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VOLUME 14
NUMBER 4

PHILIP R. EASTERLIN, Planning Engineer, Plant and Systems

Telex in Private Wire Systems

Examination into the suitability of Telex circuit switching apparatus for private wire services involves comparisons with message switching equipment and its capabilities. It appears that circuit switching apparatus is less complex and therefore easier to maintain, but that more circuit facilities are required with Telex. For message switching, on the other hand, although switching center equipment is more complicated, employment of circuit facilities is more efficient.

THIS PAPER discusses the application of the circuit switching principles of Western Union's new Telex exchange equipment to meet the private wire system needs of large telegraph users who require instantaneous and direct communication between a number of distant offices located throughout the country. A private *circuit switching* system such as this, planned to meet specific customer requirements, can offer in some cases a superior and more economical communications network than a *message switching* system.

The application and operation of a private system of this kind would be almost identical to that of the Telegraph Company's new automatic dial teleprinter exchange service, known as Telex, which is now being provided between New York, Chicago, San Francisco, Los Angeles and to 36 exchange areas throughout Canada. The new subscriber-to-subscriber service will be extended to 44 U. S. cities in 1960-61.

In order for you to appreciate fully the potentialities of a circuit switching system, I would like to explain the operation of Telex, the over-all system layout and the modern teleprinter exchange equipment which sets up long-distance connections in less than 10 seconds. Also, I would like to describe how the characteristic answer-back feature is used to confirm that the proper dial connection has been made and that transmission—even to unattended stations—is being correctly received by the distant teleprinter. I am sure you will recognize the possibilities which are offered in one basic system for handling either telegraph or data, as well as for automatic connection outside of the private system to any of the subscribers in the regular Western Union Telex network and to our many message refile points.

Photo H-2286-A

Figure 1. Telex subscriber's set

Private Wire Systems

I should like first to review briefly the present-day private wire systems in general use which heretofore have been in the broad category of message storage or a message relaying type of system. For many years the Telegraph Company has furnished and maintained for many companies privately-operated telegraph systems which have been especially planned

A paper presented at the Annual Meeting of The Petroleum Industry Electrical Association, Kansas City, Mo., April 1960.

to carry the bulk of their communications between distantly located offices. In the beginning, these were all manually-operated systems and some were started as early as the Morse era and later were converted to teleprinter operation. In the following years, the demand has been for automatic operation and for increasingly higher teleprinter speeds to handle greater traffic volume, and now in some systems provision must be made for high-speed data transmission as well.

Where more than one telegraph circuit has been involved, these systems have invariably followed the basic message relaying principles used by the Telegraph Company for handling public telegrams. The message system follows the general form of filing the telegram at an originating point for transmission to one or more intermediate relay offices, which in turn retransmit the message over another circuit to its ultimate destination. With the advent of automatic equipment at relay offices or centrally located switching centers, this technique of handling messages has become known as a "message storage" system to differentiate it from the circuit switching principle described in this paper.

In message storage systems, there have been many advancements over the years which have speeded up and reduced the cost of handling messages at switching center locations, and savings in operating personnel are almost at an irreducible minimum. This has been accomplished principally with reperforator tape systems where either the tape is torn and retransmitted on another circuit or a push button is pushed for reswitching each message, or by fully automatic systems which read the routing characters in the tape preceding each message and automatically switch the message without manual intervention. Also, there are continuing developments on message storage systems where the individual reperforator tape storage at incoming receiving and outgoing sending positions is replaced by a random access "common store" in which the incoming line signal pulses are stored in magnetic tape, magnetic drums or ferrite cores, and are later retransmitted to the proper outgoing circuit.

The operating savings which have been made in switching centers of automatic message storage systems have been effected with highly developed and expensive automatic equipment. However, the versatility of these systems has permitted greater efficiency in the use of line facilities, and the higher equipment cost is offset somewhat by the ability to place a greater number of offices or drops on one circuit, thereby reducing the required equipment terminations at the switching center.

A Brief Comparison

The cost for equipment as well as for labor has continued to rise over the years while, on the other hand, due to the microwave and coaxial cable expansion, there has been a corresponding increase in the availability of line circuit facilities. This situation now makes it desirable to consider the operating features and economics of both types of systems—message storage or circuit switching—when planning new automatic private wire communications networks. A brief comparison of the two systems is as follows:

A. The message storage system, because of its character-by-character operating functions, requires rather complex switching center equipment and commensurate maintenance but does use line circuits quite efficiently.

B. The circuit switching system, on the other hand, because of the greater simplicity in switching only the line circuit, uses exchange equipment which bears a close resemblance to the less involved telephone switching equipment and accordingly requires negligible maintenance. However, because of the basic concept of having an individual connection to the exchange for each subscriber and reasonable availability of idle trunk circuits between Telex exchanges, the circuit switching system requires more line facilities than the message storage system.

In evaluating the fundamental principles of the two system arrangements, careful consideration must be given to the

Photo R-11,319

Figure 2. Telex subscriber's set with local tape functions

operating requirements which are to be dealt with. While the direct connection with automatic answer-back is admittedly an outstanding feature of the circuit switching system, some present-day operating requirements are contrary to the direct-connecting principle and become difficult to handle on an automatic basis. For example, master send or broadcast and conference functions, where there is a period of waiting time involved until a group of individual stations become idle, is wasteful of circuit time on long-distance trunks and compounds the incidence of busy conditions on the system in general. Also, a requirement for priority would have little value in a system which completes long-distance connections as rapidly as Telex, unless it also included pre-empting features on connections already established and this necessitates carefully designed operating safeguards. For the present, the master send, conference and priority features, where required in a circuit switching system, are better handled through a manual switchboard located in one or more of the Telex exchange areas.

Therefore, it is in the light of the foregoing that the merits of the message storage or circuit switching systems must be weighed for private wire applications. And now I should like to explain the operating principles of circuit switching, including the system layout and exchange equipment which is used, by describing Western Union's new subscriber-to-subscriber Telex service. (Please refer to "Telex in New York," P. R. Easterlin, Western Union TECHNICAL REVIEW, Vol. 13, No. 2, April 1959.)

The following paragraphs give a brief description of the various Telex exchange units and the special operating features which are available in a circuit switching system.

TWM System

The TWM Telex exchange incorporates versatile operating features which Western Union requires in its large key junction exchanges. This system, as distinguished from a step-by-step exchange, employs the indirect marking principle for setting the selectors. The dial pulses are stored and evaluated by dial code translators which also have the capability of selecting alternate trunk routes to other exchanges. A high-speed motor-driven uniselector switch, providing 200 routing outlets, is used in all group selector stages in order to provide maximum availability for all calls. This system provides for growth on a module or building-block basis.

TW-39 System

The TW-39 exchange equipment is being used for the somewhat smaller district exchange locations in the Western Union network. This type of exchange employs the well-proven step-by-step method of operation whereby the digits dialed by the subscriber have simultaneous and direct control in setting the selectors to the proper path. The group selector stages are equipped with two-motion switches having 100 routing outlets arranged in a decade manner. This is a simpler and more economical system for secondary exchange locations where considerable operating flexibility is not required. It also may be expanded without limitation by additional equipment modules.

TW-56 Concentrator

The TW-56 Concentrator, shown in Figure 3, is a single rack unit which com-

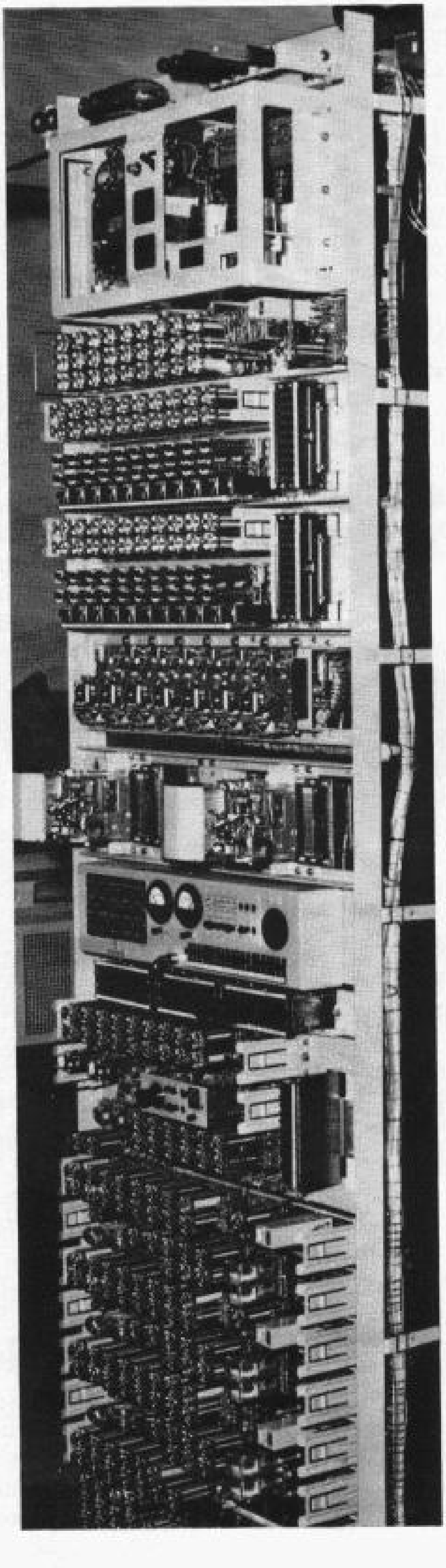

Figure 3. TW-56 Concentrator

bines a smaller number of various Telex exchange units, principally of the TW-39 design. This unit provides Telex terminations for 20 subscribers in a remote area and operates over five trunk circuits to the nearest district or junction Telex exchange. Concentrators of this type will be used initially by Western Union for opening up Telex service in new areas and, as growth develops, regular district exchange equipment will be installed and the concentrator units then will be moved to lower levels in the network. The concentrator provides no local dial stage and calls between subscribers terminated in the unit are double-trunked through the parent exchange.

10/5/5 Exchange

The 10/5/5 exchange, shown in Figure 4, has been specifically designed for small private wire applications. It has local and long-distance dial facilities for ten subscribers and can be operated over five interconnecting trunk circuits to a regular Telex exchange or to a second 10/5/5 unit. The basic switching equipment is contained on one equipment rack and where required the additional facility of time zone metering is provided on a second rack unit.

Two-Party Selector

The two-party selector is for the purpose of extending service to a remote area and allowing two nearby subscribers to share the same long-distance trunk circuit to the Telex exchange. This arrangement prohibits calls between the two subscribers and only one at a time may use the connection to the exchange, the other being automatically locked out to insure complete privacy.

Push-Button Dial Device

This is a supplementary push-button dial feature which can be used with either type of remote control unit to establish connections to any of 30 selected subscribers anywhere in a system by simply depressing the desired push button. Upon depressing one of the push buttons, this unit generates the required dial pulses to reach the selected subscriber. No restriction is imposed on the regular dial unit which can be used to reach subscribers without an assigned push button.

Station Classifying System

The station classifying feature affords the possibility of having several subscriber categories in one network with different traffic privileges. For example, classified stations can be blocked from receiving calls from nonprivileged subscribers. After a connection has been set up, a one- or two-letter code is conveyed automatically to the called station and compared at the latter for conformance with the assigned identification. Following the comparison the connection will be completed, or in case of an unauthorized call, broken down.

Automatic Broadcast

An automatic broadcast arrangement can be provided which enables one subscriber to obtain connection to and broadcast to a maximum of five subscribers located at various points in a circuit switching network. The calling subscriber dials the number of the automatic broadcast frame located in an exchange and, by means of control signals with the calling subscriber, this equipment successively sets up the five separate connections to the selected subscribers. After the automatic broadcast frame has solicited the identifying answer-back from each subscriber, the broadcast circuit is completed for transmission. Prior to terminating the broadcast hookup, the calling subscriber transmits the "who are you" signal and the automatic broadcast frame verifies the receipt of answer-backs from all of the called subscribers before a disconnect is permitted.

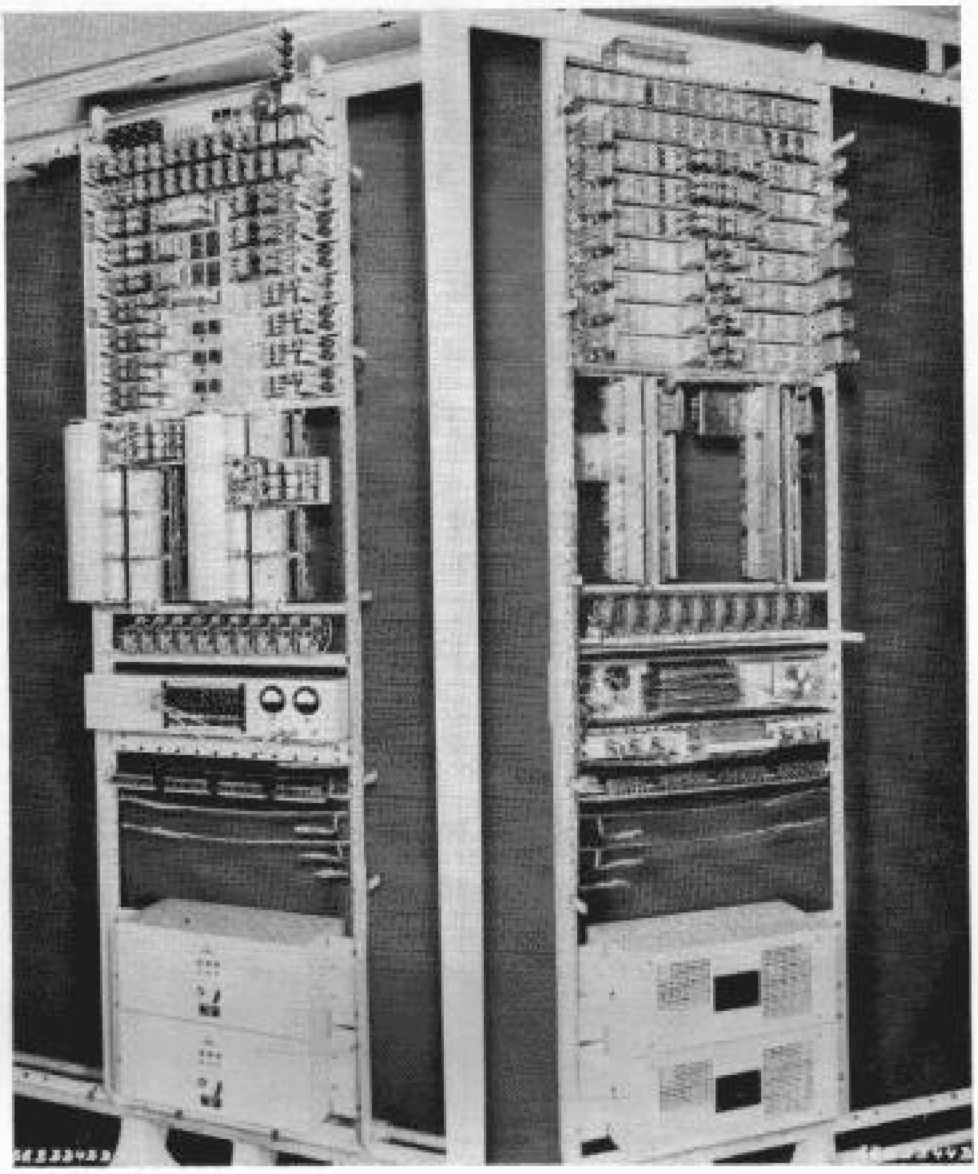

Figure 4. Automatic Teleprinter Exchange 10/5/5—front and rear views

Special Broadcast, Conference and Priority Features

The broadcast, conference and priority features necessitate control accessibility to practically all subscriber lines and this involves a considerable amount of additional cabling in the Telex exchange. Also, the specific operating requirements for one or more of these features are likely to find wide variation in different applications of circuit switching systems. Therefore, where these operating features are required, it is considered advisable to incorporate such functions in a manually-operated push-button switchboard where they can be properly supervised and controlled. A switchboard of this type can be specially engineered to meet individual system requirements, and it could be made accessible to any subscriber in the network for one or more of the following operating features:

Broadcast —Broadcast or master-send transmission in one direction only to a group of subscribers.

Conference—Interconnection of a group of subscribers on a round-robin basis whereby all subscribers can send or receive to all other points.

Priority —Provision for manually pre-empting any engaged subscriber for completion of a priority call.

★ ★ ★ ★ ★

Having examined the operating principles of circuit switching, perhaps it would be desirable now to draw some conclusions with regard to the outstanding features which such a system offers for a private communications network. These are as follows:

1. The instantaneous and direct point-to-point connection with automatic acknowledgment, even to unattended stations, provides a definitely superior speed of service and assurance that a message has reached its destination.

2. The functional switching components for such a system—consisting of one or more Telex exchanges operated on a 24-hour basis—can be located and maintained on the premises of the Telegraph Company. This makes it unnecessary for the patron to provide the necessary space and to incur the operating charges of a switching center.

3. Since the patron is associated with only the operating positions or subscriber sets in this type of system, over-all expansion to additional locations may be made quite easily without major inconvenience.

4. The circuit switching system is not limited to a particular transmission keying mode such as teleprinter operation but also can be used interchangeably for various types of data transmission up to 500 bits per second. For speeds higher than normal teleprinter service, transistorized telegraph relays are required in the Telex exchange equipment.

5. It is recognized that in order to minimize busy conditions on some heavily-loaded stations multiple subscriber set terminations, involving two or more separate connections to the Telex exchange, may be required. It is believed that additional charges of this kind would be justifiably offset by the over-all savings which are possible in the system arrangement. However, it should be pointed out that where such multiple subscriber sets are required, some consideration should be given to the increased operating capacity which would be provided at these points.

6. The time zone metering equipment in the Telex exchanges provides a very exact method of allocating system usage charges to various departments within an organization.

7. Direct point-to-point connections with no intervening relay or monitoring assure complete privacy for all messages handled over the system.

8. Provision could be made at several locations in a private circuit switching system for automatic interconnection to the regular Western Union Telex network. This would make it possible for stations in the private system to dial automatically subscribers in either the U. S. or Canadian Telex networks, or to obtain connections to the International companies for direct overseas Telex service.

Reference

TELEX IN NEW YORK, PHILIP R. EASTERLIN, *Western Union Technical Review*, Vol. 13, No. 2, April 1959.

A biographical sketch of the author appears in the April 1959 issue of TECHNICAL REVIEW.

 

GARVICE H. RIDINGS IS 1960 D'HUMY MEDALIST

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GARVICE H. RIDINGS was presented with the 1960 F. E. d'Humy Award by Western Union President Walter P. Marshall at formal ceremonies on September 28 at New York. Mr. Ridings is Facsimile Engineer, Research and Engineering Department, at company headquarters.

First speaker at the presentation was G. Stewart Paul, Vice President—Operation, who was introduced by William H. Francis, Vice President in charge of Research and Development for Western Union. In his talk entitled "Caution—Engineers at Work," Mr. Paul told how Mr. d'Humy, former vice president of engineering, had been the moving force behind many of the company's technical advances, including development of the Desk-Fax which was one of his major enthusiasms. The other principal speaker was Admiral Joseph R. Redman (U. S. N. Ret.), Communications Consultant in the company's Government Relations Department at Washington, whose subject was "National Emergency Communications."

Mr. Ridings is the sixth recipient of this honor which has been awarded annually since 1956 to a Western Union engineering, research or technical worker who has made a most significant contribution to the telegraph art. The Award includes a bronze medallion, an engrossed citation certificate, a gold lapel emblem and a $500 honorarium. The Western Union Telegraph Company established the award in commemoration of the leadership in telegraph research and engineering by Fernand E. d'Humy, who died December 22, 1955.

