1410/7010 Operating System Timing Report

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PREFACE

A. This report contains timings of the various program systems within the 1410/7010 Operating System and is being made to disseminate the timing information on the Operating System that has been accumulated to date. In addition, this report will demonstrate the type of information that can be obtained by use of tools now available through the Evaluation Technology Department. By publishing this report, we hope to exchange ideas of what type of information is required by users and to solicit suggestions that will help Evaluation Technology improve current evaluation tools and aid us in the design and development of new tools.

B. All information was obtained by running Programming Systems jobs on the 7010 and obtaining output on the Program Monitor device installed in the Bldg. 705 Computing Center. A description of the device and programs necessary to analyze the output of the Program Monitor will be available through the Evaluation Technology Department. Timing results of individual tests are accurate to .1 ms. due to hardware and program limitations. More accurate results are averages of a number of individual test cases. If more detailed data is desired about any of the tests described in this report, it is available through Evaluation Technology.

C. The 1410/7010 Operating System master file, to generate the System Operating File (SOF) used for all jobs analyzed, was the final Beta Test version, M43. The SOF was generated with the following features, and these should be kept in mind when looking at any timing results of the Monitor System itself:

1. Operating System - Tape A0
2. Standard Input Unit - 1402 Card Reader
3. Alternate Input Unit - Tape B0
4. Standard Print and Punch Unit - Tapes B5, A5
5. Monitor Work Files 1 through 6
   Tapes A1, A2, A3, B1, B2, B3
6. Go File and Job File - Tapes B4, A4
7. 7010 with 100K core storage
8. Resident Monitor upper limit, 12599

9. System sequence on tape: Bootstrap, Autocoder (IOCS macros only), FORTRAN, COBOL, Linkload, Library modules for Sort, COBOL, and FORTRAN, and SORTDEFINE. A Transitional Monitor module was inserted between each system.

D. The following systems are included in the report:

1. COBOL

2. FORTRAN

3. AUTOCODER

4. SORT

5. IOCS

6. MONITOR (During a series of FORTRAN jobs)

E. The output of the Program Monitor was analyzed using DR2 and DR7 runs on the 7090 and 7044 Systems. The DR2 Program produces printed output giving a trace of instruction counter activity against time and/or a summary of time spent within ranges of addresses. The DR7 Program produces an image of the program, with references to IC location on the vertical axis and time on the horizontal axis. This image is displayed on a Cathode Ray Tube, and pictures may then be taken of the Cathode Ray Tube output. Across the top of the picture, channel activity is shown with Channel A the topmost followed by Channels B, C, and D.

F. Short summaries of each section of the report follow the Table of Contents. A pre-addressed Comment Sheet is Table of Contents. Pre-addressed Comment Sheet is provided at the end of the report. Your criticism and comments on content, presentation, and techniques would be appreciated.

COBOL SUMMARY

The approach taken to obtain data for this part of the report was that of devising a general test which included at least one occurrence of every COBOL statement and then varying this sample program by placing emphasis on successive areas of the COBOL Compiler. By emphasizing such COBOL statements as PERFORM, MOVE-CORRESPONDING, COMPUTE, etc., the effects of these statements on Procedure Division processing were uncovered. In addition, the primary routines related to the processing of each statement were found. For example, almost 20% of total compilation time for a MOVE-CORRESPONDING statement was spent in a table search in P2MF4.

In order to analyze Data Division processing, one complete File Description entry with its associated Record Description was subjected to detailed scrutiny. Seventy per cent of processing time was caused by the Record Description and, of this, the most significant portion was spent in the UNFINBIZ subroutine in P1MF2.

It was found that the monitoring tools at hand were capable of giving detailed conclusions, as indicated, and that even more detailed analyses were possible, even to the instruction level, if the user wished to take the time.

FORTRAN SUMMARY

The FORTRAN Report contains the following information.

1. A table showing the percentage of total compilation time spent in each of the four phases for nine different programs.

2. A table giving the percentage of time spent in the FORTRAN Compiler coding as opposed to IOCS and Monitor during a typical compilation. (For card input this was 60% for I/O and Monitor.)

