WESTERN UNION Technical Review

Telegraph Terminal —
Circuit Design Aspects
Equipment Features

•

Teleprinter Concentrator —
Los Angeles

•

Overseas Telecommunication

•

Engineering Pole Lines

•

Fourier Series Analysis

•

Air-Conditioning System

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CONTENTS

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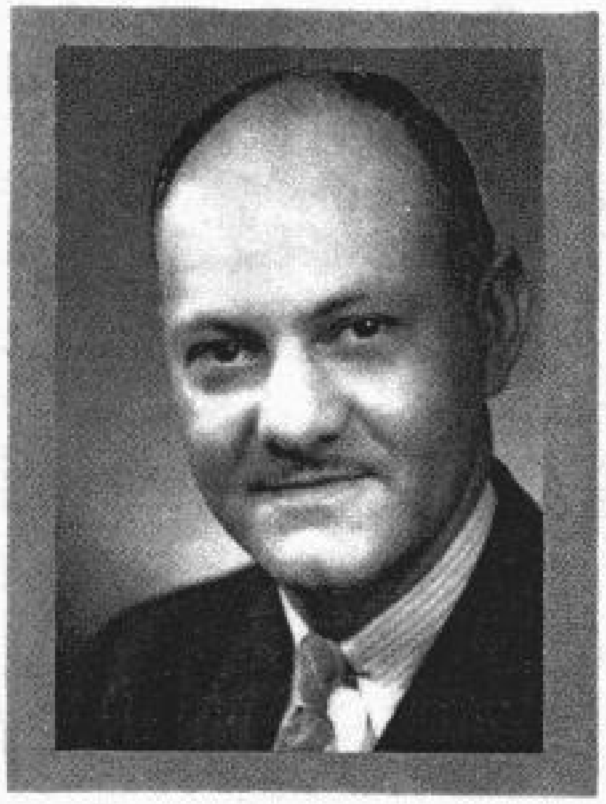
IT IS with real pleasure that I accept the invitation of the Committee on Technical Publication to greet the readers of the Western Union TECHNICAL REVIEW throughout the Western Union family. First, I want to wish you and all of your families a Happy and Prosperous New Year.

I have watched the development of our TECHNICAL REVIEW since its inception and I can think of no activity in Western Union that has given me a greater feeling of solid achievement than to see chronicled, issue by issue, the technological developments and improvements of the past several years. I am sure that we are all better informed and more capable of working as an aggressive intelligent team than we would have been without the REVIEW.



Thomas F. McMains

Our progress as the foremost company engaged in record communications, as well as our progress as individuals employed by that company, is in large measure dependent upon the quality of the research, engineering and technical skills of Western Union people. Research to keep us at least a few steps ahead of our competition, engineering skill in transforming the products of research into the most modern and efficient communications equipment possible, and the efficient installation and maintenance of operating equipment in its service applications are all basic contributions to our over-all objective of giving the kind of telegraph service that will merit the continued support of those we serve.

Forecasting the future is in most respects an unrewarding pastime, but I think that one aspect of our future can be forecast without fear of error. The future will bring engineering advances to our industry, perhaps at an even greater rate than during the years we have just passed through. I have every confidence that Western Union people will continue to achieve the kind of research, engineering and technological progress that will maintain Western Union's leadership in the record communications field. I shall be looking to the pages of TECHNICAL REVIEW for the story of that future progress as it unfolds.

T. F. McMains

VICE PRESIDENT AND
ASSISTANT TO THE PRESIDENT

January 1, 1955.

Telegraph Terminal AN/FGC-29 Circuit Design Aspects

J. E. BOUGHTWOOD

TELEGRAPH TERMINAL AN/FGC-29 was designed to meet the specific requirements of military radio communication. These requirements are necessarily of an exacting nature and the resulting circuitry involves features not commonly employed in commercial telegraph terminal equipment. The importance of securing optimum performance and continuity of operation was a major design consideration. It is the purpose of this paper to cover briefly the more significant characteristics of the equipment circuitry.

The terminal provides 16 frequency-shift, 100-wpm telegraph channels starting at 425 cycles and continuing at 170-cycle intervals to 2975 cycles. Multiplexing equipment is included to permit simultaneous utilization of both 6-kc sidebands of the radio facility for telegraph, telephone or facsimile. The telegraph channel transmitters are conventional in design employing frequency-shift oscillators such as are commonly used in wire line systems. The oscillator tank constants are varied by switching diodes so as to produce marking frequency when the sending telegraph loop is closed and spacing frequency when the loop is open. The receiving terminal is considerably more complex than wire line equipment because of the special requirements imposed by the vagaries of radio propagation.

Diversity Operation

It is common practice on long-range radio telegraph circuits to employ diversity operation, either space or frequency or both, so as to mitigate the effects of selective fading. A number of schemes have been proposed and utilized by various workers in the field, all with the purpose of extracting the maximum useful intelligence from the received signals. A comprehensive study of a number of combining systems was made for the Signal Corps by Crosby Laboratories, Inc.,[1, 2] and resulted in the "ratio squaring" method employed in the present terminal.

Briefly the method involves the following basic concepts: Firstly, the signals to be combined are added subsequent to detection so that the signal voltages add arithmetically in phase while the random noise components associated with each signal can add only on a root mean square basis. A 3-db improvement in signal to noise is thus obtained when two signals of equal amplitude are combined. This is in addition to the normal diversity improvement factor.

Secondly, to obtain the optimum signal-to-noise ratio when the received signals differ in amplitude, the theory indicates that the signals shall contribute to the combined resultant in proportion to the

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This and the following paper were first presented by the authors at an IRE-AIEE Symposium on Military Communication held in the Western Union Auditorium in New York on April 28, 1954.

Besides the Boughtwood and the Cusack papers the program included a fundamental treatment of frequency and space diversity systems by Murray G. Crosby of Crosby Laboratories, Incorporated, and a systems application paper by Alfred Mack and R. H. Levine of the Signal Corps Engineering Laboratories. The Crosby presentation was not offered for publication. The Mack and Levine paper, entitled "A New Multichannel Teletype Terminal for Use on Long Range HF Radio Systems," together with the two papers presented here, appear in the AIEE publication *COMMUNICATION AND ELECTRONICS* of November 1954, pages 531 to 544. They will appear also in *TRANSACTIONS OF AIEE*, Volume 73, Part I.

square of their relative amplitudes. This is of particular importance in the presence of a high noise level where the noise associated with a faded signal would otherwise be combined with the normal signal to effect a 3-db degradation. Further, any amplitude-modulation effects on the received carrier should be eliminated, a function normally performed by a limiter in conventional circuits, so as to preserve the advantages of frequency-shift transmission.

Combining Circuit

A circuit operating in accordance with the combining theory is shown diagrammatically in Figure 1. Common AGC amplifiers and individual logarithmic expanders are utilized. The amplifiers, having a common AGC control, always have equal gain, the gain being an inverse function of the signal possessing the higher received level. Thus the ratio of the two incoming signal levels is preserved at the amplifier outputs with the stronger signal having a constant value determined by the common delayed AGC voltage of the amplifiers. The logarithmic expanders are forward acting devices having a loss in db which is an inverse function of the input level in db. The amplitude ratio of the signals at the expander outputs thus follows the square of the input ratio as required by the theory. The signals are combined by adding the discriminator outputs in series aiding as indicated.

The design objectives for the combining system contemplated a 45-db fading range over which the common AGC amplifiers should maintain the same relative gain to close limits so as to realize fully the theoretical advantage of the ratio squaring method. Additionally the response time was required to be sufficiently short to remove the amplitude effects of noise as well as the amplitude modulation introduced by channel filters in the presence of keyed signals. The bandwidth of the channel filters, particularly the receiving filter, is the major factor determining the time constant of the AGC system. Filters having a high discrimination against adjacent channels are inherently narrower than less rigorous filters and so introduce a greater amplitude modulation transient on frequency-shift signals. The amplitude transient is in the form of a damped oscillation having a frequency of approximately twice the maximum dotting rate, or about 80 cycles in this case. This is also about the maximum cancellation rate between signal and noise components. In addition, the AGC system must not only compensate for signal fades of 45 db, but also must not interfere with the operation of the lowest frequency telegraph channel at 425 cycles,

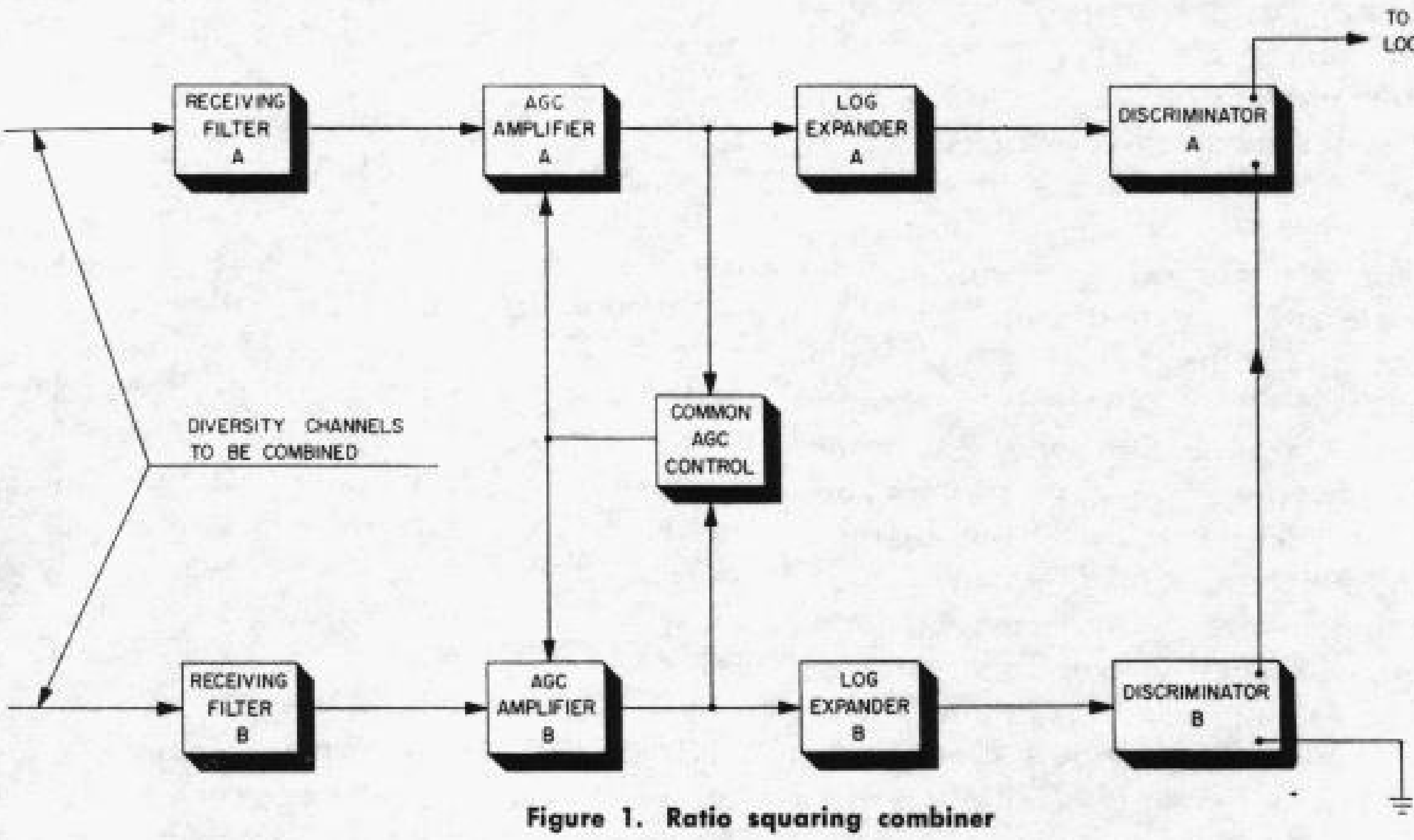


Figure 1. Ratio squaring combiner

and must have an adequate margin of stability against self-oscillation under all conditions.

It may be of interest to indicate some of the conditions which must be met if a stable system is to be realized. Three general cases are given. An AGC amplifier can be considered as a variable attenuator or variolosser followed by a fixed gain stage, a detector, and a low-pass filter feeding the d-c control voltage back to the variolosser as indicated in Figure 2. The variolosser can also be considered as a balanced modulator wherein the amplitude of the incoming signal is modulated in accordance with variations in the d-c control voltage.

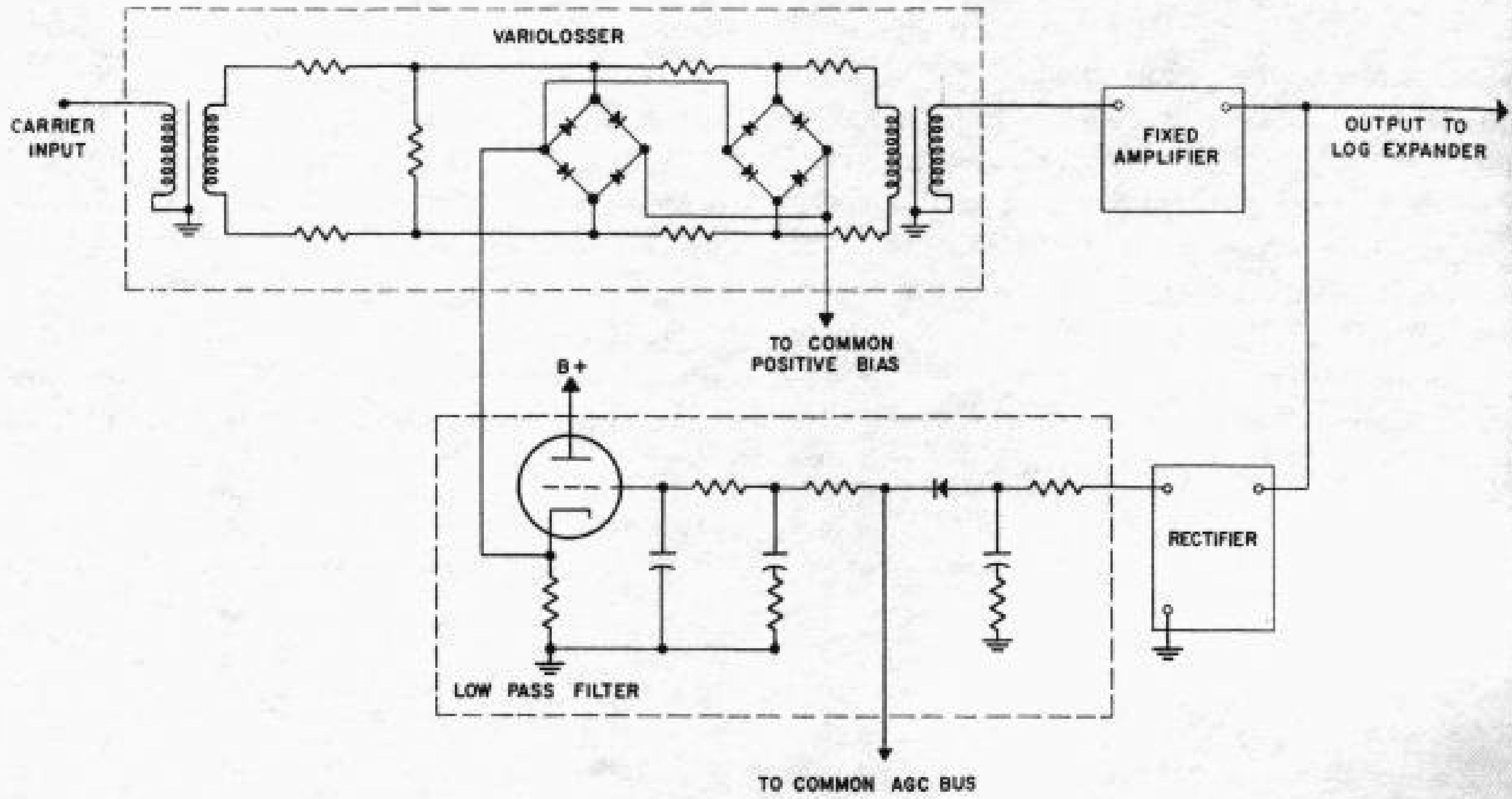


Figure 2. AGC amplifier

Case 1—Low-Frequency Stability

Low-frequency stability involves the direct regeneration of control frequencies lying below the cutoff frequency of the low-pass filter. Oscillation will occur where the loop gain is greater than unity for any frequency having a phase shift of 180 degrees. Loop gain is the sum of the fixed amplifier gain, the low-pass filter loss and the magnitude and phase of the modulator unbalance. Theoretically, a perfectly balanced modulator would provide infinite loop loss, but practically, to maintain a high degree of balance over a fading range of 45 db would require extremely close matching of components. This is undesirable from an operational viewpoint where the ability to replace components from stock items is a practical requirement. It is therefore necessary to control the loop characteristics by proper design of the low-frequency cutoff of the fixed amplifier and the high-frequency cutoff of the low-pass filter to meet the attenuation and phase shift characteristics for stable operation.

Case 2—Subharmonic Generation

Instability of this type involves the received carrier frequency, the action being similar to a 2-to-1 regenerative frequency divider. If F represents the received carrier frequency and the loop loss for F/2 is insufficient, then the F/2 component in the output of the low-pass filter will regenerate itself in the modulator stage by interaction with F, and both F and F/2 will appear in the amplifier output.

Case 3—Modulation Instability

Instability of this type produces an amplitude modulation on the received carrier. Modulation takes place in the balanced modulator or variolosser stage and is subject to the full gain of the fixed stage. The modulation is recovered in the detector and if the low-pass filter attenuation is insufficient and its phase shift is 180 degrees, the modulation will be self-sustaining. As the phase shift is decreased, a damped modulation transient will be produced each time the carrier shifts due to signalling. The decrement of the transient increases as the phase shift is further reduced.

The requirements for stability and the rapid response time needed to stimulate limiter action indicated that the desired performance was incompatible with a carrier frequency as low as 425 cycles. It was decided to limit the lowest carrier frequency to 1785 cycles so that a satisfactory network design could be achieved. As shown in Figure 2, the variable gain section of the AGC amplifier is a two-stage balanced variolosser employing germanium diodes as variable impedance elements. The variolosser is designed to have

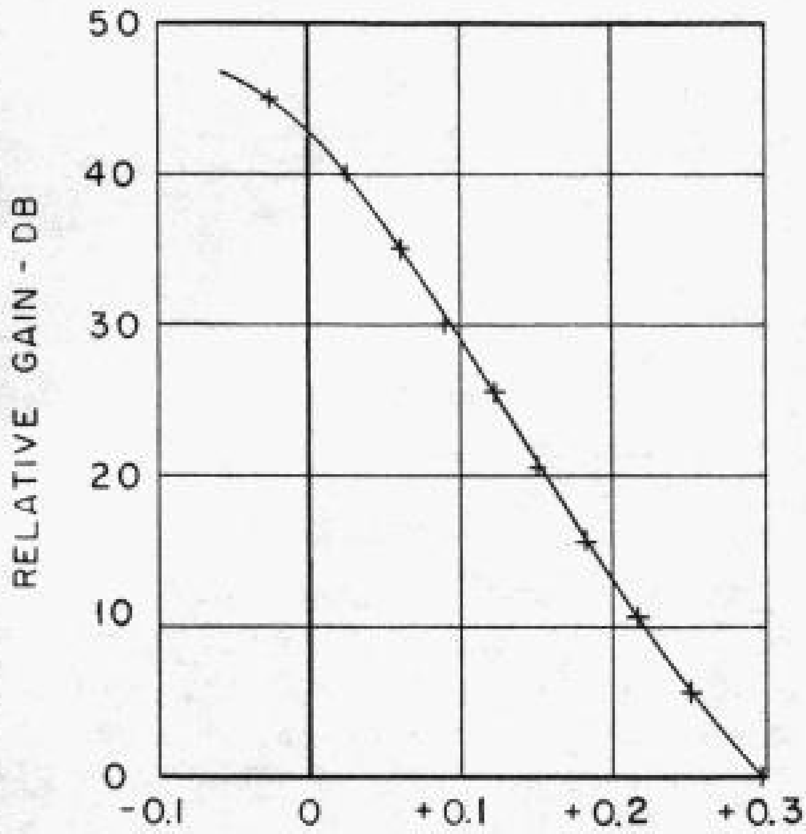


Figure 3. AGC amplifier control characteristic

a linear loss in db relative to applied control voltage so that substantially uniform AGC sensitivity is realized over the fading range with corresponding uniformity of transient response. Figure 3 shows the relation between amplifier gain and applied control voltage. Figure 4 shows the relation between the input and output levels of the AGC amplifier. A 45-db reduction in input produces only 1 db reduction in output, (a voltage ratio of 1600 to 1), so that the equivalent of limiter performance is substantially realized.

It is possible to maintain a much closer tolerance on the gain characteristic with varistor variolossers than with conventional AGC circuits utilizing vacuum tubes. This is particularly important for 4-channel combining where the four AGC amplifier gains must track over the fading range if optimum circuit performance is to be realized. If the maximum operating temperature is excessive for germanium, silicon junction diodes can be employed. In either case precautions must be taken to operate the varistors associated with a common diversity group at substantially equal temperatures for optimum performance.

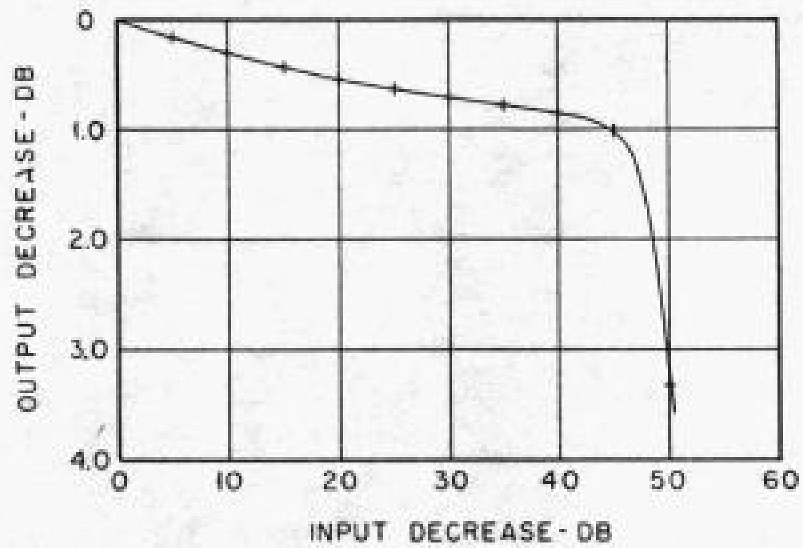


Figure 4. AGC amplifier level response

The logarithmic expander also uses germanium diodes as the loss-controlling elements as shown in Figure 5. In this case, the circuit is designed to give a 2:1-db ratio between output and input as shown in Figure 6. By definition, the action of an expander is to magnify any amplitude variations of its input. The response time of the expander has been made slower than that of the AGC amplifier so that expansion will be applied only to the fading component and not to signalling transients or high-frequency cancellations between signal and noise. Here again silicon junction diodes can be used with a slight change in circuit configuration if temperature conditions warrant. Advantage can be taken of the fact that the loss characteristic of a silicon variolosser is less influenced by temperature than germanium when the control current is essentially independent of diode resistance. This could not be done with the AGC amplifier where the variolosser control current had to be an inverse function of diode resistance in order to obtain a linear instead of logarithmic response.

Addition of the diversity signals is effected subsequent to detection by connecting the discriminator outputs in series aiding. The circuitry is conventional and includes a d-c limiting amplifier driving a pair of parallel connected output pentodes which key the receiving loop. Approximately 25 db of post-detection limiting is realized.

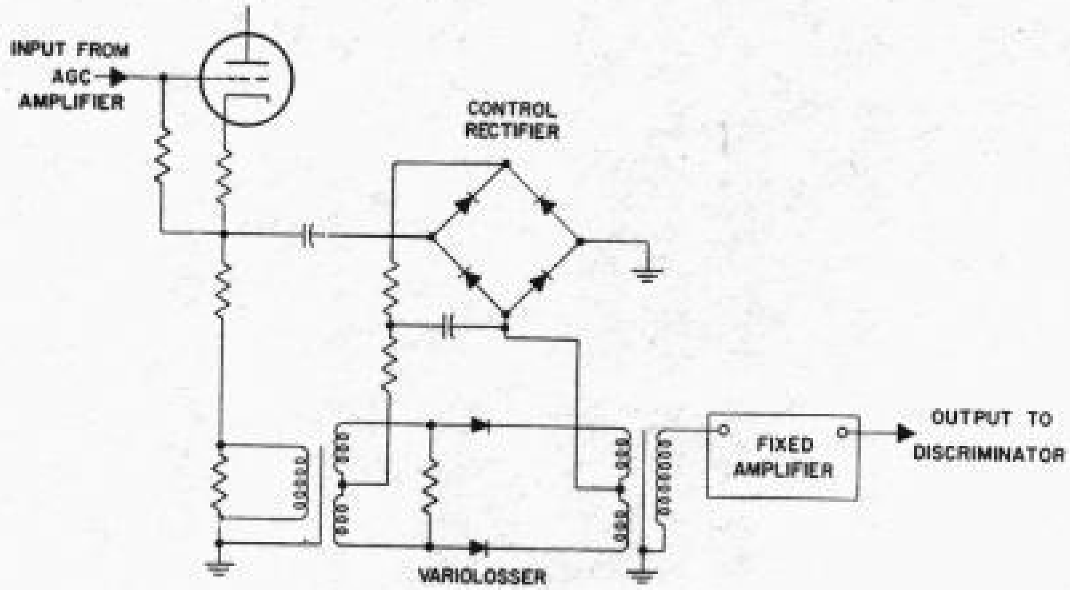


Figure 5. Logarithmic expander

Subgrouping Equipment

In order to permit a lower frequency limit of 1785 cycles in the AGC amplifier circuits and still maintain the normal 425 to 2975 channel frequencies on the line, two identical sets of 8-channel groups covering the 1785- to 2975-cycle range are employed per terminal. The method of channel designation is such that one group is assigned odd channel numbers and the other group even channel numbers. The odd group is transmitted and received without translation. The second or even channel group is translated down to the 425-1615 cycle range for transmission. A second translation at the receiver restores the even channels to the 1785- to 2975-cycle range. Not only does this method simplify the AGC amplifier design, but it also reduces the fortuitous keying loss usually associated with low carrier frequency channels. A secondary advantage is the reduction in number of channel filter types and other tuned circuits peculiar to a given frequency channel.

