WESTERN UNION Technical Review

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The Civil Aeronautics Administration's Service "C" Leased Wire Weather Network

F. A. WALKER

THE SCIENCE of weather forecasting has advanced to a point where it is no longer a trick for experienced Weather Bureau meteorologists to forecast the weather, provided they have up-to-the-minute data and information on surface and upper-air conditions at hundreds of points throughout the country. This essential information is provided by a nation-wide teleprinter network, furnished by Western Union, over which meteorological data are collected and distributed on an intricate schedule by some 700 stations. Known as Service "C" (Figure 1) and operated by the Civil Aeronautics Administration in cooperation with the United States Weather Bureau, it is the primary source of information for the preparation of weather maps such as those which appear in many daily newspapers or on bulletin boards at post offices and elsewhere.

Transmission facilities for Weather Bureau forecast reports or "signals" have been provided by the Telegraph Company over many years. Back in 1918, for example, at the close of World War I, two reports daily in code were being transmitted across the country by Morse telegraphy over special "weather" circuits which were set up for about an hour at 8 o'clock E.S.T. each morning and evening. When released, these circuit facilities were used for other telegraph services.

By 1927, however, to quote the chief of the Weather Bureau, "the limited supply of hand operators, and the fact that the circuit wires, when set up for the Weather Bureau, provide only a single channel of communication and cannot be utilized for automatic apparatus, has made maintenance of the circuit system increasingly difficult under modern conditions." So a new system for distribution of the coded "signals" was inaugurated April 1, 1928 and messages such as "NA 40 SGL ATLANTA GA = ALBANY FEMINAL MUMMAVILLE GEMMY=" began moving over multiplex printer channels.

Forecasts Aid Flyers

Expansion of aeronautics and increased needs for aviation weather reports brought the Civil Aeronautics Administration into the picture to cooperate with the Weather Bureau. For over eleven years now, Western Union has provided the CAA with the leased wire "C" network over which it transmits almost continuously (24 hours a day, 7 days a week) weather messages used by meteorologists primarily in the preparation of "6-hourly" weather maps. These maps are used principally at airports for the guidance of civil and military aircraft flights over the more than 74,000 miles of federal airways that crisscross the nation. They are also the basis for all weather forecasts disseminated to the public generally, in the press and over radio broadcast and television stations.

In addition to serving CAA and Weather Bureau stations at airports, the network is extended on a receiving-only basis to military branches of the government at Army camps, Air Force bases, and Coast Guard, Naval and Marine Corps air stations. Several government agencies other than "the military", and most Weather Bureau city offices are also served by the "C" network. Numerous private users licensed by the Weather Bureau to have receiving-only connections on the network include air lines, universities, aeronautical schools, auto clubs, weather service firms, public service companies and others whose operations or projects depend to some extent upon the weather.

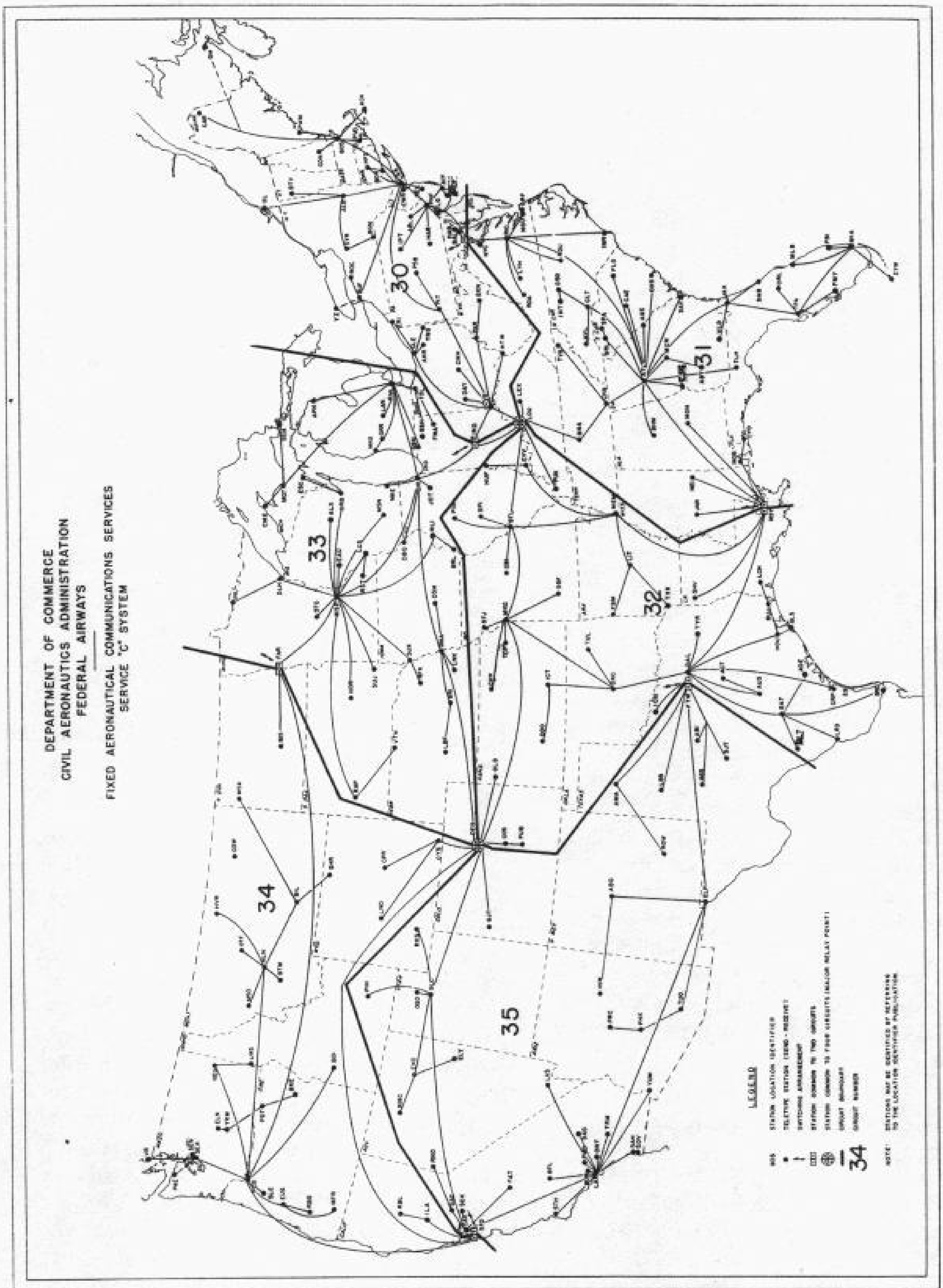


Figure 1. The Civil Aeronautics Administration's "C" network, furnished by Western Union, covers the country

Six Circuits in Network

The "C" network is composed of six circuits, each covering a geographical area, or region, of the United States as follows: Northeast (Circuit No. 30), Southeast (Circuit No. 31), South Central (Circuit No. 32), North Central (Circuit No. 33), Northwest (Circuit No. 34), and Southwest (Circuit No. 35). The six regional circuits are 65-word-per-minute single teleprinter leases and operate electrically independently of each other. The combined circuit mileage totals almost 32,000 miles.

There are approximately 115 stations, or connections, on each of the six circuits, equipped with either a receiving-only or sending-receiving page teleprinter. Most of the receiving-only printers are Western Union owned and maintained. The sending-receiving printers, about 40 of which are on each circuit, are government owned and maintained and are located at CAA Interstate Airway Communications (INSAC) stations or at Weather Bureau operated stations, generally at airports.

The reports are transmitted from the sending-receiving stations at scheduled times, each message being received by all stations and connections on the circuit, with a home copy at the station from which the message originates. Each such station sends a new report every six hours so that the cycle is repeated four times in each 24-hour period. The volume of reports provides a closely packed schedule—all stations and connections are receiving practically continuously.

Control Stations Interchange Data

There are two main CAA tape relay control stations, one at Louisville, Ky., (see Figure 2), for Circuits 30, 31 and 33, and one at Denver, Col., for Circuits 32, 34 and 35. Each of these two stations receives all matter transmitted over its respective regional circuits. Normally Louisville uses Circuit 32 to pass reports east-to-west to Denver, and Denver uses Circuit 33 to pass reports west-to-east to Louisville. Messages received at these relay stations are recorded on perforated tape. Relays to adjoining circuits, of messages received from selected stations, start five seconds after completion of transmission from all sending-receiving stations in each region and continue, one circuit at a time, without interruption until completed. In this manner national distribution is accomplished—each station and connection receiving, in addition to reports from its own regional circuit, all reports in which it is interested from selected stations on the other regional circuits.

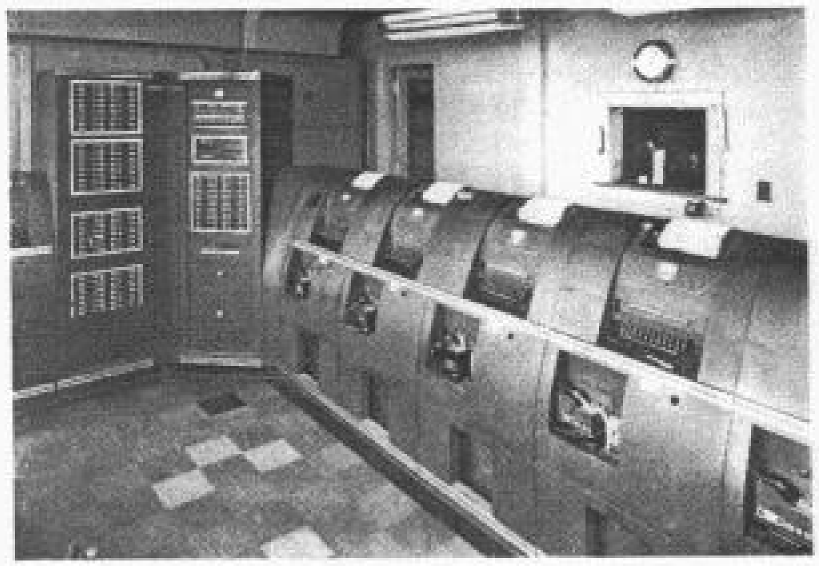


Figure 2. Civil Aeronautics Administration's Service "C" network relay control equipment at Louisville station

Coded Reports

Most of the intelligence transmitted over the network is in international weather code which consists of groups of five figures. This type of code is used not so much for secrecy as for brevity and speed in collection since the information must be used quickly to prepare the maps. The use of code permits the messages to be condensed to a few (generally not more than eight) 5-figure groups, each figure of which has a meaning depending upon its position in the message. Persons trained in its use can read the code as easily as plain language. The plotted data for New York on Figure 3 (arrow) would be transmitted in code as follows:

50316 70215 80082 41030 50831 69122

In plain words this report may be described as follows: Station code number for New York is 503, dewpoint 16 degrees, 9 tenths of sky covered by clouds, wind direction NNE, velocity 15 knots, visibility 10 miles, weather partly cloudy with no

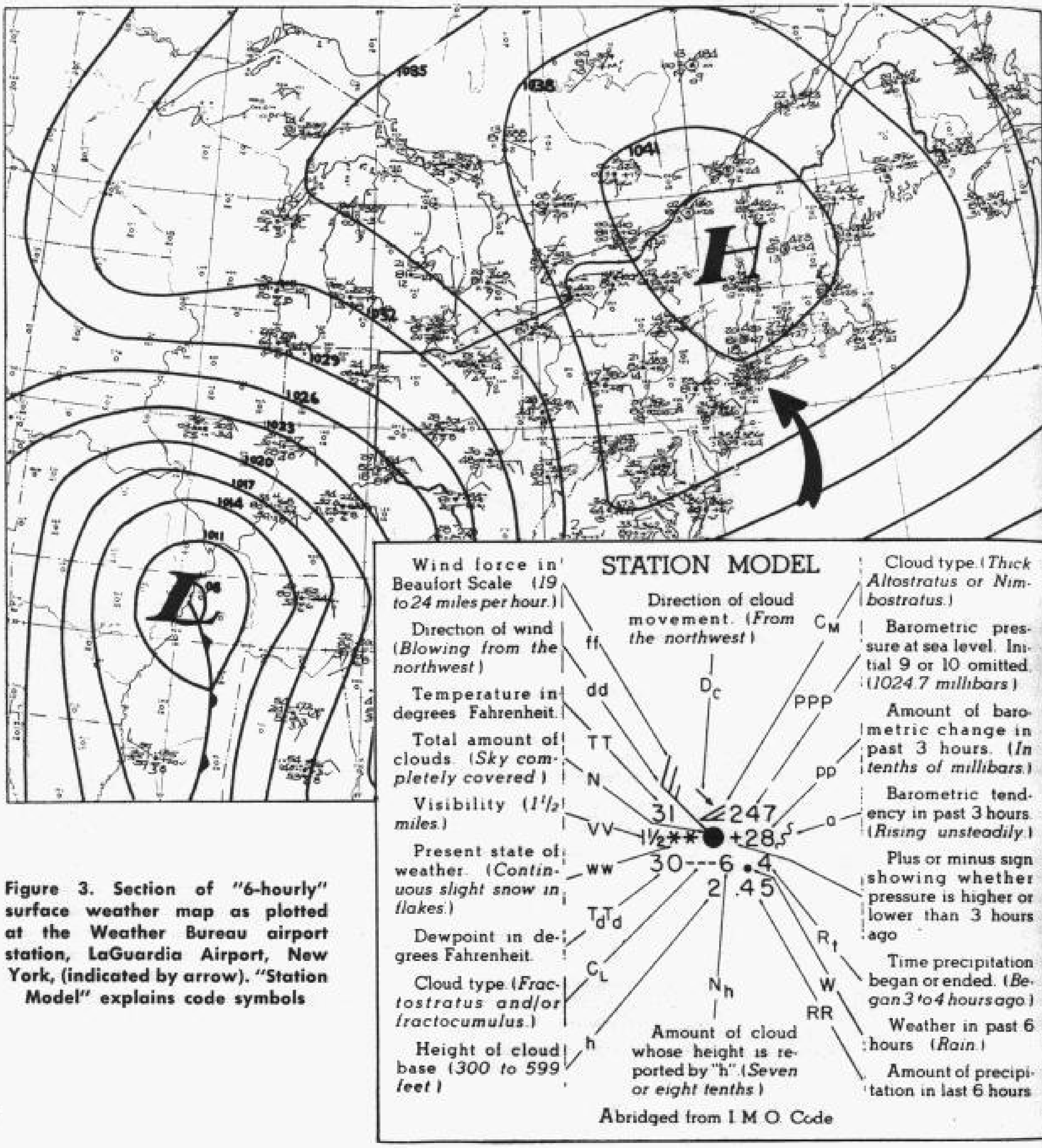


Figure 3. Section of "6-hourly" surface weather map as plotted at the Weather Bureau airport station, LaGuardia Airport, New York, (indicated by arrow). "Station Model" explains code symbols

change during past hour, sky cloudy during past 6 hours, barometric pressure 1041.0 millibars, air temperature 30 degrees F., amount of lowest layer of clouds observable 6 tenths, no low clouds, height of lowest layer of clouds observable 7000 feet, cloud types observable are altocumulus and cirrus, direction of movement of higher clouds unknown, pressure during last three hours rose then became steady, net change in pressure during that period was 2.2 millibars.

The basic weather communications traffic consists of synoptic surface weather observations, or reports, and pilot balloon and radiosonde reports, all of which are transmitted in code.

Synoptic reports, called "6-hourlies", which give a comprehensive view of the surface weather at the time observations are made, are the most important type of report transmitted on the network. They are sent every six hours in sequence order by sending-receiving stations on all circuits, promptly at the times scheduled, and continue with each station sending in rotation until completed, after which relays to the other circuits are made, as described, for distribution nationally.

