Usage Statistics For MTS

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1. Introduction

The following report is presented in response to Professor Browne's request for case studies of performance measurement projects; this study takes a macroscopic view of a large-scale time sharing and batch processing installation.

The data from the University of Michigan Computing Center presented in this paper were gathered for the purpose of constructing and validating an analytical model for a host system in a computer network (1). Since a computer network consists of several host systems, a simple model for a single host was required in order to keep the network model mathematically tractable. Consequently, measurement efforts were focussed on the limiting resource in the system, the CPU. Also, since waiting time statistics for batch jobs were not available, measurements of batch queue lengths were made in order to assess system performance in relation to batch jobs.

2. Data Sources

Considerable quantities of data are collected routinely by the University of Michigan Terminal System. The data presented in this paper come from two sources: job accounting statistics (recorded on a per-job basis) and system status measurements (recorded on a per-unit-time basis). Ultimate responsibility for the generation of these records lies with the supervisor. Both accounting and system status data are written into files which are periodically dumped on tape. There is no bias introduced in making these measurements, since the recording of these data is an integral part of the system operation. (Accounting tapes are used for billing and system status information is used to control certain dynamic scheduling parameters.)

3. Configuration

The basic system configuration during the periods in which measurements were taken is shown in Figure 1. Hardware includes a duplex IBM 360/67 with two megabytes of core storage, two channel controllers, two paging drums, and numerous disks, tapes, and terminal controllers.

The software controlling this equipment includes a time sharing supervisor known as UMMPS which implements a multi-tasking environment. The Michigan Terminal System (MTS) runs as a task under UMMPS and copies of MTS provide service to both interactive and batch jobs. Spooling services for batch jobs

are provided by a version of HASP modified to run under UMMPS. The other task of major importance in the system is the Paging Drum Processor (PDP). which oversees paging operations.

4. Workload

Similar to those of other universities, the Computing Center of the University of Michigan processes a large number of relatively short student jobs and a lesser number of larger computing requests, usually generated by the research community. A job in this context means a single session on a terminal (from dial-up to disconnect) or a single batch submission (card deck). (Although it is possible to submit batch jobs to the system via disk files during a terminal session, such jobs account for less than 5% of all batch jobs.)

Typically, 100,000±20,000 jobs are run per month, with interactive jobs comprising 50% to 60% of these. The workload does vary considerably with the time of day, as shown in Figure 2. Since this graph primarily reflects work habits of users, its shape is quite stable from month to month.

5. The Data

Figures 3 and 4 summarize the mean CPU utilization and mean batch queue length by hour of day during the month of October, 1973. (These tables are actually generated for 24-hour days, but have been truncated to fit space limitations.) An examination of these summaries indicates that the system existed in three roughly definable operating regions:

1. Lighly loaded: $0\% \leq \overline{CPU} < 60\%$; $\overline{\text{Batch Queue}} = 0$
2. Moderately loaded: $60\% \leq \overline{CPU} < 90\%$; $\overline{\text{Batch Queue}} \leq 5$
3. Heavily loaded: $90\% \leq \overline{CPU}$; $\overline{\text{Batch Queue}} > 5$

The underlined periods were chosen for more detailed study on the basis of these categories. To minimize transient effects and startup and shutdown problems, measurement periods were required to be of at least two hours duration, during which time all major hardware (CPU's, storage, and channel controllers) was in operation and the system was in a stable state.

Desired data were extracted from the system status and accounting tapes for the measurement periods, and are presented in Figure 5. The periods have been ordered by increasing CPU utilization. Statistics presented include (1) the ratio of batch to terminal jobs processed, (2) actual CPU utilization, (3) the percentage of the latter not charged to users (this represents CPU time consumed by "overhead" tasks, primarily HASP and the PDP), (4) mean CPU consumption charged to batch and interactive jobs, and (5) mean and standard deviation of the batch queue length, after adjustments. Adjustments to the batch queue length measurements were required since the recorded queue lengths sometimes included jobs which were not available for execution.

A number of trends may be observed in the data. As the CPU utilization increases, the proportion of batch jobs in the mix tends to decrease, and the mean CPU time used by a batch job tends to increase. Conversely, the mean CPU time used by interactive jobs generally decreases as system load increases.

Also, proportionately more of the non-idle CPU time is spent performing overhead operations when the system is heavily loaded. Records of time charged to individual overhead tasks are not saved on tape, but several samples collected while the system was running indicated that typically 60% of the overhead time is consumed by the PDP and about 40% by HASP and a few miscellaneous tasks. There is, however, considerable variance in these percentages with changes in the system load.

Figures 6 and 7 show histograms of CPU usage for batch and terminal jobs during two of the measurement periods. Although the means and variances of these distributions vary from period to period, the shapes of these histograms are typical. The batch queue length distribution showed more variation between periods. Figures 8-10 were obtained by summing the distributions for the light, moderate, and heavy periods respectively.

