Dr.

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Report No. UMICH 014571-7-I (Internal)

WET STEAM TUNNEL: TRAILING EDGE OBSERVED

by Sander Blome

(submitted in partial fulfillment of ME 49o)

supervised by Prof. F. G. Hammitt and Mr. W. Kim

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INTRODUCTION

This paper is presented as an update to report UMICH 014571-7-I. The topic involves observations of the trailing edge of a model turbine blade located inside a low-pressure wet steam tunnel. Please refer to report UMICH 014571-7-I for a description of the data-taking process and for the definitions of terms used within this report (i.e. fingers, film).

MAXIMUM DROP DIAMETER VS. DISTANCE

In our recent research of trailing edge phenomenon, Fastex films have provided vast amounts of data concerning steam tunnel operations. Among this data is a record of the largest drop seen beyond the trailing edge of the model turbine blade. The average diameter of the drop and its distance from the trailing edge have been recorded. (Appendix A) Tables 1, 2, and 3 present a distribution of the maximum drop diameters observed for various steam velocities and various liquid film flow rates.

MAXIMUM DROP DIAMETER VS. TIME

Records have been filed on the variation of the maximum drop diameter observed (for a given flow rate and a given steam velocity) as a function of time. Appendix B contains this data. In addition, Table 4 presents the average periodicity of the maximum drops observed. Stated differently, Table 4 presents the average time between surges of large drops observed near the trailing edge.

MAXIMUM LENGTH VS. TIME

Graphs have been drawn which indicate the maximum length of the water film extending from the trailing edge. This maximum film length is plotted as a function of time in Appendix C for various flow rates and steam velocities. Table 5 presents the average disintegration periodicity; in other words, the average time between surges of water flow observed near the trailing edge.

NUMBER OF FINGERS VS. TIME

Appendix D is a presentation of the number of fingers observed at the trailing edge as a function of time. To date no periodicity functions have been computed for this fingers phenomenon. Plans are underway to gather these functions in the near future.

CONCLUSIONS

Because this field of research is relatively unexplored, conclusions from the Fastex film data are tentative and open to debate. No conclusions have been drawn with regard to the drop distribution or number of fingers data presented in this paper. It is hoped that the data within can be used as a base from which conclusions can be drawn in the future by Professor Hammitt's research team.

A pattern in the average disintigration periodicity has been observed. Figure 1 presents the evidence that the average time between surges of water film at the trailing edge varies between .050-.065 seconds and is apparently independent of the liquid film flow rate and the steam velocity.

TABLE I : DROP DISTRIBUTION FOR $V_{SL} = 308$ ft/sec

Maximum Drop Dia. (cm.)	$\dot{Q} = 5$ cc/min		$\dot{Q} = 10$ cc/min		$\dot{Q} = 20$ cc/min		$\dot{Q} = 40$ cc/min	
	n	%	n	%	n	%	n	%
.045	2	3.8	0	0	0	0	3	5.1
.090	29	54.7	32	51.6	13	23.6	30	50.8
.135	18	34.0	16	25.8	24	43.6	15	25.4
.180	4	7.5	7	11.3	10	18.2	7	11.9
.225	0	0	1	1.6	5	9.2	2	3.4
.270	0	0	5	8.1	0	0	2	3.4
.315	0	0	0	0	1	1.8	0	0
.360	0	0	0	0	1	1.8	0	0
.405	0	0	0	0	1	1.8	0	0
.450	0	0	1	1.6	0	0	0	0
Total →	53	100.0	62	100.0	55	100.0	59	100.0

NATIONAL
42 389 200 SHEETS 5 SQUARE
42 382 100 SHEETS 5 SQUARE
12 381 50 SHEETS 5 SQUARE

TABLE 2 — DROP DISTRIBUTION FOR $V_{ST} = 522$ ft/sec

Maximum Drop Dia (cm.)	$\dot{Q}$=5A cc/min		$\dot{Q}$=10A cc/min		$\dot{Q}$=10B cc/min		$\dot{Q}$=15A cc/min		$\dot{Q}$=15B cc/min		$\dot{Q}$=20 cc/min		$\dot{Q}$=30 cc/min		$\dot{Q}$=50 cc/min	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
.045	4	8.7	1	1.9	8	13.6	11	16.9	12	16.2	3	4.2	10	15.2	7	9.3
.090	23	50.0	29	55.8	33	55.9	29	44.6	35	47.3	38	52.8	24	36.4	28	36.8
.135	12	26.1	19	36.5	11	18.6	15	23.1	23	31.1	21	29.2	25	37.9	27	35.5
.150	5	10.8	2	3.9	5	8.5	8	12.3	1	1.4	5	6.9	3	4.5	10	13.2
.225	1	2.2	1	1.9	2	3.4	2	3.1	3	4.0	1	1.4	2	3.0	2	2.6
.270	1	2.2	0	0	0	0	0	0	0	0	1	1.4	0	0	1	1.3
.315	0	0	0	0	0	0	0	0	0	0	1	1.4	0	0	0	0
.360	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
.405	0	0	0	0	0	0	0	0	0	0	2	2.7	2	3.0	1	1.3
.450	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS →	46	100	52	100	59	100	65	100	74	100	72	100	66	100	76	100

NATIONAL
42-381 50 SHEETS 5 SQUARE
42-382 100 SHEETS 5 SQUARE
42-389 200 SHEETS 5 SQUARE

TABLE 3 — DROP DISTRIBUTION FOR V_{ST} = 826 d/sec

MAXIMUM DROP DIA (cm.)	Q = 5A cc/min		Q = 5B cc/min		Q = 10A cc/min		Q = 10B cc/min		Q = 15A cc/min		Q = 15B cc/min		Q = 20 cc/min		Q = 30 cc/min	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
.045	5	12.8	11	21.2	0	0	3	7.8	3	6.0	2	2.4	1	1.3	1	1.6
.090	25	64.1	37	71.2	20	80.0	22	56.4	31	62.0	53	62.4	57	76.0	42	67.7
.135	6	15.4	4	7.6	2	8.0	12	30.8	12	24.0	23	27.1	12	16.0	12	19.4
.180	2	5.1	0	0	3	12.0	1	2.5	3	6.0	3	3.5	4	5.4	4	6.5
.225	1	2.6	0	0	0	0	0	0	0	0	2	2.3	0	0	1	1.6
.270	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1.6
.315	0	0	0	0	0	0	0	0	0	0	0	0	1	1.3	0	0
.360	0	0	0	0	0	0	1	2.5	0	0	0	0	0	0	0	0
.405	0	0	0	0	0	0	0	0	1	2.0	0	0	0	0	0	0
.450	0	0	0	0	0	0	0	0	0	0	2	2.3	0	0	1	1.6
TOTALS →	39	100	52	100	25	100	39	100	50	100	85	100	75	100	62	100

42 381 50 SHEETS 5 SQUARE
42 382 100 SHEETS 5 SQUARE
42 389 200 SHEETS 5 SQUARE
NATIONAL

TABLE 4 MAXIMUM DROP DIAMETER PERIODICITY

V_{st} = 308 ft/sec				V_{st} = 522 ft/sec				V_{st} = 826 ft/sec			
Q (cc/min)	Number of peaks	Total time (sec.)	Average period (sec.)	Q (cc/min)	Number of peaks	Total time (sec.)	Average Period (sec.)	Q (cc/min)	Number of peaks	Total time (sec.)	Average period (sec.)
5	10	1.12	.112	5A	12	1.04	.087	5A	8	1.20	.150
10	16	1.32	.082	10A	13	1.32	.102	5B	5	1.20	.240
20	14	1.30	.092	10B	15	1.44	.096	10A	5	1.20	.240
40	17	1.44	.085	15A	16	1.32	.088	10B	10	1.12	.112
—	—	—	—	15B	19	1.52	.080	15A	11	1.44	.131
—	—	—	—	20	18	1.44	.080	15B	18	1.40	.078
—	—	—	—	30	16	1.20	.075	20	11	1.32	.120
				50	19	1.32	.069	30	10	1.28	.128

NATIONAL
42-381 50 SHEETS 5 SQUARE
42-382 100 SHEETS 5 SQUARE
42-389 200 SHEETS 5 SQUARE

TABLE 5 TRAILING EDGE DISINTEGRATION PERIODICITY

V_{SL} = 308 ft/sec				V_{SL} = 522 ft/sec				V_{SL} = 826 ft/sec			
$\dot{Q}$ (cc/min)	Number of Peaks	Total Time (sec)	Average Period (sec)	$\dot{Q}$ (cc/min)	Number of Peaks	Total time (sec)	Average Period (sec)	$\dot{Q}$ (cc/min)	Number of Peaks	Total Time (sec)	Average Period (sec)
5	17	1.20	.071	0	-	-	-	0	3	1.44	.048
10	22	1.32	.045	5A	26	1.30	.050	5A	16	1.20	.075
20	24	1.30	.054	5B	15	1.20	.080	5B	16	1.20	.075
40	23	1.32	.057	10A	25	1.32	.053	10A	23	1.20	.052
				10B	28	1.44	.051	10B	23	1.44	.063
				15A	26	1.32	.051	15A	21	1.12	.053
				15B	30	1.44	.048	15B	28	1.44	.051
				20	26	1.32	.051	20	23	1.32	.057
				30	24	1.20	.050	30	26	1.30	.050
				30	21	1.32	.063	30	25	1.28	.051

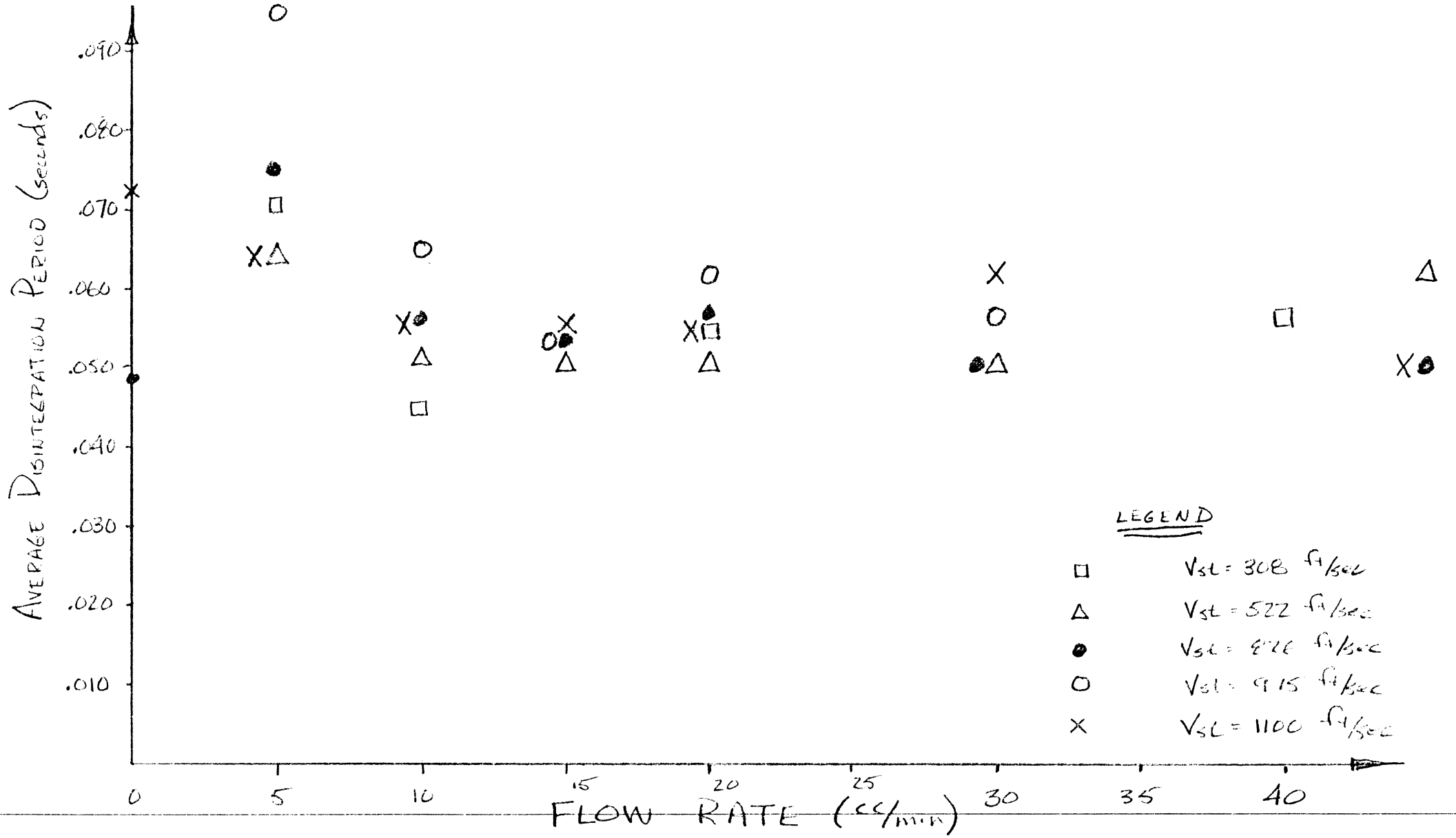
42 381 50 SHEETS 5 SQUARE
42 382 100 SHEETS 5 SQUARE
42 389 200 SHEETS 5 SQUARE

TABLE 5 (cont'd) TRAILING EDGE DISINTEGRATION PERIODICITY

V_{SL} = 975 ft/sec				V_{SL} = 1100 ft/sec			
Q (cc/min)	Number of Peaks	Total Time (sec)	Average Period (sec)	Q (cc/min)	Number of Peaks	Total Time (sec)	Average Period (sec)
0	—	—	—	0	21	1.52	.072
5A	16	1.52	.095	5A	23	1.52	.066
10A	25	1.60	.064	5B	21	1.30	.062
10B	24	1.52	.063	10A	29	1.52	.052
15A	28	1.52	.054	10B	24	1.52	.063
15B	29	1.52	.052	15A	27	1.52	.056
20A	24	1.52	.063	15B	21	1.30	.054
20B	25	1.50	.061	20A	28	1.52	.054
30A	31	1.52	.049	30A	24	1.52	.063
30B	26	1.50	.058	50A	30	1.52	.051

42 381 50 SHEETS 5 SQUARE
42 382 100 SHEETS 5 SQUARE
42 389 200 SHEETS 5 SQUARE

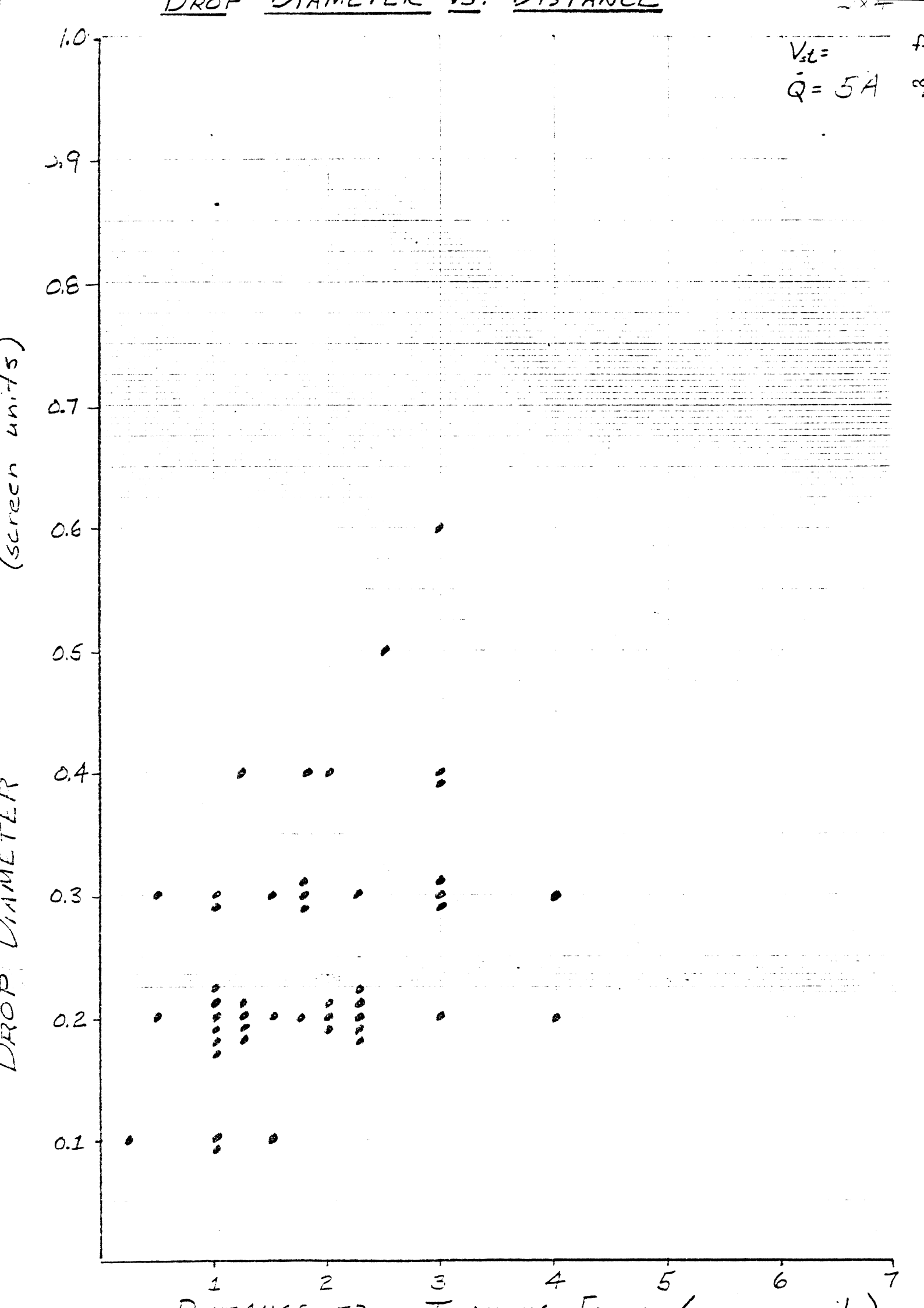
FIGURE 1: FLOW RATE VS. AVERAGE DISINTEGRATION PERIOD FOR VARIOUS STEAM VELOCITIES



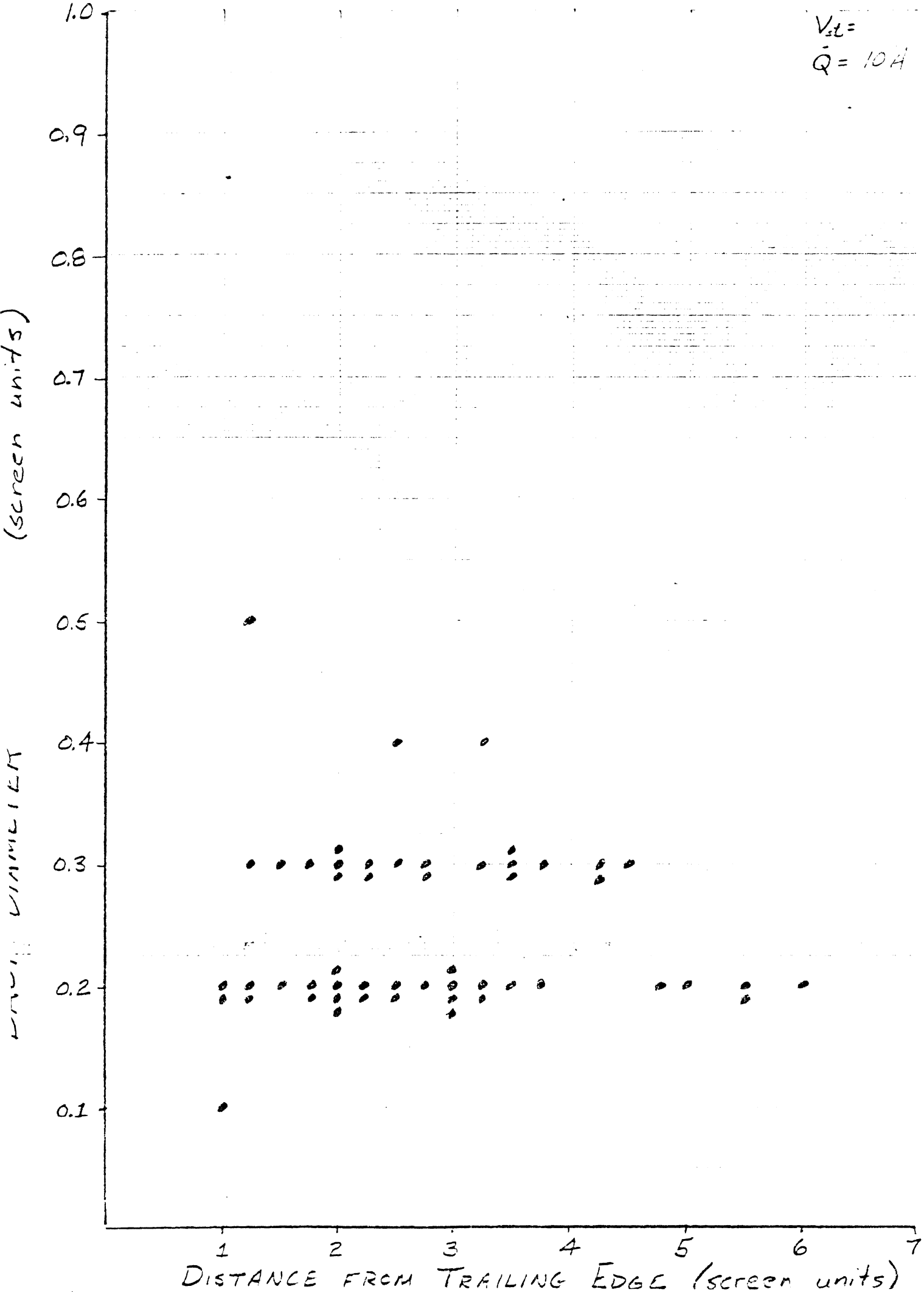
42-381 50 SHEETS 5 SQUARE
42-382 100 SHEETS 5 SQUARE
42-389 200 SHEETS 5 SQUARE
NATIONAL

APPENDIX A

MAXIMUM DROP DIAMETER VS. DISTANCE


DROP DIAMETER VS. DISTANCE
V_{st} =
Q = 5A
DROP DIAMETER (screen units)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
2
3
4
5
6
7

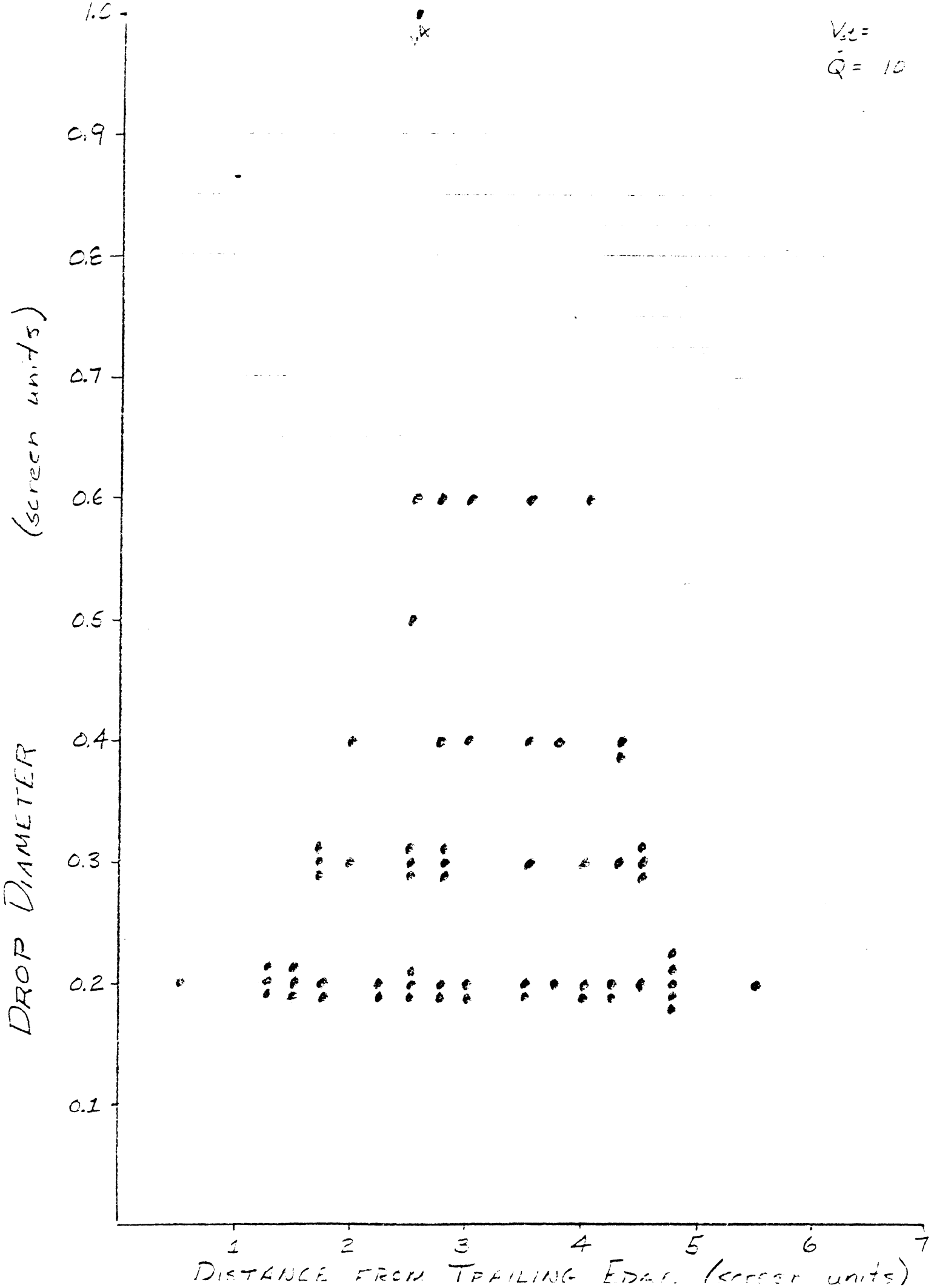
DROP DIAMETER VS. DISTANCE



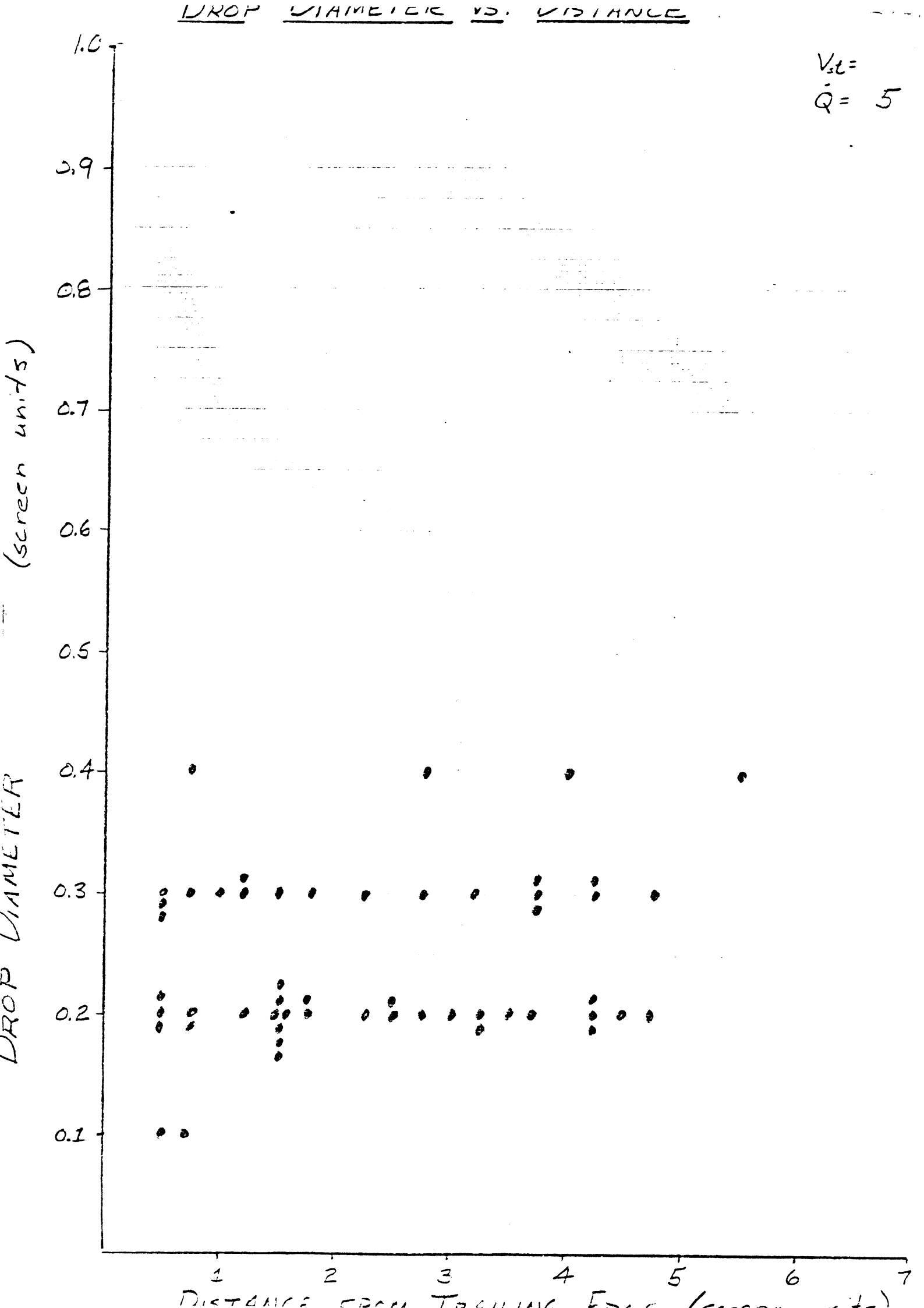
DROP DIAMETER VS. DISTANCE

V_{sl} =

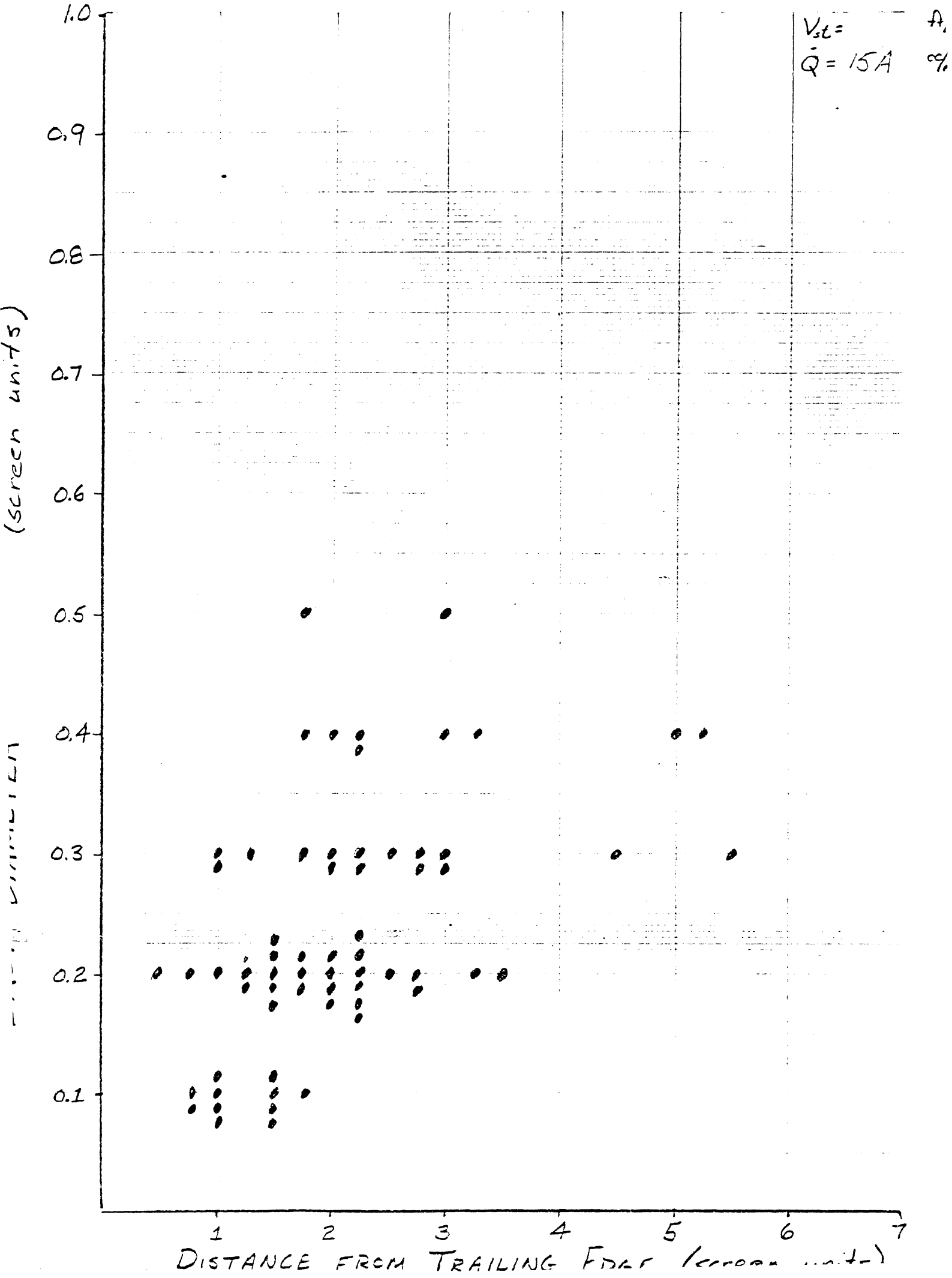
$\dot{Q}$ = 10

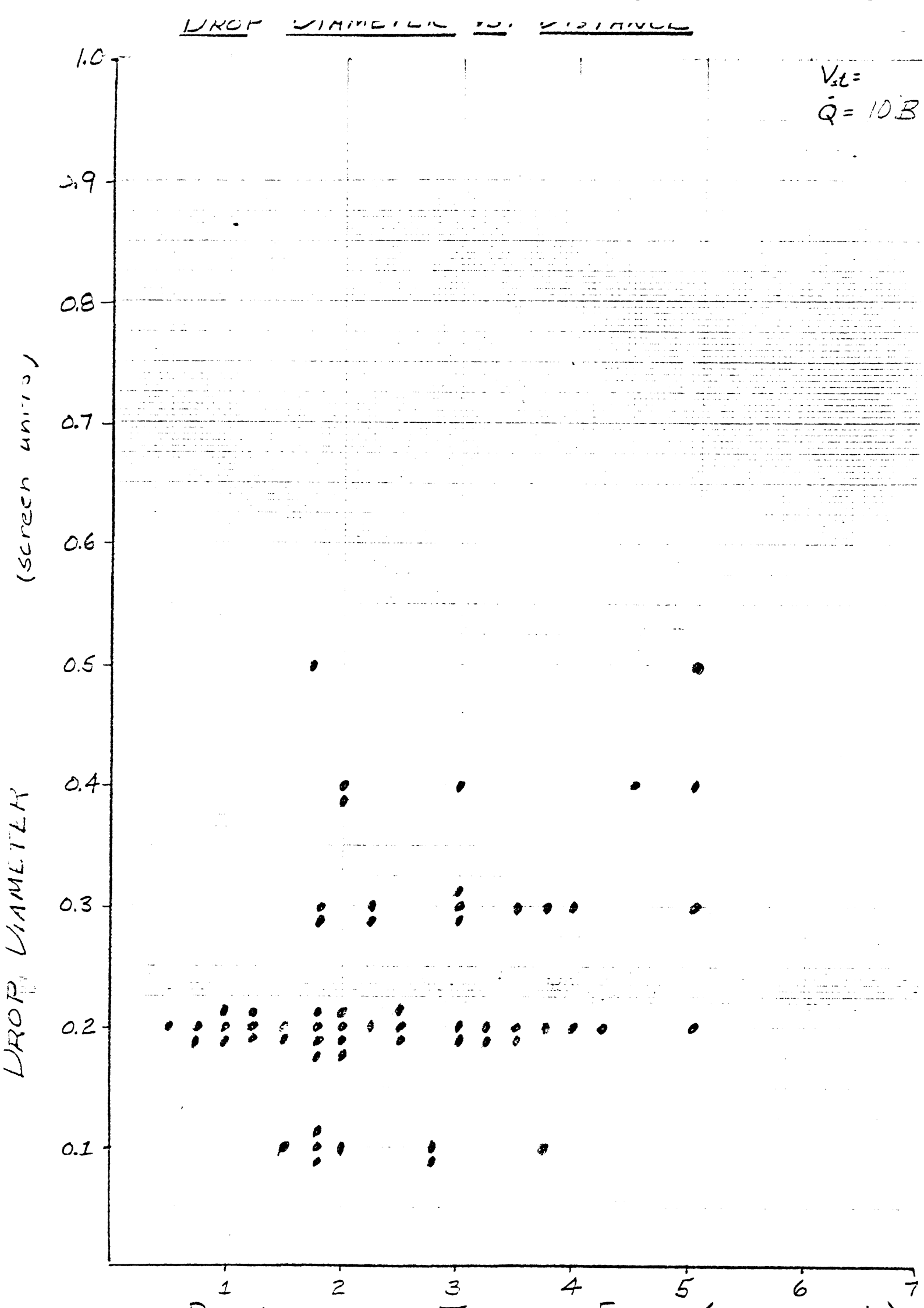


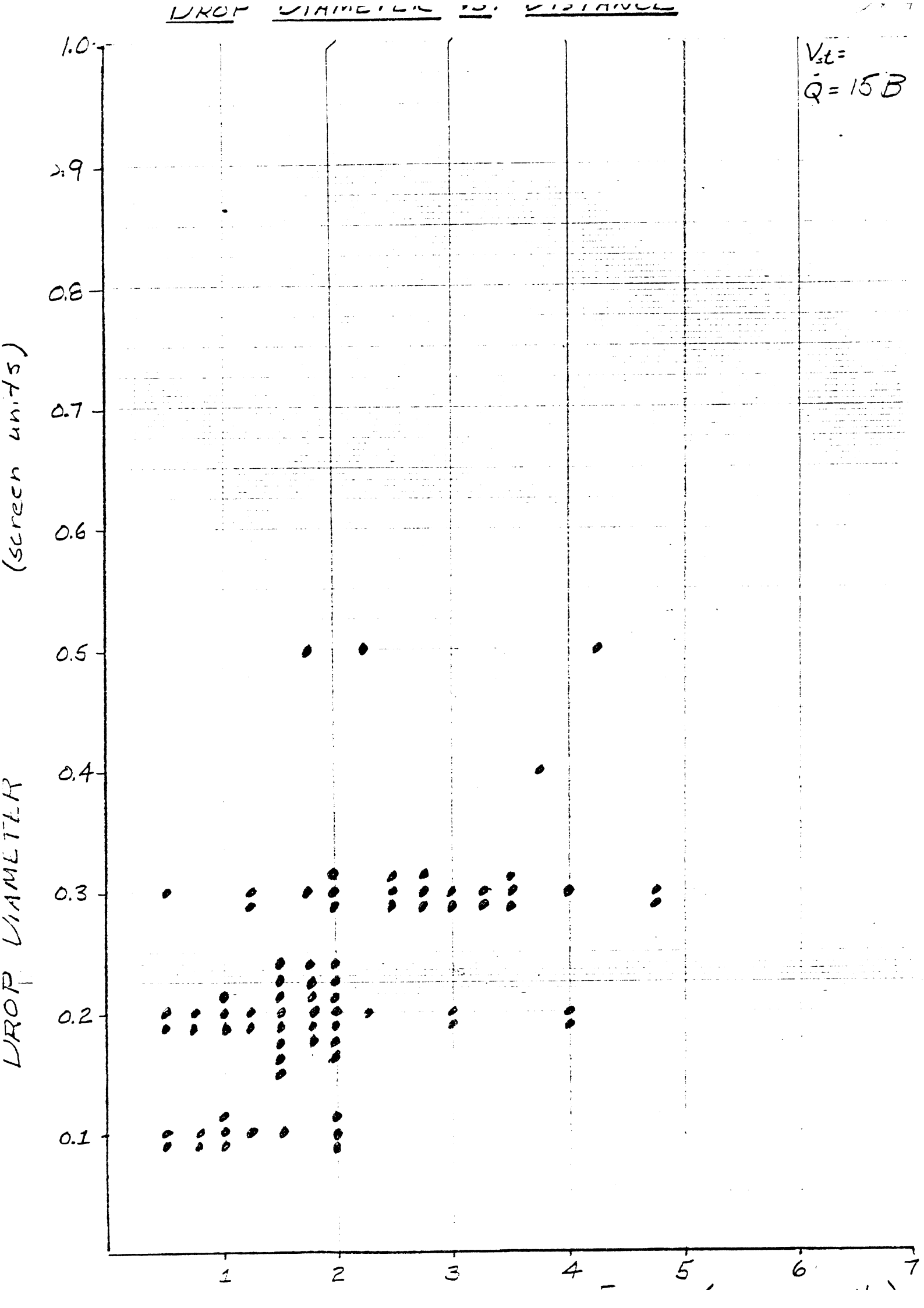
DROP DIAMETER VS. DISTANCE



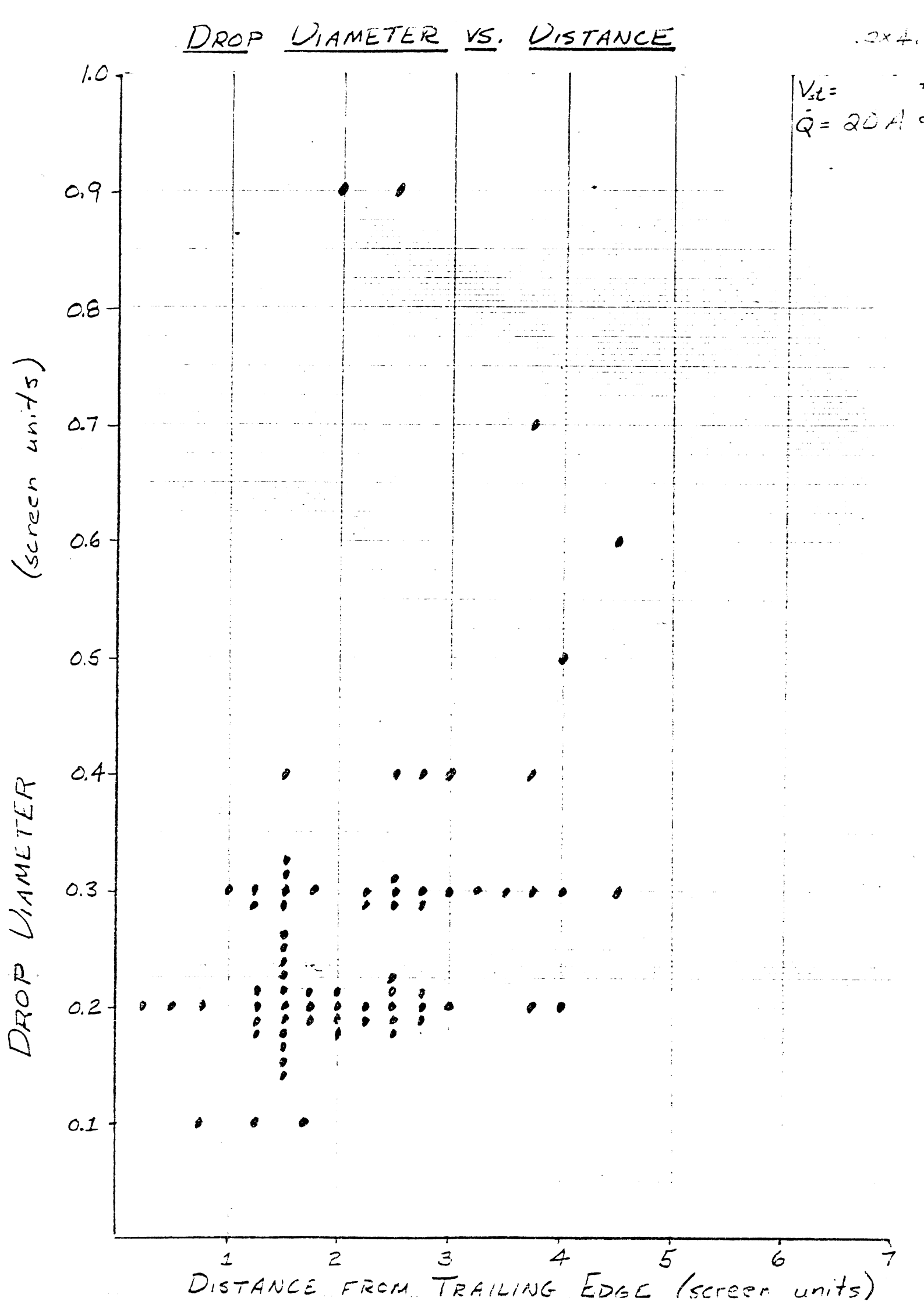
DROP DIAMETER VS. DISTANCE



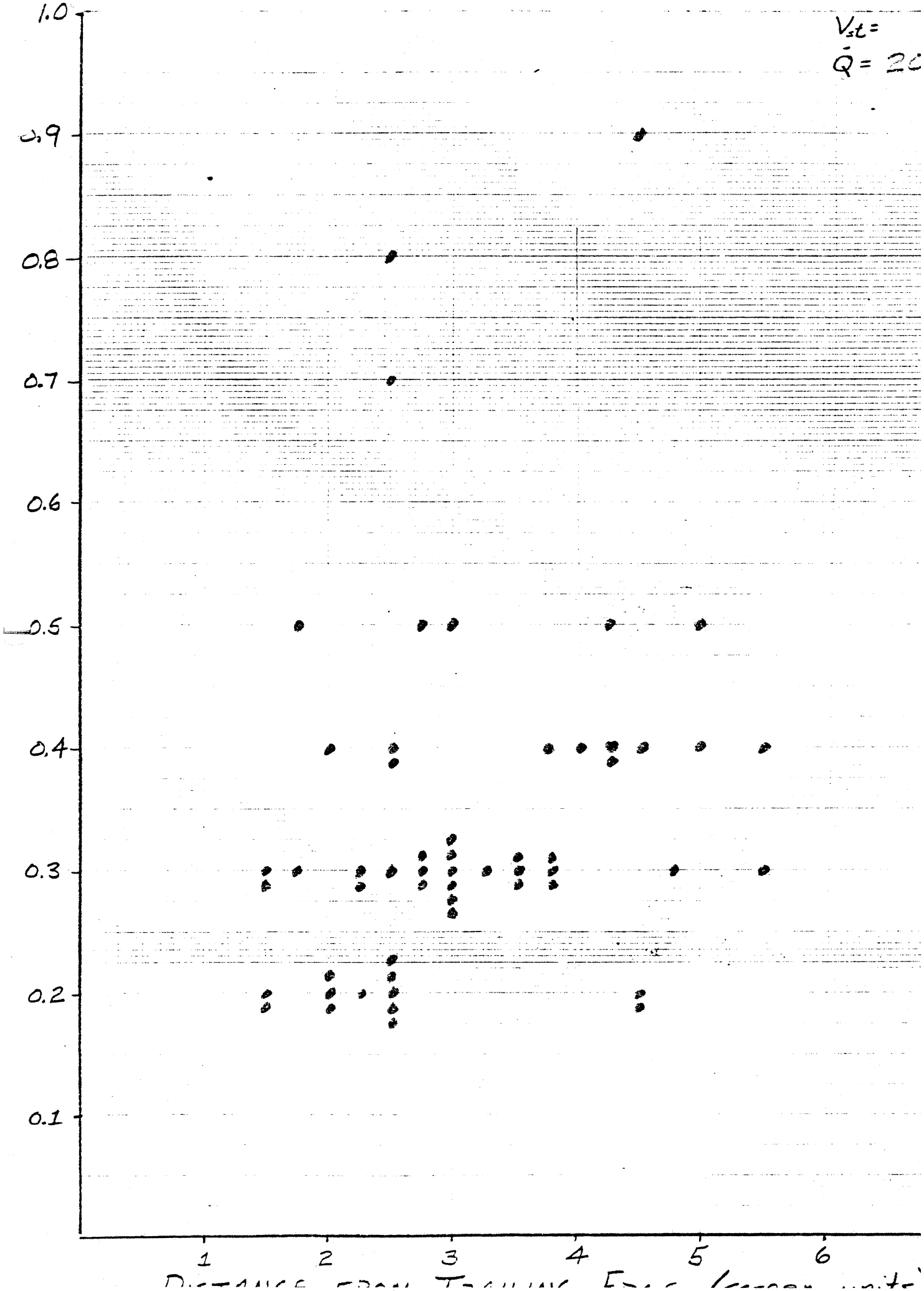

DROP DIAMETER VS. DISTANCE
V_{st} =
$\dot{Q}$ = 10 B
DROP DIAMETER (screen units)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
2
3
4
5
6
7


