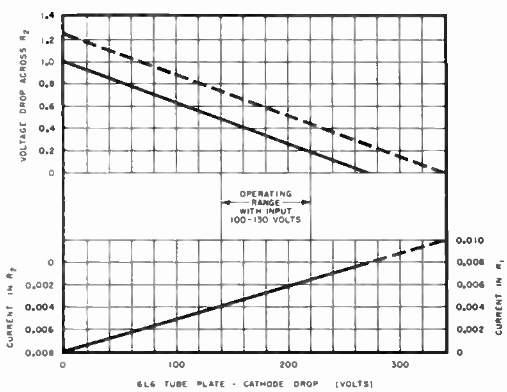

Figure 4. Current and potential relations in compensation branch as input potential varies

The table of Figure 3 lists typical data applicable to the circuit of Figure 2 as finally adopted and indicates the results obtainable. In both Figures 3 and 4, the 0.00006-ampere variation in the VR tube, while important in the functioning of the system, has for convenience been omitted from the data as given.

The two resistances in the filament circuit of the 1LN5 tube are adjusted initially to provide approximate rated filament current. The variable resistance provides a convenient means for adjusting the output potential. For example, if this resistance is decreased, the cathode of the pentode becomes less positive with respect to its grid, its plate impedance is lowered, thus making the grid potential of the regulating tube more negative to increase its impedance and lower the output voltage. While this resistance change would apparently tend to change the filament current, in fact the change in output voltage restores this current to its former value.

It might be supposed that still more exact compensation could be obtained if a larger portion of the control potential were obtained from the unregulated side of the 6L6 tube. However, stability would then be impaired, as would the capacity to compensate for voltage changes due to variations in load impedance. This latter

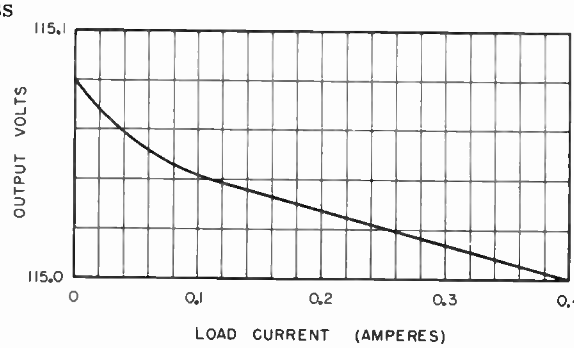

Figure 5. Regulation of output potential

property is illustrated in Figure 5 for the entire no-load to full-load range. The load capacity of the regulator may be extended up to any reasonable amount through the addition of regulating tubes in parallel, each tube being provided with individual screen and control grid resistors. The actual units built are rated at 0.4 ampere and employ five 6L6 tubes. This permits replacement of single tubes without disturbance to the output.

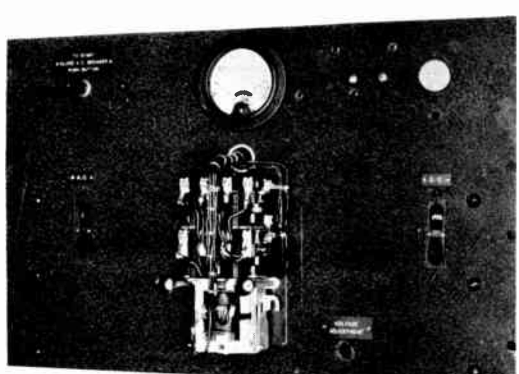

Figure 6. Front view of stabilized power supply set

Figures 6 and 7 show the front and rear views of the stablilized power supply set as assembled for cable station use. The same chassis mounts rectifier and stabilizer elements together with the vibrator unit for fallback use. The line and load circuit breakers appear on the front panel together with a relay for automatic throw-over to the emergency storage battery. A warning light glows as long as emergency power is in use. Restoration to normal is by manual reset.

Approximately 40 of these regulators are giving excellent service on the North Atlantic, Alaskan and West Indies cables. It is expected that the principle of this high precision stabilizer will find additional applications in communication equipment.

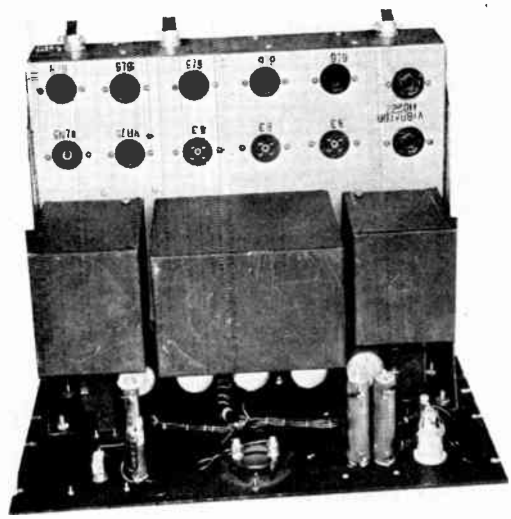

Figure 7. Rear view of stabilized power supply set

THE AUTHOR: A. A. Steinmetz, a native New Yorker who received his engineering education at Columbia University, spent most of his 31 years with Western Union in the Central Office Engineer's department as draughtsman and engineer, specializing in power plant design; in 1946 he transferred to the Equipment Research Division, where he continues work along the same lines. He holds various patents pertaining to voltage stabilizers and power conversion. During the war Mr. Steinmetz was assigned to the design of equipment for the Army's communication network and supervised the installation of the automatic power plant in the North Sydney, N. S., cable station. In conjunction with the establishment of the Company's radio relay system, he was engaged in the design of the radio tower power plants. He has been an associate member of the AIEE for 24 years.

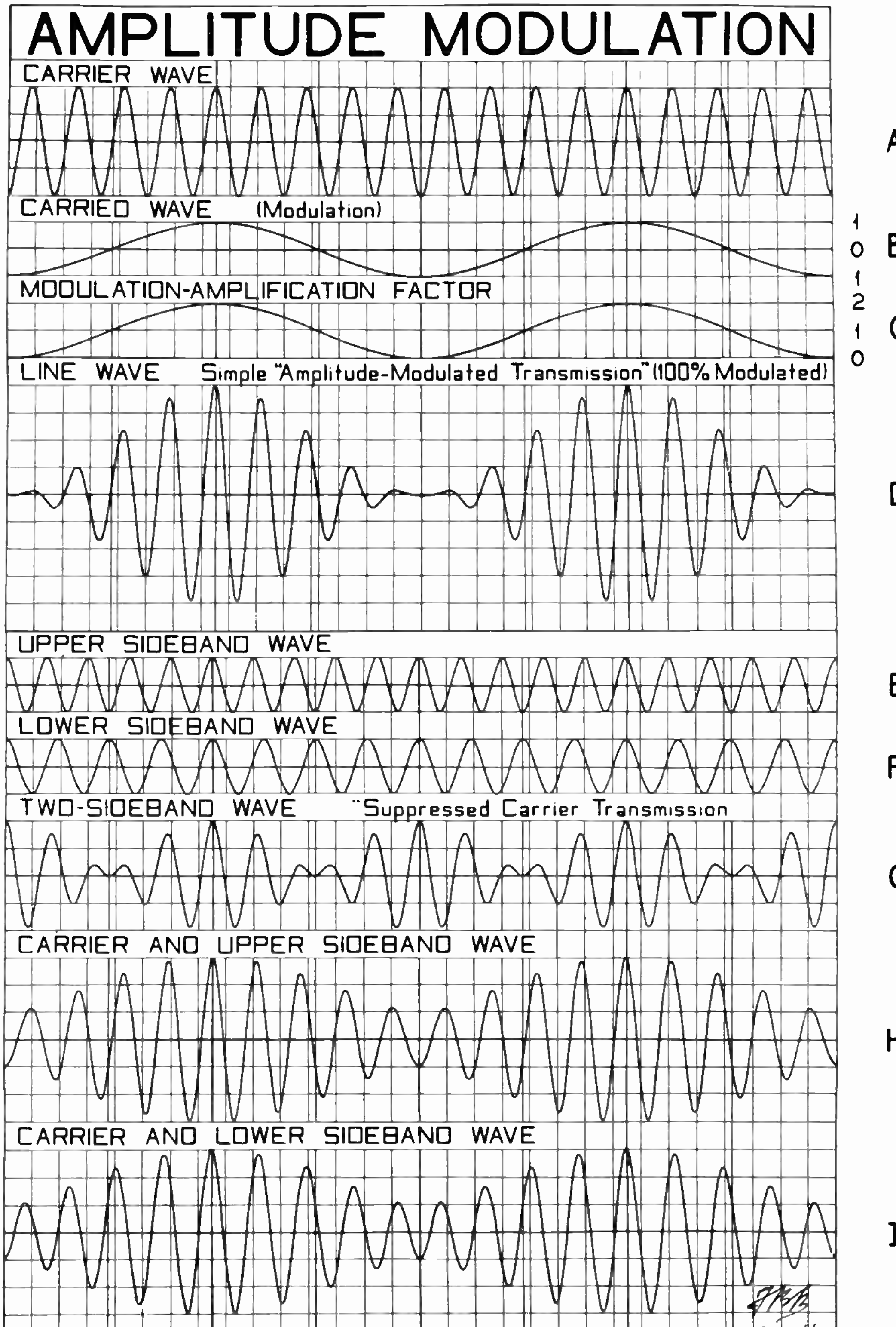

Figure 1. Amplitude-modulated wave

Properties of Amplitude and Frequency Modulated Waves

J. E. BOUGHTWOOD

TELEGRAPH CARRIER communication circuits require the use of a carrier frequency upon which the d-c telegraph signals are impressed for transmission over the line. In general the signals are impressed on the carrier by varying either its amplitude or its frequency in accordance with the signals to be transmitted. The former method is known as amplitude modulation and the latter as frequency modulation. We are concerned here primarily with the relative properties of amplitude- and frequency-modulated waves, and the various components contained therein.

