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AN OPERATIONAL EVALUATION OF THREE ELECTRIC TYPEWRITER/TAPE MACHINES FOR FLIGHT-PLAN INPUT TO ATC COMPUTERS

FOR LIMITED DISTRIBUTION

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SUMMARY

An evaluation test was conducted to compare a modified Synchro-Tape typewriter, a Flexowriter Programatic typewriter and a Model No. 19 Teletypewriter with tape perforator for use as flight-plan input devices to the UNIVAC File Computer. The tests were based on the use of a fixed-length-field format for each item of a flight plan, with the requirement that padding characters be used to fill out a field if the information characters were of insufficient length to complete the field.

This evaluation was conducted in two phases. Phase I was conducted to compare a modified Synchro-Tape typewriter with a full program tape, a Flexowriter Programatic typewriter, and a Model No. 19 Teletypewriter with tape perforator. Phase II was conducted to compare a modified Synchro-Tape typewriter with a full program tape and with an end-of-message tape, a Flexowriter Programatic typewriter, and a Model No. 19 Teletypewriter with tape perforator.

Fifteen operators processed 4,080 flight plans in 390 test runs. Flight plans used in the tests were representative of actual traffic in the Indianapolis Air Route Traffic Control Center control area. All three machines are capable of meeting the operational requirements, but for over-all performance, the modified Synchro-Tape typewriter was considered best for the purpose stated.

INTRODUCTION

During the initial operation, the flight-plan input to the UNIVAC File Computers in Air Route Traffic Control (ARTC) Centers will make use of punched tapes which will be converted to punched cards for insertion into the computer read-in equipment. At a later date, the card input will be replaced by a high-speed paper tape input system which will provide for on-line entry of data to the computer. This evaluation was made to compare several available typewriter equipments for producing punched tape which would be usable for on-line or card-input operation of the computer system. Later, other machines also will be evaluated as they become available for testing.

The present UNIVAC File Computer programs for ATC data processing require all items of flight-plan data to be entered in fields of a specific length. For example, aircraft identification consisting of a varying number of alphabetical and numerical characters must be not only in the proper sequence in the message, but must occupy certain columns on an input card, or be entered in certain word locations. If the aircraft identity is not long enough to fill the spaces provided, padding characters must be inserted to fill out the field. This requirement places an exacting demand for accuracy

upon the operator who also is expected to produce this tape at a reasonable rate of speed. In the evaluation, every effort was made to take advantage of the full capabilities of the different machines to fulfill the basic input requirements while providing optimum conditions for the operator during the test program.

EQUIPMENT

The Remington Rand Co. Synchro-Tape typewriter, the Friden Co. Flexowriter Programatic typewriter, and the Teletype Corp. Model No. 19 Teletypewriter with tape perforator were available for these tests. All three machines provide a typewritten record on a sheet of paper as the flight-plan data are typed, simultaneously producing teletype tape for computer input.

The Flexowriter and Teletypewriter keyboards include figure and letter shift keys that are required for changing from alphabetical to numerical characters and vice versa. The Synchro-Tape typewriter has a four-bank keyboard and does not require use of shift keys when mixing alphabetical and numerical characters.

The Synchro-Tape and the Flexowriter machines utilize a program control tape that automatically completes all of the end-of-message coding when the operator depresses an appropriate key. The Synchro-Tape machine also was modified locally to permit a full program tape operation so that it would insert all padding characters required to complete a field automatically and provide spacing to the start of the next field upon depression of the regular space bar. This method of operation required a full program control tape for the complete input format that stepped along with every carriage movement as the operator typed. The Flexowriter machine could not be modified in the field to operate in this same manner.

FORMAT CONTROL

To secure and maintain the alignment of input flight data with a fixed-field format and to assist the operator in maintaining accuracy, several methods were investigated for the different machines. These included.

1. Use of a paper stock with printed boxes or columns arranged according to the fixed-input format so that the operator could type the appropriate flight data and required character pads in the designated fields by conforming to the paper form as a guide. This method required sprocket-fed paper to obtain format alignment with the typewriter platen rotation and carriage position. It proved to be unsatisfactory for various reasons, but primarily because the operator could not see the printed form on the current line where he was typing, due to the typewriter ribbon and key guide. A different printed format was required for successive lines of data. The alignment of the paper stock was very critical and difficult to maintain even with the sprocket feed.

2. Use of an electrically lighted panel above the machines that would indicate carriage position in relation to a format guide. This idea was discarded because the operator would have to correlate the original flight-plan data with the record copy being printed by the typewriter and the indicator light panel while typing, and it did not appear practicable to associate these data in sufficiently close physical relationship to be worthwhile.

3. Use of line-ruled tape stock that would conform to the fields of the input format and which could be checked visually by the operator as the tape was being punched. This method was discarded since it would require an experienced operator who could read teletype tape readily to check the punched tape with respect to the proper format fields. Also, the punched tape is not readily accessible for reading when the operator is typing.

4. Use of a format guide that could be attached to the machines for convenient visual reference. This approach seemed the simplest and offered the most feasible aid to the operator. After some preliminary experiments with various configurations of the fixed format required for the UNIVAC File Computers, a two-line format guide was evolved and used in the tests. The first line contained the addressor, the kind of message, and flight-plan data other than the route of flight. The second line and any succeeding lines contained route information only. A code group was required at the end of the second line for end-of-message or to indicate a two-card operation when a long flight-plan route required more than one input card. The end-of-message coding was inserted automatically by the Synchro-Tape and the Flexowriter machines by the end-of-message program control tape. The format guide and a typical flight plan are shown below. Periods were used as padding characters.

ADR . IDENTSS D/DR FIX .TIME ALT TYPE SPD
CHI P AF12345 20NW LAF E0800 240 T33. 390
FIX AIRWY FIX AIRWY FIX AIRWY FIX AIRWY FIX AIRWY
--- ----- --- ----- --- ----- --- ----- --- ----- / LTRS
ORD DRCT. HUF V12.. IND V97.. ORD DRCT. MTC

TEST CONDITIONS

I. The Synchro-Tape typewriter shown in Fig. 1 was tested in two modes of operation. (1) with a full program control tape, and (2) with an end-of-message program control tape.

(1) When using a full program control tape, the operator typed the flight-plan data without regard to length of fields and merely depressed the space bar whenever he had completed an item. The machine automatically completed any required padding in the particular field and spaced to the next field. This assured correct field length and spacing in the input message unless the operator typed additional characters erroneously before depressing the space bar, or unless he depressed the space bar while still typing alpha-numeric characters. These latter two operator actions would cause erroneous characters or padding in the flight-plan tape and would make the data unacceptable to the computer

(2) With an end-of-message program control tape, the operator was required to type the flight-plan data and insert proper padding by memory or by visual check of a format guide. He then depressed the end-of-message key to complete the flight-plan tape.

II. The Model No. 19 Teletypewriter, shown in Fig. 2 with tape perforator, was equipped with a stationary format guide attached to the paper holders at the ends of the platen. A position pointer was mounted over the key guide on the carriage. This provided the operator with a direct indication of carriage position relative to the format guide.

III. The Flexowriter Programatic machine shown in Fig. 3 used an end-of-message program control tape in the same manner as the Synchro-Tape in mode (2), above, and the operator requirements were identical. In Figs. 2 and 3, the black perforated tape is the program tape and the white perforated tape is the output tape from the machine containing the flight-plan data.

