The decade now ending has witnessed technological progress unparalleled in history. In this ten-year period no industry has done more in harnessing the physical and electrical sciences in the service of the public than we in the field of high-speed record communications.

It is fortunate, both now and for engineers of the future, that Western Union's technical achievements since World War II have been recorded systematically and precisely in the pages of TECHNICAL REVIEW. The inspired men who founded this quarterly publication just ten years ago must have known how valuable a medium of communication would be built up through these regular printed reports on scientific advances in telegraphy. TECHNICAL REVIEW has become an invaluable reference work for the serious engineer, whether old-timer in our industry or new engineering recruit.

As the company officer responsible for improving relations within our organization, and for encouraging promising young people to choose a Western Union career, I look on TECHNICAL REVIEW as a substantial plus factor. Engineering graduates who read through any issue of the REVIEW will inevitably have a strong impulse to know more about the work and the people of our industry. From the human relations standpoint, the REVIEW provides an excellent medium for professional recognition and personal satisfaction to the men who contribute to its pages.

My wholehearted congratulations to the staff of TECHNICAL REVIEW, as you complete your first decade, and my warmest wishes for the future.

R. L. Wilcox

Vice President—Employee Relations

January 1, 1957.

HAROLD F. WILDER, Assistant to Electronics Applications Engineer

Blank-Character Translation on Submarine Cables

Military communications are being supported with utmost security and exceptional reliability over transmission facilities which may include 3000 miles of multiplex-operated deep-sea cable sections, land-line carrier channels and teleprinter circuits in combination. While the methods employed may appear straightforward to the uninitiated, a certain elegance of engineering logic and design is evident.

Implementation devices developed in Western Union's laboratories include "Coffee-grinder," described here, and "Dingbat," the subject of another article in this issue of the Review.

Of the 32 permutations of the five marking or spacing impulses explicitly denoting the alphanumerical and functional characters in the Baudot printing telegraph code, one combination, the BLANK, having all five impulses of spacing polarity, is reserved for transmission during idle periods of a multiplex channel, and except for tape ejection purposes is not ordinarily encountered in teleprinter signal communications. Military traffic, however, sometimes contains the blank character and these traffic blanks must not be deleted by the operating company providing the lease facility. If the latter is a simple direct teleprinter channel within the domestic system the traffic blanks are transmitted without special attention.

International communications channels on the submarine telegraph cables of the Western Union, however, are without exception 5-element time division or multiplex channels. During their idle intervals systemic blanks are transmitted continuously and the subscriber's line is held closed. The apparent incompatibility between our international multiplex channels and traffic containing blanks had to be resolved if the many military circuits to points abroad were to be carried without disturbance to the basic multiplex system. It is the purpose of this article to describe two of the significant cable terminal auxiliary equipments with this capability.

Plain Language Operation

Without exception, military traffic reaches the cable terminal over a direct wire in teleprinter signal form, each group of five intelligence impulses preceded by a start impulse and separated by rest intervals dependent upon the rate of transmission of the sending transmitter-distributor. Because all cable channels operate at 50 words per minute, a transmission pacer, a clockwork-driven autostopping device, is frequently used to restrain the transmitter-distributor to nearly the same average speed and so avoid unwieldy tape loop accumulation. In repeating either plain language text or military traffic the cable terminal apparatus must extract the five intelligence impulses and impress them on the sending multiplex channel. Conversely, the receiving cable terminal apparatus must redistribute those impulses sequentially to the subscriber's teleprinter with each group preceded by a start impulse.

At the sending terminal a reperforator-transmitter known as an FRXD machine is used to perforate only the intelligence. This ingeniously contrived machine has a movable transmitting arm carrying the sensing pins and a ratchet-like mechanism enabling the arm to step along the tape character by character until it is in such close proximity to the tape perforating head that the last character received there can be sensed and transmitted without the injection of extraneous tape feed-out blanks. Should the incoming signals arrive at a higher speed than that of the cable multiplex the arm slowly falls away against a stop and an intervening tape loop forms.

The receiving cable terminal basically comprises a set of five reading relays actuated by the multiplex delivery segments and a thyratron tube driving the teleprinter line at 22-millisecond intervals derived from timing segments on the distributor faceplate. Since under commercial text conditions a blank conveys no information, the reading relay bank is continuously scanned for this idle condition and if present the extinguishing circuit of the thyratron is disabled thus closing the teleprinter line. The reception of any other character reactivates the thyratron start circuit at once.

"Off-Line" Operation

The simplest method of sending military traffic over the basic system just described is termed "off-line" operation. The subscriber completely perforates the message before releasing his transmitter-distributor. The message including blanks arrives at a somewhat higher rate than that of the cable multiplex so that the latter is never autostopped insuring that all blanks received at the distant cable terminal are those in the traffic and are not systemic. While receiving off-line traffic, the usual blank deletion circuit controlling the thyratron is disabled by a timing circuit that restores blank deletion only after 20 or so successive blanks have been received, a condition certainly indicative that the entire message has been passed to the subscriber.

Off-line operation is seldom impaired by the effects of natural or man-made disturbance for the receiving multiplex will always send the correct number of characters to the subscriber even if an infrequent character is in error. To the armed services the disadvantages are the necessity to initiate starting procedure for each message and the delay occasioned by the complete message perforation at the sending subscriber's station.

Photograph R-9602

Figure 1. Four-channel Multiplex Distributor Table 7128-A and FRXD-MXPX Racks 6938-A under test in the laboratory

"On-Line" Operation

To eliminate delay and the starting procedure and to make possible telegraphic conversation or the dispatch of flash signals, so-called "on-line" equipment was developed by the Telegraph Company. In on-line operation the characters arrive at the cable terminal sporadically as the operator manipulates the sending keyboard. The cable terminal equipment developed in 1953 for this service is shown in Figure 1. The duplicate of this arrangement is installed at the London terminal for each 4-channel circuit.

Because pauses in transmission are permissible with on-line operation the delayed blank cut-off feature cannot be used and it is necessary to translate traffic blanks to an arbitrarily selected character of the alphabet and that character in turn to two others, a classic principle that had been previously used successfully. After finding that certain operators frequently used the LTRS function or unshift as a tape feed-out, the following sending-end blank translation rules were made:

1. Any traffic blank received from the subscriber is translated and transmitted over the multiplex channel as character X.
2. An incoming letter X is translated to the two letters M and X.
3. An incoming letter M is translated to the two letters M and M.

Auxiliary contacts in the transmitter unit of the FRXD machine permit each perforated character in the tape to be scanned for a traffic blank or the letters M or X. If a blank is seen the potentials corresponding to the letter X are set up on the sending segments; if an X, the transmitter is autostopped while an M is first transmitted and then followed by the actual letter X. If an M is detected in the tape, the letter M is sent twice. Once the movable transmitter has sent the last received character lying just outside the perforating punch block, the arm is autostopped and the usual systemic blanks sent over the multiplex channel during the idle period.

Complementary operations are performed at the receiving cable terminal: if one or successive blanks are received the subscriber's line is held closed and the distant receiving apparatus remains inoperative. The reception of an X causes a blank teleprinter character, that is, five spacing impulses preceded by a start impulse, to be released. If M, X is received the letter M is deleted and the X alone is passed to the subscriber. A double M is similarly handled, the subscriber receiving but the single, second M.

The equipment for one duplex 4-channel multiplex circuit, as shown in Figure 1, consists of a sending and receiving multiplex terminal set, Type 7128-A and two FRXD-MXPX Racks Type 6938-A. The subscriber's signals are reperforated by one of the four FRXD machines and the characters read by the movable transmitter arm are transmitted from segments on the left-hand distributor. Multiplex signals received on the right-hand distributor are delivered to one of the four vacuum tube operated relay banks at the top of a rack and the character read and translated if necessary before release to the subscriber. Interconnection between rack positions and the multiplex set is flexibly arranged through the usual channel switchboard. The rack incorporates not only the on-line facilities but off-line and commercial traffic handling as well. The latter facility is becoming extremely useful in the extension of teleprinter service and the equipments are standardized for cable terminal operations in New York and London. The on-line condition is usually preferred by military subscribers.

Although fast,—a flash signal can be sent to the Continent and acknowledged in less than a second,—and enjoying considerable use for military communication, on-line operation is still not ideal. Its most serious limitation is the considerable probability of the occasional injection during an idle period of an extraneous character somewhere along the transmission facility particularly when it is realized that the latter may be over 3000 miles long and composed of teleprinter leg circuits, landline carrier channels, and several submarine cable sections.

Superposition of Synchronous Systems

Recognition of these limitations has led to the development by the Department of Defense of a synchronous communication system pretty closely approaching the ideal. The new system is immune to the occasional hit or open encountered on practical telegraph connections and it can be superposed on a start-stop or on an independent synchronous multiplex channel of the operating company providing the channel connections between the military subscriber's terminal stations. This stability and facility of operation has been achieved by adopting synchronous operation between these terminals.

In the new system each blank and intelligence character is still transmitted in teleprinter signal form but the characters issue from the sending station in a never-ending stream at an extremely constant rate governed by a frequency source of great stability. The receiving station holds synchronism to this unending flow of characters. Although the receiving apparatus is susceptible to phase correction to the incoming signals, the inherent stability of the driving frequency is comparable with that at the sending station and the incoming signals can actually be obliterated for as long as 30 minutes without loss of phase. And so a printing telegraph system is obtained that is tolerant of errors or interruptions caused by apparatus or natural disturbance.

The new system can be operated over any direct landline telegraph channel without auxiliary apparatus. Because of the more efficient use of bandwidth by time-division signalling, however, only multiplex channels are available on the undersea cables of the Telegraph Company. Forty unidirectional channels standardized at 50 words per minute are now in use. These may be routed by either of two general paths across the Atlantic through flexible switching facilities provided at terminal and repeater stations. To attempt to synchronize one or more of these channels to a subscriber's synchronous channel presents operating objections not the least of which would be the loss of this system flexibility.

"Dingbat"

The Department of Defense saw the need for a device adjunct to the receiving equipment that would obviate the phasing of the independently operated multiplex channels to their superposed synchronous channels. This facility has been achieved by the Telegraph Signal Normalizer, conceived by the Department of Defense and developed by The Western Union Telegraph Company. "Dingbat," as the machine is familiarly known, is described in this issue of Technical Review by Robert Steeneck, who engineered its development.

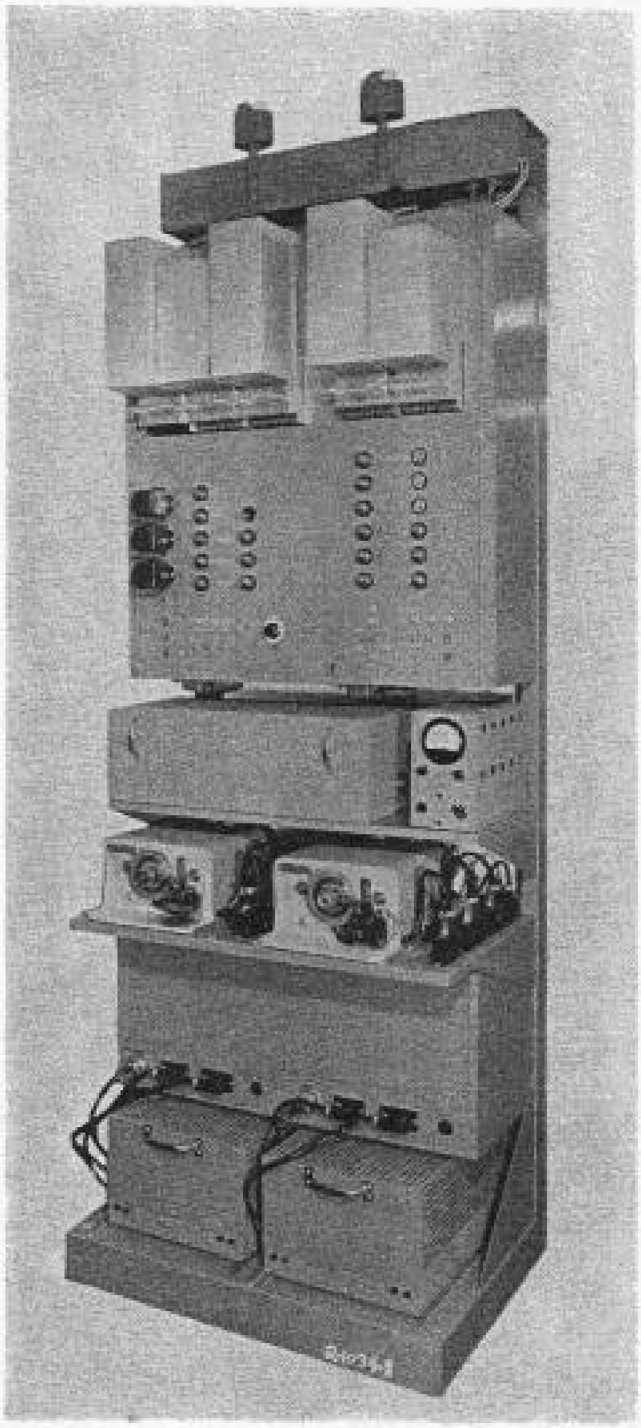
In the superposition of an external synchronous telegraph channel on an independently operated multiplex channel it is first essential that the subscriber transmit from one to five letters per minute slower than the faster multiplex channel, a range that more than allows for the maximum variations in the driving frequency sources of both systems. A channel repeater is then used by the operating company to couple the incoming steady stream of the slower speed teleprinter characters to the sending multiplex equipment. Alternate incoming characters are deposited by a start-stop receiving distributor in alternative storing relay banks of the channel, storage of one character occurring while the preceding character is being read off by the sending multiplex. Eventually the latter would, if not corrected, catch up with the incoming character and attempt to read off information before reception was completed. Some time before this condition is reached, a sensing circuit automatically causes the multiplex to cease its search between the storage banks and to send a single idle blank termed a "time differential blank" thereby setting the multiplex back in time by one character. The cycle then repeats.

To enable the receiving multiplex terminal to differentiate between time differential blanks and the traffic blanks that alone must be passed to the subscriber, it is possible to add a sixth element to a conventional 5-element multiplex channel for the purpose of "flagging down" the systemic time differential blank. Whenever the latter occurs, the polarity of the sixth element is reversed causing the outgoing teleprinter line to close. For the opposite polarity all other characters including traffic blanks pass to the subscriber. The line closures resulting from the insertion of time differential blanks by the sending end channel repeater are deleted by the Telegraph Signal Normalizer in such a subtile manner that the output to the receiving apparatus becomes once more a steady uninterrupted stream of characters of precisely the same rate of occurrence as when generated at the sending station. The Telegraph Signal Normalizer thus functions in the reverse manner to the channel repeater; instead of periodically inserting a blank and interrupting the traffic stream, the Normalizer removes the time differential blanks, slows down the rate of retransmission to consume the time occupied by these systemic blanks, and so restores the continuity of the superposed channel.

"Coffeegrinder"

When transatlantic facilities were first being prepared for the new superposed military service by Western Union, the possible modification to the 6-element condition of a few of the standard 5-element channels with their consequent isolation from the rest of the system was not seriously considered. Instead an alternate solution was developed based on the lowest common denominator of 5 and 6. If the 6-element characters resulting from the addition of the "flag" to the 5-element traffic characters are successively stored in a bank of 30 capacitors, these same 30 impulses can be removed five at a time, with the aid of appropriate circuitry, by any one of the standard 300-lpm transatlantic channels. Conversely, at the receiving cable terminal the standard multiplex receiving distributor must deliver, through supplementary distributing apparatus, to a similar storing bank of 30 capacitors from which the original 6-element characters can be removed and translated to 5-element start-stop signals. Should the sixth element of any reassembled character have one polarity the received character stripped, of course, of the sixth impulse is released to the teleprinter line that terminates in a Telegraph Signal Normalizer at the distant subscriber's receiving station; if the sixth element is of the opposite polarity the line is held closed for the duration of one character in response to the time differential blank just received.

Because of the addition of the sixth impulse to each incoming character, the net speed of transmission of the traffic must be reduced to slightly less than five-sixths that of the cable multiplex channel speed of 50 words per minute. The subscriber cooperatively established the speed of the equivalent transmitter-distributor at the sending station at 245-1/3 operations per minute, about three-quarters of a word per minute less than the intermediate 6-element multiplex.