The citation to Mr. Ridings, which reads "For his dedicated effort and notable accomplishments in the development of facsimile telegraph instruments and circuitry," takes particular cognizance of his work on development of the ingenious Desk-Fax transceiver, which was the culmination of his major assignments in facsimile research and design. Evidence of the popularity of Desk-Fax with the public is the fact that there are now over 37,000 in service and 45,000,000 telegrams are sent and received annually by its use.

Other accomplishments of the medalist include direction of the installation, at Washington during the early part of World War II, of the company's special facsimile equipment which carried British Embassy secret code messages for all parts of the empire. He has designed much of the company's line of facsimile apparatus and circuitry for both central offices and customers, devoting his attention usually to the more fully automatic devices.

A graduate of Virginia Polytechnic Institute, Mr. Ridings joined the engineering department of Western Union in 1926. He is a member of the Institute of Radio Engineers and the author of numerous technical papers on facsimile developments.

WILLIAM CORKUTT, Engineer, Switching Equipment and Systems

Magnetic Drum Recording

Electrically actuated relay banks and relays still are basic signal storage devices but in telegraphy, nowadays, perforated tape is employed so widely as to overshadow most other storage means. However, with magnetic storage now coming to maturity as a well-developed art, especially in data processing applications, it should not be surprising to find this newer technique assuming an increasingly important place in modern telegraph developments.

A ROTATING cylindrical drum having a surface capable of being magnetized may have information stored upon it by means of magnetic writing heads. When a narrow current pulse is applied to the write head, a small area or spot of the drum surface becomes sufficiently magnetized to saturate the magnetic surface. This magnetic saturation can be either positive or negative and is determined by the polarity of the current pulse in the write head. These opposite polarities may then be designated *ones* or *zeros*, and hence two-valued (binary) information can be stored on the drum. One binary digit of information is called a "bit" and represents a spot of flux on the drum in one direction or the other. The retrieval (or sensing) of a stored bit of information is accomplished by means of the relative rotation between the drum surface and the head. As the drum rotates, the flux lines are swept by the head, and a voltage is induced in the head windings. The nature of this voltage indicates a stored *one* or *zero*. In most applications the same head is used for both writing and reading information.

Access Time

The bit positions are arranged in "tracks" along the drum surface so that the bits of any one track pass sequentially beneath the writing and reading head. Since information can be read only at the time when the desired information is passing beneath the head, it is seen that time (or the position of information on the drum) is of importance in reading; practically, this means information cannot be retrieved instantaneously, but that a certain minimum or maximum "access time" exists. The access time is defined as the time required to sense a desired bit of information and ranges from a minimum of zero time if the head is just passing over the desired information, to a maximum time corresponding to one revolution of the drum if the desired bit has just passed beneath the head. The average access time equals one-half the period of revolution of the drum.

The "bit density" (sometimes called packing density) is defined as the number of bits stored per linear inch. It is limited by the necessity of providing enough space between cells of information so that interference between adjacent bits does not destroy the ability to read properly. Fringing of the lines of flux caused by the finite spacing between the head and the drum surface causes most overlapping; frictional wear precludes the head from being in contact with the drum surface.

The total storage capacity of the drum also depends upon the number of tracks along the direction of the axis. The number of tracks is a compromise between the desired read signal amplitude and the desired reliability, since fringing also occurs in the axial direction. A wide track and head will give larger output voltages since more flux lines will be cut; however, this widening will reduce the total number of tracks and thus reduce the total storage capacity. If the tracks are spaced too close to each other the possibilty of undesired pickup from adjacent tracks exists. The "track density" is defined as the number of tracks per inch in the axial direction.

Figure 1 illustrates the meanings of the terms defined here.

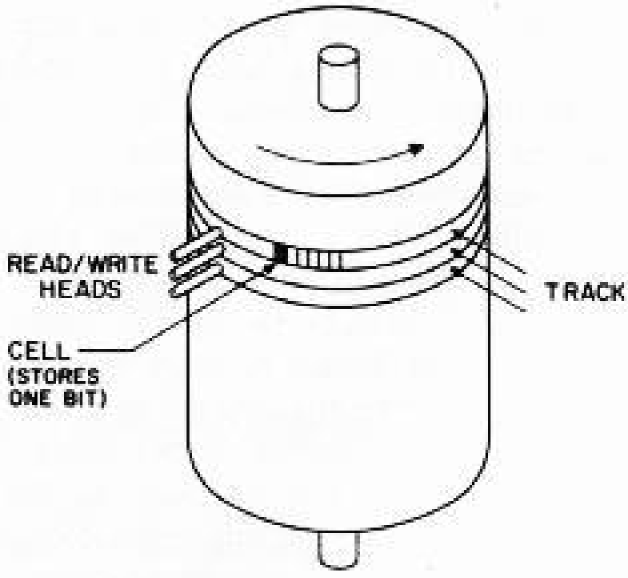

Figure 1.

Return-to-Zero Recording

The most straightforward method of recording on a magnetic surface is to apply a discrete pulse of current in one direction through the coil of the head for a *one* and a pulse of current in the opposite direction for a *zero*. Since no current flows in the head between the time of these pulses, this method is called the Return-to-Zero (RZ) method of recording. The surface and head will be moving with respect to each other during the writing process; therefore, each pulse of current is made extremely short in time so as to keep the flux from spreading into adjacent cells.

Figure 2 shows the relationship between the write current, drum surface flux, and output read voltage for a single pulse and also for a series of pulses. In the figure the horizontal direction can represent either time or the distance along the track of the drum.

The read voltage is proportional to the rate of change of flux with respect to time. Observe in the single pulse illustrated that the induced voltage is positive as the flux rises to its maximum, becomes zero at the peak of the flux (since no flux change takes place here), and then becomes negative as the flux decreases to zero. The single pulse of current produces an output voltage approximating a single sinusoid. If no overlapping of the flux occurs between adjacent cells, the output of a series of *ones* or *zeros*, or any combination thereof, will be of an amplitude equal to that of a single pulse. However, if overlapping occurs the flux on the surface will not return to zero and a string of *ones* or *zeros* will produce a reduced output. The degree to which this reduction in output is acceptable sets the upper limit of the bit density of any one track.

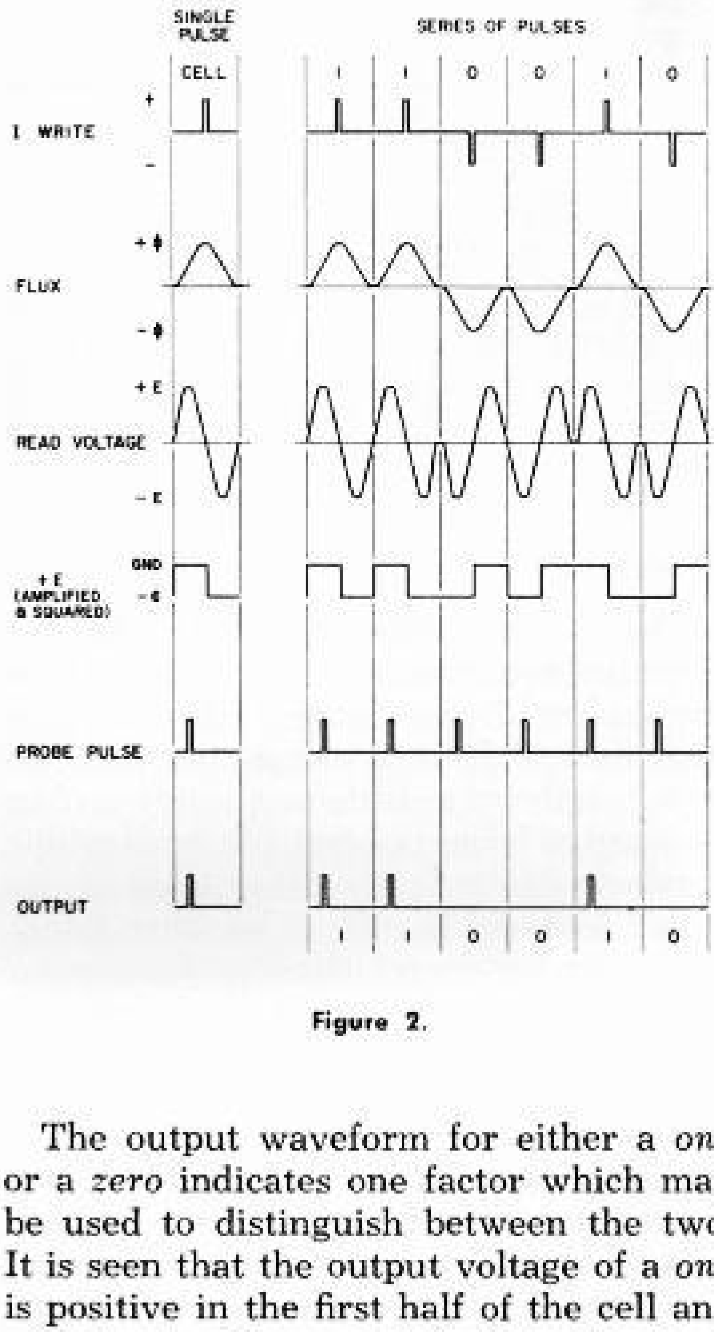

Figure 2.

The output waveform for either a *one* or a *zero* indicates one factor which may be used to distinguish between the two. It is seen that the output voltage of a *one* is positive in the first half of the cell and negative in the second half, while for a *zero* these polarities are reversed. Therefore, the read voltage can be amplified and probed in either its first or second half to recover the stored information. In practice, new information is written over the old, and in this manner the new information erases the old by saturating the head in the opposite direction if the cell is to be altered. No change takes place if the bit to be written is the same as that which had been stored previously in that particular cell.

Non-Return-to-Zero Recording

One other basic method of recording exists. It is called the Non-Return-to-Zero (NRZ) method because the current does not return to zero between bits of information, but continues flowing in one direction or the other at all times. Reversals of this current flow are used to indicate the change from a *one* to *zero* or vice versa.

Within the two basic categories referred to there are a number of variations. These variations are refinements of the principles outlined here and generally are used in the interest of obtaining higher packing densities. As the packing density is increased, the methods used for recovering the stored information are not as simple as those described for the basic RZ method. However, these complex methods will not be discussed.

Practical Considerations

The storage capacity of a drum is directly proportional to the total area of the surface. Drums have been built with diameters of from 2 inches to 3 feet and with lengths of as little as a quarter of an inch and as large as 4 feet. Most fall within narrower limits, having diameters of less than 1 foot and lengths of less than 2 feet. The other factors which affect the storage capacity are the bit density and the track density. Bit densities range from 50 bits per inch up to 200 bits per inch, and much higher bit densities have been obtained using special techniques. Track densities range from 15 to 40 tracks per inch. High rotational speeds are desirable since they decrease the access time of the drum, produce high-output voltages, and enable higher write pulse repetition rates to be used; however, high speeds introduce additional mechanical problems which generally can be overcome only by compromising total storage capacity of the drum, and which require special power equipment to drive the a-c driving motors. Speeds of as low as 1190 rpm and as high as 22,000 rpm have been used. Pulse repetition rates for feeding the head, which together with the diameter and speed of the drum determine the bit density, run from 50,000 pulses per second up to 500,000 with the upper limits now pushing into the megacycle range.

Coating of the drum surface usually consists of iron oxide or an alloy of cobalt and nickle, which is sprayed or electroplated onto the hard surface of the drum proper; its thickness is in the order of 0.0005 to 0.002 inch. A thin surface is desirable in order that it be easily saturated throughout its thickness. Magnetic flux retentivities of from 450 to 12,000 gauss result from these magnetic coatings.

Drum storage systems have been designed to store from 100,000 up to over 2,500,000 bits of information.

Head Considerations

The magnetic read/write head is a piece of ring-shaped magnetic material with an air gap at one end. Coils are wound on the ring for writing and for reading. In the interests of low writing current, large reading voltage, and minimum flux spreading, the gap of the magnetic path in the head should be small; spacing between pole tips is usually 0.001 inch or less. A high-output voltage and low writing current require a large number of turns on the coils; however, simplicity of construction and small size favor a small number of turns. The inductance of the coils must be considered too, for in writing a high-inductance head may require too high a voltage to force the current through the head. In addition, low-impedance heads have other advantages: narrow pulses of high repetition rates can be used since low-impedance heads afford fast rise and fall time for the write pulses; at the time of reading from the drum, low-impedance heads act as voltage generators of low internal impedance capable of driving a low-impedance cable with little attenuation; low-impedance heads minimize the interaction between the heads themselves. Head windings of from one up to 400 turns have been used. The core and windings are usually encapsulated in a nonmagnetic metal for physical strength.

The head can be placed as close as 0.0003 inch to the drum surface. Closer spacing, while desirable, is not feasible due to minor eccentricities of the drum surface, expansion of metal parts due to heat, and mechanical difficulties of maintaining alignment.

In practice currents as high as an ampere have been used for writing. Read voltages range from 10 millivolts up to 100 millivolts.

Western Union Drum Storage

Drum storage in one investigation at Western Union was performed using a Bryant Model 512A magnetic drum. The diameter of the drum is 5 inches and its length 1 foot. The magnetic coating is iron oxide which is sprayed onto a hard steel surface and then machined to a uniform thickness of 0.001 inch. The drum is rotated at 3600 rpm by a 3-phase 60-cps induction motor.

Each track is divided into 2048 cells. This number is chosen so that binary counters may be used to identify each cell: $2^{11} = 2048$; therefore, an 11-stage counter will perform the required count.

The bit density is

$$\frac{2048 \text{ bits}}{\text{circumference}} = \frac{2048}{\pi D} = \frac{2048}{5\,(3.14)} = 128 \text{ bits/inch}$$

The write pulse repetition rate is

$$\frac{2048 \text{ pulses}}{\text{period of drum}} = \frac{2048}{1/3600 \text{ rpm}} = \frac{2048}{16.7\text{X}10^{-3} \text{ sec.}} = 123{,}000 \text{ pulses/sec.}$$

The drum has a maximum of 240 tracks; thus the track density is

$$\frac{240 \text{ tracks}}{\text{length}} = \frac{240}{12 \text{ inch}} = 20 \text{ tracks/inch}$$

The total storage capacity is

$$240 \text{ tracks} \times 2048 \text{ bits/track} = 491{,}520 \text{ bits}$$

If it is assumed that each character is composed of five bits of information, the drum will be capable of storing

$$\frac{491{,}520}{5} = 98{,}304 \text{ characters}$$

If six characters are considered to make a single word, then the drum will store

$$\frac{98{,}304}{6} = 16{,}384 \text{ words}$$

The head is spaced 0.0005 inch from the drum surface. The read output voltage varies from track to track due to minor irregularities in the surface and will be from 10 to 20 millivolts at a write pulse frequency of 123,000 pulses per second. As the write pulse repetition rate is increased the read voltage will decrease.

Write Amplifier

The purpose of the write amplifier is to generate the narrow current pulses which produce the flux to saturate the drum surface. A high bit density with little overlapping of flux into adjacent cells requires a pulse as narrow as possible; this pulse should be of sufficient amplitude to saturate the surface of the drum. However, since the head will have a certain inductance which opposes the build-up of current, the write pulse must be wide enough to pass the required write current. The write pulse should have a fast rise and fall time to minimize flux spreading at its leading and trailing edges, for by minimizing the area over which the flux is spread, we maximize the read voltage by cutting the flux lines in a very short time. The inductance of the read/write head is 0.15 millihenry and its d-c resistance is approximately 0.7 ohm. One hundred milliamperes of current is sufficient to saturate the head. The width of the generated write pulse is one microsecond. A current-limiting resistor is usually connected in series with the head to prevent excessive current flow through the head and its driving transistor. If this resistor is chosen to be 56 ohms, then the current build-up in the head will be

$$I_{head} = \frac{E}{R}\left(1 - e^{-\frac{t}{T}}\right)$$

where

I_{head} is the write current

t is the width of the write pulse or the time that current actually flows in the head

T is the time constant of the head circuit composed of the head inductance and the limiting resistor

E is the driving voltage

R is the series limiting resistor

The driving voltage is determined by the voltage limitations of the transistors of the write amplifier and is selected to be 18 volts.

$$I_{head} = \frac{E}{R}\left(1 - e^{-\frac{t}{T}}\right)$$

$$T = \frac{L}{R} = \frac{0.15 \times 10^{-3}}{56} = 0.268 \times 10^{-5}$$

$$I_{head} = \frac{E}{R}\left(1 - e^{-\frac{1 \times 10^{-6}}{0.268 \times 10^{-5}}}\right)$$

$$= \frac{18}{56}\left(1 - e^{-0.374}\right)$$

$$= 0.32\ (1 - 0.691)$$

$$\therefore I_{head} \simeq 100\ ma$$

Therefore, it is seen that sufficient current flows to saturate the drum surface.

Figure 3 shows the circuit configuration of the write amplifier.

The write amplifier operates in the following manner. Suppose that a series of *ones* are to be stored on the drum. Squared timing pulses having a period equal to the cell width are produced from a timing track of the drum. Since there are 2048 cells on a track and the drum makes a single revolution in one-sixtieth of a second or approximately 17 milliseconds, the period of these pulses is

$$\frac{17 \text{ milliseconds}}{2048} = 8.3 \text{ microseconds.}$$

The levels of these pulses are ground and negative 6 volts. When writing is desired, the command input of CR-2 is opened so that the clock pulses turn transistor Q-1 on and off at the timing track pulse rate. The output of Q-1 is a square wave which feeds the differentiating circuit consisting of C1 and R1. The positive output of this circuit is passed by diode CR-3 to act as a trigger for the blocking oscillator consisting of transistor Q-2 and transformer T-1. For each positive trigger pulse at the base of Q-2, a narrow, fast-rising pulse will be generated at the collector. The width of this pulse is independent of the input and dependent mostly on the transformer characteristics. This transformer is chosen to produce a pulse of one microsecond width. Diodes CR-4 and CR-5 form a gate which when opened will write *ones* on the drum. Making the input of CR-4 negative will open the gate and pass the pulses from the blocking oscillator to the base of Q-3. Q-3 will conduct for the period of the blocking oscillator pulse. The conduction of Q-3 forward biases the base emitter junction of driver amplifier Q-4. The result is that a current pulse 1 microsecond wide and of 100-milliamperes amplitude is delivered to one side of the drum head. The drum head consists of a center-tapped winding whose center tap is grounded. By applying the driving voltage to one side of the head, current is applied in either of the two possible directions, thus writing a *one* or a *zero*. During the writing of a *one*, the input of CR-7 is held at ground so that no blocking oscillator pulses are delivered to Q-5. Driving amplifier Q-6 does not conduct. If *zeros* are to be written, the gate consisting of diodes CR-6 and CR-7 would be opened to pass the 1-microsecond pulses and CR-4 would be ground to close gate CR-4, CR-5.

