BELL TELEPHONE LABORATORIES
INCORPORATED

SUBJECT: Telephone Aids for the Deaf - Computer Recognition and Generation of Sign Language - File 38794-43

DATE: 15 May 1970

FROM: C. A. Argila

The attached term paper was prepared as partial requirements for a course in Heuristic Programming and Machine Intelligence at New York Universities Courant Institute.

This paper describes a dactylological analysis program which performs rudimentary generation and recognition of Sign Language. Techniques have been developed which permit Sign Language input via a special teletypewriter keyboard and Sign Language output via a CRT screen.

C. A. Argila

HO-3217-CAA-CP

C. A. Argila

Copy to

Messrs. M. L. Almquist, Jr. - HO - 3F620
R. Black, Jr. - HO - 3E621
E. Bloom, Jr. - MH - 1A378
A. Busala - IN - W119
R. L. Cohen - HO - 3E611
J. S. Courtney-Pratt - HO - 4G506
V. H. Cutler, Jr. - HO - 3F608
C. G. Davis - HO - 1C631
F. E. DeMotte - HO - 2C425A
I. Dorros - HO - 3F636
G. M. C. Fisher - HO - 4G526
J. L. Flanagan - MH - 2D536
F. E. Froehlich - HO - 1C637
E. G. Hallins - WH - 1J214
L. D. Harmon - MH - 2C420
A. E. Hirsch, Jr. - MH - 3B321
C. J. Hoffman - HO - 1F610
J. J. Horzepa - HO - 3B603
J. R. Logan, Jr. - WH 3E219
J. R. Nelson - MH - 15106
H. J. Peters - HO - 1B532
W. G. Reichert, Jr. - IN - 2D208
J. F. Ritchey - IN - W127
A. E. Ruppel - HO - 2B527
D. L. Scharfetter - MH - 2A403
J. I. Sheetz - MH - 1C247
C. D. Stockbridge - HO - 4F513
W. G. Turnbull - IN - B205

C. A. Argila
15 May 1970

COMPUTER GENERATION AND RECOGNITION OF SIGN LANGUAGE

1. Introduction

It has been relatively well established in the literature that manual techniques are no less important in educating and communicating with the deaf than the more popular oral techniques. A primitive form of manual communication probably predated oral communication in man. Furthermore, man still possesses a large number of "natural signs" which, though never overtly learned, and seldom even noticed, play an important role in the communication process (4).

Little has been done to study the structure of Sign Language; the author feels that there are two reasons for this. First, in modern times Sign Language has been looked down upon as inferior to oralism. But more important, the tools and techniques available have been too limited to perform any extensive analysis of the Sign Language; dactylologists must spend long hours watching motion pictures of persons communicating in Sign Language, relying much on their memory.

With this as background, the author has attempted to take an entirely new and unique approach to the problem. Utilizing a Control Data Corporation (CDC) 1700 digital computer at Bell Laboratories a rudimentary program has been written which translates Sign Language to English and vice versa. Sign Language is input via a special teletypewriter keyboard and Sign Language output is via a cathode ray tube (CRT) screen.

2. Sign Language Structure

Just as spoken language can be analyzed as a set of basic sounds, phonemes, and rules dictating how they may be combined to form spoken words, Sign Language can be analyzed as a set of basic positions, configurations and motions, cheremes, and rules dictating how they may be combined to form manual signs. This has been done by Stokoe (3) in 1960 and it is his technique and notation (with some changes) which we describe in this section.

It should be mentioned that Stokoe's techniques, which are quite laudable for a first attempt, have been adopted because they are the best available in the literature. However, the cheremes defined by Stokoe do in fact lack "resolution," i.e., not all signs can be uniquely (or easily) expressed using these cheremes.* This set of cheremes is adequate for the scope of this paper; furthermore expanding upon this set would only have detracted from our primary purpose which was the development of computer techniques.

2.1 Cheremes

Cheremes are basic positions, called Tabula (TAB), basic configurations, called designators (DEZ) and basic movements, called signations (SIG). Table 1 defines the symbols used for the TAB cheremes; these refer to various parts of the body to which the motion of the sign refers.

Table 2 defines the symbols used for DEZ cheremes; these are configurations of the principal hand (right hand for a right-handed person). The various letters used in defining the DEZ cheremes refer to the hand configurations of

---

* Ironically, this is not unlike the situation encountered when deaf persons are taught to speak. Because they are unable to learn the forty-some-odd phonemes which English speaking hearing persons use, their speech lacks "resolution" and hence sounds peculiar.

the American Manual Alphabet (Figure 1). These cheremes may also serve as TAB cheremes; in this case the helping hand (left hand for a right-handed person) assumes the cheremic configuration and motion within the sign refers to this hand.

Table 3 defines the symbols used for the SIG cheremes; these refer to the various motions which the DEZ can make with reference to a TAB. A "Double DEZ" means that both hands assume DEZ configurations (not necessarily the same) and SIG motion refers to both DEZ hands.

A very important aspect of manual communication is the expression assumed by the face. Facial expressions are as important, and used as frequently, in manual communication as intonation is used in oral communication. These expressions are indicated by a vinculum written over the cheremic symbols. Single, double and triple vincula are used as defined in Table 4.

2.2 Rules for Combining Cheremes

A number of rules are established for writing and combining cheremes. Cheremic representations of signs are written linearly from left to right in the form "a, b, c" where "a" represents symbols for TAB cheremes, "b" represents symbols for DEZ cheremes and "c" represents symbols for SIG cheremes. Signs are separated by "/" except when two signs are combined to form a new sign; the symbol ":" is used to separate component portions of a compound sign.

In the sign "a, b, c" "a" consists of precisely one TAB symbol, or DEZ symbol used as TAB. "b" may consist of one or two DEZ symbols; if one DEZ symbol it refers to the principal hand; if two DEZ symbols, the left most symbol refers to the helping hand, the right most symbol refers to the principal hand. A SIG symbol may become part of a TAB or DEZ symbol, being joined to it by "-". In this case the SIG symbol denotes the orientation of the TAB or DEZ chereme. Finally, "c" may consist of any

number of SIG symbols. Successive SIG symbols indicate successive motions of DEZ with respect to TAB. SIG symbols separated by "-" indicate simultaneous motions.

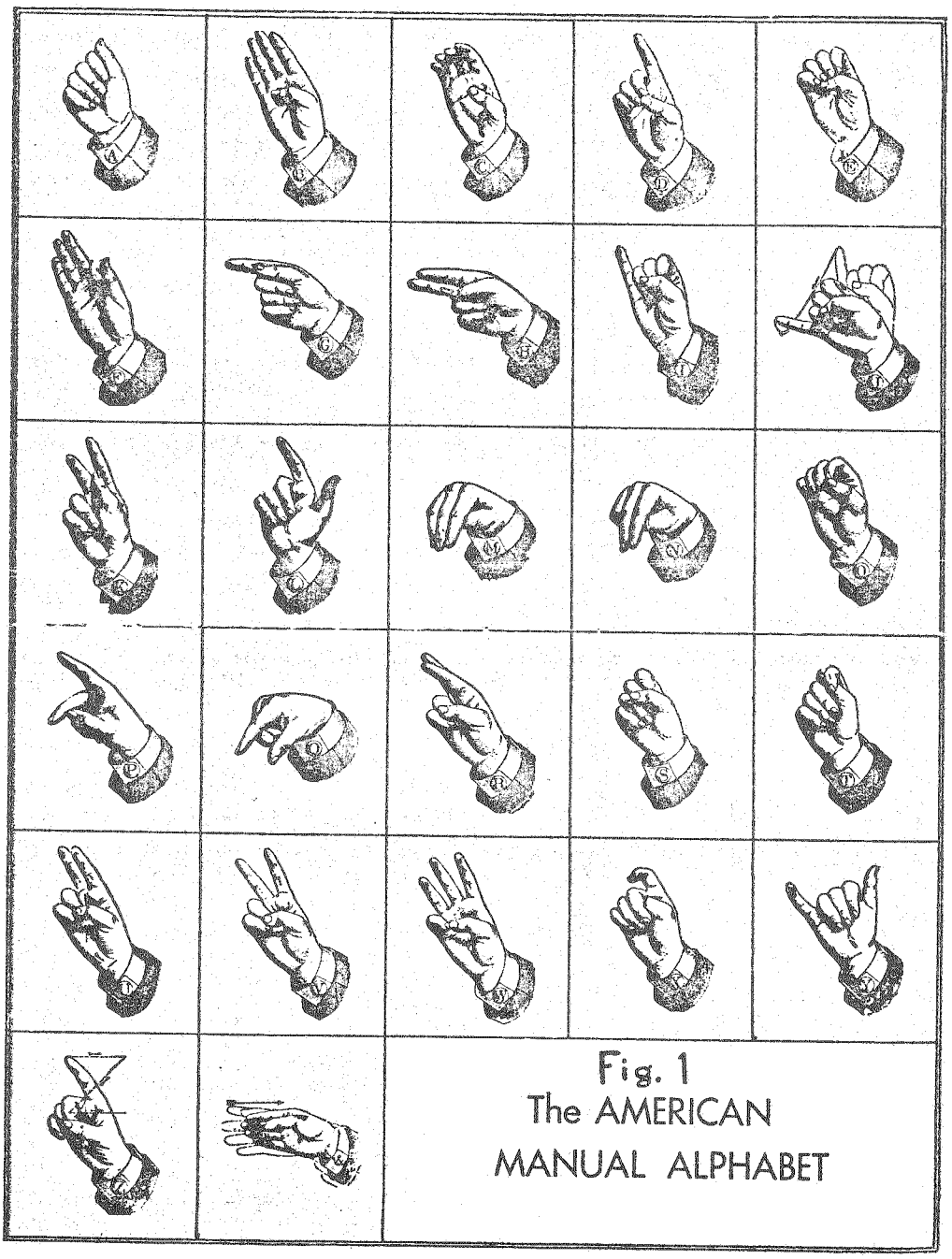


Fig. 1
The AMERICAN
MANUAL ALPHABET

TABLE I – TAB SYMBOLS

NAME	SYMBOL	DESCRIPTION
ZERO TAB		THE SPACE IN FRONT OF SIGNERS BODY WHERE HAND MOVEMENT IS EASY AND NATURAL; ALLOCHERS – REGIONS WITHIN THE WHOLE SPACE
FACE		THE HEAD ITSELF AND SPACE AROUND IT
BROW		THE UPPER FACE FROM BROWS TO HAIR LINE INCLUDING TEMPLES
MID-FACE		THE EYES, NOSE, OR ANY POINT BETWEEN ⌒ AND ⌣ CONTRASTING WITH THEM
LOWER FACE		THE CHIN, MOUTH OR LIPS
SIDE FACE		THE CHEEK, EAR, OR JAW
NECK		THE SPACE BETWEEN CHIN AND CHEST
BODY OR TRUNK	[]	THE SPACE FROM SHOULDERS TO HIPS INCLUSIVE
UPPER ARM		THE REGION OF THE BICEPS
ELBOW		THE DISTAL SIDE OF FOREARM, OR ELBOW ITSELF
SUPINE ARM		THE PROXIMAL SIDE OF FOREARM, OR WRIST
PRONE ARM		THE DISTAL SIDE OF WRIST OR BACK OF HAND

TABLE 2 – DEZ SYMBOLS

NAME	SYMBOL
FIST	A
FLAT HAND	B
CURVED HAND	C
RETRACTED HAND	E
F-HAND	F
INDEX	G
H-HAND	H
PINKIE OR I-HAND	I
K-HAND	K
L-HAND	L
BENT-HAND	M
O-HAND	O
R-HAND	R
FIST	S
T-HAND	T
V-HAND	V
W-HAND	W
Y-HAND	Y
OPEN HAND	5

TABLE 3 — SIG SYMBOLS

NAME	SYMBOL	DESCRIPTION
VERTICAL MOTION	^	UPWARD MOTION
	v	DOWNWARD MOTION
	^v	UP AND DOWN MOTION
LATERAL MOTION	>	RIGHTWARD MOTION
	<	LEFTWARD MOTION
	><	RIGHT AND LEFT MOTION
TO AND FRO MOTION	T	TOWARD SIGNER
	⊥	AWAY FROM SIGNER
	T̲	TO AND FRO
TWISTING MOTION	ɑ	SUPINATIVE MOVEMENT
	ɒ	PRONATIVE MOVEMENT
	ω	OSCILLATING TWIST
CARPAL MOTION	ɳ	NODDING OR SHAKING MOTION, PIVOTING AT WRIST; MAY BE PROXIMAL, DISTAL, OR BOTH
FORAL MOTION	□	OPENING MOTION OF A CONFIGURATION
	#	CLOSING MOTION OF A CONFIGURATION
APPROACH	X	DEZ APPROACHES TAB
TOUCH	><	DEZ TOUCHES TAB
GRAZE	↑, →, OR ↘	DEZ BRUSHES OR SLIDES ACROSS TAB
LINK	⨉	DOUBLE DEZ CLASP, HOOK, ETC., OR DEZ GRASPS TAB
ENTER	Ⓐ OR Ⓥ	DEZ IS INSERTED OR THRUST THROUGH TAB
CROSS	ǂ	DOUBLE DEZ CROSS, ONE OVER OTHER
SEPARATE	÷	LINKED, CROSSED, INSERTED, OR ADJACENT DEZ MOVES AWAY
INTERCHANGE	,,	DOUBLE DEZ OR TAB AND DEZ HANDS REVERSE RELATIVE POSITIONS
REPEAT	·	SIG MOTION IS PERFORMED AGAIN
STACCATO	⨪	SHARP, STACCATO MOVEMENT IS INDICATED
ALTERNATE	∽	INDICATES THAT SIG MOTION IS PERFORMED IN ALTERNATION BY DOUBLE DEZ
REVERSE	Я	INDICATES THAT LEFT HAND IS DEZ, RIGHT IS TAB, ETC.