DROP DIAMETER VS. DISTANCE
V_{st} =
$\dot{Q}$ = 15 B
DROP DIAMETER (screen units)
1.0
.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
2
3
4
5
6
7

DROP DIAMETER VS. DISTANCE

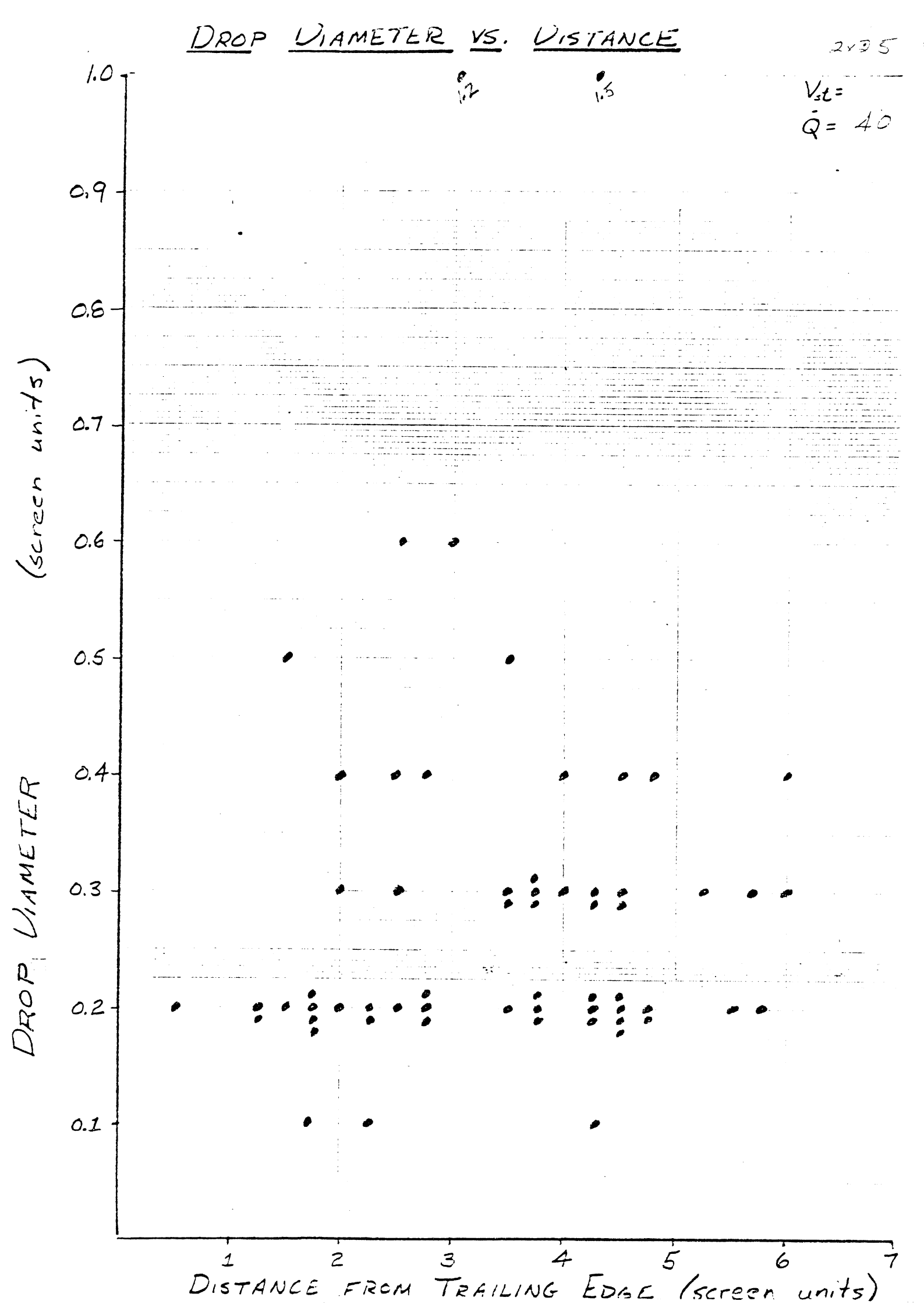


DROP DIAMETER VS. DISTANCE



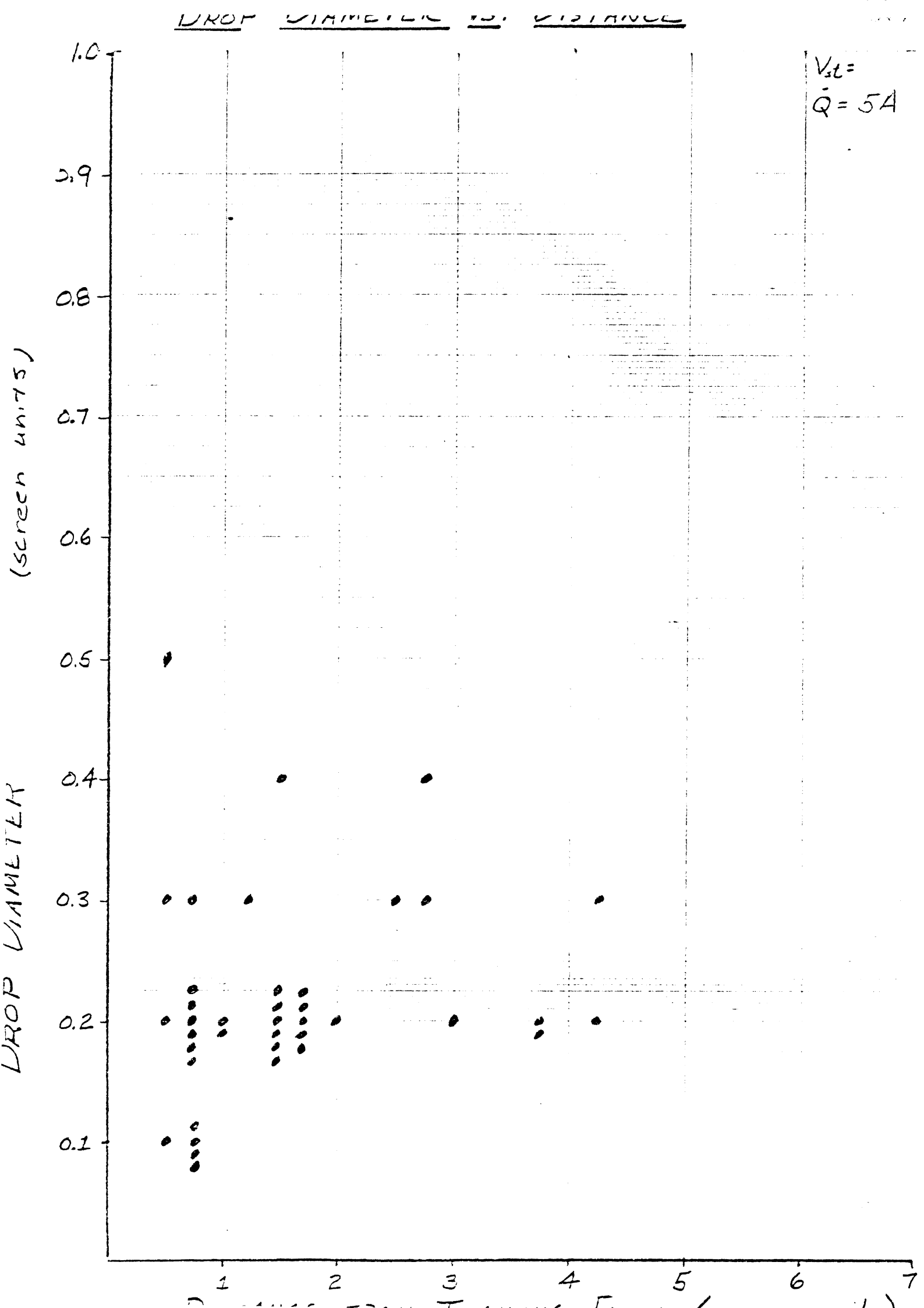
DROP DIAMETER VS. DISTANCE

2x25



APPENDIX B

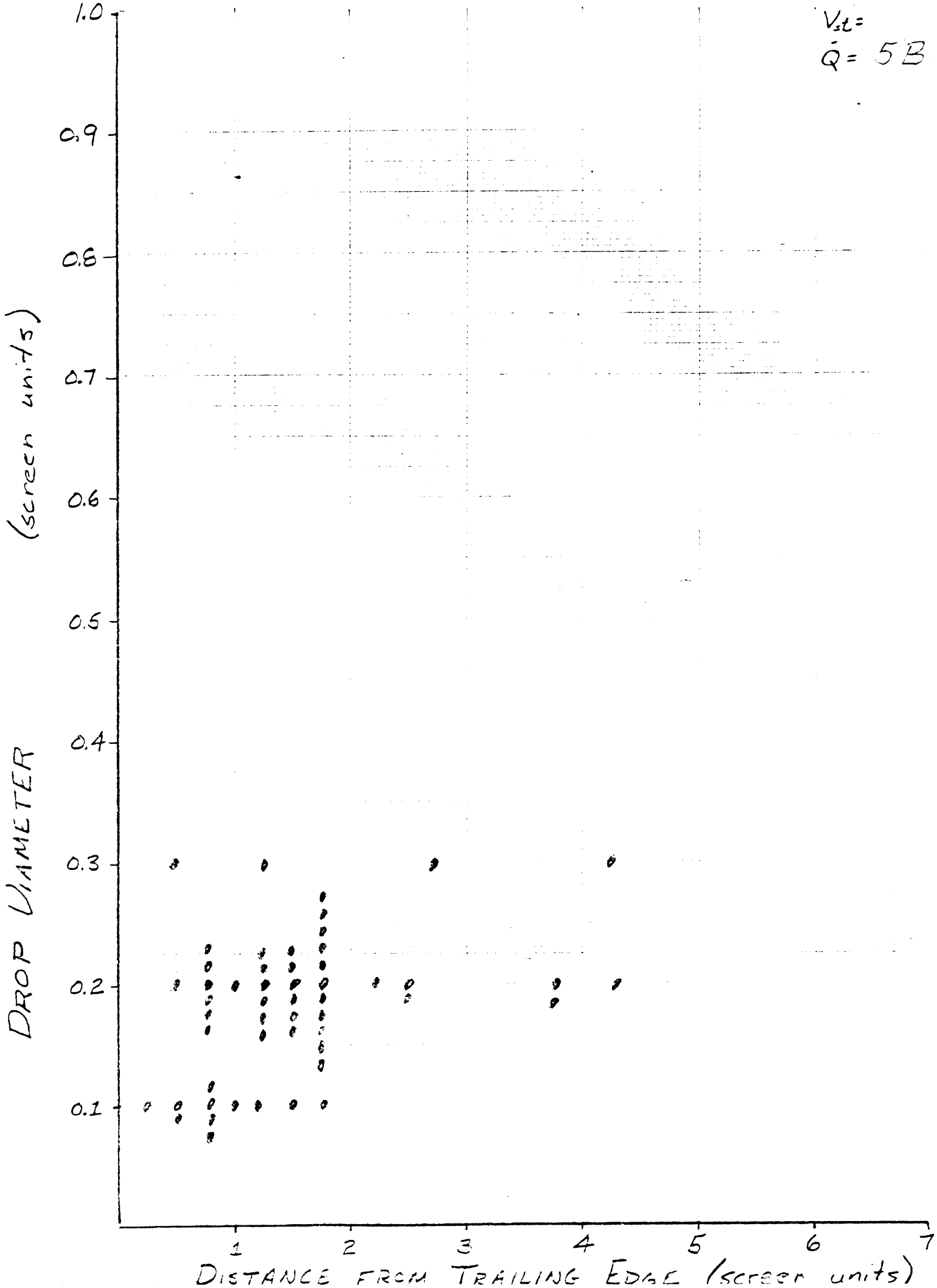
MAXIMUM DROP DIAMETER VS. TIME

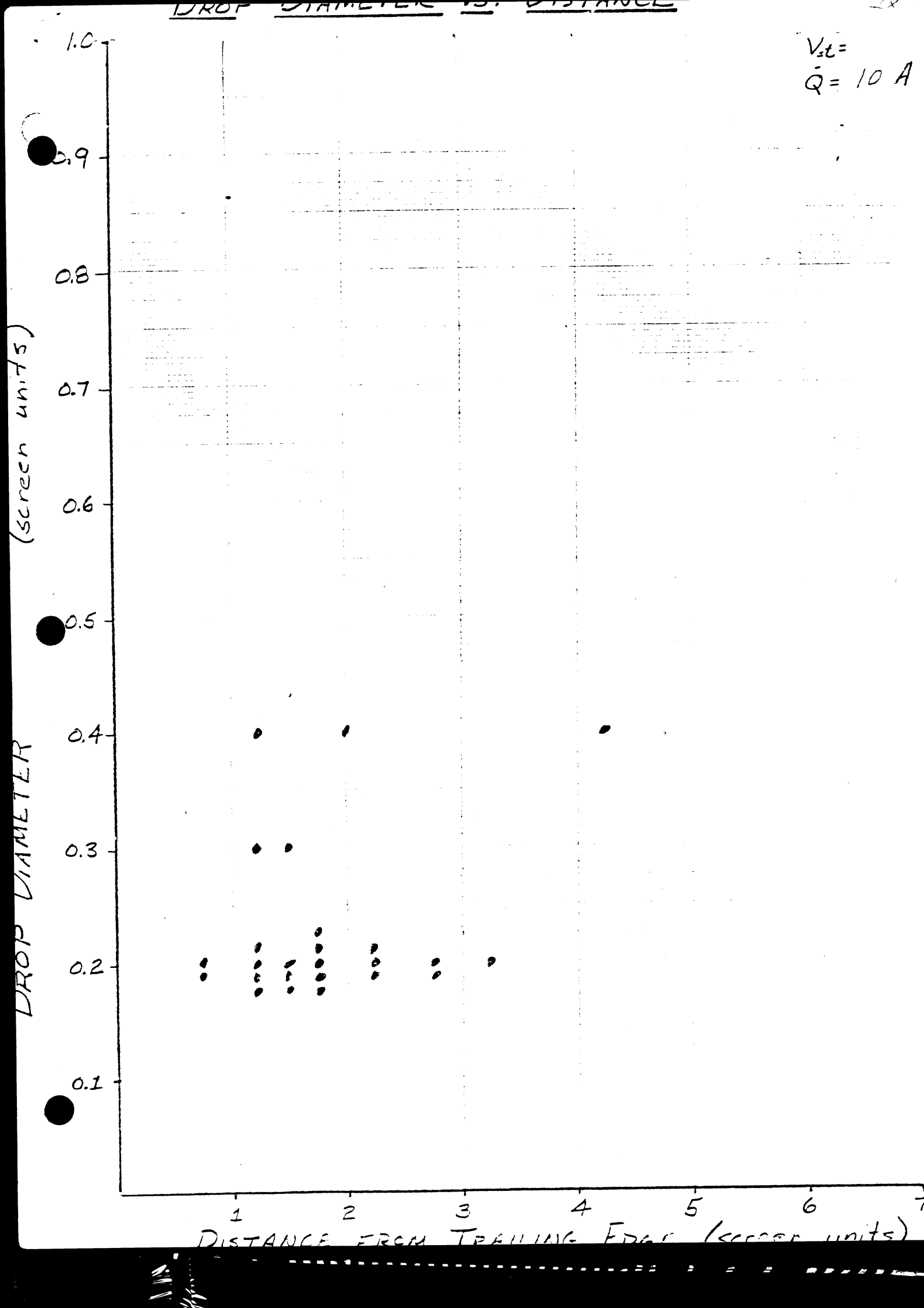

DROP DIAMETER VS. DISTANCE
V_{st} =
$\dot{Q}$ = 5A
DROP DIAMETER (screen units)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
2
3
4
5
6
7

DROP DIAMETER VS. DISTANCE

V_{st} =

$\dot{Q}$ = 5B

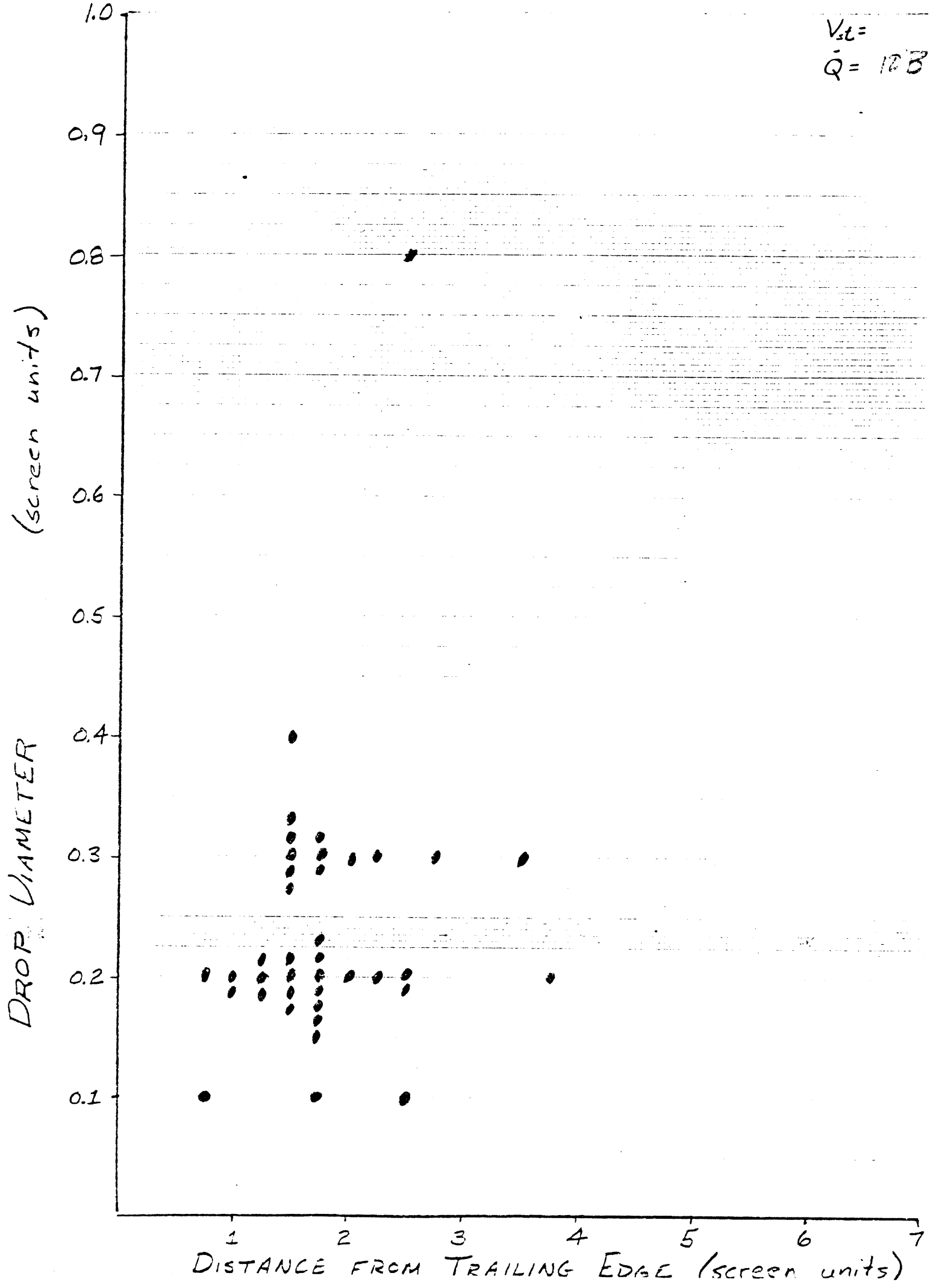


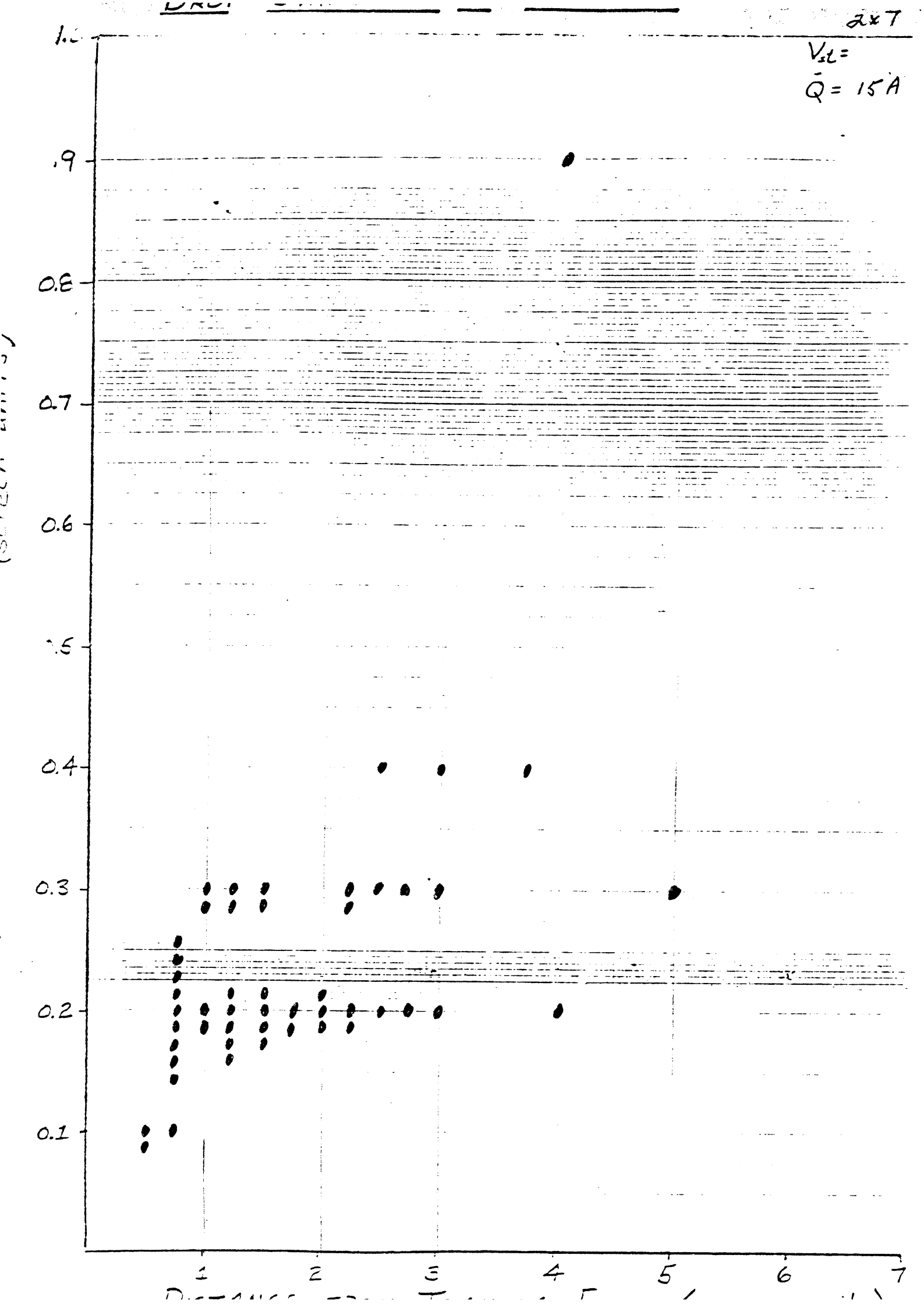

DROP DIAMETER VS. DISTANCE
$V_s t$ =
$\dot{Q}$ = 10 A
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
DROP DIAMETER (screen units)
1
2
3
4
5
6
DISTANCE FROM TRAILING EDGE (screen units)

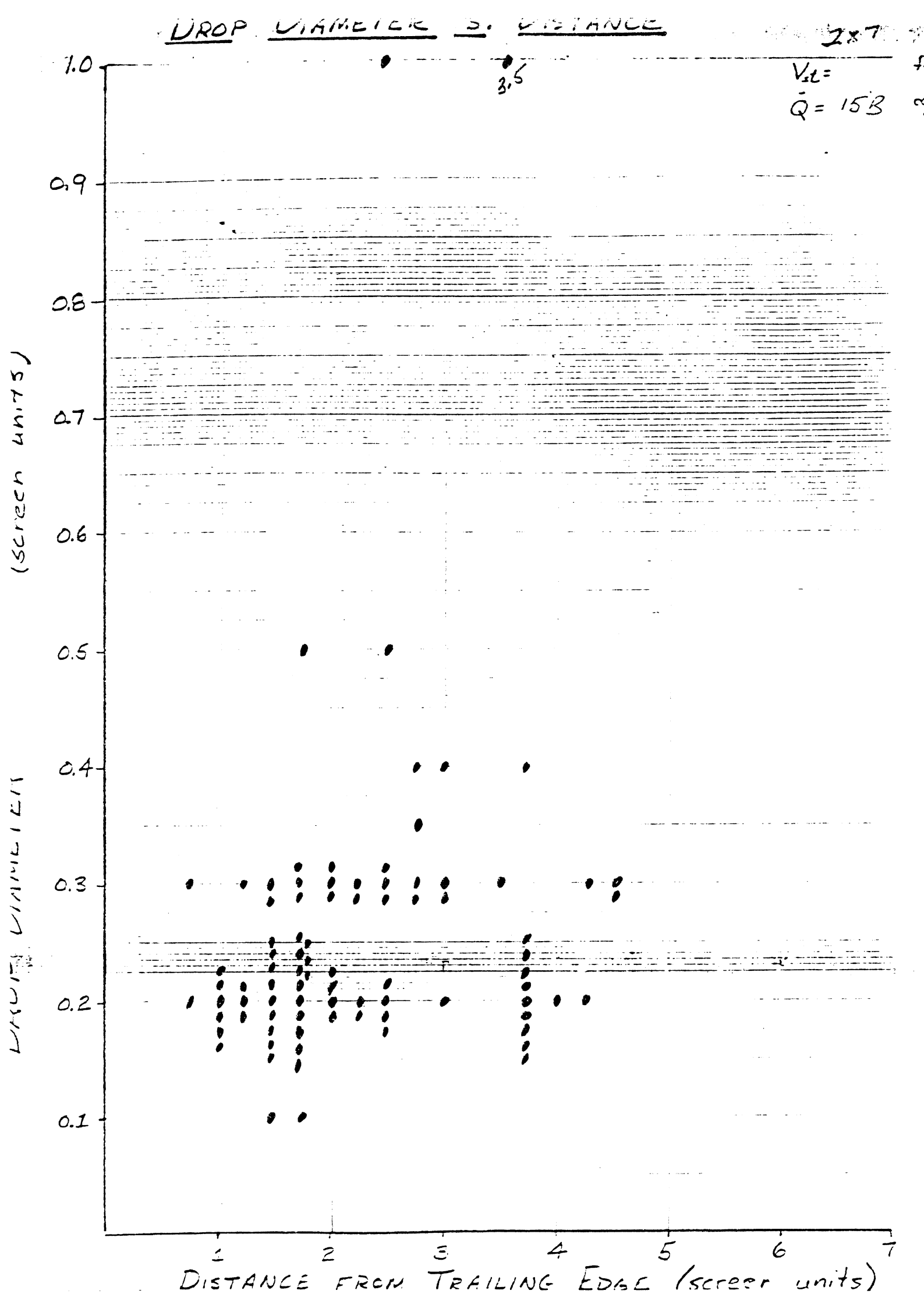
DROP DIAMETER VS. DISTANCE

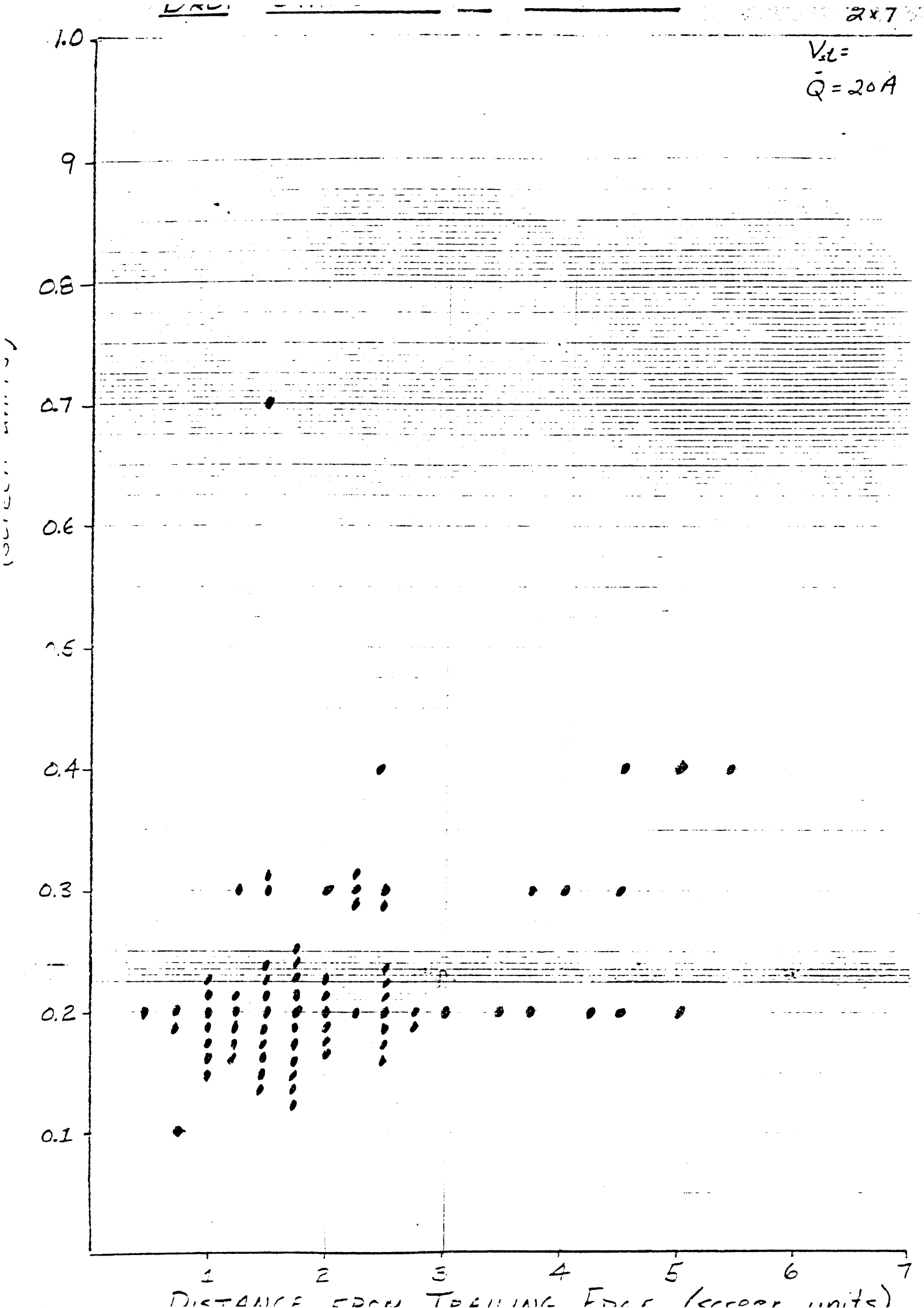
V_{st} =

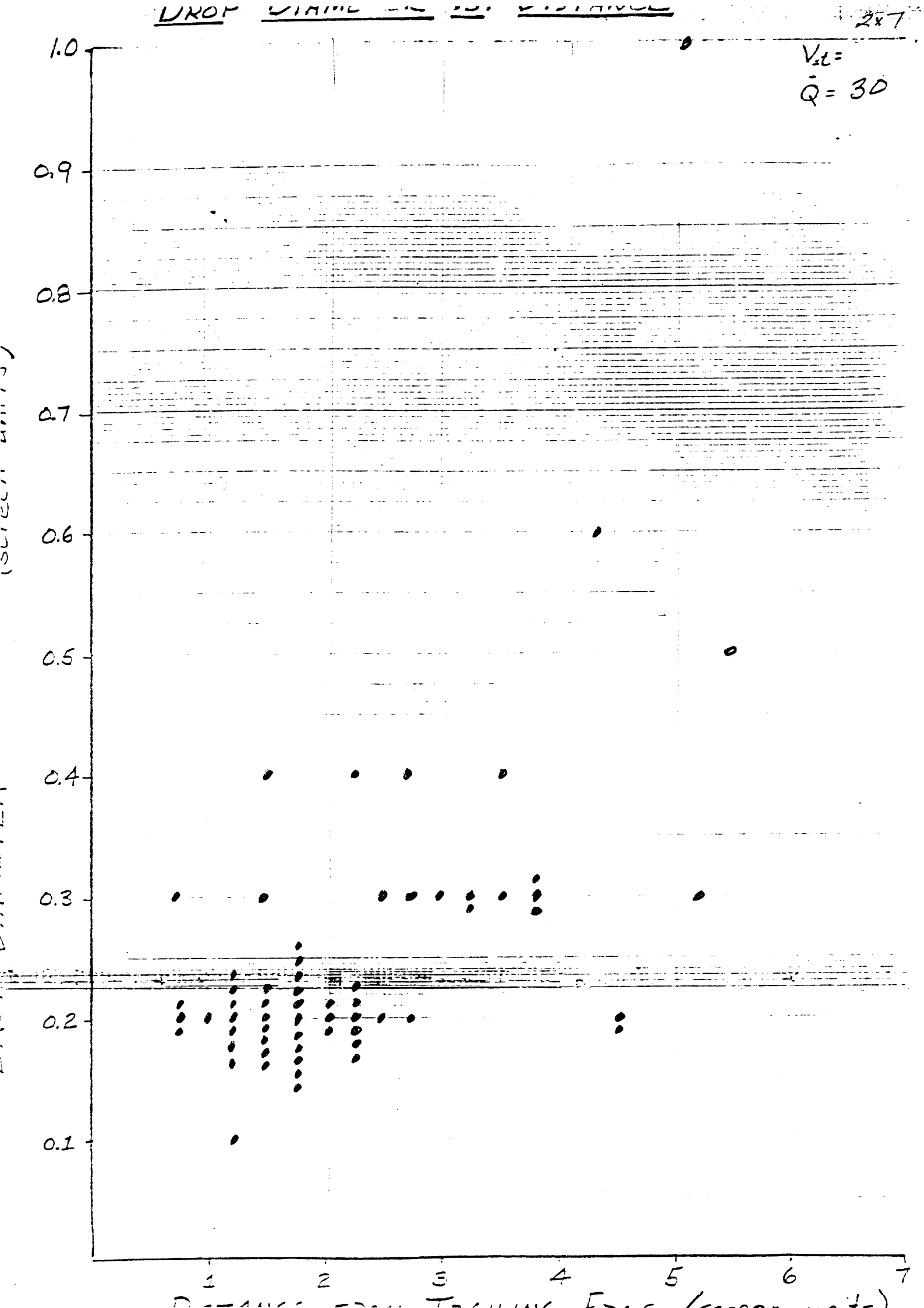
$\dot{Q}$ = 18B



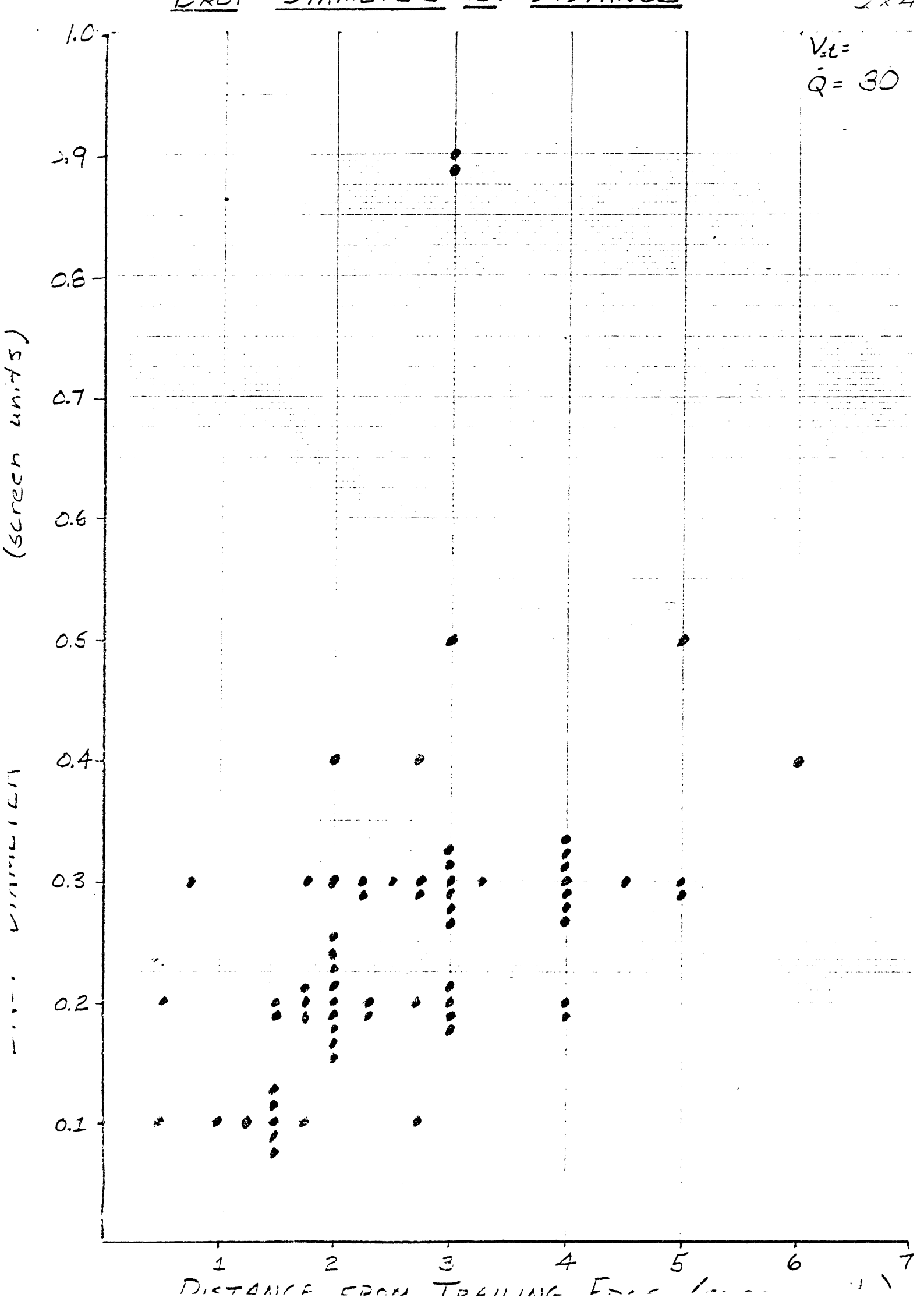

2x7
V_{st} =
$\bar{Q}$ = 15 A
1.0
.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
2
3
4
5
6
7


DROP DIAMETER D. DISTANCE
2×7
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
3.5
V_{∞} =
$\dot{Q}$ = 15B
DROP DIAMETER (screen units)
1
2
3
4
5
6
7
DISTANCE FROM TRAILING EDGE (screen units)


V_{sL} =
$\bar{Q}$ = 20 A
1.0
9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
2
3
4
5
6
7
DISTANCE FROM TRAILING EDGE (screen units)

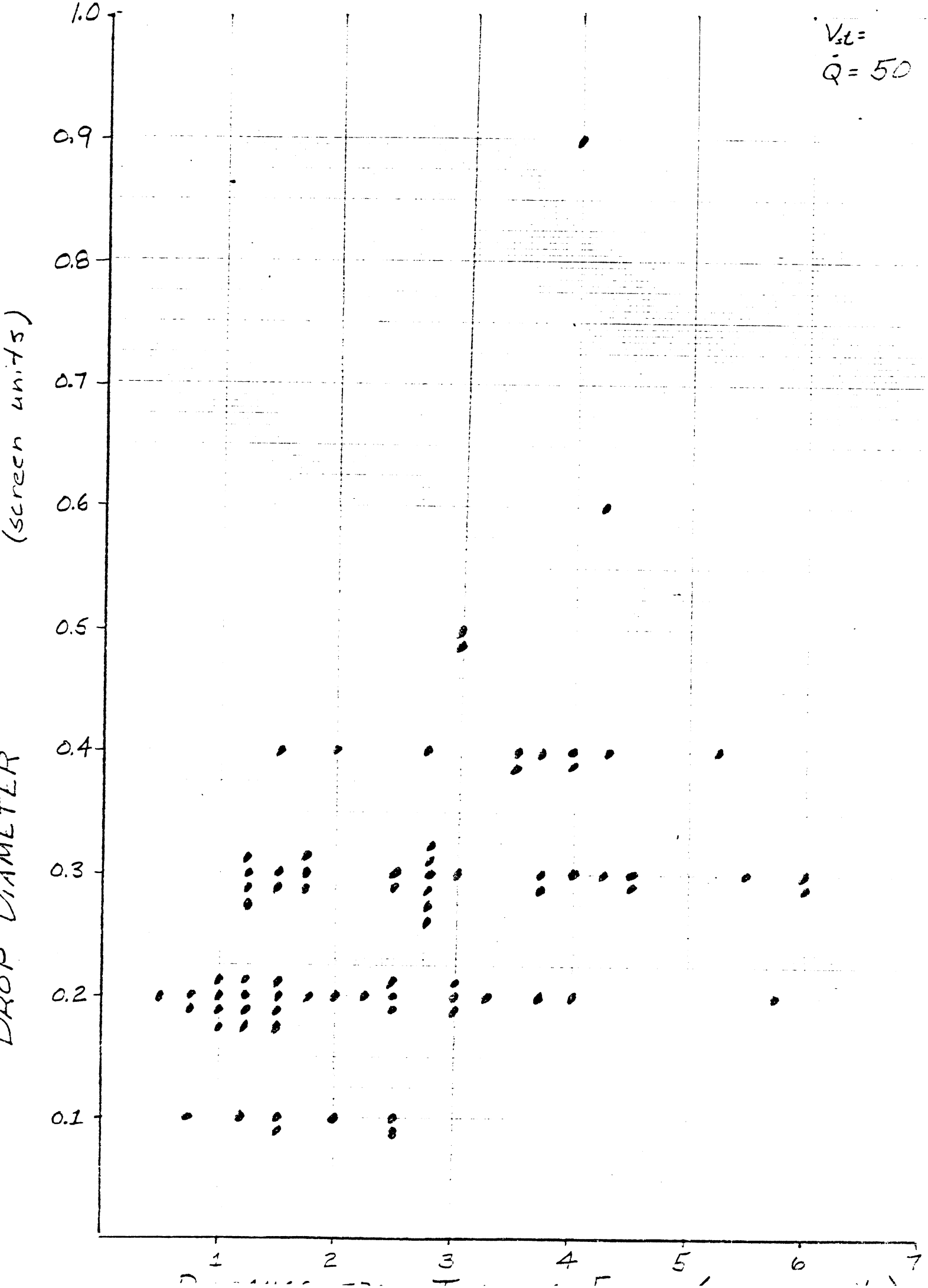


2x7
V_{st} =
$\dot{Q}$ = 30
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
2
3
4
5
6
7


V_{st} =
$\dot{Q}$ = 30
1.0
.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
(screen units)
1
2
3
4
5
6
7

DROP DIAMETER VS. DISTANCE

2x4



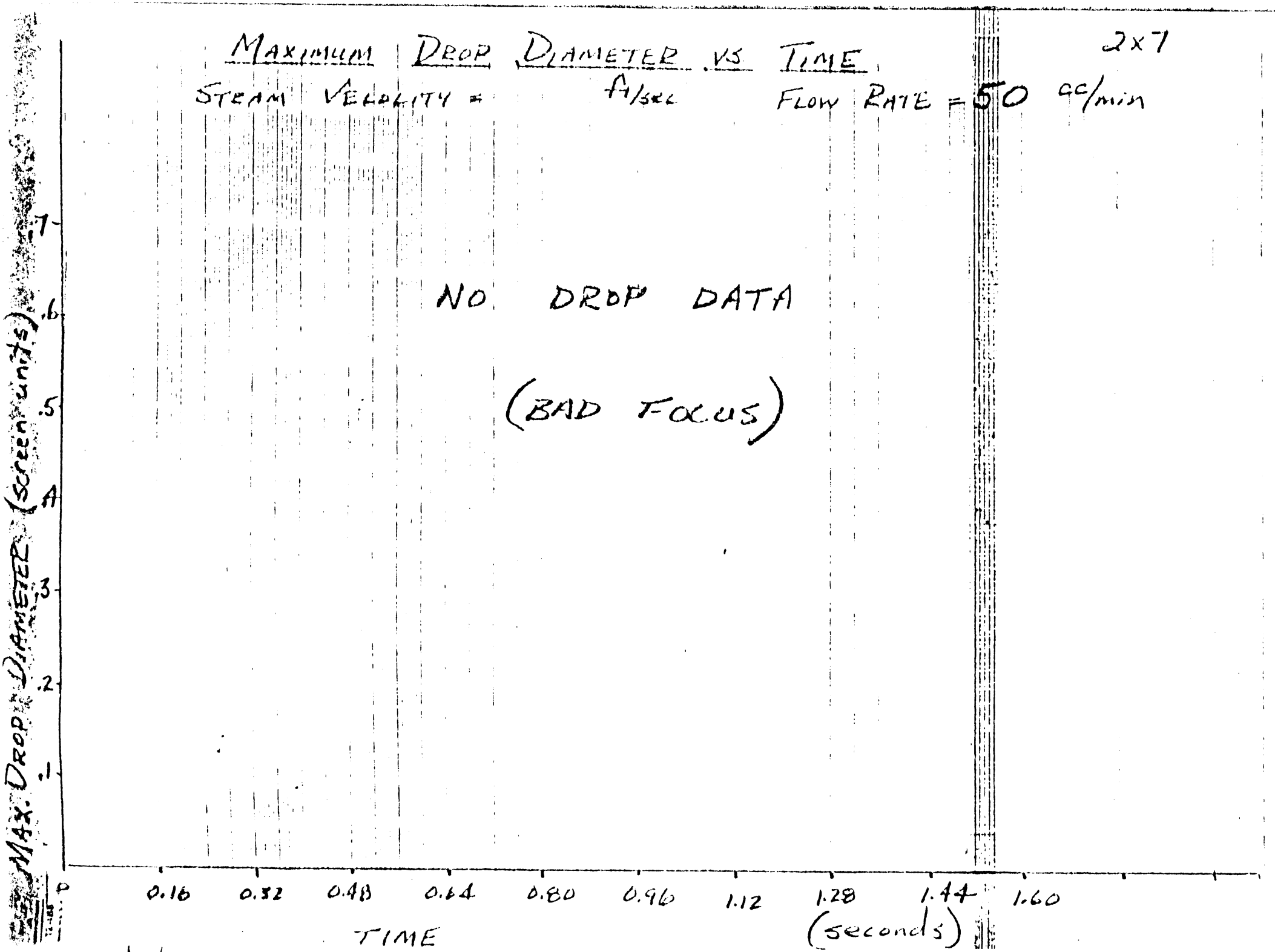
2x7

MAXIMUM DROP DIAMETER VS TIME

STEAM VELOCITY = ft/sec FLOW RATE = 50 cc/min

NO DROP DATA

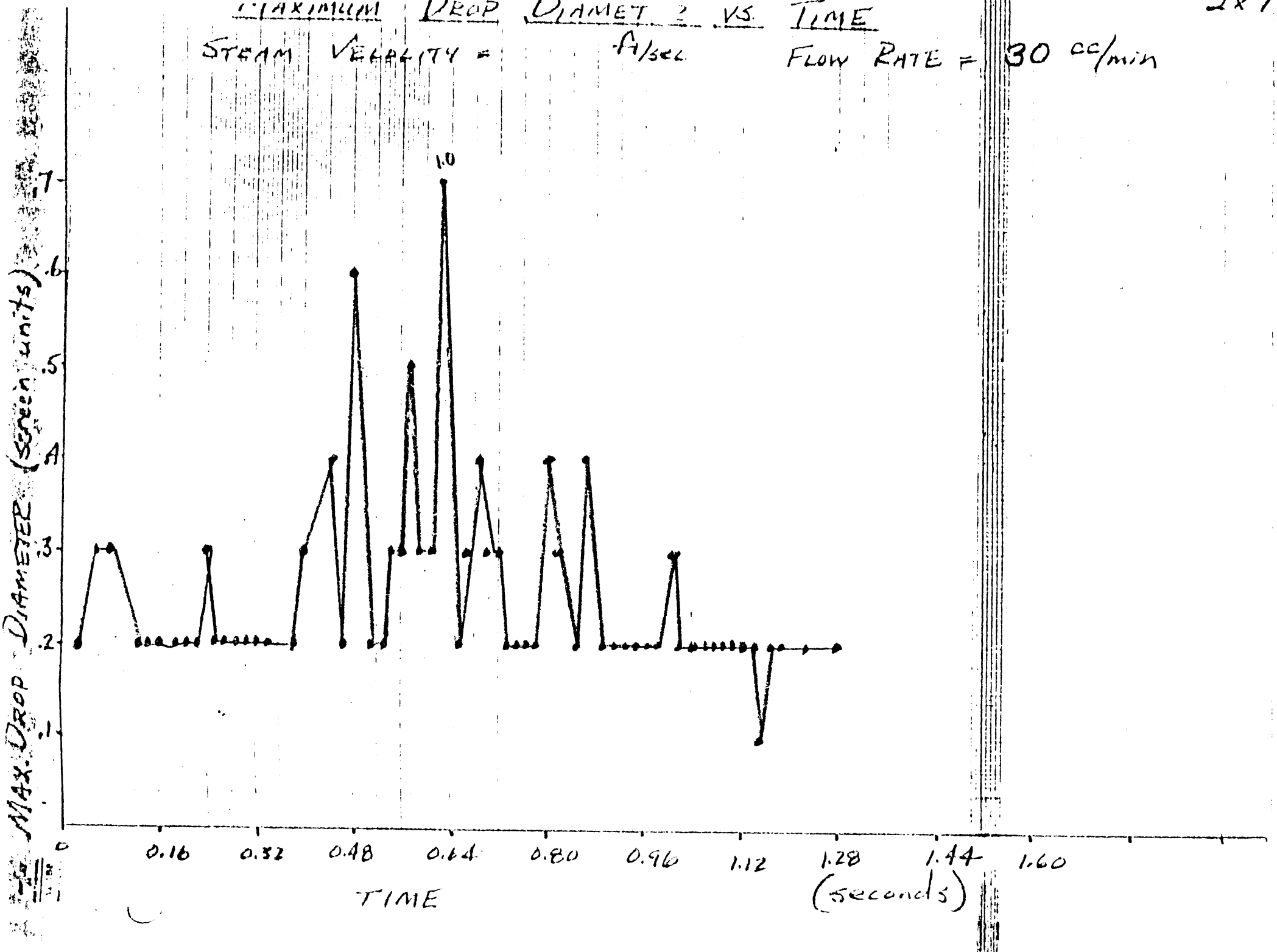
(BAD FOCUS)



