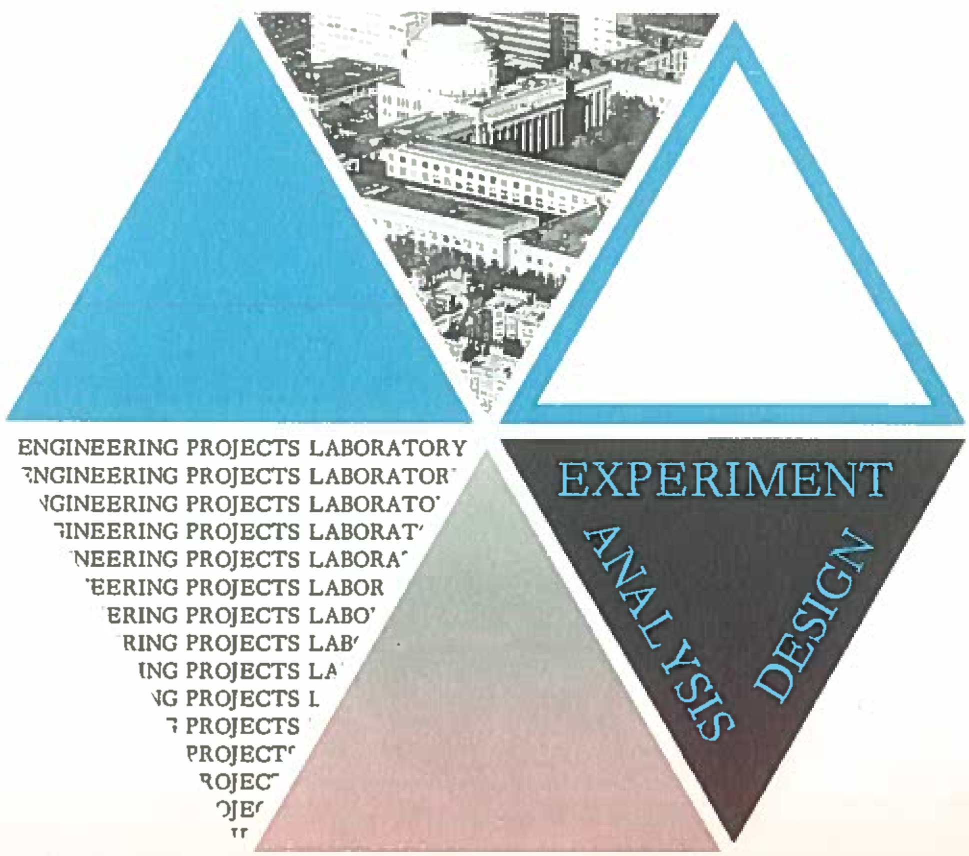
BRAILLE TRANSLATION BY COMPUTER

ROBERT C. GAMMILL

October 1963

Report No. 9211-1
Department of Mechanical Engineering
Massachusetts Institute of Technology

Contract No. SAV-1011-62



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Department of Health, Education and Welfare
Vocational Rehabilitation Administration
Washington 25, D.C.

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FOREWORD

The Sensory Research Discussions originated and chaired bi-weekly at M.I.T. in the Fall of 1959 by John K. Dupress, at that time Director of Technological Research of the American Foundation for the Blind, influenced several faculty in the Mechanical Engineering Department at M.I.T. to interest themselves and their students in research and development problems associated with human deprivation. Initial investigation were unsupported, conducted entirely within the context of undergraduate laboratory and design projects and thesis work. Subsequently a small grant from the American Foundation for the Blind made possible the fabrication of, and experiments with several research devices. By January 1961 the activity blossomed under the formal support of the Office of Vocational Rehabilitation (now the Vocational Rehabilitation Administration) of the Department of Health, Education and Welfare under contracts SAV-1004-61 and SAV-1011-62, which partially supports the principal investigators, Professors Dwight M. Baumann, Robert W. Mann, and Thomas B. Sheridan, a number of graduate student research assistants in the Engineering Projects Laboratory (EPL), as well as underwriting the work of non-salaried, full-time students engaged in related design and laboratory projects and theses. This report is one of two summarizing the second year's program under VRA-DHEW support through contract SAV-1011-62.

With the exception of the work described in this report, EPL 9211-1, all projects referred to in EPL Report No. 9211-2, the Evaluation Report on Work in Progress during the period June 1962 to May 1963 have already been or will be reported in detail in the form of undergraduate or graduate theses. The original of each of these theses is in the public domain in the M.I.T. Library and is available for reference and for photocopy. The Engineering Projects Laboratory retains a reproducible master of all theses from which ozalid copies can be prepared upon request to the Librarian, EPL Document Room, 3-156, M.I.T.

The material in this report was prepared by Mr. Robert C. Gammill, a full-time graduate student in the Department of Meteorology as a term project in conjunction with two graduate courses, Mathematical Theory of Computation in Symbol Manipulation taught by Dr. James C. Slagle and Language, Symbolic Processes, and Computers taught by Dr. Victor H. Yngve.

A bibliography appended to this report identifies reports, theses, projects, and design and laboratory projects conducted under the EPL-M.I.T. Sensory Aids and Prosthetics Research and Development Projects.

ABSTRACT

This report describes work which has been done in the field of Braille translation by computer. Three programs are discussed, two of them written by the author. These are:

1. A program for the 7090 using a photoelectric tape reader to convert Wall Street Journal teletypesetter tape to IBM cards in a standardized format.

2. A program for the 7090 (using COMIT) to convert the IBM card information to Braille.

3. A program written originally for the 704 by a Mrs. Schack[1+] of IBM, (now converted by the author for use on the 7090) which is the best operational translator of grade 2.0 Braille available at the present time.

The report is intended to serve as a manual for future research in Braille translation at M.I.T. and elsewhere. It assumes that the reader has a fair amount of knowledge of computers, programming, and Braille. It contains a comprehensive bibliography of materials available at M.I.T. which can provide this background. It is hoped that this report will substantially reduce the leg-work necessary for future research in this field.

Printed outputs, program listings and card decks of the programs which cannot be included in the report are available through Mr. John K. Dupress at M.I.T.

+ References are Listed in the Bibliography on page 25.

TABLE OF CONTENTS

1. HISTORY OF TACTILE READING AND BRAILLE TRANSLATION

1.1. Early Disagreements and Standardization.

The history of tactile reading by the blind, through raised or incised figures, dates back several thousand years.[2] It is only since the invention of the printing press that large scale production of tactile reading material and standardization of coding systems have occurred. In the United States seven different systems have been used, but in the early 1900's a standardization movement was begun, which resulted in English Braille. This end was achieved only with considerable effort, and not without personal conflicts.[2,3]

Although it provides interesting reading matter, the history of Braille is important to us for one reason: it provides us with an understanding of the reasons why Braille authorities are reluctant to allow anything but the most minor changes to the system. Thus, changes such as those proposed by Mr. Gerald Staack of M.I.T.[4] allowing for ease of machine production of Braille, meet with considerable resistance. It is hoped that this paper will help to clarify some of the problems of automatic translation to Braille.