For comparison, Figures 11-12 present data from October, 1974-one year after the original measurements. The average batch queue lengths indicate the increased load on the system. The CPU usage distributions for batch and terminal jobs summed over the entire month of October, 1974, are presented in Figures 13 and 14. Again, the shapes of these distributions are typical, although means vary from month to month. (During January-November 1974, mean CPU consumption by terminal jobs varied between 20 and 29 seconds. The corresponding figures for batch jobs varied between 7 and 23 seconds, with the higher figures generally occurring in the summer months when fewer short student jobs are run.)

6. Postscript and Acknowledgments

The University of Michigan Computing Center obtained a single processor IBM 370/168 CPU with two megabytes of storage in January, 1975; future statistics will reflect this increase in CPU power. Preliminary reports indicate that CPU utilization has dropped from near 100% to about 40% with the new CPU.

The statistics collection facilities used in gathering the data were constructed by M. T. Alexander, D. W. Boettner, W. S. Gerstenberger and other members of the University of Michigan Computing Center staff, whose work is gratefully acknowledged.

Reference

1. Landwehr, C. E., Load Sharing in Computer Networks, A Queueing Model. MERIT Computer Network MCN-1174-TR-18, Ann Arbor, Michigan, November, 1974.

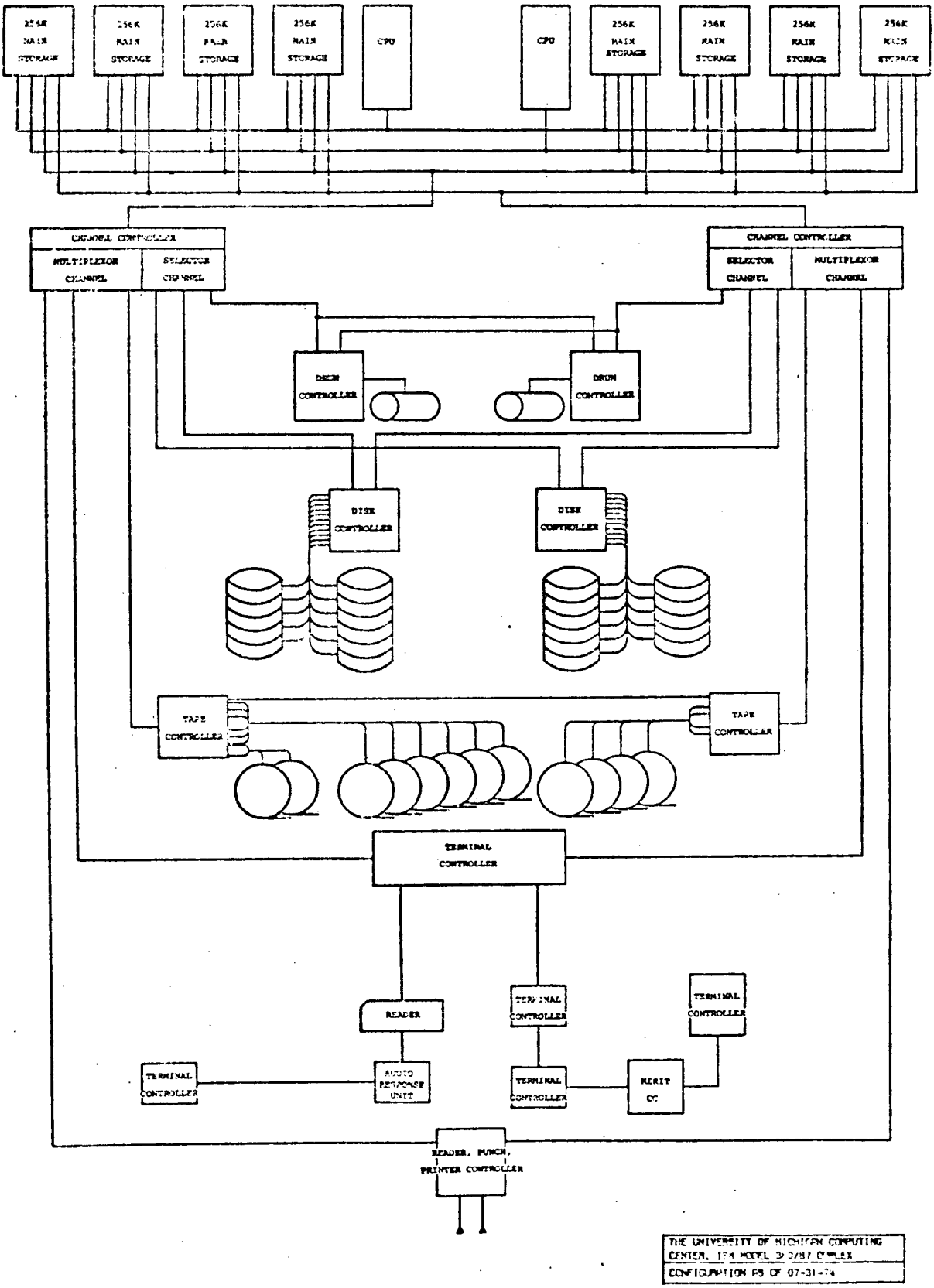


Fig. 1 University of Michigan Computing Center Machine Configuration

NUMBER OF BATCH AND TERMINAL USERS SIGNED ON
BY 15 MINUTE INTERVALS OVER DAY
AVERAGED OVER ALL DAYS

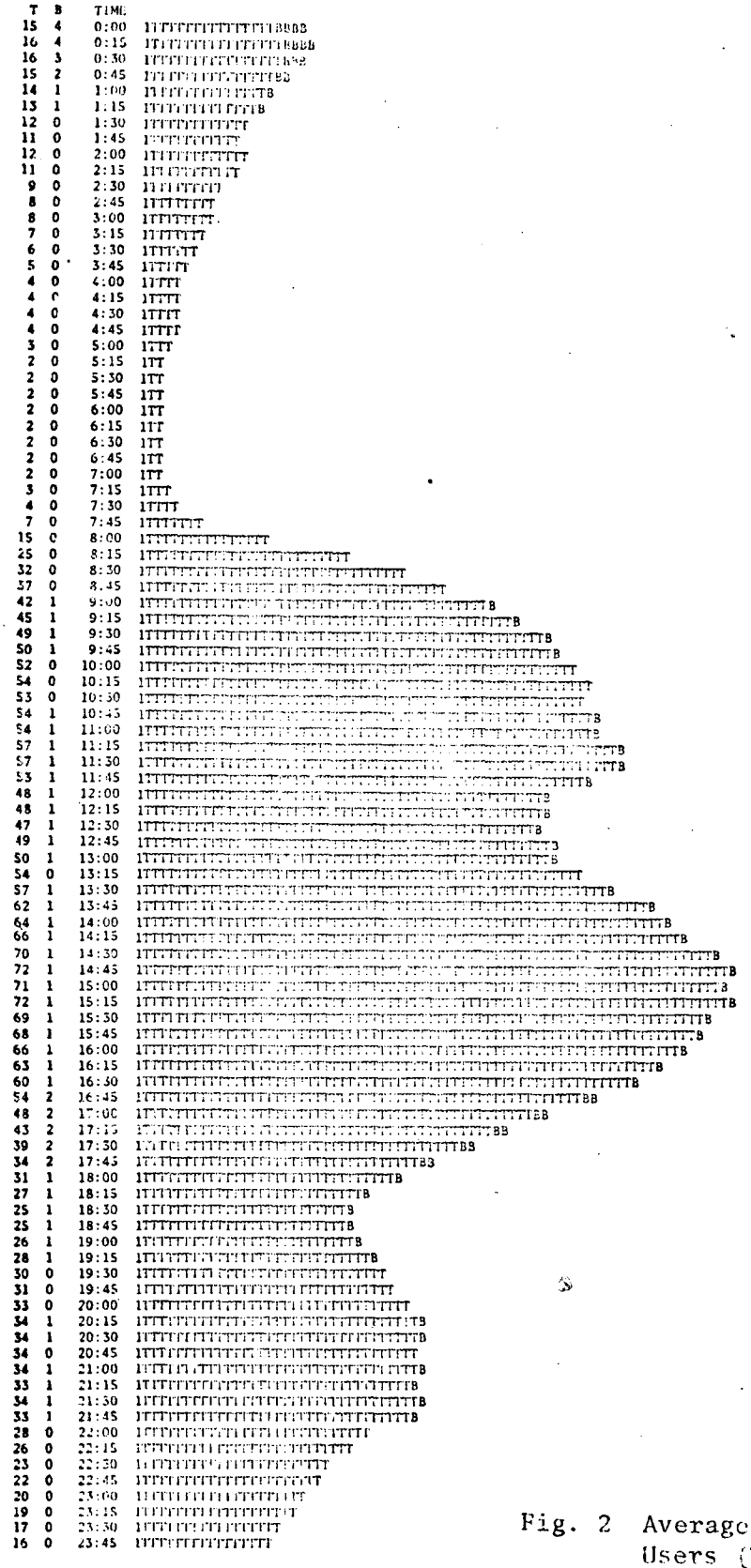


Fig. 2 Average Number of Terminal Users (T) and Batch Streams (B) Active by Time of Day - October 1974

