Saltzer

MPL-51

TO: Multics Performance Log

FROM: J. Ammons, M. Schroeder

SUBJECT: Initial report of Measurement of 645 CPU with Electronic Counters

DATE: June 10, 1970

Introduction

Over the past few weeks we have been counting various pulses in the 645 CPU to determine the frequency of occurrence of hardware events of interest. This MPL is an initial report of the data gathered. A report analysing the data will follow. Measurements were made by attaching electronic counters directly to the CPU logic while Multics was running, and counting the number of pulses that occurred in a known time period. Four associative memory sizes are represented in the measurements: 16, 8, 4, and 0 active registers.

With full associative memory (16 registers)

Events monitored with the full 16 register associative memory in operation were:

- total instruction executions (Figure I)
- RTCD instruction executions (Figure II)
- RCU instruction executions (Figure III)
- EAPn instruction executions (Figure IV)
- associative memory requests (Figure V)
- associative memory "not found"s (Figure VI)
- associative memory SDW matches (Figure VII)
- associative memory clears (Figure VIII)
- memory accesses (Figure IX)

With half the associative memory (8 registers)

Events monitored with half the associative memory in operation were:

- total instruction executions (Figure X)
- associative memory requests (Figure XI)
- associative memory "not found"s (Figure XII)
- associative memory SDW matches (Figure XIII)
- memory accesses (Figure XIV)

With one quarter the associative memory (4 registers)

The same events were monitored with 4 associative memory registers in operation as with 8 (see above). (Figures XV - XIX)

With no associative memory

With the associative memory turned off the following events were monitored:

- total instruction executions (Figure XX)
- memory accesses (Figure XXI)

Measurement results

The data gathered for each measurement listed above is presented in the 21 Figures that follow. In each case the average rate of occurrence of the event listed is given, along with a list and a graph of the raw data.

	Measurement	Figure	Total Duration**	Min*	Max*	Ave*
with 16 registers AM	Instruction executions	I	340	317,940	385,030	341,945
	RTCD instruction executions	II	1800	605	1,881	1,157
	RCU instruction executions	III	1200	146	228	192
	EAPn instruction executions	IV	1800	15,064	22,401	20,076
	AM search requests	V	220	390,800	453,300	414,668
	AM "not found"s	VI	220	2,892	6,988	5,180
	AM SDW matches (paged only)	VII	500	435	1,422	826
	AM clears	VIII	260	15	343	166
	Memory accesses	IX	500	394,600	447,749	419,425
with 8 registers AM	Instruction executions	X	500	300,828	348,376	322,912
	AM search requests	XI	230	363,822	397,535	377,391
	AM "not found"s	XII	230	8,912	13,780	11,002
	AM SDW matches (paged only)	XIII	230	573	3,921	2,057
	Memory accesses	XIV	230	399,770	444,551	418,284
with 4 registers AM	Instruction executions	XV	270	265,980	309,883	286,531
	AM search requests	XVI	270	321,902	356,902	337,442
	AM "not found"s	XVII	600	32,499	37,732	35,710
	AM SDW matches (paged only)	XVIII	600	3,136	9,071	5,189
	Memory accesses	XIX	260	437,023	465,095	451,895
with no AM	Instruction executions	XX	900	121,649	124,482	123,198
	Memory accesses	XXI	500	535,143	555,855	541,832

Summary of Data Taken

* per second

** in seconds of observation

1 CPU, 256 K Memory

Instruction Executions Observed in 10 Seconds	Date & Time	Number of Users
3,339,849	(5/20/70) 1955	17
3,550,415	2045	15
3,438,391	2100	16
3,544,112	2115	17
3,366,441	2130	20
3,317,820	2145	18
3,292,982	2200	16
3,304,615	2219	16
3,361,478	2230	18
3,395,799	2245	19
3,500,848	2300	18
3,646,412	2315	14
3,549,229	2330	13
3,422,115	2345	12
3,570,436	(5/21/70) 0015	12
3,457,993	0045	9
3,850,309	0115	8
3,483,451	0145	9
3,179,401	0215	8
3,585,578	0245	5
3,480,434	0313	4
3,347,964	0345	5
3,592,846	0415	5
3,592,134	0445	6
3,587,440	0515	5
3,453,331	0545	5
3,449,449	0615	5
3,382,840	1025	23
3,413,435	1045	22
3,356,012	1100	27
3,390,845	1125	27
3,361,018	1215	18
3,270,270	1250	25
3,425,631	1310	25

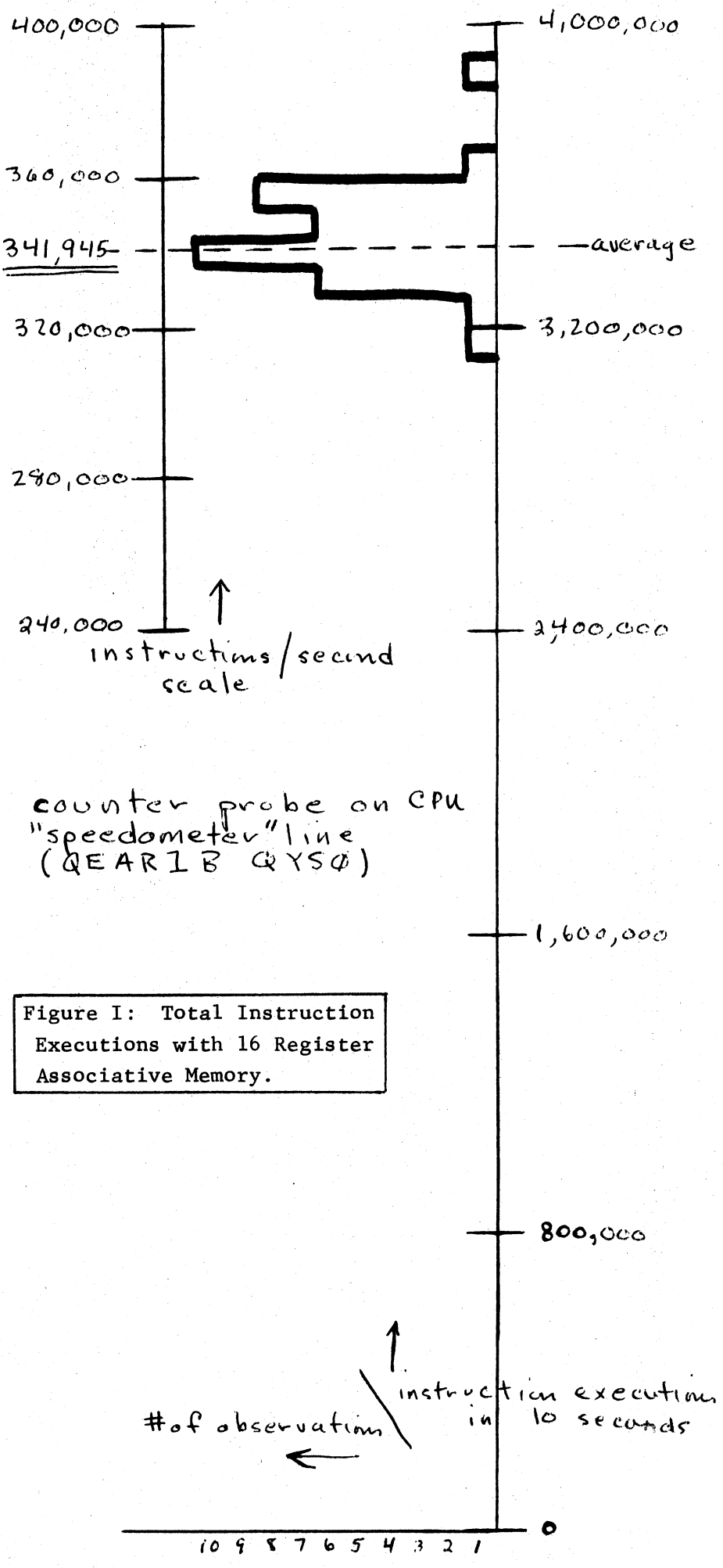


Figure I: Total Instruction Executions with 16 Register Associative Memory.

1 CPU, 256 K Memory

RTCD Instruction Executions Observed	Duration of Observation	Date & Time	Number of Users
45,175	1 min.	(5/29/70) 1533	28
50,289	"	1535	
36,329	"	1537	
81,879	"	1539	27
79,484	"	1540	
70,367	"	1542	
62,084	"	1544	
65,744	"	1545	
53,962	"	1547	27
68,871	"	1549	
564,271	5 min.	1556	
105,518	1 min.	1603	26
60,123	"	1605	
61,715	"	1607	
274,309	5 min.	1609	
68,424	1 min.	1615	
54,436	"	1616	
279,650	5 min.	1618	

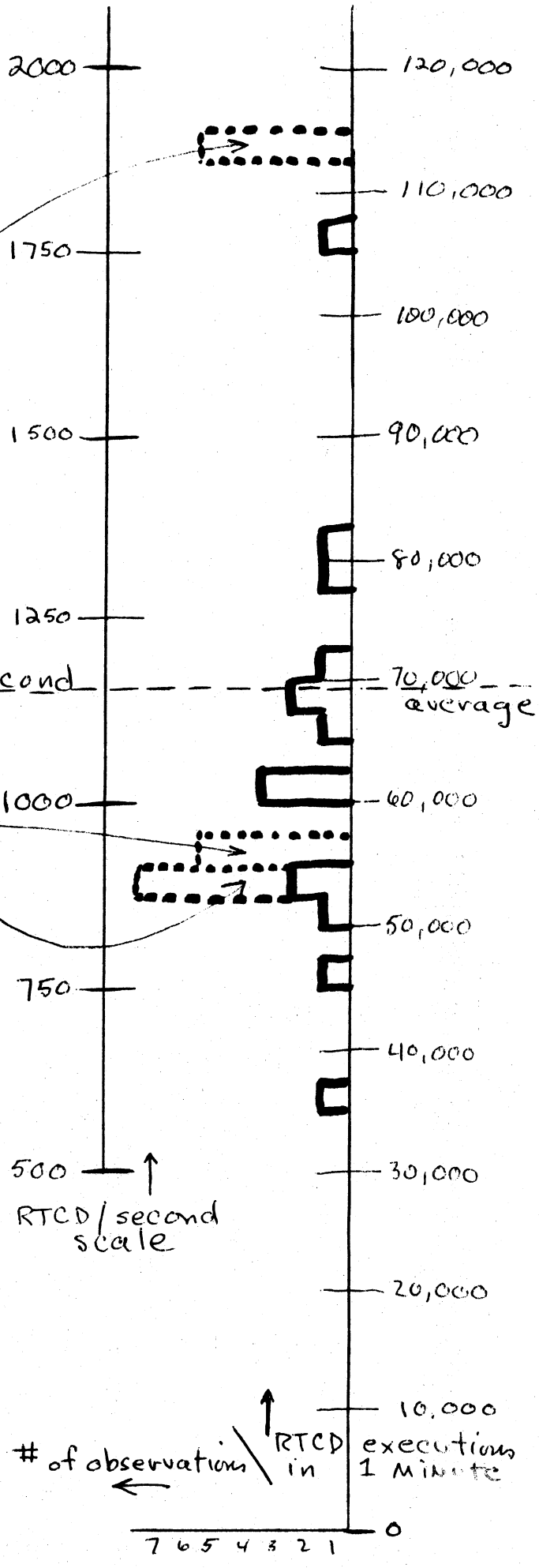


Figure II: RTCD Instruction Executions with 16 Register Associative Memory.