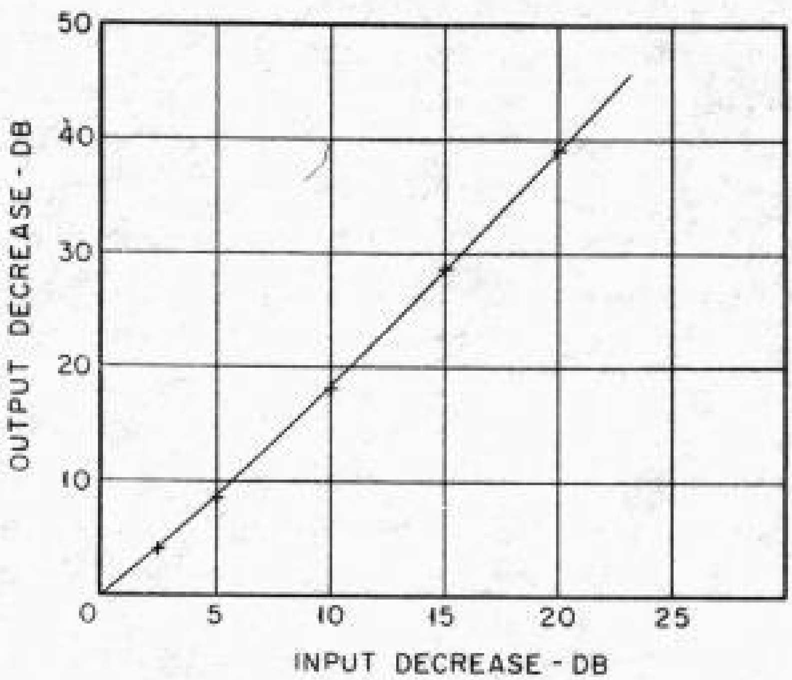


Figure 6. Logarithmic expander level response

The group translators employ two successive stages of modulation to achieve the desired frequency conversion. Conversion in two stages eliminates the need for extremely sharp cutoff in filter characteristics with a corresponding decrease in delay distortion for channels lying adjacent to cutoff. The possibility of a normal level received signal in the odd group interfering with a faded signal in the even group due to direct signal leak through a single-stage modulator is also eliminated. Figure 7 is a block diagram of the sending translator. Conventional double balanced germanium diode modulators are used with carrier frequencies derived from crystal-controlled oscillators by regenerative type frequency dividers. Figure 8 is a frequency allocation chart showing the translation process. The even channel group is first modulated by a carrier of 9.69 kc. A band-pass filter selects the lower sideband lying between 6715 and

7905 cycles. This sideband is then modulated by a 6.29-kc carrier. The lower sideband selected by a low-pass filter now lies between 425 and 1615 cycles in the normal line-frequency allocations of the system. The translator at the receiving terminal employs a similar technique to restore the even channel group to its original frequency band.

Delay Equalization

In a diversity telegraph system, it is important that the discriminator output signals to be added be in proper time phase. Any time displacement of diversity channels inherent in the system design due to filters, interconnecting wire facilities or radio equipment will directly reduce the tolerance to fortuitous displacements resulting from selective fading or noise. An adjustable delay network has therefore been provided at the output of each channel receiving filter so that systematic delay differences between channels to be combined may be equalized. A maximum delay of 6 to 7 milliseconds is realized by the bridge type phase shifter shown in Figure 9. This amount of delay is easily achieved because of the narrow bandwidth allocated to each channel relative to its carrier frequency.

The measurement of systematic delay differences introduced by transmitting and receiving equipment separated by an intervening radio circuit is complicated by the effects of selective fading which cause random time shifts in the received signals and may cause them momentarily to fall below the noise level. To alleviate this difficulty the differential delay indicator shown in Figure 10 has been incorporated in the receiving terminal metering facilities. In practice a single dotter transmits a-c reversals on the two channels to be equalized in respect to each other. The two channels are terminated in separate loops which are patched to the delay comparator. The comparator consists of a pair of balanced bridge arms, R, connected to an integrating zero center d-c meter circuit through a switching type detector operated in synchronism with the incoming loop reversals. If the dotting reversals on the two loops are received in exact time phase, the voltage across the bridge arms R will be zero and the meter will read zero. When the two loop signals have the time relationship indicated at A and B, the signal appearing across the bridge will be as shown at C. The diode reversing switch is in effect controlled by the sum of the differentiated loop signals having the shape shown at D for this case. The voltage to the integrating meter circuit is shown at E and produces a negative deflection of the meter. If the time relation of the two loops is reversed, the bridge and switch output voltages also reverse to produce a positive meter reading. Random jitter of the loop transitions due to fading or noise will integrate to zero so that only systematic differences in delay will be indicated. The signal having the least delay

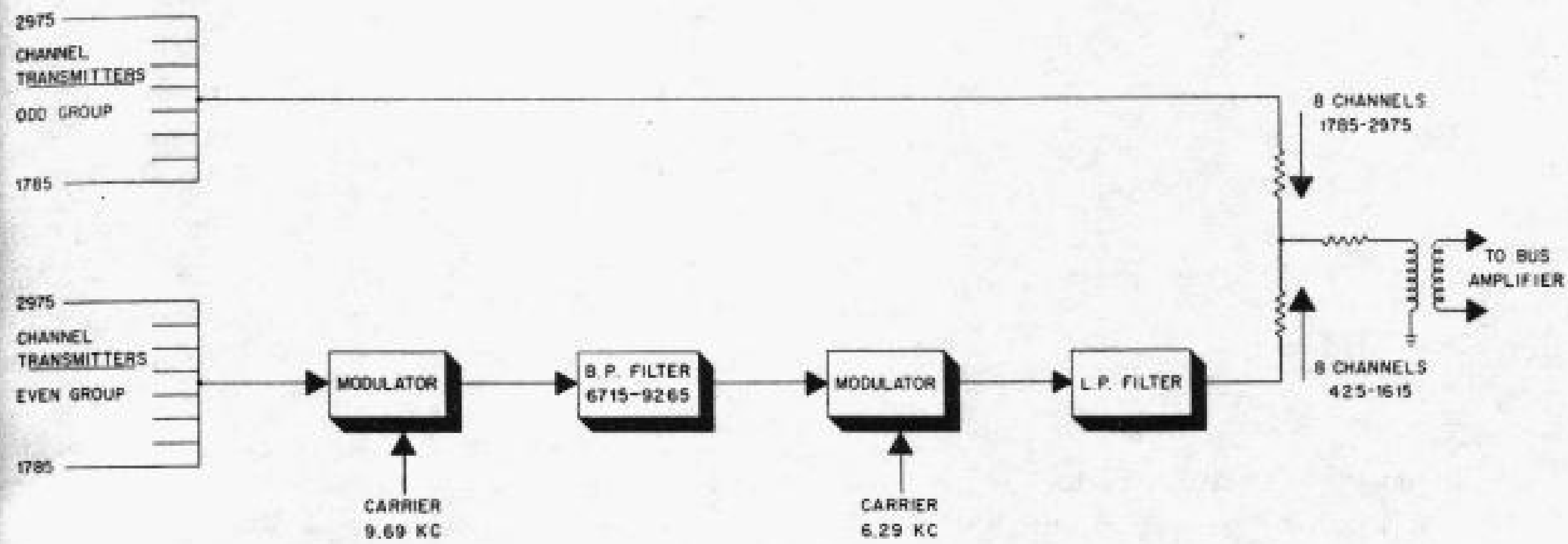
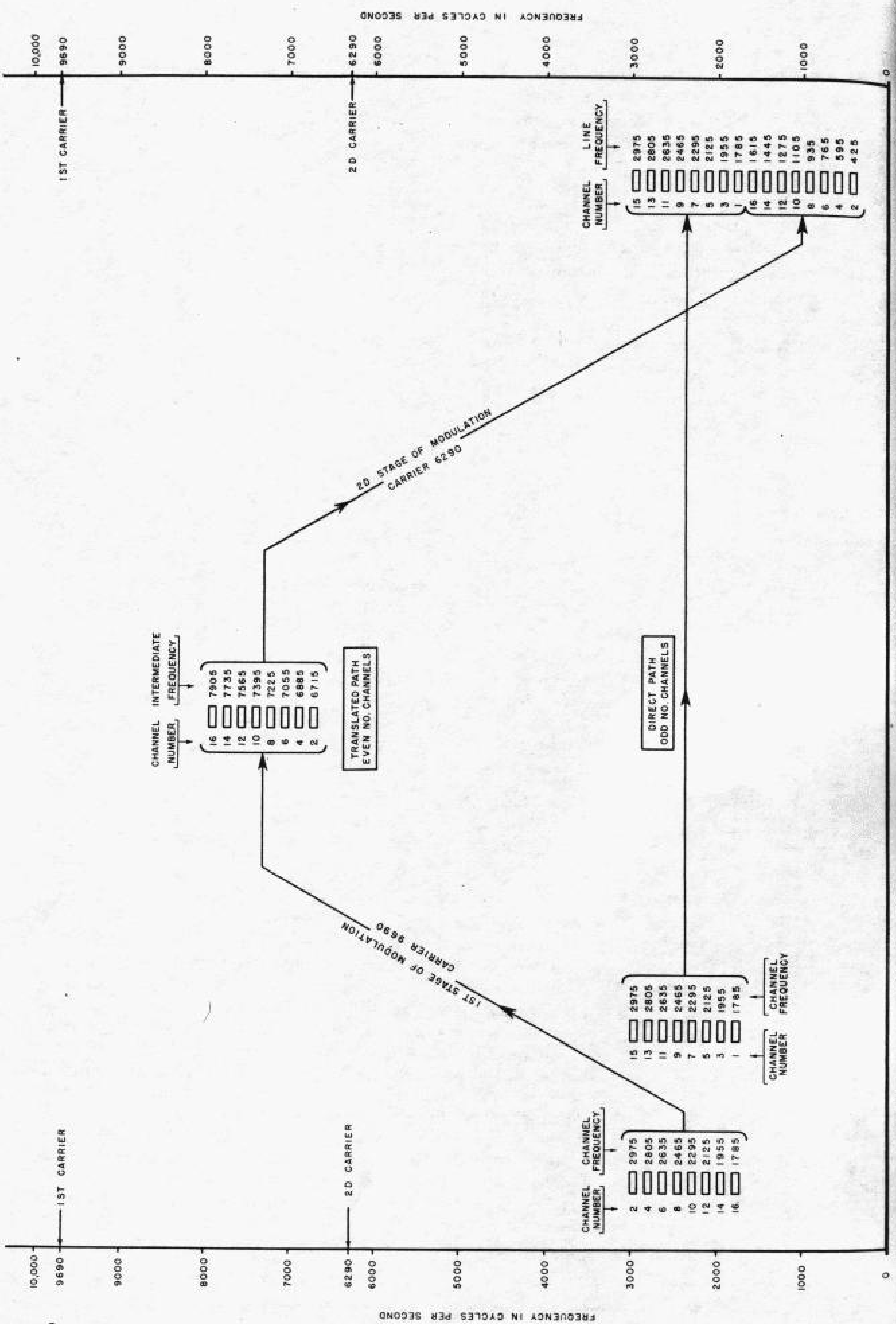


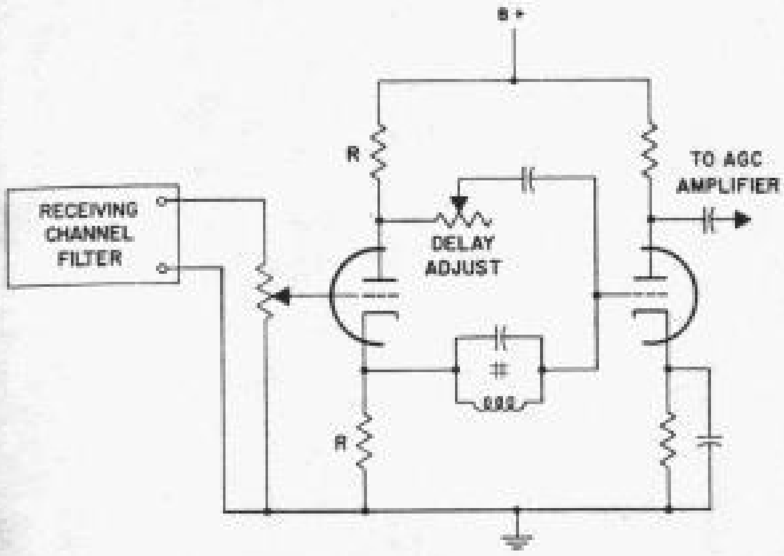
Figure 7. Sending translator


FREQUENCY IN CYCLES PER SECOND
1ST CARRIER
2D CARRIER
CHANNEL NUMBER
CHANNEL FREQUENCY
1ST STAGE OF MODULATION
CARRIER 9690
INTERMEDIATE FREQUENCY
TRANSLATED PATH EVEN NO. CHANNELS
2D STAGE OF MODULATION
CARRIER 6290
DIRECT PATH ODD NO. CHANNELS
LINE FREQUENCY

is brought into proper alignment by means of its adjustable delay network. Delay adjustments are required to be checked when changes in the system arrangement are made and not as a routine operation.

Conclusions

Telegraph Terminal AN/FGC-29 is not yet in production but comprehensive tests have been conducted on a design approval model to evaluate the electrical design and substantiate the combining theory. A multiple path fading simulator and noise generator were employed to simulate a long-range radio circuit. Performance was definitely superior to currently available equipment but qualitative data must await further testing on actual circuits.



TUNED TO MID BAND FREQUENCY

Figure 9. Adjustable delay network

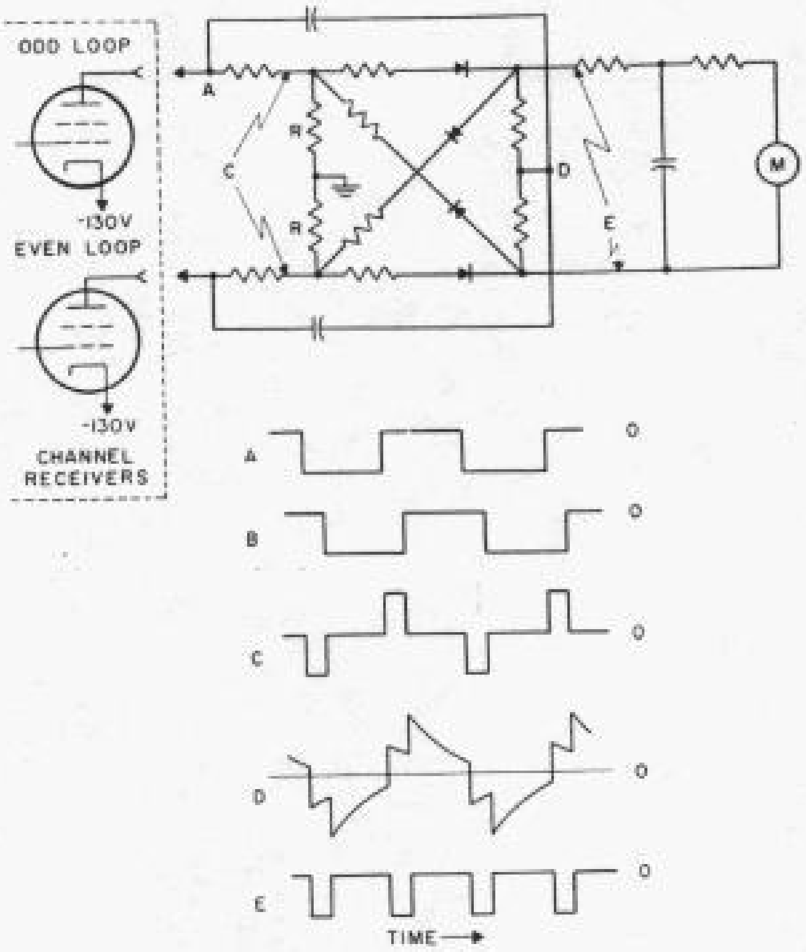


Figure 10. Differential delay indicator

References

1. Final Report–Signal Corps Contract No. DA-36-039 SC-15359.
2. U. S. Patent Application No. 365964.

J. E. Boughtwood came directly to Development and Research upon graduation from Northeastern University in 1930. His early work in d-c telegraph transmission resulted in increased speed and reliability in time-division multiplex working. For the past several years, as Assistant to the Transmission Research Engineer, he has led a large group engaged in the development of carrier systems. Under his guidance have come both the narrow-band telegraph channels and the wider "vehicle" channels which provide paths by wire line and radio relay for multichannel telegraph groups. His original work and valuable contributions in frequency-modulated telegraphy led quite naturally to his selection to direct the development of the highly specialized system required for military radio application. Mr. Boughtwood is the author of numerous technical papers, holds several patents in his field, and is a Member of both AIEE and IRE.

Telegraph Terminal AN/FGC-29 Equipment Features

F. H. CUSACK

TELEGRAPH TERMINAL AN/FGC-29 is the terminal equipment for a voice-frequency carrier telegraph system, designed in accordance with military requirements and intended for use in transmission over long-distance military radio circuits. The equipment is being developed by Western Union under a Signal Corps contract at the present time. So far, the developmental phase of the project has been completed and a design approval model constructed. This was accepted after extensive tests by Signal Corps engineers, and a final model now under construction will incorporate certain technical changes found necessary in the course of that work. Up until the present time, no operating experience has been obtained with the FGC-29 terminal in field service, so information on the subject that can be presented now is in the nature of a preliminary report on the project. However, the results of the acceptance tests indicate that the equipment will meet all of the specified requirements and that the system will provide dependable operation under extremely adverse conditions of selective radio fading.

Technical Characteristics

Telegraph Terminal AN/FGC-29 provides facilities for 16 carrier telegraph channels capable of operation at speeds up to 100 words per minute. The telegraph channels use frequency-shift carrier signals with a deviation of plus or minus 42.5 cycles from the mean channel frequency. The center frequencies of the channels are spaced 170 cycles apart, starting at 425 cps and continuing up to 2975 cps.

Electronic keying is employed on both the sending and the receiving telegraph loops. The loops use neutral d-c signal currents of either 20 milliamperes or 60 milliamperes. Loop power supplies are provided in the equipment, and the transmitting terminal will also meet situations where loop battery of either polarity is to be furnished by the associated telegraph equipment connected to the loop.

The FGC-29 terminal will be used to provide teletype communication over twin-channel, high-frequency, single-sideband radio circuits. Operation through selective fading is accomplished by means of diversity combining methods with facilities provided for both two-channel and four-channel diversity combining, using frequency diversity, or space diversity, or both.

The performance requirements for two-channel diversity combining are that the over-all peak telegraph distortion introduced by the terminal equipment shall not exceed 5 percent at 100 wpm, provided either of the incoming diversity signals is being received at normal level. If one signal fails completely and the second is attenuated by as much as 40 db, the peak distortion shall not exceed 7 percent. These requirements have been met despite the unusual degree of discrimination against interchannel interference which had to be provided in the receiving channel filters. Because of the selective nature of radio fading, it is required that any channel be capable of satisfactory operation even though the fading produces a 40-db difference in level between channels.

In addition to carrier telegraph facilities, the complete terminal includes multiplexing equipment to derive two 3-kc voice-frequency circuits from each of the 6-kc sidebands of the radio. Equalizing and amplifying equipment is also provided to permit operation of the terminal over cable pairs to remotely located radio stations.

Diversity Combining

The FGC-29 equipment employs a unique method of diversity combining which provides a high degree of system flexibility. The incoming signals which are received over two different space diversity or frequency diversity paths are applied to two separate inputs of the receiving terminal, designated as the A Path and the B Path. For each telegraph channel, signals from the A Path are combined with those from the B Path to provide a single output. With two-channel diversity combining, the signals so combined are always of the same frequency.

Under adverse fading conditions, further operational improvement is obtainable by employing four-channel diversity combining. This is done in accordance with a prearranged system whereby the even-numbered telegraph loops are made idle and each of the odd-numbered transmitting loops is made to drive two channel transmitters simultaneously. For example, if Channels 1 and 2 are switched to four-channel diversity, transmitting Loop No. 2 becomes idle and the telegraph signals on Loop No. 1 drive both channel transmitters together. At the receiving end, four incoming signals are combined to produce one output. Two of these are at the frequency of Channel 1, and the other two at the frequency of Channel 2. The output telegraph signals appear on receiving Loop No. 1, while Loop No. 2 becomes idle. The channel frequency allocation is such that the odd-numbered and even-numbered channels to be combined are always 1360 cycles apart in frequency. Transferring from two-channel to four-channel diversity combining is accomplished by operating one switch in the transmitting terminal and one in the receiving terminal for each pair of channels to be combined. No realignment or readjustment of the equipment is necessary. If four-channel diversity is employed throughout the terminal, the capacity of the system is reduced to eight channels.

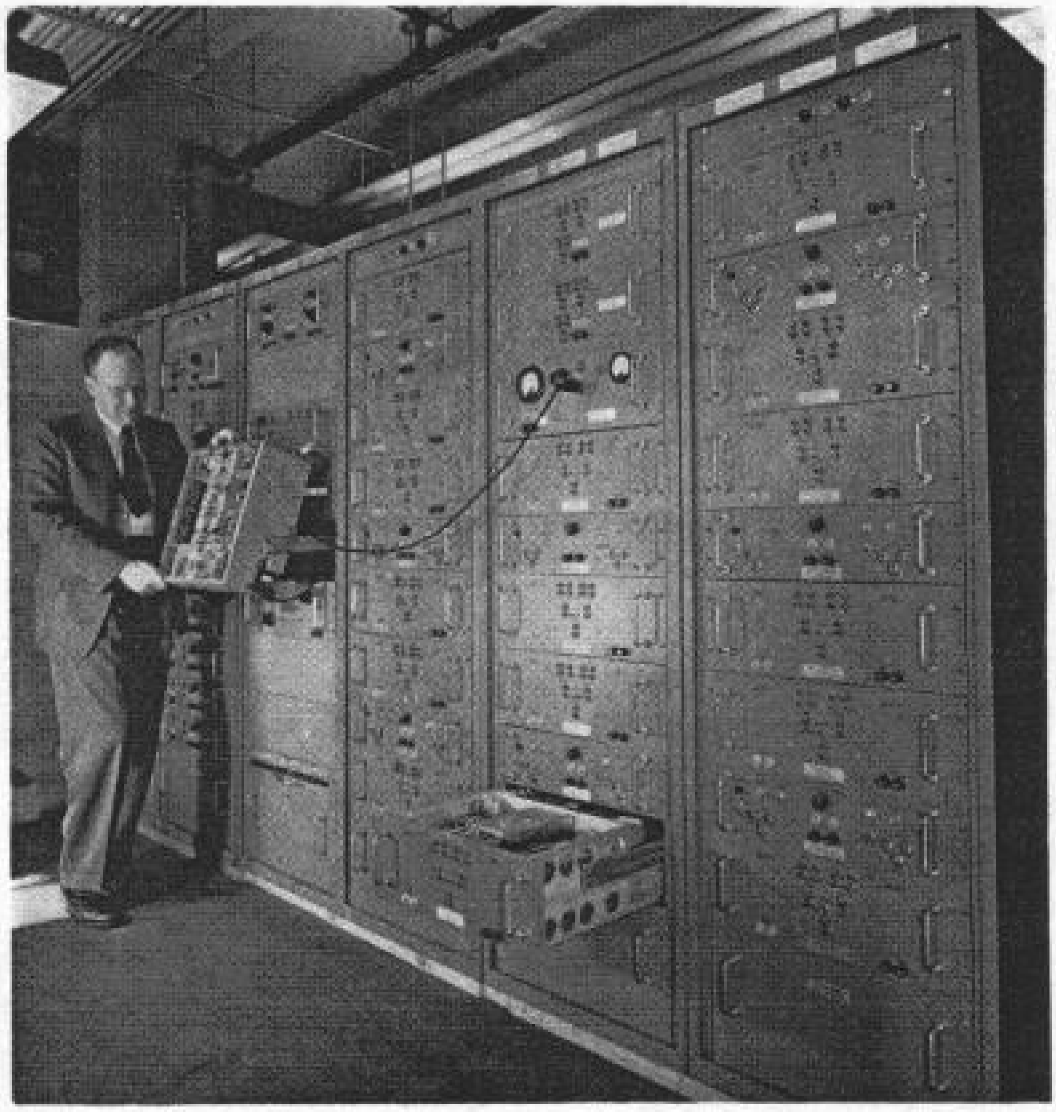


Figure 1. Telegraph Terminal AN/FGC-29, design approval model

Equipment Description

The AN/FGC-29 terminal is designed specifically for military fixed plant installations where it must provide long periods of reliable service with a minimum amount of maintenance and readjustment. Service conditions include ambient temperatures ranging from 32 degrees F to 122 degrees F and relative humidities up to 95 percent. Ruggedness and the ability to withstand the rigorous handling encountered in military service are important considerations in the mechanical design. Military transportation conditions impose unusual requirements on the ability to resist shock and vibration. Storage under temperatures from minus 80 degrees F to plus 160 degrees F is contemplated.