1.2. Standard English Braille.

Standard English Braille is based on a "cell" of six embossed dots, positioned and numbered for reference, as shown. The 63 possible com-

1 o	o 4
2 o	o 5
3 o	o 6

binations of these six dots are used to represent letters, numbers, punctuation marks, common groups of letters, whole words, and signs.[5,6,7,8]

Braille is classified by grades. The two most important are:

a. Grade 1.0 is uncontracted. Except for occasional signs, there is a one-to-one correspondence between Braille and inkprint characters.

b. Grade 2.0 has a total of 185 contractions which are employed under a strict set of rules.

Other grades of Braille are classified as to their degree of contraction. Grade 3.0 is very highly contracted and difficult to learn. Grade 1.5 is between Grade 1.0 and 2.0. Literary English Braille is usually Grade 2.0.

The complexity of Grade 2.0 Braille can be fully appreciated only by reading the manual.[5] However, in summary: The most difficult rules to automate in a computer are those which concern the non-use of a contraction due to pronunciation or syllabrication of the word. The result is that programs written for the purpose of producing pure Grade 2.0 transcriptions must contain large empirically compiled lists of words, which are exceptions to the general rules. All programs without such a list, or its equivalent, must produce something other than pristine Grade 2.0 Braille.

1.3. Dilemma Posed by Machine Methods.

The horns of the dilemma are now apparent.

a. It is highly desirable to make no changes in the Braille system, so that the reader will have nothing new to learn.

b. Grade 2.0 in its pure form cannot be produced without fairly sizable computers and considerable human intervention, especially at first, when libraries of exceptions must be compiled by careful proofreading.

The dilemma has produced two results:

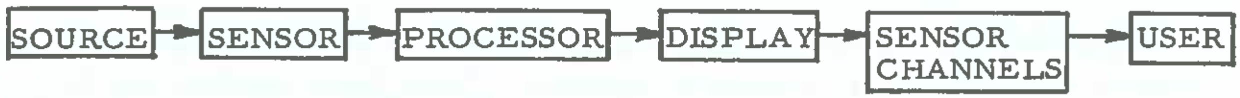
a. The development of Grade 2.0 translator by Mrs. Schack of IBM and initial testing and compilation of a library of exceptions.

b. The study of Grade 2.0 Braille by Mr. Staack of M.I.T. to see what changes would make it easily translatable without causing difficulty for the reader.

If Mrs. Schack's library of exceptions is ever considered large enough and all further "minor errors" accepted as correct Grade 2.0 translation, then the study of changes to Braille will become unnecessary. If, however, the library must be allowed to grow unwieldy, then serious consideration must be given to changes in the Braille system to enable economical production of material.

1.4. Flow of Information in Braille Production.

The flow diagram below gives a general description of all Braille translation systems.[9]



SOURCE of information

a. human mind
b. printed material
c. punched cards
d. teletypesetter tape
e. monotype tape

SENSOR

a. typewriter keyboard
b. braille writer keyboard (Maskrey)
c. character recognition scanner
d. card reader
e. paper tape reader

PROCESSOR

a. human mind
b. computer (Schack and Nemeth)
c. mechanical-electrical (Dirkman and Eglinton)
d. switching circuitry (Milne and Friedrich)

DISPLAY

a. brailler (Baumann, Kennedy and others)
b. stereotyper
c. braille reader (Wheeler, Troxel, Blanco, Bellows and others)

SENSOR CHANNELS - tactile

USER

1.5. Discussion of Approaches to Automatic Processing.

The preceding flow diagram demonstrates that many alternative schemes can be presented for production of Braille material. The simple and economical schemes all involve considerable information processing by a human being. It is our desire to eliminate the human being, and provide an economical, automatic system. Three basic approaches to the problem have become apparent:

1. Digital computer programming: expensive, but offers flexibility and possibility of a complete solution.
2. Switching circuitry: less expensive--essentially a special purpose computer.
3. Mechanical-electrical: most economical, but incapable of producing Grade 2 translation.

The area of interest covered by this report is that of computer programming. Only two computer translation schemes have been attempted to date--those developed by Mrs. Ann Schack of IBM for the IBM 704 and Abraham Nemeth of Michigan University for the IBM 650. Mr. Nemeth's work is being done as a doctoral research and is not yet completed. For the most complete description of his work available, see Ref. 10).

In translation by switching circuitry, work has been done by Friedrich of Brooklyn Tech.[11] Wheeler of IBM (diode matrix), and Milne of Stanford (Beta, Braille Electronic Translator Automatic).

In mechanical-electronic systems, work has been done by Dirkman, M.I.T.[12] and Eglinton, M.I.T. [3]

Although computer translators are expensive, they offer relatively simple testing of models of Braille translation systems and the advantage of flexibility. If a good system can be developed and economized, ultimately it may be possible either to build a special purpose electronic and mechanical system or to use the most economical computer possible. In either case, computer translators are considerably easier to develop and test and do not result in useless hardware. Thus, they have definite advantages for initial development.

As previously stated, only two attempts have been made to produce Grade 2.0 computer translators. Mr. Nemeth's work has not produced any visible results at present. Mrs. Schack's program has been completed except for continued additions of exceptions to the library. The main disadvantage to Mrs. Schack's program is that it may still require human intervention after much use.

In addition, the program is sufficiently large and complex that there is little possibility of building a special purpose device or using a very small computer. Thus, there is considerable reason to look for simplifications to the Grade 2.0 Braille system, especially in areas where exceptions must be made to otherwise hard and fast rules.[4]

2. INTRODUCTION TO WORK BY THE AUTHOR

The first impetus for the author to begin work in the field of Braille was an announcement by Dr. James C. Slagle that a program was needed to convert teletypesetter tape (for the Wall Street Journal, World-Wide column) into the input format specified by Mrs. Schack for her IBM 704 Grade 2.0 Braille translator. It was intended that the output from this translation would be put through a Braille press at American Printing House for the Blind and used in a feasibility study of a daily newsletter.[14] Another use visualized was as an input to the electric brailler embosser[15,16,17] being built in the Mechanical Engineering Department M.I.T. (under supervision of Prof. D.M. Baumann), or as input to punched tape-to-Braille readers under development by Prof. E. E. Blanco and Mr. A. Bellows, M.E. Dept., M.I.T.

An FAP program using the photoelectric tape reader on the 7090 was written, and initial tests were run. Fairly rapid success with this program resulted in availability of input data before the arrival of the translation program from IBM. For this reason a project for translation to Braille (Grade 1.0+) was undertaken in connection with the author's class in Languages and Symbolic Processes to see how difficult such a translation would prove when programmed in COMIT (a symbol manipulation language.) The other computer translators have been programmed in machine language.

It was found that COMIT provided a flexible means of programming, except in producing binary codes for output, but would be too time consuming for production work. However, for development and testing its programming ease made it ideal.

The COMIT translator was written and tested on the input cards produced for the IBM translator. Because of the difficulty in its production, binary output was left in the form of mnemonics, and printed out in lines conforming to Braille format.

Upon the arrival of Mrs. Schack's program (for the 704) from IBM, the deck was converted from absolute 704 to relocatable 7090 form. All patches made since the final assembly at IBM were put into the symbolic deck, and other minor changes for ease of usage under the 709-7090 systems were made.

After completing these programs, the author discovered a thesis by Gerald Staack [4] on revisions of Grade 2 Braille to make it easily machine-translatable. Mr. Staack proposed a set of rules which would not allow exceptions, and would develop a translator which, theoretically, would not need correction. Because of the flexibility of the COMIT translator, the author feels that it would be ideal for the testing of Mr. Staack's proposed system.