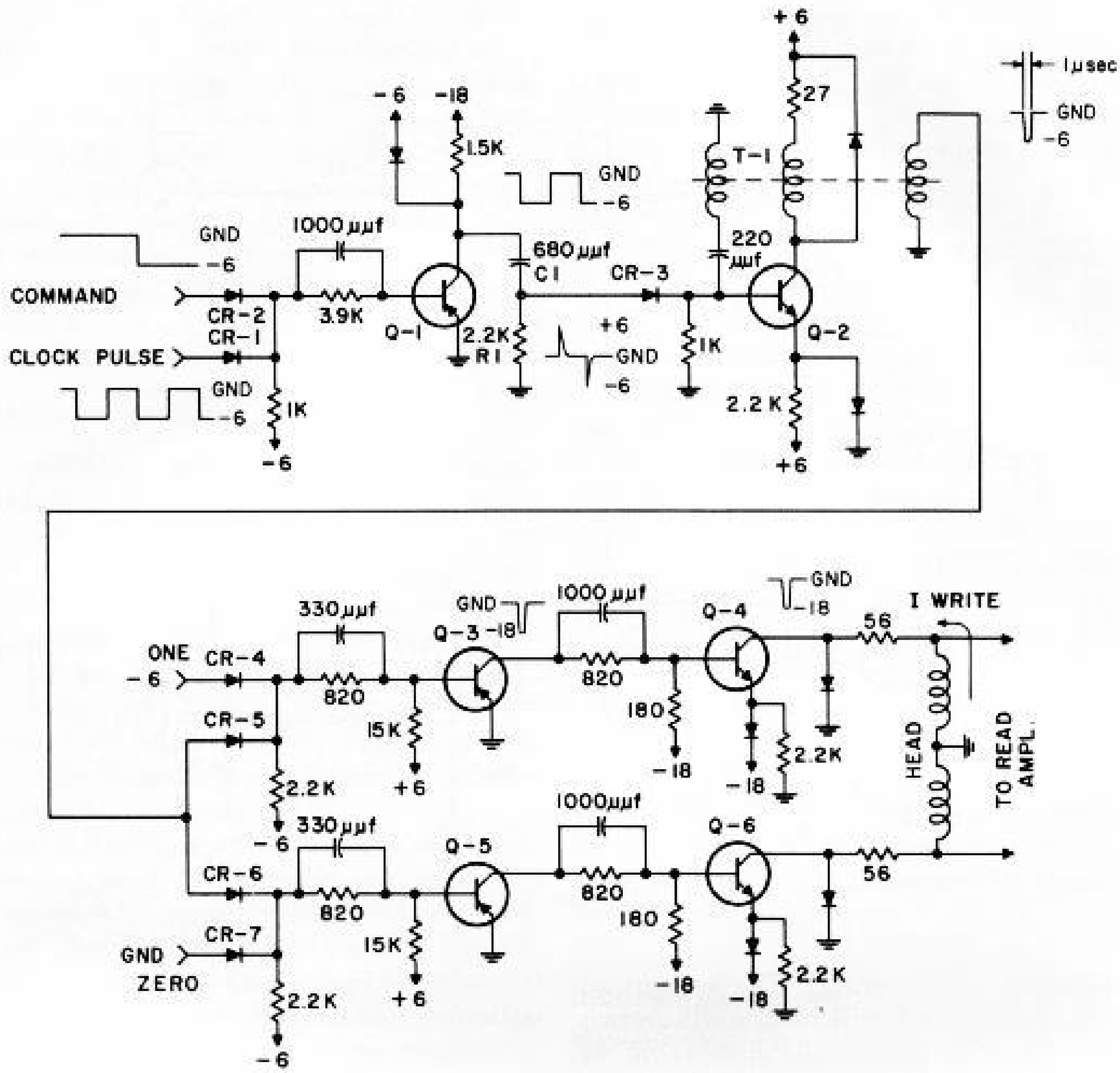

Figure 3.

Most storage material would consist of a mixture of *ones* and *zeros* so that diodes CR-4 and CR-7 would be constantly opening and closing their respective gates to correspond to the information. When writing is to cease the command gate is closed so that no pulses are generated by the blocking oscillator, and neither driver amplifier supplies current to the head. External logic circuits control the command, *zero*, and *one* gates.

The Read Amplifier

The purpose of the read amplifier is to amplify the voltages induced in the head windings to a level high enough to enable probing circuits to determine whether the induced voltage is a *one* or a *zero*. The voltage at the head will be on the order of 10 millivolts at write pulse repetition rates of 123,000 pulses per second. A balanced input amplifier consisting of two identical difference amplifiers is attached to the head. The difference configuration offers advantages in noise rejection due to the common mode effect. It also presents a high-input impedance to the head, which eliminates the necessity of coupling transformers.

Figure 4 is a circuit of the read amplifier.

Transistors Q-1, Q-2 form a difference amplifier in which the base of Q-1 is connected to one end of the center-tapped head, while the base of Q-2 is held at a-c ground potential by C1. R1 connects the bases of the transistors so that they are

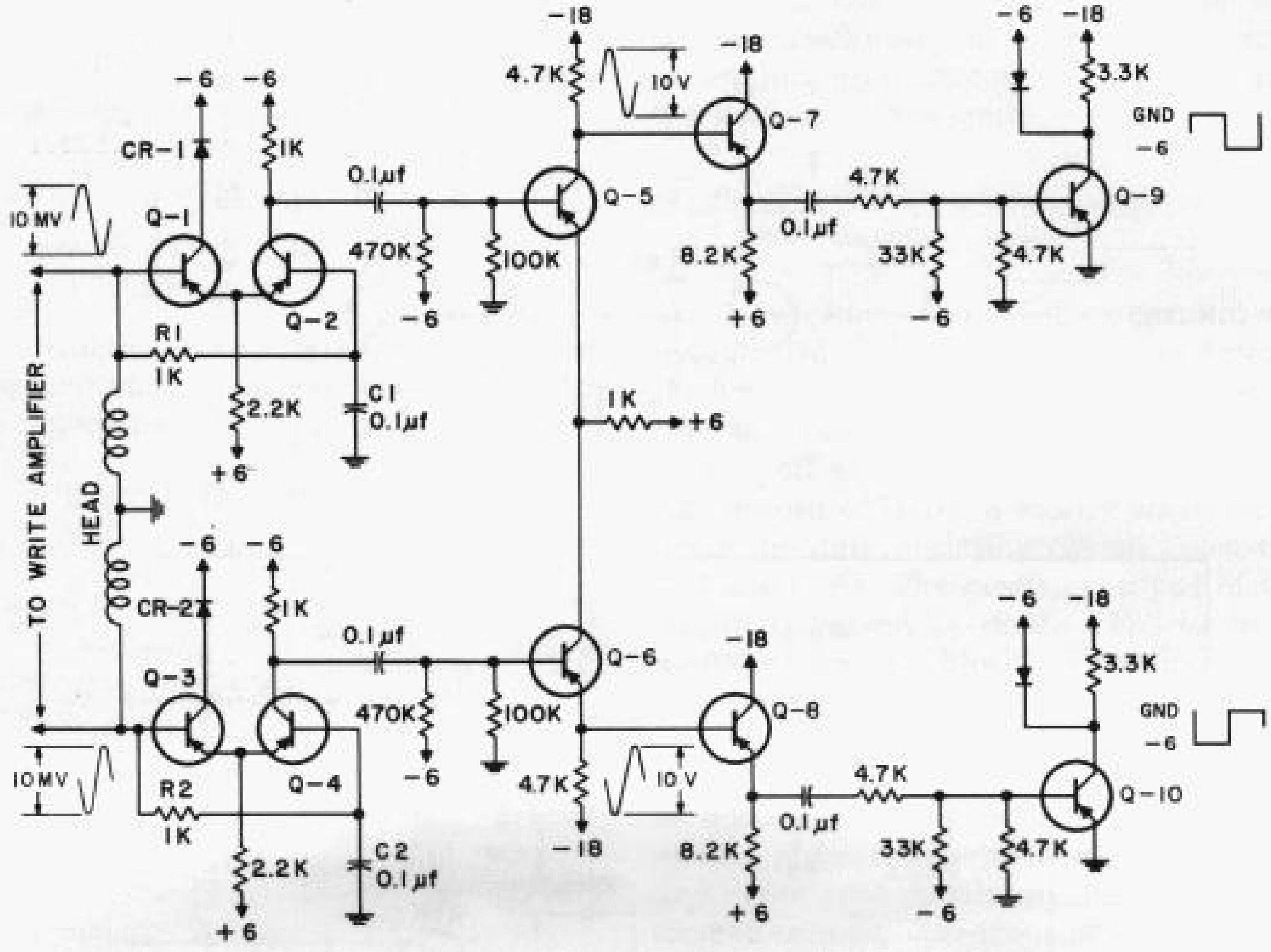

Figure 4.

at the same d-c potential. The output at the collector of Q-2 will be the difference between the a-c potentials appearing at the bases of Q-1 and Q-2. The input impedance of this emitter coupled amplifier is that of a common collector amplifier and is

$$R_i = \frac{h_{ie} + (h_{oe}h_{ie} - a_{fe}h_{re})R_L}{1 + h_{oe}R_L}$$

For transistors having a cutoff frequency in the region of 8 megacycles, the h parameters may be taken to be

$h_{ie} = 2000$ ohms

$h_{re} = 1$

$a_{fe} = -75$

$h_{oe} = 46\ \mu$mho

Substituting these values results in an input impedance of more than 150,000 ohms. This high-input impedance enables the read amplifier to be connected directly to the same bus bar as the write amplifier without affecting the writing.

The output of amplifiers Q-1, Q-2 and Q-3, Q-4 are of equal amplitude and opposite phase. They are capacitively coupled into the bases of Q-5 and Q-6 which provide further amplification. The combined voltage gain of the first two stages measured at the collectors of Q-5 and Q-6 is in the order of 1000. Therefore, for a 10-millivolt (peak-to-peak) input from each half of the head, a 10-volt swing may be expected at the collectors of Q-5 and Q-6. These outputs are opposite in phase. Q-7 and Q-8 are emitter followers whose emitters will reproduce the voltage of their bases at a reduced impedance level, thus producing a power gain. The outputs are used to drive Q-9 and Q-10 into their saturated and cutoff conditions. The outputs of Q-9 and Q-10 will be square waves 180 degrees out of phase. By probing either of these square waves it is determined if a bit of information is a *one* or a *zero*.

Diodes CR-1 and CR-2 in the collector leads of Q-1 and Q-3 are used to block collector-to-base current flow during writing, for at this time the base of these transistors would be more negative than the collector potential thus biasing the base-collector junction in the forward direction. Potentials of greater than −6 volts were not used in the first stage in order to keep the dissipation in these stages low.

Access to Information

In practice, there are usually many more tracks on a drum than read or write amplifiers, and in order to select particular information from the drum, a track selection matrix is used to connect the read/write amplifiers to the particular track to be written upon or read from. Electromagnetic relays, magnetic core devices, vacuum tube switches, and transistors have been used in these applications.

Once a track is selected, the counting of the bit cells around the periphery of the drum along any track requires the use of the timing (also termed clock) track. The timing track is an ordinary storage track in which each cell contains a *one*.

A counter is used to count the *ones* on the timing track, and a cell position is identified by its number on the timing track. By using the timing track of the drum as the timing source for all electronic circuitry associated with the drum, the entire storage system is synchronized. Information may be stored or read by a single amplifier in a serial fashion or a series of amplifiers may be connected to a like number of heads so that parallel (simultaneous) reading or writing takes place. The manner in which the information is put on, taken off, or transferred is determined by the type of system being designed. Examples of the various methods may be found in the accompanying bibliography.

The principles outlined here are used in digital computer storage devices where the relatively long access time is not detrimental to high-speed computer operation. Core storage devices having very fast access time are used in conjunction with drum storage when high-speed operation is a necessity. Magnetic drums are now in use for storing telegraphic information in high-speed automatic switching systems and have also been successfully used for telephone switching applications.

★ ★ ★ ★ ★

The work outlined here was carried out by the electronics group under E. J. Chojnowski of the Systems Development Division.

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Autofax and Desk-Fax Agency Offices

THE ORIGINAL Autofax* facsimile telegraph transmitting unit was replaced some time ago with a unit which is improved both in size and appearance and is in service at the Westside Airlines Terminal in New York City. The replacement made it possible to relocate the unit to a space which is more accessible to the public and as a result the number of telegrams sent automatically has increased substantially. Operation of the unit by Western Union patrons involves only three easy steps which eliminates any possible confusion. Furthermore, the depositing of coins to cover the charges and federal excise tax is not required. Telegrams, if not sent collect, are billed directly to the sender's name and address. The circuit for operation of the Autofax terminates in the central office Concentrator Unit 176-A which operates at 180 rpm.

Four additional units, similar to the one at the Westside Airlines Terminal, have been made available and two of the four are now in service at the Coliseum and at 26 Broadway, New York. A unit is also scheduled for installation at the Empire State Building in the near future, and the installation of another unit in a suitably located hotel in New York is under consideration. Installations in the various types of locations were arranged for the purpose of determining the places where the greatest use will be made of the Autofax by the public.

> **Agencies.** In many small places the volume of telegraph business is insufficient to justify the maintenance of an independent telegraph office. In some such places the company authorizes a retail or service establishment to act as an agent of the company in sending and receiving telegrams to and from that community. The agency is usually connected to the nearest independent Western Union office by a teleprinter, telephone or Telefax* circuit.

Photo H-2538

Autofax push-button facsimile telegram transmitter where messages may be written and dispatched immediately by the writer to a Western Union central office.

Some of the large hotels at Baltimore, Washington, New York City, Houston and Los Angeles are served by Autofax equipment (Transmitter 6449, Recorder 6450 and Transmitter 7120-A). These installations serve as replacements for Western Union branch office representation in some instances. However, Desk-Fax* Transceivers 6500 have proved to be more acceptable because they occupy a small space and are less expensive. Therefore, no additional Autofax equipment as described herein has been manufactured recently.

As of January 1, 1960 a total of 3545 telegraphically-equipped agency offices were in operation. Of this number 892 were served by Desk-Fax. The greater

*Registered Trademark, W. U. Tel. Co.

portion of Desk-Fax operated agencies are Class 9-B, 802 in number, located within the corporate areas already served by independent telegraph offices. Therefore the agencies serve as substitute or supplemental representation, and many are located in hotels, motels, hospitals, colleges and other types of institutions. The 90 Desk-Fax agencies representing the Telegraph Company as Class 9-C agencies (outside areas) include newly established agency offices as well as those which formerly were served by telephone or teleprinter.

Obvious advantages of Desk-Fax agency operation over other methods are numerous. The fact that agents are not required to utilize a substantial part of their time for the purpose of recording and transmitting messages by telephone or sending and receiving messages on teleprinters serves to maintain pleasant relations from compensation and service standpoints. Additionally, the appearance of Desk-Fax delivery copies is generally improved considerably as compared to longhand, typewritten or teleprinter copies. Thus agency representation turnover is lessened a great deal.

The supporting evidence of agency satisfaction with Desk-Fax is the fact that from January 1, 1958 to January 1, 1960 the number of Desk-Fax agencies increased 247 as compared to an increase of only 119 in teleprinter agencies. — W. J. TUCKER, General Supervisor — Terminal Operations.

Photo H-2587

Intrafax* facsimile recorder and transmitter (below) provide fast, direct handling of telegrams for hotel guests.

WILLIAM F. MARKLEY, Assistant Lines Engineer

Instrument Wire Design to Reduce Service Outages

It is possible, within the next few years, that polymer chemistry may make available to the communications and electronics industries new insulating materials for general instrument and hookup wire having improved cold flow characteristics and superior over-all performance. Reduced diameters and lowered costs of these wire products will be obtainable, thus opening new service horizons.

In wire consuming industries, billions of conductor feet of instrument and hookup wire are required annually for wiring equipment and for use as the conductors in multipair plastic-jacketed office cable which is employed for the most part in relatively short lengths. In these cable lengths, the jacket is frequently stripped for several feet at each end and the conductors fanned out along metal frames and over supports for termination. In all these applications, the resistance of the wire covering to deformation and electrical leakage plays an important part in reducing outages and providing adequate operating efficiency of the circuits under the various conditions of temperature and humidity encountered in service.

Flow is one of the most important properties of a plastic employed in the manufacture of many articles, both from the standpoint of processability as well as performance in service, and this characteristic is no less important for plastics intended for use as an insulating covering on instrument and hookup wire.

From the very beginning, when extruded thermoplastic insulations, particularly the polyvinyl chloride (PVC) formulations, were first introduced as an insulating covering for instrument and hookup wire and up to the present time, the cold flow characteristics or crushing and deformation of these compounds in normal use at or slightly above room temperature presented a problem in that, under relatively slight but sustained pressure, the insulation would be pushed from the conductor thus exposing the bare copper. This condition caused electrical shorts with adjacent conductors at crossovers or with the metal frame and equipment supporting members in cabinets, distributing frames, and so forth.

In fact, initially, instrument and hookup wire having a single extrusion of PVC insulation as the only covering for the conductor, employed for communication equipment wiring, gave so much trouble due to cut-through of the insulation in normal service, resulting in extensive outages and high maintenance cost, that serious consideration was given at that time by Western Union to reverting to rubber insulation, even though the PVC compounds possessed a unique combination of properties such as inertness, good electrical characteristics, high flame resistance, and adaptability or ease of adjusting physical properties to meet specific requirements.

However, after careful study and consideration of the factors involved, it was concluded that the relatively soft or conventional type of PVC insulation did not possess sufficient cut-through resistance to withstand small sustained crushing or deformation loads in service occurring where handmade forms were tightly bound with cable sewing twine at sections along the form, or where contacting wires crossed over each other and were pulled fairly tight, such as at the back of relay panels and at various points in other equipment, or where the wires were bent and held fast over metal angles and strip of equipment supporting frames in cabinets, and so forth.

Extra Jacket Tried

It was obvious, therefore, that in order to take care of the mechanical abuse normally encountered during installation and in service, some type of protection or additional covering or jacket was necessary if plastic-insulated wire were to be employed for wiring equipment. After some experimentation, it was found that a lacquered cotton serving would adequately reinforce and protect the plastic insulation against the various types of deformation or crushing met with in service, and at the same time would have a minimum effect on increase in diameter, a consideration that was extremely important where space limitation was a serious factor. In fact, in instances where a nominal 25 mils of PVC was employed, a drastic reduction in over-all diameter was obtained by substituting 10 to 15 mils of PVC and a lacquered cotton serving. Although considerable quantities of this type of wire were employed in Western Union for wiring equipment, it was subsequently found that manufacturing difficulties were being experienced resulting in large rejections during factory inspection due to the fact that contamination, caused by migration of the solvent for the lacquer into the plastic insulation, would materially degrade the insulating compound electrically so that extreme care had to be employed in the lacquering operation to reduce this type of trouble to a minimum. This processing difficulty had a serious adverse effect on the cost of the finished wire.

Later, when extruded nylon became available for this application, it developed that a very desirable substitute was found as a jacket for instrument wire to replace the lacquered cotton serving. The nylon-jacketed wire, which has been used for some time and which is still being employed to a considerable extent in the communications and electronics industries, has proven extremely satisfactory in protecting the plastic insulation against crushing and deformation at temperatures approximating room conditions and higher. However, the nylon has introduced certain objectionable factors, such as increased stiffness of the wire which has affected the time required to make handmade forms, increased stripping or skinning force which has resulted in a tendency to introduce work hardness in the conductor during the stripping operation thus resulting in brittle terminations, and increased diameters and excessive rigidity due to manufacturing difficulties involved in controlling the thickness of the nylon jacket. In fact, according to field complaints, the stiffness of the nylon-jacketed wire is a continual source of annoyance with this type of covering. It has also been observed that, in some instances, extruded nylon has a tendency to adhere tightly to the primary insulation, and on severe bending and forming of the wire the nylon will crack and pull the PVC compound causing it to crack also.