The equipment must tolerate power supply variations of plus or minus 10 percent from the nominal 230 or 115 volts alternating current. Regulated power is provided in the terminal wherever needed to meet this requirement. There are three a-c voltage regulators, each with a capacity of 500 watts. Total power consumption for the terminal is 3500 watts.

As shown in Figure 1, the complete terminal consists of six steel cabinets, each 75 inches high, 22-1/2 inches wide, and 24 inches deep. Each cabinet is ventilated by a blower with filtered air intake. The first two cabinets contain the transmitting equipment and the remaining four comprise the receiving equipment. The sending and receiving equipments are completely independent of each other and need not be installed in the same location. The installation work required for the terminal has been made very simple and

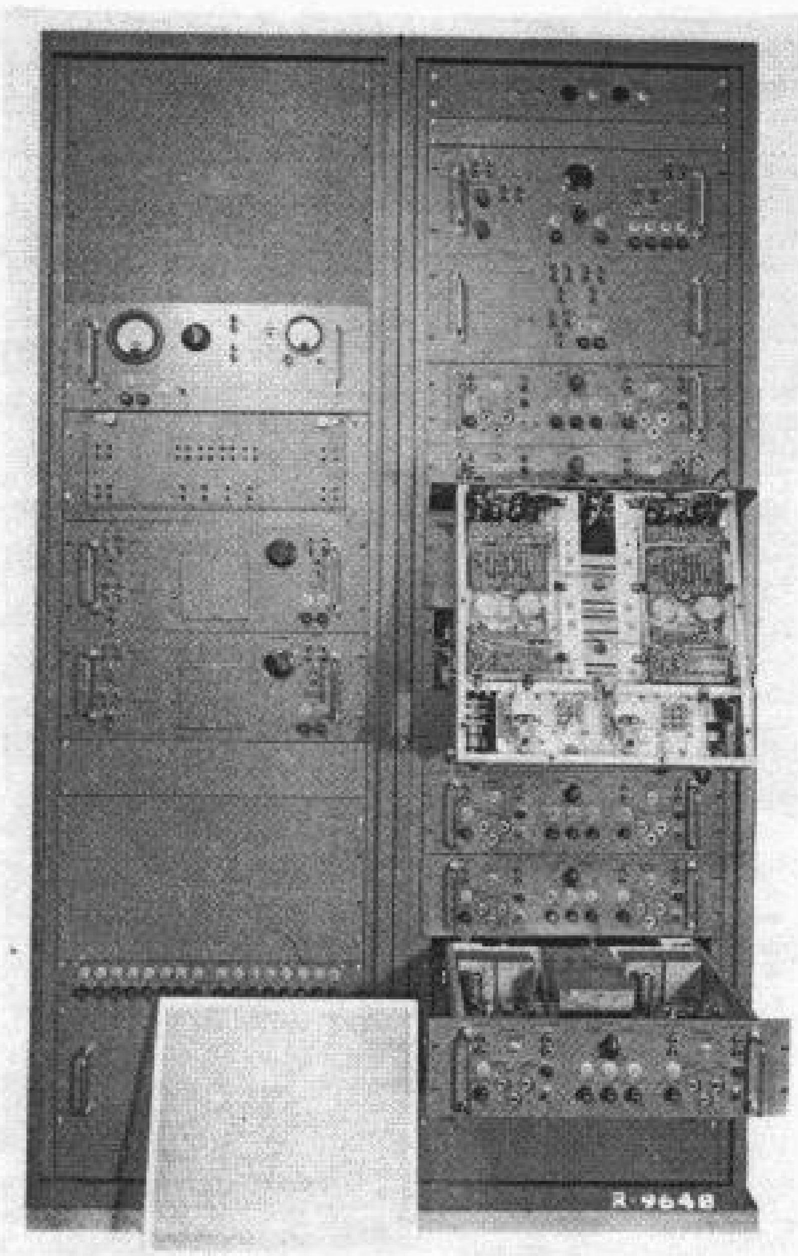


Figure 2. Transmitting terminal, showing drawer-type chassis

is largely a matter of running in the a-c power and the telegraph loop circuits. All interconnections between cabinets and between units within a cabinet are quickly made by means of plug-in multiconductor cables which permit installation without resorting to wiring lists and without making soldered connections.

Figure 2 shows the transmitting terminal alone. Carrier transmitters for the 16 telegraph channels are contained in eight panels mounted in the cabinet on the right. Each panel contains the two transmitters which are associated with each other for four-channel diversity operation. Metering and jacking facilities required for the operation of the terminal are contained in the cabinet on the left, along with multiplexing and power supply equipment.

As shown, drawer-type chassis construction is employed so as to afford the maximum accessibility for maintenance. Drawers may be drawn out to permit work on the top or bottom of a chassis without interrupting service. Those drawers which are associated only with specific channels may be removed from the cabinet without interfering with the rest of the system. The drawers containing multiplexing and equalizer amplifier equipment are independent units, complete with power supply. When needed at a remote location, they are removed from the drawer slides in the cabinet and are then mounted by their front panels on any standard 19-inch relay rack. No wiring

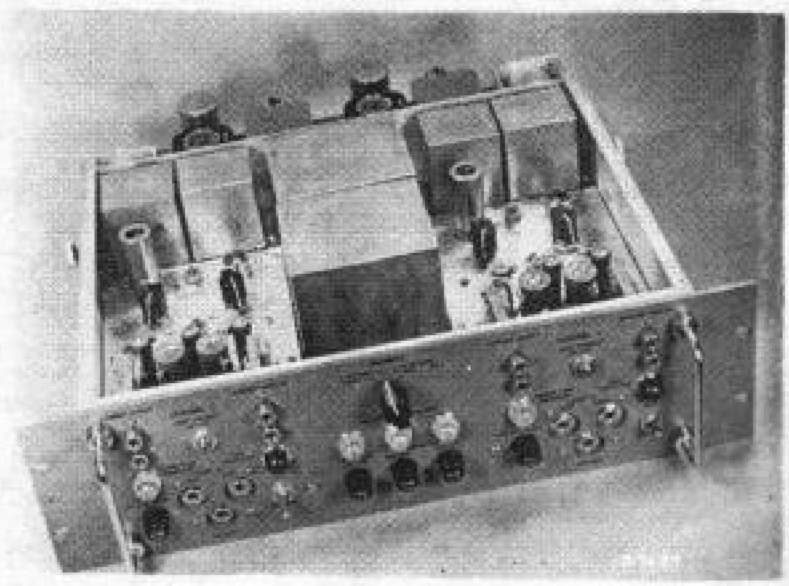


Figure 3. Transmitter drawer

changes are required in the terminal when this is done. The missing units are replaced by dummy circuit panels provided with connectors which cut through the transmission circuits from which the equipment was removed.

Figure 3 shows one of the channel transmitter drawers and will serve as a representative example of the chassis construction employed throughout the FGC-29 equipment. This particular drawer contains the carrier telegraph transmitters for Channel 1 and Channel 2. When the DIVERSITY switch in the center of the front panel is in the 2 CHANNEL position, the two transmitters are keyed independently by d-c telegraph signals from Loop No. 1 and Loop No. 2. But when this switch is thrown to the 4 CHANNEL position, both transmitters are keyed from Loop No. 1 in the manner explained previously. Also located on the front panel are carrier and loop jacks, fuses and blown fuse indicators, and such other controls as are needed for day-to-day operation and maintenance practices. Test points and controls that are used less frequently are located inside the drawer and become accessible when the drawer is pulled out.

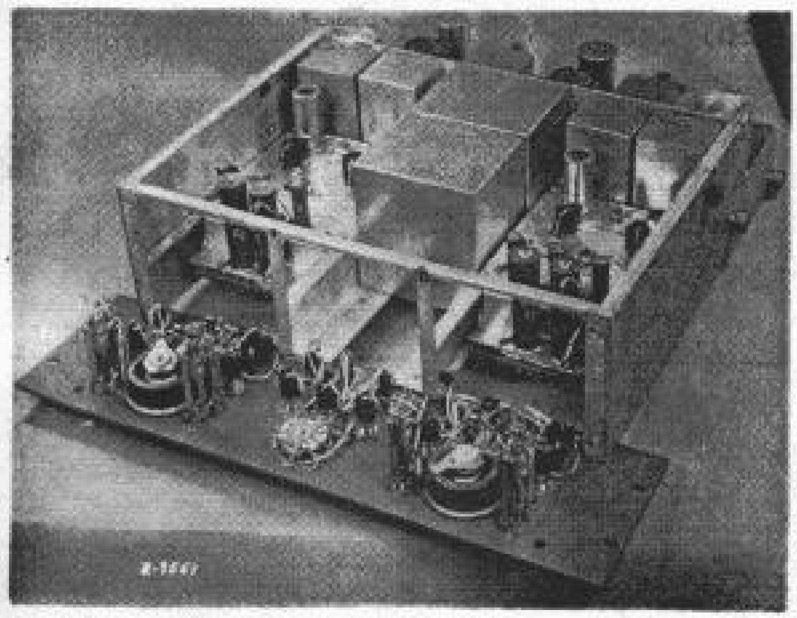


Figure 4. Transmitter drawer, front panel dropped

Figure 4 shows the same drawer with the front panel dropped down to reveal the internal construction. It will be seen that the drawer chassis forms a framework on which unitized subassemblies are mounted. Filters and similar sealed units are located in the center with electronic subassemblies, such as amplifiers, oscillators, modulators and the like, on either side. Power supplies are mounted in a separate compartment across the rear. External power is brought to a connector at the rear right and external signal wiring to a multiple pin connector at the rear left. Cabling in the bottom of the drawer interconnects these with the various subassemblies and with the components located on the front panel.

A typical subassembly is shown in Figure 5. This is a miniature amplifier used repeatedly throughout the terminal for a variety of different circuit applications. It has a gain of 50 db and is stabilized with about 25 db of negative feedback. It is used in 600-ohm circuits over the frequency range from 350 to 6000 cps. Rated power output is plus 22 dbm, at which level the second and third harmonic distortions are each down by at least 60 db.

Three cabinets of the receiving terminal

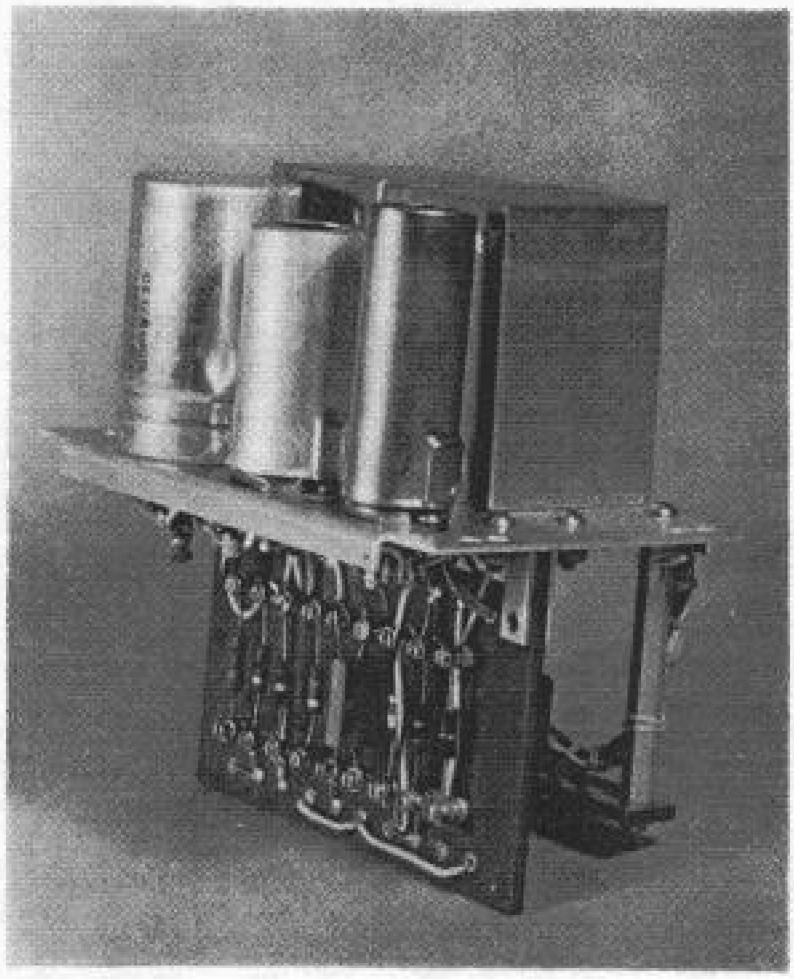


Figure 5. Typical subassembly

are shown in Figure 6. Channel receivers for 16 carrier telegraph channels are contained in 16 separate panels, each of which provides for incoming signals from A Path and B Path of one channel. In this illustration the receiver for Channel 1 is the large panel near the top of the first cabinet. Directly below it is a smaller panel, the combiner for Channels 1 and 2, and below that is the receiver for Channel 2. These three units perform the receiving function corresponding to that of the transmitter drawer shown in Figure 3. When the DIVERSITY switch on the front panel of the combiner is in the 2 CHANNEL position, incoming signals from the A Path and B Path of Channel 1 are combined to provide d-c telegraph signals for Loop No. 1. The process is repeated independently for Channel 2 and Loop No. 2. But when this switch is in the 4 CHANNEL position, all four inputs are combined to key Loop No. 1 only. The arrangement described for Channel 1 and Channel 2 is repeated for all the rest of the channels in pairs, each pair consisting of an odd-numbered channel and an even-numbered channel.

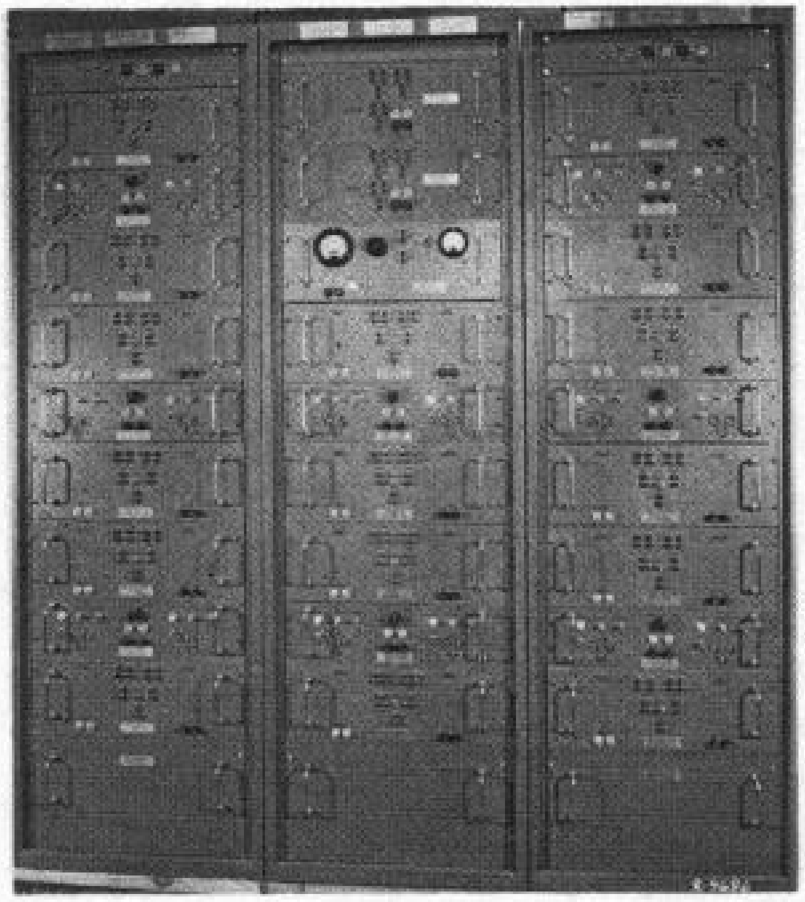


Figure 6. Part of receiving terminal

The receiving terminal has its own metering facilities, including a meter for measuring the difference in propagation time for the signals which are combined. Adjustable time delay networks in the receivers permit these differences to be equalized. Also included in the receiver are jacking and alignment facilities, multiplexing and equalizer amplifier equipment, and power supplies contained in the fourth cabinet, which is not shown in this illustration.

Conclusion

In closing, it might be well to repeat that this brief discussion is no more than a preview of Telegraph Terminal AN/FGC-29. Only the more significant features of the equipment have been described and its more important characteristics mentioned. Because this terminal is quite versatile in its application and can be adapted to a number of different situations, it is expected that the FGC-29 will be used widely in establishing future military communication networks.

F. H. Cusack joined the Development and Research organization of the company upon graduation from Cornell in 1929. His foundation for modern transmission development is based on a number of years spent in d-c telegraphy, in mitigation of power interference, crossfire correction, wave-shaping networks and allied problems. For the past several years he has devoted much effort to carrier equipment design and has made valuable contributions to the technology. He is perhaps best known for a fundamental improvement in suppressed carrier modulators. Mr. Cusack's reputation in the carrier telegraph field and his recognized ability at technical writing were factors in his assignment to the dual diversity radio-carrier project. He was recently advanced to the title of Assistant to the Transmission Research Engineer. Mr. Cusack is a Member of AIEE and currently vice chairman of its Telegraph Systems Committee.

Plan 6 Receiving Teleprinter Concentrator in the Los Angeles Office

R. D. SWANSON

IN ORDER TO utilize fully the increased speed of service obtained with the recent Western Union mechanization program, a system for expedient pickup and delivery of telegrams between patrons' offices and central offices was essential. While teleprinter concentrators were not new, an efficient, rapid, production-line type of operation was needed for large tie-line installations. A system as nearly automatic as possible, which would still permit central office operators to be in close contact with each patron for necessary corrections, routings, rates and acknowledgements was required. A most essential condition was immediate connection to the central office equipment on an equal basis for all patrons.

It was to meet these conditions that the Plan 6 Concentrator was developed.

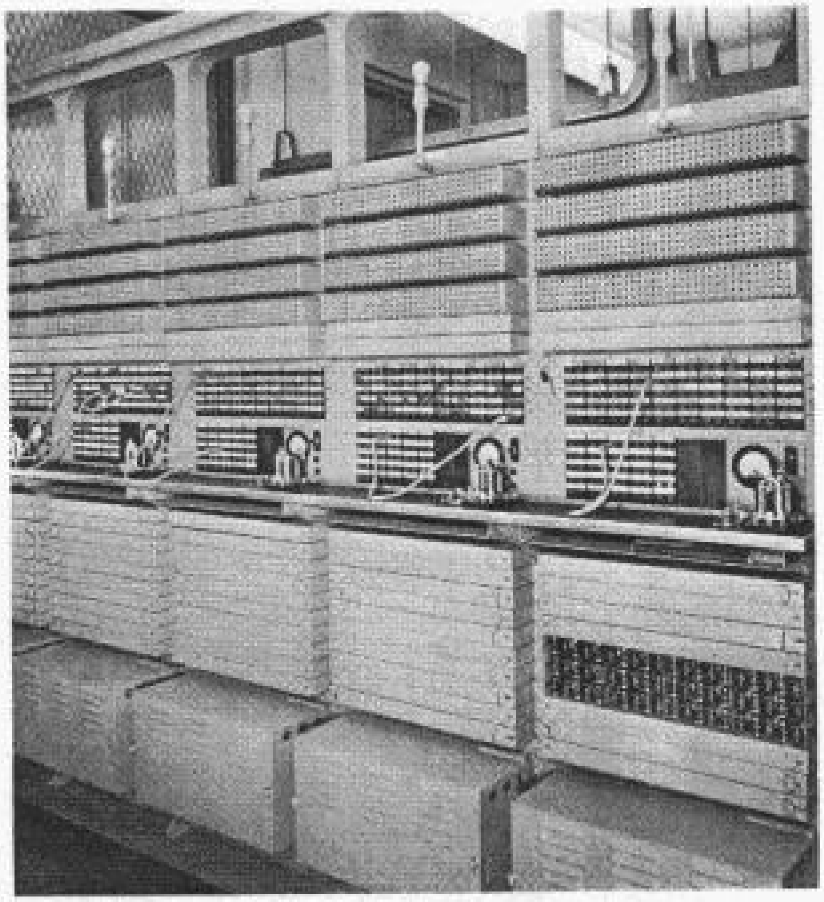


Figure 1. Concentrator Rack 104-A

Concentrator Components

Concentrator Rack 104-A, Figure 1, is the line terminating position. It provides termination for a basic group of 100 tie lines and contains individual line jacks for testing and monitoring, and a line current regulating resistor. A set of two relays associated with each line is used for detecting the busy condition of the line.

Primary Line Finder 1076-A, Figure 2, consists of relay banks, rotary switch banks and a potential cabinet containing the necessary relay current limiting resistors and d-c battery terminals. Each rack has a 100-line capacity, which is divided into two groups of 50 lines. Conventional 50-point two-level magnetically operated rotary switches are used to provide the basic concentration of the two 50-line groups into two 8-line groups.

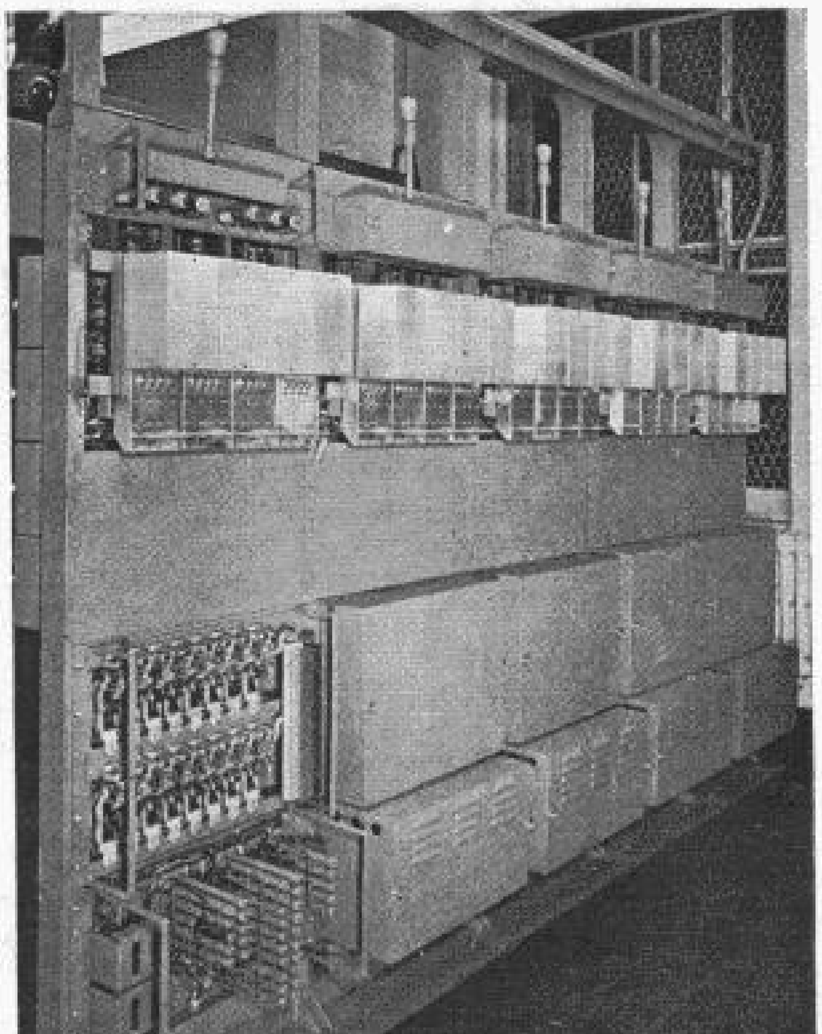


Figure 2. Primary Line Finder 1076-A

A paper presented before the Summer and Pacific General Meeting of the American Institute of Electrical Engineers in Los Angeles, Cal., June 1954.

Secondary Line Finder 1078-A, Figure 3, is similar in appearance and operation to the primary line finder and accomplishes the second stage of concentration. This rack has a 50-circuit capacity since all 16 rotary switches are connected in one group multiple. The wipers of these switches may connect to 16 receiving teleprinters, or to a second secondary 1078-A for further concentration.