3. A comparison in timing between card input to Phase 5 and tape input to Phase 5.

4. A detailed breakdown of a 65-card program giving the time taken for each statement as that statement passed through each of the four phases of compilation.

5. Several tables showing the percentage of time spent in major subroutines within a phase.

AUTOCODER SUMMARY

The 1410/7010 Operating System Autocoder Assembler was monitored during the processing of five programs. Various approaches for timing evaluation were investigated. These included gathering data on time required to load each phase, time spent in each phase, time spent in Resident Monitor IOCS routines per phase, and time spent in specific routines of the assembler. Data was obtained on process-time per instruction in Phases 001, 020, 030, and 040. Through this approach data on 370 one-for-one instructions, representing 43 different operation codes, several I/O macros, and one DTF were acquired.

Process-time in Phase 001 for a DTF with 5 subentries took 159.1 ms. Generation of the file table during Phase 020 took 835.2 ms. Total time to process such a DTF in Phases 001, 020, 030, 040 is 1356.4 ms.

SORT SUMMARY

With the sorts run in this analysis, compare times in Phase 1 were affected very little by the size or number of control fields and averaged 3.0 ms. per entry to the network. In addition, there were few entries to the equals routine, indicating most of the records were sorted using only the major control field. The times in the Phase 2 merge network were not affected when the number of control fields were increased. However, again there were few entries to the equals routine so most of the decisions were made on the major control field. The times averaged .24 ms. per entry to the Phase 2 merge network. In Phase 3 the order of merge affected the average time in the merge network: again the number of control fields affected the time very little. A reduction in the size of the control fields reduced the time in the merge network somewhat.

Considerable time overall was spent in the IOCS routines. During the Phase 1 process-bound routine the per cent of time in IOCS ran from 6% to 17% depending on input blocking, rewind time, and number of entries to the error routine. During Phase 2, which was I/O-bound, the per cent of time in the IOCS routines varied from 32% to 46% and was affected by the number of errors encountered during the run. The I/O-bound Phase 3 varied from 51% to 63%, depending on order of merge, output blocking, and rewind time. The percent of channel utilization remained quite stable and, as may be expected, had a higher per cent of utilization during the I/O-bound phases.

The File Sort, a batch sort (Tape Sort is a replacement sort) had a great affect on the various routines analyzed. An interesting fact is that, especially in Phase 1, the rotational delay caused most write times in that phase to be doubled. The next write, even though waiting to be executed, could not be executed in the time allotted after a full track write. It also shows very little channel or process overlap during Phase 1. A large share of the time is spent waiting for I/O to complete and when merging the G in Phase 1, no I/O activity is taking place. It would appear, from the runs looked at, that considerable time could be saved if less than full track operations were used, and if the reading of the next G could be overlapped with the internal merging of the previous G.

IOCS SUMMARY

The IOCS report contains data and analysis of GET, PUT, OPEN, CLOSE, and Card-Read routines. The data presented was accumulated from a DR2 analysis of multiple runs of a test program and a DR7 analysis of Phase 3 of a Sort Program.

The test programs presented various degrees of process-bound and I/O-bound situations. It showed the effect that record format has on IOCS. The number and size of I/O areas were changed between runs. The DR7 Sort Analysis presents the IOCS in a "real" context. It primarily shows the interaction of the IOCS routines.

The data contained in the IOCS report was accumulated from repetitious execution of the same IOCS routine. The GET/PUT data is the most valid in that it was accumulated from a sample of at least 40 test cases. The OPEN/CLOSE data was less thoroughly tested and, therefore, the data presented on them is less conclusive.

It is interesting to note that of the total time spent in IOCS per I/O-bound entry only approximately 1.7 ms. to 2.6 ms. is really processing information necessary to IOCS, the rest of the time is spent waiting. The time spent processing depends upon channel activity, format of records, and number of areas associated with the file. Process-bound entries require even less processing time in IOCS.