Photograph R-10,348

Figure 2. Synchronous military traffic terminal equipment, Translator Rack 8012-A

The physical outlines of the new intermediate apparatus, Translator Rack 8012-A, not inappropriately called "Coffeegrinder," are shown in Figure 2. The physical dimensions and the power and interconnection ducts are comparable with FRXD-MXPX Rack 6938-A so that their installations are compatible. Unlike its predecessor, Translator Rack 8012-A supports the apparatus for but a single duplex channel, the sending equipment being mounted more or less on the left-hand side with the receiving components located on the right, and it possesses but a single mode of operation, that of the superposition of a synchronous traffic circuit on a standard speed 5-element multiplex channel of the Western Union transatlantic system.

Fundamentally, either side of the rack is a 5-to-6 or 6-to-5 element auxiliary multiplex set that is introduced by means of the cable channel switchboard between the teleprinter line and the regular cable terminal multiplex, and to which channel repeating, blank character control, and testing and regulating functions have been added. The heart of this equipment is a newly designed cam-contact distributor, Multiplex Distributor 8050-A shown in Figure 3. The 50-cycle self-starting synchronous motor of this machine is energized by a power amplifier which is driven on the sending side by the office common sending frequency generator, and on the receiving side by a multiplex driving fork correcting to the sixth pulse of the receiving quadruplex multiplex set. The 1500-rpm motor drives a 300, a 250, and a 50-rpm shaft to provide the rather complex sequence of cam contacts necessary. A start-stop distributor is also driven by the 300-rpm shaft; at the sending terminal this mechanism receives the teleprinter signals from the subscriber's sending station and delivers the regenerated impulses alternately to one or the other of the storing banks in the channel repeater, while if receiving from the multiplex the faceplate is automatically restrapped to send polar teleprinter signals to the subscriber's receiving station.

Photograph R-10,428

Figure 3. Distributor 8050-A — the timer for Translator Rack 8012-A

As is customary with all cable terminal equipment, this rack terminates on send and receive jacks in the cable channel switchboard and can be patched at will to any transatlantic channel. Following each connection, auxiliary contacts on the Multiplex Distributors 8050-A enable the technician correctly to phase these machines by comparison circuits working with the sixth pulses of the sending or receiving multiplex distributors. For the former a continuously rotatable phase shifter enables the technician to add or subtract revolutions until an indicating lamp is ignited; on the receiving side the phase is corrected by shifting the frequency of the otherwise corrected auxiliary fork on the rack.

Automatic Controls

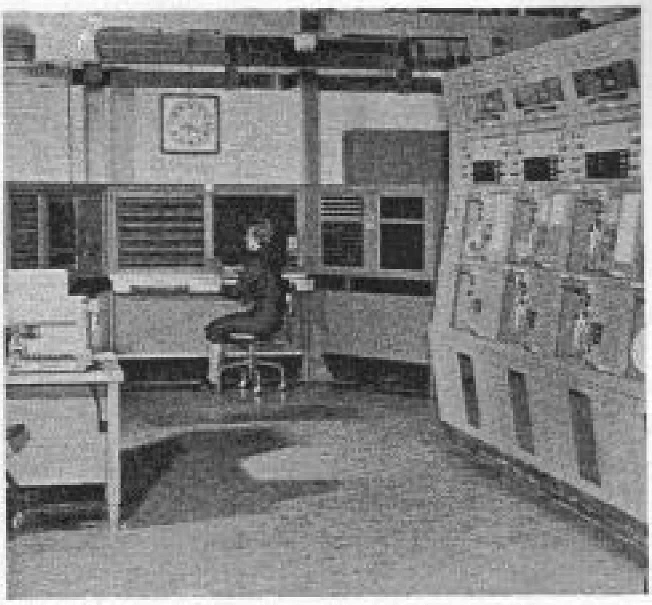
In the design of Translator Rack 8012-A a very considerable effort was devoted to the supervisory features and automatic alarms to facilitate diagnosis and correction of circuit operating difficulties and to simultaneously tell the distant receiving station that the circuit was receiving attention. Particularly to this latter effect, circuitry was provided responsive to the opening of the subscriber's incoming line, or to loss of phase of either the rack distributor or the interconnecting multiplex cable circuit, that will immediately call in the attendant and close the outgoing teleprinter line. The cessation of the normally steady stream of incoming characters at the subscriber's receiving station is an indication that the circuit is receiving attention by Western Union personnel. Upon correction of circuit difficulties the line closure is automatically removed and if the outage has been of short duration superposed operations resume without delay.

Conclusion

While FRXD-MXPX Rack 6839-A is still the work-horse of the cable system both for asynchronous military traffic and for commercial traffic, the gratifying reliability and satisfaction to the subscriber of the new synchronous channels made possible by Translator Rack 8012-A lead to an expectation of further expansion in the use of "Dingbat" and "Coffeegrinder."

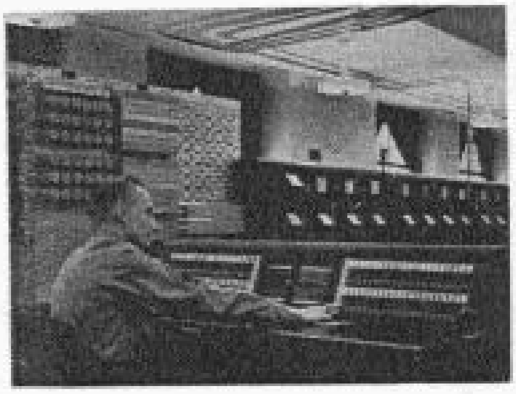
The author wishes to acknowledge the role of a colleague, T. A. Newman, in the application of these principles and the incorporation of the invaluable supervisory controls in the design of Translator Rack 8012-A.

Harold F. Wilder, Assistant to the Applied Electronics Engineer, joined the Company as an engineer in 1929 after graduation from Northeastern University. Mr. Wilder directs an engineering group concerned primarily with the design of signal shaping amplifiers and multiplex terminal equipment for ocean cables. Equipment for handling military traffic is one facet of these activities. Mr. Wilder is a member of AIEE.



Modern automatic message switching apparatus and associated traffic control boards developed by Western Union for military telegraph systems. Technician uses intercom set to talk with testboard or other areas of installation.

Modernization of Military Communications By Western Union



Traffic control supervisor's console at semiautomatic message center installed by Western Union for U. S. War Department during World War II

Military message switching equipment known as "Package Unit" was produced in quantity by Western Union for armed forces about 1943

Military message centers of World War II employed semiautomatic switching equipment of Postal Telegraph Company design. It was type most readily available then for rapid expansion of U. S. War Department telegraph network.

ROBERT STEENECK, Assistant to Systems and Equipment Engineer

Teleprinter Signal Normalizer

A new kind of automatic regenerative repeater developed by Telegraph Company engineers as proposed by E. N. Dingley, Jr., gives the advantage of fully synchronous operation when long synchronized teleprinter leg circuits are superposed on multiplex channels, a condition which obtains in world-wide military communications.

The combination of electronics and modern telegraph mechanics is effectively illustrated in the unique and interesting design features employed. Application of this equipment—called "Dingbat"—is referred to in another article in this issue of the REVIEW.

In military communication it is often most desirable to operate on a synchronous basis even though start-stop signals are being used. It is possible with synchronous operation to reduce the number of errors in messages by preventing an increase or decrease in the number of characters apparently received during a "garble." Synchronous operation, of course, cannot produce correct characters during a garble but can be made to produce the garbled characters without altering the character count.

To operate simple direct circuits on a synchronous basis is relatively easy, but it is not always possible to obtain direct teleprinter circuits especially where long distances are involved. Most long military circuits are carried through synchronous time-division multiplex equipment such as the AN/FGC-5. Each channel of the multiplex is fed by a teleprinter circuit operating at a speed slightly lower than that of the multiplex, a difference which is necessary to avoid pile-up of information at the multiplex input terminal.

Thus a single multiplex channel, by transmitting information slightly faster than it is made available, will periodically find nothing to transmit. Under this condition the multiplex channel will operate through one complete character cycle without handling a teleprinter character and the receiving multiplex terminal will pause for the duration of one character in its transmission to the receiving teleprinter leg. Although the multiplex is a synchronous device, it can insert an extra character in the received text when a garble occurs during a rest period. (Also, characters may be dropped by the failure of the circuit itself.)

Under normal operation the instantaneous character rate of the teleprinter receiving legs extended from the multiplex equipment is slightly higher than that of the teleprinter legs feeding the multiplex. The *average* rate, however, is precisely the same. It is made so by the one-character pauses automatically inserted between groups of characters in the receiving legs. The problem is how to take advantage of synchronous teleprinter operation from this type of broken-rhythm signal at the receiving end.

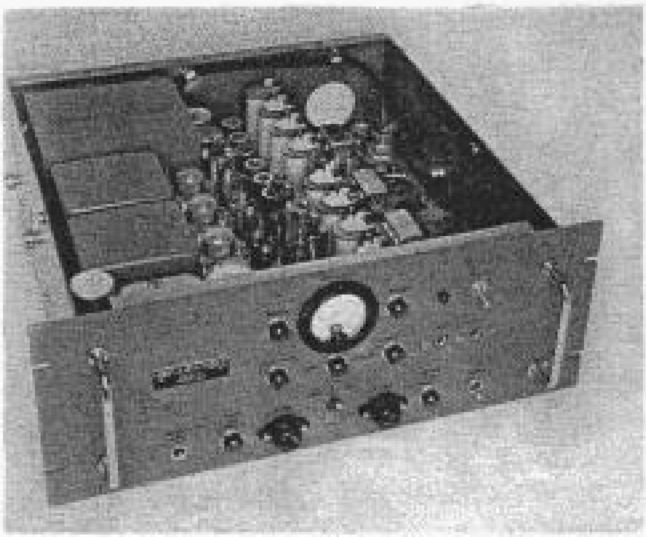
Since the difference in speed between the time-division multiplex and the input legs is the basic cause of the difficulty, it may seem most simple to pace the teleprinter input circuit from the time-division multiplex and thus get away from the troublesome rest periods. This is indeed a simple solution where only short input legs are involved; however, many input legs are in themselves quite long and under such conditions circuit flexibility would greatly suffer.

The need is then in some way to obtain over-all synchronous operation when one synchronous system is superposed upon another entirely independent synchronous system.

The Dingbat Solution

E. N. Dingley, Jr., of the Department of Defense, presented a basic solution disclosed in U. S. Patent No. 2,721,230. In this solution, he proposed a device that would accept the broken-rhythm signals delivered by the multiplex equipment and retransmit these signals at their original normal input speed. Means were provided to recognize and correct for normal speed differences and thus establish a synchronous circuit from the teleprinter input terminal to the output terminal of the Signal Normalizer or "Dingbat" as the device was called.

At the request of a government agency, Western Union first built a model to test the Dingley theory, since opinion was divided as to whether a normalizer could ever be made to operate satisfactorily. In fact, even after the first model had been built and successfully tested, independent investigation still cast doubt on the operability of Dingbat. Since Mr. Dingley's patent disclosure was mainly for the purpose of establishing the basic idea, many construction changes were made and new features added before production of the final Western Union Dingbat design. The Dingbat theory, however, remained unchanged and proved to be quite sound.



Photograph R-10,381

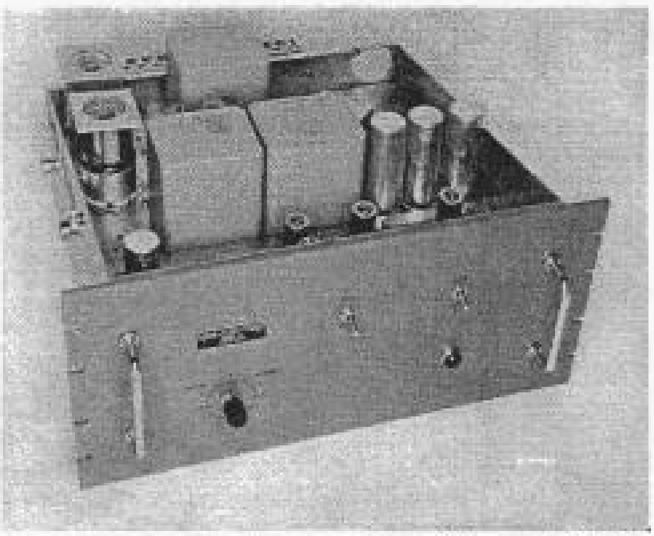
Figure 1. Power unit

Dingbat itself is essentially a regenerative repeater accepting signals in groups separated by rest periods and repeating these signals at a steady rate with no inserted rest periods. The retransmission rate must thus be slower than the instantaneous reception rate to account for the time of the deleted rest periods. This is the prime function of Dingbat and it would be quite easy to accomplish if the sending and receiving equipment could be kept in synchronism by operating it from one common source of power. Since this was impossible, it became necessary to drive the equipment from a stable timing device and, from the information received from the multiplex, determine what phase corrections must be applied to keep Dingbat in synchronism with the sending terminal.

Equipment

In its recent form, Dingbat consists of three units: the power unit, the timing unit, and the distributor unit. The power unit, shown in Figure 1, houses the control relays, positive and negative 120-volt rectifiers, control switches, fuses, indicator lamps and the main power transformer which allows operation over a wide range of power line voltages and frequencies.

The frequency standard used for the output drive is a crystal oscillator, and is included in the timing unit shown in Figure 2. Its frequency is divided down in



Photograph R-10,383

Figure 2. Timing unit

six steps with multivibrator units until the desired frequency suitable for operating a standard synchronous motor is obtained. The timing unit provides an accurate frequency that closely matches that which drives the input terminal. The frequency can be corrected automatically for slight drifts that occur under normal operation.

The distributor unit, shown in Figure 3, houses both input and output distributors. The input distributor is a start-stop device driven by a series-governed motor while the output distributor is a continuously running device driven by a synchronous motor operating from thyratrons in the timing unit.

Operation

To successfully repeat signals from the multiplex equipment, Dingbat has two storage banks consisting of two 5-unit groups of 2-µf capacitors which store marking signals as negative charges and spacing signals as positive charges. To avoid the necessity of switching from one bank to the other on alternate characters, both distributors have been designed to scan half a revolution per character. Alternate halves of both distributors are connected permanently to their respective storage banks and under normal reception of information no storage bank switching is necessary since alternate characters are automatically stored in alternate banks. Switching does become necessary, however, when line failure conditions cause an odd number of characters from the multiplex to drop out. Under such a condition the receiving distributor will be at rest during the drop-out period and the first character received after this period will be stored in the wrong bank. All following characters will also be stored in the wrong banks. To correct this it is necessary to shift the receiving brushes 180 degrees. In Dingbat this is accomplished by having another set of receiving brushes already displaced 180 degrees. By transferring the receiving functions to the second set of brushes a 180-degree phase shift may be effected quickly.

Photograph R-10,386

Figure 3. Distributor unit

Figure 4 shows how Relay Z, when energized, transfers the input signals from one set of brushes to the other by shifting a single circuit from R2 to R1. Dingbat must not only know when this 180-degree shift of brushes is required but must also know when a slight correction of the output distributor phase is needed in order to maintain synchronism with the sending terminal.

The rate of the signals coming from the multiplex is of little use for this purpose since it bears no relation to the terminal speed. The average rate of signals from the multiplex, however, does agree precisely with the sending terminal speed and this is what enables Dingbat to maintain synchronous operation. If the phase of the output distributor brushes is observed with respect to that of the input distributor, it will be noticed that the output distributor will progressively lag behind the input distributor until there is approximately one character or half a revolution difference between them. At this time, however, the multiplex system will deliver its rest signal and the accumulated loss in phase will be completely recovered.

In Dingbat this is made visible by mounting two neon lamps spaced 180 degrees apart on the output distributor brush arm. These lamps are made to flash alternately by the respective alternate characters received by the input distributor. The flash signals are sharp and are produced by differentiating the incoming start signals. The differentiated start signals are directed down alternate paths to the two neon lamps and are kept separated by a diode network.

Observation of these neon lamps during operation shows the output distributor brushes progressively lagging for approximately half a revolution and then recovering their original phase position after the rest signal has been received.

Observation over a period of time during normal operation shows that this pattern of flashes falls entirely within a 180-degree arc of the output brush rotation. The output distributor is driven through differential gears which allows the phase of the brushes to be adjusted by hand until the pattern of normal operation is confined to the lower half of the output distributor. Should Dingbat's output speed precisely match that of the sending terminal the pattern of operation will remain within this 180-degree sector. Should Dingbat's output distributor run slightly faster than the sending terminal the pattern will drift in a counterclockwise direction, and should it be running slower the pattern will drift in a clockwise direction.

