WESTERN UNION
Technical Review

Ocean Repeaters and Global Telegraphy

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Teleprinter Codes

•

Message Numbering

•

G.E.'S Wire Service

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Graphical Symbols

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Facsimile Systems

•

Automatic Switching

VOL. 8 NO. 4
OCTOBER 1954

WESTERN UNION Technical Review

VOLUME 8
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Presenting Developments in Record Communications and Published Primarily for Western Union's Supervisory, Maintenance and Engineering Personnel.

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The Impact of Submerged Repeaters on Global Telegraphy

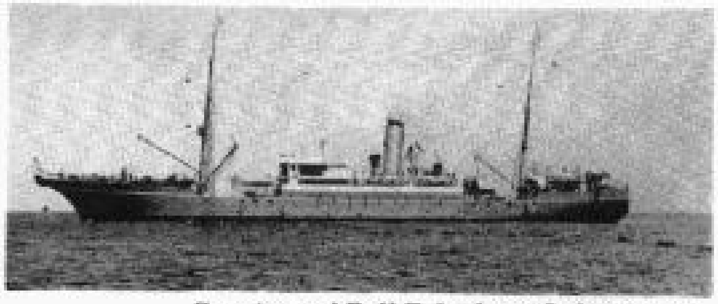
C. S. LAWTON

Introduction

PRIOR TO World War II when global transportation was rapidly taking to the air, it may have seemed to some that global communication by wire soon might be in the same apparently unenviable position as surface transportation media in competition with the airplane. But to the communication engineer it was apparent that—romance aside—the ocean cable possessed qualities which still made it attractive in its own field, and that the potential for improvement in transmission techniques had been by no means exhausted. Thus it happened that when the electronic art reached the stage where an unattended amplifier of satisfactory gain and reliability began to look feasible, cable engineers already had begun to explore the attainment of higher signalling speeds through the introduction of intermediate submerged repeaters.

Naturally the shorter coastal cables lying in shallow water offered the easier solution of the mechanical problems, and at the same time did not require the employment of potentials high enough to damage gutta-percha insulation which, until just recently, was in almost universal use, either alone or admixed with other organic materials to make a compound known as paragutta. Eleven years ago the British Post Office pioneered in the installation of a submerged repeater in a coaxial telephone cable 43 nautical miles long between Anglesey (Holyhead) and the Isle of Man.[1] Three years later one was inserted in a cable 197 nautical miles long between Lowestoft and Borkum (Germany).[2] No depths over 50 fathoms are encountered on these routes.

The French began experiments in much deeper water in the same year, but the first really deep-sea submerged repeater, and the first to be used in a transatlantic cable, was installed in 1950 by Western Union in 270 fathoms depth off Newfoundland in an old gutta-percha-insulated telegraph cable between Bay Roberts, Nfld., and Sennen Cove (Lands End), England.[3] This Company at present has ten submerged repeaters in operation, nine of them in main transatlantic sections, and the deepest in 1230 fathoms. Also in 1950, Western Union's Cable Ship *Lord Kelvin* laid for the Cuban-American Telephone Company two coaxial polyethylene-insulated telephone cables between Key West and Havana, each containing three submerged repeaters, the deepest of which lies in about 900 fathoms of water.[4,5] Figure 1 shows *Lord Kelvin* laying one of the Havana shore ends of the cables, and Figure 2 shows the ship's forecastle head during the laying.

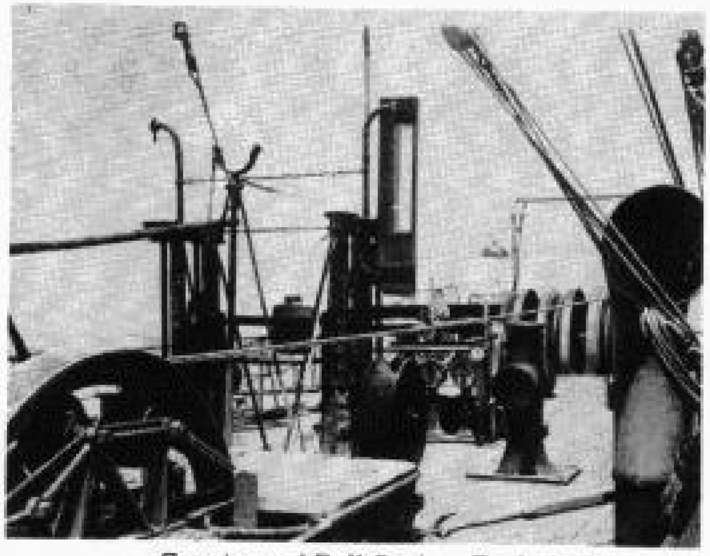


Courtesy of Bell Telephone Laboratories

Figure 1. Western Union's *Lord Kelvin* laying shore ends of Key West-Havana telephone cables

The whole British development has been covered comprehensively in three papers presented in March of this year to the

A paper presented before the Institute of Radio Engineers' Symposium on Global Communications, Washington, D. C., June 1954.



Courtesy of Bell System Technical Journal

Figure 2. Forecastle head, Cable Ship *Lord Kelvin*

Institution of Electrical Engineers in London,[6,7,8] and ambitious plans were announced jointly last fall by the American Telephone and Telegraph Company and the British Post Office for a transatlantic telephone cable which will carry at least 36 voice channels, 29 of them between New York and London, and will employ well over 100 submerged repeaters. This development has been in the planning stage for about 25 years and undoubtedly was accelerated by the development in England in 1933 of polyethylene with its low dielectric constant, extremely high dielectric strength, low power factor, and negligible water absorption characteristic, making it the ideal submarine cable insulator.[9]

PART I

Comparison of Repeater Types

In the matter of whether it is better to design submerged repeaters for one-way use or for two-way simultaneous operation, there are two schools of thought, but both agree that one-way repeaters are by far the simpler. For ordinary telegraph frequencies, no duplex balance is involved. For carrier operation they do not require directional filters, and are more efficient in that they permit the full frequency band to be utilized. The advantage of simultaneous two-way operation of each cable is largely vitiated when repeaters are to be installed in a number of cables serving the same route, some of which cables can be operated in one direction and the remainder in the opposite direction.

When, as in an existing transoceanic telegraph cable, only one or two repeaters can be employed to advantage, and these are to be placed on the receiving side of the ocean, provision in each cable can be made for installations on both sides which are designed to work in opposite directions and can be switched in or out by the nearer shore station. This permits the reversing of each cable at will by selecting the repeater or repeaters to be powered and bypassing the others. Such an arrangement is necessary in the case of interruption of one or more cables working in the same direction in order to restore to the plant the desired balance of eastward and westward traffic flow pending full restoration of facilities.

On the other hand, in the case of a new coaxial telegraph cable for carrier operation with repeaters spaced at uniform intervals, one such cable would far outstrip the whole of the existing transatlantic telegraph cable capacity. Here the initial advantages of simultaneous two-way operation are clear. Even so, if the need for several more cables within a few years were foreseeable, the comparative simplicity of design of one-way repeaters, coupled with the present lack of service experience with the rigid type of casing in any ocean depths greater than 1230 fathoms conceivably might tilt the scales against simultaneous two-way operation, just as doubtless was the case with the new transatlantic telephone cable project.

A rigid, weighty casing is needed for any two-way repeater, and for those one-way repeaters which operate at telegraph (i.e., subaudio) frequencies, in order to accommodate the relatively bulky components. This type of casing has been used for all submerged repeaters now in service except those on the Key West-Havana route.

From the standpoint of handling by the laying or repairing vessel, the ingenious articulated type of one-way repeater developed for carrier frequencies by Bell Telephone Laboratories is ideal for deep-water use. Whether it is to be the ultimate form probably will depend upon the success of intensive research now going on to overcome the obstacles inherent in the rigid type of casing, which cannot be accommodated in a ship's cable storage tanks and will not go through the existing paying-out machinery. This necessitates stopping the ship to get each such repeater overboard. The extra weight of such repeaters also puts additional stress on the cable while in suspension during laying and recovery for repairs. On the other hand, the articulated design leaves much to be desired in the wide physical dispersion of electronic components, even when such components can be made small enough to fit inside a long narrow tube.

Use of Repeaters in Tandem

Transmission by cable of voice frequencies across the ocean has had to wait on the development of means of withstanding high terminal voltages and of boosting the signal level at frequent intervals along the way. On the other hand, the lower frequencies required for telegraphy have been transmitted for almost a century without intermediate amplification between shore points, and with the application of modest potentials at the terminals (anything over 100 volts being considered high).

In applying submerged repeaters to cables insulated with gutta-percha the transmission engineer is limited to a few hundred terminal volts. With the edge of the Continental Shelf anywhere up to 600 d-c ohms from the shore station, there is not enough scope to power more than one or two deep-water repeaters using vacuum-tube amplifiers without running the risk of breaking down the cable insulation. Cables which have been in use over many years are bound to contain some joints which have had to be hastily made due to poor conditions of sea and weather during repairs, and which are low in dielectric strength. The teredo worm, which is found mostly in shallow depths, has chewed some of the older cables where the gutta-percha was not protected by brass tape. Although such damage in Northern latitudes progresses too slowly in general to have been the cause of an excessive number of actual faults under the previous conditions of operation, it has reduced the effective wall thickness of insulation in these cables to an unpredictable degree in the long shallow shore approaches which, with repeater operation, must withstand much higher potentials. Unfortunately these approaches also represent the most expensive parts of a cable to replace because they have to be more heavily armored than the deeper portions.

When, and if, the power required by a repeater can be reduced, naturally more repeaters can be installed. The rapid development of the transistor art gives cause for optimism, but until transistors with characteristics and reliability suited to the demanding requirements of submerged repeaters are available, it is idle to speculate upon their effect on repeater and system design.

The signalling frequency of existing transoceanic cables is limited to something well under one kc. They all use a single conductor with earth-return and no matter how many repeaters may become practicable from a transmission standpoint, obviously there is a fairly low limit to the number which can be installed economically in cables already laid. The most recent long telegraph cables are inductively loaded and in general do not lend themselves readily or inexpensively to repeater operation, it being impracticable to transmit power to the repeaters over a loaded conductor used for signalling.

Selection of Repeater Position Along an Existing Cable

In the absence of induction from other cables, signals which have crossed the ocean in deep water reach the outer edge of the Continental Shelf almost free from contamination, although much attenuated. Therefore, by placing a repeater in this position, at a depth of 250 fathoms or so, it can re-shape and amplify the signals without amplifying the atmospheric noise which penetrates to the lesser depths in the path across the Shelf. Unfortunately, however, there are many cable crossings. Inductive cross-fire interference was fairly common before the days of submerged repeaters. Where transmission is in opposite directions, induction caused by strong outgoing signals in one cable is superimposed on weak incoming signals in the other. Providing such cross fire is not too overpowering, it can be neutralized by connecting a corrective network between the head of the offending cable and the receiving end of the other, but the location of a submerged repeater calls for great care. The signal level on the input side will be much lower than at corresponding points along the cable before, due to greater attenuation at higher frequency, but the strength of the inductive pickup from the other cable will not be affected. It follows that the repeater should be placed beyond crossings with other cables on the same side of the ocean if possible, and this usually involves going beyond the above-mentioned depth of 250 fathoms. In some cases it may involve such a distance from the shore station as to be impracticable. The limiting factors are of course the high IR-drop in powering the repeater and the inability to compensate for the greater attenuation by increasing the signal level at the repeater output.

Crossings several hundred miles seaward of a repeater are not likely to cause serious trouble if they are made at a reasonable angle and if the two lines are well separated in the approaches. Enough evidence has been accumulated to indicate that where abnormal induction occurs at such a crossing, it probably is due to one or both cables being badly out of position and the actual crossing not having been made as intended or as charted. Some old repair work nearby may have been the cause. The plain fact is, of course, that when poor visibility interfered with solar and stellar observations, as it frequently did for days at a time during laying operations, a navigator, until the advent of loran and similar electronic aids, had no way of telling exactly where his ship was being set by wind and current. When next he got a position, he corrected his dead reckoning and tied it in with his last position, but either one or both might have been several miles out, and what had happened in between was still anyone's guess. Consequently, it is not uncommon during repair work to find a transatlantic cable in mid-ocean several miles north or south of its previously charted line. This is no reflection upon the brave seamen, most of them long since gone, who undertook these tasks. They did the best they could with the few aids available, and what they accomplished was nothing short of remarkable, all things considered.

In those cases where the situation prevents installing a repeater on one side of the ocean, one usually may be installed on the other side for operation in the reverse direction, so that the only loss is flexibility in turning the cable around.

It has been regular practice in the case of long earth-return telegraph cables to provide an extra insulated conductor in the shore end for the purpose of making the receiving earth connection out at sea at a sufficient distance to help neutralize interference picked up in shallow water from atmospheric disturbances. Even in the case of coaxial carrier-operated cables, if use is to be made of the lower end of the frequency spectrum a careful study of the shore-end conditions is desirable in order to avoid this type of interference. The value of a separate coaxial tube running out to sea for a suitable distance and properly impedance-terminated to earth at the seaward end has been demonstrated in at least one such case already.

Characteristics of Deep-sea Cable

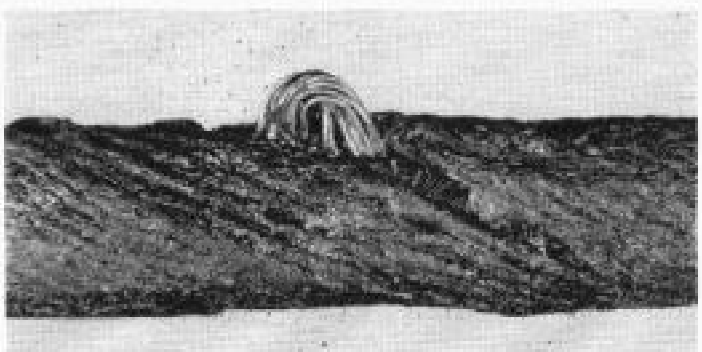
Submerged repeaters have to be conveyed to and from the sea bottom by the cable of which, electrically, they are an integral part. The biggest headache in the laying and recovery of deep-sea cable is torsional stress. At various times consideration has been given to designs which under tension would not twist, but the only instance in which this condition has been approached in actual practice is in some nonarmored cable laid experimentally by Western Union in 1951 at a depth of 1250 fathoms and which, incidentally, is still in use.[10] Ordinarily, torsional balance can be achieved only by applying two sheaths of wires in opposite direction of lay. Cable of this type is expensive and critical to manufacture, difficult to coil down in a ship's tanks, and liable to be erratic in performance. The strength member in the conventional design is a single sheath of galvanized steel wires with a helical lay. The angle with the axis of the cable is kept as small as practicable so as to reduce torsional stress, and the tensile strength of the steel as high as possible without too much sacrifice of other essential physical characteristics, so as to give the maximum ratio of strength to weight. Despite galvanizing and further protection, deterioration of the armor over the years is inevitable. In any subsequent attempt to raise the cable, unit stresses will be developed which are higher in some spots than in others because the deterioration is not uniform along the cable.

Gravity acting upon a helically-sheathed cable in vertical or near-vertical suspension tends to untwist the cable near the top and, if the bottom be prevented from twisting, to twist up the lower suspended portion tighter, since the total number of twists cannot change.[11] If a repair ship with an end raised drops suddenly on the swell, or for other reasons permits slack to accumulate at the bottom, this portion of the cable, not being in torsional equilibrium, will throw itself into round turns which, with resumption of tension, may be drawn out into kinks. When a ship is under way and paying out cable at a uniform rate this is not apt to happen, because it takes time for cable to sink laterally through the water, and the angle made by the cable with the horizontal in its nearly straight-line descent into the depths is small. But if the ship has to stop, the cable sinks into the form of a catenary in which the angle in the upper portion is much steeper. Any relaxation of tension then allows the cable to slide down its own axis, which it can do comparatively quickly and with disastrous result. Hence the cable-man's horror of stopping a ship to put a repeater over or for any other purpose while making a long pay-out in deep water. When such risks have to be taken in repairing a cable or inserting a single repeater, the repair ship is ready and prepared to correct at once anything which goes wrong, but the laying of a long cable with repeaters at frequent intervals is quite a different and more hazardous operation. Before it becomes practicable to lay long cables with closely spaced repeaters of the rigid type, a radical redesign of cable ships' existing paying-out machinery and storage tanks is essential to permit the laying operation to proceed continuously while the repeaters are passing overboard.

Polyethylene is a comparatively new cable-insulating material. It has outstanding advantages, and a few peculiarities which are better understood now than when it first was put into service. As already mentioned, under tension a cable develops torsional stress and, unless forcibly restrained, will untwist. This is accompanied by some elongation of the sheathing wires themselves. Thus the length of the sheath along its axis is increased through both causes, and with it the length of the core (insulated conductor).

Gutta-percha insulation has one thing in common with soft-drawn copper: a low elastic limit. When stretched appreciably it yields and takes a permanent set. However, unless the tension imposed on the cable is extremely high the sheathing wires, in contrast to the core, do not take any appreciable permanent set and, when tension is relaxed, resume normal length and lay themselves up again, substantially, if not entirely, as before the application of the load, thereby shortening the cable just about as much as it had been lengthened. This, one may assume, is the normal cycle when cable is being laid in deep water. Obviously the core cannot retract and, upon the cable being relaxed, becomes wavy inside the sheath, pressing against it and tending to burst through if there be any opening between the wires. When this happens, as it may under extreme conditions, the core protrudes in a long crescent known as a "spew" and, with any subsequent re-application of tension to the cable, may be gripped between adjacent armor wires and squeezed to the point where there is danger of an electrical fault.

Polyethylene being known to be much tougher than gutta-percha, it was assumed that if "spewing" ever developed with this material it would be more fault-resistant than the older insulation. Unfortunately, its "toughness" makes itself evident in other less desirable ways. If stretched it develops a tremendous retractive force.[12,13,14] When a polyethylene-insulated cable with a soft copper conductor is relieved of tension the insulation tries to retract along with the sheathing wires, but the soft copper conductor cannot. Here is a situation where something has to give.



Courtesy of Submarine Cables Ltd.