Forty sample flight plans were used for testing the operators on each machine. These flight plans were based upon a recent peak-day survey of traffic in the Indianapolis ARTC Center control area, and were representative of actual traffic according to class of operator, type of aircraft, speed, altitude, route, and destination. In one test, the 40 flight plans were copied by the operators visually from sheets of paper, and in another test they were copied as received verbally over an interphone headset. All operators completed a total of 80 flight plans with each of the three equipments.

The testing program was conducted in two phases. In the first phase, a total of nine personnel were used, consisting of three experienced teletype operators (CAA communicators), three experienced IBM 826 typewriter operators (Center assistant controllers), and three operators with general experience on various keyboards and machines. There were women employees of TDC called "ACE" (automatic communication equipment) operators. Operators were instructed to attempt to obtain a perfect tape copy of the flight plans, and if an error was detected, to start the complete flight plan over (restart). Corrections to the tape by backspacing were not made since most of the operators were not able to read the punched tape. The total time per run, restart times, and individual flight-plan times were recorded for each run. Upon the completion of test runs, all the punched tapes were run through the tape-to-card converter, and the cards were checked with a master set for accuracy. Types and numbers of errors on the tapes were tabulated and categorized.

Each operator in this test phase was given up to 4 hours of actual practice on each machine prior to testing, and each was asked to advise when he considered his training to be sufficient. During the test runs, operators were scheduled and rotated as practical to distribute the influence of the learning processes among all the equipments. The machine availability and maintenance did not permit complete randomizing of the use

of the machines. Also, the same test flight plans were used throughout the tests, and there was definite improvement in all the operators by the end of the test phase due to familiarity with the text of the flight plans.

In the second phase, a total of six personnel was used, consisting of two ACE operators who were experienced in the use of Teletype, IBM 826 typewriter punch card machine, the Remington Rand Model 3 alphabetic punch Type 306-2, and standard typewriters, one partly experienced ACE operator with some experience on the teletypewriter, the Remington Rand Model 3 alphabetic punch Type 306-2, and the standard typewriter, one ARTC Center assistant controller with only partial experience on teletypewriter and a standard typewriter; one inexperienced ACE operator with very little experience on the teletypewriter and who could type with one finger only on a standard typewriter; and one Center assistant controller with no experience on the teletypewriter or on a standard typewriter.

In this phase, operators were instructed again to attempt to obtain a perfect copy of the flight plans and to make a restart any time an error was detected. Corrections were not made for the same reasons stated in Phase I. The total time per run, restart times, and individual flight-plan times were recorded for each run. Upon the completion of the test runs, all the punched tapes were checked in the same manner stated in Phase I. Each operator in this test phase was given up to 4 hours of actual practice time on each machine prior to testing, and was directed to advise when he considered his training to be sufficient. During this test run, the operators were scheduled and rotated on each machine according to a randomized schedule. The flight plans on each machine had the same route of flight but the aircraft identity, type of aircraft, altitude, speed, proposed or actual time, and so forth, were mixed as practical to preclude the memorizing of the flight plans.

RESULTS

Phase I.

Nine operators and the following equipments were used.

1. Synchro-Tape typewriter (with full program control tape).
2. Model No. 19 Teletypewriter with tape perforator.
3. Flexowriter Programatic typewriter with end-of-message program control tape.

A total of 2,160 flight plans were processed during 108 test runs. Test data are shown in Figs. 4, 5, and 6 and Table I.

When using the modified Synchro-Tape machine, the operators averaged the smallest number of errors, 90.7. However, the average time, 45.4 seconds, to process a flight plan was highest, even though less time was lost due to restarts. The time advantage gained from fewer restarts was negated by the waiting time required for the program tape to run through its complete cycle

to the starting position. Since a maximum length flight plan normally is the exception rather than the rule, this interval of operator inactivity adds about 8 seconds to the total time for processing the average flight plan on this machine. This equipment required a considerable amount of maintenance and was quite unreliable in the first phase of testing. Most of the difficulties were minor but they made the equipment inoperative and required a person of technical experience with the machine to return it to operation.

When using the Flexowriter machine, operators averaged slightly more errors (95) than when using the modified Synchro-Tape but the average flight plan time was slightly less, 43.7 seconds. The operators were somewhat critical of the keyboard arrangement and operation on this machine. The numerical figure 1 was located at the right end of the figure bank, which was confusing. Intermittently, the entire keyboard would lock and none of the keys could be depressed. This situation tended to result in some typing errors, since the operator never was completely sure of the keyboard action.

The Teletypewriter with tape perforator had the lowest average flight plan processing time, 40.7 seconds, but averaged the largest number of errors (169.4). The keyboard action of this machine was preferred by the operators, who felt that an experienced person probably could obtain a higher rate of production compared to the other two machines tested.

Operator Opinions.

1. The modified Synchro-Tape typewriter was preferred because of good over-all performance, highest operator accuracy, ease of processing flight plans received aurally via headset, and because of the desirable keyboard configuration.

2. The Teletypewriter was preferred because of the speed of keyboard action, ease of processing flight plans visually, and because it appeared to have contributed least to operator fatigue during sustained operation.

3. The Flexowriter machine was not preferred over the other two machines in any of the significant operational factors.

4. The Synchro-Tape machine with a full program tape afforded a psychological "crutch" and advantage for an operator inexperienced with this type of equipment and a fixed-input format, since he could concentrate on the data required only for one field at any given time.

Phase II.

Six operators and the following equipment were used:

1. Synchro-Tape typewriter, with full program control tape.

2. Synchro-Tape typewriter, with end-of-message program control tape.

3. Model No. 19 Teletypewriter with tape perforator.

4. Flexowriter Programatic, with end-of-message program control tape.

A total of 1,920 flight plans were processed during 192 test runs. Test data for Phase II are shown in Figs. 7, 8, 9, and Table I.

Based on over-all averages, the Synchro-Tape typewriter with the end-of-message program tape produced fewer errors (51.3) than the Flexowriter (79.6), or the Teletypewriter (166.3), or the Synchro-Tape with the full program tape (77.0). The average flight-plan time (41.4 seconds) for the Synchro-Tape with limited program tape also was better than the Flexowriter (53.6), the Teletypewriter (59.9), or the Synchro-Tape with full program tape (77.0). Maintenance was no factor throughout this test phase.

The Phase II tests indicated that the Flexowriter performance was similar to that in the Phase I tests. The same operator objections to the keyboard were apparent during this phase, as noted previously in Phase I. The Teletypewriter resulted in a larger percentage of total errors and considerable increase in average flight-plan time (59.9 seconds versus 41.4 seconds) in this phase. This probably can be attributed to the effect of inexperienced personnel. A new operator seems to have appreciably more difficulty learning to operate this machine than the others. This probably is due to the necessity for figure and letter shifts with the three-row keyboard. The Synchro-Tape machine with limited program tape was consistently low in percentage of total errors and average flight-plan time for all three classes of operators.

Operator Opinions.

1. The original Synchro-Tape typewriter with limited program tape was preferred because of good over-all performance, high operating speed, ease of processing flight plans visually, and desirable keyboard configuration.

2. The modified Synchro-Tape typewriter with full program tape was preferred because of good operator accuracy, and ease of processing flight plans via headset.