In the future it is hoped that it will be possible to produce a parallel study of the newsletter idea using both Mrs. Schack's translator and a COMIT translator for modified Grade 2. It would then be possible to see the reactions of the blind to Mr. Staack's proposals when they are presented in hard copy form.

3. THE TELETYPESETTER TAPES

The teletypesetter tapes provided by the Wall Street Journal from their World Wide column included some typographical errors, contrary to beliefs expressed in the minutes of recent conferences.[10] The tapes were procured through the aid of Professor Robert W. Mann of the Mechanical Engineering Department and Mr. Brumley of the Boston office of the Wall Street Journal. Each tape included one or two news items. Each began with one line of identification and instruction to the editors at the receiving plant, and terminated with information about material to be inserted for item separation, such as "STARS," "DASH", etc.

The teletypesetter tape is of the same width as common, seven-track tape (as used on the TX-O computer, flexowriters, etc.), but only six tracks are punched. The sprocket holes are in the exact center of the tape, with the result that most commercially available seven or eight track paper tape readers will not accept this tape. Possible solutions to this problem are:

1. Find a reader which will accept this tape and (a) build it into a system, or (b) use it to produce tape of acceptable dimensions for direct computer read-in.
2. Rebuild an available tape reader for use as in (a) or (b) above.
3. Strip some paper from the 1 track edge of the tape.

The third method proved the quickest, but for larger scale production serious consideration must be given to solutions 1 and 2.

3.1. To Prepare Teletypesetter Tape for Reading by PETR.

Approximately 1/16 inch of paper must be stripped from the track No. 1 side of the tape (all letters have no track No. 6 hole). This was done by the author with the aid of Mr. Clarence W. Christianson, of the M.E. student shop (1-006). A guide for the tape was obtained from Mr. Daniel Kennedy of the electric brailler embosser project (M.E., Room 3-355). The guide was used with a razor blade mount designed for use in a tape splitter for a Braille transducer, available from Mr. Christianson. Several tapes were ruined in this stripping process, due to the necessity for holding the tape against the blade to assure cutting. Enough space must be allowed so that balls of paper which build up in front of the blade do not cause tearing of the tape.

Once stripped, the teletypesetter tapes were reproduced into one continuous tape of uniform dimensions on a flexowriter. If large scale production is visualized, it will be necessary to build a tape stripper or a teletypesetter tape reader for the system. One solution might be to rebuild the tape read mechanism of a flexowriter. Recently a reader has been installed in the RLE Braille project (Building 20A) which can easily be modified to read and duplicate teletypesetter tape. For more information see Prof. Donald E. Troxel.

3.2. Editing of Teletypesetter Tapes.

Three methods of editing extraneous material from the tapes are available:

1. Removal during reproduction of the tapes on the flexowriter. (This is difficult due to moderate differences in teletypesetter and flexowriter codes.)
2. Removal from the output cards.
3. Programmed removal.

The simplest method is to edit the output cards. However, this prevents the realization of our ideal of a completely automatic system. Programmed editing presents many difficulties which may have to be faced if larger scale production is undertaken.

4. FAP TELETYPESETTER TAPE PROGRAM

4.1. Description.

This program reads paper tape through the channel D photoelectric tape reader, called the PETR, and produces a tape B-4 in the form specified by Mrs. Schack[1] for input to her program. The program could easily be converted to be used as the input program for either the COMIT or Schack translator so that direct paper tape input could be achieved. The editing and proofreading problems are large for such a systems.

4.2. Results

Two tests were run on this program. The first was run on stock quotations provided by the Boston Globe. The test was successful, but inconclusive because few of the problems inherent in copy were tested. The second test was run on Wall Street Journal tapes. The photoelectric tape reader caused most of the problems. The first was binding of the paper tape, which indicated end-of-tape to the program. This resulted in paragraphing at unusual positions. Another problem was that the tape reader occasionally did not recognize track 1 punches and produced garbage. Several programming problems were evident in the output, but were minor enough to allow hand correction, thus producing correct input for the translation programs. Due to the 7090 being down, it was impossible to run a test on the corrected program. Examples of output can be found in the appendices.

4.3. Operation of FAP Program for the PETR on the 7090.

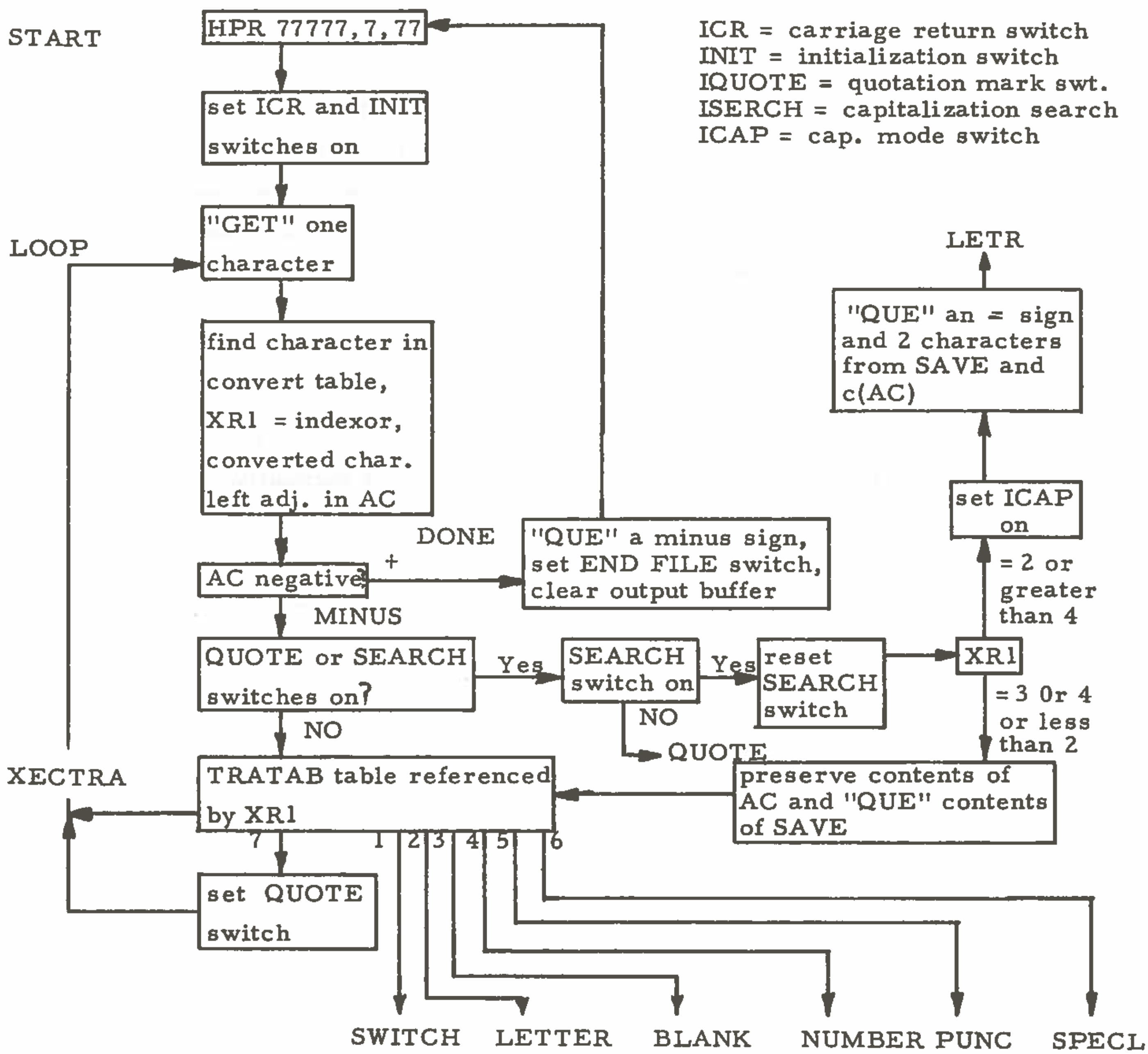
1. Load paper tape into photoelectric tape reader, hereafter called "PETR." Experts on this device are:

Ron Krosovec	Room 26-061
Alex Rutchka	Room 26-263
Mike Kudlick	Room 26-261

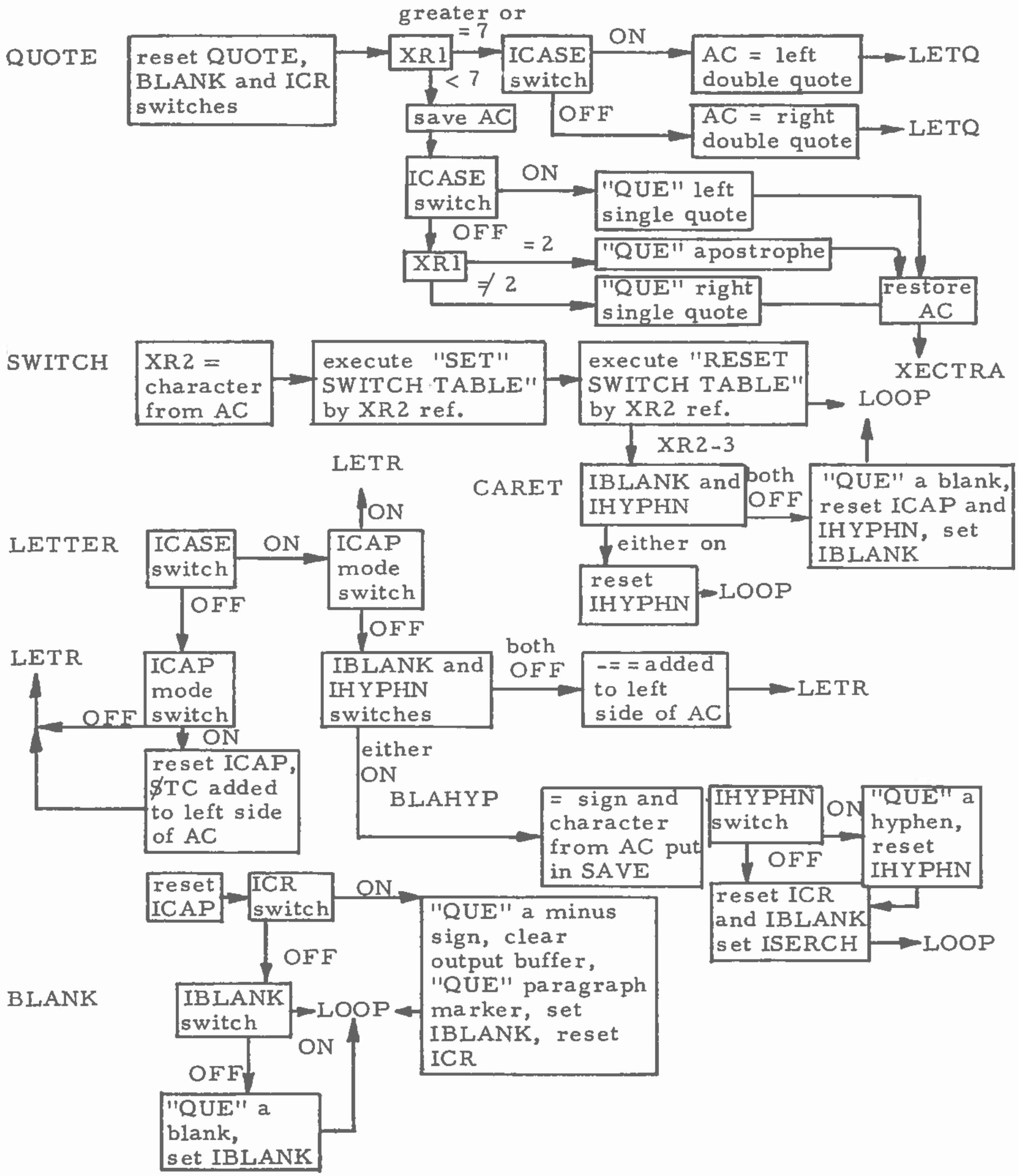
2. Turn off carriage return stop switch on PETR.
3. Push start switch on PETR.
4. Mount output tape on B-4 to be punched BCD.
5. Load binary cards into card reader.

6. Push load cards button.
7. Program will stop at HPR 77777,7,77
    a. all switches up
    b. push start
8. Do not allow paper tape to bind or pull as a delay of approximately 1/2 second between characters read on the PETR will indicate end of tape to the 7090, causing an end of file to be written and backspaced over on the output tape. Binding also causes a tendency for the PETR to lose track No. 1, producing garbage.
9. To restart after a halt at HPR 77777,7,77, push start. The first write will obliterate the end of file previously written.
10. When last paper tape is finished, rewind B-4 manually.

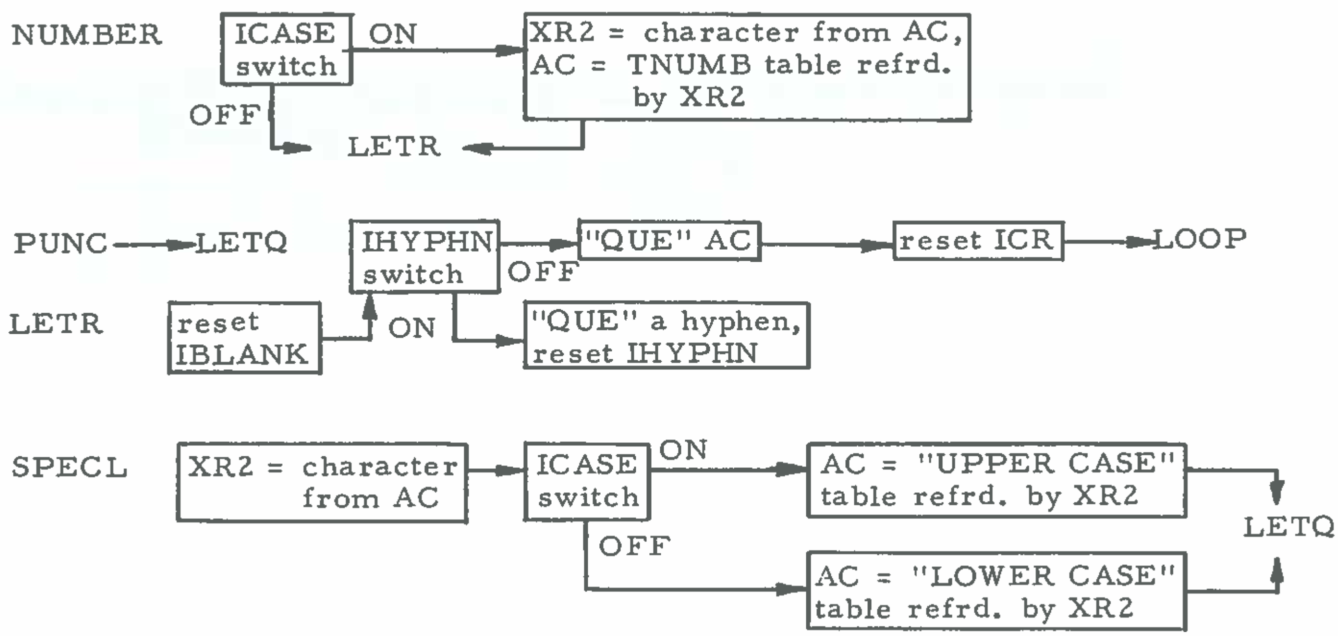
4.4. Teletypesetter Conversion Program Flow Diagram.