Ship Reports Included

Collection and distribution of synoptic reports from stations and observation points outside the United States are accomplished by the transmission of "group" reports from designated stations immediately following relays of domestic reports. Such designated stations are at Seattle, Wash., Buffalo, N. Y., and Washington, D. C., which have interexchange arrangements on the Canadian Meteorological Service's network; at El Paso, Texas, which receives reports from Mexico; at Miami, Fla., where reports are received from points in Cuba and the Bahamas, and at Key West, Fla., for the Gulf of Mexico. Additional synoptic reports are put on the network at San Francisco, Cal., and Washington, D. C., based on data received from ships in the Pacific and the Atlantic, respectively.

The "6-hourlies" contain meteorological data observed at each station; i.e., amount and type of clouds, wind direction and speed, visibility, weather, atmospheric pressure, precipitation and special phenomena. In addition to those originating at locations having sending-receiving service, certain reports received by radio telephone or telegraph are included in these sequences.

Weather Bureau meteorologists interpret the "6-hourly" reports as they are received at stations throughout the country and plot the information on a large map of the United States on which are shown the locations of sending-receiving stations. (See Figure 3). The data are noted on the map in a prescribed pattern around the reporting station, in figures, code and symbols, so that prevailing conditions at any such station can be readily observed. Upon completion, the "new" map is posted, together with three other maps which, progressively, have become obsolete. Four "Daily Weather Maps" covering current weather conditions for the prior 24-hour period are therefore always on display. These maps are identical at all Weather Bureau offices throughout the country. While the maps are redrawn every six hours, they are considered "good" for flight planning purposes, by CAA and W.B. standards, for nine hours.

Typical meteorological instruments used to record weather data. Relative humidity and air temperature are charted by Hygro-thermograph at left. Wind direction and its velocity are recorded by meter shown in center. Pressure changes are plotted by Microbarograph at right. Illustrations by courtesy of The Instruments Corporation

Balloons Give Weather Aloft

Pilot balloon and radiosonde reports are also transmitted every six hours, at their scheduled times, and in the same manner as "6-hourlies". Pilot balloon reports, called "pibals", contain data on observations of wind direction and speed aloft and are obtained through the use of electronic and/or optical instruments which continuously track the path of freely ascending balloons which are released to rise until they disappear from view or burst. Radiosonde reports contain data on weather elements above ground level and, in the case of certain stations, wind direction and velocity. Coded observations for these reports are sent out by miniature radio transmitters attached to the free-air balloons from which signals are received giving temperature, pressure and relative humidity data even after the balloons have disappeared from view.

As in the case of "6-hourlies", pilot balloon and radiosonde reports are collected from points outside the country, but on a more limited scale, and are distributed throughout the system in the form of group reports. Group reports of this type, and those based on data received via U. S. Air Force circuits in connection with observations made at Air Force bases, are transmitted from the Louisville and Denver relay stations.

Numerous other reports are transmitted from Washington, some in plain language and some in code, such as state forecasts, surface map analysis reports and prognostic weather map analyses for over-all areas and for varying periods of time. Surface analysis reports also originate at San Francisco, for Pacific weather. Other types of reports, transmitted from designated Weather Bureau offices in code or plain language depending upon the type of report, include, in season, winter sports forecasts, crop, river, corn and wheat, fruit service, fire weather, and horticultural

Instrument racks in Weather Bureau office, Washington, D. C.

reports. The schedule also provides for special reports and storm or hurricane warnings in the event of impending severe disturbances, for either local or national distribution.

Aviation forecasts are of three types: (a) regional, covering an area of selected states; (b) terminal, for selected airports; and (c) Canadian airways, from Canadian points. The regional and terminal forecasts are prepared and transmitted by designated Weather Bureau forecast centers and the Canadian airways forecasts are received from Canadian circuits and transmitted from Seattle and Buffalo.

Courtey Washington Institute of Technology

Front end of radiosonde showing pressure-actuated switch which telemeters barometric readings as radiosonde ascends

Printer Keyboards Have Special Symbols

Special "weather-keyboard" teleprinters, equipped with special symbols on certain of the upper case type pallets, are used on the network, principally for the transmission of forecast and meteorological messages. Receiving-only printers have receiving units mounted on a standard base, but without the keyboard proper or transmission assembly. Sending-receiving printers are complete units. Figure 4 shows the characters used on the special "weather-keyboard".

Wind direction is indicated in symbol form by arrows, as ↑ (south), ↗ (southwest), → (west), and so forth, and used in combinations as ↑↗ (south-southwest) and →↗ (west-southwest). Wind velocity is indicated by figures showing the velocity in miles per hour immediately following the wind direction arrows with a plus sign (+) added to indicate gustiness. Sky conditions are indicated by symbols as follows: ○ (clear), ⦶ (scattered clouds), ⊕ (overcast), ⦷ (broken clouds), and ✕ (sky completely hidden by precipitation or obstruction to vision). These symbols are also used in combinations, with the / character to show cloud formations above 20,000 feet, and figures preceding the symbol to indicate height above the ground in hundreds of feet for lower clouds. Lower clouds are shown first, with higher clouds indicated in ascending order. The + or − preceding the cloudiness symbol indicates "dark" or "thin", respectively.

Most types of forecast messages are transmitted in abbreviated plain language and are distributed nationally. These include state forecasts, which embrace selected states and coastal areas prepared at designated stations, and weather summaries and special reports, which originate at Washington, D. C.

alert supervision of its operation. Transmissions are suspended for a ten-minute "line-up" period each day to permit tests on the circuit at Western Union repeater points and to allow time for adjustments or equipment changes where necessary. Monitor printers are provided at repeater stations so that circuit interruptions can be quickly located and corrective action taken. Speed in correcting faulty circuit performance is essential, since the flow of traffic is practically continuous and if one or more stations were to be without service for an appreciable length of time, important information might be missed. Any part of a message which is missed by a station is lost to it, since the reports are not repeated. In the case of interruptions to sending-receiving stations, other stations on the network which depend upon their reports at the regularly scheduled times might have to go without needed information.

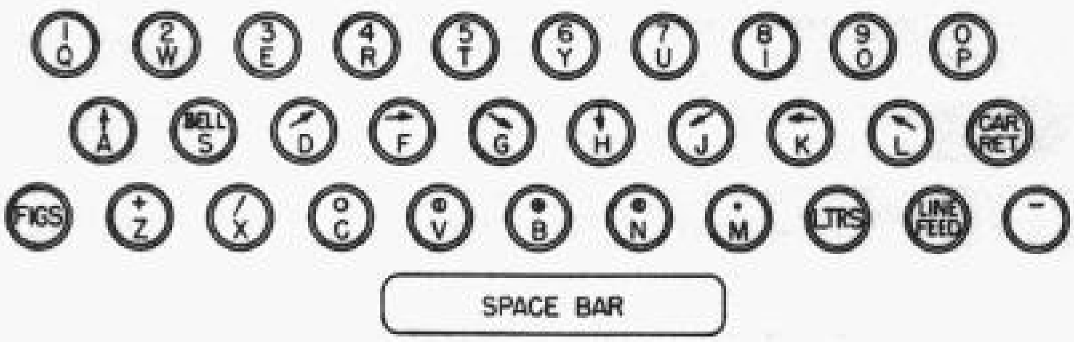


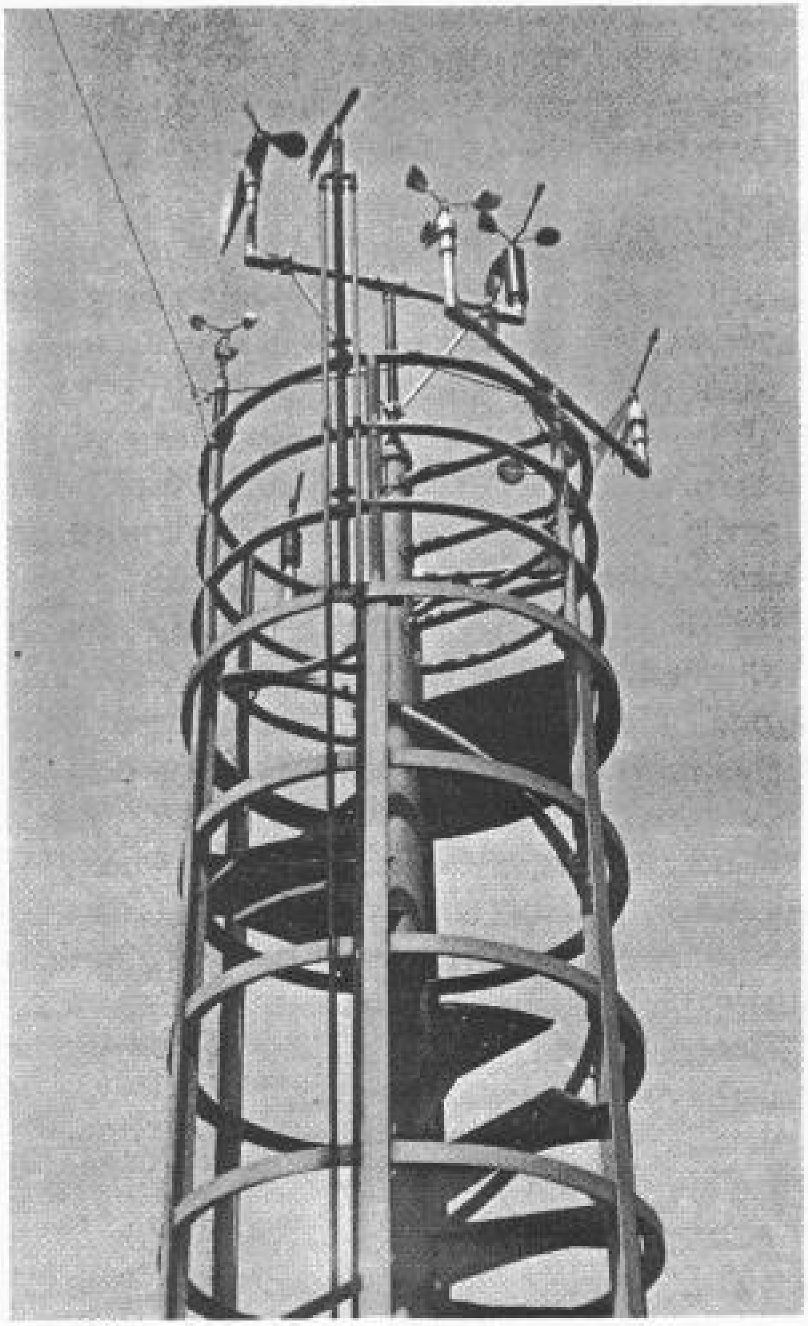
Figure 4. Special "weather teleprinter" keyboard

Reliable Circuits Are Essential

While the CAA operates the network, Western Union provides the circuits and is responsible for their proper functioning. These circuits are made up on carrier channel facilities interconnecting major hubbing cities from which the service is distributed. At these major points signals are regenerated to insure maximum operating margins, and are distributed, mainly over carrier channels, to smaller hubbing points and thence to the several service drops. Distribution points are equipped with repeaters for tying together the circuit stems which radiate from them. The high degree of circuit performance required on the "C" network necessitates periodic maintenance of equipment and

The map of the "C" network (Figure 1) shows places at which there are government equipped sending-receiving stations. At some of these locations there are also receiving-only government equipped drops, generally at military establishments. Also, at most of these places there are one or more other users with receiving-only extension service connections to the network. Among such users are Weather Bureau city offices, air lines, private firms and "the military". Not shown on the map are a number of places off the main-line where there are extension service users who are connected to the nearest on-line service point.

In addition to the "C" network, furnished by Western Union, the CAA has



Wind measuring equipment on roof of Weather Bureau office, Washington, D. C.

several other networks carrying weather, aircraft movement and traffic control information.

Mark Twain may have been sincere when he said that everybody talks about the weather and nobody does anything about it. But that was before the development of scientific weather forecasting techniques and the installation of high-speed weather communications networks. Now weather facts are speeded coast-to-coast in seconds so that people are forewarned and can take measures to avoid injuries or death and damage to crops and property.

Western Union, communications-wise, has always played an important part in the handling of weather messages. Largely due to the growth of aviation and the stepped-up needs of industry and the public, the methods of collecting and disseminating weather data have changed. The Weather Bureau has kept abreast of the times, however, and through the use of modern communication systems supplied by the CAA is able to furnish the nation with the up-to-the-minute information on the weather which is so vital to present-day living.

Forbes A. Walker has been with Western Union since 1933. Prior to his present assignment in the Private Wire Services section, Public Relations and Sales Department, he held various positions in the Metropolitan Division, in branch offices, superintendents' offices and in the General Manager's office. He was district manager for eight years and for three years was manager of the Metropolitan Division school. He attended the Wharton School of Finance and Commerce of the University of Pennsylvania. In the Private Wire Services Mr. Walker is responsible, in addition to other duties, for the Civil Aeronautics Administration, Weather Bureau, Aeronautical Radio Inc., and other accounts in connection with the Service "C" network.

Application of the Theory of Probability to Western Union Switching Systems

G. STRUNZ and R. E. HUBLEY

THE EFFICIENT allocation of circuits and associated equipment in Western Union switching systems is dependent to a large extent upon being able to predict accurately any waiting time incurred by messages passing through these systems. Such delays as are normally encountered in a properly designed system are so small that they are generally not noticed in operation, and have no appreciable effect on speed of service. Heretofore, allocations have been made largely on the basis of empirical formulae developed through past experience. These empirical formulae cannot accurately predict excess elapsed time, nor are they adequate when applied to Western Union installations where message length, transmission speed, or any other factors influencing delay differ from the conditions under which the empirical formulae were developed. The increasing importance of establishing circuit requirements accurately to provide the best possible speed of service at reasonable costs has emphasized the need for a more reliable means of predicting delay.

How Probability Works

Fortunately, the nature and operation of Western Union switching systems is such that the theory of probability can be applied to forecast time delays. The laws governing the theory of probability, and their analagous application in Western Union installations, can be illustrated by considering a grocery supermarket. The customers' shopping carts are equivalent to telegrams, and the checking aisles are the outlet channels. The length of time a customer will have to wait in line to pass through a checking aisle with her cart is dependent upon the number of checking aisles which are open at the time, the number of other customers ahead of her in line, how heavily loaded the carts of the customers ahead of her are, and how rapidly the checkers work. From experience, a shopper is soon able to predict that, if she does her marketing between 9 and 10 o'clock Saturday morning, she "probably" will have to wait in line only a few minutes. If, on the other hand, she shops between 7 and 8 o'clock on a Friday night, she "probably" will wait a half-hour or more in the checking lines. Unconsciously, such a shopper is employing probability—anticipating the number of customers who will be shopping and the number of checking aisles which will be open at these two particular times, and calculating a probable delay on the basis of comparable delays encountered under similar conditions in the past.

The conditions governing the waiting time—in seconds—which telegrams may incur in obtaining connections into outlets in Western Union switching systems are very much the same as encountered by our hypothetical shopper. The greater the number of telegrams (carts) attempting to pass through a given number of channels (checking aisles), the greater will be the delay. If the telegrams to a particular

TABLE I

PROBABILITY OF DELAY VERSUS LOAD

These data are based on telegrams having an average holding time of 0.65 minutes, following normal Western Union message length distribution, and seeking connections to a destination having a single channel.

Number of Telegrams per hour seeking connections.	Average Time Required to obtain a connection in seconds per telegram
0	0
10	2.5
20	5.8
30	10.0
40	15.7
50	24.6
60	39.2
70	66.8

outlet are especially long (i.e., the carts are heavily loaded with groceries), the delay will be greater than it would be if the telegrams were extremely short. If more channels are provided, or if equipment speeds are increased (a slow checker replaced by a more rapid checker), the delay will be reduced. By making use of the theory of probability, the mathematical relationship between the various factors influencing delay can be established. For example, the increase in waiting time as message load is increased is shown in Table I. Similarly, the relationship between channels available and messages per channel for a given waiting time is shown in Table II.

TABLE II

MESSAGES PER OUTLET VERSUS NUMBER OF OUTLETS IN MULTIPLE FOR AN AVERAGE WAITING TIME ON ALL TELEGRAMS OF 5 SECONDS

These data are based on telegrams having an average holding time of 0.65 minutes, and following normal Western Union message length distribution.

