762-1762 A426

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Collation methods for the UNIVAC system, 2 vols.
[Eckert-Mauchly Computer Corp., 1950]

Collation is the individual-string-merging — planned carefully and desk checked.

Merging describes the ~~whole~~ process
of taking tapes which are all in sequence → one ~~tape~~ sequence.

UNIVAC I designed to facilitate sorting (had to compete with cards)

'Internal collation' of 7 items → blocks.

'External collation' of blocks: balanced 2 and 3 way merge → tape. reading backwards

'Merging' 2 and 3 way merging of full tapes as input. ≤99 tapes.

BINAC developed for classified airborne work,
specs lifted from previous development of UNIVAC
Used to prove feasibility of components
and to simulate sort routines for UNIVAC. ←

Experimented with (and rejected) radix sort
UNIVAC I code: test for equal without destroying was put in to help sorting
signed magnitude (packed data), reading backwards.
Programmer training on sorting, with prototype code

[Prefabrication] [Collation] ← original title.
Master Generating Routine for 2-way sorting ~~to single~~
Copyright 1952 Eckert Mauchly Div. of Rem Rand
by F E H. First sort generator; to single tapes. Had prediction.

~~At beginning~~

Goetz did UNIVAC II sort generator

Prediction technique: memo to Mauchly Sep 3 '48

ACM conf. U of Penn Stephen Wright

Lib. Resources & Tech services

LRTS 59 03300 Sorting backwards. D W Johnson Fall '59

~~J. H. [illegible]~~ 2724
~~E. C. D.~~

MASTER GENERATING ROUTINE

for

2-WAY SORTING

Eckert-Mauchly Division
Philadelphia, Pennsylvania

965-1
9/3/52

By Frances E Holberton

965-1
9/3/52

I Master Generating Routine 965-1 has been devised to produce on the UNIVAC in less than three minutes a 2-Way Sorting instruction tape, a final report edited copy of coding, and a routine to test the sequence of data operated on by the sorting routine, according to specifications determined by a programmer. It is hoped that the following processes may be eliminated for sorting routines involving four or five UNISERVOs:

1. Programming and writing of reports
2. Checking of coding and logic
3. Unityping of instruction tape
4. Proof reading of Unityping and corrections
5. UNIVAC proving of routine
6. Hand typing of final report
7. Proof reading of final report

A. Sorting Routine

An Internal Sorting and 2-Way External Sorting Routine are produced on tape. The routine contains only the coding and constants required to produce an ascending ordered series determined by a set of parameters. The Master Generating Routine 965-1 can produce a sorting routine to handle any one of twelve different item sizes and as many as five key words. The sorting routine is not a generalized routine, but a custom built routine designed to produce an efficient sorting procedure for a given set of parameters based upon methods and techniques described in the Collation Manual and some more recently devised.

B. Edited Copy

The edited copy produced on tape at 20/in can be printed by the UNIPRINTER on fan-fold paper, single page copy of ozalid, mimeograph master or for photographic offset printing.

The copy will contain the necessary Copyright information, date, problem number and page number.

A two-page description of the sorting routine and the operating instructions precede the copy of coding.

Each subroutine contains the necessary connector entries, descriptive information, alternate instruction words, and modified words referred to in Flow Chart 965-1. The copy produced is to eliminate the need of hand typing a final coding copy and to facilitate any modifications to the routine a programmer may wish to make.

An example of a mimeograph copy produced by the UNIVAC and UNIPRINTER appears at the end of this report.

C. Sort Check Routine

A routine enabling the operator to check the sequence of information arranged by the sorting routine is produced. The routine handles only the item size and key words determined by the parameters, and will check information sorted in an ascending sequence. No edited copy of this two block routine is produced.

II Operating Instructions for 965-1

A. UNIVAC

Master Generating Routine 965-1 contains 131 blocks at 100/in and is mounted on UNISERVO #1.
Parameters for problem (1 block) on UNISERVO #2.
Blank tapes on UNISERVO #3, #4, #5.

S.C. Printer set to normal.
No breakpoints set.
Initial read #1.

S.C. Printer will print "DATE TODAY"
Type in one word--the date, followed by a carriage return and ignore symbols. e.g. [6-17-52R̸1̸1̸1̸1̸]

The computer will proceed automatically to produce all three output tapes.

UNISERVO #3	Edited Sorting Routine for UNIPRINTER at 20/in.
UNISERVO #4	10 blocks of instructions for Sorting Routine at 20/in.
UNISERVO #5	2 blocks of instructions to Check the Sorted Data at 20/in.

The routine takes less than 3 minutes to perform, so that no rerun procedure has been incorporated.

Information printed on S.C.Printer

"Tape 4 UNIVAC coding"
"Page xx is last page" (represents how many pages of copy is expected on UNIPRINTER copy from UNISERVO #3 output tape)
"Tape 5 Sort Check Inst."

If a tape mounted on UNISERVO #2 is not a set of Parameters, the following will be printed out. "Parameters not for Problem 965-1."

If the Parameter tape contains an item size outside of the range, the following is printed "item size not allowed." The tapes will be rewound.

Modifications to be made to Master Generating Routine.

If only 4 UNISERVOs are available when using the Generating Routine, modifications can be made to the routine so that the Sort Check Routine will be written on UNISERVO #4 instead of #5. The following changes must be made:

Block #	Location	Change to		Was	
129	06	740200	740260	750200	750260
129	08	840000	900000	850000	900000
129	40	X̸TAPEΔ	4ΔSORT	X̸TAPEΔ	5ΔSORT

After the sorting routine has been coded and written on UNISERVO #4, the tape will be rewound with interlock. Mount a blank tape on UNISERVO #4 to record the two block sort check routine.

In order to keep the Copyright year up to date, the following word must be changed each year:

Block	Location	Contents
59	01	1952ΔEYT̸'7T̸i̸i̸

B. UNIPRINTER

Type of Printer required for best results:

1. 12 characters to the horizontal inch, and 6 characters to the vertical inch.
2. Lower case letters in lower case.
3. The following symbol should appear in the upper case of the corresponding character.

Lower Case	Upper Case
2	"
3	#
8	'
9	(
0	)
;	:
minus	underline

Paper Size

8 1/2 by 11 inch paper, either fan-fold or single copy may be used.

Margin and Tabular Settings

Margin set not more than 1 1/2 inch from left of page.
Tabs set (M = margin setting) M + 7, M + 13, M + 23, M + 34, M + 65 (or 1 1/2 inch from right edge of page)

Line Spacing

Set for single space page.

Page Alignment

Start printing with carriage to left and top of page not more than 1/2 inch from first line of printing. First words printed will be "Copyright 1952 by".

Single Page Printing

If single page printing is required, set the Printer Breakpoint Stop. The stop will occur after an 8 1/2 by 11 page has been ejected by repeated carriage returns. A new page should be entered with the top margin not more than 1/2 inch.

Each page is numbered and contains a breakpoint stop, to facilitate reprinting if necessary.

Setting too large a left hand margin may cause printing to excede the right hand margin.

III Parameters for 965-1

One block of parameters is Unityped and mounted on UNISERVO #2 with Master Generating Routine 965-1 on UNISERVO #1.

Parameters

0. Problem965-1

The first word of parameters is a constant and contains the number of the Generating Routine. It is used to check the correctness of the parameter set entered with the routine.

1. Your Problem No.

This is a 12 digit word containing the number to be supplied to your sorting routine, and will appear at the top of each page on the edited copy. This word should be in edited form, but contain no carriage return or tabular characters. The printer carriage is in lower case when approaching this word, and must be in lower case after completion. e.g. [L̸CCØΔ-Δ257i̸i̸]

2. Number of UNISERVOs
010000 00000X

Either 4 or 5 UNISERVOs may be programmed. If 4 UNISERVOs are used, the Instruction tape #1 and the Data Tape must be removed after rewinding, and blank tapes mounted to complete the sorting process.
If 5 UNISERVOs are used only UNISERVO #1 is reused after reading the Instruction Tape. The UNISERVO containing the data tape is not reused during the sorting of this information.

3. Input and Output UNISERVOs
00000X 00000Y

The input data tape (X) and the output sorted tape (Y) may not be the same UNISERVO number.
When programming for 4 UNISERVOs, numbers 1-4 are used; for 5 UNISERVOs, 1-5 are used. Any UNISERVO of the group including #1 may be used as input or output.

4. Item Size
020000 0000XX — Any one of the following item sizes may be selected: 2,3,4,5,6,7,8,10,12,14,20, and 30 words. Item sizes 7,8, and 14 assume the last 4 words of each block to be unused, and the items do not split between blocks.