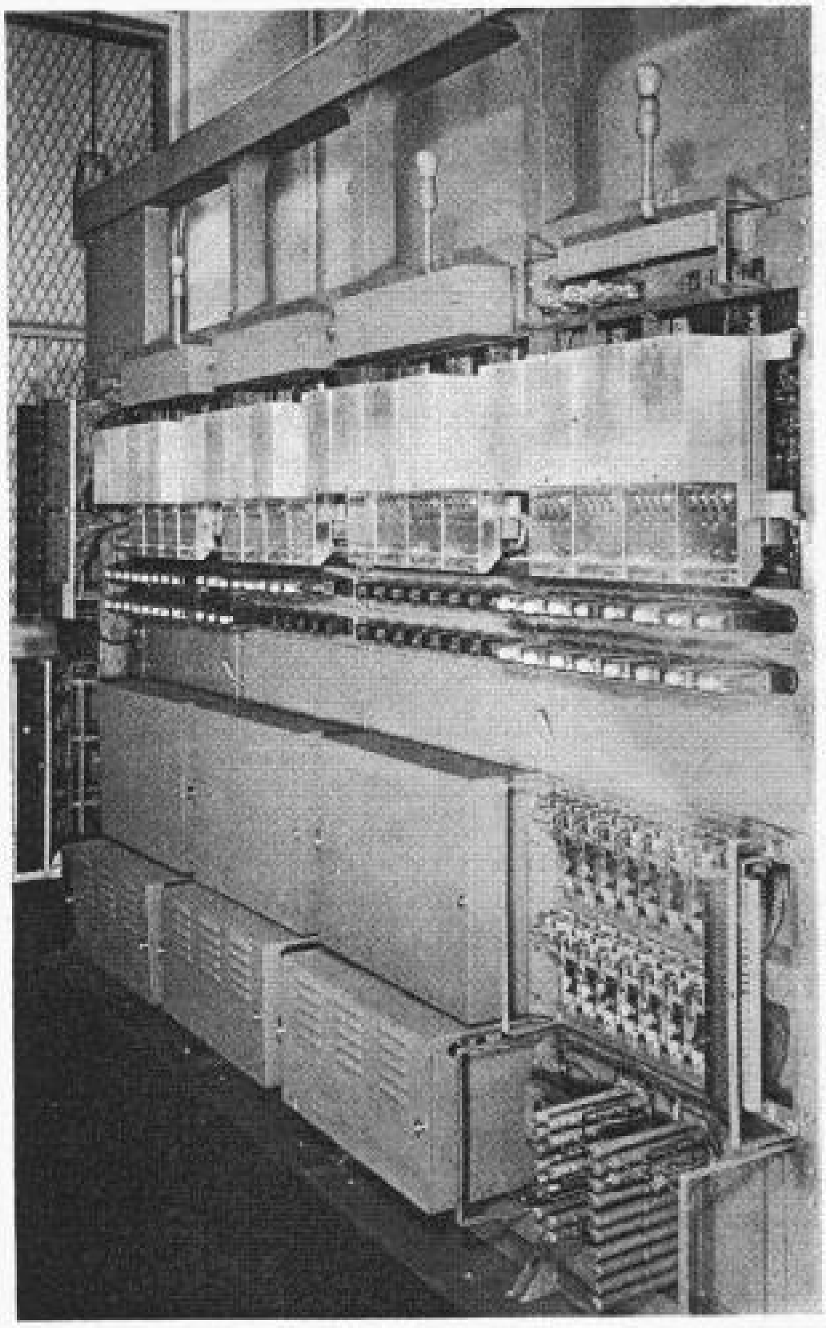


Figure 3. Secondary Line Finder 1078-A

Auxiliary Line Finder 1079-A is assembled on the same rack frame as the 1078-A Secondary Line Finder. It contains a bank of 16 rotary switches and necessary control relays for stepping the switches. This rack is used when it is necessary to provide more paths from either a primary or secondary line finder. This is accomplished by extending the lug multiple of the line finder switches to the lugs of the auxiliary switches.

The teleprinters used for tie-line operation are both tape- and page-type machines. In large offices where there are several hundred tape tie lines and as many or more page tie lines, it is feasible to install a complete tie-line concentrator section for each type of operation, the only equipment difference being in the receiving tables. Figure 4 shows a 5111-A tape receiving position where one operator attends three receiving printers from a seated position.

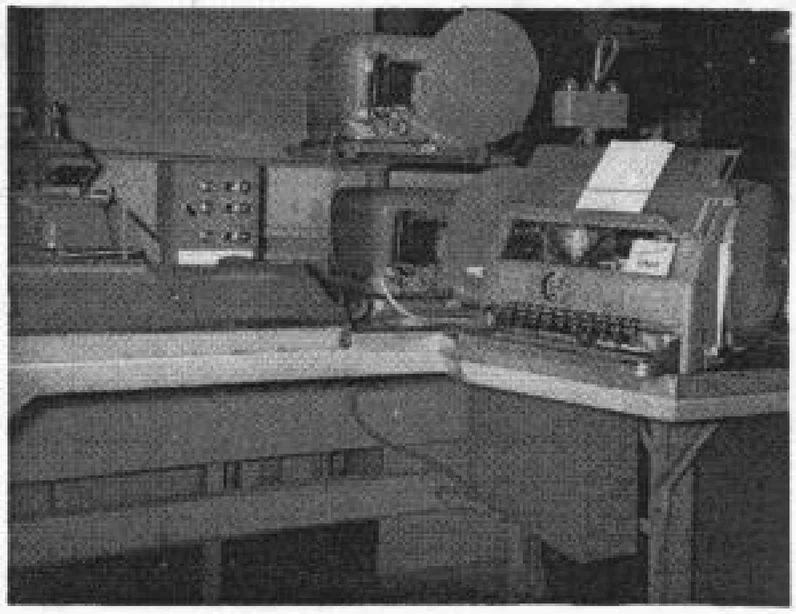


Figure 4. Tape Receiving Table 5111-A

Figure 5 pictures a page receiving position consisting of a 336-A and 337-A table. The two tables, each containing two teleprinters placed adjacent to one another, constitute an operating position.

Equipment Arrangement

Various arrangements of the concentrator equipment will provide terminations for 100 to 600 tie lines in varying degrees of concentration. In the Los Angeles reperforator office both the tape and page receiving concentrators terminate 400 tie lines. The load assignment is such that the tape section can be concentrated to 30 receiving printers and the page section to 44 receiving printers.

Figure 6 shows the concentrating plan for the tape section. Four 104-A Concentrator Racks terminate the 400 lines, providing eight 50-line groups for four primary line finders.

printer not in use. The next three calls, if received while the first five teleprinters are busy, will be directed to the second secondary, then to the first secondary and the lowest numbered idle teleprinter.

Figure 5. Page Receiving Tables 336-A and 337-A

Each 50-line group terminates on the lugs of a 50-point rotary switch group consisting of eight rotary switches. This provides the first concentration of the 400 lines to 64 paths. Of these, 40 are connected directly to the first secondary line finder and its auxiliary line finder serving 30 receiving teleprinters. The remaining 24 paths are further reduced, by the use of a second secondary, to 10 paths and then

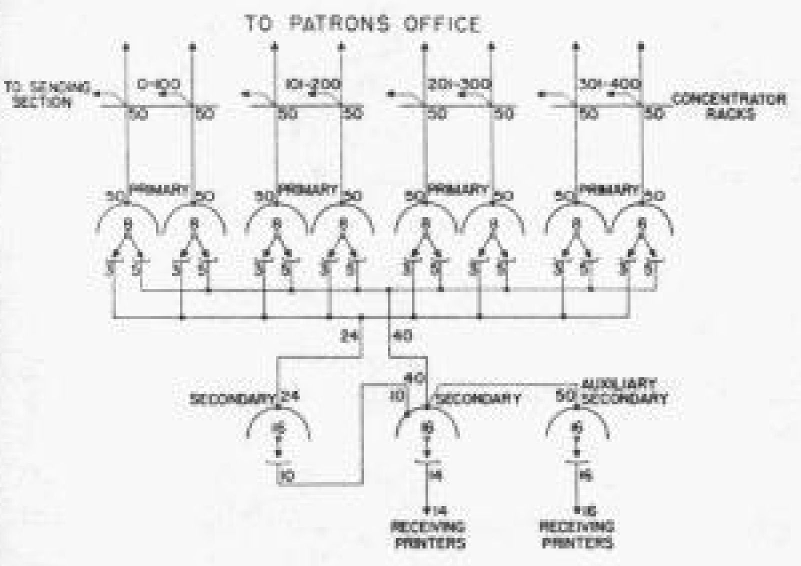


Figure 6. Tape tie-line section concentration plan—Concentration of 400 lines to 30 receiving positions

directed to the first secondary line finder and its auxiliary. The over-all result is that the first five calls of a 50-line group go directly to the secondary line finder and connect to the lowest numbered tele-

The 400-line page tie-line section handles considerably more message volume than the tape section. It was necessary in the Los Angeles installation to provide more receiving printers and to provide for maximum use of all the receiving printers.

First it was necessary to decrease the degree of concentration in the initial step. This was accomplished by modifying an auxiliary line finder rack so that one rotary switch group multiple consisted of only four switches each, instead of the usual eight as found on the primary line finder or 16 as found on the secondary line finder. Each of these smaller switch groups was multipled to the first 50-line switch groups of the four primary line finders, as indicated by Figure 7. The second 50-line switch group of the primary line finders maintained their eight switch group multiples. By load control assignment the busiest tie lines are assigned to the first 50-line switch group of each primary rack. The first concentration step then provides 12 paths for the first 50 lines of each primary line finder and eight paths for the second 50 lines. All of the paths of the first and second primary racks are directed to the first secondary rack and its auxiliary rack. In addition, the first secondary rack handles the two groups of four switches that are multipled to the third and fourth primary racks, thus providing an overflow path from these line groups to the first secondary rack. This makes a total of 48 lugs used on the first secondary rack and its auxiliary.

The first secondary switch group of 16 switches is connected to 12 receiving printers with four switches available for future growth. The 16 switches of the first auxiliary are directed to the second secondary rack and its auxiliary. The 32 switches of the third and fourth primary are also directed to the second secondary and its auxiliary, making a total of 48 lugs used on these switch groups. The 16 switches on the second secondary and the 16 switches of its auxiliary serve 32 receiving teleprinters.

The over-all effect is that the first 200 lines have use of the first 12 teleprinters of the first secondary, and when they are all busy the calls will be extended to the second secondary and auxiliary and any idle printers of that group.

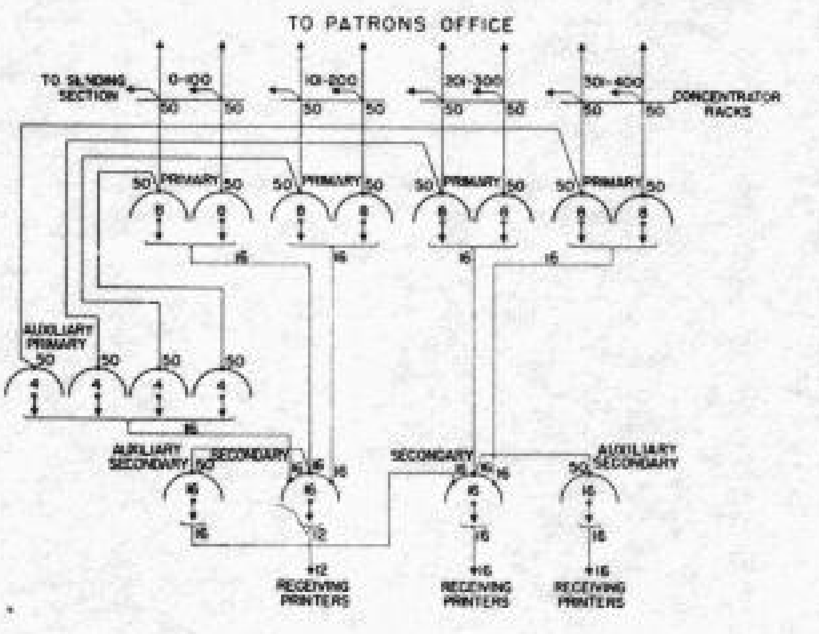


Figure 7. Page tie-line section concentration plan—Concentration of 400 lines to 44 receiving positions

If the eight paths of the first 50-line groups on the third and fourth racks are all used, the ninth call will be directed to the auxiliary primary and on to the first secondary. If a printer is available from this group it will receive the call; if not, the call will be passed on to the second secondary and auxiliary, picking up one of their idle printers. With overflow paths provided between groups, idle printer time during peak load periods is reduced to a minimum.

Since the lowest numbered idle rotary switch always answers the next call, a minimum number of operating tables can be used during light periods. By assigning three low-numbered rotary switches to one operating table group of four printers and assigning one high-numbered switch, only three of the printers will receive calls during slack periods. Thus, not until all other operating positions are busy will the fourth printer of a position take a call. This provides more equitable load distribution among operators.

Operation of the Concentrator

A simplified schematic showing the operation of the Plan 6 Concentrator is illustrated by Figure 8. The tie line originates in ground at the patron's office, passing through a call-in key, the printer keyboard contacts, printer magnets, and a polar motor control relay. A single line conductor connects to the concentrator rack line jack, through a line current limiting resistor, through contacts of a line transfer relay used when sending to the tie line, passing to the primary line finder through released contacts of the line relay, to the coil of the cut-off relay to positive battery energizing the cut-off relay.

As mentioned earlier, a set of two relays associated with each tie line is located in the concentrator rack. They are used in conjunction with the tie-line sending section to determine if the line is idle. If transmission to the tie line is desired and the line is idle, indicated by positive battery on the line, a holding circuit is applied to the cut-off relay in the line finder and the line is transferred to the sending position. The line is returned to the line finder when transmission to the patron has been completed.

The patron requesting a connection to a receiving position initiates a call by momentarily operating the call-in key opening the line by removing the terminating ground. The cut-off relay in the line finder releases. The length of the open is not timed and since the patron's printer motor has not as yet turned on, false characters are not recorded. The release of the cut-off relay transfers the line to released contacts of the cut-off relay to the left coil of the line relay to positive battery. When the call-in key is released, ground is again applied to the line, the line relay operates, but the cut-off relay remains unoperated.

Operation of the line relay applies positive battery from the coil of the cut-off relay, through the right coil of the line relay, to the marking level of the rotary switch bank.

To initiate the operation of an idle rotary switch, a ground is applied to a common start lead from released contacts of the cut-off relay. This same ground is used to operate an alarm relay. The alarm relay is adjusted to operate a visual and audible alarm in the event the switching operation has not been completed within three seconds. The start lead ground follows a path through a busy switch to battery through a start relay, energizing that coil. Operation of this relay opens the start circuit to any higher-numbered start relay.

Switching Functions: At this point the cut-off relay is still released, the line relay operated, the alarm relay operated, and the switch relay operated waiting to actuate the stepping circuit of the rotary

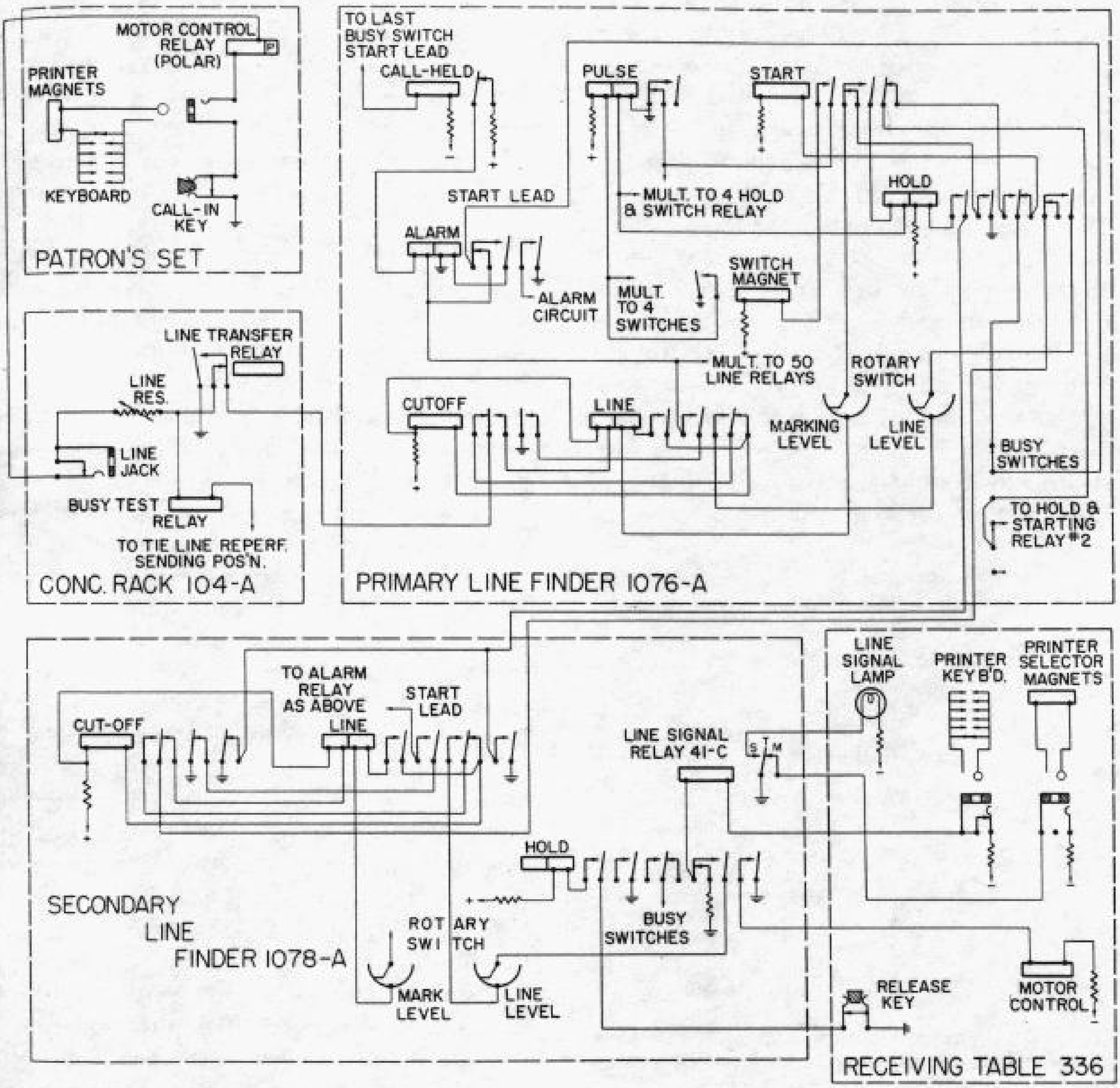


Figure 8. Plan 6 Concentrator—Simplified schematic for one tie-line receiving circuit

R. D. Swanson was graduated from Southern Methodist University in 1948 with the degree of Bachelor of Science in Electrical Engineering. Immediately after graduation, he joined the Telegraph Company as Field Engineer at Dallas. He was later assigned to testing Plan 21 Reperforator Switching at Kansas City, Los Angeles and Portland, and transferred to the Los Angeles Area office in 1949, where he has been concerned mainly with field installation of Patron Switching Systems and Private Wire Systems. Mr. Swanson is an Associate Member of AIEE.

switch. This is accomplished by applying ground through contacts of the pulse relay, operated contacts of the start relay, through the rotary switch magnet coil to positive battery. The rotary switch magnet energizes and closes contacts on the switch to apply ground to the left coil of the pulse relay. The pulse relay operates and opens the ground circuit that energizes the rotary switch magnet. The rotary switch magnet releases and permits the rotary switch to advance to the next lug. Release of the switch magnet also opens the ground circuit for the pulse relay, it releases, and the sequence starts over. This cycle is repeated until the rotary switch steps to the point marked by positive battery. As the switch magnet releases and steps the switch onto the marked point, current flows from battery through the cut-off relay, the right coil of the line relay, the marking level of the rotary switch, operated contacts of the start relay, the left coil of the hold relay, and the right coil of the pulse relay. The pulse relay is held operated even though the rotary switch magnet and contacts are now released. This stops the stepping cycle and prevents the switch from going beyond the marked point. The line relay is held operated through the right coil since the cut-off relay now operates and opens the left coil circuit of the line relay.

The hold relay is operated through the left coil and locked up through the right coil to ground on released contacts of the cut-off relay in the secondary line finder.

Upon the operation of the hold relay the start relay circuit is opened, but the start relay is equipped with a copper sleeve which delays its release until the cut-off relay operates to remove ground from the start lead and the alarm relay releases. It can be seen that when the start relay released, the start lead multiple was extended to the next idle start relay through the busy switch, through operated contacts of the holding relay, released contacts of the start relay, to the second busy switch and second hold and start relays. Release of the start relay released the pulse relay, making it and the alarm relay available for the next call placed on the start lead.

Contacts on the hold relay placed ground on the marking level of the switch to hold the line and cut-off relays operated. The ground at this point on the rotary switch prevents other rotary switches of the bank multiple from stopping on that point as other calls are initiated. As the cut-off relay reoperated, the calling line was transferred to the line level of the rotary switch. The conditions of the relays now are cut-off, line and hold relays operated, start relay released, pulse and alarm relays released and available for other calls. The line has now been transferred to the secondary line finder but is still terminated in positive battery through the coil of the secondary line finder line relay, energizing that relay.

The secondary relays are now in the same condition as the primary relays were just after the patron initiated a call. The secondary rack has its own alarm relay, start lead, pulse relay, and so forth. The same sequence is followed of grounding the start lead, operating the start relay, stepping the rotary switch, marking and stopping on the point and transferring the line.

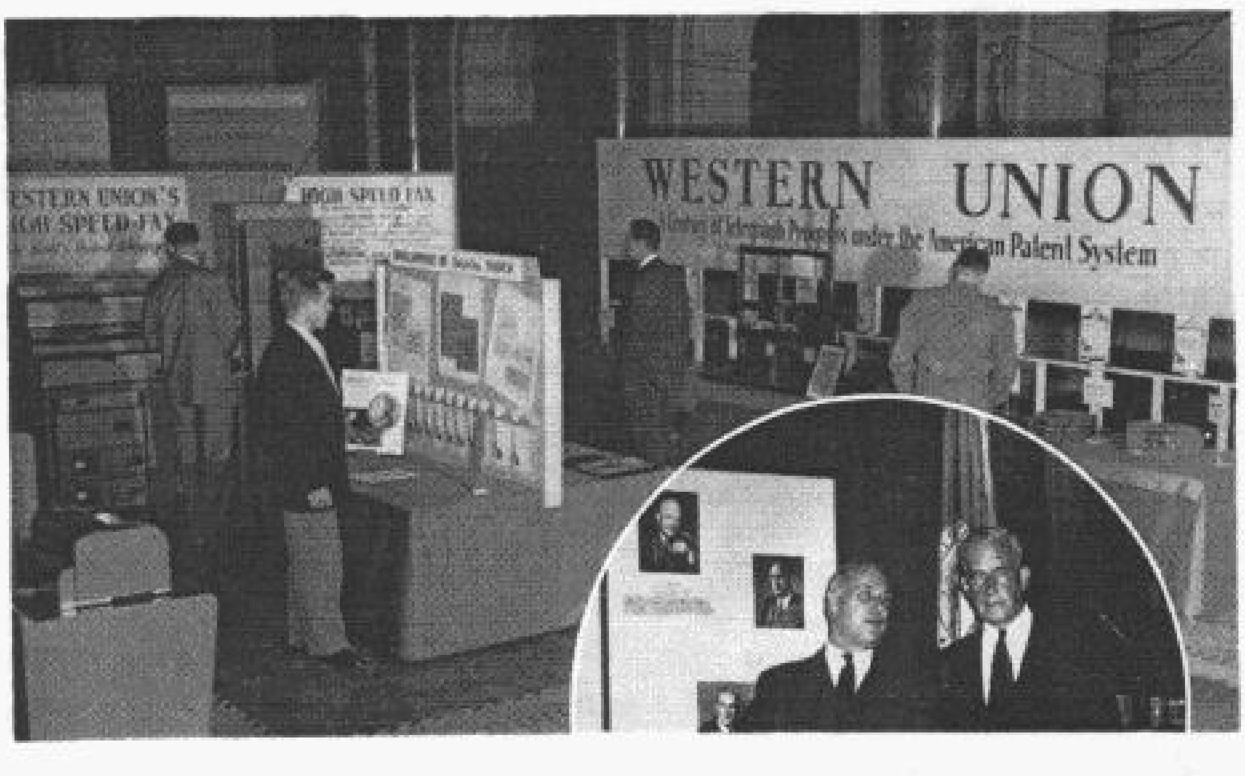
Teleprinter Pickup: The line now is extended to the receiving teleprinter position associated with the particular secondary line finder rotary switch. It will be noted the line signals drive a single current line signal relay 41-C and terminate at the receiving table through the printer keyboard contacts to negative battery. The printer coils are operated from contacts of the line signal relay. The line signal relay provides better teleprinter signal characteristics than would be obtained by having the printer coils directly in the line. Operation of the secondary line finder hold relay applies ground to the motor control relay, starting the receiving printer motor.

Conclusion

Plan 6 Concentrators have been installed in several of the large Western Union reperforator centers, where message volume per operator was increased considerably with less physical exertion. Patrons are enabled to maintain their individuality by close supervision of a minimum number of receiving printers assigned each operator. A production-line type of operation is obtained by extending a message conveyor belt directly in front of each receiving table. As each message is removed from a machine and edited, it is placed on the belt and thus becomes an integral part of the reperforation system.