TABLE 4 – EXPRESSION SYMBOLS

AFFIRM	—	HEAD BENDS VERY SLIGHTLY FORWARD AND RETURNS, OR EYES LOWER AND RAISE, OR BOTH TOGETHER
QUERY	=	FACE 'OPENS', EYEBROWS RAISE, EYES OPEN WIDE, CHIN OR MOUTH LOWERS
NEGATE	≡	HEAD SHAKES

3. Input Output Techniques

Because of hardware constraints a number of cheremic symbols were altered for actual computer use. The only significant changes were for the "Graze" symbols, only one symbol ( )<) is now used, direction being indicated by a connecting SIG symbol and for the "Enter" symbols, only one symbol, a large circle, is used; it appears superimposed over the preceding SIG symbol to indicate the "Enter" motion. Since these symbol changes are used only for computer interface we shall continue to use the symbols introduced in Section 2 throughout this paper.

3.1 Input

Cheremic symbols are input via a special teletypewriter keyboard shown in Figure 2. In addition to the conventional mode of operation, the keyboard may be operated in a TAB Mode, DEZ Mode and SIG Mode for the input of TAB and Expression symbols, DEZ symbols and SIG Symbols, respectively. When in any given mode operation of the X-OFF character key (CTRL-S) returns the keyboard to the conventional mode, likewise operation of the EOT (CTRL-D), RU (CTRL-F) or BELL (CTRL-G) characters returns the keyboard to the TAB, DEZ or SIG mode, respectively.

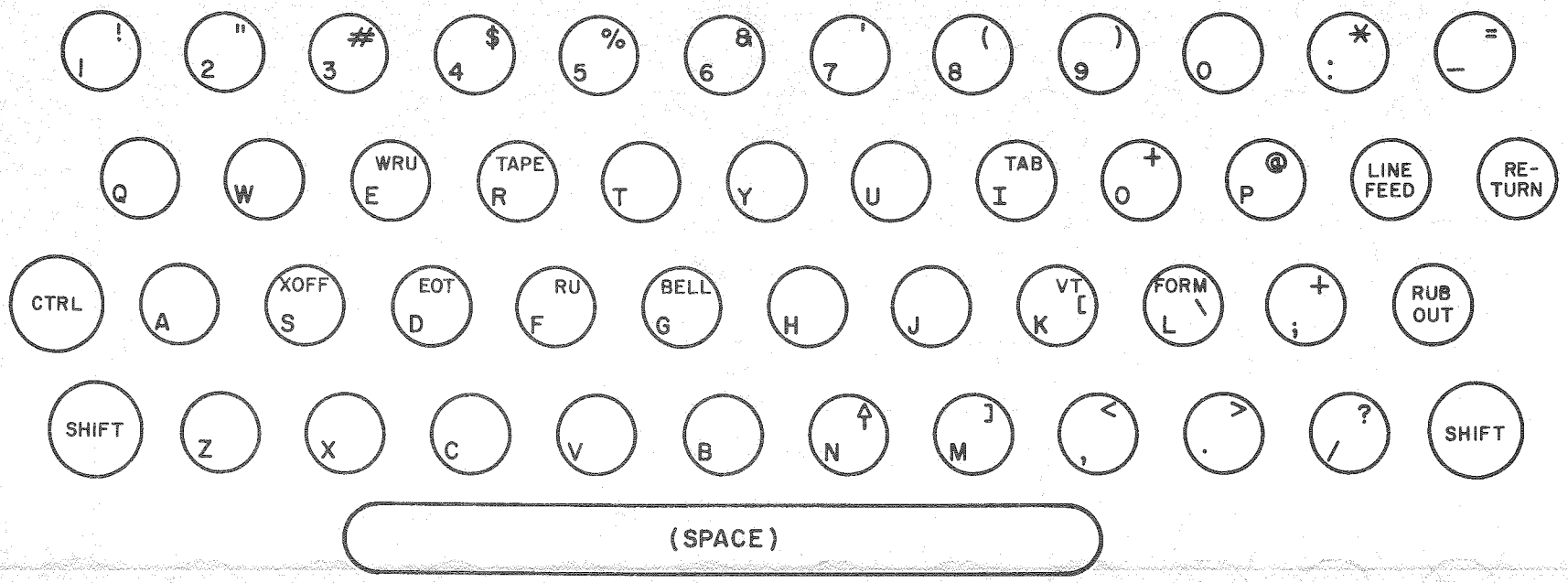
We have attempted to configure these keyboards in a logical and convenient manner, however as more is learned about the cheremic representations of signs these keyboards might be rearranged to improve the speed and accuracy with which symbols can be input.

As mentioned in (1) an ever growing number of deaf persons are utilizing 5-level teletypewriters (with three-row keyboards) for telephone communication. It is important to consider this "obsolete" three-row keyboard since it might well be used for some future application of these techniques; hence, we have defined in Figure 3 the various modes for a three-row

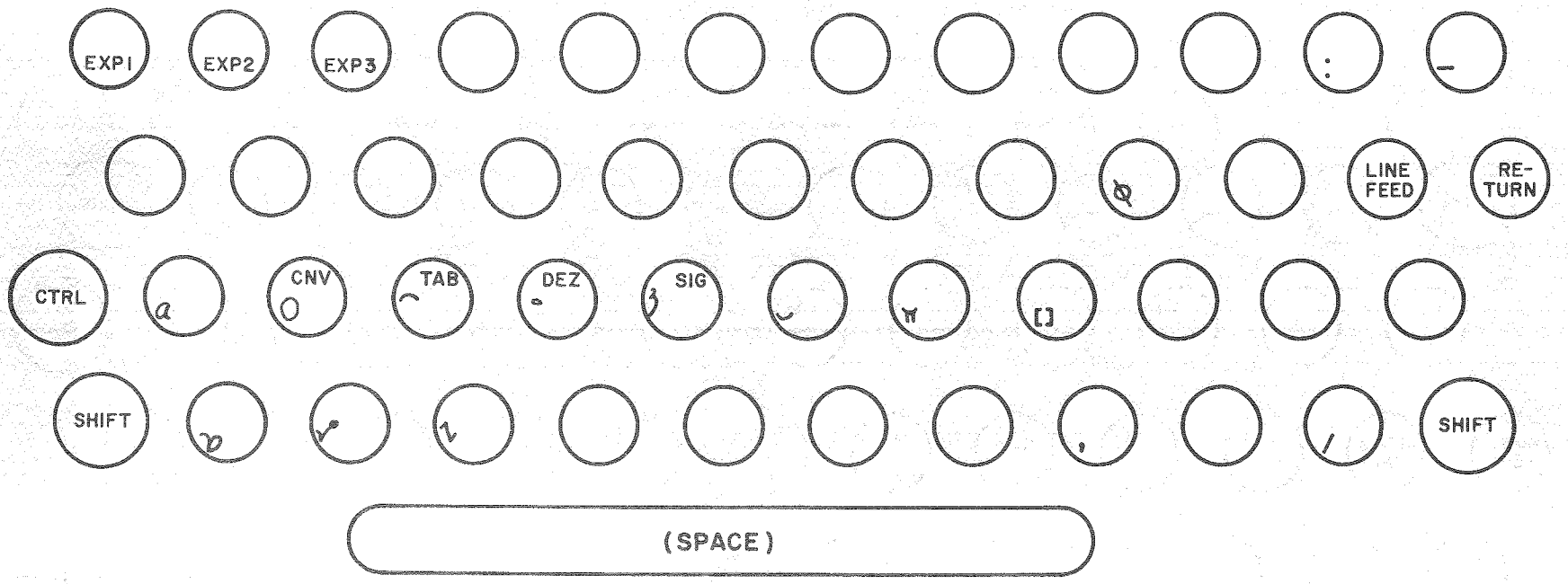
keyboard, maintaining as much as possible compatibility with the four-row keyboard.

3.2 Output

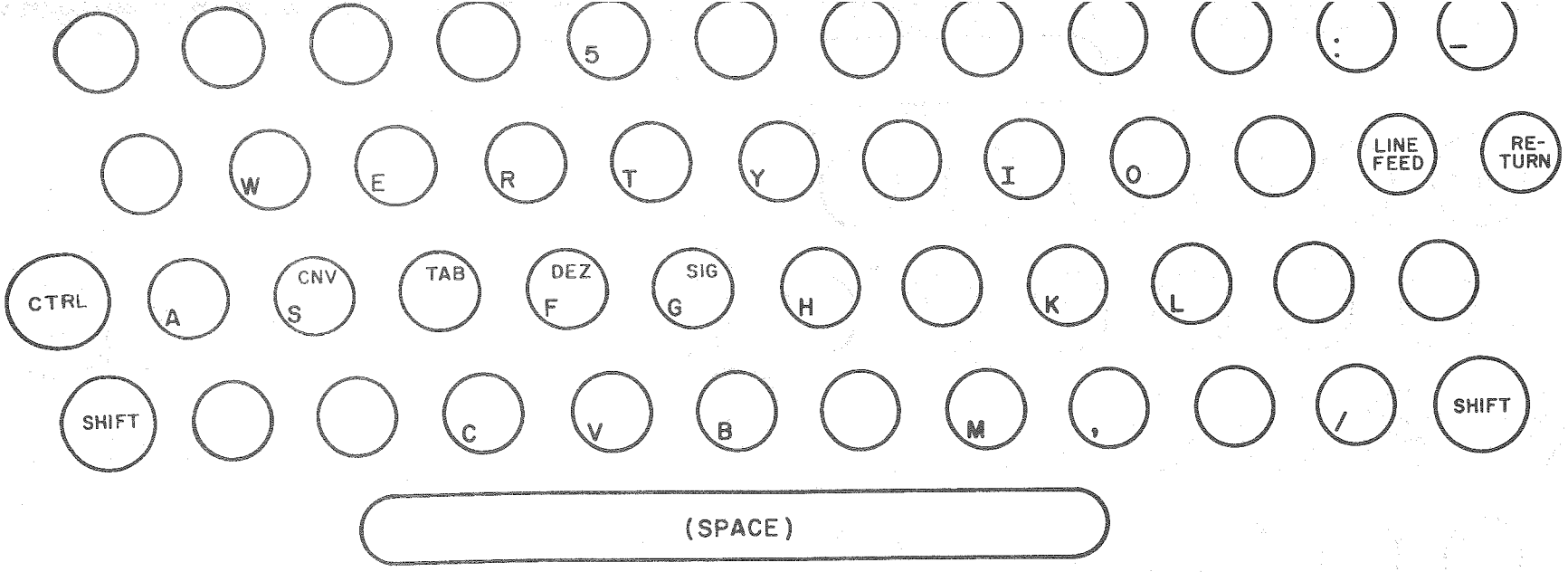
Cheremic symbols are displayed on a simulated printed page on a CRT screen. Figure 4 shows actual cheremic symbols used in this study. The four rows are the conventional, TAB, DEZ and SIG symbols, respectively.