Number of Outlets in multiple available	Number of Telegrams per outlet per hour
1	18
2	41
3	52
4	59
5	64
6	67

A Fundamental Formula

The basic formula applicable to the calculation of waiting time in Western Union switching systems under normal operating conditions is:

$$P > t = (P > 0)\ (e^{-(c-a)\,t/h})$$

where:

$P > t$ = Probability of delay greater than any given time (t).

$P > 0$ = Probability of delay greater than time (0).

e = The base of Napierian Logarithms.

c = The number of channels in multiple.

h = The average holding time per call.*

a = The number of calls originating, on the average, during the holding time (h).

t = Time.

*Holding time, as used in this paper, is the total time a channel is held busy by a telegram such that the channel is unavailable to any other telegram. This time, the time a channel is *held*, should not be confused with time consumed in *waiting* to obtain a connection into a channel.

(For the derivation of this formula, refer to "Application of the Theory of Probability to Telephone Trunking Problems," by E. C. Molina.)

The use of the above formula in the determination of delays is valid only if the following assumptions are fulfilled:

1. Telegrams originating independently of each other, and at random with reference to time, have complete access to a single group of channels.
2. The probability of a telegram originating during a particular infinitesimal interval, dt, is practically independent of the number of channels busy, or number of waiting messages at the beginning of said interval. (This assumption implies that the total interval of time during which the messages fall at random is very large compared with the average holding time per message, and that the total number of messages under consideration is very large compared with the number of messages originating per average holding time interval.)
3. Telegrams are served in the order in which they originate. This restriction applies only to maximum delay values obtained.
4. The average holding time being (h), the holding times of individual telegrams vary around this average in such a way that $e^{-t/h}$ is the probability that for a telegram taken at random the holding time is greater than (t).

Under normal operating conditions, assumptions 1 and 2 are fulfilled in Western Union switching systems. Assumption 3 is not fulfilled by either the manual or automatic load distributing methods used to connect messages to available channels. Consequently, maximum waiting time values are not accurately predictable in present Western Union switching systems. Assumption 4 is fulfilled subject to the modification discussed in the following paragraph.

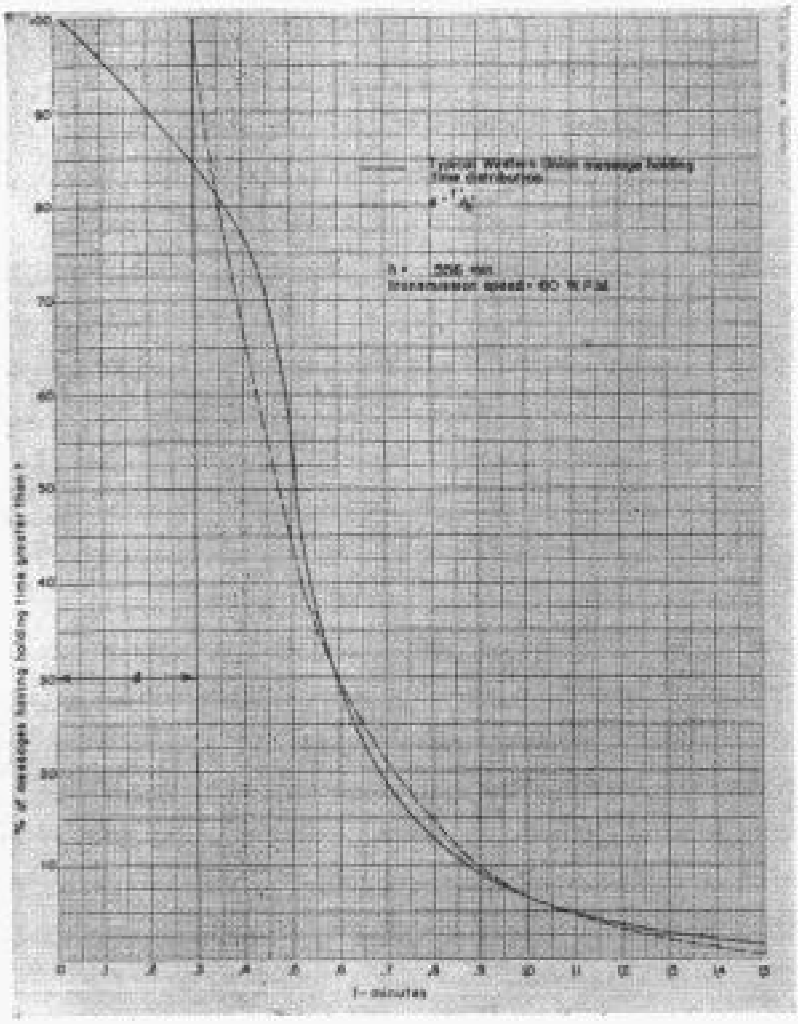


Figure 1.

Referring to Figure 1, the holding time distribution curve for a typical Western Union installation is most closely approximated by an exponential curve of the form $e^{-t'/h'}$ where $t' = t - d$ and $h' = h - d$. This curve is of the form stated in assumption 4, but is displaced a distance (d) along the horizontal, or X axis. This displacement results from the necessity of providing identifying numbers, address, and so forth, on all revenue messages handled in Western Union systems. Accordingly, the minimum holding time does not approach zero, but approaches a finite value approximately equal to the average holding time of a revenue message containing one text word. This minimum value is represented by the distance (d) as shown in Figure 1. (A small percentage of the holding times shown in Figure 1 are less than this stated minimum. These are certain "Bust This", RQ, BQ, and supervisory wire holding times, and are neglected in establishing the interval (d) as they have a negligible effect on the results of this discussion.) For all values of holding time greater than (d), the distribution for a typical Western Union installation closely approximates the exponential form stated in assumption 4. To provide for the displacement of the holding time distribution curve shown in Figure 1, the basic formula which was presented previously becomes, for application to Western Union switching systems:

$$P > t = (P > 0)\ (e^{-(c-a)\,t'/h'})$$

where all quantities are as have been previously defined.

In the above formula, the expression $P > 0$ has been presented in simplified form for convenience. Its actual value is:

$$P > 0 = \frac{\left(\frac{a^c\, e^{-a}}{c}\right)\left(\frac{c}{c-a}\right)}{1 - P(c,a) + \left(\frac{a^c\, e^{-a}}{c}\right)\left(\frac{c}{c-a}\right)}$$

where all quantities are as have been defined previously, and $\frac{a^c\, e^{-a}}{c}$ and $P(c, a)$ are obtainable from tables of "Poisson's Exponential Binomial Limit".

Typical Applications

It is evident from the complex nature of this probability of delay formula that calculations are extremely tedious. However, by insertion of various values of a and c, a series of charts have been drawn from which delay values are more readily obtainable. (Figures 2 and 3 illustrate two of these charts.) The use of these charts in determining delays is best shown in conjunction with their application to a typical installation.

Assume that a Plan 51 reperforator switching center is to be provided for a customer, and it is desired that service to a particular destination be provided such that not more than one message out of ten (or 10 percent) seeking this destination will be delayed a few seconds in obtaining a connection.

Assume further that investigation discloses that messages to this destination are initiated independently, at random, and will have complete access to any channels

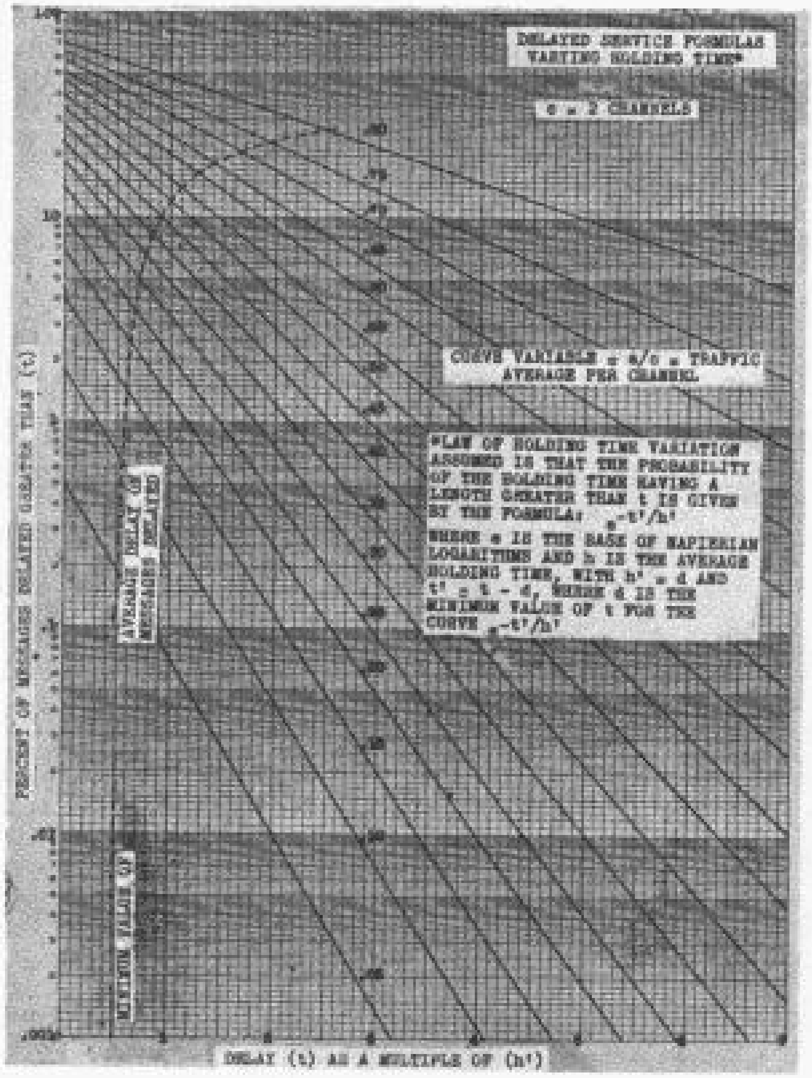


Figure 2.

serving the destination. In addition, examination of the customer's telegraph file between the center and the destination under consideration reveals that the peak hour load will average 100 messages in each direction; that the average length of message transmitted to the destination is, in tape form, 18 words for the minimum patrons' message and 35 words for the average of all messages; and that distribution of message lengths approximates an exponential curve of the form $e^{-t'/h'}$. The channels to be provided are to be duplex channels, with a transmission speed of 65 words per minute. Automatic load distribution is also to be provided, but calls will not necessarily be served in the order in which they originate. Studies show that the average equipment connection and disconnection time per message will consume 0.02 minute.

On the basis of the preceding information, the theory of probability is applicable to determination of the percentage of messages which will be delayed in obtaining connections to the destination under consideration. To find the percentage of messages delayed, the value of (d), (h), and (a) must be determined. (d), the minimum holding time, is equal to $18/65 + 0.02$, or 0.30 minute; (h), the average holding time, is equal to $35/65 + 0.02$, or 0.56 minute; and (a), the number of messages originating, on the average, during the holding time (h), is equal to $\frac{100}{60}$ (0.56), or 0.933.

It remains to obtain values of percentage of messages delayed from the curves provided. Assume two channels in multiple will be provided. The ratio, a/c, for two channels is 0.933/2, or 0.4665. Referring to Figure 2, and interpolating between the curve for $a/c = 0.45$ and $a/c = 0.50$, the percentage of messages which will be delayed $(t = 0)$ is 30 percent. Since this percentage is above that desired by the customer, two channels will not suffice. Assume three channels in multiple will be provided. The ratio, a/c, becomes 0.933/3, or 0.311. Referring to Figure 3, interpolating for the a/c curve $= 0.311$, the percentage of messages which will be delayed is now 8 percent. This is within the customer's stated requirements, and therefore three channels are required to this particular destination.

In addition to the percentage of mes-

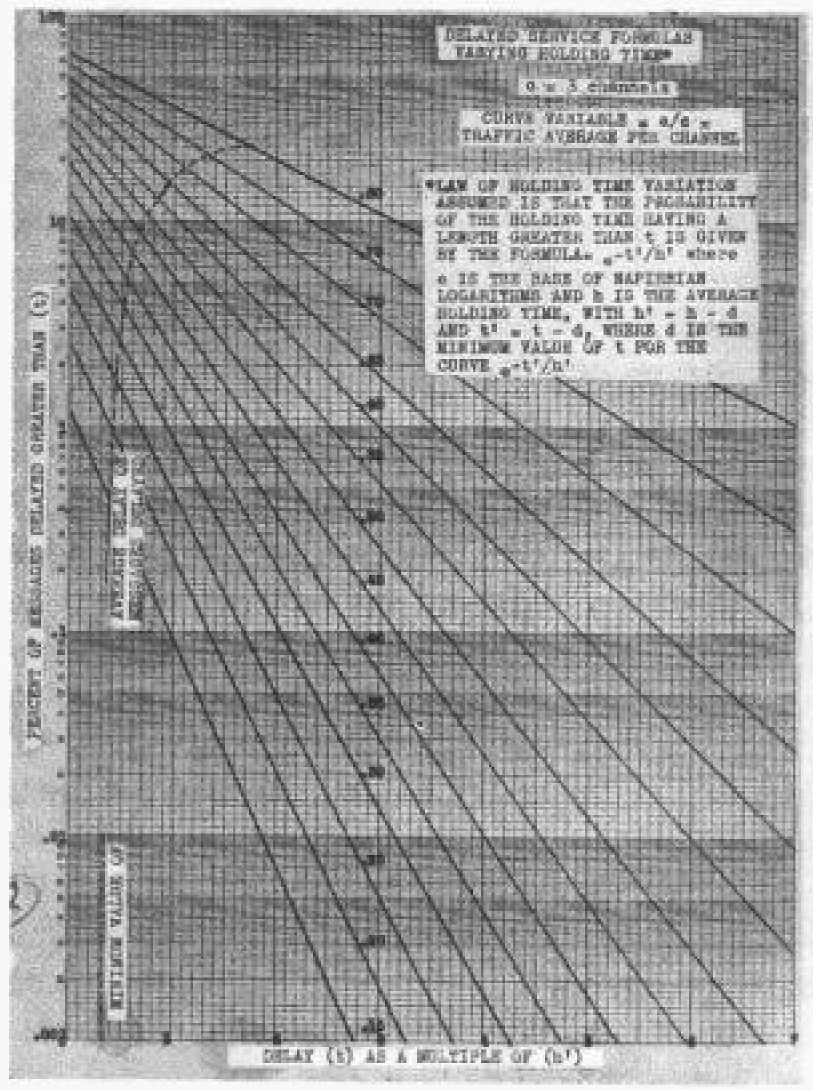


Figure 3.

sages to this destination which will be delayed during the peak hour, other delay information is readily obtainable. Referring again to Figure 3, for the a/c ratio of 0.311 as previously calculated, the average waiting time on calls delayed will be 0.49 (h'). Since $h' = h - d$, its value is $0.56 - 0.30$, or 0.26 minute, and therefore the average delay on messages delayed is (0.49) (0.26), or 0.127 minute. Since the percentage of messages delayed was found to be 8 percent, the number of messages delayed is (8 percent) (100), or 8 messages. The total delay will be (8) (0.127), or 1.02 minutes. The average delay on all messages is $\frac{1.02}{100}$ or 0.0102 minute (or 0.61 second).

Through similar calculations, the number of channels required to all other destinations from the proposed switching center may be established. In addition, the channels required if peak hour loads, equipment transmission speeds, or holding times increase or decrease can be ascertained. For instance, using the data given in the example above, if the peak hour load were to be increased to 150 messages, the value of (a) would become $\frac{150}{60}$ (0.56), or 1.40. With three channels in multiple available, referring again to Figure 3, for an a/c ratio of 1.40/3, or 0.467, the percentage of messages delayed would increase to 21 percent. Similarly, the average waiting time on messages delayed becomes (0.61) (0.26), or 0.159 minute; the number of messages delayed is (21) (150), or 31.5 messages; the total delay is (31.5) (0.159), or 5.0 minutes, and the average waiting time on all messages becomes (5.0) / (150), or 0.033 minute (or 2.0 seconds). Since the percentage of messages delayed is now greater than the customer's stated limitation, more than three channels would be required.