TELETYPESETTER CONVERSION PROGRAM FLOW DIAGRAM CONT.



TELETYPESETTER CONVERSION PROGRAM FLOW DIAGRAM CONT.



GET This routine loads the accumulator with the next 6 bit character, right adjusted, with negative sign. If the sign of the accumulator is positive, no character is available and the end of the paper tape has been reached.

QUE This routine outputs card images on tape B-4 (bcd) by queing the number of characters specified in the right 6 bits of the accumulator from the left 30 bits of the accumulator.

5. COMIT TRANSLATOR

5.1. Description of COMIT Program.

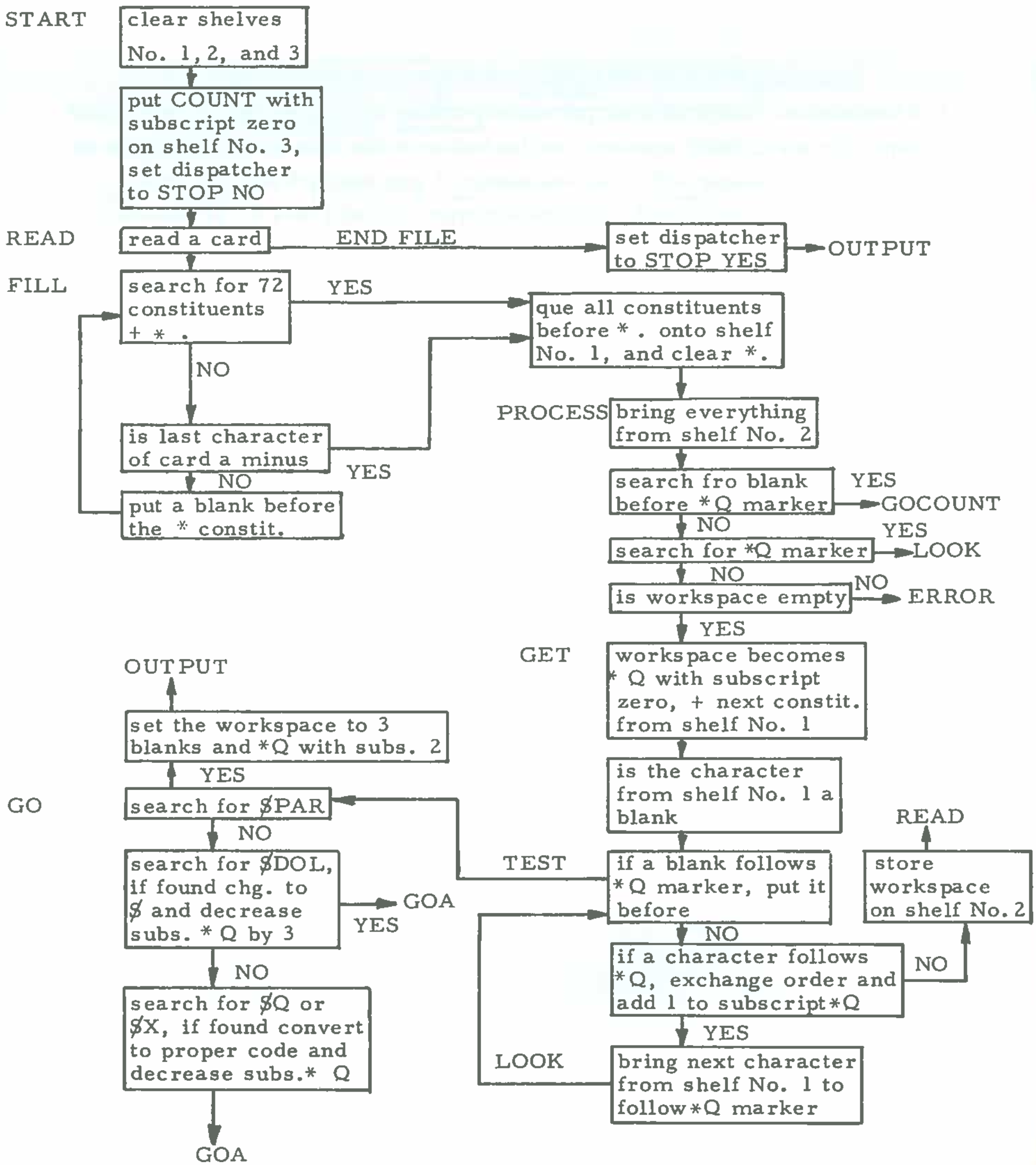
This program was originally written as a very simple Grade 1.0 translator. Lack of time prevented writing of a direct paper tape input scheme for the COMIT system, but inclusion of the data as cards works no hardship. The major difficulty encountered was the fact that the most desirable output would be 8 track paper tape. COMIT has no provision for the handling of paper tape, or for the output of binary codes without considerable manipulation. For this reason it was decided to concentrate more on the translation processing and leave the output in a mnemonic form to be printed. If use is made of the output of this program in the future, as in the automation of Mr. Staack's [1] proposals concerning Grade 2.0 Braille, it will be necessary to devise a method for producing output in the Braille stereograph card format.

Upon successful testing of a Grade 1.0 translator, the translator was upgraded by the insertion of table search for whole words, a few final contractions, and one initial contraction. These contractions are allowed only if they are at the end or beginning of the word. Considerable saving of space resulted, although less than that provided by Grade 2.0 Braille.

