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AN OPERATIONAL EVALUATION OF THE IBM CARDATYPE FOR PREPARING FLIGHT PROGRESS STRIPS

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SUMMARY

This report covers an operational evaluation of the IBM 858 Cardatype accounting machine installed in the New York Air Route Traffic Control Center. This evaluation was conducted by FAA Technical Development Center personnel, and is based on data gathered from November 1957 through January 1958. During this period, the IBM Cardatype was used to prepare printed flight progress strips for approximately one-half of the IFR departure flights from the major terminals in the New York metropolitan area. Using three operators, this system has a maximum processing capacity of 36 7 flight plans per hour. Theoretically, two men, preparing strips manually and working at 100 per cent loading factor, can prepare strips for 37.9 flight plans per hour, or slightly more than the Cardatype system. At the time of this evaluation, peak demands reached 40 departures per hour in the area served by the Cardatype. Flight plans filed less than 9 minutes before proposed departure had to be prepared manually. Fifteen per cent of all departure flight plans were filed with a lead time of less than 9 minutes.

The complete route of flight was not printed for all flights processed by the Cardatype system, since it was impractical to have card packs for all possible routes beyond the New York Air Route Traffic Control Center area The additional routing, if not covered by a standard route card pack, was added manually. Analysis of the strips indicated that 25 per cent of all the flight plans processed by the Cardatype system required manual additions to the route of flight

INTRODUCTION

The IBM 858 Cardatype accounting machine system is located in the operating quarters of the New York Air Route Traffic Control (ARTC) Center. The evaluation was conducted by the FAA Technical Development Center (TDC) at the request of the Bureau of Air Traffic Management. Tests and observations made during the period from November 25, 1957, to January 28, 1958, were analyzed at TDC The objective of this evaluation was to determine the operational utility of the IBM 858 Cardatype accounting machine system for air traffic control (ATC) data processing

CARDATYPE SYSTEM

The equipment used in the New York ARTC Center included the following units·

1. IBM 026 Card Punch
2. IBM 858 Cardatype Accounting Machine
3. IBM 972 Auxiliary Keyboard

4. IBM 866 Nontransmitting Typewriter
5 IBM 863 Arithmetic Unit

The IBM 026 card punch unit, Fig. 1, was used to prepare card packs for the various departure routes. One card was required for each fix to be posted on the flight progress boards. Seventy-six standard departure route card packs were used

The IBM 858 Cardatype accounting machine, Fig. 2, was used to combine the route information from a selected card pack with other information required on the flight strips, this information being entered through an auxiliary keyboard. The output of the 858 Cardatype unit can feed one to four electric typewriters either simultaneously or selectively All functions of the machine are directed by a control (program) panel which can be changed easily for other applications. From 1 to 200 punched cards may be inserted simultaneously in the card input hopper. Cards are read at the rate of ten card columns per second, and the machine output to the electric typewriters is ten characters per second (less tabulations, spaces, line feeds, and carriage returns).

Two IBM 972 auxiliary keyboard units, shown in Fig. 2, were used to enter the flight identity, type of aircraft, estimated ground speed, and proposed cruising altitude

Two IBM 866 nontransmitting electric typewriters printed the flight progress strips Either upper or lower case and black or red typewriter ribbon may be used, with these functions being controlled by the IBM 858 Cardatype accounting machine unit.

The IBM 863 arithmetic unit was not in operation at the time of this evaluation. It was planned for use in computing estimated elapsed times between fixes for printing on the flight progress strips. This computation would be made using the estimated ground speed inserted on the keyboard and the mileage from the preceding fix which had been punched into the fix cards.

Flight plans for aircraft departing the New York area normally were received at the Center over a voice interphone circuit by an assistant controller, who wrote the flight plan on a flight progress strip and transferred this strip to the operator of the Cardatype equipment. The Cardatype operator selected a card pack for the corresponding route of flight and inserted the pack in the input card hopper of the 858 Cardatype accounting machine The Cardatype operator then inserted the variable information (flight identity, type of aircraft, estimated ground speed, and proposed cruising altitude) through the IBM 972 auxiliary keyboard units A start button was depressed on the IBM 858 Cardatype accounting machine and the flight progress strips were printed by the IBM 866 typewriters on a continuous roll of perforated paper strips. After these strips were printed, they were cut apart, inserted in holders, and delivered to the control boards.

At the time of evaluation, the IBM 858 Cardatype system at the New York Center was used to prepare flight progress strips for all departures from the Newark Airport, and for all westbound departures from La Guardia and Idlewild Airports.

FLIGHT-PLAN LOAD

The following statistical information was derived from an analysis of traffic between November 25, 1957, and January 28, 1958. The average number of flight progress strips prepared in the New York (domestic) Center was 7,844 per day On the most active single day, 12,543 strips were prepared, and on the least active day, 4,895 strips were prepared. The average number of departures in the New York ARTC (domestic) Center was 678 per day. On the busiest single day, there were 1,171 departures and on the least busy day, there were 309 departures.

The portion of the New York control area served by the IBM 858 Cardatype system averages 297 per day. The largest number of departures in a single day was 478, and the least number was 163. The area served by Cardatype handles, on the average, 43.8 per cent of all departures in the New York Center area Peak periods of traffic in the New York Center occur from 7·30 a.m. to 9:30 a m., and from 4 p.m. to 6 p.m., with the evening peak being slightly higher

In the area served by the Cardatype system during these two 2-hour peak periods, departures averaged 29 per hour and reached a maximum of 40 per hour. The average departure flight plan during these peak periods required 6.45 flight progress strips

PROCESSING RATE AND CAPACITY

Stop-watch measurements were made by observers during the test period to compare processing times of both Cardatype and manual operation. The average time required to prepare flight progress strips in the Cardatype system is shown as follows.

