APPLICABILITY OF MAGNETIC-DRUM INFORMATION STORAGE TO THE CAA TELETYPEWRITER CIRCUITS

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Navigation Aids Evaluation

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APPLICABILITY OF MAGNETIC-DRUM INFORMATION STORAGE TO THE CAA TELETYPEWRITER CIRCUITS

SUMMARY

This report is the result of a study made at the Technical Development and Evaluation Center to determine whether a magnetic-drum information-storage system could improve the existing CAA teletypewriter service

It was found that a large percentage of CAA teletypewriter-message traffic consists of weather observations and forecasts It was concluded that a better and more efficient service could be rendered by a system which combined magnetic-drum storage of some weather messages with a suitable, fully automatic, teletypewriter system. Savings in the amount of traffic handled by various circuits can be achieved by enabling stations to request from the magnetic-drum storage those weather observations and forecasts that are needed infrequently This would substantially reduce the number of stations requiring routine transmissions of a given weather message

The new system would be economical only for a heavy volume of traffic such as that now carried by CAA circuits Furthermore, it can initially be implemented in a small area and can readily be interconnected with existing CAA circuits on the perimeter of that area

Administrative and traffic-control messages such as those now handled on Service B could be efficiently transmitted over the same circuits The suggested system is compatible with that being developed under the sponsorship of the Air Navigation Development Board for transmitting air-traffic-control messages

INTRODUCTION

The Civil Aeronautics Administration maintains and operates extensive teletypewriter and telephone networks to gather, distribute, and transmit a mass of information that is essential to the safety and the efficiency of modern aviation

This information consists almost entirely of short messages having an average length of less than 35 words Some of the messages are gathered from many different geographical points and are assembled for use by the aircraft pilot and his associates who are concerned with planning the flight of aircraft Weather reports, forecasts, advisories, and notices to airmen are in this category The remainder of the messages are concerned with the flight plans of aircraft, predicted and actual progress of aircraft, estimated times of arrival, and other information of a similar nature Because of the speed of modern aircraft it is essential that this information be transmitted and processed rapidly and that it be quickly accessible on demand

Weather, for example, changes rapidly, and available techniques and equipment are not sufficient to predict weather accurately and precisely for long periods in advance For this reason, when the pilot plans the flight of his aircraft he requires current weather information from distant points It is desirable that information pertaining to aircraft in flight be transmitted ahead and processed rapidly enough so that traffic-control decisions can be made well in advance of the arrival of the aircraft at their destinations

At the present time, traffic-control information for instrument flights has been transmitted principally over the long-distance-telephone network known as CAA Service F Weather information, notices to airmen, and other information have been transmitted principally over 60-words-per-minute (wpm) teletypewriter circuits known as CAA Services A, B, C, and O At the present time the A system comprises 1703 drops distributed over 12 circuits and is used principally for airways weather reports, special weather reports, and notices to airmen The B system serves only CAA facilities at 400 locations distributed over approximately 25 circuits and is used to transmit important but less urgent flight-plan information such as VFR flight plans and flight-plan approval requests for the mass movement of military aircraft The C system serves 384 drops distributed over six circuits and is used to handle 3- and 6-hourly weather data, forecasts, and weather advisories The O system serves 87 drops and is used for overseas weather information needed in the preparation of maps and forecasts in connection with overseas flights

In the beginning these facilities were modest in scope, but as the number of aircraft increased, new circuits, stations, and equipment were added to handle the increasing quantities of information required for the safer operation of the growing number of aircraft

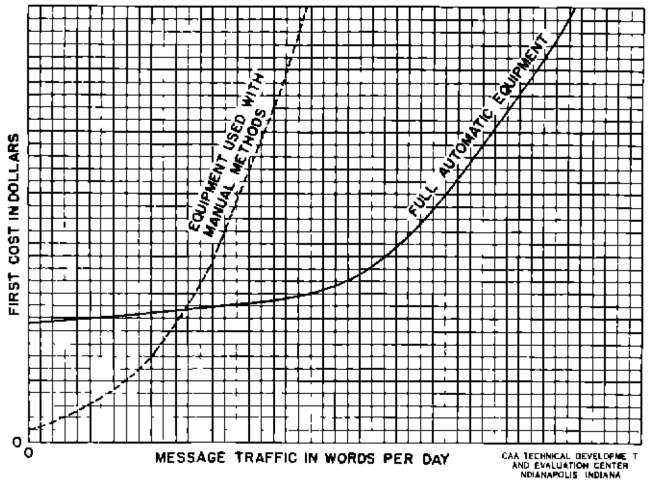

Fig. 1 Hypothetical-Cost Curves for Nonautomatic and Automatic Equipment

This process of expanding existing communication facilities has provided an efficient service for many years. However, as the number of aircraft flights per peak hour increases, a point will be reached where simple expansion of existing types of facilities will not safely handle the traffic Since it appears that this point will be reached in some high-density areas in the foreseeable future, the time is at hand to develop and to evaluate new and radically different communication devices.

Although the first cost of the new devices may be high, the total cost per message should be much less than it would be if the present system were used to handle the heavy traffic In many industries, experience has shown that automatic machines capable of mass production usually have a much higher first cost than those used with manual methods at lower production rates. However, operating costs per unit of production are usually much lower with automatic machines Curves of total cost versus production are often similar to those of Fig 1, in which automatic machines are represented as being very costly for low production rates but very economical for high production rates Before the equipment suggested in the report is accepted, tests should show that it can handle at low cost a substantially greater volume of traffic than the present system.