HASP BATCH QUEUE BY HOUR OF DAY
AVERAGE LANGTH FOR EACH HOUR October 1973

DATE	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
01 MON	13	9	13	50	12	13	47	65	104	41	4	3	4	4	4	3
02 TUE	0	0	3	26	30	40	65	89	108	63	4	3	5	5	4	3
03 WED	0	0	4	12	3	16	71	68	71	24	2	2	2	2	3	3
04 THU	1	27	89	90	120	93	63	96	117	57	6	1	1	2	5	6
05 FRI	1	1	3	4	3	6	19	27	17	2	1	1	1	2	2	2
06 SAT	0	0	0	0	0	1	1	1	1	1	2	2	1	1	0	0
07 SUN	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
08 MON	0	0	0	1	1	3	26	15	67	11	3	4	4	50	15	5
09 TUE	0	0	7	12	2	11	38	31	23	12	7	7	7	7	7	7
10 WED	1	0	9	2	0	3	3	3	10	8	5	5	5	5	5	6
11 THU	0	1	16	15	41	16	65	42	27	15	8	0	0	3	16	0
12 FRI	0	5	15	14	24	12	11	9	3	3	3	3	3	3	3	3
13 SAT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14 SUN	0	0	0	0	0	0	9	2	0	0	0	0	0	0	1	0
15 MON	7	0	1	3	2	3	8	1	10	1	1	1	1	1	1	1
16 TUE	0	1	0	11	3	3	3	6	8	3	3	3	3	3	3	3
17 WED	0	0	3	4	2	7	17	8	2	2	2	2	2	2	2	2
18 THU	2	18	1	3	2	3	3	4	4	4	4	4	4	4	5	5
19 FRI	4	8	7	8	1	1	3	3	3	4	4	4	4	4	4	4
20 SAT	0	0	0	0	2	0	1	1	0	0	0	0	0	0	0	0
21 SUN	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0
22 MON	0	0	1	2	2	18	56	11	7	4	4	4	4	4	5	5
23 TUE	0	0	4	5	0	20	16	9	10	6	3	3	3	3	5	3
24 WED	1	3	3	3	2	3	7	3	4	4	4	4	4	4	4	5
25 THU	0	0	0	1	1	3	24	36	4	1	1	2	3	6	2	2
26 FRI	0	0	0	6	2	3	5	17	10	1	1	1	1	1	1	1
27 SAT	0	0	0	1	0	0	0	0	0	0	8	0	0	0	0	0
28 SUN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	16
29 MON	5	8	18	27	51	6	64	106	63	6	4	4	4	4	4	4
30 TUE	0	1	4	9	1	2	4	7	2	3	2	2	2	2	2	2
31 WED	0	0	2	17	8	59	119	197	158	9	3	3	3	3	3	3

Fig. 3 Mean Batch Queue Length by Hour

CPU UTILIZATION BY HOUR OF DAY (%) October 1973

DATE	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
01 MON	86	97	71	98	85	98	97	93	96	70	57	53	49	62	74
02 TUE	81	91	95	100	100	100	100	100	100	97	81	98	99	96	89
03 WED	85	91	92	64	88	92	96	99	96	53	54	61	57	48	46
04 THU	90	93	98	84	92	97	97	95	98	74	48	70	85	81	32
05 FRI	76	92	93	85	89	96	98	96	81	40	20	41	30	32	28
06 SAT	10	28	44	30	33	37	37	27	27	21	24	27	26	0	0
07 SUN	0	0	0	0	0	21	74	90	51	46	29	28	36	32	27
08 MON	73	76	97	72	89	99	100	99	86	50	49	68	38	89	76
09 TUE	79	93	100	98	96	100	96	99	86	39	49	78	58	39	46
10 WED	83	98	99	66	82	87	74	63	57	33	39	52	56	57	30
11 THU	75	98	92	80	98	100	98	100	97	47	0	0	40	21	0
12 FRI	96	100	99	100	100	100	98	97	68	35	31	32	28	27	22
13 SAT	15	27	39	0	0	0	18	31	31	17	23	32	24	10	6
14 SUN	0	0	0	0	0	24	46	44	34	28	24	32	33	29	29
15 MON	82	89	95	96	86	92	94	95	66	36	30	44	73	54	32
16 TUE	83	86	99	70	91	85	97	86	53	45	47	47	50	35	26
17 WED	64	75	96	58	81	100	98	98	58	35	45	38	56	44	32
18 THU	100	88	93	72	79	96	94	85	56	51	38	45	54	41	31
19 FRI	99	100	96	72	73	92	90	85	59	25	20	32	42	25	29
20 SAT	10	15	27	55	23	21	32	20	24	12	8	13	23	6	16
21 SUN	0	0	0	0	0	14	32	57	42	21	33	66	57	29	33
22 MON	51	77	63	62	73	85	94	94	58	43	54	59	64	55	55
23 TUE	84	88	92	64	89	100	94	99	76	31	50	69	65	67	51
24 WED	71	79	91	56	53	89	93	90	62	29	36	47	75	72	55
25 THU	69	90	91	61	78	99	96	89	49	42	40	76	77	45	39
26 FRI	75	84	92	79	66	85	99	98	61	32	18	26	28	26	26
27 SAT	6	13	28	50	47	50	30	39	16	5	0	31	15	41	0
28 SUN	0	0	0	0	0	0	0	0	66	72	57	63	58	51	31
29 MON	96	22	99	79	99	100	100	99	61	39	45	67	71	54	43
30 TUE	97	99	84	85	88	98	96	71	76	35	56	57	56	72	56
31 WED	88	90	66	85	48	99	91	90	79	48	60	94	91	98	83