Operation	Average Time for Flight Plan (min.:sec.)
Time to receive flight plan	0:41
Transfer to Cardatype operator	0:05
Card-pack selection	0·05
Addition of variable information	0·13
Machine time to print strips (average flight, 6.45 strips and 13.2 seconds printing time per strip)	1:25
Cut and stuff in strip holders	1.20
Delivery to control board and return to operating position	0:17
Total Time	4.06

A flight plan with normal handling and no delay in processing can be on the control board 4 minutes 6 seconds after the start of filing the flight via the interphone circuit

In determining the capacity of the IBM 858 Cardatype system, the 5 seconds required to select a card pack can be eliminated. After entry of the first flight, this operation can be performed while the machine is printing flight progress strips. The maximum processing rate and capacity of this Cardatype system are as follows

Operation	Total Time (min. sec.)	Capacity Flights Per Hour
Receive flight plan and transfer	:46	78.0
Cardatype operation	1·38	36.7
Cut, stuff, delivery and return	1·37	37.0

Assuming that additional personnel could be assigned as necessary, the limiting factor in the Cardatype system would be the speed of operation of the Cardatype machine. Peak period demands of 40 flights per hour, which occur almost daily, exceed the capacity of the Cardatype equipment for strip preparation. Therefore, the system must be supplemented by manual strip preparation during these periods. Although three operators are required for the Cardatype system, the operator receiving flight plans need work at only a 47 per cent load factor to load the Cardatype machine completely.

During the period covered by this evaluation, a special study was made on the following days.

Total Flight Progress Strips

January 7, 1958 - 9,295
January 15, 1958 - 11,451
January 17, 1958 - 10,643
January 26, 1958 - 9,891
January 27, 1958 - 9,829

On these 5 days, an average of 10,222 flight progress strips per day were prepared, which was well over the average daily count and definitely indicated heavy IFR traffic conditions. In the area served by the IBM Cardatype, there were 2,002 departures for these 5 days. Of these departures, 1,739 flights were processed on the IBM Cardatype equipment, and 263 flight plans (13.14 per cent) were processed manually.

Measurements and time studies were conducted from January 27 to 31, 1958, to determine the number of minutes prior to the proposed takeoff time that a flight plan is called into the Center. The time interval between call-in and proposed takeoff was called "lead time," and this was the determining factor in deciding whether the flight plan could be handled by the IBM Cardatype equipment or would have to be completed manually.

For example, if a proposed departure time of 1600 was filed, it was desirable from a control planning standpoint that the flight progress strips be at the control board at least 5 minutes prior to departure. Since 4 minutes was required to process a flight plan by means of the IBM Cardatype equipment, then any flight plan that was received with a lead time of less than 9 minutes could not be processed If the IBM Cardatype equipment already was busy processing flight plans when a flight plan was received with a lead time of only 10 to 12 minutes, manual preparation usually was required. Approximately 15 per cent of all departure flight plans were filed with a lead time of less than 9 minutes, representing the percentage of flights that probably would require manual preparation Fifty per cent of all departure flight plans were filed with a lead time of less than 24 1/2 minutes. Figure 3 shows the percentage of flight plans filed versus the number of minutes lead time for a part of the period analyzed.

It can be noted from the printed flight progress strips, Fig. 4, that the latter portions of the route information often were handwritten Standard departure routes were mandatory in the New York Center area. The most frequently used routes to Chicago, Boston, and Washington had complete route card packs When a flight proceeded via a standard departure route in the New York area, and then via a route for which no card pack exists, the Cardatype equipment could be used provided that the additional route information was handwritten It was not practical to store a card pack for every route of flight beyond the New York area Handwritten additions to the route information increased the utilization of the Cardatype system. During the 5 days of traffic analyzed, of the 1,739 flight plans processed by the Cardatype equipment, 430 flights, or 24 7 per cent, had manual additions

For purposes of comparison, measurements also were made at the New York Center of the time required for processing flight plans by hand The average time for a man to prepare flight progress strips manually was as follows

Operation	Average Time Per Flight (min ·sec.)
Time to receive flight plan	0·41
Prepare flight progress strips for the average length of flight	1 52
Delivery to control board and return	0·17
Stuff and position stripholders	0 20
Total strip preparation	3·10

With a total time of 3 minutes 10 seconds required for the average flight plan, the manual capacity per man, working at 100 per cent loading, would be 18.94 flight plans per hour Theoretically, two men working at 100 per cent loading could complete 37.88 flight plans per hour.

The curves in Fig 5 show the amount of lead time required at various flight plan rates for both manual and Cardatype processing Since the demand in the New York area exceeds the capability of one IBM Cardatype

accounting machine, the expected results from a second and third machine are shown. In establishing the comparison chart, it was assumed that the average number of strips required was 6.45 per flight plan. The criterion for establishing lead times was that 99 out of 100 flight plans would be processed early enough so that strips would arrive at the control boards at least 5 minutes before flight departure. For example, one Cardatype could process 26 1/4 flights per hour when all flight plans were filed 20 minutes prior to departure If these flight plans were filed 15 minutes in advance, the capacity of the Cardatype equipment would be 19 1/2 flights per hour. If two Cardatype machines were installed and each flight plan filed 15 minutes in advance, the capacity would be 54 1/4 flights per hour. Three operators, preparing strips manually at a 100 per cent loading factor, could produce strips for 40 1/2 flights per hour, providing each flight plan was filed 15 minutes in advance.