Calculation of expected elapsed time in Western Union switching systems through the theory of probability enables speed of service comparisons to be made with the economical aspects of a proposed system. On the basis of results of such comparisons, the optimum in requirements for fast service at reasonable cost can be decided.

A typical illustration of the application of the theory of probability in Western Union switching systems is in providing delay data on connections from a switching center to a destination which is at a great distance from the switching center. The high facility cost per channel to such a destination will make it desirable to keep all channels working continuously. Conversely, calculations based on the theory of probability may indicate that provision of an additional channel will relieve congestion of messages in the switching center enough to justify the cost of an added channel to a local destination. Another practical application is the use of delay data as a basis for determining comparative channel and equipment requirements when transmission speeds are varied. This latter application is especially useful at the present time because of the various transmission speeds employed in Western Union switching systems, and because of the contemplated use of other transmission speeds in the future.

The methods and formulae presented in this paper for the calculation of probability of delay were applied in a study of the General Electric Switching Center at New York. Observed waiting times agreed closely with calculated values. Further verification of the application of the theory of probability to Western Union switching systems was obtained in studies carried out on the Bank Wire Switching Center at New York, and on an experimental basis in the laboratory. At present, the determination of equipment requirements for the proposed New York Reperforator Center is being investigated using the methods and formulae presented in this paper.

Conclusions

Expected delay data are a necessary requisite to the efficient determination of the number of channels and associated equipment required in Western Union switching systems. The prediction of waiting time in such systems is possible through use of the theory of probability provided conditions upon which the theory is based are fulfilled. These conditions are fulfilled under normal operation of switching systems. The theory of probability permits not only the prediction of waiting time but provides, through delay data, speed of service forecasts for comparison with economic considerations over the wide range of load conditions and message and equipment characteristics encountered in Western Union installations. Through such comparisons, the optimum channel assignments for best possible speed of service at reasonable cost can be decided.

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2. Poisson's Exponential Binomial Limit, E. C. MOLINA, D. Van Nostrand Co., Inc., New York, 1949.
3. Western Union Engineering Bulletin No. 80, January 1952.

George Strunz, Jr., was graduated from Worcester Polytechnic Institute in June 1948 with a degree of Bachelor of Science in Electrical Engineering, having previously served in the U. S. Navy as an Electronic Technician's Mate. Immediately after graduation, he joined the Systems Development & Statistical Engineering Division of Western Union. Since coming with the Telegraph Company, Mr. Strunz has been primarily concerned with statistical research and study in connection with switching and other systems developments.

R. E. Hubley was graduated from Worcester Polytechnic Institute in June 1948 with a degree of Bachelor of Science in Electrical Engineering. He joined the Methods Engineering Department of Western Union in July 1948 and spent six months at Boston in connection with various studies made during the Plan 21 cutover there. Mr. Hubley has since been occupied mainly with economic studies of Western Union installations including Patron Systems and Facsimile. Many of these studies have required determination of optimum equipment requirements through application of the theory of probability. He is presently working on the proposed New York reperforator switching center.

Switching Facilities For Multiple Address Telegrams

R. L. PARCELS and F. A. LUCK

In addition to handling single copy messages, area center offices, like manual offices, have the problem of handling large multiple address files called "books" of messages. In manual offices copies of book messages may be readily duplicated in the Duplicating and Addressing Bureau, sorted and sent on a large number of trunk outlets as single copies. In area center offices the number of local sending positions is small in comparison to large manual offices, and other methods must be used to transform large multiple address files into perforated tape as single copies, or to transform multiple address messages received from tributary or branch offices in perforated tape into single copies for retransmission.

For example, a multiple address message may be received from a tie-line at an area center office, the same text to be sent to a large number of addresses. The address tapes are prepared on local perforators in the book center. During this period a number of text tapes are prepared, edited and spliced as loops.

Area center offices are provided with at least one book switching turret, as shown in Figure 1, or several book switching adapters which may be placed on the upper switching positions of a regular switching turret. The book switching turret is a standard push-button type of turret with the exception that a second cross-office transmitter is provided below and to the right of the regular cross-office turret transmitter at each position. The printer-perforators are removed from the turret and additional relay banks are provided for proper functioning of the two transmitters in switching a multiple address message. The text tapes are prepared as follows:

> B.LSA320 BOOK PD = BOSTON MASS. 2 424P=. EFFECTIVE IMMEDIATELY PRICES WILL BE (*etc.*) = BROWNIE = (*confirmation if any*) = . .

The address tapes are prepared as follows:

> B.LSA001—320 F P HOLMES= ALBANY NY=. (*etc.*)

The text tapes are spliced as loops and placed in the bottom of text transmitters. The address tapes are separated in equal strings and placed in the top or address transmitters.

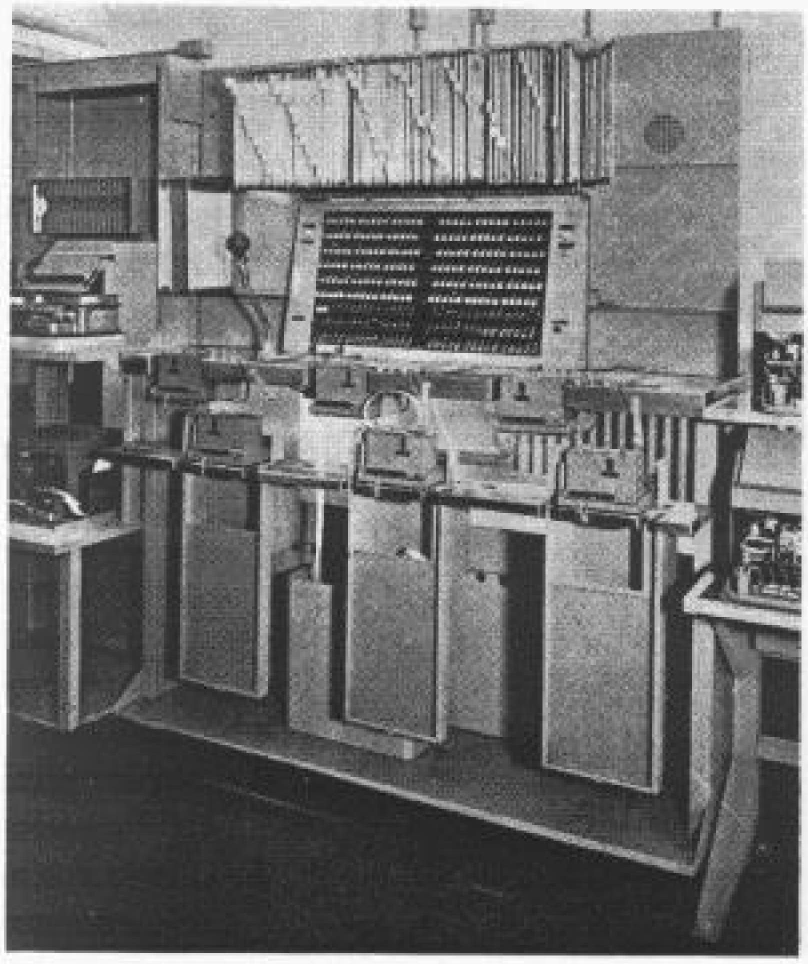


Figure 1. Book switching turret

The switching operation begins with the switching clerk selecting and operating the push button to Albany, N. Y. When a cross office circuit to the Albany sending position is established, a reperforator number is perforated in the Albany sending position tape from the automatic numbering machine at that position and the text transmitter sends the top line of the message and is stopped by the equals sign period characters appearing at the end of the first line. Those =. characters are read and recorded by relays which cause the switching relay to transfer the connections from the text transmitter to the address transmitter. The address transmitter then sends the address and at the end of the address =. again appears. These characters this time cause the switching relay to transfer the pulse conductors back to the text transmitter, which proceeds to transmit the rest of the text of the message. At the end of the message, double period (..) is read by the reading relays at the sending table in the normal manner, and results in a complete disconnect of the connection. Thus one message is transmitted.

The form of the message as received by Albany, N. Y., would be as follows: BA050 B.LSA320 BOOK PD=BOSTON MASS 2 424P=.B.LSA001—320 F P HOLMES= ALBANY NY = EFFECTIVE IMMEDIATELY PRICES WILL BE (*etc.*)= BROWNIE= (*confirmation if any*)=..

The Albany operator then gums the message in the usual form down to the equals sign following the filing time 424P where she cuts the tape and compares the second address number 320 with the text number 320; if these two numbers agree the second number B.LSA001—320 is gummed over the first or text number B.LSA320, the tape cut and the rest of the address, destination and text gummed down in the usual message form.

Multiple address messages may be received at the Book Message Center from branch or tributary offices which work with the reperforator office. These are received on the book message receiving table which is equipped with two 36-A printing reperforators and can be selected automatically by the outside branch or tributary office using the selection *BK*. The outside office sends a pilot wire giving the number of copies, followed by two copies of the text and the addresses.

Upon receipt of the above, the book center supervisor compares the two text tapes by inserting them in two comparison transmitters on the book message editing table The two tapes are stepped through the two transmitters simultaneously by means of the step pulses unless a point is reached where they differ. If that occurs, a wrong comparison relay operates which opens the step pulse to the transmitters and they stop the stepping operation. The supervisor then observes the difference, determines the correct character, notches the incorrect tape at that point and advances the two tapes one step. The two transmitters are started stepping again by throwing a toggle switch that releases the wrong comparison relay and the same sequence of operation occurs as described above.

When a correct text tape is obtained additional text tapes may be made by placing it in a distributor-transmitter located on the book message preparation table which has facilities for sending simultaneously to as many as six printer reperforators located alongside, thus furnishing six text tapes which may be spliced separately as loops and used in the text transmitters at the book switching turret. The switching operation at the book switching turret with this type of book message is the same as has been previously described.

Another feature of the book center provides for connecting a separate bank of transmitters on the book message preparation table to a number of spillover positions in the switching aisle. If a book is received where a large number of copies are destined to a few cities where duplicating and addressing facilities are available, the reperforator office may "subbook" or relay parts of the original book, as smaller books, to each of the destination cities. This is accomplished by sending two text copies and the addresses of like destination to each of the spillover positions, from which they are "sub-booked" to the destination city as smaller books.

New Developments

A new type of universal book adapter has been designed to increase the flexibility of book switching equipment and provide book handling capacity comparable with that of manually operated relay offices. This capacity will be gained through the use of automatic equipment.

The adapter is a small, compact moveable unit that can be readily wheeled to various sections of the office and plugged into most types of reperforator receiving and sending terminations. These will include the heavy tributary "4930's", push-button switching turrets, manual local transmitting positions, and reperforator sending racks. They will be used at the manual local sending positions with an associated tape preparation table. With minor changes in routine and message form, these adapters will perform in a manner similar to the book switching turrets and book switching adapters described above. The main points of difference will be the inclusion of sending position selecting characters for the automatic selection of outgoing destinations, and the ability to use them at practically any type of reperforator office termination. Once the address and text tapes are started in their transmitters, automatic selection and transmission, in single copy message form, will continue until all addresses in the tape have been transmitted.

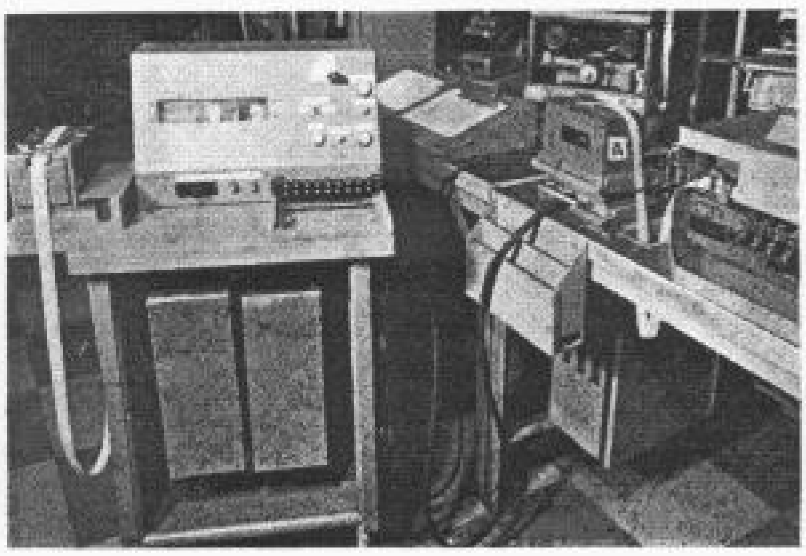


Figure 2. Laboratory model of book message adapter connected to a Plan 21 Type local operator's position (A) Address transmitter

At the manual local sending positions a text tape is manually perforated which, when compared and any errors corrected, is made into a loop for insertion in a text transmitter. If the number of addresses is large or the text long, a number of text loops may be prepared and set up in many adapter text transmitters. Manual perforation of address tapes is then started and after a few have been perforated, the tape is started through one of the adapter address transmitters. These tapes include the sending position selecting characters and automatic selection and transmission, in single message form, begins. Transmission across office proceeds at the usual rate of 125 words per minute. This permits a sort of balance between the manual rate of perforating addresses only and the automatic transmission of the complete message. If the length of the text is such that the operator perforating addresses gets ahead of the adapter, a second adapter is started, the address tape being separated at convenient points and fed to the two adapters so that the complete transmission of the book is accomplished almost simultaneously with the completion of the perforation of all addresses. This assures a good speed of service, and a minimum requirement for manual attention which relieves the strain on the normal operating force when large books are received for processing. This is true also of the terminating office, since the messages are received as normal single copies requiring no additional processing before delivery to the patron.

Messages which cannot be automatically directed to the proper sending position are automatically sent to special manual switching positions where they are switched in the normal manner.

Books of messages received from heavy tributaries on 4930 positions will have been prepared by the tributary office in a manner similar to manual local sending position preparation. Two text tapes are followed by the address tapes which will include sending position selecting characters. After comparison and preparation of the text loops, the book will be automatically switched by one or more adapters. Frequently the adapter will be plugged into the same 4930 on which the book is being received, and complete single copies will be transmitted from this position simultaneously with the receipt of addresses only from the tributary office. Reception from the tributary will be at the normal rate, usually 65 words per minute, while cross-office transmission will be at the regular rate, which is usually 125 words per minute. Here again the length of the text and the speed with which address tapes are being received will determine whether more than one adapter will be required for transmission to keep pace with reception.

Books of messages from light tributaries terminated on line finder equipment will go to the book center, where the text loops will be prepared and an appropriate number of adapters set up with text loops and address strings, on spare 4930 equipment or 4930 channels (2nd or 3rd channels from heavy tributaries) which are not in operation at that time.

Books with very long texts will be transmitted by plugging the adapters directly into the line sending position of the destination office, which may be another reperforator office or a local area office. This will prevent the congestion of cross-office circuits that would otherwise occur. Depending on the length of the text, the number of addresses, and the processing facilities of the office to which the book is being sent, it will either be sent as ordinary single messages, or sub-booked in book form.

Field trials of these adapters are under way at the Plan 21 area centers in Detroit, Mich., and Philadelphia, Pa., (Figure 2). After a satisfactory shake-down period, any changes in design or routine indicated as needed will be made and the units made available for general field use. There is every reason to expect that these adapters will greatly facilitate the handling of multiple address messages in high-speed message centers.

Biographies and pictures of **Mr. Parcels** and **Mr. Luck** appeared in TECHNICAL REVIEW for July 1952.

Thirty-Line Concentrator for Private Facsimile Systems

FACSIMILE has played a key part in the mechanization and modernization of the telegraph industry. Sending and receiving telegrams instantly and automatically in picture form has improved the speed and efficiency of telegraph service and made it more convenient and attractive to the public.

Now, Western Union is building and leasing custom-built facsimile telegraph systems for private customer use in speeding intra-company communication. The new system, called "Intrafax," offers a revolutionary cost-cutting method of expediting letters, orders, requisitions, drawings—any type of document — over short distances at high speed.