Semirigid PVC

In recent years the development of semirigid PVC compounds, having increased toughness, deformation resistance and hardness as compared with the conventional PVC formulations, has made available to wire consuming industries instrument wire having a single extrusion of this material, which would appear to provide equivalent performance in crushing and deformation of, and at the same time overcome the principal objections to, the PVC nylon-jacketed wire with a saving in cost resulting from the omission of the nylon jacket.

The semirigid PVC compounds are formulated with a much higher resin-to-plasticizer ratio than is normally used in conventional PVC compounds in order to improve such characteristics as deformation and abrasion resistance. This increase in resin-to-plasticizer ratio is attained through the substitution of resin for filler which is employed in considerable quantity in conventional formulations. Because fillers are lower in cost than resin, semirigid PVC compounds generally cost more than conventional compounds.

However, study of a number of the semirigid compounds indicated that while some of these formulations possess appreciable increased hardness initially as compared with the conventional compounds, their resistance to cold flow, crushing and deformation at or a little above room temperature was only slightly better than the conventional PVC compounds. Other of these elastomers appeared to possess greatly improved deformation resistance under these various conditions of service. The problem then was to develop a test procedure that would characterize these various formulations from the standpoint of acceptable resistance to crushing or deformation in service. Since nylon-jacketed PVC-insulated wire is considered an acceptable product in general hookup wire use wherein the various types of mechanical deformation of the covering on the conductor are encountered, it was felt that any high-strength semirigid formulation that would approximate the nylon-jacketed wire in its resistance to crushing and deformation under simulated service conditions would be adequate for wiring equipment, assuming of course that it met all the various other important requirements pertaining to physical and electrical characteristics, heat shock, flammability, and the like.

In view of the wide variety of polyethylene compounds available and the possibility of their use for insulation on instrument and hookup wire it was considered desirable to include these formulations in this study along with the conventional and semirigid PVC compounds. Preliminary tests indicated that conventional polyethylenes in combination with a protective jacket of nylon exhibit desirable physical, electrical and deformation characteristics. Conventional polyethylenes are considered to increase in deformation resistance with increase in molecular weight. Linear polyethylenes, per se, possess excellent electrical characteristics and are extremely tough with inherently high resistance to crushing and deformation.

TEST METHODS

Accordingly, Western Union engineers considered it desirable to attempt to develop a so-called cold flow or deformation test for instrument wire that would approximate in some degree the relatively severe conditions of deformation encountered in service resulting from slow compression or crushing of the insulation at or slightly above room temperature. It was obvious that any sharp-edged component employed to create deformation of the insulating covering under pressure would be undesirable because the formation of a severe notch would automatically create an initial weakness in the insulation that would readily cause cracking of the compound. It was indicated that some form of small rounded edge to transfer the pressure would be more significant.

From the many methods of transferring pressure to the test wire that were considered, it was found that a desirable means was by the use of No. 20 A.w.g. bare solid tinned copper wire. Furthermore, in order to reduce to a minimum the various factors that enter into a test of this kind, it was decided to employ only one size and kind of commercial wire for the conductor of the test specimens, namely, No. 22 A.w.g. tinned solid annealed copper which is the principal type employed by Western Union and others for wiring equipment.

With these preliminary factors established, it was decided to take a 12-inch length of instrument wire to be tested from which the covering was stripped for about ½ inch at each end. This wire was

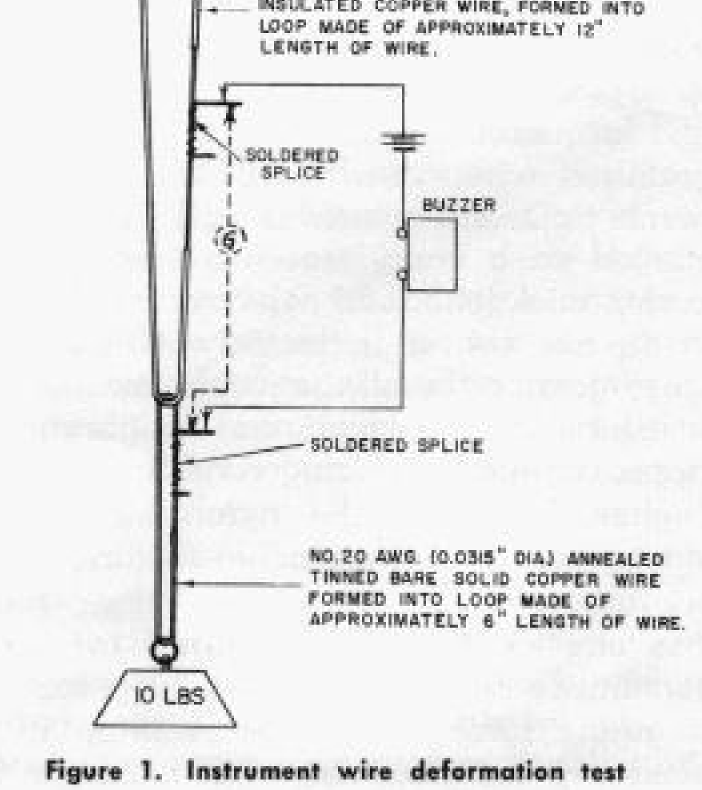


Figure 1. Instrument wire deformation test

then formed into a loop and the ends soldered together. A similar loop was made using the No. 20 A.w.g. copper wire (diameter 0.032 inch), referred to above, formed to interlock the test loop in planes 90 degrees to each other. A weight was suspended from the No. 20 gage copper wire. This system of loops and weight was hung vertically, with a dry battery and low-voltage buzzer inserted in an electrical circuit through connections to the soldered joints of each loop as indicated in Figure 1.

A number of deformation tests have been developed by other investigators but in general these involve light loads at elevated temperature or gradually increasing loads applied at a uniform speed at room temperature until the insulation is severed involving a short space of time. Most of these tests do not approximate normal general service conditions herein discussed or provide adequate discrimination to distinguish between compounds having good resistance to failure by slow compression or crushing under sustained load at or slightly above room temperature and those having much less toughness and rigidity under similar conditions.

In the initial tests a weight of 5 pounds was employed with the system suspended at room temperature. Under these conditions it was observed that various types of covering on the conductor showed only slight deformation at the point of contact with the No. 20 gage bare wire after a period of several months. In order to increase the severity of the test the weight on the bare copper wire was increased to 10 pounds but this change was not sufficient to increase materially the deformation in a relatively short period of time.

Heating Added

At this point, it was observed that instrument wire in service is frequently subjected to slight heating which has a marked effect on deformation. In view of this condition and the desire to speed up the test, the system of loops of the wires and the suspended 10-pound weight was placed in an oven arbitrarily maintained at a temperature of 122 degrees F and continuously recorded on "America Recorder" charts of the Consolidated Ashcroft Hancock Company. The relative humidity was not controlled but was measured and showed a value of approximately 15 percent throughout the test. This slightly increased temperature over room conditions was found to be extremely helpful in accelerating deformation of the formulations under consideration.

Preliminary tests indicated that the standard conventional PVC-insulated and nylon-jacketed wire was capable of withstanding this test for a period of 6 to 7 days before drastic deformation of the covering took place and, accordingly, the duration of the test in this study was confined to this period of time. In a few instances check tests were made after a 4-day test period. It was further considered that any other type of covering that would provide equivalent performance in this test would, in all probability, be equal to the commonly used conventional PVC insulation and nylon jacket in normal service. Moreover, in these initial tests, it was observed that discriminating deformation results were obtained for insulating compounds having different degrees of rigidity and toughness.

Leads from the electrical circuit of the system of loops were brought out of the oven for use in performing the buzzer test and determining insulation resistance with a Northrup galvanometer. The buzzer test employed to detect complete severing of the insulating covering on the test specimen was made periodically during the day. In specimens which showed complete severing of the insulating covering as indicated in the buzzer test, no further examination was made. In the case of those specimens which did not fail in the buzzer test, the specimen test loop, while still in the oven at 122 degrees F and supporting the weight, was subjected to an insulation resistance test at 135 volts d.c. measured between the soldered joints of the two loops (See Figure 1). After removal from the oven and cooling to room temperature, the lower part of the specimen test loop where the load was concentrated and without disturbing its shape, was then immersed in water at 75 degrees F for 1 hour after which the insulation resistance was measured again to indicate the extent of the electrical protection still afforded by the depressed section of the insulating covering of the specimen at the point of application of the load.

After allowing the specimens to dry at room temperature, a longitudinal section of each specimen test loop along the point of application of the load was skived with a razor blade to the surface of the conductor and then gently abraded by hand, using extra fine grade sandpaper, to a depth of about one-half the conductor diameter so as to expose the thinnest point of the insulating covering. The thickness of this covering at the point of load concentration (thinnest section) was then measured under a Gaertner microscope using a magnification of approximately 30 times. Because of these time-consuming examinations, every specimen was not measured but at least one specimen representative of each type of insulating covering was so examined.

Only commercially available PVC primary and nylon jacket formulations, although some were in the experimental stage when this work was started, are included in this study. All of these PVC compounds are considered to have adequate physical, electrical, heat shock, aging and flammability characteristics and are recommended by the various suppliers for service as the primary insulation on instrument wire. Similarly, the nylon compounds were recommended by the different producers for wire jacket service.

The various kinds of extruded insulating coverings, comprising the commonly used (for No. 22 A.w.g. wire) nominal 10-mil radial wall thickness of primary insulation in combination with an extruded heat-stabilized clear nylon jacket, having a nominal 2- to 3-mil radial wall thickness, that were included in this study are listed below. This construction is employed in large quantities as instrument and hookup wire and in multiconductor cables for wiring electronic and automatic equipment in many industries, is specified by Government agencies, and is a stock item with most of the wire and cable suppliers. Because of interest in extra-thin walls of insulation for use where space considerations are important, a group of samples were included in which a 7-mil wall of primary insulation was substituted for the 10-mil wall referred to above. The nylon employed for jacketing consisted of the conventional nonplasticized formulations except in one instance where a plasticized nylon was used with the idea of improving the stripping characteristics of the finished wire.

(a) Conventional PVC compounds in combination with various makes of nylon jacket (Western Union Standard).

(b) Conventional PVC compound with a plasticized nylon jacket.

(c) Extra-thin wall (7 mils) of conventional PVC compounds with a nylon jacket.

(d) Low- and medium-density polyethylenes with a nylon jacket.

(e) Flameproof polyethylene in two types with a nylon jacket.

The various extruded formulations, in a nominal 10-mil radial wall thickness, without any jacket, that were considered in these tests included the following:

(a) Conventional PVC compounds

(b) Semirigid PVC compounds

(c) Low- medium- and high-density polyethylenes.

TEST RESULTS

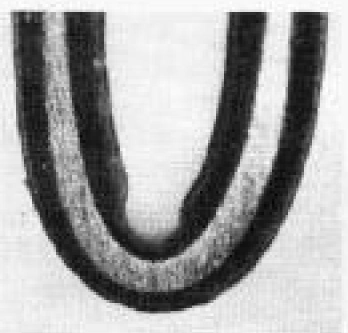
NYLON-JACKETED WIRE

Compilations of the test results and observations of the performance of the foregoing insulating coverings, all of which can be supplied on a reasonably competitive basis from a cost standpoint, are shown in Tables 1 and 2. These include the tensile characteristics of the primary insulation of the samples as received, the radial wall thickness of the components of the covering before and after the deformation test, and the dry and wet insulation resistance measurements of the section of the test specimens subjected to the concentrated sustained load. The manufacturers' hardness values, based on tests of molded specimens of the primary insulations where readily available, are also tabulated.

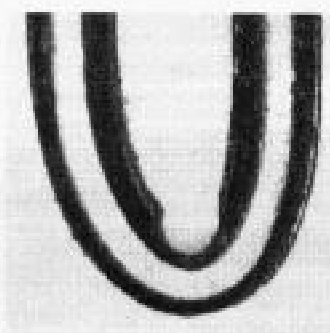
From an examination of the data in Table 1, which shows the test results on the nylon-jacketed wire, it will be observed that the extruded nylon jacket of the different manufacturers provides excellent rigidity and resistance to deformation regardless of the type of primary insulation employed. All of these samples, even those having only

7 mils of conventional PVC primary insulation, withstood the test without cut-through, and all except the one having the plasticized nylon showed a dry insulation resistance value after the deformation test of practically infinity. The relatively soft plasticized nylon jacket permitted a greater transfer of the concentrated load to the primary insulation thus causing increased deformation of the PVC compound and somewhat lower insulation resistance values. In the wet test, the low- and medium-density polyethylenes, the flameproof polyethylenes, and the conventional 10-mil PVC compounds also had insulation resistance values of practically infinity except one of the flameproof polyethylene compounds which showed a value of 175,000 megohms.

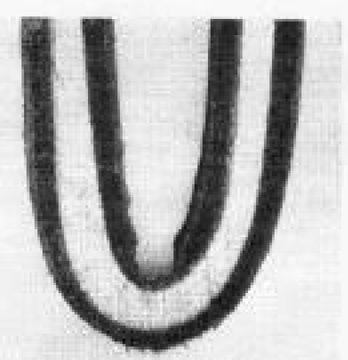
In the case of the samples having the extra-thin wall (7 mils) of conventional PVC primary insulation, the insulation resistance of some specimens in the wet test was low



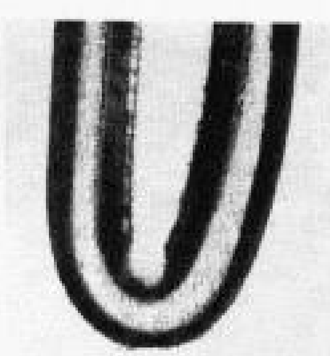
Identification "BN" (a)
Opalon 1038 & Zytel 33
Thickness—
Before Test—
Primary 10 mils
Jacket 4 mils
After Test—
Primary 3 mils
Jacket 3 mils



Identification "CN" (a)
Geon 6373 & Spencer 600
Thickness—
Before Test—
Primary 10 mils
Jacket 3 mils
After Test—
Primary 2 mils
Jacket 2 mils



Identification "EN" (c)
Geon 8801 & Zytel 33
Thickness—
Before Test—
Primary 7 mils
Jacket 3 mils
After Test
Primary 0.5 mil
Jacket 2 mils



Identification "FN" (a)
Exon 5360 & Firestone 210
Thickness—
Before Test—
Primary 7 mils
Jacket 4 mils
After Test—
Primary 3 mils
Jacket 2 mils

Figure 2. Skived sections of PVC-insulated and nylon-jacketed test specimens. Mag. 8.5 X

and consistent with the marked thinning out of these compounds during the deformation test, as indicated in Table 1. As would be expected, the performance of the nylon-jacketed wire having only 7 mils of conventional PVC primary insulation is dependent, in large measure, on the degree of toughness and resilience of the PVC formulation employed. It would appear that the use of semi-rigid PVC polymers is necessary in this construction in order to insure adequate physical and electrical characteristics particularly in areas where sustained relatively high temperature and humidity are encountered.

Referring to the radial wall thickness values of the primary insulation and nylon jacket on the samples included in Table 1, it will be observed that the nylon jacket exhibited marked resistance to deformation and decreased in thickness by only 1 to 2 mils. Practically all of the cold flow occurred in the primary insulation. The samples having the 10 mils of conventional PVC formulations showed uniform and consistent deformation of the primary insulation as compared with a wide variation in the degree of deformation that was observed in those specimens having only 7 mils of primary insulation. In the case of the polyethylenes, the medium molecular weight low-density compound (M.I.-1.8, density 0.923, ASTM Type 1) showed greater resistance to deformation as compared with the formulation having somewhat lower molecular weight and medium density (M.I.-3.0, density 0.93, ASTM Type 2). The flameproof polyethylenes displayed a low resistance to deformation notwithstanding the heavy wall (5 mils) of nylon. Figure 2 shows the skived sections of some of these samples at a magnification of 8.5 times. The appearance of the test specimens before skiving is illustrated in Figure 3.

Buckling of Nylon

A factor that contributes considerably in the deformation resistance of the nylon-jacketed wire is that, on bending the wire, the nylon buckles and ridges in varying degrees on the concave side as indicated in Figure 4, which shows specimens with and without the nylon jacket bent at 90 and 180 degrees respectively. This condi-

NO. 22 A.W.G. SOLID TINNED COPPER WIRE COVERED W

Identification	Processor of Finished Wire	Characteristics of Samples as Received: Type of Primary Insulation	Primary Color	Nylon Jacket		Radial Wall Thickness: Primary mils	Jacket mils	Primary Tensile psi
		Polyvinyl Chloride (PVC) Primary Insulations and Nylon Jacket ('						
AN	General Cable Corp	Opalon 1038	Brown	Zytel 33		10	3	2500
BN	Superior Cable Corp.	Opalon 1038	Black	Zytel 33	(a)	10	4	2500
			Black		(b)	10	4	2500
CN	Plastic Wire & Cable Co.	Geon 6373	Black	Spencer	(a)	10	3	2160
			Black	600	(b)	10	3	2160
			Black		(c)	10	3	2160
DN	General Cable Corp.	Un. Carbide QFD-9921	Orange	Zytel 69 (Plasticized Nylon)		10	5	2700
EN	General Cable Corp.	Geon 8801	Black	Zytel 33	(a)	7	3	2800
			Black		(b)	7	3	2800
			Brown		(c)	7	3	2800
			Black		(d)	8	2	2700
FN	General Cable Corp.	Exon 5360	Black	Firestone	(a)	7	4	2900
			Black	210	(b)	7	4	2900
						Polyethylene Formula		
GN	General Cable Corp.	DuPont 3066 M.I.-3.0, Dens. 0.93 Type 2	Green	Zytel 33		10	4	2200
HN	General Cable Corp.	DuPont 5N-BC-10 M.I.-1.8, Dens. 0.92 Type 1	Green	Zytel 33		10	5	2500
IN	General Cable Corp.	DuPont Rulan (Flameproof) M.I.-3.6, Dens. 1.30	Green	Zytel 33		10	5	2300
JN	General Cable Corp.	Gen. Cable R-1756-26A (Flameproof) M.I.-0.6, Dens. 0.92 base resin	Green	Zytel 33		9	5	1820

N.M.—Not Measured

M.I. —Mfr's Melt Index, dg. per min, ASTM Spec. D-1238-57T

E 1

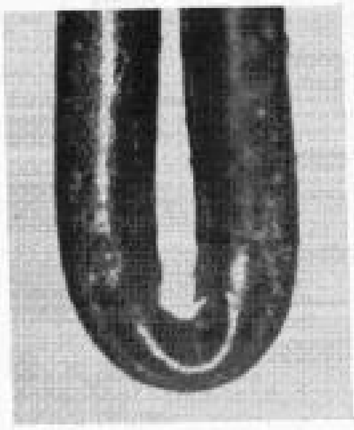
ITH PRIMARY INSULATION AND CLEAR NYLON JACKET

Insulation Elong. in 2" %	Manufacturer's Shore Hardness (Molded Specimen)	Buzzer Test	Characteristics After Deformation Test: Insulation Resistance: Dry Test 122°F, 15% R.H. megohms	Wet Test In Water–1 hr. 75°F. megohms	Radial Wall Thickness: Primary mils	Jacket mils
AN," "BN" and "CN" represent standard Western Union construction)						
125	89-A	OK—4 days	infinity	infinity	3	2
125	89-A	OK—6½ days	700,000	700,000	3	3
125	89-A	OK—4 days	700,000	700,000	N.M.	N.M.
125	83-A	OK—7 days	700,000	700,000	2	2
125	83-A	OK—4 days	infinity	425,000	3	2
125	83-A	OK—4 days	infinity	425,000	3	2
135	88-A	OK—7 days	14,000	70	1	4
90	91-A	OK—7 days	700,000	9	0.5	2
90	91-A	OK—6½ days	700,000	19	0.5	2
100	91-A	OK—6½ days	700,000	12	0.5	2
100	91-A	OK—6½ days	350,000	0.14	0.5	2
325	89-A	OK—6 days	infinity	37,000	3	2
325	89-A	OK—6 days	infinity	3,400	3	2
ions and Nylon Jacket						
500	—	OK—7 days	infinity	infinity	1	2
375	—	OK—7 days	infinity	infinity	4	3
400	—	OK—7 days	infinity	infinity	1	3
325	—	OK—7 days	700,000	175,000	0.5	4

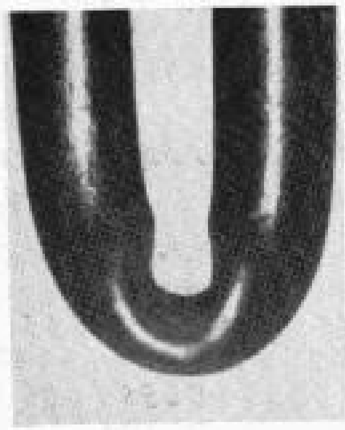
Type No.—Refers to ASTM Spec. D-1248-58T
Density —Mfr's value, refers to ASTM Spec. D-792-50

tion does not generally exist when no nylon jacket is present. Even the semirigid PVC compounds and the tough linear polyethylenes do not exhibit this type of buckling on bending the wire. The characteristic has the effect in service of materially increasing the nylon thickness at all points where the wire is bent and formed during installation.