Although the arithmetic unit was not in operation at the time of this evaluation, it will, when incorporated, calculate "plus" times (flying time between fixes) to be printed on the flight progress strips This additional calculating and printing will lengthen the time required to print flight progress strips. It is estimated that the processing rate of the Cardatype system with the arithmetic unit will be reduced to 30 flights per hour.

ACCURACY AND READABILITY

The accuracy of the Cardatype-printed flight progress strip depends primarily upon the accuracy of the operating personnel. The flight plan received via interphone by an operator is handwritten on a flight progress strip and transferred to the IBM Cardatype operator. Here, the proper card pack must be selected and the variable information entered into the machine. These operations, if completed correctly, produce accurately printed flight progress strips During the observation and test periods, no errors were noted However, to insure accuracy, the operational speed was reduced at times because of lack of operator proficiency on the machine In general, it appears that fewer errors are made in preparation of flight progress strips with the machine equipment than are made when all strips are prepared by hand.

The IBM Cardatype equipment prints easily readable flight progress strips. The type size used in the New York Center IBM 866 typewriter is 0.3125-inch high and 0.1875-inch wide Spacing between printed lines is 0.1875-inch This type size is well above the minimum size recommended by Courtney and Co.[1] No hypnotic effect was reported from use of the printed

[1]Courtney and Co , "Human Factors Recommendations for Flight Progress Strips," unpublished Memorandum Report No 1, October 1, 1957. This report recommends that the minimum height for all characters to be read horizontally should be 0.1242-inch (9-point) and the width should be approximately 75 per cent of height.

flight progress strips in the New York Center In informal discussions with operating personnel at the New York ARTC Center, they indicated that they were satisfied with the size of print and format of the printed flight progress strips In radar display areas where reduced ambient lighting is used, the Cardatype strips are more satisfactory than those prepared manually.

The Cardatype system is capable of printing either black or red characters, and this feature is used as follows in the New York Center All departing flights are routed via standard preferential departure routes. Flight plans, which specify the standard route, are printed in black. If a flight plan having other than the standard departure routing is received, the flight progress strips are printed with the standard route in red and the route filed by the pilot is omitted. This indicates to the departure controller that the route of flight in the departure clearance must be given to the pilot in detail, rather than by using the single phrase, "cleared via flight plan route."

Figure 4 shows flight progress strips prepared by the Cardatype system with and without handwritten route information, and with insertions made during actual use in control Single letters are used to represent fixes as follows. E, Newark, L, La Guardia; and I, Idlewild.

MAINTENANCE

The IBM Cardatype was operated on a 24-hour basis during this evaluation The maintenance log from November 25, 1957, to January 27, 1958, follows

Date	Time Out	Time In	Remarks	Total Time Off
11/25	1630	---	Printing Fig. 5 instead of letter V and failing to line feed.	EST 16 + 00
12/7	2310	---	Not printing correctly.	EST 8 + 00
12/13	1610	1615	New ribbon put on.	0 + 15
12/30 12/31	0915	--- 1700	Machine released to IBM to install Arithmetic Unit.	No failure
1/2	1105	1650	Install Arithmetic Unit.	No failure
1/3	0955	1545	Install Arithmetic Unit.	No failure
1/5	0000	0500	Machine not printing.	5 + 00
1/8	0835	1155	Card read inoperative.	3 + 20

Date	Time Out	Time In	Remarks	Total Time Off
1/12	1441	1500	Ribbon change - using "Miller" line nylon ribbon	0 + 19
1/15	2330	---	Omitting letters and figures	EST 8 + 30
1/17	---	---	Nylon ribbon removed from typewriter. Weak print - 5 days	EST 0 + 17
1/25	1120	1145	Not printing correct letters, no repairs needed Piece of paper found on contact points by operator	0 + 20
			Total outage time	42 hours 01 minutes

On several occasions, no return-to-normal operation time was given, in which case it was estimated that operations returned to normal at the start of the following day. This period covered 63 days (1,512 hours), during which the system was available 97 2 per cent of the time. It should be borne in mind that this equipment is leased from the IBM Company and that maintenance service is provided, as necessary, on a call basis.

ECONOMIC FACTORS

The IBM Cardatype system, as installed in the New York ARTC Center, is owned by the International Business Machines Corp., and is leased to the FAA at the following monthly costs·

Quantity	Machine	Model	Description	Rental (mo)
1	026	1	Card Punch	$ 60 00
1	858	4	Cardatype Control Unit (as installed in New York)	220 00
1	863	1	Arithmetic Unit (as installed in New York)	100 00
2	866	2	Nontransmitting Typewriters (with color control devices) - $35 each	70.00
2	972	1	Auxiliary Keyboards - $20 each	40.00
			Total	$490.00

Approximately 300,000 flight progress strips are prepared per month at the New York Center. In the sectors serviced by the IBM Cardatype, approximately 8,000 IBM strips are used. Of these, 6,000 are printed and 2,000 are used as spacers between printed strips This spacing is necessary at present to expedite cutting and stuffing procedures. The cost of these strips is $1.34 per thousand

The IBM cards used in the card packs have an average life of 13 days. At present, there are 76 card packs requiring 386 IBM cards. On this basis, approximately 1,000 IBM cards are required per month. The cost of the IBM cards is $2 34 per thousand

The weights of the IBM Cardatype equipment are as follows

Quantity	Machine	Description	Weight (lb)
1	026	Card Punch	250
1	858	Cardatype Control Unit	450
1	863	Arithmetic Unit	200
1	866	Typewriter and Stand	57
1	972	Auxiliary Keyboard (Est.)	25

The area required for this equipment is approximately 100 square feet. No special requirements, such as humidity control and power units, are necessary for the operation of the IBM Cardatype equipment

OTHER SYSTEMS

Other systems similar to the Cardatype can be used for printing flight progress strips One system of greater capacity could use IBM 826 card punch units and an IBM 407 accounting machine printer With this system, assistant controllers would copy flight plans on the 826 card punch in the normal sequence. Flight identification, type of aircraft, speed, departure point, proposed departure time, and requested altitude would occupy 24 columns of an 80-column card. The remaining 56 columns could be used for route-of-flight information, which should be adequate for the complete route of practically all flight plans (10 to 18 fixes or airways).