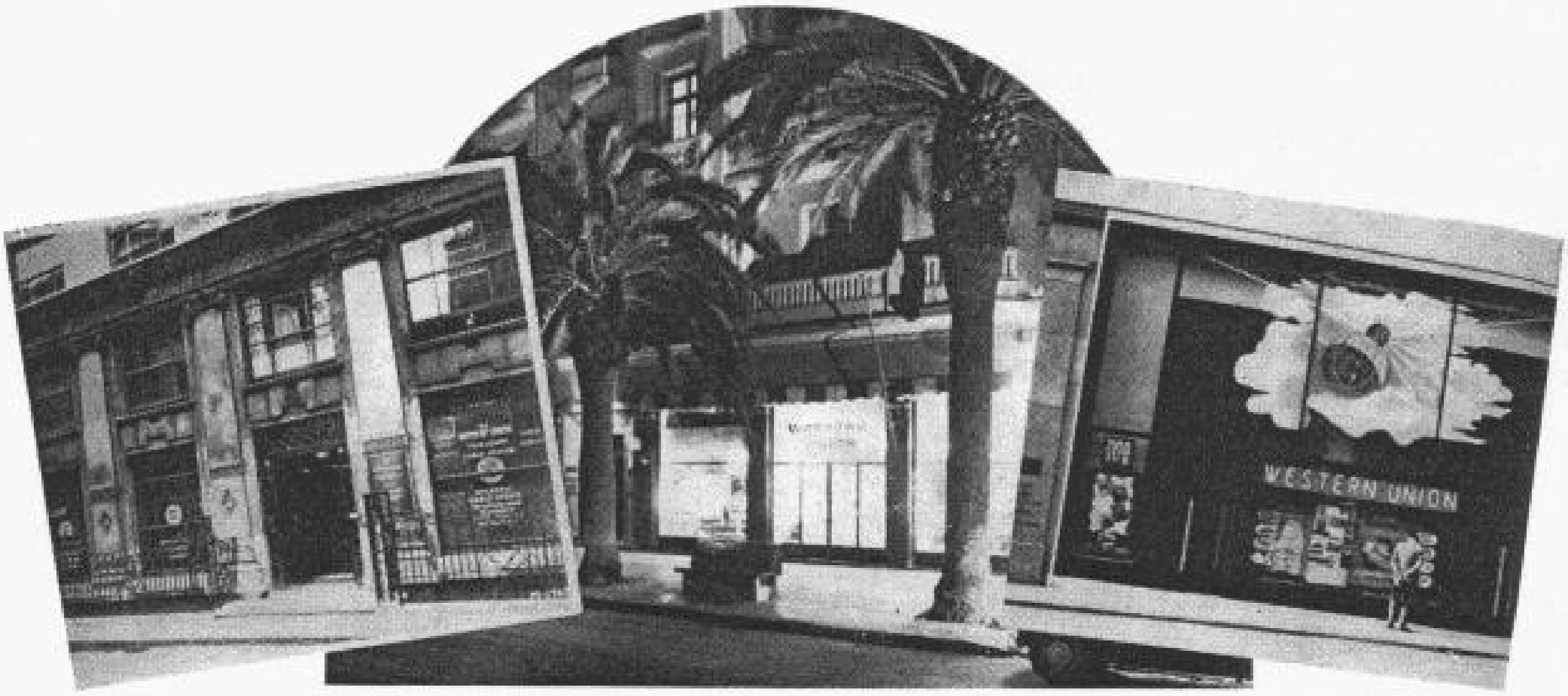
The Plan 6 Receiving Concentrator, coupled with automatic torn-tape switching to patrons' tie lines, provides an extremely rapid and efficient method for handling a large volume of tie-line traffic.

Western Union Exhibits in Washington



"A Century of Telegraph Progress Under the American Patent System" was the theme of Western Union's participation in a recent public exhibit sponsored by the U. S. Patent Office at the Department of Commerce Building in Washington, D. C. Included in the telecommunications display was a sequence showing development of telegraph equipment from the first instruments of Samuel F. B. Morse to today's "Desk-Fax"; also the High-Speed Fax, Letterfax, new Ticketfax, "Teledeltos" paper and Western Union zirconium arc lamps. Patent office papers and scientific awards associated with the various developments were shown, too. This interesting exhibit is scheduled to be repeated in January at company headquarters in New York.

Pictured in inset are Secretary of Commerce Sinclair Weeks (left) and Commissioner of Patents Robert C. Watson who officiated at the opening.



Three Western Union Overseas Offices
London — Casablanca — Paris

Planning Overseas Telecommunication For World Trade

(This excerpt from an address given by Dr. I. S. Coggeshall before the Forty-first National Foreign Trade Convention, New York, in November 1954, suggests that Western Union employees, in the future even more than in the past, will be handling new circuits and furnishing new services to the Telegraph Company's customers who do business abroad. — Ed.)

THE PROVISION of electrical facilities between the United States and the world is more than an omnibus affair. Although there is nothing more basic to our business than to accept and give good service to anybody's message, anywhere, at any time, on a common carrier basis, additionally we have tailor-made our competitive international services to anticipate your specialized needs and even to meet some of your whims.

In the months to come, as a result of research already accomplished, the industry's plans call for more tailoring of modern-age service to your order. For one thing, we are going to give more of you the opportunity to type directly from a keyboard in your headquarters offices into teleprinters located in your foreign agencies or branches. The volume and urgency of a parallel problem applying to the Armed Services and the Press lent impetus for the cable companies and later the radio companies to crack it during World War II. In subsequent years the idea has caught on commercially. Direct keyboard operation for international metered communications, with service measured other than by word-counts, is the fastest growing department of international rapid written communication today, both because of its scaled, wholesale, pre-Korean rates and because of its unmatched kick-off and completion speeds.

Again, our plans for the future do not overlook those of you who engage in foreign trade from the interior of the United States. We are aiming to give you direct connection to international networks comparable with those furnished customers in the seaboard gateways where the shipping and communication routes of greatest traffic density happen to converge. In overseas telephony you already have direct connections by assimilating a tariff differential. The attainment of a similar objective in record communication (and wherever possible without the tariff increment) is one of the reasons leading some competent executive, regulatory, and legislative experts to feel that eventually this country's internal and external telegraphs, emulating the telephone model, ought to be a single entity, organically and physically.

Transportation and communication lines from ours to distant shores may be classified into two groups: First, there are those which carry people, goods, or messages between the United States and overseas terminations cooperatively, under circumstances where net revenues are split more or less evenly between the United States and the overseas terminal. Second, there are the enterprises—often historical, like Western Union cables, going back to the '80s—where the United States has sole private ownership of both terminals and the facility connecting them. Cable companies centered in the United States have been fortunate in being able to turn to good U. S. economic advantage the benefits of operating their own cable offices in the dense traffic areas of the communication world. Telecommunications—cable and radiotelegraph alike—barter in the world's marketplaces with foreign nationals, corporations, and cartels; and even more than most foreign exporters and importers do, with the foreign governments themselves as owners of the far-end terminals and landline pickup-and-distribution telegraphs. As one result of this, a practical, working, Good-Neighbor policy, so far as American telecommunication was concerned, predated by three generations its dramatized political proclaim around the time of World War II.

The plans which the industry has for increasing the carrying capacity of its plant are manifold—but meaningless to you except as related to keeping your communication costs down and the service up. You know from your newspapers that as a result of laboratory and field experiment the technology of the radio and cable arts is caught in a turmoil of change that will produce future reflexes in financial planning and regulatory policies certainly, and in legislation more than perhaps. At a time when the supply of overseas radio frequencies has all but run out, the experiments successfully pioneered by Western Union in inserting vacuum-tube amplifiers in transoceanic cables at the bottom of the Atlantic have more than doubled cable traffic capacity; and are giving rise to plans, some already made public, to lay new transatlantic submarine cables embodying strings of undersea amplifiers. These plans are backed by organizations capable of seeing the cables laid.

Once the facilities are in use, the competitive reins, already tight, will be drawn more taut. But in the attendant rivalries of accomplishment it is to be expected that new technical resources will have been tapped, making it possible for the first time in a quarter-century for Americans, granted the necessary legislative backing, to match the freedom now enjoyed by the British cable and wireless Merger to operate cables and radio in parallel and in end-to-end connection around the world for mutual support and for maximum service and national economic advantage.

A new urge, too, should be felt to apply efficient, low-cost, American domestic telegraph and telephone operational technology—universally conceded to be unrivalled—to more and more international circuits and networks. Our landline communication practices for many years wielded an influence over a directly connected cable system before becoming a factor in international radiotelegraphy. The latter followed the introduction of surplus teleprinter equipment into the Pentagon, and American telephone circuitry into military radio telegraph uses, during the Second World War. Pre-war domestic teleprinter techniques are now practically standard for the radio world. The modern U. S. orginated Desk-Fax is gradually making its appearance in Europe and Latin America. Enhancement of this country's leadership in this field will depend, in part, upon how well we ensure a perpetually free transfer of domestic knowledge and experience to the continuing problems of overseas telegraphy of all kinds. — I. S. Coggeshall, Director of Planning, International Communications Department.

Engineering of Pole Lines

H. H. WHEELER

A WESTERN UNION pole line, as viewed from the window of a rapidly moving train, is apt to have some resemblance to a picket fence and probably most people, if they give the question merely a fleeting thought, assume that the design of such a pole line does not involve appreciably more engineering than a well designed fence. Actually, the design of a line, adequate in strength to furnish uninterrupted service under all but the most abnormal weather conditions, at the least first cost and with low maintenance charges, is neither simple nor easy.

The design of pole lines involves engineering consideration of a wide variety of factors such as timber strengths; resistance to decay of wood poles and crossarms with and without preservative treatment; the physical and electrical characteristics, splicing, terminating, and durability of various types of line wires and cable supporting messengers; strengths of guys and anchors; types of associated hardware and line insulators; protection of plant and personnel against high potentials due to lightning or to accidental contact with or induction from electric supply lines; and, finally, development of the various construction methods and maintenance practices. The wide variety of climatic conditions and the many types of soils encountered throughout the United States further complicate the problems encountered in engineering wire communication plant. The more important structural engineering features will be discussed in this paper.

In designing a pole line, consideration must first be given to the kind, strength and spacing of the poles to be employed; the type of crossarms to support the conductors; the kind of insulators,—that is, whether glass or rubber or some of each; and the strength, diameter, weight and number of the conductors that will have to be supported. As explained by Mr. T. F. Cofer in the April 1952 issue of the TECHNICAL REVIEW, the anticipated external load, that is, ice and wind, to which a pole line may be subjected more or less regularly every winter, has an important bearing on most of these factors.

Pole Loadings

Obviously, the required amount of timber per mile can be provided by using either large diameter poles spaced several hundred feet apart or small poles set relatively close together. Where only a few wires are involved the strength of the conductors might be the limiting factor in selecting the span length, while if a large number of wires are to be supported, it would be impracticable to obtain poles of sufficient strength to support them in spans several hundred feet in length in sections of the country where sleet formation is common. Thus, it is necessary to strike a balance between the strength and spacing of the poles and the strength, size and number of the wires to be carried.

Let us suppose that it becomes necessary to design a line to carry a maximum of 30 wires to be built along a railroad traversing central Ohio where combined loadings of ice 1/2 in. in radial thickness and winds up to 40 miles an hour are known to occur practically every year. This loading is designated as "heavy loading" and such an area is classified as a "heavy loading district." Prior to the last revision of the National Electrical Safety Code "heavy loading" was assumed to be 1/2-in. radial ice and a 57-mile-per-hour wind which produces twice as great a load per square foot as a 40-mile-per-hour wind. In computing pole strengths the 40-mile-per-hour value with an appropriate increase in factor of safety is now used, but in determining loaded tensions of wires and messengers the older figure is retained.

Further, assume that this line is of average importance and that the wires will be No. 9 A.w.g. copper, which is the size and material that experience has proved is best suited for normal telegraph service because of its good conductivity, reasonably satisfactory tensile strength, long life and general over-all economy. Since it is the wires that impose the load on the poles, the first step is to assume a distance between poles and thereby obtain a trial length of wire for each pole to support. A pole spacing of 130 ft. (approx. 40 poles per mile) provides a length that is not too great for No. 9 copper in normal sections of the heavy loading district so this is a reasonable starting point.

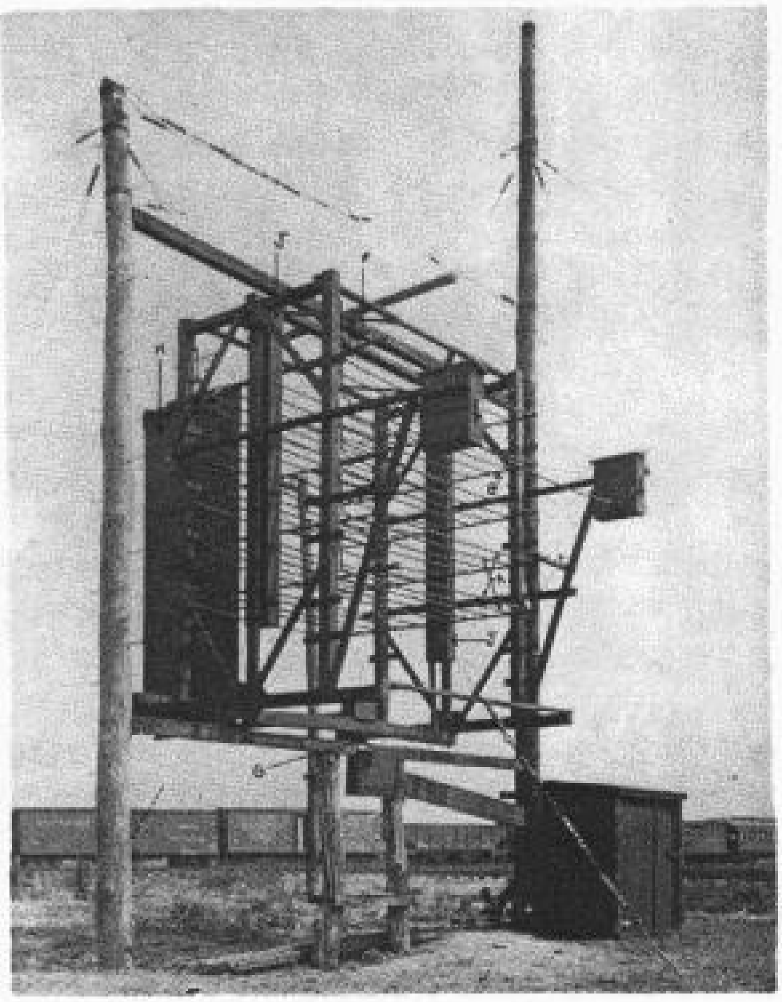


Figure 1. Wind pressure shielding test structure with wood rods simulating ice-covered wires

The second step is to determine how much force a wind of 40 miles per hour, acting on 30 ice-covered wires each 130 ft. long, will exert on a pole. There are two methods of computing this force. One is to assume that the ice-covered wires are perfectly stiff straight bars that will not deflect under the wind pressure and will, therefore, exert a direct transverse thrust on the pole through the insulators, pins and crossarms. The second method is to determine the tension in the wires due to the assumed ice and wind load, compute their angular displacement from the vertical plane due to the wind, and then determine the horizontal component of the tension acting through the insulators, pins and crossarms to pull the pole over. These two methods produce practically the same results and, consequently, since the former is much simpler, it is almost always employed.

No. 9 copper wire has a diameter of 0.114 in. and, assuming that the ice forms a practically perfect cylinder 1/2 in. in thickness around the wire, the total diameter will, of course, be 1.114 in. A 40-mile-per-hour wind exerts a pressure of 4 lbs. per square foot of projected area on a cylindrical surface and since 1 ft. of ice-covered wire 1.114 in. in diameter has a projected area of 0.093 sq. ft., the horizontal load per foot of wire will be 0.372 lb. and the load, due to 30 wires each 130 ft. in length will be 1451 lb. However, these wires will be divided among three 10-wire crossarms spaced 2 ft. apart vertically and the wires on each crossarm will be spaced slightly less than 12 in. except at the pole. Some years ago, Western Union engineers in an extensive series of tests, in which wind pressures on the structure shown in Figure 1 were continuously registered on the automatic recorders shown in Figure 2, proved that on poles carrying more than one 10-pin crossarm there is a shielding action on ice-covered wires which causes a reduction of one-third in the average effective wind load on the pole. This "shielding factor" of one-third is now a nationally recognized standard in communication line engineering. Applying this factor to our problem the actual load on the pole becomes 967 lb.

(NOTE: Letters in Figure 1 were used in the detailed report on these tests.)

Calculations of Pole Size

Now that the load which the pole is intended to withstand is known, it is necessary to compute the size of pole that will be required and this necessitates determining the height of pole needed to provide a minimum clearance of 10 ft. between the lowest wires and the ground in a level section of the country. The wires on the top crossarm will be approximately 6 in. below the top of the pole so with a vertical spacing of 2 ft. between rows of wires the lowest wires will be 4½ ft. below the top of the pole at their point of attachment. Since Western Union specifications do not require even the largest 20-ft. pole to be set deeper than 4¾ ft. in the ground, it is obvious that a pole of this height will provide the required minimum clearance.

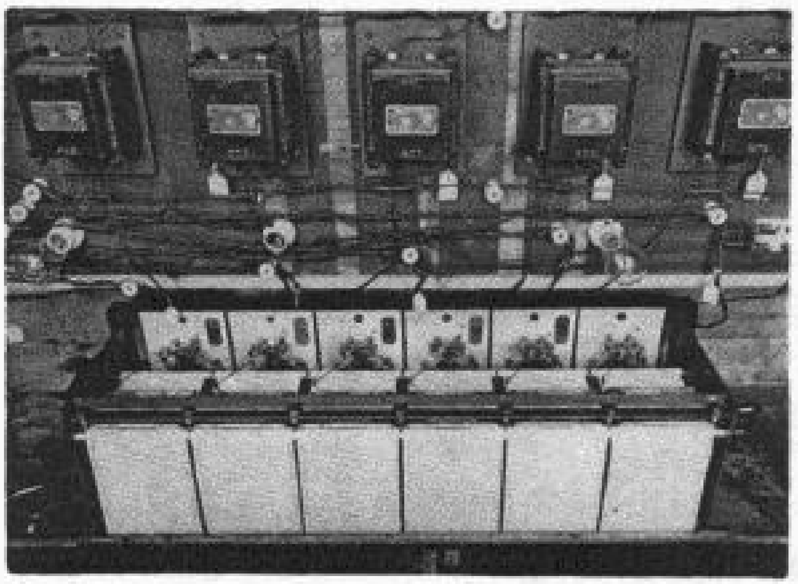


Figure 2. Recorders automatically register wind pressure on single wire and on each arm of shielding test structure

A pole set in firm ground can be considered as a cantilever beam and, although it has some taper, the weakest section is theoretically at the ground line for most poles less than 30 ft. in height. The center of load of the wires in the line under discussion is, of course, at the second crossarm. If a setting of 4½ ft., which is the depth specified for a medium-size 20-ft. pole, is assumed, the center of load will be 13 ft. above the ground. Therefore, the bending moment, M_b, (load times lever arm) tending to break the pole is $967 \times 13 = 12{,}570$ ft. lb., or 150,850 in. lb.

Next, it is necessary to compute the theoretical breaking moment of the pole at the ground-line section and this requires another assumption as to the timber to be used, since southern pine poles, for example, have a much higher average ultimate fiber stress than cedar poles.

Based on tests made by various pole-using companies, average ultimate fiber stress values for all of the commonly used timbers have been established and adopted as a national standard. Also, the nationally standardized pole circumference values have been so adjusted that the strength of any particular class of pole is approximately the same regardless of species of timber. However, in order to determine the class of pole required in this specific problem, it will be assumed that pine having an established fiber stress of 7400 psi will be used.

The resisting moment, M_r, of a pole at the ground-line section is the ultimate fiber stress times the section modulus or

$M_r = f\dfrac{C^3}{32\pi^2}$ where f = fiber stress and C = circumference of the pole at the ground line in inches.

$$C = \sqrt[3]{\frac{32\pi^2 M_r}{f}} \quad Since\ M_r = M_b$$

$$C = \sqrt[3]{\frac{32\pi^2 \times 150{,}850}{7400}} = 18.60\ in.$$

Therefore, any 20-ft. pine pole having a circumference at the ground line of 18.60 in. would in theory just sustain the assumed loading when the pole is new.

Factor of Safety

In practice three additional factors must be taken into consideration in deciding on the proper size of pole. First, gusts of winds having greater velocities than 40 miles per hour are not uncommon; second, the strength when new of individual poles of the same class varies within quite wide limits, and third, the pole will gradually deteriorate as it gets older. Thus, if a reasonable margin of strength in the poles is not provided initially, the line is apt to suffer considerable damage even the first year and require continually increasing maintenance in later years. The obvious answer, therefore, is to provide a liberal factor of safety.

In practice, normal lines in the heavy loading district are designed to have an average factor of safety of about 2¾, while lines of unusual importance or those located in areas having a record of abnormally frequent or severe loading are designed with a safety factor of from 3 to 3½. Applying a safety factor of 2¾ to the bending moment of 150,850 in. lb. in the above formula gives a required circumference of 26.07 in. for a 20-ft. pine pole.

Referring to the pole classification table, a 20-ft. Class 4 pine pole is required to have a minimum circumference 6 ft. from the butt of 25½ in. Applying the average circumferential taper for pine poles, which is 0.25 in. per foot of length, the minimum Class 4 pole would have a 25⅞ in. circumference at the assumed ground line which is 4½ ft. from the butt. The 20-ft. Class 4 pine poles include all of those whose circumference 4½ ft. from the butt lies in the range from the 25⅞-in. minimum to 27⅞ in., which is the minimum for the next larger class of pole. It is obvious, therefore, that the majority of Class 4 poles will have circumferences greater than 25⅞ in. at the assumed ground line, and hence would be considered entirely adequate for our assumed line.

Use of Guys and Anchors

The depths of setting specified for poles are the result of theoretical engineering studies and tests combined with many years experience and are designed to develop practically the full strength of a pole against suddenly applied or intermittent loads when the pole is set in soil of average stability. At points of constantly unbalanced load, such as corners and terminals, it is necessary to provide guying, since the continual pull of the wires would cause the pole to lean if it were not restrained. Guying is used at other points where there is no load unbalance, such as railroad crossings, long spans and in long exposed sections of line as insurance against failure of the poles under unusual storm conditions.

In computing guying, it is customary to make certain assumptions as to the behavior of the wires and poles under load, since experience has demonstrated that it is unnecessary in most cases to guy for the full theoretical load. The probable breaking of a percentage of the line wires under full assumed load, the flexibility of the structures which permits some adjustment for heavy loads, the assistance rendered by guys on adjacent or nearby poles, all enter into the design picture. Also, there is usually resistance to movement on the part of the pole itself, although this factor is customarily neglected in guying calculations, the pole being assumed to act merely as a strut.

The lower ends of guys are attached to anchor logs or to some form of patented guy anchor. The kinds and sizes of anchors specified are based, to a considerable extent, upon extensive tests of anchors, in soils ranging from sand to hardpan, conducted not only by Western Union but also by the Bell System and other pole-using utilities. The method of applying load to the anchor in one of the Western Union tests is illustrated in Figure 3.

Figure 3. Testing holding power of guy anchor

Crossarms, Pins and Wire

As indicated above, the crossarms used will each support 10 wires. These crossarms are 10 ft. long and either 3 in. by 4¼ in. when steel pins are used or 3¼ in. by 4¼ in. where wood pins are employed. The pin spacing is 11¼ in. except between the 5th and 6th pins (so-called pole pins) where it is increased to 22 in. to provide space for linemen climbing the pole to pass through the wires.

These crossarms are fir or yellow pine and are shown by tests to have sufficient strength vertically to withstand the load of 10 wires covered with ½-in. radial ice. They are not sufficiently strong to withstand the horizontal pull of 10 wires and for that reason at deadends, sharp corners and other points where the pull may be greater than normal, a second crossarm is attached on the opposite side of the pole and the two crossarms are held together at the ends with bolts. This is known as double crossarm construction.

. At the termination of heavy open wire lines, at sharp corners and at the ends of long spans a single pole, even when equipped with double crossarms, lacks the necessary strength and rigidity, so two pole structures called "H" fixtures are specified. Some years ago theory indicated that by means of simple bracing a very rigid two-pole structure could be constructed economically. Tests made by Western Union engineers on full size "H" fixtures, as illustrated in Figures 4 and 5, proved that a structure consisting of two poles spaced approximately 6 ft. apart, braced with two ⅜ in. by 2 in. steel bars 10 ft. long and properly guyed will sustain four times the transverse load required to break one of the poles alone and, at the same time, the strength of the crossarms is greatly increased due to their having two points of support. In this application, the guys serve chiefly to counterbalance the upward thrust transmitted by the tension brace to the pole on the windward side of the structure.

For many years the Telegraph Company used steel pins ½ in. in diameter for most situations or ⅝ in. at terminals and heavy corners, for supporting insulators, but now wood pins are so much cheaper that they are used almost exclusively. The steel pins have threaded truncated cones of paraffin treated wood, which are known as cobs, screwed on them to provide a cushion support for the glass insulators. Wood pins have the same insulator threads, tapers and treatment so the insulators fit on either kind interchangeably. The strength of Western Union wood pins is only slightly less than that of the ⅝-in. steel pin.