Let us first examine an amplitude-modulated wave as shown in Figure 1. Curve *A* is the Carrier Wave upon which the d-c telegraph signals are to be impressed. This is a pure sinusoidal wave, constant in frequency and amplitude, and nothing more. Curve *B* is the Carried Wave or signal to be impressed, and for the sake of simplicity is taken as a sine wave of constant frequency instead of the usual square topped wave ordinarily associated with telegraph signaling.

The act of impressing the Carried Wave upon the Carrier Wave in the form of amplitude modulation involves the use of the Carried Wave as a factor by which the Carrier Wave is multiplied at any point to determine its instantaneous modulated amplitude. For example, if the Carried Wave were absent, i.e., its amplitude were zero, the Carrier Wave naturally could not be modulated and our multiplication factor for this condition of necessity would be unity and not zero as one might thoughtlessly assume. This follows as any quantity, such as a Carrier Wave, multiplied by unity becomes equal to itself. This is the basis upon which curve *C* is drawn and it is an exact replica of curve *B* except that the wave axis now lies at unity instead of zero and its peaks lie at zero and plus two instead of plus one and minus one as formerly. If we now multiply any point on curve *A* by the corresponding point, in respect to time, on curve *C* with due regard to algebraic signs, we obtain one point of the modulated wave *D* shown as the Line Wave. If we repeat this process at sufficiently close intervals we will obtain a plot of the Line Wave as shown.

In the case illustrated, curve *C* is of such magnitude as to modulate the carrier 100 percent; i.e., the amplitude-modulated line wave varies between zero and twice its average value. This represents the maximum size signal which can be impressed upon the carrier wave and any attempt to increase it further results in over-modulation and distortion. If the carried wave were reduced in amplitude a corresponding decrease in curve *C* also would occur, the wave collapsing symmetrically about unity as an axis, its peak values being uniformly less than plus two and greater than zero. If this wave were now multiplied by the carrier wave as before, we would find the percentage modulation of the line wave correspondingly reduced.

When we examine the amplitude-modulated line wave, we find its fundamental frequency, as indicated by intervals between axis crossovers, is identical to the carrier wave frequency. Also the amplitude variation or "envelope" of the line wave is an exact replica of the carried wave. The carrier wave has been modified

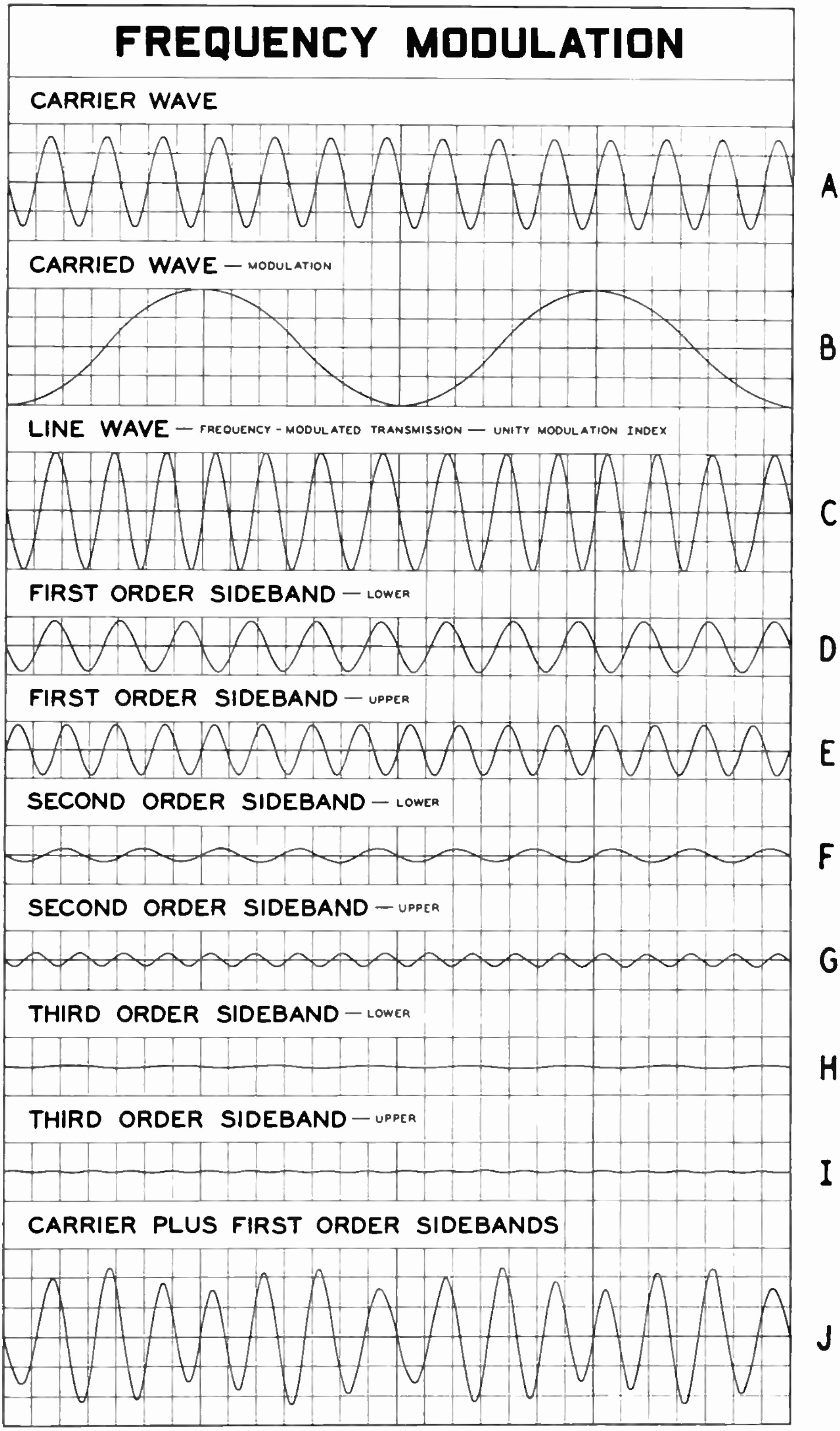

Figure 2. Frequency-modulated wave

in such a manner that its amplitude varies at the signal frequency rate, thus fulfilling the requirements for amplitude modulation.

It is obvious that the line wave must contain something more than a single frequency, inasmuch as it no longer resembles our initial carrier wave which we know was taken as a pure sinusoidal wave. It remains to determine what we have added to our carrier wave by the process of modulation to vary its amplitude in accordance with the carried wave. A mathematical analysis of the line wave will show it to contain not only our original carrier frequency but in addition two new frequencies, one higher than the carrier frequency by an amount equal to our signal frequency and one lower than the carrier frequency by an equal amount. These frequencies are known as the upper and lower sideband waves respectively and are shown as curves *E* and *F* in Figure 1. As proof of this, we have only to add algebraically or graphically the instantaneous amplitudes of the upper and lower sideband waves to the carrier wave to obtain the same line wave derived by the modulation process. This type of amplitude modulation is known as double-sideband operation.

In special applications the carrier wave is suppressed and only the two sideband waves are transmitted, the line wave in this case appearing as curve *G*. Similarly either the upper or lower sideband waves can be suppressed to produce line waves similar to curves *H* or *I*.

We now can state that an amplitude-modulated wave is characterized by a constant fundamental frequency and an amplitude envelope which varies in accordance with the transmitted signal. We have also shown that the sideband waves are supplemental waves *added* to the carrier wave to produce the amplitude modulation, the carrier wave itself being unaffected in magnitude or frequency by the application of modulation.

Let us now examine the properties of a frequency-modulated wave as shown in Figure 2. As might be surmised, the carried wave, *B*, is utilized to vary the instantaneous frequency of a given carrier wave instead of its amplitude. If closely examined, the frequency of the line wave *C* is seen to be a minimum when the carried wave is negative, and a maximum when the carried wave is positive. The amount by which the frequency shifts is dependent upon the circuit design and can be made any desired value. In Figure 2 a modulation index of unity has been chosen. Modulation index is simply the ratio of the frequency shift, either side of center divided by the frequency of the carried wave. For example, if the carried wave is 35 cycles the line wave will be deviated plus and minus 35 cycles either side of its unmodulated value when the modulation index is equal to unity.

As we learned from our examination of an amplitude-modulated wave, any variation in the amplitude of a pure carrier wave can be accomplished only by the introduction of sideband waves. This also is true if we try to alter or modulate the frequency of a pure carrier wave. One important difference exists in that the power in the sideband waves of amplitude modulation must be furnished from some external source since the power in the carrier wave is always constant whether modulated or not. On the other hand, with frequency modulation the total transmitted power is always constant since the amplitude is constant and therefore the sideband power must be derived from the unmodulated carrier. The amount by which the carrier is reduced when modulation is applied is a function of the modulation index. For instance, if a frequency-modulated transmitter were not being modulated, all the transmitted power would be at the carrier frequency. If this carrier had an amplitude equal to that shown by *C* in the unmodulated state, it would reduce itself to the value shown by *A* upon the application of frequency modulation having an index equal to unity. The power represented by this reduction in amplitude is now contained in the various sideband waves shown as *D, E, F, G, H,* and *I*.

These waves are symmetrically located about the carrier frequency, the first order pair being separated from the carrier wave by a number of cycles equal to the carried wave frequency, the second order pair by twice the carried wave frequency, and the third order pair by three times the carried wave frequency, etc. The frequency-modulated line wave thus can be closely synthesized by a carrier wave and three sets of sideband waves or a total of seven separate sinusoidal waves. As proof of this statement, we can reconstruct the line wave by graphically or algebraically adding together the carrier and sideband waves. The effect of eliminating second and third order sideband waves is shown by curve *J* and closely approximates the condition existing in our frequency-modulated telegraph carrier circuits.

It is interesting to note that in both amplitude and frequency modulation the line wave is a composite of several sinusoidal waves. The amplitude and phase relations of these waves are such as to produce an amplitude-modulated line wave in one case and a frequency-modulated line wave in the other case. It should be pointed out that in amplitude modulation, where the carried wave is a single frequency (sine wave), one set of sideband waves only is produced. If the carried wave contains other frequency components, however, then each frequency component will have its own private set of sideband waves, one upper and one lower, each separated from the carrier wave by an amount equal to the particular carried wave frequency component concerned.