A runner could pick up the flight plan card, read the route-of-flight information, and select one card from a rack coinciding with the proposed or assigned preferential routing The two cards could be inserted into the IBM 407 printer and flight progress strips would be printed for all fixes in the Center area For airway flights, the second card selected from the rack could contain a list of all fixes on the preferential route and also could provide plus times between fixes For example, assume that a flight on route A requires five fix postings. Several route A cards,

based on different ground speeds (180 knots, 210 knots, and so forth), could be available in the card rack for route A. By selecting the card corresponding to the estimated ground speed, five strips would be printed, including fix identifiers and plus times between fixes. For direct-route flights, the second card selected from the rack would not include fix identifiers but would be coded to provide the total number of strips required. Fix identifiers then could be filled in manually.

Table I has been prepared to show system capacity and personnel requirements. The time required to receive and transfer an estimate to an IBM card, 52 seconds, is based on use of the IBM 826 card punch units at the Indianapolis Center It is estimated that a runner can pick up the flight plan card, select a route/speed card from a rack, and transfer it to the IBM 407 operator in 20 seconds. The IBM 407 printer can print 50 strips per minute. The time required to cut, stuff, and deliver strips is based on measurements made at the New York Center using the IBM 858 Cardatype equipment.

TABLE I

826/407 FLIGHT PLAN CAPACITY AND PERSONNEL REQUIREMENTS

Flight Plans Per Hour	826 Operator	Runners (Select Card and Transfer)	407 Operation	Runners to Cut, Stuff, and Deliver	Total Personnel
69	1*	1	1	2	5
110	2	1	1	3*	7
138	2*	1	1	4	8
180	3	1*	1	5	10
240	4	2	1	7	14
360	6	2	1*	10	19

*Limiting operation at this rate.

The theoretical capacity of this system, with one IBM 407 printer, is approximately 360 flight plans per hour based on the average requirement for all flight plans, both departure and arrival, in the New York Center of 7.5 strips per flight plan. It appears that one IBM 407 printer with several 826 card punch units could service both departure and inbound flight plans in a FLIDAP operation.

This proposed arrangement also could be used with the addition of data transceivers to forward flight plan data between adjacent ARTC Centers. For example, assume a flight whose flight plan is filed with the Cleveland Center will enter the New York Center area A flight plan card is punched by the assistant controller receiving the flight plan at the Cleveland Center. This card, plus the second card, is used to prepare the necessary flight progress strips required in the Cleveland Center area. The first card, called the flight plan card, then could be placed in a data

transceiver and sent to the New York Center. Nonessential items, such as proposed time of departure and altitude, could be eliminated by internal wiring. Flight progress strips with plus times then could be prepared by the New York Center with a second card for fix identifiers and speed. Subsequently, the Cleveland Center would have to forward only the estimated time, altitude, and ground speed to the New York Center via interphone.

An alternate arrangement would be to hold the initial flight plan card at a FLIDAP position until the estimated time and altitude are received. By adding this information to the flight plan card and by using the second fix/speed card, the IBM 407 printer could produce flight progress strips with estimates printed on all strips. If an adjacent Center had other than IBM equipment, a card-to-tape unit could be used and the information transmitted via teletype to the adjacent Center.

The equipment rental charges for this proposed system are as follows:

Equipment	Rental Cost (mo.)
IBM 407 Accounting Machine Printer (basic machine)	$800.00
Additional cost for special print wheels to conform with proposed printed strip format	195.00
IBM 826 Card Punch (per machine - several required)	115.00
Additional Features:	
Data Transceiver	90 00
Telephone or Telegraph Line Converter	85.00
Tape-to-Card Unit	140.00
Card-to-Tape Unit	75.00

It will be noted that this arrangement for semiautomatic preparation of flight progress strips is similar to initial phases of the ATC computer programs. The computer functions of selecting fixes and computing estimates are replaced for airway flights by a human operator selecting a card for the appropriate route and estimated ground speed. For direct-route flights, the desired number of printed strips would be obtained, but human operators would be required to plot and determine the fixes to be posted manually and compute estimated times over or adjacent to these fixes. Other combinations of equipment which may be available also should be investigated.

CONCLUSIONS

The following conclusions are based on analysis of data obtained and observations made during the evaluation period described in this report:

1. Time Requirements. The average time required to process a flight plan with the Cardatype system is 4 minutes 6 seconds, as compared to 3 minutes 10 seconds for manual preparation This includes receiving the flight plan, processing, and delivery to the control board.

2 Processing Rates and Capacity. The Cardatype system will process 36.7 flight plans per hour with a complement of three personnel. However, peak period demands of the departure sectors served by the Cardatype exceed the capacity of the system for flight progress strip preparation and must be supplemented by manual strip preparation. The theoretical capacity of one man handwriting flight progress strips is 18.9 flight plans per hour. Two men, working at 100 per cent loading factor, theoretically could prepare 37.9 flight plans per hour, or slightly more than the Cardatype machine using three men. However, 100 per cent personnel utilization cannot be expected from manual operations for 60 minutes of each hour.