One of the projects sponsored by the Air Navigation Development Board at this Center has as its objective the development of a teletypewriter system for transmitting traffic-control information This system consists initially of magnetic-drum flight-plan storage equipment, an automatic teletypewriter switching system, and electromechanical displays of tabular information. The details of the development and evaluation of this equipment for air traffic control will be described in subsequent reports.

The contract for the magnetic-drum flight-plan storage equipment was authorized in June 1951, and the equipment was developed and constructed by the Engineering Research Associates Division of Remington Rand, Inc ,at St. Paul, Minnesota. Several months after the start of this contract, the Office of Federal Airways suggested that this type of equipment could also be used to provide a more efficient weather-communication service. Since it appeared that a new weather-communication system utilizing the magnetic-drum storage could be introduced without requiring any significant change in the message texts or in their manner of use, the study of such an application was undertaken at the Technical Development and Evaluation Center. This report is a result of that study project.

During the course of the study, the ideal characteristics desired were investigated. Information was obtained from Mr. I. D. Boyle of the U. S Weather Bureau and also from numerous CAA personnel in the regions and in Washington. It was found that weather reports, forecasts, analyses, and other such information are a unique type of message for the following reasons

1 They deteriorate in value quite rapidly.

2 They require wide and varied distribution
3 The originator is not familiar with the distribution required
4 The variety and number of messages required differs between different offices, even between offices in the same city
5 The variety and frequency of messages required change from one weather situation to another
6 Although the minimum routine requirements at a station may be quite limited, a large reserve of data must be available for occasional use
7 Each office or station would prefer that its teletypewriter machines print only those messages that it needs

The study disclosed that if the present CAA teletypewriter system were replaced by a fully automatic teletypewriter system and by a few magnetic-drum storage devices for teletypewriter messages, then any station could obtain infrequently needed weather observations, forecasts, and so forth by sending a brief request message to the nearest magnetic-drum device and could receive a prompt reply. More frequently needed observations, forecasts, and so forth could be sent to each station on a routine program basis each time such a message was prepared However, the provision for request service from magnetic-drum storage would substantially reduce the number of routine transmissions to any one station over the number required in the present system. With this type of system weather observations, forecasts, and so forth could be originated more frequently under stormy-weather conditions and less frequently when the weather is settled and changing slowly. Each weather observation should carry the time at which it was made, and each forecast should carry the time for which it should be valid Some individuals in the U S Weather Bureau have expressed personal opinions that, if such a communications system were available, the present program of taking operational weather observations and of making operational forecasts at scheduled times might be modified to a plan of taking the observations and making the forecasts to suit the changes in the weather situation Such a program would give the greatest assistance to aviation when such assistance would be needed most

Routine or programmed distribution of any message could be accomplished by requiring the originating station to send the message to a central point The multiple addresses for each such message would be stored at the central point and would be prefixed to the message immediately upon its arrival The message with its multiple-address prefix would then be sent to a switching center of the fully automatic teletypewriter switching system for prompt distribution

Before describing the proposed system in detail, automatic equipment that is either in existence or under construction will be described These include the magnetic-drum teletypewriter message storage equipment and the Western Electric 81D1 automatic teletypewriter switching system now being installed at the Technical Development and Evaluation Center A brief description of the SECO, MEDIS, and ASID devices used by CAA is also included

MAGNETIC-DRUM FLIGHT-PLAN STORAGE EQUIPMENT

Although the characteristics of the flight-plan storage equipment will be used to illustrate this report, it is desired to point out that an equipment specifically designed to store weather information might differ in capacity, maximum lengths of messages, methods of processing messages, speed, number, and kind of teletypewriter input and output circuits.

The present magnetic drum will store 2,000 teletypewriter messages, of which 750 may have a length of not more than 230 characters (letters, digits, or weather symbols) and 1,250 may have a length of not more than 115 characters Two thousand such messages would require nearly 12 hours to pass over one 75-wpm teletypewriter circuit.

The flight-plan storage equipment will accept messages from remote stations via a fully automatic teletypewriter switching center and in one-half second will prepare a reply to the remote station for transmission via the same switching center The present equipment includes two input circuits and two output circuits for standard 75-wpm teletypewriter transmission. It also includes an input circuit and an output circuit for 1,000-wpm operation Additional input and output circuits can be added at any time The magnetic-drum equipment is capable of serving 50 to 100 fully loaded teletypewriter circuits. This is greatly in excess of any known practical requirements.