counter probe on line BERTOF ANSO of CPU

1 CPU, 256 K Memory

RCU Instruction Executions Observed in One Minute	Date & Time	Number of Users
10,146	(6/2/70) 1626	21
8,909		
11,816		
11,600	1630	
12,459		21
8,750		
12,213		
12,237	1635	
12,953		
10,208		
10,973	1639	
12,142		
12,767		
10,010		
12,713	1644	
11,213		
12,877		
11,619		
13,652		
11,334	1649	27

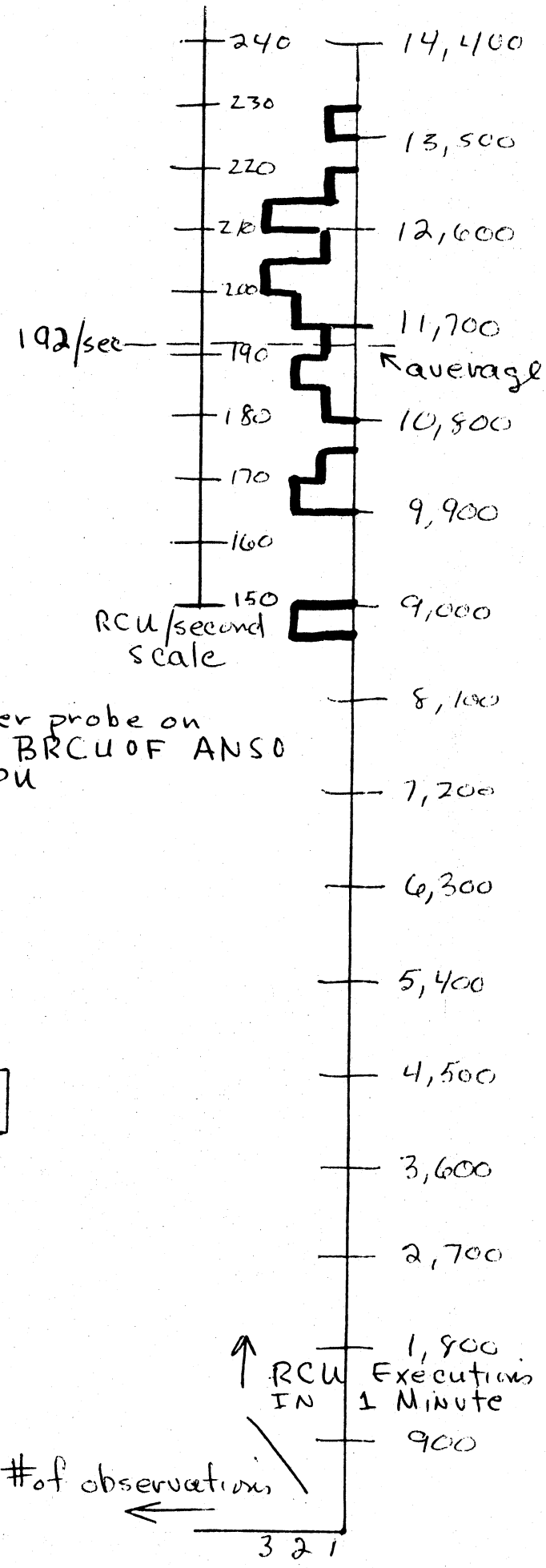


Figure III: RCU Instruction Executions with 16 Register Associative Memory.

1 CPU, 256 K Memory

EAPn Instruction Executions Observed	Duration of Observation	Date & Time	Number of Users
1,115,953	1 min.	(5/29/70) 1533	28
1,140,582	"	1535	
903,829	"	1537	
1,225,657	"	1539	27
1,216,420	"	1540	
1,180,638	"	1542	
1,006,393	"	1544	
1,020,675	"	1545	
1,193,572	"	1547	27
1,247,093	"	1549	
6,287,422	5 min.	1556	
1,344,043	1 min.	1603	26
1,295,873	"	1605	
1,327,483	"	1607	
6,030,751	5 min.	1609	
1,321,396	"	1615	
1,135,951	"	1616	
6,143,348	5 min.	1618	

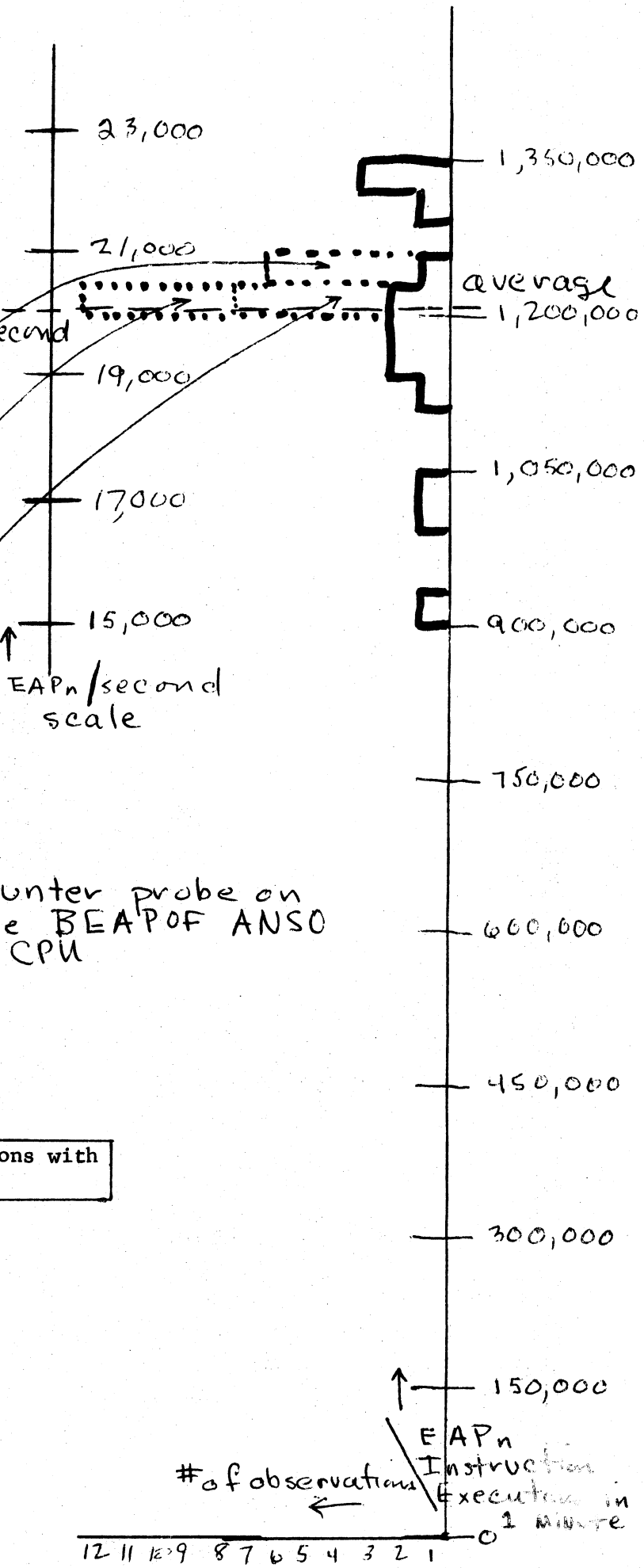


Figure IV: EAPn Instruction Executions with 16 Register Associative Memory.

1 CPU 256 K Memory

14 Users (5/27/70)

AM Search Requests
Observed in 10 Seconds
(Observations separated
by 1 second).

8	4,069,000
7	3,361,000
6	4,147,000
5	4,256,000
4	4,193,000
3	4,113,000
2	4,233,000
1	3,952,000
0	3,923,000
	3,978,000
	4,496,000
	4,340,000
	3,908,000
	4,132,000
	4,123,000
	4,033,000
	4,533,000
	4,188,000
	4,290,000
	3,965,000
	4,011,000
	3,983,000

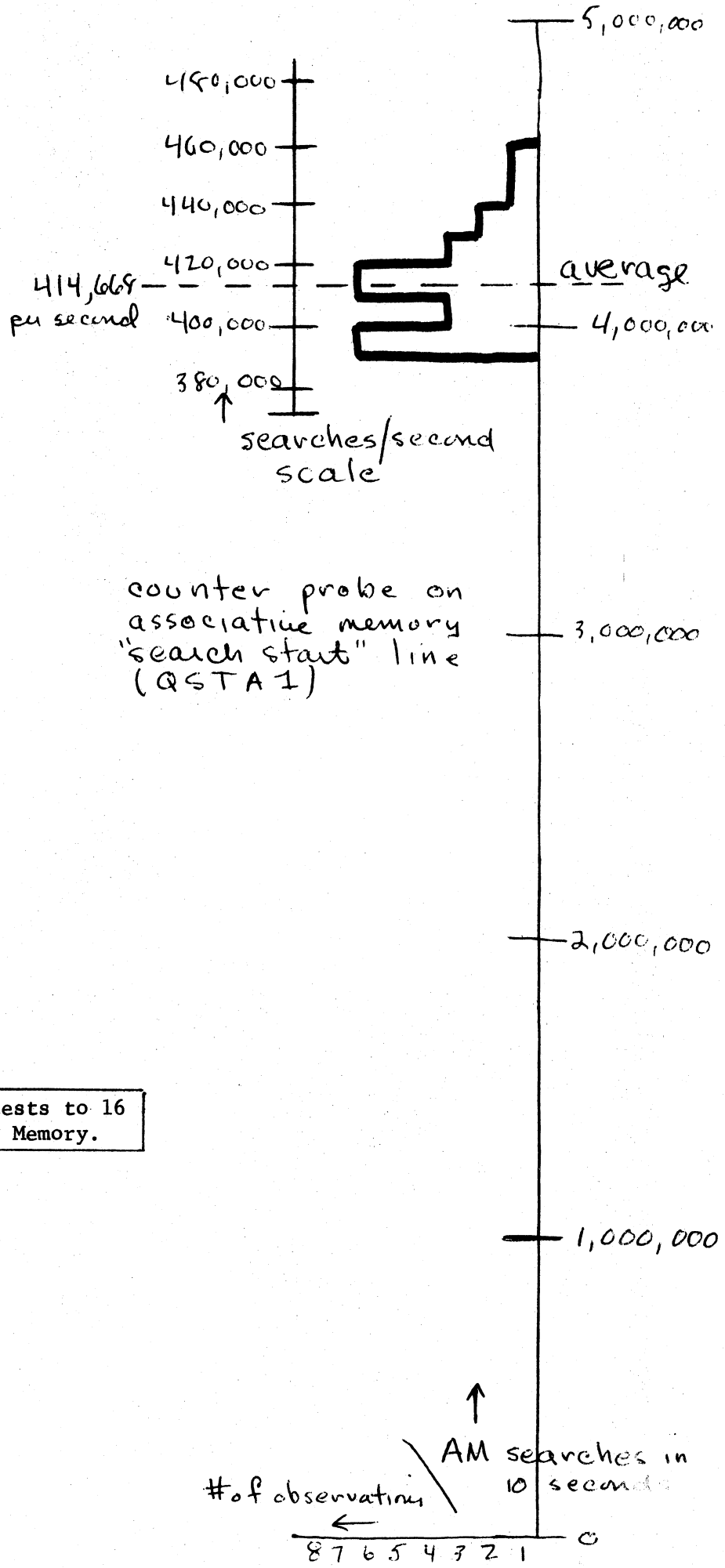


Figure V: Search Requests to 16 Register Associative Memory.