MONITOR SUMMARY

The Monitor report contains a graph, a table, and a prose explanation of the time spent to handle monitor control cards, load compiler phases, execute compiler phases, load transitional monitor, load linkload program, execute linkload program, and EOP routine for a

typical stacked FORTRAN compile and go job. The most surprising fact is the cost of typing.

Report on SORT Number PT573

Picture 1

Monitor Load Routine - time 0 to 1.5 seconds
Assignment Routine - time 1.5 to 2.5 seconds

1. Nine control cards are being read and analyzed.

   a. The "Read Card" routine is located at 10,500.
   b. Process of cards in the "assignment routine" is at 13750-14375.
   c. Operation is card-bound with 75 ms. between reads and the balance, other than process time, is in the IOCS wait loop.
   d. There is very little channel activity, only the time required to transfer 80 characters per card-read and print two lines.
      After reading control cards, IBSRTGAS3R is entered (16345-28516) which calculates blocking factors, areas, and G for the sort. This routine begins about 2.3 seconds and ends at 2.5 with output on SPR on Channel 2. Routine at 23,625 is Routine A of IBSRTGAS3R which calculates sort blocking maximum for Phase 2 and Phase 3.

2. IOCS is taking 71% of total assignment time.

3. Channel 1 and 2 active 2% of total assignment time.

Monitor Load Routine - time 2.5 to 2.9 seconds

1. Load Phase 1 of SORT.

   a. Channel 1 active 76% of time.
   b. Routine is I/O-bound.

Phase 1 Routine

1. Initialize Phase 1 of SORT 2.9 to 3.2 seconds.

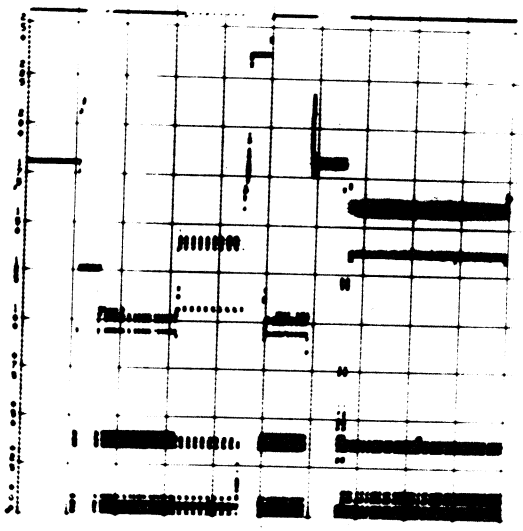
   a. Heavy black line is IBSRTPIASN which initializes RSA, initializes input area and compare instructions.

2. Opens and First Get 3.2 to 3.4 seconds.

   a. "Open" enters IOCS at 4515 - there are 3 opens, 2 showing on picture because 2 are very close together for output files.

b. First "Get" at 3.2 activates channel and holds in IOCS for 50 ms.
c. Filling of RSA begins at 3.2 and continues through 5.0 seconds. One break appears in the routine and is waiting in IOCS for an input record to complete reading. The read took twice as long as usual perhaps due to an extra long record gap. Channel 1 reads of 1000 characters records took, in most cases, 23 ms.
d. Compare routine IBSRTREPLQ begins at 15783 and ends at 16670 indicated by heavy upper band and input routine in IBSRTIO102 (SIOC/) at 13671 which consists of 12 instructions and 86 locations indicated by narrow lower band.
e. "Run-in routine" of blocked 10, 100 character records is process bound.

```
*  1410/7010 TAPE SORT UNDER THE OPERATING SYSTEM ****
*  PT573  A WAY SORT  20000. 100 CHARACTER RECORDS. BLOCKED 1
RESTART ***** TO *****    FRAME    001
BASE  *****   TOP 20000   TIME INT 000000
```