Speed Correction

The pulses flashing the neon lamps are also directed by brushes on the output distributor to a common segmented ring. Two segments just outside the 180-degree sector of normal operation are used to sense clockwise or counterclockwise pattern drift.

A pulse falling on the counterclockwise segment indicates that Dingbat is running too fast and must slow down. This slowdown is accomplished by suddenly decreasing the frequency of the crystal oscillator by approximately 100 parts per million for about four seconds and then returning it to normal frequency. The frequency is decreased by adding capacitance in the order of 180 μμf to each side of a quartz crystal oscillator used in the timing unit.

The relay inserting this capacitance is located in the power unit and switches the small capacitors over conductors having relatively high capacitance associated with their normal run. Each capacitor, therefore, is switched electronically by controlling the cathode bias of a diode as shown in Figure 5.

Diode A, and diode B with its cathode grounded (Figure 5), provide paths for

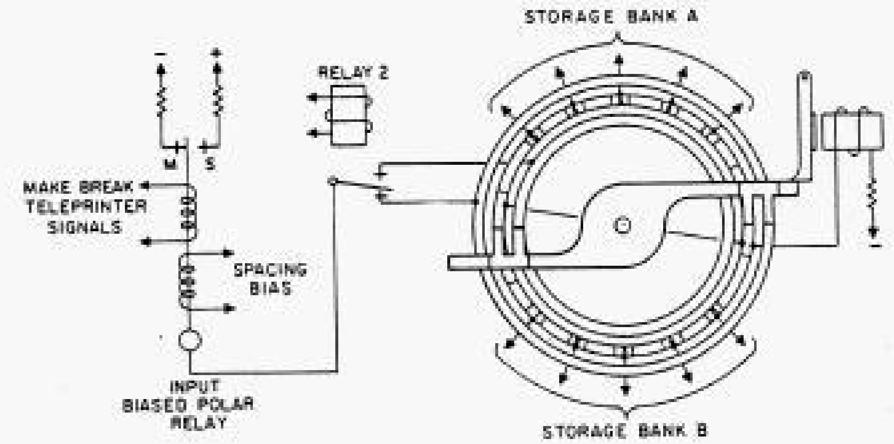


Figure 4. Circuit for shifting brush phase 180 degrees

both positive and negative current and thus effectively connect the 180-μμf capacitor to ground. If the cathode of diode B is raised to 150 volts positive potential, however, it will not function as a path for positive current and will leave only the negative path of diode A in circuit. Diode A will then pass current for the first half cycle only and charge the 180-μμf capacitor so that no more current can flow. Thus with one diode path removed the capacitor is effectively removed from the circuit and capacitance in the wiring has no effect upon the circuit. A similar circuit is used to advance the frequency of the crystal oscillator when required.

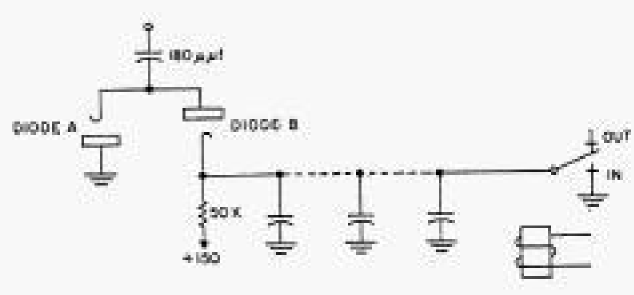


Figure 5. Switching of small capacitance

Wherever a retard or advance frequency function is requested a small permanent adjustment in the order of a few parts per hundred million is also permanently inserted in the crystal oscillator circuit by a geared-down reversible motor rotating a variable air capacitor. Thus the frequency at the Dingbat terminal slowly and automatically adjusts itself to that of the sending terminal.

The storage capacity of two characters makes it possible under circuit trouble conditions for Dingbat to get 180 degrees out of phase. The neon lamps under such a condition will flash in the upper 180-degree sector of the output distributor. A circuit is provided on Dingbat to recognize this as a condition requiring a shift of 180 degrees in the input brushes. Since this information is obtained when the start pulse is received the 180-degree brush correction can be made before the selection pulses arrive, and thus correctly store the incoming selection.

During certain conditions of circuit failure Dingbat will receive a steady flow of signals from the multiplex with no interspersed rest periods. Under this circuit failure condition, Dingbat will periodically observe a pulse upon the advance segment before the pulse advances into the upper 180-degree zone and calls for the 180-degree brush phase shift. Since this is obviously a false advance signal a cancel circuit is associated with the 180-degree phase shifting function which cancels the request for a speed change. In fact, whenever a 180-degree phase shift is required circuit trouble is indicated and all speed change requests are canceled. The cancel circuit holds the advance and retard circuits inoperative for approximately ten seconds so that during periods of continuous line trouble when periodic requests are made for 180-degree corrections no corrections at all will be made to the frequency of the crystal oscillator.

Under these conditions Dingbat can hold synchronism for 30 minutes. Actually a much longer period can be tolerated because it is also possible to hand-phase Dingbat to correct for a speed drift that may be beyond Dingbat's ability to handle automatically.

Dingbat may also be used on direct circuits involving no multiplex at all in their make-up. Under this condition both input and output speeds of Dingbat are the same and no drift of the neon lamps should be observed. The advance and retard segments are brought much closer together for this type of operation. The input distributor brushes are also started from the output faceplate to prevent a runaway condition of the input distributor under line failure conditions. Thus a received character with a single garbled rest pulse may not even produce one error whereas with standard start-stop operation such a single garbled pulse could result in about six errored characters.

Dingbat equipments have been operating on communication circuits for some time. Operation experience indicates that they have provided a practical answer to the perplexing problem of establishing a synchronous communication circuit when it becomes necessary to superimpose this circuit upon another independent synchronous system.

Robert Steeneck, after graduating from Stevens Institute of Technology in 1926, joined the Telegraph Company on the staff of the Apparatus Engineer. In 1928 he transferred to the Engineer of Automatics to assist the Ticker group in the development of the newly established Teleregister service. In addition to his accomplishments in the Ticker field, he was responsible for the development of Western Union's line of Sport Timers; he assisted in the development of the varioplex system and worked on the Navy Radar Contact Trainer project at the company's Water Mill laboratories. In 1954 he was transferred to the Switching Development Engineer's division to develop an electronic one-wire cross-office control for the Air Force switching system. At present Mr. Steeneck is Assistant to the Systems and Equipment Engineer and is engaged in data handling developments.

GEORGE O. VINCENT, General PWS Supervisor, Facsimile and Private Wire Services

Self-Checking Codes for Data Transmission

Increasing use of telegraph facilities for transmission of business data in numerical form has generated studies of accuracy assurance. While, currently, all practical error detection systems involve redundancy, which reduces transmission speed or capacity, there are various pulse count methods and other means available for automatic error-checking.

In a recent press release about the installation of a "giant" electronic computer being placed in operation for the Signal Corps it was stated: "The computer collects and memorizes 8,000,000 different facts on more than 150,000 items required to keep the Army's global communication-electronics systems in operation. It uses these facts to process 6,000 orders for supplies received each day from troops throughout the world. It can make 30,000 logistical decisions per second and process 8,000 tabulating machine cards per minute."

Another announcement is about an electronic printer for use with such "brains" that is capable of translating and printing speeds up to 240,000 letters and numerals a minute. This produces in one minute 40 complete and different 8-1/2 by 11 inch business documents.

Such developments are occurring these days with increasing frequency and these two are mentioned here to point up the pressing requirement for speed and accuracy in telegraph transmission, with particular emphasis on private wire services. Communications facilities and equipment will be necessary to interconnect computer equipments for the rapid interchange of data in the growing use of more general and expanded applications of computers in the increasing pace of today's business. The greatest potential growth in private wire services is in the field of data handling to feed such "giants," and greater speeds will obviously be required if information is to be fed to such extensive data digestive capacities. It is the consensus in Western Union that a means of assuring accuracy in transmission is essential in this field and several ways of doing it are being devised and tested by our engineers. Western Union as the leader in the written communications field will be prepared to meet this need in integrated data processing.

Modern record communications facilities, particularly those utilizing frequency modulation, which Western Union pioneered for telegraph purposes, lend themselves readily to almost any practical signalling speed that may prove most advantageous from the standpoint of the computer and the work it must perform. Only relatively minor new developments in terminal equipment are required to accommodate a variety of speeds. However, speed of transmission is another subject.

As to accuracy, examples of our experiences in operating present facilities and equipment for data purposes may be of interest.

At Boston not long ago, IDP problems were introduced directly into an "Alwac" computer by Western Union teleprinter keyboard. There is nothing very startling about direct keyboard entry, but in this case the keyboard was in Boston on the Atlantic Coast and the computer, manufactured by Logistics Research, Inc., was located in Redondo Beach on the Pacific Coast, the two being connected by Western Union frequency-modulated carrier circuits. Mortgage computations, arithmetical problems, and trigonometric functions were being handled and the results printed in Boston within seconds of input. The same demonstration was repeated from Chicago. Combined, there was a total of six days of errorless transmission and computing.

Another experience was with an insurance company which in handling data by private wire service reported there were "only" (that is the customer's word) 32 errors in 25,000 punched cards which were converted from punched tape received by wire and not one of the errors was traced to our facilities but rather all were due to original punching.

Photograph R-10,526

Friden Add-Punch used in Western Union's payroll application

The Telegraph Company has been testing an internal payroll operation between the Baltimore office and New York headquarters. All phases are being carefully checked and analyzed. At Baltimore, on a Friden "Add-Punch" machine, the payroll data for each person are punched into 5-channel code paper tape as read from time cards. After the data for each person are perforated, the total of all the digits in the data for that person is recorded in the tape as a "nonsense" check total. The tape is then transmitted from Baltimore to New York. At New York the tape is run through a tape-to-card converter. Then the cards are run through a calculator and "zero balanced" to the "nonsense" total. If each card does not zero balance, an error is evident. Errors which did occur were directly traceable, the majority being due to operator error, and some few to the various pieces of equipment involved.

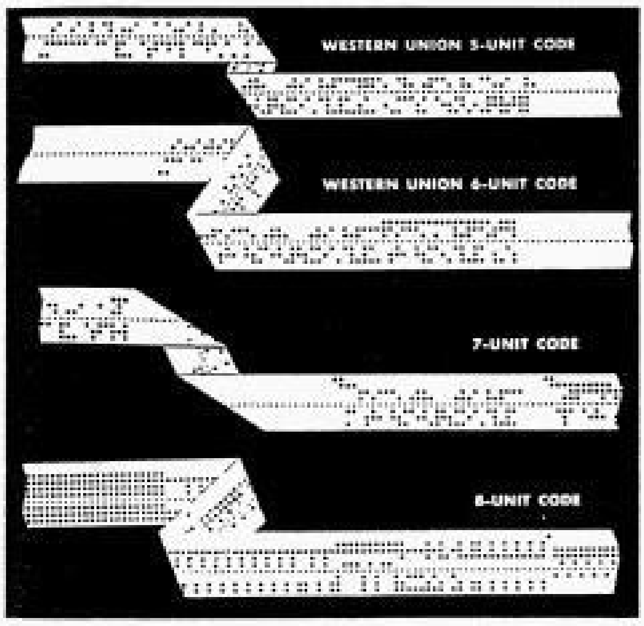
The occasional error in words is readily apparent, but in a string of random numbers it becomes more difficult to discern. If the cost of occasional errors to a particular type of business is not too great, and the cost of an error-detecting device is relatively high, it is more economical either to accept the errors or to provide a different means of detection. There are applications, similar to that mentioned in Western Union's handling of payrolls, where summary totals will show whether errors have occurred, and it may thus be cheaper to ferret the occasional mistake rather than to pay for a seldom useful but continuously operating checking device.

It remains, however, that everyone concerned with IDP is interested in error checking. While there are several automatic checking methods, there is a balance to be struck between time loss from retransmission of the section of data containing an error and the time loss from tautology or signalling redundancy for error checking purposes. This means that if the error rate is relatively frequent it would be advantageous to check frequently, in order to identify and mark the error as early as possible and thus save considerable retransmission time for whole sections of data.

The 5-channel or 5-level code used in both telegraph and private wire services, consisting of various combinations of "marking" and "spacing" pulses, does not in itself provide a self-checking feature. A gain or loss of a pulse whether due to "hits" on the line or faulty equipment will result in an error. Incidentally, in referring to a 5-channel code, the start and stop pulses which cause it sometimes to be referred to as a "7-unit" or "7.42-unit" code are being disregarded.

A 6-channel code is used for Teletypesetter operation to obtain more character assignments than are available with a 5-channel code. Also the Commercial News Department of Western Union employs a 6-channel code for ticker service in the distribution of stock quotations. Here the object is to obtain the required number of character assignments without the use of upper-case and lower-case shift functions. Neither of these applications provides for error detection by virtue of the code.

A sixth channel could be added to the standard 5-channel telegraph code and provide error detection by means of a parity check. However, this fails to satisfy the requirements for computer input for several reasons. In the first place, the code assignments of the digits in the standard telegraph code have no natural arithmetical progression for computer operation. Therefore, to avoid translation the code assignments must be changed. In the second place, the shift functions are as undesirable for computer operation as they are in telegraph ticker service. Thus computer designers have adopted 6-channel codes of their own to obtain code assignments of their own choosing without shift functions. A seventh channel is customarily added for parity checking.



Code tapes

The 7-channel code used with many computers provides 1-channel redundancy for an odd-even parity check. A 7-channel code is also used by RCA Communications for automatic error detection in telegraph transmission. In one application each character has three marking and four spacing pulses. If the received character fails to satisfy this ratio of marking and spacing pulses, the error is detected.

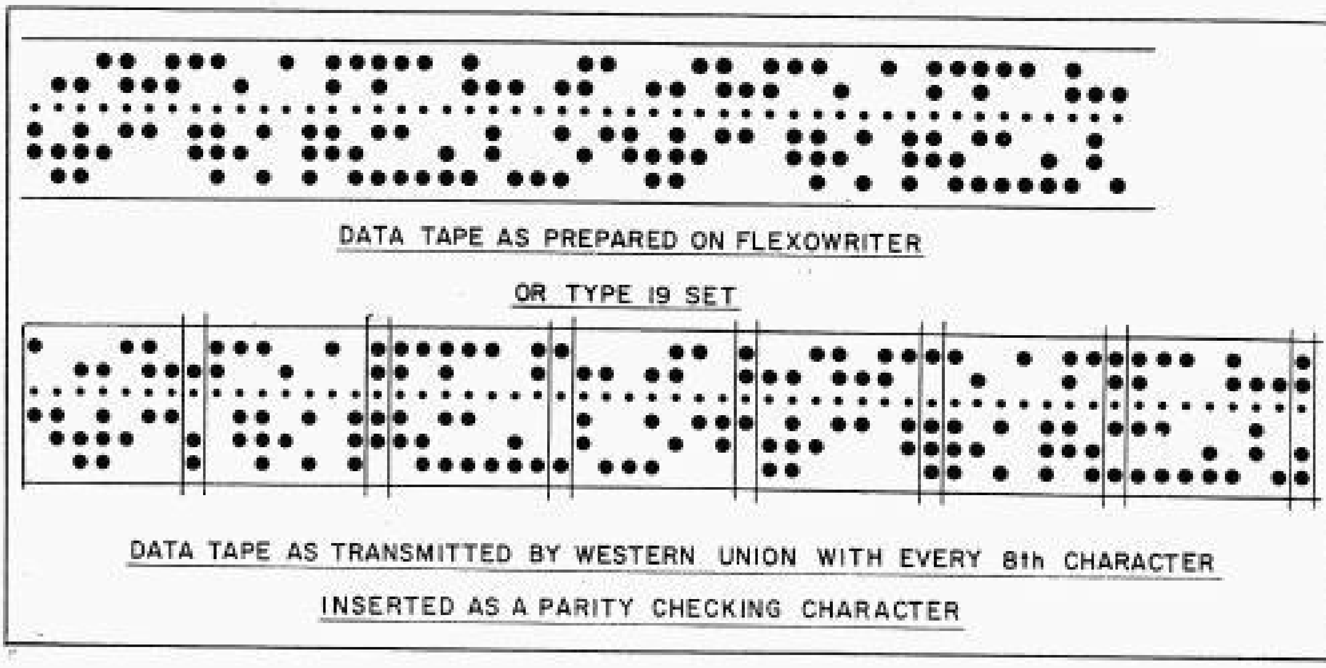
An 8-channel code, used with the IBM card transceiver, provides four marking and four spacing pulses per character. Errors in transmission are detected if a received character has more or less than four marking pulses. There are other variations of the 8-channel code used in some types of tape-to-card and card-to-tape converters.