Figure 3. Typical knuckle fault

The conductor usually is of stranded construction, which makes it particularly weak in resisting axial compression. The excess length of the conductor strands is greatest, and their resistance to buckling therefore is least, at some points where the grip of the insulation is weakest; the concentrated stress presses them against the polyethylene and, as the individual strands are small in size, one of them is liable to split it, following which the whole conductor ruptures the insulation and relieves itself of compression by knuckling (Figure 3). The development of faults of this nature was one of the compelling reasons for going to higher molecular weights of polyethylene which are less liable to rupture, but the fundamental cause can be largely removed by the redesign of the conductor in one of two radically different ways:

a. By adopting a solid conductor which has enough strength in axial compression to resist knuckling.

b. By giving a stranded conductor a greater helical angle of strand lay, thereby making the conductor so limp at all points that no dangerous concentration of compressive stress can develop at any one place. When tension is relaxed, such a core develops a slight uniform helical ripple which is harmless.

Naturally, in a carrier cable with a coaxial return conductor gripping the outside of the polyethylene, there is less likelihood of the center conductor being strong enough to rupture the insulation.

Repair operations seldom can afford the luxury of waiting for ideal weather conditions. It is well to remember that with any sea running, a ship is bound to be an unsteady platform. In addition to the dead weight of the cable and the steady tension necessary to the operation, there is always the live load imposed by yawing and the vertical motion of the ship; occasionally even impact forces develop due to slippage of cable on the drum and sudden restoration of the frictional grip. Radial compression and bending always have to be reckoned with. Yet, it is rare that well-made cable gives any trouble in its early years when properly handled. The size of drums and sheaves over which cable is taken is recognized now as being of prime importance in the control of bending stresses. In 1936 Western Union enlarged the bow sheaves of their Cable Ship *Lord Kelvin* to seven feet diameter to facilitate bringing weakened cable inboard for stoppering off during deep-sea repairs, and in 1950 one of the cable drums and one of the lead sheaves were increased to the same diameter.

Design of Casings

The early model of the Western Union repeater was in the form of a long heavy box which was suspended vertically from the cable by reason of being attached to it at one end only. The cable was gripped by stoppers on both sides beyond the attachments to the casing. The tension was transferred across the top of the repeater by means of a chain span which carried the weight of the repeater and entirely relieved of stress the cable attachments to the casing. Such an arrangement gives no trouble in moderate depths, but is not safe in deep water because the weight imposes a torsional lock which prevents the cable from rotating. Consequently turns cannot be passed along in either direction, and there is a greatly increased propensity to form kinks through a concentration of torsional stress, and most particularly so when a cable has been in service long enough for the sheathing wires to have deteriorated nonuniformly. The kink always finds the weakest point.

rectifiers are sealed in air in small steel tubular casings capable of withstanding sea-bottom pressures which at 1230 fathoms depth amount to over 3000 psi. This makes possible a light repeater casing, built to withstand a reasonable amount of impact but with no idea of subjection to more than a few pounds pressure differential inside and out. This large oil-filled casing being equipped with a pressure-equalizing device, the only real function of the gaskets sealing the covers and the glands which bring the stub ends of core through these covers into the jointing heads, is to keep the oil from leaking out

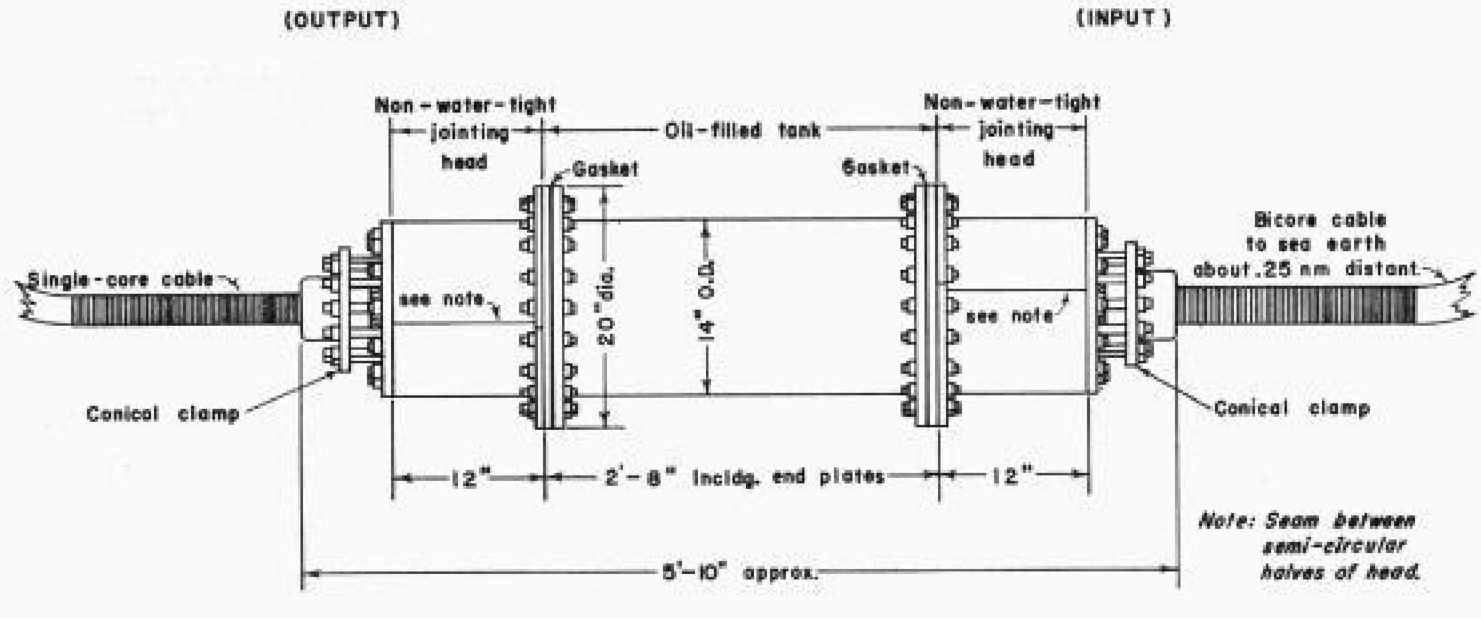


Figure 4. Diagram of Western Union Type 503 submerged repeater connected to cable

In later models used in deep water, the cable enters the repeater at one end and leaves it at the other, both attachments being on the center line of a symmetrical cylindrical casing, and carrying the full load. (See Figure 4.) Thus no torsional lock occurs.

The problem of excluding high pressure from small containers is much easier than in the case of large ones, especially where weight is a factor in the design. Western Union engineers feel that many electronic components including capacitors, wire-wound resistors, transformers and certain types of inductors should work as well in oil as in air, and under one pressure as another, and that it is logical to let them. Other components including vacuum tubes, switches, composition resistors and

before the repeater goes into the water. This presents no problem. High-pressure seals are confined to the small casings, the covers of which are machined to a close press fit, and to the small wires connected therewith. Figures 5 and 6 present two views of the new repeater.

Notwithstanding the general soundness of the design, some early "glandular disorders" were experienced. The trouble was due to a gland cavity not being completely full of insulating fluid. The bare copper conductor knuckled inside the tail end of the gland under compression and touched the steel, causing a ground. With subsequent availability of high-molecular-weight polyethylene-insulated stubs, the gland design was changed to permit the stubs to project inward directly into the

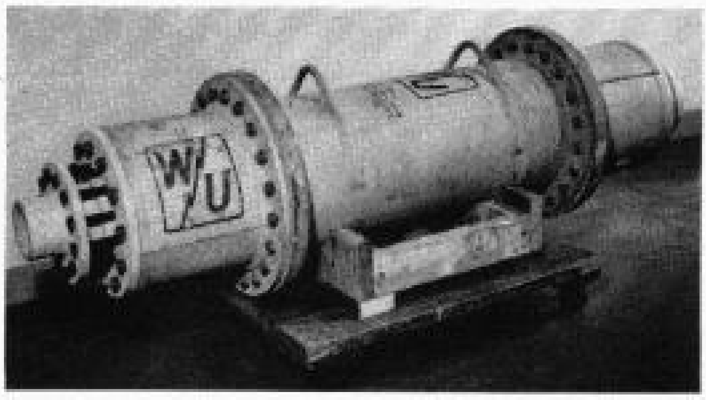


Figure 5. Latest model Western Union submerged repeater with jointing heads at both ends

oil-filled body of the repeater casing. With a pressure tank now available ashore for testing, such troubles at sea do not arise. It has been found advisable to fit a short monel metal compression spring between the gland nut and the follower, because under pressure there is some cold flow and possibly compression of the polyethylene as well, for which the spring effectively compensates.

PART II

Amplifiers at Cable Stations

Electronic signal-shaping amplifiers replaced magnifiers of the D'Arsonval-galvanometer type several years ago at the terminals of all Western Union transatlantic cables. These amplifiers are quite capable of handling the higher speeds of signalling made possible by the insertion of submerged repeaters. It has been necessary only to modify the input networks to compensate for the change in signal shape due to the repeaters.

Channelizing Equipment

All Western Union transatlantic cables are operated by time-division multiplex. The increase in cable speed has required a complete replacement of the old conventional 2-, 3- and 4-channel multiplex equipment. Six-channel equipment is provided for most of the cables and, in order to obtain the best possible operation, face-place transmission has been adopted as against relay transmission used with the older multiplex equipment. Curbed signals also are found to be an advantage.

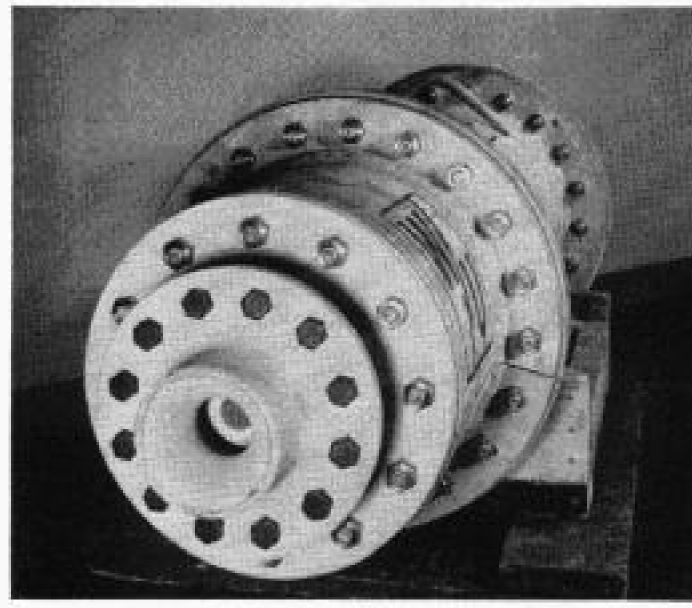


Figure 6. End view of repeater

These requirements dictate very accurately-cut face plates of a larger size than that formerly used on all but the loaded cables and, in order to transmit into the low cable impedance at potentials up to 120 volts, a special arrangement of the transmitting segments is required to prevent arcing-over as the brushes pass from one segment to another. Figure 7 shows one of the new 6-channel distributors. To maintain more accurate synchronism than was required for the old 3- and 4-channel circuits, fork correction is incorporated in the new distributor equipment.

Channel Repeating Equipment

Whereas regenerative rotary repeaters were used formerly to repeat all the signals passing over any one transatlantic cable into a single connecting cable in Newfoundland and in Ireland, the channels of the transatlantic sections are now repeated individually through channel-repeating banks. In general, all channels are now operated at the same speed; therefore channels can be repeated from any transatlantic section into any of the short connecting sections with complete flexibility. For instance, four channels reaching our cable station in Ireland over one 4-channel duplexed circuit from London may be combined with two more channels arriving over another connecting link and be retransmitted into a 6-channel transatlantic cable without regard to phase relationship between the signals, and with

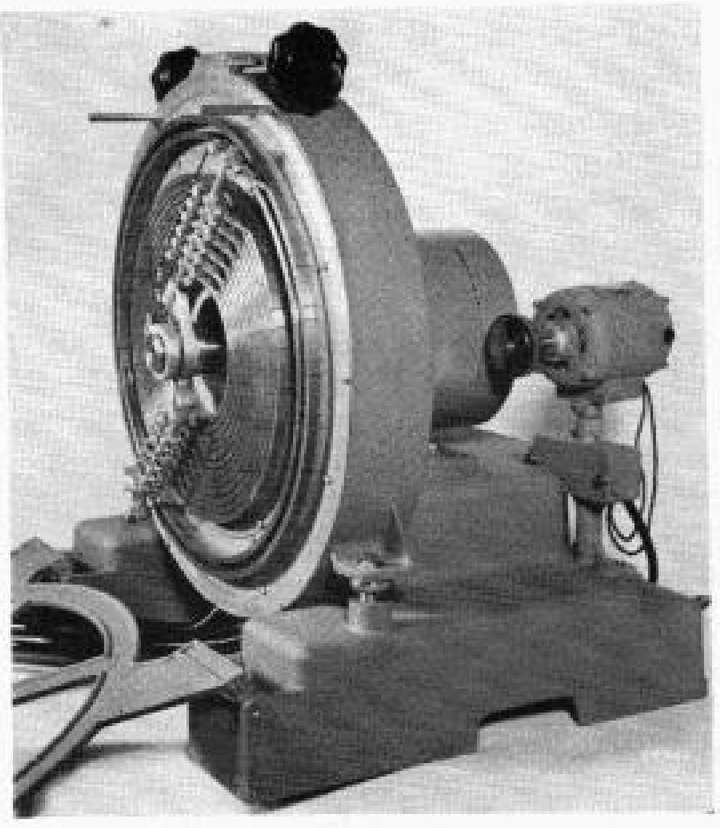


Figure 7. Six-channel distributor

the same freedom and facility usually associated with interconnecting teleprinter circuits. Similarly, when these signals arrive in Newfoundland the channels can again be separated and retransmitted to New York over one or more routes. Some multiplex channels are in fact terminated in Montreal while others coming over the same transatlantic cable terminate in New York. In addition to flexibility, at least two other advantages result. Firstly, there is storage of a whole character in the channel-repeating bank; the loose coupling provided between the receiving and transmitting distributors effectively eliminates synchronizing correction losses so that retransmission at the cable station is practically equivalent to an original transmission. Secondly, maximum utilization of the connecting cables is made possible—their usage is no longer determined by the long section—and practically all connecting cables and landlines are now set up on a 4-channel duplex basis. This provides a feeder capacity in excess of that of the simplex transatlantic sections. If any connecting cable fails, or is taken out of service for line-up or other service interruption, the channels normally carried thereon can be moved immediately to a spare connection; the possibility of losing a transatlantic facility due to connecting-cable or landline interruptions is thus eliminated.

Extension of Facilities

In order to obtain maximum capacity, ocean-cable channels are operated by means of the 5-unit code. Modern demands, however, dictate that it shall be possible and convenient to extend any or all of these channels as teleprinter circuits beyond the normal cable terminals, without introducing delays due to loops of tape or other means of storage. To meet these demands, new and much more flexible extended-channel equipment has been provided. Repetition into a cable channel from a teleprinter circuit requires a perforated tape but, by means of printer-perforators and transmitters of unique design, if the incoming traffic does not exceed the ocean-cable speed, the lag essential in the transition from teleprinter to multiplex is reduced to one character. The transition from multiplex to teleprinter signals at the receiving end of the cable channel involves only a relay bank which imposes a delay of less than one complete character. The teleprinter circuits are readily switchable; hence the cable channels can be extended to any point to which teleprinter circuits are available.

A further feature of the modern extended-teleprinter-channel facility provides for the use, in traffic transmission, of all 32 combinations of the 5-unit code, instead of reserving one combination to indicate the "channel-idle" condition. This feature is of particular advantage in the handling of enciphered traffic.

PART III

IMCO

During the last war a new service became available to the Government whereby, through the use of Western Union's Varioplex system,[15] it was possible for several users simultaneously to share one or more transatlantic channels, thus economizing in cable usage and expense. It was employed notably for secret top-level "conversations" between Washington and

London and aided materially in the successful conduct of the war. A scrambling device further enhanced the inherent secrecy of cable transmission.

Since 1948 essentially the same service between fixed points has been offered to the general public under the name of "IMCO" (a contraction of "International Metered Communications"). It connects a private patron on one side of the Atlantic with his branch or correspondent on the other side. When one or the other wishes to send, he signals Western Union over a teleprinter line used for this service. He is immediately connected to a reperforator which records his message, it then being retransmitted over an available channel and extended to the correspondent on the other side. No salutation or signature is required. Billing is at a fixed rate per character with a monthly minimum character count instead of a minimum charge per message.

With limited cable facilities IMCO could not be expanded much until the submerged repeater came along. Since then, as plant capacity has grown, IMCO has grown steadily along with it. The average transit time for an IMCO message of average length now is under two minutes. Recently completed engineering studies indicate that, as the demand for IMCO grows, the application of sound principles already established as effective in Western Union reperforator switching centers throughout the country can be made to yield greater economy in the use of channel space, flexibility even beyond that which for many years has been engineered into Western Union's global network and, best of all, a still more rapid and dependable service.

Facsimile

Before the advent of frequency-modulated radio, Western Union transmitted press photographs through its loaded cable between New York and London.[16] Although excellent quality of output was achieved, the transmission was very slow by present-day standards. While submerged repeaters in carrier-operated links may make it profitable to engage again in this business by cable, the facsimile method is too demanding of bandwidth to compete now, or in the foreseeable future, with ordinary telegraphy in the handling of message traffic between continents separated by oceans except for pickup and delivery at the terminals.

In the case of a regular subscriber in an urban area whose message volume is too small to justify the use of a teleprinter tie line, the pickup and delivery of international messages often can be handled efficiently by a Western Union Desk-Fax transceiver[17] instead of a call box in the subscriber's office, just as in the case of domestic messages. In fact, there is no technical reason why one such machine should not handle both kinds where both are involved in the same office. A number of customers already use Desk-Fax for handling international messages in London and Montreal as well as in this country.