3. The keyboard arrangement and method of operation of the Synchro-Tape typewriter (no figure and letter shift keys required) was preferred by the operators, but they did object to its general stiffness which reduces an experienced operator's speed, becomes fatiguing, and encourages errors. However, a definite majority felt that this keyboard would be very desirable providing its touch sensitivity could be adjusted to that of a Teletypewriter.

Other Factors.

In fairness to the experienced communications personnel who participated in the Phase I tests, it should be stated that the test procedures conflicted directly with many of their regular working methods and

procedures. This was necessary to provide some uniformity of testing all the equipments, and still conform to the computer system requirements. Undoubtedly, many of their errors were incurred because the fixed-field format conflicted with their deeply memorized standard operating format and coding, and they probably felt a mental strain because errors were not corrected, but required restarts. The remainder of the test operators were not so highly trained or specialized and therefore, did not seem to encounter similar difficulties.

It is planned to run additional tests in which the operators will be permitted to backspace in order to correct the tape. Also, additional tests are planned to compare flight plans of a rigid-field-length format with those of a variable-field-length format, and to compare other flight-plan input devices.

CONCLUSIONS

1. On the basis of these tests, the Synchro-Tape typewriter was the best machine for ATC computer input purposes inasmuch as it can be operated with an end-of-message or full program control tape. The latter method is an adjunct for training new operators or those using the machine only periodically. They can concentrate on one item at a time and actually watch the keyboard, if necessary, while processing the flight plan, because there is no need to be concerned about the fixed fields of the format. As a result, they tend to remain relaxed and unconsciously memorize the format while improving their speed, yet process an appreciable amount of data free of error. However, when the operators show a considerable improvement in their production speed, they should change to the end-of-message program control tape method of operation. An experienced operator continues to maintain a relatively low percentage of total errors using this method, and his average flight-plan preparation time is considerably less than when using the full program control tape.

The four-row keyboard configuration of this machine is preferred to a three-row keyboard, because it requires no figure and letter shifts. The "feel" or touch sensitivity needs improvement.

The maintenance on the Synchro-Tape machine was extensive during the first phase of testing, but was nil during the second phase. Indications are that this was a temporary situation of production "bugs" and possibly some engineering design limitations. It is understood that the later models of the Synchro-Tape typewriter are specifically designed and manufactured to avoid the type of difficulties encountered in the Phase I tests.

2. The Flexowriter has the advantage of an end-of-message program control tape. It appeared to be a well made piece of equipment and had a good keyboard touch to the operators. However, the arrangement and operation of the keyboard was considered the least desirable of the three machines tested. If this keyboard could be modified to a configuration and

method of operation similar to that of the Synchro-Tape, this machine would be more appropriate for the operators using this equipment for ATC computer functions.

3. Although the Model No. 19 Teletypewriter with tape perforator resulted in the highest number of errors in both phases of the test evaluation, it is capable of continous, high-speed operation with an experienced operator. It seemed to be the most difficult machine for the new operator to learn to operate. However, this is a standard piece of equipment that already is available, without need of any modifications, at many facilities. Therefore, an experienced operator readily can furnish a computer with the desired input data using this machine. Although it probably will have a higher total rate of error, it can be used at locations where the time for data processing may not be a critical factor, and where the availability of this machine may more than offset the advantages and the cost of a new specialized machine.

RECOMMENDATIONS

It is recommended that additional evaluation tests be made of other types of flight-plan input devices such as the FLIDEN when it becomes available.

TABLE I

BREAKDOWN OF TIME AND ERRORS OF EACH OPERATOR USING DIFFERENT MACHINES

Type of Machine Used	Type and Number of Operator	Average Time in Seconds	Number of Flight Plans	Number of Characters in Flight Plan	Total Number of Characters Typed Because of Errors (Restarts)	Total Number of Errors	Number of Errors Detected by Operator	Number of Errors Undetected by Operator
				PHASE I				
Synchro-Tape Typewriter	Center - operator 1	45 8	80	6 398	451	27	13	14
	ACEO - operator 2	49 6	80	6 398	247	21	18	3
	ACEO - operator 3	39 3	80	6 398	84	17	4	13
	ACEO - operator 4	47 9	80	6 398	592	48	33	15
	Center - operator 5	46 2	80	6 398	654	35	25	10
	Center - operator 6	47 0	80	6 398	655	40	28	12
	INSAC - operator 7	49 2	80	6 398	796	62	49	13
	INSAC - operator 8	42 8	80	6 398	0	16	0	16
	INSAC - operator 10	40 7	80	6 398	30	6	3	3
Total	9 operators	45 4	720	57 582	3 469	272	173	99
Teletypewriter	INSAC - operator 1	44 5	80	6 398	969	60	48	12
	Center - operator 2	49 0	80	6 398	783	86	28	58
	Center - operator 3	50 2	80	6 398	1 170	81	55	26
	Center - operator 4	39 2	80	6 398	485	58	37	21
	ACEO - operator 6	36 0	80	6 398	689	32	24	8
	ACEO - operator 7	42 2	80	6 398	824	41	29	12
	ACEO - operator 8	58 3	80	6 398	562	43	16	27
	INSAC - operator 9	22 5	80	6 398	61	44	7	37
	INSAC - operator 10	31 4	80	6 398	212	63	22	41
Total	9 operators	41 5	720	57 582	5 755	508	266	242
Programatic Flexotyp writer	ACEO - operator 1	41 5	80	6 398	1 442	56	46	10
	ACEO - operator 2	37 2	80	6 398	348	25	16	9
	INSAC - operator 5	49 0	80	6 398	139	24	6	18
	INSAC - operator 6	42 6	80	6 398	99	13	3	10
	INSAC - operator 7	44 4	80	6 398	782	55	28	27
	ACEO - operator 9	47 4	80	6 398	256	16	10	6
Tota	6 operators	43 7	480	38 388	3 066	189	109	80
				PHASE II				
Synchro-Tape Typewriter (Ful Program Tape)	Exp - operator A	41 6	80	6 398	342	11	8	3
	Exp - operator B	47 7	80	6 398	110	11	9	2
	Semiexp - operator C	60 4	80	6 398	767	50	34	16
	Inexp - operator D	65 9	80	6 398	598	47	46	1
	Semiexp - operator E	47 4	80	6 398	1 000	81	64	17
	Inexp - Operator G	54 3	80	6 398	495	31	16	15
Total	6 operators	52 9	480	38 388	3 312	231	177	54
Te e ypewriter	Exp - operator A	40 3	80	6 398	674	45	39	6
	Exp - operator B	56 3	80	6 398	557	40	24	16
	Semiexp - operator C	53 3	80	6 398	470	21	20	1
	Inexp - operator D	71 4	80	6 398	767	47	39	8
	Semiexp - operator E	40 4	80	6 398	1 275	123	71	52
	Inexp - operator G	97 5	80	6 398	1 956	199	143	56
Total	6 operators	59 9	480	38 388	5 699	475	336	139
Programatic Flexotypewriter	Exp - operator A	35 4	80	6 398	358	17	10	7
	Exp - operator B	45 7	80	6 398	374	14	10	4
	Semiexp - operator C	61 1	80	6 398	1 323	76	57	19
	Inexp - operator D	72 9	80	6 398	631	28	25	3
	Semiexp - operator E	45 4	80	6 398	1 082	65	39	26
	Inexp - operator G	60 6	80	6 398	782	39	37	2
Total	6 operators	53 5	480	38 388	4 551	239	178	61
Synchro-Tape Typewriter (Erdirg Program Tape)	Exp - operator A	29 2	80	6 398	246	13	8	5
	Exp - operator B	40 7	80	6 398	182	7	7	0
	Semiexp - operator C	42 0	80	6 398	184	44	42	2
	Inexp - operator D	49 6	80	6 398	452	14	13	1
	Semiexp - operator E	35 7	80	6 398	1 110	50	41	9
	Inexp - operator G	50 9	80	6 398	346	26	21	5
Total	6 operators	47 4	480	38 388	2 520	154	132	22