1 CPU 256 K

14 Users
(5/27/70)
"Not Found" responses observed in 10 seconds (Measurements taken simultaneously with those of Figure V).

41,300
53,240
53,020
53,260
53,030
54,210
65,710
69,880
51,560
58,720
34,940
49,460
65,570
55,570
28,570
52,620
28,920
54,350
51,110
58,590
45,270
60,780

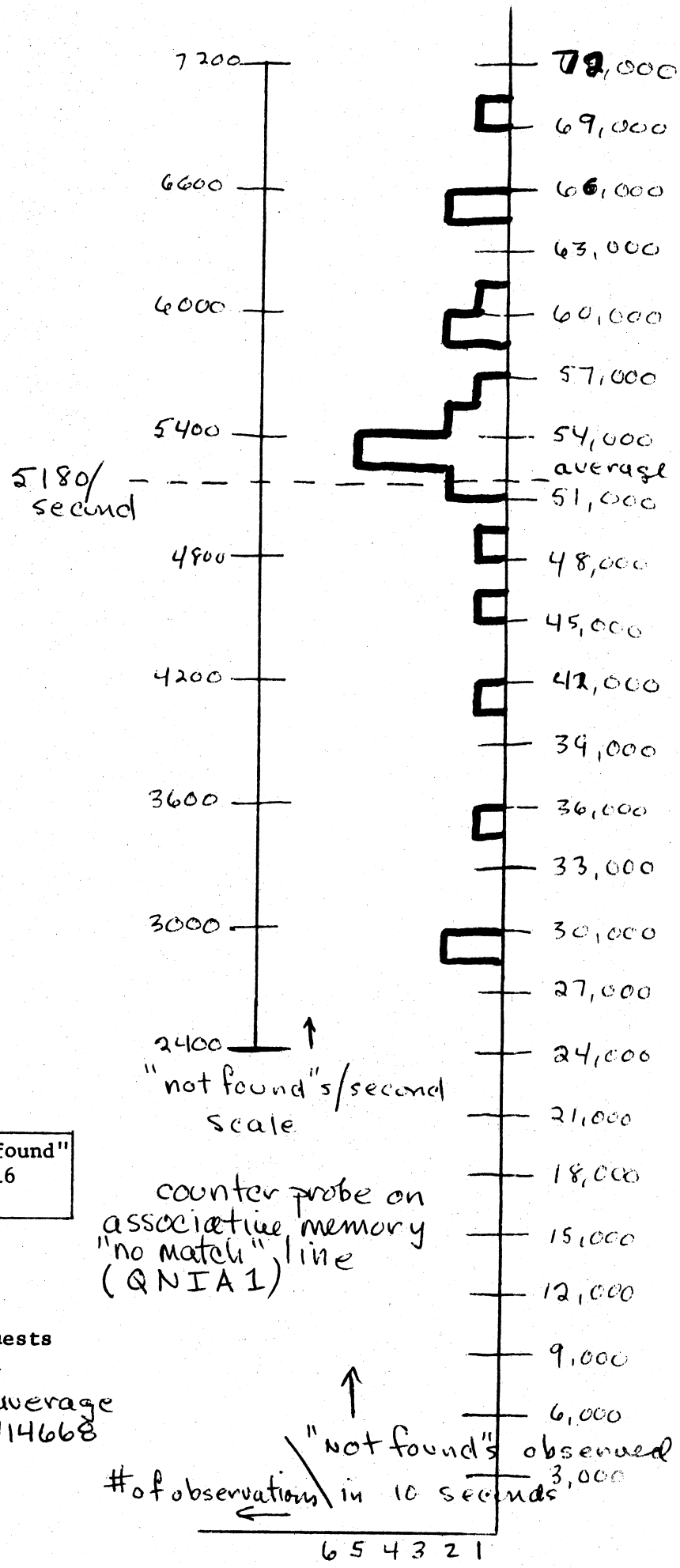


Figure VI: Associative Memory "not found" Responses To Search Requests With 16 Register Associative Memory.

Note: "Not found"s occur on 1.25% of requests to the full associative memory, i.e. average from this Figure ÷ average from Figure V = 5180 ÷ 414668 = .0125

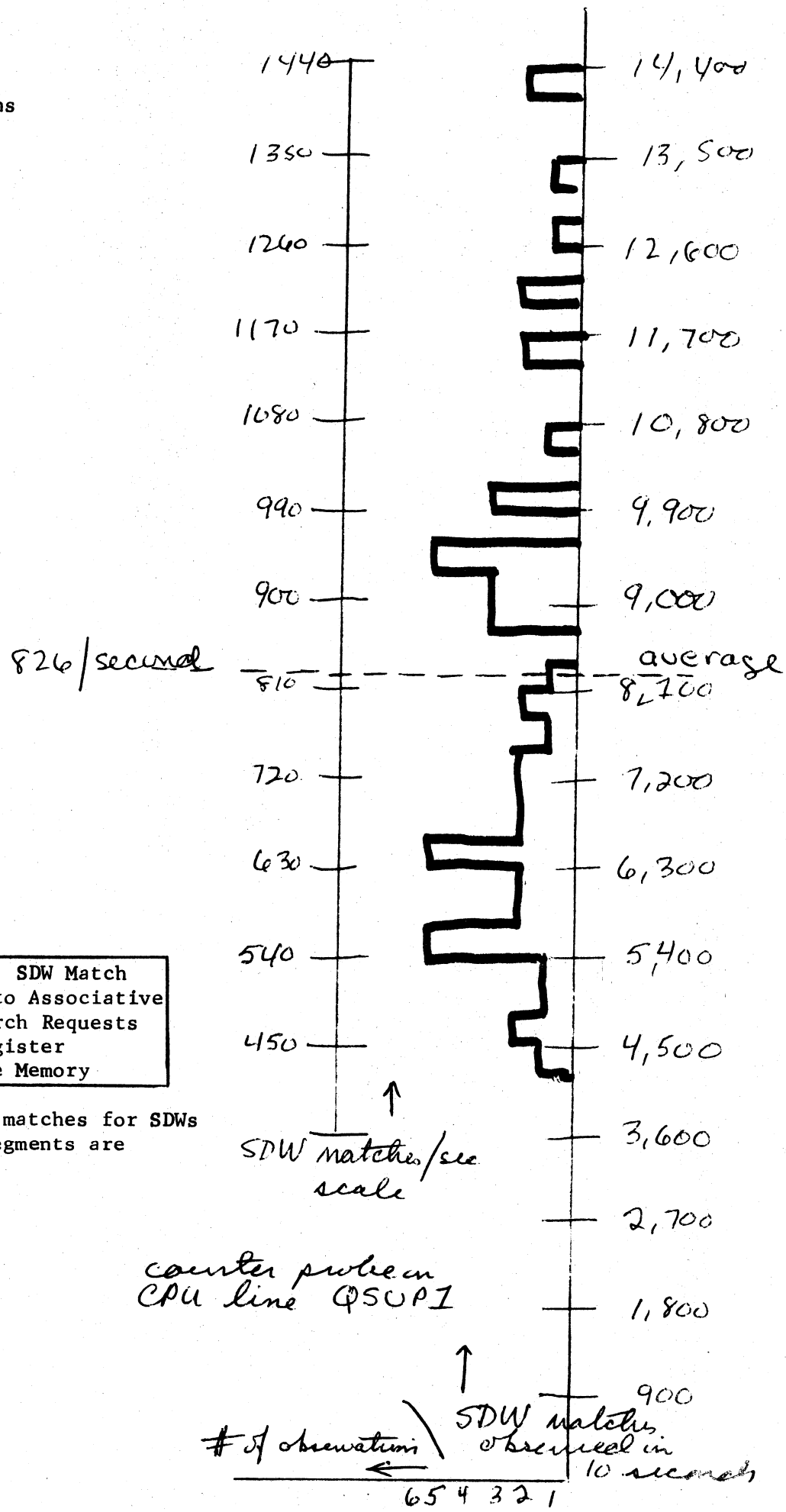
1 CPU, 256K Memory
35 Users
5/10/70

AM SDW matches Observed in 10 Seconds (Observations made continuously)

8,829	
6,092	
11,669	
5,497	
7,080	
14,216	
11,454	
9,280	
10,149	
9,309	
6,150	
12,035	
8,754	
8,155	
5,600	
6,459	
4,352	
5,205	
9,332	
8,769	
10,747	
5,572	
6,511	
5,618	
9,535	
9,942	
4,949	
12,765	
7,433	
14,194	
13,263	
10,182	
7,390	
6,446	
6,993	
4,594	
6,876	
12,216	
7,831	
6,720	
5,951	
5,504	
9,187	
9,162	
7,891	
9,583	
5,936	
7,728	
9,338	
4,556	

Figure VII: SDW Match Responses to Associative Memory Search Requests with 16 Register Associative Memory

Note: Only matches for SDWs of paged segments are counted.



1 CPU, 256 K Memory
14 Users
(5/27/70)

AM Clears Observed in
10 Seconds (Observations
Separated by 1 Second)

3319
741
155
1972
1473
675
641
1344
1928
673
1134
3433
1879
1592
702
2070
1809
1968
1153
1559
1322
2237
2557
2310
1822
2626