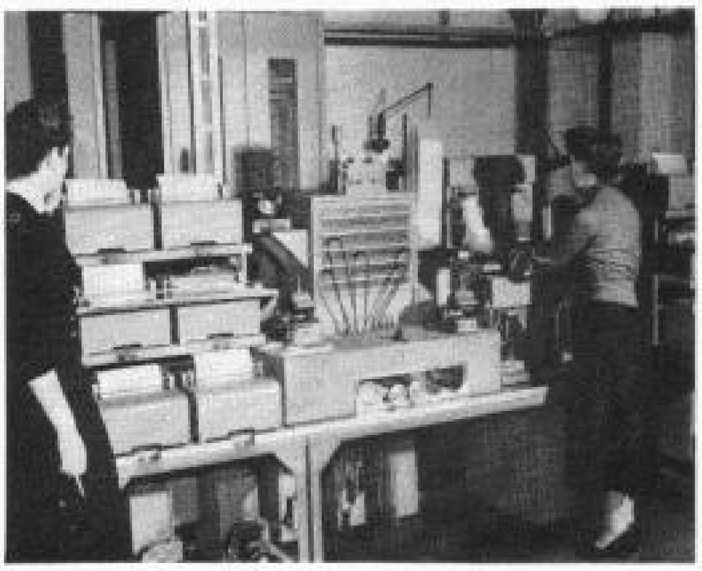


Figure 8. Desk-Fax circuit concentrator position in Western Union's London telegraph office

Government Leases

One of the prime beneficiaries of the increase in capacity brought about by submerged repeaters has been the government which, as a large user of the telegraph, is particularly sensitive to the high degree of secrecy and dependability of ocean cable circuits, as well as to the value of a domestic landline system and an international cable system in which a single engineering control has resulted in the closest possible coordination of design and operating practices. Every governmental cable lease, to a greater or lesser degree, employs both elements in combination, even in peacetime, and the fairly obvious fact would seem to be that in a national emergency, if this country is to achieve without delay the utmost efficiency in the handling of its global telegraph traffic, an international telegraph plant, closely integrated with the domestic plant, will be a necessity.

Further Expansion

With a further growth of ocean cable plant capacity expected when tandem submerged repeaters drawing less current can be installed in the older nonloaded cables, and the advent of carrier telegraphy in new intercontinental cables, it is expected that many new ways will be found to serve the public and the governments of the world, as well as the means further to enlarge existing services.

As the number of channels to be derived by time-division is increased, it is obvious that a point will be reached beyond which multiplex faceplates carrying brushes revolving on commutator rings become too large and cumbersome. Some forms of electronic time division already are in use. Others are under development to ensure that means will be available for deriving the additional channels for which there will be space on the older cables with repeaters in tandem but operating below the speeds at which frequency division of the signalling spectrum becomes practicable.

As far as is known, frequency modulation is not employed by any of the European national administrations in their inland or international cable networks, but in view of its wide acceptance in this country for telegraph channeling [18,19] and its superiority to amplitude modulation in any well-designed application, it would be the natural choice for any transatlantic carrier telegraph system. Western Union uses FM on its overland carriers between New York and North Sydney (Nova Scotia), and between Penzance and London. FM carrier is also employed on Western Union's Key West-Havana cables.[20]

Automatic reperforator switching,[21] so successful in this country's domestic telegraph systems, both public and private, has yet to be applied to ocean cable networks, but message volume is reaching the point where the same underlying economic factors are operating to extend it to global telegraphy.

The Ultimate Objective

A steady trend throughout Europe toward the integration of domestic and international telegraphy has been apparent for the last twenty years, and frequently has been discussed in print.[22,23,24] The inland switching network which the Germans had built by 1939 was designed not only as a national domestic system but as the foundation for an international subscriber-to-subscriber service. All the other Western European domestic networks are now either established or well on the way to establishment on the same basis of through-calling and switching with teleprinters of universal characteristics for conducting two-way conversations. Submerged repeaters have played a large part in the provision of the requisite circuits as far as European connections to the United Kingdom are concerned.

Whereas the high cost of transoceanic channels probably will limit the global expansion of this kind of service for some years to come, the advent of the submerged repeater already has opened up a new vista for on-demand no-premium subscriber-to-subscriber working between countries, and it is reasonable to think that eventually carrier-operated ocean cables will usher in the day when either a governmental or a private subscriber located anywhere on one continent not only can communicate by telegraph directly and privately with any other subscriber, or subscribers, located anywhere on any other continent, but can do so with almost the same dispatch and reliability of service as is provided domestically. Surely this must be the ultimate goal of global telegraphy.

Meantime, the standardization of operating practices and the characteristics of apparatus present problems which, while relatively minor, admittedly will be thorny. Personal-user two-way transoceanic telegraph service will be difficult to justify on economic grounds for some time to come, even between well-developed areas. Meanwhile, the additional intercontinental circuits resulting from the use of submerged repeaters will be operated mainly on a bulk basis between reperforator terminals, with the individual user feature confined to the subscribers' local connections with those terminals. The aim will be to provide such rapid transmission of messages over the reperforator-switching system that a pair of subscribers can exchange communications with a good degree of approach to the two-way user combination.

So much ingenuity has been displayed already that we must be prepared for anything. Please do not take this too seriously, but who knows? If, by the time the Utopian era of global telegraphy has come, a universal language has not come with it, some engineer probably can be counted upon to devise the truly Utopian translator: one which will permit an international subscriber to type his message in his own language and have it delivered automatically and accurately in the language of his correspondent. When that happens, facsimile really will have to look to its laurels!

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Mr. Lawton is General Plant Engineer, International Communications Dept., The Western Union Telegraph Co. His biography appeared in the October 1953 issue of TECHNICAL REVIEW.

Teleprinter Codes: 7-Unit Versus 7.42-Unit

F. W. SMITH

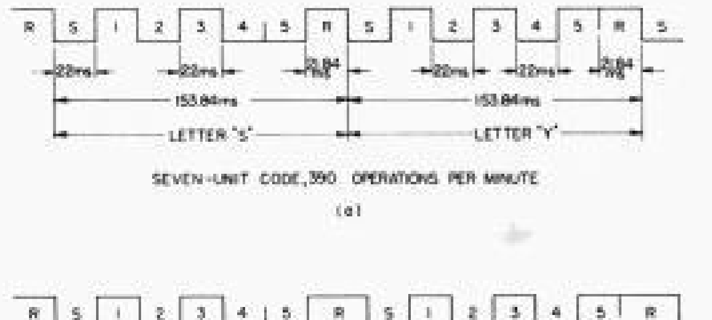
IT IS frequently necessary to operate a 65-word-per-minute teleprinter in the same circuit with a so-called 60-wpm teleprinter (actually 61.25 words per minute). The question is often raised as to how teleprinters of different speeds can send to and receive from each other with no loss in range or operating margin to either teleprinter. It is the purpose of this article to explain the compatibility of the two speeds. For the sake of completeness, the teleprinter signaling code is described and the principles of operation of a receiving teleprinter mechanism are outlined.

Start-Stop Teleprinter Code

The start-stop teleprinter signaling code is an electrical code consisting of seven current and no-current intervals, called pulses. A current interval, which energizes the selector magnets, is called a marking pulse; a no-current interval, which does not energize the selector magnets, is called a spacing pulse.

The first pulse in the signaling code is always a spacing pulse. This pulse releases the receiving shaft of the teleprinter and allows it to start rotating, for which reason it is called the "start" pulse. The next five pulses in the signaling code are intelligence pulses and any one of them may be either marking or spacing. There are 32 possible combinations of these intelligence pulses and the combination received by a teleprinter determines the character to be printed or the function to be performed. The seventh and final pulse in the signaling code is always a marking pulse, which stops the rotation of the selector shaft and causes it to remain at rest until receipt of the start pulse for the next character transmitted. For this reason the seventh pulse is called a "stop" or "rest" pulse.

The length of the start pulse is always the same as the length of an intelligence pulse. This seems to be a universal practice, used wherever the 5-unit Baudot code has been adapted for start-stop teleprinter signaling. There has been no such standardization, however, on the length of the rest pulse in relation to the length of the intelligence pulses. For example, Western Union uses a signaling code, commonly referred to as a "7-unit" code, in which the rest pulse is approximately the same length as the intelligence pulses. Other commercial telegraph users in this country employ a code in which the rest pulse is 1.42 times as long as the intelligence pulses, and which is called a "7.42-unit" code. In Europe, both the 7-unit and the 7.42-unit codes are used, as well as a 7.5-unit code with a rest pulse 1.5 times as long as the intelligence pulses.



SEVEN-UNIT CODE, 390 OPERATIONS PER MINUTE (a)

7.42-UNIT CODE, 367.5 OPERATIONS PER MINUTE (b)

START-STOP TELEPRINTER CODES

Figure 1

Figure 1(a) illustrates the 7-unit code commonly used by Western Union for transmission at 390 characters (65 words) per minute. The two signal trains shown represent the letters "S" and "Y". The start pulse and each intelligence pulse is 22 milliseconds long and the time required to transmit one character is $60/390 =$ 153.84 milliseconds. The rest pulse is 21.84 milliseconds long. The rest pulse is slightly shorter than the intelligence pulses as a result of "rounding off" the angular dimensions of the transmitting cam sleeve. In order to obtain seven exactly equal pulses, the angular spacing between cams would have to be $\frac{360}{7} = 51.43$ degrees. The actual spacing chosen was 51.5 degrees.

Figure 1 (b) illustrates a 7.42-unit code, in which the start pulse and each intelligence pulse is 22 milliseconds long. The rest pulse is 31.24 milliseconds long and the time required to transmit one character is, therefore, 163.24 milliseconds. The maximum speed of transmission is $\frac{60}{0.16324} = 367.55$ characters per minute. The angular spacing of the start and intelligence cams has been rounded off to 48.5 degrees so that the actual length of these pulses is $\frac{48.5}{360} \times \frac{60}{367.55} = 0.02199$ seconds. The rest pulse length is $\frac{69}{360} \times \frac{60}{367.55} =$ 0.03128 seconds. The speed of the transmitting shaft may also vary slightly from the nominal value shown in Figure 1. This speed is usually considered to be 368 opm. All of these differences are, of course, insignificantly small.

Only a small portion of the total selector pulse length is required to set up a selection in a teleprinter. The remainder of the length of the pulse is used to provide an operating margin so that the teleprinter will be able to operate when the received signals are distorted or when the teleprinter itself has internal irregularities which cause variations in the times at which the selections are made. These variations may be caused by worn or defective parts or by maladjustment of the teleprinter. A device called a range scale is used to orient the selector mechanism to the received signals, by determining the point at which each pulse is sampled. The manner in which the range scale is utilized to obtain optimum operating margins will be explained in detail in the following paragraphs.

Teleprinter Selector Mechanism

Figure 2 is an exploded schematic drawing of the receiving selector mechanism on a teleprinter widely used in Western Union services. The selector cam sleeve assembly of this mechanism consists essentially of a stop arm and five selector cams assembled on the cam sleeve by means of a nut and soldered together so that the peaks of the selector cams are 55.5 degrees apart. This assembly is mounted on a main shaft which rotates continuously. The cam sleeve is free on the main shaft and is driven by a pair of friction clutches. When the selector cam is in the stopped position, it is prevented from rotating by the latching surface on the lower arm of the stop pawl, which engages the stop arm on the cam sleeve assembly. When a start pulse is received by the selector magnets, the armature is pulled away from the magnet by a spring (not shown in the figure). The trip-off screw on the armature extension then moves the trip plunger to the left and this, in turn, rotates the bell crank counterclockwise. The horizontal arm of the bell crank rotates the latch about its pivot, and the left end of the latch unlatches the upper arm of the stop pawl which is then free to rotate about its shoulder screw. The stop arm on the cam sleeve is thus unlatched and the cam sleeve is free to rotate.

During the early part of the revolution of the cam sleeve assembly, the No. 1 selector cam rotates the No. 1 selector lever about its pivot and causes the No. 1 sword to move towards the two vertical arms on the armature extension. If the armature is in the marking position at the time the selector lever rides to the peak of its cam, the right arm of the sword will strike the right arm of the armature extension and the sword will pivot in the selector lever so that the tip of the sword will move to the left. If the armature is in the spacing position at the time the selector lever is rotated about its pivot, the left arm of the sword will strike the left arm of the armature extension and the tip of the sword will be moved to the right. As the cam sleeve continues to rotate, the remaining four selector swords are positioned in the same manner. The positioning of the swords is transferred to associated mechanical members which determine the character to be printed or the function to be performed by the teleprinter. After all five selections have been made, a sixth cam (not shown) on the cam sleeve assembly trips off another clutch to cause the printing or the function to be performed.

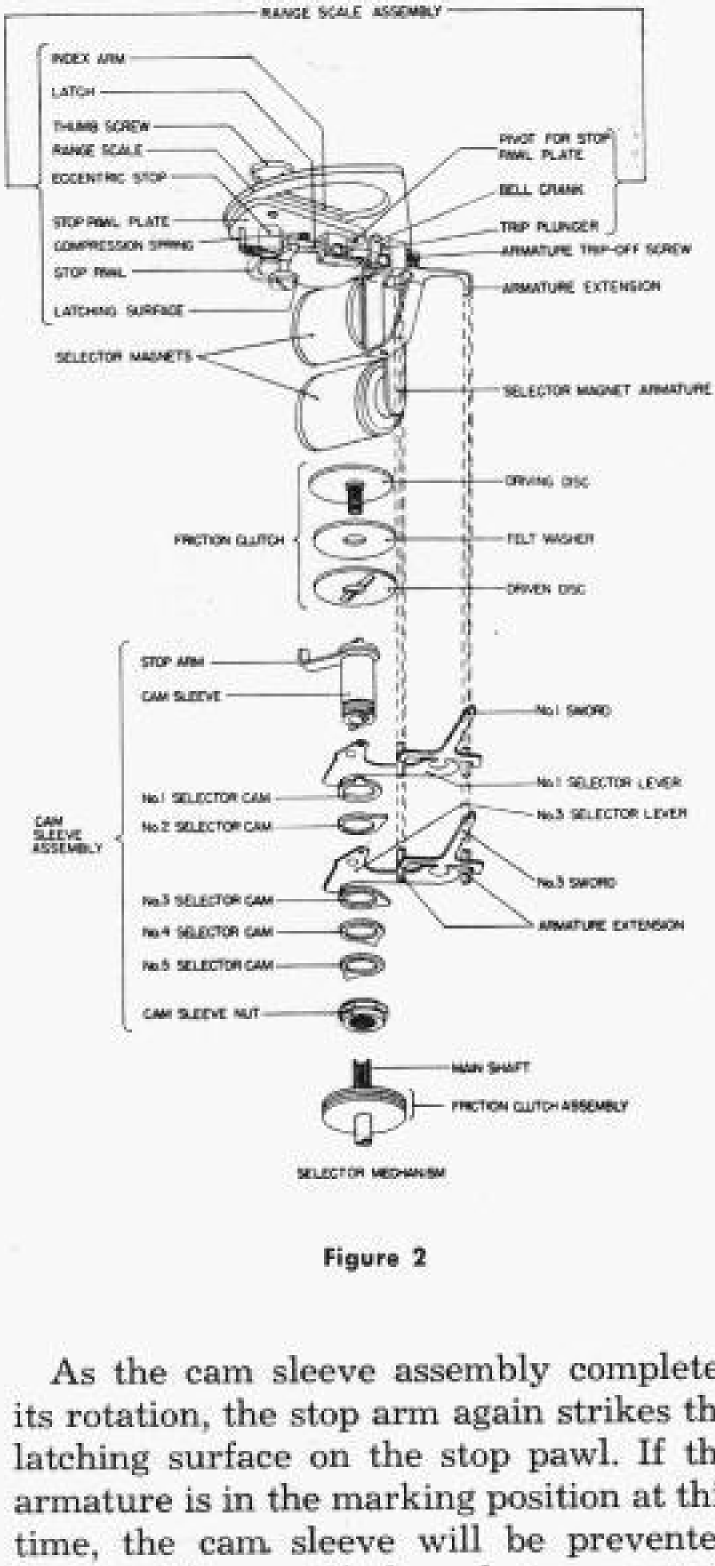


Figure 2

As the cam sleeve assembly completes its rotation, the stop arm again strikes the latching surface on the stop pawl. If the armature is in the marking position at this time, the cam sleeve will be prevented from rotating until the selector magnets are again deenergized.

The stop pawl and its latch are mounted on a plate which is pivoted directly above the center of the main shaft. An index arm on the top of the range scale is pivoted about the same point. The index arm and the stop pawl may be rotated together about their pivot through an angle of approximately 66.6 degrees and clamped in any position in this arc by means of the thumb screw. This changes the position of the stop pawl and therefore determines the position from which the cam sleeve assembly will begin its rotation. The top plate of the range scale assembly has an engraved scale which is marked off in percent of a pulse length, from 0 to 120. A pointer on the index arm indicates the point at which the stop pawl is set.

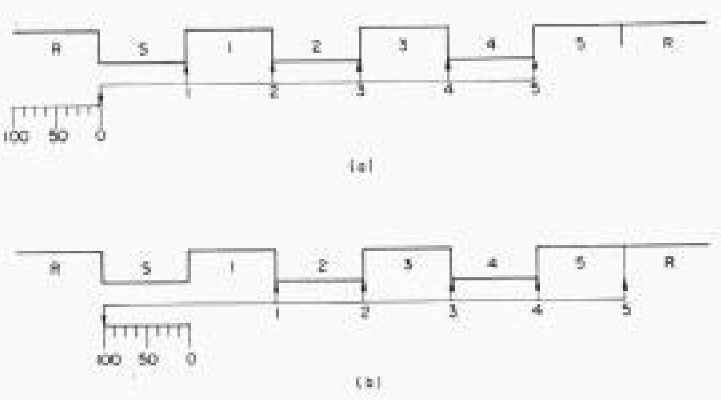
> NOTE: For the sake of clarity, a locking cam on the cam sleeve assembly and an associated locking lever have been omitted from the drawing. Just before each selection is transferred to its sword, one end of this locking lever drops into an indent in the locking lever cam and the lever pivots about the selector lever post. The other end of the locking lever engages a wedge (not shown) on the armature extension and locks the armature in its selected position until just after the transfer has been completed so that the armature will be prevented from moving if a pulse transition occurs while a selection is being set up.