Each message intended for the magnetic-drum equipment must be prefixed by an address which will enable the fully automatic teletypewriter switching center to deliver it to one of the drum input circuits. Such a prefix must be followed by the switching code for the reply message This code will be placed at the beginning of the reply message that is automatically prepared by the magnetic-drum equipment

To be accepted by the flight-plan storage equipment, each incoming message must also contain a code called the "kind" character which indicates that the contents are to be stored, that a message already stored in the drum is to be found and included in the reply, or that a stored message is to be cancelled so that it can no longer be read out

Garbled messages are received by the magnetic-drum equipment and are automatically printed out on a printing-reperforator so that the operator in charge of the equipment can analyze them and take appropriate action. Such a message is referred to as an "erroneous message "

If the incoming message requests storage of its contents, the magnetic drum performs the storage operation in one-half second and then replies with a copy of what it has stored This enables the originator to verify the accuracy of the stored information and gives him positive assurance that the storage function has been completed

The eighteen characters which follow the kind character in an accepted message are known as the criterion They serve as the identification of the stored message. A request from a remote teletypewriter station to find and to read back a stored message must accurately specify the first three characters and the last ten characters of the desired criterion The magnetic drum compares these characters with the criterion of each of the 2,000 stored messages at a speed of 114,000 characters per second. The message will be found in less than one-half second If there is no such message stored, the reply will contain an X instead of an R in the kind-character position. A reply containing an X in the kind character is termed an "alarm reply "

If the incoming message requests that a weather observation be stored, the magnetic-drum equipment searches out the old weather observation for that location identifier and replaces it with the new observation.

In the proposed air traffic control application of this equipment, the first three characters of the criterion represent the departure airport for the flight plan, the next four characters represent the time of departure, and the remaining characters represent the aircraft identification. It is suggested that for weather observations, the criterion consist of the location identifier of the point of observation, a clock time, and the type of weather report as illustrated in Table I.

In addition to the features already enumerated, the equipment has an internal program device that has been given the name of "clock read-out " A clock-driven stepping switch inaugurates a time search of the stored messages every ten minutes. It finds those flight plans which have an expected departure in the next twenty minutes and transmits each one via the teletypewriter switching center to the appropriate departure airports Once a stored message is transmitted in this manner it is marked so that it will no longer be transmitted on a clock read-out but can still be requested via the teletypewriter circuits. It is believed that this feature is useful only for certain flight plans and is not useful for the stored weather observations.

Technical details for magnetic-drum equipment in general have been explained in previous articles.[1] Technical details concerning the flight-plan storage equipment will be described in subsequent reports.

The features built into the flight-plan storage equipment are included in a specification prepared at this Center.[2] This specification also describes many functions not included in the present equipment. The size and arrangement of this equipment are illustrated in Figs. 2, 3, and 4.

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[1] Arnold A Cohen, "Magnetic Drum Storage for Digital Information Processing Systems," Mathematical Tables and Other Aids to Computations, Volume IV, No. 29, pp. 31-39, January 1950.

[2] "Specification for a Flight Plan Data Storage and Processing Equipment for Air Traffic Co-ordinating Equipment " CAA, Technical Development and Evaluation Center, Specification No. TD-114, February 5, 1951.

TABLE I

CRITERION IDENTIFIERS FOR WEATHER MESSAGES STORED ON MAGNETIC DRUM

Hourly and Supplementary for U S	AWUS	00
Hourly and Supplementary for Canada	AWCN	00
Terminal Forecasts for U. S	FTUS	00
Terminal Forecasts for Canada	FTCN	00
Piballs* for U. S	PBUS	00
Piballs* for Canada	PBCN	00
Pilot Reports for U. S	PRUS	00
Pilot Reports for Canada	PRCN	00
Radar Storm Reports for U. S.	SDUS	00
Severe-Weather Forecasts and Bulletins for U. S	SVWX	00
Area Forecasts for U S	FAUS	00
Area Forecasts for Canada	FACN	00
Upper-Wind Analysis for U. S.	WAUS	00
Raobs** for U. S.	RSUS	00
Raobs** for Canada	RSCN	00
Six-Hourly for U S.	MTUS	00
Six-Hourly for Canada	MTCN	00
Three-Hourly for U S	THUS	00
Three-Hourly for Canada	THCN	00
Regional Forecasts for U S.	FRUS	00
Regional Forecasts for Canada	FRCN	00
State Forecasts for U. S.	FPUS	00
Five-Day Forecasts for U S.	FEUS	00
Winter Sports, Etc., for U S.	FWUS	00
River Reports for U S	CRUS	00

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*Pilot-balloon reports
**Radiosonde reports

Fig 2 General View, Flight-Plan Storage Equipment

CAA AUTOMATIC TELETYPEWRITER DEVICES

Because of the fast processing time of magnetic-drum teletypewriter-message storage systems, some form of automatic teletypewriter switching is required for the economical and efficient use of such storage systems Furthermore, other automatic devices can contribute to the efficiency of the system. Three automatic devices now in use on the CAA circuits are the SECO, the MEDIS, and the ASID equipments

The SECO equipment[3] is designed to work on a half-duplex circuit which interconnects a multiplicity of transmitting and receiving stations Each station is assigned a distinctive, three-character, location identifier At a scheduled time, the station designated as a master control seizes the circuit and by means of various codes of nonprinting characters and the location identifier instructs each station to transmit its weather report in the proper sequence

[3]SECO (Sequential Control), CAA Airways Operations Training Series, Bulletin No 5, April 1949