counter probe on line BCAMF1

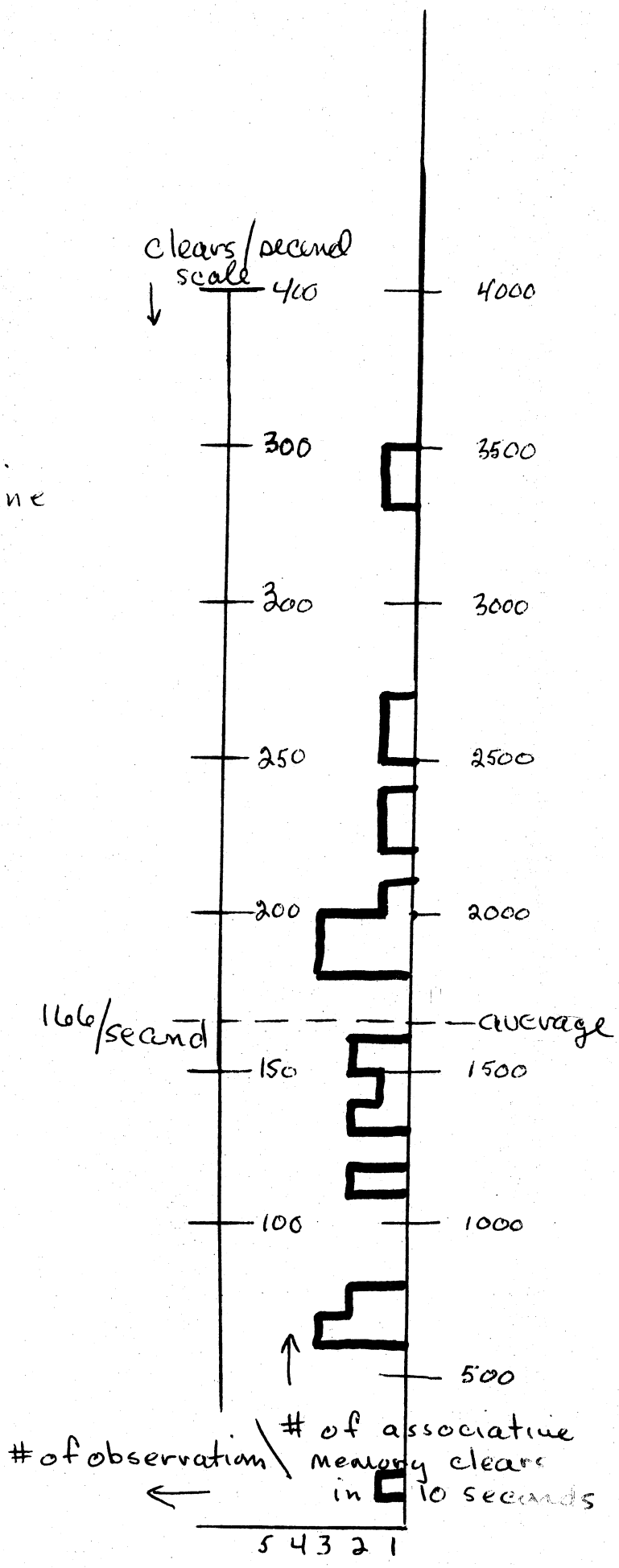
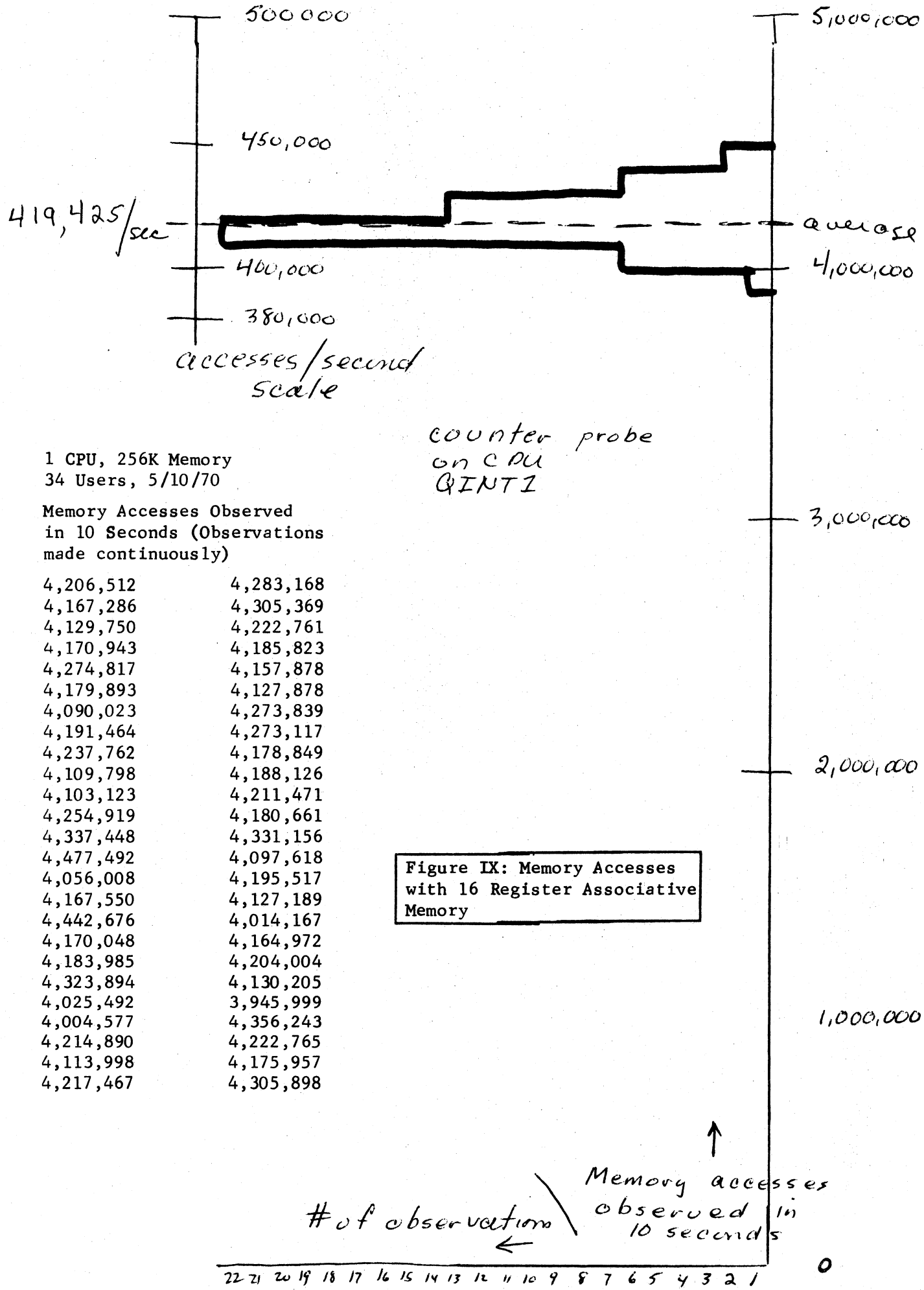


Figure VIII: Associative Memory Clears with 16 Register Associative Memory



1 CPU, 256K Memory
34 Users, 5/10/70

Memory Accesses Observed in 10 Seconds (Observations made continuously)

4,206,512	4,283,168
4,167,286	4,305,369
4,129,750	4,222,761
4,170,943	4,185,823
4,274,817	4,157,878
4,179,893	4,127,878
4,090,023	4,273,839
4,191,464	4,273,117
4,237,762	4,178,849
4,109,798	4,188,126
4,103,123	4,211,471
4,254,919	4,180,661
4,337,448	4,331,156
4,477,492	4,097,618
4,056,008	4,195,517
4,167,550	4,127,189
4,442,676	4,014,167
4,170,048	4,164,972
4,183,985	4,204,004
4,323,894	4,130,205
4,025,492	3,945,999
4,004,577	4,356,243
4,214,890	4,222,765
4,113,998	4,175,957
4,217,467	4,305,898

Figure IX: Memory Accesses with 16 Register Associative Memory

1 CPU 256 K Memory
8-13 Users
6/5/70

Instruction Executions
Observed in 10 Seconds
(Observations separated
by 1 Second)

3,008,278
3,358,278
3,330,513
3,162,857
3,229,477
3,142,089
3,310,434
3,432,582
3,276,145
3,279,092
3,128,477
3,248,919
3,208,127
3,089,042
3,131,998
3,224,596
3,406,378
3,289,973
3,183,973
3,186,657
3,053,827
3,247,717
3,243,981
3,093,047
3,208,988
3,100,186
3,015,186
3,208,860
3,103,770
3,120,383
3,071,199
3,188,683
3,435,216
3,184,018
3,212,254
3,270,806
3,153,594
3,160,866
3,139,246
3,483,759
3,431,851
3,290,286
3,292,765
3,340,633
3,328,900
3,413,608
3,280,245
3,180,076
3,261,750
3,302,906

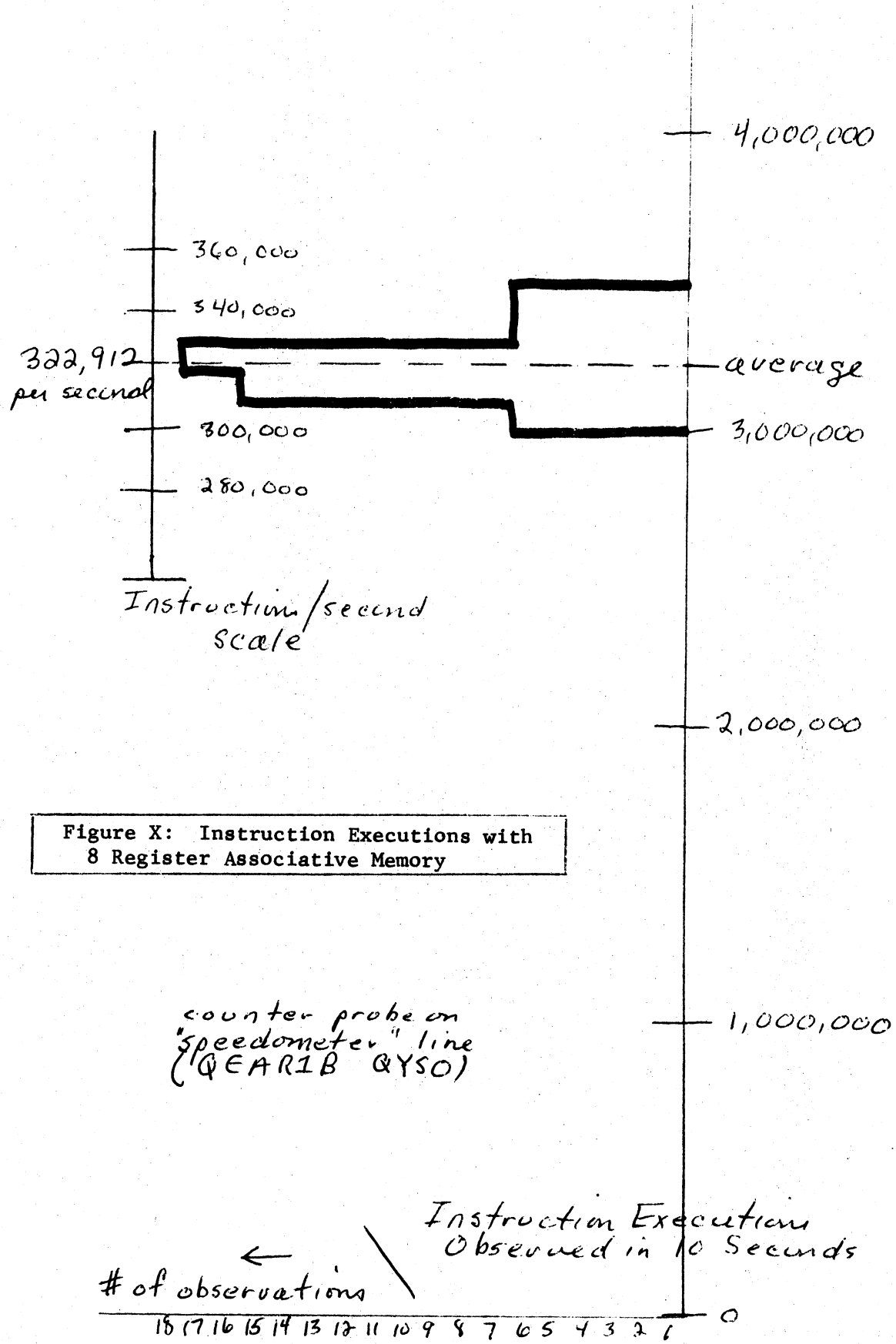


Figure X: Instruction Executions with 8 Register Associative Memory

1 CPU, 256 K Memory
19-21 Users
6/5/70

AM Search Requests
Observed in 10 Seconds
(Observations Separated
by 1 Second)

1	3,680,805
2	3,693,177
3	3,689,589
4	3,751,024
5	3,745,828
6	3,669,819
7	3,716,944
8	3,638,221
9	3,804,695
10	3,953,161
11	3,869,111
12	3,812,508
13	3,731,450
14	3,800,585
15	3,825,318
16	3,695,892
17	3,784,825
18	3,851,015
19	3,884,723
20	3,975,347
21	3,731,202
22	3,764,069
23	3,730,826