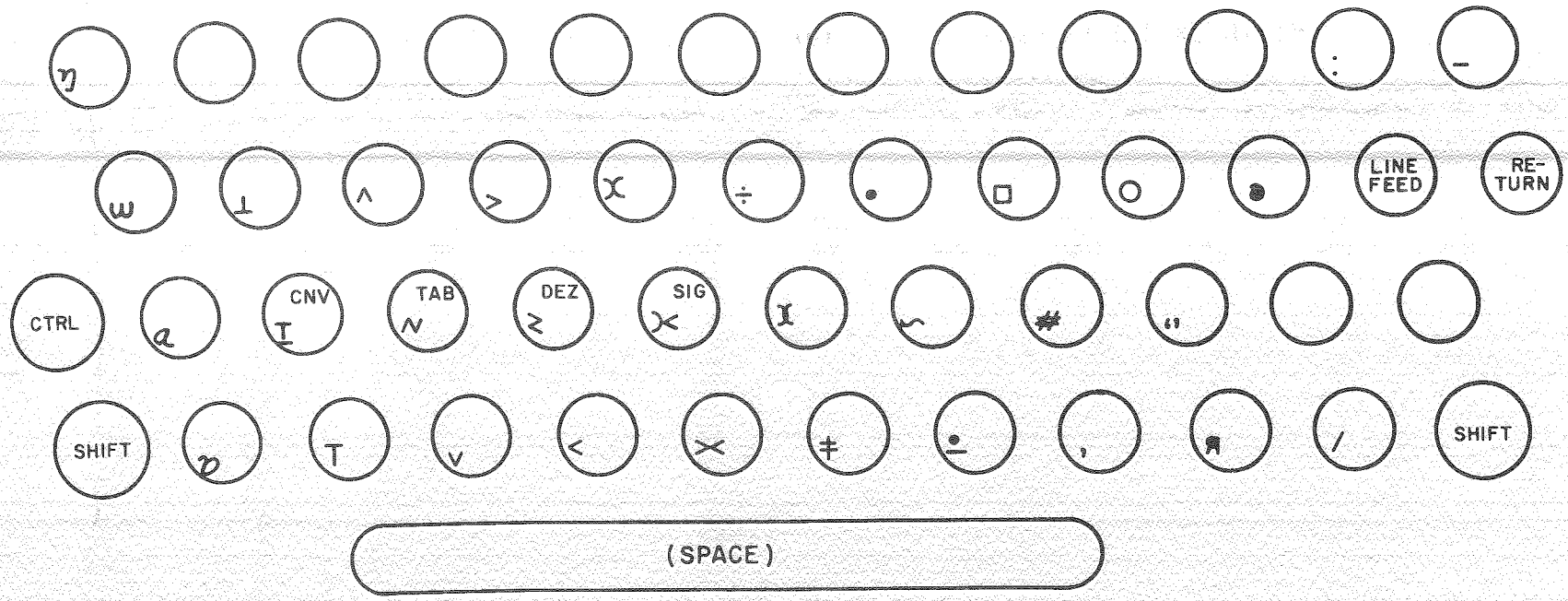
CONVENTIONAL FOUR-ROW (8-LEVEL) TELETYPEWRITER KEYBOARD



FOUR-ROW KEYBOARD IN TAB MODE

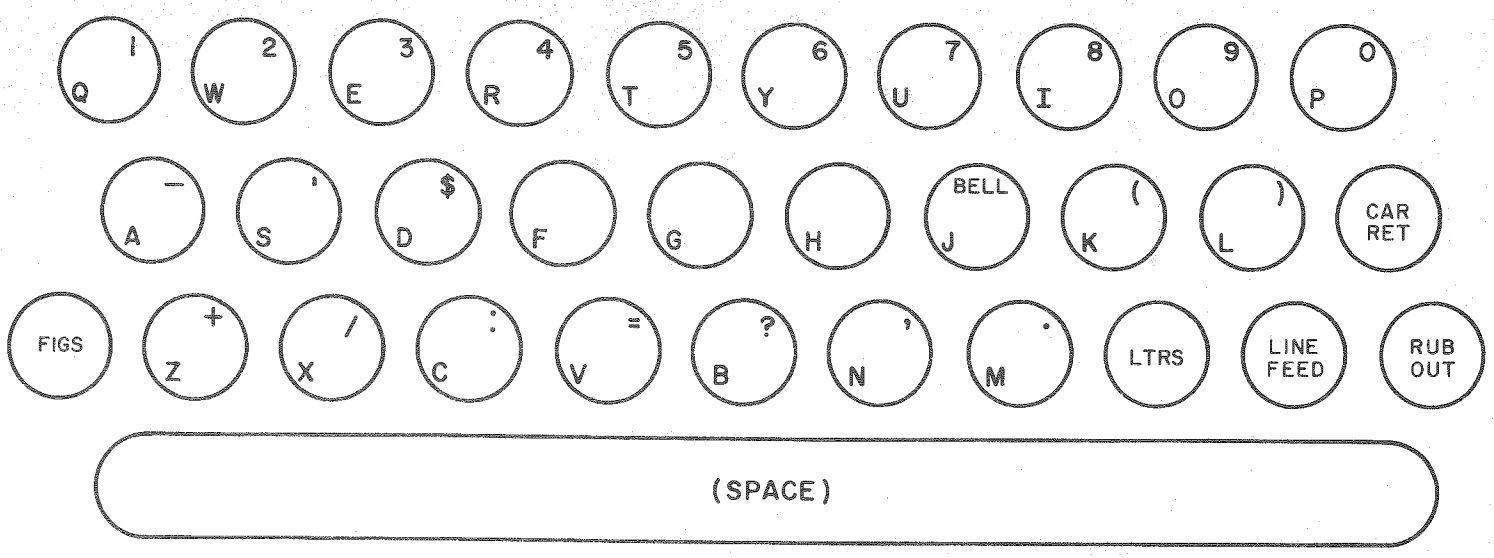


FOUR-ROW KEYBOARD IN DEZ MODE

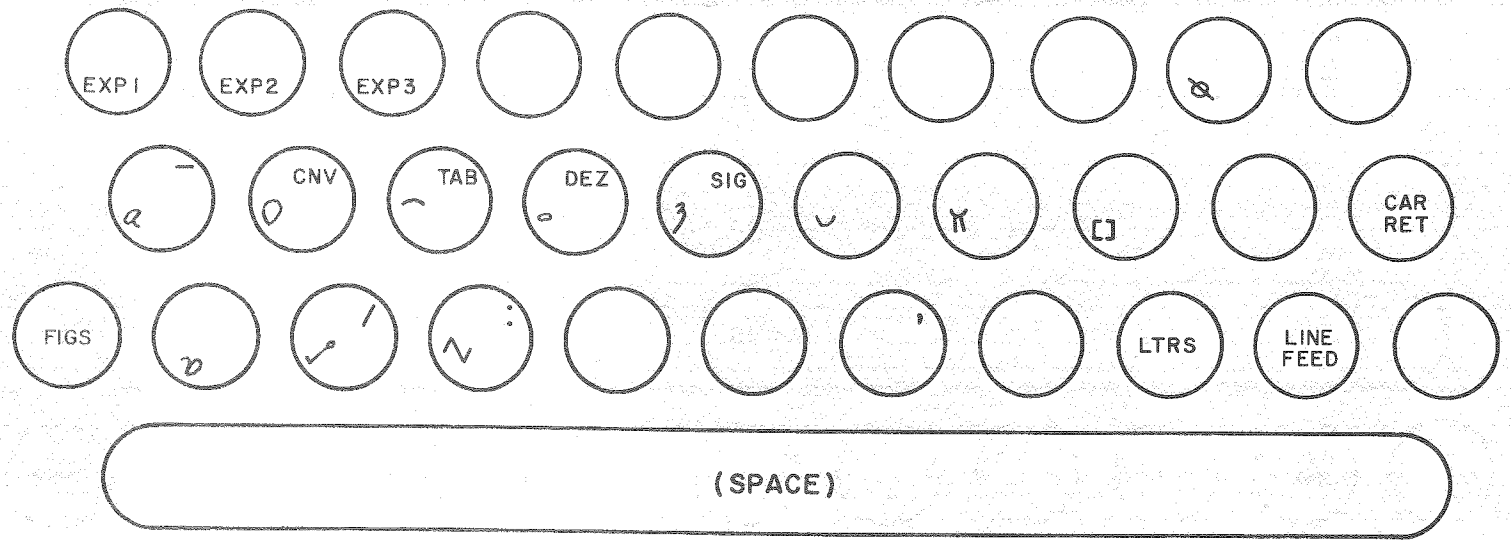


FOUR-ROW KEYBOARD IN SIG MODE

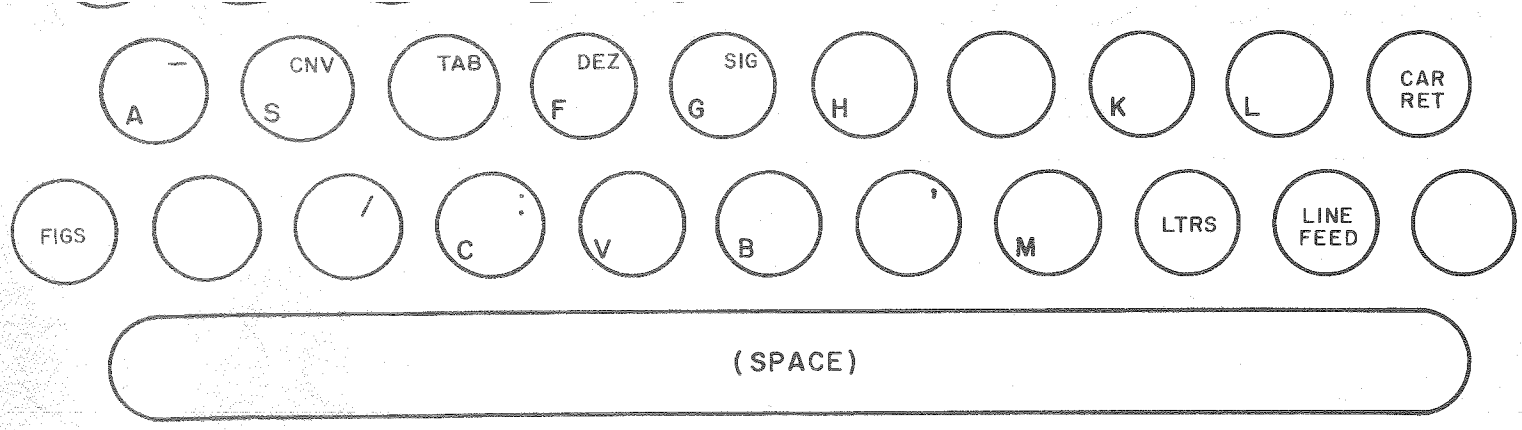
Figure 2



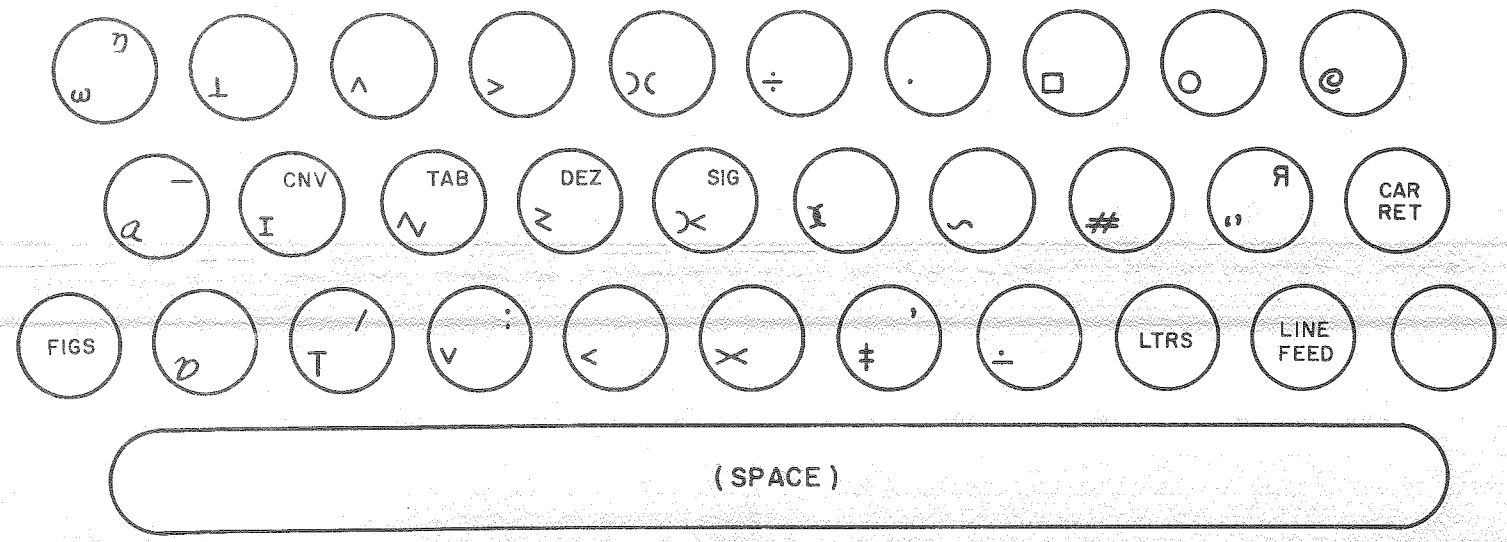
CONVENTIONAL THREE-ROW (5-LEVEL) TELETYPEWRITER KEYBOARD



THREE-ROW KEYBOARD IN TAB MODE



THREE-ROW KEYBOARD IN DEZ MODE



THREE-ROW KEYBOARD IN SIG MODE

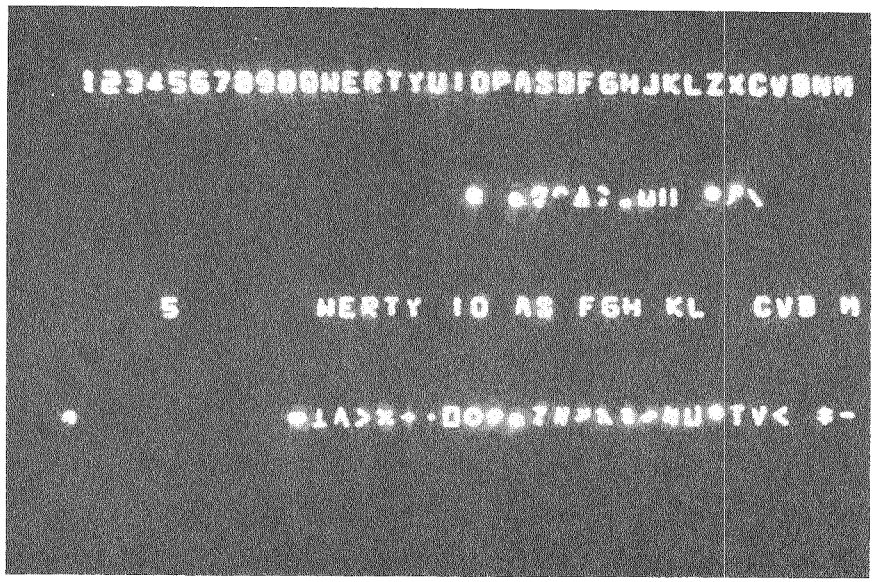


Figure 4 - Cheremic Symbols on CRT Screen

4. Equipment

The CDC-1700 computer installation at Bell Laboratories, shown in Figure 5, was utilized for this study. Appendix I shows detailed photographs of the actual computer installation.