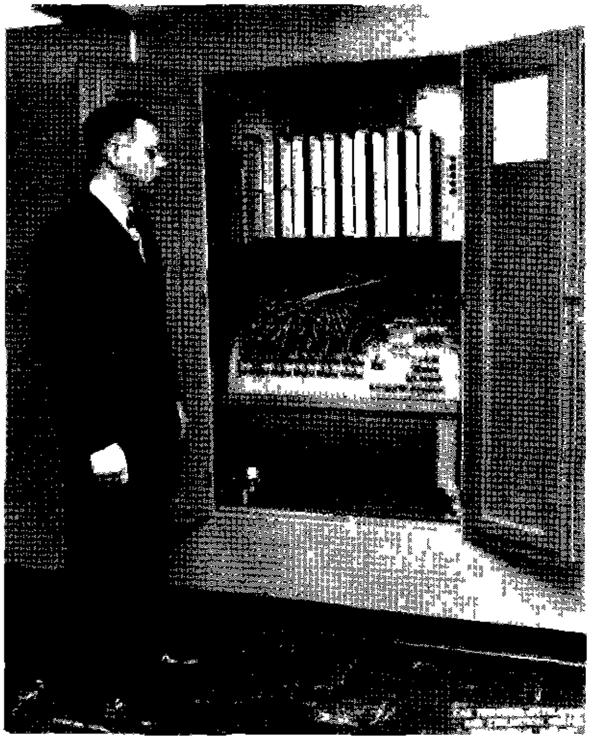

Fig 3 Magnetic-Drum Cabinet

The reports are printed on all printers connected to the line This equipment, therefore, makes efficient use of the line time to collect a sequence of weather reports without confusion or overlap A modified form of SECO will be suitable for collection circuits in the suggested system

The MEDIS equipment[4] is designed to select certain weather reports from a sequence collected on one circuit and to perforate them on another tape which an operator can conveniently transmit to specified circuits on a specific time schedule The system to be suggested is capable of providing weather-report users with more useful information than the MEDIS equipment can provide

The ASID equipment is installed at a transmitting station on a multistation half-duplex line When the station wishes to transmit a message prepared on perforated tape, the ASID stands watch over the line and attempts to seize it when it is free In general, the ASID units on the same line have different relay pick-up times However, if two of them do pick up and start transmitting simultaneously, garble results and they drop If this happens, the operator usually has to reset the tape in the transmitter, which is not serious on a manually controlled system but which might result in lost messages on a fully automatic system

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[4]MEDIS (Message Diversion), CAA Airways Operations Training Series, Bulletin No 8, November 1951

Fig 4 Monitor and Maintenance Console for Flight-Plan Storage Equipment

THE WESTERN ELECTRIC TYPE 81D1 FULLY AUTOMATIC TELETYPEWRITER SWITCHING SYSTEM

This type of equipment has been described in the literature [5,6] Several airlines and industries use such a system for their long-distance teletypewriter communications Essentially, the system consists of switching centers interconnected by trunk lines Each center has one or more local lines radiating from it A local line may have several transmitting and receiving stations connected to it Each station is assigned a two-letter identification However, since only 20 letters of the alphabet are used for this identification a maximum limit of 400 codes for each system is imposed

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[5] W M Bacon and G A Locke, "A Full Automatic Private-Line Teletypewriter Switching System," Transactions of the American Institute of Electrical Engineers, Vol 70, pp 473-480, 1951

[6] Walter M Bacon, "The 81-C-1 Teletypewriter Switching System," Bell Laboratories Record, Vol 28, No 4, pp 145-152, April 1950

When a single-address message is transmitted in this system, it is preceded by the two-character directing code of the destination and is ended by "figures-N-letters" The message is stored on a perforated tape in a reperforator-transmitter-distributor unit in the switching center and the two-character code is read to an equipment called a "director" The director locks up a circuit through a crossbar switch from the transmitter of the incoming unit to the perforator of a reperforator-transmitter-distributor unit associated with the outgoing line. The director is only occupied a fraction of a second The "figures-N-letters" code breaks the crossbar switch connection at the end of the message. If the outgoing line is a multistation circuit, a device called the SOTUS equipment co-operates with a control equipment at each station to make certain that only the printer of the destination station is connected to the line while the message is being transmitted. Transmitting stations on a multistation line are interrogated sequentially at frequent intervals. A station having a message to transmit may start sending only when its call letters occur during this interrogation. A type of priority is available by which on a given line some stations are given more frequent opportunity to transmit than others.

Full-duplex lines are used throughout the 81 type systems Such lines permit simultaneous transmission to and from the switching center. Full-duplex-line lease charges are only 25 per cent greater than the half-duplex-line lease charges.

Multiple-address messages can be transmitted through the 81 system. This is done by preceding such messages with a multiple-address code which is followed by the addresses of all stations which are to receive the message The two-character directing code which precedes each multiple-address message is the code for the multiple-address equipment located in the switching center. As soon as such a message is received in the switching center, it is transmitted to the multiple-address equipment. This device proceeds to detect all the address codes preceding the text of the message and requests the director to seize one of the two outgoing reperforator-transmitter-distributor units for each of the required circuits. When this is completed, the multiple-address equipment sends the text and the necessary codes simultaneously to all circuits

Group-address messages can also be handled by the 81 system. Such messages are preceded by only two directing codes. The first takes the message to the group-address equipment which is located in the switching center. The second two-character code is used by this device to select a predetermined group of directing codes previously wired into it. The group-address equipment then requests the director to seize circuits corresponding to the prewired codes. When this is completed, the text plus the necessary codes are sent to all circuits simultaneously.

Although the 81-type system is not entirely suitable for use in CAA communications, it is a fully automatic teletypewriter switching system. A modified version of it will be used in the evaluation experiments with the magnetic-drum flight-plan storage equipment.