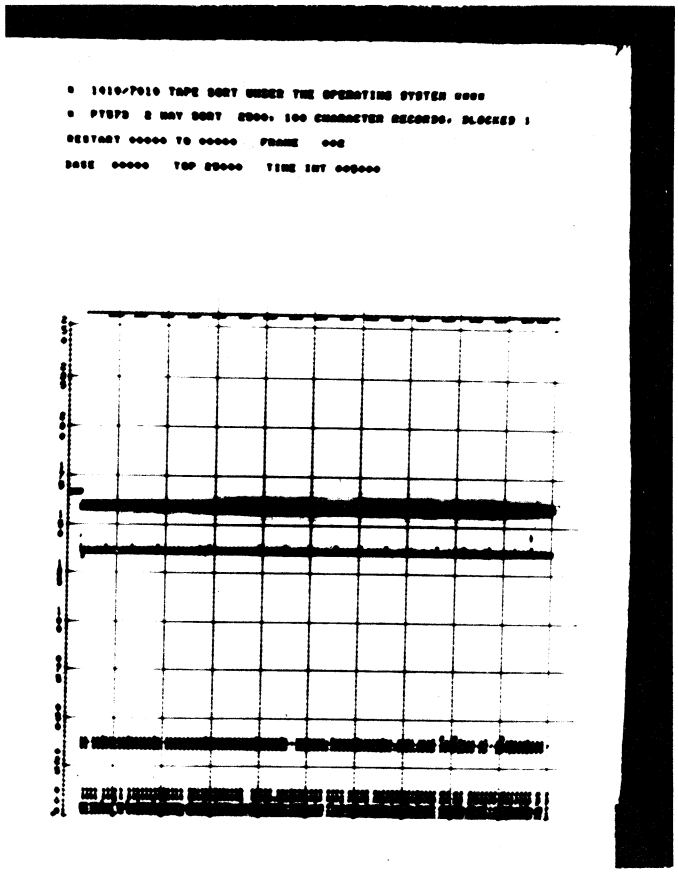
Sort Number PT573
Picture 1

Picture 2

Continues in Phase 1 from 5 to 10 seconds

1. Routine at UBSRTI0103 is executed at 5 seconds which clears the output area at end of filling the RSA. Routine is at 16694 and in this program lasts for 200 ms.

2. At time 5.2 the replacement sort is entered. Upper dark band is compare routine, IBSRTREPLQ, beginning at 15783 and the IO routine being the lower narrow band beginning at 15533. The spots above this narrow band are entries to the output interface routine, beginning at 13747 which contains 15 instructions and occupies 133 locations in the main routine. Upper line, at top of picture, shows activity on Channel 1 and Channel 2 activity on lower line.



Sort Number PT573
Picture 2

Picture 3

Continues in Phase 1 from 10 to 15 seconds.

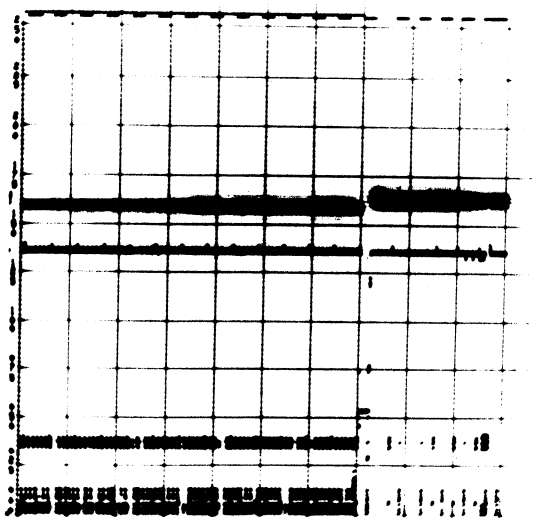
1. At time 13.5 seconds the input file tape mark is read and the input file is closed which takes 101 ms. in IOCS. Note heavy activity at 5300 to 5500. At this point the "Run-Out" of RSA begins indicated by entering different locations in compare routine and no input activity recorded on the lower line of heavy activity. Channel 2 only is getting any activity and appears to be tape bound only at time 14.85 seconds, due to sequence break.