The nominal speed of the main shaft is 420 rpm and the peaks of the selector cams are spaced 55.5 degrees apart. The time between two consecutive selections is, therefore, $\frac{60}{420} \times \frac{55.5}{360} = 0.022$ seconds. As shown in Figure 1, this is the length of a code pulse in the 7-unit code at 390 opm and also in the 7.42-unit code at 367.5 opm. Since the shaft speed is 420 rpm, the shaft rotates once in $\frac{60}{420} = 0.14285$ seconds. Neglecting the release time of the selector magnet and the take-up time of the selector clutch, the cam sleeve will complete its revolution approximately eleven milliseconds after the beginning of the rest pulse. During the remainder of the rest pulse, the cam sleeve is held stationary as previously explained. Thus, a receiving teleprinter will operate satisfactorily when receiving signals from either a 367.5-opm, 7.42-unit-code keyboard or from a 390-opm, 7-unit keyboard. When receiving at the slower speed, the teleprinter receiving shaft will remain at rest for a longer period of time at the end of each revolution than it will when receiving at 390 opm. There will be no other difference in the operation of the receiving teleprinter at the two different speeds.

Effect of Range Scale Setting

Figure 3(a) illustrates schematically the effect of setting the index arm on the range scale at zero. At this setting, the stop pawl is positioned so that the cam sleeve begins its rotation with the No. 1 selector cam approximately 45 degrees from the peak of the No. 1 selector lever. The first selection, and each succeeding selection, will be made at the beginning of the pulse. With the range scale index arm set at 100, as shown in Figure 3(b), the cam sleeve will begin its rotation with the No. 1 cam approximately 100 degrees from the peak of the No. 1 selector lever and the selections will be made at the ends of the pulses. If the range scale index arm were set above 100 or below 0, errors would result in the copy.

If it were possible to construct a perfect teleprinter, with no internal distortions and with zero time required to set up each selection, the range of the teleprinter, when receiving perfect signals, would be 100 points. Because a finite time is required to set up a selection, a range of 100 points is not possible, even when there are no internal distortions in the teleprinter.



RANGE SCALE SETTINGS

Figure 3

In order to insure that the sampled portion of the pulse is located near the center, the index arm is moved towards the high end, while signals are being received, until errors begin to occur in the copy, then moved slowly back towards the low end until the errors cease. The low end of the range is then determined in a similar manner and the index arm is set midway between these two points.

Synchronism

If synchronism is to be maintained between the receiving teleprinter and the transmitter, the selector magnets must be energized at the time the cam sleeve assembly completes its revolution, in order that the cam sleeve may come to rest and remain at rest until the next start pulse is received. If the rest pulse begins too late or ends too early the stop pawl will not latch up the cam sleeve at the end of its revolution and errors will result.

At 420 rpm the receiving cam sleeve completes one revolution in 0.1428 seconds and this time is entirely independent of the range scale setting. When a start pulse is received, a definite time is required for the selector magnet to release and time is also required for the clutch to accelerate the cam sleeve assembly to 420 rpm. The total of this release time plus the clutch take-up time for the teleprinter illustrated in Figure 2 is approximately 6 milliseconds. The cam sleeve assembly will therefore complete one revolution approximately 148.8 milliseconds after the beginning of the start pulse. The total length of the start pulse and the five code pulses is 132 milliseconds and the rest pulse thus begins 132 milliseconds after the beginning of the start pulse. That is, the rest pulse begins 16.8 milliseconds before the shaft completes its revolution. This provides ample margin to allow for the operate time of the selector magnets and also to permit the teleprinter to operate satisfactorily when the signals are affected by spacing bias and the fifth pulse is a spacing pulse. Since spacing bias delays the beginning of a marking pulse, a spacing bias of sufficient magnitude may cause the selector cam sleeve to fail to stop at the end of its revolution. The teleprinter will then make errors and these errors will occur regardless of the range scale setting.

Send-Receive Ratios

A typing unit equipped with a selector mechanism such as that illustrated in Figure 2 may be used on a keyboard geared for 367.5 opm or on a keyboard geared for 390 opm. If the transmitting shaft on the keyboard is geared for 367.5 opm, the transmitting cams must be cut to transmit a 7.42-unit code. If the typing unit is used on a 390-opm keyboard the cams must be cut to transmit a 7-unit code. In either case the nominal speed of the receiving shaft is the same. The actual speeds of the receiving shaft and the transmitting shaft may vary slightly because of the limitations imposed by the necessity for selecting practicable gear ratios and standard motor speeds.

In the 7.42-unit code, the nominal ratio of the transmitting shaft speed to the receiving shaft speed is $\frac{367.55}{420} = 0.8751$. The actual gear ratio used is $\frac{7}{8} = 0.875$. In the 7-unit code, the nominal ratio is $\frac{390}{420} = 0.9285$. The actual gear ratio used is $\frac{12}{13} = 0.9230$. (The reason for choosing a gear ratio of $\frac{12}{13}$ instead of $\frac{13}{14}$ when the 7-unit code was first developed is not evident from the early design data still available.) Thus, a slight variation from the optimum speeds is unavoidable. The usual design practice is to increase the receiving shaft speed slightly or decrease the transmitting shaft speed slightly, or both. In no case, however, does the speed of either shaft vary from the nominal by more than three-fourths of one percent.

There is no standard method of compromising on the send-receive ratio. If a teleprinter is driven by a synchronous motor, the receiving shaft speed is nearly always exactly 420 rpm and the compromise necessary is made by reducing the transmitting shaft speed. On the other hand, if a governed motor such as a d-c shunt or an a-c series motor is used, the compromise may be effected in a number of ways, depending on the location of the target used in conjunction with a tuning fork to adjust the motor speed. If this target is located on the transmitting shaft of the teleprinter, the transmitting shaft is usually held at the nominal speed and the receiving shaft speed is therefore greater than the nominal speed because of the compromise in the send-receive ratio. If the target is located on the motor governor, either the transmitting shaft or the receiving shaft speed may vary from the nominal, depending on the number of spots on the target and the frequency of the tuning fork used.

The differences in speeds of the transmitting and receiving shafts of various types of teleprinters account for the occasional loss of several points in range when a teleprinter equipped with a synchronous motor is used in the same circuit with a teleprinter equipped with a governed motor. For example, if a keyboard operating at 387.7 rpm transmits to a teleprinter whose receiving shaft speed is 422.5 rpm, the range of the receiving teleprinter will be reduced by several points.

Even in the design of distributor-transmitters, where there is no send-receive ratio to be considered, it is usually necessary to compromise on the transmitting speeds, the pulse lengths, or both. For example, when a Model 14 Distributor-Transmitter is powered by an 1800-rpm synchronous motor and geared for 367.55 opm (nominal), the gear ratio used is $\frac{9}{44}$. This gives a transmitting speed of 368.18 opm. The start segment and each intelligence segment is 48.5 degrees long and the actual length of the start pulse and each intelligence pulse is 0.02195 seconds. The rest segment is 69 degrees long and the rest pulse is 0.03123 seconds long.

7-Unit Versus 7.42-Unit Code

In the 7-unit code, the end of the rest pulse occurs approximately 5.2 milliseconds after the cam sleeve has completed its revolution. This allows ample margin for variations in the release time of the selector magnets and the take-up time of the clutch. It also permits some variation in the speed of the receiving shaft, which may occur when a governed motor is used to drive the teleprinter. Since no selection is made during the rest or the start pulse, the end of the rest pulse does not affect the range obtained on the teleprinter; that is, if the transition from the rest pulse to the start pulse occurs too early the teleprinter will make errors and these errors will be independent of the range scale setting.

In the 7.42-unit code, the end of the rest pulse occurs approximately 14.4 milliseconds after the cam sleeve has completed its revolution. This allows greater margin for the variations cited in the preceding paragraph.

The 7-unit code permits transmission of a greater number of characters per minute than the 7.42-unit code, and this is the only real advantage obtained by using a 7-unit code. This is a considerable advantage, however, since the 6.12 percent increase in output results in a saving of line time and operator time.

A 7.42-unit code provides greater margin against error in the receiving teleprinter motor speed than does the 7-unit code. If a teleprinter motor runs too fast, the teleprinter will have the same margin regardless of which code is used, but if the motor runs too slowly, the 7.42-unit code with its longer rest pulse will provide greater margin than a 7-unit code. This advantage may have been of some importance during the early days of the printing telegraph industry, but with the development of fractional horse-power synchronous motors and improved governors for nonsynchronous motors, this advantage is now of little significance.

This discussion has been restricted to a comparison of the 7.42-unit code at 367.5 opm with the 7-unit code at 390 opm, since Western Union uses the 7.42-unit code at all speeds greater than 65 words per minute. One reason for this is that the teleprinters developed by other companies in this country are designed to use a 7.42-unit code and there is considerable advantage in using commercially available equipment without special modifications to suit Western Union requirements. Another reason is that the selector magnet release time, which does not vary with speed, represents a greater percentage of the rest pulse length at the higher speeds and thus reduces the margin by a greater amount.

F. W. Smith joined the Applied Engineering Division of Western Union in 1946, after having served four years as a radar maintenance and repair officer in the U.S. Army Signal Corps. He has worked on the design and field application of mechanical equipment used in start-stop printing telegraphy and in reperforator switching. He is now in charge of the Mechanical Equipment Group in the Apparatus Engineer's office. Mr. Smith graduated from the Georgia Institute of Technology in 1938, with the degree of Bachelor of Science in Electrical Engineering.

A New Automatic Message Numbering Machine

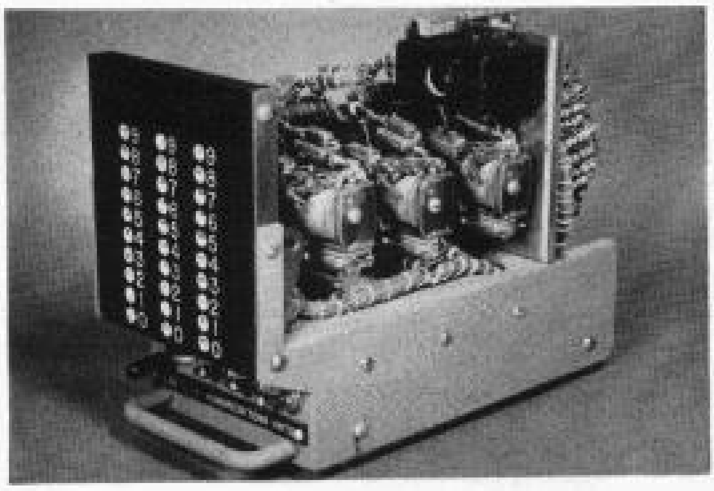
For the past two decades Western Union has used its well-known drum type automatic message numbering machine in reperforator switching systems that handle the general public's telegrams, and in private wire systems leased to patrons such as U. S. Steel, United Air Lines, General Electric, Sears Roebuck, U. S. Air Force and many others. Recently, a rotary switch type machine was developed, primarily to reduce first cost and to obtain greater flexibility in application to the ever increasing requirements imposed by newer designs of reperforator switching systems.

The original drum type numbering machine provided for 2-digit numbering of messages and was capable of sending ten characters, eight of which could be arranged for any combination occurring in the "fixed" portion of a message number series, the other two being the tens and units digit numbers. It was equipped with a main drum having ten rows of removable studs that permitted setting up the desired arrangement of characters, and two other drums for controlling the 2-digit numbers. Later, in order to make the numbering machine more applicable to heavily loaded circuits, it was redesigned to include a hundreds-digit drum, thus enabling it to send 3-digit numbers and seven fixed characters.

Subsequently, it was found desirable, in the development of many varied private wire switching systems, to have the automatic numbering machine transmit more than ten characters. This was accomplished by equipping it with a new main drum that permitted the transmission of twelve characters (a 3-digit number and nine fixed characters).

This type of change is expensive and has obvious limitations, but it was not until the introduction of the small 10-point rotary switch that it became feasible to develop a numbering machine that would be more flexible than the drum type and yet would mount in the same space. Three of the small switches are used to control the hundreds, tens and unit digits, while a larger 20-point or 25-point switch transmits the successive characters, the total number being limited only by the number of points on the larger switch. A panel with three rows of ten neon lamps displays the message number last sent.

In addition to its lower cost and ability to send more characters, the new machine has other advantages. The lamp display of the message number is easier to read; the reset time is extremely short, less than one second;



and no manual manipulation other than operating a nonlocking switch is required when restoring the number to 000. The three digit switches may be stepped independently by means of three push buttons, thus permitting any particular message number to be set up readily in the machine during times of transmission difficulties or when a machine due to be serviced is replaced by a spare.

A multiconductor receptacle on each rotary switch numbering machine is wired to the points on the large rotary switch that transmit the call letters of the circuit with which the numbering machine is associated. A cooperating multiconductor coding plug is appropriately strapped for indicating the specific call letters to be transmitted. When it is necessary to remove a machine for servicing, the coding plug is transferred to the substitute machine. This simple operation avoids the necessity of providing spare machines with each of the various call letter combinations, or of changing the studs on the main drum as would be required with the drum type machine.—J. E. Stebner, Engineer, Switching Development Division.

MAIN SWITCHING CENTERS OF THE GENERAL ELECTRIC SYSTEM

General Electric's Telegraph Switching System After Five Years

V. L. HUGHES

TECHNICAL REVIEW articles usually and properly treat primarily with the engineering development of telegraph apparatus. However, there is much of interest and satisfaction to be found in examining the final product of an engineering project after it has been in active service for some time.

For such an examination, and also as a sequel to past articles in TECHNICAL REVIEW about the development of apparatus for private telegraph switching networks,[1,2] a typical customer-operated Plan 51 system might be taken. The widespread General Electric network, now five years old, is a good example. It is a nationwide network with 9 main switching centers, the largest of which is in Schenectady, and 302 offices; the network employs 63,430 miles of telegraph circuits for the direct two-way exchange of volume communications, the longest circuit being 2350 miles in length. As the accompanying map shows, each main switching center has an alternate route to every other main switching center for use in case the regular circuit is temporarily out of service. Equipment for the network was engineered and is maintained by Western Union and some centers, notably that at 60 Hudson St., New York, are in Western Union buildings, but operation is entirely by General Electric.

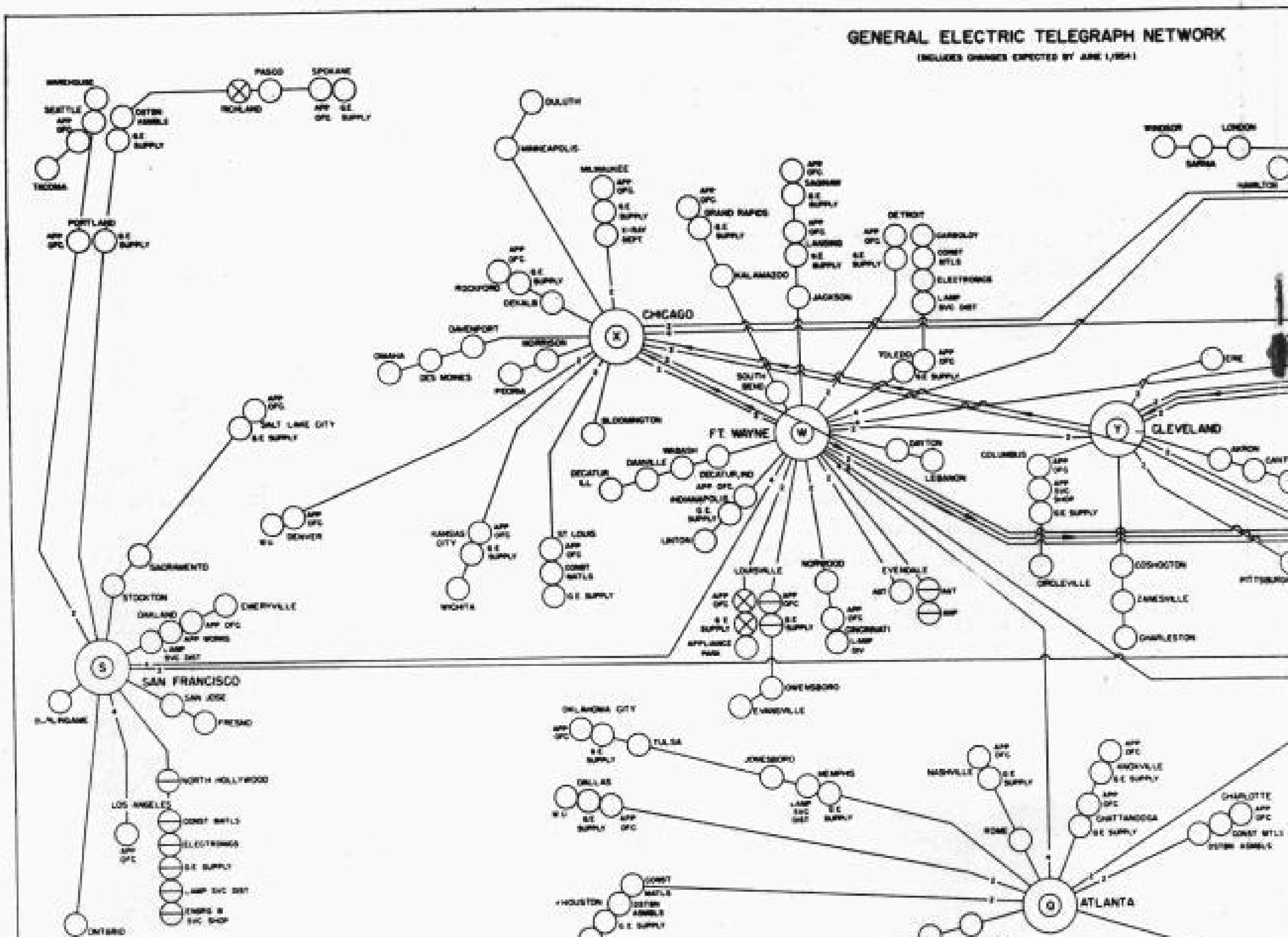
The measure of continued success of any large leased telegraph network is the sum of three factors: customer performance in efficiency of operation and quality of service rendered; telegraph company performance in engineering, maintenance and continued improvements and refinements to suit customer's requirements; and the joint efforts of both in all respects.

The area of joint cooperative effort between the customer and the telegraph company really is not a separate area at all, but it is the all-important attitude and atmosphere of understanding and helpfulness in which customer performance and telegraph company performance mesh smoothly and make the whole network venture profitable for both. If that atmosphere did not exist it is extremely doubtful that, however good the customer's performance or that of Western Union, the system could have achieved the success which it has.