Assembled units for "Intrafax" System

"Intrafax" is finding many new uses on patrons' premises. A large department store transmits facsimile copies of sales slips from store to warehouse, thereby speeding up delivery of the orders to customers. A large banking institution transmits signature cards from main office to branch banks when a customer not well known at the branch bank brings in a check to be cashed. Air lines and other large users of telegraph service employ "Intrafax" between communication centers and various departments to pick up and deliver messages.

To meet these needs three new pieces of apparatus have been standardized: Telefax Transmitter Console 6840-A, Telefax Recorder Console 6842-A, and Telefax Concentrator Console 6844-A. When grouped together they form a complete concentrator assembly which, except for size, is the exact equivalent in respect to operating equipment, schematic wiring, maintenance and operation, of our standard main office Concentrator 176-A described in TECHNICAL REVIEW, January 1950. This fact simplifies maintenance since personnel already familiar with the 176-A type need no further instructions for servicing the new units.

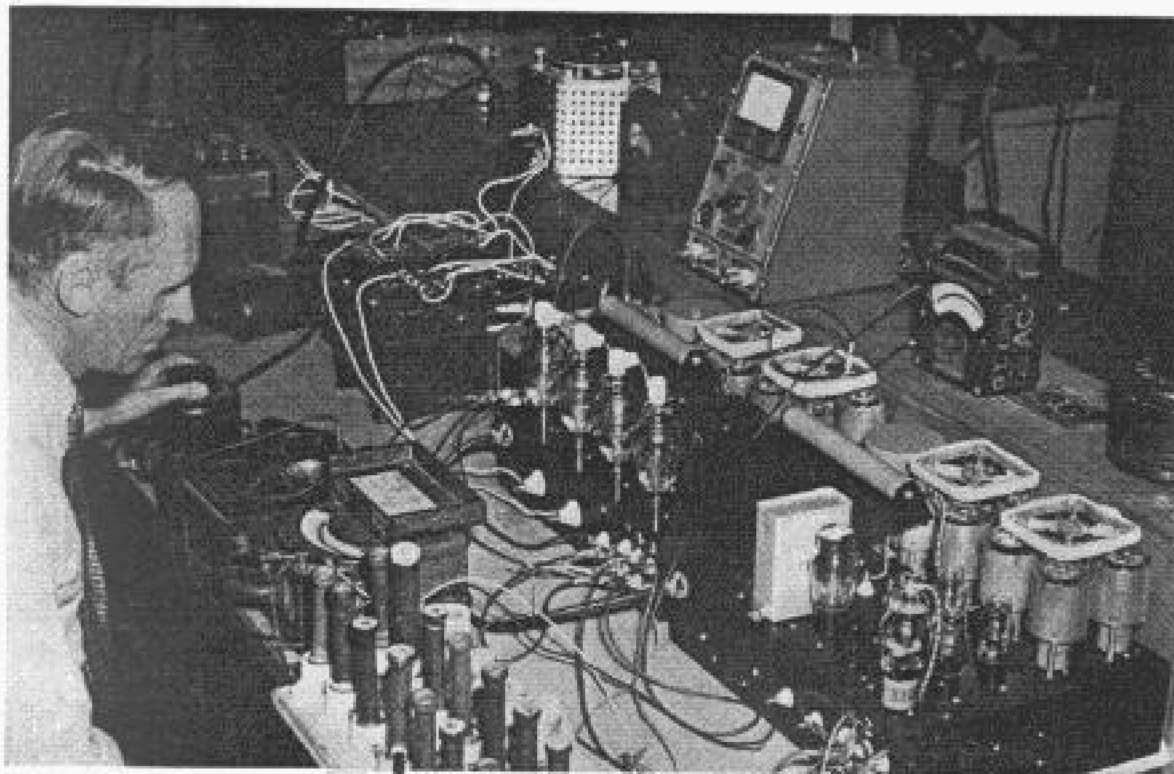
To further simplify the maintenance problem all auxiliary equipment has been arranged to be accessible from rear aisle space without disturbing the operating personnel in any manner. Most of the auxiliary equipment such as relay banks, amplifiers, and so forth, are mounted on a panel attached to the rear door of the console. If a relay bank is to be removed the door is opened to stand at a right angle to its closed position. In this position the banks face outward and can be removed easily. If it is desired to get at the connections to the equipment the door is opened to a position 180 degrees from its closed position. This permits access to the connections on the back of the door panel, and to the inside of the console.

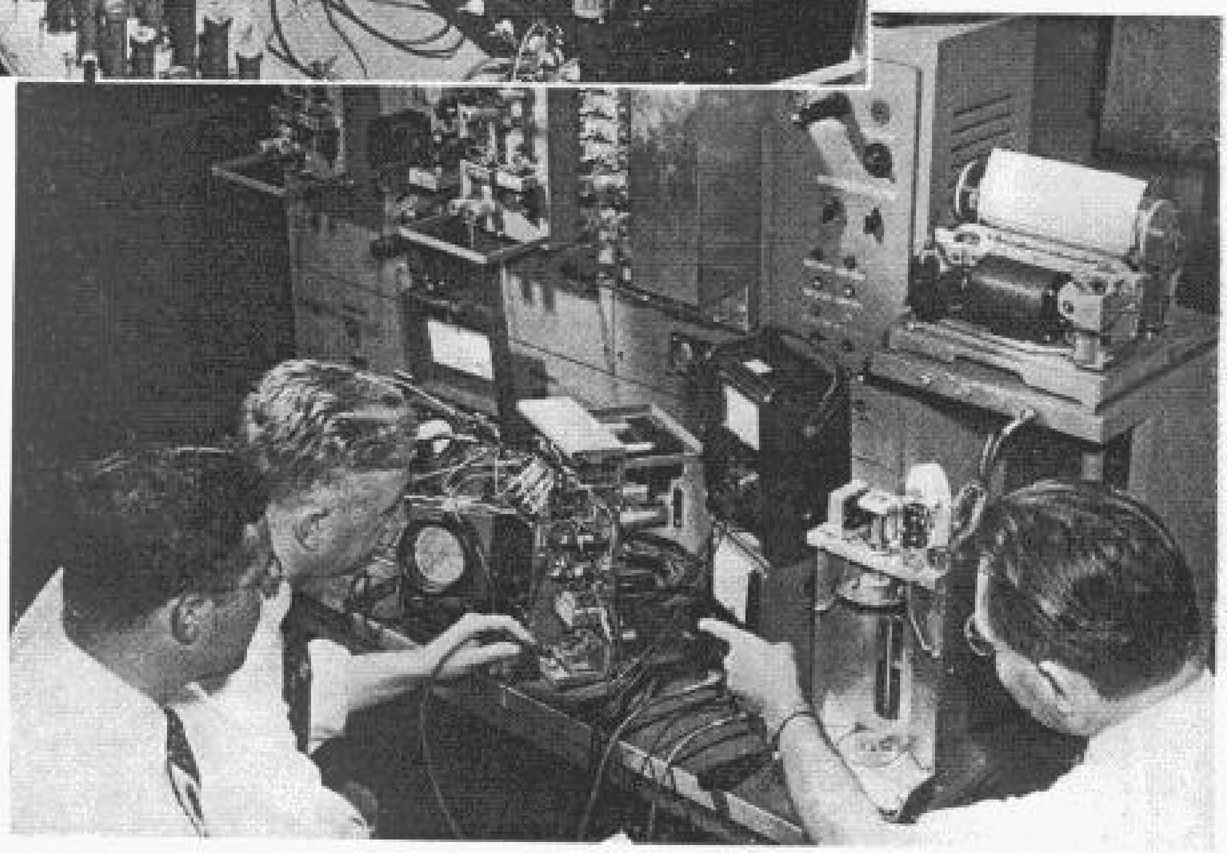
For easy installation, power and lines are terminated in the line concentrator unit from which power is distributed laterally inside the consoles. A maximum of 30 lines can be ac-

Transmitter Console — Line Concentrator — Recorder Console commodated in the concentrator console and a total of eight transmitting or recording tables, as required to handle the load, can be added to the assembly. All eight may be either type or any combination of transmitting or recording positions. The consoles are of uniform size, being 20 inches wide, 57 inches high and 28 inches deep. They have built-in receptacles for sent and received messages and extra transmitting drums, and are styled to match present-day ideas of functional equipment design.

Standard Desk-Fax transceivers are employed as terminal sets on the lines which are connected into the "Intrafax" system concentrator.—H. H. Haglund

WESTERN UNION ENGINEERS DESIGN NEW DEVICES





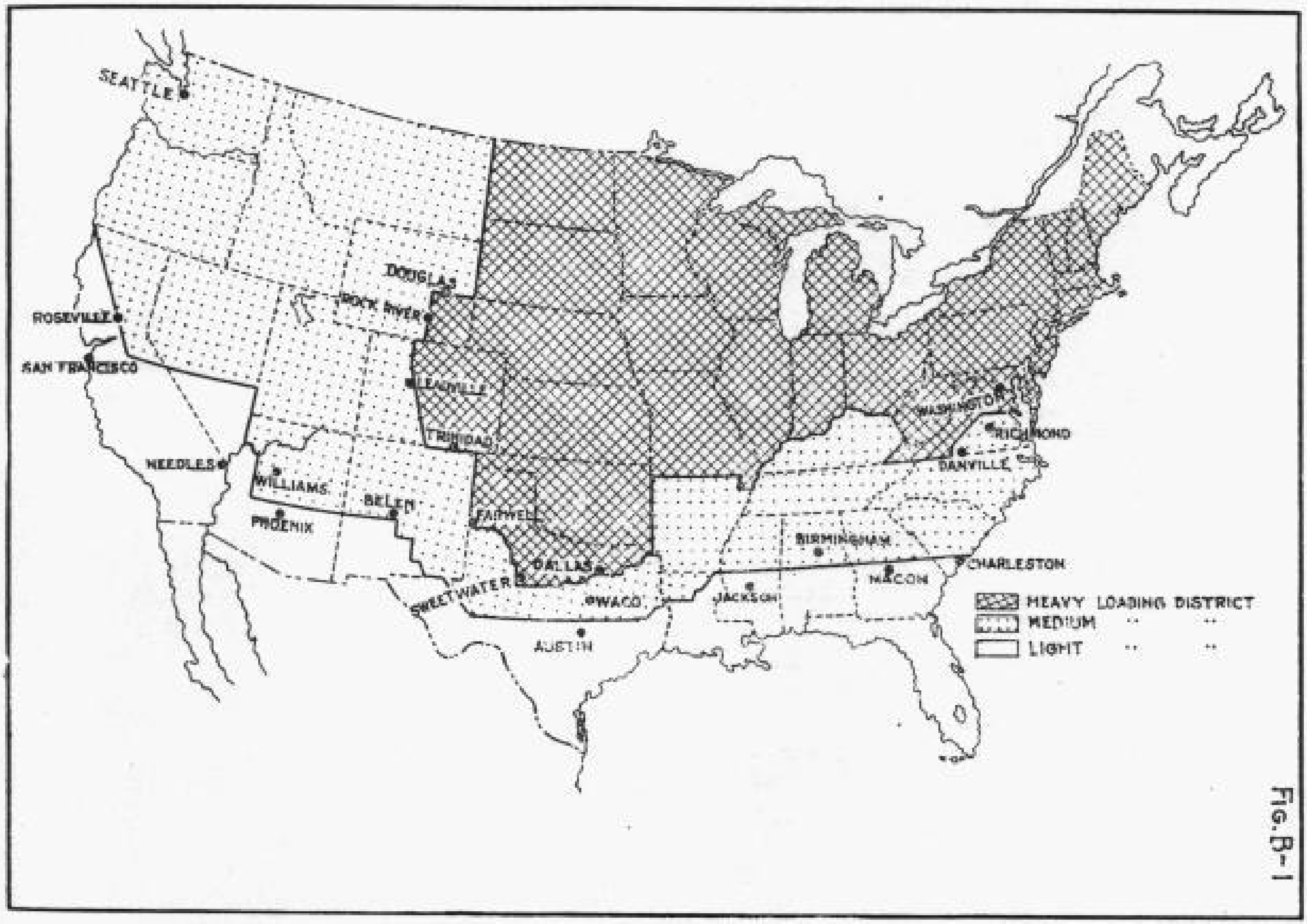
(Above) Testing current and voltage control amplifiers associated with new under-water repeaters of Western Union's ocean cable system. These control amplifiers, installed ashore, maintain power supply current flowing through cable to repeater within 1/3 of 1 percent of required 320 milliamperes.

(Below) Telegraph engineers employ regulation Western Union Telefax test table with standard transmitter and recorder (right) to study effects of a proposed circuit modification.

Weather and Communications

T. F. COFER

WEATHER has always profoundly affected communications all over the world. Footpaths, roads, and waterways, the earliest channels of communications by messenger, were always subject to blockade by adverse weather conditions. Visual and sound systems, essentially short range by their nature, could also be stopped by storms. Pigeons, the earliest air mail, would not fly when the weather impeded their actions.



The United States has been divided into three areas, on the Loading Map, according to the severity of ice storms

Weather Also a Factor Today

With the electromechanical devices of today, the vagaries of weather are of less importance. It is only when the most severe of Nature's manifestations put to nought all the latest devices for communications that the fact is brought home; that what is called civilization is still largely dependent upon weather conditions. In the frigid voids of the polar areas as well as in the steaming equatorial jungle, weather is King. With all the developments of modern technology, ventures outside the temperate zones of the earth are likely to be on a "weather-permitting" basis. Even the transport airplane, flying high above the weather altitudes, must consider ground conditions at refueling points.

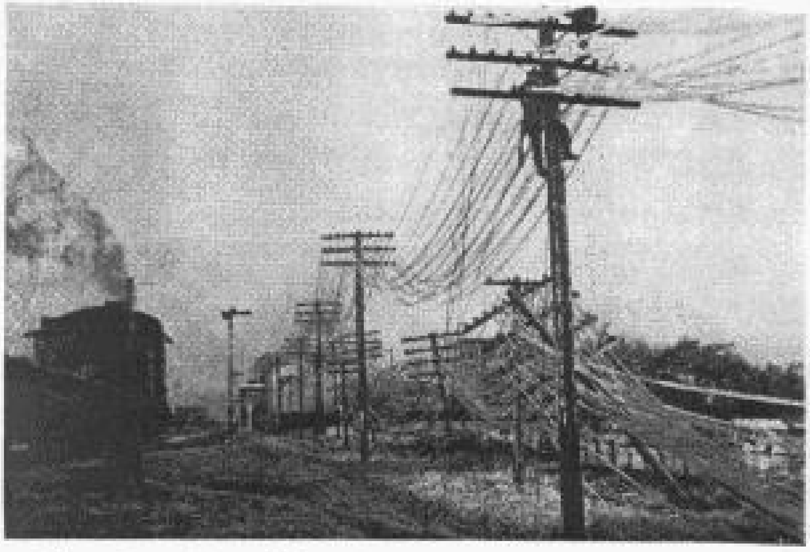
In the temperate zones, where the bulk of world communications exists, good roads, railroad systems, scheduled airlines, and wire-using types of communications are found in profusion. The latter are perhaps the forms of communication construction that have been influenced most directly by the weather.

The telegraph, telephone, and power lines that may be seen along the highways or railways have acquired their method of construction by evolution in a ceaseless struggle between the public utility engineers and the elements. Some services too important for compromise have been driven underground in response to the primordial urge to escape the weather. Equipment and apparatus is sometimes sheltered in airtight enclosures where ambient weather may be controlled. But in the general operation of communications the factors of wind, storm and flood, with their accompanying damages to lines and equipment cannot be ignored. Somewhere in the chain of line connections there is usually an exposed portion, like Achilles' heel, where harm can be done.