Conventional PVC Primary Insulation and Nylon Jacket

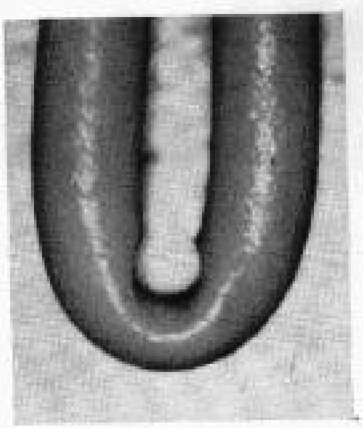


Identification "EN" (d)
Geon 8801—8 mils
Nylon —2 mils
Withstood 6½ days in test

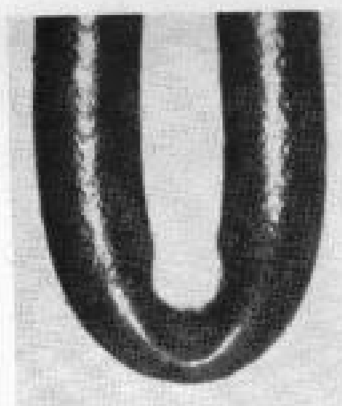


Identification "BN" (a)
Opalon 1038—10 mils
Nylon — 4 mils
Withstood 6½ days in test

Semirigid PVC Insulation, No Nylon



Identification "Q" (a)
Opalon 71344—10 mils
Failed after 4 days in test



Identification "J" (a)
Turbo 80—11 mils
Withstood 6 days in test

Linear Polyethylene

Identification "GP" (a)
Hi-fax 1605—11 mils
Withstood 7 days in test

Figure 3. Typical appearance of test specimens after the deformation test, *before* skiving. Mag. 8.5 X

TEST RESULTS

NONJACKETED WIRE

Table 2 shows the relative performance of the various formulations employed as the primary insulation without any overcovering or jacket of any kind. It will be observed from the test values that conventional PVC compounds, whose tensile values usually run less than 3000 psi, exhibit low resistance to crushing and deformation as indicated by cut-through in a short period of time. This is in marked contrast to the performance of these compounds when used in combination with a nylon jacket as indicated in Table 1 discussed above.

Semirigid PVC compounds, all of which generally have tensile strengths in the range of 4000 to about 5600 psi, showed varying degrees of resistance to crushing and deformation as indicated in these tests in Table 2. Some of these compounds lacked homogeneity or uniformity in processing which resulted in a variation in performance from good to poor. The deformation or crushing resistance of a PVC compound does not appear to be characterized entirely by its hardness or tensile properties. Probably resilience plays an important part in the deformation quality of the compound. The behavior of a PVC compound in crushing and deformation seems to be dependent more on the type of plasticizer employed and its solvent action, together with adequate processing control and extrusion technique to insure uniformity and homogeneity in the finished extruded dialectric.

Some of the semirigid PVC compounds displayed consistent and outstanding performance in these tests in their resistance to crushing and deformation. For instance, the Goodrich Geon 8850, the Synthinol No. 801 by Rome Cable Corporation, the Union Carbide QFDB 9250, and the Formulation No. V-116 by General Cable Corporation exhibited the greatest resistance to crushing and deformation in that the original 10- to

Conventional PVC Primary Insulation and Nylon Jacket

Identification "CN"
Geon 6373—10 mils
Nylon — 3 mils

Identification "BN"
Opalon 1038—10 mils
Nylon — 4 mils

Semirigid and Conventional PVC Insulation without Nylon Jacket

Identification "J"
Turbo 80—11 mils
(Semirigid Compound)

Identification "M"
Synthinol 801—11 mils
(Semirigid Compound)

Identification "B"
QFD 9909—11 mils
(Conventional PVC Compound)

Figure 4. Typical buckling of nylon-jacketed wire on bending in contrast to freedom from buckling of the nonjacketed wire. 90- and 180-degree bends on No. 20 A.w.g. wire. Mag. 8.5 X

11-mil wall of compound thinned out to only about one-third to one-half the original thickness and consequently showed high insulation resistance values in both the dry and wet tests. Figure 5 shows skived sections of semirigid PVC-insulated specimens at a magnification of 8.5 times.

20-Percent Faster

By analyzing the deformation data shown in Table 1, it would appear that the primary insulation on the wire having the conventional 10-mil PVC formulations and nylon jacket deform or thin out at an average rate of about 1¼ mils per day over a 6-day test period in this simulated slow compression test, notwithstanding the mechanical reinforcement of the nylon jacket. In the case of the semirigid PVC compounds of equivalent thickness, which made a good showing in these tests as listed in Table 2, indications are that these deform or thin out at an average rate of approximately 1 mil per day over a 6-day period. In other words, the commonly used conventional PVC compounds, even with the nylon protection, deform about 20 percent faster than the semirigid PVC formulations.

This is an interesting phenomenon, because it indicates that the conventional PVC compound would be completely crushed, leaving only the nylon in contact with the conductor, long before complete severing of the semirigid PVC formulation would occur. Consequently, in areas where prolonged periods of high temperature and relative humidity are encountered, on the order of 90 degrees F and 90 percent and higher, respectively, the performance from the standpoint of electrical leakage in electronic hookup wire service could be expected to be superior for the semirigid PVC-insulated conductor. Although an appreciable thickness of nylon might be present on the nylon-jacketed wire after the conventional PVC compound had completely deformed, practically no protection from an electrical leakage standpoint could be expected because of the low-volume resistivity inherent in nylon at high humidities.

The importance of the foregoing electrical considerations can be emphasized by referring to the performance in Western Union reperforator switching centers of multipair office cable formerly processed with enamel- and textile-insulated conductors. During periods of adverse weather conditions, as noted above, it had been difficult to operate the circuits adequately, even when using fans and heaters to dry out the wire and cable. When the proposal was made to substitute PVC-insulated and nylon-jacketed wire for the enamel- and textile-insulated conductors in these cables as at present, the installation and operating divisions refused

TABLE 2

NO. 22 A.W.G. SOLID TINNED COPPER WIRE COVERED WITH PRIMARY INSULATION ONLY

	Description of Insulation—Samples as Received							Characteristics After Deformation Test			
									Insulation Resistance		
Identification	Processor of Finished Wire	Type of Compound	Color	Radial Wall Thickness (mils)	Tensile (psi)	Elong. in 2 in. (%)	Mfr's Shore Hardness (Molded Spec'm)	Buzzer Test	Dry Test (122°F. 15% R.H.) (megohms)	Wet Test in Water—1 hr. 75°F. (megohms)	Radial Wall Thickness of Insulation (mils)
			Conventional Polyvinyl Chloride (PVC) Formulations								
A	Gen. Cable Corp	Opalon 1038	Black	11	2700	150	89-A	Failed—3 hr.	—	—	Cut-through
B	Judd Mfg. Co.	Un. Carbide QFD-9909	Black	11	2680	150	71-A	Failed—48 hr.	—	—	Cut-through
C	Firestone Chem. Co.	Exon 5360	Pink	12	2900	325	89-A	Failed—1 hr.	—	—	Cut-through
			Black	7	2900	325	89-A	Failed—15 min.	—	—	Cut-through
D	Firestone Chem. Co.	Exon 5090	Pink	11	2900	310	88-A	Failed—5 min.	—	—	Cut-through
E	Gen. Cable Corp.	Un. Carbide VFD-9033	Black	10 (a)	3000	225	82-A	Failed—30 min.	—	—	Cut-through
				(b)	3000	225	82-A	Failed—30 min.	—	—	Cut-through
				(c)	3000	225	82-A	Failed—30 min.	—	—	Cut-through
			Semirigid Polyvinyl Chloride (PVC) Formulations								
F	Firestone Chem. Co.	Exon 1063X	Pink	11	4400	350	98-A	OK—5 days	300,000	0.14	0.5
G	Firestone Chem.	Exon 5190	Pink	10	3890	245	94-A	Failed—4 days	—	—	Cut-through
H	Firestone Chem.	Exon 5205	Pink	12	4670	335	95-A	Failed—2 days	—	—	Cut-through
I	Firestone Chem.	Exon 5168	Pink	10 (a)	4300	300	100-A	OK—6 days	350,000	0.14	0.5
				(b)	4300	300	100-A	Failed—8 hr.	—	—	Cut-through
				(c)	4300	300	100-A	Failed—8 hr.	—	—	Cut-through
J	Wm. Brand & Co.	Turbo 80	Brown	11 (a)	4100	105	—	OK—6 days	350,000	0.12	2
				(b)	4100	105	—	OK—7 days	350,000	0.18	4
K	Goodrich Chem. Co.	Geon 8800	Black	14 (a)	4200	500	79-C	Failed—3 days	—	—	Cut-through
				(b)	4200	500	79-C	Failed—1 day	—	—	Cut-through
L	Gen. Cable Corp.	Gen. Cable Code V-116	Gray	11 (a)	3900	130	—	OK—7 days	700,000	700,000	3
				(b)	3900	130	—	OK—7 days	140,000	23,000	2
				(c)	3900	130	—	OK—7 days	infinity	infinity	4
			Orange	11 (a)	3720	150	—	OK—7 days	infinity	700,000	3
				(b)	3720	150	—	OK—7 days	360,000	36,000	2
			Striped	10 (a)	3650	125	—	OK—7 days	infinity	infinity	3
			(Red-Green-White)	(b)	3650	125	—	OK—7 days	700,000	700,000	3

M	Rome Cable Corp.	Synthinol No. 801-Rome	Black	11 (a)	5280	275	—	OK—7 days	infinity	infinity	6
				(b)	5280	275	—	OK—4 days	infinity	infinity	N.M.
				(c)	5280	275	—	OK—4 days	infinity	infinity	N.M.
N	Goodrich Chem. Co.	Geon 8733	White	10	4300	260	85-C	Failed—1 hr.	—	—	Cut-through
O	Goodrich Chem. Co.	Geon 8830	White	10	5000	265	65-D	Failed—90 min.	—	—	Cut-through
P	Goodrich Chem. Co.	Geon 8850	White	10 (a)	5680	250	71-D	OK—7 days	infinity	350,000	4
				(b)	5680	250	71-D	OK—4 days	infinity	infinity	N.M.
Q	Gen. Cable Corp.	Opalon 71344	White	10 (a)	4190	300	94-A	Failed—4 days	—	—	Cut-through
				(b)	4190	300	94-A	Failed—1 day	—	—	Cut-through
				(c)	4190	300	94-A	Failed—4 hr.	—	—	Cut-through
R	Gen. Cable Corp.	Un. Carbide QFDB-9250	Black	10 (a)	4300	154	100-A	OK—4 days	infinity	infinity	5
				(b)	4300	154	100-A	OK—4 days	infinity	infinity	4
				(c)	4300	154	100-A	OK—4 days	infinity	infinity	N.M.
			Polyethylene Formulations—Low and Medium Density								
AP	Gen. Cable Corp.	DuPont-3066 M.I.-3.0, Dens. 0.93 Type 2	Green	11	2100	450	—	Failed—1 hr.	—	—	Cut-through
BP	Kerite Co.	DuPont-Alathon 3B M.I.-0.45, Dens. 0.92 Type 1	Natural	10 (a)	2910	500+	—	Failed—6 days	—	—	Cut-through
				(b)	2910	500+	—	Failed—8 hr.	—	—	Cut-through
CP	Gen. Cable Corp.	Monsanto 12203 M.I.-0.3, Dens. 0.92 Type 1	Natural	10 (a)	2500	500+	75-C	Failed—8 hrs.	—	—	Cut-through
				(b)	2500	500+	75-C	Failed—8 hrs.	—	—	Cut-through
			Polyethylene Formulations—High Density								
DP	Kerite Co.	Un. Carbide DGDB-4100 M.I.-0.4, Dens. 0.95 Type 3 (Linear)	Natural	10 (a)	3340	500+	—	OK—7 days	infinity	350,000	1
				(b)	3340	500+	—	OK—7 days	infinity	infinity	4
				(c)	3340	500+	—	OK—7 days	360,000	51,200	2
EP	Gen. Cable Corp.	Same as "DP"	Natural	9 (a)	3500	500+	—	OK—7 days	240,000	42,400	2
				(b)	3500	500+	—	OK—7 days	360,000	8,480	3
FP	Gen. Cable Corp.	Hercules Hi-fax 1605 M.I.-0.3 max. Dens. 0.945, Type 3 (Linear)	Natural	11 (a)	3750	500+	65-D	OK—7 days	infinity	infinity	4
				(b)	3750	500+	65-D	OK—7 days	infinity	infinity	5
				(c)	3750	500+	65-D	OK—7 days	infinity	infinity	6
GP	Superior Cable Corp.	Same as "FP"	Red	11 (a)	3000	600+	65-D	OK—7 days	infinity	infinity	6
				(b)	3000	600+	65-D	OK—7 days	infinity	350,000	5
HP	Kerite Co.	Phillips Marlex 50 M.I.-0.60, Dens. 0.96 Type 3	Natural	10 (a)	3320	500+	—	OK—7 days	700,000	Cracked on outside of bend but intact on inside of bend	
				(b)	3320	500+	—	OK—7 days	700,000		

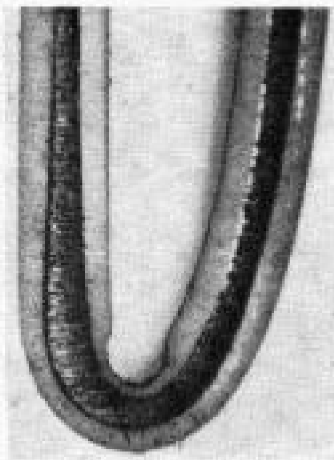
N.M.—Not Measured
M.I. —Mfr's Melt Index, dg. per min, ASTM Spec. D-1238-57T
Type No.—Refers to ASTM Spec. D-1248-58T
Density —Mfr's value, refers to ASTM Spec. D-792-50

to approve the substitutions unless the new cables were guaranteed to be superior in electrical leakage performance during periods of high temperature and humidity.

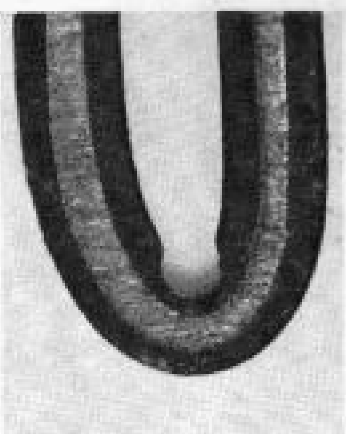
Certain polyethylenes showed outstanding performance in these tests, particularly the high-density (ASTM Type 3) linear types such as the Hercules Hi-Fax 1605 and the Union Carbide DGDB-4100, both of which have a tensile strength of only 3000 to 3700 psi; these displayed a high percentage of their original thickness after the deformation test and excellent dry and wet insulation resistance values. Figure 6 shows skived sections of these samples at a magnification of 8.5 times. The high molecular weight low-density (ASTM Type 1) polyethylenes, such as DuPont Alathon-3B and Monsanto No. 12203, exhibited erratic resistance to crushing and deformation. The low molecular weight medium-density (ASTM Type 2) polyethylene, such as DuPont PE-3066 showed little resistance to deformation.

The high-density Phillips Marlex 50 polyethylene, which is known to develop stress cracking readily on bending even at room temperature, exhibited good crushing resist-

Identification "R" (b)
QFDB 9250
Thickness—
Before Test—10 mils
After Test — 4 mils



Identification "P" (a)
Geon 8850
Thickness—
Before Test—10 mils
After Test — 4 mils

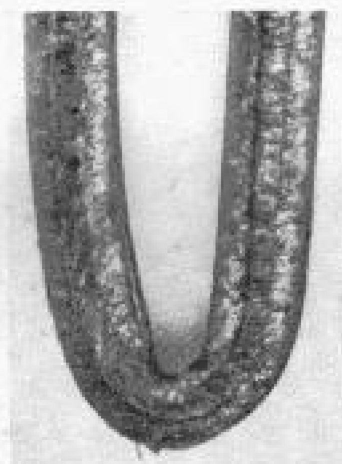


Identification "M" (a)
Synthinol 801
Thickness—
Before Test—11 mils
After Test — 6 mils

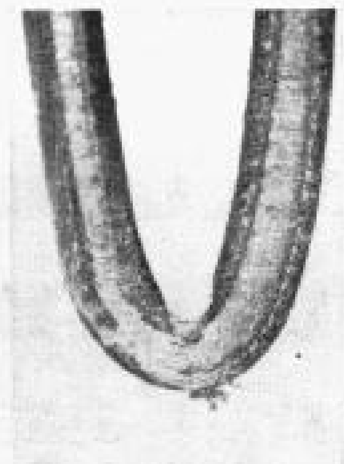
Identification "J" (b)
Turbo 80
Thickness—
Before Test—11 mils
After Test — 4 mils

Identification "L" (c)
Code V-116
Thickness—
Before Test—11 mils
After Test — 4 mils

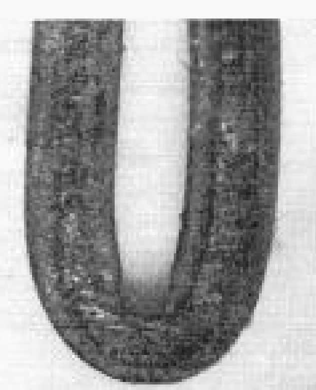
Figure 5. Skived sections of semirigid insulated test specimens. Mag. 8.5 X



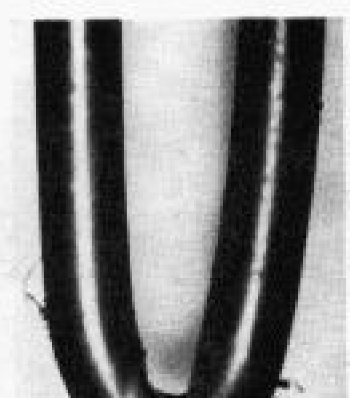
Identification "FP" (b)
Hi-fax 1605
Thickness—
Before Test—11 mils
After Test — 5 mils



Identification "GP" (b)
Hi-fax 1605
Thickness—
Before Test—11 mils
After Test — 5 mils



Identification "DP" (c)
DGDB 4100
Thickness—
Before Test—10 mils
After Test — 2 mils



Identification "HP" (a)
Phillips Marlex 50
Showing Stress—Cracking on Convex Side of Specimen.