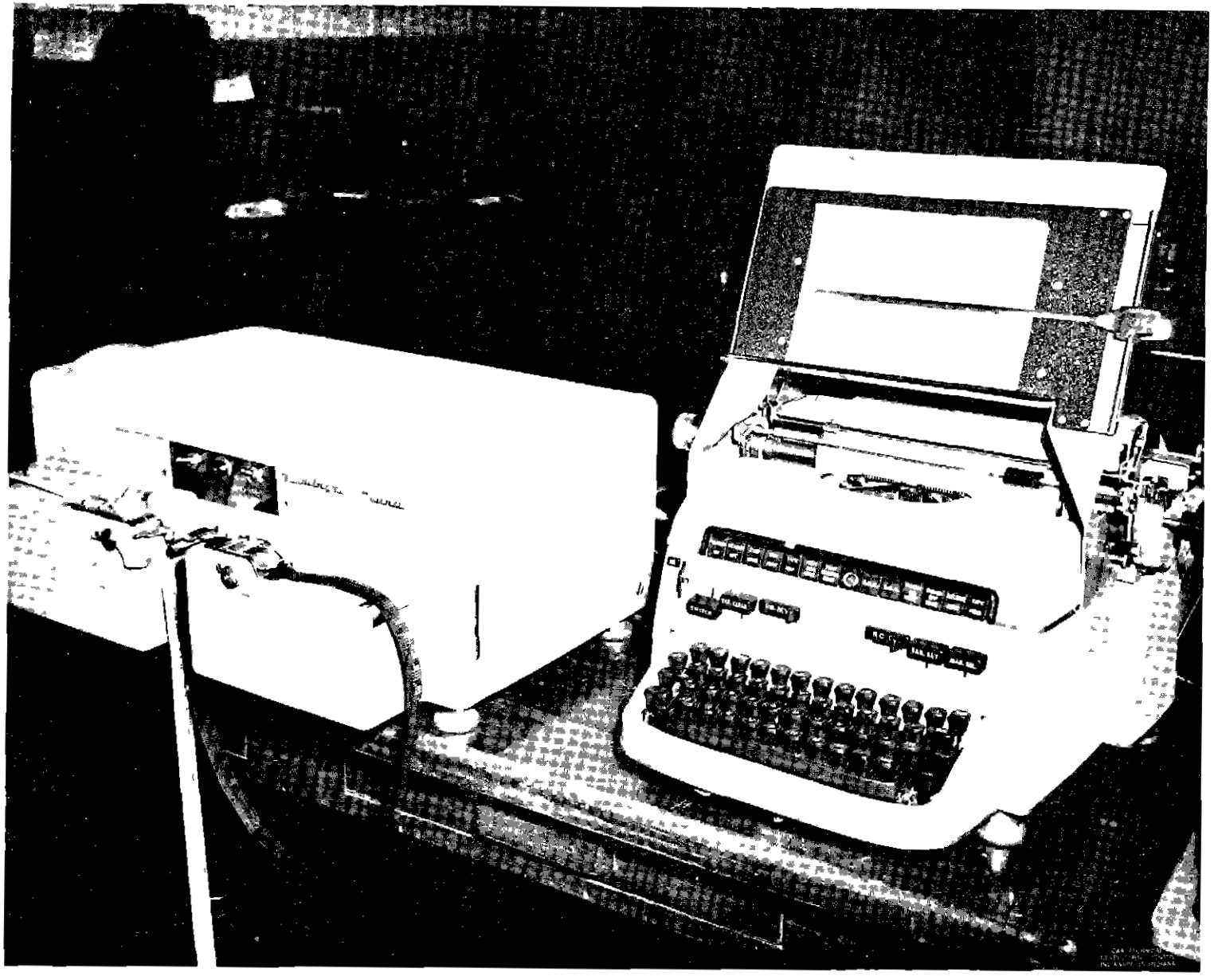

FIG 1 THE REMINGTON RAND CO SYNCHRO-TAPE TYPEWRITER

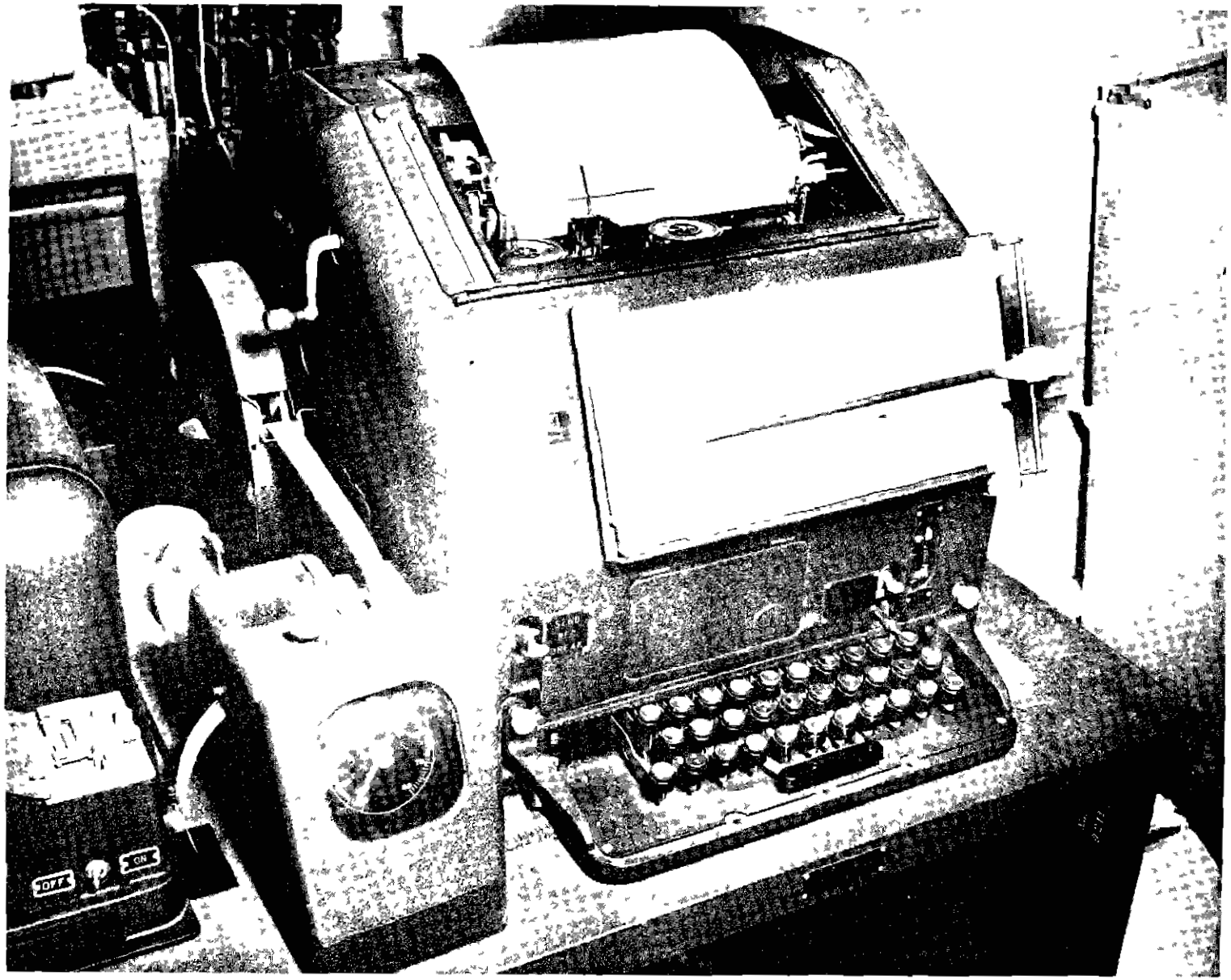

FIG. 2 THE TELETYPE CORP MODEL NO. 19 TELETYPEWRITER