Line Construction Influenced by Climate

The importance of weather considerations is nowhere so clear as in the design and construction of the open-wire pole line. Despite advances in transmission engineering which have given us conductors in sheathed cables and microwave systems, there remain many thousands of miles of open line wires. While the strength required for almost any degree of "storm proofing" could be built into such lines, considerations of economy govern the practical limits of construction. The more important the service, the less must be the probability of failure. Hence the climate must be a factor in construction, since climate infers the usual weather conditions. Additional factors are introduced by the necessity for two or more pole lines to cross each other, or for two or more utilities to use the same poles. A pole line occupied by only one utility traversing its own right-of-way can be constructed with the degree of safety suitable to its own importance, but when the integrity of one line affects the continuance of other services, some means of insuring proper construction are necessary.

The fundamental factors relating the strength of pole lines to probable weather have long been worked out through cooperation between the wire-using companies and the National Bureau of Standards. A map showing the "loading districts" for line construction has been drawn, which divides the United States into three parts according to the standard of construction deemed necessary to resist all but the most unusual storms. The boundaries shown have been adopted by most wire-using companies for inclusion in their own specifications and by many of the states for their regulations.



The intensity of local storms sometimes exceeds established construction safety factors

The basic strength built into a line of given size and importance is dependent upon the load the poles must carry. Within the boundaries of the Heavy Loading District, large deposits of ice can be expected to form on the wires at times, thus not only increasing wire-tension and loading the poles by adding weight, but also increasing the "sail area" exposed to the capsizing pressure of cross winds. In the Medium Loading District less ice is expected to form, and in the Light Loading District no ice is expected. Thus, in order to give equivalent strength to carry anticipated loads and to provide equivalent reliability, a pole line of a given number of wires in the Heavy Loading District will require thicker poles more closely spaced and equipped with auxiliary guy wires more frequently than in other districts. It may be seen that the expectation of bad weather conditions greatly increases the cost of constructing a pole line for commercial purposes. Also, since it is impracticable to build completely storm-proof open-wire lines, a winter season seldom passes without a local storm exceeding the violence used in determining general strengths, bringing the wires, poles and crossarms ignominiously to earth. This fact has in late years contributed greatly to the widespread practice of putting line wires into cables which can be run underground or which even when carried on poles, have the benefit of a steel cable "messenger" support and less total area exposed to storm icing.

Floods Also Cause Damage

Besides the ice and wind storms which the pole line must suffer there is also flood. The probability of floods causing damage to communication lines is increased by the fact that both highways and railroads customarily follow natural pathways through the country. These paths were usually originally opened along the easiest grades, often along the watercourses. Furthermore, since the early heavy freight traffic was largely water-borne, the most important centers of population today are at the mouths or confluences of rivers, or at the shores of larger bodies of water. It is therefore necessary to consider the possibility of floods affecting lines approaching these centers of business activity.

The poles of an open line are supported only by the resistance of the earth surrounding the cylindrical hole dug for them in the ground. There is no root structure to assist the holding power such as a tree of similar dimensions would have developed. In consequence when flood waters soak the surrounding soil, or wash part of it away, the poles often fall to the earth. Side-guys which provide additional lateral strength are of little assistance in flood conditions since their anchors may pull out of their beds through the softened dirt. Where the pole line is undermined by flowing water and falls into a stream, subsequent repair is usually made more difficult by the net-like character of the tangled crossarms and wires which tend to trap and hold all manner of flotsam.

Again the use of cable instead of open wires offers improvement since the cabled line may produce less load on the poles. On the other hand, underground cable runs should not be located where flood waters can undermine them since the duct line can be seriously damaged even though the lead sheath of the cables may protect the wires inside from moisture. Cable lines may continue to operate satisfactorily under conditions of mechanical distortion which would completely prostrate an open-wire line, but they are not entirely free from weather damage. For instance, the usefulness of cables contained in iron pipes may be destroyed by the expansion of ice formed around them from leakage of snow, rain, or surface water.

Humidity Affects Both Inside and Outside Plant

The presence of large bodies of water near important cities also brings other troubles due to high humidity. Less cataclysmic than storm or flood but nevertheless a serious deterrent to operation is the presence of heavy fog or excessive dampness. The usual open wires carried on the poles are bare, being insulated only at their points of support on the crossarms. The insulator is ordinarily a dome-shaped piece of moulded glass grooved to receive the wire, with a threaded hole up the middle for attachment to the supporting pin. The leakage of electricity over the surface of the glass varies directly with the diameter of the insulator and the conductivity of the surface film, and inversely with the length of the leakage path to the pin. The dimensions of the device can be proportioned suitably for the purpose, but the exposed surface of the glass always collects dust and other small particles of conducting matter during dry periods. In a heavy deluge the washing action of the rain drops tends to clean the surface, particularly of loose particles or substances which dissolve in water. But when fog, mist, or extremely high humidity causes drops of water to condense gently on the

Communications following watercourses are subject to floods dust film, a spreading action takes place which may increase the leakage from a dry weather value of less than 0.0001 micromho to as much as 0.1 micromho per insulator, and this condition may persist throughout the duration of the high humidity. In some sections of the country, notably near the Pacific coast, recourse to insulated open line wires has been necessary in order to maintain service during periods when dense fog blankets blow in from the sea.

Wet snow and melting sleet will also produce leakage over the insulators in somewhat the same fashion. A large absorption of high-frequency power may take place under such conditions, which is very harmful to carrier transmission. These phenomena usually occur, however, at times when more serious damage than leakage may be expected.

Effects of humidity are also felt on equipment in offices, where operation of telegraph electrical apparatus depends upon narrow strips of insulating material between points of moderately high potential. Ventilating fans and heating devices must sometimes be used in periods of extreme dampness to prevent the formation of moisture in critical places. Wiring in offices must always be covered with non-hygroscopic insulation, some of the new plastics being of great help lately in such usage. Cable houses, where underground cables are connected together through test frames, often are furnished with electric heaters controlled by humidity-testing devices to prevent the occurrence of excessive leakage across the connecting blocks.

The need for de-weathering of telegraph station apparatus reaches its peak in modern area centers where the reperforator and switch rooms contain large numbers of intricate relays, commutators, perforators and tape transmitters. Here the electrical contacts must be kept free from dust, and the punched paper tape, which stores the telegraph intelligence between machine operations, must be maintained at the proper humidity. The presence of so many electrically operated devices in close quarters would also raise ambient temperatures to inconvenient values if some control was not exercised. Most of these offices are therefore equipped with air-conditioning systems designed to provide dust-free air at a temperature around 75 degrees and at 50 percent humidity in all seasons. An added advantage in employee comfort, leading to most efficient manual operations, accrues in such offices.

Lightning Produces Disturbances

The more spectacular weather disturbances also affect the construction and operation of communication systems. Protection against the damaging proclivities of lightning is necessary whenever a wire line exposed to the elements joins a cable section or enters a building. The method of protection is to provide a spark gap from each wire to ground through which the very large voltages induced by the collapsing field of the lightning currents may discharge. To insure the proper operation of these gaps, the separation and insulation between conductors elsewhere must be capable of withstanding voltages higher than the gap. The breakdown voltage of the spark gaps is controlled according to whether protection against damage to equipment or danger to operators is the prime requisite. It is customary to provide protectors of 1000 volts breakdown or more at the junctions of open wire and cable, and of 500 volts or less at the office end of such cables. The steep wave front of the lightning surge enables the outermost high-voltage gaps to bear the brunt of the protection, since once the spark gaps are ionized the line will almost completely discharge.

Various combinations of metal or carbon electrodes are used to form the spark gaps in the protectors, the criterion being that permanent grounding of the wires will not take place from lightning discharges except under unusual conditions. Fuses are provided to disconnect the line in case of sustained high voltages such as might be obtained when power lines fall into the communication wires. The spark gaps are often arranged to become permanently grounded under this condition, through the action of a thermal delay device.

Even cables buried in the earth are not

safe from the effects of lightning. Especially in areas where the earth is of high resistance, lightning strokes to trees often follow the root structure to the cable, sometimes damaging it severely. Extra wires of low resistance are sometimes buried with the cables to absorb the lightning currents.

On metallic circuits, consisting of two similar wires, balanced to ground and to other wires by transpositions, carrier circuits transmitting a very large number of telegraph channels may be operated. Interruptions of such circuits by the operation of the protectors are extremely undesirable. It has been found practicable to reduce the number of interruptions to the metallic circuit through the use of "arrester balancing coils". The latter are small inductance coils, on a laminated iron core, connected between the normally-grounded ends of the protector gaps of the two wires of a pair. An accurately located center tap of the coil is connected to ground. If the two spark gaps have nearly the same voltage breakdown, this balancing coil will assist them to discharge each wire at exactly the same instant so that no voltage will be produced across the metallic circuit. The series inductance of the coil prevents short-circuiting of the line by the discharge path through the gaps, but the effective inductance in the ground path is very low to currents flowing toward the center tap.

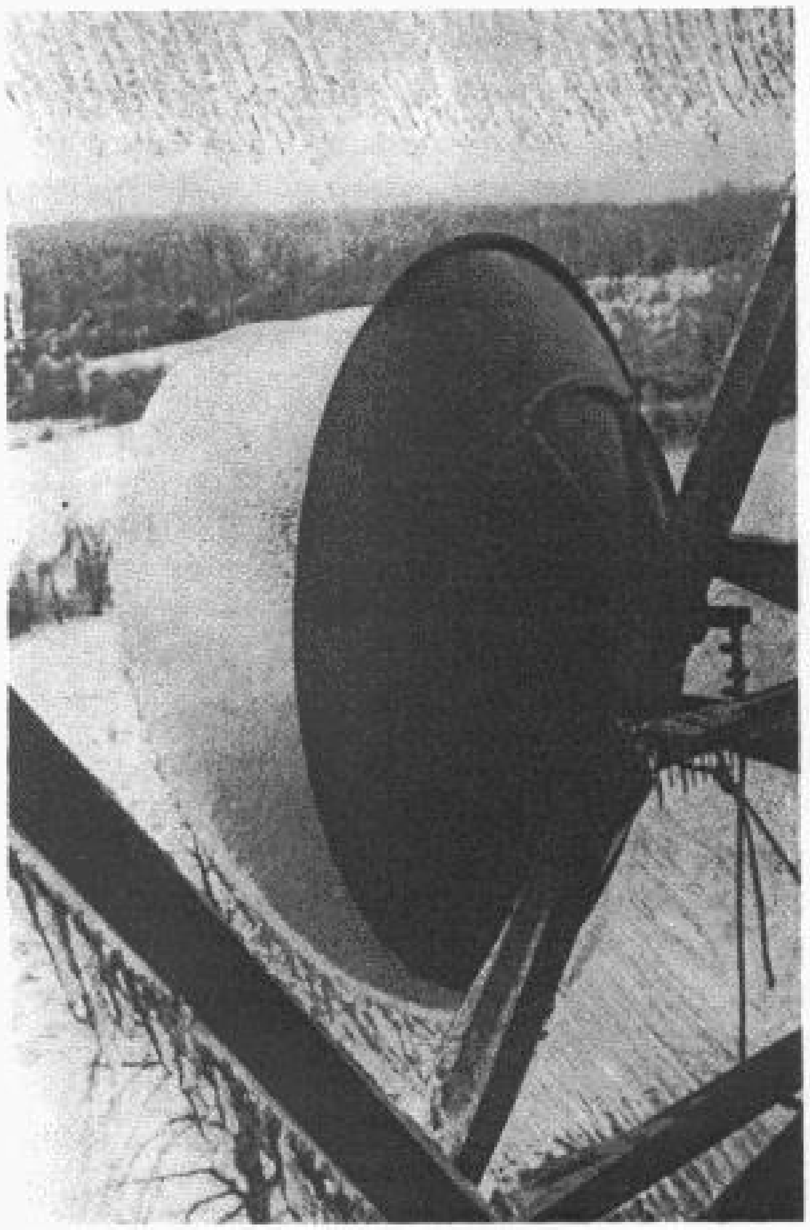
Earth Potential Storms Can Be Troublesome

A less frequent display of atmospheric electricity is the aurora borealis. This phenomenon, when visible in the more southerly latitudes, is accompanied by "earth currents" which sometimes seriously disrupt wire communications. At times the earth currents occur in serious magnitude without the appearance of the aurora. These "earth potential storms" are evidenced by the observation of large potential differences between points of connection of communication wires to the earth. Several hundred volts between locations a hundred miles or so apart are not unusual. The potentials are normally very low-frequency alternating currents of irregular wave shape. The paralyzing effect of such uncontrolled natural voltages on grounded telegraph circuits operating at lesser potentials can be imagined. Prior to the wide use of carrier circuits it was necessary to convert all important grounded telegraph circuits to some form of metallic operation in order to maintain service. Other circuits were abandoned and their wires used to form the return conductors for the top grade services. Since the storms do not ordinarily continue for more than a few hours at the high voltage levels, such arrangements were practicable. Metallic carrier-current operation for most long important circuits has today greatly decreased the effects of earth currents.

Metallic circuits are not disturbed by the earth currents unless the potentials between points traversed by the circuits exceed the breakdown voltages of the protector gaps. Such cases are rare, but when they do occur, prostration of communication services can take place on a large scale.

The wire-communication companies have studied earth current phenomena for more than twenty years in an effort to predict accurately the time of occurrence and the magnitude of the storms. So far no exact prediction of day and hour is practicable. The phenomena are believed to be associated with the number, size, and location of spots on the face of the sun. Predictions of probable "good and bad" years are made by plotting the day by day "sunspot numbers" in the form of a curve and extrapolating the curve shape into the future.

Long-range short-wave radio communications experience weak or otherwise unreliable signals during periods of sunspot maxima. One of the larger radio communication companies has for some years maintained a full-time observer to correlate disturbances with visible solar phenomena and make predictions of failures of particular circuits. The effect of the interrelations of certain large planets has been found to coincide with disturbances that heretofore were unexplainable from sunspot data. The results of this study are apparently worth while commercially and are being continued.



Microwave systems can work through storms that paralyze other communications

Special Bad Weather for Microwaves

Microwave radio circuits, whose signals leap from tower to tower with the speed of light without benefit of wires, are free from most of the weather-caused interruptions of other communication media. Little affected by aurora phenomena and unresponsive to static which plague electromagnetic waves of lesser frequency, they are essentially immune to losses from rain, snow, or ice, especially when provided with sleet melters on the antennas. With equipment mounted on steel towers, or steel reinforced towers, that are not vulnerable to lightning, the field stations are even equipped with auxiliary power plants which make them independent of local primary power which may fail during storms. Since, in addition, the tower locations are always on high points out of reach of flood waters, the microwave systems would seem completely impervious to weather. But Nature has "put a Joker in the deck" especially to annoy microwaves. Sometimes on quiet windless summer days when vegetation has been steaming in the muggy air and then the heat of the sun is withdrawn, a phenomenon called "inversion" takes place. Atmospheric density ratios, usually decreasing with altitude and thus bending the microwaves around with the earth's surface, suddenly become reversed or seriously altered to such an extent that the beam transmission path from tower to tower is deflected, received signal strength falls below the minimum on both regular and diversity antennas, and complete prostration of operations follows. Luckily this condition does not occur often or for very long at a time. But the occurrences are sufficient to prove the rule that weather can always get you if you stay out of doors long enough.

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Biography and picture of **Mr. Cofer,** now Assistant to the Coordinating Engineer, D. & R. Department, appeared in the October 1950 Technical Review.

Electrolytic Capacitors in ADT Protective Signaling Service

WERNER G. HOLZBOCK

THE FIRE ALARM sounds, fire engines race through the streets, and shortly thereafter a dangerous blaze is extinguished. "And what," one might ask, "has this to do with electrolytic capacitors?" The answer is that capacitors are important components of the devices used by the American District Telegraph Company for the protection of life and property. They assume a critical role in systems for the automatic detection and reporting of fire, such as ADT's Sprinkler Supervisory and Waterflow Alarm Service. This service keeps an automatic sprinkler system under the constant electrical supervision of an ADT Central Station, to detect and report abnormal conditions affecting the water supply and its distribution, and to give prompt notification to fire-fighting forces when water flows.