2. Overall Phase 1 Percentages.

   a. Channel 1 activity 45%.
   b. Channel 2 activity 37%.
   c. Compare Routine 56% and averaging 2.9 ms. per data record.
   d. IOCS activity 9%
   e. Process time* 74% and averaging 4.0 milliseconds per data record.
   f. Channel 1 reads average 23 ms.
      Channel 2 writes average 108 ms.
   g. Time between Channel 1 activity is 20 ms.
      Time between Channel 2 activity is 118 ms.

*Time to read, process, write a data record including IOCS time.

```
*  1410/7010 TAPE SORT UNDER THE OPERATING SYSTEM ****
*  PT573  A WAY SORT  20000. 100 CHARACTER RECORDS, BLOCKED 1
RESTART 00000 TO 00000    FRAME   000
BASE  00000   TOP 20000   TIME INT 000000
```



Sort Number PT573
Picture 3

Picture 4

Continues output "Run-Out" until time 15.9 seconds. Padding routine is entered, indicated by heavy black line at 14500 to 14750, for 125 ms.

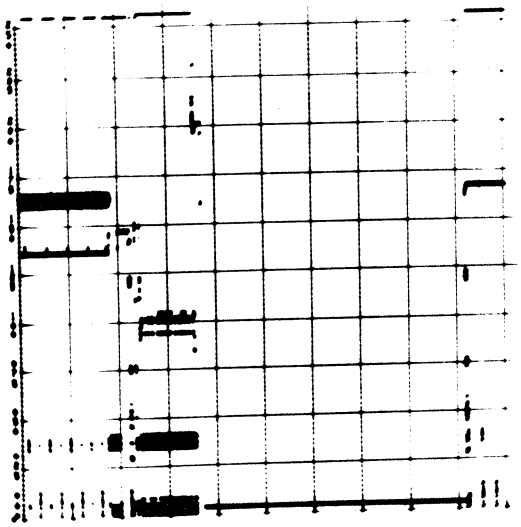
1. At 16.1 seconds the two output closes are executed and entry is made to 9024 (LOD) to load the next phase in. This is approximately at time 16.2 seconds.

2. Load routine is executed from 16.2 seconds until 16.7 seconds, Channel 1 getting heavy use and again becoming IOCS bound, indicated by heavy activity in the lower area of core.

3. At 16.7 seconds the assignment section of Phase 2 is executed and the open of the first file is given at 16.8 seconds and the program waits in IOCS until the rewind is completed at 19.2 seconds and then the other 3 opens are executed.

4. At 19.7 seconds the "Run-in" of the input files begins and continues through the end of this picture or 20 seconds of time. Four gets are issued, two for each input file.

* 1410/7010 TAPE SORT UNDER THE OPERATING SYSTEM ****
* PT573 8 WAY SORT 20000, 100 CHARACTER RECORDS, BLOCKED 1
RESTART 00000 TO 00000 FRAME 000
BASE 00000 TOP 20000 TIME INT 000000



Sort Number PT573
Picture 4

Picture 5

Continues "Run-in" of the input files until time 20.1 seconds.

1. At time 20.1 seconds the Phase 2 merge routine is entered.

   a. "Input block empty" routine begins at location 14678, contains 20 instructions and occupies 207 locations.
   b. "Output block empty" routine begins at location 13814, contains 15 instructions, and occupies 133 locations.
   c. Mainline begins at SIA9/ and ends at SIA7/
   d. Merge network for two-way merge begins at 18325 (SM031) and returns to 13723 (SIA9/).

2. The lower heavy block saw tooth design at 13750 is the mainline routine and entry to output interface. The black spots just above this line at 14750 is the interface to the input routine. The heavy black intermittent line at 18300 is the merge network.

   a. From the picture the program does not appear to be I/O bound due to no "wait loop" indicated in IOCS. However, Phase 2 holds in the sort for a tape I/O operation not finished. This is verified in the picture by the intermittent process time in the merge routine at 18300. From DR2 runs, we find the program waiting for output to be completed on Channel 1. This hold is at location 13826 (IOPH2OP012) in IBSRTIO201. The picture again verifies this by matching the upper black line of sawtooth design at 13800 with the breaks in the compare routine at 18300.