Figure 6. Skived sections of specimens insulated with linear polyethylenes and Phillips high-density polyethylene. Mag. 8.5 X

ance but lacked strength in tension as indicated by the fact that these specimens exhibited cracks or splits through to the conductor on the convex side of the test samples (see Figure 6) and consequently showed a zero value in the wet insulation resistance test.

SUMMARY

From the limited number of compounds and tests considered in this study, the following general conclusions are drawn relative to the test method and performance of the various instrument wire extruded coverings in the normally used 10-mil radial wall thickness of primary insulation on No. 22 A.w.g. solid wire, herein considered, based on electrical efficiency and resistance to crushing, deformation and cut-through under sustained slow compression at slightly above room temperature:

1. A *new concept, herein described, presents to industry a realistic, simplified, reproducible, specification test method for determining resistance to slow compression and cold flow (crushing at or slightly above room temperature) of thermoplastic insulating formulations employed for instrument and hookup wire.* It is believed that, in general, only about 4 or 5 days would be required to obtain significant results from a specification test standpoint. This does not appear to be excessive, since it is consistent with that required for specification heat shock tests like those called for in Western Union and other wire specifications. It would seem that a simplification of the test, from a specification consideration, would be the substitution for the insulation resistance measurements referred to herein, of a minimum voltage breakdown requirement, or a percentage of original breakdown or both, after the deformation test.

2. *Semirigid PVC formulations are commercially available which are superior in deformation characteristics to the commonly used conventional PVC compounds in combination with a nylon jacket based on overall physical and electrical performance.* These formulations can be expected to exhibit high resistance to slow compression and cold flow in normal instrument and hookup wire service. Also, these semirigid compounds will effect reduced diameters and generally lower cost of the finished wire due to the fact that one extrusion operation of an expensive component is eliminated. Furthermore, decreased installation and terminating costs and greater freedom from brittle terminations can be anticipated.

3. In view of the relative performance of these semirigid PVC compounds and the regularly used combination of conventional PVC formulation and nylon jacket as applied to No. 22 A.w.g. solid wire in these tests, it would appear that, in stranded wire of the same gage or in other gages of solid and multistrand instrument wire where the combination of PVC and nylon formulations is employed, the substitution of an equal thickness of semirigid PVC formulation for the conventional PVC compound now specified, and the omission of the nylon jacket, would provide equivalent or superior performance in service including less flammability, as well as reduced diameters and lower cost.

4. *Heat-stabilized nonplasticized clear nylon of the various manufacturers exhibits a high degree of resistance to crushing* and adequately reinforces in all probability almost any type of conventional PVC or polyethylene 10-mil formulation from the standpoint of resistance to deformation and cold flow.

5. *With thin walls of conventional PVC formulation (such as 7 mils on No. 22 A.w.g. wire) in combination with a nylon jacket, indications are that deformation performance is critical with respect to kind of primary insulation employed and the thickness of nylon specified.* It would seem that the substitution of a semirigid PVC elastomer for the conventional PVC compound would be more effective in this construction to insure an acceptable degree of resistance to deformation and good over-all performance for the finished wire, particularly abrasion resistance.

6. *In accordance with expectations, high-density polyethylenes (ASTM Type 3) are characterized by outstanding resistance to deformation.* These formulations are economical but are objectionable from a flammability standpoint for use as instrument wire.

7. *Low- and medium-density polyethylenes (ASTM Types 1 and 2), with and without flameproofing ingredient, do not display adequate resistance to deformation for use as the primary insulation on instrument and hookup wire* unless a protective jacket such as nylon is applied to insure acceptable performance from this standpoint.

Further Developments

Space considerations are becoming so compelling that, within the recent past, the use of high-strength, high-conductivity copper base alloys having superior flex-life is being promulgated in the finer sizes of instrument wire such as No. 24 A.w.g. and small diameter wire where breakage during installation and in service of standard annealed copper has been a serious deterrent to size reduction.

To take full advantage of reduced wire diameters, much thinner walls of insulating compounds than those presently employed are a requisite. Since new advances in technology of synthesizing materials have become an almost everyday occurrence it is possible, within the next few years, that polymer chemistry may make available to the communications and electronics industries new dielectric materials, for general instrument and hookup wire use, capable of improved cold flow characteristics and superior over-all performance to the extent that drastically reduced diameters and cost of these wire products will be effected, thus opening new service horizons.

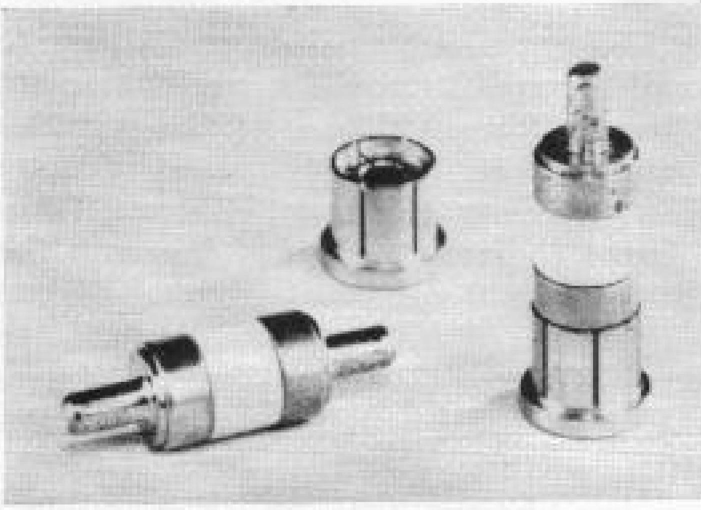
* * * * *

Appreciation is expressed to the representatives of the various resin manufacturers and processors of wire and cable for their cooperation in this study. The constructive criticism and helpful comments, during the final preparation of this paper, of P. Groop, Technical Representative of the Carbide Plastics Co., Division of Union Carbide Corporation, and of Dr. G. S. Eager, Jr., and B. A. Blewis of the Research Department of the General Cable Corporation, are gratefully acknowledged. The author also wishes to thank M. Haifter for carrying on much of the detail work and E. B. Gebert for the photographic work.

WILLIAM F. MARKLEY joined the Construction Engineer's division after graduation from Stevens Institute of Technology in 1917 and for a number of years was engaged in all phases of outside plant construction. More recently he developed standards for outside plastic cable to replace paper-insulated, lead-covered cable and supervised the preparation of installation practices for this cable. He directed the development of a rubber pole-line insulator suitable for use in high-frequency carrier operation for which a patent application has been filed. He initiated the work of developing plastic molded modular terminal blocks designed to accommodate both soldered terminations and solderless wire-wrap terminations on which a patent has been issued. He serves in a consulting capacity for the design of various inside and outside wires and cables required for special applications in data processing and other electronic and transmission equipment. At present, he is engaged in developing standards for high-voltage needle-point static eliminators for tape printers and for the warm-wire method of neutralizing static in page printers. Mr. Markley is the author and co-author of various articles in the TECHNICAL REVIEW and other publications and is a member of Technical Committees of the ASTM and ASA, and the newly organized EIA Committee dealing with Solderless Wrapped Terminations.

Technical Associates of Western Union—III
Microwave Associates, Inc.

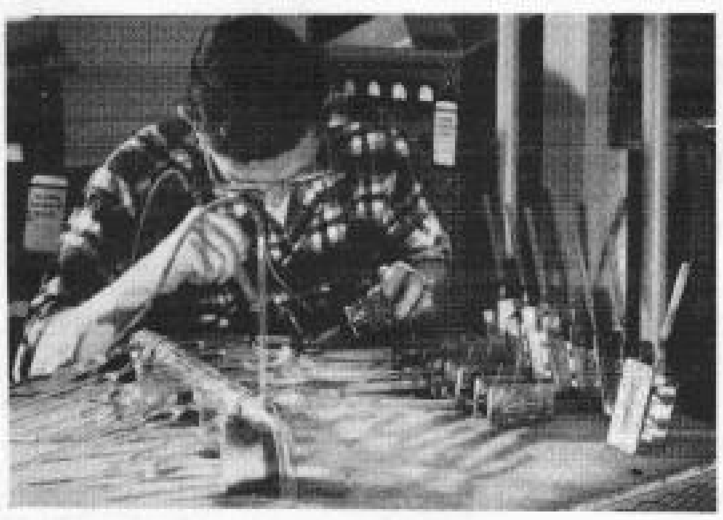
FOUNDED in 1950, Microwave Associates, Inc., is located in Northwest Industrial Park, Burlington, Massachusetts, as are Dynametrics and Technical Operations, Incorporated, also Western Union affiliates.



Typical of the specialized semiconductor devices developed and manufactured by Microwave Associates are these varactor diodes.

The firm concentrates on the design and manufacture of specialized microwave devices which are used in current radar, microwave communications, and missile systems. Strong research orientation on solid-state physics, electron physics, and gas phenomena has maintained a position of leadership for the company, most notably in the fields of high-power microwave tubes and in microwave semiconductors.

Products typically developed by the three divisions of Microwave Associates are: compact magnetrons, gas and ferrite duplexers, microwave modulators, ferrite devices (Tube Division); microwave semiconductors, varactor diodes, and computer diodes (Semiconductor Division); and microwave test equipment, pressure windows, and custom engineered microwave components (Components Division).



Duplexer (switching) tubes and crystal protectors are evacuated and then gas-filled for optimum performance.

The most recent product development has stemmed from research and experience gained in the company-pioneered varactor (variable capacitance-voltage variable) diode program. Microwave Associates recently introduced a line of ultrahigh-speed diodes for use in computers and other electronic data processing equipment which operates at microwave speeds.

Extensive test equipment is required for research evaluations in ultrahigh-power duplexing.

The research and engineering capabilities of Microwave Associates coupled with their microwave products complements Western Union's development of, and expansion into communications systems. At present, Western Union holds approximately 25 percent of the common shares of Microwave Associates stock.

FRED W. SMITH, Assistant to Apparatus Engineer

European Teleprinter Developments

For years Western Union has been active in teleprinter development. Often with material aid from Western Union, the earlier designers in this country assiduously developed instruments suitable for American telegraph services. Now, widespread introduction into the Western Union system of printing telegraph apparatus made abroad has generated an increased interest in European designs.

WHEN the Committee on Technical Publication first requested an article comparing European and American teleprinters, there did not appear to be sufficient differences in the fundamental concepts of the two versions of printing telegraph apparatus to justify a full-length article on this subject. However, a study of various European teleprinters indicated that perhaps there were enough interesting variations to warrant a paper. The difference in geographical size of countries in Europe as compared with the United States, the different population densities, the many languages used, and the relatively short distances between industrial centers in most European countries resulted in a somewhat different approach to the solution of telecommunications problems in Europe.

Consultative Committee on International Telegraphy

In Europe the necessity for intercommunication between many countries each with its own language, concentrated in a comparatively small area, prompted early study of the possibility of establishing international standards for record communications equipment. While the telegraph industry was still in its infancy, the International Telecommunication Union (ITU) was established to promote adoption of standards acceptable to all member nations of the union. When the ITU was first established, telegraphy was the most widely used form of international telecommunications. When other forms of telecommunications, such as telephony and voice radio, became commonly used, the ITU organized separate committees to assume responsibility for various forms of telecommunications. The Consultative Committee on International Telegraphy (CCIT) was established to set up standards for the telegraph industry, and the Consultative Committee on International Telephony (CCIF) was organized to accomplish the same purpose in international telephony. Later these two committees were combined to form the Consultative Committee on International Telegraphy and Telephony (CCITT). The standards recommended by them and adopted by most of the countries of the world account for the major differences between European and American teleprinters.

The United States is not a signatory to these international agreements, however, and has not adopted the international standards for telegraphy. There are several reasons for this. At the time the standards were first proposed, Western Union had several thousand teleprinters in service and the United States was well in the lead in the use of printing telegraph apparatus. In deference to this fact, the CCITT abandoned the five-unit Baudot code assignment, then used in Europe for multiplex telegraphy, and adopted the Western Union Murray code character assignment for all letters of the alphabet. The marking and spacing pulse assignments for the letters of the alphabet in these two codes were different for almost every character.

Thus, the European members of the ITU made a major concession to the United States partly, perhaps, to encourage adoption by the USA of the ITU standards. However, the ITU did not adopt all of the upper-case character assignments then in use by Western Union. This resulted in several differences between the keyboards used in the United States and those adopted as the international standard. (Details of the differences as they exist today will be described later.) The United States participated in the ITU conference which adopted the new standard keyboard, but did not sign the agreement. The remote location of the United States and the relatively small volume of international telegraph communications between this country and Europe *at that time* probably did not seem to justify the expense involved in converting Western Union teleprinters to conform to the new standards.

Perhaps another reason for failure of the United States to adopt the CCITT standards was the fact that several independent companies provided telegraph communications service to the American public and each company operated independently of the others. By contrast, telegraph service in most of the countries in Europe was and is a government-owned monopoly and the problem of resolving conflicting interests did not exist within these countries.

The CCITT Keyboard

The standard page teleprinter keyboard[1] adopted by Western Union several years ago differs from the present standard CCITT No. 2 keyboard only in the upper-case character assignments of six letters. These differences are listed below:

LETTER	UPPER-CASE CHARACTER	
	W.U.	CCIT
D	$	Who are you?
F	¶	Not Used
G	&	Not Used
H	#	Not Used
V	;	=
Z	"	+

The CCITT standards prohibit use of the upper-case F, G, and H in international traffic. These three character positions are reserved for internal use and each member country is free to assign any desired character to the upper case of these three letters. Thus, there is no real conflict between Western Union's standard keyboard and the CCITT No. 2 keyboard on these three characters.

The CCITT agreement also prohibits the use of monetary symbols in international traffic, for rather obvious reasons. The many different currencies in use in various contries make it impractical to provide a monetary symbol for each currency on a keyboard limited to only 64 characters, including the essential non-printing functional characters. Either by intent or by a fortunate coincidence, the CCITT chose to use the upper case D as the "who-are-you" character. Since Western Union uses the dollar sign on the upper case D and monetary symbols are prohibited in international traffic, this difference is of minor importance.

The two remaining differences between the two keyboards are possible sources of confusion and misunderstanding when direct customer-to-customer teleprinter communications between the United States and foreign countries becomes a substantial part of Western Union's business, as seems likely in the years to come. The plus sign used on the upper-case Z in international communications denotes the end of transmission. The plus sign followed by a question mark means "I have completed my message. Do you have anything to send?" The equals sign on the upper case V is used for its conventional purpose and has no other significance.

When Western Union established the first Telex exchange in New York[2] to permit direct customer-to-customer teleprinter connections with Canadian Telex subscribers,[3] a temporary solution was worked out to resolve the conflict between the Western Union keyboard used by our Telex subscribers and the CCITT No. 2 standard keyboard used in Canada. It was necessary to eliminate the dollar sign normally used on upper case D in order to use this code assignment as the who-are-you character. The key caps of the remaining five characters were modified to show the Canadian upper-case symbols in the upper right quadrant and the corresponding Western Union characters in the upper left quadrant. Thus, the upper right quadrants on the F, G and H key caps were left blank and the equals sign and plus sign, respectively, were embossed on the upper-case V and Z key caps. The standard Western Union symbols were printed on the upper left quadrants of these key caps. When an American subscriber communicates directly with a Canadian subscriber, he must not use the upper case F, G or H. If he uses the upper case V or Z, he must remember that these characters will not print a semicolon and quotation marks, respectively, on the Canadian teleprinter.

No discussion of the differences between the CCITT and United States keyboards would be complete without some mention of that used by the American Telephone and Telegraph Company. When the latter first decided to inaugurate a manual teleprinter exchange service (TWX) in the United States, it was apparently intended principally for brokerage use. The keyboard was equipped with fractions on many of the upper-case characters, presumably to expedite stock quotations. In addition, the bell signal was assigned to upper case S instead of J. This resulted in a keyboard that is radically different from both the standard Western Union and the CCITT keyboards, but is almost identical to the Western Union Type "C" keyboard used by many brokerage customers in leased-wire systems. The problems created in using it for direct customer-to-customer connections between foreign and TWX customers have discouraged the use of such connections and have probably had some effect on retarding the growth of international point-to-point connections to and from the United States.

The CCITT Code

The most significant difference between European and American teleprinters is in the speed of operation. The standard CCITT code has been described in the Technical Review previously,[4] but a brief review will be given for the benefit of readers who may not be familiar with it. This code uses a speed of operation of 400 characters per minute and a 7.5-unit code pattern. The start pulse and the five code pulses are each 20 milliseconds long and the rest pulse is 30 milliseconds long. The modulation rate is 50 bauds. (A baud is the inverse of the unit-pulse length in seconds.)

The code adopted by the CCITT is naturally attractive to engineers because of its numerical simplicity as compared to the roughly equivalent American codes with their 22-millisecond pulse lengths, 45.45-baud modulation rates, and 7.0- or 7.42-unit code patterns. There are, however, more tangible advantages in the CCITT code. The 400-opm speed simplifies the design of gears when a standard synchronous motor rotating at 1800 or 3600 rpm is used to drive transmitting apparatus, since no compromises in speed are necessary to obtain practical gear ratios. The 7.5-unit code pattern also simplifies the design of electronic distributors, use of which is rapidly increasing, as compared to the design for a 7.42-unit code pattern.

In Europe it is common practice to refer to the modulation rate in bauds, rather than to the speed in operations per minute or words per minute. This has the advantage of eliminating the necessity for specifying the code-pattern used, since all codes employing the same baud rate are compatible,[5] regardless of whether a 7.0-, 7.42-, or 7.5-unit code pattern is used.

To a telegraph engineer, the baud has additional significance. A square wave such as that generated by a teleprinter keyboard consists of a fundamental frequency plus an infinite number of odd harmonics. Theoretically, a perfect square wave cannot be produced without these harmonics. In actual practice, however, an essentially square wave can be generated by combining the fundamental frequency and the third and fifth harmonics. Thus, a circuit which will transmit all frequencies from the fundamental to the fifth harmonic without distortion will satisfactorily transmit the square wave. Since the baud rate is twice the fundamental frequency, a circuit which will satisfactorily pass frequencies up to 2.5 times the baud rate will transmit telegraph signals without appreciable distortion.

In some systems, when customer-to-customer teleprinter communication service is established between a customer in America and one in Europe, equipment must be provided to convert east-bound traffic from 45.45 bauds to 50 bauds and west-bound traffic from 50 to 45.45 bauds. In the case of TWX subscribers in the USA, equipment must also be provided to convert the upper-case characters used in TWX so that the character transmitted by a TWX subscriber will print the correct character or sequence of characters on the CCITT teleprinter. If the fraction ⅞ (upper case N) is transmitted, it must be converted to print three characters: upper case U (7), upper case X (diagonal), and upper case I (8). Similarly, transmission from a European to a TWX teleprinter must also be converted. Under the CCITT regulations, the burden of furnishing the necessary conversion equipment must be borne by the company or country which does not use the CCITT standards, and since this equipment must be provided for every telegraph channel, the initial cost and the maintenance cost could be burdensome to American companies which provide Telex service to Europe. Also, the speed differences and keyboard variations prohibit *direct* interconnection of American and European subscribers. In the case of west-bound traffic, tape storage is necessary because of the higher transmission speed used in Europe.