Capacitors are employed in connection with waterflow alarm transmitters which signal the central station upon the operation of the sprinkler system. This occurs normally when a sprinkler head fuses, causing a sudden pressure drop in the system. The drop in pressure is followed by a flow of water through the piping. Either the pressure drop or the flow can be detected by alarm devices which convert mechanical action into electrical impulses.

In spite of check valves and other precautionary measures, however, normal conditions do not always exist in a sprinkler system, and surges in the water-supply lines often cause disturbances which the detection device might interpret as caused by an open sprinkler head. To overcome this condition, a time element is introduced to retard the operation of the waterflow transmitter for a short period, say ten seconds. When the disturbance is less than ten seconds, there is an immediate recycling; if another disturbance occurs right away, it too must continue for ten seconds before an alarm is transmitted.

This time delay can be accomplished mechanically, but the most practical method is to connect an electrolytic capacitor across the alarm relay. The capacitor discharges through the relay and, when sufficiently discharged, causes the relay to drop out and release the alarm mechanism. Circuits usually carry 10 to 12 volts direct current. The time delay is relatively long, so it is necessary to work with characteristics that are not too common. A 3100-microfarad 15-volt capacitor is a typical application.

Practically all electrolytic capacitors use aluminum foil for their structure. Recent advancements in the design of the tantalum electrolytic capacitor are noteworthy[1, 2], but are not treated here. The electrolytic capacitor offers more capacitance per unit volume and per dollar than any other. Capacitors above eight microfarads almost exclusively are electrolytic. Brotherton[3] gives a graph which is reproduced here in Figure 1, showing the capacitance of different types of capacitors versus relative cost.

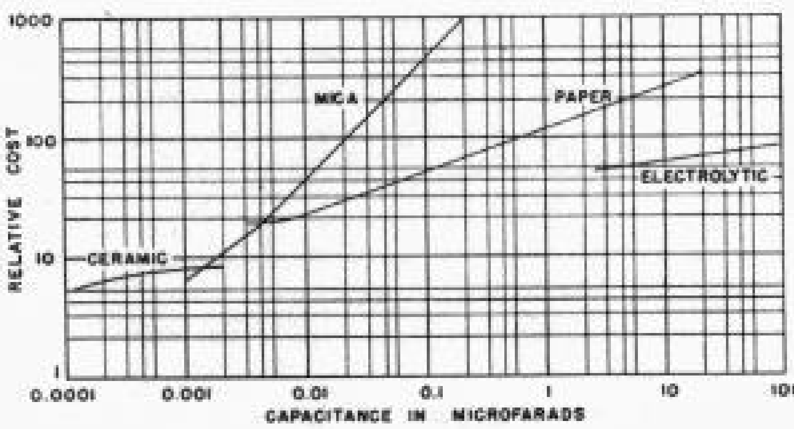

Figure 1. The relation of cost versus capacitance for different types of capacitors

Electrolytic capacitors have certain disadvantages in comparison with others,— the leakage current is larger, the power factor is higher, the temperature characteristics are inferior, and the problem of corrosion produces difficulties. This last characteristic is particularly troublesome.

Practically all defective capacitors investigated were found to have had their electric continuity disrupted because of corrosion which takes place generally in the outermost winding of the roll which is formed by the aluminum foil. When the aluminum corrodes it starts to crumble and, in a more advanced stage, forms disconnected flakes, breaking the electrical continuity of the foil.

These special considerations, combined with the capacitor's important role, warrant continuous study of its performance and characteristics. This article will give sóme of the results of such studies, in the form of a general description of electrolytic capacitors; for the application under discussion, so far only that type can be considered. After a description of the construction of the electrolytic capacitor and the different kinds of foils used, some problems of capacitance, leakage, voltaic action, and time factor characteristics will be presented.

Construction of the Electrolytic Capacitor

A capacitor is essentially a dielectric placed between two conductors (Figure 2). When a voltage is applied to the conductors, the dielectric stores up an electrical charge. When the voltage is removed and, say, a resistor is placed across the capacitor terminals, the capacitor will discharge through the resistor.

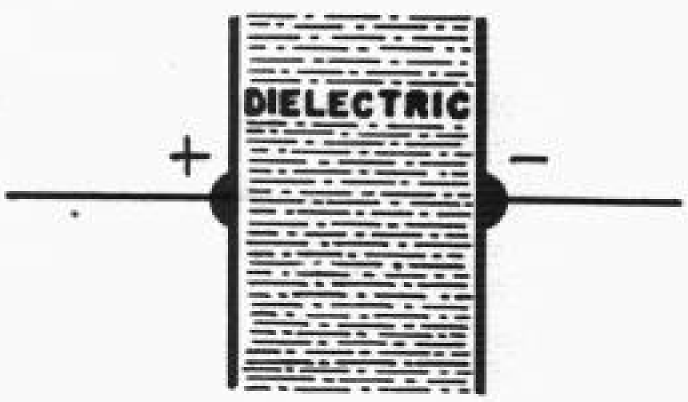

Figure 2. The basic arrangement of a capacitor

With the electrolytic capacitor, the positive potential of an outside voltage source is connected to an aluminum foil, called the anode, which is coated with a film of aluminum oxide, the dielectric. The cathode of the capacitor is an electrolytic paste which is in direct contact with the dielectric on one side and with another aluminum foil on the other side. This foil is called the cathode foil, and serves to back the electrolytic paste and to connect to the negative potential of the outside voltage source.

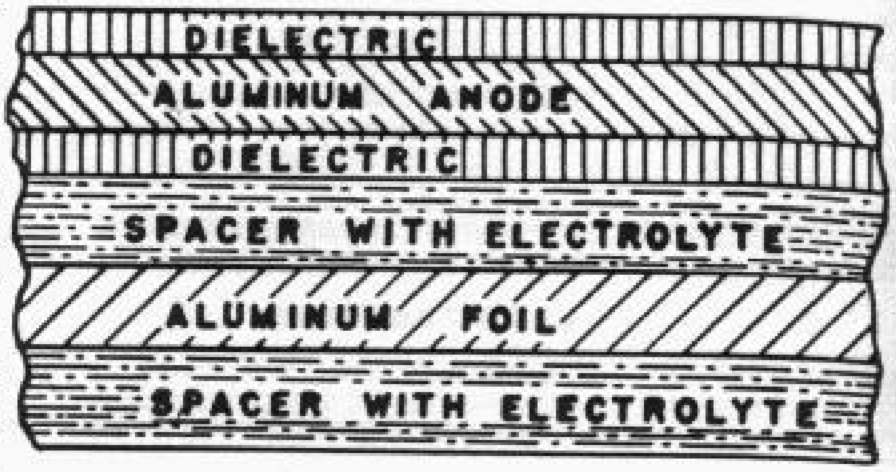

Figure 3. The various layers of an electrolytic capacitor

Figure 3 shows the physical arrangement schematically: It consists of the aluminum anode covered on both sides with aluminum oxide film as dielectric; one or two layers of absorbent paper, usually called spacers, which are soaked with an electrolytic paste; another aluminum foil; and again paper with electrolytic paste. The two sheets of aluminum foil are provided with tabs to which the electrical connections are made. The whole assembly is rolled into a tight bundle, placed in a container and sealed. It will be seen that this arrangement allows covering both sides of the anode with oxide and getting active use from them, hence the utilized surface area of the aluminum foil is the sum of the areas of both sides of the foil.

The aluminum oxide on the anode is produced by passing the aluminum foil through an electrolytic bath. The aluminum serves as an anode and the higher the voltage applied to the bath, the thicker will be the film of aluminum oxide. The maximum voltage used in the electrolytic bath is called the forming voltage. The magnitude depends on the rating for which the capacitor is built, and generally exceeds it by 10 to 20 percent. After the electrolytic bath, the oxidized aluminum foil, the paper spacer, a non-oxidized aluminum foil, and a paper spacer are rolled together.

The electrolytic paste is usually prepared as a mixture of ethylene glycol, boric acid, and ammonium acetate or borate. In the capacitor it serves as a chemical capable of repairing small flaws in the aluminum oxide. Because of its plasticity, it also provides a much better electrical contact with the dielectric than would a metallic foil. There are a number of other functions for which complete explanations have not yet been found. It suffices that they make the capacitor work.

It is necessary to force the electrolytic paste between the foils to every last spot of the paper spacer while the unit is already made up in a roll, without leaving air pockets or allowing uneven distribution. The usual procedure is to put capacitor and paste in a centrifuge. The capacitor proper is now ready. Tabs for the electrical connection have been provided, and frequently at this stage the capacitor is connected to a voltage which corresponds to the rating for which the capacitor is being built. The reason for this operation is that in the mechanical handling the aluminum oxide might have been damaged causing minute breaks or pinholes to occur. With the voltage applied, the electrolytic paste will quickly repair such minor imperfections. If the leakage current at this point is excessive, the capacitor will be rejected.

The remainder of the manufacturing process consists of making the container, soldering the connections, placing the capacitor in the container, sealing it (usually with pitch) and closing it. Finally, an aging process is used which leaves the capacitor under voltage for a considerable time, frequently up to 24 hours.

The foregoing is a general outline of the manufacture of electrolytic capacitors and does not do justice to the meticulous details required; such as, for instance, the care with which the electrolytic bath through which the anode foil passes must be purified. Frequent checking for chlorine in the water is a normal practice, for should it contain only a few parts in a million, the foil becomes unsuitable for use. Nevertheless, impurities creep in from time to time and early corrosion is the natural consequence. The statement is justified that the quality of today's electrolytic capacitor depends to a large extent upon the elimination of contamination in the process of its production.

Foils

The history of the dry electrolytic capacitor started with plain foil; today etched and fabricated foils are also used, the former having gained widespread acceptance because of its superior economy in volume. For etching, the aluminum foil is treated with acid which forms roughnesses and crevices that enlarge the surface considerably. Thus an etched capacitor obtains from the same length of foil about four to eight times the capacitance of one using plain foil. Much has been said against etched foil, much in favor of it. The difficulty lies in the necessity for complete removal of acid from the crevices after the etching. If only a trace is allowed to remain, the life of the electrolytic capacitors is greatly impaired. Manufacturers, in general, claim that this difficulty has been overcome entirely, and etched foil is coming into more and more use. Its undisputable advantage is its smaller volume and resultant saving in aluminum, a factor of considerable importance today.

Lately, "fabricated" foils are also gaining acceptance. Instead of aluminum foil, aluminum-sprayed paper is used. The capacitance per area of such foil is even greater than that of etched foil. In low-voltage applications, the area of fabricated foil for a given capacitance may be only one-twelfth of the area of plain foil. While objections to the use of fabricated foil seem to exist where ripple or alternating currents are involved, it might become a satisfactory choice for steady direct-current applications. No data concerning durability are available thus far.

Capacitance

The formula usually given to determine the theoretical capacitance of a capacitor is:

$$C = \frac{0.2244KA}{t} \tag{1}$$

where C is the capacitance in microfarads
K is the dielectric constant
A is the area of one plate in square inches
t is the thickness of the dielectric in inches

In applying this formula to an electrolytic capacitor, however, a curious discrepancy will be found. Opening a plain foil capacitor of, say, 1000 mfd and 18 volts direct current and measuring the foil, it may be found that the foil is some 17 feet long and 2½ inches wide, giving an area of 510 square inches. Since both sides of the foil are used, the useful area is 1020 square inches.

The dielectric constant of aluminum oxide lies between 7.5 and 10, and $K = 8.5$ might be arbitrarily chosen. Inserting these values in equation (1), one obtains:

$$1000 \times 10^6 = 0.2244 \frac{8.5 \times 1020}{t}$$

i.e.,
$$t = \frac{0.2244 \times 8.5 \times 1020}{1000 \times 10^6}$$

which is 2×10^{-6} inches approximately.

The thinnest oxide film used with electrolytic capacitors is about 25 millionths of an inch. This is more than twelve times the value for "t" (thickness) obtained by calculation. This discrepancy has not yet been explained. Probably, the dielectric constant must be considerably higher than 8.5. If it is, it cannot be aluminum oxide. Several theories exist; none can explain all the phenomena observed in this connection. The aluminum oxide continues to be known as the dielectric, and this is acceptable for practical purposes. Nevertheless, considering these open questions, it may be expected that the electrolytic capacitor will sometimes surprise with its irregularities.

Leakage Current

The capacitor is not able to block direct currents completely. A minute current always leaks through, and this leakage current is higher proportionately with electrolytic than with other capacitors. Generally, it is assumed that the leakage current is the consequence of cold emission, which is the emission of electrons from a cathode under the stress of a very high voltage gradient. The voltage gradient across the dielectric of an electrolytic capacitor is high. Assume a thickness of the dielectric of 10^{-5} inches across which a potential of 10 volts is applied. The voltage gradient is $\frac{10}{10^{-5}}$ or one million volts per inch, and under such high electric stress cold emission can be expected. A formula is known from vacuum-tube engineering which can be used to determine the current due to cold emission:

$$I = AE^2 e^{-(B/E)}$$

where I is the leakage current
E is the voltage applied
A and B are constants.

Deeley[4] and others give this formula for the calculation of leakage current. In checking some low-voltage capacitors, it was found that the results were not compatible with this formula.

There is another approach based on a formula given by Poole and quoted by Straimer[5] which is derived from experiments and covers the specific resistance of solid nonconductors up to a maximum voltage gradient of 10^6 volts per inch. From this formula the following equation was derived:

$$I = Ae^{BE}$$

For one specific test, for example, it was found that $A = 1.48$ and $B = 0.285$ and on this basis the leakage currents in column "a" of the following table were calculated, which show good approximation to the actually measured values listed in column "b" of the table.

Capacitor 3100 mfd, 18 volts, direct current

volts	*a*	*b*
2.0	2.6	2.4
4.0	4.6	4.0
5.8	7.7	8.5
8.0	14.5	20.5
10.0	25.0	29.0
12.0	45.2	48.0
14.0	80.0	80.0
16.0	141.5	127.0
18.0	250.0	250.0

In any event, the leakage current decreases very rapidly with decrease in voltage. Since it is possible to use a capacitor at any potential below its rating without doing it harm or changing its characteristics, the use of the capacitor at a less than rated voltage is a ready means for the reduction of leakage current.

The leakage current decreases during the first 1000 to 2000 hours of the capacitor's use. Afterwards, it remains relatively constant. If at any time the leakage current rises considerably, it is almost a sure sign that the end of life due to corrosion is at hand. An open in the capacitor will probably follow soon. It is wise to discard immediately a capacitor which exhibits increased leakage current.

Where very low leakage currents are required, it should be borne in mind such currents will decrease very rapidly not only during the first minutes but also during the first hours or even days. Voltage applied across the capacitor for 24 hours will sometimes reduce the leakage current to a very satisfactory low value, and it will remain there provided a slight voltage is maintained across the capacitor to keep it "formed".

Voltaic Action

Another characteristic of electrolytic capacitors is their voltaic action. Without any voltage applied across its terminals the capacitor may become the source of an electromotive force because of the electrochemical reaction of its internal components. The e.m.f. might reach a few millivolts, increasing when the ambient temperature rises.

A very high quality capacitor will show little voltaic effect. Nevertheless, where even the slightest effect is objectionable, a little trick might help: The polarity of the e.m.f. of the voltaic effect is independent of the polarity of the capacitor. Where the capacitor is used at about 1.5 volts or less, the polarity of the capacitor matters little and the capacitor can safely be considered to be nonpolarized. Under these conditions, the voltaic effect may be eliminated by connecting two capacitors of half the capacitance in parallel, with their e.m.f.'s opposing each other as shown in Figure 4.