The CDC-1700 is a 32K digital computer, designed primarily for real time process control. Peripheral equipment (Figure 6) includes a Model 35 teletypewriter (used for input of Sign Language, input of English and communicating with the computer system), an INKTRONIC® line printer (a high speed, nonimpact line printer), a combination card reader/punch, a CRT display unit, a magnetic tape drive (The Sign Language - English dictionary is stored on tape), and a random access mass storage device (during program execution the dictionary is transferred to disc for fast access).

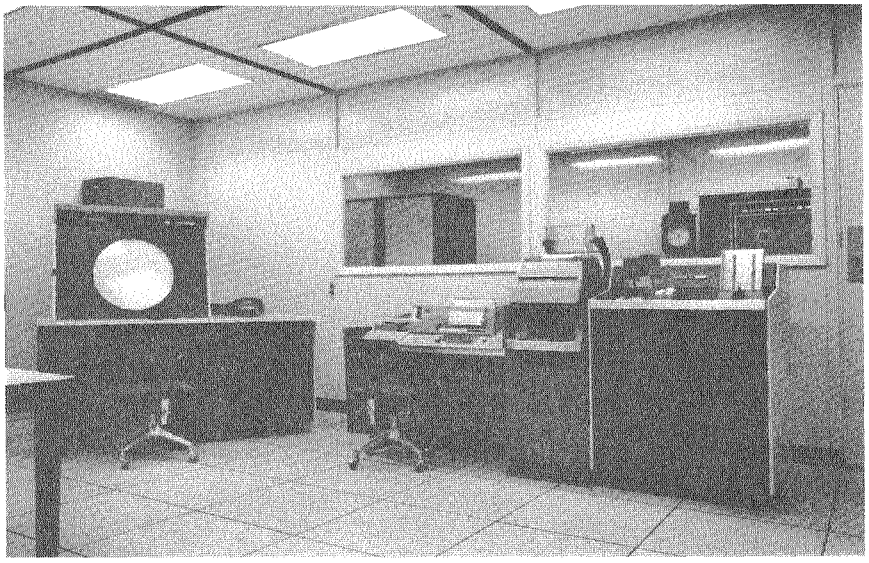
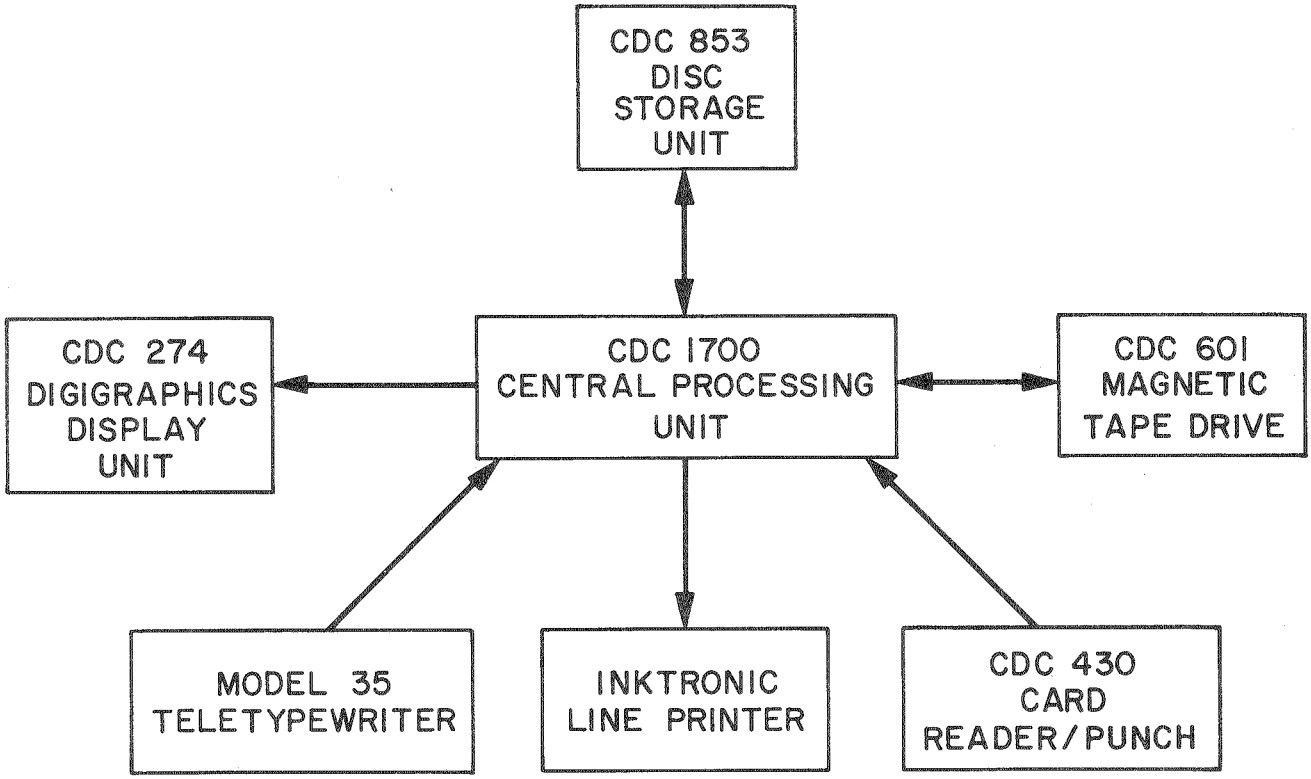


Figure 5 - CDC-1700 Computer Installation at Bell Laboratories



CDC-1700 COMPUTING SYSTEM

Figure 6

5. Dactylological Analysis Program

An overall flow diagram of the Dactylological Analysis Program (DACTY) is shown in Figure 7. In addition to the Sign Language - English translation note that several functions are provided for manipulating the dictionary and for displaying cheremic symbols directly on the CRT screen from the teletypewriter keyboard.

This rudimentary program simply scans the cheremic representation of each sign which is input for translation, locates the sign in a dictionary and inserts the proper English word(s); the situation is reversed when translating from English to Sign Language. An elementary grammar is "wired" into the program, in fact each English word appearing in the Dictionary is accompanied by a "part-of-speech" code; however at present this information is not utilized. When English statements are input for translation to Sign Language words which are not located in the dictionary are checked for endings (such as -ing, -est, etc.); if the word without ending appears in the dictionary the appropriate translation is made. In cases where a word cannot be translated (i.e., it does not appear in the dictionary with or without the various endings) it is translated as "finger spelling." This is analagous to the very common situation when talking in Sign Language of being forced to spell a word manually in English because no appropriate sign exists or because the English word conveys the desired meaning better than a sign.

In future versions of this program a "grammar book" should be used as opposed to the "wired" grammar now used; this would provide flexibility and greater scope in translation. Also, a dictionary of idioms, both for English and Sign Language would be required for any high level translation.*

---

* An ideal choice for this would appear to be A Dictionary of Idioms For The Deaf published by the National Association of the Deaf.

Figure 8 shows the linkage between subroutines within the DACTY program. We describe below the function of each of these routines. Appendix II gives detailed flow diagrams of each of these routines.

5.1 The Main Program, DACTY

This is a simple driver which performs some initialization, prints an introductory message describing the various functions now available within the Dactylological Analysis Program and transfers to the monitor control routine.

5.2 Subroutine MONCON

This is the heart of the Dactylological Analysis Program; it performs all of the basic functions which are germane to this paper. After reading in a command request from the teletypewriter, MONCON transfers within itself to perform the requested function.

5.2.1 Transfer TTY-CRT

This function simply transfers conventional and cheremic symbols from the teletypewriter to the CRT screen. It is accomplished simply by looped calls from the read routine to the write (CRT) routine and back to the read routine. Provisions are made within the read routine (INPUT4) to transfer to the start of MONCON (for another command) if the character "*" is input.

5.2.2 Read Dictionary

This function transfers the dictionary from magnetic tape to disc. The tape is rewound at the completion of the read. Control is transferred to the beginning of MONCON.

5.2.3 Write Dictionary

This function transfers the dictionary from the disc storage unit to magnetic tape, again the tape is rewound upon completion of the operation. Control is transferred to the start of MONCON.

5.2.4 Update Dictionary

The dictionary is updated (or initially started) with this function. The cheremic representation of a sign is input (terminating with a "/") followed by up to 10 words or groups of words which best define the sign. Each word or group of words is separated by a ",". The dictionary is then scanned to determine if the new sign has been previously defined. If so, the English words associated with that sign are removed and the new words input are entered into the dictionary. If the sign does not have an entry in the dictionary a new entry is made for both the signs and the words. Updating entries are successively input until INPUT4 transfers to the beginning of MONCON (i.e., an "*" is input).

5.2.5 Sign Language - English

This function translates a Sign Language statement into an equivalent English statement. The cheremic representations of the signs in the Sign Language statement are input via the teletypewriter. Each sign is isolated and the dictionary is scanned for a corresponding entry. If no entry is found (i.e., the sign has not been defined) the entire statement is not translated. If the sign is found, facial expressions are then checked to determine if the negation of the English translation is required, or if a "?" should terminate the translation.

Sign Language statements may be input successively, control being returned to MONCON by inputing "*".

5.2.6 English - Sign Language

This is by far the most difficult function. When an English statement is input, each word is isolated and the dictionary is checked for these words. Words which do not appear in the dictionary are then examined to determine if they end in -ing, -est, -es, etc., if so, the dictionary is then scanned for the occurrence of that word without the ending and

if found, the appropriate translation is made. When a word cannot be found in the dictionary it is "finger spelled," as mentioned earlier.

English statements may be input successively, control being returned to MONCON by inputing "*".

5.3 Subroutine INPUT4

This routine serves as the general input driver for the Dactylological Analysis Program. It keeps track of the mode in which the teletypewriter keyboard is in (in order to interpret the proper cheremic symbol) and transfers directly to the start of MONCON whenever an "*" is input.