Fig. 4 Mean CPU Utilization by Hour

Fig. 5 Summary of MTS Measurements

Period	Date & Time	Length (hours)	#Batch / #I.A.	CPU Util.	% of Util. CPU not Charged	Mean CPU use Batch	Mean CPU use I.A.	Adj Mean Batch Q	Std. Dev.	
1	10/26 8pm	4	2.32	26.31	29.82	5.77	21.18	.374	.65	
2	10/12 7pm	4	2.03	29.52	24.02	7.34	29.29	.405	.63	light
3	10/27 12noon	3	2.01	48.90	34.07	9.00	24.72	.823	1.23	
4	10/24 8pm	4	1.53	60.33	22.16	7.43	29.00	2.08	3.68	
5	10/22 7pm	5	1.90	57.36	28.48	8.78	14.40	1.65	1.88	
6	10/23 8pm	3	2.07	66.91	28.81	6.93	14.83	2.27	3.51	
7	10/26 9am	5	.952	79.1	31.5	10.72	18.33	3.39	5.64	moderate
8	10/10 1pm	3	.63	80.51	37.72	7.21	15.81	1.80	1.76	
9	10/26 2pm	3	.938	91.95	38.7	7.81	18.77	12.2	9.46	
10	10/17 1pm	4	.792	93.95	37.17	14.43	13.00	10.34	8.84	
11	10/25 1pm	3	.751	90.02	44.3	8.28	15.74	19.4	16.1	
12	10/9 1pm	5	.974	95.32	26.48	10.27	18.59	25.8	14.4	heavy
13	10/8 1pm	5	.835	94.67	38.35	11.23	16.46	27.3	26.0	
14	11/21 10am	8	.796	98.30	44.55	10.17	15.86	50.1	37.8	
15	10/12 10am	5	.776	99.43	35.7	11.41	19.28	13.8	9.6	

HISTOGRAM/FREQUENCIES

MIDPOINT	COUNT	FOR CPU(SEC) (EACH X = 2)
0.	0	+
1.0000	61	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2.0000	60	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
3.0000	35	+XXXXXXXXXXXXXXXXX
4.0000	19	+XXXXXXXXXX
5.0000	28	+XXXXXXXXXXXXX
6.0000	21	+XXXXXXXXXX
7.0000	11	+XXXXXX
8.0000	9	+XXXXX
9.0000	8	+XXXX
10.000	2	+X
11.000	4	+XX
12.000	3	+XX
13.000	6	+XXX
14.000	6	+XXX
15.000	1	+X
16.000	1	+X
17.000	2	+X
18.000	1	+X
19.000	6	+XXX
20.000	1	+X
21.000	0	+
22.000	1	+X
23.000	0	+
24.000	0	+
25.000	0	+
26.000	0	+
27.000	0	+
28.000	0	+
29.000	0	+
30.000	0	+
31.000	0	+
32.000	0	+
33.000	1	+X
34.000	0	+
35.000	0	+
36.000	1	+X
37.000	0	+
38.000	0	+
39.000	0	+
40.000	1	+X
41.000	0	+
42.000	0	+
43.000	0	+
44.000	0	+
45.000	0	+
46.000	2	+X
47.000	0	+
48.000	0	+
49.000	0	+

BATCH
CT123 19-23 - light
Period 2

Fig. 6 Batch CPU Service Distribution -- Period 2

HISTOGRAM/FREQUENCIES

MIDPOINT	COUNT	FOR CPU(SEC) (EACH X = 6)
0.	93	+XXXXXXXXXXXXXXX
2.0000	208	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
4.0000	126	+XXXXXXXXXXXXXXXXXXX
6.0000	77	+XXXXXXXXXXX
8.0000	41	+XXXXXXX
10.000	33	+XXXXXX
12.000	29	+XXXXX
14.000	15	+XXX
16.000	27	+XXXXX
18.000	13	+XXX
20.000	11	+XX
22.000	16	+XXX
24.000	6	+X
26.000	8	+XX
28.000	8	+XX
30.000	4	+X
32.000	6	+X
34.000	9	+XX
36.000	7	+XX
38.000	4	+X
40.000	2	+X
42.000	4	+X
44.000	5	+X
46.000	3	+X
48.000	2	+X
50.000	4	+X
52.000	0	+
54.000	1	+X
56.000	3	+X
58.000	1	+X
60.000	2	+X
62.000	0	+
64.000	2	+X
66.000	2	+X
68.000	2	+X
70.000	0	+
72.000	3	+X
74.000	2	+X
76.000	1	+X
78.000	1	+X
80.000	2	+X
82.000	0	+
84.000	0	+
86.000	1	+X
88.000	1	+X
90.000	3	+X
92.000	0	+
94.000	2	+X
96.000	1	+X
98.000	0	+
100.00	1	+X
	21	> 100.00
TOTAL	813	(2.0000 = INTERVAL WIDTH)