To make the issue more confusing, the number of pairs of sideband waves created by frequency modulation, where the carried wave is a single frequency, is theoretically infinite but fortunately the number of sideband waves of appreciable magnitude is a function of the modulation index. To illustrate, if the number of cycles by which the line wave is deviated is large compared to the carried wave frequency, then a large number of pertinent sidebands is produced. If the frequency deviation is small compared to the carried wave frequency, then only a single pair of sidebands is produced as in amplitude modulation. This does not mean that amplitude and frequency modulation are identical under this condition, since the sideband waves in the two cases have different amplitude and phase relations in respect to their carrier waves and so produce an amplitude-modulated line wave in one instance and a frequency-modulated line wave in the other.

In designing a carrier current circuit, in order to determine the required channel bandwidth, it is necessary to know how many sideband waves must be transmitted in order to hold signal distortion within the desired limits. As the separation of the sidebands from the carrier in amplitude modulation is proportional to the carried wave frequency, we simply take the maximum signaling speed desired and design our channel width so as to pass the resulting first order sidebands with no more than 20 percent attenuation. Roughly our required bandwidth is 2.3 times the maximum signaling speed.

To adapt frequency modulation with its more numerous sidebands to this same bandwidth, a modulation index of unity was chosen. This means that the carrier frequency is deviated above and below its mid-position by an amount equal to the maximum signaling frequency as illustrated in Figure 2. Three pairs of sideband waves result, but the power contained in the second and third pairs constitutes only 2.8 percent of the total power in the line wave, and although the channel tuners eliminate all but the first order pair only a small amount of distortion results. As provisions are made for correcting this distortion in our terminal channel amplifiers, a carrier system employing frequency modulation is quite practical.

At this point the skeptic might inquire and with pardonable sarcasm, "Why employ frequency modulation?" To recapitulate for a moment, we will recall that an amplitude-modulated line wave which is being 100-percent modulated is carrying the maximum size signal possible to be impressed upon the carrier wave. If we try to further increase the magnitude of the impressed signal, to overcome the effect of extraneous interference for example, without a corresponding increase in the carrier wave amplitude, severe distortion results. As certain definite practical limits exist as to maximum transmitted carrier power or amplitude, we soon reach a point where no further improvement is possible. This is where frequency modulation steps into the picture and in the following manner.

The advantage of frequency modulation lies in the fact that the amount by which it can be modulated (the degree of frequency deviation) has no definite upper limit as is imposed by the 100-percent limitation existing with amplitude modulation. This follows because no increase in transmitted power or amplitude is required when the percentage modulation or deviation is increased. The only requirement is that the transmission band be wide enough to properly accommodate the increased frequency swing. Where the interference amplitude is appreciably less than the signal amplitude, the effect of increasing the frequency deviation is somewhat similar to increasing the percentage modulation in amplitude modulation in so far as reducing interference is concerned. Furthermore, this is accomplished with no corresponding increase in transmitted power. For these reasons a frequency deviation of ± 35 cycles is employed in our telegraph carrier circuits, this being the maximum permissible on a 150-cycle channel spacing. As a result, the effect of a given amount of interference is reduced 3 decibels below that experienced with amplitude modulation. In addition, if we make the *maximum* transmitted amplitudes of our amplitude- and frequency-modulated line waves equivalent (a condition fulfilled in practical carrier circuits), twice as much power can be transmitted when frequency modulation is employed, contributing another 6 decibels reduction in signal loss. This follows since the frequency-modulated line wave is always of constant amplitude representing a maximum power output while the amplitude-modulated line wave varies between zero and maximum representing about one-half or less as much power on the average. Thus for equal channel bandwidths a theoretical interference reduction of about 9 decibels results from the use of frequency modulation. Another advantage lies in the elimination of bias troubles due to line attenuation changes. Line attenuation changes are equivalent to amplitude-modulating the carrier at a very slow rate and since our frequency modulation receiver is designed to respond only to frequency changes, the amplitude effects are negligible.

THE AUTHOR: For photograph and biography of Mr. J. E. Boughtwood, see the April 1948 issue of TECHNICAL REVIEW.

The Development of Western Union Switching Systems

W. B. BLANTON and G. G. LIGHT

(Continued from TECHNICAL REVIEW, July 1949)

THIS ARTICLE continues the description of the Plan 21-A Reperforator Switching System by describing the automatic checking of the call letters, channel designation and sequence number of each message that is automatically switched from receiving positions of heavily loaded tributary and branch office circuits and from local operators' sending positions.

Need for Sequence Numbering of Messages

In handling commercial telegrams over a telegraph circuit, unrelated and relatively short messages are transmitted, one after the other, from the sending end of the circuit to the receiving end of the circuit. Normally, the operating personnel, the line circuit, and the transmitting and receiving apparatus function to transmit and receive this flow of telegrams swiftly and accurately. However, to guard against the abnormal, it has long been telegraph practice to apply safeguards to protect each of the unrelated messages that flow over a circuit against possible delay or failure.

In manual operation, each telegram that is brought to a sending position is placed under a numbering stamp which, when actuated by the operator, imprints on the blank the call letters of the distant office, the channel designation of the particular sending circuit terminated at that position, and the channel sequence number for that message. The channel sequence numbers for each channel start with the number "1" at the beginning of each day, and each succeeding message on a channel is numbered in sequence.

When the sending operator transmits a message, she prefixes it with her office call letters, and the channel designation and sequence number that were stamped on the blank by the numbering stamp. At the receiving end of the circuit, the receiving operator notes the sequence number of each received message and draws a pencil line through the corresponding number on a number sheet individual to that receiving channel, thus checking off that number. The receiving operator therefore becomes immediately aware of any omitted or duplicated sequence number. In such cases, she takes routine measures to protect against omitted or duplicated messages by querying the sending operator on the sequence number discrepancy. Omitted messages may be caused by line or apparatus trouble, or by a sending operator mistaking an unsent message for a sent message and simply failing to transmit it. A duplicated message may be caused by an operator sending the same message twice or by the transmitting tape being reset improperly for the resumption of transmission after a circuit interruption.

Prefixing all messages with the call letters of the sending office, the channel designation and the channel sequence number not only serves to protect against the possible failure of messages but also provides a ready and concise means of designating and identifying any particular message. This is of particular value when a receiving office wishes to query a sending office on a specific message, or when a receiving office wishes to advise a sending office to resume operation on a circuit at a specific message after some line or apparatus trouble has been corrected.

Sequence Number Checking at Reperforator Offices

The same procedure of checking the sequence number of incoming messages, and of prefixing office and channel identifying characters and sequence numbers on outgoing messages, is followed in reperforator offices. As previously mentioned in these articles, the switching clerks at plug-and-jack or push-button switching positions mark off on the number sheet at each line receiving position the sequence number of each message received at that position. Also, when these received messages are switched and transmitted across the office into line sending positions, automatic numbering machines function to add to each message a new prefix that consists of the call letters of the reperforator office, the channel designation of the particular sending position, and the channel sequence number for each message. These sequence numbers are, of course, checked by the switching clerks or receiving operators at the distant end of the outgoing circuits.

In Plan 21-A reperforator switching centers, automatic switching is employed on messages which are transmitted into the switching system from tributary and city branch offices and from local operators' sending positions. The vast majority of these messages pass through the switching center without any human attention. In order to apply the same message safeguards as are applied to the manually switched messages, automatic facilities are provided for checking the sequence numbers of the automatically switched messages. Not only do these facilities insure that all of the telegrams at the sending offices or positions have been transmitted into the switching center, but the protection is extended to checking, character by character, to assure that the call letters, channel designation and sequence number preamble of each message is actually received and perforated correctly in the tape of the intra-office reperforator at the selected line sending position. If the preamble is not received and perforated correctly, further transmission of the message is stopped, the received portion of the message is automatically cancelled to the next office, and routine measures are taken to have the message retransmitted correctly from the sending office or position. Insuring that the identifying portion of each message is received and recorded correctly in the perforated tape at the selected line sending position permits tracing back any message, even though equipment or circuit trouble should cause the remainder of the message to be mutilated or lost.

The facilities for automatically switching and transmitting messages through a Plan 21-A reperforator office fall into two general categories.

Local operators' sending positions and line receiving positions that terminate heavily loaded tributary and branch office circuits fall into one category. At each of these positions, the messages are produced in perforated tape form prior to being switched and transmitted. The perforated tapes are produced at local operators' sending positions by the operators manipulating keyboard perforators while the perforated tapes are produced at line receiving positions by receiving reperforators. The perforated tapes flow through intra-office transmitters and, by means of selection characters prefixed to each message, the messages are automatically switched and transmitted to the appropriate line sending positions. Transmission is at the rate of 125 words per minute.

Lightly loaded tributary and branch office circuits that terminate in line finders fall into another category. Upon the receipt of the selection characters that precede each message, these circuits are automatically switched through receiving distributors to the selected line sending positions. The messages are then transmitted from tape transmitters at the branch and tributary offices directly into the sending positions at 65 words per minute.

The automatic checking of the call letters and sequence number preamble takes place on all automatically switched messages. However, this article will be confined to describing the preamble checking that takes place on messages switched from intra-office transmitters at local operators' sending positions and at line receiving positions.

Call Letters and Sequence Number Comparison Equipment

The checking of the call letters and sequence number preamble of a message takes place while the preamble and the first few characters of the message are being transmitted from the intra-office transmitter into the intra-office reperforator of the selected line sending position.

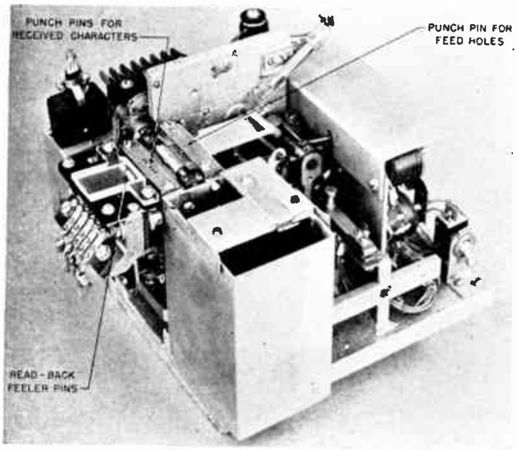

Figure 43. Intra-office reperforator equipped with read-back pins

In fact, the transmission of character code combinations from the intra-office transmitter into the intra-office reperforator alternates with the transmission in the opposite direction of the code combinations previously punched in the intra-office reperforator tape.