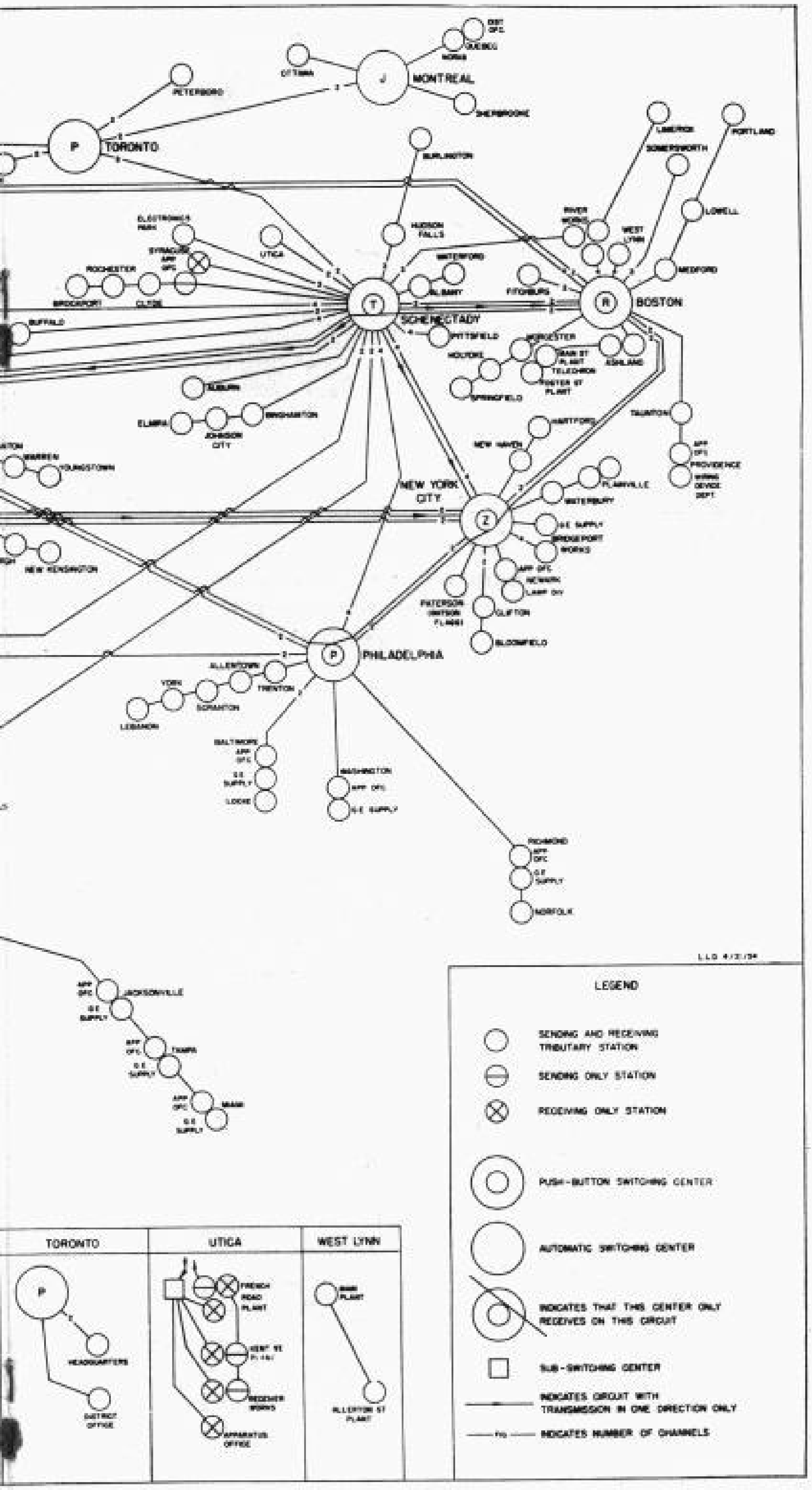
Tight, efficient administrative control of network operation by the customer is essential to insure high quality service and close control of costs. Fortunately General Electric has an exceptionally able administrative group at headquarters with many years' experience with telegraph service and equipment. This experience covers the use of apparatus obtained from Western Union as well as from the telephone company, including a "fully-automatic" Type S-81 system which five years ago was replaced by the telegraph company's Plan 51 system.

The administrative group is headed by Mr. E. I. Hibbard, Manager of Interplant Communications and Transportation, who has general executive supervision over the network as well as many other nontelegraph activities. Mr. E. H. Nelson, Supervisor of Interplant Communications, has direct supervision over the network and is assisted by a staff of six experienced people. There is also a local supervisor at each switching center.

It will assist in understanding the functions and problems of this group to visualize it as having somewhat the same relationship to General Electric departments and individuals using the private system as the telegraph company's management bears to the general public. The group has to provide service of a quality which will attract usage from more expensive or slower methods of communication and at a price acceptable to the user. On a



somewhat smaller scale these specialists have nearly all of the operating and service problems of the telegraph company—labor, force assignments, complaints, claims, budgets, and even the occasional cantankerous user who will not be satisfied with anything. If the General Electric administrative staff did not have the ex-



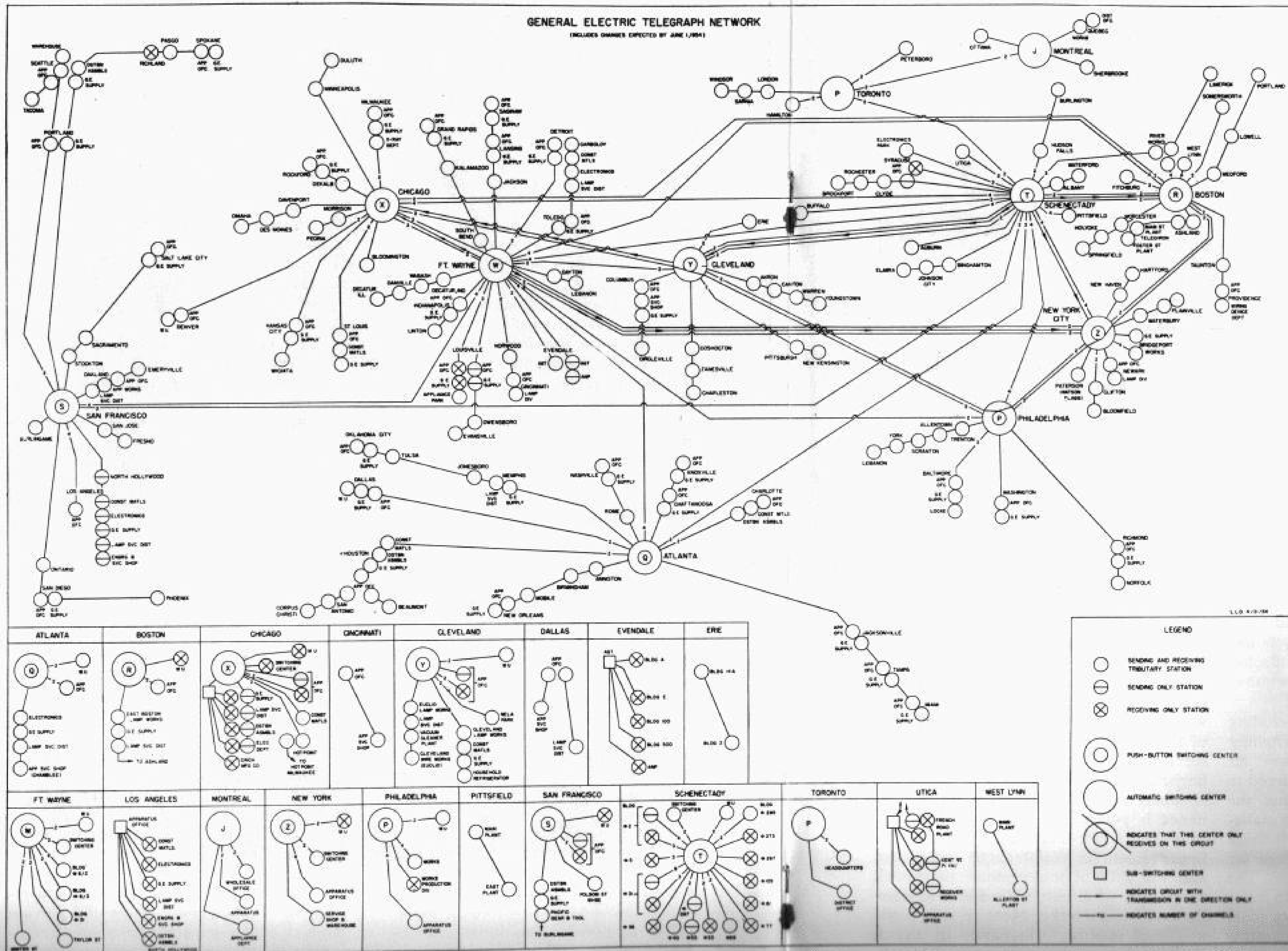
perience and ingenuity to meet successfully all of these problems, the network could not have attained the importance it has in General Electric operations.

The adequacy of circuit facilities and equipment over the whole network is subject to continuous review. Basic information is obtained by having each switching center report at the end of each week the sent and received message loads for service drops and for trunk circuits for each day of that week.

Whether circuits are overloaded, or too lightly loaded, readily comes to light and remedial action can be taken, plans can be made to add more service drops to existing circuits, or drops which have become uneconomical can be eliminated; the efficiency of use of switching center apparatus can be judged and alterations can be made in trunk circuits as required.

In addition to the points now served by the system there are about 75 other small General Electric plants and offices throughout the country not now having network service because their communications volume does not warrant it. Periodically and frequently data on the communications usage and expense at these places are examined and network connections are provided when service requirements and economics so dictate.

A day-to-day watch is kept on the continuity of service at all drops and each switching center supervisor reports by wire to Schenectady headquarters any drop or circuit which may be out of service for any reason for a period of longer than 30 minutes. This of course is in addition to trouble call reports to local Western Union maintenance personnel. The switching centers also report at the end of the month details



somewhat smaller scale these specialists claims, budgets, and even the occasional

perience and ingenuity to meet success- of cour

V. L. Hughes served Western Union as a Morse operator for four years starting in 1917. After various managerial assignments in the Eastern Division, including that of Chief Clerk in the District Superintendent's office, ten years' experience as District Manager and District Sales Manager followed. Mr. Hughes then served on the General Manager's staff which experience equipped him well for his assignment in 1946 as Division Manager—Private Wires Services. In this position he has been influential in the planning, sale and installation of the General Electric, U.S. Air Force, General Services Administration and other private wire systems. He maintains and supervises customer relations with all these companies and with the U.S. Steel Corporation for their leased systems. His work with GE has been particularly fruitful as is attested by the accompanying article.

of all interruptions during the month. These reports are brought to the telegraph company's attention whenever that appears necessary.

General Electric headquarters is at all times aware of the quality of performance with respect to continuity of service and maintenance. This is most welcome, of course, because it gives assurance that either commendation or criticism will be factual and fair and based upon the telegraph company's whole performance rather than on incomplete and scattered evidence. Thus the entire day-to-day operation of the network by General Electric and by the telegraph company is under constant scrutiny, as is any developing need for additional or reduced requirements.

The total cost of the network including the cost of facilities, wages for switching center labor, rent, light, heat, power, air conditioning and supervision is charged to the various GE departments using the service. This is done by means of a statistical study once yearly from which there is developed a flat rate per message for each point connected to the system. The rate applies to all normal length messages regardless of the distance they must travel. A higher rate applies to accounting reports and other long transmissions.

General Electric considers its leased system a special part of the nationwide public telegraph system and features this in its intracompany publications about the network. It is interesting that in the total cost of the network operation the expense for "refile" service is included so that the rate-per-message charge to a using department contemplates that cost also. A "refile" message, of course, is a message to a point not on the network and which travels part way over the leased system and then is transferred to Western Union for handling to destination. At switching center points, and at some other points, these refile messages are simply push-button switched to the local Western Union office for onward handling. Approximately 26,000 refile messages are transferred to Western Union monthly.

Western Union's part in the success of the network is vital also. Of initial importance was the superior engineering skill which went into the design and building of the equipment which has enabled it to serve its purpose so well. Of continuing importance is the excellent maintenance of apparatus. Adequate preventive maintenance is performed, response to trouble calls is prompt, and there is continuous improvement in maintenance techniques and the skill of maintenance personnel. Continuity of circuit operation is another factor of importance. Mention was made above of monthly summaries of circuit outages prepared by General Electric. Comparisons made between the total operating hours monthly of all GE circuits and the total amount of lost time reflected in these reports indicate that the percentage of lost time monthly is approximately four-tenths of one percent. The quality of the circuits and apparatus used in the network contributes to this achievement, of course, but nevertheless it is also a high tribute to all of the Plant and Engineering personnel whose devoted and skillful work make it possible.

Basically the Plan 51 apparatus remains the same as when it was installed late in 1948, but many refinements and improvements have been introduced over the years which have increased the system's efficiency and value. Many of them were suggested by General Electric's expert telegraph people and others grew out of some special requirement.

An arrangement to have perforated tape, produced by telephone-recording Flexowriter equipment, feed directly into distributor-transmitters and thence into the network enabled General Electric to achieve economies in the telephone recording of messages and improvement in the service. Selected switching cabinets were equipped so that during certain hours of the day they could be used for the double termination of one circuit and during other hours as single terminations for two circuits; thus in certain circumstances greater efficiency of switching cabinets is obtained.

For use at nonswitching center cities having a multiplicity of local delivery drops, a small continuous-tape, cord-and-plug unit was devised to permit rapid distribution of incoming traffic after directorizing. A special feature of this equipment is a device at each drop to transmit an "answer-back" letter to the switching unit as an acknowledgment for each message.

Another refinement which has resulted in much economy and service improvement is a duplex way circuit, so-called, to interconnect groups of three Plan 51 switching centers. A circuit of this kind, for example, connects the Boston, New York and Philadelphia switching centers. It consists of one duplex circuit between New York and Boston and another between New York and Philadelphia. The Boston switching center has two push buttons, one labelled New York and the other Philadelphia. When Boston depresses the New York button the message is received at a printer-perforator position in the New York switching center; when Boston depresses the Philadelphia push button the message does not go into the New York switching aisle but is automatically switched to the sending side of the New York-Philadelphia duplex and is received in the Philadelphia switching aisle. Operation in the other direction is performed in the same manner.

Prior to the introduction of this type of circuit all of the Boston-Philadelphia traffic in both directions was switched by push button at New York. The new circuit saved switching labor at New York and improved service between Boston and Philadelphia. There are seven such circuits now in the General Electric network and these with the conventional switching center-to-switching center trunks give 50 direct trunk outlets instead of the 34 which existed before the introduction of the new circuit. Many other improvements and refinements of varying degrees of importance have been introduced and still more are under consideration.

The unhesitating willingness with which all sections of the Plant and Engineering Department entered into consideration of suggested improvements and the ingenuity which followed in the design and installation work was most heartening to the customer and to those who carry on customer relations with General Electric.

That the network has been highly successful is amply attested by the following brief statistics:

	5 Years Ago	Now	Percent of Increase
Number of service drops	149	302	102
Number of Plan 51 switching centers	7	9	28
Number of channel miles of circuit....	31,656	63,430	100
Number of daily originating messages	8,000	20,000	150

It is of great satisfaction that the growth from General Electric's standpoint has been sound every step of the way. No service drop was added and no additional circuit ordered until the GE officials had proved it to be justified as to both economics and service.

All that has been said above about the General Electric network applies with equal force to the other Plan 51 telegraph switching systems leased from Western Union. Because the GE system has recently passed its fifth birthday, almost coincidental with the celebration of General Electric's 75th anniversary, it seemed to be a very appropriate system for the subject of this article.

References:

1. A Modern Reperforator Switching System for Patron Telegraph Service, R. F. DIRKES, *Western Union Technical Review*, Vol. 2, No. 4, October 1948.
2. Patron Switching Systems, *Western Union Technical Review*, Vol. 4, No. 1, January 1950.

Standardized Graphical Symbols

The 1954 meeting of the International Electrotechnical Commission in Philadelphia marked the 50th anniversary of an organization which gives continuous, methodical study to problems of standardization in electrotechnical matters. National committees from many countries participate in the work of the I.E.C. In the United States the Electrical Standards Committee of the American Standards Association is responsible for the U. S. National Committee of I.E.C.

Among the many subjects discussed at the 1954 I.E.C. meeting was Graphical Symbols. It has long been recognized that standardization results in appreciable economies. The adoption of standard types of equipment, for example, permits reducing the variety of individual components which must be manufactured and carried in warehouse stocks. The adoption of standardized circuit and operating procedures results in reduced training and operating costs. The value of these and similar forms of standardization are readily acknowledged, but the desirability of standardizing graphical symbols is not always fully appreciated by the average engineer.

Fortunately, the problem has been given serious attention by small groups of engineers representing industries of all types. Considering graphical symbols employed only in communications and allied fields, the present status appears sufficiently stabilized to warrant a brief review of recent advances and a summarization of the accepted practices. A primary reason for this discussion is to point out that failure to adhere to standards, once adopted, can create much confusion. Deliberate individualism in this matter should not be condoned; inadvertent deviation should be guarded against. Only through wholehearted cooperation will the full benefits of standardization be realized.

Early in the last world war, it was realized that the symbol —||— as used on electrical diagrams was the cause of many costly misunderstandings. When used on power drawings, it represented an open contact; on communications drawings it represented a capacitor. When power and communications groups joined the military effort and collaborated in preparing drawings for battleships, warplanes and other armament, it frequently happened that radar, intercoms, power plants and the like were indicated on the same drawings, As a result, that symbol was confusing and at times meaningless.

In 1941, agreement was reached whereby that symbol would be reserved to represent an electrical contact, with the alternative symbol being permitted for showing open contacts on communications relays and other devices. At the same time, the symbol —|(— was adopted to represent a capacitor.