The fixed mark-to-space ratio method of error detection is superior to the parity check for telegraph transmission. The distinction would be minor if the transmission errors were due to random effects. Analysis of actual transmission shows that the fixed ratio check will detect certain errored characters which will be passed by a parity check, while other compensating errors are undetectable by either method. While neither method is perfect it must be recognized that both the parity check and the fixed ratio check have considerable merit and that they are eminently satisfactory for many applications.

Where a higher degree of accuracy is required the character by character parity check may be supplemented by an odd-even check of the marking pulses in each channel of a group of characters. This is sometimes referred to as horizontal parity checking. There are several arrangements in which a horizontal check may be applied and unrestricted application of this principle will provide any degree of accuracy that may be required. There are practical and economic limitations, however, so it is necessary to establish the accuracy requirements of a particular service. Generally speaking, more redundancy results in higher accuracy. But more redundancy produces lower transmission efficiency and the equipment and circuitry are more expensive.

When operation is restricted to the 5-channel code one may examine the situation where the required number of characters is limited to the ten digits. There are exactly 10 code combinations having 2 marking pulses and 3 spacing pulses. Thus it is possible to apply a "2 out of 5" ratio check to this restricted application. If more than 10 but less than 16 combinations satisfy the requirements they may be derived from four of the channels and the fifth channel used for an odd-even parity check.

every 8th character. It could just as easily be every 10th, 12th or 80th character. It is most important, however, to recognize that the more characters transmitted between



Western Union's automatic 5-channel parity check

The general case in which the required number of character assignments is 60 or less, any error detecting scheme for a 5-channel code must insert check characters at appropriate intervals.

In one method the transmitted signals include a check character which is added to each block of signals by an insertion unit. The insertion unit counts the marking pulses horizontally by channels for, say, a block of seven characters, as illustrated. If the marking pulse count is odd in channel 1, for example, no marking pulse is added at channel 1 of the eighth character. If the marking count is even, as in channel 2, a marking pulse is inserted. Thus, every eighth character shown in the illustration is inserted as a "parity" check to make each block of eight characters show an odd number of marking pulses in each horizontal channel as transmitted to the circuit. A dropped or added pulse in any block obviously will change the arithmetic so that lack of parity will appear. This is considered a practical method of error checking and one which does not require excessive line transmission time.

The check character spacing need not be parity mark insertions, the greater the probability of experiencing a "compensating" error.

It is interesting to note the effect upon traffic volume with different check character spacings:

Check Character Spacing	Percent Traffic Increase
8	14.3
10	11.1
12	9.1
80	1.3

For example, a sales order comprising 200 characters of intelligence would make 28.5 blocks of seven characters so the total number of characters transmitted to the line would be about 228 with every eighth character a check character. With 8-character spacing, the signals to be transmitted are increased by approximately 14 percent.

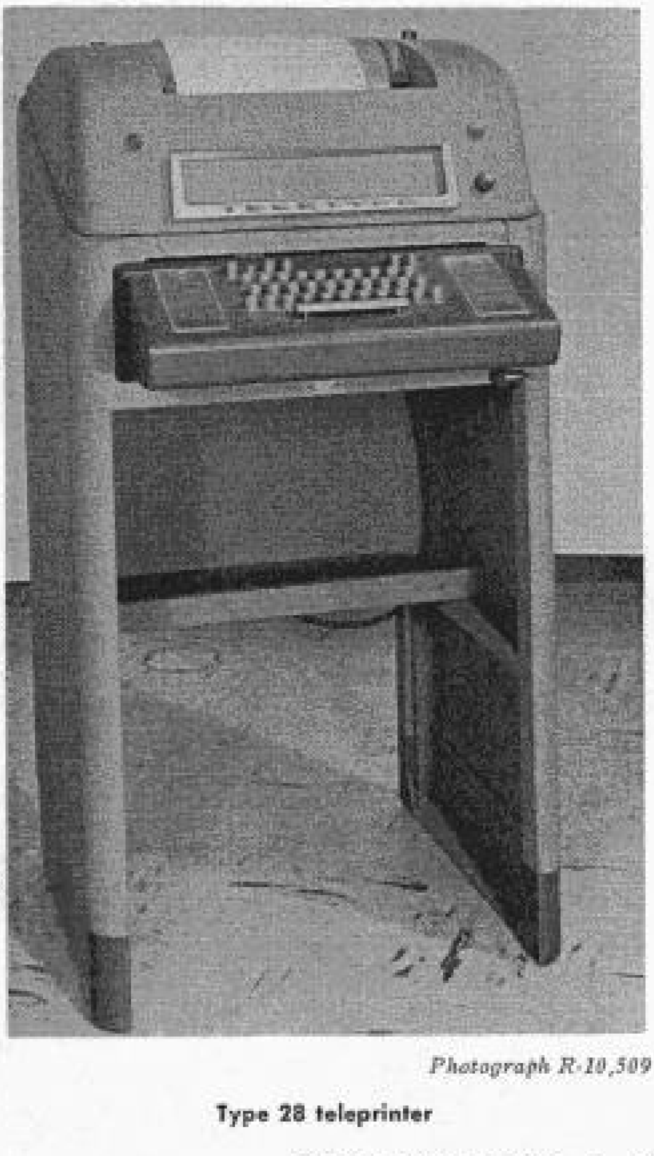
It is possible also to take a 6-level code; i.e., five levels and a parity check, and transmit it on 5-unit equipment and preserve the sixth level. For each group of five characters, the parity check "bit" is stored in memory equipment, and then the group of five parity bits is transmitted as the sixth character. Although not a startling development, it does illustrate a certain amount of compatibility between 5- and 6-unit code systems, when the sixth unit is for parity checking.

The 5-channel code has long been recognized as a standard in the communications field. At the same time, however, 6-, 7- and 8-unit codes are becoming increasingly popular which presents a problem of compatibility. IBM, Remington Rand, and others are working on methods of assuring accuracy in 5-unit transmission, and it is hoped that all will settle on a common method so that the transmission of 5-unit tape will be compatible in order to take complete advantage of the tremendous modern plant now operating on the 5-unit principle. The Telegraph Company is directing efforts toward this end, and also toward providing facilities and equipment for the transmission of 6-, 7- and 8-unit tape.

As mentioned before, many computers are working on the basis of 7-channel code, the sixth channel being added to provide additional functions, and the seventh channel being utilized for parity check. Work is in progress on multi-unit code equipment which will comprise a data communications network, and which ultimately will be capable of transmitting and terminating on magnetic tape for computer operations. At the same time, such a system would require teleprinters for intercepting data not required on magnetic tape. A system of this nature could provide transmission directly into a magnetic drum.

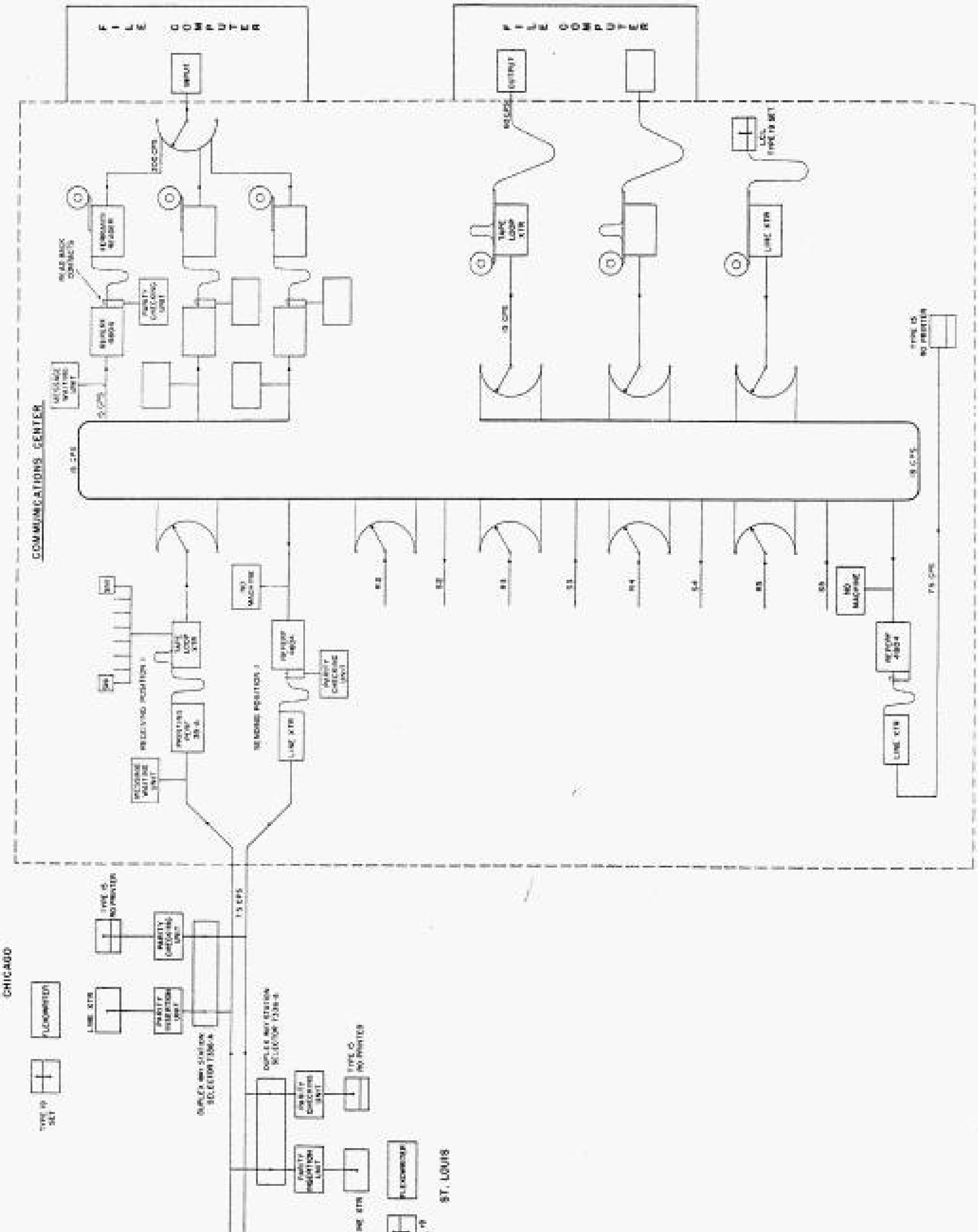
Extensive development work, resulting from market, equipment and system studies, is being done on another Western Union project entitled EDIT (Error Deletion by Iterative Transmission.) The EDIT system will be sufficiently flexible to accommodate 5-, 6-, 7- or 8-channel codes and will provide automatic error detection and *deletion*. Data will be prepared in blocks. Upon receipt of an errored character, the perforator will stop and at the end of the block the transmitter will be notified that an error has been received, and a "delete this block" symbol will be punched in the received tape after the errored character. The transmitter will reset the tape automatically and retransmit the group.

There is still the problem of 5-channel code with respect to the many applications and equipment which have been designed to utilize it. These applications simply cannot be converted overnight. Yet more accuracy is one of the objectives and necessities of IDP, and the standard 5-unit code as currently used does not provide a channel for obtaining a parity check. The use of a unit which can provide accurate 5-unit transmission without a parity checking channel was explored. Telegraph engineers developed a means of sending the signals for a character, followed by an inversion of the same signal, which are compared at the receiving end, and any



Photograph R-10,509

Type 28 teleprinter



Schematic of proposed communications network for file computer system with parity insertion and checking unit

errored character thus detected. This system was thought to have accuracy advantage over the single pulse parity check system since it eliminated the possibility of gain or loss of two pulses erroneously being read as a proper check.

It may appear that the same accuracy could be obtained by sending the data twice and comparing the two transmissions. However, the "5-by-5" system, as it was named, does more than this. Comparison is automatic, character by character, with reversal detecting possible line bias errors.

Another promising method of checking utilizes the "stunt box" of a Type 28 teleprinter. The marking pulses in each channel are "counted." A transmitter-distributor is used to read and send the check character to the circuit, and also back to the stunt box after a combination of CR LF LTRS (carriage return, line feed, letters shift) has been read. If the return signals are correct, the stunt box is cleared to check the next line. This comprehends a "flip-flop" arrangement in the stunt box for each channel in the code, which changes its state for each marking pulse in its channel. At the end of the line the state of the five "flip-flop's" determines the check character.

This possible check method uses 13 of the available 42 positions for function mechanisms within the stunt box. Ten are used for the check itself, one for marking and one for spacing for each of the five channels, and three for the CR LF LTRS sequence.

This method can be operated from either tape in the transmitter, or the keyboard, or both. Incoming material is checked by inserting a received tape in the transmitter and running it on a local circuit basis. If the odd-even count in the received tape for each line does not agree with the check character for the line in the tape, the equipment stops.

While some modifications may well be required in this method, it is probable that the stunt box mechanism in at least some applications will provide more accurate 5-channel code transmission systems and would be attractive to users.

These certainly are not the only means of providing more error-free received data, but were chosen to illustrate the point that data can be transmitted and received with a high degree of accuracy. Of course, the 5-channel code will convey more information than a 6-, 7- or 8-channel code in any time period if all bits are of the same length. All practical error-detection systems at present involve redundancy of some sort, and this redundancy is paid for by a reduction in speed or capacity.

Mr. Vincent's biography appeared in the October 1956 issue of TECHNICAL REVIEW

BERNARD L. KLINE, Assistant to Physical and Chemical Engineer

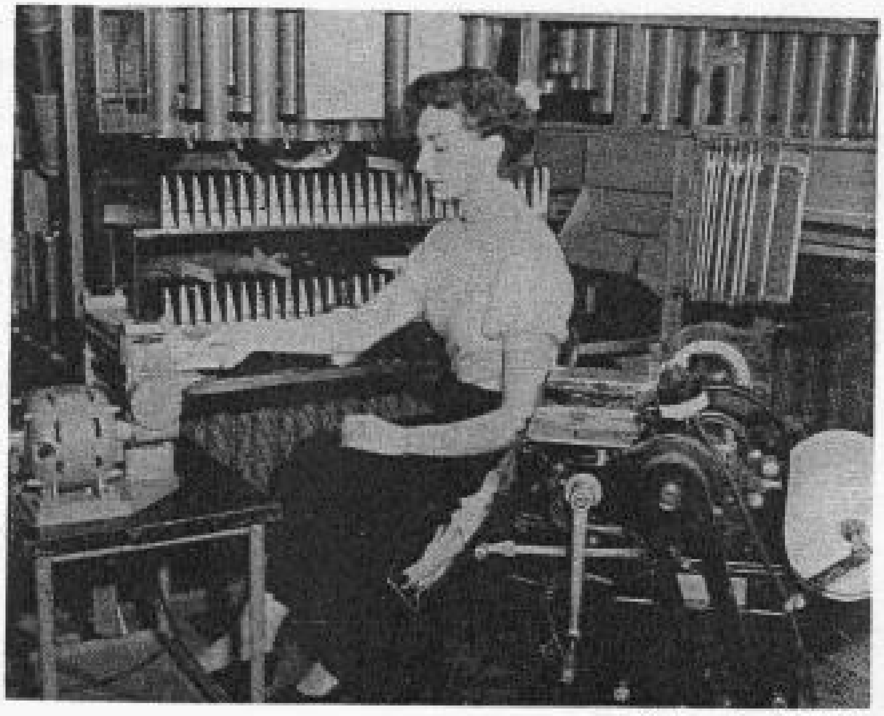
BERNARD E. LING, Operating Practice Engineer

A New Copying Typewriter Ribbon, Nonsmudging

In the early days of Telefax around 1935, either heavy or tall, dark and handsome characters could be transmitted satisfactorily; not so for light characters. And light characters usually could be traced to typewriters with "purple copy" ribbons. Through Chemical research in Western Union laboratories and cooperative testing in telegraph offices, a new and better water-copy typewriter ribbon has been developed.

WESTERN UNION's need for a quick, easy and inexpensive method of making copies of certain types of messages is responsible for the fact that telegrams have been processed with a purple copying ink for longer than most of us can remember.