5.4 Subroutine PRINT9

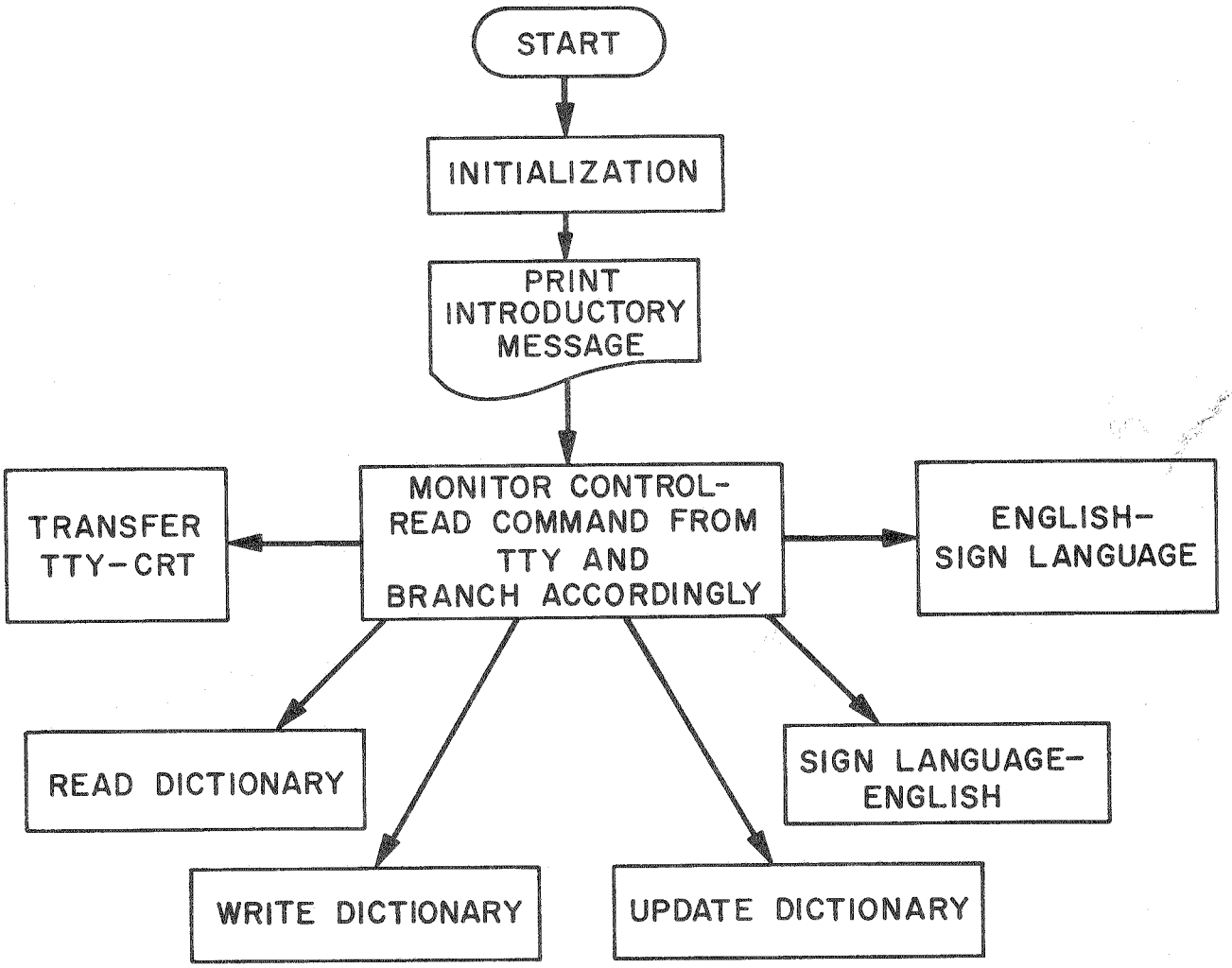
This routine displays the conventional and cheremic characters on the CRT screen for the Dactylological Analysis Program. It has provisions for continuously drawing vincula when it realizes that a facial expression is desired, and terminates the vincula when the end of a sign is reached (i.e., a "/" is encountered).

5.5 Subroutine SET9

This routine clears the CRT screen and draws a border for the simulated printed page which appears on the screen.

5.6 Subroutine SPECHR

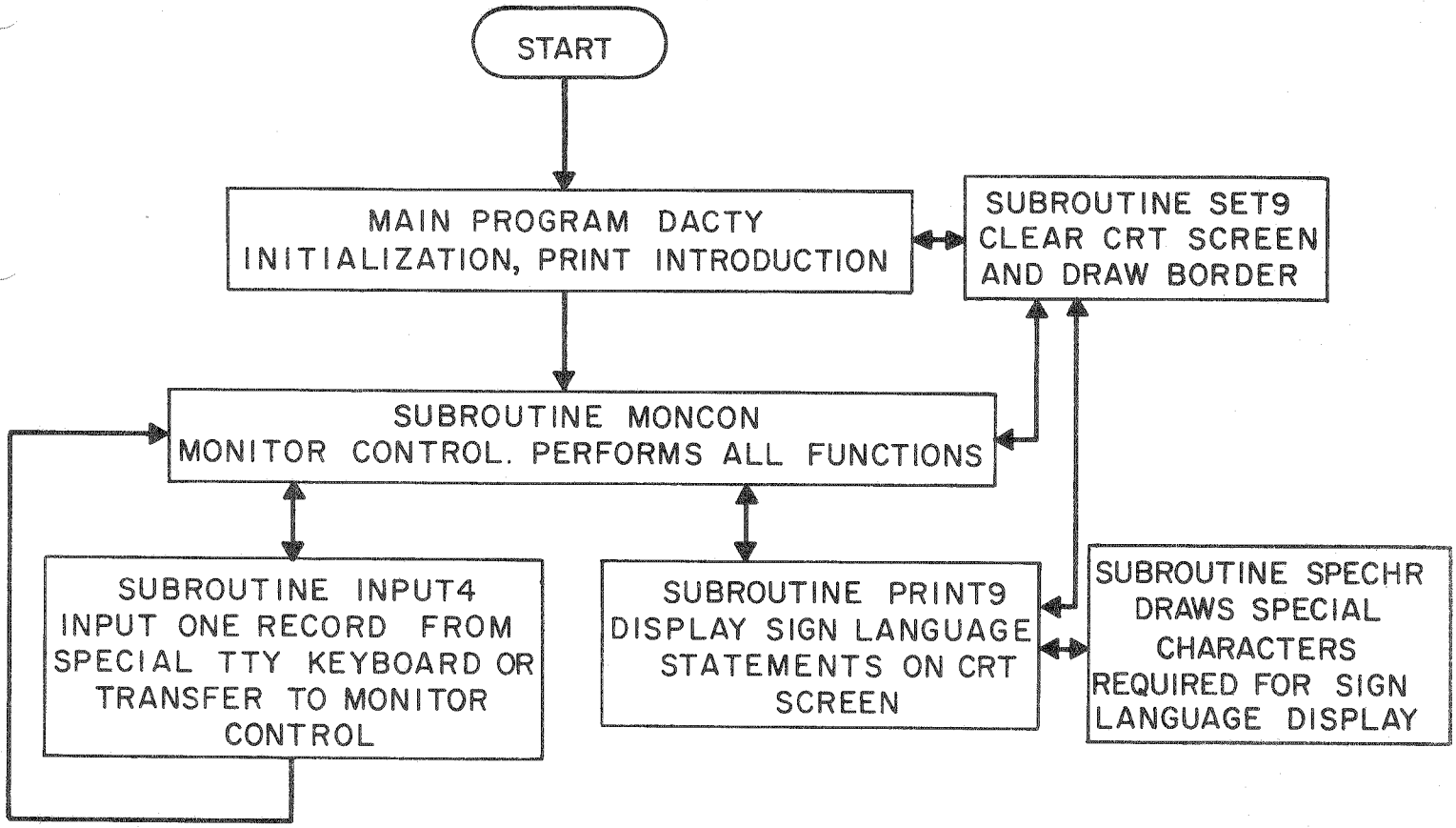
This is a long routine used to meticulously construct each of the special characters required for the cheremic symbols.



DACTYLOLOGICAL ANALYSIS PROGRAM

OVERALL FLOW DIAGRAM

Figure 7



DACTYLOLOGICAL ANALYSIS PROGRAM
SUBROUTINE FUNCTION AND LINKAGE

Figure 8

6. Example

We consider a simple example to demonstrate the translation capabilities of the program. In Figure 9 we give some signs from (4) which we use in this example. Consider the English statement:

> Now is the time for all good men to come to the aid of their country.

the germane signs are

NOW 

IS 

TIME 

FOR 

ALL 

GOOD 

MEN 

COME 

AID 

COUNTRY 

Our first encounter with DACTY is the introductory message:

```
                        DACTYLOLOGICAL ANALYSIS PROGRAM
WHEN UNDER MONITOR CONTROL SPECIFY ONE OF THE FOLLOWING COMMANDS-
     TRANSFER TTY-CRT
     READ DICTIONARY
     WRITE DICTIONARY
     UPDATE DICTIONARY
     SIGN LANGUAGE - ENGLISH
     ENGLISH - SIGN LANGUAGE
     HALT
TYPE (*) TO RETURN TO MONITOR CONTROL.

UNDER MONITOR CONTROL.  SPECIFY COMMAND-
```

6.1 Dictionary Update

We type in the command "UPDATE DICTIONARY" and start to input the various signs

```
> UPDATE DICTIONARY
> O,M-EM-E,C/O NOW
> G,G-E,TW/O IS
```

and so on, for the above signs. Note, however, that the first meaning of the sign for "men" is "man" and likewise the first meaning of the sign for "aid" is "help."

The dictionary on the mass storage device has been updated, however the magnetic tape remains unchanged. We now update this tape, and check this update by reading the dictionary in again:

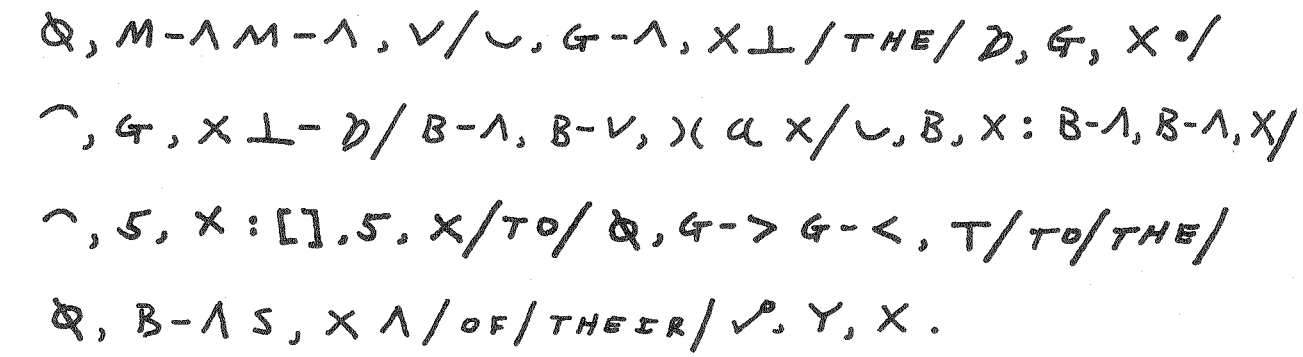
```
> *

UNDER MONITOR CONTROL.  SPECIFY COMMAND-
> WRITE DICTIONARY

UNDER MONITOR CONTROL.  SPECIFY COMMAND-
> READ DICTIONARY
```

6.2 English to Sign Language Translation

We type in the appropriate command followed by our sample statement:

```
UNDER MONITOR CONTROL.  SPECIFY COMMAND-
> ENGLISH TO SIGNLANGUAGE
> NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THEIR COUNTRY.
```

Displayed on the CRT screen is the Sign Language translation:



6.3 Sign Language to English Translation

Again we type in the appropriate command followed by the cheremic representation of the Sign Language statement for this example. As is the case when communicating in Sign Language, we do not "finger spell" articles ("the," in this case) nor do we include the word "to" in the infinitive form. Hence our translation is

Now is time for all good man come help their country.

Since the signs indicating "men" and "aid" have first meanings "man" and "help," respectively, these meanings are utilized in the translation. The program does not know that in this context the words "men" and "aid" should be used; however, the meaning of the statement remains unchanged.

This time let us input the same cheremic representation of our Sign Language statement, but adopt a negative facial expression while signing "time." The translation becomes

Now is not time for all good man come help their country.

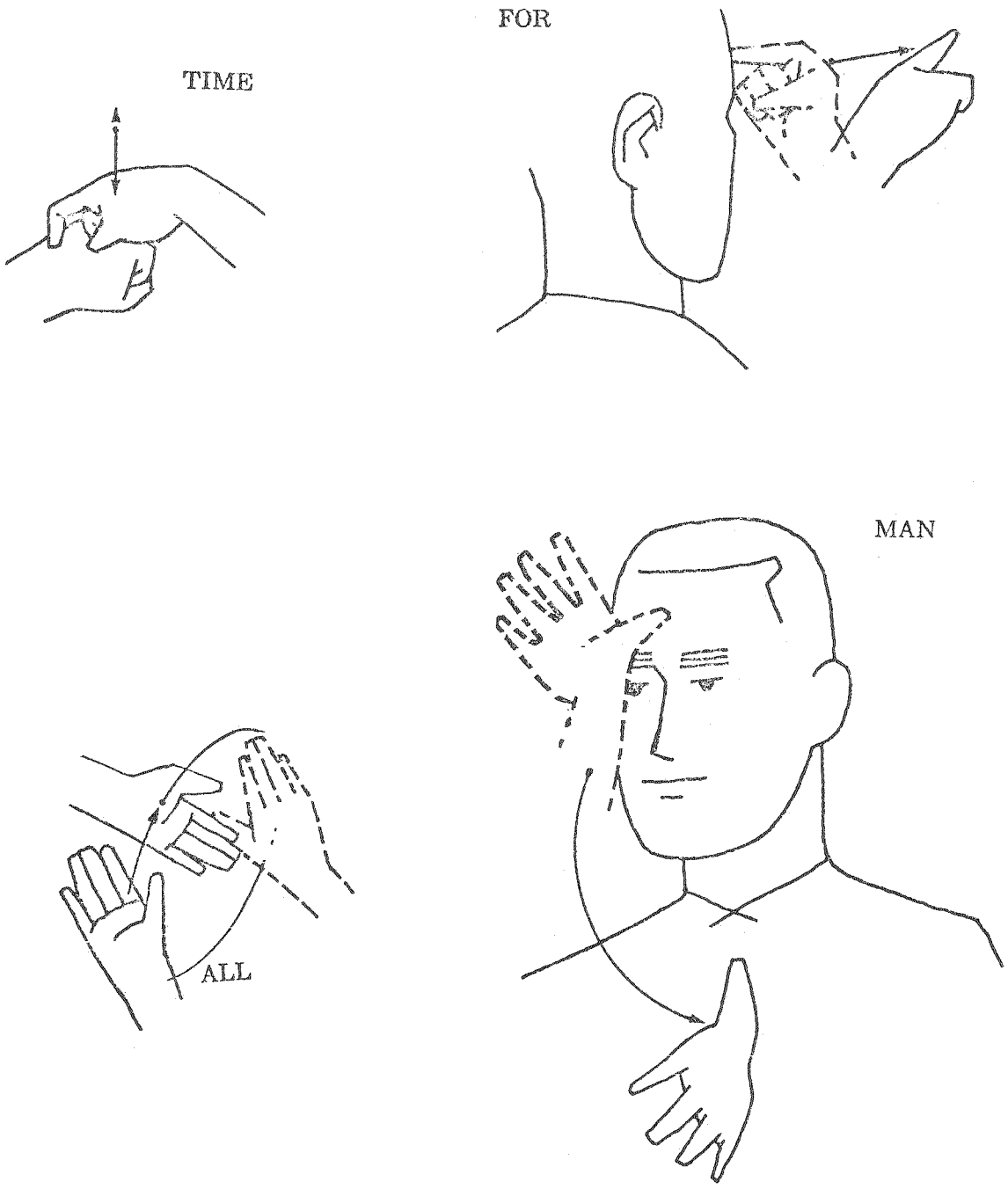


Figure 9 - Some Signs Used in the Example

7. Conclusions and Recommendations

We have demonstrated the feasibility of utilizing computer techniques for the analysis of Sign Language and have written a rudimentary program which translates Sign Language to English and vice versa; this has never been done before.