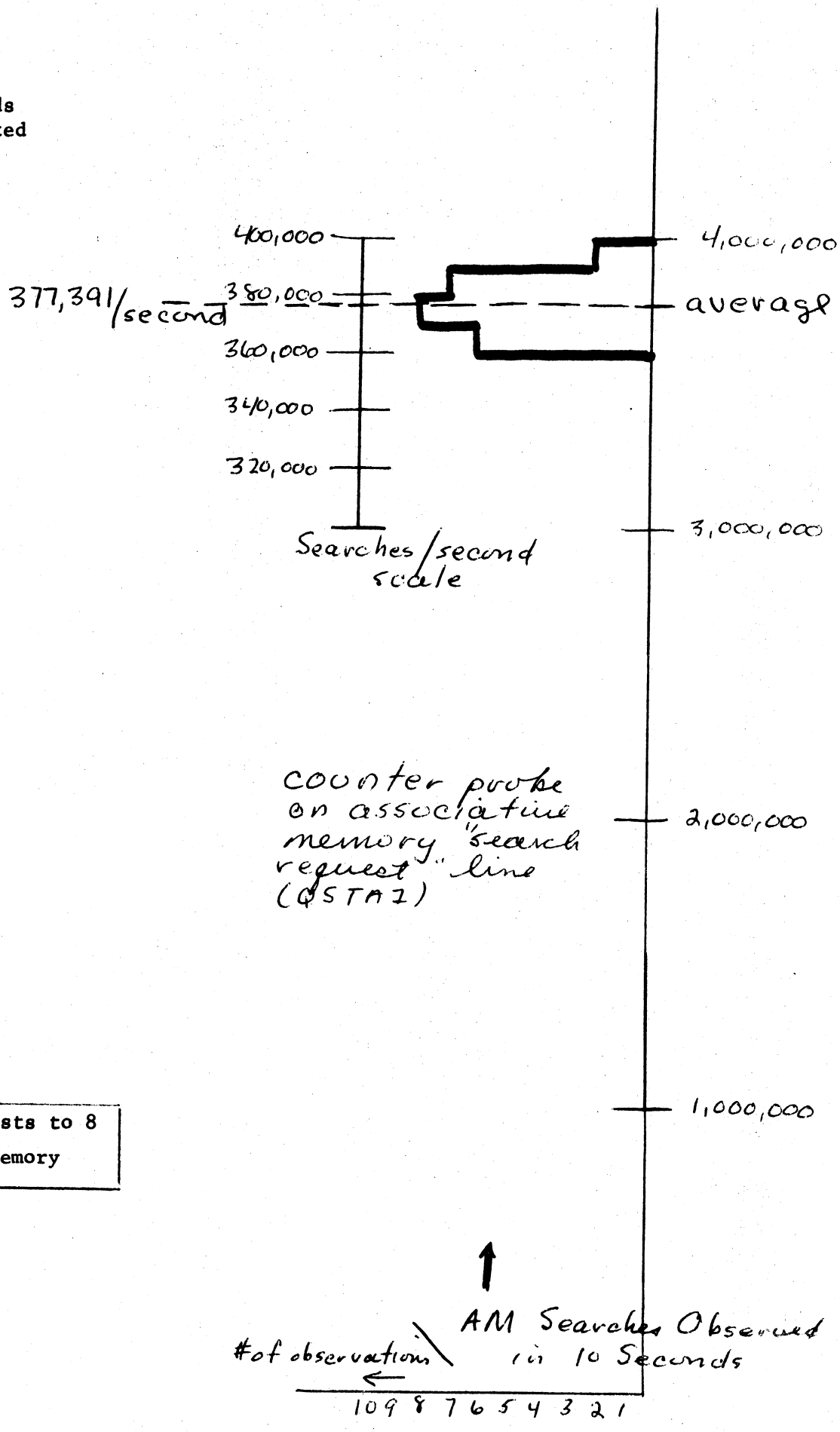


Figure XI: Search Requests to 8 Register Associative Memory

1 CPU, 256 K Memory
19-21 Users
6/5/70

"Not Found" Responses Observed in 10 Seconds (Measurements taken simultaneously with those of Figure XI)

108,603
137,803
100,508
116,228
120,837
130,565
139,639
131,463
115,041
116,570
89,120
104,138
103,084
107,034
109,054
130,878
123,004
92,691
106,860
78,044
102,499
95,170
71,808

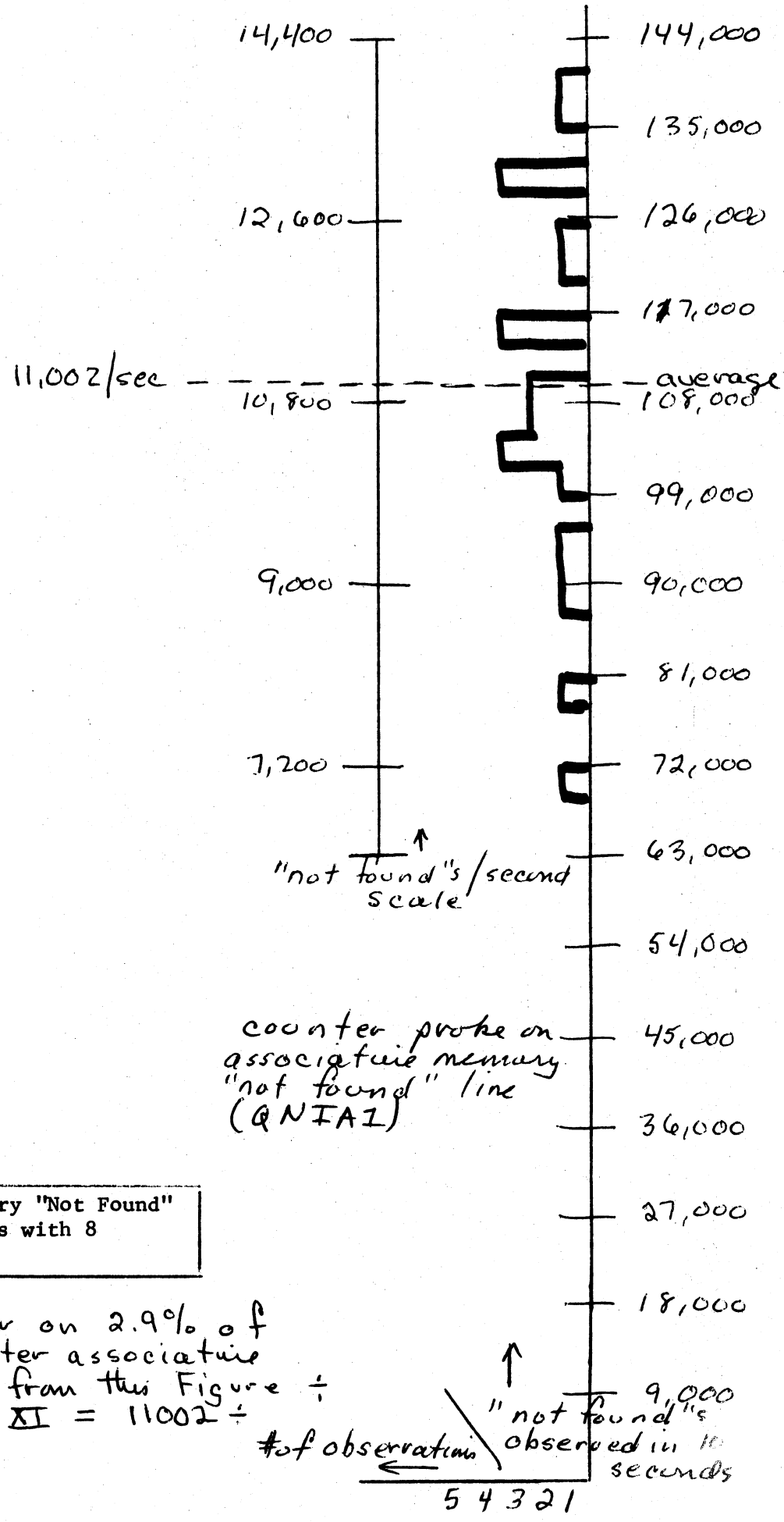


Figure XII: Associative Memory "Not Found" Responses to Search Requests with 8 Register Associative Memory

Note: "Not found"s occur on 2.9% of requests to the 8 register associative memory i.e. average from this Figure ÷ average from Figure XI = 11002 ÷ 377391 = .029

1 CPU, 256 K Memory
21-23 Users
6/5/70

AM SDW Matches Observed in 10 Seconds (Observations Made 1 second apart)

18,909
21,239
11,371
9,863
7,087
11,727
23,205
9,730
33,461
24,026
26,816
23,708
5,735
29,372
46,286
27,616
19,537
16,134
39,215
10,698
17,267
23,314
16,926

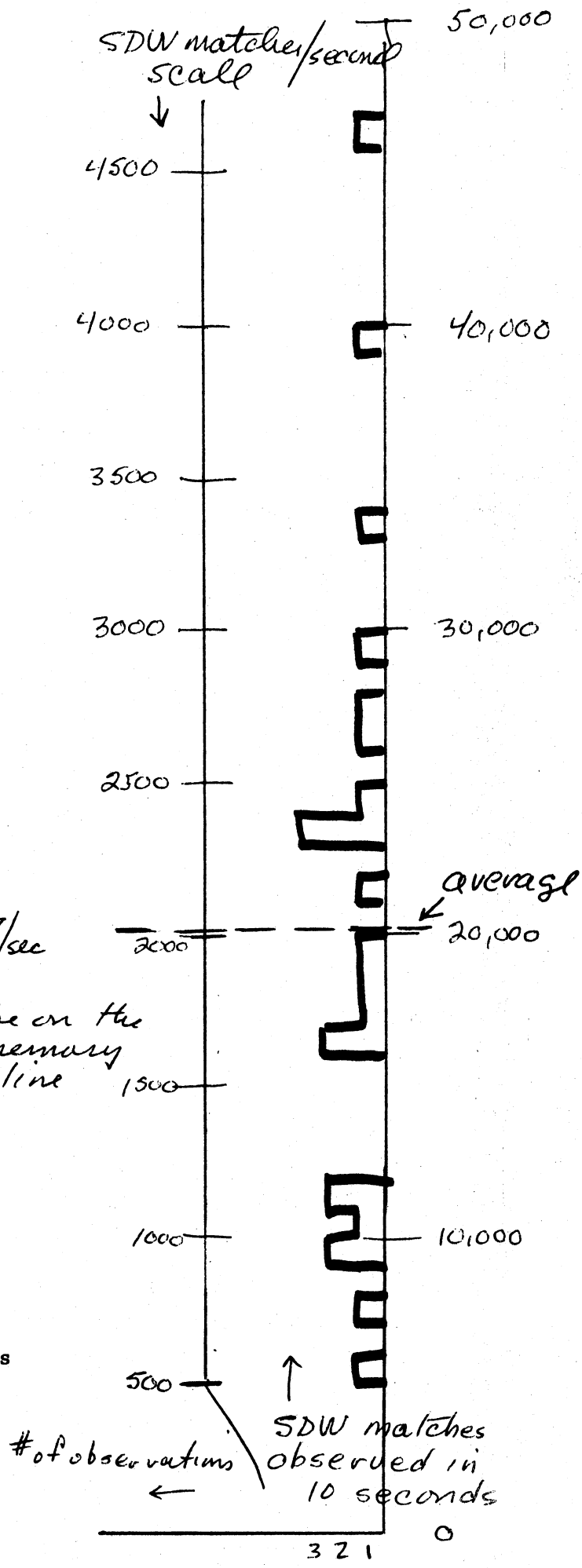


Figure XIII: SDW Match Responses to Associative Memory Search Requests with 8 Register Associative Memory

Note: Only matches for SDWs of paged segments are counted.