MAXIMUM DROP DIAMETER VS TIME

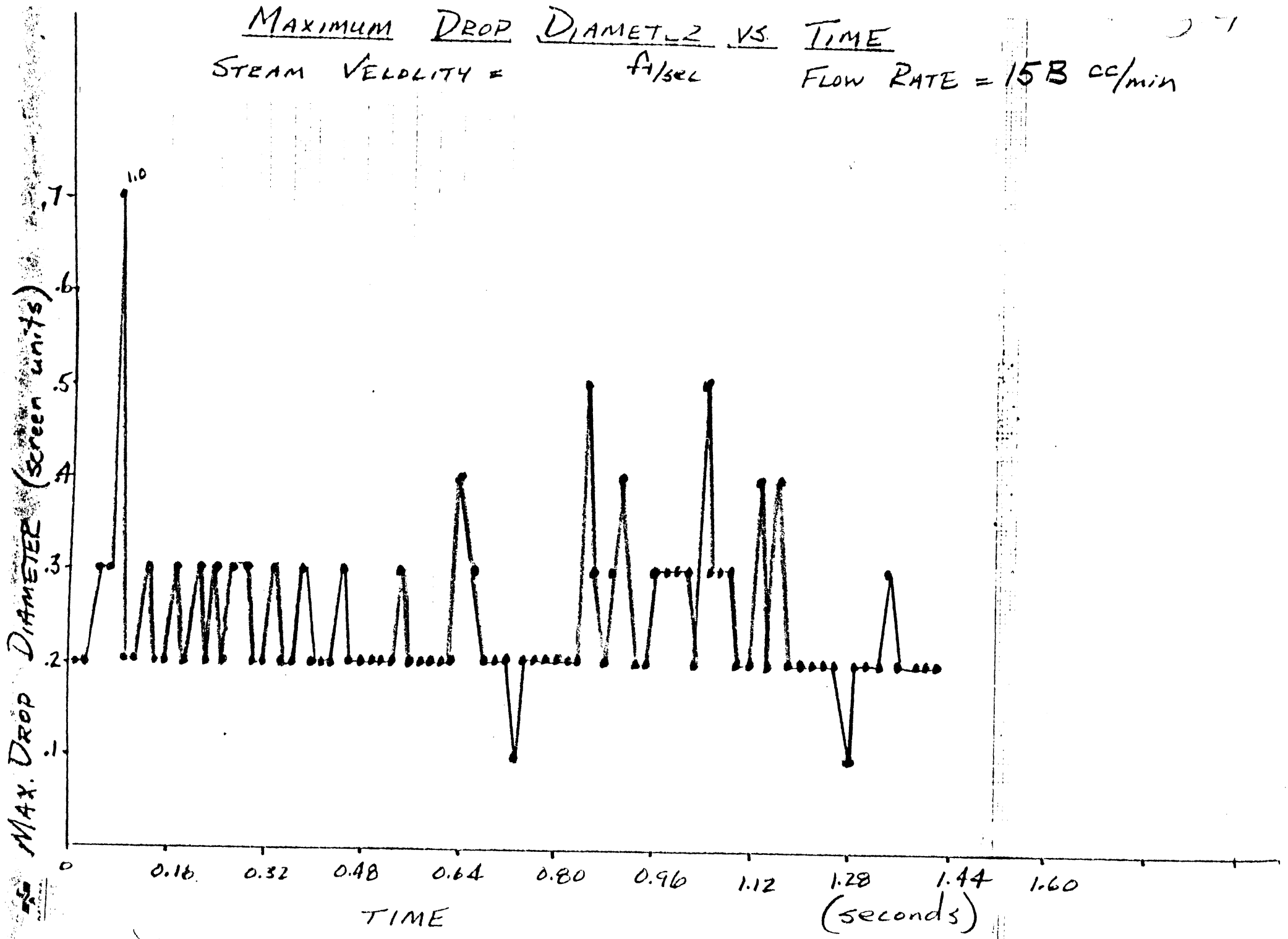
STEAM VELOCITY = ft/sec

FLOW RATE = 30 cc/min



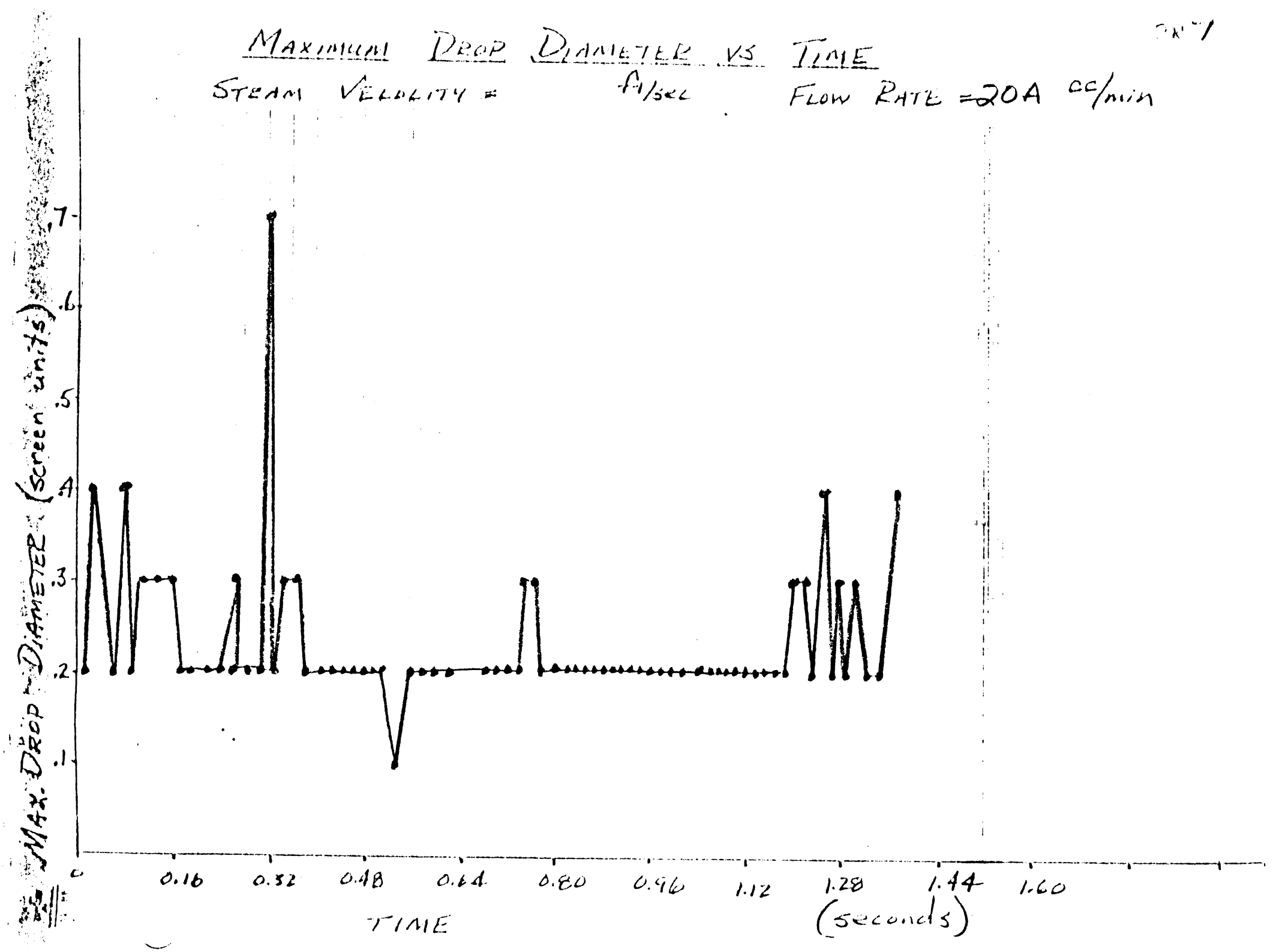
MAXIMUM DROP DIAMETER VS TIME

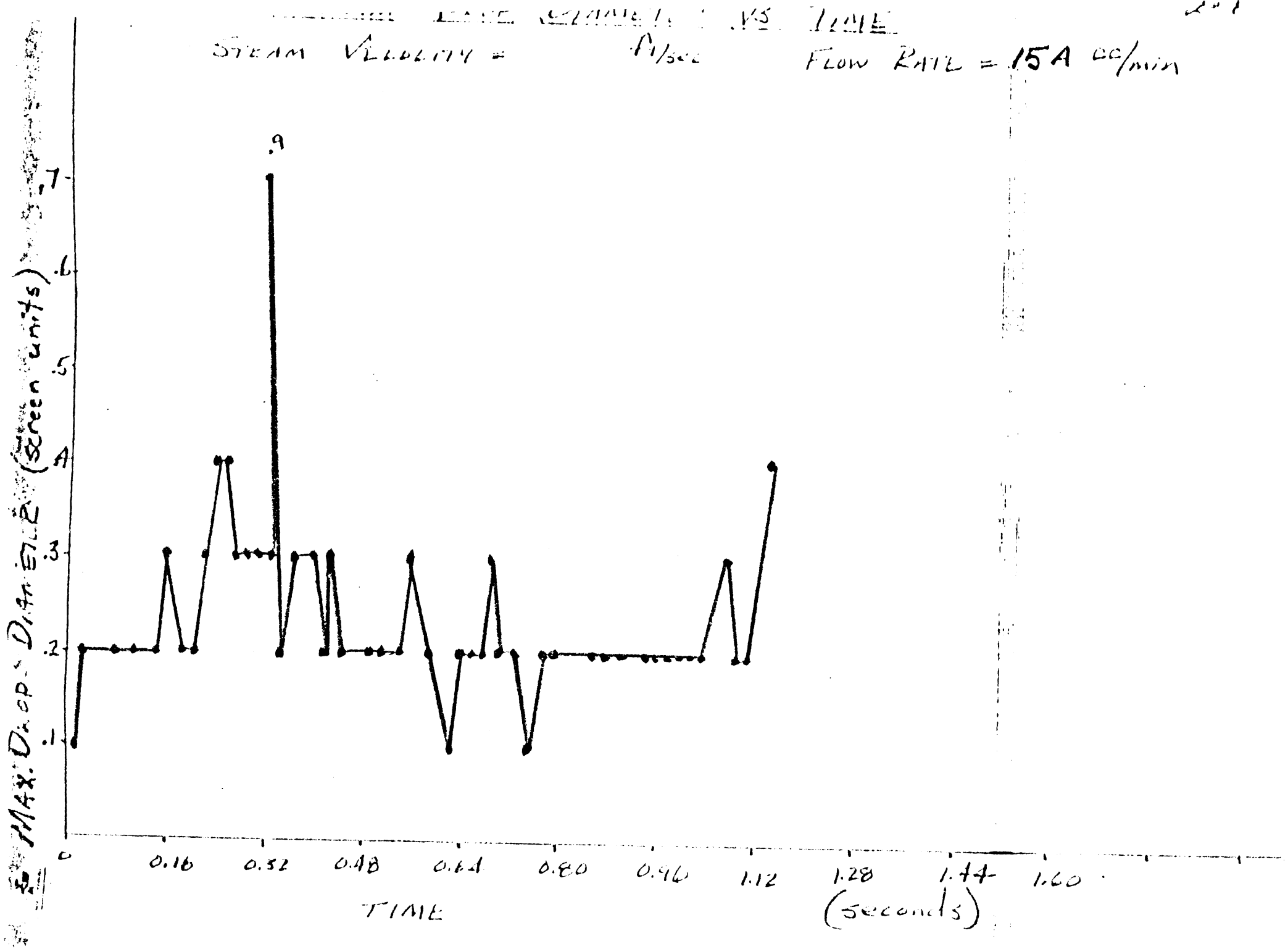
STEAM VELOCITY = ft/sec FLOW RATE = 158 cc/min



MAXIMUM DROP DIAMETER VS TIME

STEAM VELOCITY = ft/sec FLOW RATE = 20A cc/min

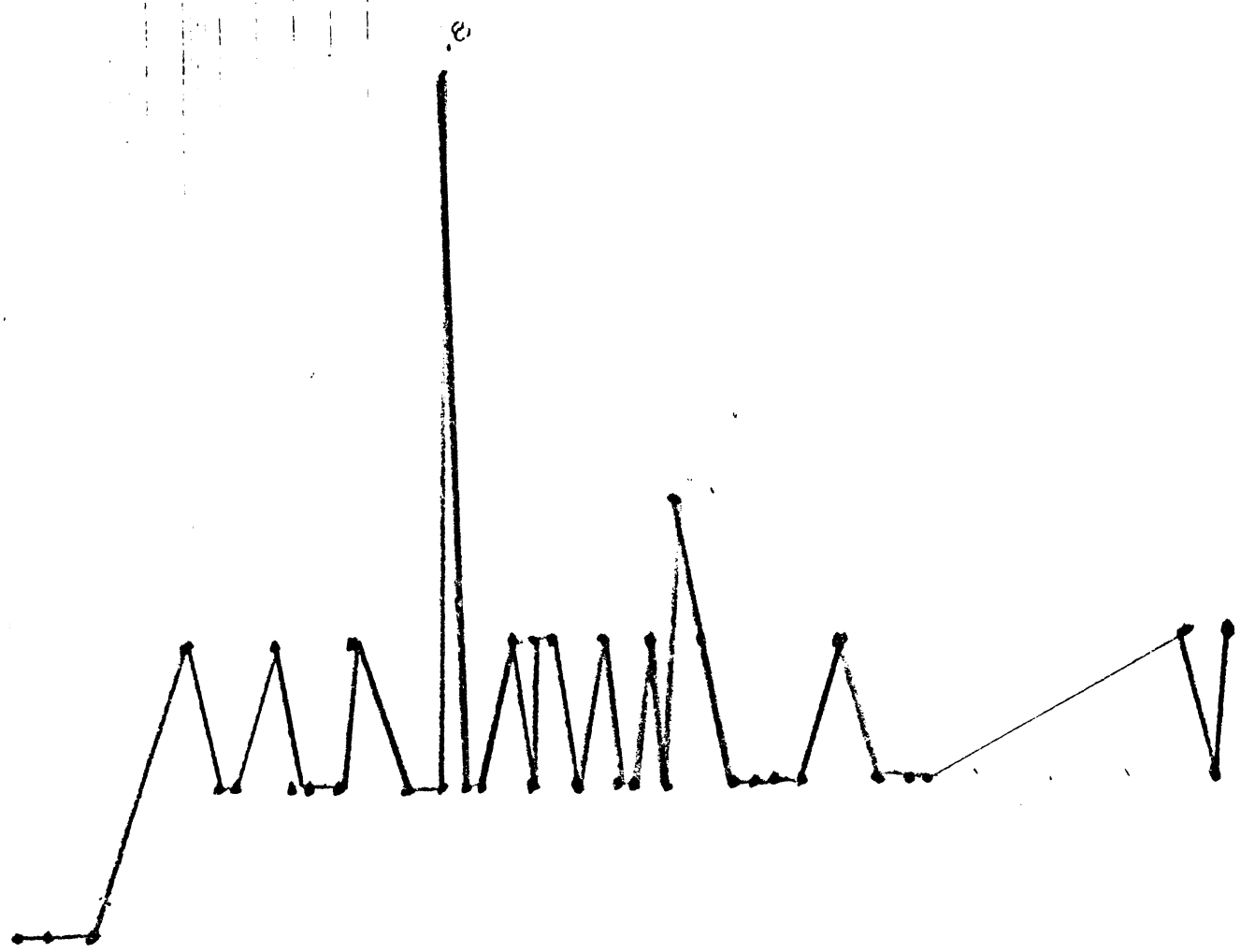




VS TIME
STEAM VELOCITY = ft/sec
FLOW RATE = 15A cc/min
MAX. DROP DIAMETER (screen units)
.9
.7
.6
.5
.4
.3
.2
.1
0
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.60
TIME
(seconds)

Maximum Drop Diameter vs Time

Steam Velocity = ft/sec Flow Rate = 108 cc/min



0.16 0.32 0.48 0.64 0.80 0.96 1.12 1.28 1.44 1.60

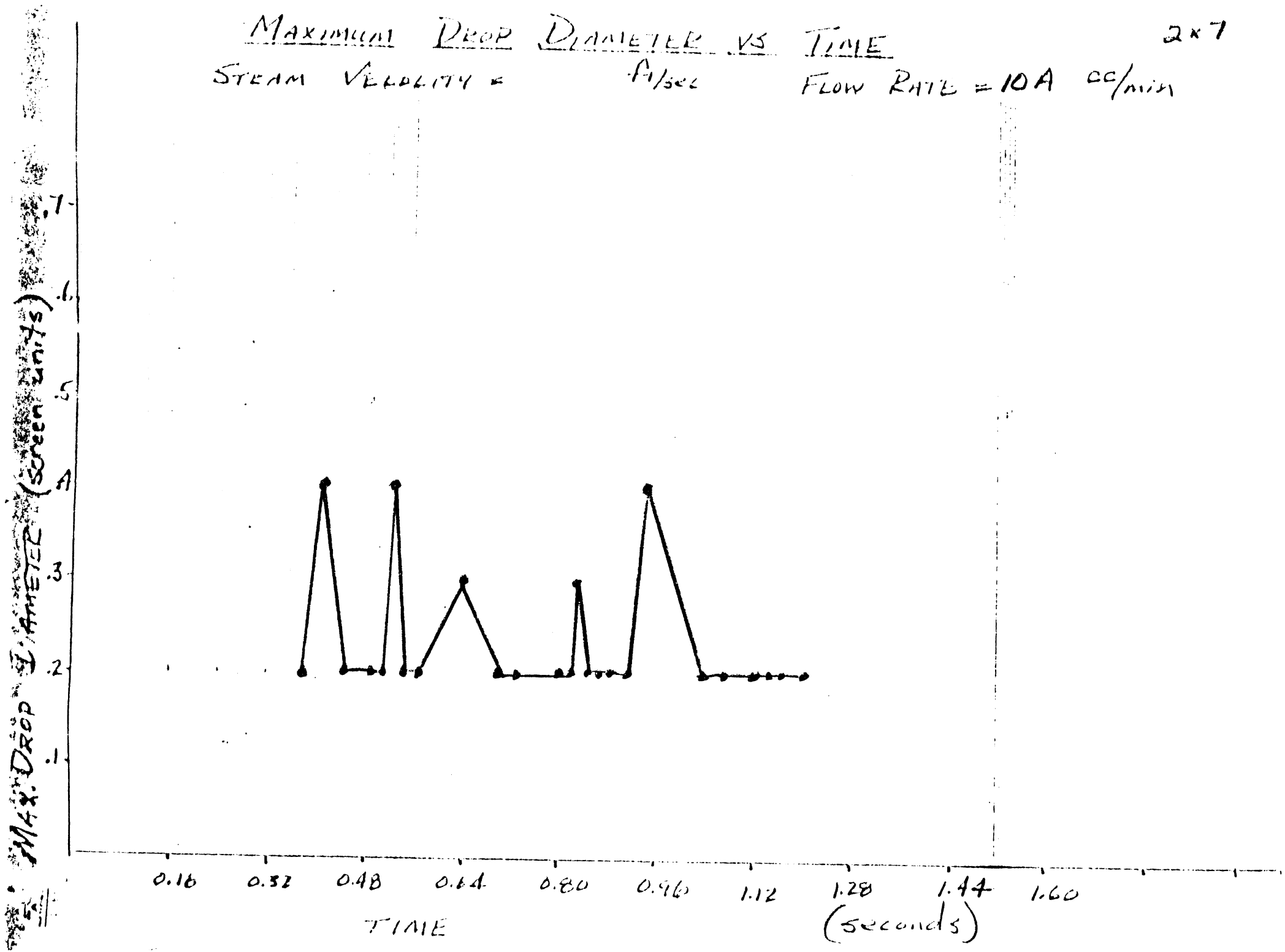
TIME (seconds)

MAXIMUM DROP DIAMETER VS TIME

2 x 7

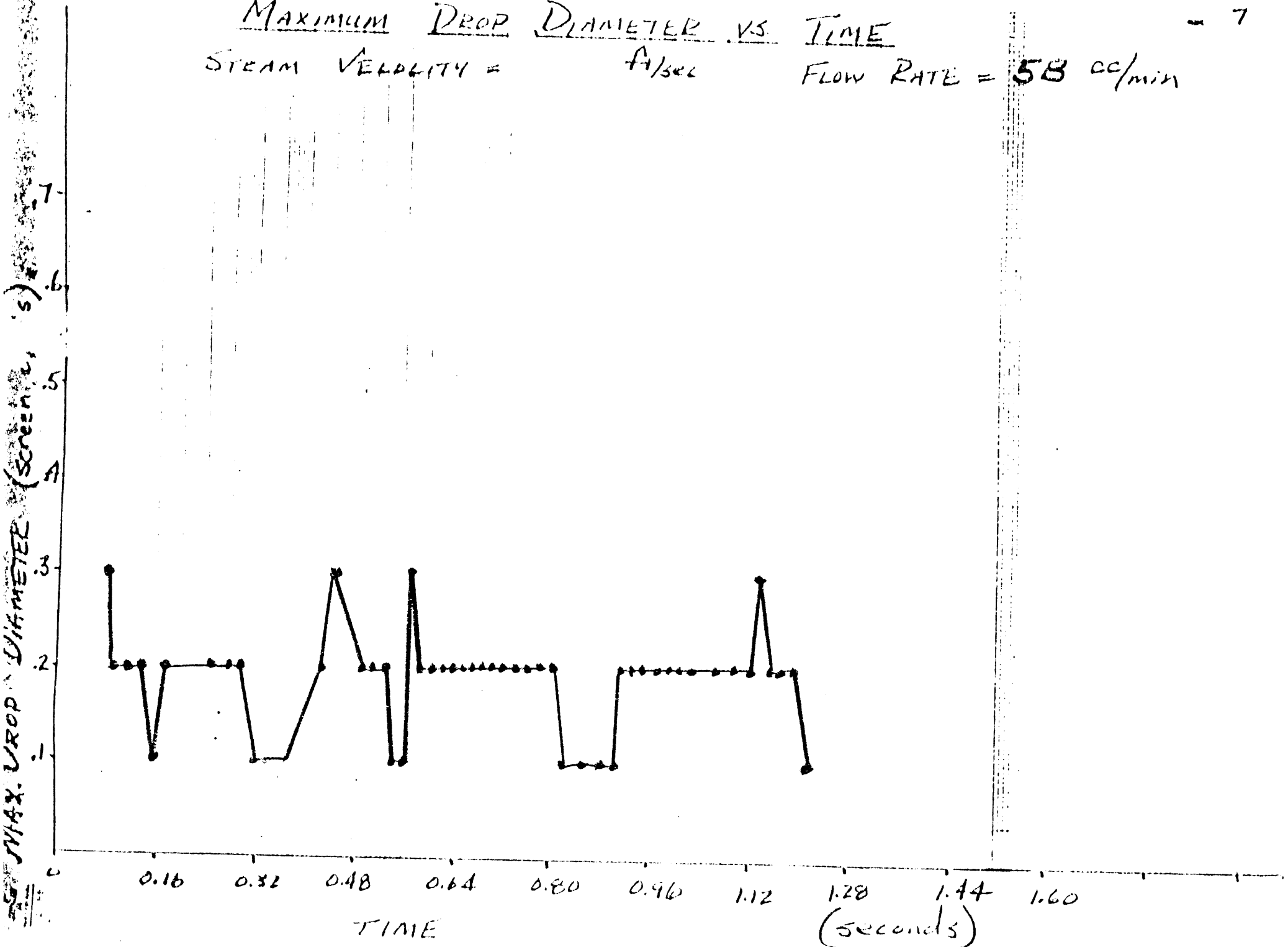
STEAM VELOCITY = A/sec

FLOW RATE = 10A cc/min



MAXIMUM DROP DIAMETER VS TIME

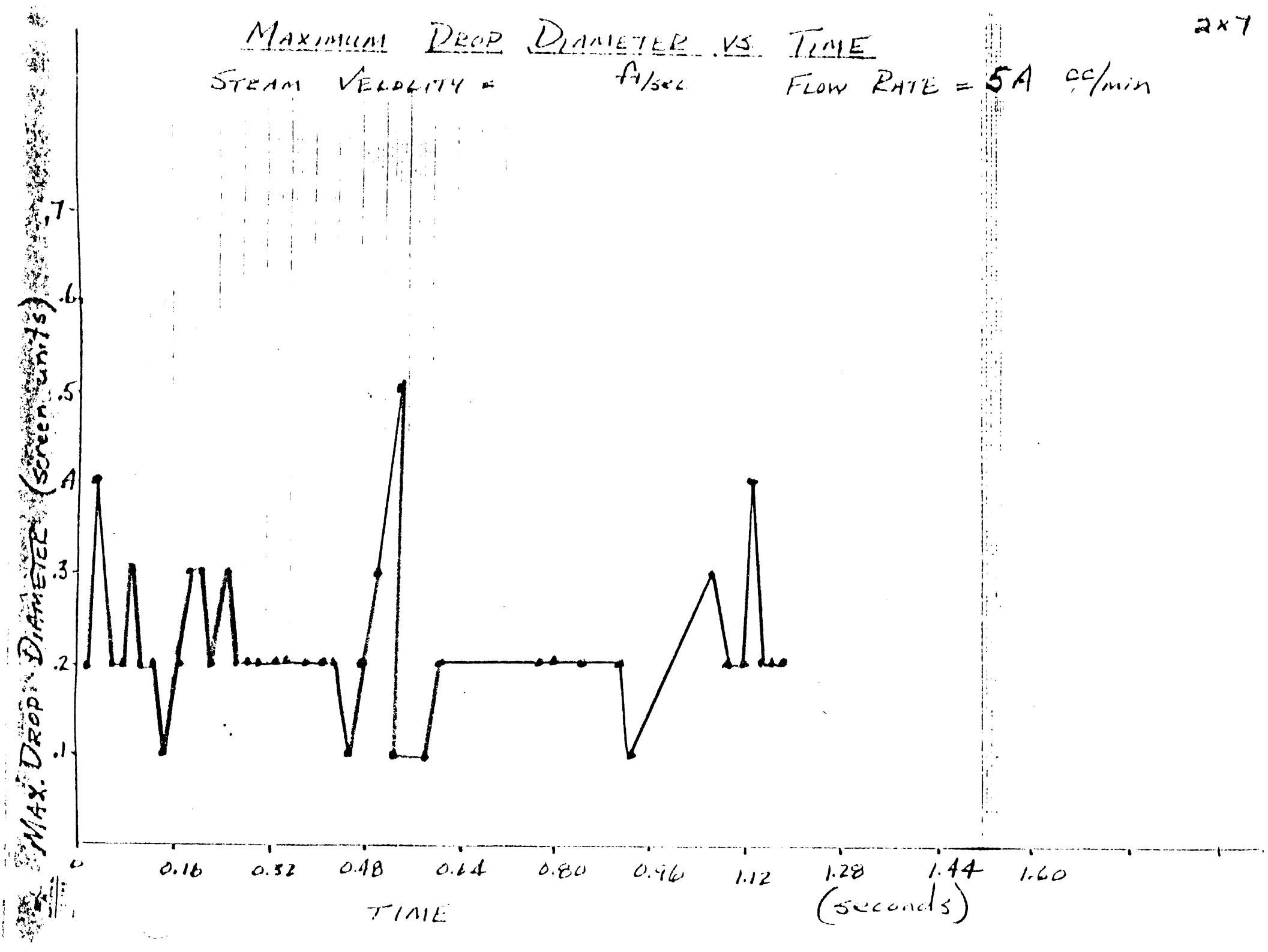
STEAM VELOCITY = ft/sec FLOW RATE = 58 cc/min



2x7

MAXIMUM DROP DIAMETER VS TIME

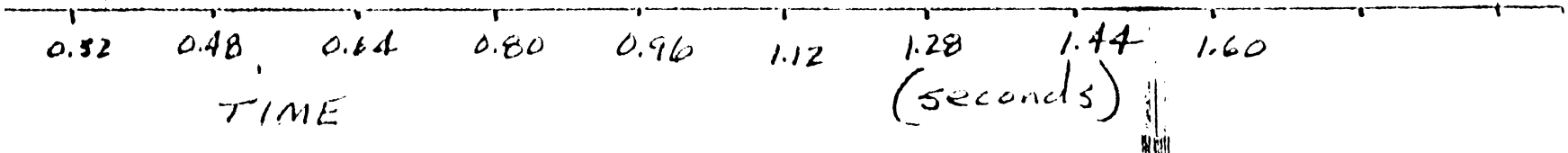
STEAM VELOCITY = ft/sec FLOW RATE = 5A cc/min



MAXIMUM DROP DIAMETER VS TIME

STEAM VELOCITY = ft/sec FLOW RATE = 0 cc/min

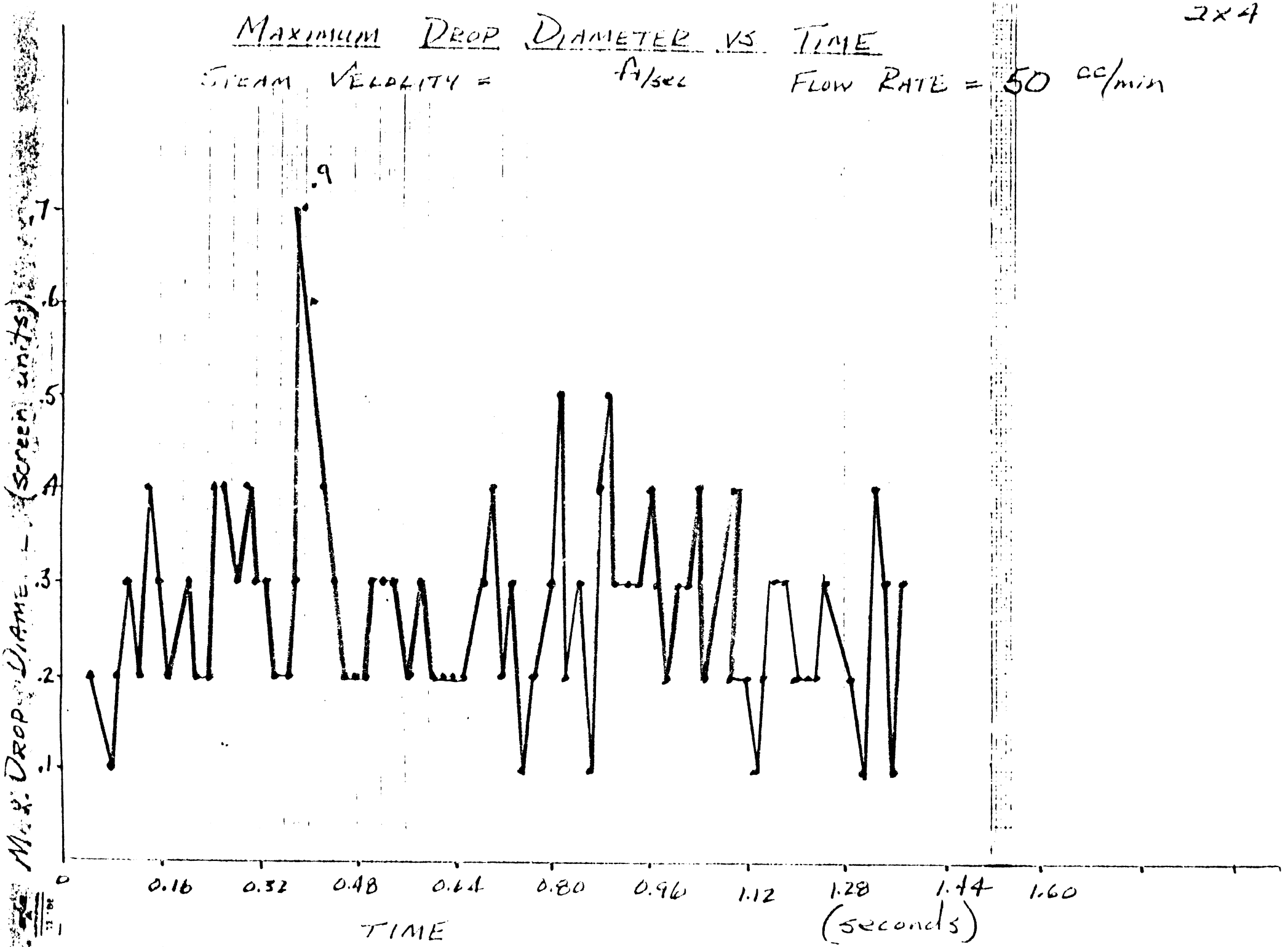
(NO DROPS)



2x4

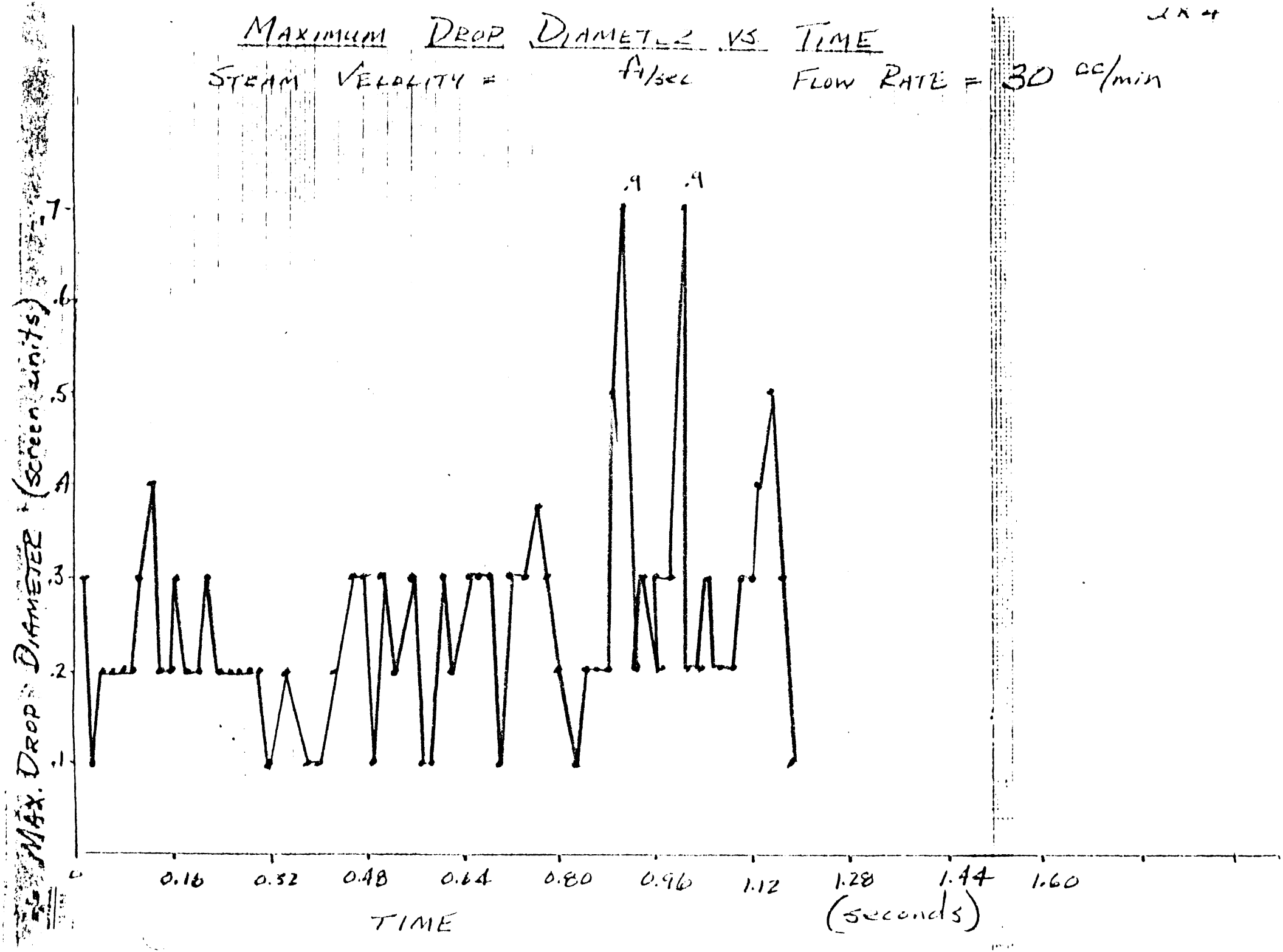
MAXIMUM DROP DIAMETER VS TIME

STEAM VELOCITY = ft/sec FLOW RATE = 50 cc/min



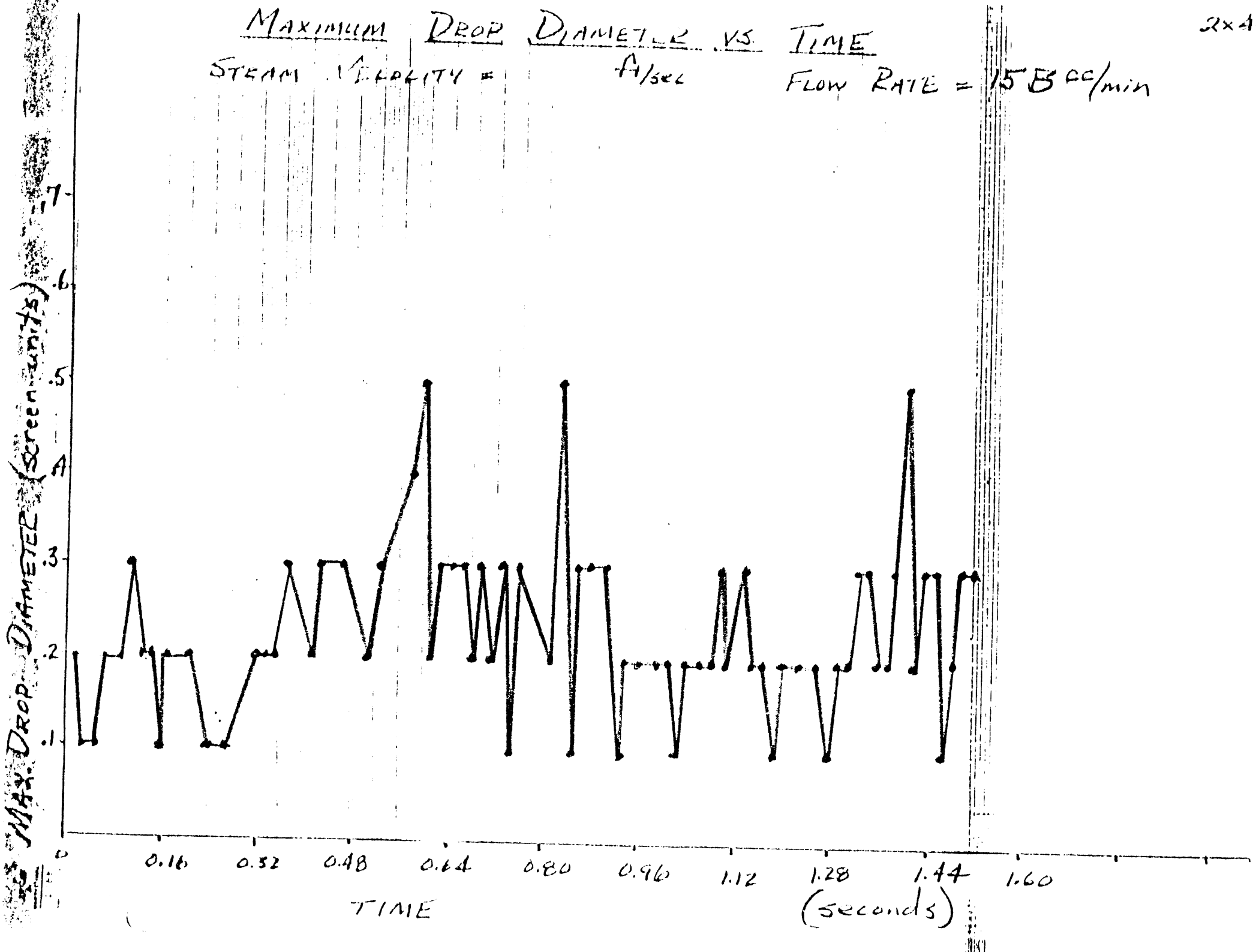
MAXIMUM DROP DIAMETER VS TIME

STEAM VELOCITY = ft/sec FLOW RATE = 30 cc/min



MAXIMUM DROP DIAMETER VS TIME

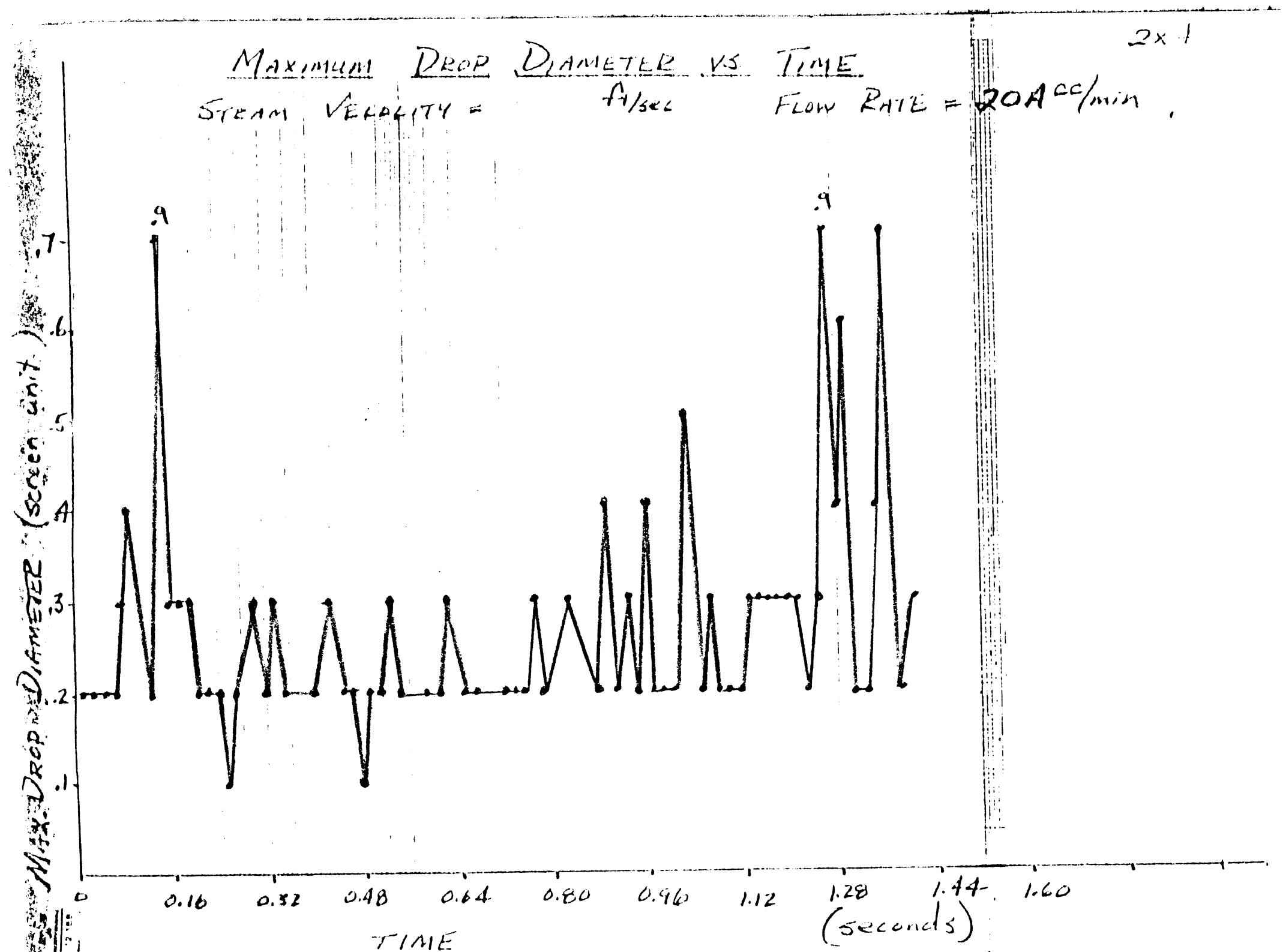
STEAM VELOCITY = ft/sec FLOW RATE = 155 cc/min



2x 1

Maximum Drop Diameter vs Time

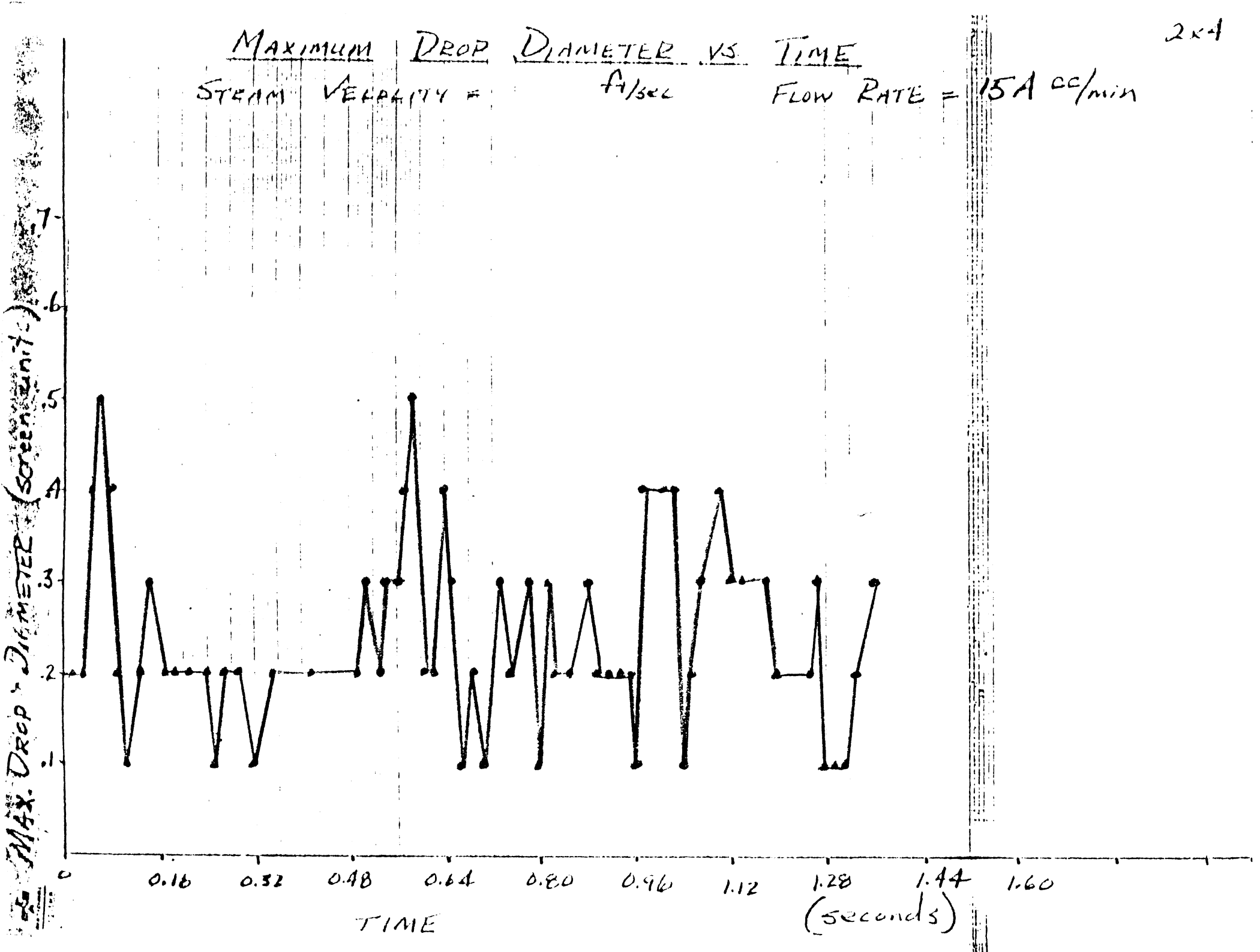
Steam Velocity = ft/sec Flow Rate = 20A cc/min.