The intra-office reperforator (Figure 43) on each Type 4812 reperforator sending position is equipped with read-back feeler pins much like the feeler pins on a tape transmitter. Because of mechanical limitations, these read-back feeler pins are spaced five characters away from the punch pins. While a reperforator is punching into its tape a code combination received from an intra-office transmitter, the read-back feeler pins are "reading" the fifth preceding code combination that was punched in the tape. The read-back feeler pins actuate cooperating contacts which transmit this code combination back to the intra-office transmitter position. The five conductors of the intra-office circuit over which the five-unit code combinations are transmitted from an intra-office transmitter into an intra-office reperforator are also utilized for transmitting the read-back code combinations in the opposite direction. The read-back code combinations received at an intra-office transmitter position for the characters comprising the call letters and sequence number preamble of each message, are electrically compared with the code combinations for these characters as set up in a sequence number indicator, in order to determine if they are correct.

Each intra-office transmitter position is equipped with a sequence number indicator (Figure 44) which consists principally of three rotary switches termed "tens", "units" and "call letters" switches. The indicator plugs into a cooperating subbase with the external connections being made through jack clips. The call letters switch is wired for the code combinations of the fixed characters required in the preamble of each message received at that position. For example, at the Quincy A channel receiving position in Boston, the

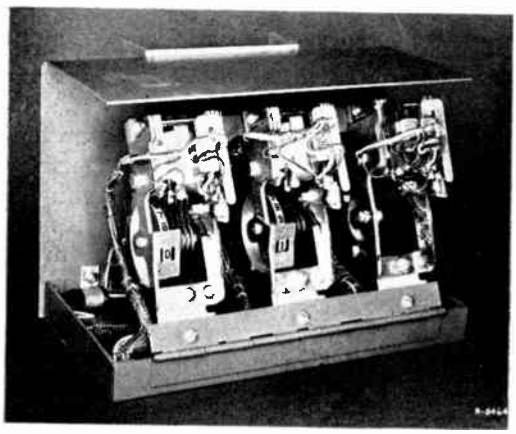

Figure 44. Sequence number indicator

call letters switch is wired for B.QYA *figure-shift*. The strap wiring for the call letters and channel designation (QYA) is not made directly on the call letters switch but instead, the wiring for these three characters is brought out through the jack clips to a multi-conductor receptacle mounted in the signal indicator for that position (See Figure 45). Inserting a cooperating plug, strapped for the characters QYA, into this receptacle arranges the sequence number indicator for use at the Quincy A channel receiving position. If the Quincy A channel receiving circuit were moved to another receiving position, the QYA plug would also have to be moved to that position.

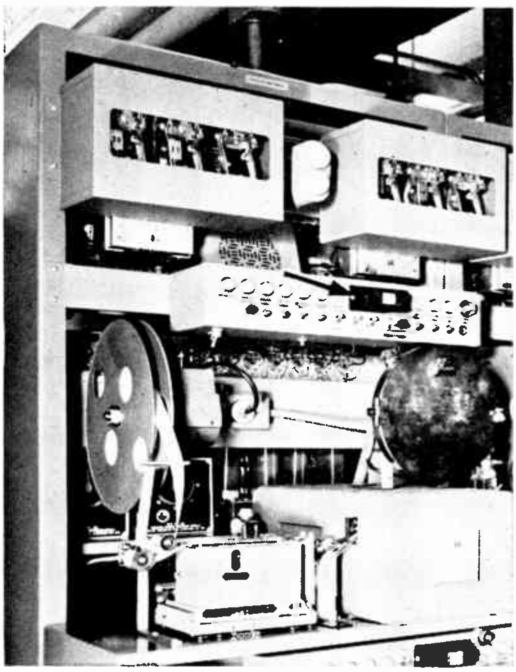

Figure 45. Line receiving position showing multi-conductor plug and receptacle (indicated by arrow) in signal indicator

The tens and units switches are each wired for code combinations for the digits 1 to 0 inclusive. These two switches always indicate the tens and units digits of the sequence number of the next message to be checked at that position. The sequence number of each automatically switched message consists of three digits. For example, the first message is numbered 001, the fifteenth 015, etc. While the sequence number of each message has a hundreds digit, a check is not made to determine if that digit is correct, but the checking functions require that there be a hundreds digit.

Review of Automatic Switching

The last issue of TECHNICAL REVIEW described the automatic switching of a message from the Quincy A line receiving position in the Boston reperforator office. The message used as an illustration was prefixed with the characters =P*space* B.QYA*figure-shift*236. Reference should be made to Figure 46 while reading the following brief review of the operation of the automatic switching equipments.

The messages sent over the Quincy A line circuit are received and recorded in perforated tape form by the reperforator located on the Type 4930 line receiving position. The two periods that terminate each message will cause the message waiting indicator to add one digit. With the message waiting indicator indicating at least one complete message on hand and with the first character of a message over the feeler pins of the intra-office transmitter, an electrical request is made for the automatic switching unit. In response to that request the automatic switching unit, by means of its selector switch, connects to the Quincy A position and establishes circuits for controlling the *A*, *B* and *C* connector switches associated with the Quincy A position. The automatic switching unit then causes the two selection characters and the following space character to step through the intra-office transmitter. The two selection characters, =P, are stored in the office call selector of the automatic switching unit. The automatic switching unit immediately acts upon these two characters and steps the connector switches to establish a potential connection between the Quincy A intra-office transmitter and a line sending position to Philadelphia. Figure 46 shows this potential connection set up through connector switch *A*. This figure also shows an intra-office connection established from a local operators' sending position through its *A* and *C* connector switches to the Kansas City line sending position.

Figure 46 shows two sending channels to Philadelphia. The following description will be confined to that number of channels although actually there are six send-

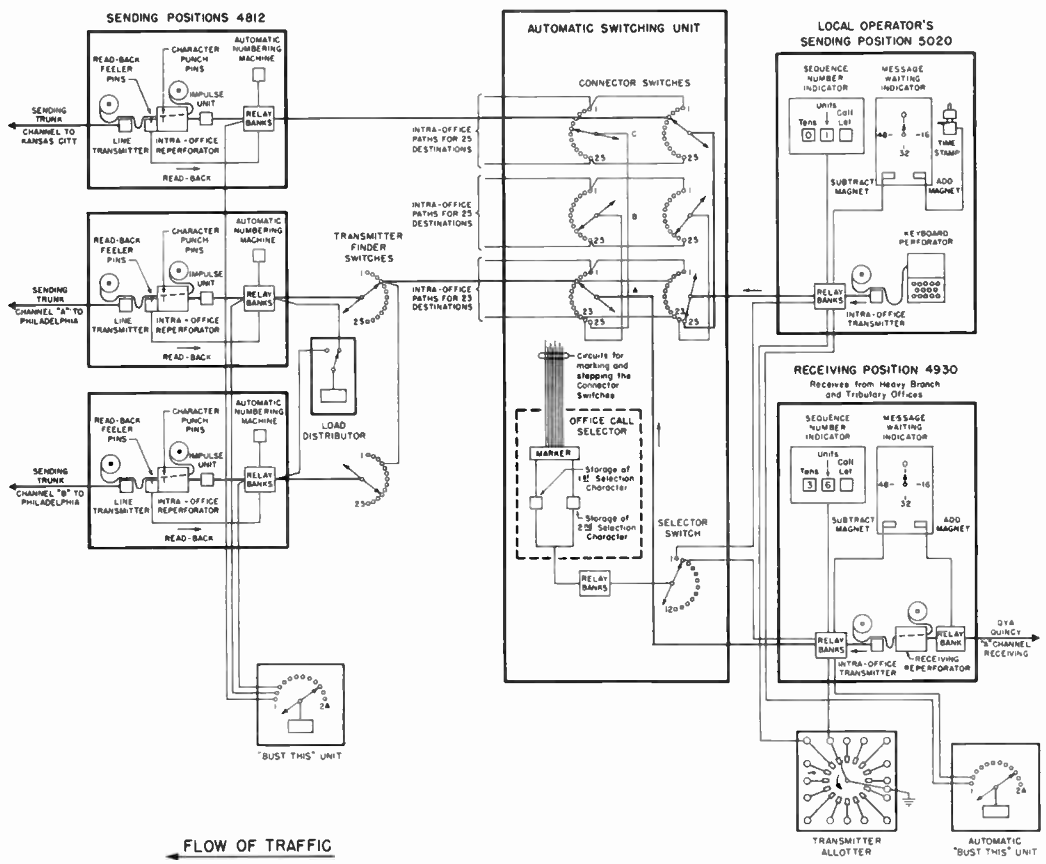

Figure 46. Automatic switching from line receiving positions and local operators' sending positions

ing channels to Philadelphia from the Boston office.

Since the path to the Philadelphia line sending positions for this potential connection is shared by other intra-office transmitters, one or more of which may desire a connection to a Philadelphia line sending position at the same moment, the transmitter allotter functions to permit only one potential connection at a time to be converted to an actual connection. When the transmitter allotter indicates to the Quincy A intra-office transmitter that it has the use of this Philadelphia intra-office path, a calling condition is set up on the transmitter finder switches associated with the Philadelphia line sending positions.

If one or more of the Philadelphia line sending positions are idle, or when one becomes idle, the load distributor indicates which one of these idle positions shall pick up the next intra-office connection. In Figure 46 it is assumed that the A channel is directed to pick up the next connection. Hence the transmitter finder switch associated with that channel is stepped to the point where it makes connection with the intra-office path to which the Quincy A intra-office transmitter has a potential connection. An actual connection is thereby established between the transmitter and the A channel line sending position. Immediately upon the establishment of this connection, the automatic numbering machine functions to send into the intra-office reperforator a series of characters such as the following: *Letter-shift*BA*figure - shift*465*letter - shift space.* B is the call letter for the Boston office, A is the channel designation, and the digits 465 designate that message as being the

465th message to be sent over the Philadelphia A channel that day. Following the operation of the numbering machine, the Quincy A intra-office transmitter functions to send the message.