5. First Key Word
030000 0000XX — The key words of the item are numbered starting with 1 as the first word of the item. Any word or part of word may be used as any key and no restrictions are placed on the use of different parts of the same word for different keys. Each key must not be more than one word.

6. First Key Word Extractor
XXXXXX XXXXXX — This extractor word will select the specific digits in the first key word used in the first magnitude comparison on the data. If no extractor is required set up all zeros for extractor (NOT ALL ONES).

7. Second Key Word
040000 0000XX — If no split key is required, supply zeros in the least significant digits of the word. The code in the most significant part of the word must be present even though least significant digits are zeros. The code is used within the generating routine.

8. Second Key Word Extractor
XXXXXX XXXXXX — Extractor used with second key word; zeros if not used.

9. Third Key Word
050000 0000XX — Similar to Second Key word.

10. Third Key Word Extractor
XXXXXX XXXXXX — Extractor used with third key word. zero if not used.

11. Fourth Key Word
060000 0000XX — Similar to Second Key Word

12. Fourth Key Word Extractor
XXXXXX XXXXXX — Extractor used with Fourth Key word, zeros if not used.

13. Fifth Key Word
070000 0000XX — Similar to Second Key word.

14. Fifth Key Word Extractor
XXXXXX XXXXXX — Extractor used with Fifth Key Word, zeros if not used.

15. Identification Block
080000 00000X — If there is no Identification Block preceding the data on the input tape supply zero to least significant digit. If there is an identification block on the tape supply "one" as the least significant digit. (NO = 0; YES = 1) When an identification block appears on the input tape and accounted for, it will appear on the output tape in the same form at 20/in. No reference is made to this information in the sorting routine.

Note: If an identification block is entered into the computer, the first word of the block is stored in memory location 013 at connector 3, and the remaining part of the identification block with an Intermediate Sentinel in the first word location is transferred each cycle to the next tape as the sentinel block. At the beginning of the last cycle of sorting, the first word (013) is supplied and the block is written at the beginning of the final output tape at 20/in. (connector 20). There is ample memory space available within the completed coding to make any changes for examining the identification block, but it must be inserted at connector 3 or connector 20.

16. Initial Read
090000 00000X

Does the routine initiate from Initial Read? NO = 0, YES = 1
If the routine does not initiate from Initial Read, the following assumptions have been made:

1. The first block of instructions is in the memory at 000-059.
2. The second block is in rI with the tape moving forward.
3. A transfer of control to 000 has been executed after completing the first two assumptions.

17. Position of Input Tape Sentinel
1000XX 0000YY

Sentinels appear in two locations on the input tape and will appear at the same position on the sorted tape.

(XX) Position of Sentinel following the last item. If the position is the first word following the last item supply 00. If some other position than the first word is desired, type the corresponding position.

(YY) Position of the last sentinel in block. If position is last word supply 59. If any other position supply the corresponding block positions e.g.: 100004 000054 Sentinels are in the fifth word of the item and location 54 of block Numbering is from 00-59.

18. Input Tape Sentinel
XXXXXX XXXXXX

Designate the contents of the word used for the input data tape sentinel. Any set of computer characters may be used for the input sentinel.

19. Output Tape Sentinel
XXXXXX XXXXXX

The output tape sentinel may be different from the input tape sentinel and will appear at the end of the sorted tape.

The following restrictions have been placed upon the choice of the output tape sentinel:

1. The sentinel must have a pulse code, larger or smaller, than the pulse code of the corresponding key digits of the first key word of all items on the tape.
2. The sentinel may not be all periods, because this combination is used as the intermediate sentinel during the sorting process.

If the pulse code of the sentinel is smaller than any key word (such as ignore), the partial block fill in will appear at the beginning of the first block on the sorted tape.
If the pulse code of the sentinel is larger than any key word, the partial block fill in will appear at the end of the sorted tape.

The remainder of the Parameter block is filled with zero.

The following is a table of UNISERVO numbers and a designation on which cycle of operation the various UNISERVOs first start to operate. The first two columns are the input and output parameters. All possibilities are listed.

Using Four UNISERVOs

Input Tape	Output Tape	1st Cycle Write	2nd Cycle Write
1	2	3 , 4	2 , 1
1	3	2 , 4	3 , 1
1	4	2 , 3	4 , 1
2	1	3 , 4	1 , 2
2	3	1 , 4	3 , 2
2	4	1 , 3	4 , 2
3	1	2 , 4	1 , 3
3	2	1 , 4	2 , 3
3	4	1 , 2	4 , 3
4	1	2 , 3	1 , 4
4	2	1 , 3	2 , 4
4	3	1 , 2	3 , 4

Using Five UNISERVOs

Input Tape	Output Tape	1st Cycle Write	2nd Cycle Write
1	2	3 , 4	2 , 5
1	3	2 , 4	3 , 5
1	4	2 , 3	4 , 5
1	5	2 , 3	5 , 4
2	1	3 , 4	1 , 5
2	3	4 , 5	3 , 1
2	4	5 , 3	4 , 1
2	5	4 , 3	5 , 1
3	1	2 , 4	1 , 5
3	2	4 , 5	2 , 1
3	4	2 , 5	4 , 1
3	5	2 , 4	5 , 1
4	1	3 , 5	1 , 2
4	2	3 , 5	2 , 1
4	3	2 , 5	3 , 1
4	5	2 , 3	5 , 1
5	1	2 , 3	1 , 4
5	2	3 , 4	2 , 1
5	3	2 , 4	3 , 1
5	4	2 , 3	4 , 1

Unityper Layout for Parameters (1 Block)

000	PROBLE■	M965-1	
001	XXXXXX	XXXXXX	Your problem number (edited but not T̸ or R̸)
002	010000	00000X	Number of UNISERVOs (4 or 5)
003	00000X	00000Y	Input date UNISERVO (left); output UNISERVO (right)
004	020000	0000XX	Item size
005	030000	0000XX	1st Key word (First word of item = "1")
006	XXXXXX	XXXXXX	Extractor for 1st key word (if none type all zeros)
007	040000	0000XX	2nd key word (if not required, type zero in last two digits)
008	XXXXXX	XXXXXX	Extractor for 2nd key word
009	050000	0000XX	3rd Key word
010	XXXXXX	XXXXXX	Extractor for 3rd key
011	060000	0000XX	4th Key word
012	XXXXXX	XXXXXX	Extractor for 4th key
013	070000	0000XX	5th Key word
014	XXXXXX	XXXXXX	Extractor for 5th key
015	080000	00000X	Is there an identification block on data tape? "1" = yes "0" = no
016	090000	00000X	Does routine initiate from intial read? "1" = yes, "0" = no
017	1000XX	0000YY	Where is the end of tape sentinel after last item (left) 00 = first word. Where is the end of tape sentinel for block? (right) 59 = last wd.
018	XXXXXX	XXXXXX	What is the input sentinel?
019	XXXXXX	XXXXXX	What is the sentinel on the sorted tape to be?
020	000000	000000	
•			
•			Zeros to end of blocks
•			
059	000000	000000	

IV Characteristics of the sorting routine

Ten blocks of instructions are generated for all sorting routines, even though less blocks may be required. Since any number of Data tapes may be sorted from one reading of the instructions, this presents a small loss of computer time. Any unused blocks may be eliminated by modification of the instructions stored on 000 - 004.

The constants, variables, and counters are stored at the beginning of the routine, and only those constants required for the particular problem are supplied. Memory locations used for Instruction read orders are reused for overflow control and counters.

The External Sorting routine follows the constants, beginning on the next available memory location containing a "three" in the least significant position. Starting the routine in such a location allows the use of Vm, Wm, Ym, Zm instructions to alternate tape and comparison instructions for ascending and descending sorting.

One of four types of main comparison instructions is used, depending upon the need for a first key extractor and/or a split key.

The type of Data transfer instructions chosen, is based upon the item size, the position of the first key word, and whether an extractor is required in the main comparison instructions. The type selected is set up to produce the minimum number of words and constants required to make the transfer.

The completion of sorting a block of data is detected by overflow control.

Six blocks of memory are reserved for data, two working locations and four auxiliary. Data is transferred from the auxiliary blocks to the working blocks to facilitate the transferral of Sentinel Blocks to the next tape, where Identification Block information may be stored in this block, and to facilitate the handling of item sizes not an integral multiple of sixty.

The method used to eliminate the interlocking of tape read instructions is described fully in the Collation Manual.

If a split key is required, one of three methods is selected for External Sorting, based upon the presence or absence of an extractor. The three cases are as follows:

1. No extractor in first key, no extractor in any other key.
2. No extractor in first key, but extractor in at least one other key.
3. Extractor in first key, with or without extractor in any other key.