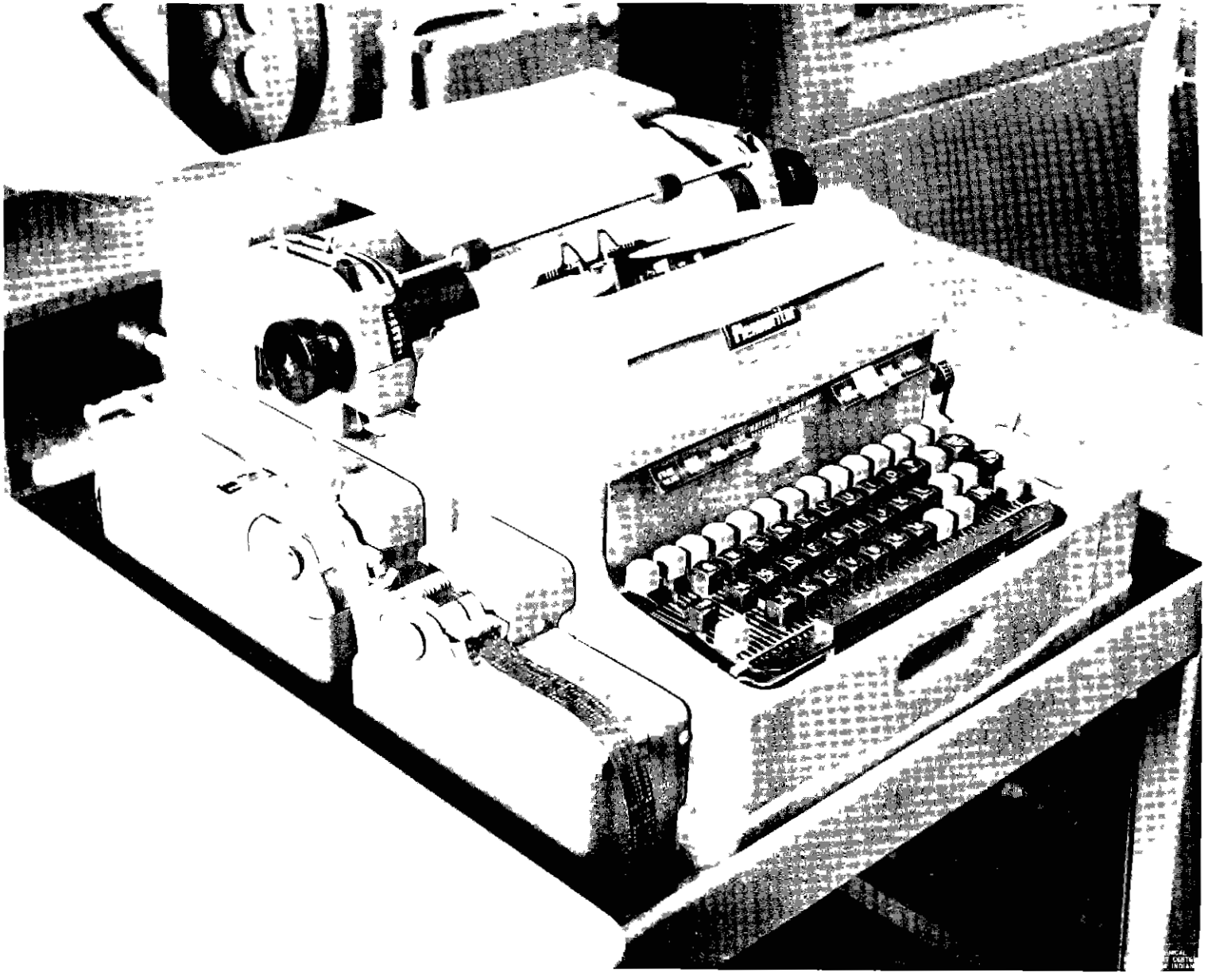

FIG. 3 THE FRIDEN CO FLEXOWRITER PROGRAMATIC TYPEWRITER

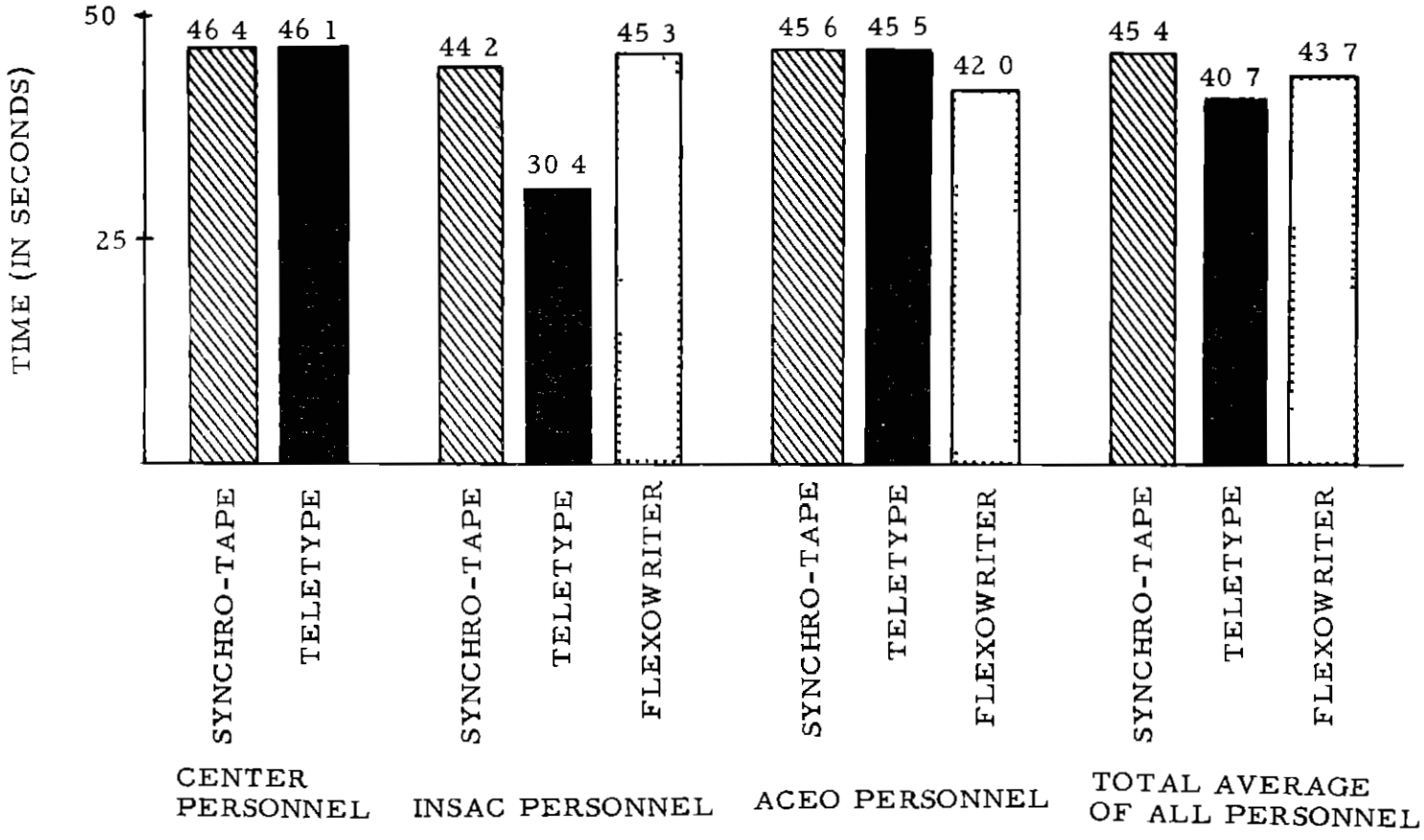

FIG. 4 PHASE I - AVERAGE TIME IN SECONDS