Call Letter and Sequence Number Comparison

As the automatic switching unit functioned to set up a potential connection to Philadelphia in response to the selection characters =P, the character B was left over the feeler pins of the Quincy A intra-office transmitter. This is the first character transmitted after the automatic numbering machine completes its operation. While the intra-office reperforator is perforating the code combination for B in the tape, the read-back contacts on the reperforator transmit back to the intra-office transmitter position the code combination for the fifth preceding character perforated in the tape. This will be one of the characters sent into the intra-office reperforator by the automatic numbering machine. The following table shows the characters transmitted by the intra-office transmitter, and opposite each of these characters the particular read-back character that should be received from the intra-office reperforator.

Numerical Order of Characters	*Transmitted Characters*	*Read-Back Characters*
1	B	4
2	.	6
3	Q	5
4	Y	letter-shift
5	A	space
6	figure-shift	B
7	2	.
8	3	Q
9	6	Y
10	letter-shift	A
11	space	figure-shift
12	X	2
13	X	3
14	X	6
15	X	(Indicator advances to next higher number)

It will be seen from the above table that while the transmitter is sending its first five characters (B.QYA) the read-back characters will be characters that were transmitted into the intra-office reperforator by the automatic numbering machine. No camparison is made on these read-back characters. The sequence number indicator merely counts them and causes its call letters switch to take five steps. Now the sequence number indicator is in readiness to compare for the character B. As the intra-office reperforator punches the sixth transmitted character (figure-shift), the read-back contacts on the reperforator transmit back to the intra-office transmitter position the code combination for the fifth preceding character perforated in the tape, which should be B. This read-back code combination is compared with the code combination for B in the sequence number indicator. If the comparison is correct, the call letters switch advances to the next position in readiness to compare for the character "period". When the transmitter sends the seventh character 2, the read-back combination is compared with the code combination for "period" in the sequence number indicator. Again, if the comparison is correct, the call letters switch advances to the next position in readiness to compare for the character Q. This comparison procedure continues until the transmitter sends a sufficient number of characters to cause read-back code combinations to be received for the entire preamble B.QYA*figure-shift*236. As stated before, a check is not made to determine if the hundreds digit is correct. Any read-back code combination is accepted for that digit.

In the above table, the characters "X" shown as the 12th to 15th characters transmitted by the transmitter will actually be message characters that follow the preamble. It will be noted that after transmitting 14 characters, read-back code combinations have been received for all of the characters in the preamble. If a correct comparison takes place on all of the characters in the preamble, transmission continues. A read-back code combination is also received after the 15th character is transmitted. No comparison is made on this read-back code comparison but it causes the sequence number indicator to advance to the next higher number in readiness to compare the sequence number of the following message, and it serves to indicate to the intra-office transmitter circuit arrangement that a correct comparison for that message has been completed.

The intra-office transmitter is operated at half speed (62½ words per minute) while sending its first fifteen characters, in order to give the comparison equipment sufficient time to perform its functions. The transmitter operates at full speed for the remainder of the message.

Wrong Comparison

When a read-back code combination differs from the code combination set up in the sequence number indicator, a wrong comparison results. If the preamble characters or sequence number of a message is incorrect in the perforated tape passing through an intra-office transmitter, obviously a wrong comparison takes place. Thus all messages are detected that have incorrect identifying characters or are not in proper sequential order. When a wrong comparison occurs, the portion of the message received at the line sending position is automatically cancelled to the next office. Steps are taken at the intra-office transmitter position to have the necessary correction made and to reinitiate switching.

Occasionally a wrong comparison may occur because of trouble in the intra-office equipment even though the preamble characters are correct in the perforated tape that is passing through the intra-office transmitter. In this case, not only is the portion of the message received at the line sending position cancelled to the next office and the switching reinitiated at the intra-office transmitter position, but an endeavor is made to detect the equipment that is giving trouble.

On a wrong comparison, the intra-office transmitter is stopped immediately but the intra-office connection to the line sending position is maintained. The intra-office transmitter position automatically makes an electrical request for a "Bust This" unit that serves as many as 24 transmitter positions. The Bust This unit, an arrangement of rotary switches and relays that functions to transmit a series of fixed characters, connects to the intra-office transmitter position and proceeds automatically to send over the intra-office circuit into the connected intra-office reperforator the following characters:

*letter-shift space*BUST*space*THIS . .

In the same manner as when the intra-office transmitter was sending, the intra-office reperforator transmits read-back code combinations to the Bust This unit. This unit, which is equipped with comparison facilities, compares those read-back code combinations which should be identical to the code combinations of the first six characters (*letter-shift space* BUST) transmitted by the Bust This unit. The reason for only the first six characters being compared is readily evident when it is remembered that the read-back code combination for a particular character is received after the fifth following character is transmitted. This is illustrated in the following table:

Numerical Order of Characters	*Transmitted Characters*	*Characters Compared by Bust This Unit*
1	letter-shift	
2	space	
3	B	
4	U	
5	S	
6	T	letter-shift
7	space	space
8	T	B
9	H	U
10	I	S
11	S	T
12	.	
13	.	

If the comparison is correct on the six characters compared by the Bust This unit, it is indicative that the message preamble wrong comparison was caused by an incorrect character or sequence number in the preamble of the message. The characters BUST THIS sent into the intra-office reperforator serve to cancel to the next office the trunk channel sequence number and that portion of the message received there. The two periods following the BUST THIS cause the intra-office circuit to be disconnected, thereby immediately freeing the line sending position for another intra-office connection without any human attention being required at that position.

A "wrong comparison" signal is operated at the intra-office transmitter position to attract the attention of the operator or supervisor. She examines the perforated tape and sequence number indicator to determine the cause of the wrong comparison. Routine measures are taken to protect against loss or duplication of messages and to restore the position to operation.

If a wrong comparison takes place on any of the six characters that the Bust This unit compares, transmission of further characters from that unit is immediately stopped. Such a wrong comparison is indicative that there is equipment or tape trouble at the line sending position. The Bust This unit is released so that it is free to serve other transmitter positions, but the intra-office connection between the intra-office transmitter and the line sending position is maintained. "Wrong comparison" signals are operated at both positions.

In response to the "wrong comparison" signal at the line sending position, a supervisor determines by inspection if the wrong comparison was caused by tape failure or by any other obvious reason. If necessary, testing and regulating personnel are called to inspect the position. When the position has been restored to proper operating condition, a "Bust This" push-button is depressed to cause the characters *space letter-shift*BUST*space* THIS*space* . . to be transmitted into the intra-office reperforator by another type of Bust This unit that is common to as many as 24 line sending positions. No comparison takes place on the transmission from this Bust This unit, but the supervisor observes that the reperforator functions correctly. The double period following the BUST THIS causes the intra-office circuit to be disconnected, thereby freeing the line sending position for another intra-office connection. The necessary routine measures are taken at the intra-office transmitter position to restore it to service.

Failure of Comparison Equipment

When all of the characters in the preamble of a message have compared, or when a wrong comparison takes place, the circuit arrangements at the intra-office transmitter position are conditioned so that an intra-office circuit disconnect will occur when two periods (end-of-message signal) are transmitted into the intra-office reperforator. If the comparison equipment fails to register either a correct or a wrong comparison when a message is transmitted into the intra-office reperforator, the two-period end-of-message signal will stop the transmission from the intra-office transmitter but the intra-office connection to the line sending position will be maintained. Equipment Failure and Supervisory signals will be actuated at the line sending position. Steps are then taken to protect the message involved, and to locate and correct the condition that caused the comparison equipment to fail to function on that message.

Subsequent articles will continue the description of the Plan 21-A Switching System.

THE AUTHORS: Biography and picture of Mr. W. B. Blanton, recently appointed Switching Development Engineer of the Development and Research Department, appear in the January 1948 issue of TECHNICAL REVIEW. Those of Mr. G. G. Light, recently appointed Assistant Switching Development Engineer, appear in the April 1949 issue of TECHNICAL REVIEW.

Apparatus for the Modern Reperforator Office

W. H. FISHER

How MANY TIMES in the course of our everyday lives do we speculate as to why our new home appliances, automobiles, even our homes, are shaped as they are or operate as they do? If the truth were known, most of us would answer "Rarely!" This is a natural tendency in a fast-moving era in which new ideas and products are accepted for what they will do for us rather than for what they are and how they came into being. The inclination is not absent in our new high-speed switching centers.