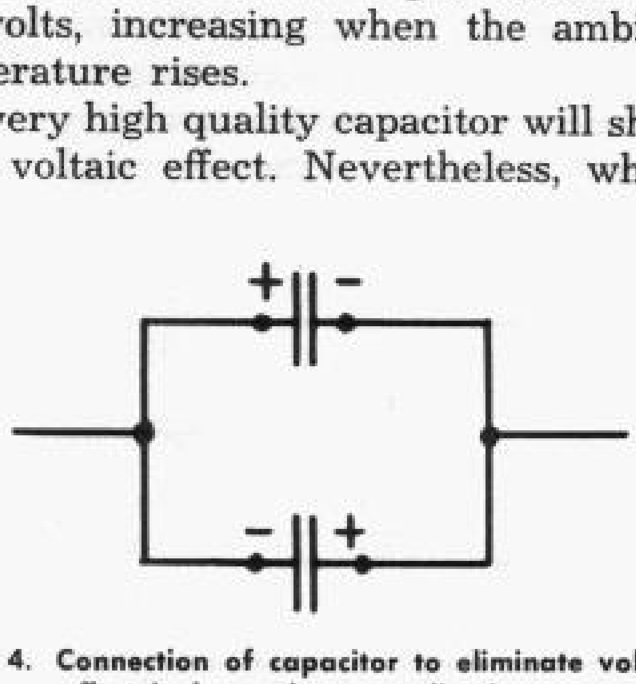

Figure 4. Connection of capacitor to eliminate voltaic effect in low-voltage applications

It also seems feasible to connect two capacitors in series, connecting minus to minus, or plus to plus, and thereby eliminating the voltaic effect. This is equivalent to using a nonpolarized capacitor.

Discharge Time and Capacitance

The voltage across a discharging capacitor is determined by the formula:

$$E_c = E_o e^{-\frac{t}{RC}} \quad (2)$$

Where E_o stands for the voltage which was applied to the capacitor before discharge, and E_c for the instantaneous voltage measured across the capacitor at any time (t) during discharge, R is the resistance through which the capacitor discharges, and C is the capacitance of the capacitor. When $t = RC$, then, according to equation (2), one can write

$$E_c = E_o e^{-1} = 0.368\, E_o$$

In other words, at $t = RC$ the voltage across the capacitor has decreased to 36.8 percent of its initial value. For example, when the resistance is 5 megohms and the capacitance is 5 mfd, then:

$$t = 5 \times 10^6 \times 5 \times 10^{-6} = 25 \text{ seconds}$$

i.e., the voltage across the capacitor decreases to 36.8 percent of its maximum value within 25 seconds. The length of time obtained by multiplying R times C, is called the time constant or the RC constant.

The R is usually taken as the circuit resistance connected to the capacitor. This is the fallacy which makes itself noted when in practice the increase of capacitance does not produce a corresponding increase in the time factor. It is necessary to consider not only the circuit resistance but also the leakage resistance. The leakage current of a capacitor is defined (RMA) as the conductor current flowing through the capacitor. An equivalent circuit connecting a capacitance in parallel with what can be called the equivalent leakage resistance can be used to represent the leakage current condition. The equivalent leakage resistance would then correspond to a resistor in parallel with the load connected across the capacitor.

A 25-volt, 50-mfd, electrolytic capacitor might have a leakage current of 4 mils, and the equivalent leakage resistance would be about 6,000 ohms.

Suppose a voltage of 25 volts is applied across this capacitor. The voltage is then removed and the capacitor discharges into a 12,000-ohm resistance. Without taking into consideration any equivalent leakage resistance, the *RC* constant would be

$$12{,}000 \times 50 \times 10^{-6} = 0.6 \text{ second} \quad (3)$$

If the equivalent leakage resistance is taken into account, the total resistance into which the capacitor discharges would be

$$R_t = \frac{12{,}000 \times 6{,}000}{18{,}000} = 4{,}000 \text{ ohms}$$

and the *RC* constant becomes

$$4000 \times 50 \times 10^{-6} = 0.20 \text{ second}$$

This might be called the *RC* factor for a constant leakage condition. It does not correspond to actual facts because the leakage current, and therefore the equivalent leakage resistance, is not a linear element. One can only conclude that the actual *RC* constant would be somewhere between 0.20 and 0.60 second. The larger the resistor into which the capacitor discharges, the more will the equivalent leakage resistance modify the *RC* constant.

Taking now two capacitors of the same values as above and connecting them in parallel, an *RC* constant is obtained (not including equivalent leakage resistance) of

$$12{,}000 \times 2 \times 50 \times 10^{-6} = 1.20 \text{ seconds}$$

or twice the *RC* constant calculated in equation (3) for one capacitor only. The assumption of constant leakage condition and inclusion of equivalent leakage resistance would result in an equivalent circuit which would represent the two equivalent leakage resistances in parallel with the load resistance. Lumping the three resistances results in a total circuit resistance of 2,400 ohms and the *RC* constant would be

$$2400 \times 2 \times 50 \times 10^{-6} = 0.24 \text{ second}$$

which is only 20 percent more than the *RC* factor calculated for one capacitor only. Again, one must correct for the rapidly decreasing equivalent leakage resistance, but it can be stated that the total time constant is somewhere between 0.40 and 0.24 second with a marked tendency towards the lower value.

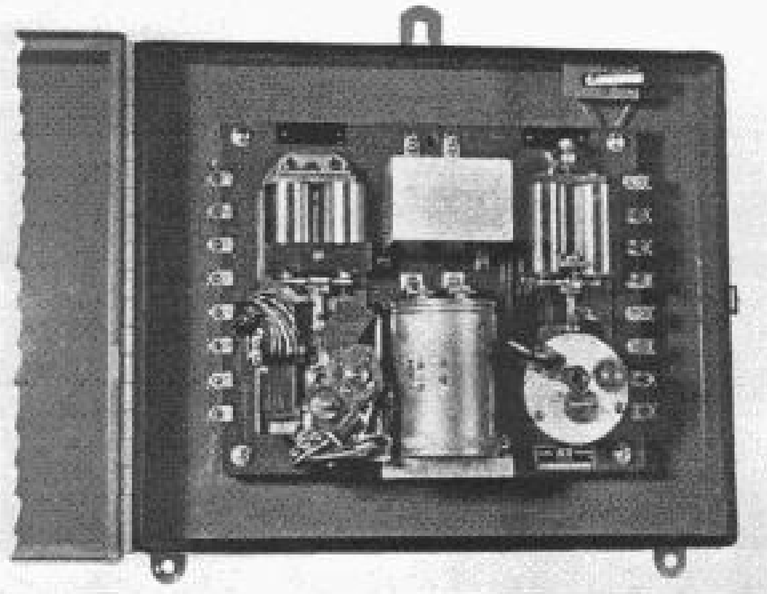

Figure 5. Typical ADT transmitter with 3100-mfd capacitor

Probably the most frequent use of electrolytic capacitors in circuit design is where time delays of a few seconds are involved. Assume a relay with a resistance of 1200 ohms operates one or several electrical contacts. When the power is removed from the relay, the contact switching action takes place immediately. If it is desired to delay the action for 12 seconds, for instance, a capacitor can be used, the size of which is determined by the methods discussed before, i.e.,

$$RC = t$$
$$\text{or } 1200 \times C = 12$$
$$\text{and} \quad C = 0.01 \text{ farad}$$

or 10,000 microfarads. Only electrolytic capacitors allow concentrating so much capacitance into relatively small space, and therefore no other type of capacitor can be used for this purpose.

Werner G. Holzbock has been with the A.D.T. Company, Inc., a Western Union subsidiary, since 1947. He is a Bureau Supervisor and in charge of Industrial Process and Heating Supervisory Services. In addition, he handles special research assignments similar to the one on electrolytic capacitors on which he reports in this issue. Mr. Holzbock studied in Germany and Chile, and is now a candidate for the Master's degree in Mechanical Engineering at Columbia University. He is the author of a number of articles which appeared in INSTRUMENTS, CHEMICAL ENGINEERING, and HEATING and VENTILATING.

Application

Figure 5 shows a typical application of an electrolytic capacitor in one of ADT's devices. To replace it in the field, only a few screws have to be loosened to slip out the capacitor and mount a new one. Figure 6 shows the circuit. Without going into the details of operation, it can be seen that relay A is normally de-energized because of the high voltage drop in T_2, the transmitter supervisory winding. When the contacts on the actuating device close, indicating an alarm condition, they shunt the T_2 winding, and enough current will then flow through relay A to energize it. When this happens, relay A opens its contact A_1 and the circuit through relay R is opened. This relay will not drop out until the capacitor has sufficiently discharged. The time constant in this case is 4.34 seconds, as can be easily verified, which means that the potential across the relay R drops to 36.8 percent of its initial value within this time. Since, however, the relay is adjusted for a smaller drop-out value, it operates only after ten seconds. If the contacts of the actuating device open again at any moment within the retard, even if only momentarily, the initial conditions are restored immediately. Once, however, the relay R drops out, it locks itself out by its contact R_2 and the transmitter is tripped to send in an alarm signal.

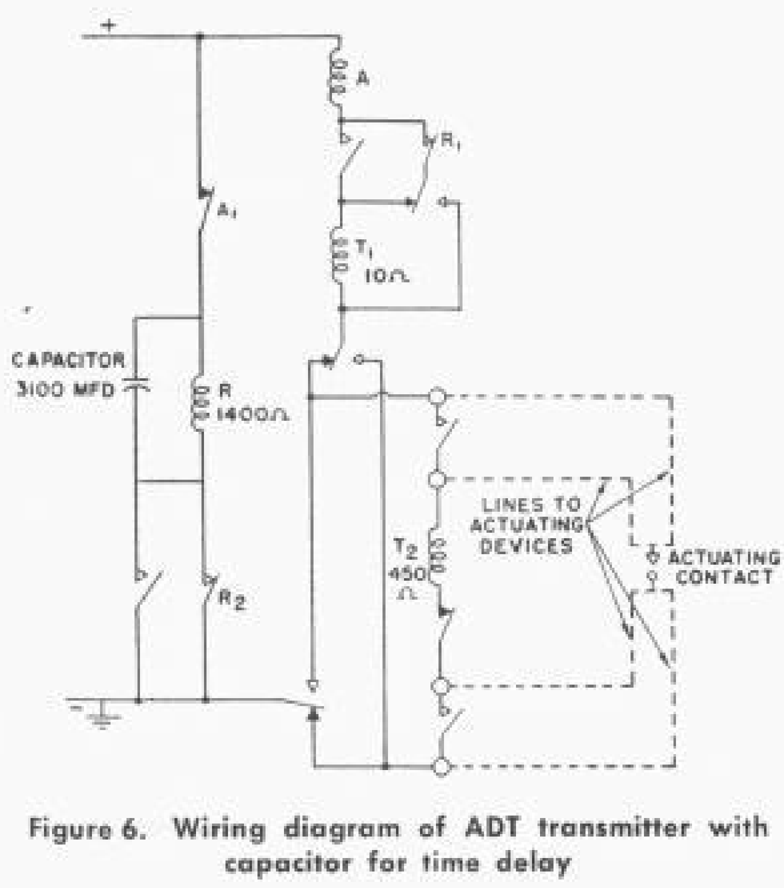

Figure 6. Wiring diagram of ADT transmitter with capacitor for time delay

Conclusion

The purpose of capacitors as used with ADT equipment is usually to obtain time delays similar to the one described above. Other time delay components are available, such as thermal delays which require a heater to supply sufficient heat before switching action can occur, or orifice types which require a gas or a liquid to escape through a small orifice before switching action takes place, but none has proved to be more acceptable for our applications than the electrolytic capacitor. In the first place, electrolytic capacitors are immediately recycling. When the power across the relay and, therefore, across the capacitor, is restored, the capacitor obtains its full charge almost immediately, and any new open in the electrical circuit produces a new full time delay. In the second place, the electrolytic capacitor has no moving parts, thus eliminating possible mechanical failures. A capacitor may fail, but by careful supervision of production methods and by a fully air-tight sealing of the capacitor can, it is possible to boost its life up to as much as 15 years.

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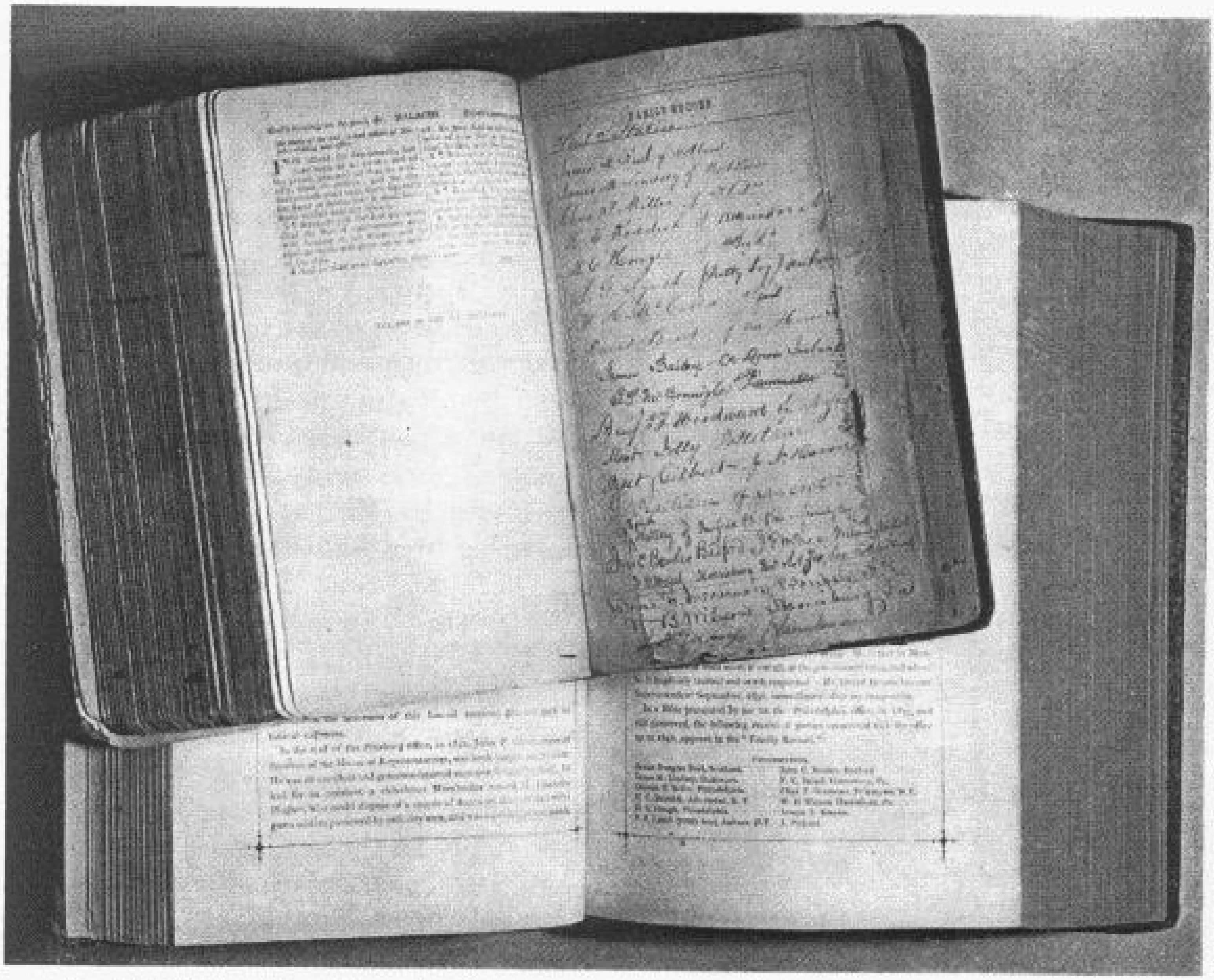

In 1849 The Atlantic and Ohio Telegraph Company's superintendent, James D. Reid, inscribed the names of his associates in a Bible which he presented to the Philadelphia office of the company. Among the names are those of men who figured prominently in the organization, construction or operation of early telegraph systems.

The fact of the presentation was recorded by Mr. Reid some thirty years later when he wrote his monumental work "The Telegraph in America" as a Memorial to Samuel Morse. The Bible is preserved today at the headquarters of Western Union, of which the Atlantic and Ohio became a part in 1864.

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A selected list of reference books in the field of telecommunications compiled by the Chairman of the Committee on Technical Publication at the request of a reference library. Certain very old items are included to cover fields in which no new material has appeared in many years.

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