PER FLIGHT PLAN INCLUDING RESTARTS

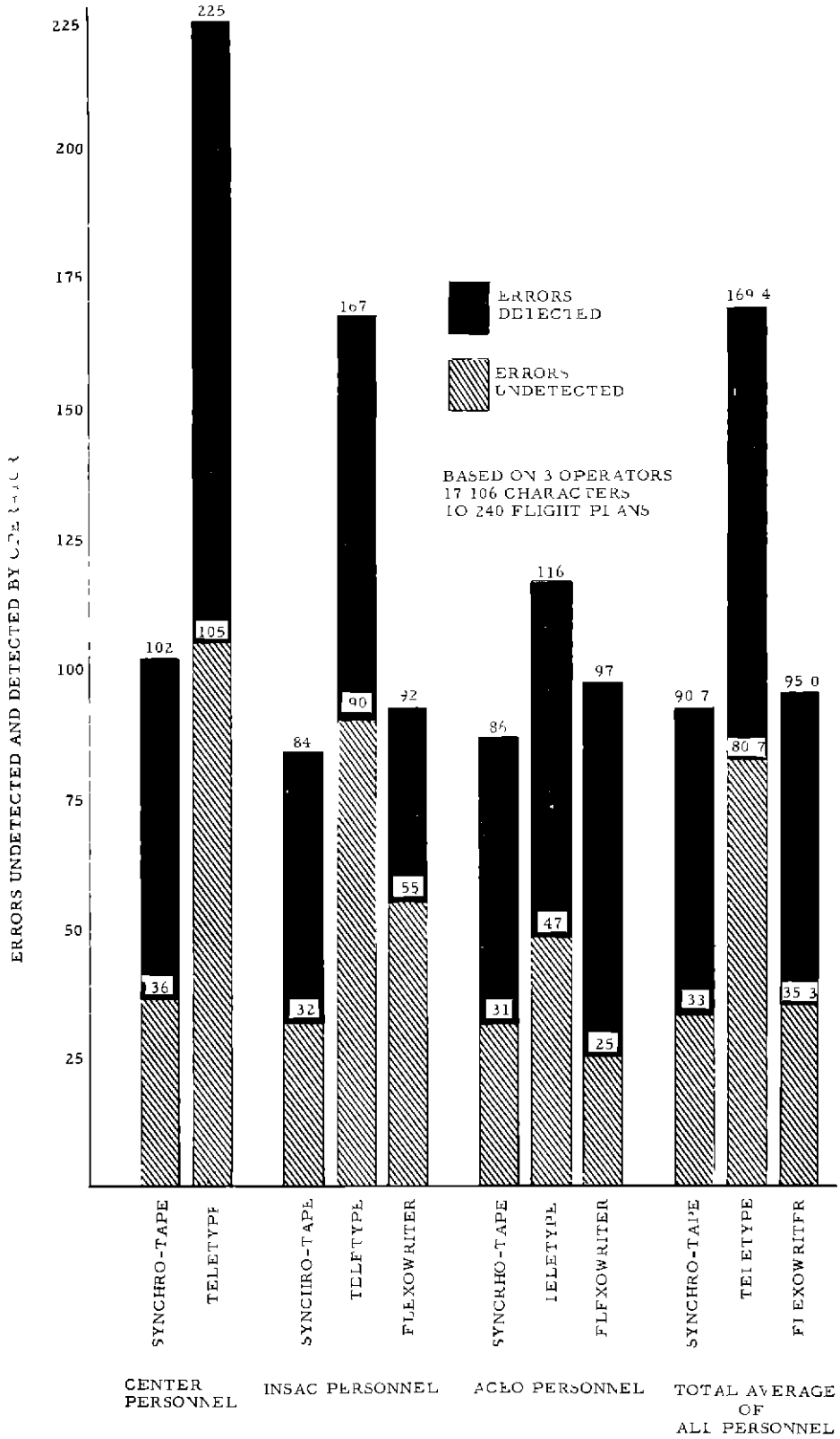

FIG 5 PHASE I TOTAL NUMBER OF ERRORS

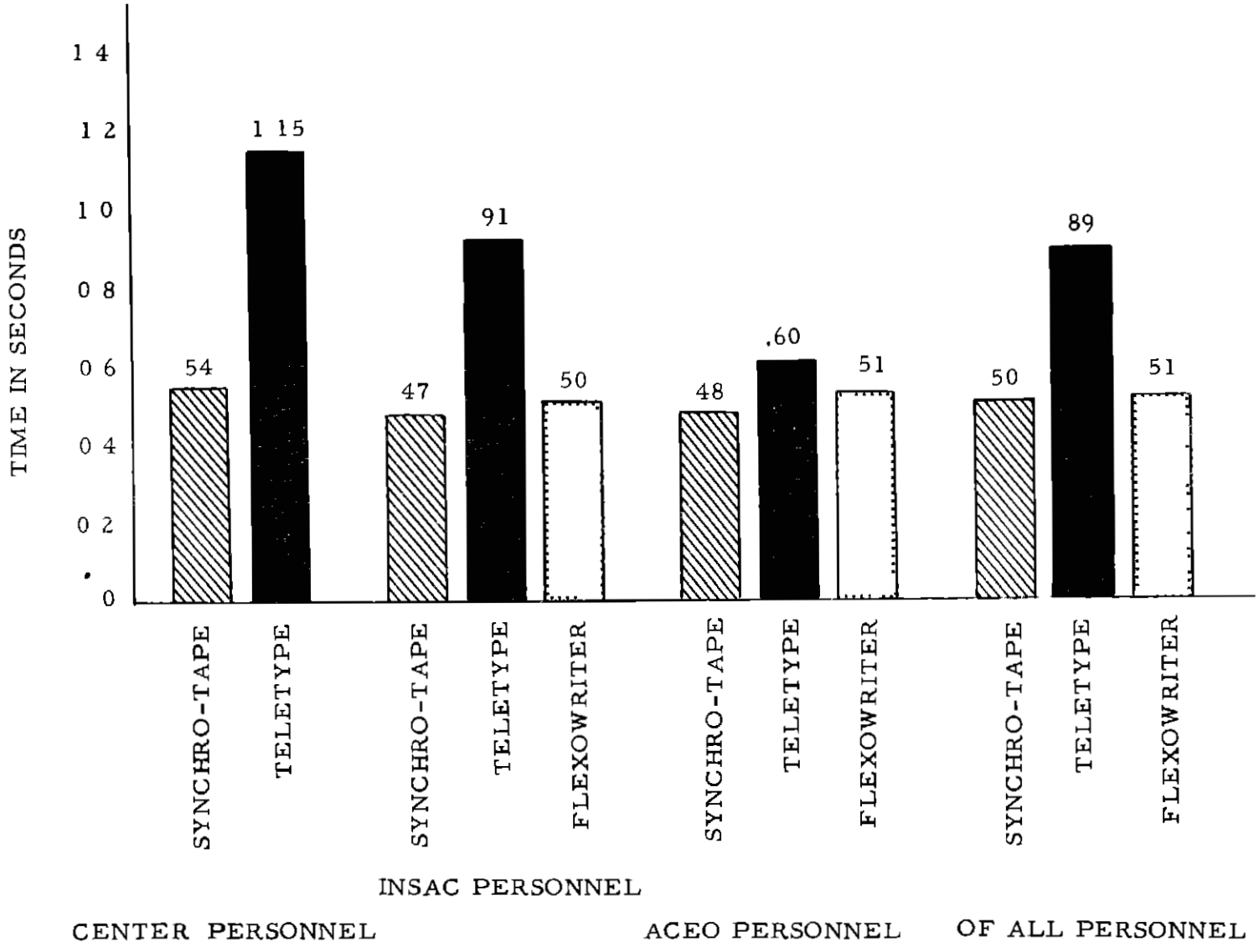