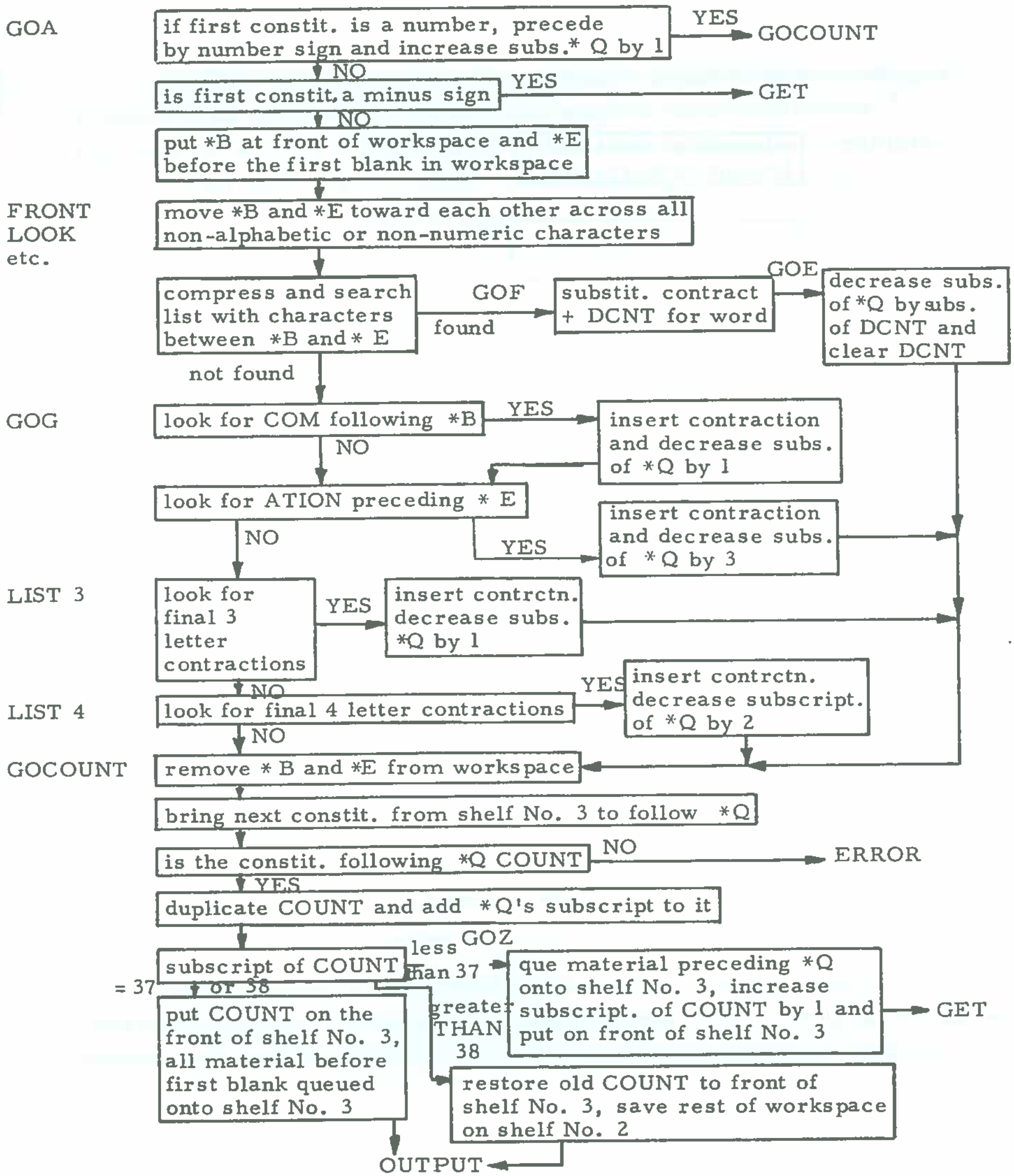
5.2. Results: See Appendices for Printed Output.

COMIT proved slow for the amount of table searching that must be done for Braille translation.

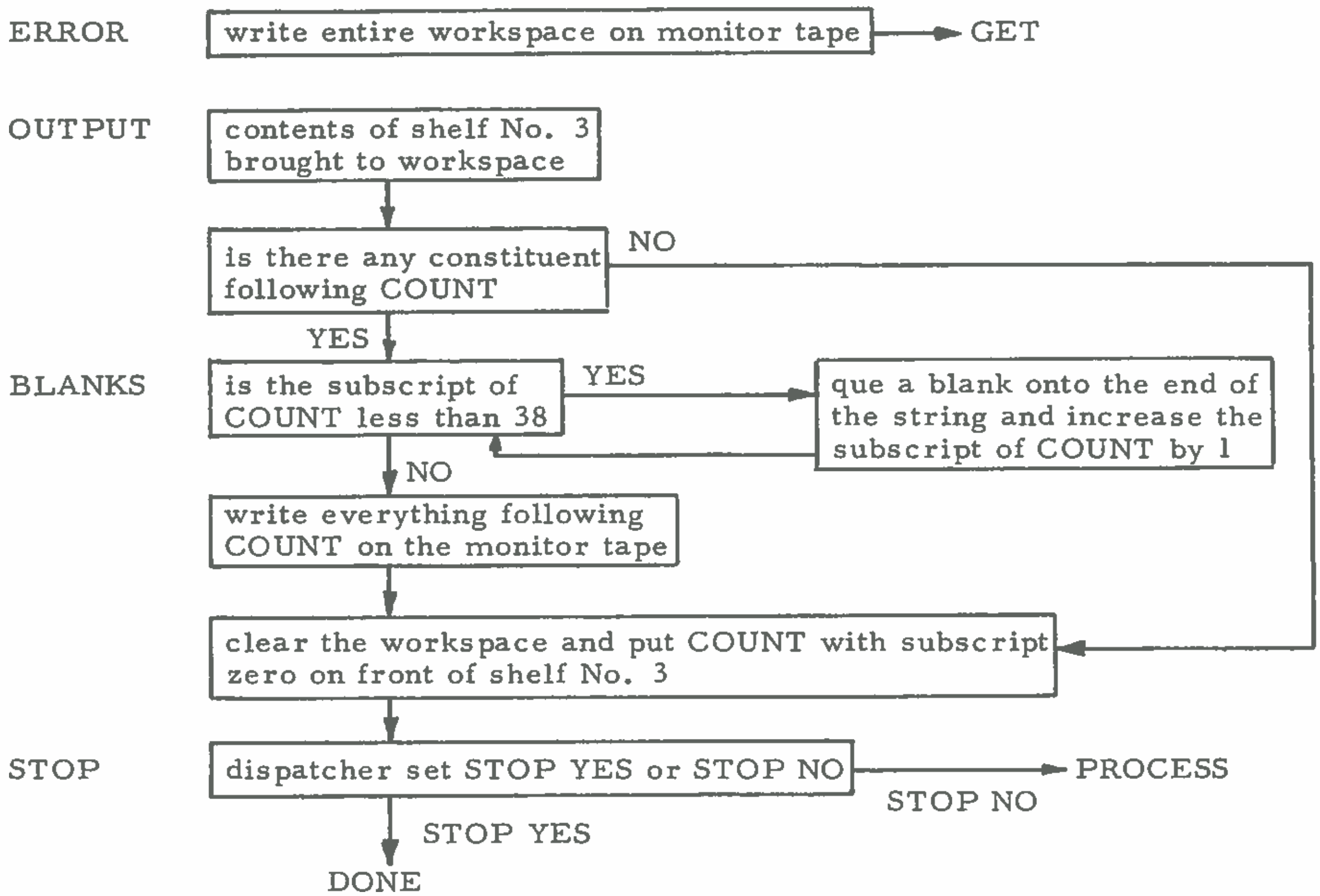
5.3. Comit Translator - Flow Diagram



COMIT TRANSLATOR - FLOW DIAGRAM CONT.



COMIT TRANSLATOR - FLOW DIAGRAM CONT.



6. BRAILLE TRANSLATION SYSTEM, GRADE 2.0, IBM

6.1. Description of Program.

The 7090 modifications of Mrs. Schack's program involved the removal of all sense switch options, and program dump capabilities.[1] Input was assigned to A-2 and output to B-4 contemplating the possibility of future runs under the FORTRAN monitor system. Buffered input and output programs have been added, and tables which were originally at the front of Mrs. Schack's absolute 704 deck have been moved to the rear of the relocatable 7090 deck. Mrs. Schack's specially devised 5 card loading system was removed, and a 9 card BSS loader for row binary relocatable cards was used instead. All patches included in the object deck from IBM were decoded and added to the symbolic deck.