The ink in printer ribbons has consisted of an oily vehicle in which a purple dye, methyl violet or crystal violet, has been finely ground and dispersed as a pigment coloring. The difference between this and ordinary pigment colors is that while conventional pigments are insoluble in water, these dyes, although substantially insoluble in the ink vehicle, are immediately soluble in water. This has enabled the Company to employ a thin translucent tissue moistened with water to make a copy of the message, when required, by merely pressing the wet tissue against the message. The undissolved water-soluble dye in the printed characters dissolves in the moisture in the tissue and, on drying, leaves a colored copy of the message which is readily legible through the tissue by reason of the fact that the tissue is translucent and also that the dye solution penetrates somewhat through it.



Photograph H-2086-B

Wet tissue copies of collect telegrams are made singly or in batches with press at left. Copies are made continuously with machine at right. Original telegrams then are sent through adjacent pneumatic tubes to branch office for delivery

Disadvantages of Past Practice

This method certainly meets the basic requirements of speed, simplicity and economy; but there are two very important objections. First, these dyes being undiscriminating will respond promptly without distinction to moisture in any form. This includes not only the wet copy tissue paper but also moisture from the gumming operation, moist hands, rain, and so forth, and the obvious result is smudged messages, purple stained fingers, and purple discoloration generally of anything that touches the ribbon or messages. This had been the cause of dissatisfaction not only with operating employees but with patrons. Much work was done on means to overcome this difficulty in the past but with little or no success.

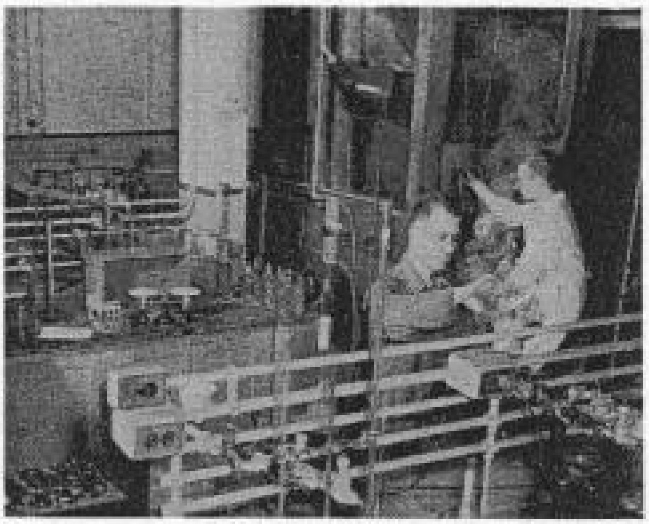
The second objection is of more recent date. With the advent of Telefax it was immediately apparent that the optical scanning devices had great difficulty in "seeing" the purple characters and when they did "see" them they also recognized smears on the message and transmitted these as well. This meant that the messages had to be prepared with special care to avoid smears, and also that the life of a ribbon for facsimile purposes was shortened considerably because only relatively heavy dark characters would transmit satisfactorily.

In order to improve this situation efforts were directed toward making an ink that would absorb wavelengths of light to which the photocell was most responsive and therefore not reflect them. However, dyes having this characteristic and also the ready solubility, and therefore copying qualities, were unsatisfactory because of low color strength, high cost, poor chemical and mechanical characteristics for ink making, or other reasons.

Chemistry Points to a Novel Method

A completely new and fresh approach seemed necessary, aimed simultaneously at eliminating the smudging characteristic and improving the phototransmission qualities, and work was begun on the project of making an ink in which the record and phototransmission qualities were divorced from the copying quality. There was no problem regarding the combination of record and phototransmission properties, for there are a number of intense oil-soluble and water-insoluble dyes of shades that are readily discerned by photocells and are also free from smudging tendencies.

The copying properties were quite another matter and required adaptation of a phase of analytical chemistry devoted to the detection of trace quantities of certain metals in solution by means of organic reagents. This type of reaction combines a minute quantity of a metal salt with a large quantity of practically colorless organic reagent to form an intense, characteristically-colored reaction product.



Photograph H-157

Part of Western Union chemistry research section where improved inking for teleprinter ribbons was perfected

If then a water-soluble metal salt is dispersed in the ink, all of the printed characters will contain trace quantities, and if a substantially colorless organic reagent is dissolved in the water used to moisten the tissues, a colored copy will result when the metal salt dissolves in the solution in the tissues if they are pressed together in the usual fashion.

The obvious advantage is that the metal salt in the ink can't smear even when wet because no colored reaction product is formed in the absence of the organic reagent, and the tissues will not acquire an impression until they receive their trace of specific metal salt.

There are many combinations of metal salts and specific organic reagents that will function in this manner and a wide range of colors can be produced. After selection of those that produced good legible contrasting color, the various metal salts required careful investigation to be sure that they would be compatible chemically with the preferred black dye, have no effect on the ribbon fabric, have no tendency to absorb moisture from the air, be free of toxic or dermal effects, and of course be inexpensive. Naturally most of these characteristics were also required of the organic reagent and after considerable study it was decided to employ iron sulfate as the metal salt in the ribbon ink, and tannic acid as the organic reagent in the wet press solution. This combination makes a blue-black copy which appears to be quite satisfactory in all respects.

It should be observed that tannic acid required some additives because of its tendency in natural state toward discoloring and darkening on exposure to air both in water solution and after drying in the tissue. It was therefore necessary to correct this behavior by addition of a special chemical which effectively inhibited this tendency. Tissues will now resist darkening for long periods of time because each little bag furnished with the ribbons contains the special chemical premixed with the tannic acid powder.

After concluding that this combination could produce a ribbon that would meet the requirements of the telegraph company's operations—phototransmission, tissue copies, and nonsmudging qualities—the ribbon manufacturers were requested to submit samples for use in field trials.

Field Trials Uncover Early Defects

The first of these trials was conducted in Cincinnati in April 1955, and while a solution to the long-existing problem seemed within attainment, further refinements in the inking and tannic acid developer appeared necessary before they could be considered entirely satisfactory.

Early in June 1955, a test was conducted in Atlanta, incorporating the refinements developed in the Cincinnati trial. The reaction of the employees to the new ribbons was one of complete approval. Conscientious employees who had long taken pride in their work found immediately that a major obstacle to gumming a neat appearing copy with ordinary care had been removed when the nonsmudge ribbon was substituted for the purple copy ribbon. In another part of the office, Telefax clerks whose hands necessarily come in contact with the printed copy in the process of wrapping a message around the transmitter drum were pleasantly surprised to find that any discoloration from the new ribbon was not only slight but could be removed readily by normal washing of the hands. In the bookkeeping and accounting centers, where

Photograph R-10,816

Extensive service trials were made by operating staffs at Atlanta (local receiving position pictured) and elsewhere

considerable handling of messages is a normal function in the processing work, the greater degree of cleanliness in the message blanks was welcomed; even more helpful was the much improved legibility of the tissue copies of collect messages.

Further trials were made in representative offices around the system, one reperforator office in each division being selected for the tests. Results at these offices were uniformly satisfactory except for a tendency toward type clogging noted when a new ribbon was placed on a printer. This characteristic necessitated more frequent cleaning of the type than previously, but since there are relatively few receiving printers in use in the reperforator office locals section the extra work involved at the test cities was negligible.

In view of the favorable results obtained at the selected offices, it was decided to extend the trial to all other offices where there was an appreciable volume of collect messages to be water-copied. Included in this category were the other reperforator centers and approximately fifteen large manual offices.

It soon became apparent that the type clogging would become a serious problem in the larger offices where the number of printers in use was substantial, unless some means of eliminating it could be

Photograph R-9669

Chemical engineering assured excellent phototransmission for facsimile operation combined with non-smudging characteristics

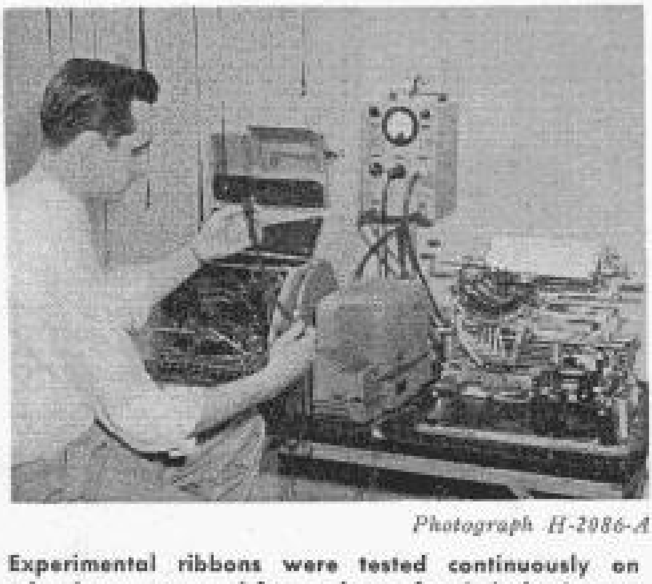
found. Scrapings of the clogging material were removed from the type and, when examined by microscope, it was found to be composed mainly of thread filaments from the ribbon fabric, and not particles of iron sulfate as might be suspected. Some lack of uniformity in the degree of inking was apparent also, owing either to the original inking or conditions developing in the ribbon winding process. At any rate it was evident that a solution must be found to the problem, if the operating advantages were not to be more than offset by the maintenance difficulties.

Formula Change Makes Big Improvement

The immediate problem was solved by an adjustment in the formula whereby the ink was made more fluid and thus more penetrating, resulting in a more thorough saturation of the ribbon fabric. At the same time tackiness was decreased and thread filaments were no longer lifted from the ribbon by the typewriter. The change caused no impairment in the operating performance of the ribbon; that is, even though the number of water copies obtainable was lessened, the coloring affecting Desk-Fax transmission was increased. There still remained a generous margin of good tissue impressions beyond the point where a ribbon would need to be replaced on a printer for Desk-Fax transmission requirements.

Further tests made using the newer formula showed that a reduction made in the degree of inking would permit usage of a new ribbon soon after its original manufacture, whereas ordinarily new ribbons are known to require a period of aging before use, as well as to continue to "settle" while in storage over several months. It was necessary therefore to reach a balance between a degree of inking that would permit fairly prompt usage of the ribbon and one that would be sufficient to insure a reasonably long shelf life in the warehouse and stockrooms during the interval between manufacture and placing in service.

Here again it developed that ribbons not sufficiently aged were affected by the incidence of prolonged periods of high humidity. Fortunately this condition was encountered during the trial stages in only two cities; and with the return to normal



Photograph H-2086-A

Experimental ribbons were tested continuously on teleprinters operated from a loop of coded plastic tape

weather, together with the passing of additional aging time, the condition was alleviated.

One problem remaining is that of determining the most nearly ideal degree of inking to be provided by the manufacturer. This feature is still under observation while the use of the ribbon continues, and when a sufficiently representative period has elapsed, final determination will be made as to the most satisfactory degree for all purposes.

Cooperation Speeds Success

Actually the difficulties encountered were fewer and easier to overcome than those generally experienced in the case of most new products, particularly those that must perform satisfactorily under various conditions of end use by large numbers of individuals and under diverse climatic conditions.

This may be due in part to the fact that in the course of transition from laboratory through experimental manufacture to full scale production comments about the behavior of this new ribbon, whether favorable or not, were solicited from field operating and maintenance forces. Their helpful cooperation proved of great value in deciding what adjustments and refinements should be made, and expedited putting the modifications into effect.

Studies and observations are continuing in the hope that field experience will point the way to even more improvements so that the benefits to both the Company and the employees who use the ribbons may be increased.

Mr. Kline's biography appeared in the April 1956 issue of Technical Review.

Bernard E. Ling joined Western Union in 1926 at Boston, Mass., working at night as a Morse Operator while a student at Boston University, and as Chief Operator at Littleton, N. H., and White River Junction, Vt., while on leave from the University. Upon graduation he was enrolled as a Traffic Department Engineering Apprentice, receiving his training in Boston and Washington, D. C. From 1935 to 1942 he was Chief Operator at Portland, Maine, and Division Traffic Inspector in the Eastern Division Headquarters at New York from 1942 to 1944. Since that time he has been in the office of Vice President—Operations where he is now Operating Practice Engineer.

CHARLES J. HOLLOMAN, Senior Engineer, Oakland Area

A High-Speed Fully Automatic Teleprinter Switching System for Brokerage Firms

Speed, efficiency and reliability of communications always have been vital to successful security and commodity brokerage organizations. A discussion of their telegraphic requirements and a description of methods and equipment devised to meet these requirements are of interest not only in respect to the specific situation described but perhaps more importantly because similar telegraph practices and apparatus can be adapted to meet the communications needs of many other businesses.

IN THIS ERA of speed and technological advancement, the boundaries of the business world have been changed from geographical dimensions to those of time. Rapid dissemination of information concerning supply and demand by modern communications has made even the most remote locality an intimate part of the business world. The brokerage business is a unique example of the critical effects on communication requirements induced by this change in dimension. As the pace and tempo of business increase, the placement of orders and the reports of execution must be speeded in order to participate in the new business dimension. The broker placing an occasional order from the desert cities of Arizona must be able to compete on the nation's stock exchange with an active broker on Wall Street; if he can't, he won't remain in business. If he is to have equal access he must have a communication system enabling him to deal with a representative on the exchange who can execute his orders and supply reports of the transactions. Telegraphic communication lends itself well to this application.

It was to satisfy the unique requirements of the brokerage business that Western Union Switching System 56-A was developed.

Communication requirements of the brokerage business differ somewhat from those of other businesses in that, during the market period, outlying branches communicate with the various exchanges rather than with one another. If a network of brokerage offices on the West Coast doing business on the New York and Chicago exchanges is considered, it is seen that orders and requests for quotes collect and funnel east; reports of execution and quotes are distributed westerly. Logically, these eastbound orders and requests could be collected at some central point, sorted and transmitted to the eastern market in order of priority so that buy and sell orders would be handled in preference to deferred traffic during busy market periods. Subsequent reports of execution and quotes from the east could be sent to the central western control point and redistributed to the outlying offices as required.

During morning hours before the market opens a series of letters are sent from writers in the east analyzing the previous day's market and giving information on the status of the various grain, produce and stock markets. During market hours, additional flash broadcasts are sent on the progress of the various markets. These broadcasts are of common interest to all branches and are usually reproduced for distribution to the patrons of the local brokerage offices. After the close of the market, summaries are sent out on the day's business.

As each order to buy or sell stock is executed, a confirmation in the form of a bill or credit is prepared. This confirmation is often forwarded at the end of the market day over the communication system so that the brokerage office patron will know the status of his account the next morning. These confirmations are prepared on a uniform billing form and it is quite advantageous to have the confirmation received in a finished form ready for addressing and mailing.

The private wire system shown in Figure 1 for E.F. Hutton & Company, as an example, serves a large brokerage firm with a concentrated group of offices on the West Coast and a main office and relay center in Los Angeles, doing business on Chicago and New York exchanges. Local branch offices do the majority of their business on the New York and Chicago exchanges but also trade on the Los Angeles and San Francisco stock exchanges.

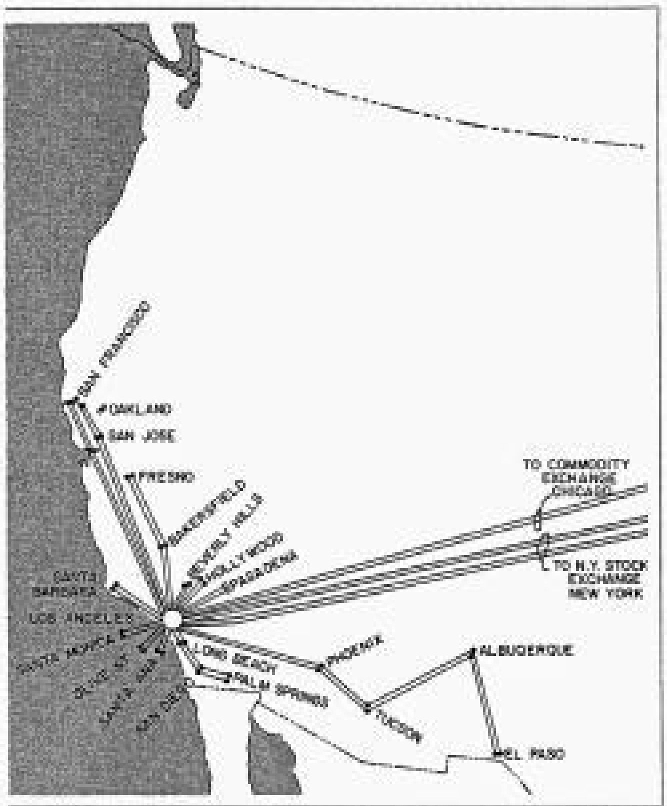


Figure 1. Private wire system map—E. F. Hutton & Company

Each of the outlying offices is connected to the switching center with two-way circuits so that an outlying office may send and receive simultaneously. The switching center is also divided into a two-way operation so that traffic originating in the west may be distributed eastward at the greatest possible speed and the lengthy market letters as well as brief reports may be expedited to the branches. In actuality, there are two completely independent switching centers, one for eastern transmission and one for westward distribution. This separation reduces the number of required destinations so that the directing equipment becomes quite simple and extremely fast and efficient. Separation also would prevent switching delay, if any should occur, from reflecting from one system into the other.