Within each of the three preceding cases there are four possibilities, since as many as five keys are permitted. Any one sorting routine will be coded to handle only the number of key words or digits specified by the parameters.

If a split key is required, the Internal Sorting Split Key routine will precede the Internal Sorting routine sequence and one of three methods will be selected, based upon the same criterian as above. Since the probability of having two items with equal first keys, within the same block of initial data, is small, only one routine is stored to handle any item comparison. The control to handle the correct set of split keys is based upon the use of an Rm instruction preceding each Qm instruction.

Internal Sorting is performed by successive comparisons and transferring the item to the output block in its relative position, retaining counters on the relative position of unselected items. The number of comparisons required to arrange a block of data is $\frac{N}{2}$ (N-1); N = number of items per block. Each time an item is transferred to the output storage block, the number of comparisons required to transfer a single remaining item is reduced by one.

The partial block of data at the end of the input tape is filled with the output sentinel, in all unused locations starting with the position designated by the first input sentinel position.

The number of blocks is counted on each external cycle and compared at the end of each cycle with the number of initial data blocks. If through manual intervention or a computer read or write failure, a block is gained or lost, the Supervisory Control ~~Printer~~ will print "Error Sort" and all tapes will be rewound.

No rerun procedure is included, since a minimum of six

UNISERVOs is required to perform 2-Way Sorting from a rerun position. Information must be retained from a previous cycle.

The Sorting routine will handle any number of blocks from one partial block to 2000. If the number of blocks on the tape is such that the sorted information would normally terminate in a descending series, an additional tape pass is instigated automatically to reverse the series.

At the completion of any sorted tape, the instructions are reset to handle another data tape which is mounted on the same input UNISERVO used by the previous tape.

The process is stopped by either failing to mount a new data tape or by setting Conditional Breakpoint 1, after starting the last data tape of a series.

The initial data tape is read in a forward direction.

If an Identification Block precedes the information on the data tape, the first word of the block is stored in the memory. The remainder of the block with an intermediate sentinel in the first location is transferred each cycle as the sentinel block. At the beginning of the last cycle the first Identification word is supplied and the block written at 20/in. on the beginning of the final output tape. Handling the Identification Block in this manner enables up to 60 words of pertinent information to be retained without setting aside 60 words of memory for storage.

The routine is set up for 4 or 5 UNISERVOs using the

Instruction Tape #1 as one of the auxiliary servos. A special tape has been prepared from Master Generating Routine 965-1 to produce a 2-Way Sorting Routine using 6 UNISERVOs, and labeled for "6 UNISERVO SORTING". The same parameters are used as for the regular 965-1 except the number of UNISERVOs is typed as "6". The modified 965-1 routine is used only when 6 UNISERVOs are specified never with 4 or 5. Using the wrong routine will cause the generating routine to go into an endless loop. The modified 965-1 routine will produce a sorting routine with the following characteristics:

1. Only one data tape may be sorted.
2. All tapes are rewound without interlock after the sorting process except #1.
3. The first and second blocks of instructions following the sorting routine on the instruction tape are read into 000 - 059 and register I, respectively, after completing the sorting process. Control is transferrud to 000.
4. Any UNISERVO except #1 may be used for input or output.
5. Modifications have been made in the editing of the routine so that the description of the routine and operating instructions agree with the coding.

The following is a table of UNISERVO numbers and a designation on which cycle of operation the various UNISERVOs first start to operate.

Using Six UNISERVOs

Input Tape	Output Tape	1st Cycle Write	2nd Cycle Write
2	3	5 , 6	3 , 4
2	4	5 , 6	4 , 3
2	5	4 , 6	5 , 3
2	6	4 , 3	6 , 5
3	2	5 , 6	2 , 4
3	4	5 , 6	4 , 2
3	5	4 , 6	5 , 2
3	6	4 , 5	6 , 2
4	2	5 , 6	2 , 3
4	3	5 , 6	3 , 2
4	5	6 , 3	5 , 2
4	6	3 , 5	6 , 2
5	2	6 , 4	2 , 3
5	3	6 , 4	3 , 2
5	4	6 , 3	4 , 2
5	6	2 , 3	6 , 4
6	2	4 , 5	2 , 3
6	3	4 , 5	3 , 2
6	4	3 , 5	4 , 2
6	5	2 , 3	5 , 4

Sort Check Routine

A two block check routine tests the sequencing of data arranged by the sorting routine. The instruction tape is mounted on UNISERVO #1 and the sorted tape on the UNISERVO designated as the output UNISERVO from the sorting routine. When an error is detected the following information is printed on the Supervisory Control Printer:

"Error in Block XXXX".

If Conditional Transfer Breakpoint 1 is set, the computer will stop and allow the operator to chose whether to continue to detect any other irregularities in the sequence or rewind the UNISERVOs.

Operation of No Transfer switch will terminate the routine.

Operation of the transfer switch will cause the computer to continue examining the data. For each error detected, the block number will be printed, and the transfer switch must be actuated. Data being examined is stored in locations 500-559.

The Identification Block, if present, is bypassed without examination.

V Description of Methods used in 965-1 to Produce a Sorting Routine

The specifications for this problem were as follows: To program a routine which when used on the UNIVAC with a set of parameters would produce an efficient coding to arrange items from any number of tapes in series, into an ascending sequence within each tape, using only 4 or 5 UNISERVOs.

The item sizes chosen are those most frequently encountered, and those which represent an additional saving of tape (but not time of operation) such as 7, 8, and 14 word items. Item sizes 1 and 60 are not included because the most effieient method of operation is not the same for other item sizes.

Up to 60 digits (5 words) of key information is tolerated in order to handle the extreme cases of name and address files.

The speed of the collation routine is a function of the item size, and the position and number of key words. The use of the first full word of the item (without an extractor) as the key produces, generally, the fastest routine. Items involving 10 word transfers have no preference of key word. With items involving 2 word transfers, a key in the first word of any two word group has the same effect on time of operation as the first word of the item.

A generalized flow chart of the sorting process was first drawn, and from this, each subroutine was coded in relative coding, taking into account the various changes in the subroutines caused by the parameters. From the relative coding, it was determined that 99 specific constants are present in any sorting routine, although about 80 percent of these constants contain variable information stored within them. A maximum of 14 additional constants plus a function table of N values will exist. The fact that so many constants could be located in a fixed position at the beginning of the sorting routine in 000 - 098 solved one of the major problems of coding such a generating routine. This meant that over 30 percent of the sorting instructions to be coded could refer to known memory locations. The remaining addresses of instructions must be computed, using the parameter information or the position of the instruction word in relation to the rest of the sorting routine.

No complete flow chart of the Master Generating Routine process was made, although various subroutines such as editing of instruction words, and the all over master control of handling the effect of parameters upon the coding of the sorting routine was flow charted. Since the major process involved producing instruction words for the sorting routine a flow chart would be of little help.

During the process of using M.G.R. 965-1 to produce a sorting instruction tape, the instructions for sorting are built up in the memory in locations 000 - 579 (the actual final operating position of the routine). Since 131 blocks of instructions are required to generate and edit any specific sorting routine, the operating instructions are inserted into the memory a few blocks at a time, and executed in memory locations which are reserved for data in the final sorting routine (580 - 999). About 100 memory locations (900 - 999) hold information which is generated in the process of coding the sorting routine, and is the true "memory" of the operation. A large portion of the information stored, is the control counter reading of connector points, both fixed and variable, to facilitate the insertion of instruction words. The process of UNIVAC coding the sorting routine parallels a human coders method of leaving the memory location of an exit point in the coding blank, until the subroutine to which it must transfer has been coded, then supplying the appropriate memory location to the exit point.

M.G.R. 965-1 is a set of subroutines whose use is determined by the parameters entered with the problem. The insertion of each word of coding or constant in the sorting routine is performed by a basic subroutine which is stored constantly within the memory. The word is inserted in accordance with the current "sorting routine control counter" (999) and the counter increased by one. The sorting routine is completely coded using blocks 1 - 56 before the editing procedure (Blocks 57 - 127) and the sort check routine (Blocks 128 - 131) are initiated.