A SUGGESTED TELETYPEWRITER SYSTEM INCORPORATING MAGNETIC-DRUM STORAGE AND FOR WEATHER AND ADMINISTRATIVE MESSAGES

Some of the major components having been described, the system evolved during the study project will be outlined. The system was evolved by a comparison of the requirements, which were discussed in the introduction to this report, and the characteristics of the major equipment which have been described. The single integrated system suggested here can replace the present CAA systems known as Services A, B, C, and O. It would include a number of automatic teletypewriter switching centers interconnected by trunk lines

For the ultimate nation-wide system, a network of trunks and switching centers such as that shown in Fig. 5 could be used. Although the arrangement of centers and trunks shown in Fig. 5 is used in this report only for illustrative purposes, the reader may wish to consult the study made for the Air Navigation Development Board which proposed this system for air traffic control purposes.[7] A TDEC specification based on that study was also prepared [8]

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[7] "Airport Time Utilization Equipment - Phase I - Systems Engineering Study," Cornell Aeronautical Laboratories for the Air Navigation Development Board, March 1, 1950.

[8] "Specification for Automatic Switching and Communication System for Air Traffic Co-ordinating Equipment," CAA, Technical Development and Evaluation Center, Specification No. TD-115, February 7, 1951.

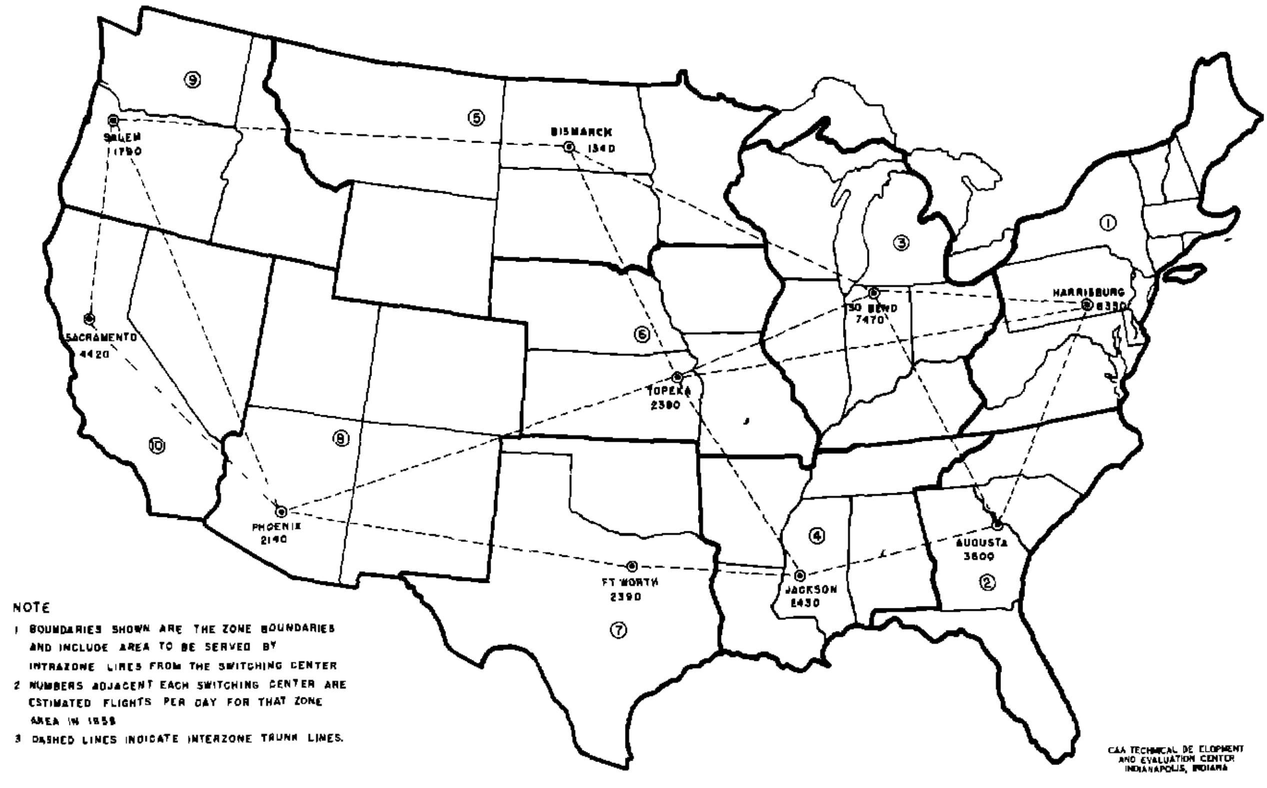

Fig 5 Location of Switching Centers Suggested in Cornell Aeronautical Laboratories Report

Each switching center would serve the stations in its area by means of a radial network of multistation local lines. Each message introduced into the system would be preceded by one or more three-character directing codes. Each directing code is to represent a receiving station to which the message is to be sent. The first character of the directing code would uniquely define that switching center with which the destination station is associated. Messages will be sent to a switching center, either from its associated stations over the radial system of multistation lines or from adjacent switching centers via trunk lines Each switching center is to contain an equipment, known as a director, which functions in a manner similar to that of the director in the Western Electric 81 system.