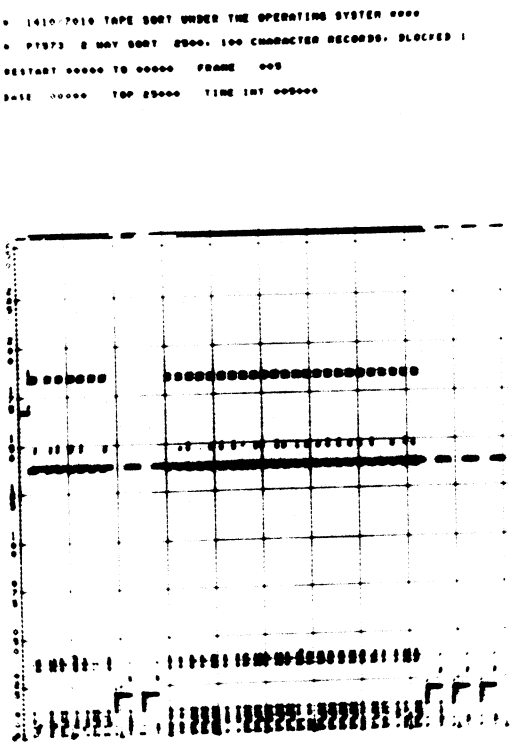
3. Following percentages were found for Phase 2:

   a. Channel 1 activity 65%.
   b. Channel 2 activity 41%.
   c. IOCS activity 46%.
   d. Compare routine 5% and averaging 250 usec. per record.
   e. Process time* 16% and averaging 770 usec.
   f. Writes on Channel 1 - 108.6 ms.
      Reads on Channel 2 - 108.6 ms.

*Time to read, process, write a data record including IOCS.

g. Time between writes on Channel 1 - 2.1 ms.
   Time between reads on Channel 2 - 1.1 ms.

4. Five entries are made to the IOCS error routine on the output file. Two at time 21 seconds and 3 at time 24.3 seconds.



Sort Number PT573
Picture 5

Picture 6

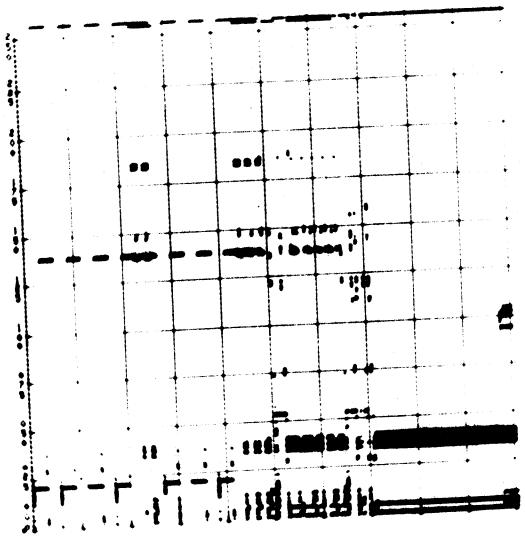
Continues Phase 2 until time 28.5 seconds.

1. At start of Picture 6 are four more entries to the error routine on Channel 1. At time 26.2 seconds, two input blocks are merged, then 3 more entries to error routine. Beginning at time 27.2 seconds the remaining records are merged.

2. The first input file was closed at time 27.5 seconds and required approximately 122.8 ms. The second input file is closed at 28.2 seconds. Runout of the final input file begins at 27.6 seconds. The output files are closed at time 28.5 seconds.

3. At 28.5 seconds the program exits to load in Phase 3. The program goes to IOCS and finds Channel 1 busy typing error messages from Phase 2 (18 character message) which lasts for 1.3 seconds and then begins the load of Phase 3.

```
*  1410-7010 TAPE SORT UNDER THE OPERATING SYSTEM 8000
*  PT573  2 WAY SORT  25000, 100 CHARACTER RECORDS, BLOCKED 1
RESTART 00000 TO 00000   FRAME   006
BASE  00000   TOP 25000   TIME INT 005000
```



Sort Number PT573
Picture 6