"TABLE" in the main program refers to the binary table which must follow immediately after the program. The table deck provided by IBM is row binary, which precludes running under the FORTRAN monitor. Column binary cards may be produced when the table generator program[1] can be obtained from IBM and modified, or when a program is found for converting row binary to column binary cards. The program card of the table deck is not used by Mrs. Schack's loading system and had been discarded. A program card was produced by assembly of a dummy program of sufficient size to cover the subroutine.

6.2. Results.

The lateness of arrival of the program precluded intensive testing, but one run was successfully completed, producing Braille stereograph cards[1] for the Wall Street Journal "World-Wide" column of Wednesday, November 28, 1962. These cards were converted to 8 track paper tape, which was given to Mr. Daniel Kennedy for testing of the electric brailler embosser.[15,16,17]

Hand checking of the Braille cards indicated that the program had operated correctly. To know how satisfactory the system really is, it will be necessary to generate Braille copy and ask for comments from readers.

6.3. Operation of Program.

Follow directions in Mrs. Schack's manual [1]except:

1. No sense switch options.
2. Input on tape A-2

3. Punch output on tape B-4.
4. Clear and load binary cards.

   HTR 1, 2 halt in loading indicates checksum error.
   Push start to ignore.

Binary deck must be in the following order:

1. 9BSS or other relocatable row binary loader
2. main program
3. table deck
4. relocatable transfer card (9 punch in leftmost column)

7. CODE TABLES

Braille Codes

	0	1	2	3	4	5	6	7
00	(300) space	a	ea comma	b but	apostrph	k knowledge	be bb ;	l like
10	accent sign	c can	i I	f from	st still	m more	s so	p people
20	contractn sign	e every	con cc :	h have	in	o	to ff !	r rather
30	contractn sign	d do	j just	g go	ar and poetry sign	n not	t that	q quite
40	capital and contractn signs	ch child	en enough	gh	com hyphen	u us	(left ") ? his	v very
50	italic, decimal pt. and contractn signs	sh shall	ow	ed	ing	x it	the	and
60	letter and contractn signs	wh which	dis dd period	ou out	was by (right ")	z as	( ) were gg	of
70	contractn sign	th this	w will	er	ble and numeral sign	y you	with	for

CHANNEL 7 (octal 100) is used for parity. The sum of the holes must be even.
CHANNEL 8 (octal 200) indicates control characters.
TRACK ORDER: 1, 2, 3, sprocket holes, 4, 5, 6, 7, 8.

DOT 1 = TRACK 1 = octal 1
DOT 2 = TRACK 2 = octal 2
DOT 3 = TRACK 3 = octal 4
DOT 4 = TRACK 4 = octal 10
DOT 5 = TRACK 5 = octal 20
DOT 6 = TRACK 6 = octal 40
PARITY = TRACK 7 = octal 100
CONTROL = TRACK 8 = octal 200

300 = space
201 = line space and carriage return
202 = back space
303 = end of page
204 = end of card
305 = paper advance
306 = stop
377 = rub out, error, no operation

WALL STREET JOURNAL TELETYPESETTER TAPE CODES

	0	1	2	3	4	5	6	7
00	Blank tape	T t	carriage return	O σ	space	H h	N n	M m
10	Line feed	L ℓ	R r	G g	I i	P p	C c	V v
20	E e	Z z	D d	B b	S s	Y y	F f	X x
30	A a	W w	J j	↑ shift up	U u	Q q	K k	shift down ↓
40	Thin space	5/8 5	6 ,	9	Thin space	EM Leader (.)	comma	period
50	Paper feed	EM space	1/2 4	: ;	Dash 8	? ¢	EN space	QUAD center
60	3/8 3	( )	@ Hyphen	Upper rail	EM space	3/4 6	QUAD Left	1/8 1
70	! $	1/4 2	Bell	Lower rail	7/8 7	EN Leader (.)	QUAD right	RUB out

Track	Octal No.
1	01
2	02
3	04
4	10
5	20
6	40

Tape orientation can be most easily found from the fact that copy will not have many track 6 punches (no letter has a 6 track punch).

8. REFERENCES

1. Schack, Ann S., and Mertz, R. T., Braille Translation System for the IBM 704. New York, IBM, Data Systems Division, Mathematics and Applications Department, MA-10, 1961.

2. Best, Harry, Blindness and the Blind in the U.S., New York, the MacMillan Co., 1934.

3. Ruggles, Stephen P. Report of Stephen P. Ruggles to the Committee of the American Association of Instructors of the Blind. Boston, 1872, 31 pages.

4. Staack, Gerald, A Study of Braille Code Revisions. Thesis (S.M.), Dept. of Mech. Engr., Mass. Inst. of Tech., 1962, 124 pages.

5. English Braille, American Edition, 1959. Louisville, American Printing House for the Blind, 1960.

6. Addendum to English Braille, American Edition, 1959. Louisville, American Printing House for the Blind, October 1960.

7. English Braille - American Edition - Grade 1. Thermofax copy of paper of unknown origin.

8. Lipton, Arthur. Introductory Notes on the Braille System of Reading and Writing for the Blind. New York, Research and Development Division, Prosthetic and Sensory Aids Service, Veterans Administration, 1959, 6 pages.

9. Bliss, James C., Communication Via the Kinesthetic and Tactile Senses. Thesis (ScD.), Dept. of Elec. Engr., Mass. Inst. of Tech., 1960, 28 pages.

10. Minutes of the Conference of Automatic Data Processing and the Various Braille Codes., Mass. Inst. of Tech., March 17-18, 1961.

11. Friedrich, Sidney., Teletypesetter Punched Tape to Braille Translator. Thesis (S.M.), Dept. of Elec. Engr., Polytechnic Institute of Brooklyn, 1956.

12. Dirkman, Robert J., An Encoder for a Grade II Braille Typewriter. Thesis (S.M.), Dept. of Elec. Engr., Mass. Inst. of Tech., 1960, 72 pages.

13. Eglinton, David G., Preliminary Design of the Mechanical to Electrical Coding Conversion for a Typewriter to Braille Converter. Thesis (S.B.), Dept. of Mech. Engr., Mass. Inst. of Tech., 1961, 40 pages.

14. Summary of Conclusions and Recommendations of Conference on Braille Research, Mass. Inst. of Tech., October 9-10, 1962.

15. Lichtman, Stuart A., The Design of a High-Speed Slave Brailler for a Braille Converter Device. Thesis (S.B.), Dept. of Mech. Engr., Mass. Inst. of Tech., 1961, 61 pages.

16. Kennedy, Daniel W., A High Speed Braille Embossing System. Thesis (S.M.), Dept. of Mech. Engr., Mass. Inst. of Tech., May 1963 (3 vols.).

17. Maskrey, Robert H., Design and Construction of a Braille Keyboard for the High Speed Electric Brailler. Thesis (S.B.), Dept. of Mech. Engr., Mass. Inst. of Tech., June 1963.

Bibliography Associated With the EPL-M.I.T. Sensory Aids and Prosthetics Research and Development Project

REPORTS

1. Saslow, L., Tactile Communication Using Air Jets. Engineering Projects Laboratory Report 8768-1, 8649-1, Mass. Inst. of Tech., March 1962.