Each instruction supplied to the sorting routine may have one or more of the following characteristics:

1. No memory location expressed in the word [K 000 00 000] or a memory address fixed by known constants stored in locations 000 - 098. [B 016 A 018]
2. An instruction which is a function of the "current sorting control counter", such as fabricating a word in the current subroutine being coded into another location within the same subroutine. [A (cc-5) C (cc+2)]. (Take the current control counter subtract 5, add the control counter plus 2 add A 000 C 000 to create the required word.)
3. An instruction or constant which makes reference to another subroutine, which may, or may not, have been coded at the time the instruction is encountered. [C (^{o}A2) J (^{o}L1)] (Here, ^{o}A2 and ^{o}L1 are memory locations to which variable connectors are being supplied. If subroutine A2 and/or L1 have not been coded at this time, it is necessary to "remember" the control counter reading where the word of coding is placed, in order to supply the required memory locations at some future time.)
4. An instruction or constant which is a function of one of the parameters, such as tape instructions. [5Y 640 4B 700] (Y and B are tape numbers determined by the number of UNISERVOs used, and the input and output UNISERVOs designated in the parameters).
5. An instruction which contains the address of a constant which is not present in all collation routines.

Wherever possible the operational part of an instruction word has been predetermined to facilitate the coding of the problem. Under certain conditions of the parameters, half a word may be altered, such as supplying an Fm when an extractor is required. There is only one operation within the final coding which may not be pertinent to the code, and at most will operate only once per sorted tape. e.g. the contents of the F register are held in temporary storage during the partial block fill in, although the contents may not hold an extractor if the first key word is a complete word. All other operations coded are pertinent to the required result.

At the beginning of M.G.R. 965-1, the subroutine for increasing the "sorting control counter" and supplying the instruction fabricated into the desired location is read into the memory and stored in 580 - 599. The word "Date Today" is printed on the S.C.Printer. The operator then types in the date.

Memory locations 905 - 999 are cleared in readiness for holding future control information. The parameters for the problem are read from tape #2 and stored in 880 - 899. The first word is compared to ascertain whether the parameters are ones referring to problem 965-1. If by chance a tape not containing the word is mounted, tapes #1 and #2 are rewound and the following printed on the S.C.Printer. "Parameters not for problem 965-1".

The partially completed constants for the sorting routine, overflow routine, and read instructions are entered into 000 - 098.

From a 32 word function table the necessary tape numbers are determined using the parameters: number of UNISERVOs, input and output UNISERVOs. A pre-arranged pattern has been set up of the 32 choices, 12 for 4 UNISERVOs and 20 for 5 UNISERVOs. This table is reproduced in the report to aid the programmer.

A six block function table of data transfer relative coded instructions is read into the memory from 120 to 479. These blocks contain all the necessary information for coding the most efficient build up and transfer of data items, based upon the location of the first key, the use of an extractor, and the item size. A word containing the letter Z in the most significant position separates each data transfer set in the function table. The remaining 11 digits of this word contain the following information:

1. Item Size
2. The value of a special 2 digit constant required for this particular transfer set, if needed.
3. A code designating whether this set can be used (a) with or without an extractor, (b) no extractor only (c) with extractor only.
4. Which word of the item to accept as the first key word. A special code (00) designates that any word may be the key word (e.g. 10 word item)
5. The number of words of coding required in the build up and transfer of item.
6. A code designating whether this set requires none, either or both of the following constants (a) the key word minus the first word (b) 000002 000002
7. The starting location of the output transfer instructions. If the information is transferred to output storage not in numeric sequence because the key word is other than the first word, the starting location for transferring the first output item is not the beginning of the block.

The third digit of each instruction of the transfer set is coded to enable the modification of the associated memory location to fit the routine. The following codes are used:

0. The instruction is complete and do not modify the address part.
1. Supply the memory location associated with the storage of the special constant 000002 000002.
2. Add the current control counter to the existing address in the instruction.
3. Supply the memory location associated with the storage of the constant "Key word minus the first word".
4. Supply the memory location associated with the storage

of the constant, "Unusual constant". The value of this constant is determined by digits in the "Z word".

Twelve words, one for each item size, are stored at the end of the sixth block. The information is used for Internal Sorting and the words contain the following:

1. The instruction code letters required to execute the transfer of data, (B, C; V, W; Y, Z)
2. The numeric size of the transfer (1, 2, or 10 word)
3. The number of transfer instructions required.
4. The number of items per block.
5. The number of Ym, Zm instructions required to transfer the internal sorting function table for operation.
6. A code digit to facilitate the coding of the build up of transfer instructions. Four cases are represented:

   a. One Transfer (1,2,10 word items)
   b. Two Transfers (4,20 word items)
   c. Three Transfers (3,6,30 word items)
   d. Four Transfers or more (5,7,8,12,14 word items)

If four or more transfers are required, an additional code expresses the number of X000 Hm instruction words required in the build up of the transfer instructions. The appropriate transfer instructions and code words are located and stored in the memory for future use.

At this point all the information is available to supply the extra constants required. The Internal Sorting Function Table constants are generated and stored in the memory starting at 100. Any additional constants required in the transfer instructions are next supplied following the function table. Since the size of the function table varies with the item size, the memory location of constants stored following it, must be remembered.

The routine then determines from the parameters in which one of four general classifications the sorting main comparison will fall:

1. Single key word using no extractor
2. Split key using no extractor in first key
3. Single key word using an extractor
4. Split key using extractor in the first key

Classifications 2 and 4 are further examined to determine how many keys and whether they require extractors. All additional constants are stored during this process. The result of the various classifications is stored as variable connectors (900 - 903) to be supplied to the appropriate generating subroutine during the process of coding the sorting routine.

The sorting control counter is then advanced so that the coding will start in a memory location with the least significant digit a 3. The routine is then coded in a prearranged pattern starting with the External Sorting Write-Read subroutine (^{O}P) and ending with the Internal Sorting subroutine.

When the coding has been completed the 10 blocks allocated for the sorting routine are written on UNISERVO 4 at 20/in and the tape is rewound.

The editing procedure makes the necessary changes in six blocks of a pre-determined write up of the problem and operating instructions to comply with the parameters.

A two block subroutine is stored in the memory to handle the individual words to be edited. The routine counts the number of carriage returns applied and advances to a new page supplying the heading for the next page. The subroutine is entered from the main routine at seven different places depending upon the type of information to be edited:

1. Regular word of instruction-the sorting control counter and both halves of an instruction word are edited. The control counter is increased before editing.
2. Connector entry-the edited connector symbol is supplied by the main routine to the subroutine which enters it in the output block and procedes to edit the control counter and instruction word.
3. Inserted instruction word-variable connectors and substituted words are edited without advancing the control counter reading.
4. Dotted line-the dotted line precedes and follows the inserted words.
5. Long line-separates the connector entry points.
6. Word to count carriage returns-descriptive information which may contain a carriage return symbol.
7. Word with no carriage return-descriptive information which contains no carriage return symbol.

The basic editing words which contain the symbols for parenthesis, capitol letters and staggered or unstaggered format are supplied to the subroutine from the main routine prior to entering the subroutine. If more memory could have been allocated to the editing subroutine, the subroutine could have supplied the basic editing word.

The edited output is written on UNISERVO 3 as each block of output data is filled in the memory. (700 - 759)

The code check routine will contain constants and coding which are not used for the particular parameters listed. The last two blocks on the instruction tape is the basic sort check routine for five key operation. The parameters are used to modify this routine to fit the particular case, deleting and substituting the necessary instructions for operation. The two block routine is written on UNISERVO 5.

FEH:pdv

pencil comments by DEK may be faulty!

TWO WAY SORTING USING FIVE UNISERVOS
Six Word Item - Four Keys

First key	Word 3	Extractor	000001 100000
Second key	Word 2	Extractor	111000 000000
Third key	Word 5	Extractor	(None)
Fourth key	Word 1	Extractor	000111 000000

Identification Block on input and output tape.
Routine commences from Initial Read.
End of Input Tape Sentinel is zzzzzz zzzzzz and appears
in word 59 of the block and word 00 following the last item.
End of Output Tape Sentinel and block fill in is zzzzzz z-sort.

Internal Sorting - The process to arrange information within each block is performed by successive comparisons and the data is written on two tapes.
The input data is stored in memory locations 580 - 639.
The sorted data is stored in memory locations 940 - 999.

External Sorting - Follows Internal Sorting automatically after the first tape pass, reading the tapes in a backward direction. The process to arrange information on the tape is performed by building up the number of sorted blocks by powers of two until all of the information is arranged in an ascending series. This is accomplished by alternating ascending and descending sorting on alternate tape passes of the data. The routine eliminates the Tape Read Interlock by controlling tape read instructions from tape write instructions.

Memory allocation for External Sorting

Instructions	000 - 579 (10 blocks)	
Output block	940 - 999	
	Tape A	Tape B
Input	580 - 639	640 - 699
1st Auxiliary	700 - 759	820 - 879
2nd Auxiliary	760 - 819	880 - 939

The initial data tape is read in a forward direction and any number of tapes may be sorted in succession by mounting tapes on the initial data UNISERVO.

Flow Chart number 965-1 is associated with this routine.