If for any message the first character is that of some other switching center, the director will cause the message to be transmitted over a trunk line to an adjacent switching center which lies along the most direct route to the destination. However, if the first directing-code character is that of its own switching center, the director will sense the second and third characters and will cause the message to be transmitted to the local line serving the destination station. A magnetic-drum storage equipment for teletypewriter weather messages would be associated with each switching center and would be assigned a directing code.

Two types of multistation local lines are suggested for this new system One of these should be a full-duplex line which will be referred to as a request circuit. The other may be a half-duplex line and will be referred to as the program circuit.

On a multistation request circuit, each station will be supplied with a receiving-only teletypewriter printer, a control cabinet, and a transmitting set. Each station will have an assigned three-letter address code, and the receiving-only printer will print only those messages that are prefixed by its code. Only one transmitter will be permitted to transmit at any one time. One way of accomplishing this latter function is to frequently interrogate all stations for traffic as is done in the Western Electric 81D1 system. An example of such a circuit is shown in Fig. 6.

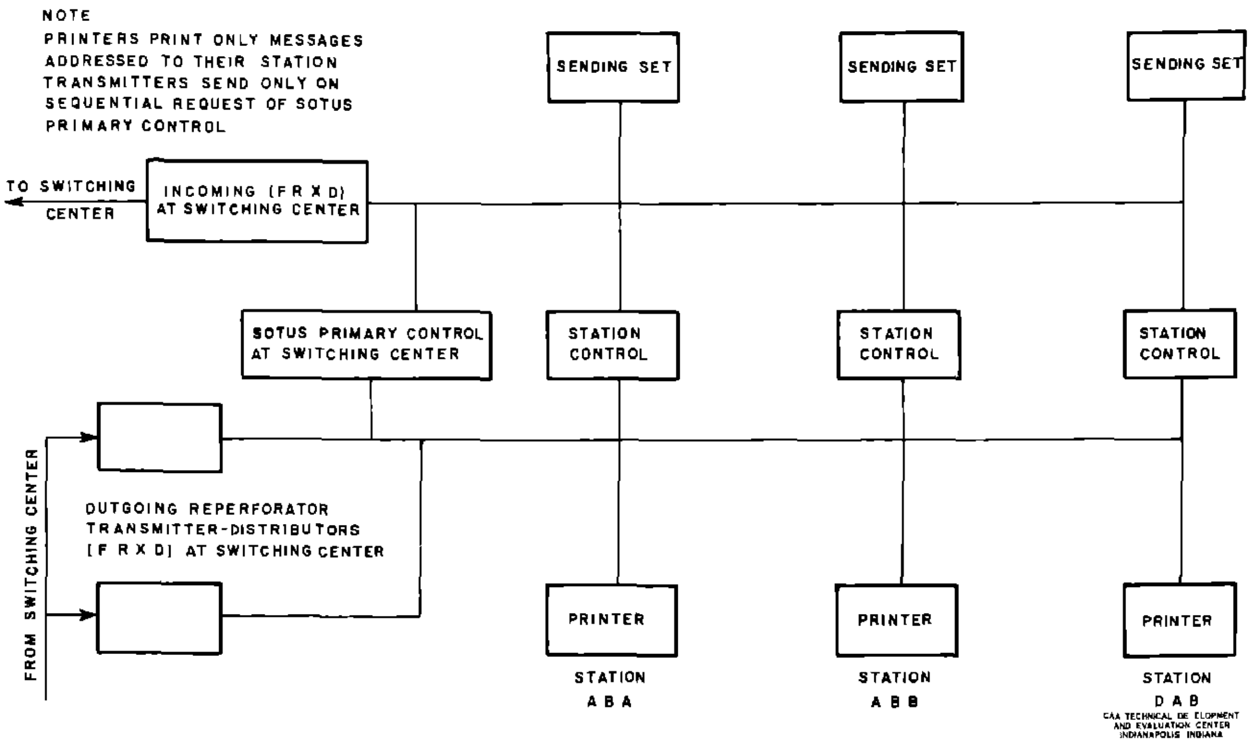

Fig. 6 Block Diagram of a Request and Administrative Circuit

Although a station on a request circuit will be capable of sending any message to any station in the system, its primary function in this system is to enable an operator to request from the magnetic-drum storage those weather observations and forecasts which he requires infrequently. With the present magnetic-drum equipment, the transmitter would send the following request over the system.

ADR ¢ C_R L_F ¢ Sp ABA Sp V Sp S Sp IND Sp #9999 Sp ¢ AWUS #00 Sp # C_R ¢

The symbols are interpreted as follows

ADR	= Directing code for drum, (may be any assigned three-letter code)
¢	= Lettershift character
C_R	= Carriage-return character
L_F	= Line-feed character
#	= Figure-shift character
Sp	= Space-function character
ABA	= Directing code of requestor's station
IND	= Location identifier for which weather report, forecast, or other stored information is requested.
V, S, and 9999	= Fixed characters required by the drum
AWUS #00	= Type of stored weather information desired (See Table I)