3. Accuracy and Readability. It appears there is less likelihood of human errors when using the Cardatype system than in the manual system. The size of type and strip format are satisfactory, and the printed flight progress strips are well liked by New York Center personnel.

4. Usable Time. During the period of this evaluation, a total of 1,512 hours, the Cardatype equipment operated 97 2 per cent of the time.

5. Economic Factors. The IBM 858 Cardatype system requires one additional man per shift over that normally required if all flight progress strips are prepared manually. In addition, there is an equipment rental cost of $490 per month, excluding the additional cost of the IBM cards and special flight progress strips.

RECOMMENDATIONS

Although the IBM 858 Cardatype equipment produces relatively desirable printed flight progress strips, additional capacity is required. Equipment for faster input and printing, which would provide an improved system for this purpose, should be investigated

It also is recommended that the Cardatype system be used to preprint strips for scheduled departure flight plans. This would permit preparation of flight progress strips during periods of low activity, reducing the demand in peak periods.

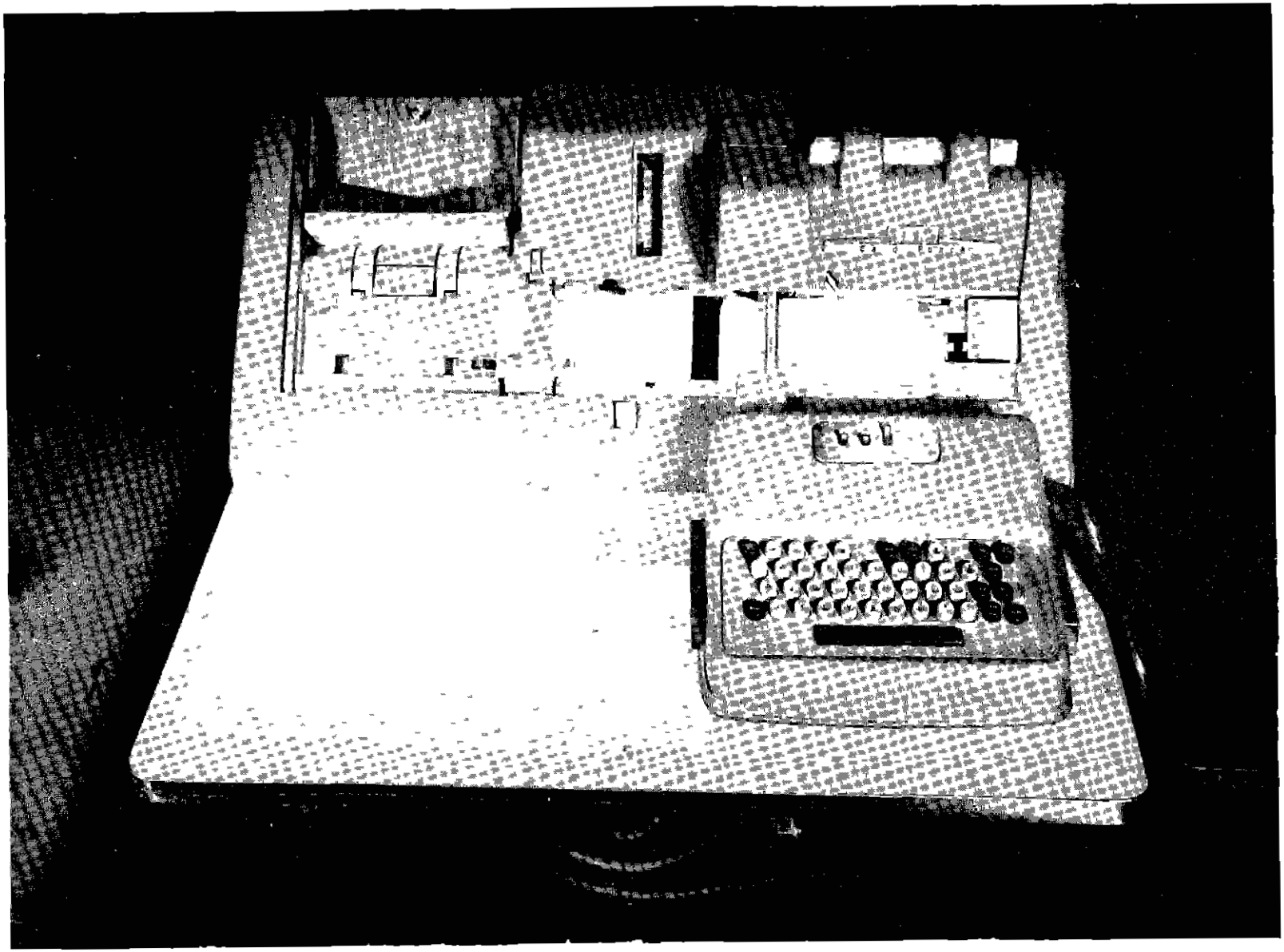


FIG. 1 IBM 026 CARD PUNCH UNIT

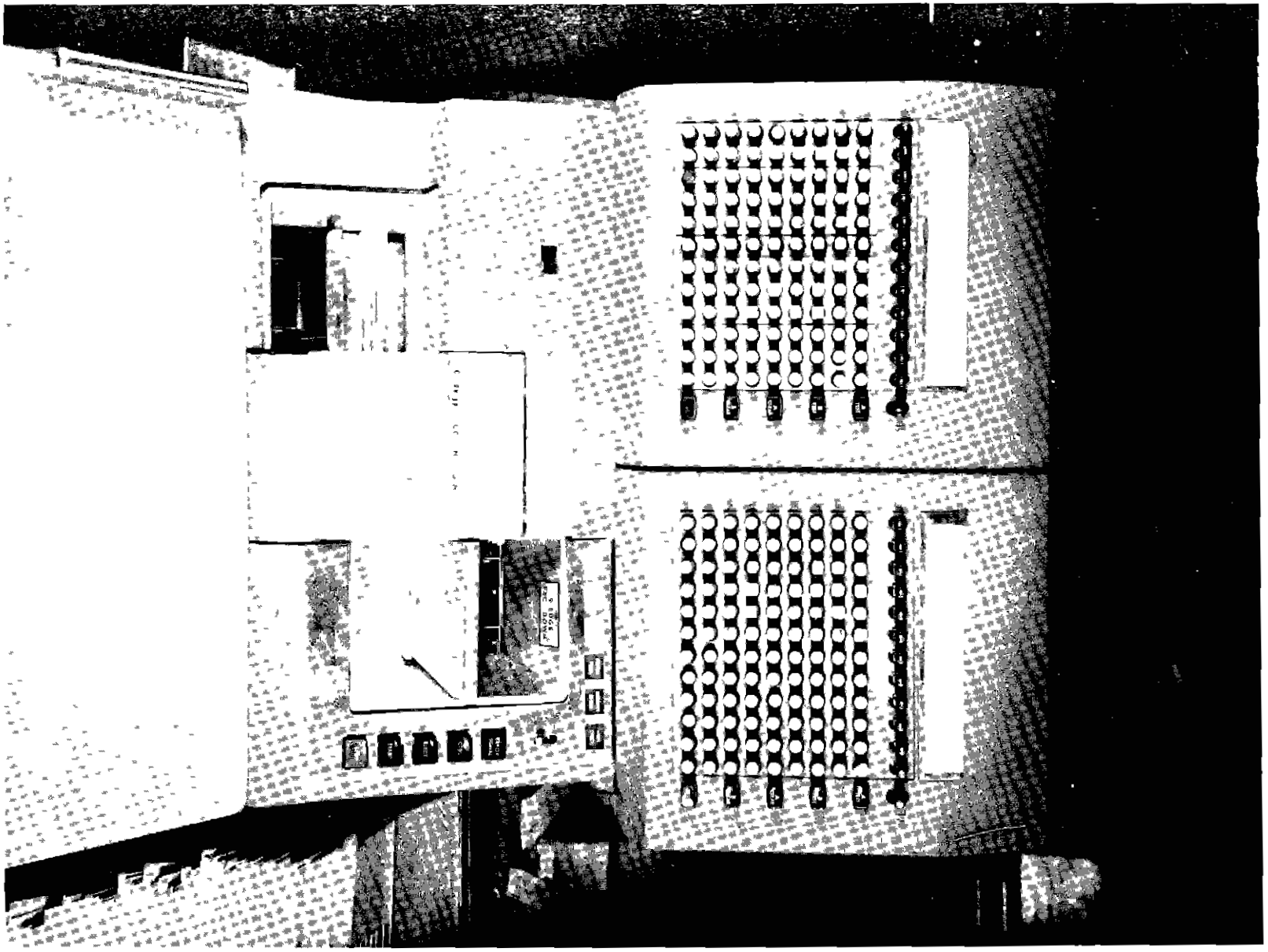


FIG. 2 IBM 972 AUXILIARY KEYBOARD UNITS

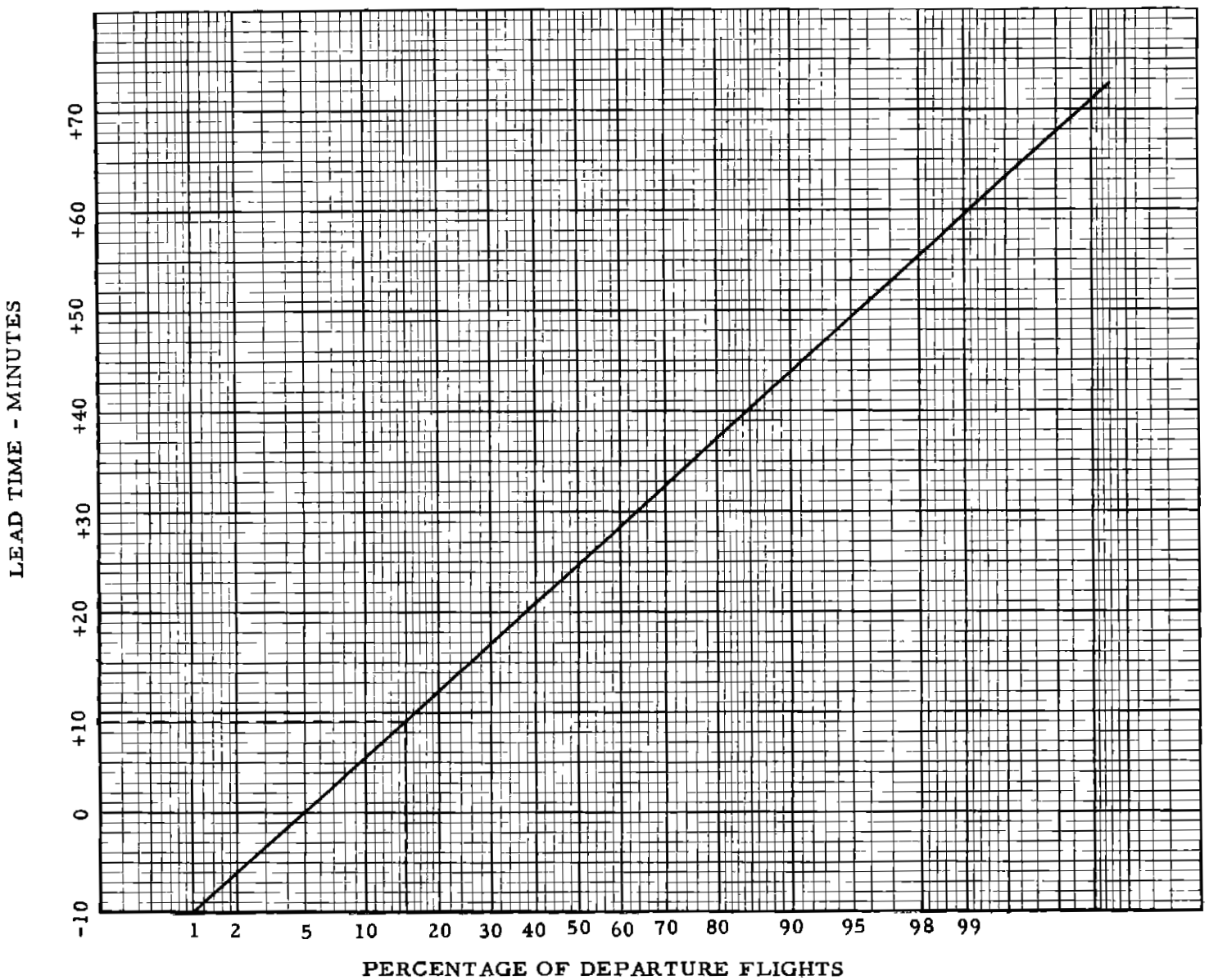
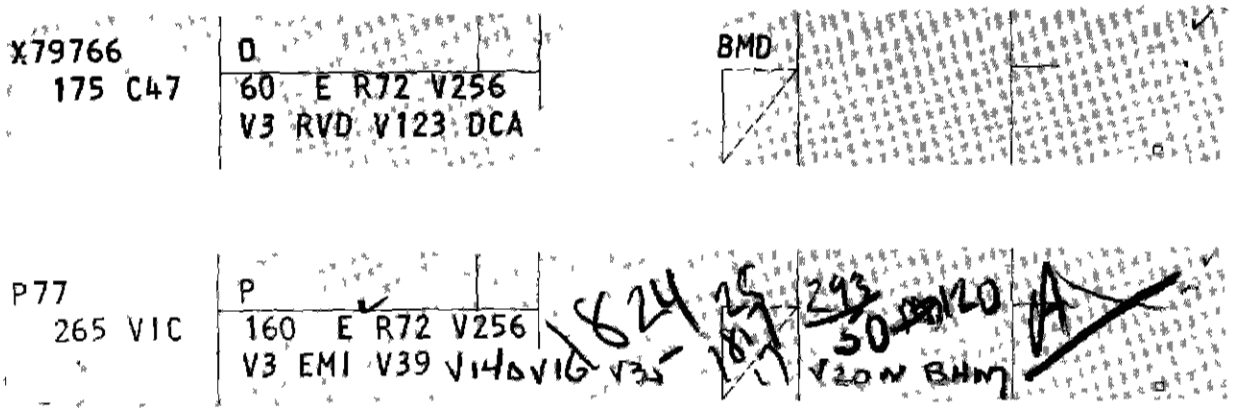