Terminals
CT08.13-18 Heavy

Fig. 7 Terminal CPU Service Distribution -- Period 13

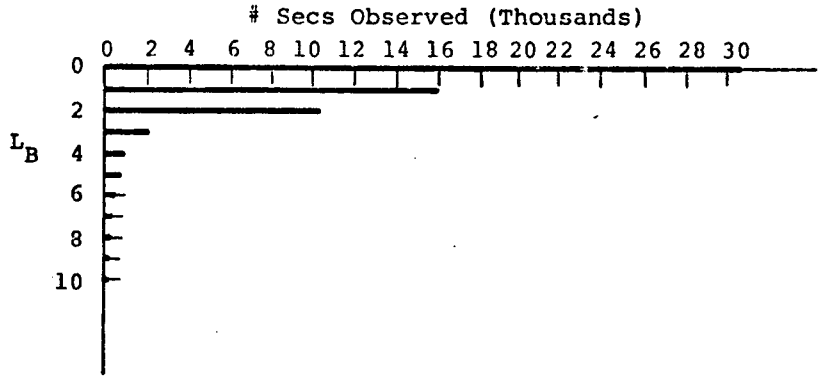
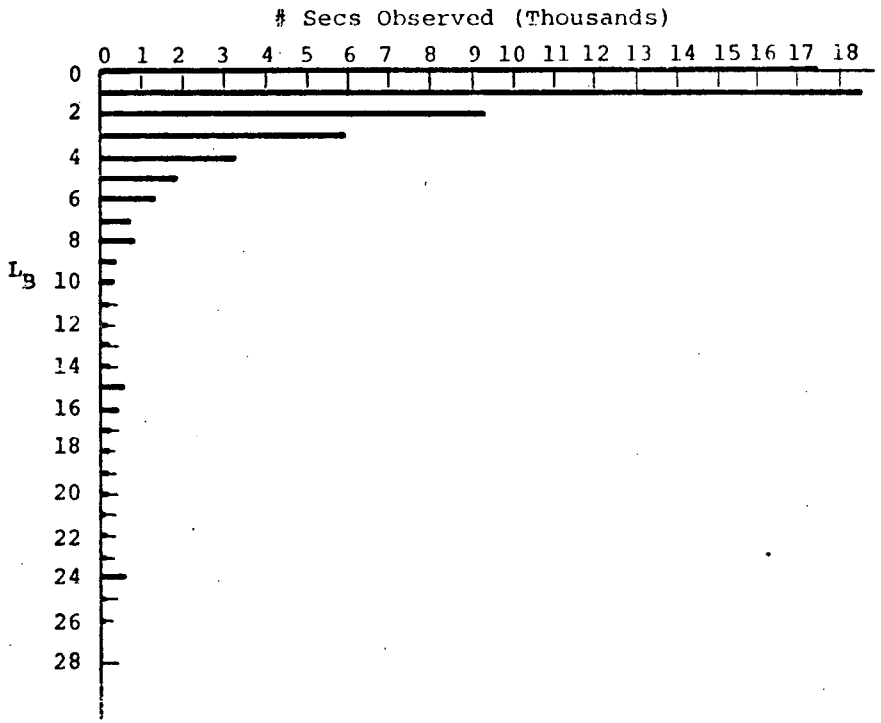