1 CPU, 256 K Memory
23 Users
6/5/70

Memory Accesses Observed in 10 Seconds (Observations taken 1 second apart)

4,005,793
4,138,498
4,237,895
4,409,977
4,328,967
4,121,089
4,162,155
4,236,029
4,074,800
3,997,709
4,312,395
4,395,378
4,445,512
4,192,657
4,120,719
4,406,850
4,164,635
4,175,629
4,013,062
4,019,243
4,051,468
4,104,979
4,089,966

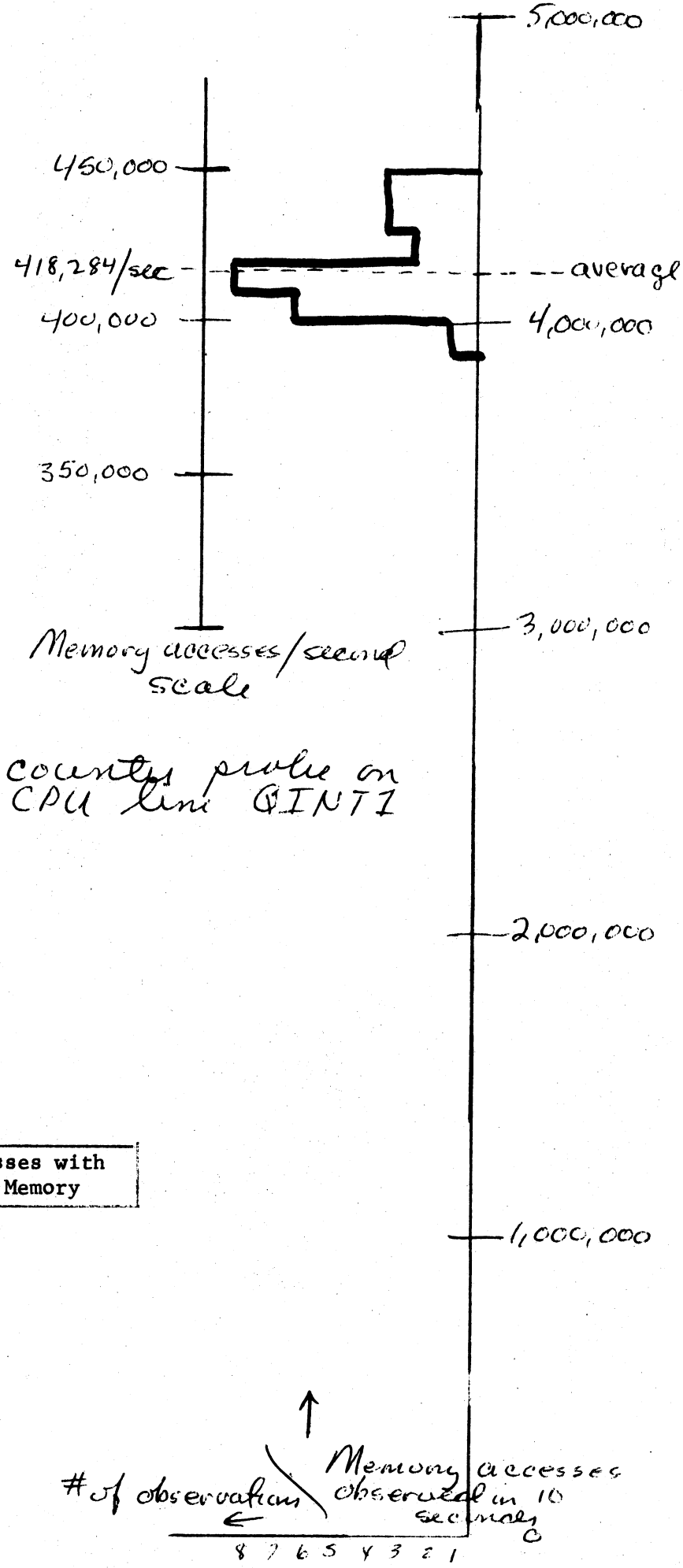


Figure XIV: Memory Accesses with 8 Register Associative Memory

1 CPU, 256 K Memory
23-25 Users
(6/8/70)

nstruction Executions Observed
in 10 Seconds (Observations
Separated by 1 second)

3,098,832
2,878,935
2,942,036
2,736,823
2,774,232
2,659,807
2,812,790
2,907,201
2,922,241
2,853,799
2,902,243
2,906,417
2,857,889
2,759,485
2,850,818
2,930,195
2,879,630
2,813,044
2,938,669
2,844,671
2,800,314
2,896,227
2,839,223
2,856,875
3,007,658
2,738,780
2,925,622

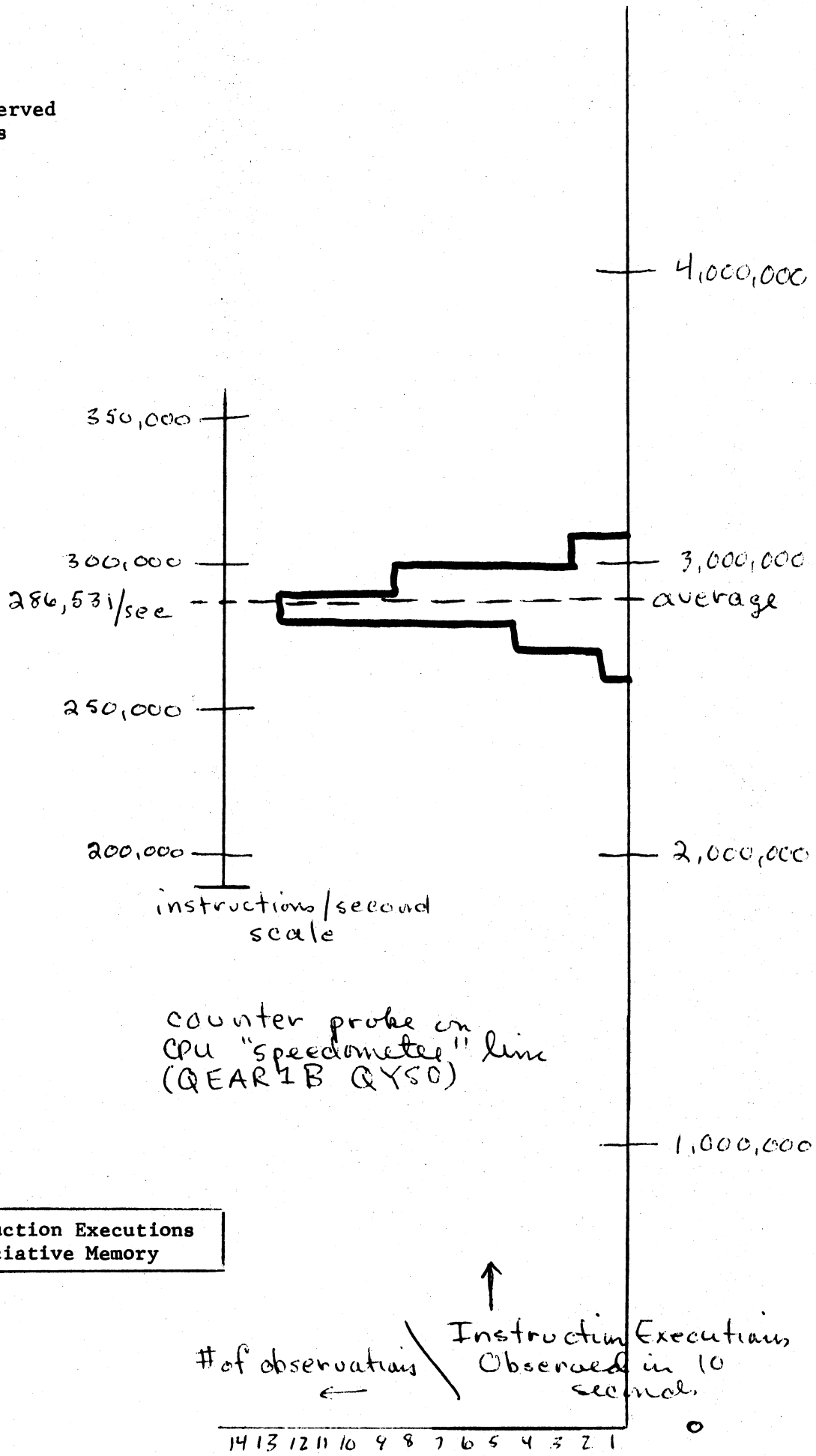


Figure XV: Total Instruction Executions with 4 Register Associative Memory

1 CPU, 256 K Memory
23-25 Users
6/8/70

AM Search Requests Observed
in 10 Seconds (Observations
Separated by 1 Second)

3,410,957
3,417,383
3,338,417
3,300,361
3,219,028
3,259,103
3,382,606
3,388,663
3,326,615
3,355,778
3,387,002
3,556,197
3,302,264
3,397,732
3,388,880
3,405,604
3,348,536
3,354,186
3,363,319
3,261,174
3,369,305
3,419,950
3,414,968
3,569,023
3,304,411
3,421,537
3,447,449

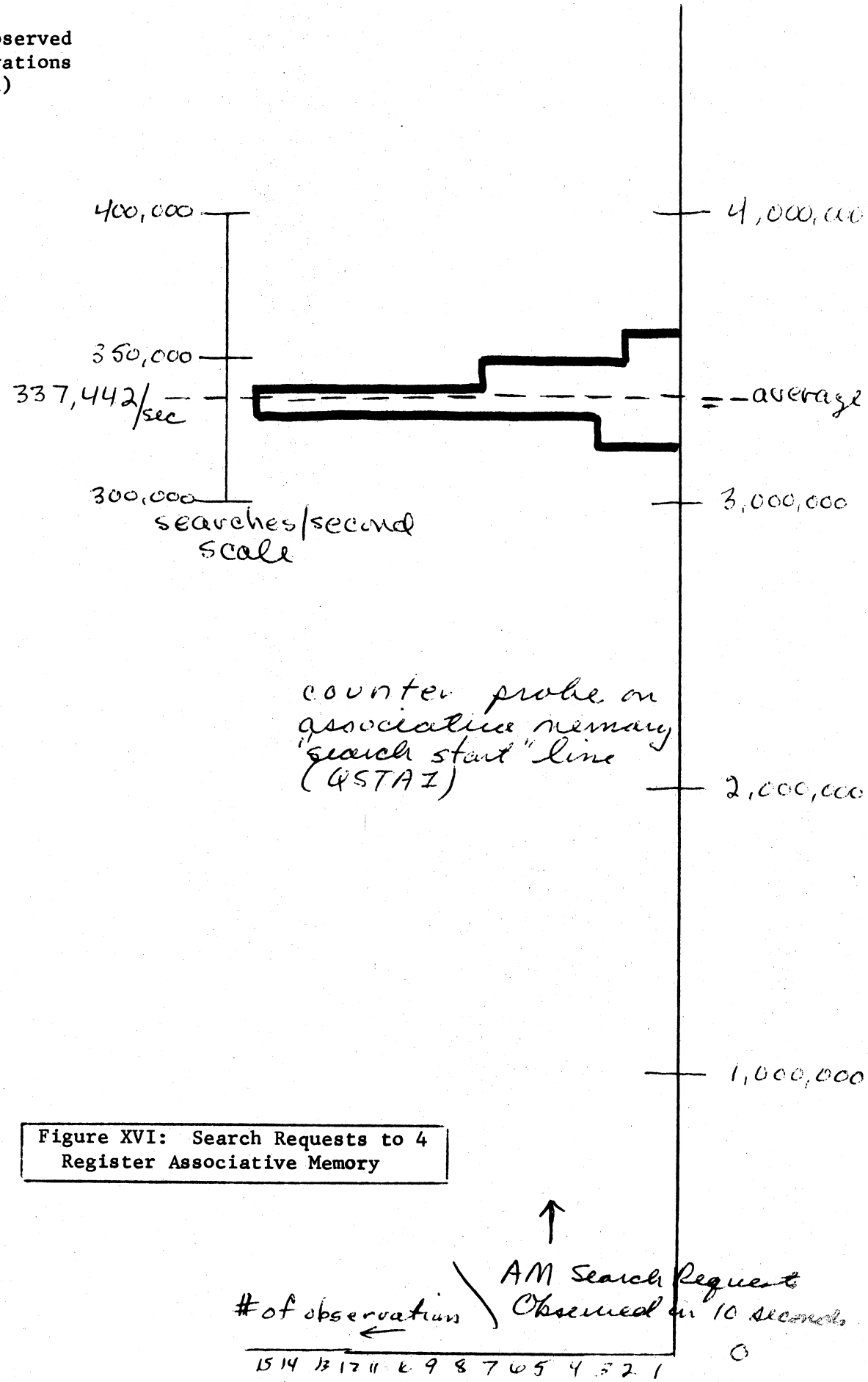


Figure XVI: Search Requests to 4 Register Associative Memory

1 CPU, 256 K Memory
24-25 Users
6/8/70

AM "not found" Responses Observed in 1 Minute (Observations Taken Between 1048 and 1101)