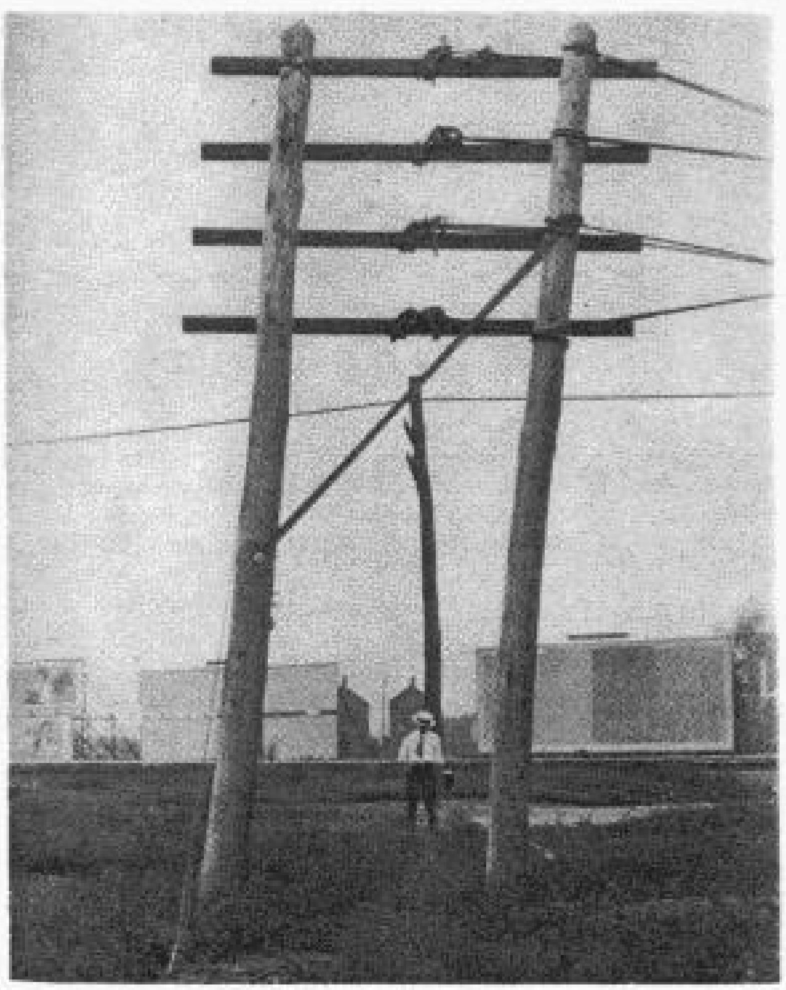


Figure 4. Test "H" fixture under 7900-lb. load just before 5/8-in. bolt at lower end of braces sheared

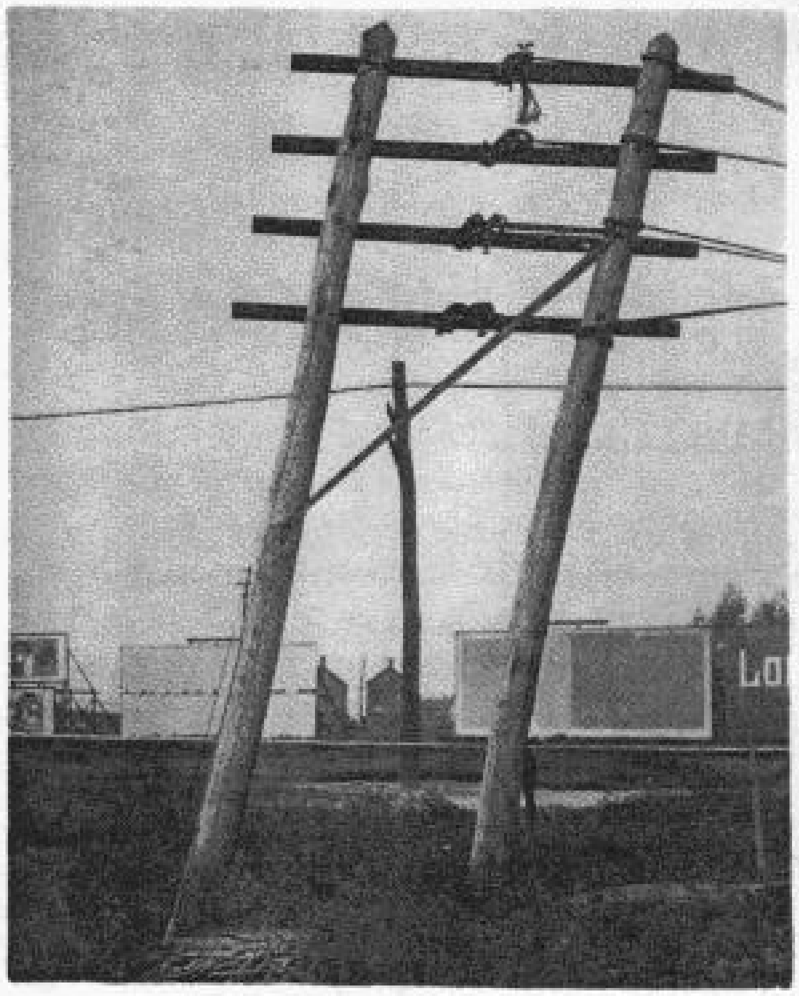


Figure 5. Same fixture as Figure 4 under 10,000-lb. load after 3/4-in. bolt replaced sheared 5/8-in. bolt

The proper material and size of conductor and the best stringing tension have been the subject of extensive study and investigation. The electrical requirements of equipment usually rule out conductors of high resistance material such as steel for circuits of considerable length, leaving the choice at the present time between copper, bronze and copperweld. As mentioned previously, No. 9 copper is the most commonly used line conductor in our plant, even though its strength is marginal when subjected to heavy ice and wind loading. Bronze has been used quite extensively in sections of line frequently subjected to abnormally heavy loading, while copperweld conductors are standard for unusually long spans.

Sag Allowance

The computation of stringing sags and initial tensions is simple but to determine loaded tensions and sags and the final sag of the conductor after the load has been removed requires rather complicated calculations. For the comparatively short spans normally used in communication lines a parabolic curve is sufficiently accurate and is much easier to use than the catenary curve which theoretically represents a wire hanging freely in a span.

The formula $T = \frac{w\,Y^2}{8d}$ where T = tension w = the weight of wire per foot, Y = span length in feet and d = sag in feet gives the stringing condition; for example $T = \frac{0.0395 \times 130 \times 130}{8 \times 1} = 83.7$ lb. at 60 degrees F for a No. 9 copper wire having a 1-ft. sag in a 130-ft. span.

Several steps are necessary in order to obtain the tension of the wire at 0 degrees F when loaded with ½-in. radial ice and an 8 lb. per sq. ft. wind. First, the length of the wire in the span is found from the formula $L = Y + \frac{8d^2}{3Y}$. Substituting

$$L = 130 + \frac{8 \times 1}{3 \times 130} = 130.0205 \text{ ft.}$$

The next step is to determine the length of this section of wire before it is subjected to the 83.7-lb. stringing tension, or what is termed the "unstressed length," at 60 degrees F (L_0^{60}). Since stress is proportional to strain $\frac{T}{a} = E\,\frac{L - L_0^{60}}{L_0^{60}}$ where a is the cross-sectional area of the wire in square inches and E is the initial modulus of elasticity which is given in the National Electrical Safety Code as 14,500,000 for solid hard-drawn copper wire. Substituting and solving

$$L_0^{60} = 129.9476 \text{ ft.}$$

Since the fully loaded condition is assumed to occur at a temperature of 0 degrees F, it is necessary to determine the contraction in the unstressed wire due to a 60-degree-F drop in temperature. The formula is $L_0^0 = L_0^{60}\,(1 - K60)$ where L_0^0 is the unstressed length of the wire at 0 degrees F and K is the coefficient of linear expansion of copper the generally accepted value of which is 9.4×10^{-6}.

Solving $L_0^0 = 129.8743$ ft.

Now this unstressed wire is assumed to be subjected to a load of 0.855 lb. per ft., which is the resultant of a vertical load of 0.419 lb. due to the weight of 1 ft. of wire covered with ½-in. radial thickness of ice and a horizontal load of 0.740 lb. per ft., due to an 8 lb. per sq. ft. wind pressure. This load will stress the conductor and produce a very considerable tension. However, this tension will cause the wire to stretch thus increasing the sag, reducing the tension and, eventually, resulting in a condition of equilibrium.

One method of determining the equilibrium tension is to locate the intersection of one curve representing the tension-length condition of the wire hanging in the span with a second curve representing the tension-length relationship based on the stretch of the wire.

The equation of the first curve is:

$L_l = Y + \frac{W_l^2\,Y^3}{24\,T_l^2}$ where L_l = loaded length of the wire corresponding to a loaded tension T_l when it is subjected to a resultant load W_l of 0.855 lb. per foot.

The equation of the second curve is:

$$\frac{T_l}{a} = E\,\frac{L_l - L_0^0}{L_0^0}$$ where L_0^0 is the 129.8743 ft. unstressed length at 0 degrees F found previously.

The two curves may be obtained by assuming several values for T_l in the first equation, solving for the corresponding values of L_l, substituting these values of L_l in the second equation and obtaining corresponding values of T_l which will differ from the assumed T_l values except at the point of intersection. In the assumed problem the tension value at equilibrium is found to be 480 lb. Substituting this in the formula $d = \frac{W_l Y^2}{8 T_l}$ the loaded sag is 3.76 ft. Figure 6 shows a 130-ft. span loaded with ice that caused the wires to sag more than 4 ft.

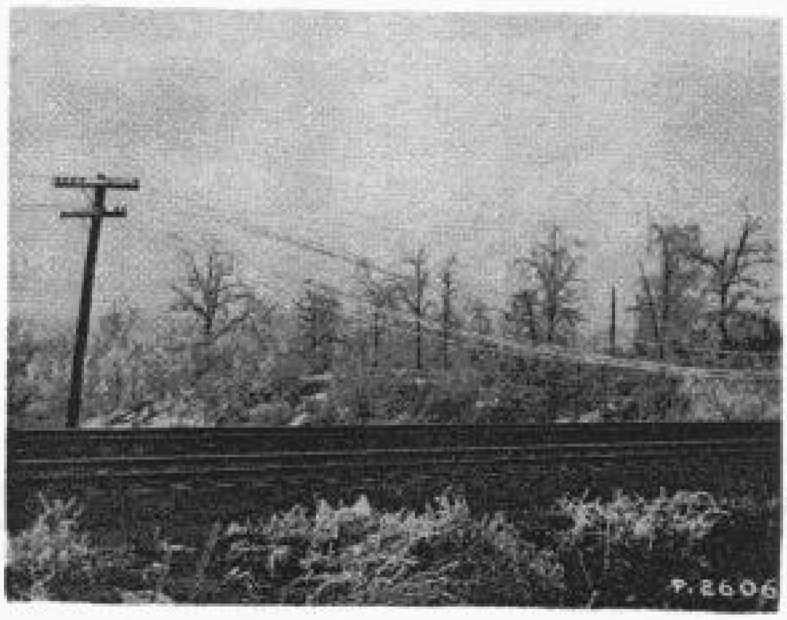


Figure 6. Wires loaded with ice in excess of 1/2-in. radial thickness but no wind

The final unloaded sag at 60 degrees F is always greater than the initial sag since there is some permanent elongation of copper wire whenever it has been subjected to an external load or a temperature condition which will cause a very appreciable increase in tension. To determine this sag the above process is reversed but the final modulus, which is given in the National Electrical Safety Code as 17,000,000, must be used to obtain the unstressed length of the wire after the load is removed and from this length the tension and sag can be computed readily. In the above problem the final tension was found to be 55 lb. and the final sag approximately 1.5 ft. In many cases it is necessary to untie the conductors and pull out the excess slack after a line has been subjected to a heavy ice load.

Various short cuts have been devised for reducing the time required to make wire and cable calculations. These include charts, families of tension-length curves based on the equation of the wire in the span together with corresponding sliders having tension-length curves based on the stretch of the wire, and a very useful set of tables known as Martin's Sag Tables.

The sags specified for line wires are generally as large as are practicable from the standpoint of physical interference between adjacent conductors in order to keep the stringing and loaded tensions at safe values. Due to the low fatigue limit of copper (often assumed to be 15 percent to 20 percent of the ultimate stress) the life of copper wire is materially increased by stringing the conductor at a sufficiently low tension to insure that the stresses developed throughout the normal range of temperatures experienced in the district in which the line is located do not exceed the fatigue limit.

Messenger for Cables

Aerial lead sheath cables are supported on high-strength 7-wire strand usually referred to as messenger strand. This strand may be composed of galvanized steel, stainless steel, copperweld or special bronze wires. The cable may be suspended from the messenger by means of cable rings or metal straps, or attached to the messenger by wire spun spirally around both messenger and cable as a unit.

The computation of the tensions and sags of aerial cable messenger follows a pattern similar to that described above for wire, but the presence at all times of the heavy continuous load represented by the cable introduces an additional complication.

In setting up specification values for the

H. H. Wheeler, Lines Engineer, entered Western Union service under the Construction Engineer in 1917 shortly after receiving his engineering degree from the University of Minnesota. In 1929 he headed a group in the investigation of means for reducing the leakage of current from line wires, which resulted in the development of the practicable, nonbreakable, and now widely used rubber insulators described in an earlier TECHNICAL REVIEW. In 1942, he became Assistant to the Engineer of Lines, and the following year assumed his present position. Mr. Wheeler has been closely and continuously identified with the designing of pole lines and other types of outside telegraph plant and has participated in, or supervised the preparation of all of the company's present standards for materials, tools and methods employed in the construction and maintenance of such plant.

stringing tensions of messengers, the maximum desirable sag at 60 degrees F with cable in place was taken as the starting point, and the strength of messenger required for each standard size of cable and the proper tension at which this messenger should be strung were then computed.

To determine the factor of safety of a messenger its unstressed length must be computed, first at 60 degrees F, then at 0 degrees F. To this unstressed length must be applied the resultant load per foot calculated from the vertical weight of ice-covered cable and messenger plus rings, and the horizontal load due to an 8 lb. per sq. ft. wind blowing on messenger, cable and rings. The intersection of two tension-length curves, similar to those developed in line wire calculations, gives the loaded tension in the messenger which, divided into the ultimate tensile strength of the messenger, gives the factor of safety under load. Since the fully loaded tension in a messenger is normally materially less than half the ultimate strength of the strand, there is a negligible permanent stretch in the messenger and, consequently, the final sag need not be computed.

Since the sags with cable in place at 60 degrees F are designed to be approximately the same at a given temperature for a particular span regardless of the weight of the cable or material of the messenger, it is necessary to specify the specific tension at which each kind and size of messenger should be strung for various weights of cable, but it was found practicable to group the span lengths somewhat without introducing any appreciable difference in sags with cable in place.

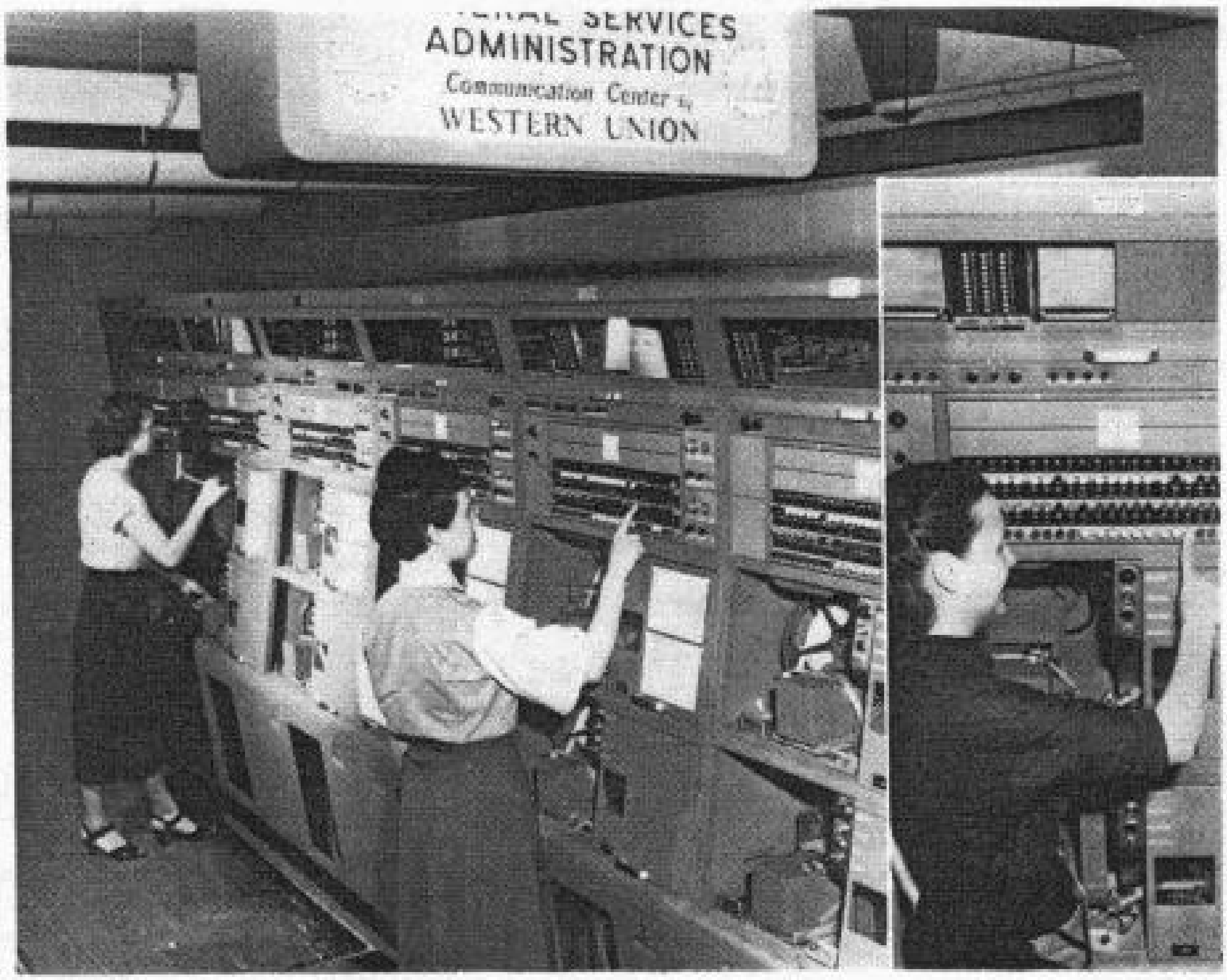
Special Considerations

In the engineering of lines economic factors must not be lost sight of for even a moment. While the first cost of materials and labor is of course important, maintenance cost, life of plant from the standpoint both of deterioration and of obsolescence, and other factors affecting annual charges, must all be given careful consideration.

Extensive studies on timber preservation have enabled the company largely to overcome increasing first costs of poles and crossarms by greatly extending their useful life. Comprehensive tests of steel to which small quantities of copper had been added demonstrated that the presence of approximately 0.18 percent by weight of copper practically doubled the life of many hardware items, including low carbon steel wire, in areas of excessive corrosion. The substitution of Western Union patented rubber insulators for glass insulators in locations where the breakage of glass is frequent and the use of either special bronze or stainless steel messenger strand in lieu of galvanized steel strand in rapid corrosion areas are also examples of reduction in maintenance costs through engineering.

Due to the many variable and uncontrollable factors involved, it is impossible to reduce the engineering of pole lines to an exact science. However, even though under maximum assumed loads a structural factor of safety of 2¾ to 3½, a wire factor of safety of only slightly more than one, and a messenger factor of safety of two for spans of heavy cable, may seem shockingly low to a bridge engineer or an architect, extensive studies of pole line damage, of pole life and of service records, indicate that lines built and maintained in accordance with existing Western Union specifications represent a satisfactory balance between serviceability, reliability and over-all economy. The preservation of this desirable condition will require both continued reappraisal of existing materials and methods, and the study, investigation and development of new materials and labor saving devices and of improved techniques in order to meet the changing requirements and expansion of telegraph service.

Federal Telegraph Service Modernized



Pictured here is a section of the General Services Administration telegraph communication center at Washington, D. C., showing modern push-button switching turrets, distributor-transmitters, printer-perforators, and new indicating automatic numbering machines mounted above the turrets. The inset picture shows one of the switching positions in greater detail.

GSA's telegraph switching system furnished by Western Union is a 15,000-mile private wire network interconnecting 51 major cities and handling about 40,000,000 words a year. This system, which uses modern electronic equipment and embodies new trends in design which make it easy to operate, serves virtually all the civilian agencies in the executive branch of the Federal Government as a carrier of administrative-type telegrams. Weather, flight, market and security information is transmitted over other wire systems.

Additional circuits, centers and stations may be added quickly and easily to keep up with growth in the volume of business.

Fourier Series Analysis of Local Circuit Telegraph Waves

ROBERT F. COUGHLIN

THE 7-unit telegraph code is a familiar method of Western Union communication. All characters not transmitted via Morse or facsimile apparatus are interpreted by teleprinters in the language of current or no-current time intervals. Each transmitted character is composed of seven equal intervals of 22 milliseconds. The first interval is a no-current or spacing pulse and the last interval is a current or marking pulse. Both of these pulses hold the sending and receiving ends of the circuit in synchronism. The remaining five pulses in combinations of marking or spacing intervals determine the character. Since each of the five intelligence pulses may be marking or spacing, the maximum number of combinations is the fifth power of two or 32 possible different characters.

The purpose of this paper is to apply the Fourier Complete Series Analysis to a telegraph wave so that the component sinusoidal waves may be obtained. The components will then be plotted and added graphically to observe how these sinusoidal waves of different phase angle and amplitude integrate to build 7-unit telegraph waves. To simplify the analysis, only lumped parameters will be considered. Effects due to distributed capacity and inductance change caused by teleprinter armature motion will not be treated.

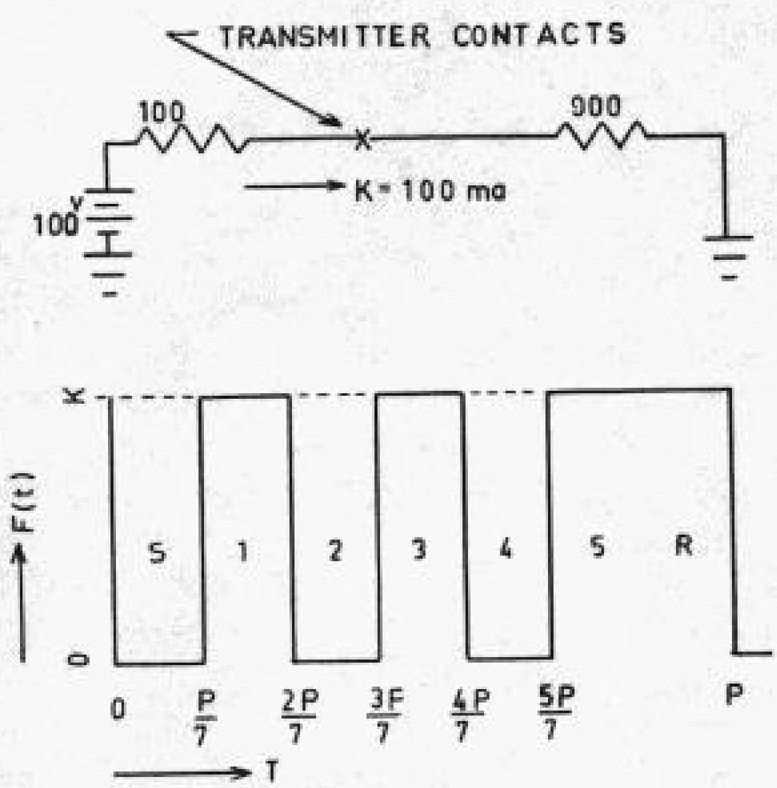


Figure 1. Wave shape of character Y in pure resistance circuit

In applying the analysis a further restriction is imposed. The complex wave must be periodic; therefore it will be assumed that the letter Y (start, second and fourth pulse spacing) is being transmitted continuously in a pure resistance circuit. This wave shape is pictured in Figure 1.

Since the wave is defined to be a periodic function of time, the necessary condition is fulfilled that the period of the wave will be P, or expressed mathematically:

$$f(t+P) = f(t), \quad -\infty < t < \infty$$

The numerical value of P is 154 milliseconds or seven times the length of each 22-millisecond pulse.