FIG. 3 PERCENTAGE OF FLIGHTS FILING WITH A LEAD TIME LESS THAN TIME SHOWN



ROUTING PRINTED IN RED ON THE ABOVE TWO FLIGHT PROGRESS STRIPS

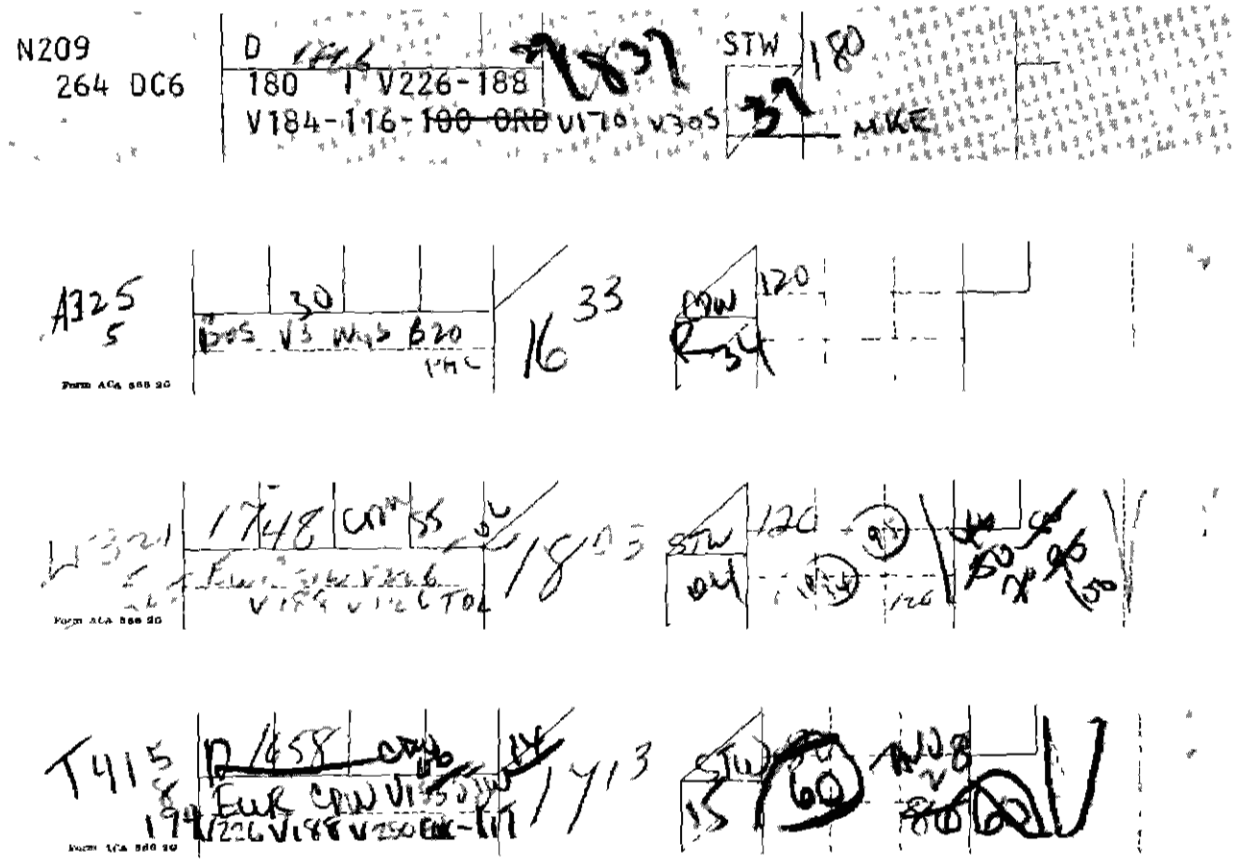


FIG. 4 EXAMPLE OF FLIGHT PROGRESS STRIPS

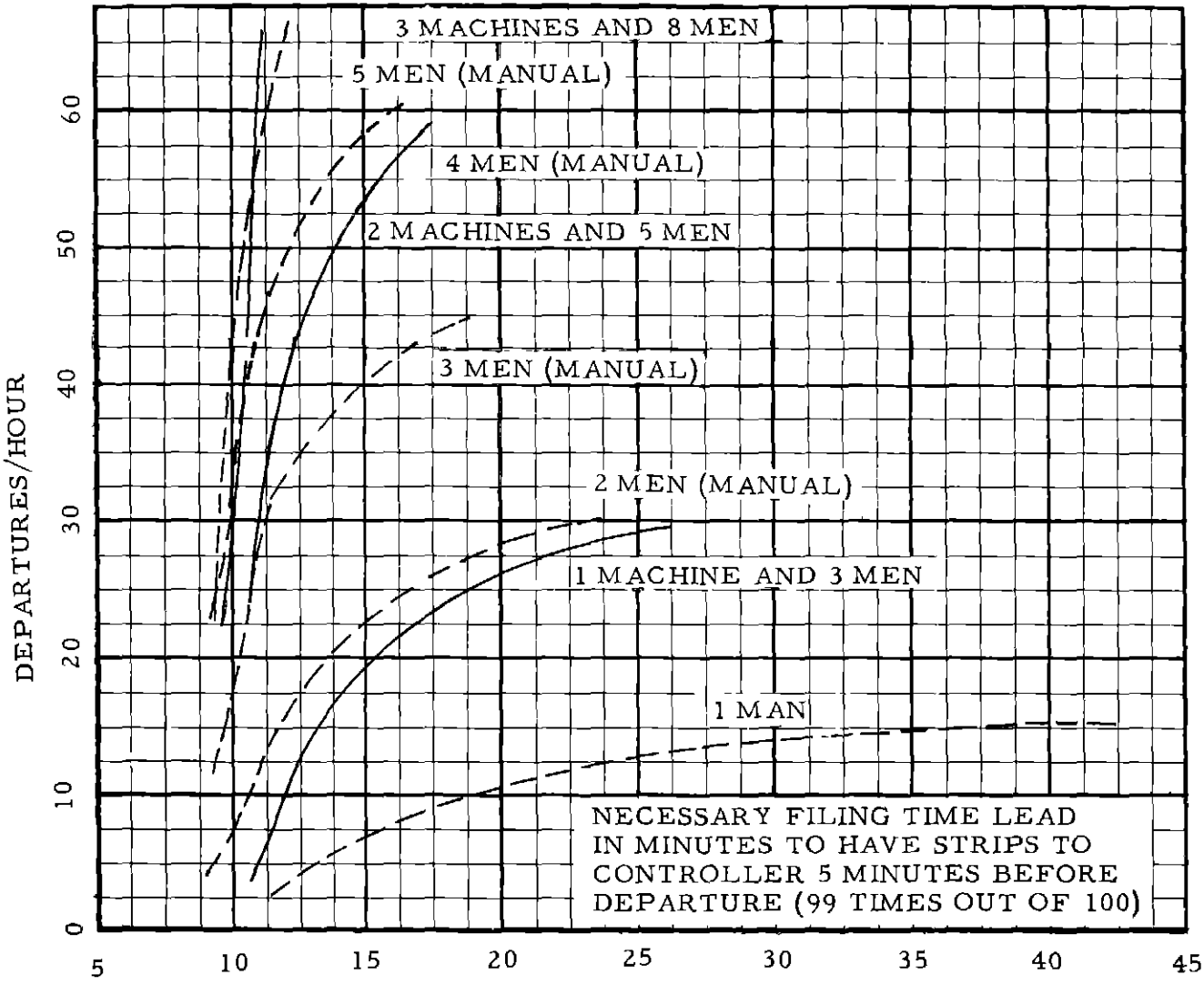


FIG. 5 LEAD TIME VERSUS FLIGHT PLAN RATE