2x4

MAXIMUM DROP DIAMETER VS TIME

STEAM VELOCITY = ft/sec FLOW RATE = 15A cc/min

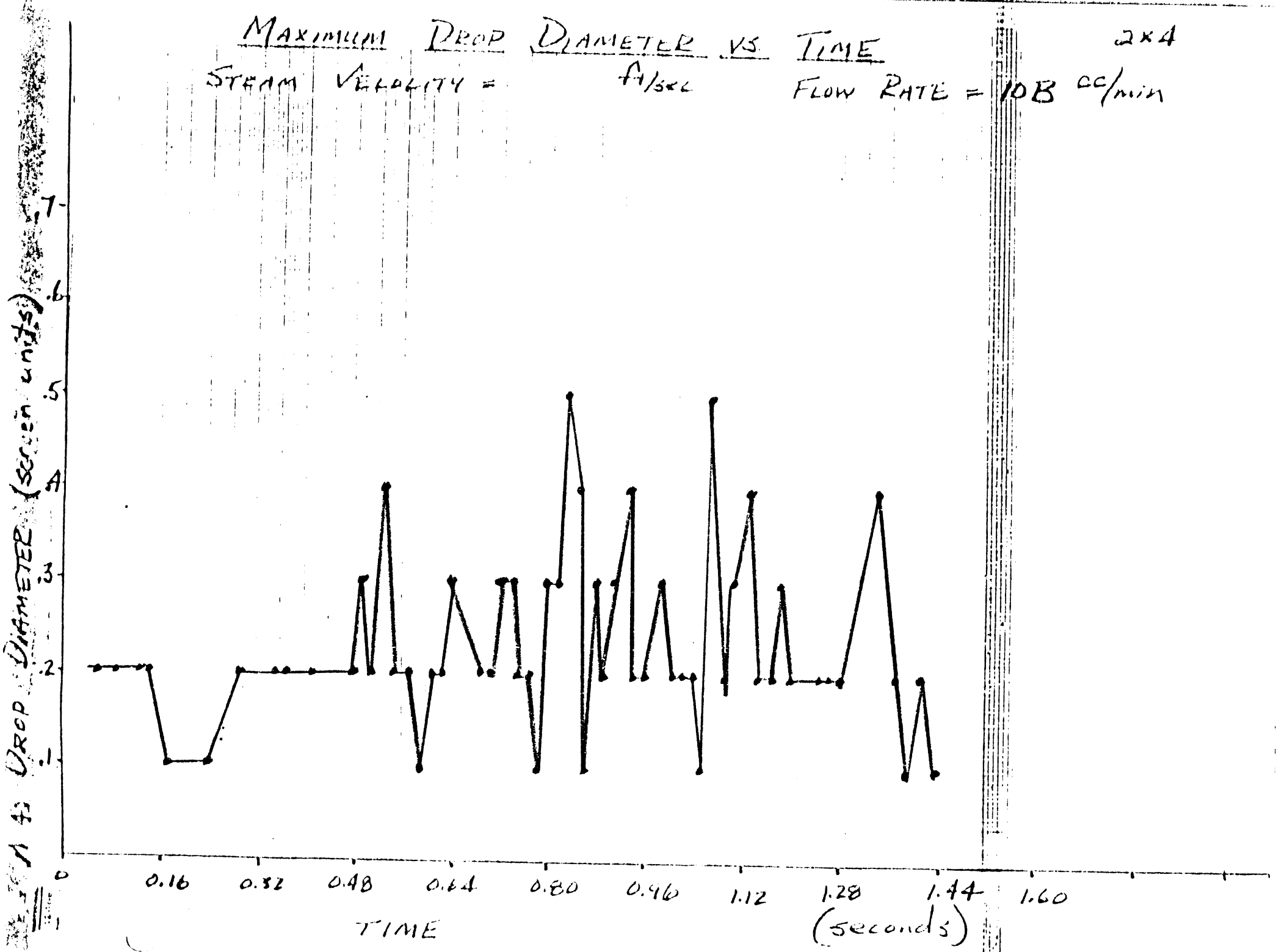


MAXIMUM DROP DIAMETER VS TIME

STEAM VELOCITY = ft/sec

FLOW RATE = 108 cc/min

2×4

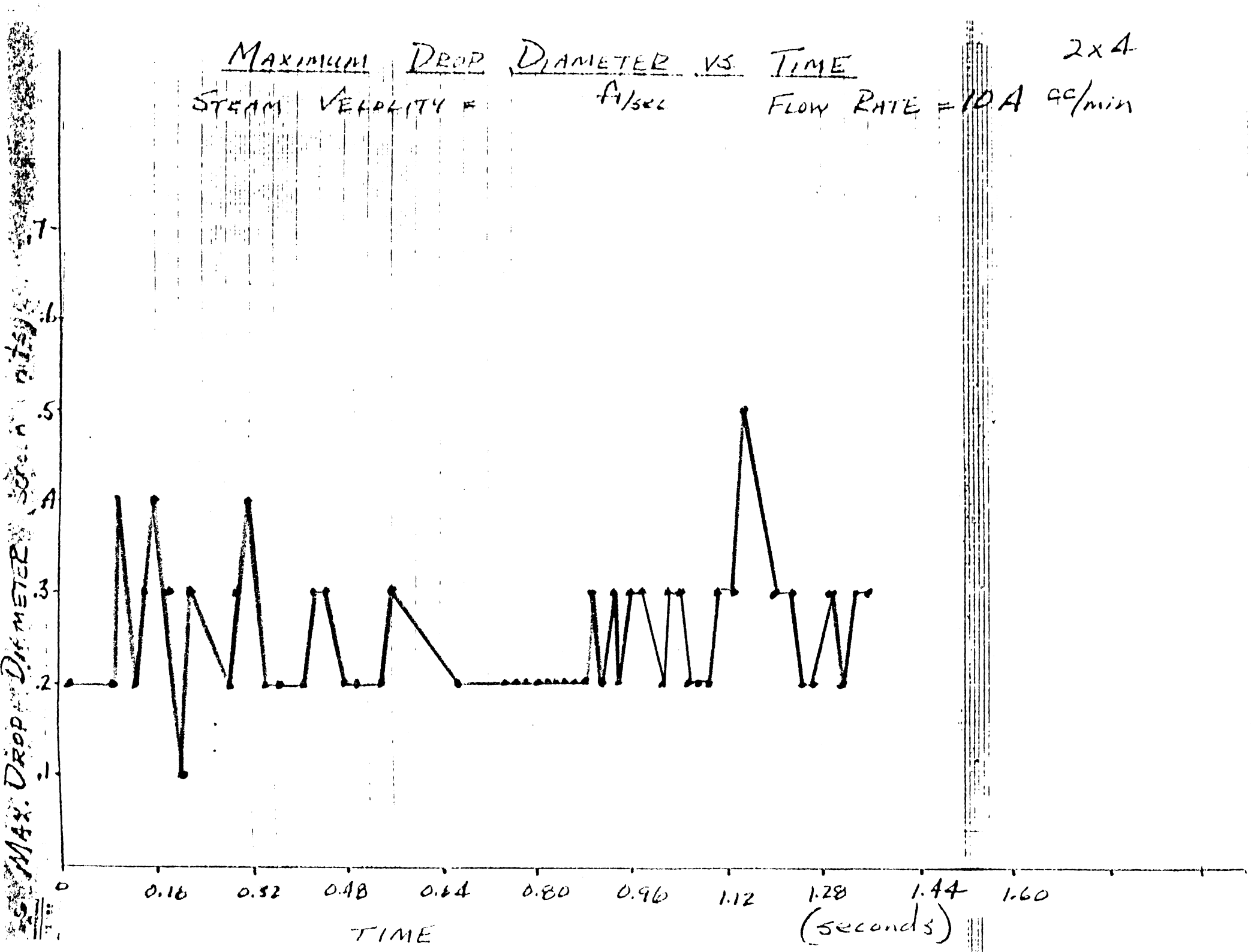


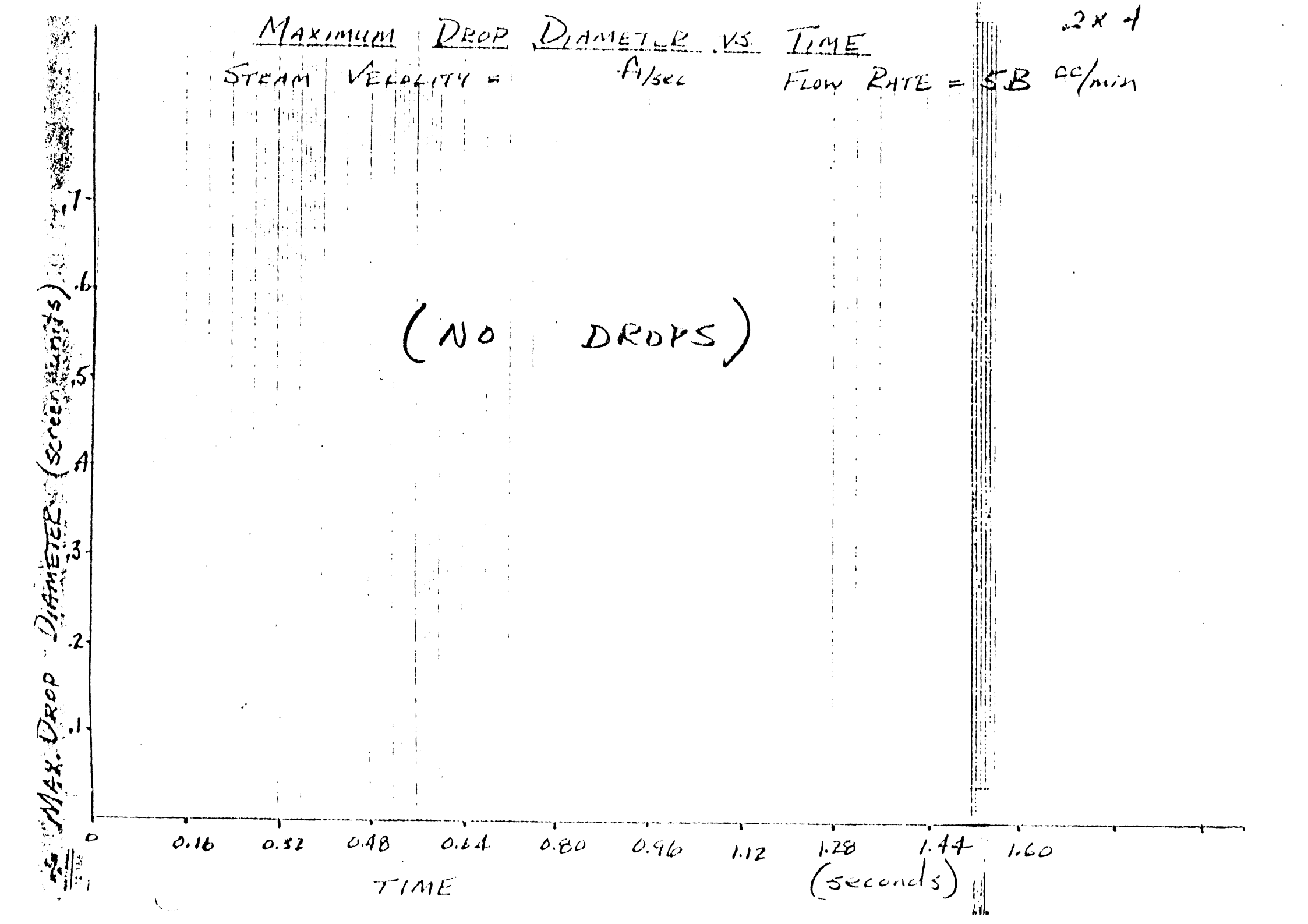
MAXIMUM DROP DIAMETER VS TIME

2x4

STEAM VELOCITY = ft/sec

FLOW RATE = 10 A cc/min



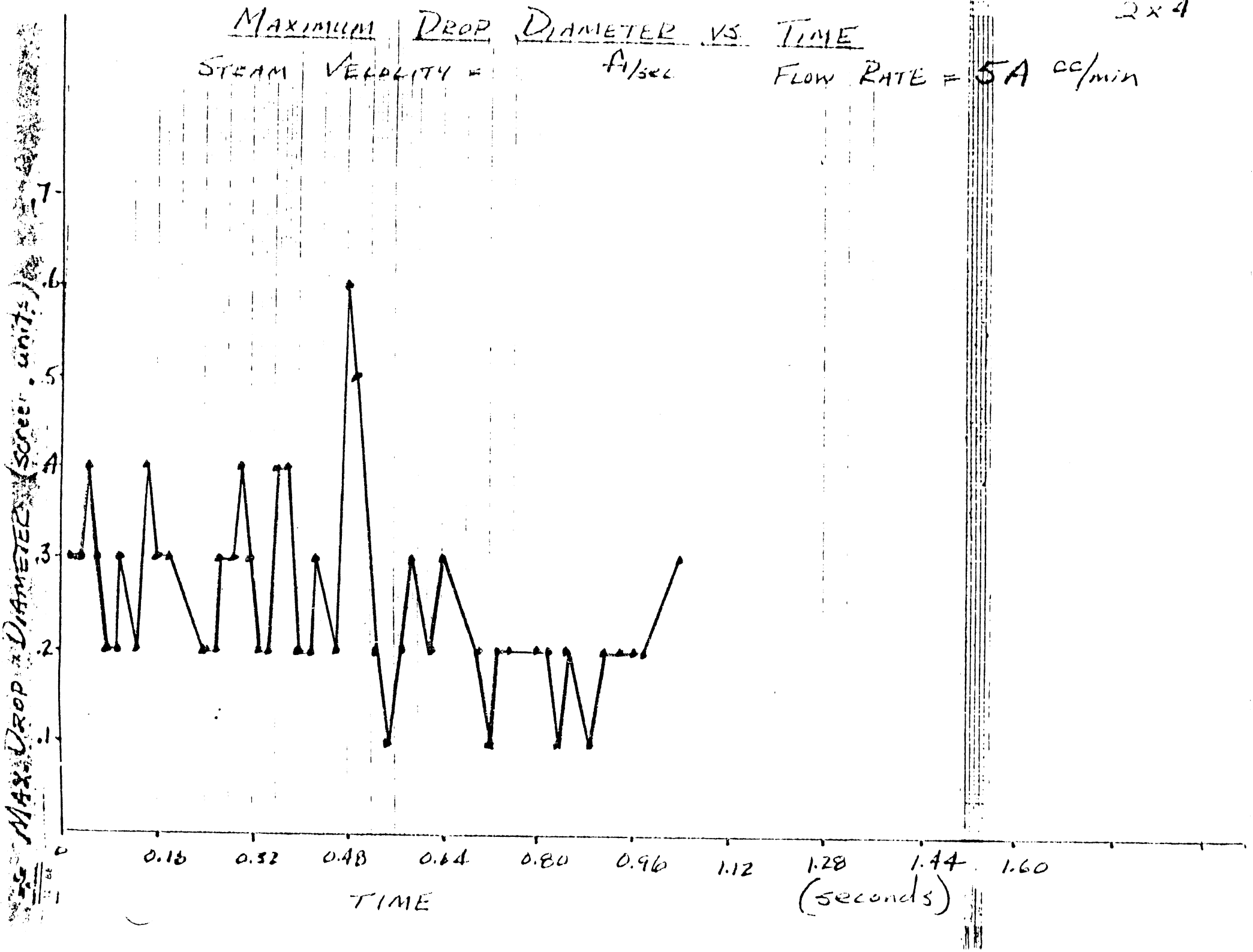

MAXIMUM DROP DIAMETER VS TIME
STEAM VELOCITY = A/sec
FLOW RATE = 58 cc/min
2 x 4
(NO DROPS)
MAX. DROP DIAMETER (screen units)
.1
.2
.3
.4
.5
.6
.7
0
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.60
TIME
(seconds)

2 x 4

MAXIMUM DROP DIAMETER VS TIME

STEAM VELOCITY = A/sec

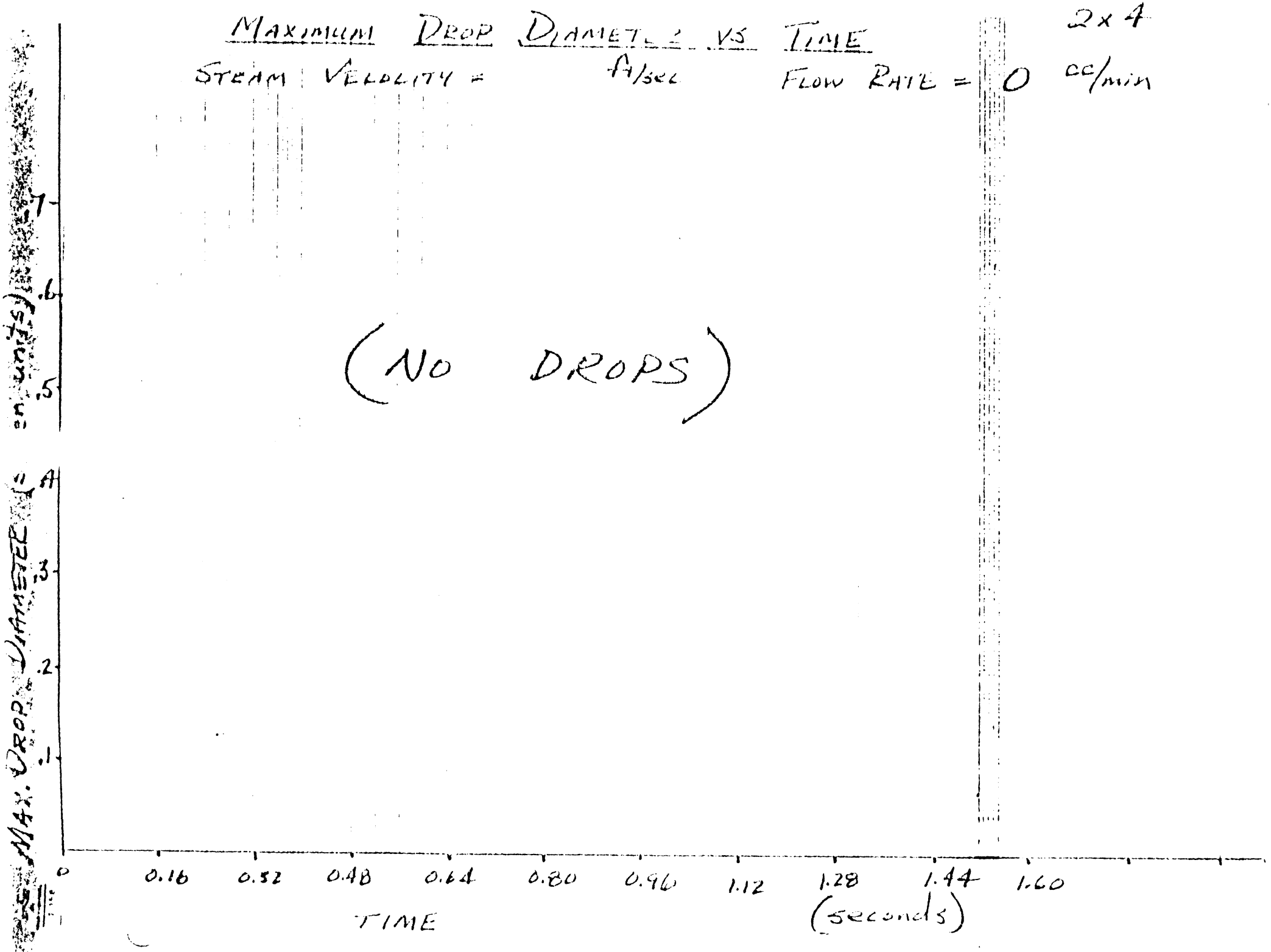
FLOW RATE = 5A cc/min



MAXIMUM DROP DIAMETER VS TIME

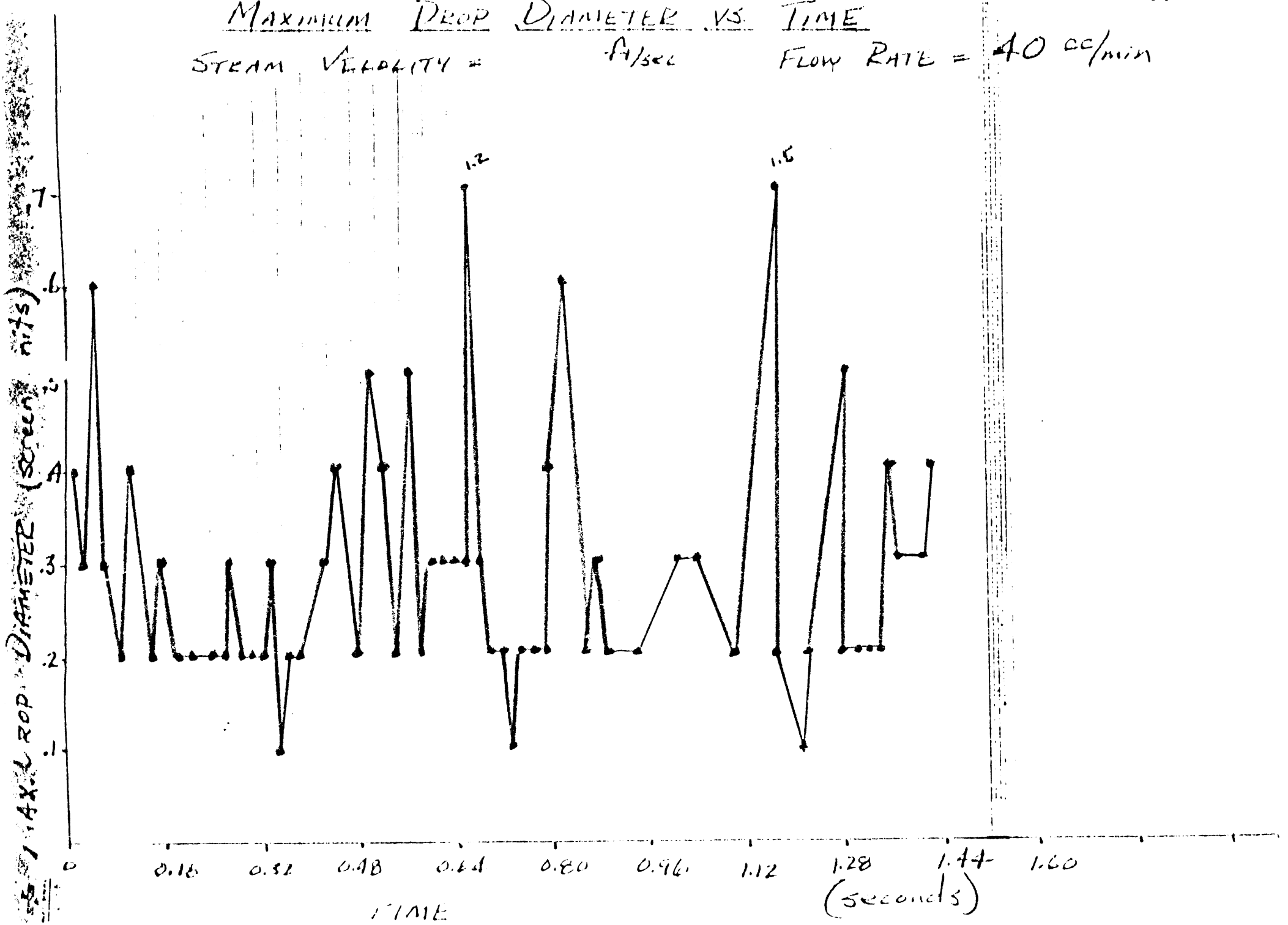
2 x 4

STEAM VELOCITY = ft/sec FLOW RATE = 0 cc/min



Maximum Drop Diameter vs Time

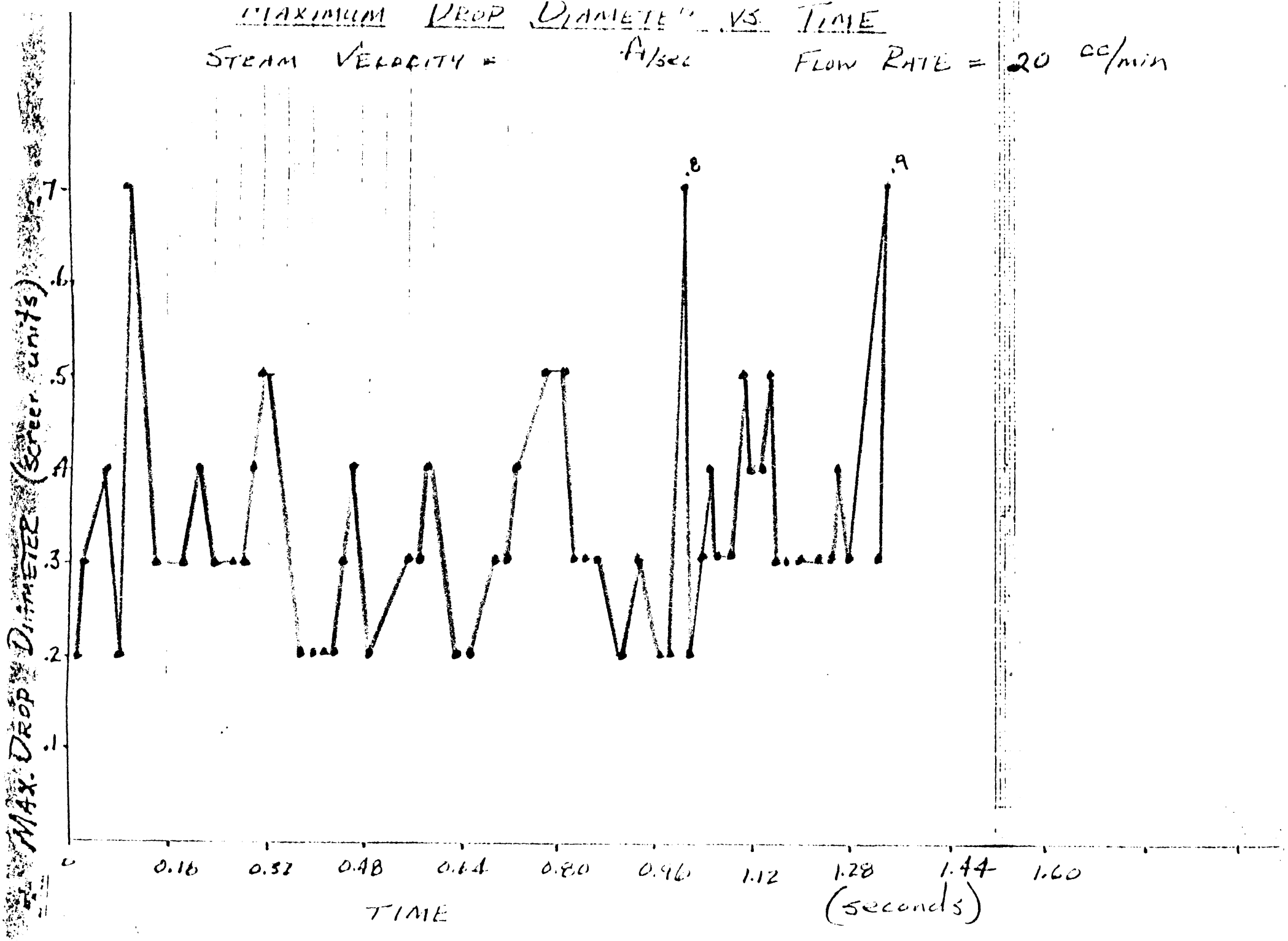
Steam Velocity = ft/sec Flow Rate = 40 cc/min



MAXIMUM ROD DIAMETER (screen units)

MAXIMUM DROP DIAMETER VS TIME

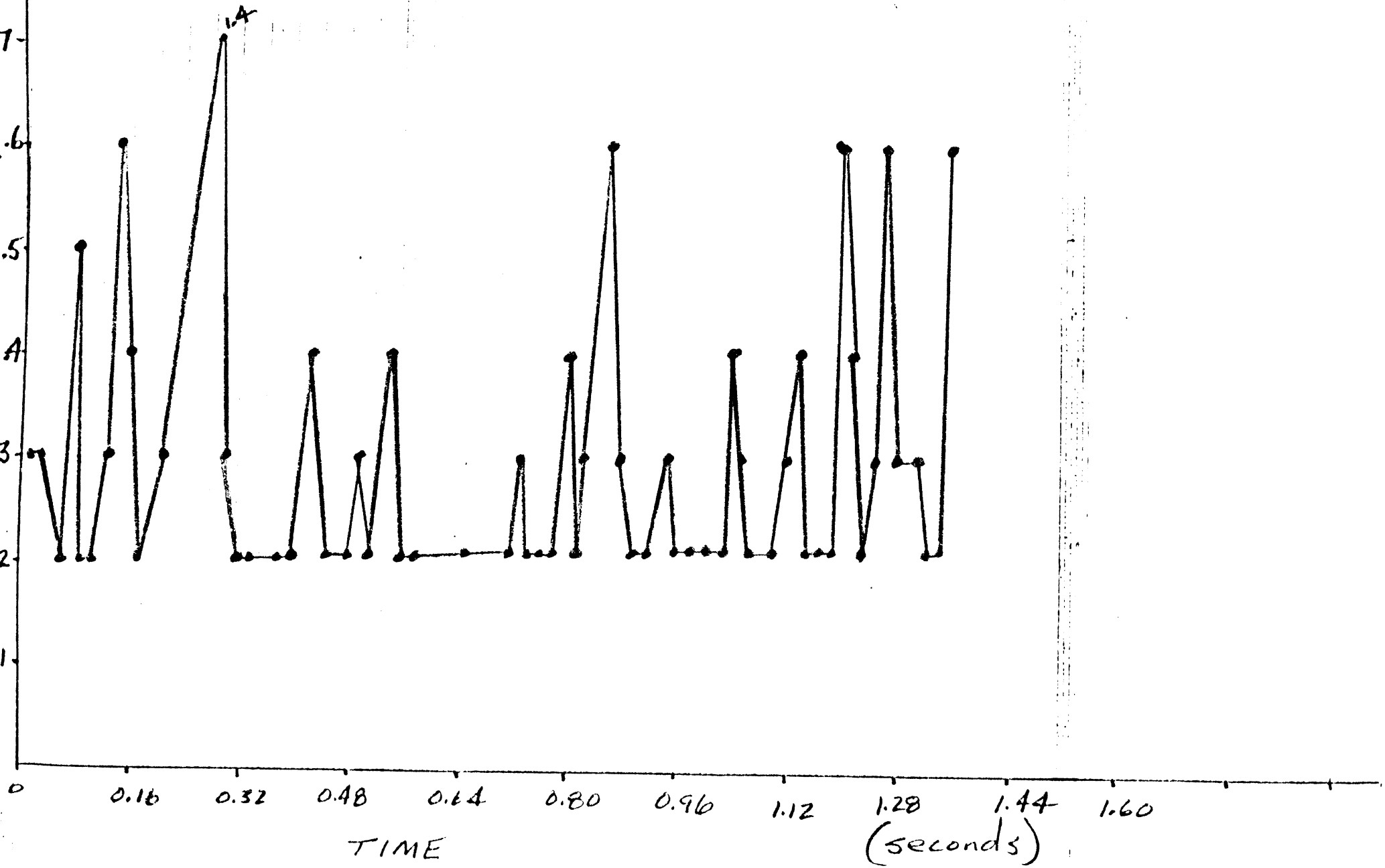
STEAM VELOCITY = ft/sec FLOW RATE = 20 cc/min



2×2.5

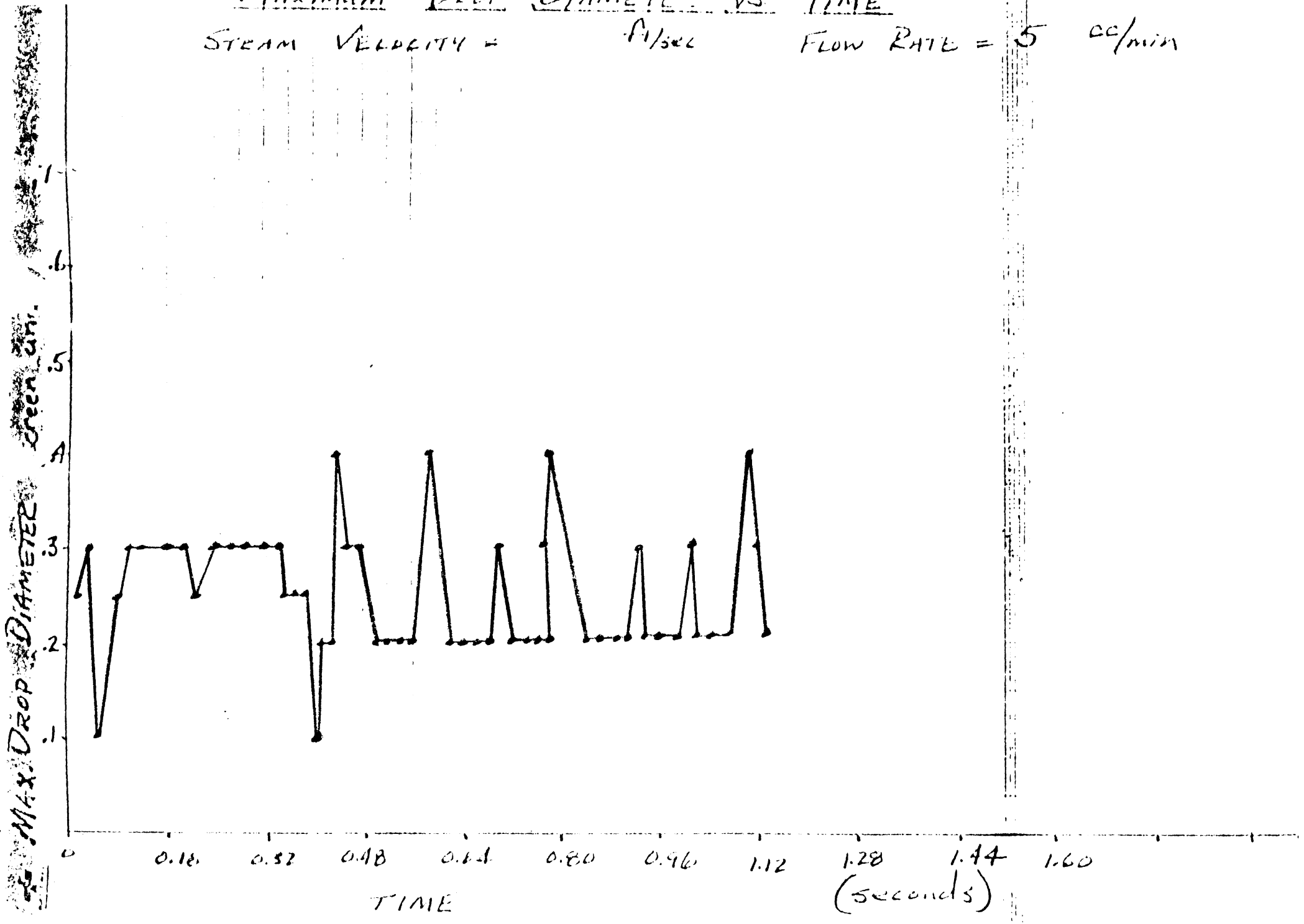
Maximum Drop Diameter vs. Time

Steam Velocity = ft/sec Flow Rate = 10 cc/min



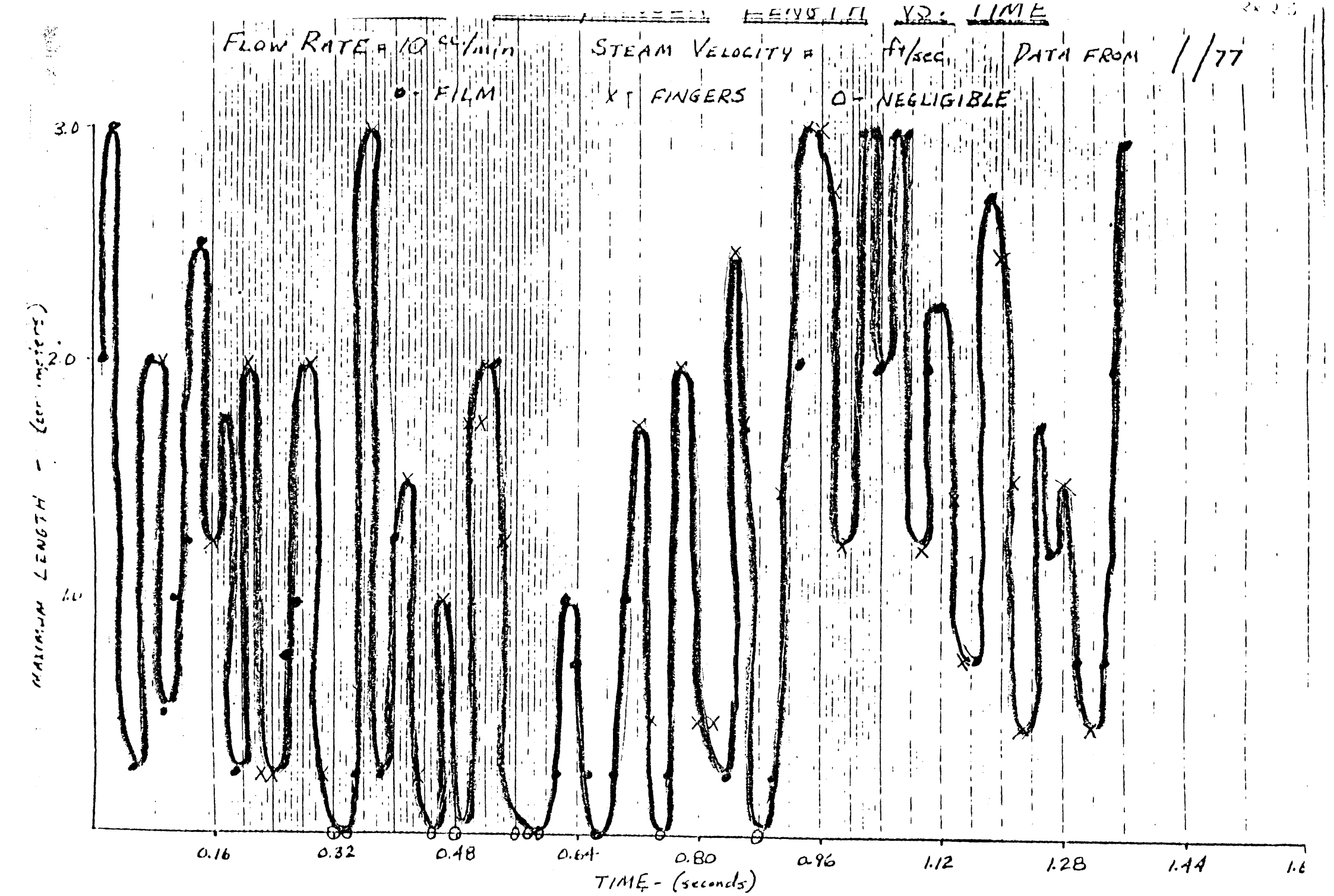
MAXIMUM DROP DIAMETER VS TIME

STEAM VELOCITY = ft/sec FLOW RATE = 5 cc/min



APPENDIX C

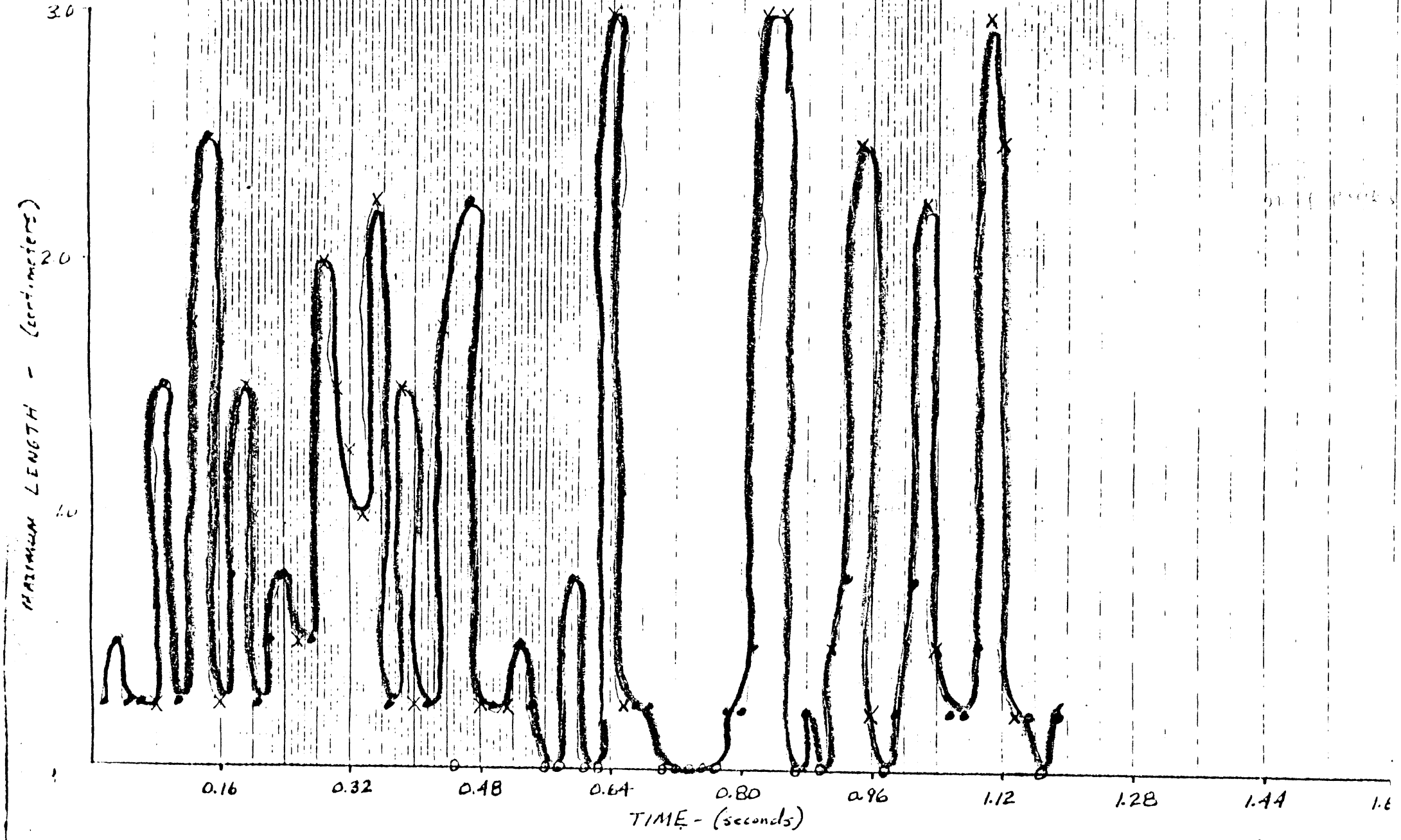
MAXIMUM LENGTH VS. TIME

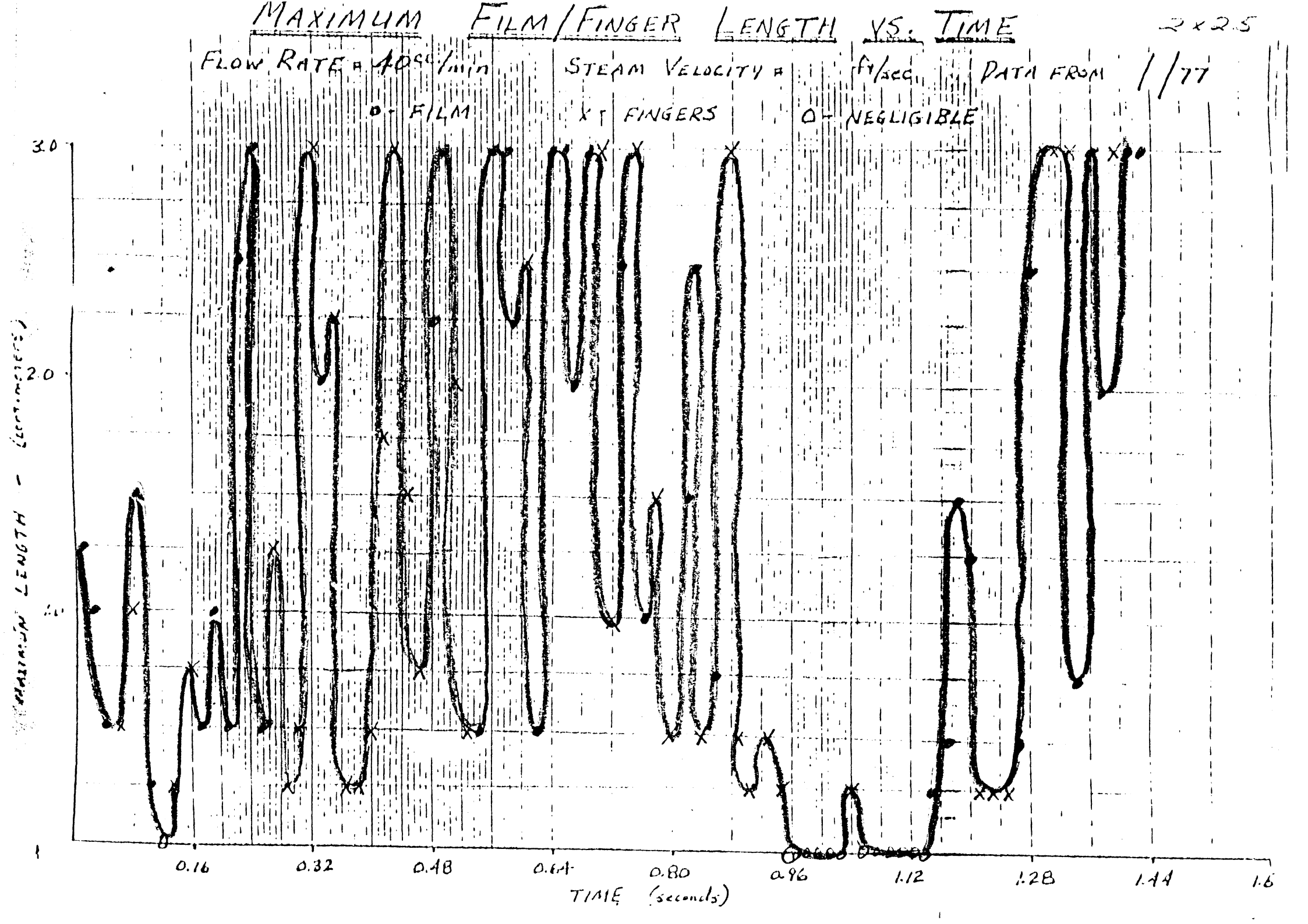

LENGTH VS. TIME
FLOW RATE = 10 cc/min
STEAM VELOCITY = ft/sec
DATA FROM 1/77
• FILM
X FINGERS
0 - NEGLIGIBLE
3.0
2.0
1.0
MAXIMUM LENGTH - (cm. meters)
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
TIME - (seconds)