FIG. 6 PHASE I - PERCENTAGE OF ERRORS BASED ON TOTAL NUMBER OF CHARACTERS TYPED

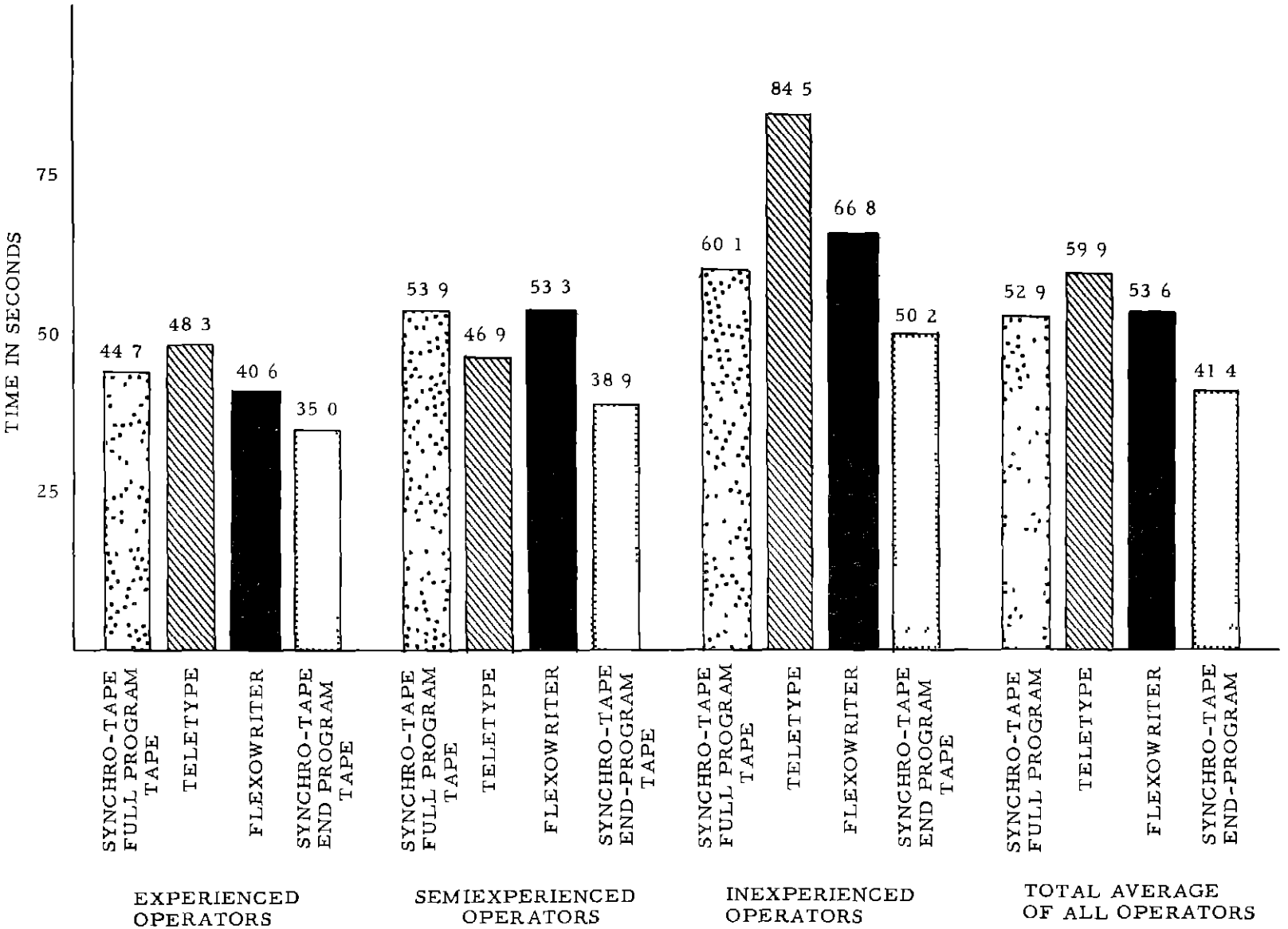

FIG. 7 AVERAGE TIME IN SECONDS PER FLIGHT PLAN INCLUDING RESTARTS