Admittedly, there was dissatisfaction among communications people, and many failed to conform with the newly designated standard. Even today, a few die-hards can be found who insist on using the antiquated symbol. Actually, time and usage has proved the wisdom of adopting the new capacitor symbol. It is more useful than the older one because the curved line permits distinguishing constructional differences in a capacitor, such as the negative plate of an electrolytic capacitor or the movable plate of an adjustable capacitor.

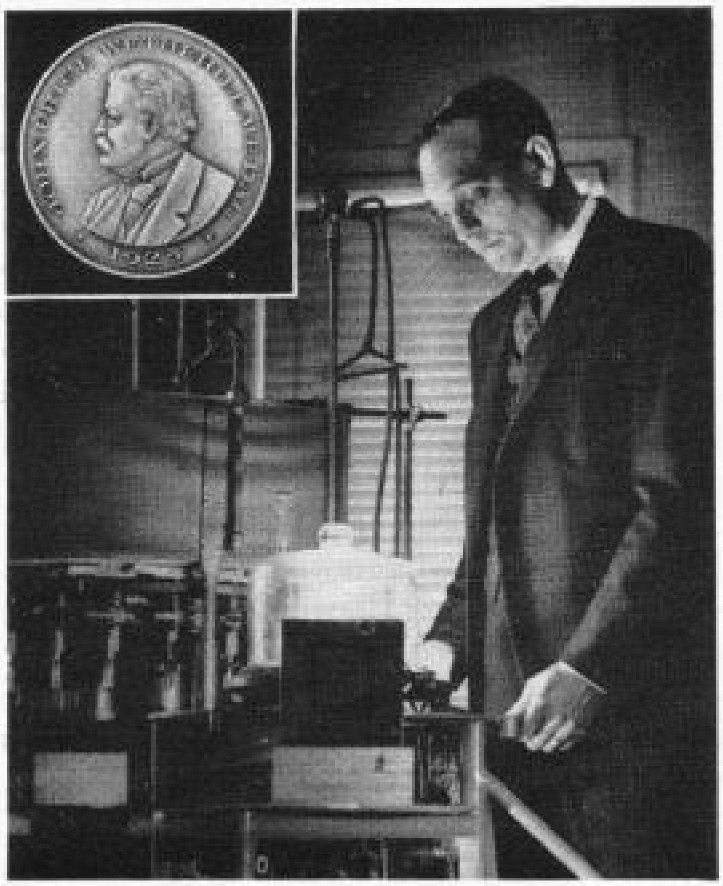
Other existing symbols have been carefully reviewed and conflicts similar to the example cited have been eliminated. Complicated symbols have been simplified, and new ones to cover late developments have been devised. The end results now have been assembled in an official publication by the American Standards Association (ASA) entitled *American Standard Graphical Symbols for Electrical Diagrams Y-32.2 1954.*

Since the scope of this publication is limited to theoretical presentations, many concerns, including Western Union, are issuing company standards which broaden the scope of the ASA publication to cover specific details met within their own practices. At first this may appear unnecessary, but it should be apparent that while a symbol such as —|(— is entirely adequate to indicate a capacitor on schematic and theory drawings, standard designations and letter symbols must be added to distinguish between different types of capacitors actually used as component parts in the assembly of equipment. Such expansion of the scope of the ASA graphical standards will also assist, especially where the physical aspects of the component part can be incorporated in a symbol to produce a more readily understood drawing.

Adoption of standard graphical symbols for use in Western Union research and engineering is an implementation of the basic principle; the designated symbols are the result of a comprehensive review of the problem by Western Union engineering and drafting personnel and do not conflict with the ASA accepted symbols. They include, in general, necessary additions for use on detailed wiring diagrams and usually involve a simple mechanical representation of the particular type of unit.

Since variations from accepted standards may result in erroneous interpretation by manufacturers, field personnel and others, a sincere effort should be made to conform to the published symbols. Items which are inconsequential to the engineer may be of major importance to the installer or maintainer and vice versa. Quick and accurate recognition of all graphical symbols employed on a drawing must be the goal for all drafting practices if the pitfalls are to be avoided. If every one will cooperate, meticulous usage of this symbolic language will become habitual and the inevitable benefits will become readily apparent.—L. A. SMITH, Ass't to Planning Engineer, P. & E. Dept.

William D. Buckingham, a physicist of the Development and Research Department of Western Union, is to receive a John Price Wetherill Medal, according to an announcement by The Franklin Institute of the State of Pennsylvania. Presentation will be made at the annual Medal Day exercises at the Institute in Philadelphia on October 20, 1954.



A citation accompanying the medal, which is awarded for discovery or invention in the physical sciences, reads: "In consideration of his invention of the Zirconium Concentrated-Arc Lamp, a device capable of producing a high intensity, sharply defined, extremely small beam of light and with modulation characteristics heretofore unobtainable in practical devices."

Mr. Buckingham, Assistant Electronics Research Engineer at the Water Mill Laboratories, developed the zirconium lamp as a light-beam communications device for the armed forces but in recent years its use for industrial and scientific applications has greatly exceeded military requirements.

Facsimile Systems

A. S. HILL

FOR THE PAST twenty-odd years, concurrently with its program of mechanization of its nationwide printer-operated network, Western Union has followed a program of development of facsimile equipments to which are applied the family name of "Telefax"*. Since World War II, this program has been accelerated. At the present time, the telegraph company is using some 14,000 Telefax machines, mostly in its terminal handling operations at about 60 cities, by which more than 17,000,000 messages are handled per year. More than 60 private systems have been installed for business concerns in 35 cities throughout the country. More than 3500 additional machines are scheduled for installation during 1954.

Although most of the "Telefax" apparatus mentioned in this article has been described in detail previously, the article is intended to provide a valuable summary of current applications.

Introduction

It seems important to many writers on the subject to point out that the facsimile idea is very old. It is in fact one of the oldest ideas for electrical communication. Six months before Professor Morse sent his famous first message from Baltimore to Washington, Alexander Bain was granted a British patent to a facsimile system.

Despite the fact that the idea is very old, the fascination of newness clings to it. While its wonderful baby brother "TV", which transmits and reproduces many complete pictures per second, has become commonplace, people are still impressed at seeing a document transmitted from a distance speedily reproduced before their eyes on a sheet of paper.

Many ingenious machines and systems were developed over the years since Bain. Telegraph people, recognizing the advantages of errorless transmission, inherent with facsimile, followed with interest all developments in the art and cooperated in the operation of some earlier systems.

For good reproduction about 10,000 picture elements must be transmitted per square inch of subject copy. To get any kind of production at all the picture element signals must be transmitted at a rapid rate and receiving machinery must respond to those rapid signals. It is understandable, therefore, that real success in the art had to await the development of the vacuum tube and the photoelectric cell. With those marvelous devices available, the development of a commercial facsimile machine was in a large measure reduced to a problem of mechanical design.

With the universal acceptance of the idea that "a picture is worth ten thousand words", it was only natural that the first of the modern family of machines was designed for picture transmission. The high commercial value of pictures, delivered rapidly over distances, justified costly facsimile machines and the necessarily associated photographic equipment, high quality transmission lines and specially trained operating personnel. Progress in picture transmission has been so rapid and successful that the public takes for granted that pictures of today's happenings most anywhere in the world will appear in today's newspaper.

We of the telegraph industry sincerely admire and fully appreciate the splendid achievements of our friends in the picture transmission branch of the art. We feel, however, that economically and systemwise our task of applying facsimile to the public message and private wire services was the much more difficult one. To be acceptable in public message service, the facsimile method had to handle millions

A paper presented before the IRE National Convention, New York, N. Y., March 1954.

*Registered Trademark of The Western Union Telegraph Co.

of message units at a very low unit cost dependably and economically.

TELEGRAPH APPLICATION

Recording Paper

At the time that the telegraph company undertook facsimile development to meet its requirements, all existing machines employed either photographic film or wet chemically-treated paper for recording. These methods, requiring developing or drying of the recorder copy, were unsuitable for rapid message handling. The first problem, therefore, was to develop a dry paper on which, without further processing, the received message would be permanently recorded and ready for immediate forwarding. This problem was solved with the invention by a Western Union engineer of "Teledeltos"*, an electrically-conductive dry paper with a light colored coating which turns permanently black at all points where electrical impulses flow through it.

First Applications

During the early years of the program a variety of Western Union Telefax equipments were developed. These included transmitters, recorders and transceivers as well as switching, signalling and control equipments, each designed with a view to efficient performance in some phase of telegraph operations. A few systems were engineered for private concerns. One of these, for the delivery of messages at unattended stations along a railroad to control the movement of trains, included many novel features.[1] Some long distance operations were successfully conducted also. Of the many Telefax machines of prewar design, however, only the automatic-feed slot transmitter fits in with the present program.

By the beginning of World War II, some heavily loaded branch offices in New York City and a few hundred heavy telegraph user customers, in four cities, were being served by Telefax.

For many years teleprinter connections had been provided between central telegraph offices and the offices of the bigger customers, but many tens of thousands of customers making regular use of the telegraph were served by the branch office-messenger method. With the high costs obtaining at the end of the war, it was imperative that a less costly substitute be found for this method and at the same time the speed of service be improved in keeping with the tempo of the age. Not only is the teleprinter expensive and bulky, but when operated at far below capacity it is inefficient, and frequently it is not acceptable to small business establishments. Although simpler and less expensive than teleprinters, earlier types of Telefax machines were nevertheless too costly and bulky and a bit too complicated to be considered for the widespread application contemplated. Conditions demanded the development of a lower cost, smaller, less complicated and more easily maintained Telefax transceiver.

CURRENT APPLICATIONS

The Desk-Fax System

In the Desk-Fax system, as with earlier arrangements for intracity operation, synchronized commercial power available throughout most cities is depended upon to keep connected machines in synchronism during operation, thereby avoiding the cost of precisely controlled power supplies for each customer machine. The inversion of the transmitted facsimile signals necessary to produce a positive copy by direct recording is provided for at the relatively few transmitters and recorders at the central office. A speed of 180 scanning strokes per minute is used to permit operation over telegraph and telephone line pairs commonly available throughout cities. Account was taken of every possibility inherent to the facsimile principle to bring to an irreducible point the cost of the Desk-Fax[2,3] machines for use in customers' offices. At the same time every possible safeguard against message failure is incorporated in the system as a whole. Simplicity of operation, essential to economical performance and customer acceptance, has been achieved to a remarkable degree.

Today's modern Desk-Fax (Figure 1) occupies a space 11½ by 12 inches on a table or desk in the customer's office. Being a handsome device with an easy to clean hammertone finish, it blends with the decor of the modernly appointed office. Weighing only 24 pounds, it can be carried in and installed or exchanged for maintenance with a minimum of effort and confusion. It is permanently connected with the central telegraph office and kept plugged into a 115-volt a-c outlet in the customer's office. It draws no power when not in use and consumes 150 watts while sending or receiving messages.

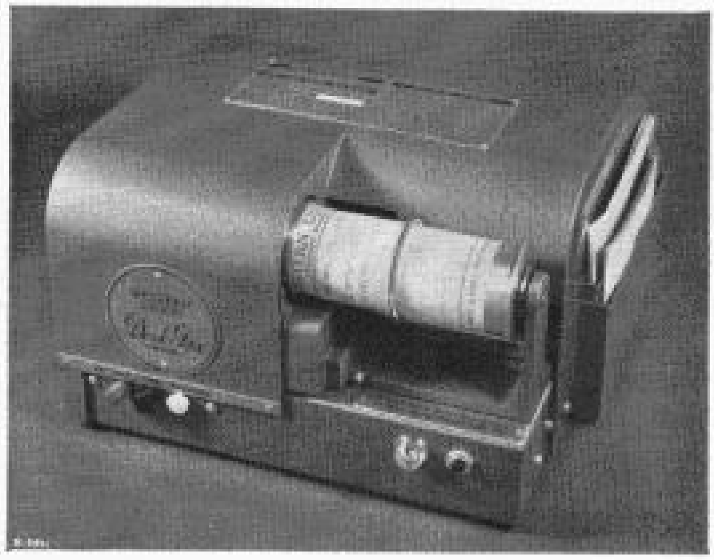


Figure 1. Over a million telegrams a month are sent or received by customers using simple W.U. Desk-Fax

Central office concentrator positions (Figure 2) equipped with four vertical drum transmitters[4] and six page recorders[5] serve up to 100 customers' lines each. Any one of the 100 customers' lines must be operable with any one of the ten central office transmitters or recorders without adjustment of any kind. Therefore, all lines must be equalized by attenuation padding and resistance loading, and output levels and receiving gains must be kept at predetermined values throughout the system.

Central office equipment is arranged for best operating efficiency. As many as possible of the electronic components and line terminating units are located apart from the mechanisms with which the operator is solely concerned. As with the Desk-Fax, the central office machines are activated by push buttons.

In this system the a-c facsimile signals are transmitted over the line pair at voice frequencies. The line pair is "simplexed" to provide a d-c path for calling and acknowledging in both directions and for the automatic performance of all control functions.

Figure 2. With six recorders, four transmitters, central office operator serves 100 Desk-Fax lines

Only seconds are consumed in activating the machines for sending or receiving messages at the customer's office and at the central office. The machines require no attention while in operation. Customers' personnel need no training. The Desk-Fax can be operated by anyone following the few simple instructions on the cover. Central office operators already schooled in rules and practices common to all telegraph methods need only simple instruction in routine.

The Desk-Fax system has been very successfully applied. Customer acceptance has been enthusiastic. Additional usage of telegraph service has been stimulated by the easy-to-use machines. There are clear indications that with the completion of the present program providing for 17,500 customer installations by the end of 1954, estimated economies will be realized.

OTHER SYSTEMS IN PUBLIC MESSAGE SERVICE

While since World War II the emphasis has been on the customer tie-line program for which the Desk-Fax system was developed, Telefax has been applied to some other phases of terminal message handling.

The Autofax System

The term "Autofax" has been applied to a slot transmitter[6] and a recorder which are about as completely automatic in operation as can be imagined. These machines (Figure 3) are installed in hotels, hospitals, and similar institutions, usually authorized agencies of the telegraph company. The message chute of the transmitter is closed on stand-by. To send a telegram, a button is pressed and the message chute opens. When the telegram has been inserted into the chute, it closes and remains closed until the message has been transmitted and the original deposited into a locked receptacle in the bottom of the transmitter housing. During transmission, the push button has no control over the unit. Along the top front of the machine are panels which are illuminated to display plainly certain legends in proper sequence, such as "deposit telegram," "telegram being transmitted," and "telegram received—thank you." This transmitter somewhat resembles the smaller type corner mailbox.

Like the transmitter, the Autofax recorder[7] is completely enclosed. It is loaded with a continuous roll of "Teledeltos" sufficient for about 800 telegrams. It answers calls, records telegrams, cuts them off and deposits them in a closed receptacle in the bottom of the housing. Upon receipt of a telegram, a visual or audible signal is activated and remains so until the door of the receptacle is opened for removal of the telegram.

Figure 3. Fully automatic recorder and transmitter

One form of this recorder crimp-seals the received telegram so that only the address information is readable until the seal is broken.

The Telecar System

The Telecar system has been developed to provide better delivery service to the outlying areas of larger cities as an improvement over the branch office-motor messenger arrangement. An experimental system[8] was installed in Baltimore in 1947, and early in 1952 a permanent system was put into operation there.

Four fixed radio stations operating on frequencies of 35.22, 35.46, 43.22 and 43.46 megacycles, respectively, are strategically located within the 120-square-mile area served. From one to three Telecars can be served by each of the four fixed stations. Each fixed station consists of a 250-watt transmitter for voice and facsimile signals to the Telecars and a receiver for voice communication from the cars to the central office. The radio stations are connected with the central office by physical line pairs.

On stand-by the fixed radio station assumes the condition of a receiver, with the output of the receiver connected to the line pair to the central office in readiness for reports from the cars being served.

Facsimile transmission is only from the central office to the cars. The central office equipment includes a Telefax transmitter for each of the four lines connecting the fixed stations; remote control apparatus for causing a fixed radio station to assume the condition of a transmitter, and for starting the Telefax recorder in a selected car and causing it to phase with the connected central office Telefax transmitter; and microphones and loud speakers for conversing with the cars by voice.

Each car (Figure 4) is equipped with a radio transceiver, a Telefax recorder driven by a standard frequency power amplifier, control gear, and a microphone and speaker for conversing with the central office. The cars are equipped with high-capacity 6-volt generators and oversize storage batteries to supply all of the power for car operation, and for the radio and Telefax equipment.

Figure 4. Mobile delivery car has Radio-Telefax

The radio gear in each car can operate with either of two fixed stations by the manipulation of a switch as directed by the dispatcher. Dispatching of telegrams to the several cars as they are moving about is a very important feature in the operation of the system. It requires the services of a person who is thoroughly familiar with a large area. He must know in detail traffic conditions and travel routes so that travel times between points can be closely estimated.

The central office transmitter operates at 300 rpm. Scanning is at 80 lines per inch. A telegram is transmitted in about one minute. The continuous paper roll recorder in the telecar reproduces copies somewhat reduced in size from the transmitted original. Operation of the recorder is completely automatic.

Briefly, operation of the system is as follows:

The dispatcher places a telegram on the transmitter connected to the fixed radio station which serves the car in the area in which the addressee is located. He sets the car selector switch and presses a start button. The following functions are then performed automatically. The fixed radio station assumes the condition of a transmitter. The line from the central office to the station is switched from the stand-by voice input to the Telefax output. An audio-frequency tone to alert the equipment in the selected car is transmitted for two seconds. Cessation of the tone causes power to be applied to the recorder in the car. After a very short no-signal period, the central office transmitter will start rotating and the tone will be sent, interrupted by contacts operated by a cam on the transmitter shaft to form phasing pulses. After eight such pulses the Telecar recorder is in phase and facsimile transmission starts.

At the end of transmission, the recorder cuts off the telegram and deposits it in a receptacle in easy reach of the driver-operator. All equipments in the Telecar and the central office automatically assume the stand-by position and the fixed radio station assumes the condition of a receiver.