In addition to an improved set of cheremes and the inclusion of a "grammar book" and dictionary of idioms it appears quite feasible to improve Sign Language display on the CRT screen, possibly utilizing some form of "stick figures."

REFERENCES

1. The Deaf American, February 1970.

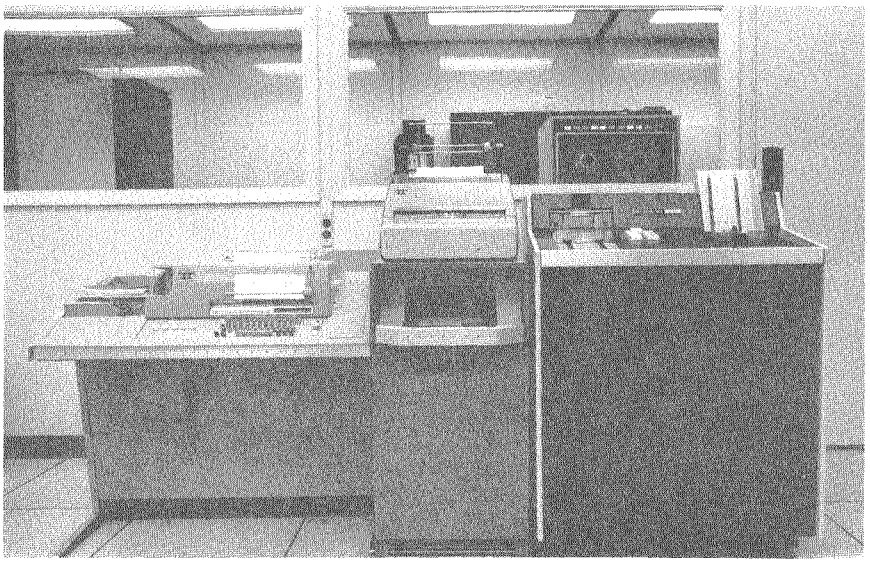
2. Fant, Louie J., Jr., Say It With Hands, Gallaudet College, 1964.

3. Stokoe, William C., Jr., Sign Language Structure: An Outline of the Visual Communication Systems of the American Deaf, University of Buffalo, 1960.

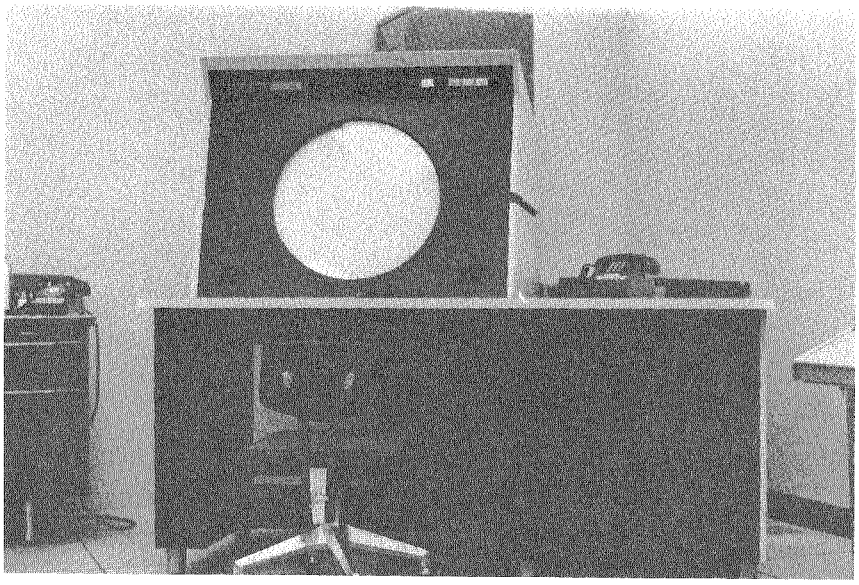
4. TIME Magazine, "The Body - Man's Silent Signals," June 13, 1969.

APPENDIX I

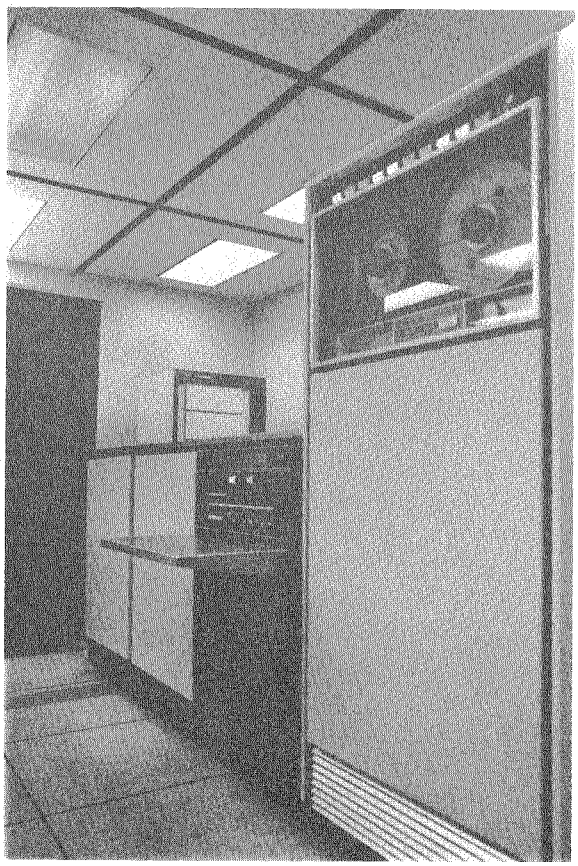
Detailed Photographs of CDC-1700 Computer Installation Used For This Study



Model 35 Teletypewriter (l.), INKTRONIC Line Printer (c.)
CDC-430 Card Reader/Punch (r.)



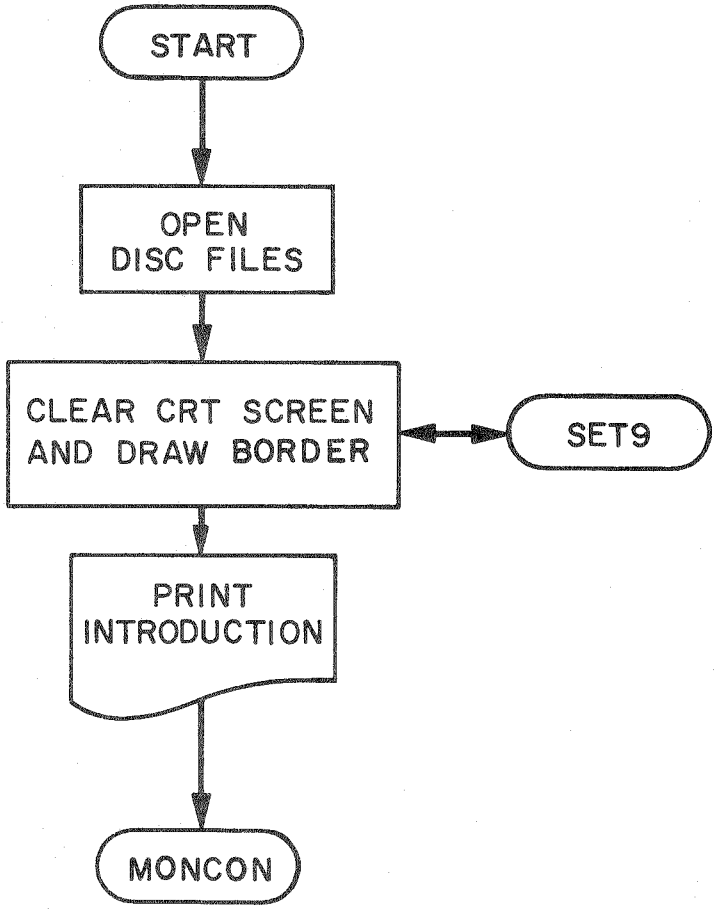
CDC-274 Digigraphics Display Unit



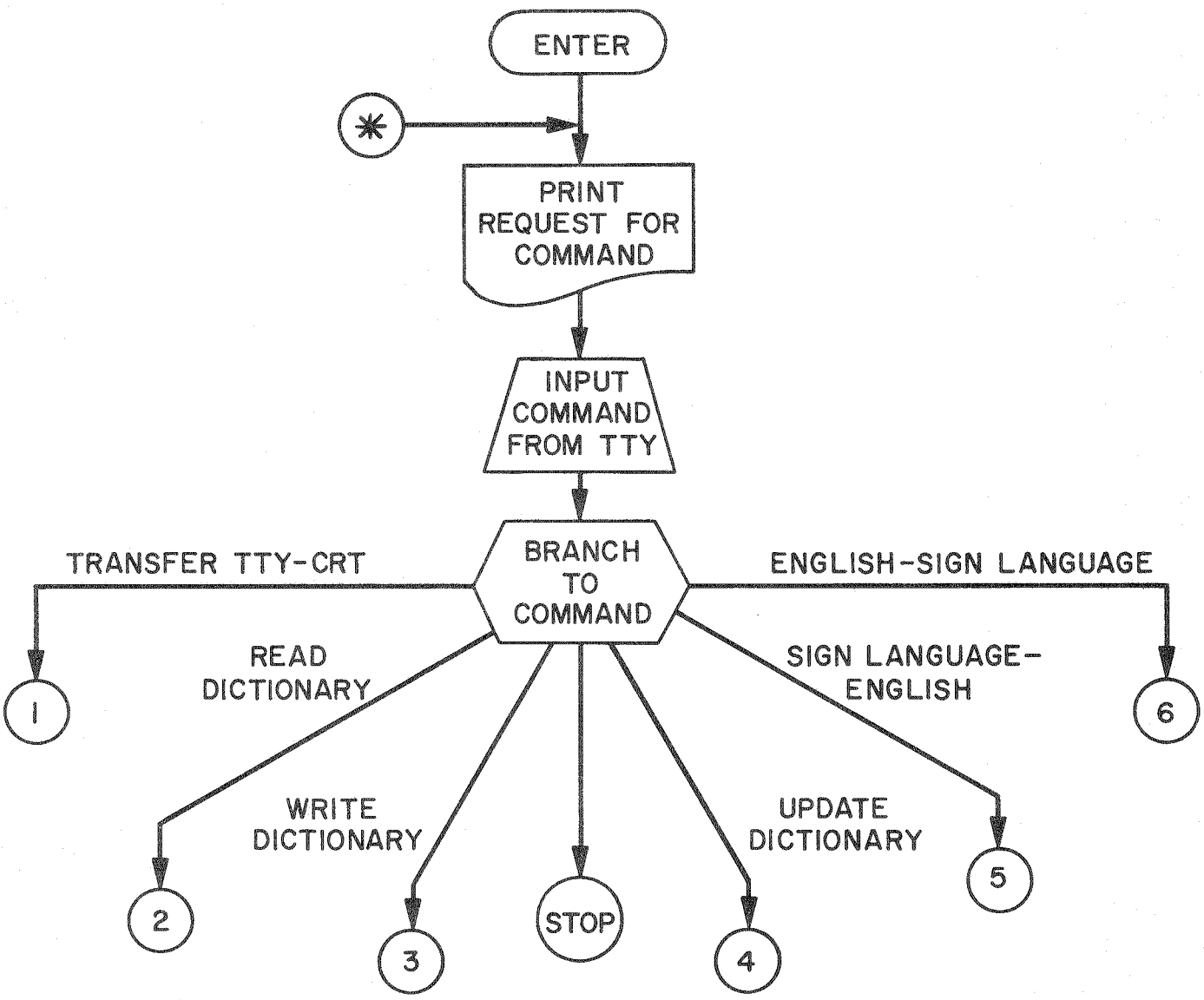
CDC-1700 Central Processing Unit (l.) and CDC-601 Magnetic Tape Drive(r.)