Eastbound Transmission

Traffic received at the switching center from branches is distributed according to address to the New York, Chicago, Los Angeles and San Francisco exchanges; to the administrative offices at Los Angeles and the other branches, or to the switching center for supervisory handling. Because of the sharp rise in activity on the eastern exchanges as the general market changes, it is important that only high priority traffic and orders be sent over transcontinental circuits during busy periods, and that all traffic of a routine nature that is introduced into the system be held. To accomplish this, the Chicago and New York channels are each assigned a routine and a priority tape repeater so that the routine traffic will be held automatically until the circuit is able to handle the extra traffic. In addition, this segregation of priority and routine traffic to New York and Chicago produces additional capacity for the branches to enable the routine traffic to be cleared rapidly from the incoming line and stored, so that subsequent priority traffic will not be delayed.

Multiple channels are provided on the busier circuits, to allow additional outlets for clearing traffic, and are so arranged that traffic will be distributed to an idle channel on either a rotating basis or on a lowest order available basis. Trunk circuits are usually on a rotating basis to distribute the loads and allow the routine traffic to clear. Local outlets are set on a lowest order available basis to concentrate the traffic on a few machines.

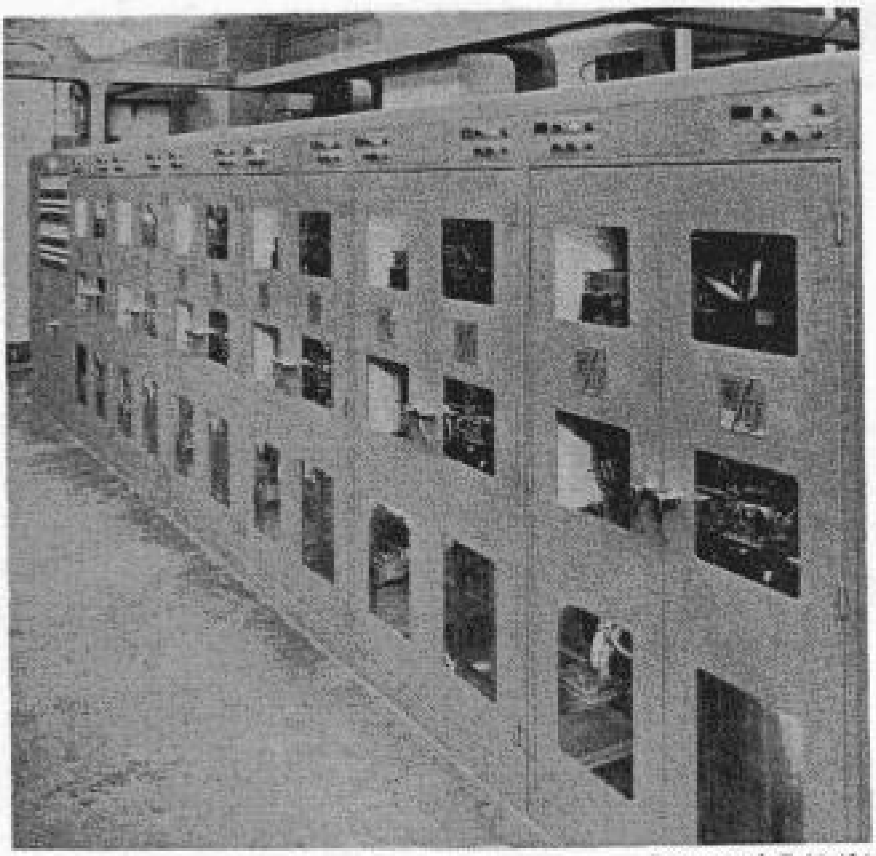
Westbound Distribution

The greatest volume of traffic for the branches originates at New York, Chicago and Los Angeles, and a small portion originates from among the branches. Local branches insert a special directing code which directs the message into a reversing position which in turn will send back to any of the branches. Los Angeles has a direct outlet to the branches as do Chicago and New York. Because the number of available destinations greatly exceeds the number of originating stations, each transcontinental trunk is arranged so that the incoming traffic will alternate between two terminating positions. This dual termination effectively doubles the distribution speed of the trunks and prevents accumulative delays on trunks that are busy continually.

The major problem in the westbound distribution is to distribute the market letters and news flashes to all offices. This is done by assigning a single destination address to the master message; the equipment associated with this destination seizes all the outgoing lines when idle or as the current message is completed, and transmits the master message to all stations simultaneously. The heavier local outlets that have multiple channels receive the master messages on a preassigned channel to facilitate reproduction of the message for distribution and still have the other channels available to receive messages while the flash or master message is in transmission.

Operating Routine

In an automatic switching system, an orderly sequence of directions must be used to direct the message through the equipment to its destination, yet must be brief enough so as not to encumber the originating operator. Each station was assigned a three-character code which serves both as the directing code and the station identification. A simple message-ending code functions to disconnect the equipment at the end of the current message and prepare it to receive the next directing code. A typical message originating from San Francisco would be as follows:



Photograph R-10,636

Figure 2. Switching aisle—E. F. Hutton & Company

PNY FRA 128	(CR LF) - - -	Directing Code and Destination Address, Office of Origin, Daily Consecutive Order Number, Carriage Return and Line Feed
BUY 100 X MKT	(CR LF) - - -	Order
0972158	(LF) - - - - -	Customer Code
FRA	(CR LF) - - -	Signature
(FIGURES) H	(LETTERS) -	Message-Ending Group

This is the 128th order from San Francisco (FRA) to the order desk in New York (PNY) ordering the purchase of 100 shares of United States Steel common stock (code X) at the market price for customer account No. 0972158 at San Francisco (FRA). The complete order including all routing instructions, shift functions, and terminating code is less than 10 words.

Switching Aisle

Equipment shown in Figure 2 forms the receiving aisle, terminating the branch office circuits. Each cabinet contains two independent receiving positions and all the directing equipment required to route the message through to its destination. Key unit of the receiving position is a typing reperforator - transmitter - distributor known as an FRXD unit. The right-hand element of the units shown in Figure 3 produces coded, partially perforated tape with the typed message superimposed on the partial perforations. The left-hand element contains a transmitter which searches the tape for its directing code and transmits the message to its destination after the connection is established. The transmitter is normally located against the punch block to allow the last character punched to be read and transmitted but pivots away from the punch block if there is a delay in transmission. The tape forms a loop and is forced down the guide channels into a temporary tape accumulator pending its transmission. In operation, the transmitter is transmitting the message through to its destination with a delay of about two words or about one inch of tape. After the tape is transmitted, it is wound on the automatic tape winder shown in Figure 3.

The opposite aisle, not shown, contains the receiving trunk terminating positions sending westward and the tape repeater positions sending eastward.

The dual terminations of the Chicago and New York trunks are identical to the position shown except for the addition of control equipment which switches the termination from one position to the other upon receipt of the message-ending group,

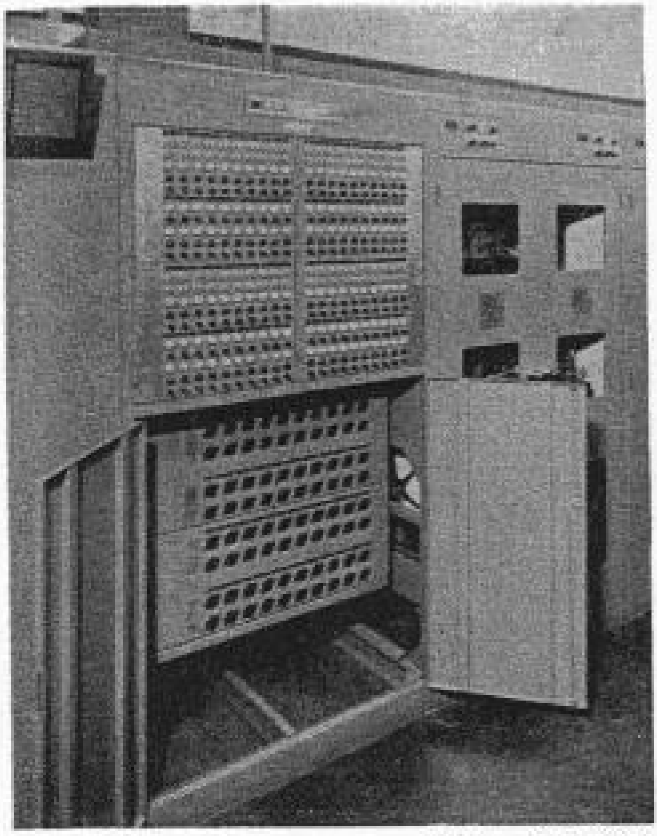
Photograph R-10,506

Figure 3. Two-position receiving termination showing acoustic treatment

"FIG H LTRS." A message counter is also provided on these cabinets to total the received messages for load survey purposes and management control.

Tape repeaters are provided on the eastbound trunks to Chicago and New York; they are identical in appearance to the receiving aisle switching cabinet but are arranged to transmit to a single destination and do not have the directors as does the receiving aisle switching cabinet. The top position of each tape repeater is assigned as the priority position and the lower as the routine position. The top position will transmit its traffic if there is any tape loop in the transmitter. If the pivoted transmitter is against the perforator punch block and a message termination has been transmitted, the routine position will then send one message. If the priority position is still clear, a second message will be transmitted by the routine position and so on until clear. The priority position must be completely clear of traffic before its routine position will attempt to send a message. This insures that priority traffic will be sent prior to routine messages yet a routine message in transmission will not be interrupted.

The cabinet at the far end of the aisle, Figure 4, is a routing indicator board that indicates each message in transmission, who originated it and where it is going. Test facilities are also provided to indicate if other stations are attempting to send to a destination that is busy. Each outgoing line may be closed out temporarily from this central position for supervising purposes. A patching panel is located behind the half-doors of the lower portion which permits the switching center supervisor to set up an alternate routing for any station as the need arises. In the event that one local branch is out of service, its traffic may be routed automatically to a nearby branch without interferring with the normal transmission to the branch. In addition, traffic to any outgoing line may be intercepted at the switching center at the discretion of the switching supervisor.



Photograph R-10,686

Figure 4. Routing indicator board

The routing indicator board also contains a supervisory lamp panel which signals the supervisor that attention is required at some position or that some irregularity exists. This panel, in conjunction with the routing indicator board, will indicate the nature and location of the irregularity.

Sending Circuit Cabinet

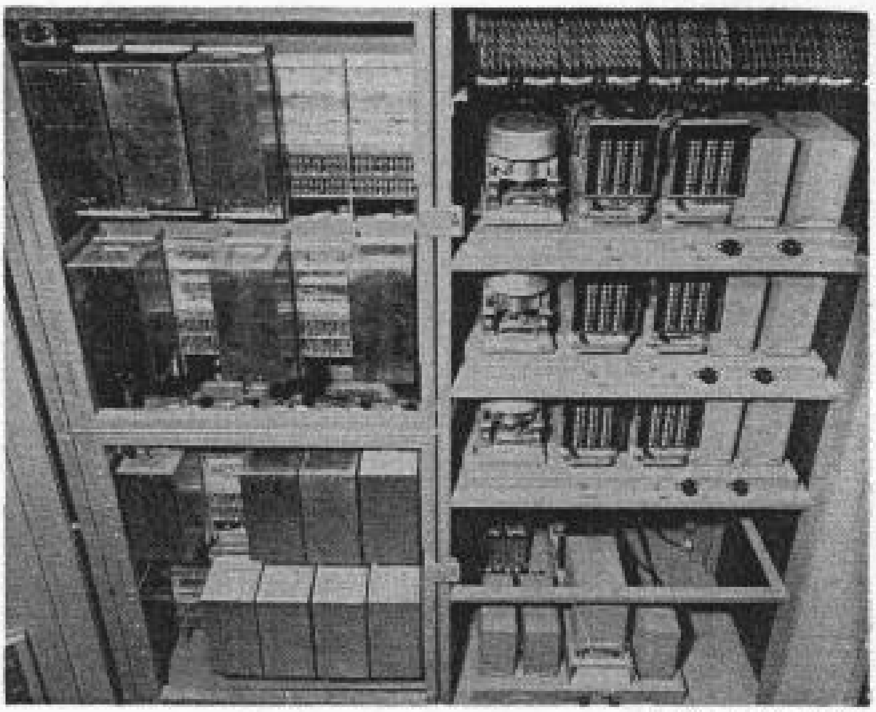
Each outgoing line from the switching center is terminated in a relay bank located in the sending circuit cabinet, Figure 5. One side of this cabinet houses the relay banks for 20 eastbound sending lines, and the other side houses 20 westbound sending line relay banks. The purpose of these relay banks is to keep the outgoing lines closed while they are idle, and to provide controls so that only one receiving aisle position can send to one destination at one time.

The master sending shelf is used to send a message to all stations simultaneously and consists of a group of repeating relays. The master address relay bank is similar to the sending line banks and is used to connect all sending lines assigned to the master patterns to the master sending shelf.

The multichannel relay shelf controls the transmission to the destinations with multiple channels. Each channel of a multichannel destination uses one of the signal relays shown. The switch on the top of the signal relay directs the traffic on a rotating basis for equal distribution or on a lowest order available basis for concentrating the traffic on the lowest order channel. Both will route the message to an idle channel if one is available. This multichannel distribution feature may be applied to any destination with more than one channel.

The machines shown in Figure 5 are automatic message numbering machines which automatically introduce a channel identification code and a sequence number for each message on any channel to which they are assigned. Each priority and routine tape repeater on the Chicago and New York channels is assigned one of these automatic numbering machines. The channel identification code and automatic sequence number are punched in the tape repeater just preceding the message, which automatically routes the message to the priority machine or the routine machine at New York. Each machine then has its own class of traffic, for convenience, and its own sequence of numbers for circuit security purposes. If reruns are required, the messages are in sequence order in separate tape repeater storage positions and may be located without difficulty.

In the event that two receiving positions attempt to send to the same destination at the same time, a transmitter-allotter (Figure 5) allows only one position to establish a connection at one time. This transmitter-allotter is arranged to give each transmitter an equal chance for establishing a connection, rather than assigning the priority arbitrarily to one position as in a sequencing type arrangement.



Photograph R-10,685

Figure 5. Sending circuit cabinet

Auxiliary Equipment

Monitor copy of all traffic to and from New York and Chicago is used for administrative purposes at Los Angeles and six receiving machines were provided for this purpose.

The Los Angeles office requires hundreds of copies of certain morning market letters and only a few dozen copies of various flashes or spot reports on the market. As each master transmission is sent to the branches a tape copy is made on an auxiliary typing reperforator. This tape is run through a local transmitter, to a local Type 28 teleprinter, to cut a stencil or hectograph master.

An additional typing reperforator is assigned a switching center code to receive notes and the confirmations from New York after the close of the market. The tape from this perforator is also run through a local transmitter and Type 28 teleprinter to produce forms suitable for mailing. Also all notes to the switching center, or traffic intercepted for an office out of service by the switching center, is received on this typing reperforator for screening and reintroduction into the system after service is restored.

Any message that has a mutilated address code, or a code which does not exist, is intercepted by the Los Angeles operating room, not the switching center. The reason for this is that an invalid code message may be an order and it is desirable to get it into the hands of the operating personnel for rehandling. The switching center personnel do not handle any live traffic, except rerouted messages and special tapes for reproduction.

Outstation Equipment

The Los Angeles operating room is like any outlying branch office and has the same type of equipment, Figure 6. The operator punches up his traffic on a typing reperforator so that he may check his tape prior to transmission, and the tape is held in the transmitter. When his message is complete, he starts sending by pushing a button and the message then goes through to the switching center at full speed, not dependent upon the punching speed of the operator.