Fig. 8 Batch Queue Length Distribution-
Light Periods



Moderate Periods

Fig. 9 Batch Queue Length Distribution-
Moderate Periods

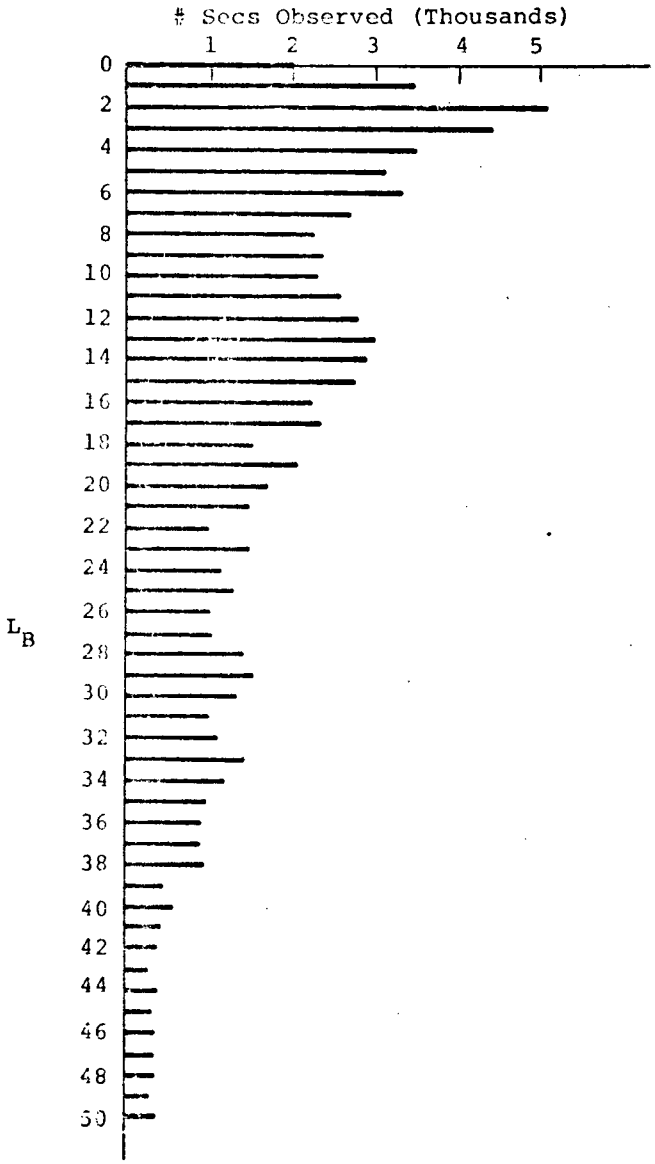


Fig. 10 Batch Queue Length Distribution-
Heavy Periods

CPU UTILIZATION BY HOUR OF DAY (%) October 1974

DATE	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
01 TUE	73	95	92	96	88	99	99	100	96	93	57	79	95	94	99	76
02 WED	50	86	95	98	90	92	97	97	99	100	91	88	98	98	98	100
03 THU	50	95	99	96	91	99	98	95	95	100	100	100	100	100	98	70
04 FRI	65	91	100	100	67	69	94	99	87	67	27	25	33	31	52	31
05 SAT	5	11	27	61	54	43	43	80	91	83	82	73	72	67	15	29
06 SUN	0	0	0	0	0	0	29	71	81	65	50	44	71	70	46	35
07 MON	50	67	87	98	96	97	96	83	0	0	0	0	0	70	0	0
08 TUE	100	100	99	98	99	97	95	96	96	100	100	98	98	100	100	100
09 WED	56	87	98	100	100	100	100	97	99	99	42	43	55	57	92	83
10 THU	60	78	90	100	99	97	100	98	100	100	100	90	82	86	61	45
11 FRI	50	88	95	97	93	97	98	100	0	0	0	0	0	0	0	0
12 SAT	0	34	6	51	41	50	66	22	33	39	26	16	24	21	11	0
13 SUN	0	0	0	0	0	0	47	74	93	91	78	65	67	69	58	0
14 MON	41	71	79	100	97	97	99	99	99	99	67	68	90	72	49	47
15 TUE	43	78	99	99	98	95	80	95	79	80	85	90	80	71	57	60
16 WED	42	98	100	98	77	84	95	96	82	59	36	38	62	54	74	24
17 THU	47	66	78	93	83	91	99	99	97	56	45	55	63	56	45	29
18 FRI	63	78	98	100	93	88	100	99	98	48	30	38	60	59	51	53
19 SAT	12	19	34	62	64	52	62	60	79	70	43	19	25	36	4	0
20 SUN	0	0	0	0	0	13	33	95	93	87	57	54	59	78	31	38
21 MON	48	86	90	96	87	72	98	99	97	96	51	61	85	72	72	44
22 TUE	47	76	84	94	96	100	98	97	99	83	46	46	77	85	72	29
23 WED	42	96	99	99	92	83	99	99	98	95	59	78	77	83	68	42
24 THU	73	98	100	98	90	100	99	99	100	99	98	96	94	95	83	80
25 FRI	50	90	100	85	98	93	92	97	85	79	56	48	48	48	63	34
26 SAT	7	19	44	45	33	46	36	55	65	39	23	45	29	25	8	0
27 SUN	0	0	0	0	0	0	44	58	95	90	62	75	73	59	54	39
28 MON	65	96	98	94	81	75	97	96	98	63	42	77	81	86	73	45
29 TUE	70	93	36	3	99	100	92	96	94	100	65	53	68	96	79	60
30 WED	58	99	100	100	100	89	99	99	97	100	93	58	73	75	56	55
31 THU	68	96	100	99	99	100	100	100	100	75	39	52	56	66	56	40