The Marine News Service

For many years, the Telegraph Company has rendered a ship reporting ticker service[9] to tugboat and ship owners, pilot associations, hotels, and so forth. Formerly

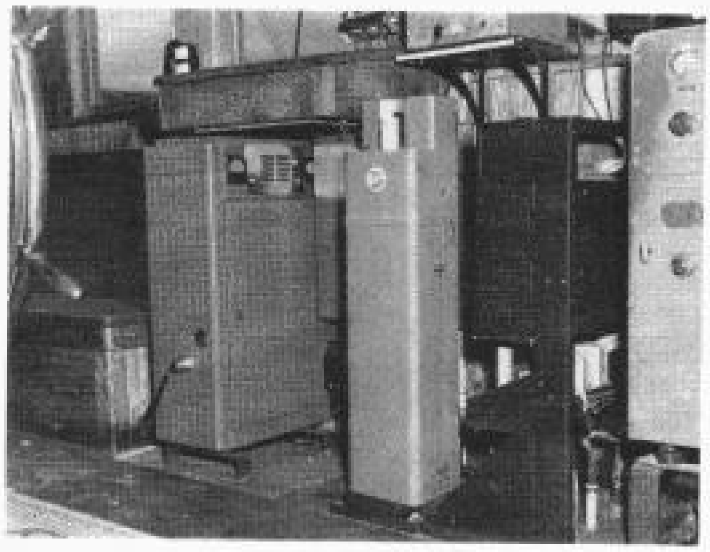


Figure 5. Shipboard Radio-Telefax apparatus

all reports were made by observers in strategically located towers and transmitted by landline to the ticker transmitting department in the New York main office and broadcast to ticker subscribers.

A large percentage of all shipping in and out of New York harbor is through Ambrose channel. In 1946, in cooperation with the New York and New Jersey Pilots Association, it was arranged to report by Telefax all shipping through that channel. Telefax transmission is via radio operating in the miscellaneous-common-carrier band.

Each of three pilot boats sharing continuous watch duty in Ambrose channel is equipped with radio and Telefax gear. Telefax transmission is shoreward only. The small bottle type transmitter (Figure 5, center) is used on the boats. Reports to be transmitted are handwritten on forms with a writing area of about 5 by 3 inches. These messages are scanned at 100 lines per inch at 300 scanning strokes per minute. Transmission time is about one minute.

The reports are received in the central office on the older type transceiver. The transmitted message is enlarged at reception to about 7⅛ by 3½ inches with about 78 scanning lines per inch.

The High-Speed Fax

Over the past few years, considerable use has been made of a two-way High-Speed Telefax (Figure 6) circuit between New York and Washington, operating over a microwave system band. Facsimile signals ranging from less than one cycle to 15.5 kc per second modulate a 25-kc carrier on a double-sideband basis. A bandwidth of 31 kc extending from 9.5 to 40.5 kc is required.

The Telefax machines employed handle any size of subject matter up to 8½ by 15 inches. They operate at 1800 scanning strokes per minute. The transmitter[10] drum is in the form of a transparent cylinder. Copy to be sent is formed cylindrically by hand and inserted into the drum with subject matter facing outward. Transmission is at the high rate of 2⅛ square inches per second. Because of the high transmission speed, two transmitters are operated in "flip-flop" order. While one sheet of copy is being transmitted the other transmitter is loaded and permitted to come up to speed to be ready to start scanning as soon as the transmission of the first message has been completed. Operating at full capacity, about 80 sheets of 8½-by 11-inch copy can be transmitted per hour. To conserve line transmission time in handling random length messages, the positions at which scanning starts and stops are quickly adjustable for each message.

Figure 6. Experimental high-speed Telefax turns out letters in 44 seconds, telegrams in 20 seconds

The recorder[11] is of the multiple stylus continuous paper roll type. All but the lower inch or so of the copy is visible while recording is in progress. When a message has been received some additional paper is fast-fed, the message cut off and deposited in a wire basket in front of the recorder.

Transmitters and recorders are driven through amplifiers from frequency standards of high accuracy insuring synchronization throughout the transmission of the longest message. Phasing and other control functions are performed by tone signals.[12]

NEWER PRIVATE SYSTEMS

With Telefax machines serving dependably day after day in thousands of business offices throughout the country, it is not surprising that many business people have recognized possibilities of applying the method to some of their operational problems.

Special arrangements of the equipments developed by the telegraph company for its own purposes, and newer equipment designed to meet private systems needs more adequately are now being marketed under the name of Intrafax.

Intrafax Collection and Distribution System

Hundreds of the larger business organizations with widely separated plants or offices operate private telegraph networks. Economical use of lines and equipments requires the concentration of operation—a communications center at each location. At the large plants and office buildings, there are collection and distribution problems somewhat similar to those of the telegraph company.

To meet this problem a special arrangement (Figure 7) of the previously described Desk-Fax system was engineered.[13] Three basic operating units have been provided; namely, a line terminating console accommodating up to 30 lines in units of ten, a transmitting console mounting two transmitters, and a recording console mounting two recorders. Numbers of these units can be assembled to meet most any set of requirements. All units are self-contained requiring a minimum of installation or get-ready work on the patron's premises. Electronic and control units are enclosed in the lower sections of the consoles and are accessible from the rear for maintenance.

Figure 7. Intrafax is for private wire service

While designed primarily for handling messages, other uses have been found for this equipment, such as the following.

Signature Verification by Telefax

A bank with many branches throughout a county aims to give complete service to any depositor at any branch. This requires a means of quickly verifying signatures. To do this by a card file system would require a card for every depositor at every branch—a very expensive arrangement. Instead of that, the authorized signatures of all depositors at all branches are on file at the main office. A signature card can be located and extracted from the motorized file cabinet in seconds. A teller at the branch requiring verification of a signature notifies the main office by private telephone and the authorized signature is Telefaxed from the card in less than a minute.

Money Transferred by Telefax

A large financial institution acts as the money transfer agent for a group of banks. Transfer orders involve great sums of money and must be authenticated by one or more signatures. On the average day, more than a thousand of these signed orders are Telefaxed in both directions between the agency institution and the group of banks.

Tickets by Telefax

A leading railroad has put into operation, at one of its larger terminals, a system whereby the selling of reserved accommodations has been greatly simplified. All train space is controlled at one point. Branch ticket offices within the city and in suburban towns and quite a number of industrial concerns have direct Telefax connections to the space control center.

Train space request forms are Telefaxed to the control center and space tickets are Telefaxed back to the ordering station or customer. Space available charts are also Telefaxed to branch ticket offices frequently.[14]

ONE-TO-ONE TRANSCEIVER SYSTEMS

All of the systems so far described employ concentrator equipment and a model of Desk-Fax which can operate only with concentrator equipment. Another Desk-Fax transceiver commonly referred to as the one-to-one type will operate with another machine of the same type. Two such machines connected by a line constitute a complete two-way circuit. Inversion of the facsimile signals is accomplished optically in either machine as it operates as a transmitter. Operation of the machines requires two d-c paths which are obtained by compositing the pair and using the line wires separately.

Five-Line Concentrator

A small push-button operated concentrator (Figure 8) for up to five lines serves as a subbase for mounting a Desk-Fax machine for sending to or receiving from any of the outstations. One-to-one type machines are employed throughout the system. At the front of the concentrator there is a push button and a calling lamp

Figure 8. Push buttons in subbase make connection to any one of five other Telefax machines

associated with each line. An incoming call lights the calling lamp and if the home station Desk-Fax is not already in use, a calling buzzer also sounds. If the home Desk-Fax machine is working with another line, only the calling lamp indicates the waiting call. In making an outgoing call, the home station connects to the proper line and operates its Desk-Fax as a transmitter. The buzzer of the called station sounds and is operated as a recorder. By equipping other stations with similar concentrator units, almost any desired direct station-to-station connection may be provided for.

Thirty-Line Concentrator

A more versatile system (Figure 9) ordinarily employing one-to-one type

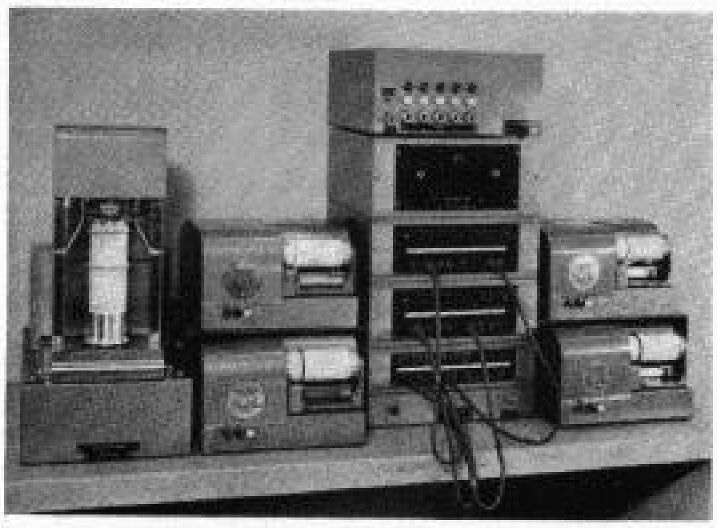


Figure 9. Telefax manual switching turret may be made from units, including repeater, for 30 lines

Desk-Fax machines radiates from a central station concentrator comprising a potential cabinet unit and one or more of such functional units as are required.[15] The base dimension of all units is approximately 13 square inches, to permit stacking, starting with the potential unit forming the base. Using the necessary units, the following operations can be provided.

1. Two-way operation between the central station and any substation.
2. Two-way operation between any two substations.
3. Operation between two central station machines for copying purposes.
4. Simultaneous transmission from the central station to up to five substations.

If desirable because of the nature of subject copy to be transmitted or for operational advantages, one or more central station Desk-Fax machines may be replaced by vertical drum transmitters.

Conclusion

Except for the High-Speed Fax, all of the systems described have been applications of equipments designed primarily for the handling of telegrams in intracity service over physical line pairs with losses up to 25 db. Western Union is using these equipments in some phases of its public message service in large and rapidly increasing numbers. The facsimile method is entirely satisfactory economically and servicewise. Results of research suggest expanded application to additional phases of operations. A variety of leased private systems are giving satisfactory service; some of them meeting requirements which cannot be met by other forms of electrical communication. Recent developments not described herein were undertaken to meet private business needs, determined by market research, for which telegram handling equipments are inadequate. The telegraph company management is confident that facsimile will play an increasingly important role in the future of record communications.

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A. S. Hill, Assistant to the Systems Development and Statistical Engineer, entered Western Union service in the Testing and Regulating Department in Buffalo, N. Y., in July 1916, after six years with the Postal Telegraph Company as messenger, clerk and morse operator. After service in World War I with the Aviation Section of the Signal Corps, he was for many years Assistant General Traffic Dispatcher in New York City. He transferred to the Engineering Department after the beginning of World War II and thereafter contributed much to the solution of problems stemming from the heavy wartime demands on the company's facilities. Mr. Hill has been closely associated with the accelerated Telefax program launched after the close of the war. He actively participated in the planning and successful field trial of a Desk-Fax installation at Newark, N. J., and with many of the installations which followed throughout the country. More recently he has contributed materially to the successful application of Western Union's Telefax to business needs in Private Wire Service. Mr. Hill is a Pratt Institute graduate in Industrial Electricity.

Expansion of Automatic Switching in Western Union's Nationwide Reperforator Network

G. G. LIGHT

EARLY IN 1950, Western Union completed its network of 15 reperforator switching centers for handling the public telegraph business of this country. Six of the centers, installed prior to 1948, are provided with reperforator switching equipment that operates on a manual switching basis, while the other nine employ the latest design of equipment in which a portion of the office is operated on an automatic switching basis. This article describes recently developed automatic switching arrangements for use in the earlier reperforator centers to give them the same benefits of automatic switching as are obtained in the latest centers.

Brief Description of Existing Offices

A series of articles in previous issues of TECHNICAL REVIEW on Western Union's nationwide telegraph network stated that the country was divided into 15 areas, each area comprising one or more states, and described the types of reperforator switching equipments that were installed in the 15 area center offices. The Plan 2 (plug and jack) and the Plan 20 (push-button) methods of setting up intraoffice connections between line receiving positions and line sending positions were utilized in the earlier area center offices. The remaining nine centers were equipped with the Plan 21 type of equipment.

In a Plan 21 office, messages received over trunk circuits from other areas are manually switched by the push-button method to line sending positions in essentially the same manner as in a Plan 20 office. Messages which originate within the area and are transmitted into the switching system at the area center are automatically switched, by means of selection characters prefixed to each message, into interarea trunk sending positions and into a selected number of intra-area sending positions. Those messages from within the area destined for intra-area points that are not included in the automatic switching are prefixed with the selection characters of the "home" area center. This causes them to be switched automatically and transmitted into push-button positions, from whence they are manually switched.

The decision to switch messages automatically through the area center of origin, and by push-button through the area center of destination in the Plan 21 system, was based primarily on the routing problems involved in a public telegraph system. With the block-state routing plan, it is a relatively simple process for sending operators, either from memory or by reference to a brief and simple route chart, to route and prefix each message with selection characters to switch it through the area center of origin. However, about half of the messages received at an area center from other area centers are destined to tie lines, branch offices and so forth in the area center city, and to small communities served by telegraph offices in adjacent towns. It is necessary to maintain elaborate route charts for the guidance of the switching clerks in directing these messages. For the present, it is not deemed practicable to provide this routing information to all the telegraph offices throughout the country in order to permit automatic switching through the area center of destination.

In the Plan 21 system, each message to be automatically switched is prefixed with two selection characters and an identifying preamble, and is terminated with two periods. A majority of these messages originate at heavily loaded tributary offices and are transmitted into line receiving positions at the area center. When a complete message is received, an automatic switching unit is called in to read the two selection characters and connect the intraoffice transmitter at the receiving position to the intraoffice reperforator at the selected line sending position. As each message is transmitted intraoffice, read-back feeler pins on the reperforator, much like the feeler pins of a tape transmitter, cooperate with other devices at the receiving position not only to check the sequence number of each message, but actually to check, character by character, to assure that the entire preamble of the message is perforated correctly in the tape of the intraoffice reperforator at the line sending position. These receiving and sending positions, which comprise additional equipments and automatic devices, are more costly and differ in many respects from those required solely for manually switched messages. However, the efficiency and reliability with which messages are automatically switched has fully justified the additional expense.

The improved speed of service and operating economies resulting from the automatic switching of messages in Plan 21 offices led to consideration of extending it to the earlier types of area center offices. It would be desirable from an operating standpoint to use the Plan 21 method of automatic switching and number checking. However, although the line receiving positions would have to be replaced in any event, utilizing the Plan 21 method of number checking also would require replacing all of the line sending positions into which messages would be automatically switched. Since this was not economically feasible, it was necessary to design special arrangements that would involve only the line receiving positions. The first installation making use of these arrangements was cut into service in Richmond, Virginia, in June 1954. A brief description of the Richmond (Plan 2) center before conversion is given in order to bring out the problems that had to be met.

Plan 2 Reperforator Switching System

Plan 2 area center offices utilize the plug and jack method of setting up intraoffice connections between line receiving and line sending positions. Figure 1 shows the

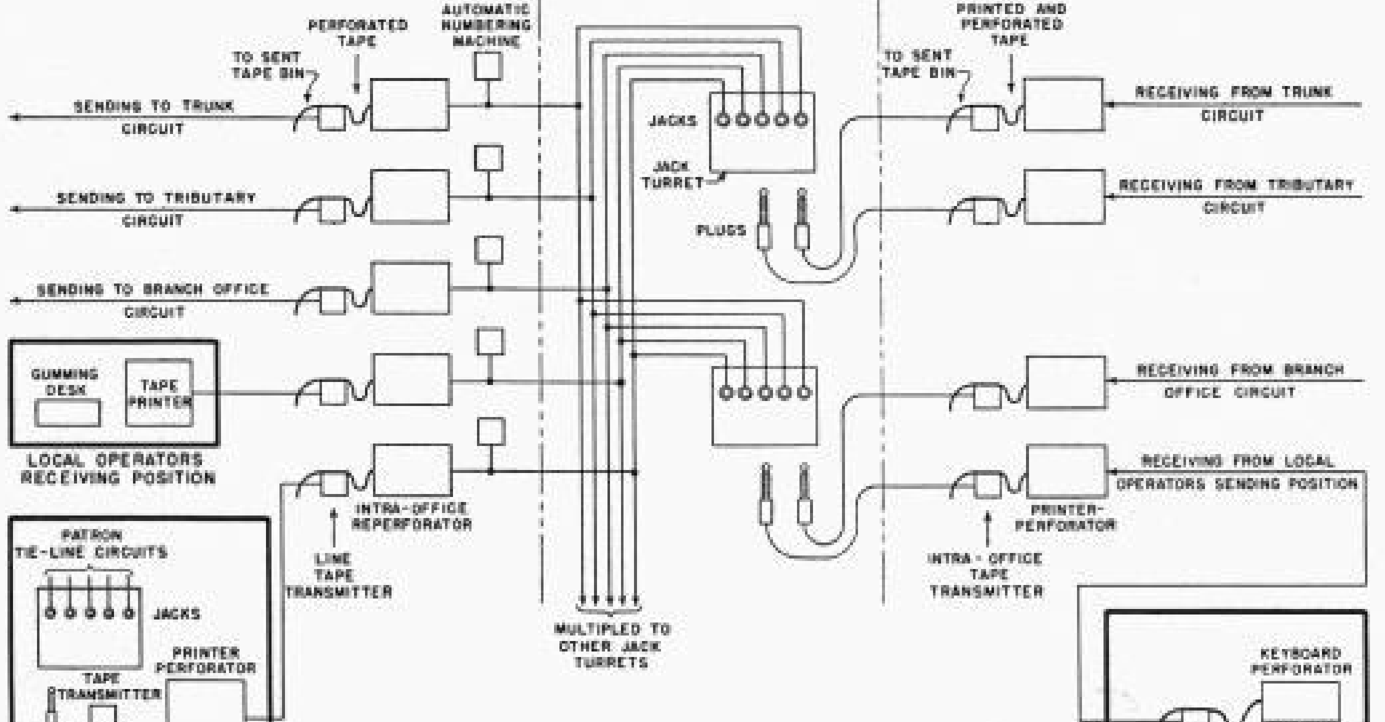

Figure 1. Principal equipment and circuit arrangements of a Plan 2 (plug and jack) reperforator office

principal equipment and circuit arrangements of a plug and jack office. The principal items of equipment at a line receiving position comprise a receiving printer-perforator and an associated intraoffice transmitter which is connected to a cord and plug mounted at a switching turret. The principal items at a line sending position consist of an intraoffice reperforator, the line transmitter and an automatic numbering machine. The intraoffice facilities over which messages are switched from line receiving to line sending positions comprise essentially the transmitting path, an impulse unit, reading circuits for detecting the double period termination of each message, and the necessary control circuits.