2,243,977
1,949,944
2,006,642
2,263,931
2,226,550
2,014,818
2,157,998
2,166,748
2,258,391
2,137,513

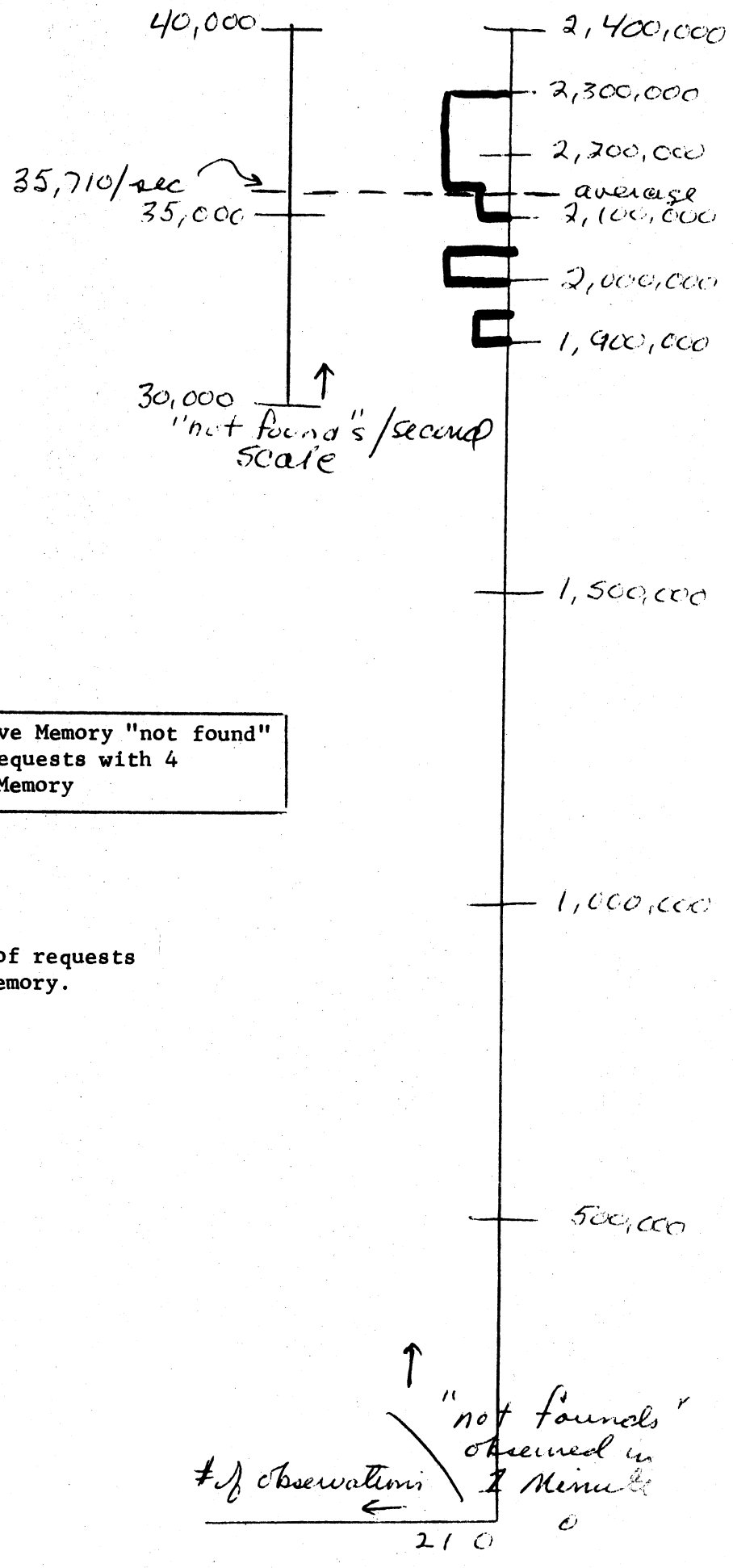


Figure XVII: Associative Memory "not found" Responses to Search Requests with 4 Register Associative Memory

Note: "not found"s occurred on 10.4% of requests to the 4 register associative memory.

1 CPU, 256 K memory
24 Users
6/8/70

AM SDW Matches Observed in 1 Minute (Observations made between 1104 and 1119)

235,568
544,243
352,208
260,191
243,439
188,289
463,499
304,260
253,318
268,977

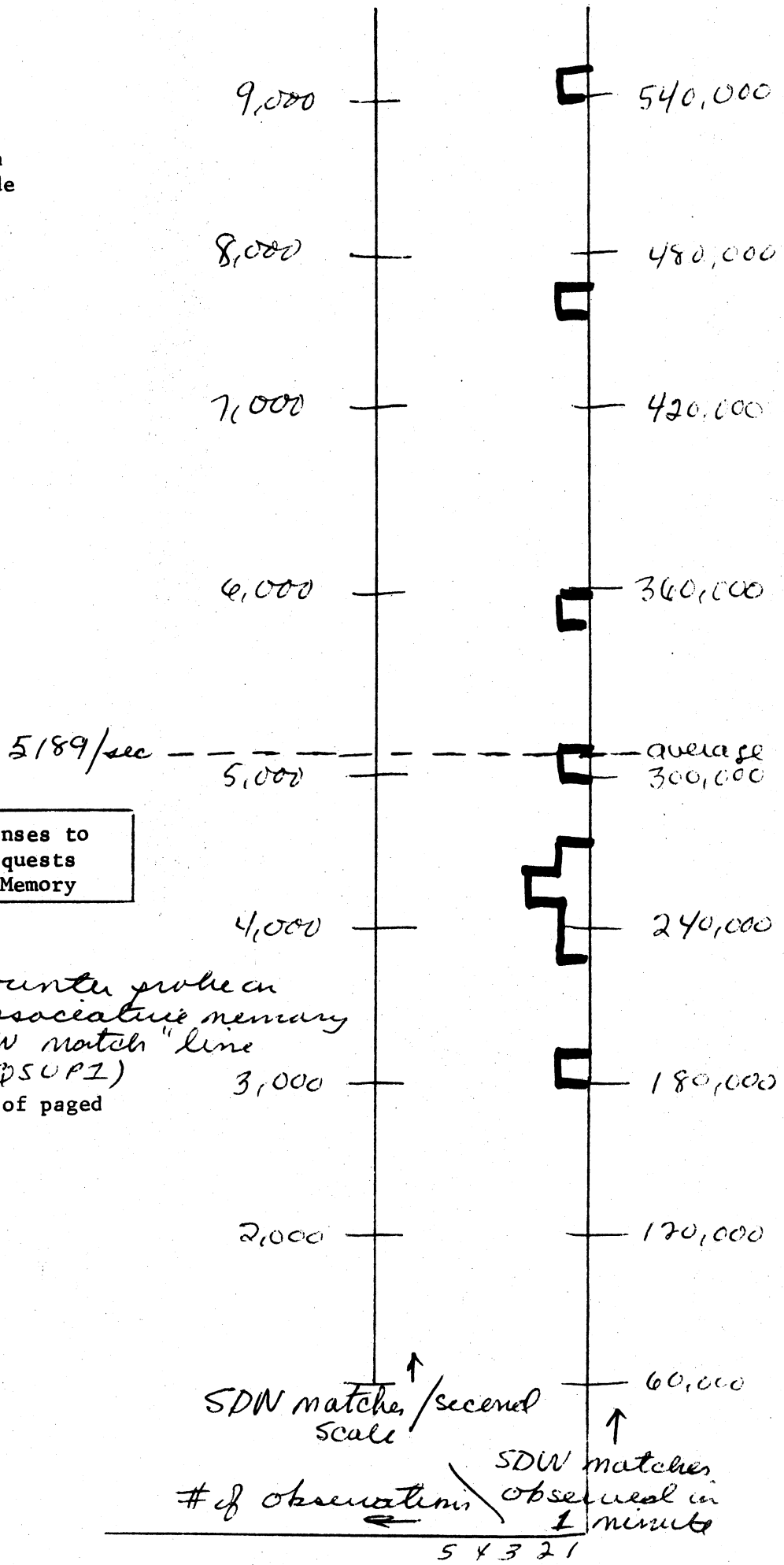


Figure XVIII: SDW Match Responses to Associative Memory Search Requests with 4 Register Associative Memory

Note: Only matches for SDWs of paged segments counted.

1 CPU, 256 K Memory
25-26 Users
6/8/70

Memory Accesses Observed
10 Seconds (Observations
Made 1 Second Apart)

4,556,812
4,567,942
4,553,271
4,500,912
4,532,276
4,486,486
4,517,929
4,573,434
4,370,230
4,387,624
4,505,462
4,436,854
4,397,213
4,618,221
4,560,362
4,487,186
4,546,092
4,554,831
4,650,946
4,618,190
4,596,589
4,566,398
4,476,545
4,501,812
4,501,986
4,427,169