The coding of this routine has been performed by the UNIVAC from Master Generating Routine 965-1. This edited copy has been prepared by the UNIVAC and printed on the UNIPRINTER.

Operating Instructions for

Two Way Sorting Using Five Uniservos
Six Word Item - Four Keys

Supervisory Control Printer is set to Normal.
No Conditional Transfer Breakpoints are set.

Instructions	UNISERVO 1
Data tape	UNISERVO 3
Blank tape	UNISERVO 4
Blank tape	UNISERVO 5
Blank tape	UNISERVO 2
Blank tape	UNISERVO 1 after reading instructions

Sorted data will be on UNISERVO 2.

Initial Read 1.

Any number of tapes may be sorted in succession by placing each data tape on the original data tape UNISERVO. The process is terminated after any completely sorted tape by setting Conditional Transfer Breakpoint 1 after starting the last tape or by the failure to mount a new data tape. All tapes will be rewound.

Errors.- The number of blocks written on each cycle of the operation is compared with the original number of blocks on the input tape. If through a computer read or write error or manual intervention this test is not met, all tapes are rewound and the following word is printed "error sort". To initiate the procedure, the instructions must be read into the computer again.

Errors.- To rewind all tapes after a computer failure, clear the Control Counter and skip (do not execute) 000. Rewind instructions are located in 001-003, followed by a stop instruction.