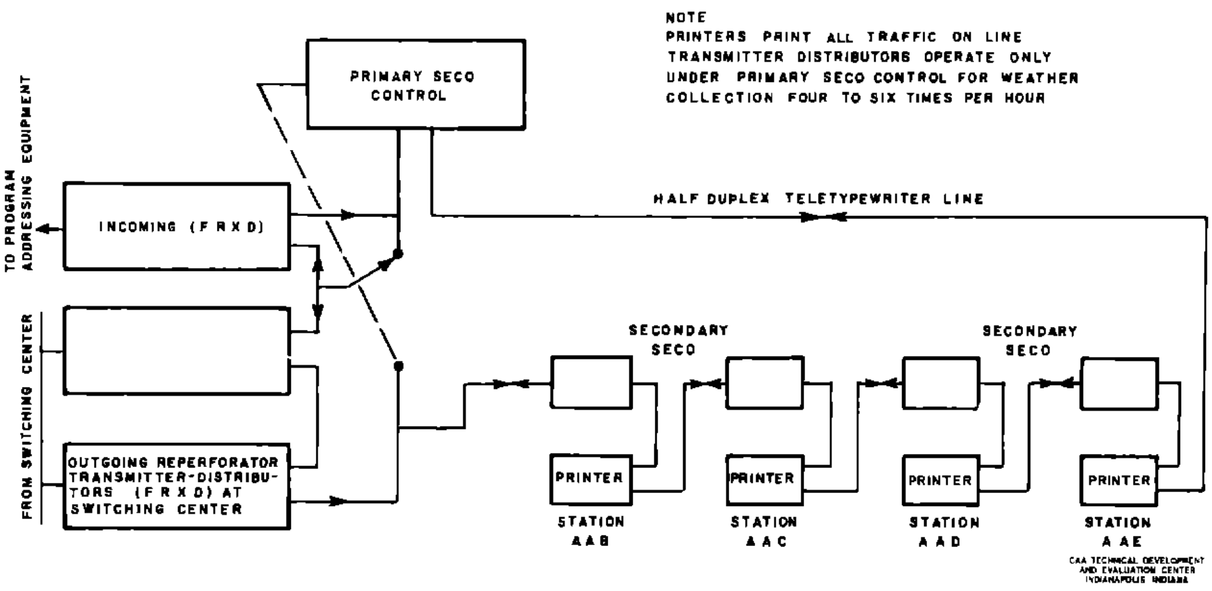

Fig 7 Block Diagram of Program Circuit

Upon receipt of the last character in this message, the magnetic drum will, in less than one-half second, automatically prepare the following reply

ABA ¢ C_R L_F ¢ Sp ADR Sp V Sp S Sp IND Sp # 1040 Sp ¢ AWUS #00 L_F C_R ¢

(Text of weather report or forecast) # C_R ¢

The printed reply will appear as follows if the ABA characters have been absorbed in the switching process

ADR V S IND 1040 AWUS 00

(Text of weather report or forecast)

The figures such as 1040 in this reply can represent the time at which the weather report or forecast was filed.

In addition to the receiving printer and to the sending set associated with the request circuit, each location should be provided with a transmitter for sending its own weather observation or forecast as well as with a printer for those observations and forecasts which it wishes to receive on a routine or program basis as often as they are transmitted. In the system suggested here, the latter equipment is to be connected to a teletypewriter line which will be referred to as the program circuit. An example is shown in Fig 7.

Each program circuit will have only one receiving code. It will be a half-duplex circuit, and each printer on the circuit will print all messages transmitted or received by the circuit All transmissions from such a circuit will be controlled by equipment similar to the primary and secondary SECO equipment now used on CAA Service A. The primary SECO control unit for such a circuit will send all transmissions to the magnetic-drum storage equipment at its associated switching center by prefixing each one with the appropriate single-address code.

The magnetic-drum storage equipment will be capable of permanently storing the necessary multiple-address code for distributing the weather observation or forecast to the program circuits that require it. Therefore, each time that the magnetic-drum equipment receives a new weather observation or forecast it will immediately read out to the switching center the appropriate multiple-address code group and the newly stored message. This outgoing message will then be a multiple-address message which the switching center will distribute. The present magnetic drum can be modified to provide this function. This modification will not impair any existing functions of the equipment, except that one of the 2,000 message-storage positions will be required for each multiple-address group stored. Each 115-character message position can hold approximately 24 three-letter codes

With respect to the collection of messages for transmission from the program circuit, the maximum frequency of scan should be that required under stormy-weather conditions. If desirable, the frequency of scan could be varied by the switching-center supervisor in response to request messages from local stations via the request and administrative circuit.

The number of stations on each program circuit and the number of such circuits associated with each switching center should be engineered to handle the message traffic with minimum line mileage and a message delay that is equal to or less than the maximum that can be tolerated.

Although Fig. 5 illustrates the system as it might be implemented on a nationwide scale, an initial installation of such a system would very probably be made within a moderate area because of costs, training problems, and other factors. The suggested system can readily be made compatible with the present systems at the junction points on the periphery of the area. For the suggested system, each such junction point could be assigned a directing code address and could be equipped with two reperforator-transmitter-distributors (FRXD), one for each direction. For the Services A, B, C, and O at such points, the ASID, MEDIS, or SECO units with manual supervision could be used to accept messages from and deliver them to the junction point

The end-of-message code recommended for the suggested system is "Figures-Carriage Return-Letters " This is the same as the unlock code used in the SECO system. Printing characters are not recommended for this purpose because of their well-established use as weather symbols in the weather reports. It will be obvious that, if the end-of-message combination should accidentally occur in the middle of the text, the message will be prematurely terminated.