FILAMENT LENGTH VS. TIME

FLOW RATE = 5 cc/min STEAM VELOCITY = ft/sec DATA FROM 1/4/77

● - FILM X - FINGERS O - NEGLIGIBLE

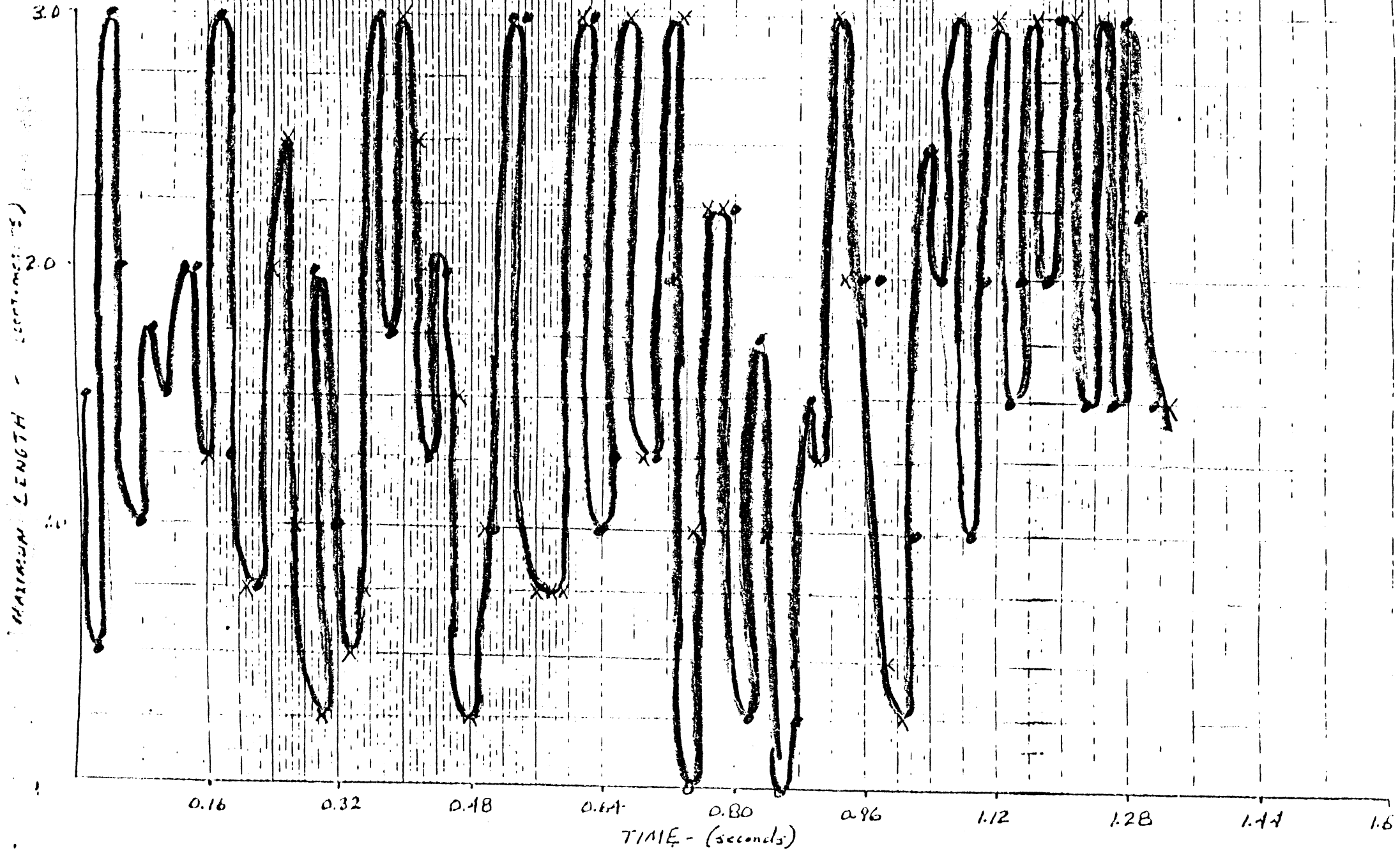


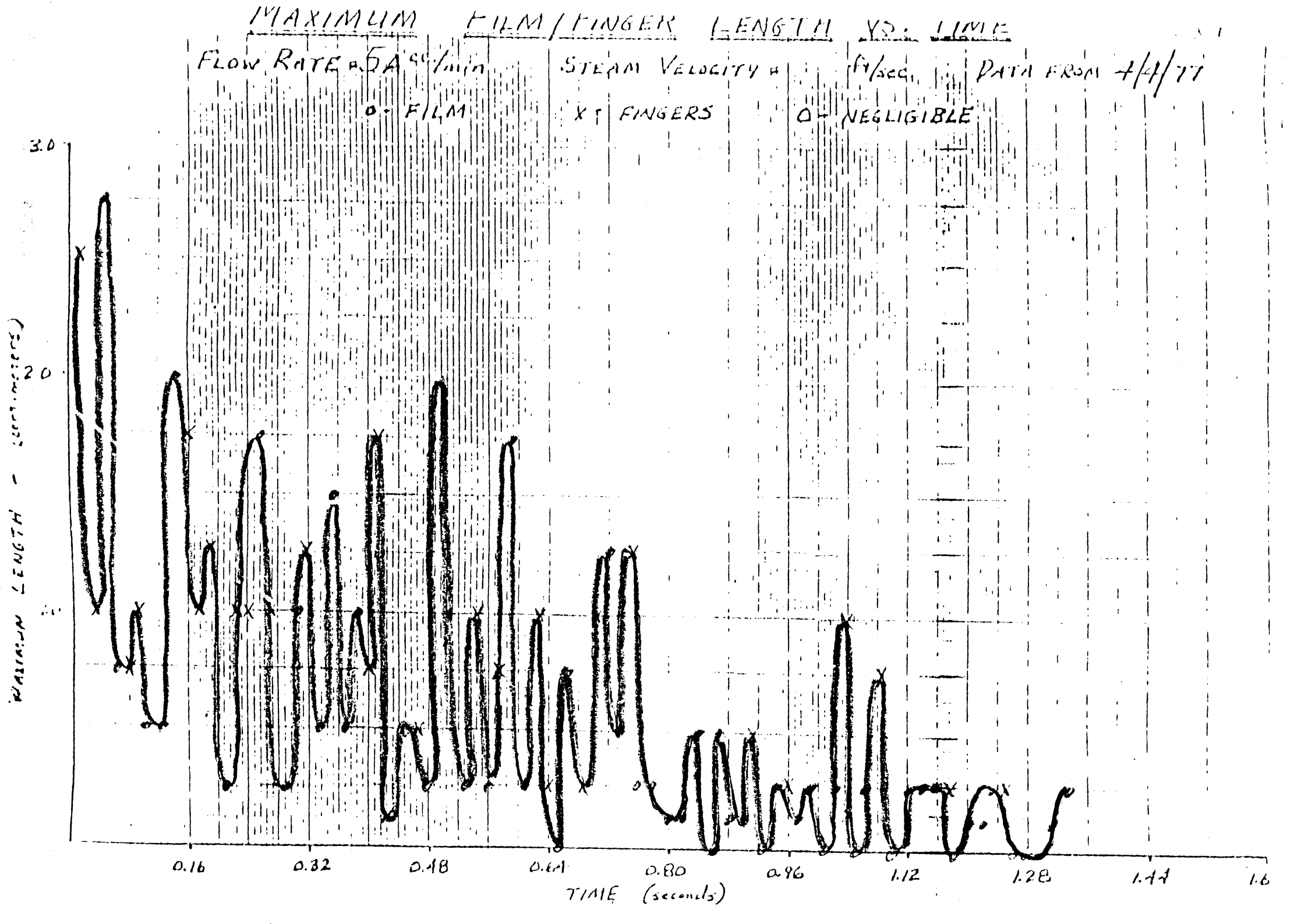

MAXIMUM FILM/FINGER LENGTH VS. TIME
2 x 2.5
FLOW RATE = 40cc/min
STEAM VELOCITY = ft/sec
DATA FROM 1/77
O - FILM
X - FINGERS
O - NEGLIGIBLE
MAXIMUM LENGTH - (centimeters)
3.0
2.0
1
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.6
TIME (seconds)

MAXIMUM FILM/FINGER LENGTH VS. TIME

FLOW RATE = 20 cc/min STEAM VELOCITY = ft/sec DATA FROM 1/77

O - FILM X - FINGERS O - NEGLIGIBLE




MAXIMUM FILM/FINGER LENGTH VS. TIME
FLOW RATE = .5A SCFM/in
STEAM VELOCITY = ft/sec
DATA FROM 4/4/77
O - FILM
X - FINGERS
O - NEGLIGIBLE
3.0
2.0
MAXIMUM LENGTH - (centimeters)
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.6
TIME (seconds)

MAXIMUM FILM/FINGER LENGTH VS. TIME

FLOW RATE = Q cc/min STEAM VELOCITY = fr/sec DATA FROM 4/4/77

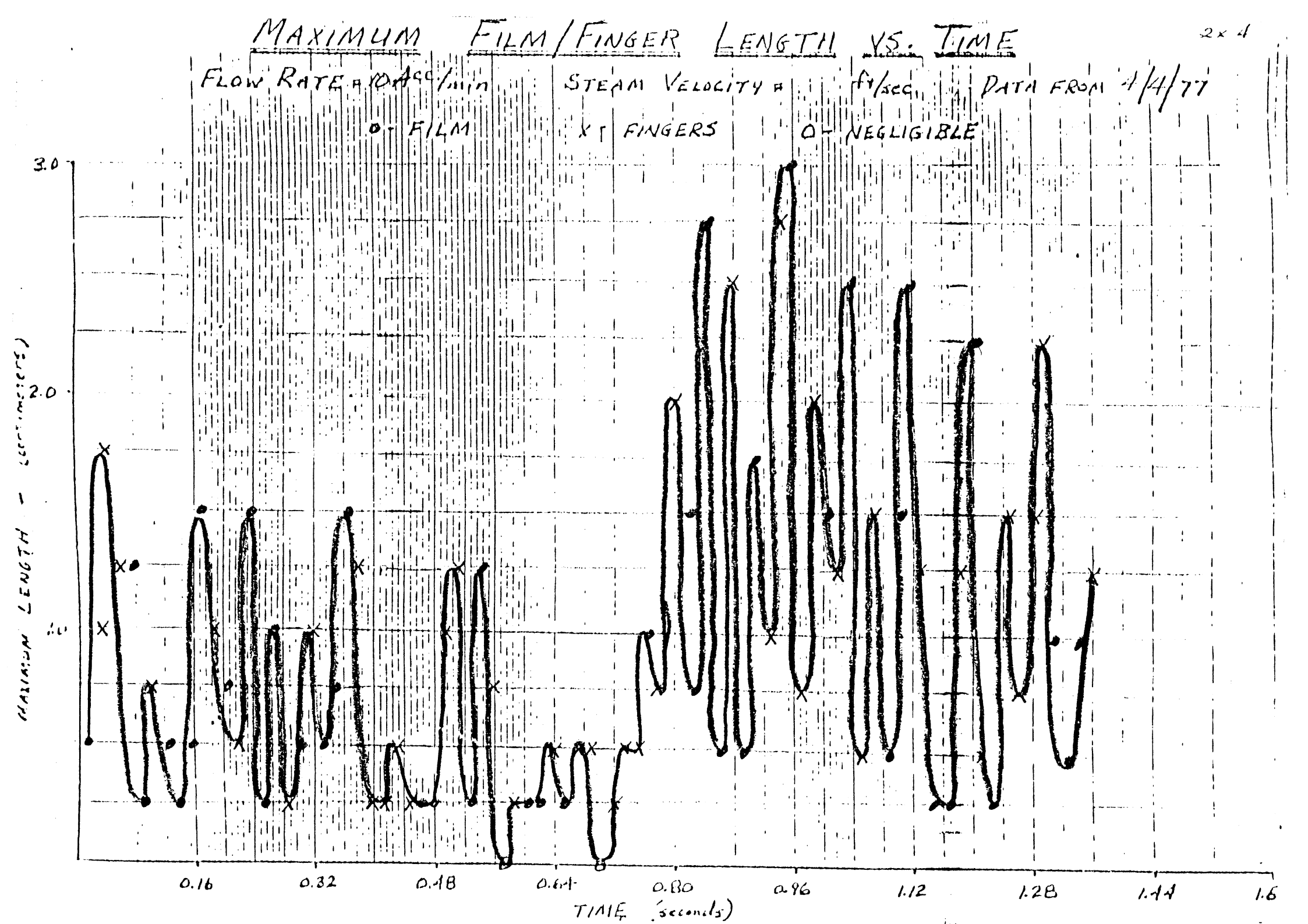
O - FILM X - FINGERS O - NEGLIGIBLE

MAXIMUM LENGTH - (centimeters)

2.0

0.16 0.32 0.48 0.64 0.80 0.96 1.12 1.28 1.44 1.6

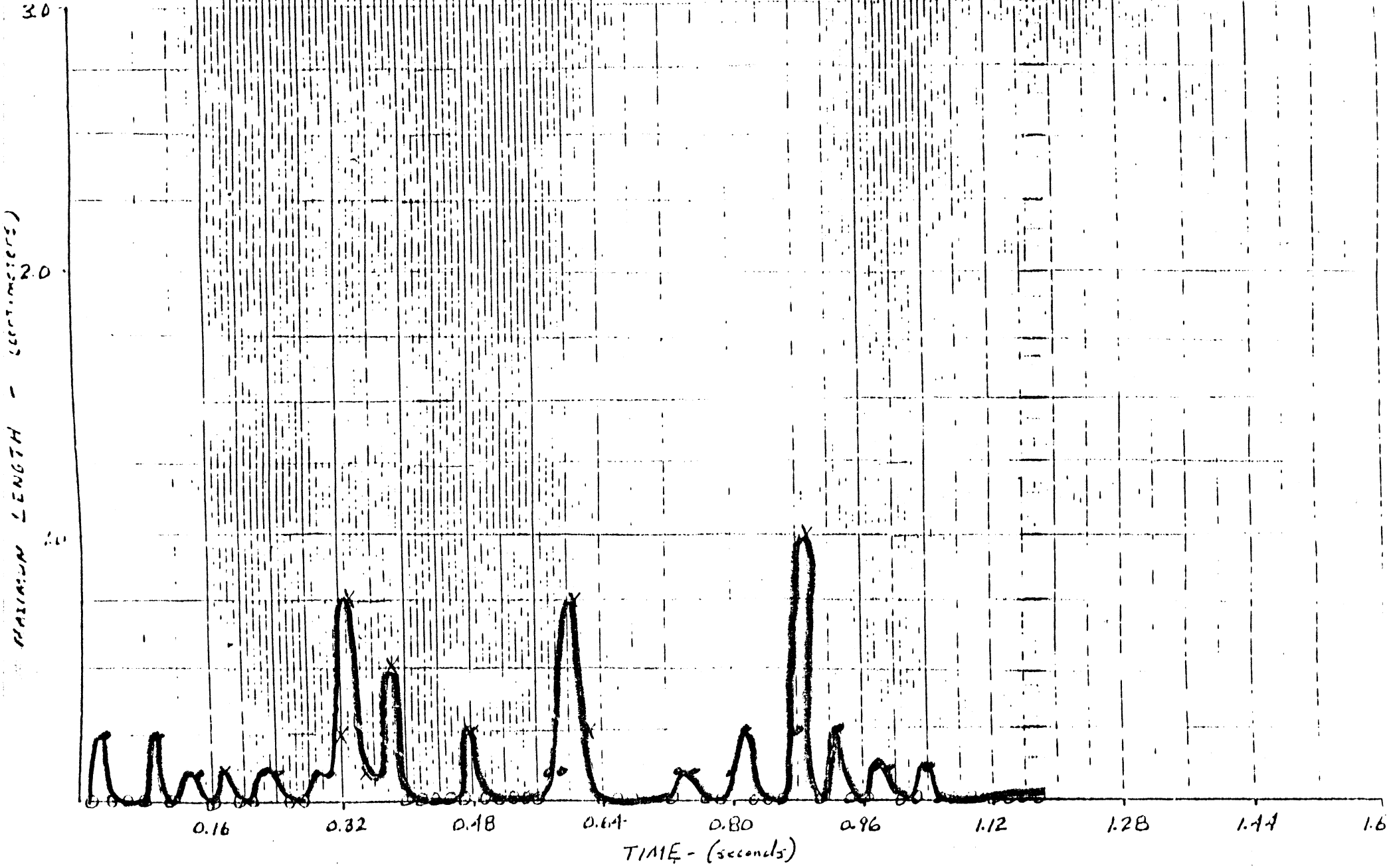
TIME - (seconds)

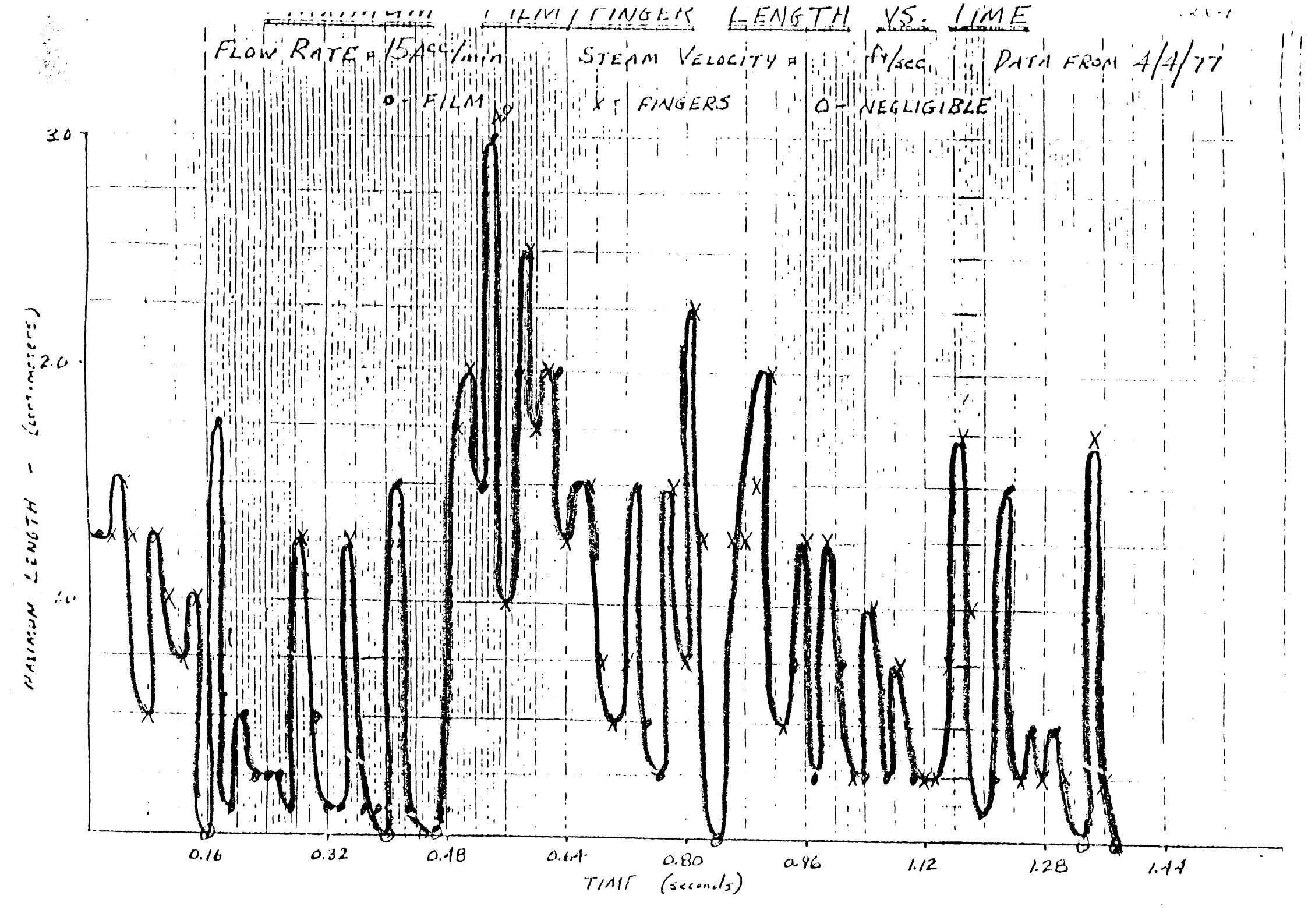

MAXIMUM FILM/FINGER LENGTH VS. TIME
2x4
FLOW RATE = 10 Acc/min
STEAM VELOCITY = ft/sec
DATA FROM 4/4/77
o - FILM
x - FINGERS
O - NEGLIGIBLE
3.0
2.0
1.0
MAXIMUM LENGTH - (centimeters)
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.6
TIME (seconds)

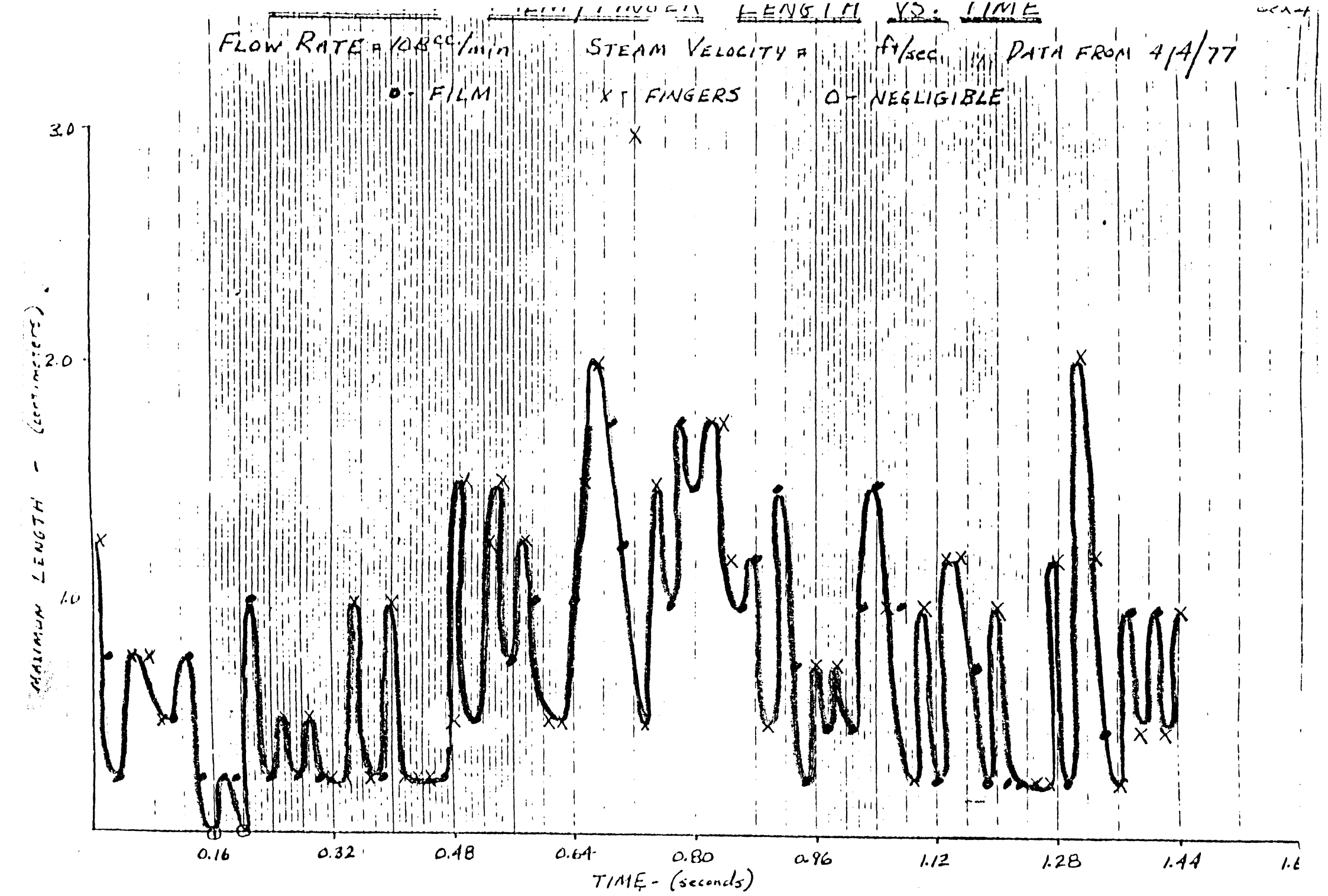
MAXIMUM FILM/FINGER LENGTH VS. TIME

FLOW RATE = 5.8 cc/min STEAM VELOCITY = ? ft/sec DATA FROM 4/4/77

O - FILM X - FINGERS O - NEGLIGIBLE



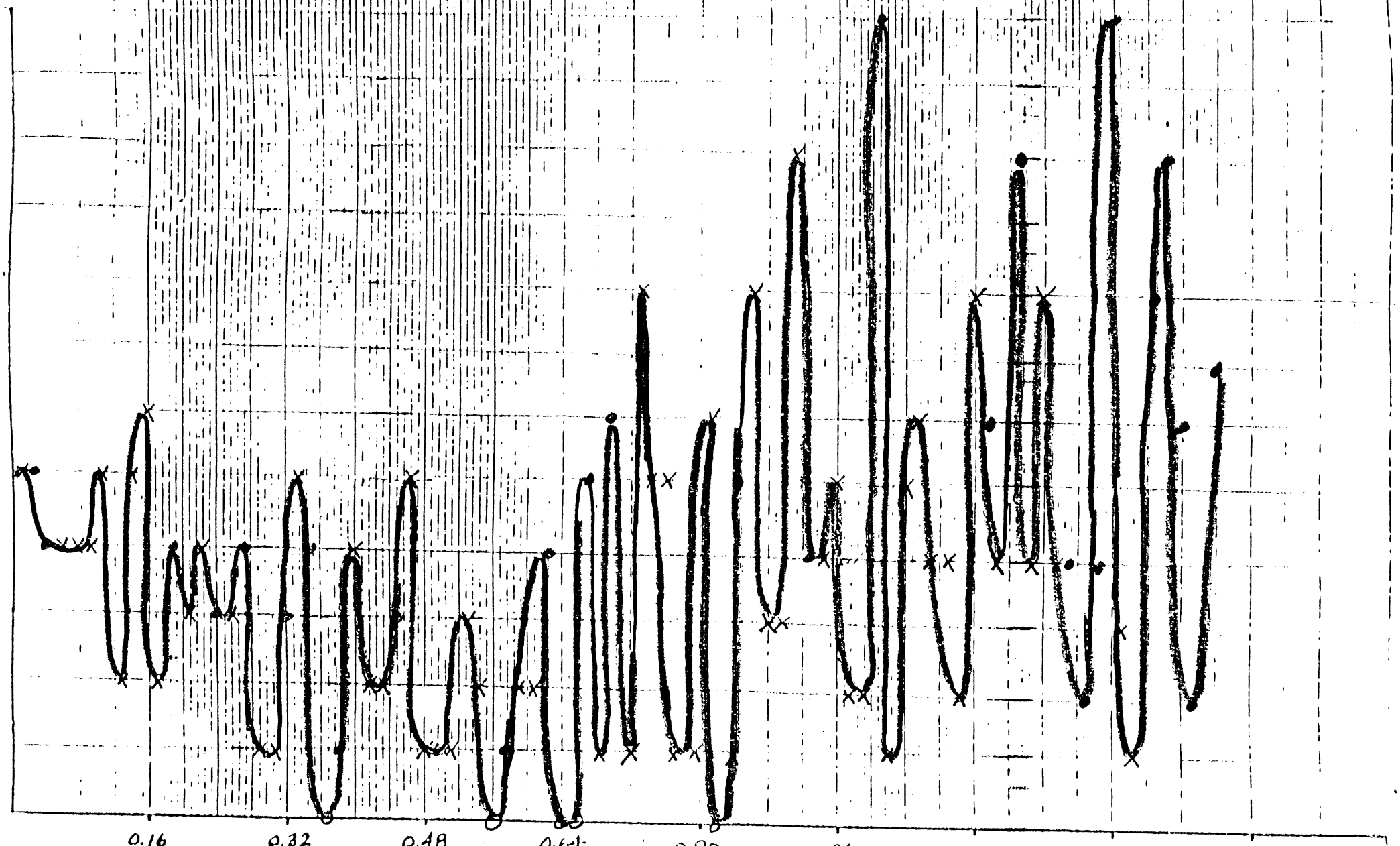

FILM / FINGER LENGTH VS. TIME
FLOW RATE = 15 Acc/min
STEAM VELOCITY = ft/sec
DATA FROM 4/4/77
O - FILM
X - FINGERS
Δ - NEGLIGIBLE
MAXIMUM LENGTH - (centimeters)
3.0
2.0
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
TIME (seconds)

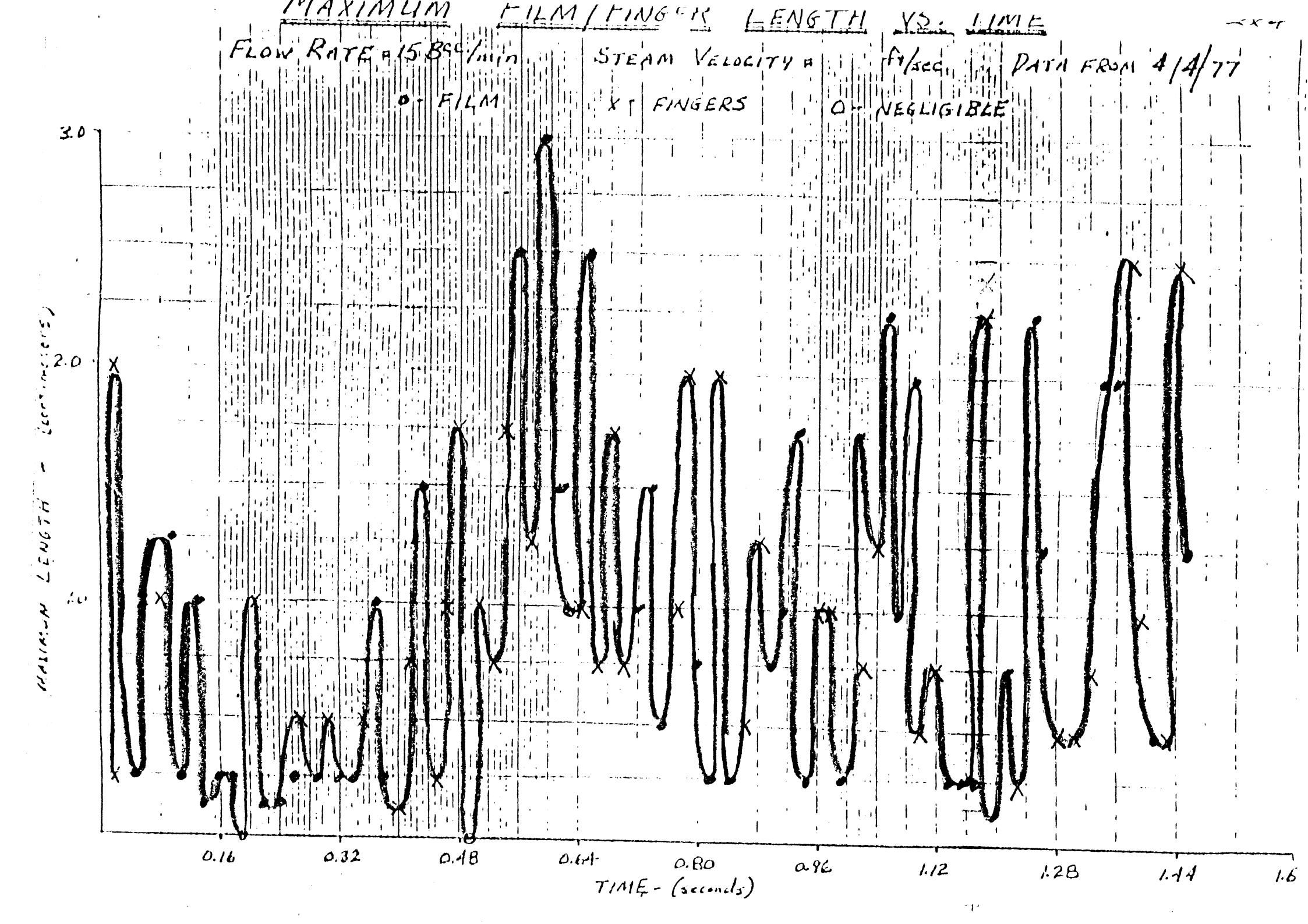

FLOW RATE = 108 cc/min
STEAM VELOCITY =
ft/sec
DATA FROM 4/4/77
• - FILM
X - FINGERS
O - NEGLIGIBLE
3.0
2.0
1.0
MAXIMUM LENGTH - (centimeters)
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
TIME - (seconds)

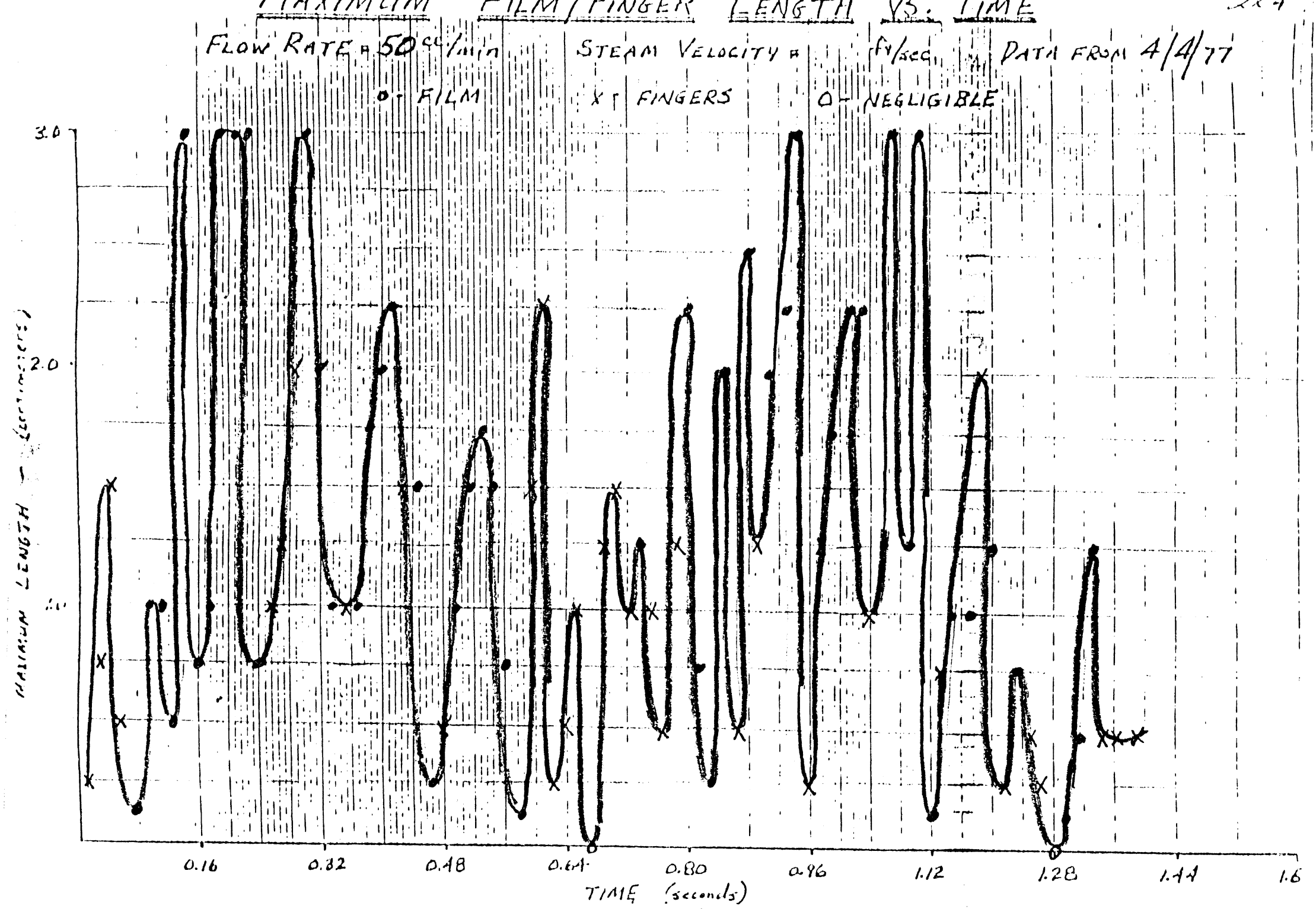
MAXIMUM FILM/FINGER LENGTH VS. TIME

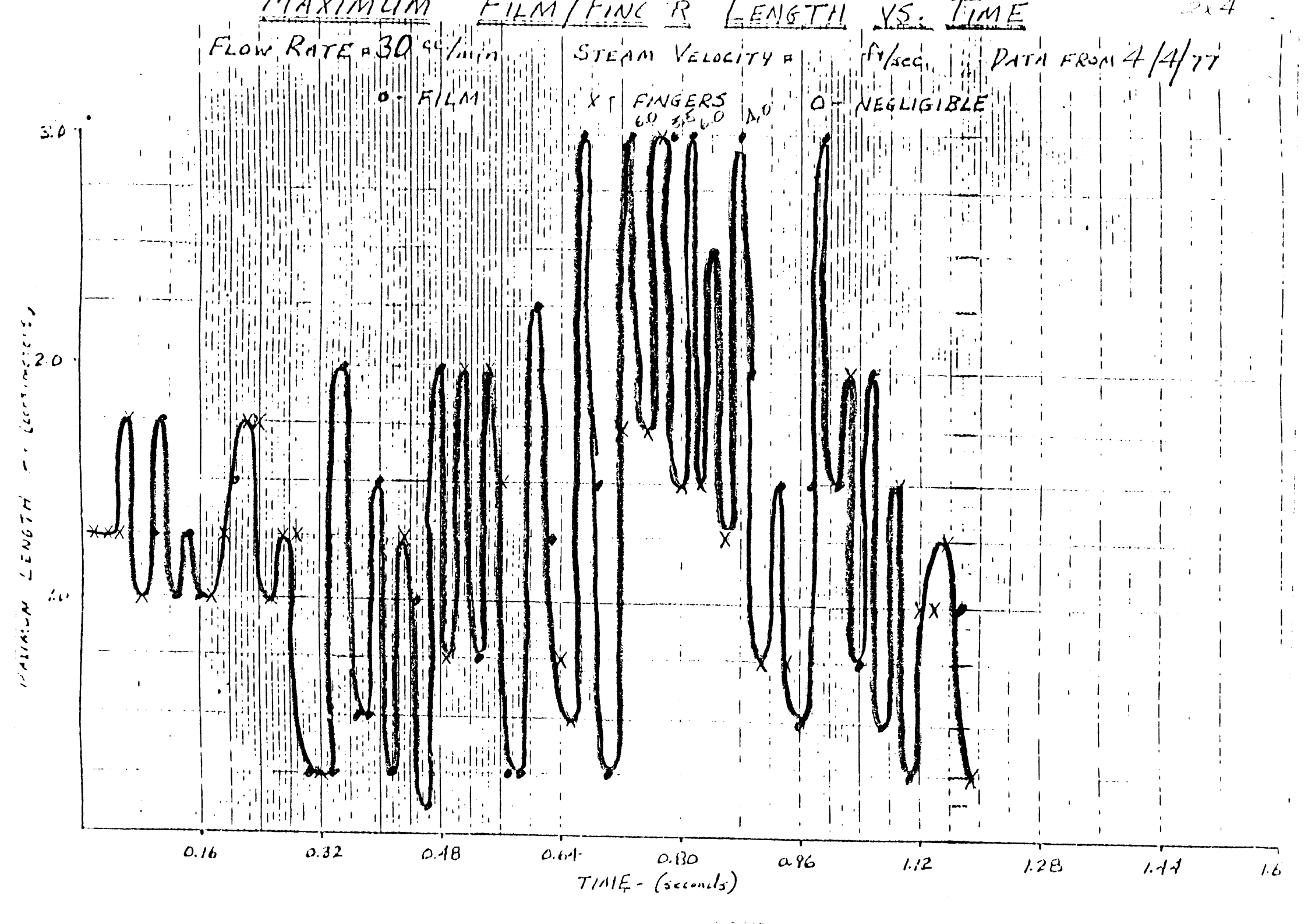
FLOW RATE = 20 Acc/min STEAM VELOCITY = ft/sec DATA FROM 4/4/77

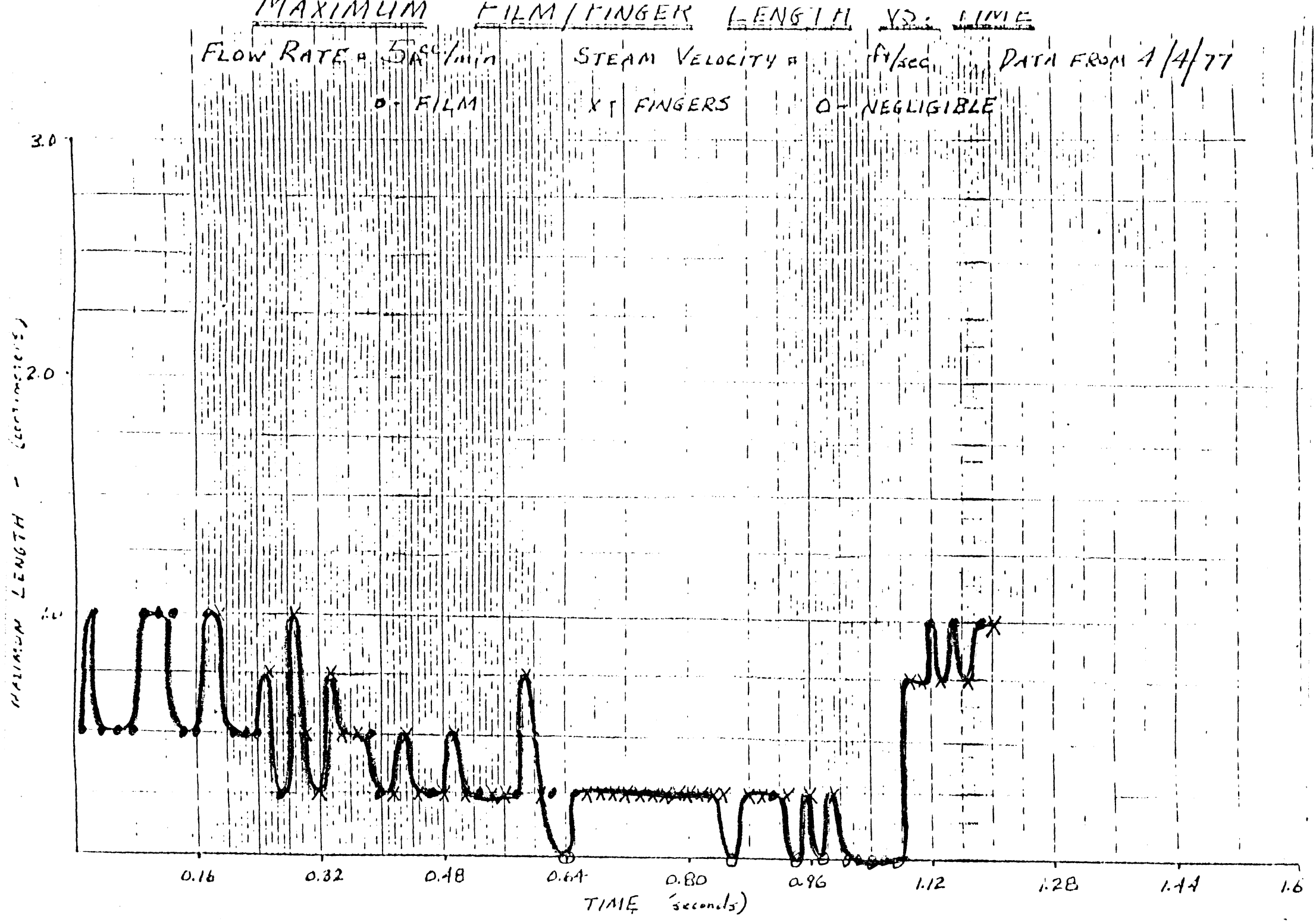
O - FILM X - FINGERS O - NEGLIGIBLE

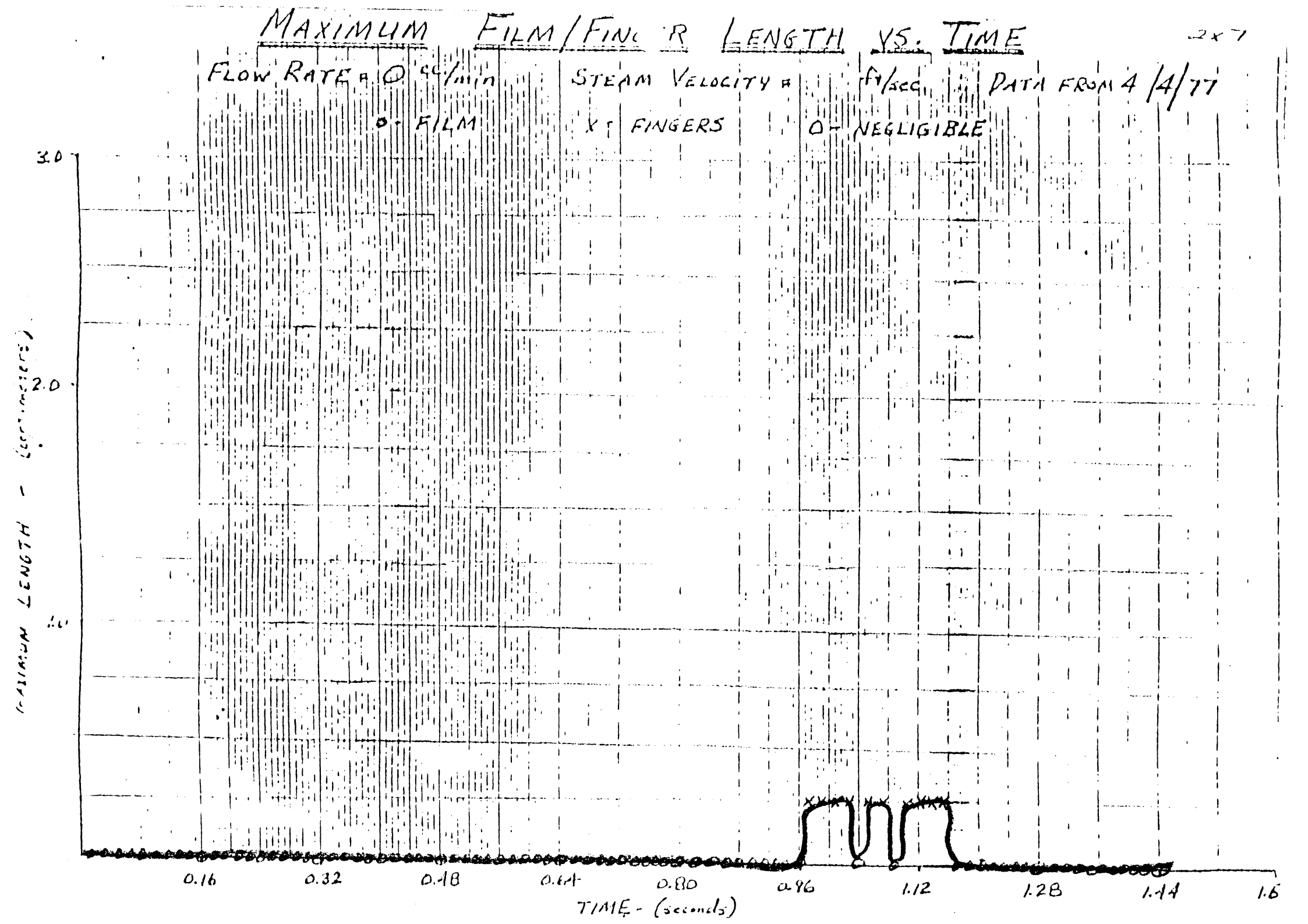


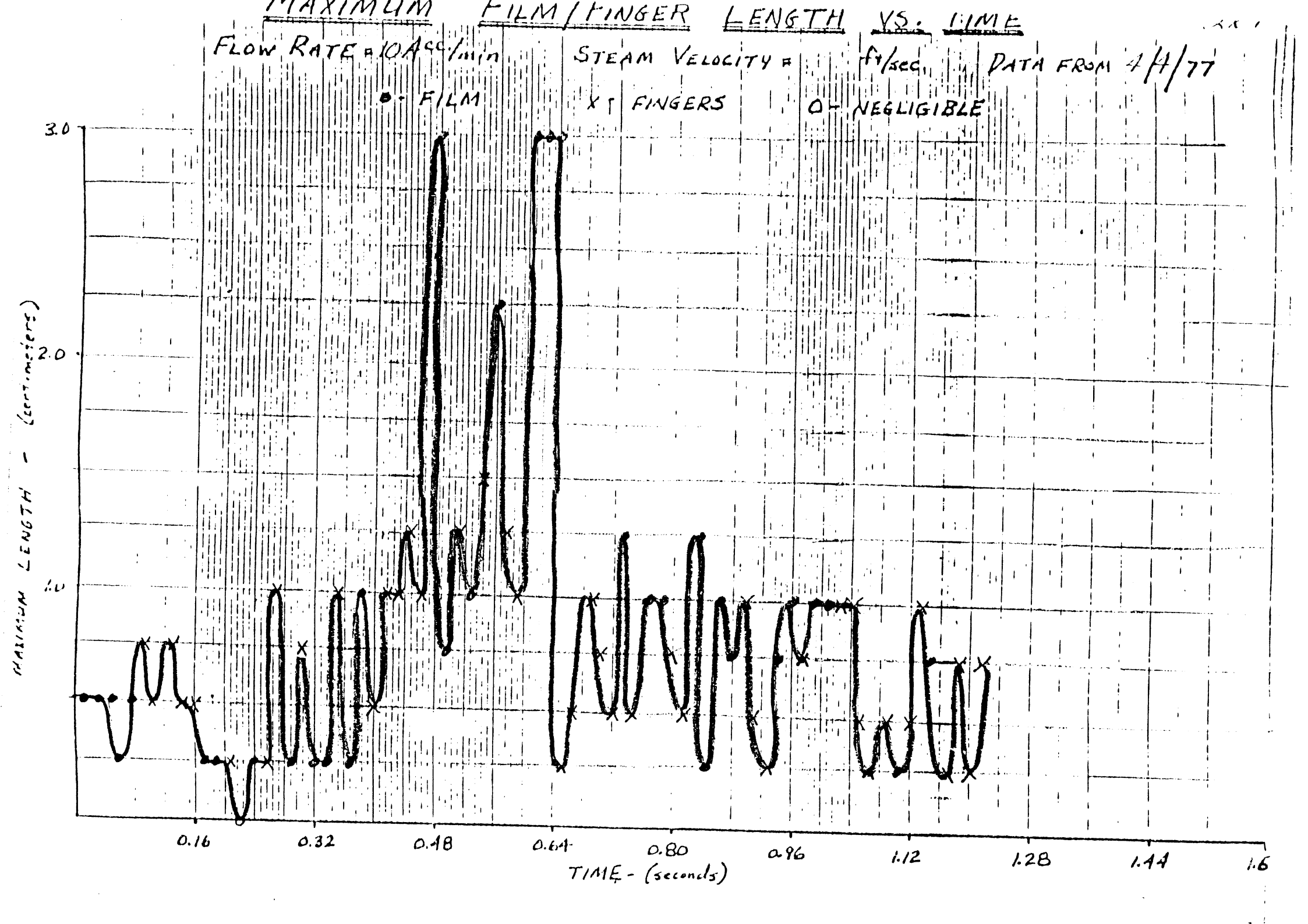

MAXIMUM FILM/FINGER LENGTH VS. TIME
FLOW RATE = 15 gpm
STEAM VELOCITY = ft/sec
DATA FROM 4/4/77
O - FILM
X - FINGERS
O - NEGLIGIBLE
3.0
2.0
MAXIMUM LENGTH - (centimeters)
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.6
TIME - (seconds)