Following is the Fourier Complete Series formula:

$$f(t) = A_o + \sum_{n=1}^{n=\infty} \left(A_n \cos \frac{2n\pi}{P} t + B_n \sin \frac{2n\pi}{P} t\right) \qquad (1)$$

and the coefficients are obtained from the formulae:

$$A_o = \frac{1}{P}\int_0^P f(t)\,dt \qquad (2)$$

$$A_n = \frac{2}{P}\int_0^P f(t) \cos \frac{2n\pi}{P} t\,dt \qquad (3)$$

$$B_n = \frac{2}{P}\int_0^P f(t) \sin \frac{2n\pi}{P} t\,dt \qquad (4)$$

where $f(t)$ is the expression for the current as a function of time and made up of a d-c component A_o, plus a sine and cosine series. In the character Y of Figure 1, K in milliamperes is the direct current determined by Ohm's Law and

$$f(t) = K, \ \frac{P}{7} < t < \frac{2P}{7}, \ \frac{3P}{7} < t < \frac{4P}{7}, \ \frac{5P}{7} < t < P$$

$$f(t) = 0, \ 0 < t < \frac{P}{7}, \ \frac{2P}{7} < t < \frac{3P}{7}, \ \frac{4P}{7} < t < \frac{5P}{7}$$

Applying equation (2) to Figure 1:

$$Ao = \frac{1}{P}\left[\int_0^{\frac{P}{7}} o\,dt + \int_{\frac{P}{7}}^{\frac{2P}{7}} k\,dt + \int_{\frac{2P}{7}}^{\frac{3P}{7}} o\,dt + \int_{\frac{3P}{7}}^{\frac{4P}{7}} k\,dt + \int_{\frac{4P}{7}}^{\frac{5P}{7}} o\,dt + \int_{\frac{5P}{7}}^{P} k\,dt\right]$$

$$Ao = \frac{K}{P}\left[\frac{P}{7} + \frac{P}{7} + \frac{2P}{7}\right]$$

$$Ao = \frac{4}{7}k = \text{Direct Current Component}$$

The T&R men will recognize this term as the 40-milliampere reading obtained from a locked Y in a 70-mil resistance circuit. Applying equation (3) to Figure 1:

$$An = \frac{2}{P}\left[\int_{\frac{P}{7}}^{\frac{2P}{7}} k\cos\frac{2n\pi}{P}t\,dt + \int_{\frac{3P}{7}}^{\frac{4P}{7}} k\cos\frac{2n\pi}{P}\,dt + \int_{\frac{5P}{7}}^{P} k\cos\frac{2n\pi}{P}t\,dt\right]$$

$$= \frac{K}{n\pi}\left[\sin\frac{4n\pi}{7} - \sin\frac{2n\pi}{7} + \sin\frac{8n\pi}{7} - \sin\frac{6n\pi}{7} + \sin 2n\pi - \sin\frac{10n\pi}{7}\right]$$

It is evident that there is a term in An for each transition from mark-to-space or space-to-mark. Since An is a scalar quantity the following substitutions may be made to simplify calculation:

$$\sin\frac{8n\pi}{7} = (-1)^n \sin\frac{n\pi}{7},$$

$$\sin\frac{10n\pi}{7} = (-1)^n \sin\frac{3n\pi}{7},\quad \sin 2n\pi = 0$$

$$An = \frac{K}{n\pi}\left[(-1)^n\sin\frac{n\pi}{7} - \sin\frac{2n\pi}{7} + (-1)^{n+1}\sin\frac{3n\pi}{7} + \sin\frac{4n\pi}{7} - \sin\frac{6n\pi}{7}\right] \quad (5)$$

Let $n=1$ in equation *(5):*

$$A_1 = \frac{k}{\pi}\left[-\sin\frac{\pi}{7} - \sin\frac{2\pi}{7} + \sin\frac{3\pi}{7} + \sin\frac{4\pi}{7} - \sin\frac{6\pi}{7}\right]$$

$$A_1 = 0.303\,\frac{K}{\pi}$$

In like manner applying equation *(4)* to Figure 1:

$$Bn = \frac{K}{n\pi}\left[\cos\frac{2n\pi}{7} - \cos\frac{4n\pi}{7} + \cos\frac{6n\pi}{7} - \cos\frac{8n\pi}{7} + \cos\frac{10n\pi}{7} - \cos 2n\pi\right]$$

$$B_1 = -0.376\,\frac{K}{\pi} \quad (6)$$

Substituting the values of *Ao, A1* and *B1* in equation (1)

$$f(t) = \frac{4}{7}k + 0.303\frac{K}{\pi}\cos\frac{2\pi t}{P} - 0.376\frac{K}{\pi}\sin\frac{2\pi t}{P} + \sum_{n=2}^{n=\infty}\left(An\cos\frac{2n\pi}{P}t + Bn\sin\frac{2n\pi}{P}t\right)$$

For comparison purposes the character E may be analyzed as shown in Figure 2. Applying equations (2), (3) and (4) to Figure 2 results in:

$$Ao = \frac{2}{7}k \quad (7)$$

$$An = \frac{K}{n\pi}\left[-\sin\frac{2n\pi}{7} + \sin\frac{4n\pi}{7} - \sin\frac{12n\pi}{7} + \sin 2n\pi\right] \quad (8)$$

$$Bn = \frac{K}{n\pi}\left[\cos\frac{2n\pi}{7} - \cos\frac{4n\pi}{7} + \cos\frac{12n\pi}{7} - \cos 2n\pi\right] \quad (9)$$

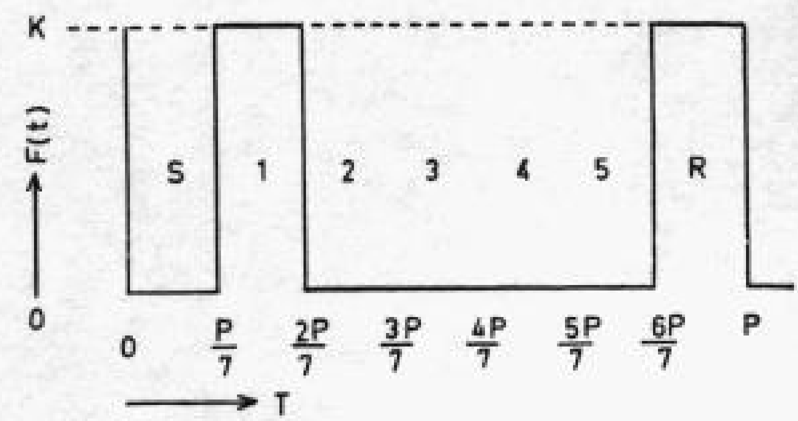


Figure 2. Wave shape of character *E* in pure resistance circuit

From equation (1) each character is seen to be the sum of a d-c term plus an infinite number of related sine waves and cosine waves. To halve the work of plotting, the sine waves and cosine waves whose frequencies are equal may be combined vectorially to produce a single sine wave whose phase angle will be different from zero. Thus for a character Y the fundamental is:

$$n=1 \quad f_1(t) = A_1\cos\frac{2\pi t}{P} + B_1\sin\frac{2\pi t}{P}$$

$$= 0.303\left(\frac{100}{\pi}\right)\cos\frac{2\pi t}{P} - 0.376\left(\frac{100}{\pi}\right)\sin\frac{2\pi t}{P}$$

$$= 9.55\cos\frac{2\pi t}{P} - 11.98\sin\frac{2\pi t}{P}$$

$$= 15.3\sin\left(\frac{2\pi t}{P} + 141^\circ\right)$$

$$= 15.3\,\underline{|141^\circ}$$

where $\frac{2\pi}{P} = w_1 = 2\pi f_1$, and $k = 100$ milliamperes

$f_1 = \frac{1}{P}$ = frequency of first harmonic

$f_n = \frac{n}{P}$ = frequency of n th harmonic

The d-c component and first four harmonics in the letter Y of equation (10) are shown in Figure 3. Care must be taken to plot the second harmonic at twice the frequency of the fundamental and the other

Following is a table of the first fourteen harmonics of the characters Y and E where the units of *An*, *Bn* and *fn(t)* are milliamperes, *fn* is in cycles per second, and the steady-state d-c current is 57.14 and 28.57 milliamperes respectively.

	Character Y			Character E			
n	*An*	*Bn*	*fn(t)*	*fn(t)*	*An*	*Bn*	*fn*
0	57.14	—	—	—	28.57	—	—
1	9.55	−11.98	$15.3\underline{/141}$	$34.4\underline{/64}$	31.03	14.94	1/p
2	− 4.44	−19.46	$20.0\underline{/193}$	$11.1\underline{/218}$	− 6.91	− 8.66	2/p
3	−41.88	−20.17	$46.5\underline{/244}$	$37.3\underline{/193}$	− 8.30	−36.34	3/p
4	31.41	−15.13	$34.9\underline{/116}$	$28.0\underline{/167}$	6.22	−27.26	4/p
5	1.78	− 7.78	$8.0\underline{/167}$	$4.4\underline{/141}$	2.76	− 3.46	5/p
6	− 1.59	− 2.00	$2.6\underline{/218}$	$5.7\underline{/296}$	− 5.17	2.49	6/p
7	0	0	0	0	0	0	7/p
8	1.19	− 1.50	$1.9\underline{/141}$	$4.3\underline{/64}$	3.88	1.87	8/p
9	− 0.99	− 4.32	$4.4\underline{/193}$	$2.5\underline{/218}$	− 1.53	− 1.92	9/p
10	−12.56	− 6.05	$13.9\underline{/244}$	$11.2\underline{/193}$	− 2.49	−10.90	10/p
11	11.42	− 5.50	$12.7\underline{/116}$	$10.2\underline{/167}$	2.26	− 9.92	11/p
12	0.74	− 3.24	$3.3\underline{/167}$	$1.8\underline{/141}$	1.15	− 1.44	12/p
13	− 0.74	− 0.92	$1.2\underline{/218}$	$2.7\underline{/296}$	− 2.39	1.15	13/p
14	0	0	0	0	0	0	14/p

It is interesting to note that every eighth harmonic has the same phase angle. The sum of the phase angles of the first and sixth harmonic equals 360 degrees. In like manner the second and fifth harmonic phase angles and third and fourth harmonic phase angles add to 360 degrees. The series converges rapidly since the values of *fn(t)*, excepting the tenth and eleventh harmonics, are relatively small after the fourth. Ignoring all harmonics beyond the fourth an approximate series expression may be written from the table as follows:

Letter Y

$$f(t) = 57.1 + 15.3\,\underline{/141} + 20.0\,\underline{/193} + 46.5\,\underline{/244} + 34.9\,\underline{/116} \qquad (10)$$

Letter E

$$f(t) = 28.6 + 34.4\,\underline{/64} + 11.1\,\underline{/218} + 37.3\,\underline{/193} + 28.0\,\underline{/167} \qquad (11)$$

harmonics accordingly. The period is divided into 120 equal divisions. The amplitudes of the harmonics are added alge-

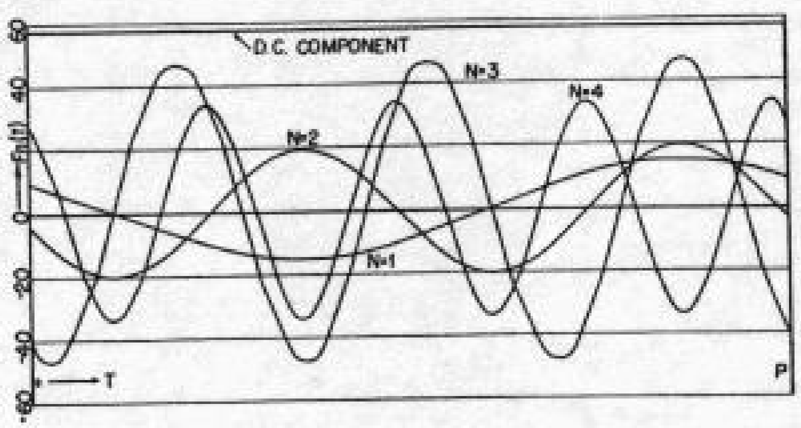


Figure 3. First four harmonics as a function of time—letter Y

braically at every fifth division and plotted to produce the resultant curve drawn in Figure 4.

Figure 5 shows the d-c component and first four harmonics of the letter E in equation (11). As above, the harmonics and d-c components were added to produce the resultant wave shown in Figure 6.

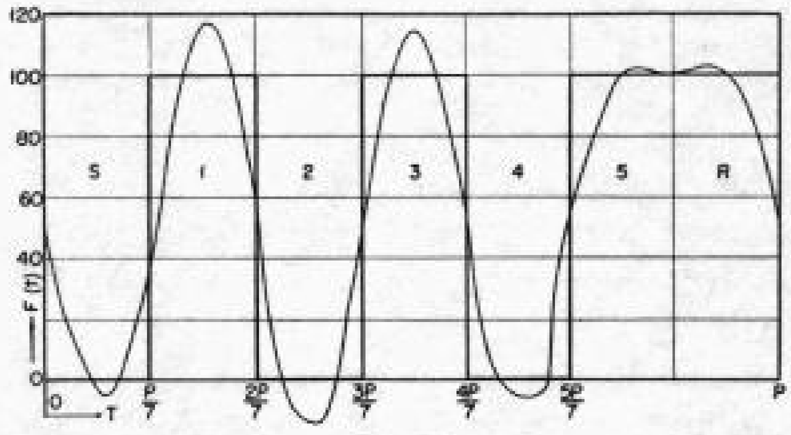


Figure 4. Summation of first four harmonics—letter *Y*

The fundamental frequency is the inverse of the 154-millisecond period or 6.5 cycles per second with the frequencies of the second, third and fourth harmonics being 13.0 cps, 19.5 cps and 26.0 cps, respectively. The third and fourth harmonics play a dominant role in forming the resultant wave because their total number of peaks, six and eight respectively, are closest to the number of seven pulses.

To analyze the character *R* add 180 degrees to each component of equation (10) and look at Figures 3 and 4 upside down. Thus a fair reproduction of each of the 32 characters can be constructed with

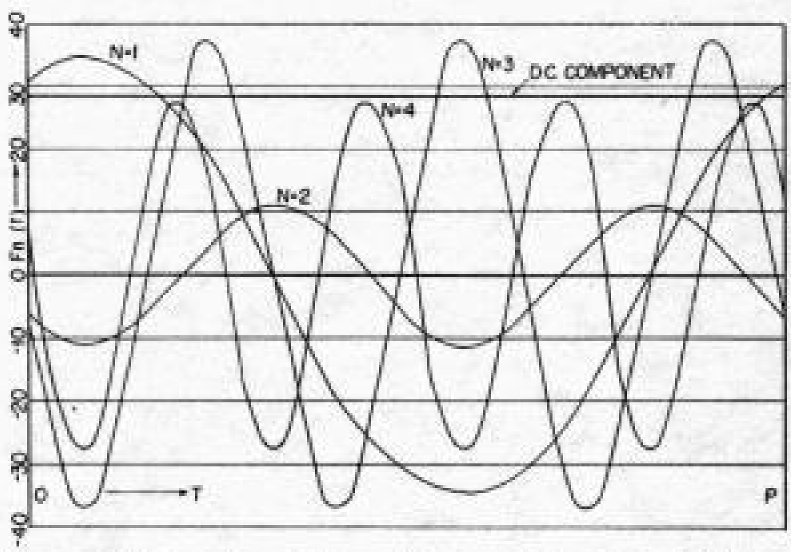


Figure 5. First four harmonics as a function of time—letter *E*

four sine waves by merely varying the phase angle and amplitude of each. Polar signals will contain waves of identical frequency, amplitude and phase, but with different d-c components. Conversely, the telegraph keyboard contacts may be considered a harmonic generator rich in related sinusoidal waves whose amplitude, phase, and frequency can be accurately calculated.

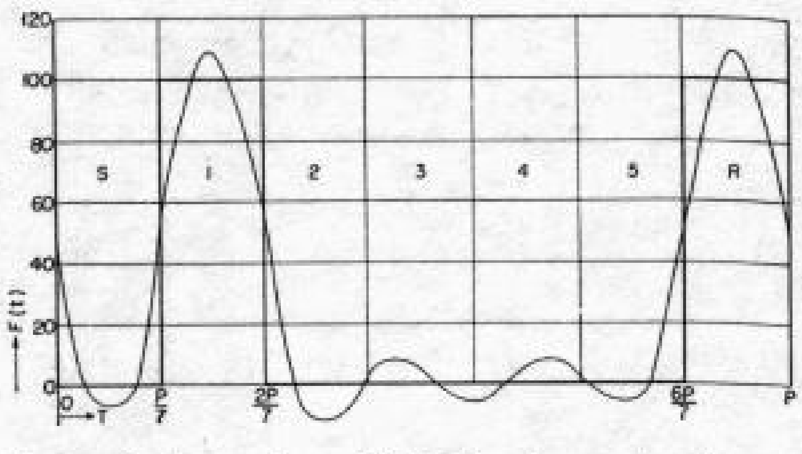


Figure 6. Summation of first four harmonics—letter *E*

Experience has shown that the addition of inductance to a pure resistance circuit will change the wave shape by rounding off the space-to-mark transition because inductance corresponds to mechanical inertia and tends to prevent the change of current. This effect is shown in Figure 7. The mark-to-space transition remains a vertical line to indicate that the current drops instantly since the energy stored in the inductance is dissipated as both a spark across the opening contacts and radiation into the surrounding medium.

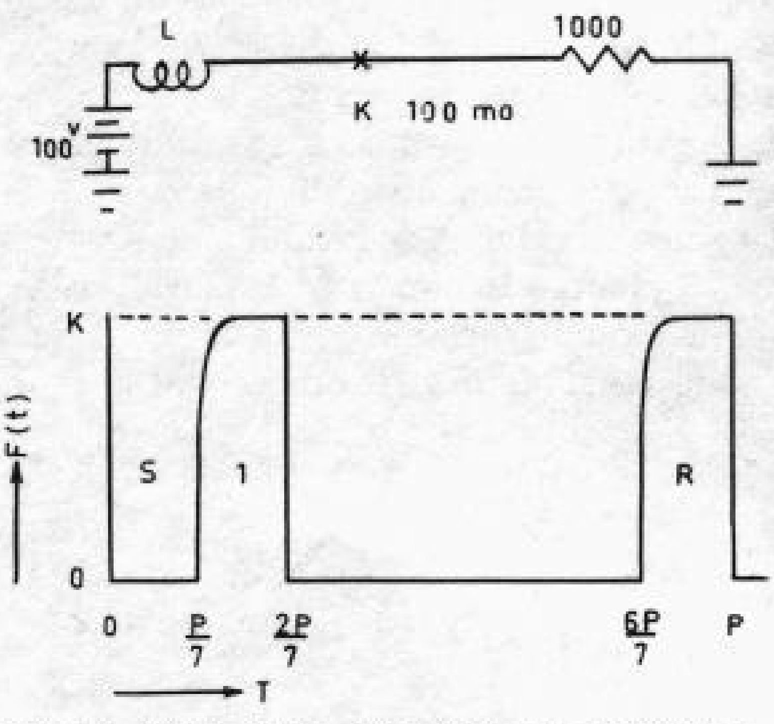


Figure 7. Wave shape of character *E* in inductive circuit

If the Fourier Complete Series Analysis is applied to the letter *E* of Figure 7, imposing the same conditions of periodicity, the effect on each component frequency may be observed. Before applying the analysis, however, a point of caution must be made. The *Ao* term represents the d-c component of the wave and, practically speaking, it is the area of each pulse divided by its base to obtain the average height and then averaged over the whole period. The instantaneous equation for current rise plotted against time in a resistance-inductance circuit is the solution of the differential equation:

$$L\frac{di}{dt_1} + iR = V$$

which is

$$i(t_1) = k\left(1-e^{-\frac{R}{L}t_1}\right) \tag{12}$$

where K is the normal value of the direct current, R is the total series resistance, L the total series inductance, and $i(t_1)$ is current as a function of time.

If the value for $i(t_1)$ in equation (12) is used to calculate the areas of the first and rest pulse of Figure 7, they will be found to differ since the same exponential expression will be integrated over different limits.

To remedy this situation the following substitution must be made:

let $t_1 = t - d,\ i(t_1) = f(t)$

where t is the same variable used in previous calculations and d has a time value equal to the value of t at the lower limit of integration. This corresponds either to the exponential shift familiar to students of the Laplace transformation, or to the change in phase angle of a sinusoidal wave, or to a change in limits of integration by substitution of variable.

Thus in summary, for the character E

$$f(t) = 0,\ 0 < t < \tfrac{P}{7},\ \tfrac{2P}{7} < t < \tfrac{6P}{7}$$

$$f(t) = k\left[1-e^{-\frac{R}{L}\left(t-\frac{P}{7}\right)}\right],\ \tfrac{P}{7} < t < \tfrac{2P}{7}$$

$$f(t) = k\left[1-e^{-\frac{R}{L}\left(t-\frac{6P}{7}\right)}\right],\ \tfrac{6P}{7} < t < P$$

Now substituting the new values of $f(t)$ into equation (2):

$$A_0 = \frac{1}{P}\left[\int_{\frac{P}{7}}^{\frac{2P}{7}} k\left(1-e^{-\frac{R}{L}\left(t-\frac{P}{7}\right)}\right)dt + \int_{\frac{6P}{7}}^{P} k\left(1-e^{-\frac{R}{L}\left(t-\frac{6P}{7}\right)}\right)dt\right]$$

$$A_0 = \frac{2K}{7} + \frac{2KL}{RP}\left[e^{-\frac{RP}{7L}} - 1\right] \tag{13}$$

Comparing equations (13) and (7) reveals the factor

$$\frac{2KL}{RP}\left[e^{-\frac{RP}{7L}} - 1\right]$$

subtracting an amount of current from the normal direct current depending on the value of the circuit parameters. This is the reason a lower current reading is observed with a locked character when a teleprinter or relay is added to a pure resistance circuit.

To see the effect of inductance on the component sine waves use equations (3) and (4) again as follows:

$$A_n = \frac{2K}{P}\left[\int_{\frac{P}{7}}^{\frac{2P}{7}}\left(1-e^{-\frac{R}{L}\left(t-\frac{P}{7}\right)}\right)\cos\frac{2n\pi}{P}t\,dt + \int_{\frac{6P}{7}}^{P}\left(1-e^{-\frac{R}{L}\left(t-\frac{6P}{7}\right)}\right)\cos\frac{2n\pi}{P}t\,dt\right]$$

$$\begin{aligned} A_n = {} & \frac{K}{n\pi}\left[-\sin\frac{2n\pi}{7} + \sin\frac{4n\pi}{7} - \sin\frac{12n\pi}{7} + \sin 2n\pi\right] \\ & + \frac{2K}{P}\left[\frac{b}{(-a)^2+b^2}\right]\left[\sin\frac{2n\pi}{7} - e^{-\frac{RP}{7L}}\sin\frac{4n\pi}{7} + \sin\frac{12n\pi}{7} - e^{-\frac{RP}{7L}}\sin 2n\pi\right] \\ & + \frac{2K}{P}\left[\frac{a}{(-a)^2+b^2}\right]\left[-\cos\frac{2n\pi}{7} + e^{-\frac{RP}{7L}}\cos\frac{4n\pi}{7} - \cos\frac{12n\pi}{7} + e^{-\frac{RP}{7L}}\cos 2n\pi\right] \end{aligned} \tag{14}$$

and

$$\begin{aligned} B_n = {} & \frac{K}{n\pi}\left[\cos\frac{2n\pi}{7} - \cos\frac{4n\pi}{7} + \cos\frac{12n\pi}{7} - \cos 2n\pi\right] \\ & + \frac{2K}{P}\left[\frac{a}{(-a)^2+b^2}\right]\left[-\sin\frac{2n\pi}{7} + e^{-\frac{RP}{7L}}\sin\frac{4n\pi}{7} - \sin\frac{12n\pi}{7} + e^{-\frac{RP}{7L}}\sin 2n\pi\right] \\ & + \frac{2K}{P}\left[\frac{b}{(-a)^2+b^2}\right]\left[-\cos\frac{2n\pi}{7} + e^{-\frac{RP}{7L}}\cos\frac{4n\pi}{7} - \cos\frac{12n\pi}{7} + e^{-\frac{RP}{7L}}\sin 2n\pi\right] \end{aligned} \tag{15}$$

where $a = \frac{R}{L}$ and $b = \frac{2n\pi}{P}$

Comparing equations (14) and (8) and (15) with (9) shows the identical expression for the noninductive An and Bn terms plus two additional terms for each transition of mark-to-space and space-to-mark added by the inductance. These additional terms result in a rather unwieldy expression but their magnitude is in the order of a few percent of the noninductive coefficients. Their effect on the first few harmonics is relatively small. As an example, with a 2-henry inductance in the circuit of Figure 7, consider the effect on An in equation (14). With $k = 100$ mils the value of $\frac{k}{\pi}$ is 31.8 as compared to the values of 0.21 and 2.58 for the coefficients

$\frac{2K}{P}\left[\frac{b}{(-a)^2+b^2}\right]$ and $\frac{2K}{P}\left[\frac{a}{(-a)^2+b^2}\right]$ respectively. The effect from the terms resulting from added inductance will not be noticeable until enough higher order harmonics are plotted to make the series closely approximate the actual signal shape.

The addition of capacity to a resistance-inductance circuit is beyond the scope of this paper although analysis of the waves would follow the same principle. The solution for the current wave equation in the RLC circuit is rather long since the three conditions, oscillatory, nonoscillatory and borderline must be treated. The last two conditions would result in equations similar to those of (12) and (13). However, an oscillatory condition would give rise to higher frequencies which just could not be duplicated, even in general outline, by a fundamental plus a few harmonics.

In conclusion, then, it is possible to start with four fixed frequency sine waves along an axis; shift them to the right or to the left with respect to one another; raise or lower their amplitudes with respect to one another; and add the amplitude of the waves point by point to obtain any one of the 32 letter combinations. The resultant wave thus obtained is a reasonable facsimile of a telegraph "square wave," good enough, in fact, to be interpreted by a teleprinter. Adding inductance, resistance, or capacitance in any combination to the circuit will not affect the frequencies of the component sine waves but only their amplitudes and phase angles. The frequencies are determined solely by the fundamental period of the transmitting device.