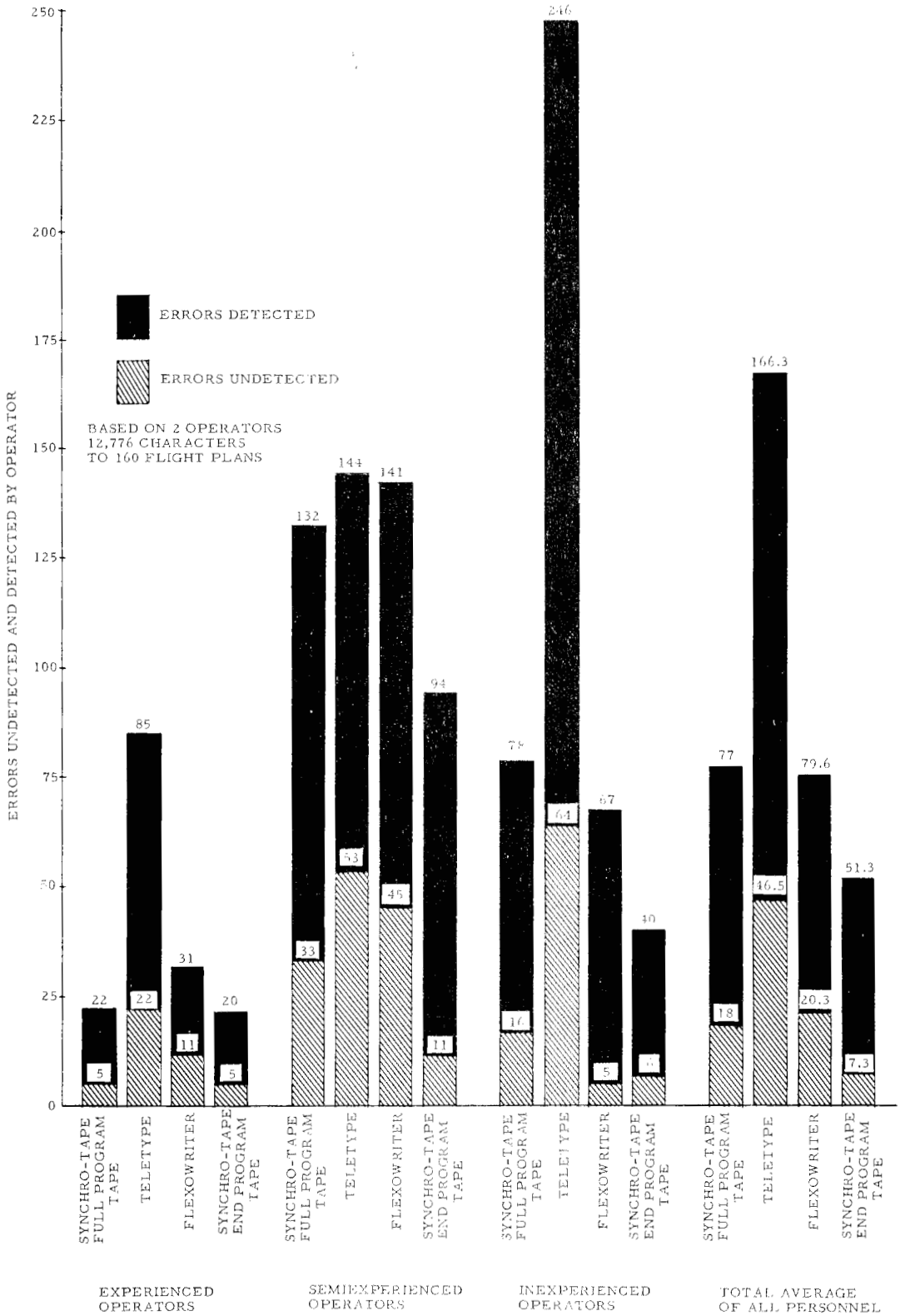

FIG. 8 PHASE II - TOTAL NUMBER OF ERRORS

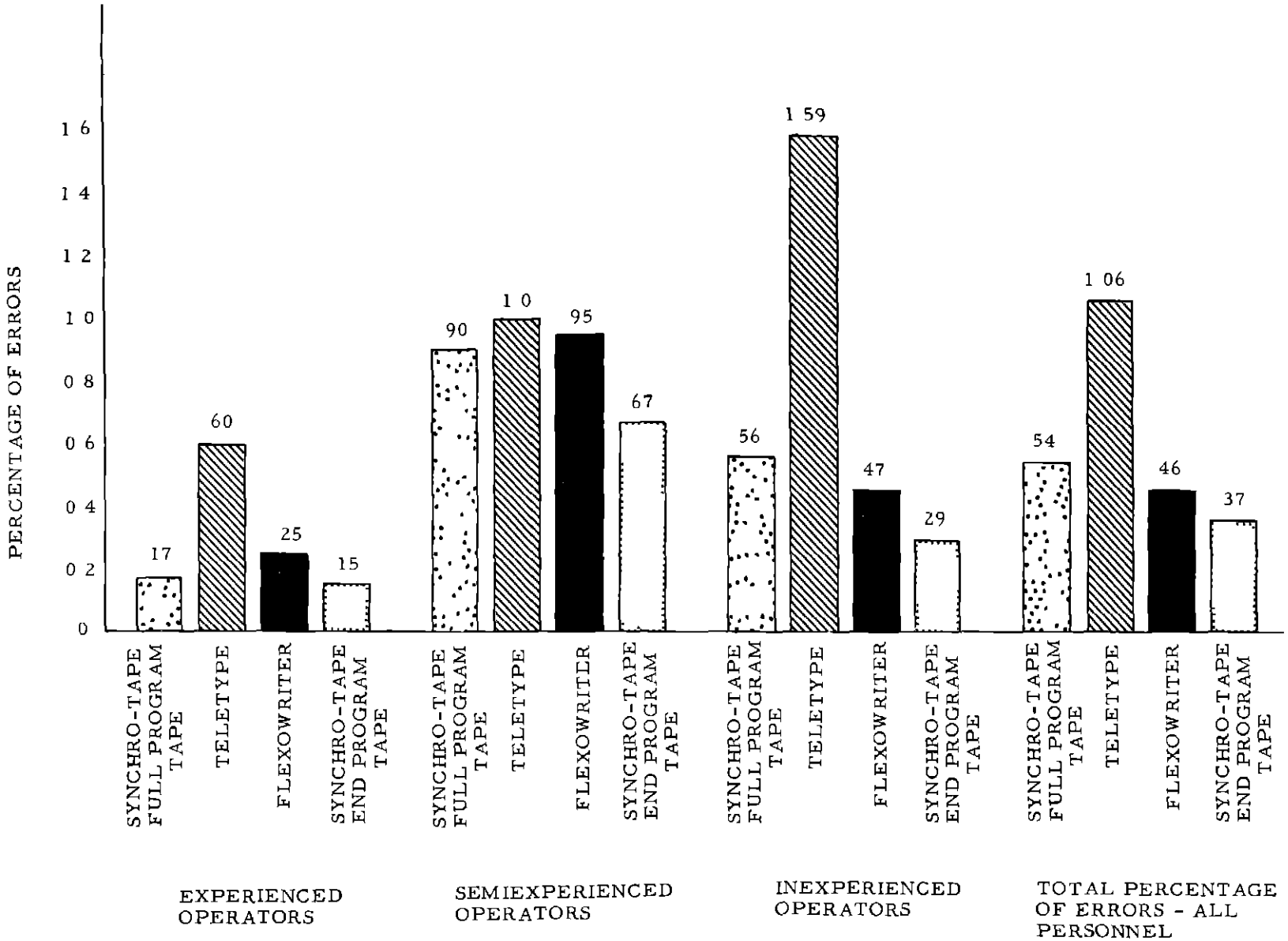

FIG. 9 PHASE II - PERCENTAGE OF ERRORS BASED ON TOTAL NUMBER OF CHARACTERS TYPED