MAXIMUM FILM/FINGER LENGTH VS. TIME
FLOW RATE = 50 cc/min
STEAM VELOCITY = ft/sec
DATA FROM 4/4/77
o - FILM
x - FINGERS
0 - NEGLIGIBLE
MAXIMUM LENGTH - (centimeters)
3.0
2.0
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.6
TIME (seconds)


MAXIMUM FILM/FINGER LENGTH VS. TIME
FLOW RATE = 30 cc/min
STEAM VELOCITY = ft/sec
DATA FROM 4/4/77
o - FILM
X - FINGERS
Δ
o - NEGLIGIBLE
6.0
6.0
6.0
3.0
2.0
1.0
MAXIMUM LENGTH - (centimeters)
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.6
TIME - (seconds)


MAXIMUM FILM/FINGER LENGTH VS. TIME
FLOW RATE = 5 cc/min
STEAM VELOCITY = ft/sec
DATA FROM 1/4/77
O - FILM
X - FINGERS
O - NEGLIGIBLE
3.0
2.0
1.0
MAXIMUM LENGTH - (centimeters)
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.6
TIME (seconds)

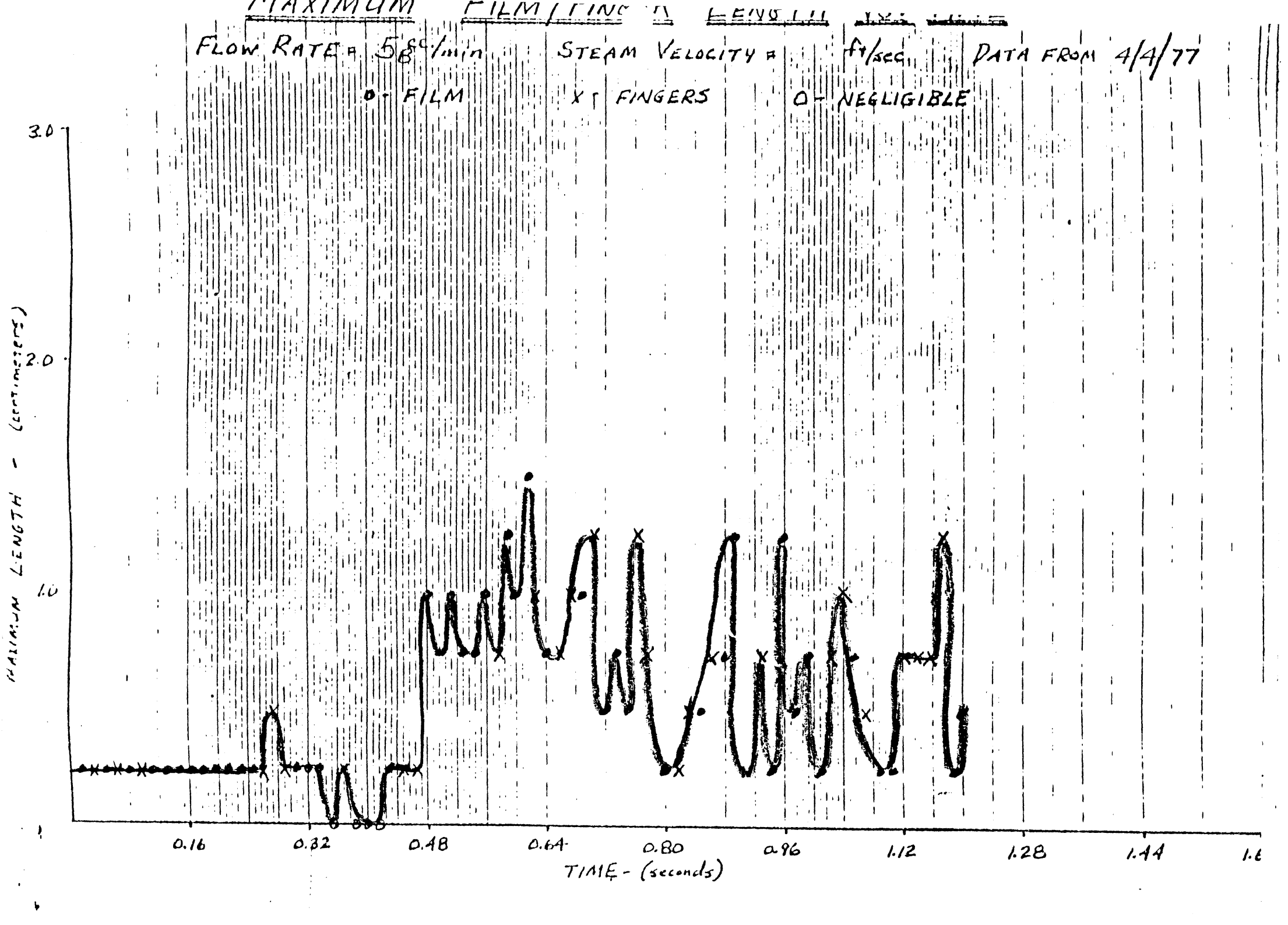

MAXIMUM FILM/FINGER LENGTH VS. TIME
2 x 7
FLOW RATE = Q cc/min
STEAM VELOCITY = ft/sec
DATA FROM 4/4/77
O - FILM
X - FINGERS
O - NEGLIGIBLE
3.0
2.0
MAXIMUM LENGTH - (centimeters)
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.6
TIME - (seconds)

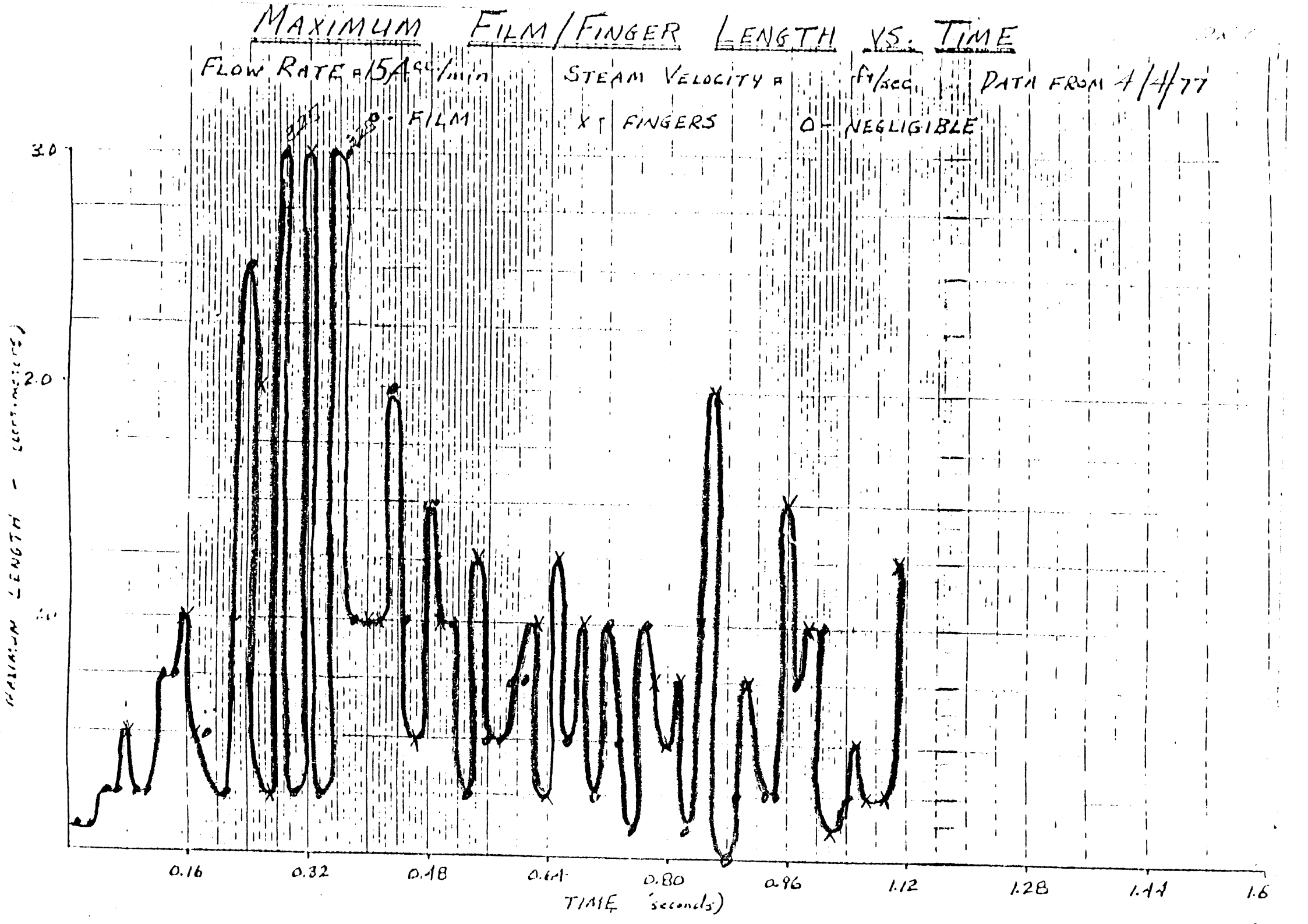

MAXIMUM FILM/FINGER LENGTH VS. TIME
FLOW RATE = 10 Acc/min
STEAM VELOCITY = ft/sec.
DATA FROM 4/4/77
• - FILM
X - FINGERS
O - NEGLIGIBLE
3.0
2.0
1.0
MAXIMUM LENGTH - (centimeters)
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.6
TIME - (seconds)

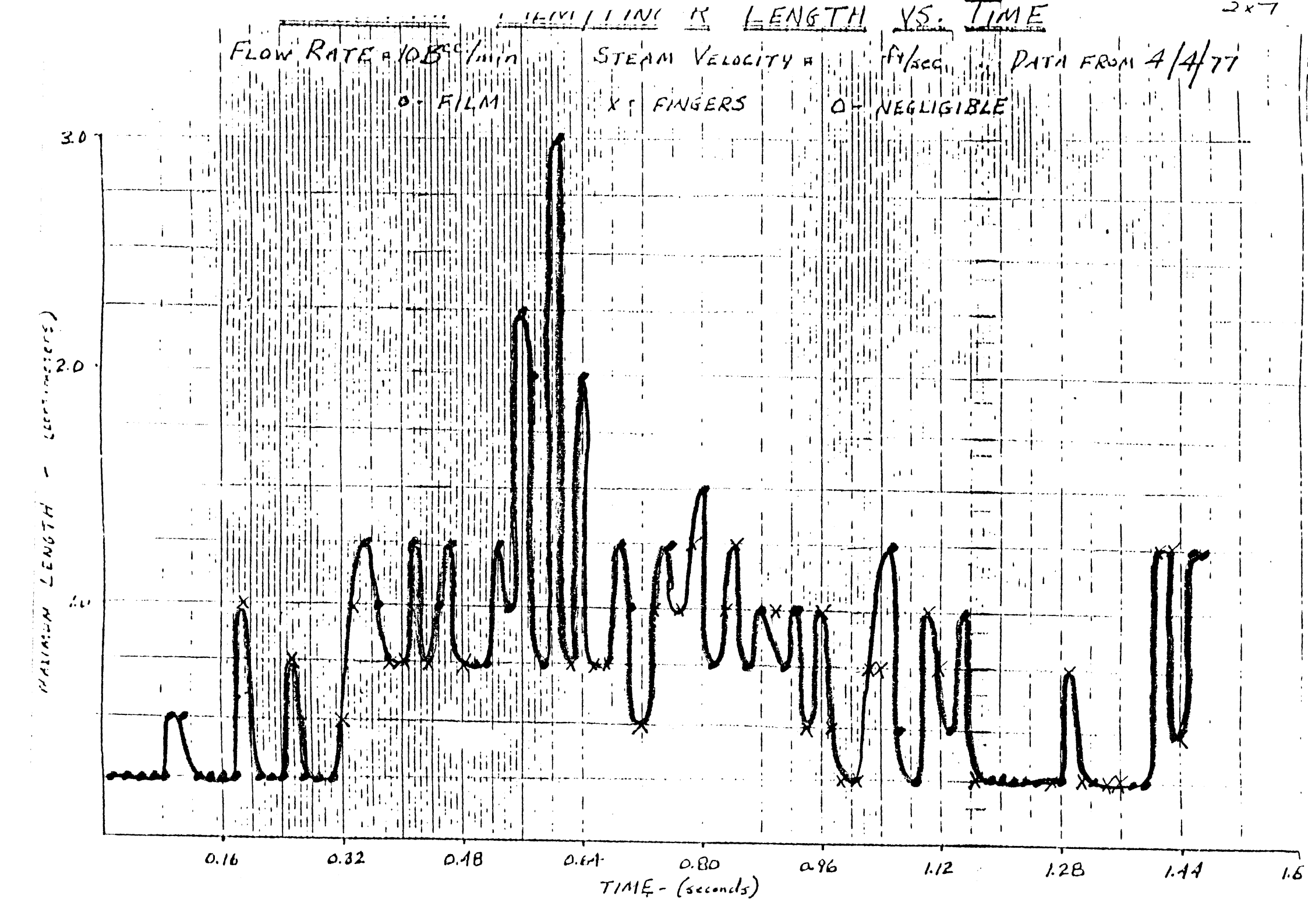
MAXIMUM FILM FINGER LENGTH

FLOW RATE = 58 cc/min STEAM VELOCITY = ft/sec. DATA FROM 4/4/77

O - FILM X - FINGERS O - NEGLIGIBLE




MAXIMUM FILM/FINGER LENGTH VS. TIME
FLOW RATE = 15 Acc/min
STEAM VELOCITY = ft/sec
DATA FROM 4/4/77
X = FINGERS
O = NEGLIGIBLE
3.0
2.0
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.6
TIME (seconds)

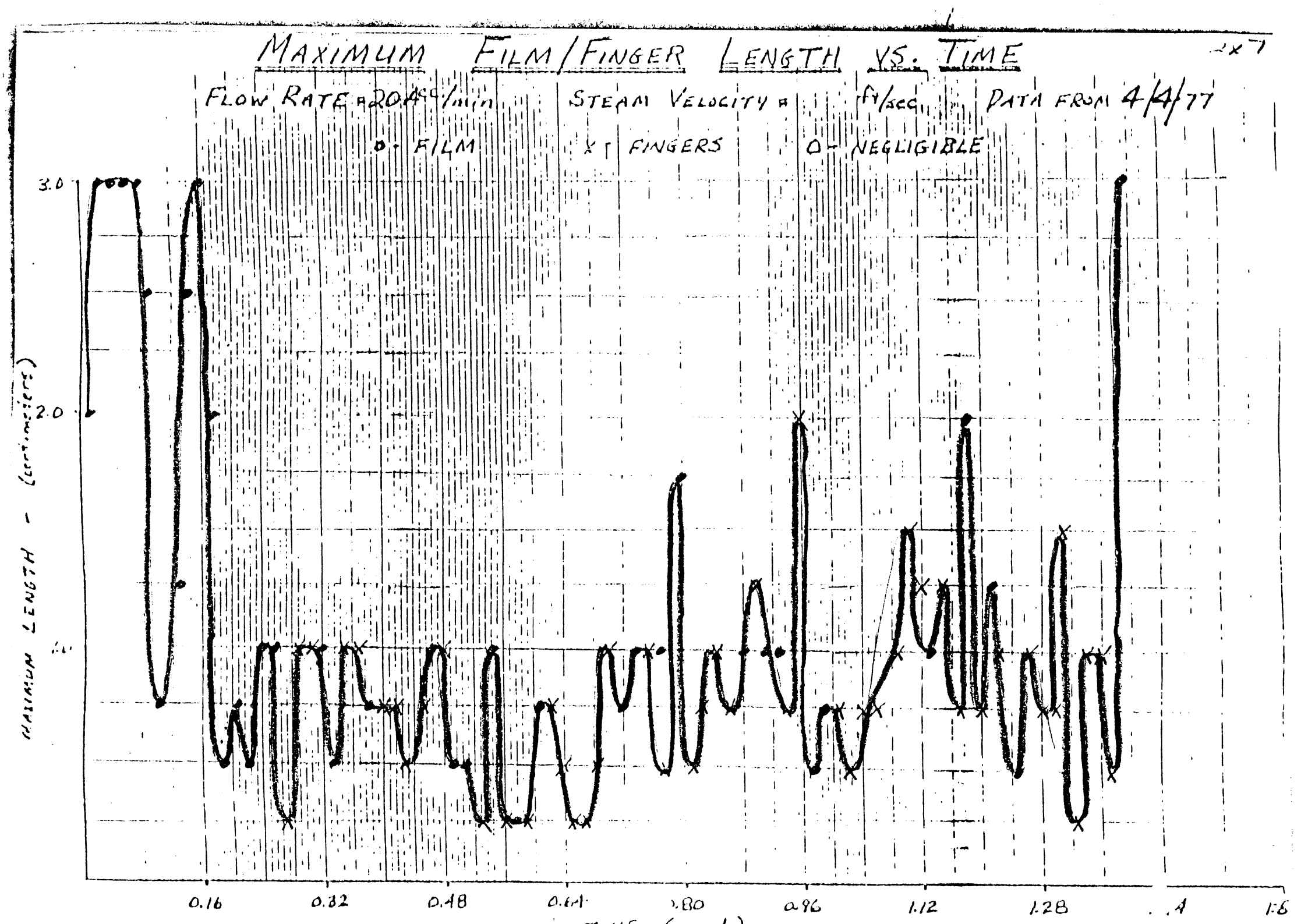


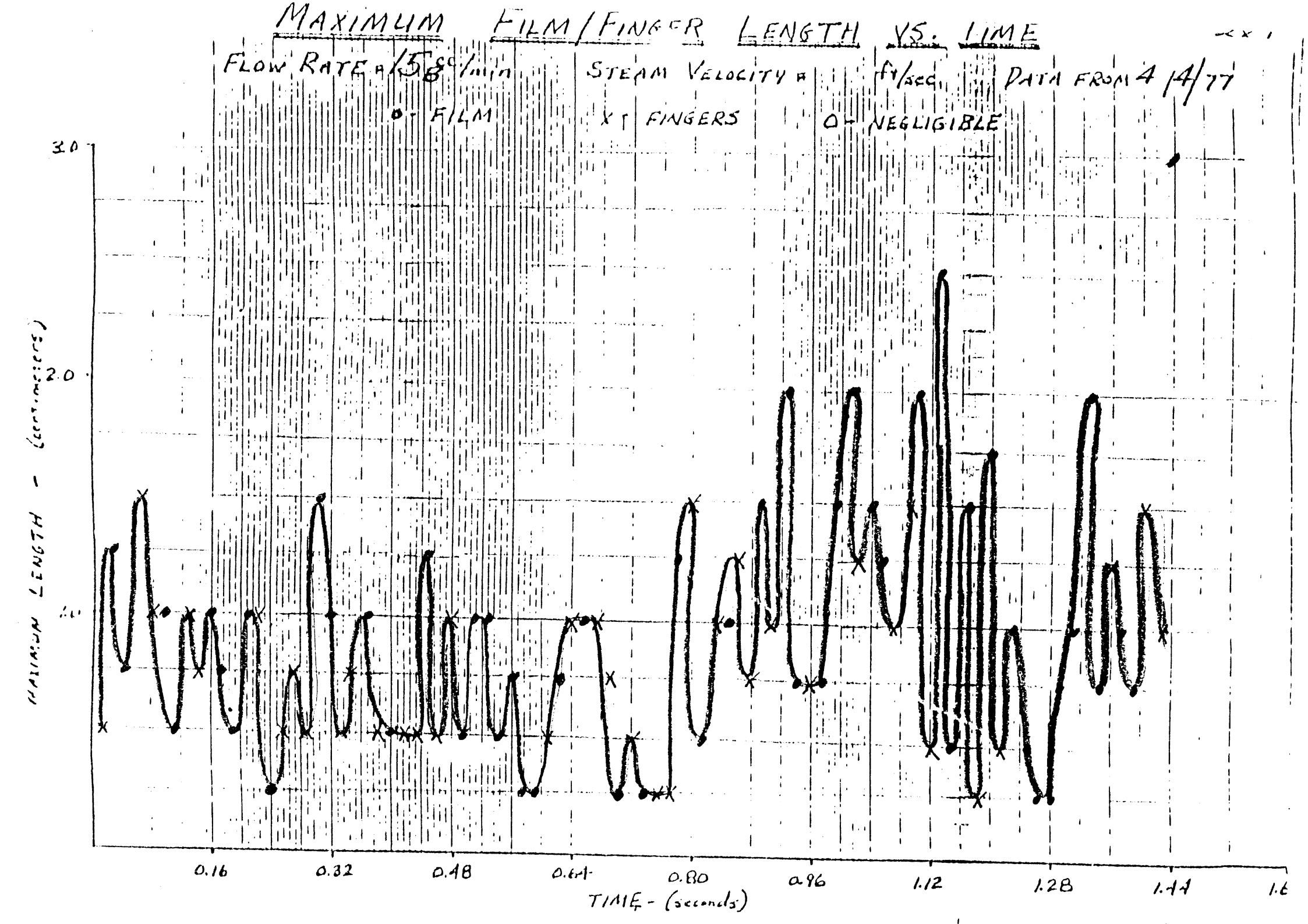
LENGTH VS. TIME
FLOW RATE = 10B cc/min
STEAM VELOCITY = ft/sec
DATA FROM 4/4/77
O - FILM
X - FINGERS
O - NEGLIGIBLE
3.0
2.0
1.0
MAXIMUM LENGTH - (centimeters)
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.6
TIME - (seconds)

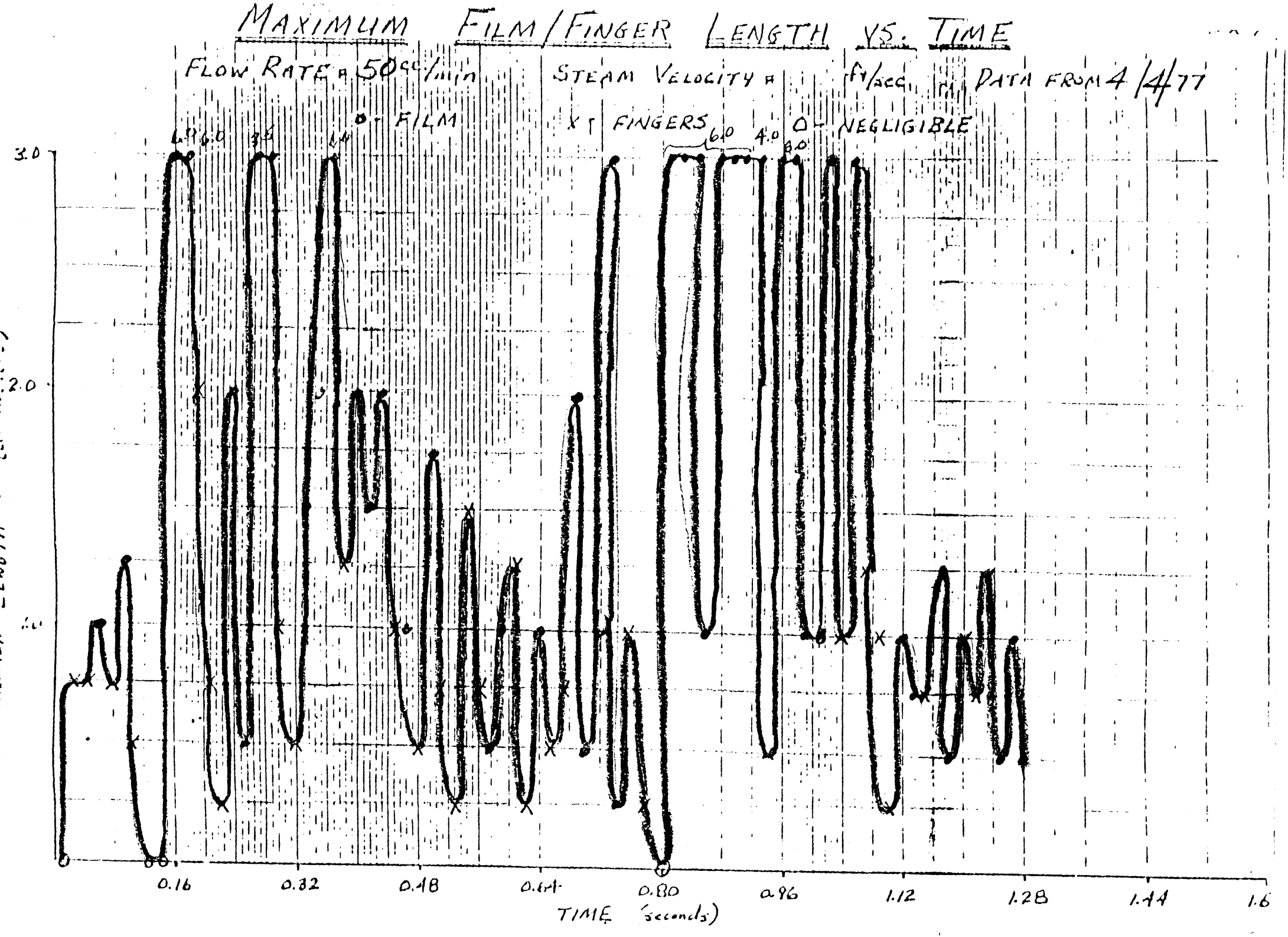
MAXIMUM FILM/FINGER LENGTH VS. TIME

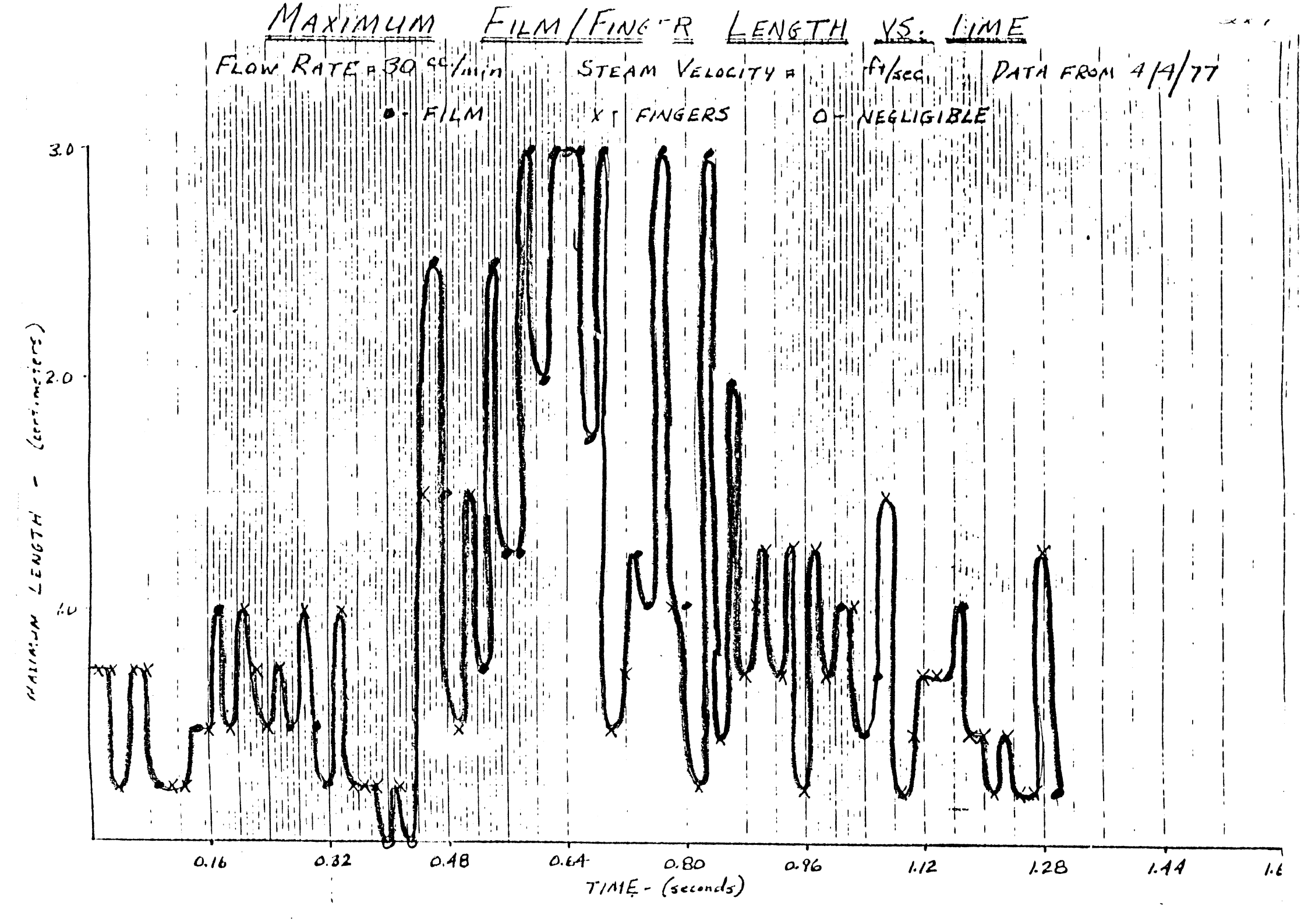
FLOW RATE = 20 Acc/min STEAM VELOCITY = [illegible] ft/sec DATA FROM 4/4/77

O - FILM X - FINGERS O - NEGLIGIBLE




MAXIMUM FILM/FINGER LENGTH VS. TIME
FLOW RATE = 15 cc/min
STEAM VELOCITY = fr/sec
DATA FROM 4/4/77
• FILM
X FINGERS
O NEGLIGIBLE
MAXIMUM LENGTH - (centimeters)
3.0
2.0
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.6
TIME - (seconds)

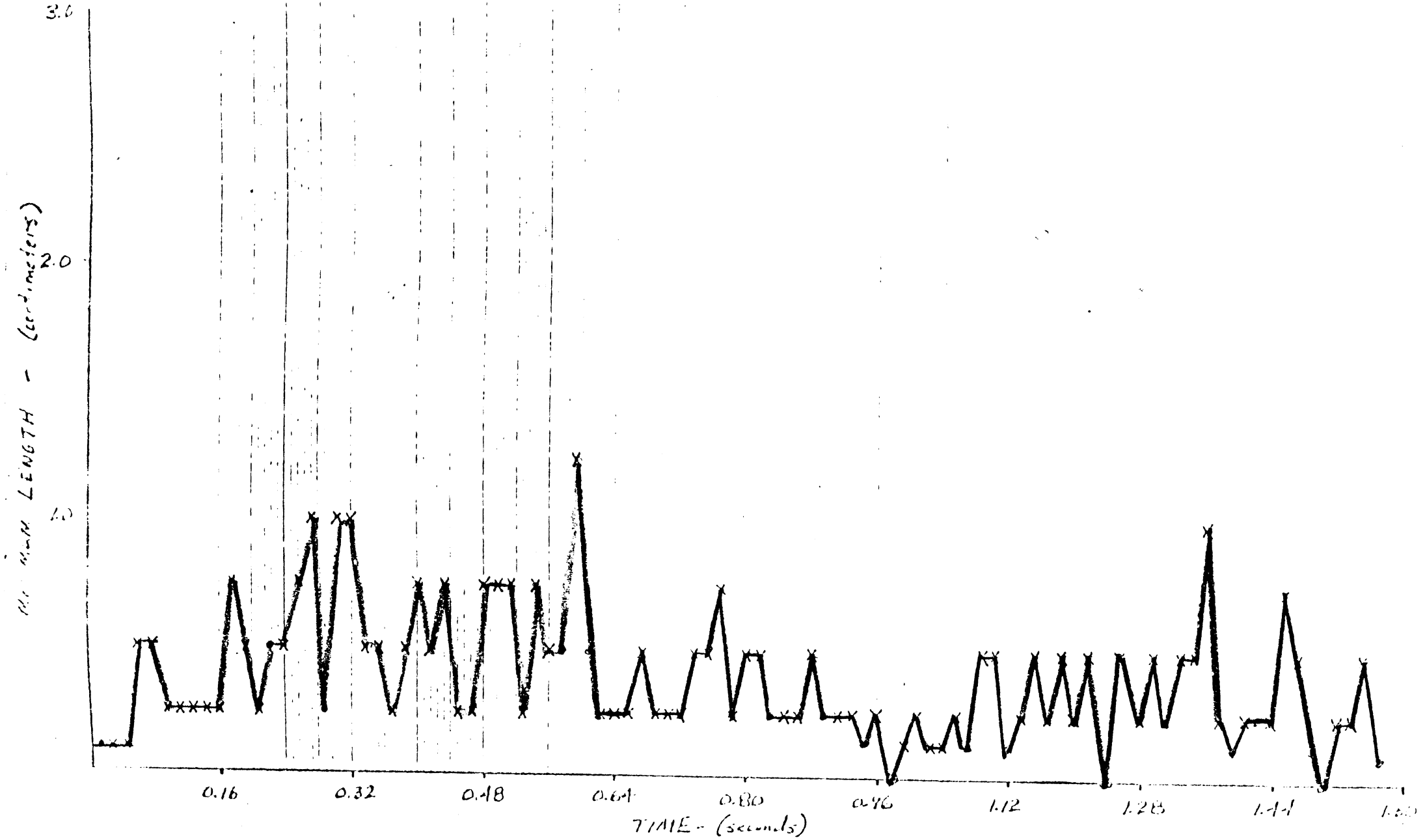

MAXIMUM FILM/FINGER LENGTH VS. TIME
FLOW RATE = 50 cc/min
STEAM VELOCITY = ft/sec
DATA FROM 4/4/77
o - FILM
x - FINGERS
0 - NEGLIGIBLE
3.0
2.0
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.6
TIME (seconds)


MAXIMUM FILM/FINGER LENGTH VS. TIME
FLOW RATE = 30 cc/min
STEAM VELOCITY = ft/sec
DATA FROM 4/4/77
• - FILM
X - FINGERS
O - NEGLIGIBLE
MAXIMUM LENGTH - (centimeters)
3.0
2.0
1.0
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
TIME - (seconds)

MAXIMUM FILM/FINGER LENGTH VS. TIME

FLOW RATE = 10 cc/min (A) STEAM VELOCITY = 975 ft/sec. RUN FROM 3/9/77

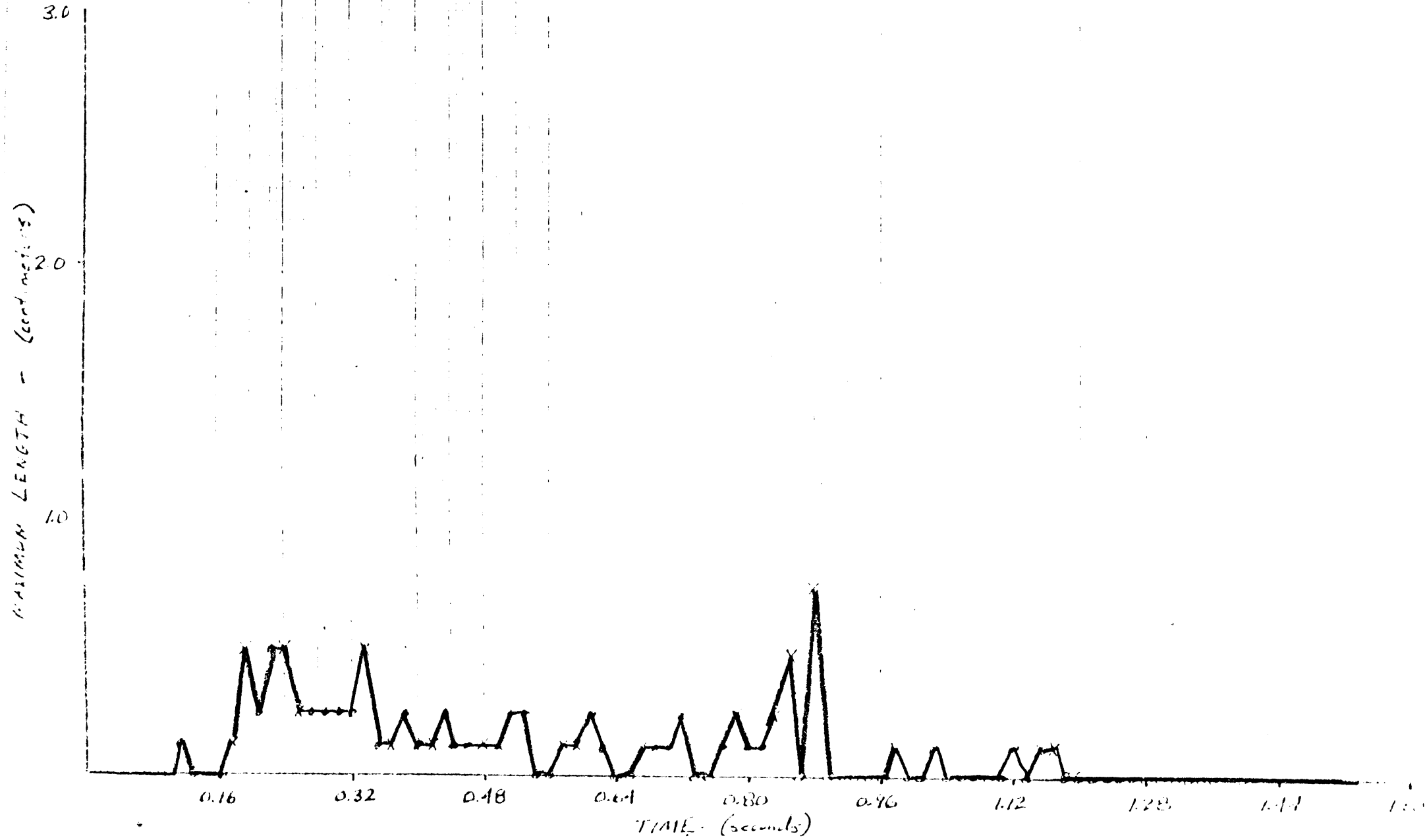
O - FILM X - FINGERS O - NEGLIGIBLE



MAXIMUM FILM/FINGER LENGTH VS. TIME

FLOW RATE = 5 cc/min (?) STEAM VELOCITY = ? ft/sec. DATA FROM 1/11

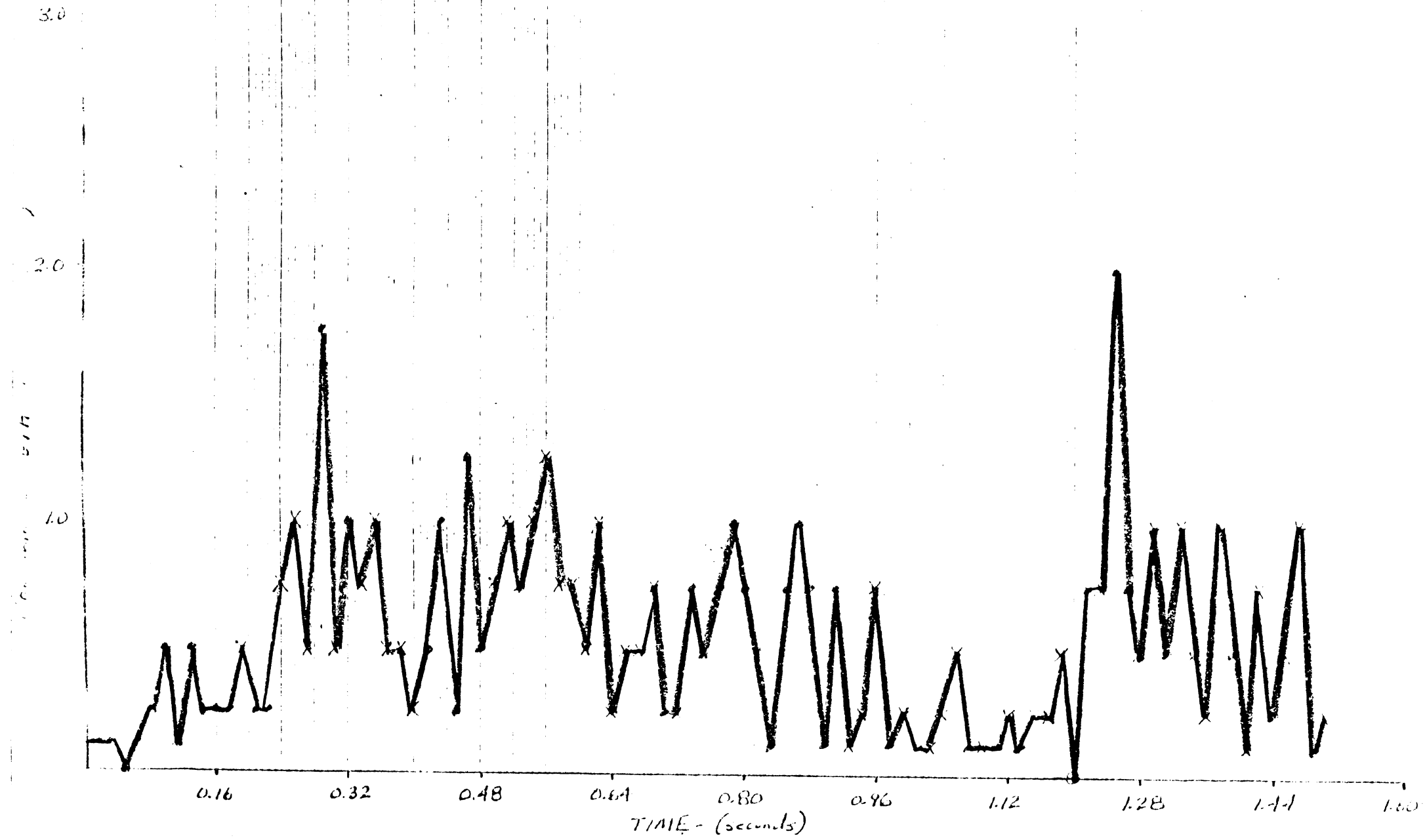
● - FILM X - FINGERS O - NEGLIGIBLE

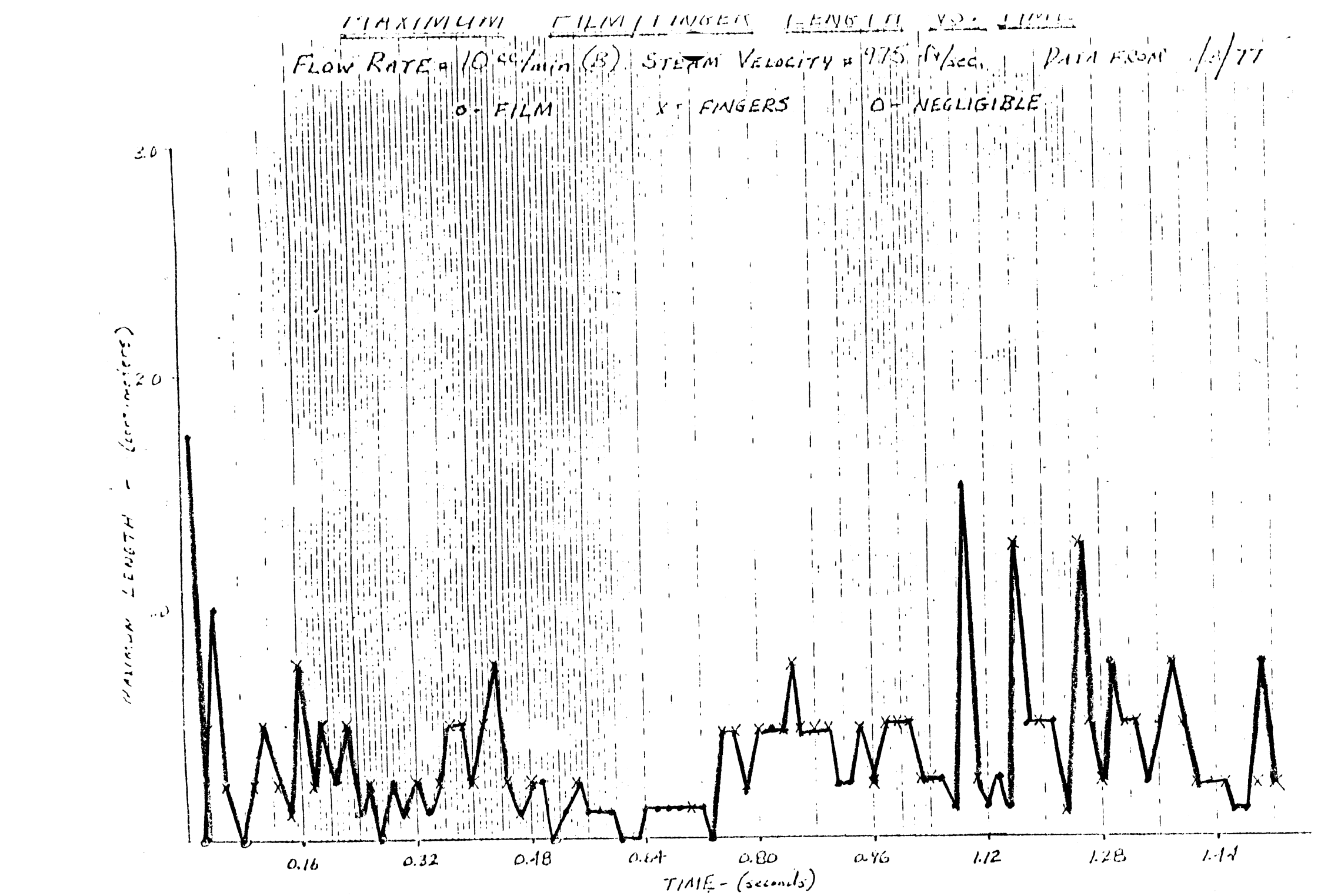


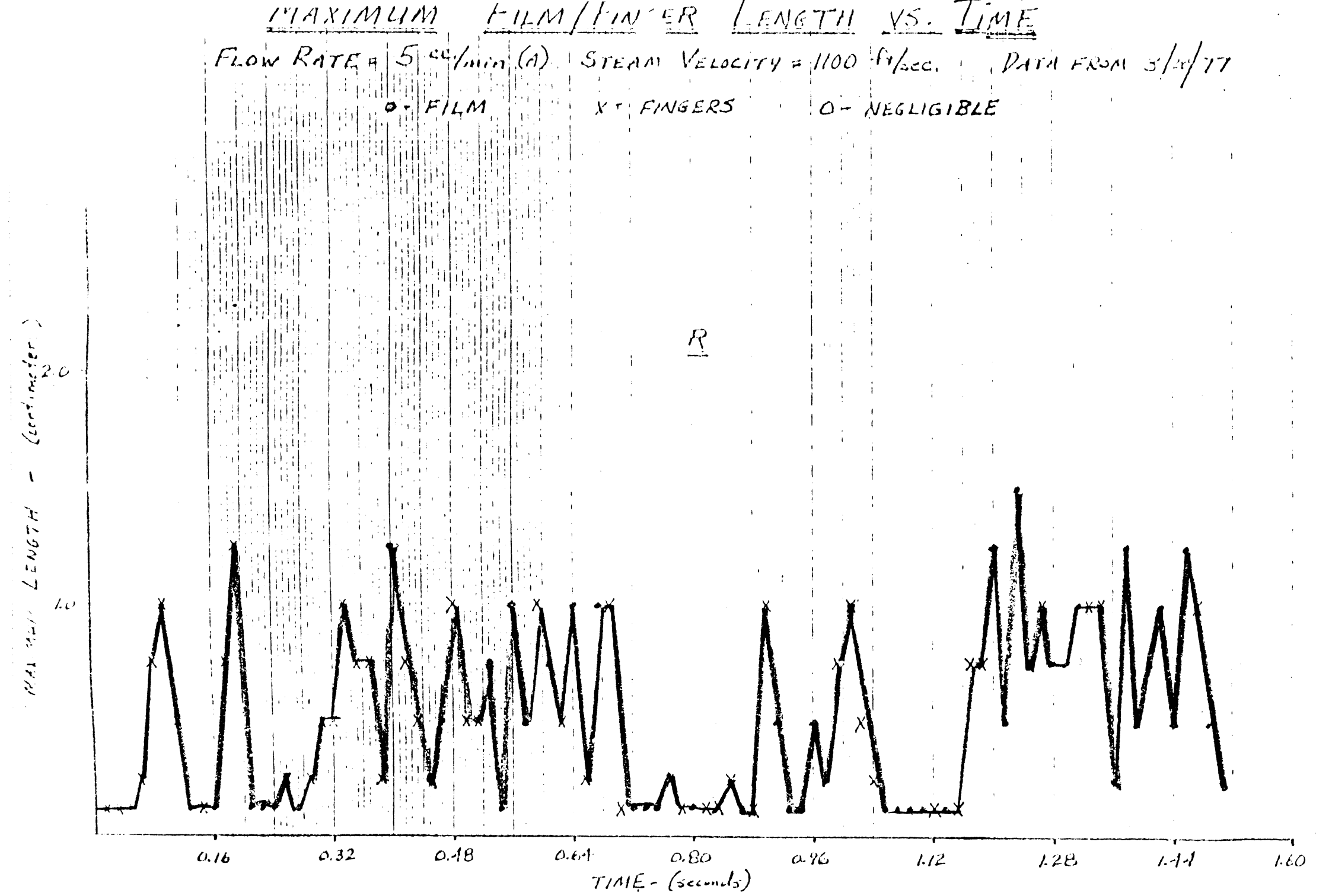
MAXIMUM FILM/FINGER LENGTH VS. TIME

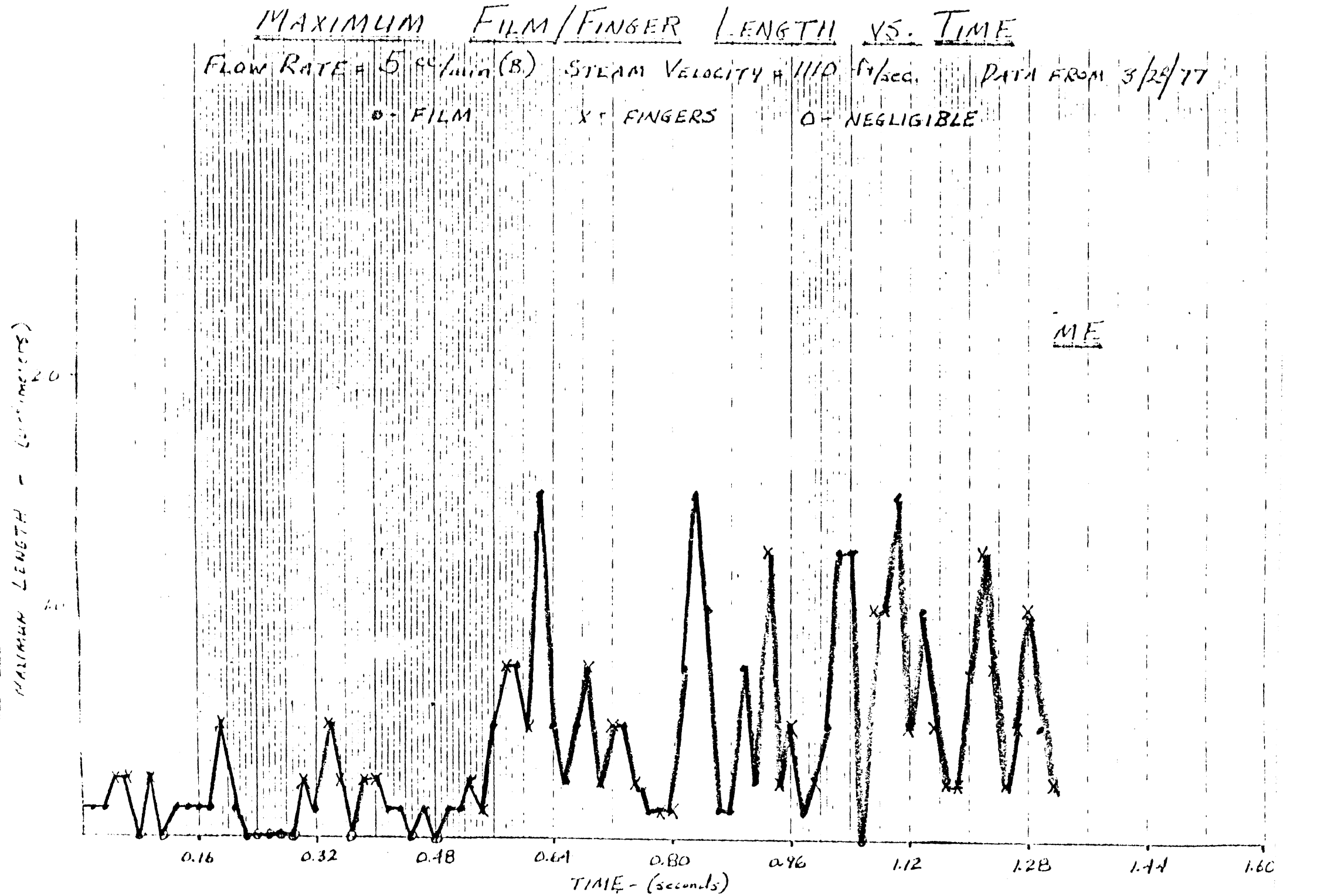
FLOW RATE = 15 cc/min (A) STEAM VELOCITY = 775 ft/sec. DATA FROM 1/11