Preparatory to switching a message at a line receiving position, the switching clerk checks the sequence number and reads the address of the message as recorded on the receiving printer-perforator tape. She marks off the sequence number on the number sheet for the circuit and endorses, alongside the number, the call letters of the circuit to which the message will be switched. She then inserts the plug of the intraoffice transmitter into the proper jack in the switching turret, thereby establishing a potential connection from the receiving position to the desired sending position. From then on to completion of the transmission of the message, all operations are performed automatically without further attention from the switching clerk.

If the sending position is idle, or when it becomes idle, the potential connection is converted to an actual connection and the automatic numbering machine at the sending position functions to send into the intraoffice reperforator the call letters of the area center office, the channel designation and the outgoing circuit sequence number for that message. Following this, the intraoffice transmitter functions to send the message into the intraoffice reperforator. When the two consecutive periods at the end of the message are detected by code reading relays in the intraoffice circuit, the transmitter is stopped and electrically disconnected from the intraoffice circuit.

Automatic Switching from Tributary Circuits

The approach followed in converting from manual to automatic switching was to adhere to the same operating procedures and techniques, and yet to accomplish automatically all of the operations normally performed by a switching clerk; namely:

Checking the sequence number of each incoming message and observing that the call letters are correct.

(These operations assure that all messages sent from the originating point are received at the switching center, and that each message has a correct identification.)

Recording opposite the message sequence number the call letters of the circuit to which the message will be switched.

(This record is consulted only on rare occasions, but is an important one. Protective devices are provided to detect when messages transmitted intraoffice are not being perforated correctly at a line sending position. Normally, these protective devices function promptly to stop transmission and bring up signals at both the line sending position and the line receiving position in order that corrective action may be taken on the message involved. Occasionally, however, the protective devices do not function promptly to detect the trouble and two or more messages may be switched into a defective line sending position. In this case, the record maintained at each switching position is examined to locate and identify the message or messages that were switched into the faulty line sending position.)

Reading the address of the message and establishing a potential connection from the line receiving position to the appropriate line sending position.

(In automatic switching, this involves reading the selection characters prefixed to the message and establishing the connection automatically.)

Provision is made for switching automatically to 73 destinations. Included are all of the interarea trunks, certain positions within the area center office, and a selected number of tributaries. Messages destined for points that are not included in the automatic switching are prefixed with the selection characters of the "home" area center. This causes them to be switched automatically and transmitted into manual switching positions, from whence they are directed to their destinations.

a sequence number indicator, consisting of three rotary switches termed "call letters," "ten" and "units" switches. As the tape feeds through the number checking transmitter, the call letters as well as the sequence number of each incoming message are checked before the message is switched intraoffice.

Each receiving position is provided with a message waiting indicator that adds one

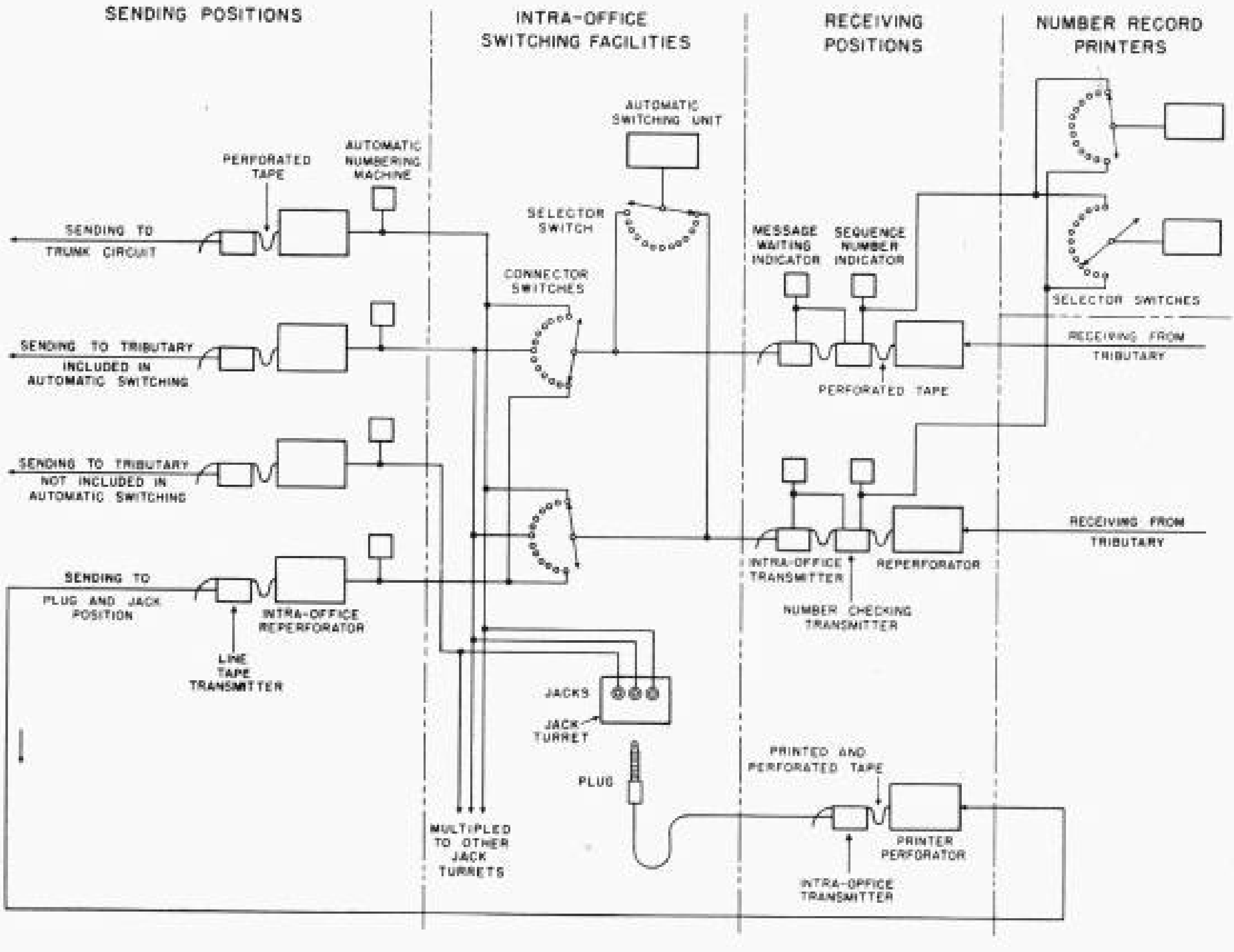

Figure 2. Principal equipment and circuit arrangements for automatic switching in a Plan 2 reperforator office

Figure 2 shows the principal equipment and circuit arrangements for automatic switching from tributary circuits in a Plan 2 area center. The tributary circuits to which automatic switching is applied are terminated in start-stop reperforators at line receiving positions, several of which are illustrated in Figure 3. The tape from the reperforator feeds through a number checking transmitter and thence to an intraoffice transmitter. Cooperating with the number checking transmitter is

count each time the two-period termination of a message is read by the number checking transmitter and subtracts one count each time a message is switched by the intraoffice transmitter. Thus a continuous record is maintained of when there is one or more complete messages on hand to be switched. This information is used to indicate when a switching operation should take place.

Common to all of the line receiving positions, and electrically associated with the number checking transmitter and sequence number indicator of each, are several page printers (see Figure 4) hereinafter referred to as number record printers. As a number checking transmitter functions to check the call letters and sequence number of a message, this message identifying information and the prefixed selection characters (call letters)

Figure 3. Line receiving positions for automatic switching

of the circuit to which the message will be switched are recorded on one of these number record printers. This record takes the place of the record maintained on circuit number sheets in manual switching.

An automatic switching unit (see Figure 2) is provided for each 12 line receiving positions and serves to switch the received messages in accordance with their prefixed selection characters.

Once a circuit is opened for traffic for the day, no control signals are required. The tributary office sends at will. The sequence number indicator at the receiving position is reset at the start of business each day and the tributary office begins its number sequence with 001. A tributary office follows the same routine in preparing messages as prescribed for tributary offices in Plan 21 areas, i.e., =B R.CFA169 address, text, signature . . The first two characters are the selection characters (in this instance, for Boston) which are followed by a "Space." R is the area designation (Richmond), CF the tributary call letters (Charlotte), A the channel designation and 169 the three-digit message sequence number.

The reperforator on which the incoming messages are received is arranged to feed out blank tape when a taut tape condition occurs following the double period termination of a message. The number checking transmitter idles "Blanks," "Letters" and "Periods" at the rate of 100 words per minute until some character other than these is encountered. At this time, the number checking transmitter stops and a request is made for one of the common number record printers. As a number record printer connects, the number checking transmitter starts stepping at the rate of 65 words per minute. Each character stepped through is transmitted into the number record printer. The "Equals" character utilized in some selection combinations and the "Period" character that follows the area designation are both translated into "Space" characters as they are transmitted. The call letters switch of the sequence number indicator at the position also is advanced one step on each character stepped through the transmitter.

After three characters (the two selection characters and Space) have been stepped through, the call letters switch of the sequence number indicator is on its point to check the area designation (R). If a correct comparison takes place on the R, the next character (.) is checked, and so on up to and including the units digit of the message sequence number. Actually, a check is not made to determine if the hundreds digit is correct, but the checking functions require that there be a hundreds digit. Immediately following a correct comparison, the sequence number indicator is advanced one number to prepare it for checking the next message, the number checking transmitter is stopped temporarily and the following characters, which are set up on the call letters switch of the sequence number indicator, are transmitted directly into the number record printer: *Letters Space "Position Identification Character" Space Space Space.* The "Position Identification Character" is a single character such as A, B, C, etc., that identifies the particular position that is connected at this time to the number record printer.

Figure 4. Number record printers

Following transmission of the last "Space" character, the number record printer is disconnected and the number checking transmitter is restarted. The transmitter again steps at the rate of 100 words per minute, examining each character stepped through in order to detect the double period termination of the message. As the double period is read, the message waiting indicator is advanced one count. The number checking transmitter continues stepping at the rate of 100 words per minute until the first character of the succeeding message is encountered or until a taut tape condition occurs.

Normally, the intraoffice transmitter is not permitted to switch a message until the message waiting indicator has advanced two counts as the result of the number checking transmitter having checked and read the double period termination of two messages. The circuits are arranged in this manner to prevent a taut tape condition from occurring on a message being switched intraoffice. However, should a tape feed-out have taken place at the reperforator when the message waiting indicator registers one message, the intraoffice transmitter will be permitted to switch that message, as the tape feed-out indicates there are no other messages immediately following. The number checking transmitter continues to check and present messages to the intraoffice transmitter, regardless of the rate at which they are being switched intraoffice, except that should the number checking transmitter get five messages ahead, it will discontinue stepping and checking further messages until the message waiting indicator shows fewer than five messages waiting.

Each time the intraoffice transmitter is permitted to switch a message it first calls in the automatic switching unit. This unit, which is common to 12 positions, acts upon the two selection characters that precede the message and sets up a potential connection from the line receiving position to the selected line sending position. The automatic switching unit is then released so that it may serve the other positions. If the sending position is idle, or when it becomes idle, the potential connection is converted automatically to an actual connection. The automatic numbering machine functions first, after which the message is transmitted into the intraoffice reperforator at the sending position. Coincident with the actual connection, the message waiting indicator at the receiving position is actuated to subtract one count.

The above described sequence of operations is based on a correct comparison having taken place on each message stepped through the number checking transmitter. In the event of a wrong comparison on a message, the number checking transmitter is immediately stopped and a "Wrong Comparison" lamp at the position and a "Supervisory" lamp at the top of the rack are lighted. The call letters switch of the sequence number indicator continues through its cycle, however, in this instance transmitting fill-in "Space" characters to the number record printer until it reaches the point where it normally transmits *Letters Space "Position Identification Character" Space Space Space.* On a wrong comparison, these latter characters become: *Letters Space "Position Identification Character" XX Space.*

The XX on the number record printer indicates that a wrong comparison occurred on that particular message. The number record printer is disconnected immediately following the last "Space" character transmitted into it, but the number checking transmitter remains stopped. When a supervisor has taken appropriate action on the wrong comparison, the number checking transmitter is restarted by depressing a "Wrong Comparison Release" push button.

To conserve paper, the number record printers are arranged to record the selection characters, call letters and sequence numbers of four separate messages on each line. The control circuits cause a "Carriage Return" "Line Feed" to be transmitted locally into a number record printer immediately after it has recorded the identification portion of four messages.

Typical recordings on a number record printer are as follows:

SY R NFA034 B	DE R RUB121 D	CT R CFA062 A	S R AHA154 C
P R RGB075 F	B R DUA043 E	N R GSA111 G	CT R RUB122 D
DE R CFD AXX	CT R AHA155 C	P R NFA034 BXX	DE R HPA093 J
P R WLA033 H	O R RUB123 D	DE R WNA064 I	N R NFB025 M

The character following the units digit of the message sequence numbers is the position identification character. The characters XX indicate that a wrong comparison took place on that particular message.

Notes directed by the tributary offices to the Testing and Supervisory positions at the switching center are not given sequence numbers like regular messages. The control circuits associated with the number record printers, therefore, are arranged to detect the selection combinations that cause such notes to be switched automatically to Testing and Supervisory positions. Upon detection of any one of these selection combinations, the sequence number checking functions are made inoperative during the time the note is being stepped through the number checking transmitter.

Conclusions

This description has been written around the application of automatic switching in the Plan 2 (plug and jack) area center at Richmond. In the 15-area network, there are three other Plan 2 offices and two Plan 20 (push-button) offices. Since the circuitry of Plan 2 and Plan 20 offices is essentially the same, the automatic switching arrangement described is equally applicable to the Plan 20 offices.

G. G. Light, Assistant Switching Development Engineer, joined the Equipment Research Division of Western Union in 1927 following his graduation from Virginia Polytechnic Institute. Except for some time spent in the development of repeaters and terminal sets, he has been engaged exclusively in the design of manual, semiautomatic and automatic switching systems. He did circuit development for all of the major leased reperforator switching systems prior to 1942, at which time he entered upon active military duty. He attained the rank of Major in the Signal Corps while discharging important responsibilities in connection with its research and development program for wire facilities. Since his return in 1946 he has been active in the post-war mechanization program, doing circuit development work for the nationwide network of interconnected reperforator switching centers.

Telecommunications Literature

PHOTOMETRY — JOHN W. T. WALSH — Constable and Co., Ltd., London, Distributed in U. S. A. by MacMillan Co., N. Y. Second Edition (Revised) 1953. 544 pp., $12.75. The revised edition has excellent general coverage of the field including current techniques in the application of photoelectric equipment. The continuity of presentation is preserved without dwelling on details and mathematical manipulations. Useable information may be garnered with a minimum of effort. An abundant up-to-date bibliography of international periodicals and books is referred to and appears to have been well selected. Internationally standardized methods, nomenclature, and definitions are used. The major portion deals with principles and laboratory techniques. Topics receiving the more abbreviated treatment such as colorimetry, projection apparatus, and stellar photometry are suitably supplemented by the references. This book is recommended as a reference for anyone interested in the measurement of light. — G. B. WORTHEN, Engineer, Telefax Research Division.

MICROWAVE THEORY AND TECHNIQUE — HERBERT J. REICH, PHILIP F. ORDUNG, HERBERT L. KRAUSS and JOHN G. SKALNIK — D. Van Nostrand Co., Inc., N. Y., 1953. 901 pp., $12.50. The authors have given as wide coverage to the microwave field as is possible in a single volume. Many sections are too brief but bibliographies are given of other material on the subject. A review of vector analysis is followed by two chapters on field theory. Low-frequency (quasi-static) field relationships are presented in concise form with a minimum of derivations. The theory of dynamic fields is derived from Maxwell's equations and the concepts of propagation, impedance, and traveling waves are introduced. This chapter shows how a transmission line may be considered as a "waveguide" and that waveguides may be treated mathematically as "transmission lines." General transmission line relations and the problems and methods of impedance matching are presented. Properties of waveguides and field distribution for different modes of propagation are given in mathematical and graphical form. Matching devices, hybrids, attenuators, directional couplers, filters, and antennas of various types are covered in simple form; measurements at microwave frequencies briefly, resonant devices more thoroughly. Microwave oscillators and amplifiers take almost half of the book. A complete chapter each is devoted to triodes and tetrodes, 2- and 3-cavity klystrons, reflex klystrons, magnetrons, and traveling wave tubes. These sections seem to remove the book from the category of "just another textbook."—C. B. YOUNG, JR., Project Engineer, Radio Research Division.

MICROWAVE LENSES—J. BROWN—John Wiley & Sons, Inc., N. Y., 1953. 125 pp., $2.00. This is part of the "pocket-book" series — Methuen's Monographs on Physical Subjects. The author has done an excellent job of compiling all of the knowledge of practical interest concerning microwave lenses. The book includes chapters on solid dielectric lenses, metal plate and rodded dielectrics, nonhomogeneous dielectric lenses, and path-length lenses. The information is presented in sufficient detail to clarify the subject, but without over-detailed mathematical or theoretical considerations. For more detailed information on the particular type of lenses, the author includes a complete bibliography containing all of the pertinent references to date (1953) on microwave lenses. The book is highly recommended as a primary source for general information on the subject.— A. J. ORLANDO, Engineer, Radio Research Division.

MODULATION THEORY — H. S. BLACK — BELL LABORATORIES SERIES—Van Nostrand, N. Y., 1953. 363 pp., $8.75. This book provides an excellent analysis of amplitude, angular, phase, frequency and the various methods of pulse modulation. There are especially good sections on sampling, quantization, and pulse-code methods. Although the book does not present anything that cannot already be found in the literature, it provides an excellent compilation of a very complex subject. In general, it maintains the excellent record of the Bell Labs series and, except in the section on pulse-code modulation, adheres to theoretical rather than practical analysis. — J. J. LENEHAN, Ass't to Radio Research Engineer.