Recently, Western Union adopted the CCITT standard 50-baud modulation rate for use on its Telex teleprinters and Telex ASR sets and also changed the upper case F character from the paragraph sign to the dollar sign. Western Union's Telex teleprinters were also modified to print 69 characters per line, which is the CCITT standard, instead of 72. After this conversion was completed, the only remaining discrepancies between the CCITT No. 2 standard keyboard and Western Union's Telex keyboard were in the upper case V and Z character assignments previously described.

A great deal of this article has been devoted to discussing the CCITT standards because their adoption in Europe but not in the USA has created the only fundamental differences between standard American and European teleprinters. There are, of course, other minor differences, but these two (code assignment and speed) are the only ones which prevent direct interconnection. The other differences to be described are primarily due to the varying requirements that exist in Europe and America and are mainly differences in accessories rather than in fundamental design.

Message Switching Versus Circuit Switching

In Europe, the geographical size and population densities made Telex-type circuit-switching systems practical. In the United States, on the other hand, greater distances between cities and lesser population density made message-switching systems more economical. Circuit-switching systems utilize trunk circuits between major switching centers much less efficiently than message-switching systems, and this is particularly true of automatic circuit-switching systems such as Telex.

The number of trunk circuits required between two circuit-switching centers is determined by the volume of traffic and the permissible number of lost calls during the busy hour due to lack of availability of an idle trunk circuit. During periods other than the busy hour the trunk facilities available are far greater than the minimum number required to handle satisfactorily the volume of traffic. In message-switching systems, on the other hand, delays of several minutes during the busy hour are not serious and there is no lost-call rate involved in these systems. In manual circuit-switching systems where an operator must establish each connection, as in TWX, a much higher lost-call rate can be tolerated, since the manual switchboard operator can call back the customer who initiated the lost call when an idle trunk circuit becomes available, thus making it unnecessary for the customer to initiate a call the second time.

In Europe, where distances between major cities in most countries are short as compared with the United States, inefficient use of trunk circuits was relatively unimportant. In the latter country, on the other hand, greater distances between many of the major cities and the resulting high cost of trunk circuits dictated the use of message-switching systems during early development of telegraph switching systems. However, rapidly increasing population density and the growth of industry, with an accompanying increase in telegraph traffic in the business community, and technical developments such as new carrier systems which have reduced the cost per mile of telegraph circuits, are reducing the economical advantages of message-switching over circuit-switching systems.

Automatic circuit-switching systems

provide faster communication between any two subscribers than is possible in a message-switching or a manual circuit-switching system. In today's Telex, for example, any subscriber can obtain a direct point-to-point connection with any other subscriber in the system within ten seconds by dialing a six or seven-digit number. Since modern Telex is an automatic unattended service, it is essential that the calling subscriber be able to identify the station to which he is connected, even though the called station is unattended. This requirement led to the development of automatic answer-back units, available as a standard accessory on all European teleprinters.

Automatic Answer-Back Unit

Answer-back units used on most European teleprinters consist essentially of a rotatable drum or cylinder equipped with coding discs or combs which control the keyboard contacts when the answer-back unit is actuated. A ratchet and pawl are generally used to step the drum through one complete revolution when the who-are-you character (upper case D) is received by the printing unit. Power for stepping the answer-back unit is supplied by the keyboard transmitting shaft, which steps the drum once for each revolution of the shaft. At the end of one revolution of the answer-back drum, the feed mechanism is automatically disengaged and the drum stops rotating.

During the revolution of the drum, the coding elements control the characters transmitted from the keyboard transmitter. The keyboard shaft driving clutch is allowed to remain in the engaged position so that the transmitting shaft rotates continuously until the answer-back drum completes its revolution, at which time the keyboard clutch is mechanically disengaged and the answer-back unit comes to rest in its home position.

One revolution of the drum transmits from 19 to 21 characters, depending on the design of the answer-back unit, and these characters can be coded to identify the subscriber, either by transmitting his name, an abbreviation of his name, or his Telex number. However, a word or code name is almost always used in preference to the Telex number, since this provides a cross-check for the calling subscriber and gives some protection against errors in reading the Telex number from the directory.

In order to prevent simultaneous transmission of answer-back codes from both teleprinters in a point-to-point connection, the answer-back unit must be prevented from responding to an upper-case D transmitted from its own keyboard. This is accomplished mechanically by blocking the answer-back triggering device momentarily when the D key lever is depressed. A separate off-line key called a "here-is" key is provided for locally tripping off the answer-back unit without sending the who-are-you character to the line.

Perforated Tape Accessories

Tape perforating and transmitting equipments used with European teleprinters are quite different from their American counterparts. Most of the teleprinters made in Europe can be equipped with an auxiliary tape reperforator which is mechanically linked to the printing unit, so that tape and page copy can be prepared simultaneously when a message is received or transmitted. Linking the reperforator to the printer in this manner eliminates the need for a second receiving selector assembly and simplifies the design of the punching unit. However, it also imposes certain limitations on the unit. For example, a tape cannot be perforated for subsequent transmission without also obtaining a page copy of the message, since the keyboard must transmit to the printing unit in order to operate the punching unit. With this method of operation, the keyboard must always be operated as a cadence keyboard and there is no provision for manually switching to a "free" keyboard position for tape preparation without a hard copy. A mechanical switch is provided, of course, so that the reperforator can be turned on or off.

The who-are-you character must not be perforated in tape which is to be transmitted over an automatic circuit-switching system, since it would actuate the automatic answer-back unit at the distant station and result in "busting up" at least 20 characters while transmission was occurring simultaneously in both directions. In order to prevent such accidental perforation, most European perforator attachments on teleprinters are arranged so that the D character cannot be perforated from the keyboard when the teleprinter is in the upper case.

A distributor-transmitter attachment is also available as an accessory on most European teleprinters. This unit is driven by the teleprinter motor through the necessary additional gear trains. These attachments are generally very simple in design, with few special features provided other than a tape-out pin.

Compared to their American equivalents, the tape perforating and transmitting attachments used on European teleprinters are very simple but are limited in versatility. Their simplicity, however, results in a considerable cost advantage over equivalent automatic send-receive sets manufactured in America. In general, the cost of a European teleprinter delivered in the USA, duty-paid, is comparable to the cost of an equivalent American-made teleprinter, but the cost of a European teleprinter equipped with tape perforating and transmitting attachments is on the order of 30 percent to 50 percent less than the cost of an American-made ASR set. The lack of versatility of the European ASR sets is not particularly important in Telex service, where the necessary automatic controls are incorporated in the switching system rather than in the terminating equipment.

Two-Color Printing

One feature used on many European teleprinters, but almost unknown in the USA, is two-color printing for distinguishing between sent and received messages. When a teleprinter is equipped with this attachment, messages received by the typing unit are printed in black, but when messages are transmitted from the keyboard a ribbon-lifter mechanism, usually associated with the keyboard, causes printing to occur in the red half of the ribbon. The device is fully automatic so that no conscious effort on the part of the operator is required to utilize the two-color printing. This attachment is useful in automatic circuit-switching systems where two-way conversations are frequent. It also helps to distinguish between sent and received messages which have been filed away for future reference.

The Four-Row Keyboard

In Europe, three different types of keyboards are available for most teleprinters. One is the conventional 3-row keyboard used in the USA. The second type is the so-called "4-row standard" or "4-row expanded" keyboard in which every upper-case printing character is placed on a separate key lever instead of being combined with its corresponding lower-case character. For example, the letter E and the digit 3 are on separate key levers. When the letters-shift key lever is depressed, a sliding bar equipped with blocking lugs is automatically positioned so that all upper-case key levers are blocked and cannot be depressed. Similarly, when the figures-shift key lever is depressed, all letters key levers are blocked. Thus, an operator cannot erroneously transmit letters characters when the keyboard is in the figures case, and vice versa.

There are two advantages to this type of keyboard. First, it more closely resembles a typewriter keyboard than does any other type of teleprinter keyboard. Secondly, it is impossible for a touch typist using this keyboard to transmit errored characters due to the keyboard being in the wrong shift case. These two advantages are important to users who send and receive a small volume of telegraph traffic and who therefore assign a typist or secretary to operate the teleprinter. For a professional teleprinter operator, however, the large number of keys (usually 57) on this type of keyboard seems awkward and inefficient.

The third type of keyboard available is a compromise between the 3-row and the 4-row standard which appeals to many typists and teleprinter operators. This keyboard, known as the "4-row condensed", separates the ten digits from their corresponding lower-case characters and these digits are placed on a fourth row of key levers just above the top row of letters keys. Punctuation marks and symbols are not placed on separate keys. The same type of letters-figures blocking bar used on the 4-row standard keyboard is also used on the 4-row condensed version. When the letters key is depressed, this bar blocks only the row of figures keys. When the figures key is depressed, the top row of letters keys (QWERTYUIOP) is blocked. This provides the same protection, but to a lesser degree, as the blocking bar on the 4-row standard keyboards. In the English language, the top row of letters characters contains several letters that are among the most frequently used and it is difficult to type more than a few letters in normal English without using one of these characters.

Courtesy Intelex Systems, Inc.

Figure 1. Lorenz LO-15B Teleprinter with tape reperforating and transmitting attachments

A question frequently asked by those who are not familiar with the 4-row European keyboards is whether the upper-case characters are compatible with the upper-case characters on American keyboards; that is, if the digit 3, for example, is transmitted from a 4-row keyboard, will the American teleprinter print the 3? The answer, of course, is that the two are compatible except for the differences previously cited between the CCITT No. 2 and the American keyboards. Separation of the upper-case characters on the keyboard is purely mechanical and has nothing to do with the code combinations assigned to these characters.

Major European Teleprinter Manufacturers

The four major manufacturers of teleprinters in Europe are Lorenz and Siemens & Halske in Germany, Olivetti in Italy, and Creed in England. All four of these companies are major manufacturers of telegraph apparatus and all of them export their products to countries all over the world. Lorenz and the Creed company are both affiliates of the International Telephone and Telegraph Corporation.

Lorenz LO-15 Teleprinter

The Lorenz Model LO-15B Teleprinter, shown in Figure 1, was originally manufactured under license from Teletype Corporation, and the close resemblance between the Lorenz LO-15 and the Teletype Model 15 is readily apparent when the cover is removed, as in Figure 2. Minor design changes were made in the basic teleprinter by Lorenz engineers, particularly in the keyboard. The transmitting shaft clutch trip mechanism was redesigned and the universal bar mechanism was modified to reduce the force required to position the universal bar. These two relatively minor changes produced an appreciable improvement in the keyboard touch and reduced the possibility of repeat-character errors (two successive transmissions of the same character when a key lever is depressed only once). However, the principal contribution made by Lorenz engineers was in the design of the answer-back unit, the reperforator attachment, the distributor-transmitter attachment and the 4-row keyboard shown in Figure 1. In this illustration, the perforator attachment is located at the left of the keyboard and the perforated tape can be seen feeding out towards the front of the teleprinter. The two push buttons just below the perforator are the "on" and "off" buttons. The button on the left is the off button and is indicated by a circle with a dot outside the circle. When this button is depressed the perforator is turned off, or *out* of operation. The button on the right, with a dot inside the circle, turns the unit on, or puts it *in* operation. The distributor-transmitter attachment can be seen at the right of the keyboard with tape feeding from right to left. The on and off buttons for this attachment are located directly below the reading head.

The answer-back unit, mounted behind the cover on the right side of the keyboard base, can be seen in Figure 2. The here-is key is located just to the left of the answer-back unit. Depressing this key mechanically releases the answer-back unit and causes it to transmit the answer-back code once.

The Lorenz teleprinter illustrated in Figure 1 is a late model incorporating a number of design changes. In former models, such as the one shown in Figure 2, the tape fed through the transmitter from front to back. After passing over the reading head, it made a complete loop behind and beneath the transmitter and emerged from the front of the unit. The cover of the LO-15B has also been redesigned and presents a much more modern appearance than the older covers, which were very similar to the Teletype Model 15 Teleprinter covers.

Photo R-11,785

Figure 2. Lorenz Model LO-15A Teleprinter Set with cover removed. Teleprinter shown is equipped with a 4-row standard keyboard

Metric threads are used on all fasteners on the Lorenz teleprinter, as they are on most European teleprinters. The gears are also manufactured to metric standards. In spite of this, more than half of the parts used on Lorenz teleprinters are interchangeable with corresponding parts used on Teletype Model 15 Teleprinters. Western Union, in fact, has adopted the Lorenz answer-back attachment for use on Model 15 Teleprinters manufactured by Teletype for use in Western Union Telex service. It is necessary to furnish only a few minor parts manufactured by Western Union in order to permit installation of the Lorenz answer-back on Western Union's teleprinters.

Olivetti Teleprinter

The Olivetti teleprinter shown in Figure 3 is equipped with a 3-row keyboard, an answer-back unit with a 21-character capacity, a tape perforator attachment, and two-color printing. The type basket on this teleprinter is stationary and the platen assembly moves from right to left as a line is printed, as on Western Union's Type 100 Teleprinters. All keys except the carriage return key are automatically locked when the platen reaches the end of a line, thus preventing overprinting. Depressing the carriage return key unlocks the keyboard. The teleprinter is made up of seven subassemblies which can be removed readily as complete units. The receiving selector assembly, which has excellent tolerance to distorted signals, can be used to receive either make-break or polar signals. Conversion from one mode of operation to the other can be done quickly and easily. Likewise, the sending unit can transmit either make-break or polar signals.

Unlike most European teleprinters, the Olivetti does not use a friction-type receiving selector clutch. The clutch used is an all-metal one with three pawls, any one of which can engage internal teeth on a clutch drum surrounding the pawl assembly. There are 58 teeth on the drum and the three pawls are spaced 120 degrees apart. Since 58 is not divisible by three, only one pawl can engage the toothed drum at one time and there are 58 times 3, or 174 possible engagement positions. The variation in take-up time of the clutch is thus equivalent to only a little more than two degrees rotation of the selector shaft.

Mounted just to the left of the receiver range scale is a vibrating reed type of speedometer, used to indicate the speed of the governed motor. This speedometer is claimed to be accurate within 0.2 percent and is quite convenient for use in adjusting the motor speed. Governed motors, incidentally, are far more commonly used on European teleprinters than a-c synchronous motors because of the many different voltages and frequencies used in European power systems and also because of the relatively unstable frequencies in European a-c systems.

The maximum speed of the Olivetti teleprinter is 75 words per minute. The trend towards higher speeds is not as prevalent in Europe as it is in this country and until very recently European teleprinters were not designed for 100-word-per-minute operation.

The perforator attachment and its tape supply reel are located on the left side of the teleprinter. This unit punches chad tape with in-line feed holes, as do all European perforator attachments. The receiving selector, located just below the range scale which is clearly visible at the left center section of the photograph, controls the punch positioning mechanism which determines the characters to be perforated in the tape. The answer-back unit, which cannot be seen in the photograph, is located beneath the transmitting contact assembly. The latter assembly, which is to the right of the right ribbon spool shaft, is enclosed by a transparent plastic cover which protects the contacts from oil and dirt while permitting the operation of the contact mechanism to be observed.

The Olivetti model shown is equipped with

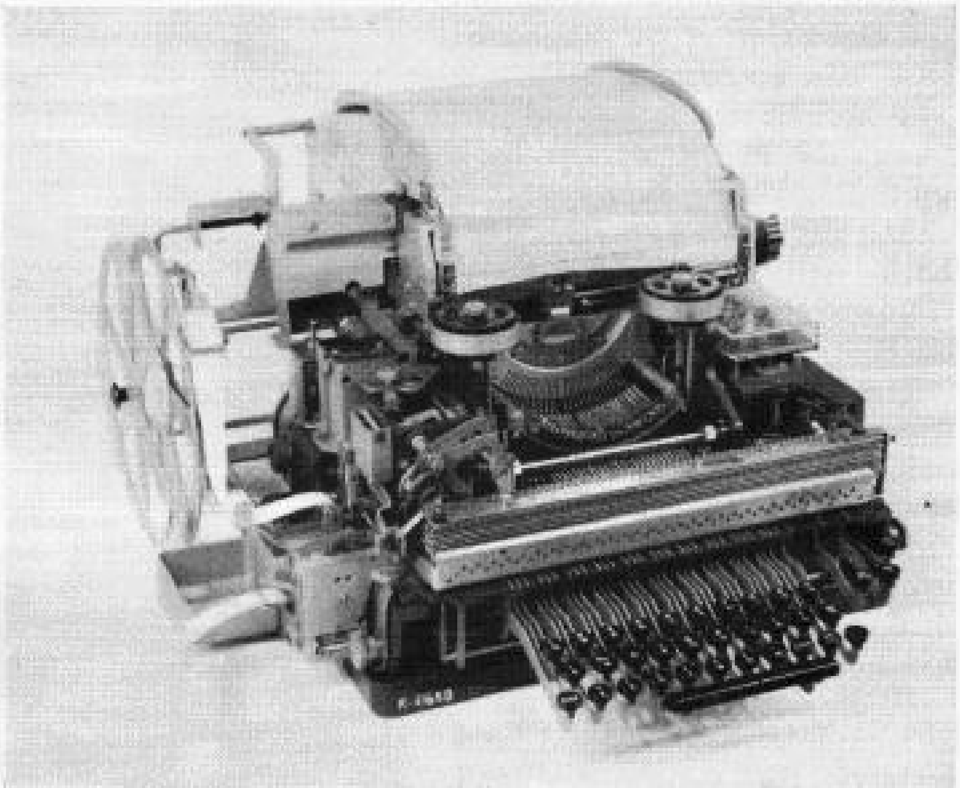


Photo R-11,658

Figure 3. Olivetti teleprinter and reperforator attachment with cover removed

a special 3-row keyboard roughly corresponding to the TWX keyboard. When the figures-shift key is depressed, the D key lever is automatically blocked so that the who-are-you character cannot be transmitted accidentally. A separate who-are-you key lever is provided for transmitting the D character when the keyboard is in the upper case. This key lever is one of the group of three separated from the three rows of standard key levers and located at the upper right of the keyboard. With the keyboard in the figures position, depressing this key lever will cause the transmitting contacts to send the D character. A second key lever in the group of three is the here-is key, which mechanically trips the answer-back unit to transmit the teleprinter's own identifying code. The third key in this group is a repeat-character key, known in European terminology as a run-out key. Holding this key lever down causes the last character transmitted to be sent continuously.

A tape transmitter attachment is not available for the Olivetti teleprinter and a separate distributor-transmitter must be used for tape transmission.

Creed Model 75 Teleprinter

In 1958, Creed and Company in England started production of a new page teleprinter designed to replace older Creed models. This teleprinter, known as Creed Model 75, is the only teleprinter described here which has not been tested or evaluated by Western Union. However, it has been demonstrated to Western Union engineers and a description of the unit has been published.[6] The Model 75, shown in Figure 4, is a very compact unit, measuring 15-3/4 inches in over-all width, 15-3/16 inches in depth, and 11 inches in height. A send-receive teleprinter weighs approximately 42 pounds.

Courtesy Intelex Systems, Inc.