COMPARISON BETWEEN SUGGESTED AUTOMATIC TELETYPEWRITER SYSTEM AND THE PRESENT SYSTEM

The need for a new system such as that suggested is most apparent from a study of the Services A, C, and O. The U. S. Weather Bureau officials advise that 650,000 words of original weather information are prepared daily but that in an attempt to attain the desired distribution 1,500,000 words are transmitted. This indicates that each word of original weather information is repeated an average of 2.3 times. It is a well-known fact that the three groups of weather circuits are now working at almost maximum capacity. In one forecast center, another printer was installed to obtain weather information from a second Service A circuit. Only 25 per cent of the information on the second circuit was new, and 75 per cent was a repeat of that already being received. In another case, the same weather report is received at one station several times for each transmission.

Any station can now request the report from another station only on a continuous basis even though the station needs it less frequently. For example, if a station has urgent need for an hourly report once a day, it can only obtain it by accepting it 24 times per day.

The heavy loading on the present circuits could be relieved by breaking them up into smaller circuits with fewer stations per circuit. But since each circuit requires some of the weather reports from each of the others, the need for additional MEDIS equipment would increase much more rapidly than the increase in the number of circuits.

Furthermore, on many circuits the hourly collection is too frequent in good weather when instrument readings change slowly but is not frequent enough in stormy or unsettled weather when the instrument readings change rapidly. Although provision is made for special reports under unsettled weather conditions, the heavy teletypewriter-circuit loadings often prevent their transmission.

It should be repeated that these conditions are a result of an expanding use of aviation in this country which use has brought us to the steep part of the curve in Fig 1 labeled "Equipment Used With Manual Methods " In prior years, Services A, B, C, and O have been adequate and economical.

The suggested system solves these problems first by providing any station with promptly answered weather request service via the switching center and magnetic-drum storage. This gives any CAA communicator or Weather Bureau forecaster access to much more weather information than he now has. It should also drastically reduce the need for programmed distribution so that the latter can be used to distribute frequently needed weather information while the request service can provide that information which is needed less frequently

The amount of program-transmission line time can be further curtailed by reducing the number of program printers per circuit to 20 or less Added interconnections are efficiently and economically handled by fully automatic teletypewriter switching systems using the director and the crossbar switch. In this respect the suggested system follows the Fully-Automatic-Equipment curve of Fig. 1, since both the automatic switching center and the magnetic drum are prohibitively expensive for light message traffic but have a very attractive per-message cost when the traffic becomes heavy.

If the suggested system is acceptable as an improvement over the existing Services A, C, and O, then the present Service B traffic can be handled over the new system with little or no additional terminal equipment such as printers or reperforators

Since maximum delay is a function of maximum message length, the inherently short CAA messages should result in a low maximum-delay figure Average delay is a function of the number of circuits available to handle the traffic Therefore, the ability of the suggested system to accommodate a multiplicity of local circuits and trunks should materially reduce the average message delay below that of the present system

One of the difficulties which will be encountered in designing a new system is the lack of precise traffic information on existing CAA circuits In one recent study, the traffic estimate was made by counting the rolls of tape used each day. A recently perfected word counter makes a more precise tally possible [9] It should be noted that administrative and request messages are not normally switched into program circuits, therefore, except on trunk lines, delays for the two classes of messages are independent of each other.

COMPATIBILITY OF THE PROPOSED SYSTEM WITH TRANSMISSION OF TRAFFIC-CONTROL INFORMATION BY TELETYPEWRITER SIGNALS

The teletypewriter switching center and the same magnetic-drum storage can be used for both weather messages and for messages of the traffic-control system which was proposed in the RTCA SC-31 report.[10] This system is to be evaluated If separate trunks and separate first-letter codes are used for weather and traffic-control teletypewriter stations, the message delays for the two classes of traffic can be made independent even though the same switching center is used. Negligible delay will be contributed by the commonly used director since it needs only a very small fraction of the shortest message time to seize a circuit On the other hand, the unified system permits the occasional exchange of messages between the two types of stations.

CONCLUSIONS

The suggested system for collecting and distributing weather information appears to offer very large savings in line time and line-lease charges for the present volume of traffic Although terminal equipment is more expensive, a net gain appears certain. It can be said that the suggested system offers service that is far superior to that of the present system for the existing volume of traffic. Furthermore, service will remain adequate for still greater traffic volume, which is something the existing system cannot provide

It should again be stressed that for a lighter volume of traffic than now exists, the

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[9] W Y. Lang, "Teletypewriter Word Counter," Bell Laboratories Record, Vol. 31, No. 6, pp. 221-224, June 1953.

[10] "Air Traffic Control Paper 27-48/DO-12," Radio Technical Commission for Aeronautics Special Committee 31, May 12, 1948.

present system is more economical and is entirely adequate The ultimate answer may be a composite system using the suggested equipment in the high-density-traffic areas of the east and west coasts of the United States and the present services in the Plains States and in mountainous areas.

An experimental evaluation of the suggested system in a moderate-size area would be desirable. Such an experiment would provide valuable data on the proper ratio of request-message traffic to program-message traffic. It would also enable CAA personnel to familiarize themselves with the characteristics and potentialities of magnetic-drum storage, as well as with the teletypewriter switching system.

It would be incorrect to assume that this study project of one year's duration could evolve a system suitable in every detail for CAA communications. However, it is believed that the basic principles described in this report are sound and may serve as a stepping stone to a better and more efficient CAA communications system.

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