The Type 28 teleprinter is a standard unit but has been modified to provide a uniform length of message blank. A vertical registration device, which is activated by the message termination signal, causes the message blank to be ejected and aligns the next blank or form in place. Each of the outstations uses a 3-inch perforated form. Long messages are received on several attached forms in 3-inch multiples.

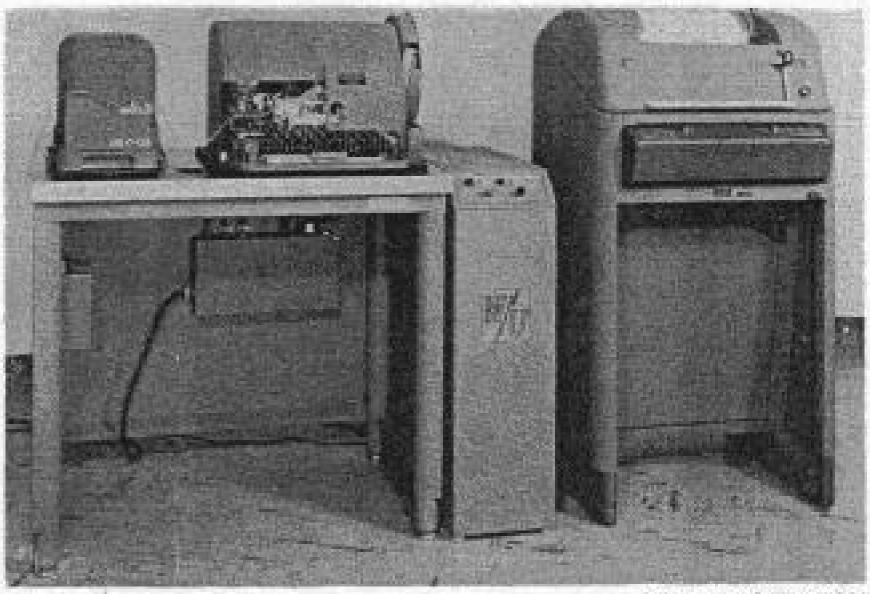
The outstation equipment in an office such as Tucson has several other unique features. The sending position is equipped with two start buttons, priority and routine. When he has punched one routine message and has confirmed its accuracy by reading the tape, the operator presses the routine push button. The associated sending control cabinet then checks its line to see if it is being used by El Paso, Albuquerque or Phoenix. When the circuit becomes idle, the control cabinet then checks to see if any other station has priority traffic. If another station has priority traffic, it will be sent before any routine traffic. If Tucson had punched a priority message and pressed the priority start push button, then its message would have gone before any routine message could be sent.

Fallback switches are provided for emergency use, in case of failure of the automatic equipment, or to receive incoming traffic on the tape reperforator in the event that the receiving Type 28 printer is out of paper or is not functioning.

In addition to the normal functions, the Type 28 teleprinter is modified so that it must receive its own directing code before it starts printing the message. Each station on a way circuit copies only the messages that are addressed to it, and the master transmissions.

In order to protect against mutilations of directing codes as they are being sent to a way circuit, one station, Phoenix in this case, is set up to intercept traffic that does not have a valid directing code for one of the other offices on its way circuit. The station assigned as an intercepting station then is held responsible for that traffic.

The San Francisco office reproduces a large number of copies of master messages and prepares its own confirmation for mailing. A typing reperforator is provided on each of the channels and is activated by the master directing code. A special directing code is provided for San Francisco's confirmations which also activates the typing reperforator.



Photograph R-10,511

Figure 6. Typical outstation equipment

Conclusions

The requirements of the brokerage business have placed severe demands on communications, especially teleprinter switching techniques. Western Union, after careful analysis, has developed Switching System 56-A, which has proven to be an effective solution in meeting these requirements.

Switching System 56-A may well be a solution to similar communication requirements of other businesses. The techniques developed through the design of this system may be applied to all teleprinter switching systems.

Its operation shows that a system developed after a careful analysis of individual communication requirements will usually prove superior to one resulting from fitting the requirements to existing packaged equipment.

Charles J. Holloman entered the Engineering Department at San Francisco shortly after graduating from the University of California engineering school in June 1948, and was promptly detailed to Minneapolis for training on Plan 21 reperforator switching; he assisted with testing and operation of Plan 21 centers at Minneapolis, Los Angeles and Oakland, and later supervised the installation and testing of Plan 51 and Plan 54 systems. Mr. Holloman has handled various other communication problems and has conducted training of maintenance personnel. He was recently detailed to the Applied Engineering section for the design and development of the fully automatic switching system 56-A. Currently assigned as a senior engineer in the Oakland Area, he assists on plans and methods and acts as engineering consultant to the Private Wire Services Department. He is a member of AIEE and IRE.

A. Z. MAMPLE, Assistant to Lines Engineer

Soldering Fluxes and Flux Principles

When studies of faults in the sensitive electrical circuits of carrier, facsimile and microwave telegraph equipment disclosed that solder fluxes may degrade such circuits seriously, basic research on flux principles and fluxes was undertaken. A previous REVIEW article[1] about this research created such widespread interest among users and makers of equipment for radio, radar, TV and the like, as well as for telegraphy, that additional information is offered to further clarify the underlying principles governing action of solder fluxes.

MUCH has been written from time to time about fluxes but when it was desired to utilize these written data, they appeared to consist of diverse and disconnected items, and Western Union could find no basic principles upon which to rely in solving a serious problem of soldering in electrical circuits. This lack of cohesion may be due to the fact that the problem of soldering involves not one but several branches of science including chemistry, physics and metallurgy.

It might be helpful to point out briefly that Western Union repeatedly found flux residues to be causing a variety of troubles which were traced to the flux. The company was supposed to be using only water-white (W.W.) rosin as a flux, but investigation disclosed that by various devices and devious ways activated, proprietary and even acid type fluxes had gained unauthorized use in the field. These facts being established, an answer was sought to the simple question, why?

The reason generally given for this unauthorized substitution was that rosin was not a good flux, was too difficult to use, and was slow in soldering. This answer appeared to be reasonably well substantiated by technical literature which, for example, places fluxes in two general classifications, "protective" and chemically active fluxes. Rosin is placed in the former class, which is further defined as exerting little or no chemical action. Other authorities refer to rosin and other noncorrosive fluxes as being in the nature of an anomaly since such fluxes do not produce much fluxing action and, they conclude, fluxing action demands some degree of reactivity between the flux and metal. Technical literature also refers to flux action as being primarily chemical; on the other hand, an authority in another art defines flux as the metallurgical name for substances which combine and entrain oxides and infusible materials separating them from metal particles, leaving the latter free to flow and adhere together as molten metal, and refers similarly to fluxes employed in the soldering process. It was these and other contradictions which led Western Union to the conclusion that rosin, and in fact other fluxes, when considered singly, would never provide an answer to the problem. It appeared that continual reference to fluxes as being a complexity of unknowns might be due rather to the failure to use a combination of known factors, particularly in the realm where the different fields of science overlap.

No authority appears to disagree with the fact that rosin flux residue is ideal for use in electrical circuits as well as in certain other fields. However, since most of them rate rosin unqualifiedly in the class of no flux, or merely as performing a "protective" function by spreading a film over the surfaces to prevent oxidation during the heating cycle in the soldering operation, the excellence of its residue is considered of academic interest. Nevertheless, numerous efforts have been made to activate rosin or to make proprietary fluxes leaving a flux residue "just like rosin."

Western Union's research on its soldering problem proved that W.W. rosin is an excellent flux when scientifically applied.

A paper presented before the American Society for Testing Materials, Atlantic City, N. J., June 1956.

Fortunately, it now appears that the principles underlying the correct application of rosin as a flux are also true, in large measure, of may other fluxes. It will soon be evident, however, that just as the fluxing action of rosin should not be considered alone, this action of other fluxes should not be considered alone.

Thermal and Mechanical Considerations

Rosin flux contains an acid but it is the only flux which at normal atmospheric temperatures retains the acid constituent in a wholly inert condition primarily because it is locked into the molecular structure of the rosin at these temperatures. The determination that rosin contained an acid was not new, but that it could release an active flux in sufficient quantities under controlled thermal conditions was more than academic; in fact, it proved to be fundamental.

Rosin melts at about 260 degrees F and at the eutectic temperature of solder (361 degrees F) it is sufficiently active for the solder to "take" even before reaching the liquidus temperature, which is 477 degrees F for 35-percent tin solder. At this liquidus temperature, rosin is very active, but at 550 degrees F seven percent of the rosin will be volatilized while at a temperature slightly higher all fluxing action will cease. Thus, the flux action is largely dependent on temperature; that is, at a minimum temperature no acid is liberated, hence no fluxing action, while at an optimum temperature considerable acid is liberated accompanied by more than adequate fluxing action. At a maximum temperature not too far above the optimum, fluxing action ceases. In fact, at the higher temperatures, the rosin with the acid constituent all volatilized will be found actually to impede soldering.

It is not difficult to recognize then that the improper application of electric irons which are designed to produce temperatures of 750 to 800 degrees F, but which are actually known to rise to nearly 950 degrees F, will readily render rosin inactive.

It must be clear, therefore, why rosin has been classed as a poor flux and why the next step was to activate it with chlorides, or some of the commonly used acids. The chlorides require higher temperatures than rosin both for melting and for the production of maximum fluxing action. Zinc chloride, for example, melts at a temperature nearly twice that of rosin. Chlorides and activated fluxes, while requiring a higher temperature of application, follow a similar thermal cycle, though at higher temperatures, and this thermal cycle affects these fluxes similarly to rosin. For example, zinc chloride at about 400 degrees F will produce a joint strength on brass of about 2500 psi, and at 575 degrees F a joint strength of about 5000 psi. At temperatures above 575 degrees F the joint strength begins to decrease. At soldering temperatures appreciably above 775 degrees F there have occurred soldered connections using this flux which had insufficient strength to hold screw heads to a cover plate involving no appreciable load. Now another flux, zinc chloride and ammonium chloride in proper proportions, will produce, as is well known, a flux which volatilizes at a lower temperature, and will produce a stronger joint at this lower temperature than the zinc chloride alone. However, at temperatures of 400 degrees F, 575 degrees F and above, the strength of the joint will be the same for both fluxes as previously given for zinc chloride.

Thus, flux action does not appear to be a separate independent action but is more metallurgical then chemical and is largely dependent on thermal considerations for both fluxing action and for mechanical characteristics of the joint.

Flux Corrosion

Flux corrosion is another phase of soldering that is very important in principle although relatively unimportant in some actual applications. Corrosion caused by fluxes is so often referred to as chemical that the one is usually associated with the other. The fact is, however, that corrosion of metal is fundamentally electrochemical.

Where several metals are in close combination, the elements of a galvanic couple are present, and in a soldered joint one always has a second metal and in some cases a third present in the combination.

In close association of different metals in any galvanic couple, all that is needed to provide all the elements for galvanic action is the humidity from the air or water otherwise supplied. This action is hastened in proportion to the rate at which the moisture is made impure to form an electrolyte. In a soldered joint an electrolyte of excellent characteristics is obtained if the flux residue is active whether the moisture is derived from the air, or the flux, or both.

In addition to galvanic potentials, in electrical joints there are high or low circuit potentials which may add to the corrosion, since the elements for stray current corrosion, or specifically electrolysis, are present. It must now be clear why rosin is noncorrosive, since at normal atmospheric temperatures no acid or other contamination is supplied by either the flux or the flux residue to change or increase the conductivity of the electrolyte present. Further, the nonhygroscopic properties of rosin and its residue neither attract nor hold water and, therefore, do not artificially add to the quantity of the electrolyte.

Western Union's tests on the corrosiveness of various types of fluxes were made so conservatively that for over 62 percent of the duration of the tests the relative humidity was only 40 to 50 percent, as shown in Table I; at no time did it exceed 92 percent. These tests may therefore be unduly conservative when it is considered that 100 percent R.H. is the usual basis for such tests. Further, the tests were made with a single metal, thus no assistance was derived from either galvanic or electrolytic action, and fresh air normally supplied during corrosion tests was not employed.

TABLE I

RELATIVE CORROSIVENESS OF VARIOUS FLUXES COMPARED TO W. W. ROSIN ON COPPER STRIPS

SAMPLE NO.	12 HRS.	18 HRS.	31 HRS.	52 HRS.	152 HRS.	
	12 hr. 40% R. H. 75° F.	6 hr. 92% R. H. 75° F.	13 hr. 92% R. H. 75° F.	21 hr. 92% R. H. 80° F.	100 hr. 50% R. H. 80° F.	
1	a	a	a	a	a	Lab sample
2-3-5	a	a	a	a	a	
4	b	b	b	a	a	
6-7	a	a	a	a	a	
8	c	d	d	d	d	
9	b	b	c	c	c	
10-11	a	a	a	a	a	
12	a	b	c	c	c	
14	a	b	b	c	d	
15	c	d	e	e	e	
17	a	b	b	b	b	
20	a	b	b	c	d	

Note 1: a=No corrosion
b=Very slight corrosion
c=Slight corrosion
d=Progressive corrosion
e=Continuing corrosion

Note 2: See Table II for classification of "Flux Sample Numbers."

TABLE II

SAMPLE NUMBERS AND GENERAL CLASSIFICATION OF FLUXES TESTED

SAMPLE NO.	CLASSIFICATION OF FLUXES BY TYPES
1	Water-white (W. W.) rosin—Laboratory sample conforming to Western Union's specifications
2-3	Rosin removed from commercial types of rosin core solders. Containing little or no plasticizer
4-5	Rosin removed from commercial types of rosin core solders but apparently containing a plasticizer (not an activator)
6-7	Rosin removed from cored solders, both containing mild activators
8	Rosin-stearine flux removed from cored solder
9	Stearine flux removed from cored solder
10-11	Proprietary activated rosin removed from cored solder
12-13-15	Paste and stick types of chloride emulsion fluxes
14	Proprietary flux claimed to be pure rosin but activated by a chemical process (foreign manufacture)
16	Proprietary flux
17	Flux claimed to be as nonconductive and noncorrosive as rosin but as active as an acid flux
18	Proprietary flux, claimed to be equal to rosin (foreign manufacture)
19	Activated rosin flux
20	Proprietary flux

Western Union has experienced difficulties from corrosion due to flux residues and is not alone in viewing corrosion trouble with considerable apprehension and also in questioning claims regarding noncorrosiveness of many of the activated and proprietary fluxes. In a situation where trouble would be least expected because of the heat dissipated in power apparatus, B. W. Erickson[2] of General Electric Company concluded, "the slightest corrosiveness of *so-called corrosion proof* soldering fluxes and the negligible amounts of chemical impurities common in insulating materials . . . is all that is needed to produce open circuits in a short period of time, often measured in days." Similarly, W. R. Lewis[3] of British Tin Research wrote "Rosin flux may be made more active (and corrosive!) by additions of oleic or lactic acid; . . ."

Self-Neutralizing Fluxes

Numerous fluxes have been developed based on a principle of self-neutralization and they have many ideal applications when properly applied and used. But the self-neutralizing action of this type of flux can take place only when all of the flux and all of the components have been subjected to the full soldering temperature. Thus, the elimination of the corrosive components of both the flux and flux residue is accomplished by evolution or chemical combination, but this neutralization is entirely dependent on the conditions of thermal application.

In this self-neutralizing type of flux, the thermal considerations of application are even more essential and critical than previously indicated, since a maximum rather than an optimum temperature is required, as well as uniformity of such temperature to all of the affected parts. Neutralization on nonmetallic parts is, of course, impossible.

Flux Conductivities

Western Union has had more serious trouble with the electrical conductivities of fluxes than with corrosion. It was found by experience that flux and flux residue conductivities are of real importance in all forms of sensitive electrical circuits such as those used in radio, microwave, carrier, television, radar, facsimile telegraph, photocell, repeaters, and in other forms of electronic circuits. The increase in these types of circuits in the past 15 years has been of tremendous proportions, while paradoxically the use of fluxes approximating the properties of rosin has decreased and during the same period the use of electrically conducting fluxes has increased almost in proportion to the use of the more sensitive circuits.