Recently Western Union has filled many rooms and many buildings in many cities with millions of dollars worth of newly designed communication marvels, varying in shape and size and capable of carrying

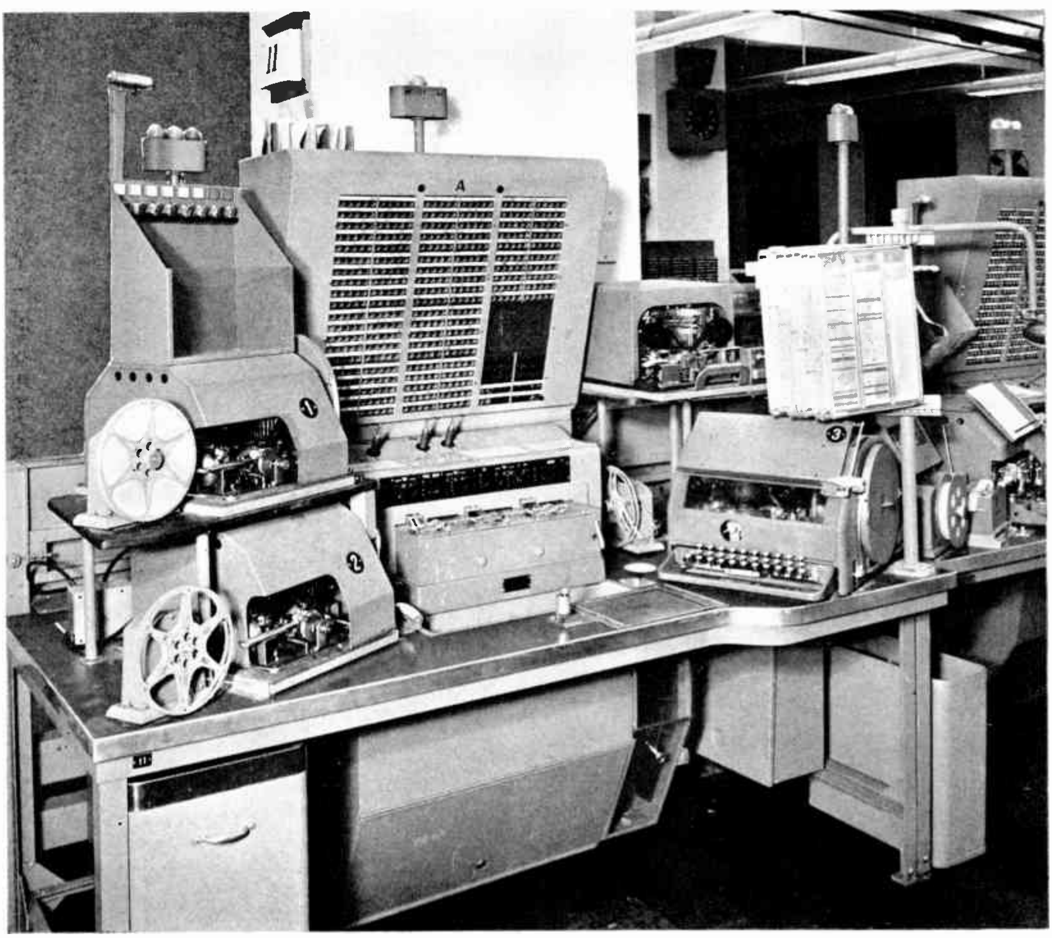

Figure 1. Tie-line switching table 346-A

out thousands of different operations. Western Union personnel is justifiably proud of this modern telegraph apparatus and its efficient operation and attractive appearance. In support of that feeling of pride and accomplishment in Western Union, this paper describes some of the problems encountered, and the reasoning behind their subsequent solution, in the design of modern and successful telegraph apparatus. Let us, therefore, join the engineer during the initial design of some of the recently created apparatus, the better to appreciate that apparatus for what it is and how it was evolved, rather than only for what it accomplishes.

Switching to Tie-Lines

Figure 1 shows Tie-Line Switching Table 346-A, the function of which is to switch from a reperforator central office messages destined for tie-line patrons in the vicinity. A switching clerk seated at the position has at her fingertips three cords associated with three tape transmitters by means of which she may transmit a message to any one of a maximum of 600 tie-line patrons, represented by 600 jacks in the inclined turret directly in front of her.

It became evident in the early stages of the design of this operating table that many of the 600 patrons' jacks, if placed in a vertical plane and, of necessity, above the three-gang transmitter and signal indicator, would be inaccessible to even the tallest operator when seated. It was also a fact that the 600 jacks must be made accessible from the front of the table, since the back was to be placed against either a belt structure or a wall or other apparatus. In order to satisfy these conditions, the turret was built with the jack field inclined toward the switching clerk in such a manner that an outstretched arm, rotated upward, would remain approximately equidistant from any point on the surface, thereby enabling an operator to reach successfully any one of the 600 jacks in the turret without undue stretch and strain. The turret face was hinged at the bottom and latched at the top so that maintenance and servicing of the jacks could be accomplished from the front by rotating the jack field forward and down, with two folding arms limiting its travel and supporting the weight when in the open position. To eliminate harsh lines in an otherwise purely utilitarian design, a square corner at the top of the turret face was replaced by a sweeping curve.

Rotary Switch Mountings

In any communications industry, lost time and lost business result from apparatus failures and every effort is made to prevent them. It is for this reason that any component of the apparatus which is subject to wear or requires periodic adjustment and perhaps cannot be repaired and put back into service in a matter of minutes, is designed on a removable basis. This means that the item which has failed can be removed from the position in trouble and replaced with a standby "spare", kept close at hand for just such an eventuality. The faulty part is serviced later at a test position located at some remote point in the central office.

Figure 2 is an illustration of the mounting of a single rotary switch, containing ten levels of 25 contacts each for a total of 250 possible wiring connections. The

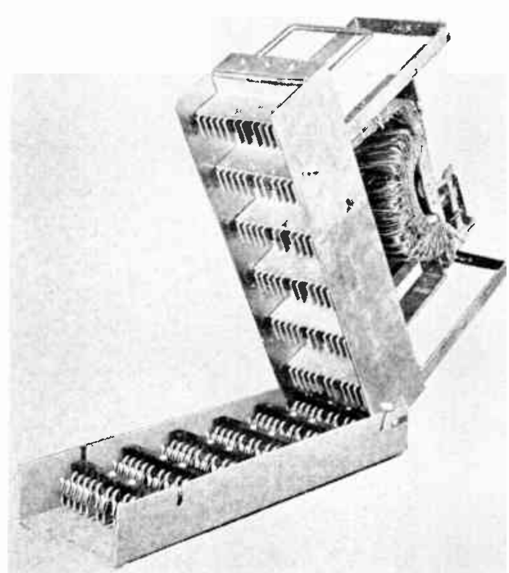

Figure 2. Rotary switch mounting

automatic switch, because of its nature, presents a potential source of circuit failure due to jamming, dirty contacts, wear or some unforeseen eventuality. For this reason, as shown in Figure 2, the switch was mounted on a base and the wiring from the switch terminated in male contacts known as base jacks. The entire switch assembly thus can be quickly inserted or removed from a mating subbase, mounted on the apparatus, containing female or frame jacks. By this means a switch in trouble can be replaced with a spare switch while the one which failed is being repaired at a remote test table, thus avoiding costly time delay.

The practice of mounting rotary switches in banks, and bringing large numbers of connections to them through frame and base jacks is not new. However, the design illustrated is vastly superior to the older arrangement, which like a relay bank mounting, called for all the jacks to engage simultaneously. The force required to set a bank home was often unduly great, and if a jack was misaligned it was difficult to locate. To overcome these weaknesses the new bank design was conceived to permit the bank to be rotated into place, engaging the jacks one row after another, and requiring the use of a minimum of force. Alignment inspection and adjustment is facilitated as each pair of jacks may be observed as they mate.

The unit shown in Figure 2 represents the solution of just one of many design problems encountered in the development of reperforator office apparatus, but the final arrangement here is indicative of the important part that maintenance plays in

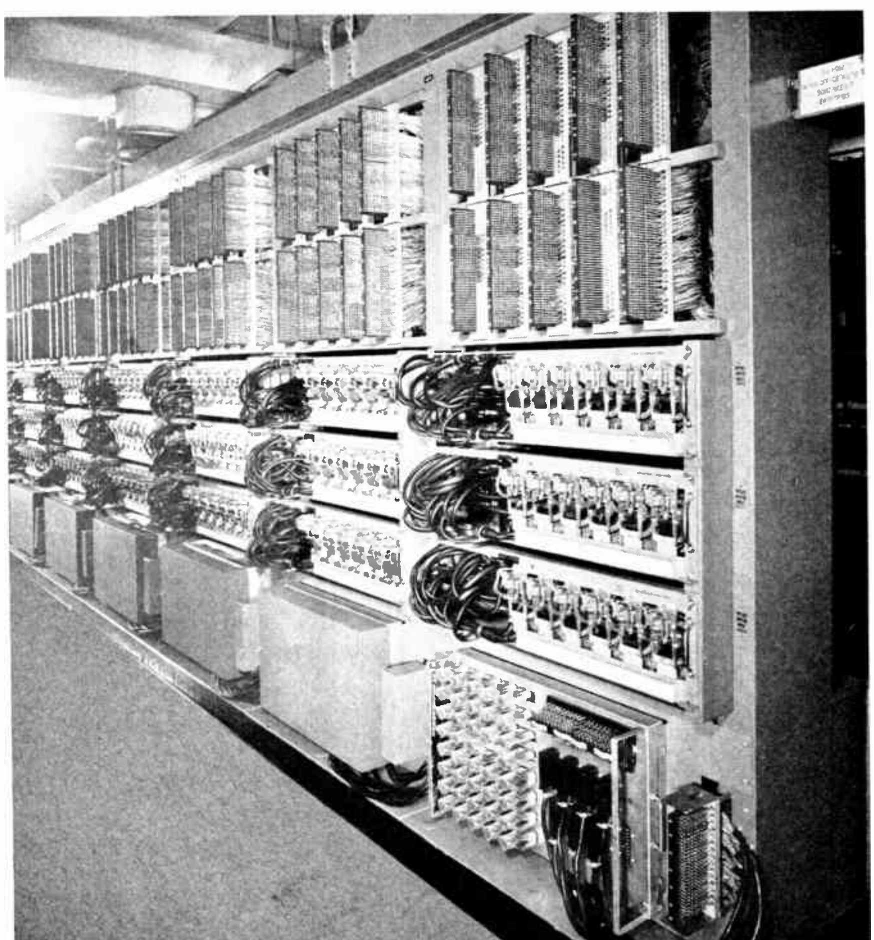

Figure 3. Switching racks 5082-A

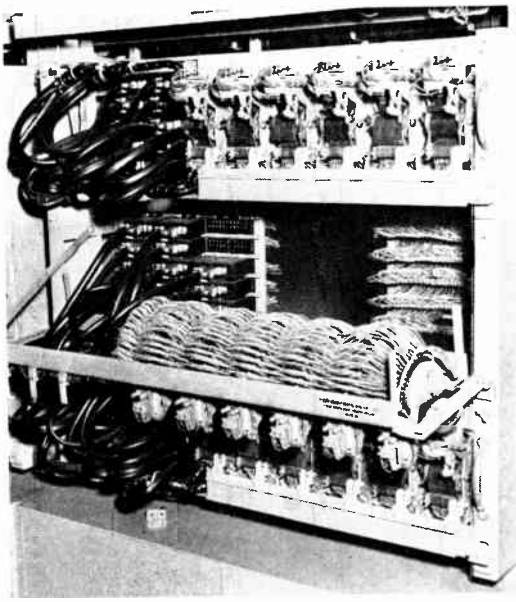

Figure 4. Switch shelf open for inspection

the planning of equipment used in our new communications system.