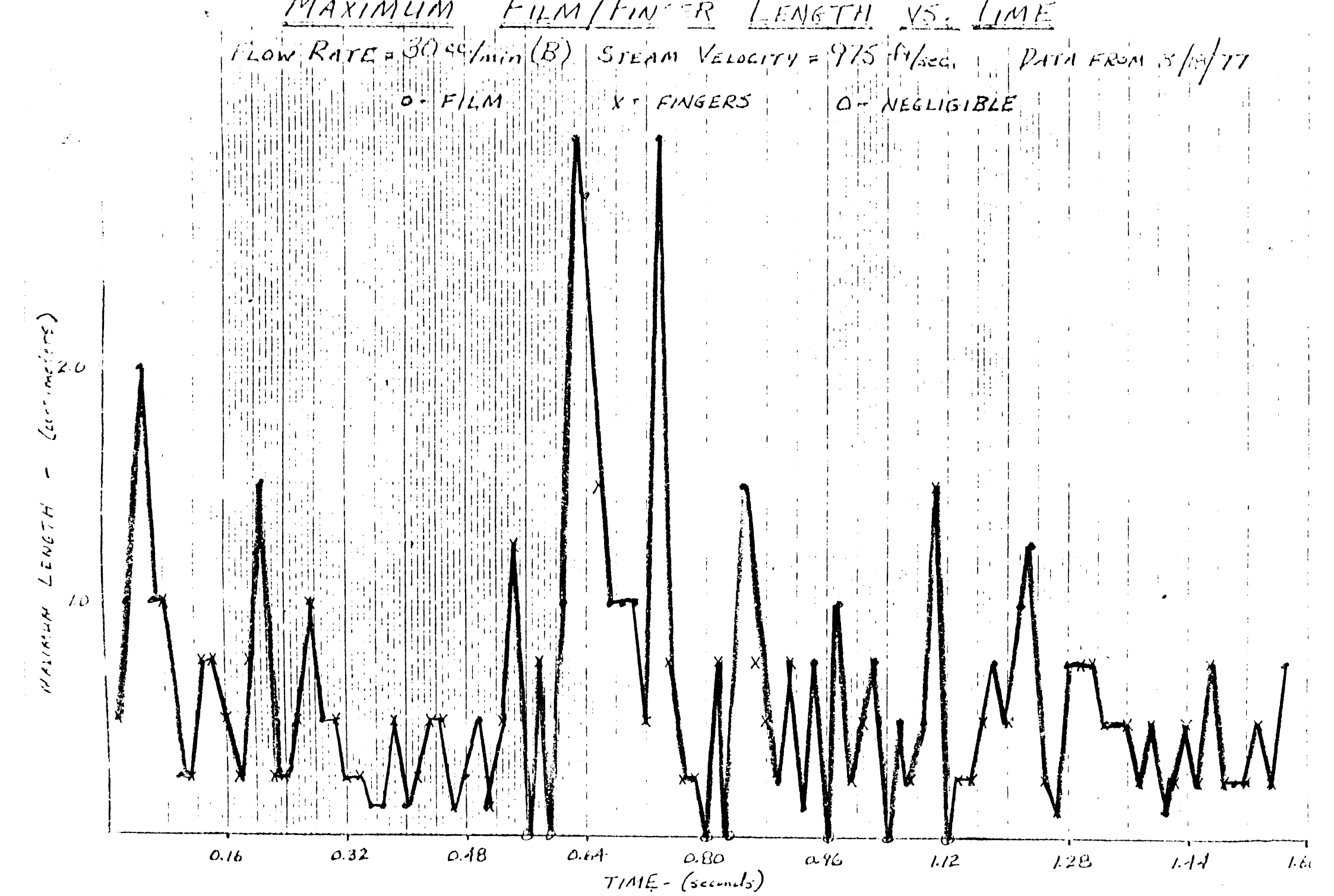
O - FILM X - FINGERS Δ - NEGLIGIBLE

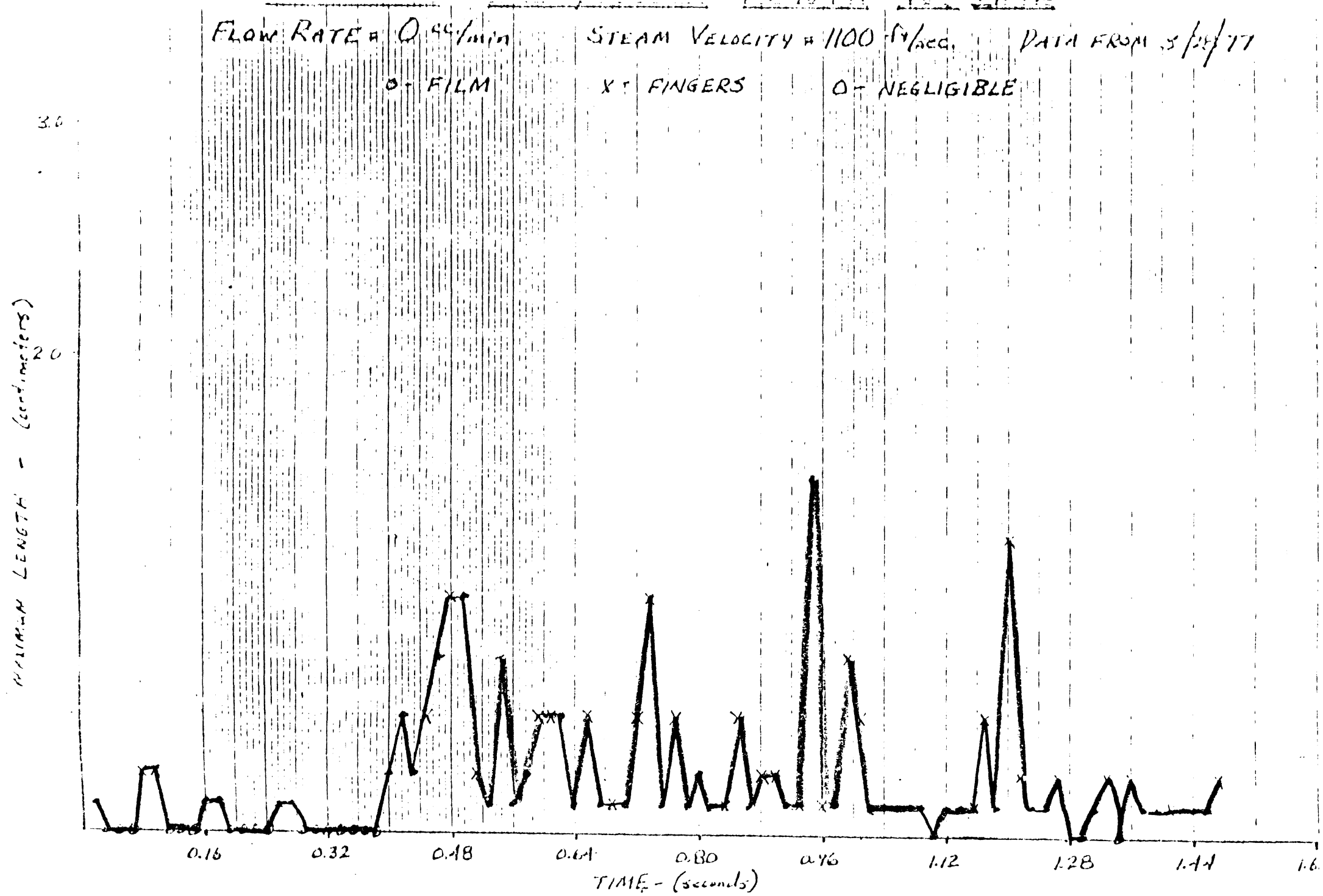



MAXIMUM FILM / FINGER LENGTH VS. TIME
FLOW RATE = 10 cc/min (B) STEAM VELOCITY = 975 ft/sec. DATA FROM 1/8/77
O - FILM X - FINGERS O - NEGLIGIBLE
MAXIMUM LENGTH - (centimeters)
2.0
1.0
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
TIME - (seconds)


MAXIMUM FILM/FINGER LENGTH VS. TIME
FLOW RATE = 5 cc/min (A) STEAM VELOCITY = 1100 ft/sec. DATA FROM 5/27/77
O - FILM X - FINGERS O - NEGLIGIBLE
R
2.0
1.0
MAXIMUM LENGTH - (centimeter)
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.60
TIME - (seconds)


MAXIMUM FILM/FINGER LENGTH VS. TIME
FLOW RATE = 5 cc/min (B)
STEAM VELOCITY = 1110 ft/sec.
DATA FROM 3/29/77
o - FILM
x - FINGERS
O - NEGLIGIBLE
ME
MAXIMUM LENGTH - (centimeters)
20
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.60
TIME - (seconds)

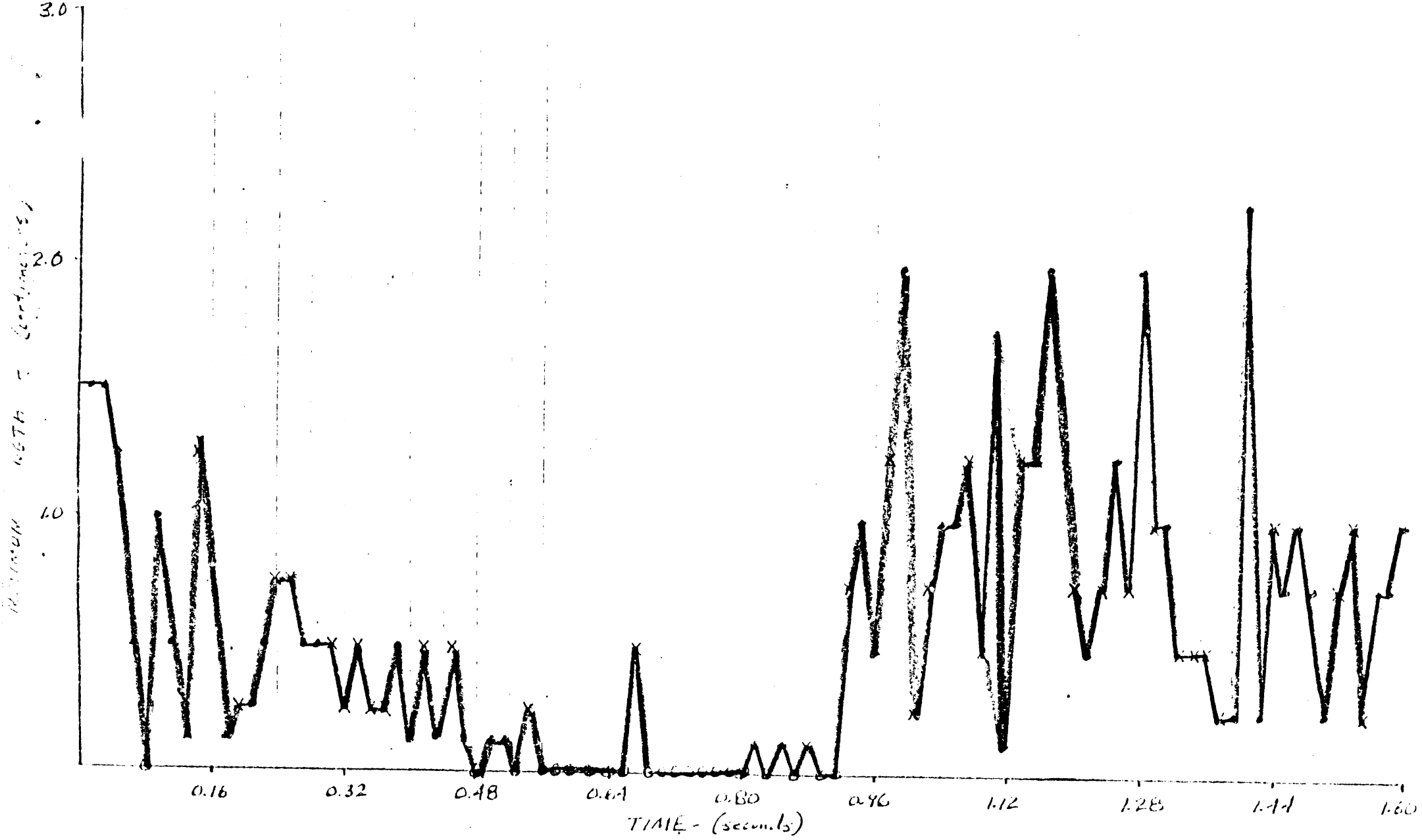

MAXIMUM FILM/FINGER LENGTH VS. TIME
FLOW RATE = 80 cc/min (B) STEAM VELOCITY = 975 ft/sec. DATA FROM 5/18/77
O - FILM X - FINGERS O - NEGLIGIBLE
MAXIMUM LENGTH - (centimeters)
2.0
1.0
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
TIME - (seconds)


FLOW RATE = Q gal/min
STEAM VELOCITY = 1100 ft/sec.
DATA FROM 5/24/77
O - FILM
X - FINGERS
O - NEGLIGIBLE
3.0
2.0
MAXIMUM LENGTH - (centimeters)
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.6
TIME - (seconds)

MAXIMUM FILM/FINGER LENGTH VS. TIME

FLOW RATE = 20 cc/min (B) STEAM VELOCITY = 775 ft/sec. DATA FROM 5/2/71

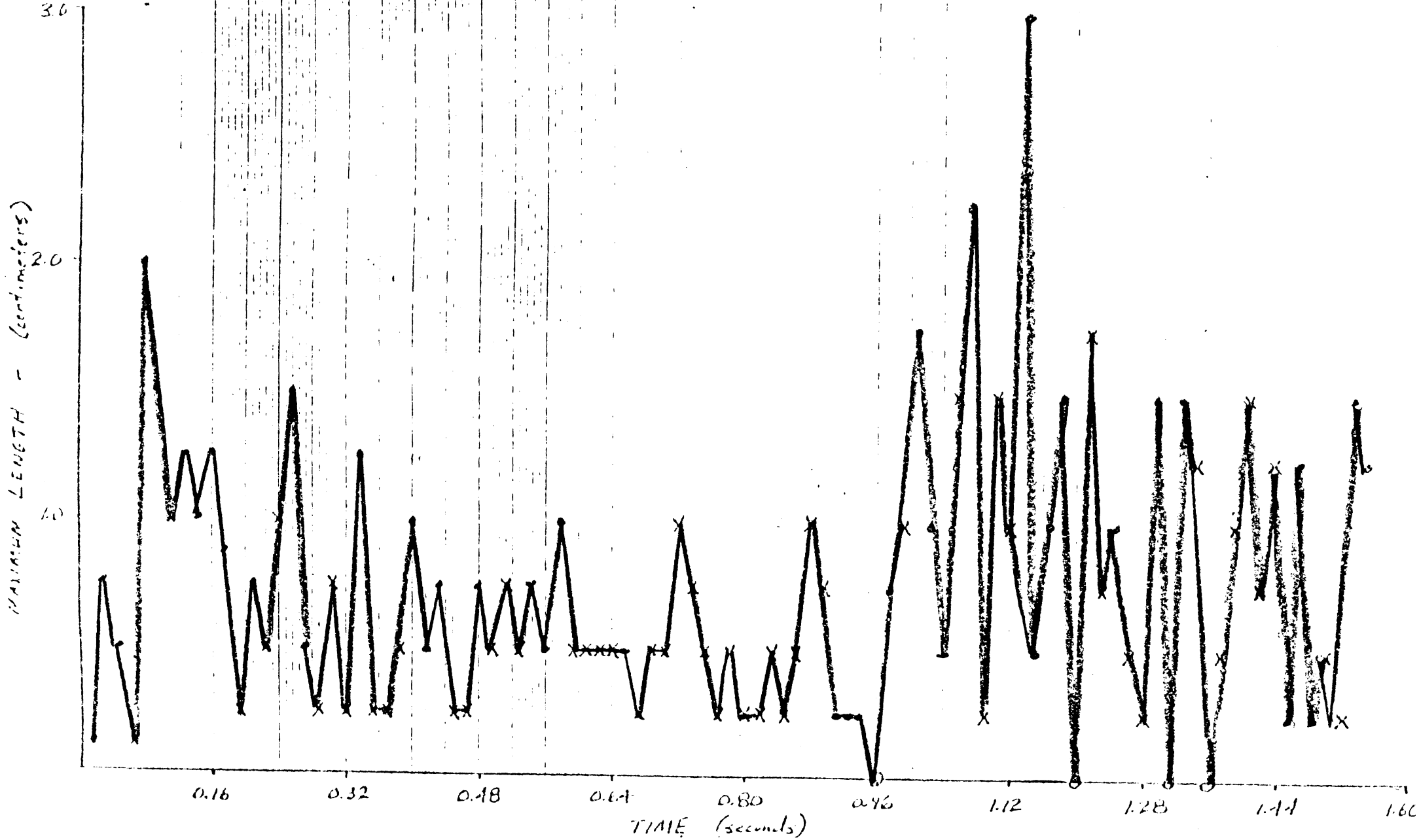
● - FILM X - FINGERS O - NEGLIGIBLE



MAXIMUM FILM/FINGER LENGTH VS. TIME

FLOW RATE = 30 cc/min (A) STEAM VELOCITY = 915 ft/sec. DATA FROM 3/18/77

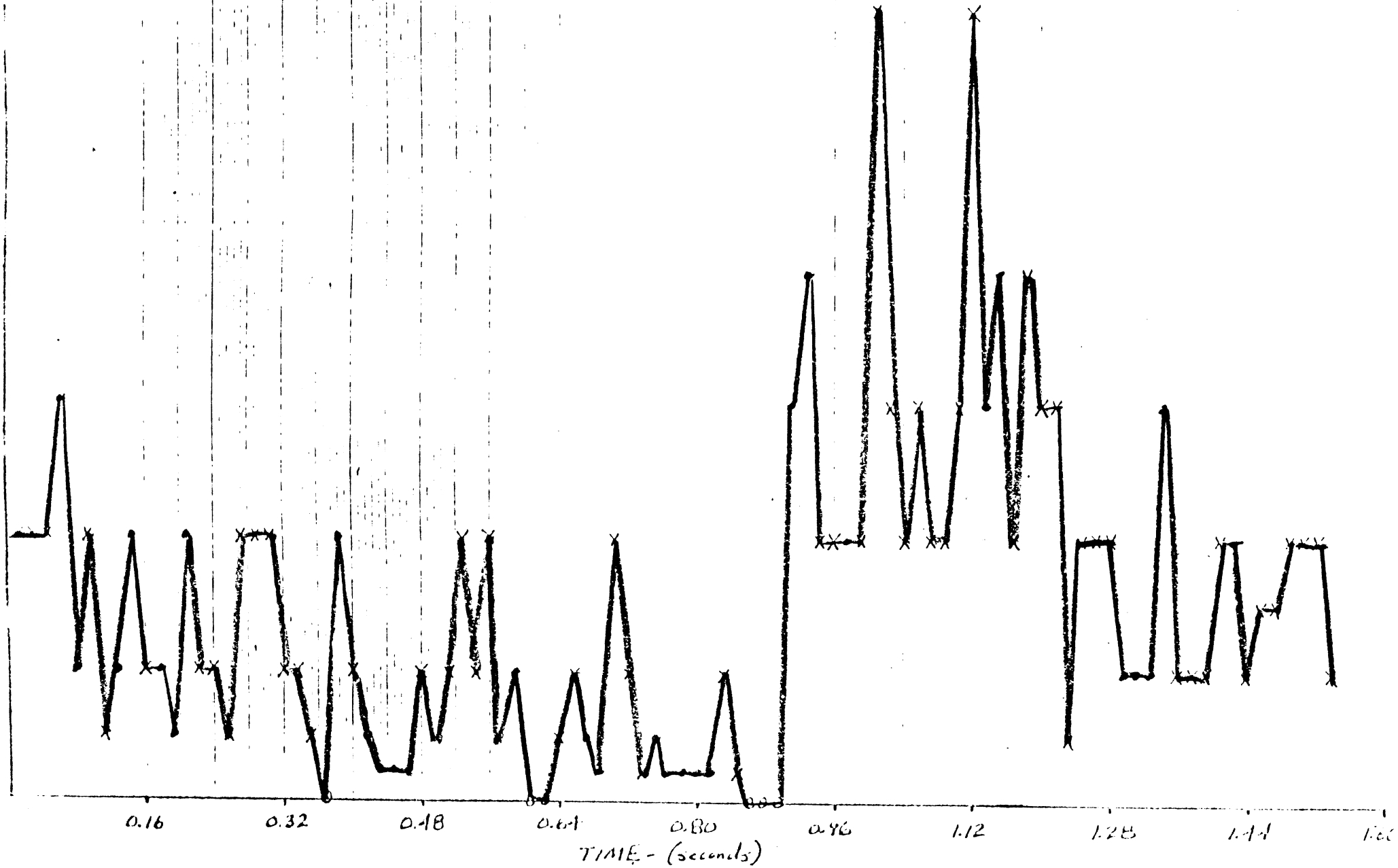
● - FILM X - FINGERS O - NEGLIGIBLE



MAXIMUM FILM/FINGER LENGTH VS. TIME

FLOW RATE = 20cc/min (A) STEAM VELOCITY = 915 ft/sec. DATA FROM 5/8/71

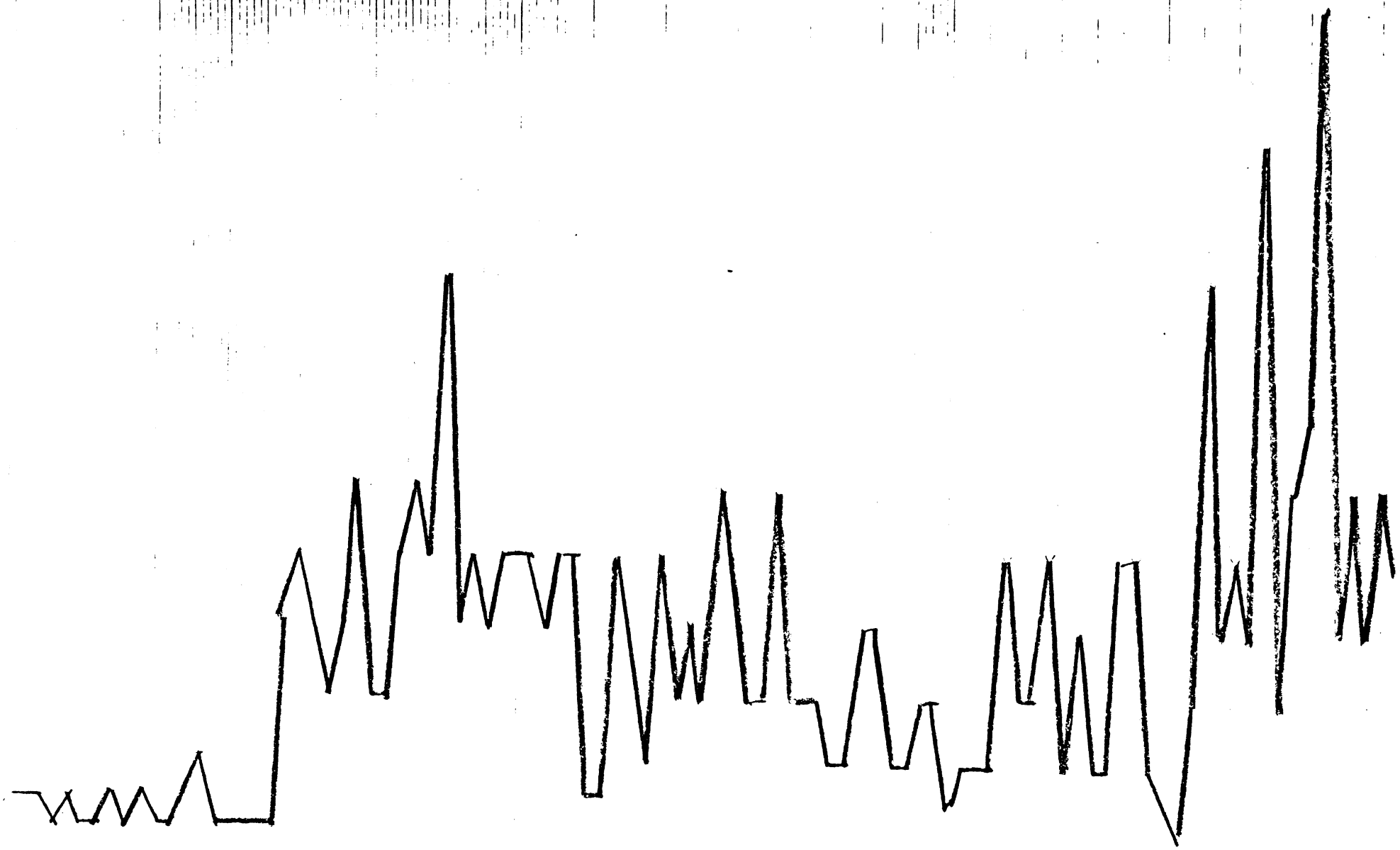
O - FILM X - FINGERS O - NEGLIGIBLE

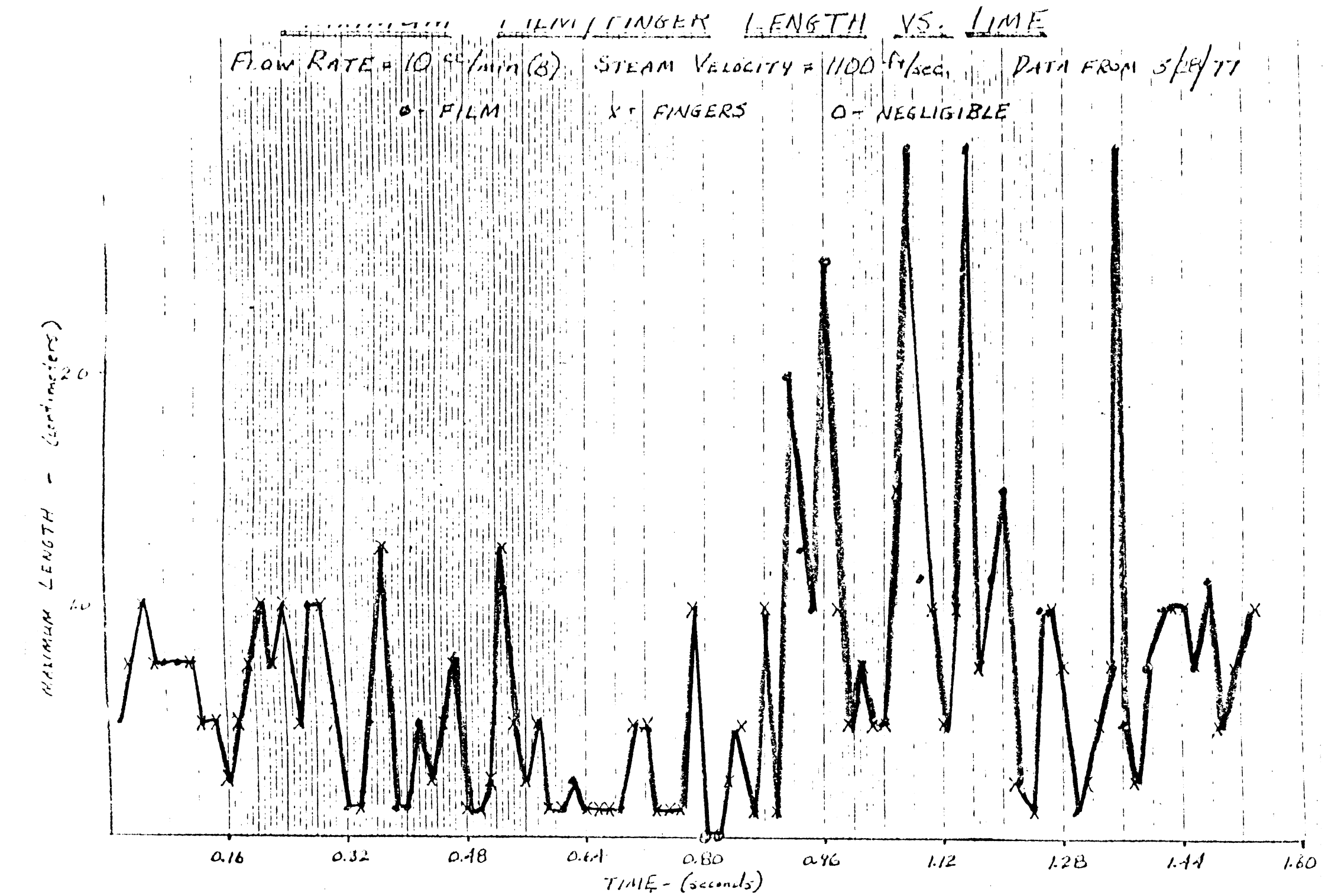


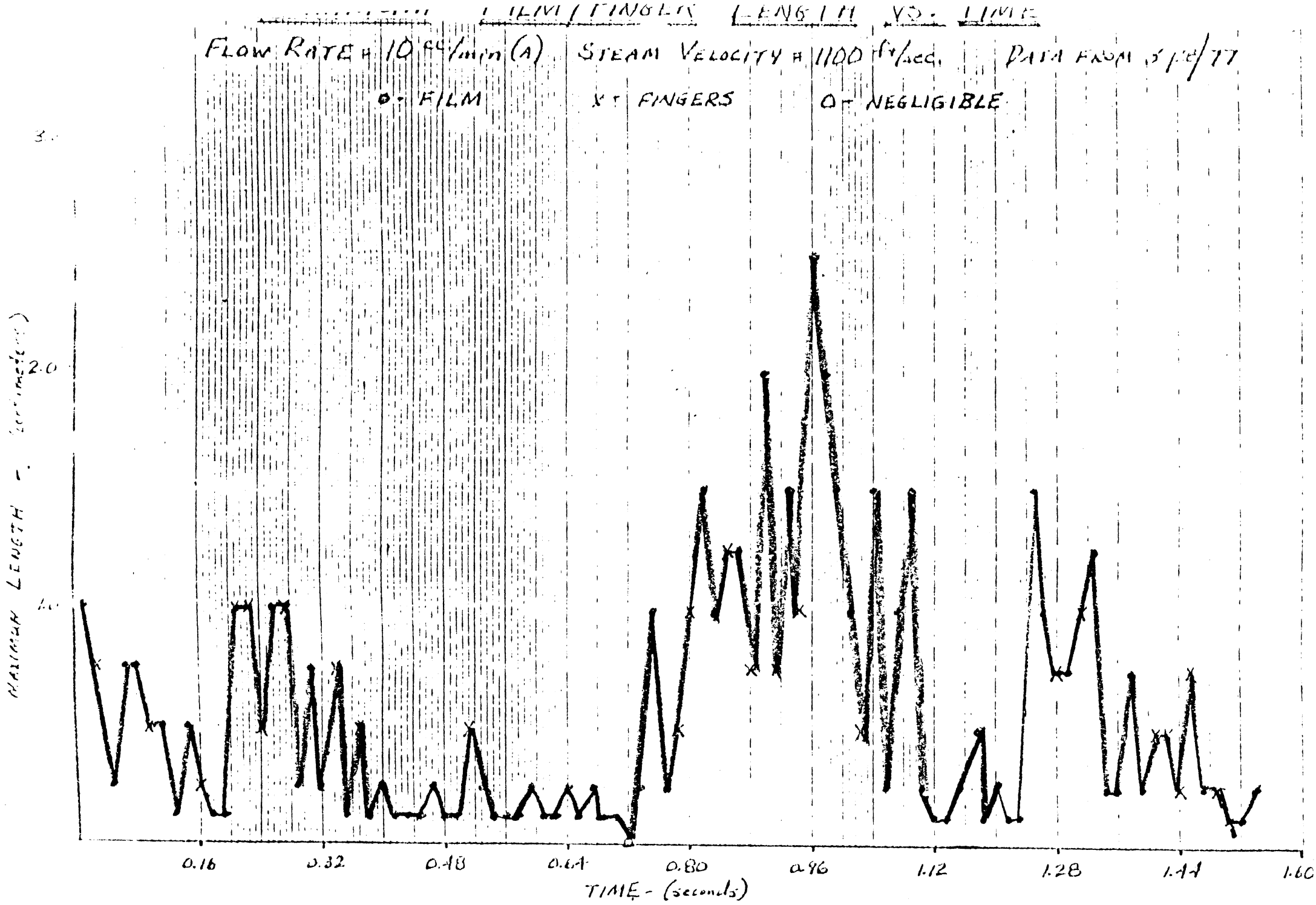
MAXIMUM FILM/FINGER LENGTH VS. TIME

FLOW RATE = 15 gc/min (R) | STEAM VELOCITY = 975 ft/sec | DATA FROM 5/18/77

● = FILM | X = FINGERS | O = NEGLIGIBLE



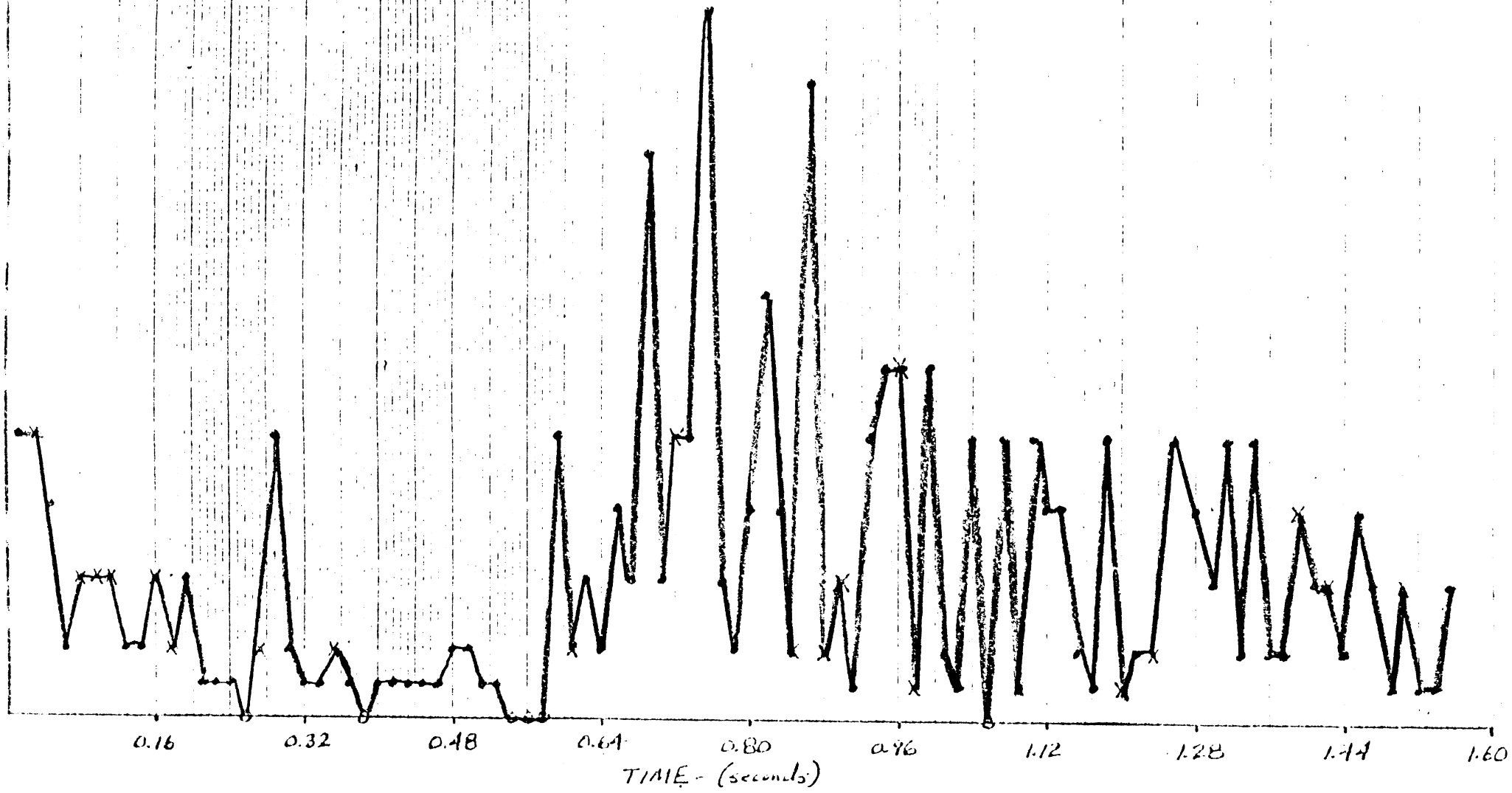

FILM / FINGER LENGTH VS. TIME
FLOW RATE = 10 cc/min (8)
STEAM VELOCITY = 1100 ft/sec
DATA FROM 5/22/77
o - FILM
x - FINGERS
0 - NEGLIGIBLE
MAXIMUM LENGTH - (centimeters)
2.0
1.0
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.60
TIME - (seconds)

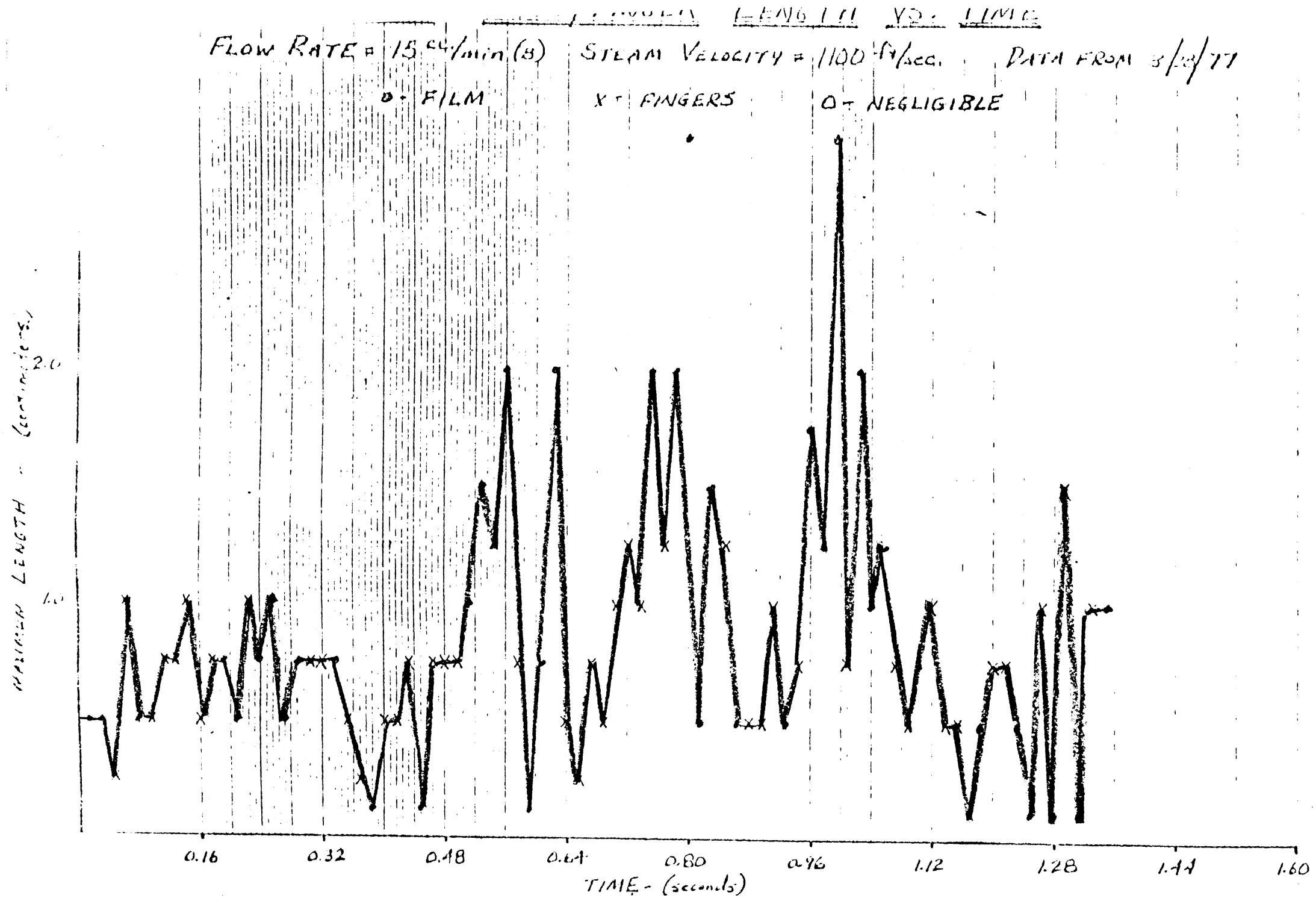

FILM / FINGER LENGTH VS. TIME
FLOW RATE = 10 ft/min (A)
STEAM VELOCITY = 1100 ft/sec.
DATA FROM 5/18/77
O - FILM
X - FINGERS
O - NEGLIGIBLE
MAXIMUM LENGTH - (centimeters)
2.0
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.60
TIME - (seconds)