2. Paul., I., Evaluation of the Energy and Power Requirements for Externally Powered Prosthetic and Orthopedic Devices. Engineering Projects Laboratory Report No. 8768-2, Mass. Inst. of Tech., May 1962.

3. Evaluation Report on Work in Progress on Sensory Aids and Prosthetic Research and Development. Engineering Projects Laboratory Report No. 8768-3, Mass. Inst. of Tech., October 1962.

4. Research Bulletin No. 1, American Foundation for the Blind, New York, N.Y., Chapters II and VIII, January 1962.

5. Research Bulletin No. 3, American Foundation for the Blind, New York, N. Y., Chapters I, II, IV, August 1963.

THESES

1. Brady, R. T., Development of an Inertial Guidance Device for the Blind Travelers. Thesis (S.B.), Dept. of Mech. Engr., Mass. Inst. of Tech., June 1962.

2. DeFazio, T. L., Tactile Feedback for Remote Manipulators. Thesis (S.M.) Dept. of Mech. Engr., Mass. Inst. of Tech., January 1963.

3. Eglinton, D. G., Preliminary Design of the Mechanical to Electrical Coding Conversion for a Typewriter to Brailler Converter. Thesis (S.B.), Dept. of Mech. Engr., Mass. Inst. of Tech., May 1961.

4. Fineman, H. E., Design Study for an Artificial Tactile Sensory System. Thesis (S.B.), Dept. of Mech. Engr., Mass. Inst. of Tech., June 1962.

5. Ferrell, W. R., A Study of the Effect of Motion Size on Performance for a Task Involving Kinesthetic Feedback. Thesis (S.M.), Dept. of Mech. Engr., Mass. Inst. of Tech., June 1961.

6. Frazier, W. C., Teaching Small Kinesthetic Motions Using a Servo-Position Device. Thesis (S.B.), Dept. of Mech. Engr., Mass. Inst. of Tech., June 1962.

7. Genachowski, A.S., Design of a Directional Photoelectric Probe with Tactile Output. Thesis (S.M.), Dept. of Mech. Engr., Mass. Inst. of Tech., August 1963.

8. Holly, J., Preparation for Psycho-Physical Evaluation of the Blanco Braille-Out, A Tape to Braille Transducer. Thesis (S.B.), Dept. of Mech. Engr., Mass. Inst. of Tech., June 1963.

9. Krigman, A., A Tactile Sensory Aid for the Blind. Thesis (S.B.), Dept. of Mech. Engr., Mass. Inst. of Tech., May 1960.

10. Lichtman, S. A., The Design of a High-Speed Slave Brailler for a Braille Converter Device. Thesis (S.B.), Dept. of Mech. Engr., Mass. Inst. of Tech., May 1961.

11. Mapes, R. D., Tactile Reading Aid for the Blind. Thesis (S.B.), Dept. of Mech. Engr., Mass. Inst. of Tech., 1960.

12. Maskrey, R. H., Design and Construction of a Braille Keyboard for the High Speed Electric Brailler. Thesis (S.B.), Dept. of Mech. Engr., Mass. Inst. of Tech., June 1963.

13. McRay, R., Development of a Plotting Table for Investigation of Tactile and Kinesthetic Pattern Recognition. Thesis (S.B.), Dept. of Mech. Engr., Mass. Inst. of Tech., June 1961.

14. Paul, I., An Investigation of Compact Power Sources for Externally Powered Prosthetic and Orthopedic Devices. Thesis (S.M.), Dept. of Mech. Engr., Mass. Inst. of Tech., June 1961.

15. Pettus, W. H. III, The Design and Construction of an External Pelvic Frame. Thesis (S.B.), Dept. of Mech. Engr., Mass. Inst. of Tech., June 1963.

16. Potash, L., Correlates of the Tactual and Kinesthetic Stimuli in the Blind Man's Cane. Thesis (S.M.), Dept. of Mech. Engr., Mass. Inst. of Tech., June 1961.

17. Rothchild, R., Design of a "Talking Ball": Sensory Aid for the Blind. Thesis (S.B.), Dept. of Mech. Engr., Mass. Inst. of Tech., August 1963.

18. Staack, G. F., A Study of Braille Code Revisions. Thesis (S.M.), Dept. of Mech. Engr., Mass. Inst. of Tech., August 1962.

19. Traver, A. E., Jr., Design of Tactile Reading Aid for the Blind. Thesis (S.B.), Dept. of Mech. Engr., Mass. Inst. of Tech., May 1961.

20. Weissenberger, S., Dynamics of the Human Operator with Tactile Feedback. Thesis (S.M.), Dept. of Mech. Engr., Mass. Inst. of Tech., May 1960.

21. Dirkman, R. J., An Encoder for a Grade II Braille Typewriter. Thesis, (S. M.), Dept. of E. E., Mass Inst. of Tech., 1960.

PAPERS

1. Mann, R. W., "Rehabilitation Via Engineering Skills", Rehabilitation Record, Vol. 3, No. 1, U. S. Dept. of Health, Education, and Welfare, Washington, D. C., January - February 1962.

2. Mann, R. W., "On Enhancing the Availability of Braille", Proceedings of the International Congress on Technology and Blindness, New York, N. Y., June 1962.

3. Sheridan, T. B., "Techniques of Information Generation: The Cane", International Congress on Technology and Blindness, New York, N.Y., June 1962.

4. Mann, R. W., and Paul, I., "Evaluation of Energy and Power Requirements for Externally-Powered Upper-Extremity Prosthetic and Orthopedic Devices", ASME, paper.

COURSE PROJECTS

Junior Laboratory

Investigation and Development of Typewriter to Brailler Converter.

Information Transmittal Via the Blind Man's Cane.

Design of Collapsable Blind Man's Canes.

Junior Design

Externally-Powered Prosthetic Limb.

Mobility Devices for the Incapacitated.

Freshman Seminar

Type Compositors Tape-to-Braille System.

10. GENERAL BIBLIOGRAPHY

1. An Introduction to COMIT Programming. Research Laboratory of Electronics and the Computation Center, M.I.T., 1961.

2. COMIT Programmer's Reference Manual. Research Laboratory of Electronics and the Computation Center., M.I.T., 1961.

3. Reference Manual, 7090 Data Processing System. IBM Corporation, New York, N.Y., 1961.

4. Denis, G.A., A Facsimile Blind Reader. Thesis (S.M.), Dept. of Elec. Engr., Mass. Inst. of Tech., 1960, 28 pages.

5. Kocher, D.G., A Reading Machine for the Blind. Thesis (S.M.), Dept. of Elec. Engr., Mass. Inst. of Tech., 1959, 132 pages.

6. Pilla, M.A., A Study of Communication by Vibratory Skin Stimulation. Thesis (S.M.), Dept. of Elec. Engr., Mass. Inst. of Tech., 1961, 55 pages.

7. Troxel, D.E., Tactile Stimulation of the Fingers as an Information Input to the Blind. Thesis (S.M.), Dept. of Elec. Engr., Mass. Inst. of Tech., 1960, 35 pages.

8. Metfessel, M. and Lovell, C., Spelled-Speech as Output for an Automatic Reader. Los Angeles Communications Laboratory, Psychology Department. University of Southern California, 1961, 45 pages.

9. Report of Proceeding of Conference on Research Needs in Braille. American Foundation for the Blind, Inc., New York, N.Y., September 13 - 15, 1961.