Figure 3 illustrates a characteristic switching rack with its many terminal blocks, rotary switches and relays. The photograph pictures a row of Switching Racks 5082-A and is a particularly good example of the manner in which large groups of related components of a particular unit of apparatus are made readily accessible for maintenance and servicing. In this case the three switch shelves shown on each rack may be rotated forward for inspection of switches, as illustrated by Figure 4, and the switches have been terminated in a plug and socket arrangement to facilitate replacement of an entire shelf. Further examination of Figure 3 reveals the new type of enclosed cable and power duct in use atop all racks which, in combination with the new fluorescent lighting and air conditioning, and the composition cork flooring designed for greater cleanliness and foot ease, greatly improves the general office appearance.

New Portable Test Set

Preventive maintenance is also of primary importance in satisfactory operation of our modern and complex communication networks. Apparatus in tributary offices or branch offices usually is remote from immediate skilled attention and repair. A service man must carry with him any tools or equipment required to effect the necessary adjustments to this apparatus. Figure 5 shows a Portable Test Set 6030-B designed to provide, in suitcase form, many of the necessary test circuits and devices needed by the maintenance man during a routine or emergency visit to an out-office. This piece of apparatus, to be practicable, had to be made as light in weight and as strong as possible, with high resistance to shock. For this reason the case was constructed of "rigidized" stainless steel. The "rigidizing" process provides a far greater strength factor with a much thinner gauge metal than would be possible with ordinary flat sheet, thereby permitting a saving in weight. The stainless steel offers the necessary toughness and resistance to shock, as well as a permanently clean and attractive surface without the use of paint or plating which soon deteriorates. The interior control panel and supporting members were constructed of weight-saving aluminum with the necessary identifying wording stenciled thereon.

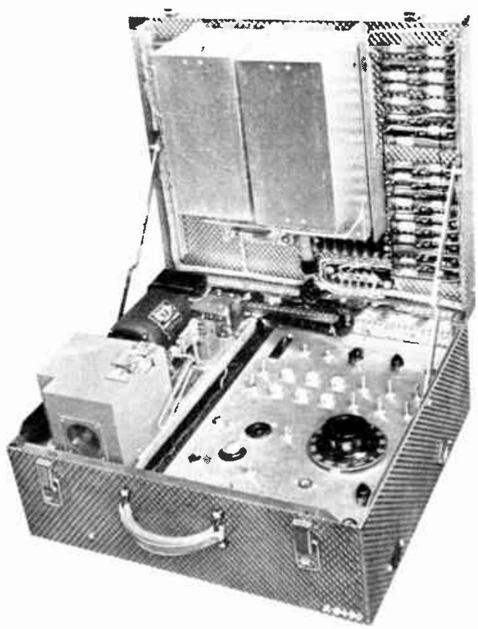

Figure 5. Portable test set 6030-B

General Design Requirements

The foregoing examples serve to illustrate the thinking behind the solution of some very specific problems in design. There are some general considerations which must also be understood and evaluated; important among these are first cost, ease of operation, maintenance and appearance.

Intelligent overall economy is a fundamental requirement. The proper selection of the building material, careful consideration to design of the part or structure to give the greatest ease of construction in the shops, familiarity with the latest developments in methods and materials, and an ability to recognize and specify the commercial parts representing the greatest value for the dollar, all play a highly important part in sensible economy. It is a temptation to produce an article using only the best of materials, the finest of parts, and having the ultimate in beauty, but such design is seldom economical.

Ease of operation with respect to layout of equipment and position of operator is likewise highly important. This applies primarily to an attended or operating position where the efficiency and production of the personnel using the apparatus depend to a large extent on proper engineering for ease of operation. The layout of equipment is a function of no one man but is the result of the cumulative experience of many men, all versed in particular phases of operating problems and procedures, pooled together to produce the ultimate design. It is the duty of the Design Engineer, before producing final specifications for a particular piece of attended apparatus, to be certain that his design will fulfill the requirements set forth by those best able to judge conditions under which the apparatus must be operated.

Since maintenance costs time and money, all apparatus, whether attended or unattended, must be so designed as to offer the optimum in accessibility to vulnerable parts for their repair or replacement. It is possible, of course, to predict in advance some of the parts which are liable to the most wear and consequent possible failure. Such parts must be so located in or on the apparatus as to permit immediate attention by a maintenance man.

Design for appearance is the final consideration. The appearance of the apparatus is, of necessity, a direct function of economy, equipment layout and design for maintenance, and is never considered of greater importance than these three. Practice has proven to industry over the past years, however, that a good mental attitude conducive to greater productivity is enhanced by pleasant and hygienic surroundings. For this reason, modern telegraph operating rooms are fluorescent lighted, cheerfully finished in a pleasing green, and in many cases air-conditioned; and reperforator apparatus is designed with an eye to beauty as well as for economy, operating ease and organized maintenance.

The remarkable record of accomplishment in Western Union's post-war improvement program reflects credit on every participant. There has been produced a new telegraph system for the nation—a system of which everyone associated with the Company is and has a right to be most proud.

THE AUTHOR: W. H. Fisher was graduated from Stevens Institute of Technology in May of 1943, with the Degree of Mechanical Engineer. Immediately upon graduation, he joined the Bethlehem Steel Company in the capacity of Test Engineer at the Sparrows Point Shipyard, Baltimore, Md. He served as Assistant Chief Test Engineer aboard Navy vessels constructed at this yard until February 1946, at which time he joined the Western Union, where he served first as a Central Office engineer. Shortly thereafter, he transferred to the Office of the Apparatus Engineer, where he has been engaged in the design of reperforator apparatus and related equipment.

Magnetic Clutches Applied to Automatic Communication Machines

E. W. HEWITT

AUTOMATIC printing telegraph machines, teleprinters, reperforators and the like must have mechanical power available on practically instantaneous notice. The tolerable delay between the demand for power and the application is but a few thousandths of a second. Since on the average the demand occurs in these mechanisms about 30,000 times each day, and since during the 154 milliseconds of each power-using interval the speed must be constant within very close limits, it is obvious that the prime mover, the driving motor, must be kept running continuously. A clutch then, coupling the driving and the driven member, is an indispensable element of all printing mechanisms.

The demands on this clutch in the terms of accuracy, uniformity, and continuity of operation are such as probably are encountered in few other pieces of machinery. When it is realized that the telegraph system includes some hundreds of thousands of clutch-driven machines, each averaging nearly a million operations a month and scattered from metropolis to hamlet across the nation, the value of even minor reductions in either initial or maintenance cost is readily appreciated. Careful study is made, therefore. of all clutches that appear adaptable to Western Union's automatic machines.

The crown clutch, so named from the appearance of its radial saw teeth, is used very extensively at present. In order to serve satisfactorily with a minimum of maintenance on heavily loaded telegraph circuits, the very best materials and a high degree of accuracy must be used in its manufacture. Experience has shown that "substitute" materials will not stand up in continuous service.

Efforts to reduce clutch costs and improve life led to a laboratory study of magnetic type clutches. Application of the magnetic clutch to machines involving much heavier loads was not new, and has been well covered in literature, but since little was known of the performance of this type of clutch in applications for smaller loads, laboratory development was undertaken. When models were made for study the results obtained were gratifying and it was decided, therefore, to test the clutch on a printer-perforator.

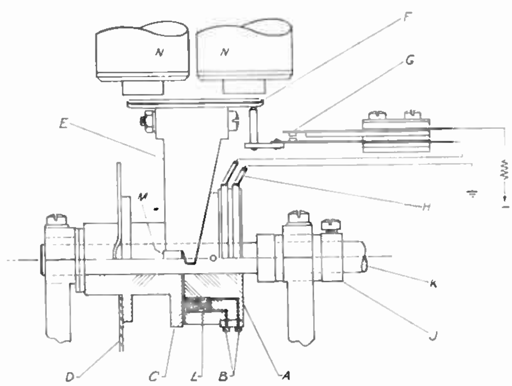

Figure 1. Magnetic clutch as applied to printer-perforator

Figure 1 shows a simplified sketch of the magnetic clutch as applied to the printer-perforator. The driving member A is fastened to the continuously rotating shaft K. The coil L lies in a deep groove in this driving member and is wired to the slip rings B. The driven member C is on the same shaft K but is not fastened and adjustments are made so there are a few thousandths of an inch between the driving and the driven member. The right flange of this driven member completes the magnetic circuit of the clutch. The operating cam D which performs various duties is fastened to the left flange.

When the operating or release magnet N is energized, the armature F is rotated upward and the armature extension E disengages a hardened stop lug M, a part of the driven member. As the armature moves upward contacts G close, completing a circuit from battery through a resistance, the contacts and the clutch coil L, to ground. As the coil L is energized, the driven member is pulled hard against the driving member, leaving no air gap between the two members. The contacts G are held closed until near the end of a complete revolution by the periphery of the driven member. As the driven member approaches the end of the revolution the contacts are opened, and at the completion of the revolution the stop lug M hits the end of the armature extension and the driven member stops until another character is received. Just at the moment the driven member is stopped, the armature extension cams the stop lug to the left so as to eliminate friction load between the clutch surfaces. In the stopped position there is no appreciable force exerted on the armature extension by the stop lug, whereas with the crown type of clutch considerable pressure is encountered. Less power is therefore required to release the magnetic clutch. There is a slight amount of residual magnetism left in the clutch after the contacts are broken, which assists the inertia of the driven member in completing the revolution to the stop position. After the driven disc has been cammed out the residual becomes negligible.