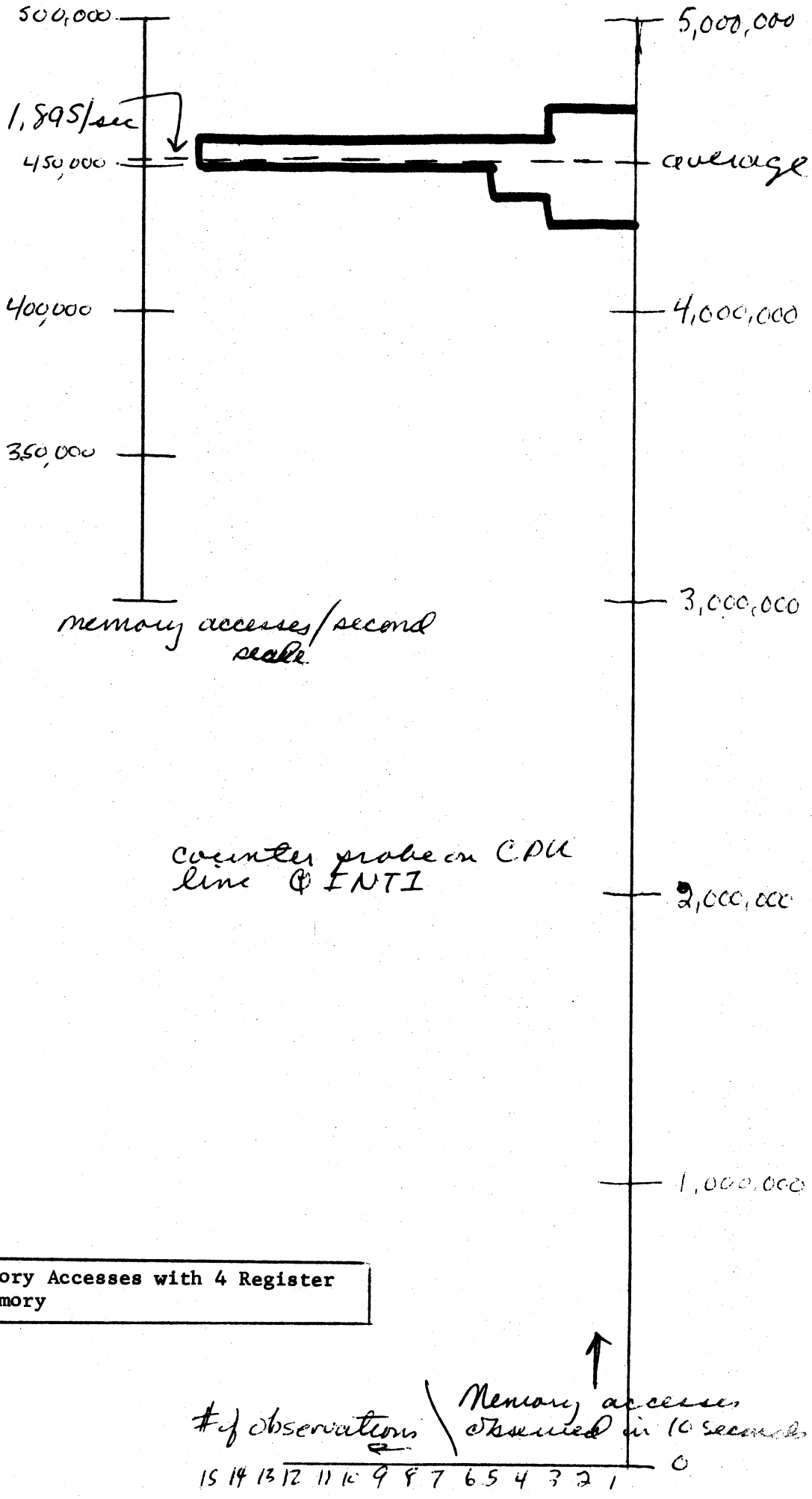


Figure XIX: Memory Accesses with 4 Register Associative Memory

1 CPU, 256 K Memory
6/5/70

Instruction Executions Observed in 1 Minute	Number of Users
7,412,020	14
7,409,882	
7,443,528	
7,360,494	
7,331,386	
7,298,917	
7,399,623	
7,397,786	
7,420,617	
7,447,495	20
7,325,603	
7,468,917	
7,439,546	
7,452,757	
7,369,736	21

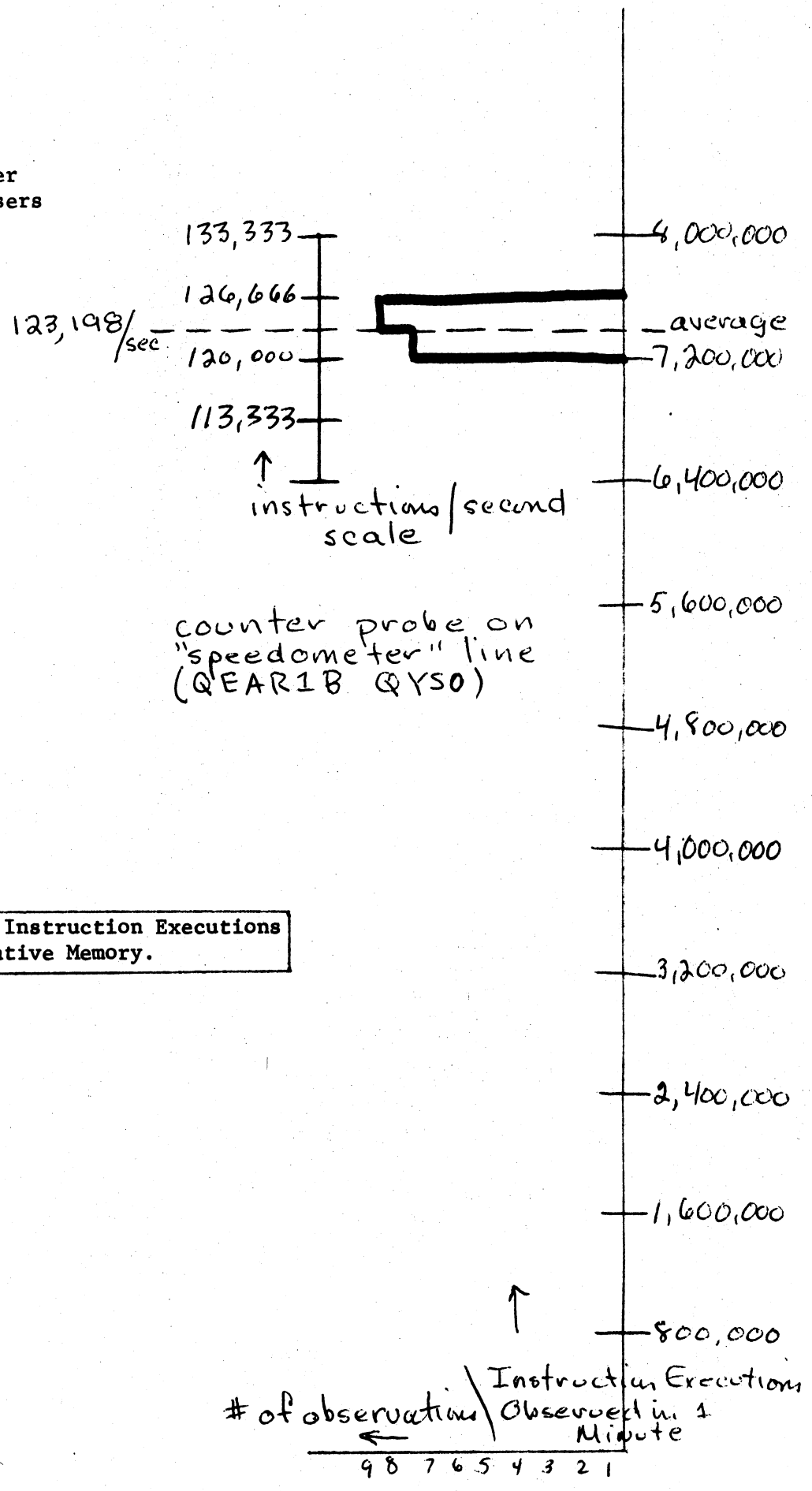
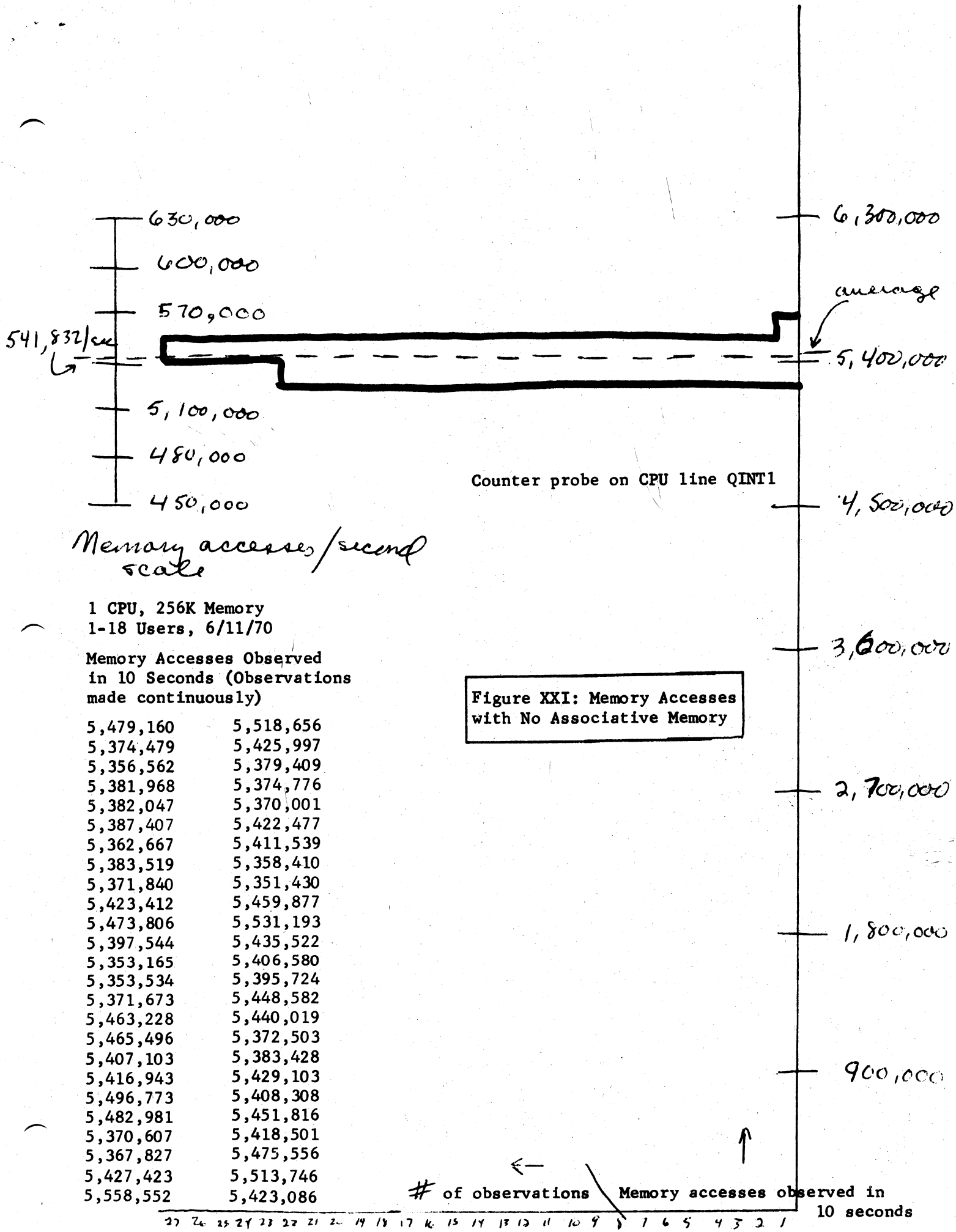


Figure XX: Total Instruction Executions with No Associative Memory.



1 CPU, 256K Memory
1-18 Users, 6/11/70

Memory Accesses Observed in 10 Seconds (Observations made continuously)

5,479,160	5,518,656
5,374,479	5,425,997
5,356,562	5,379,409
5,381,968	5,374,776
5,382,047	5,370,001
5,387,407	5,422,477
5,362,667	5,411,539
5,383,519	5,358,410
5,371,840	5,351,430
5,423,412	5,459,877
5,473,806	5,531,193
5,397,544	5,435,522
5,353,165	5,406,580
5,353,534	5,395,724
5,371,673	5,448,582
5,463,228	5,440,019
5,465,496	5,372,503
5,407,103	5,383,428
5,416,943	5,429,103
5,496,773	5,408,308
5,482,981	5,451,816
5,370,607	5,418,501
5,367,827	5,475,556
5,427,423	5,513,746
5,558,552	5,423,086

Figure XXI: Memory Accesses with No Associative Memory