CODING

```
o 1     000   (11 000
                          31 060)   INSTRUCTIONS TO MEMORY
        001   (31 120
                          31 180)
        002   (31 240
                          31 300)
        003   (31 360
                          31 420)
        004   (31 480
                          30 540)
        005   (V  010
                          W  000)
        006   (V  012
                          W  002)
        007   (81 000
                          F  009)
        008   (G  004
                          U  348)   TO INTERNAL SORTING  o 3
- - - - - - - - - - - - - - - - - -

        009   (910000     911111)

        010   (R  016     U  014)

        011   (61 000     62 000)

        012   (00 000     64 000)

        013   (65 000     90 000)
      ••••••••••••••••••••••••••
      #000    R  016      U  014    OVERFLOW
      #001    61 000      62 000
      #002    00 000      64 000
      #003    65 000      90 000
      #004    91000       911111    INSTRUCTION EXTRACTOR
      #005   (000000      000000)   U     STRING A COUNTER
      #006   (000000      000000)   V     STRING B COUNTER
      #007   (000000      000000)   S     STRING X COUNTER
      #008   (000000      000000)   F     COUNTS BLOCKS ON INPUT TAPE
      #009   (000000      000000)   T     STRING Y COUNTER      also "J"
      #010   (000000      000000)   H     CYCLE COUNTER
      #011   (000000      000000)   R     NO. OF BLOCKS IN STRING
      #012   (000000      00000)    2R
      #013   (000000      000000)   STORAGE
      ••••••••••••••••••••••••••
        014   B  016
                          A  018    OVERFLOW CONTROL
        015   C  016
                          00 000
        016   (00 000
                          U  xxx)

        017    000001     000001

        018    000000     000001

        019    000001     000000
```

```
020    000010    000010
021    000006    000001
022    001000    000006
023    000994    000000
024    000000    000006
025   (Y  880    U  180)    Z PLUS 1
026   (54 940    L  012)    TAPE A
027   (55 940    L  012)    TAPE B
028   (52 940    L  012)    TAPE X
029   (51 940    L  012)    TAPE Y
030   (V90000    W  942)    M  OUTPUT ITEM COUNTER
031   (E90696    T  187)    Y  ITEM B RESET
032   (E90636    K  000)    X  ITEM A RESET
033    54 940    B  034     •W1
034    55 940    B  033     •W2
035    ZZZZZZ    Z-SORT     S  OUTPUT SENTINEL
036    ZZZZZZ    ZZZZZZ     S' INPUT SENTINEL
037    ••••••    ••••••     S" INTERMEDIATE SENTINEL
038    45 760    B  018     Tape B
039    41 760    B  018     Tape Y
040   (44 580    Q  308)    040-049 ASCENDING SERIES RESET
041    C  010    F  004
042    52 640    52 640
043    52 640    44 580
044    51 640    45 700
045    51 640    51 640
046    45 640    44 820
047    F  113    K  000
```

```
048   E90636   K  000
049   E90696   T  187
050   42 580   Q  314     050-059 DESCENDING SERIES RESET
051   C  010   F  004
052   54 640   54 640
053   54 640   42 580
054   55 640   41 700
055   55 640   55 640
056   41 640   42 820
057   F  113   K  000
058   E90636   K  000
059   E90696   T  152
060   RERROR    SORTR
061   L  011   Q  243     .RA0
062   L  011   Q  247     .RA1
063   L  037   Q  259     .SA0
064   C  148   U  147     .A2A
065   C  148   U  187     .A2B
066   C  005   U  147     .A3A
067   C  005   U  187     .A3B
068   L  011   Q  251     .RB0
069   L  011   Q  255     .RB1
070   L  037   Q  261     .SB0
071   L  037   Q  263     .16, .SB1, .SA1
072   C  149   U  147     .B2A
073   C  149   U  152     .B2B
074   C  006   U  147     .B3A
075   C  006   U  152     .B3B
```

```
076   Y  700     Z  580      ∘L1A
077   Y  820     Z  640      ∘L2A
078   Y  760     U  215      ∘L1B
079   Y  880     U  180      •L2B
080   F  113     K  000      •14A
081   F  113     U  261      •14B
082   V  026     B  029      •17A
083   30 640     U  302      •17B
084   Y  050     F  039      •18A
085   C  151     U  299      •18B
086   A  007     Q  132
087   C  007     B  025
088   A  009     Q  136
089   C  009     B  025
090   C  421     U  362      •7A
091   E  582     L  699
092   C  010     U  370
093   000000     000005
094   C  010     U  435      a patch?
095   B  586     Q  453
096  (000000     000000)     H BLOCK COUNTER ON EXTERNAL CYCLES
097   V90000     W  942      M OUTPUT ITEM RESET
098   G  640     B  456
099   111111     111111
100   V  580     W  994      INTERNAL SORTING FUNCTION TABLE
101   V  586     W  988
102   V  592     W  982
103   V  598     W  976
```

```
        104    V  604     W  970
        105    V  610     W  964
        106    V  616     W  958
        107    V  622     W  952
        108    V  628     W  946
        109    V  634     W  940
        110    000004     000004
        111    000002     000002
        112    00 000     U  187
        113    000001     100000
        114    00 000     U  152
        115    -00001     000000
        116    111000     000000
        117    000003     000000
        118    -00004     000000
        119    000111     000000
        120    000000     000000
        121    000000     000000
        122    000000     000000
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o P     123    B  096
                          A  018        ADD 1 TO H
        124    C  096
                          00 000
        125    B  097
                          C  030        RESET OUTPUT ITEM COUNTER   M
        126    (52 940                  ← initial setting (inst 350)
                Type X    L  012)       WRITE OUTPUT BLOCK
       ○○○○○○○○○○○○○○○○○○○○○○
       #126    51 940 Type Y L  012
       #126    54 940 Type A L  012
       #126    55 940 Type B L  012
       ○○○○○○○○○○○○○○○○○○○○○○
        127    (45 960                  init setg.
                          B  018)       READ INPUT BLOCK
       ○○○○○○○○○○○○○○○○○○○○○○
       #127    45 830     B  018
```

```
         #127    45 880   B  018
         #127    45 700   B  018
         #127    44 760   B  018
         #127    44 820   B  018
         #127    44 880   B  018
         #127    44 700   B  018
         #127    41 760   B  018
         #127    41 820   B  018
         #127    41 880   B  018
         #127    41 700   B  018
         #127    42 760   B  018
         #127    42 820   B  018
         #127    42 880   B  018
         #127    42 700   B  018
         ••••••••••••••••••••••
          128   (A   007
                          Q  132)    s PLUS 1 : 2R
          129   (C   007
                          B  025)    INCREASE s
         ••••••••••••••••••••••
         #128    A   009  Q  136     T PLUS 1 : 2R
         #129    C   009  B  025     INCREASE T
         ••••••••••••••••••••••
          130    E   127
                          C  127    (z PLUS 1) TO Z   ← means address of next block to input.
          131   (00 000
                          U  xxx)    TO  o A1 OR o B1
         - - - - - - - - - - - - - -
          132    V   088
                          B  029     .P2
          133    C   126
                          W  128
          134    C   007
                          C  009     CLEAR s, T
          135    B   025
                          U  130
         - - - - - - - - - - - - - -
          136    V   086
                         00 000      .P1
          137    B   028
                          U  133
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o 13      138    K   000
                          K  111
          139    B   010
                          S  018
          140   (44  580
                          Q  308)    H - 1 : 0  ASCENDING SORTING
          141   (C   010
                          F  004)
          142   (52  640
                         52 640)     TAPE A TO A, C
          143   (52  640
                         44 580)     TAPE B TO B, D
          144   (51  640
                         45 700)     TAPE A TO R1
         145  (51 640
                          51 640)   3 SENTINEL BLOCKS TO TAPE X, Y
         146  (45 640
                          44 820)
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o Q1     147  (F  113
                          K  000)   EXTRACTOR
         148  (E90636
                          K  000)
         149  (E90696
                          T  187)   (B) : (A)
        ••••••••••••••••••••••
        #140   42 580    Q  314     DESCENDING SORTING  o Q2
        #141   C  010    F  004
        #142   54 640    54 640
        #143   54 640    42 580
        #144   55 640    41 700
        #145   55 640    55 640
        #146   41 640    42 820
        #147   F  113    K  000
        #148   E90636    K  000
        #149   E90696    T  152
        ••••••••••••••••••••••
         150   00 000
                         Q  222     TO SPLIT KEY  o 23
         151  (00 000
                         00 000)
        ••••••••••••••••••••••
        #151   00 000    U  187
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o B0     152   B  149
                         F  004     TRANSFER ITEM B TO OUTPUT BLOCK
         153   E  030
                         H  157
         154   A  111
                         H  158
         155   S  110
                         C  156
         156  (V  000
                         W  000)
         157  (V  000
                         W  000)
         158  (V  000
                         W  000)
         159   B  030          001[illegible]06
                         A  022     OUTPUT OVERFLOW CONTROL  M PLUS 1 : N
         160   C  030
                         U  162     M PLUS 1 TO M
        - - - - - - - - - - - - - - -
         161   R  131
                         U  123     TRANSFER TO PRINT SEQUENCE  o P
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o B1     162   B  149
                         A  023 (-6)  ITEM B OVERFLOW CONTROL  Y PLUS 1 : N
o B2A    163  (C  149
                         U  147)    TRANSFER TO MAIN COMPARISON SEQUENCE  o Q
        ••••••••••••••••••••••
```

```
o B2B   #163   C  149   U  152    TRANSFER TO  o B0
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o L2     164   B  031
                         C  149    RESET ITEM B COUNTER
o L2A    165  (Y  820
                         Z  640)
        ••••••••••••••••••••••••
        #165   Y  880    U  180    TRANSFER TO  o L2B
        ••••••••••••••••••••••••
         166   Y  830
                         Z  650    DATA IN D TO B
         167   Y  840
                         Z  660
         168   Y  850
                         Z  670
         169   Y  860
                         Z  680
         170   Y  870
                         Z  690
         171   B  077
                         L  079    Z PLUS 1 EQUALS D   •L2B
         172   C  025
                         J  165
         173   F  001
                         B  127
         174   E  027
                         C  127    TAPE K IS TAPE B
         175   B  640
                         F  004
o SB     176  (L  037
                         Q  261)   (B0) : S" TO  o SB0
        ••••••••••••••••••••••••
        #176   L  037    Q  263    o SB1
        ••••••••••••••••••••••••
         177   B  006
                         A  018
o RB     178  (L  011
                         Q  251)   V PLUS 1 : R   TO o RB0
        ••••••••••••••••••••••••
        #178   L  011    Q  255    o RB1
        ••••••••••••••••••••••••
o B3A    179  (C  006
                         U  147)   TRANSFER TO MAIN COMPARISON SEQUENCE  o Q
        ••••••••••••••••••••••••
o B3B   #179   C  006    U  152    TRANSFER TO  o B0
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o L2B    180   Z  640
                         Y  890    DATA IN F TO B
         181   Z  650
                         Y  900
         182   Z  660
                         Y  910
         183   Z  670
                         Y  920
         184   Z  680
                         Y  930
```

```
          185   Z  690
                         B  079     Z PLUS 1 EQUALS F    .L2A
          186   L  077
                         U  172
------------------------------------------------------------------
o A0      187   B  148
                         F  004     TRANSFER ITEM A TO OUTPUT BLOCK
          188   E  030
                         H  192
          189   A  111
                         H  193
          190   S  110
                         C  191
          191  (V  000
                         W  000)
          192  (V  000
                         W  000)
          193  (V  000
                         W  000)
          194   B  030
                         A  022     OUTPUT OVERFLOW CONTROL  M PLUS 1 : N
          195   C  030
                         U  197     M PLUS 1 TO M
          ------------------------
          196   R  131
                         U  123     TRANSFER TO PRINT SEQUENCE  o P
------------------------------------------------------------------
o A1      197   B  148
                         A  023     ITEM A OVERFLOW CONTROL  X PLUS 1 : N
o A2A     198  (C  148
                         U  147)    TRANSFER TO MAIN COMPARISON SEQUENCE  o Q
          ••••••••••••••••••••••••
o A2B    #198   C  148   U  187     TRANSFER TO  o A0
------------------------------------------------------------------
o L1      199   B  032
                         C  148     RESET ITEM A COUNTER
o L1A     200  (Y  700
                         Z  580)
          ••••••••••••••••••••••••
         #200   Y  760   U  215     TRANSFER TO  o L1B
          ••••••••••••••••••••••••
          201   Y  710
                         Z  590     DATA IN C TO A
          202   Y  720
                         Z  600
          203   Y  730
                         Z  610
          204   Y  740
                         Z  620
          205   Y  750
                         Z  630
          206   B  076
                         L  078     Z PLUS 1 EQUALS C    .L1B
          207   C  025
                         J  200
          208   F  001
                         B  127
```

```
                209   E  026
                              C  127     TAPE K IS TAPE A
                210   B  580
                              F  004
o SA            211  (L  037
                              Q  259)    (A0) : S* TO o SA0
                •••••••••••••••••••••
               #211   L  037  Q  263     o SA1
                •••••••••••••••••••••
                212   B  005
                              A  018
o RA            213  (L  011
                              Q  243)    U PLUS 1 : R   TO o RA0
                •••••••••••••••••••••
               #213   L  011  Q  247     o RA1
               #213   00 000  00 000     o RA2
                •••••••••••••••••••••
o A3A           214  (C  005
                              U  147)    TRANSFER TO MAIN COMPARISON SEQUENCE  o Q
                •••••••••••••••••••••
o A3B          #214   C  005  U  187     TRANSFER TO  o A0
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o L1B           215   Z  580
                              Y  770     DATA IN E TO A
                216   Z  590
                              Y  780
                217   Z  600
                              Y  790
                218   Z  610
                              Y  800
                219   Z  620
                              Y  810
                220   Z  630
                              B  078     Z PLUS 1 EQUALS E   oL1A
                221   L  076
                              U  207
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o 23            222   B  148
                              A  115     SPLIT KEY FOR EXTERNAL SORTING
                223   C  226
                              X  000
                224   A  149
                              C  227
                225   F  116
                              00 000
                226  (E  635
                              K  000)
                227  (E  695
                              T  187)    SECOND KEY
                228   F  099
                              Q  230
                229  (00 000
                              U  152)
                •••••••••••••••••••••
               #229   00 000  U  187
                •••••••••••••••••••••
```

```
        230   B   226
                        A   117
        231   C   233
                        X   000
        232   A   227
                        C   234
        233  (E   638
                        K   000)
        234  (E   698
                        T   187)     THIRD KEY
        235   F   119
                        Q   237
        236   00  000
                        U   229
        237   B   233
                        A   118
        238   C   240
                        X   000
        239   A   234
                        C   241
        240  (E   634
                        K   000)
        241  (E   694
                        T   187)     FOURTH KEY
        242   00  000
                        U   229
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o RA0   243   B   069
                        C   178      •RB1
        244   C   005
                        B   073      •B2B  U EQUALS ZERO
        245   C   163
                        B   075      •B3B
        246   C   179
                        U   152      TRANSFER TO  o B0
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o RA1   247   B   064
                        L   066
        248   C   198
                        J   214      •A2A •A3A
        249   B   061
                        C   213      •RA0
        250   C   005
                        U   147      U EQUALS ZERO  TRANSFER TO  o Q
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o RB0   251   B   062
                        C   213      •RA1
        252   C   006
                        B   065      V EQUALS ZERO   •A2B
        253   C   198
                        B   067      •A3B
        254   C   214
                        U   187      TRANSFER TO  o A0
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o RB1   255   B   072
                        L   074
```

```
          256   C   163
                          J   179     oB2A oB3A
          257   B   068
                          C   178     oRB0
          258   C   006
                          U   147     V EQUALS ZERO  TRANSFER TO  O Q
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o SA0     259   B   071
                          C   176     oSB1
          260   B   073
                          U   245
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o SB0     261   B   071
                          C   211     oSA1
          262   C   213
                          U   252     oRA2
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o 16      263   B   096
                          L   008     ALSO O SA1  O SB1
          264   V   086
                          Q   266     F : H
o 22      265   50  060
                          U   001     ERROR IN NO. OF BLOCKS
          266   B   072
                          L   077
          267   C   163
                          J   165     oB2A oL2A
          268   B   068
                          L   070
          269   J   176
                          C   178     oSB0 oRB0
          270   B   064
                          L   076
          271   C   198
                          J   200     oA2A oL1A
          272   B   061
                          L   063
          273   J   211
                          C   213     oSA0 oRA0
          274   B   066
                          C   214     oA3A
          275   B   074
                          C   179     oB3A
          276   B   079
                          C   025     Z PLUS 1 EQUALS F
          277   W   128
                          C   096     H EQUALS ZERO
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o 17A     278   (V  026
                          B   029)
        ooooooooooooooooooooooooo
        #278    30 640    U   302     TRANSFER TO O 17B
        ooooooooooooooooooooooooo
          279   L   028
                          W   028     ALTERNATE INPUT AND OUTPUT TAPES
          280   C   027
                          J   035
```

```
              281   B   028
                                C   126     .P1
    o 18A     282  (Y   050
                                F   039)    .Q2 .13B
              ••••••••••••••••••••••••
             #282   C   151     U   299     TRANSFER TO o 18B
              ••••••••••••••••••••••••
              283   B   112
                                H   229
              284   C   151
                                B   085     .18B
              285   Z   140
                                C   282
              286   G   127
                                B   148
              287   C   032
                                B   149     RESET X, Y
              288   C   031
                                K   000
              289   S   009
                                Q   293     T : 0
              290   A   012
                                H   007     2R - T TO S
              291   C   006
                                C   009     2R - T TO V, ZERO TO T
              292   C   005
                                U   296     ZERO TO U
              293   S   007
                                Q   291     S : 0
              294   A   012
                                H   005     2R - S TO U
              295   C   007
                                C   006     2R - S TO S, ZERO TO V
              296   B   012
                                H   011     2R TO R
              297   X   000
                                C   012     4R TO 2R
              298   00  000
                                U   138     TRANSFER TO  o 13
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    o 18B     299   B   114
                                C   229
              300   Y   040
                                F   038     .Q1  .13A
              301   B   084
                                U   285     .18A
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    o 17B     302   B   035
                                H   699     SUPPLY OUTPUT SENTINEL
              303   C   640
                                52  640
              304   52  640
                                52  640     WRITE 3 SENTINEL BLOCKS
              305   64  000
                                65  000     REWIND TAPES
              306   61  000
                                82  000
```

```
               B 080
        307    00 000
                         U 347     TRANSFER TO  O 2, NEW DATA TAPE
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
O 20    308    62 000
                         B 083
        309    44 580
                         C 278     .17B
        310    00 000
                         45 700
        311    B  013
                         C 640     RESET FIRST WORD OF IDENT. BLOCK
        312    72 640
                         00 000    WRITE IDENT. BLOCK
        313    F  004
                         U 146
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
O 21    314    B  081
                         C 047     .14B
        315    F  004
                         U 142
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
O 12    316    B  438
                         F 004  = 91000 91111   SPLIT KEY FOR INTERNAL SORTING
        317    E  325
                         H 329
        318    A  115  - 00001 0—0
                         C 325
        319    B  330
                         ;6 000    shift left 6.
        320    S  017
                         E 322
        321    C  322
                         00 000
        322    (B xxx
                         H 011)
        323    A  115
                         E 326
        324    C  326
                         F 116
        325    (E 581              where initialized??
                         K 000)
        326    (E 587
                         T 331)    SECOND KEY
        327    F  099  1—1
                         Q 334
        328    F  113  0—011—0
                         K 000
        329    (E 582
                         K 000)
        330    (00 000
                         U xxx)    exit from subroutine.
        331    F  138
                         B 330
        332    E  011  ← [illegible]
                         C 330
        333    F  113
                         U 329
        334   B  325     A  117
        335   C  337     X  000
        336   A  326     C  338
        337  (E  584     K  000)
        338  (E  590     T  331)    THIRD KEY
        339   F  119     Q  341
        340   00 000     U  328
        341   B  337     A  118
        342   C  344     X  000
        343   A  338     C  345
        344  (E  580     K  000)
        345  (E  586     T  331)    FOURTH KEY
        346   00 000     U  328
- - - - - - - K 088 - - - - - - - - - - - - - - - - - - - - -
0 2     347  ~~C 097~~
                         Q1 348     BREAKPOINT STOP       INTERNAL SORTING
0 3     348   B  090     C  422     .7A
        349   B  033     C  421     .W1
        350   B  028     C  126     .P1
        351   B  038     C  127     TAPE K IS TAPE B
        352   B  080     H  047
        353   C  147     B  082     .14A
        354   C  278     C  008     .17A  F EQUALS ZERO
        355   13 000     30 640     HOLD FIRST WORD OF
        356   B  640     C  013     IDENTIFIOATION BLOOK
        357   B  037     C  640     INTERMEDIATE SENTINEL
                                     ? I don't know UNIVAC code... seems to be two I registers
        358   13 000     54 640     TAPE A TO RI
        359   54 640     54 640     3 SENTINEL BLOOKS TO TAPE X, Y
        360   55 640     55 640
        361   55 640     F  113     EXTRAOTOR
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```