CDC-853 Disc Storage Unit

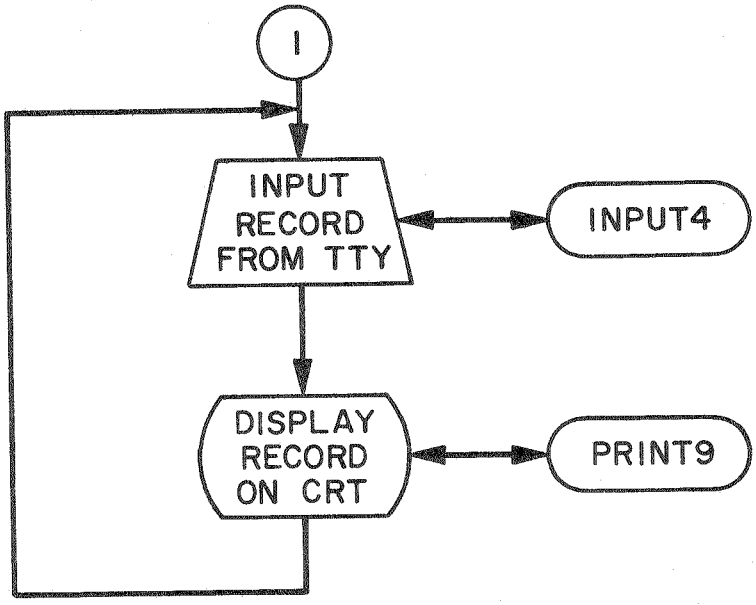
APPENDIX II - Flow Diagrams for Dactylological Analysis Program



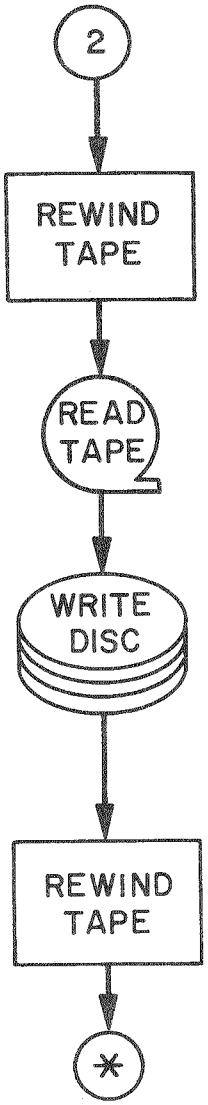
MAIN PROGRAM, DACTY



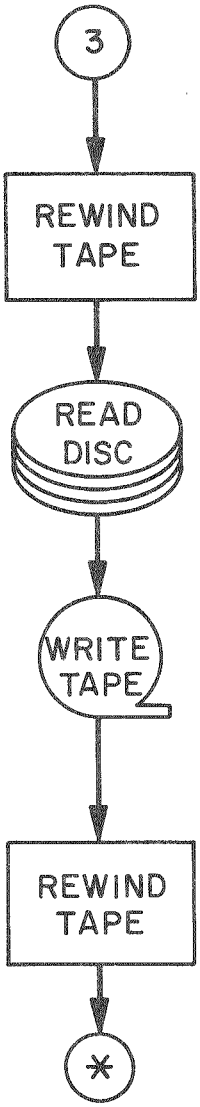
SUBROUTINE MONCON



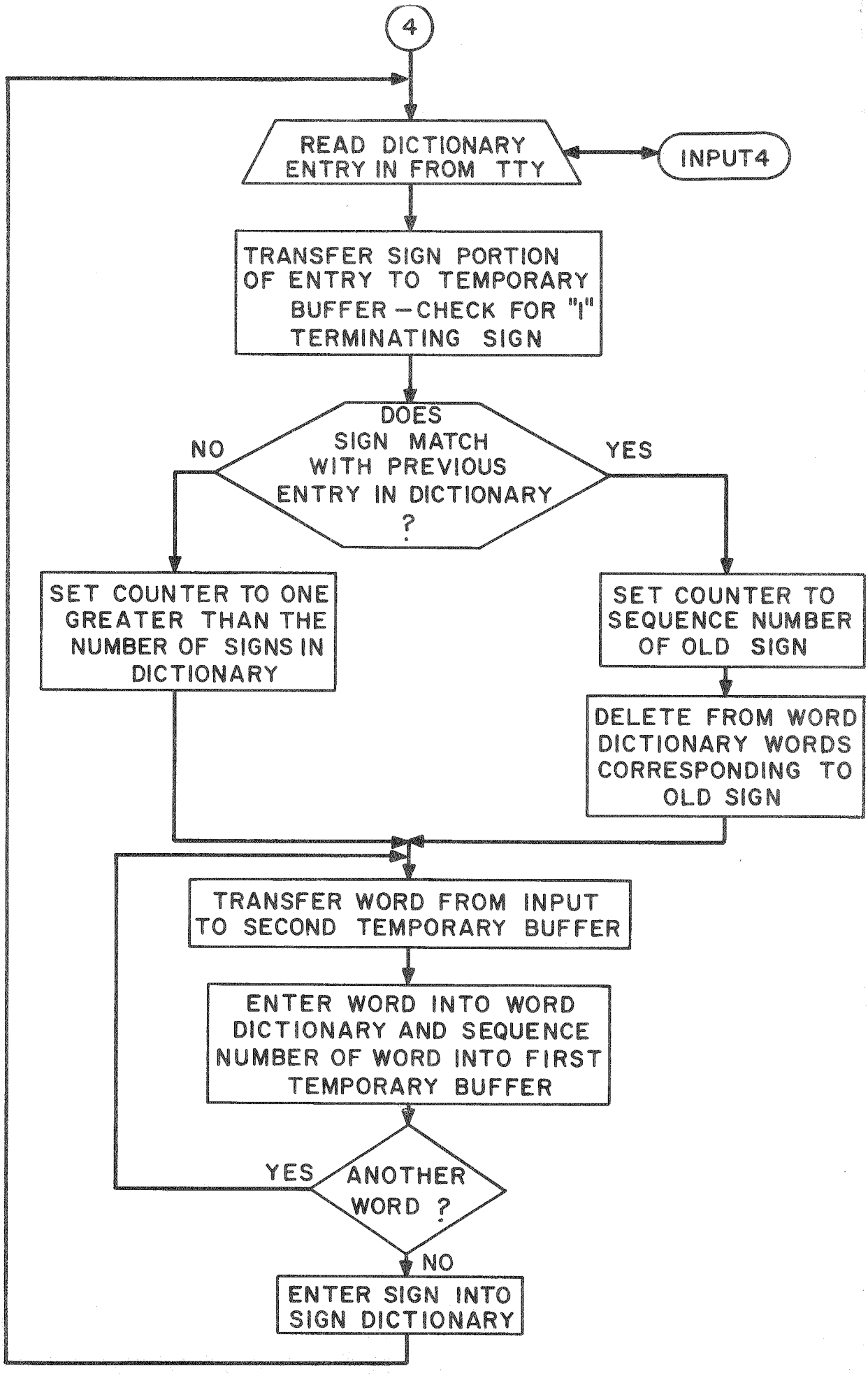
SUBROUTINE MONCON (CONTINUED)



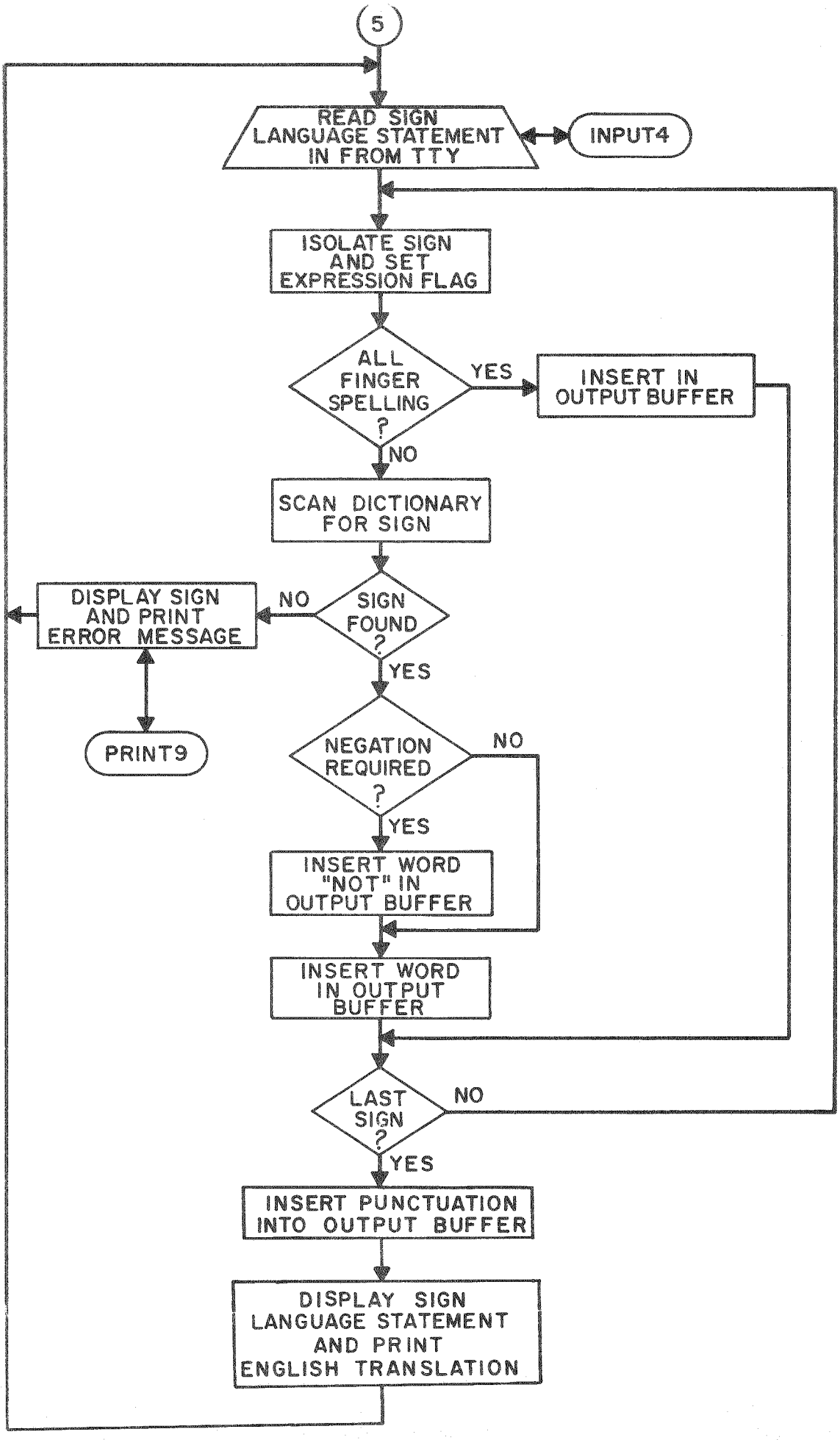
SUBROUTINE MONCON (CONTINUED)