Figure 4. Creed Model 75 Teleprinter

Unlike previous Creed teleprinters, the "75" has a stationary platen and a moving typewheel, instead of the moving platen and fixed typewheel used in previous Creed models. The typewheel has four rows of characters, with 16 characters in each row. The top row and the 3rd row contain the letters characters and the 2nd and 4th rows contain the figures characters. A link-type aggregate motion mechanism combined with rack and pinion mechanisms are used to position the typewheel to the selected vertical and rotary positions. The 2nd pulse, in combination with the letters-figures mechanism, determines which vertical row of type will be raised to the printing level. When the typing unit is in the letters-shift position, a 2nd pulse marking will select the 1st row of type and a 2nd pulse spacing will select the 3rd row. With the typing unit in the figures-shift position, a 2nd pulse marking will select the 2nd row of type and a 2nd pulse spacing will select the 4th row. The 3rd pulse determines whether the typewheel will be rotated clockwise (3rd pulse marking) so that a character in the left half of the typewheel will be selected, or counterclockwise (3rd pulse spacing) so that a character in the right half will be selected. Pulses 1, 4 and 5 determine the angle through which the typewheel will be rotated and, thus, which of the eight characters in the selected half of the row will be brought to the printing position. A type hammer is not used for printing. The typewheel itself strikes the ink ribbon and platen to perform the printing.

Perhaps the most novel and interesting feature of the Creed 75 is the translator unit. This unit positions the typewheel when signals are received by the selector magnet on the receiver. It also transmits signals to the line and positions the typewheel when the keyboard is operated. The keyboard is mechanically linked to the typing unit. When a key lever is depressed, the code corresponding to this key lever is set up on five combination bars. These bars set up the code mechanically on a set of five selecting pins on the translator unit. A group of six cams on the translator then positions the typewheel mechanically to correspond to the character transmitted. A second group of nine cams on the translator operates the transmitting contacts to send the selected character to the line and to reset the keyboard so that a key lever can again be depressed. The keyboard is reset about one-third of the way through the transmitting cycle. Operation of the keyboard thus mechanically positions the typewheel and initiates the printing cycle, independently of the line transmission from the transmitting contacts on the translator unit. This reduces the delay between the depression of a key lever and the subsequent printing of the selected character, resulting in a touch similar to the touch on a typewriter, rather than on a conventional teleprinter. With this arrangement the keyboard is not a true cadence keyboard and the speed of typing can vary somewhat above and below the speed for which the teleprinter is geared. The Creed 75 is capable of operating at speeds up to 100 words per minute.

When signals are received by the selector magnet, the five selecting pins on the translator are positioned by the selector armature instead of the key levers on the keyboard. The cams on the translator position the typewheel in the same manner as when the keyboard is operated.

A send-receive switch operated by a cam on the translator shorts out the transmitting contacts when signals are received by the selector so that the transmitting contacts will not repeat the received signals. Similarly, the selector magnet is disconnected from the receiver when the keyboard is operated.

A tape reperforating attachment is already available for the Creed 75 and a tape transmitting attachment is expected to be available soon. The reperforator attachment mounts on the right-hand side of the teleprinter instead of the left-hand side, as on the Lorenz, Olivetti, and Siemens & Halske teleprinters.

Siemens & Halske T Type 100 Teleprinter

The "T Type 100" teleprinter manufactured by Siemens & Halske in Germany is of particular interest to Western Union, since this teleprinter with its tape reperforating and transmitting attachments has been adopted for use by Western Union as a Telex ASR set after extensive laboratory and field tests. This ASR set, with a Telex remote control unit (dial box), is shown in Figure 5. The reperforator attachment, tape supply reel, and chad box are mounted on the left side of the teleprinter. There are four push buttons on this attachment. The top left button (labelled with a dot outside the circle) turns the reperforator off and the bottom left button turns it on. The top right push button (labelled "L") lifts the feed pressure roller to permit tape to be threaded into the reperforator. The lower right button (marked "R") is the backspace control. Depressing and releasing this push button once causes the reperforator to backspace one character. Just below the four control buttons is a pointed tearing edge for the perforated tape. When this edge is used for its intended purpose, a message tape from the reperforator will be torn in the shape of an arrow with the head of the arrow at the beginning of the tape and pointing in the direction in which the tape should feed through the tape transmitter. This feature is very useful since the reperforator punches nonprinted chad tape with in-line feed holes.

Photo R-11,320

Figure 5. Siemens & Halske Model 100 Teleprinter with tape reperforating and transmitting attachments. The "dial box" at right is a Telex remote control unit

The most interesting feature of the reperforator is that friction feed is used for feeding the tape. The tape passes between a feed roller and a spring loaded pressure roller which holds it firmly against the feed roller. There are no pins to engage the feed holes in the tape. This method of feeding has proven to be very satisfactory and maintaining the 10-characters-per-inch gauge of the tape has presented no difficulty.

The teleprinter shown in Figure 5 is equipped with a 4-row condensed keyboard, but both 3-row and 4-row standard keyboards are available and any one of the three types can be converted to any other. Just above the top row of keys are six off-line control levers mounted in the cover. The first lever on the left is the repeat-character (run-out) lever and is identified by a series of dots to indicate repetition. The third lever from the left is the here-is control which mechanically trips off the answer-back unit to transmit the teleprinter's identifying code.

It is identified by the here-is symbol imprinted on it. The fourth lever from the left is a latching type switch lever which turns on the copy light. It is identified by an electric lamp symbol imprinted on it. This is the only one of the three levers described which latches in the operated position. It is unlatched by pushing down on the projection at the bottom of the lever. The three remaining controls are not used at present, but are provided for use with accessories now under development, such as local carriage return, line feed, or letters shift. The copy light shield shown in Figure 5 can be tilted to any desired position to prevent reflections of external lights in the transparent copy window. It can be removed readily by the operator if it is not needed.

The tape transmitting attachment fastened to the right side of the teleprinter is equipped with two push buttons which mechanically turn the transmitter on or off. A tape-out pin mechanically operates the off push button after the end of the tape passes over the pin. A remote control magnet built into the transmitter attachment provides a means for stopping the transmitter from the distant end. This magnet is connected in series with the line. If the line is opened while the transmitter is sending a rest pulse, the magnet armature will release and trip the mechanical off push button. The receiving station can thus stop the transmitter by sending one or two blank characters or by momentarily opening the line. The transmitter will transmit from either chad or chadless tape with in-line feed holes.

The Siemens & Halske Telex ASR set is shown in Figure 6 with the cover removed. The vertical die casting at the left side of the keyboard, just to the right of the reperforator attachment, contains the keyboard transmitting contact assembly. This is a single-contact type of transmitter and the contact is operated by an insulated cam mounted on a rocker shaft. The contact assembly can be either a make-break form for transmitting single current signals or a transfer form for transmitting polar signals. The contacts are completely enclosed in a metal housing to reduce radio interference and to protect the contacts from dust and dirt.

The answer-back unit is located just to the right of the transmitting contact assembly. When the answer-back unit is tripped off, it controls the transmission of 20 characters from the keyboard transmitting contact assembly. The first and the last characters transmitted must be the letters combinations, but the remaining 18 characters can be coded for any desired combinations. The coding drum is equipped with 18 replaceable code combs which are inserted in slots around the periphery of the drum. Each comb has five tines on it, one for each of the five code pulses. A comb is coded for any desired character by breaking off tines corresponding to marking pulses. The coding drum can be removed from the answer-back unit quickly and easily by depressing a latch and sliding the drum off its shaft. This permits the coded answer-back drum to be swapped from one teleprinter to another in a few seconds.

At the extreme right side of the keyboard base is an hour counter which registers the total time in hours that the teleprinter motor has been running. This feature is very helpful in determining when routine maintenance should be done on the teleprinter, and most European teleprinters are equipped with hour counters.

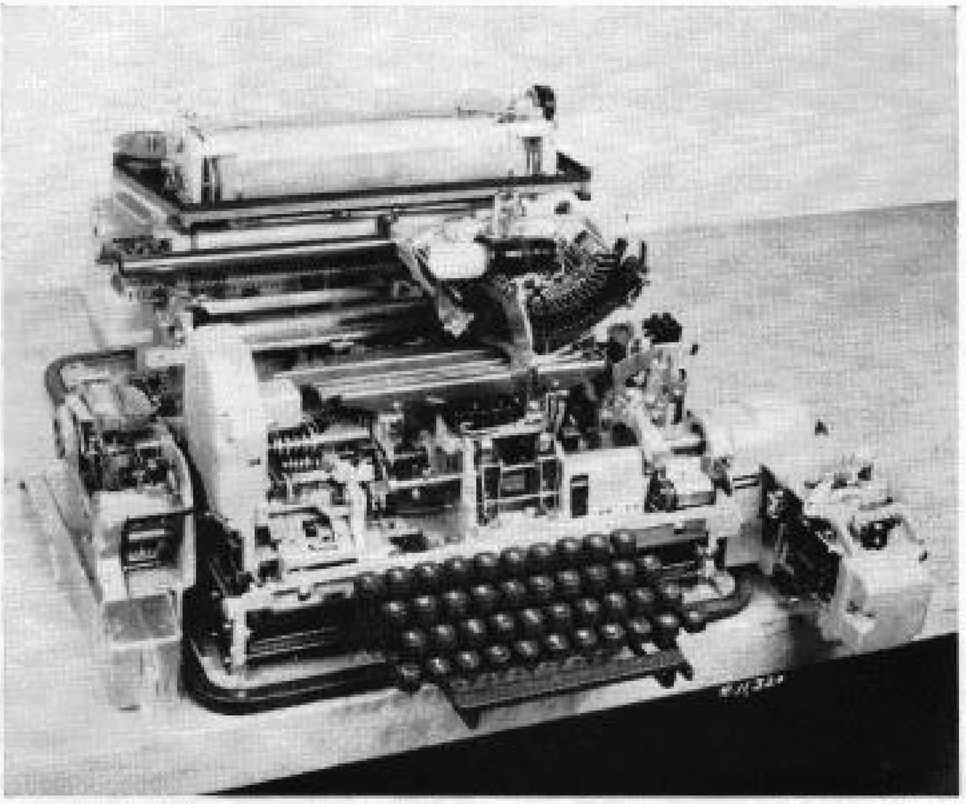


Photo R-11,319

Figure 6. Siemens Model 100 Teleprinter Set (Telex ASR Set) with cover removed. Teleprinter shown is equipped with a 4-row condensed keyboard

The platen step mechanism can be set for a line spacing of 4.3, 6.4, or 8.5 millimeters. This is roughly equivalent to 6,4 and 3 lines per inch, respectively. The teleprinter shown in Figure 6 is equipped with a bichrome ribbon and a two-color printing mechanism. Normally, only messages transmitted from the keyboard will be printed in red, but an accessory set of parts is available which automatically controls the two-color shift mechanism when tape is transmitted by the tape transmitter attachment, so that all messages sent from the teleprinter will print in red.

The Siemens & Halske teleprinters used by Western Union are driven by either a 3600-rpm a-c synchronous motor or a 3750-rpm governed motor. The motors are fully enclosed for radio-frequency suppression. The teleprinter will operate at any standard speed up to and including 100 words per minute. Since the transmitting cam sleeve is designed for a 7.5-unit code pattern, the actual transmitting speed at 100 wpm is approximately 594 operations per minute. In order to achieve satisfactory operation at 100 wpm, the moving type basket used on the Model 100 Teleprinter had to be carefully designed for the lightest possible weight consistent with rugged construction. The type basket carriage assembly weighs approximately 2 pounds. It is fed from left to right by a lead screw which ensures smooth feeding movement. The standard type pallets print lower-case letters characters, but pallets are available for printing capital letters when required. The spacing between characters is 2.6 millimeters instead of the 2.54 mm (10 per inch) spacing used on American teleprinters.

One of the most interesting features of the new Siemens teleprinter is the receiving selector unit. The selector magnet on this assembly is equipped with two armatures, one for stopping and starting the receiving selector shaft and the other for sampling the five code pulses. Both armatures are of the holding type; that is, each armature is mechanically moved to the marking position by an associated cam. If the magnet is energized at this time, the armature will be held in the marking position magnetically. If the magnet is not energized, the armature will be returned to its spacing position by an extension spring. Greater motion and more force are required to start and stop the receiving shaft than to sample the position of the selector armature in a teleprinter. Providing twin armatures to separate these two functions permits less movement and force to be used for the selector armature and results in greater accuracy in the selecting function. This design has resulted in an unusually good receiving margin. The Model 100 Teleprinter has a tolerance to signals containing 44-percent marking or spacing distortion. The holding-type armatures also permit the teleprinter to operate on line currents of from 40 to 60 milliamperes with no appreciable loss in receiving margin. (The standard line current for make-break signalling in Germany is 40 ma and the standard line battery is 60 volts.)

The receiving selector is driven by an enclosed felt-type friction clutch. The design of this clutch permits satisfactory operation for 1000 hours without reoiling. Lubrication intervals of 1000 hours have previously been obtained only by use of all-metal clutches. At the same time, the clutch retains the advantage of constant pickup time inherent in friction clutches. This also contributes to the wide tolerance to signal distortion of the receiver.

* * * * *

In Europe, there are relatively few large private wire switching systems such as those designed by Western Union for use by private industry and government agencies. There this type of traffic is usually switched over one or more of the very extensive Telex systems. Public message traffic in many countries is also handled over Telex systems built for this purpose and called Gentex (General Telex). Two-party lines can be used in Telex systems, but use of more than two stations on one line is almost unknown in Europe and the need for elaborate "stunt boxes" on teleprinters, with their associated way-station selectors, does not exist. Also, Telex systems are normally operated half-duplex and there is little demand for elaborate ASR sets which will permit simultaneous sending, receiving and off-line tape preparation. This accounts in part for the relative simplicity of design of European teleprinters and ASR sets.

Because of the many languages used in Europe most teleprinter manufacturers have adopted symbols for use on function key tops in order to eliminate the need for special key tops with different abbreviations for each language. The symbols used for carriage return and line feed are the same as those sometimes used on tape printing apparatus in this country. The figures-shift symbol is the numeral 1 followed by several dots, and the letters-shift symbol is the letter A followed by several dots. The blank is indicated by a small circle with a short horizontal line inside it.

The trend towards higher speeds did not develop as early in Europe as it did in this country, but there are indications that speeds of 100 words per minute will soon be fairly common in many foreign countries. Both the Siemens & Halske Model 100 and the Creed Model 75 are capable of operation at this speed and these two teleprinters are the most recently designed units available in Europe. The CCITT has not yet adopted a recommended standard modulation rate for 100-wpm operation, but a CCITT Study Group is now considering this problem. There appear to be only two logical choices. One would be adoption of the American standard of 74.2 bauds. With the standard 1.5-unit stop pulse used in Europe, this would result in an actual speed of 593.8 operations per minute and the CCITT standard would be compatible with 100-wpm American teleprinters. The second choice would be to adopt a 75-baud modulation rate. American teleprinters with their 1.42-unit stop pulse could be made compatible with this modulation rate by increasing the speed of operation to 606.2 opm, thereby reducing the unit-pulse length from 13.47 to 13.33 milliseconds. A 75-baud code could be operated with a 74.2-baud code, but there would be a resulting loss of at least 6 percent in the operating margin.

The use of printing telegraph apparatus in integrated data processing is becoming increasingly important in Europe, just as it is in America, and most of the European teleprinter manufacturers are developing special apparatus and accessories for use in IDP. Among the many such accessories being developed for teleprinters are horizontal and vertical tabulation, form indexing, and form feed-out.

The quality of workmanship on all of the European teleprinters is quite good and those tested by Western Union have all performed satisfactorily.

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Four-Digit Numbering Machine

THE FIRST automatic message numbering machines were two-digit machines with a numbering capacity from 00 to 99. It was soon found that this was inadequate to number the messages of one channel for a business day, and the capacity was increased by adding the third digit, giving a capacity from 000 to 999. This was sufficient for most telegraph channels but it was found that in some private wire installations a greater capacity was required, and the fourth digit was therefore added. At present the digits in the fourth position consist only of the 0 and 1 so that the numbering capacity of the machine is from 0000 to 1999.

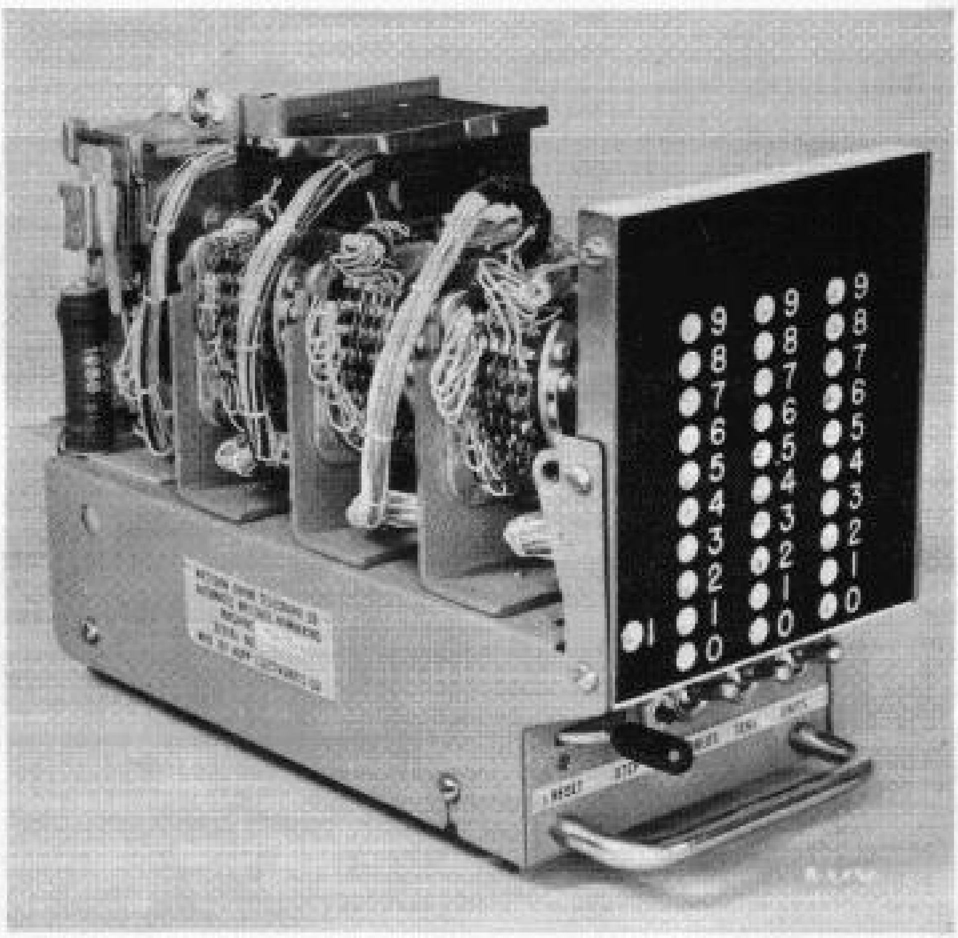

Photo R-11,595

If the four-digit machine were to have a capacity of 0000 to 9999 it would require the addition of another rotary switch which would appreciably increase the cost of the machine, as well as require the redesigning of both the numbering machine and the cabinets on which they are used. By the addition of a relay with its associated limiting resistance and a push button for control, one of the standard three-digit machines was made into a four-digit machine which can be used in place of the former with no change in plant wiring. In the four-digit machine the call letters switch of the numbering machine is wired to provide a position for the fourth digit with the zero combination 2-3-5 permanently connected. To change the zero combination to the combination for the figure 1 requires only the addition of the number 1 pulse. This is added by means of the relay which is energized when the wipers of the hundreds rotary switch are being self-stepped from their 9th position to their 0 position.

As the hundreds rotary switch is being self-stepped the added relay is energized and it locks up and remains locked to send the combination 1-2-3-5 for figure 1 as the fourth digit. This condition holds until the control button is pressed for resetting at the close of the business day.—P. L. MYER, Project Engineer, Digital and Printing Equipment.