Fig. 11 Mean CPU Utilization by Hour

HASP BATCH QUEUE BY HOUR OF DAY October 1974
AVERAGE LENGTH FOR EACH HOUR

DATE	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
01 TUE	1	9	10	8	4	16	23	40	23	9	1	3	5	2	5	1
02 WED	0	27	63	69	18	22	100	176	220	105	5	0	2	2	1	5
03 THU	0	8	38	71	123	139	162	210	264	216	64	1	27	23	6	1
04 FRI	0	4	76	93	4	1	2	14	5	1	0	0	0	0	1	0
05 SAT	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0
06 SUN	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
07 MON	0	0	5	29	95	95	195	159	0	0	0	0	0	0	0	0
08 TUE	40	222	292	348	379	351	362	416	458	368	216	60	17	27	19	10
09 WED	1	2	18	32	52	114	70	118	122	27	0	0	0	1	1	0
10 THU	0	1	8	52	33	17	56	68	110	132	57	2	1	6	1	0
11 FRI	0	3	9	27	14	3	22	59	0	0	0	0	0	0	0	0
12 SAT	0	0	25	1	10	39	13	0	0	0	0	0	0	1	8	0
13 SUN	0	0	0	0	0	0	2	2	11	8	4	1	0	1	3	0
14 MON	0	1	2	18	22	34	80	105	89	18	2	1	4	1	0	0
15 TUE	0	1	13	50	52	37	118	164	240	271	179	27	3	1	1	3
16 WED	0	13	18	8	1	1	6	7	1	1	0	0	0	0	2	0
17 THU	0	1	2	3	1	5	37	23	18	0	1	0	0		6	0
18 FRI	0	0	3	19	13	5	23	41	33	3	1	0	0	1	0	1
19 SAT	0	0	0	0	1	1	2	1	2	1	0	0	0	1	16	0
20 SUN	0	0	0	0	0	17	9	9	7	2	0	0	0	1	0	0
21 MON	0	2	10	11	2	1	19	43	92	68	0	0	4	3	1	0
22 TUE	0	1	1	5	23	26	16	24	50	9	1	1	2	7	3	1
23 WED	0	5	7	24	4	1	34	83	120	39	3	3	1	3	0	1
24 THU	2	16	31	50	81	80	93	135	196	120	21	3	2	1	0	0
25 FRI	0	10	26	82	45	35	127	193	220	68	1	0	0	0	0	0
26 SAT	0	0	1	0	0	0	0	0	0	0	0	0	0	1	8	0
27 SUN	0	0	0	0	0	0	0	21	4	3	2	1	1	1	6	10
28 MON	7	7	53	133	92	18	54	146	184	26	0	1	1	4	2	0
29 TUE	1	25	116	159	60	82	193	289	281	159	7	1	1	10	1	0
30 WED	0	13	54	61	31	30	67	145	190	113	6	1	1	1	0	0
31 THU	1	3	17	23	23	50	99	173	188	37	1	0	1	0	1	0

Fig. 12 Mean Batch Queue Length by Hour

```
CPU TIMES IN SECONDS FOR A JOB VS PERCENT OF JOBS
FOR BATCH JOBS

1% IS 602 JOBS
MEAN IS   7 SECONDS

CUM %  TIME      ONE X IS .5%
  1.8     0  1XXXX
 30.4     1  1XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 47.7     2  1XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 62.1     3  1XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 71.4     4  1XXXXXXXXXXXXXXXXXXX
 77.0     5  1XXXXXXXXXXX
 80.3     6  1XXXXXXX
 83.0     7  1XXXXX
 85.2     8  1XXXX
 87.3     9  1XXXX
 88.8    10  1XXX
 89.8    11  1XX
 90.6    12  1XX
 91.2    13  1X
 91.9    14  1X
 92.6    15  1X
 93.0    16  1X
 93.4    17  1X
 93.7    18  1X
 94.0    19  1X
 94.4    20  1X
 94.7    21  1X
 94.9    22  1
 95.1    23  1
 95.4    24  1X
 95.6    25  1
 95.8    26  1
 96.0    27  1
 96.1    28  1
 96.3    29  1
 96.7    30  1X
 96.9    31  1
 97.0    32  1
 97.1    33  1
 97.2    34  1
 97.2    35  1
 97.3    36  1
 97.4    37  1
 97.4    38  1
 97.5    39  1
 97.6    40  1
 97.6    41  1
 97.7    42  1
 97.7    43  1

 00.0  MORE  1XXXX
```

Fig. 13 Batch CPU Service Distribution -- October 1974

```
CPU TIMES IN SECONDS FOR A JOB VS PERCENT OF JOBS
FOR TERMINAL JOBS

1% IS 598 JOBS
MEAN IS  20 SECONDS

CUM %  TIME      ONE X IS .5%
  5.3     0  1XXXXXXXXXXX
 20.5     1  1XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 30.5     2  1XXXXXXXXXXXXXXXXXXXX
 38.3     3  1XXXXXXXXXXXXXXX
 44.9     4  1XXXXXXXXXXXXX
 50.4     5  1XXXXXXXXXXX
 54.9     6  1XXXXXXXXX
 58.8     7  1XXXXXXXX
 62.2     8  1XXXXXXX
 65.2     9  1XXXXXX
 67.7    10  1XXXXX
 69.9    11  1XXXX
 71.8    12  1XXXX
 73.5    13  1XXX
 74.8    14  1XXX
 76.2    15  1XXX
 77.4    16  1XX
 78.5    17  1XX
 79.5    18  1XX
 80.4    19  1XX
 81.2    20  1XX
 82.0    21  1XX
 82.7    22  1X
 83.5    23  1XX
 84.1    24  1X
 84.7    25  1X
 85.2    26  1X
 85.7    27  1X
 86.2    28  1X
 86.6    29  1X
 87.0    30  1X
 87.4    31  1X
 87.8    32  1X
 88.1    33  1X
 88.4    34  1X
 88.7    35  1X
 89.0    36  1X
 89.2    37  1X
 89.5    38  1X
 89.8    39  1X
 90.1    40  1X
 90.3    41  1
 90.5    42  1X
 90.8    43  1X

 00.0  MORE. 1XXXXXXXXXXXXXXXXXX
```

Fig. 14 Terminal CPU Service Distribution -- October 1974