References

1. Advanced Calculus for Engineers, F. B. HILDEBRAND, Prentice-Hall, Inc., New York, September 1950, pages 236–248.
2. Higher Mathematics for Engineers and Physicists, I. S. SOKOLNIKOFF and E. S. SOKOLNIKOFF, McGraw-Hill Book Co., Inc., New York and London, 1941, pages 63–81.
3. Transients in Linear Systems, M. F. GARDNER and J. L. BARNES, John Wiley & Sons, Inc., New York, Chapman & Hall, Ltd., London, 1942, pages 235–239.

Robert F. Coughlin was graduated from Northeastern University in February 1948, after having served as a Navy pilot during the war, and immediately thereafter joined the engineering staff of Western Union. As a Field Engineer assigned to General Office Maintenance, his work for the first three years was in connection with field testing of the Plan 21 offices at Minneapolis and Detroit, and patron switching systems at Chicago. His present assignment is as a Field Engineer to the Area Engineer, Boston. Mr. Coughlin is attending Northeastern University to obtain a Master's Degree. He is a member of AIEE.

Air-Conditioning A Western Union Patron's Communication Center

FRANCIS GRIFFITH

ZERO-DEGREE brine, supplied by Merchant's Refrigerating Company to cold storage warehouses in downtown New York, is used to provide economical and trouble-free air conditioning for the push-button communication center (Figure 1) of a Western Union patron's private wire system at 60 Hudson St., New York.

The design of an air-conditioning system for installation in buildings constructed years ago, when air conditioning was only a dream, presents numerous problems for the engineer. Floor space in crowded city buildings is at a premium, water conservation devices are a "must," and it is difficult sometimes to find a convenient roof or building offset on which to install a cooling tower or evaporative condenser. In addition, cooling towers are often objectionable to tenants with nearby windows, because of the noise and the discharge of hot, wet air. Furthermore, one of the greatest "headaches" in an air-conditioning system is the maintenance of the cooling tower or evaporative condenser, and much rejoicing is in order when a system can be designed to eliminate this equipment.

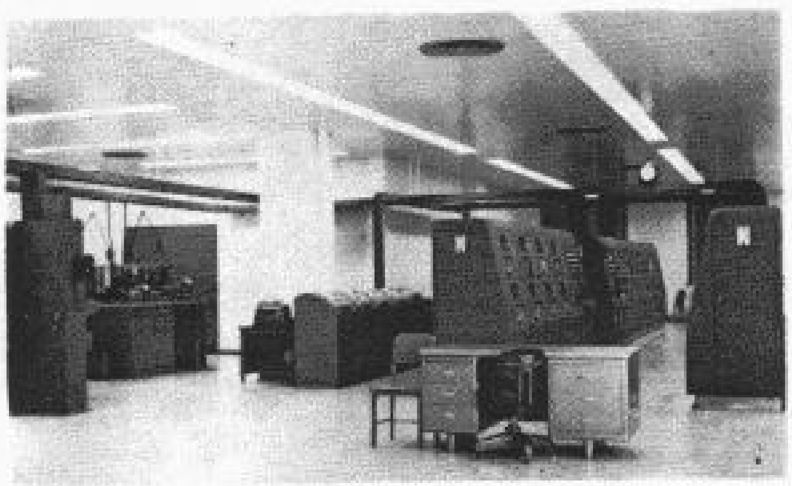


Figure 1. Communication center

Probably the most practical way to air-condition a building is by chilled water distributed through a pipe system connected to individual air-handling units on the various floors. To provide chilled water it is necessary to install a refrigerating plant either on one of the upper floors, in a roof penthouse, or in the basement. The advantage of the upper floor or the roof penthouse would be in the initial savings in piping between the refrigerating plant and cooling tower on the roof. An operating savings would also be realized due to the short distance necessary to pump the water between the condenser and the cooling tower.

To locate the equipment on an upper floor or in a roof penthouse would be economically undesirable, however, because of the value of such space for offices; construction of a penthouse especially for this purpose would be costly. Locating the refrigerating plant in the basement would be advantageous since it would then be with other mechanical building equipment, convenient to the building engineers. However, there would be the drawback of its considerable distance from the cooling tower on the roof.

Western Union engineers have solved these problems in the design of a system to air-condition the modern nerve center of a nation-wide communication system operated by Western Union for one of its patrons. The air-conditioning system uses zero-degree brine which has been pumped to cold storage warehouses in downtown New York for many years. A branch of the underground brine-piping system conveniently runs through the basement of the Western Union building, rather than under adjacent streets. In order to provide air conditioning in the patron's communication center, these brine lines were tapped and branch lines run to a heat exchanger which was installed in the basement as shown in Figure 2. In the schematic of the system, Figure 3, the heavy dashed lines show the brine supply and return lines to the heat exchanger.

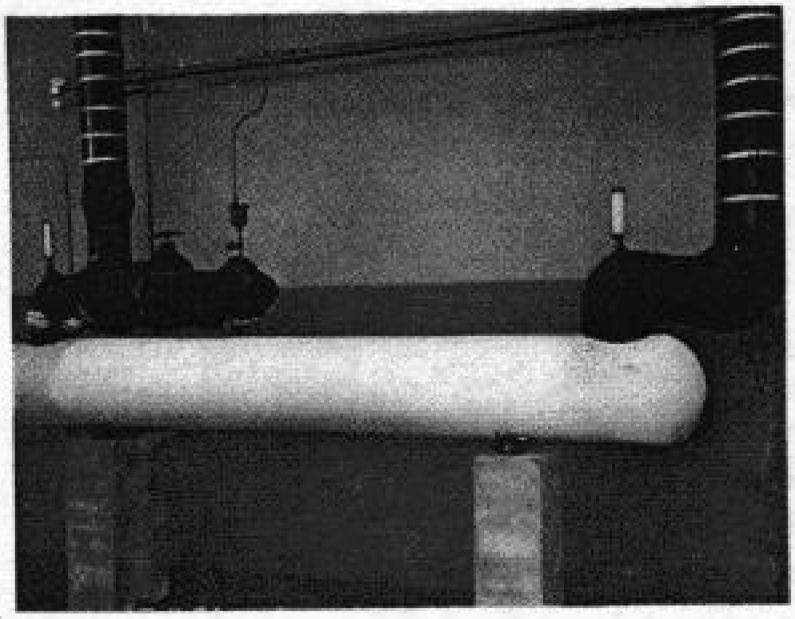


Figure 2. Heat exchanger

In the heat exchanger the brine flows through the coils and chills the water to 40 degrees F. This is accomplished by controlling the rate of brine flow with a temperature regulator and modulating valve, shown in Figure 3. The chilled water is treated with an antifreeze to prevent the formation of ice on the heat exchanger brine coils, and also a possible freeze-up in the exchanger itself. A chilled water circulating pump, adjacent to the heat exchanger and shown in Figure 4, is used to pump the chilled water to the cooling coil of an air-supply unit on the 4th floor, in a room adjacent to the communications center.

When the thermostat located in the return air duct of the air-conditioning system calls for cooling, a relay is actuated which starts the chilled water pump. Cold water is then supplied to the cooling coil in the air-supply unit and the supply air temperature is lowered. As the air-conditioned room approaches the desired room temperature, a bypass valve modulates to the open position to reduce the quantity of chilled water passing through the cooling coil. (See Figure 3.) When the thermostat is satisfied the bypass valve opens wide, the circulating pump in the basement stops, and the supply of chilled water to the cooling coil ceases.

The air-conditioned space contains numerous small electric motors and other electrical heat-generating equipment which contributes to the sensible heat load in the room and makes it desirable to cool the space when outdoor temperatures are

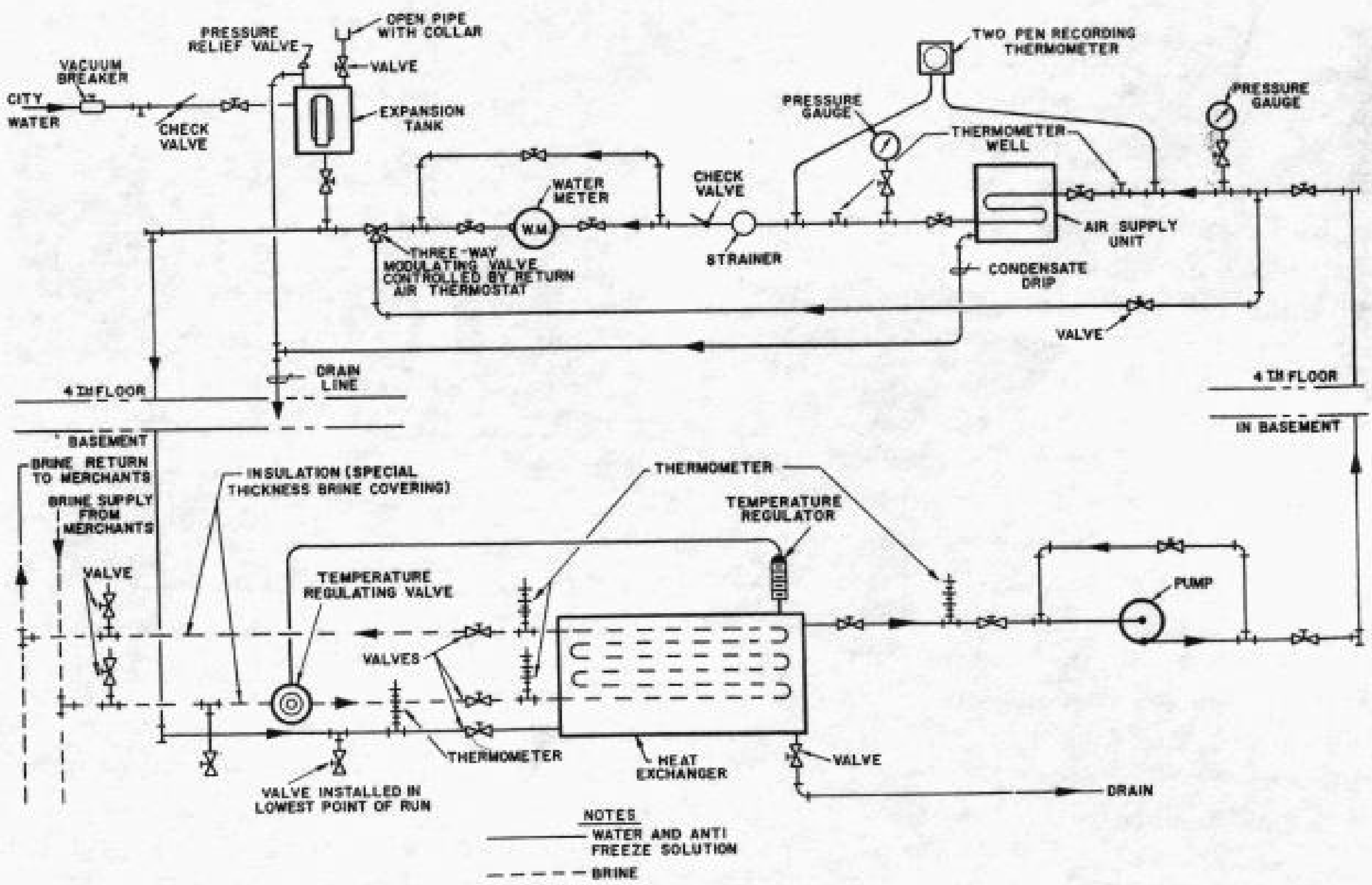


Figure 3. Schematic of cooling system

approximately 60 degrees F or above. When outdoor temperatures are sufficiently low, and the total heat in the outdoor air is less than the total heat in the recirculated air from the air-conditioned room, all outdoor air, or a mixture of out-

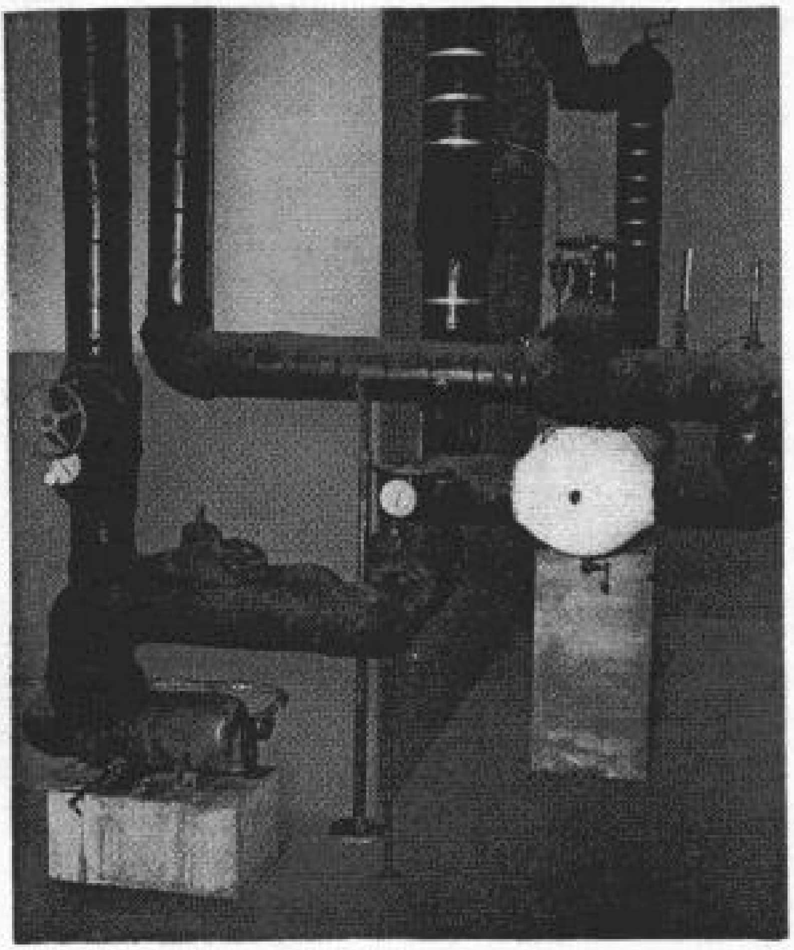


Figure 4. Cold water pump and basement piping

door and recirculated air may be supplied to the space. One of the advantages of this type of air-conditioning system is that all the necessary cooling can be provided by outdoor air during cool weather, while at the same time the chilled water is available if additional cooling is required. This system of using either outdoor or recirculated room air, or any mixture of the two, permits maximum efficiency.

The control system is centered around a wet bulb controller located in the fresh air supply duct. This controller, together with the return air thermostat in the recirculated air duct, causes the fresh air damper, recirculated air damper, and the chilled water valve to modulate as required to supply air of the proper temperature to maintain room conditions. This system operates automatically regardless of the seasons.

Charge for the service is in accordance with the number of ton-days of refrigeration used. A ton-day of refrigeration is defined as the amount of refrigeration necessary to remove 12,000 BTU's of heat per hour for a period of 24 hours. A rate for a ton-day of refrigeration was agreed upon before the installation of the system, and this rate was used in a study to determine if it would be more economical for Western Union to own and operate its own refrigerating plant or to buy brine from Merchant's Refrigerating Company.

A system of measuring the number of ton-days of refrigeration was also agreed upon. This is accomplished by the use of a water meter which measures the quantity of chilled water passing through the air-conditioning system cooling coil, and by a two-pen, temperature recording meter, with 24-hour charts, which simultaneously measures the temperature of the water entering and leaving the cooling coil. (See Figure 5.) The recording meter electric clock mechanism is so connected that it operates the meter only when the circulating pump is running. Recording meter charts are changed once for every 24 hours of pump operation and the water meter reading is recorded. With the use of a planimeter the average temperatures of the water entering and leaving the cooling

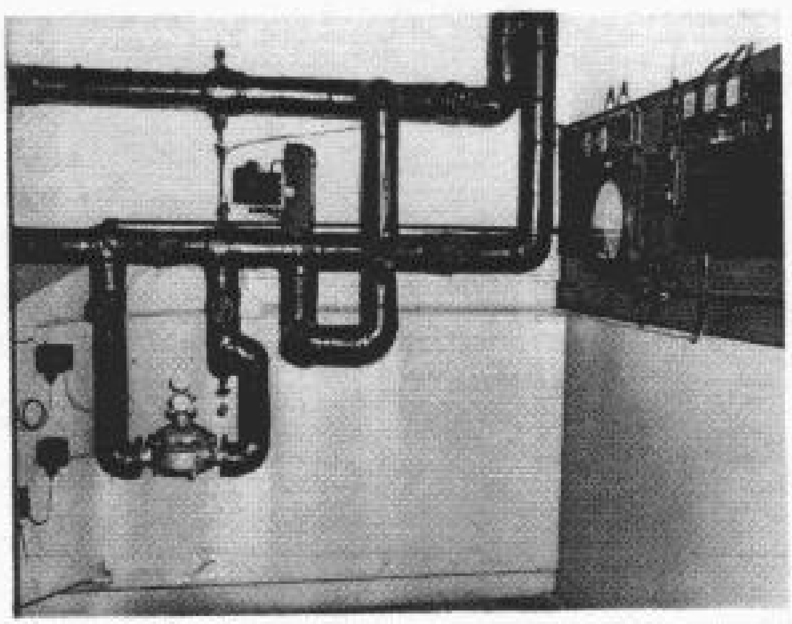


Figure 5. Fourth floor piping showing controls and recording meter

coils can be determined and the difference calculated. With this average difference in water temperature, and the number of gallons of water pumped through the coils in 24 hours of pump operation, the number of ton-days can be calculated.

The system was installed in the spring of 1950 and has given satisfactory and trouble-free service. Maintenance cost has been low since the only moving parts of the entire plant are the water pump in the basement and the fan in the air-handling unit. At the time of the installation a heat exchanger with excess capacity was installed, with liberally-sized piping, to provide for a possible increase in the air-conditioning load.

Comparison of the annual charges and operating cost of the existing equipment using brine, versus a system with a separate refrigerating plant owned by Western Union, reveals that the yearly total cost of the brine plant is a little less than the estimated yearly cost of a separate system. Moreover, the water cooling tower problem has been solved satisfactorily, no valuable space has been wasted, and a reliable system requiring the minimum amount of maintenance has been achieved.

Francis Griffith entered the employ of Western Union in 1925 after graduation from Drexel Institute with the degree of B.S. in M.E. He was first engaged in the development and design of the special Western Union conveyor systems, and recently has also been concerned with the development and installation of mechanical equipment such as heating, ventilating, plumbing and air-conditioning systems. He has designed or supervised the design of most of the air-conditioning plants in our offices. The above article was also published in the November 1954 issue of HEATING, PIPING AND AIR CONDITIONING.

Patents Recently Issued to Western Union

Electrosensitive Recording Blank

B. L. Kline

2,681,309—June 15, 1954

An electrosensitive recording blank including a marking coating comprising cuprous thiocyanate for marking purposes mixed with certain materials to prevent accumulation of decomposition products on the stylus point. In general, certain hydroxides, sulphides, carbonates and basic carbonates, mixed with the cuprous thiocyanate, either singly or in combination, are suitable for this purpose. A small amount of a suitable dye, such as titanium dioxide, may be added to the coating to increase the opacity and brightness.

Facsimile Recording Apparatus

C. Jelinek, Jr.

2,683,186—July 6, 1954

Facsimile recorder provided with various power saving features to adapt it for operation from the 6-volt storage battery of a telegram delivery car. In addition to tube cathodes, the battery supplies energy to two dynamotors, a frequency standard and a vibrator-converter. In stand-by condition some cathodes are energized and one dynamotor runs at half speed. An incoming message is preceded by a 2-second steady selector signal, then a 2-second silent interval followed by phasing pulses. During this period the first dynamotor reaches full speed, and the other power devices are energized in order as needed so that the power drain peak is minimized.

Repeater Switching Apparatus

W. D. Cannon, E. L. Newell, C. H. Cramer

2,683,188—July 6, 1954

An improvement on Patent 2,658,945, granted November 10, 1953, disclosing a switching arrangement for a submerged repeater operable from the receiving shore station which sets up various test and operating conditions including a repeater by-pass. The present invention utilizes two parallel connected cold cathode gas tubes unresponsive to the normal negative power supply potential supplied from the shore station but responsive to control pulses of positive polarity. A magnet is operated by the discharge of the cold cathode tubes, to step a rotary switch to a desired test position while a counter at the shore station indicates the repeater switch position. Advantage of the arrangement is that the parallel connected cold cathode tubes offer long life, and consume no heater power.

Concentrated-Arc Discharge Device

W. D. Buckingham

2,687,471—August 24, 1954

A Concentrated-Arc Lamp employing a cathode with zirconium or hafnium oxide as the active element and of the general type described in Patent 2,453,118, but intended for larger wattages. For the anode one or two molybdenum rods long in comparison with the arc length are used, the arc terminus being at the center of the rods so that heat flows in opposing directions for ready dissipation. While a single rod may be used the double rod construction is preferred and this latter lends itself readily to direct operation from a-c power with the two anodes functioning alternately. A further feature is a rectangular configuration for the active end of the cathode to match the aperture of projection optical systems.

Signal Amplifying System for Electrically Actuated Recording Devices

W. D. Cannon

2,687,935—August 31, 1954

An amplifier embracing a number of unique features for the suppression of interference, particularly as encountered in electrocardiography as described in patent No. 2,502,419. To suppress longitudinal interference entering the input leads from the patient an unbalanced low impedance input potentiometer is employed in conjunction with very large common self-bias resistors for the push-pull stages. An unbalanced intermediate stage is introduced so that any residual interference due to pickup or battery supply variation may be observed in the recording instrument and suitable measures invoked to suppress almost completely the longitudinal interference which would otherwise tend to overload the output stages. Features relating to calibration, battery supply and monitoring are also included.

Two-Way Facsimile Telegraph System

G. H. RIDINGS, R. J. WISE, G. B. WORTHEN
2,689,273—SEPTEMBER 14, 1954

Phasing circuitry for a two-way facsimile circuit described as applied to conductive pickup type Desk-Fax transceivers. Pressure of the transmitter start button starts both transmitter and receiver synchronous drum motors, each drum sending pulses to a jointly controlled receiver phasing relay. The receiver drum runs at a slower initial rate and quickly drifts into phase with the transmitter when the coincidence of the transmitter and receiver pulses causes operation of the phasing relay, which in turn restores the receiver motor to normal speed and starts the stylus motors at both the transmitter and receiver.

Time and Date Transmitter

W. S. W. EDGAR, JR.
2,690,474—SEPTEMBER 28, 1954

A time and date transmitter for telegrams comprising a rotary switch type of storage mechanism for setting up the time and date data under control of the minute impulses from a time service circuit but with manual settings for month and year. A collator then assembles the stored data and a distributor sends it into outgoing telegraph circuits in response to end-of-message signals. Time changes are delayed until the transmitter becomes idle and if calls for data occur while the transmitter is busy the accumulated calling circuits are all connected for simultaneous transmission as soon as the transmitter cycle is completed. The delay, therefore, does not exceed about five seconds.

Telecommunications Literature

MAGNETIC AMPLIFIER CIRCUITS — WM. A. GEYGER—McGraw Hill, N. Y., 1954. 277 pp., $4.50. This book is written for the designer of magnetic amplifiers and enables him to compare various circuits and select the one best suited for accomplishing a particular function. The book is not a text, nor is it intended as a quick, painless, self-taught treatise on the simple basic theory of magnetic amplifiers. It is primarily a handbook with emphasis upon the historical and patent aspects and as such is useful to the designer or patent attorney. The magnetic amplifier is, however, an abstruse and complex device embracing as many parameters, if not more, than are found in thermionic tubes or transistors. These parameters are hidden in innocent-appearing symbols and reveal their complete meaning only after lengthy study.—R. J. WISE, Telefax Research Engineer; J. R. HYNEMAN, Patent Engineer.

ULTRA HIGH FREQUENCY PROPAGATION — HENRY R. REED and CARL M. RUSSELL—John Wiley & Sons, Inc., N. Y., 1953. 562 pp., $9.50. This book was written as a result of propagation studies made at Patuxent River, Maryland, under authorization of the Navy Bureau of Aeronautics. It is primarily concerned with air-to-air and air-to-ground UHF propagation. The authors have presented experimental data and other valuable information in a text book approach with emphasis on a systems concept. Much of the early part of the book can be applied to ground-to-ground propagation, and of particular interest are discussions on field strength in the diffraction region, multipath propagation, and circularly polarized complex antennas. R. E. GREENQUIST, Project Engineer, Radio Research Division.

THE RADIO AMATEUR'S HANDBOOK — AMERICAN RADIO RELAY LEAGUE—30th Edition, 1953. 610 pp., $3.00. This book was prepared to serve as a handbook for amateur radio hobbyists, but the wealth of basic electronic information and the simple straightforward presentation have made it a popular handbook with technical beginners in the radio communication field. About one-third of the book is devoted to theory discussions of radio communication subjects including a-c electrical circuits, vacuum tubes, modulation methods, transmission lines, antennas, radio propagation, and microwave tubes and components. A section is devoted to measuring and testing equipment for radio apparatus and there is a very useful appendix containing miscellaneous data and engineering tables. About half of the handbook deals with the construction of amateur radio receiving and transmitting equipment and the layout and operation of an amateur station. It is recommended for the novice with an interest in electronics or radio communications. — H. M. SAUNDERS, Assistant Director, Private Wire Services.