```
o 4    362   33 550   L  036    READ INPUT BLOCK
                                input sentinel 5'
       363   B  639   Q  447    (A59) : S8    if = go to ending routine
o 5    364   B  008   A  018    F PLUS 1 TO F
       365   C  008   C  010    ZERO TO J
       366   B  091   C  438    GX IS G1
       367   B  092   C  446    oN2
       368   Y  100   Z  700    SET FUNCTION TABLE
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o N1   369   E  582   K  000    } word 3 of first record. [illegible] → [illegible]
o N2   370   E  588   T  375      2nd record.
                                if >, to 375
       371   R  330   Q  316    } to subroutine 012 if =
       372   B  701 = 'V586 W988'
                      A  024 = 6 (record size)
       373   C  701   X  000    }
       374   A  010   C  010    } J + (X) → J
o N3   375   E  594   T  380
       376   R  330   Q  316
       377   B  702   A  024
       378   C  702   X  000
       379   A  010   C  010
o N4   380   E  600   T  385
       381   R  330   Q  316
       382   B  703   A  024
       383   C  703   X  000
       384   A  010   C  010
o N5   385   E  606   T  390
       386   R  330   Q  316
       387   B  704   A  024
       388   C  704   X  000
       389   A  010   C  010
```

```
o N6    390   E 612   T 395
        391   R 330   Q 316
        392   B 705   A 024
        393   C 705   X 000
        394   A 010   C 010
o N7    395   E 618   T 400
        396   R 330   Q 316
        397   B 706   A 024
        398   C 706   X 000
        399   A 010   C 010
o N8    400   E 624   T 405
        401   R 330   Q 316
        402   B 707   A 024
        403   C 707   X 000
        404   A 010   C 010
o N9    405   E 630   T 410
        406   R 330   Q 316
        407   B 708   A 024
        408   C 708   X 000
        409   A 010   C 010
o N10   410   E 636   T 435
        411   R 330   Q 316
        412   B 709   A 024
        413   C 709   X 000
        414   A 010   U 094     = C 010  u435
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o N11   415   B 709   H 418     TRANSFER LAST ITEM TO OUTPUT BLOCK
        416   A 111   H 419
        417   X 000   C 420
        418  (V  000
                        W  000)
        419  (V  000
                        W  000)
        420  (V  000
                        W  000)
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o W1    421  (54 940                  ← initial setting   (and 349)
                        B  034)   •W2   WRITE SORTED BLOCK
        •••••••••••••••••••
o W2    #421  55 940    B  033    •W1   WRITE SORTED BLOCK
        ••••••••••••••••••••••        ← initial setting   (378)
o 7A    422  (C  421
                        U  362)   TRANSFER TO  o 4
        •••••••••••••••••••••••
o 7B    #422  00 000    00 000    ← "P" in lines 429, 434
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o S     423   L  096
                        B  008
        424   S  018
                        Q  461    F - 1 : 0
        425   K  000
                        C  005
        426   C  006
                        C  010
        427   C  007
                        C  009    ZERO TO U, V, H, S, T
        428   B  018
                        H  011    R EQUALS 1
        429   H  422
                        X  000    P EQUALS 1
        430   C  012
                        00 000    2R
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o 11    431   B  010
                        A  018    H PLUS 1 TO H
        432   C  010
                        B  422
        433   X  000                            2^H ≥ F
                        T  138    2P : F - 1  TO EXTERNAL SORTING  o 13
        434   C  422
                        U  431    2P TO P
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o 6     435   B  446
                        A  093 5  o N PLUS 1 TO o N
        436   C  446
                        B  438
        437   A  021  000006 000001
                        C  438
        438  (E  582              init at 366
                        L  699)   NEXT ITEM
        439   K  000
                        X  000
        440   S  010
                        H  443    CURRENT ITEM TO OUTPUT BLOCK
        441   A  111           [illegible]
                        H  444
```