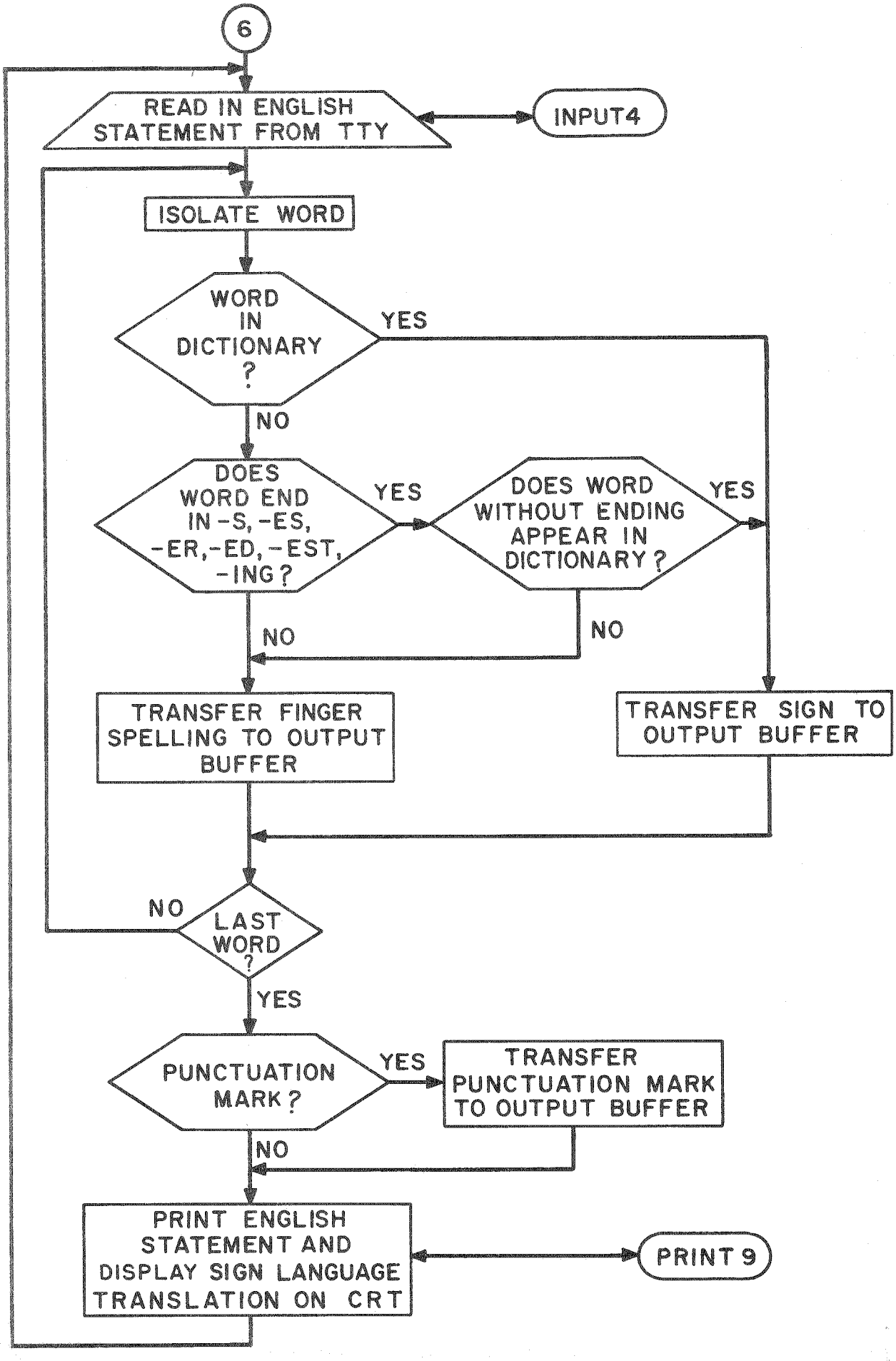
SUBROUTINE MONCON (CONTINUED)



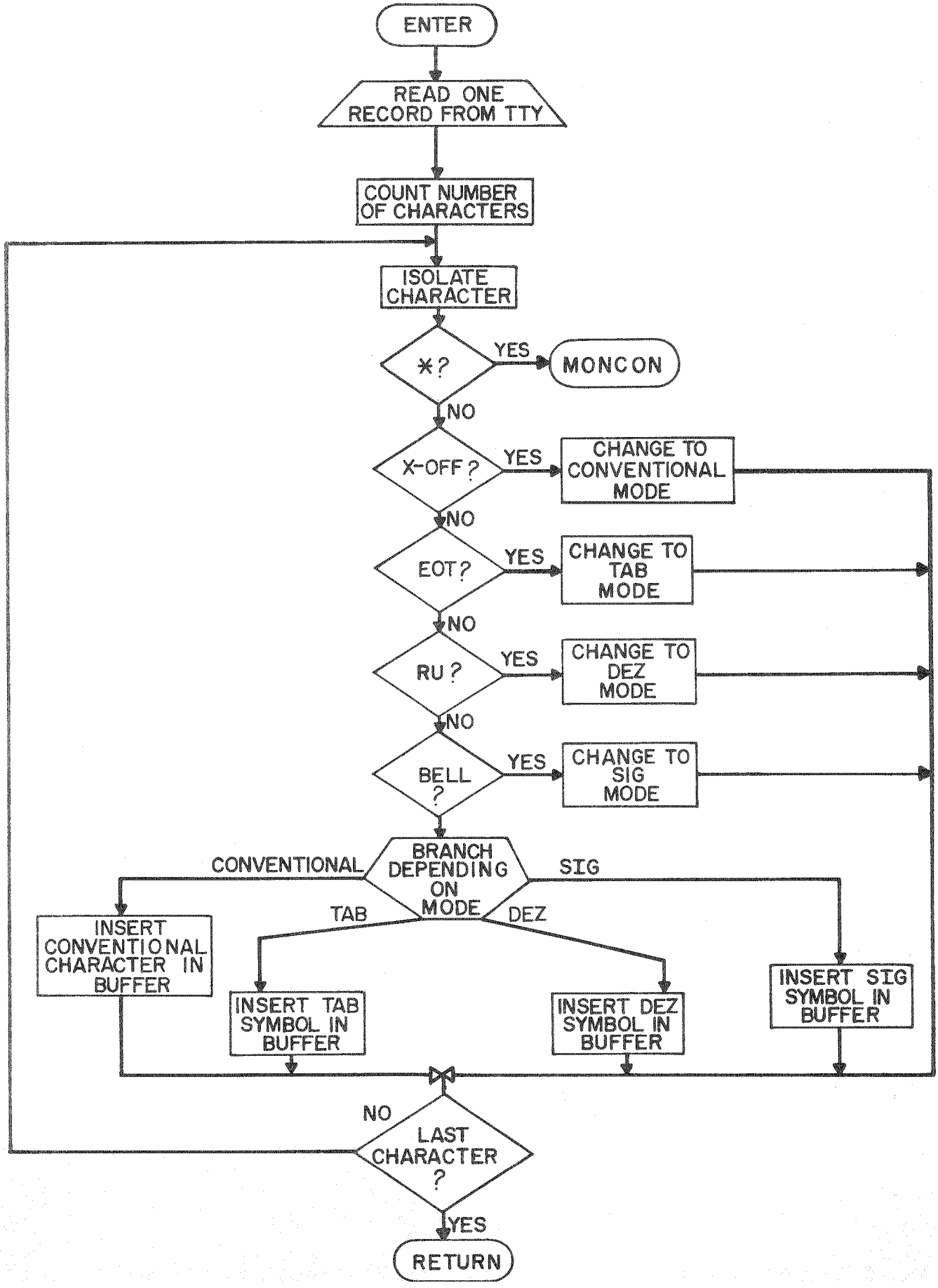
SUBROUTINE MONCON (CONTINUED)

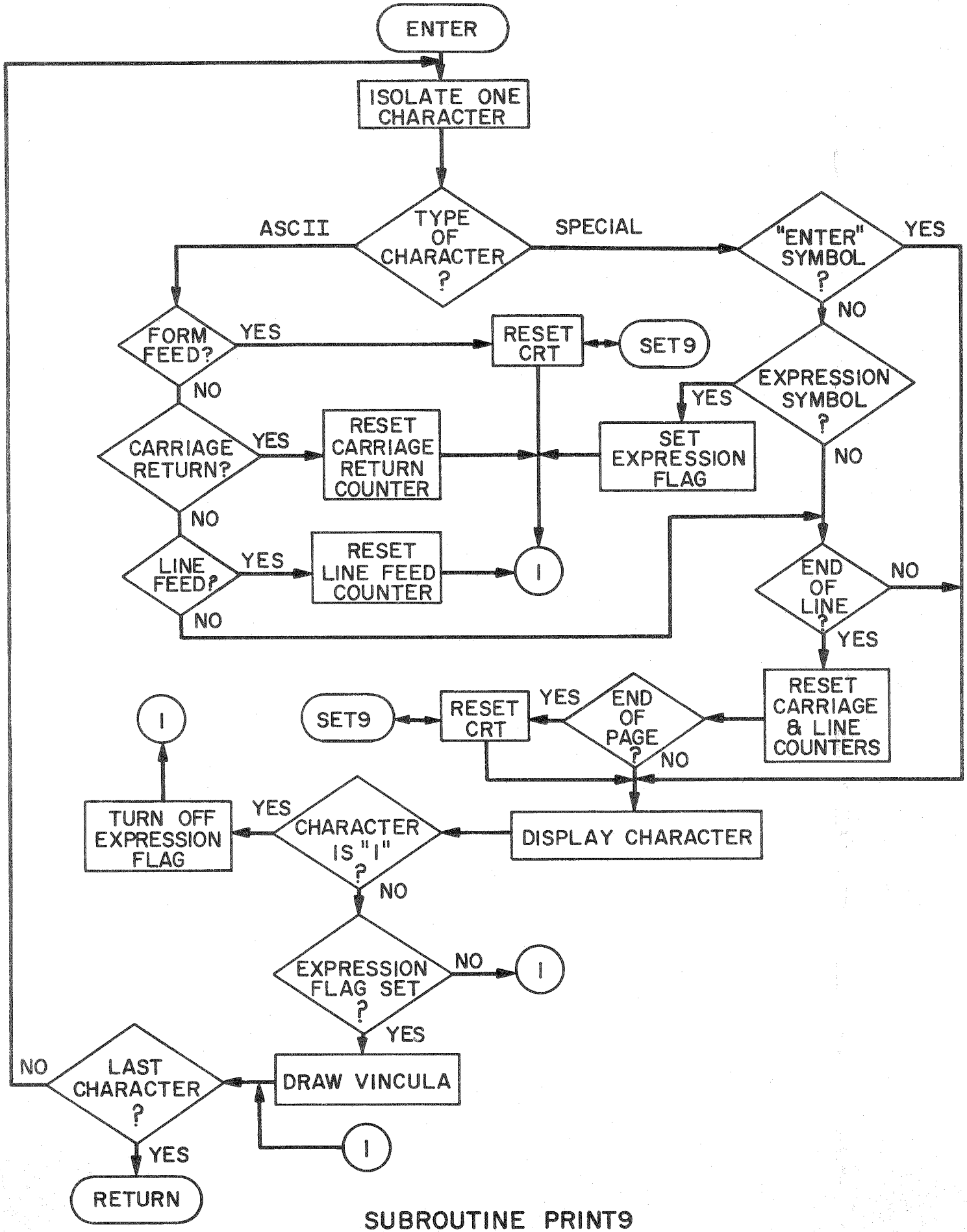


SUBROUTINE MONCON (CONTINUED)

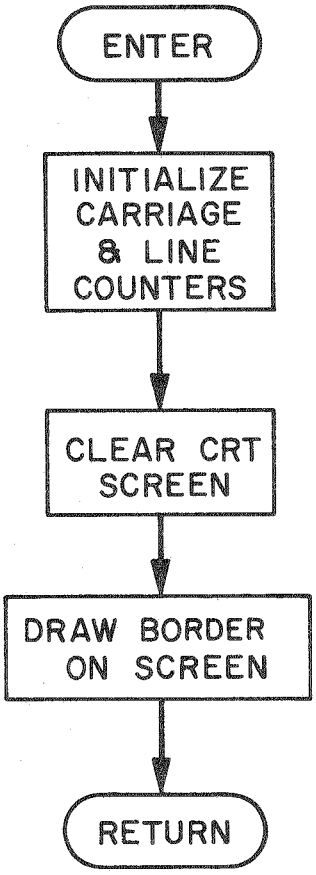


SUBROUTINE MONCON (CONTINUED)

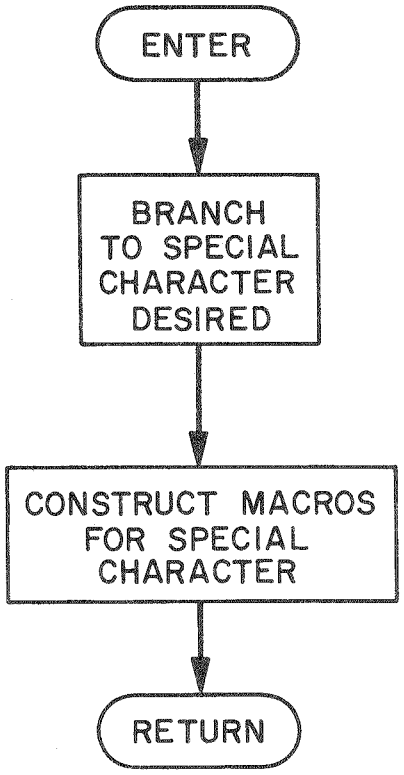

ENTER
READ ONE RECORD FROM TTY
COUNT NUMBER OF CHARACTERS
ISOLATE CHARACTER
*?
YES
MONCON
NO
X-OFF?
YES
CHANGE TO CONVENTIONAL MODE
NO
EOT?
YES
CHANGE TO TAB MODE
NO
RU?
YES
CHANGE TO DEZ MODE
NO
BELL?
YES
CHANGE TO SIG MODE
BRANCH DEPENDING ON MODE
CONVENTIONAL
TAB
DEZ
SIG
INSERT CONVENTIONAL CHARACTER IN BUFFER
INSERT TAB SYMBOL IN BUFFER
INSERT DEZ SYMBOL IN BUFFER
INSERT SIG SYMBOL IN BUFFER
NO
LAST CHARACTER?
YES
RETURN



SUBROUTINE PRINT9



SUBROUTINE SET9



SUBROUTINE SPECHR