Figure 2 shows the magnetic clutch as used on the upper shaft of Printer-Perforator 23-A. The driven disc which com-

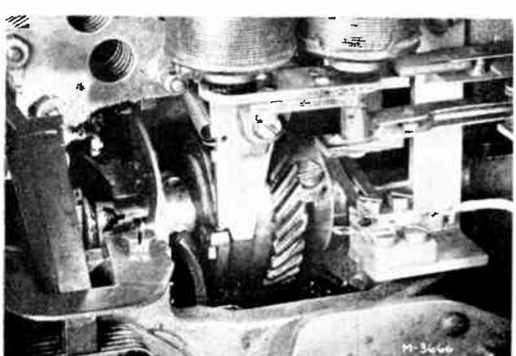

Figure 2. Magnetic clutch on upper shaft of printer-perforator

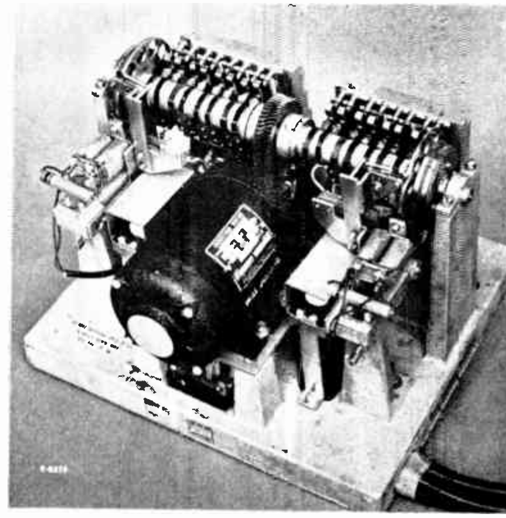

Figure 3. Magnetic clutch applied to start-stop impulse unit

pletes the magnetic circuit is a part of an oilite sleeve, not shown on Figure 1, which also carries the cams that do the work. The hardened stop lug, a part of the driven disc, can be seen on this photograph in the idle or stop position. It is being held from rotating by the release magnet armature extension. Also the armature extension has cammed the driven member to the left, separating the contacting surfaces of the clutch. The driven member is held from rotating backwards by a detent, not shown. Since they are held apart there is no wear on the clutch faces when the machine is idle and no signals are being received. Also there is no clutch load on the motor when the clutch is disengaged.

Stainless steel slip rings are used with phosphor bronze brushes. These are dissimilar metals and will give long wearing qualities. The rings are connected to the coil in the driving member and the magnetic flux rotates at the shaft speed.

The magnetic clutch has been applied experimentally to various other machines and Figure 3 is a photograph of it as applied to the Western Union Start-Stop Impulse Unit (Sub-base 4768-A). The driving member can be seen at either end of the shaft and the operating winding is imbedded in the cold rolled steel under the slip rings. The driven member is of larger diameter and the large holes which can be seen on the periphery of the driven disc are used to reduce the inertia. This large diameter was necessary to match existing parts of the machine.

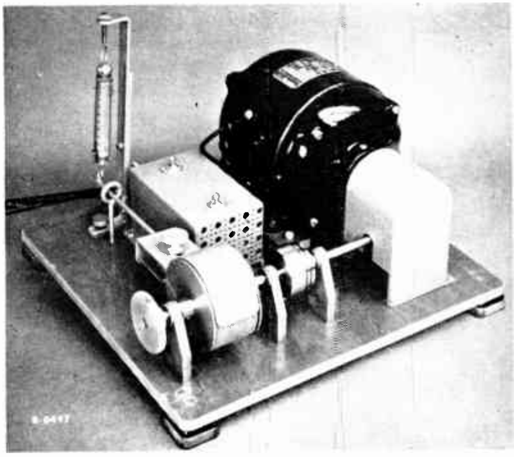

Figure 4. Laboratory model of magnetic clutch

Figure 4 is a photograph of the model which was used for laboratory tests. The diameter of the clutch used was only 1-9/16 inches. Figure 5 shows a graph of the current in the coil plotted against torque taken at the point where slip is first detectable. The last point shown at 0.050 ampere and 350 inch-ounces represents about 1/7 horsepower being delivered through the clutch to the prony brake. It is interesting to note that under the above conditions only 0.5 watt of energy in the clutch coil carries the 1/7 horsepower (106 watts) load without slippage.

The curve appears to be a straight line and indicates that magnetization is well below the saturation point of the cold rolled steel used for both the driving and the driven members of the clutch.

Figure 6 shows how uniformly the clutch picks up the operating cam assembly on Printer-Perforator 23-A. Impulse Measuring Set 3-A* using Teledeltos paper was used for the recording. The circular Teledeltos disc is rotated through one complete revolution whenever a start pulse is received. The recording stylus is moved radially across the disc from the center to its outer edge. Signal impulses cause black dots to appear on the paper in contact with the stylus whenever a signal transition appears. The stylus moves very slowly and the record develops into a concentration of dots for repeated signals. When the signals occur in exactly the same relation with respect to the start pulse, a relatively thin radial line is produced, but where variations in this time occur the dots are scattered and the width of line is a measure of the irregularity of the subject of the test.

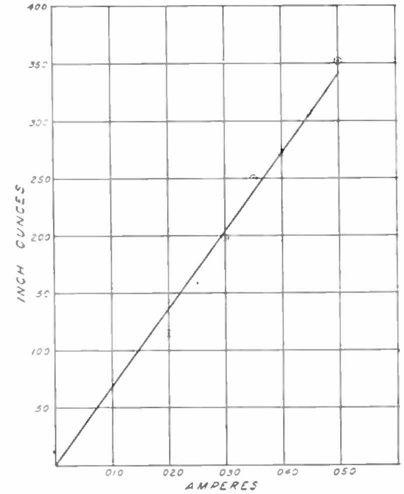

Figure 5. Torque-current curve

The start signal was received from a distributor transmitter which released the operating magnet of the printer-perforator and energized the release magnet of the impulse measuring set. *A* shows the start position of the Teledeltos disc. *B* is the end of the start pulse. Break contacts were added to the printer-perforator and were opened toward the end of the revolution by a stud on the operating cam. This shaft rotates at 750 rpm. *C* shows the point where these contacts are opened and *D* the point where the contacts are closed again. The record at *C* is of primary interest because it shows the uniformity of pickup of the magnetic clutch; that is, once the clutch has been released it picks up the load in the same time for each operation.

* This instrument is similar to the telegraph signal analyzer described in TECHNICAL REVIEW, Vol. 2, No. 3, July 1948.

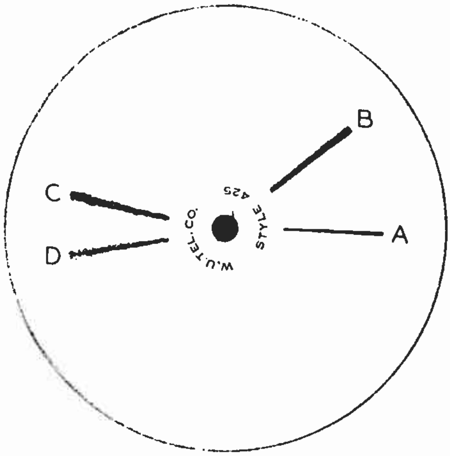

Figure 6.

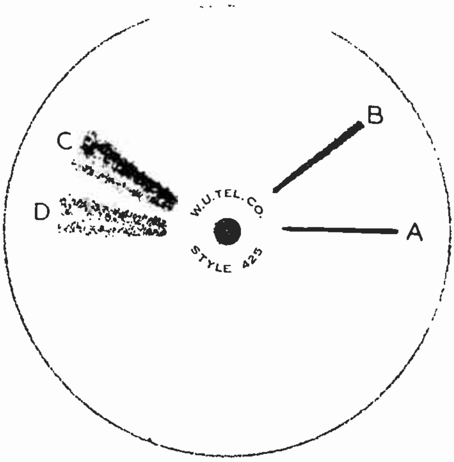

Figure 7.

Relative uniformity of pickup for magnetic and crown clutches

The standard crown clutch used in the printer-perforator has 28 teeth. When the clutch is released, the teeth on the driving member have random positions with respect to the teeth on the driven member. The time at which the load is picked up depends upon the relative positions of the teeth at the time the cluch is released. Figure 7 is similar to Figure 6 and shows the operation of the crown clutch. The record at *C* shows the irregularity of pick-up of the crown clutch. This excursion covers about 13 degrees on the record and amounts to 5 milliseconds variation in time of engagement, which is the equivalent of two clutch teeth.

From Figures 6 and 7 the pickup time of the magnetic clutch may be calculated, inasmuch as the earliest engagement of the crown clutch is instantaneous. The magnetic clutch takes 6 milliseconds from the instant when the clutch contacts are closed, energizing the coil, until the driven member is rotating at shaft speed.

The foregoing is somewhat in the nature of a laboratory progress report. Models have been made and tested but field trials have not been undertaken. For some applications, simple modifications of the instrument of which the clutch is a component appear to be quite practicable. For others, such as the Distributor 45-A, it might be necessary eventually to redesign the entire mechanism to accommodate the magnetic clutch. Evidently, too, the necessity for direct current to operate the clutch could limit its field of use.

Of course new mechanical clutch units as well as those electrically energized are being studied. The fact remains that there is room here for technical advancement in the automatic telegraph apparatus field, and that practical clutch improvement could have wide application.

THE AUTHOR: E. W. Hewitt of the Equipment Research Division was graduated from the University of New Hampshire in 1921 and shortly thereafter joined Western Union as an engineer in the office of the Engineer of Automatics. From the beginning he has been concerned chiefly with the design and development of various types of multiplex printers, teleprinters and printer-perforators. He has himself developed many types of special event projectors, and optical projectors for stock quotation and news services. Mr. Hewitt holds several patents on tape gumming equipment, full and semi-automatic motor control devices, projector tape control mechanisms and printers. He is a licensed Professional Engineer of the State of New York.

INDEX

JULY 1947 (Vol. 1, No. 1) — OCTOBER 1949 (Vol. 3, No. 4)

SUBJECT

INDEX (Continued)

AUTHORS