Western Union has had circuits which were in difficulties due to the flux residues, and has encountered cases where circuit and apparatus operation were adversely affected. In each case studies and tests showed the difficulties to be due entirely to the flux residues. In order to prove that the fluxes were wholly responsible, tests were made on the components of the equipment, or apparatus, which showed them to be free of trouble. These tests extended over a period of years. Tests were made of fluxes removed from cored solders by heating which rendered them the equivalent of flux residues, and fluxes were also removed directly from the commercial samples of solder with the

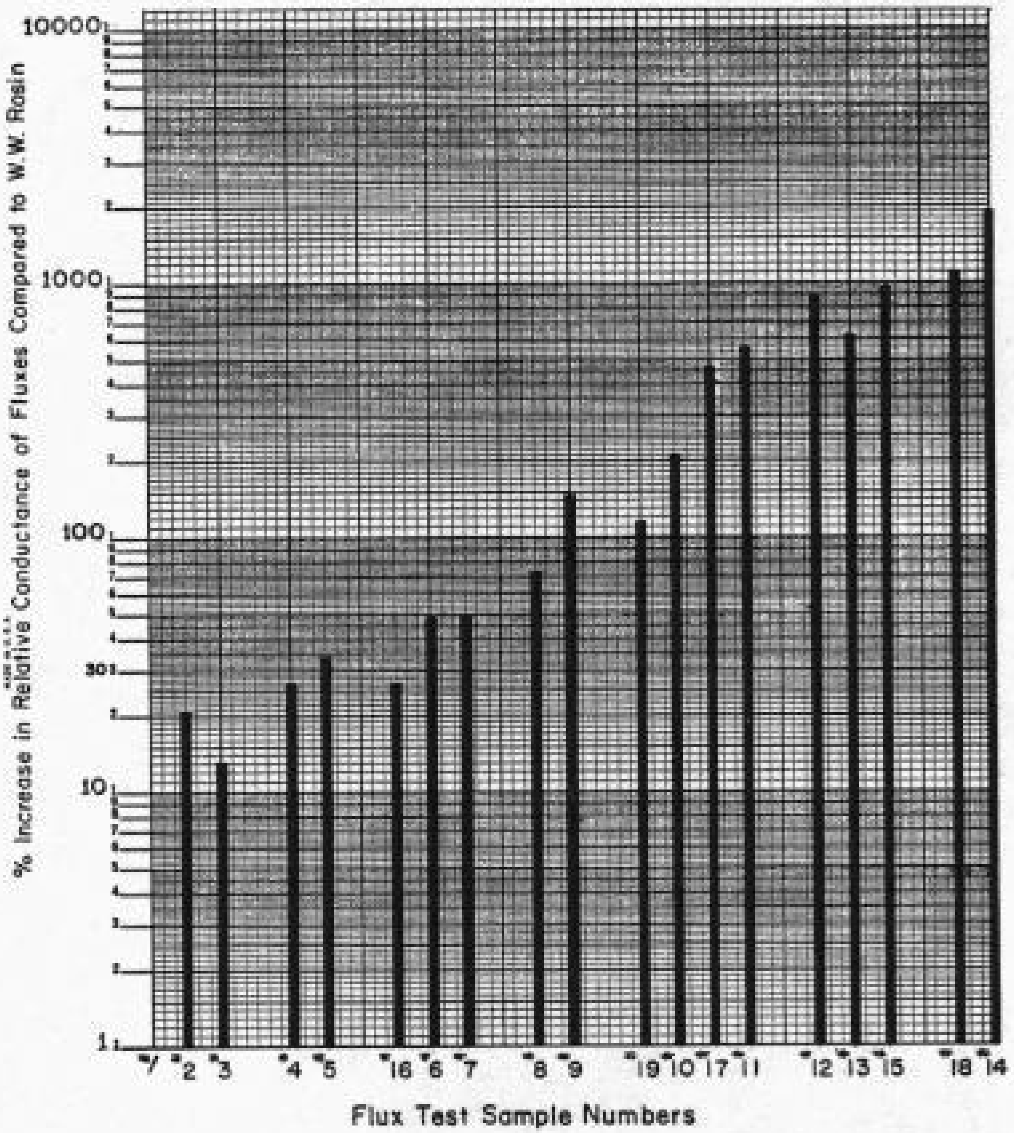


Figure 1.

Sample No. 1. Laboratory sample W.W. rosin

Samples Nos. 2 and 3. Rosin removed from solder

Samples Nos. 4 and 5. Rosin with plasticizer (from solder)

Samples Nos. 6 and 7. Rosin mild activators

Sample No. 16. Proprietary flux

Samples Nos. 8 and 9. Rosin plus stearine and stearine alone

Samples Nos. 10, 11, 17 and 19. Activated rosin

Samples Nos. 12, 13 and 15. Chloride emulsion pastes

Samples Nos. 14 and 18. Proprietary flux claimed to be pure rosin but activated exception of the standard used in the tests, namely, W.W. rosin. The test values in some cases were found to be very high, and in other cases comparatively low where the activated, proprietary or acid type fluxes were involved, but not too much relative variation was shown in the W.W. rosin values.

As has been previously indicated, flux behavior varies with different factors and combinations of factors so it was suspected that the same variation might exist in the conductance characteristics of the fluxes. Tests were accordingly made for the purpose of determining if changing one or more factors would produce any appreciable variation in results. If it did it would account, in part at least, for wide differences in available data. Accordingly, tests were made of fluxes and W.W. rosin in which all conditions were maintained the same except for the test potential. In this test, the resistance changed over ten times compared to the W.W. rosin. In another test, with an increase in relative humidity from 50 to 90 percent, but again with all other conditions remaining the same, the W.W. rosin showed several thousand times the resistance of the other fluxes at the higher humidity. In still another test, with the combined changes in the test potential, humidity and temperature, the resistance of the W.W. rosin was more than one million times greater than that of the other fluxes in the test.

It must be obvious that to use the maximum values and employ the particular conditions desired would prove one thing while the use of the minimum values with another set of conditions would enable one to prove a more serious condition. Neither condition, however, would be average. It was concluded, therefore, that absolute values would be of no use to any one since they would be true only if all of the test conditions were identical with all of the conditions of the problem at hand. Accordingly, it was decided to make a number of tests in which all the conditions would be the same for all of the fluxes and average these values.

Figure 1 presents these average values for three tests. In order to provide a further standard of comparison, it is indicated that the residue of the flux designated as Sample No. 7 actually caused the non-functioning of delicate special high-frequency test apparatus in the company's laboratory. This flux was supplied to Western Union by a manufacturer as W.W. rosin and proved by tests of both the flux and the flux residue to have been activated. If a comparative value of 48 will produce trouble in a unit of delicate and sensitive electronic test apparatus in which the components were carefully checked and found perfect, and if the trouble is traced by tests to the flux residue, then for electronic or sensitive types of electrical work it is not difficult to imagine the trouble which might be expected with other fluxes shown in Figure 1 under average conditions of application and use. The word "application" must include the determination of the particular part of the circuit where the flux is to be applied since different parts of a circuit vary greatly in sensitivity.

Surfaces and Fluxes

Surfaces of metals are a barrier in soldering and a flux is generally employed but, as has been shown, too much emphasis has been placed on the action of fluxes alone. Surfaces should be clean in all cases where production is a factor and, in fact, in some cases authorities consider clean surfaces as a primary requirement.

It is difficult, however, to rate the solderability of surfaces only on the basis of either metal coating or the base metal. Tin and cadmium are examples. Hot tin dipped surfaces are excellent to solder to and many fluxes will quickly act to join such surfaces while electroplated tin, unless heavily plated and thoroughly cleaned after plating, provides a surface very difficult to solder to, even with the best of fluxes. In the case of cadmium, however, the important factor is whether the surface is new or old, although a heavier plate does help to resist aging. Cadmium plate is of more benefit to the electroplater than to the solderer. New plating is usually quite easily soldered but even components furnished as new are often somewhat difficult to solder.

Thermal vs Production Factors

The use of higher temperatures appears to have coincided with the use of those fluxes requiring higher temperature. Electric soldering irons are supposed to heat up to 750 degrees F average but, as has been indicated, they will continue to heat up to temperatures approximating 950 degrees F. Other heating devices are employed which provide temperatures ranging from the soldering iron temperatures to as high as 2200 degrees F. But little consideration has been given to the effects of unnecessarily high temperatures. The flux-thermal-mechanical relationship and the serious resultant effects of high temperature on a soldered joint have been previously discussed but this is not the entire story. Metal surfaces that are perfectly good for soldering can be made resistant to soldering by unnecessarily high temperatures and improper application, but the production effects are even more serious in time losses even if the resulting joint is satisfactory. The cooling time from the maximum temperature to the solidus temperature will be greater while solders with tin contents higher than necessary will also require more time due to the latent heat of fusion. The cooling time from solidus to atmospheric temperature will be about the same. The higher the soldering temperature beyond that necessary, therefore, the greater is the time loss and the greater the danger of injuring the flux, the surfaces and the solder metal.

One large organization, manufacturing electrical products, still uses flame-heated irons. While the same effect can be obtained by other means of temperature control, this company apparently discerned to some degree the hazard of excess temperatures, knowing that the flame-heated iron cannot be overheated without this being readily detected on both the soldering iron point and on the iron body. The proper iron point has enabled them to conduct the heat to the soldered joint more quickly, thus saving production time in the heating cycle. The cycle is influenced not only by the temperature of the heating device but also by the ability of the heat unit to transmit heat to the work by conduction. In addition, they saved production time in the cooling cycle by avoiding too high temperatures in their work.

Optimum or lower temperatures bring out the full fluxing properties of rosin and of other fluxes as well, reduce cooling time and rate of cooling, eliminate the danger of surface oxidation, reduce the danger of injury to adjacent metal surfaces and insulating materials, and also reap the benefits of increased production.

Metallurgy and Fluxes

In addition to the previously discussed relationship of metallurgy and fluxes, the adverse effect of too high soldering temperatures on fluxes was also illustrated by test data, but the distinct influence on the metal itself was not mentioned. Metal surfaces may be made difficult to solder by excess temperatures. Further, it is known that the grain size of the tin-lead alloys is dependent on temperature and, particularly, on the rate of cooling. Consequently, the higher the temperature, the greater the rate of cooling. Under certain conditions, this rapid cooling and change in grain size will appreciably affect the strength of the solder in the joint.

From a metallurgical point of view, for a flux action to be perfect it should have no part in the finished joint since the flux action permits the molten metal and the solid metal to adhere. But for this action to take place, the cohesive attraction of the metals must be greater than the adhesive force of the flux since the flux must be displaced by the solder.

Storage batteries utilize lead straps and lead posts. In joining the straps to the posts, a flame (reducing) is employed but no flux. The lead post and filler metal form a cohesive action at the surface of the post. However, temperature of this action is just above the melting point of lead (621 degrees F). It is not much higher since the filler metal must adhere to the ring of the lead strap to which the lead must "take" on the inside but at the same time not melt the outside of the lead ring.

In cable splicing where the operation is soldering rather than welding, a flux (stearine) is employed. In this case, both the lead sleeve and the lead cable sheath are heated but not melted. The solder is heated above the liquidus point and is the source of heating in this application. The solder is applied to both the sleeve and sheath, being wiped on while in the pasty state (below the liquidus temperature).

In these two examples, welding of one metal is accomplished with no flux, whereas in the other case soldering of essentially the same metal requires a flux.

The soldering process without the use of any flux has been accomplished through the use of indium due to the characteristic of this metal to adhere tightly to metals and nonmetals. At its low melting point of 311 degrees F it adheres to metals when molten and continues to do so after solidification. Fluxes are not needed and, in fact, actually prevent the soldering effect. This work was reported by Mr. R. B. Belser[4] of the Georgia Institute of Technology.

Within the past few months, similar work has been reported by the University of California[5] in which Woods metal and an equal alloy of indium and tin were employed to develop a new method of soldering which also uses no flux. It employs the heat of friction and solders to metals as well as to ceramics. A 50-50 tin alloy is used for the actual joint. Neither flux nor surface cleaning is employed nor is pretreatment of the metal necessary.

In another method developed in England by Mullard, Inc.,[6] an ultrasonic method of soldering aluminum is now available. It also employs no flux whatsoever but uses a frequency of about 20,000 cps which destroys the oxide film by ultrasonic cavitation. Two ultrasonic methods are available, one employing a special soldering iron, and the other a bath employed in tinning wire and strip aluminum.

In another method also developed for aluminum in England, the oxide film is broken up by a 100-cps vibrating brush in conjunction with a 932-degree-F heating head. This method also uses no flux. The tool was produced by Belark Tool Company of London.[7]

These examples clearly illustrate that Western Union's research, showing that thermal, metallurgical, mechanical and other considerations are important factors in the joining of metals or in the use of metal in making joints, is well founded in principle.

Conclusion

Successful soldering is an art that requires consideration and evaluation of the solder metal, flux, temperature, quantity of heat and method of application, type and condition of surfaces involved, and the use to which the item will be put. The present practice seems to be that each interest places too much emphasis on one of these factors which is usually their particular phase of the problem, with the result that a critical field where the sciences touch or overlap appears to have been overlooked. In actual use and application, ignoring any one of the factors previously mentioned is very likely to cause difficulties either in the soldering operation, performance of the joint electrically or mechanically, or in the utility or life of the component.

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Mr. Mample's biography appeared in the Ocotber 1955 issue of Technical Review.

Patents Recently Issued to Western Union

Transferable Marking Composition for Facsimile Transmitting Blanks and Transmitting Blanks.

B. L. KLINE, D. P. RODDIN
2,751,310—JUNE 19, 1956

A facsimile transmitting blank comprising a conductive base sheet on which the message characters are impressed by means of typewriter or pencil in an insulating wax composition contained in a transfer sheet. The wax composition, which may be:

Stearic acid	19-21 parts
Carnauba wax	9-11 "
Mineral oil (SAE 10 to 30)	11-13 "
Pigment	14-16 "

is said to be effective for both heavy and light typewriter touch.

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Resonant Cavity Wavemeter

H. E. STINEHELFER
2,756,389—JULY 24, 1956

Absorption—Transmission type of wavemeter comprising a length of waveguide with closed ends and provided with an input exciting probe at one end and an absorption crystal at the other, separated approximately by one wavelength, and with an adjustable cavity containing the transmission loop and crystal iris-coupled to the waveguide at an intermediate point. In operation, a microammeter is coupled first to the absorption crystal where it roughly indicates resonance by a minimum reading, and next to the transmission crystal where a maximum reading gives a more precise indication of resonance.

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Platen

C. B. ROUNTREE
2,766,096—OCTOBER 9, 1956

A platen assembly for a high-speed page recorder of the continuous sheet type in which the paper is urged through an unsupported arcuate path where it is scanned by traversely traveling styli, the inherent resilience of the paper providing the proper contact pressure. The paper emerges through a spring-mounted slot which can be adjusted to vary the length of the unsupported path. This elimination of the rigid platen backing reduces stylus shock and bounce, paper jams and tears and simplifies threading and adjustment.

Magnetic Stylus Guide

D. M. ZABRISKIE
2,766,097—OCTOBER 9, 1956

A method of magnetically guiding belt-mounted facsimile stylus carriers. The stylus belt glides along a pair of ferromagnetic guide rails, fixed beneath the belt, and having one or more permanent magnets secured therebetween so that the rails act as pole pieces to exert an attractive influence on the carriers. By supporting the carriers from beneath, the area above is unobstructed and so facilitates stylus adjustment and changes. Examples of magnetic carrier structures in combination with metallic or nonmetallic belts are shown.

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Two-Way Facsimile Telegraph Systems

G. H. RIDINGS, R. J. WISE
2,767,242—OCTOBER 16, 1956

A two-way facsimile system employing a separate recorder and transmitter at the main office concentrator and a transceiver at the outstation operating over a two-wire line. The transceiver is conditioned to operate as a transmitter or a recorder by operating a send or receive button and automatically shuts down at the end of the message. Features include acknowledgment signals to inform the sender that the message was received satisfactorily, interlocking send and receive buttons at the transceiver permitting only one to be operated at a time and operating an alarm if the wrong button is pushed, a safety circuit which stops the central office transmitter and sets up an alarm if the transceiver drum should stop rotating, and a stop button at the transceiver by which the patron can shut down the machine after a message shorter than normal.

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Magnetic Tape Storage of Intelligence

R. STEENECK
2,767,243—OCTOBER 16, 1956

A compact assembly comprising, for each unit of the code used, a C-shaped magnet with a minute air gap for recording or transcribing telegraph signals in the form of magnetic spots recorded laterally across a periodically stepped magnetic tape. The recording air gaps are positioned in line across the tape path while the corresponding magnet cores with surrounding coils extend alternately in opposite directions perpendicular to this line. A feature is a transcribing circuit employing one-shot multivibrators.