```
          442  X   000
                          C  445
          443  (V  000
                          W  000)
          444  (V  000
                          W  000)
          445  (V  000
                          W  000)                end at 367
          446  (C  010
                          U  370)   TRANSFER TO · O N
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
o 8       447   83 000
                          G  010    REWIND DATA TAPE
          448  B   580
                          Q  423    TRANSFER IF NO PARTIAL BLOCK
          449  B   095
                          C  450
o 9       450  (B  586
                          Q  453)   LOCATE SENTINEL
          451  B   450
                          A  019
          452  C   450
                          U  450
          453  B   450
                          F  004
          454  E   456
                          C  456
          455  F   035
                          L  098
o 10      456  (G  XXX
                          B  456)   FILL IN PARTIAL BLOCK  with without sentinels
          457  A   019                                      (will probably cause
                          Q  459                             trouble with certain
          458  C   456                                       fields used as extractors
                          U  456                            since "Z-SORT" appears.
          459  F   010
                          K  000
          460  C   422
                          U  364·   o7B  TRANSFER TO  O 5
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
          461  B   081
                          C  147    •14B
          462   00 000
                          U  308    TRANSFER TO  O 20
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     MEMORY LOCATIONS 463 - 579 UNUSED
```

INTERNAL AND 2 WAY EXTERNAL SORTING USING FOUR OR FIVE UNISERVOS - TAPE INTERLOCK ELIMINATED

Key Digits - From 1 to 5 Comparisons (or words) With or Without Extraction

∴ Q word = Q1
x=0 y=0 m=0 h=0 .Q1 .A2a .A3a .B2a .B3a .SA0 .SB0 .RA0 .RB0 .18a .L1a .L2a Tk=TB Z=E 13a Z+1=F
Initial Read
Read Inst. to Memory From Tape 1, Rewind Tape 1 With Interlock
Internal Sorting
Condition Transfer Breakpoint "1"
Set
STOP
Not Set
.7a .14a .P1 .17a .W1 f=0 Tk=TB
TA → rI (rI) → J forward
TA → rI Forward
Write 3 Sentinal Blocks(S") on TX, TY
(rI) → A TA → rI forward
(A59):S'
f+1 → f (g1)…(gn)=0 g1=gx n=1 j=0 Ax=A0 .N2
Comparisons For One Less Than The Number of Items Per Block Repeat As N3 To N4
W1 Write [G0…59] → TX
W2 Write [G0…59] → TY
Rewind TA With Interlock
Second Key
Third Key
Fourth Key
Fifth Key
Split Key
H=0 P=1 R=1 2R=2 s=0 t=0 u=0 v=0
H+1 → H
2p:f-1
2p → p
TX = TA TY = TB
Ascending External Sorting
H-1:0
H-1 → H
Write 3 Sentinel Block(S") on TX and TY
Read Backward TA → A, C TB → B, D TA → rI
Descending External Sorting
Write 3 Sentinel Block(S") on TX and TY
Read Backward TA → A, C TB → B, D TA → rI
h:f
.RA0 .L1a .RB0 .L2a .SA0 Z=E .SB0 Z+1=F .A2a h=0 .A3a .B2a .B3a
Write 3 Sentinel Blocks(S) on TX Rewind TX with Interlock Rewind TA, TB, TY without Interlock
.Q2 .13b .P1 .18b TX=TA TY=TB TA=TX TB=TY TK=TB
.Q1 .13a .P1 .18a TX=TA, TK=TB TY=TA TA=TX TB=TY
2R-s:2R
2R-t:2R
t=0 2R → R 4R → 2R
Rewind TX Without Interlock
.17b
Write (J) → TX 20/in
Read Backward TA → A, C TB → B, D TA → rI
.14b
Rewind TA, TB TX, TY Print on S.C. Printer "Sort Error"
STOP
Write [G0…59] TX
Write [G0…59] TY
(rI) → Z TK → rI
s+1:2R
t+1:2R
P2, s=0
P1, t=0
Z+1 → Z h+1 → h
m+1:N
m+1 → m
m=0 .19a
m=0 .19b
x+1:N
x=0
y+1:N
y=0
Z+1=C .L1b
Z+1=E .L1a
Z+1=D .L2b
Z+1=F .L2a
TK=TA
TK=TB
(A0):S"
(B0):S"
u+1:R
u+1 → u
v+1:R
v+1 → v
.SB1 .B2b .B3b
.RB1 .B2b .B3b u=0
.RA0 .A2a .A3a u=0
.RA2 .SA1 .A2b .A3b
.RA1 .A2b .A3b V=0
.RB0 .B2a .B3a V=0

A Storage for one block of data from Tape A, and current location in block
B Storage for one block of data from Tape B, and current location in block
C Storage for one block of auxiliary date from Tape A
D Storage for one block of auxiliary data from Tape B
E Storage for one block of auxiliary data from Tape A
F Storage for one block of auxiliary data from Tape B
G Storage for one block sorted data
H Number of cycles to completely sort data
J Storage for tape identification information
N Number of items per block
R Number of blocks from one input tape to be sorted in current string
S End of tape sentinel for sorted data, and fill in
S' End of tape sentinel on input tape
S" Intermediate Sentinel
T Tape (subscripted 1, A, B, X, Y)
T_1 Instruction tape
T_k Current input tape
X First output tape subscript
Y Second output Tape subscript

Z Address of data currently stored in rI
Z+1 Address of data next to be stored in rI

a First key digits (or word) ∴ First word of item a=1
b Second key digits (or word)
c Third key digits (or word)
b Fourth key digits (or word)
e Fifth key digits (or word)
f Counts number of data blocks on input tape
g Counter which indicates relative position of input item in output block
gx Counter for item currently under consideration
h Counts no. of blocks on external cycles
j Counter which indicates the number of items of less magnitude then the current one
m Counts the number of items in G
n Counts the number of items being sorted on internal sorting
p Power of 2 to determine H
q Counter for block fillin on internal sorting
r Subscript for current item compared on internal sorting split key
s Counts number of blocks per string on first output tape

t Counts number of blocks per string on second output tape
u Counts number of blocks per string sorted from Tape A
v Counts number of blocks per string sorted from Tape B
x Counts number of items sorted from block A
y Counts number of items sorted from block B
Σ Number of words per item
[- - -] Optional operations

Note: The input tape Sentinel may be in some location other than A0 and A59. Locations are specified in the Parameters for a specific routine.

C A 5-451 (500-451)

REMINGTON RAND INC.

INTERNAL AND 2 WAY EXTERNAL SORTING USING 4 OR 5 UNISERVOS - TAPE INTERLOCK ELIMINATED 965-1			
DRAWN RODI	CHK H.A. NIDECKER	PROG F.E. HOLBERTON	DATE 6-11-52

tape codes

A	4	input A 530 ff	input B 640
B	3	aux A 700	820
X	2	Dour A 760	880
Y	1	output 940	

UNIVAC code.

A	add	
-B	load A	
-C	store A and clear.	
D	divide	
E	extract	
F	load F	
G	store F	
-H	store A and hold	
I	store L	
J	Store X	
K	clear A to L	
L	Load L	
M	Multiply	
N	Neg multiply	
O	~~[illegible] multiply~~	not used?
P	Pre multiply	
Q	Transfer equal	
R	Read out	
S	Subtract	
T	Transfer greater.	
U	[illegible] jump	
V	Load V	2-wd register
W	Store V	
X	Add X	
Y	Load Y	10-wd register
Z	Store Y	
0		
-1 t	read tape t → I forward	
	backward.	
2	[illegible] I → in forward	
-3	backward	
4		
-5 t	write m → I, t high density	
6	rewind	
7	write low density	
8	rewind with lock	
9	hold	
	alph shift right	
•	, , left	
;	num , ,	
-		
0	, , 2d	
,	breakpoint.	
φ	skip	

10 keyboard

30 store I

50 Type