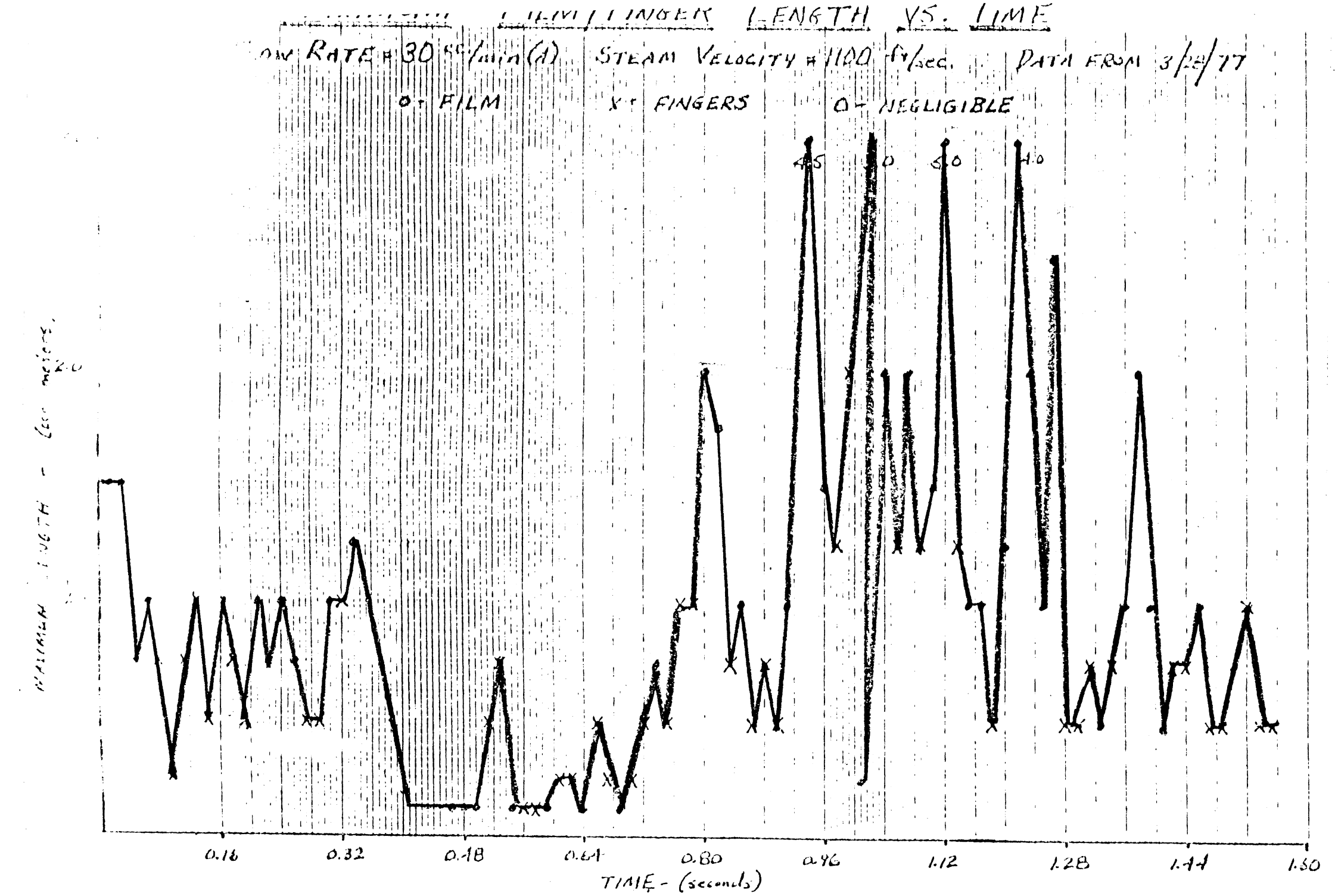
MAXIMUM FILM/FINGER LENGTH VS. TIME

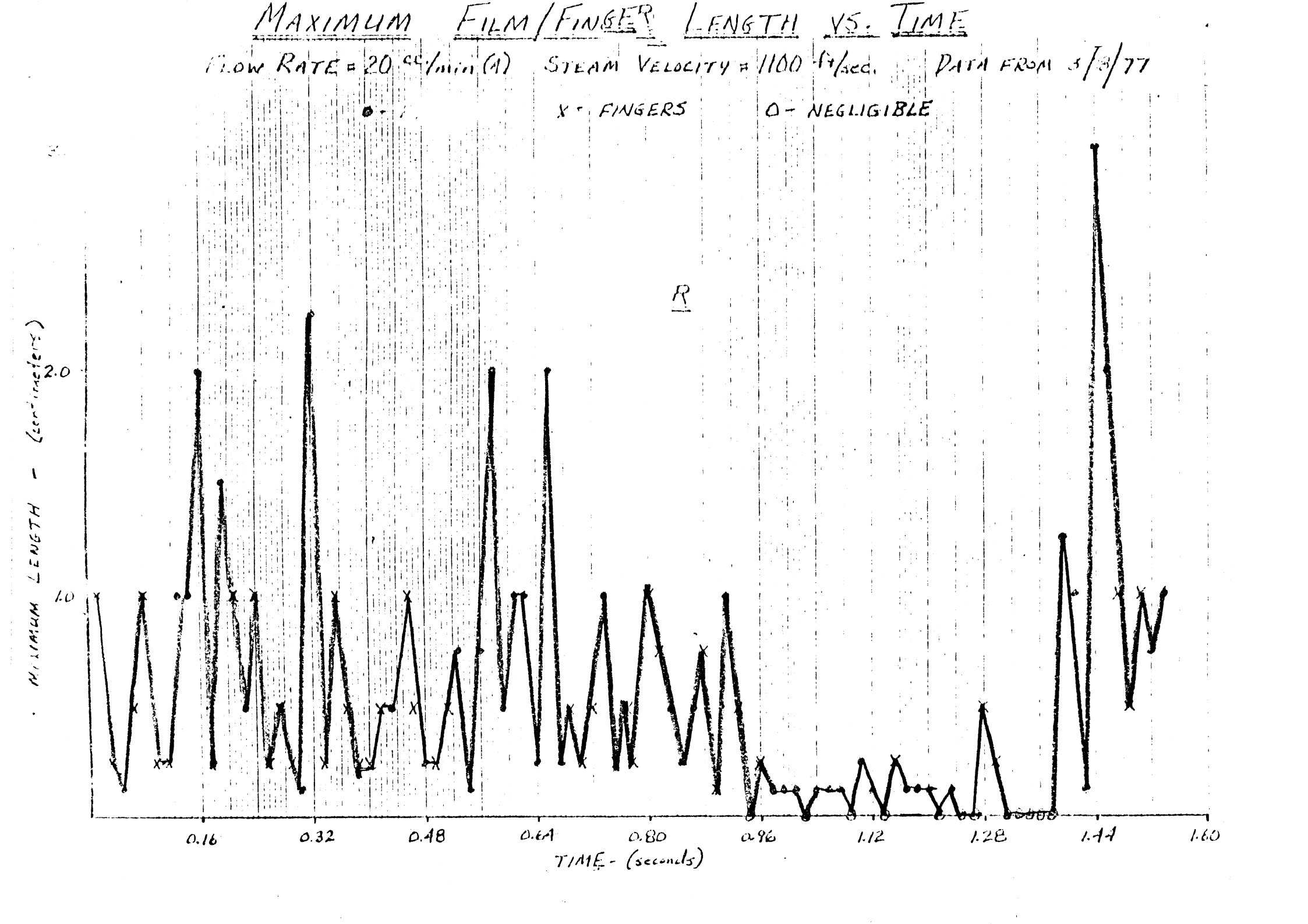
FLOW RATE = 15 cc/min (A) STEAM VELOCITY = 1100 ft/sec. DATA FROM 3/6/77

● - FILM X - FINGERS O - NEGLIGIBLE




FLOW RATE = 15 cc/min (B)
STEAM VELOCITY = 1100 ft/sec.
DATA FROM 8/24/77
O - FILM
X - FINGERS
O - NEGLIGIBLE
2.0
1.0
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.60
TIME - (seconds)


FILM/FINGER LENGTH VS. TIME
RATE = 30 cc/min (d)
STEAM VELOCITY = 1100 ft/sec.
DATA FROM 3/28/77
O - FILM
X - FINGERS
O - NEGLIGIBLE
4.5
5.0
5.0
4.0
2.0
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.60
TIME - (seconds)

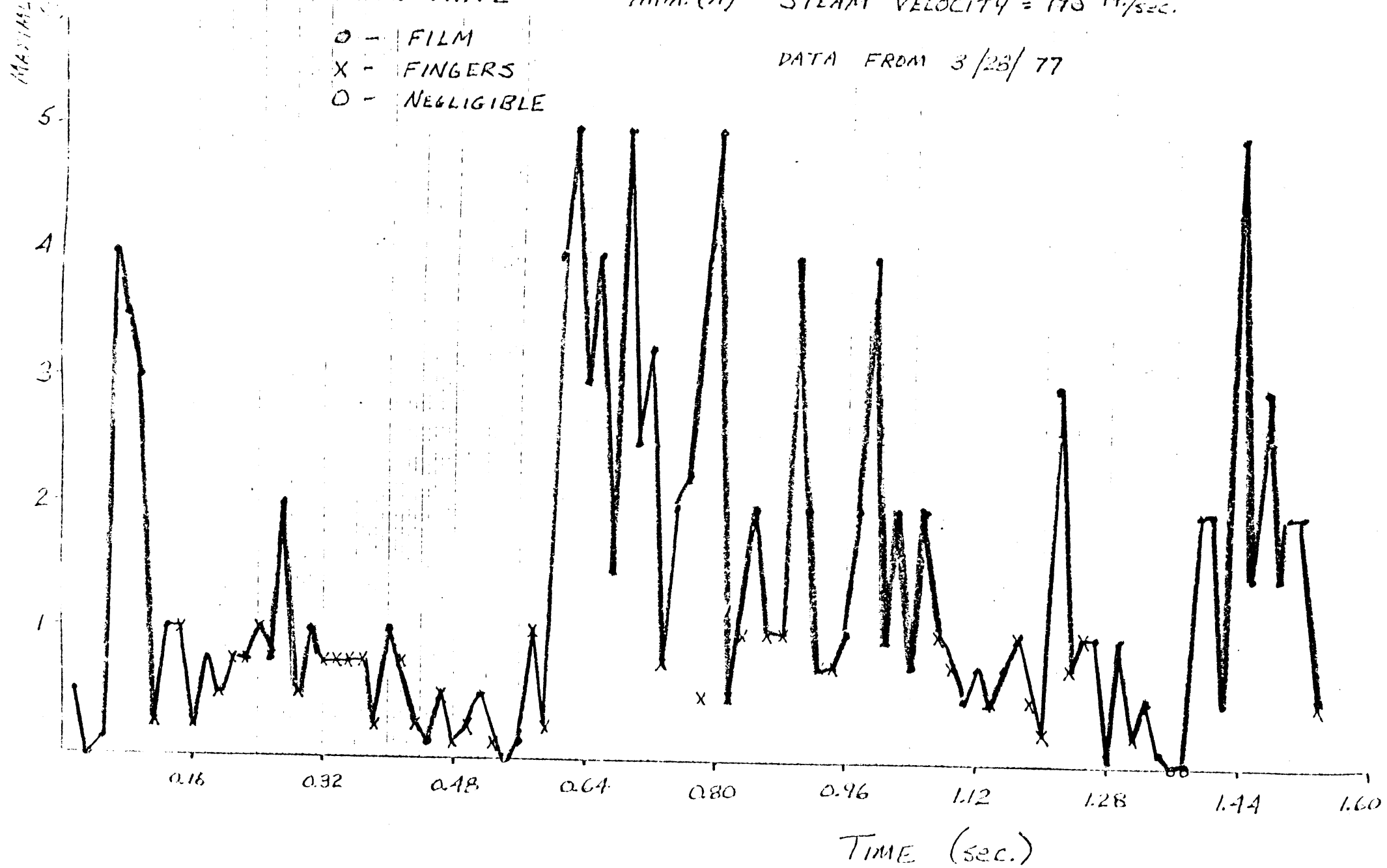

MAXIMUM FILM/FINGER LENGTH VS. TIME
FLOW RATE = 20 cc/min (A) STEAM VELOCITY = 1100 ft/sec. DATA FROM 3/8/77
X - FINGERS O - NEGLIGIBLE
R
MAXIMUM LENGTH - (centimeters)
2.0
1.0
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.60
TIME - (seconds)

MAXIMUM FILM / FINGER LENGTH VS. TIME

FLOW RATE = 50 cc./min. (A) STEAM VELOCITY = ~~975~~ 1150 ft./sec.

O - FILM
X - FINGERS
O - NEGLIGIBLE

DATA FROM 3/28/77



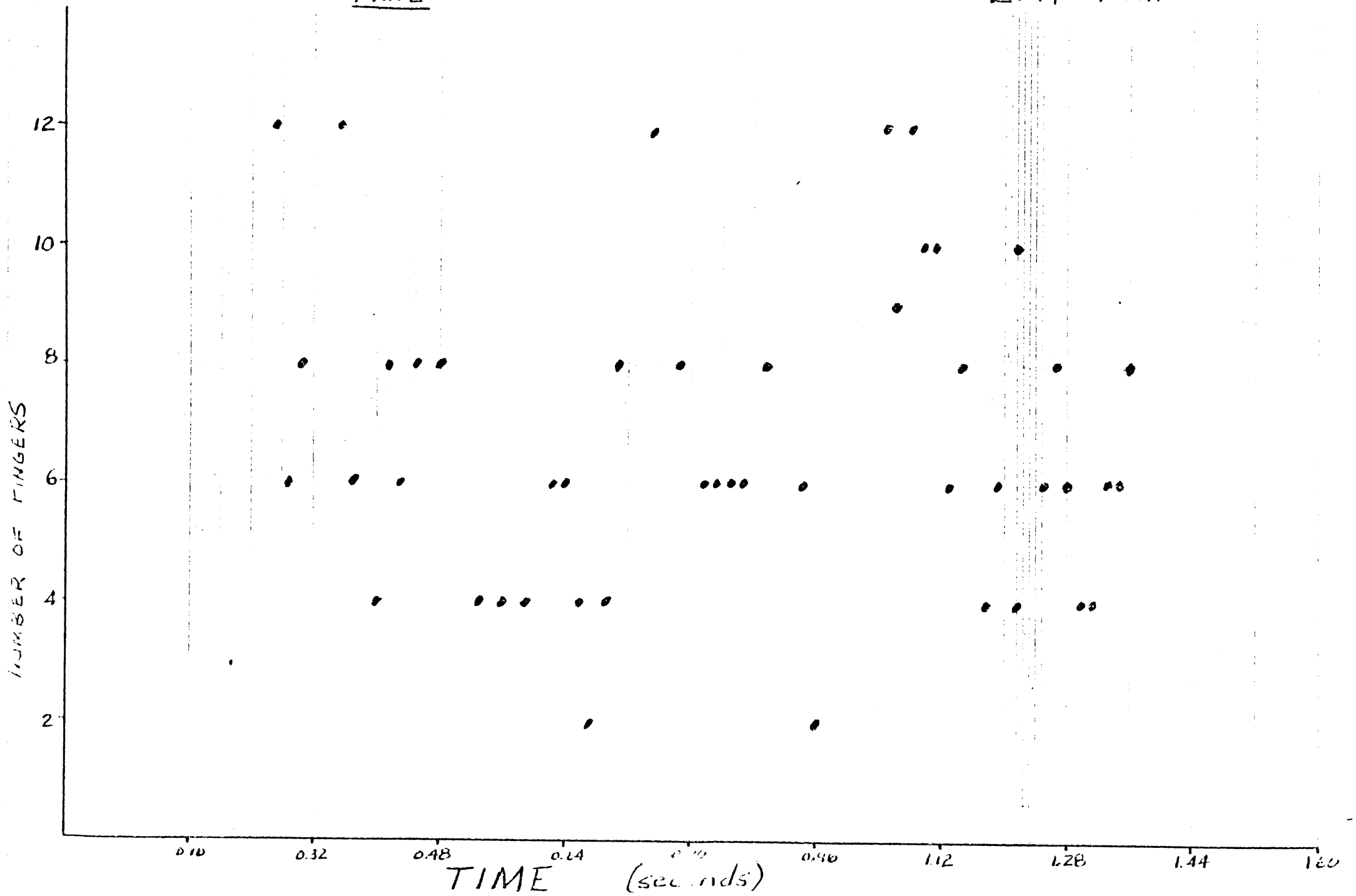
APPENDIX D

NUMBER OF FINGERS VS. TIME

NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = Ft./sec.

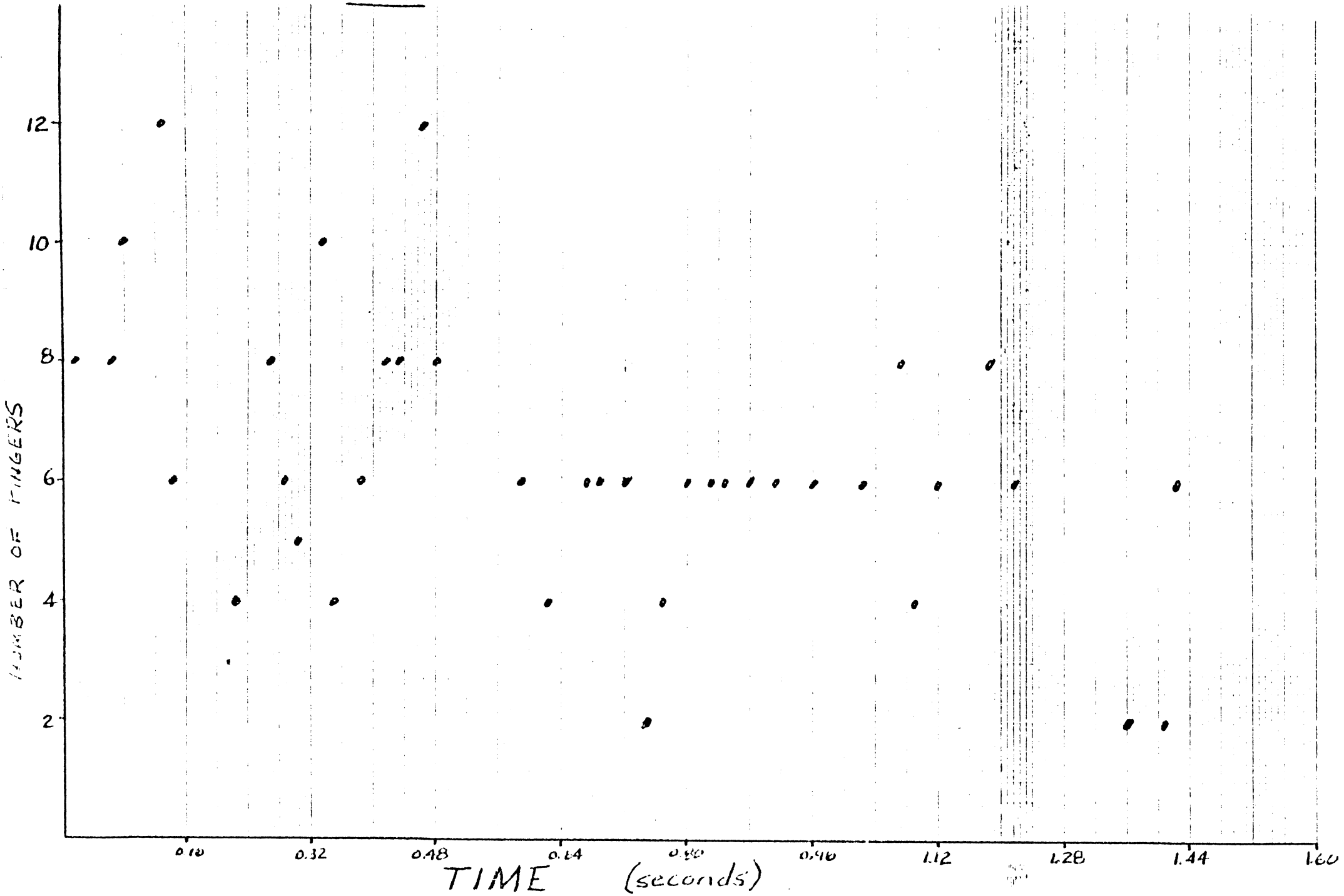
FLOW RATE = 20A cc/min.



NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = Ft./sec.

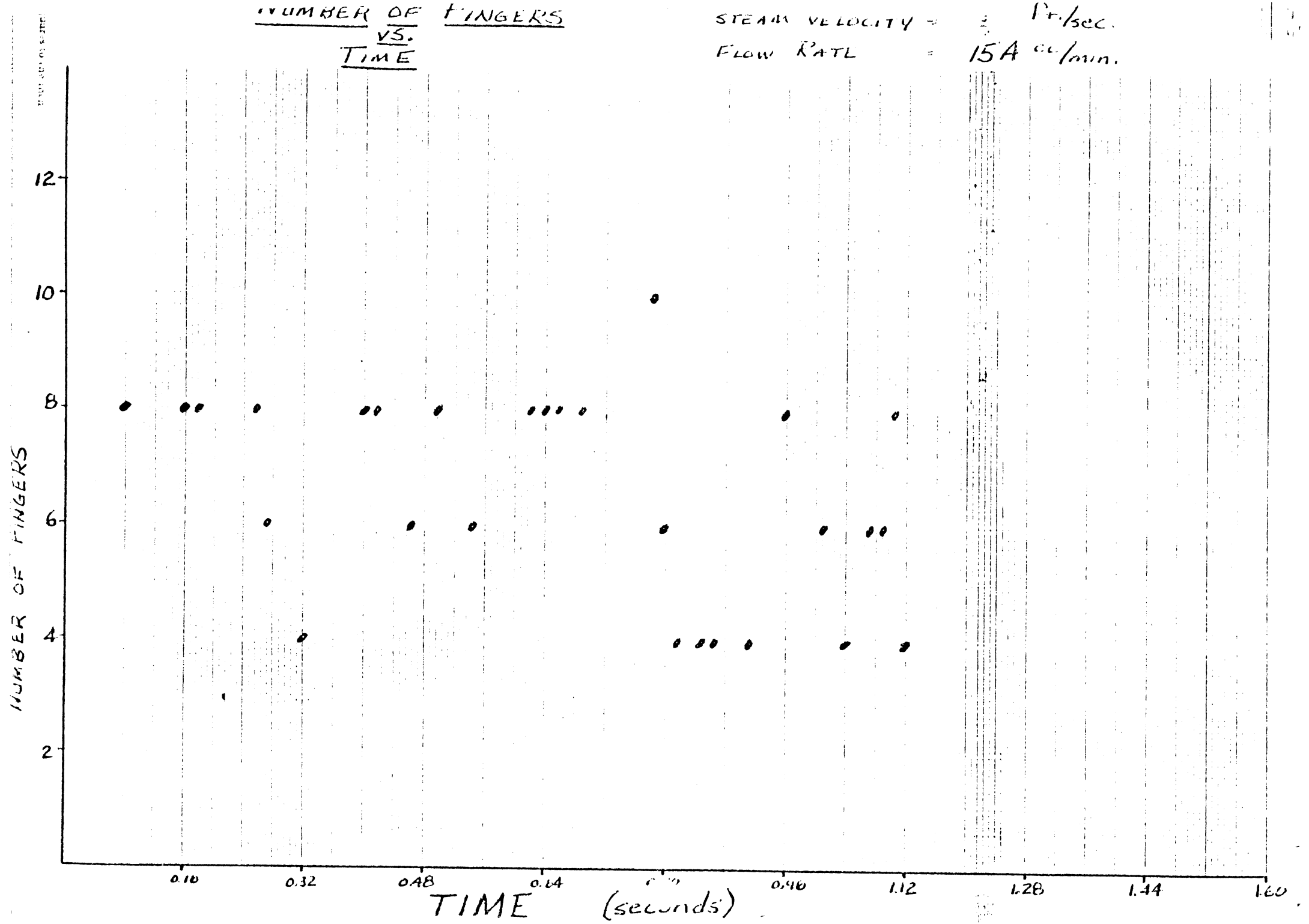
FLOW RATE = 158 cc/min.

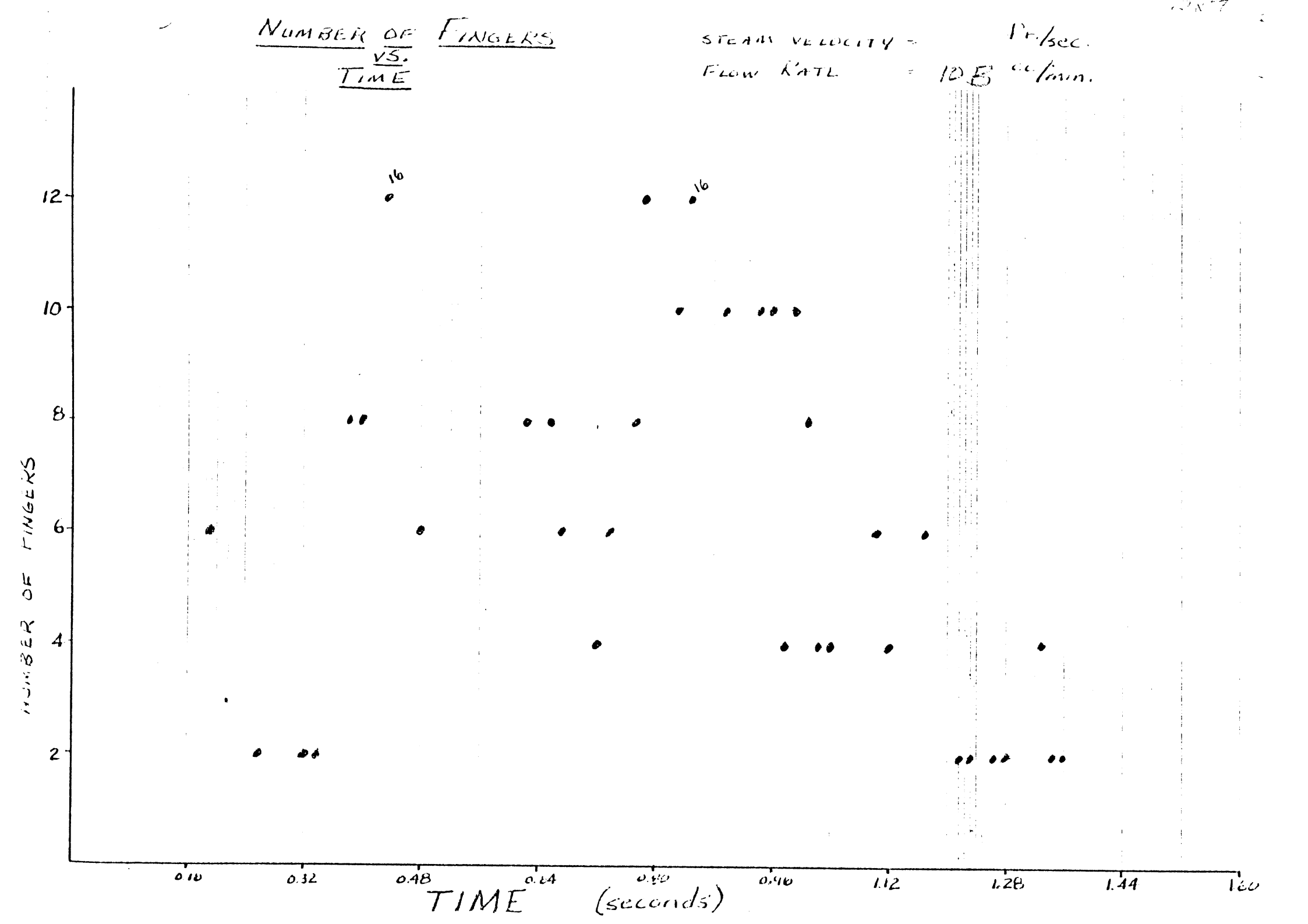


NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = ? Ft./sec.

FLOW RATE = 15A cc/min.

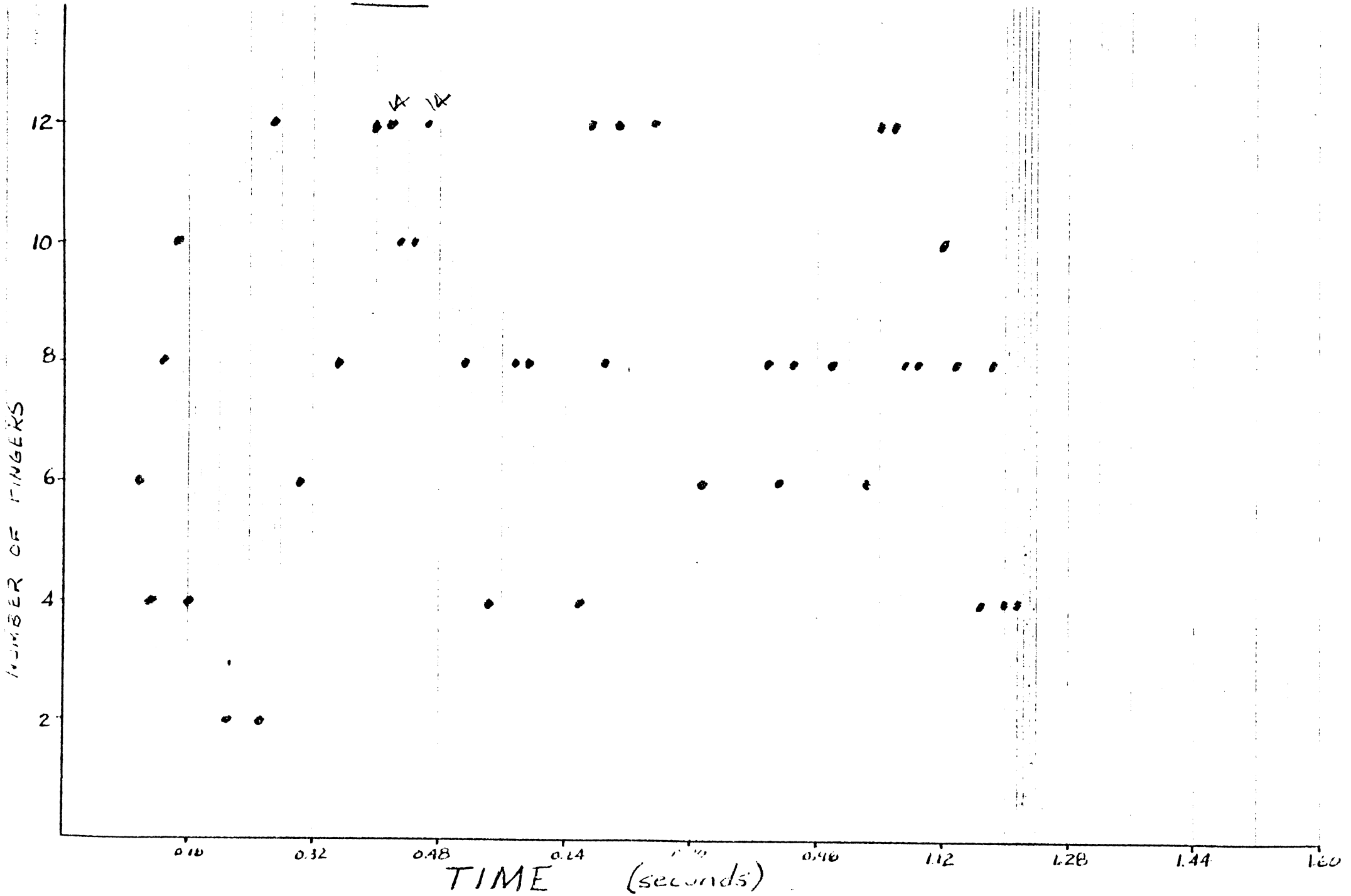


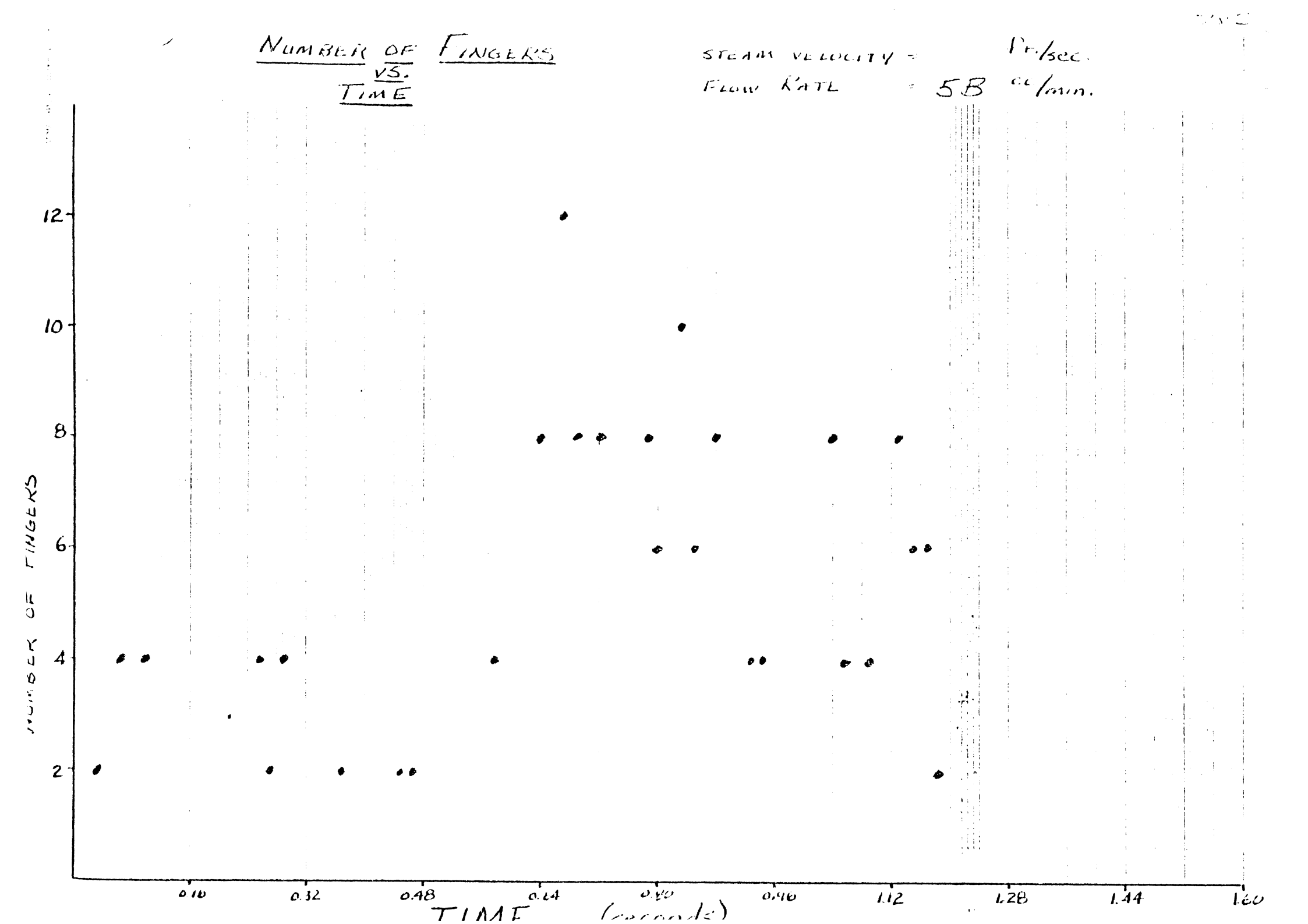

NUMBER OF FINGERS VS. TIME
STEAM VELOCITY = Ft./sec.
FLOW RATE = 125 cc/min.
16
16
12
10
8
6
4
2
NUMBER OF FINGERS
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.60
TIME (seconds)

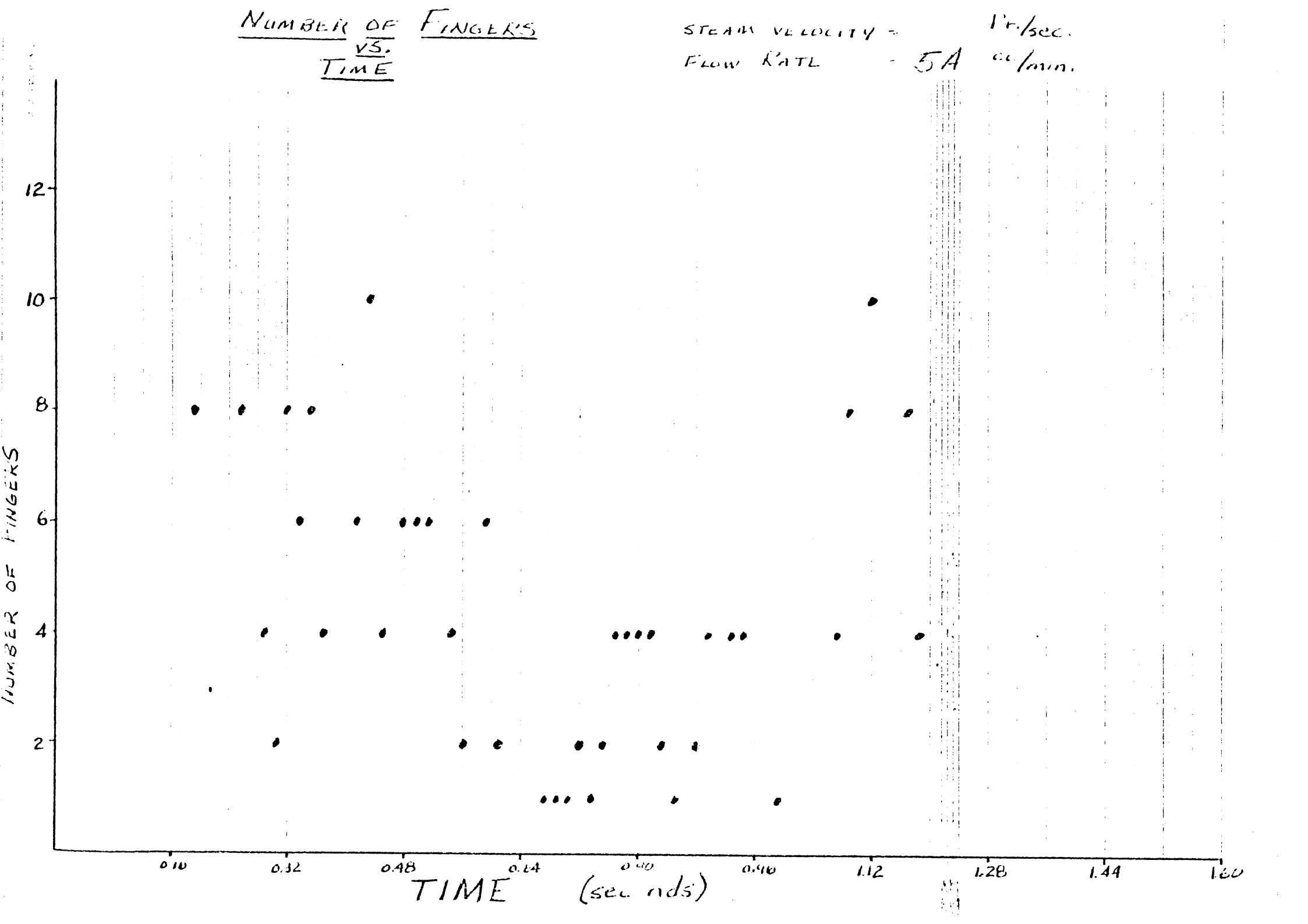
NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = Ft./sec.

FLOW RATE = 10 A cc/min.



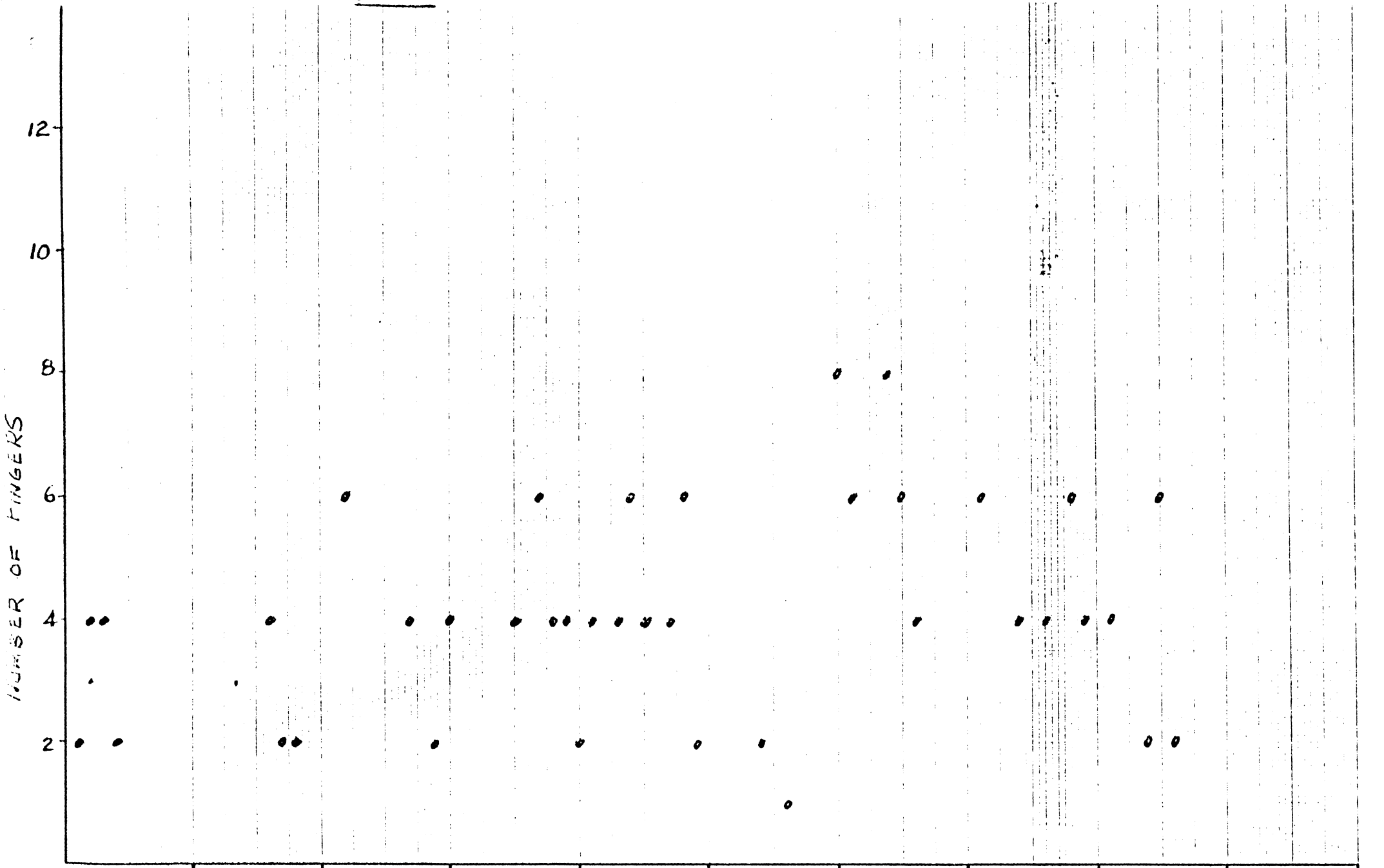

NUMBER OF FINGERS VS. TIME
STEAM VELOCITY = Ft./sec.
FLOW RATE = 58 cc/min.
NUMBER OF FINGERS
2
4
6
8
10
12
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.60
TIME (seconds)


NUMBER OF FINGERS VS. TIME
STEAM VELOCITY = 1 ft./sec.
FLOW RATE - 5A cc/min.
NUMBER OF FINGERS
12
10
8
6
4
2
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.60
TIME (seconds)

NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = ___ Ft/sec.

FLOW RATE = 50 cc/min.

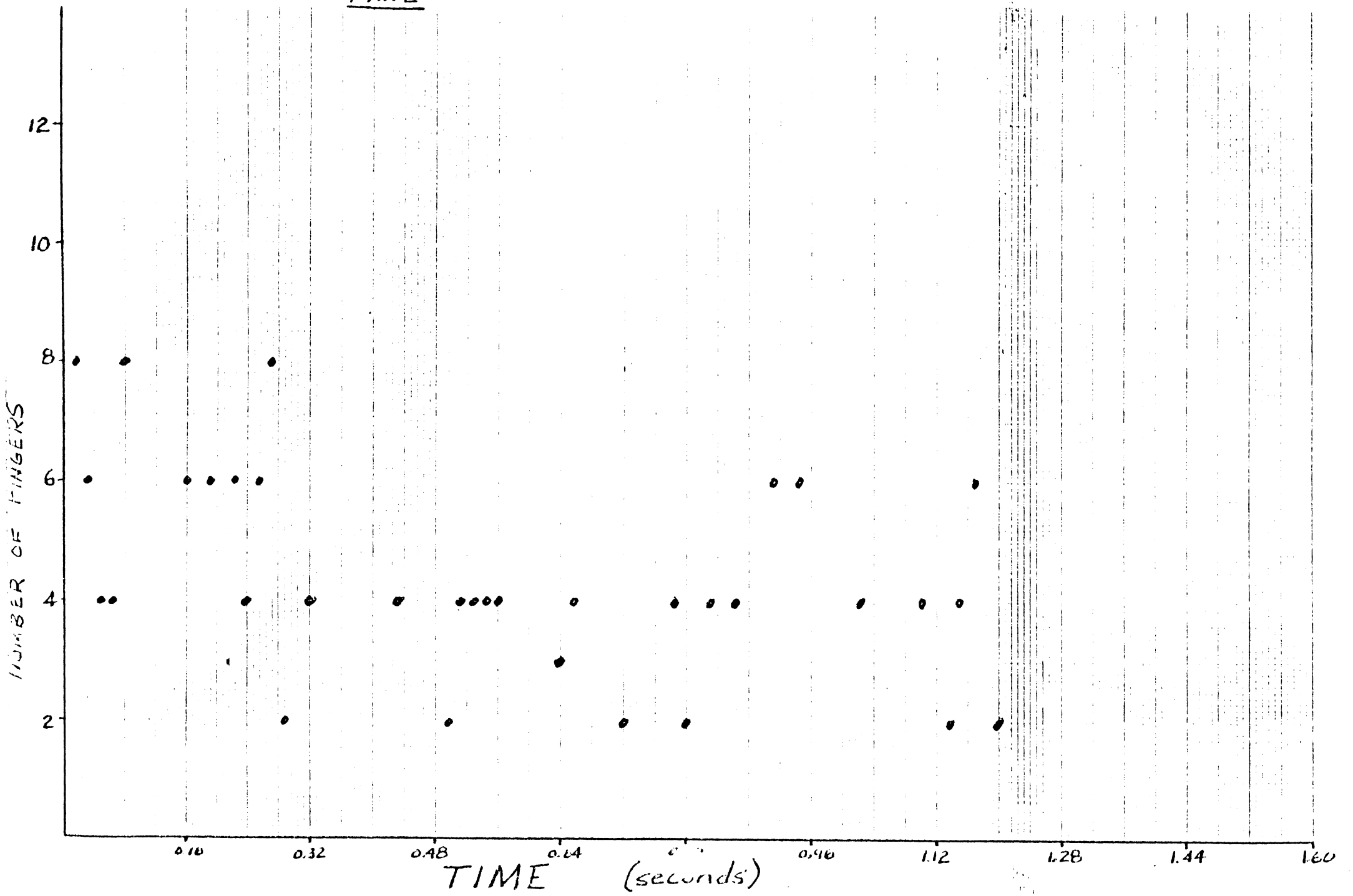


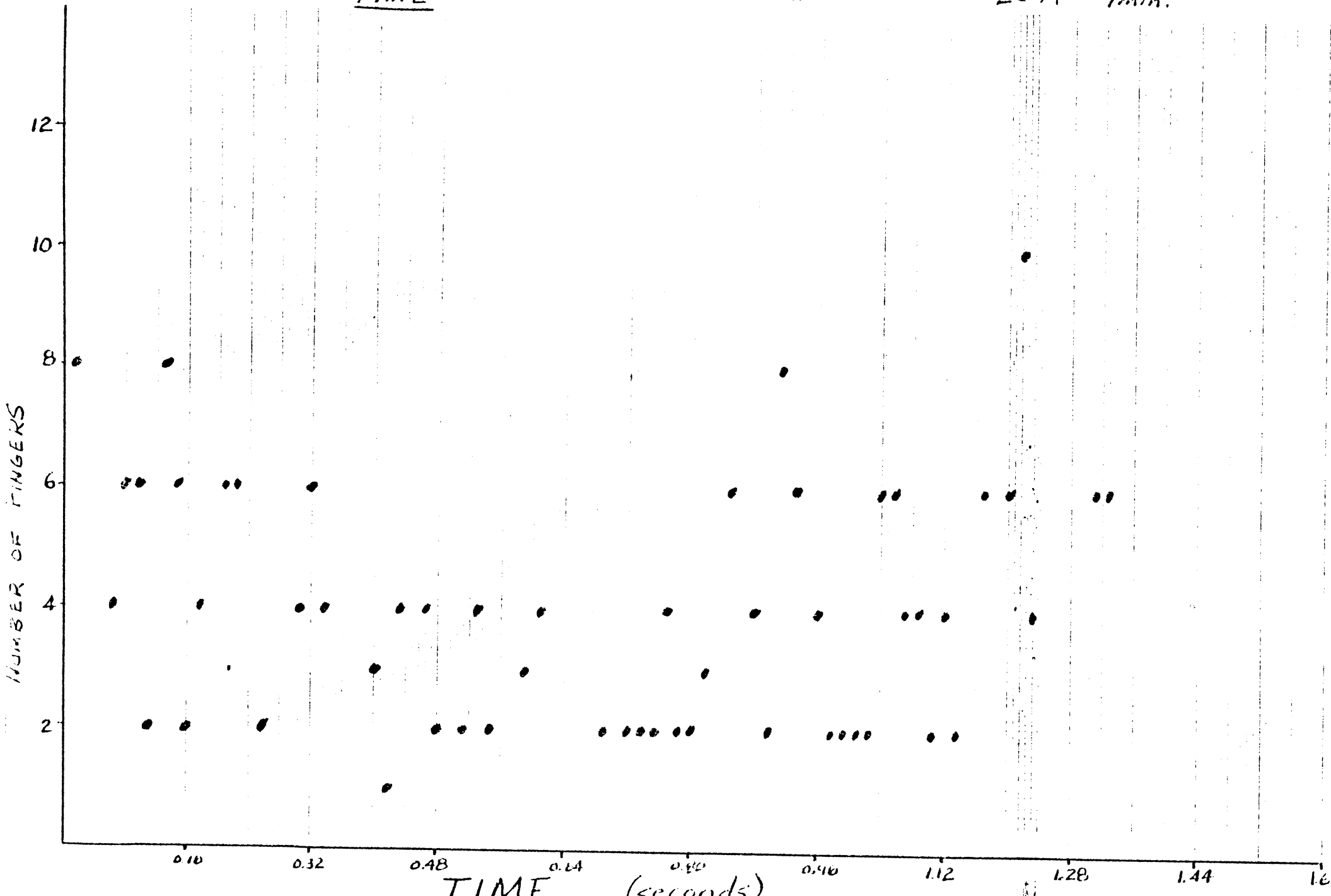
2x4

NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = ____ Ft./sec.

FLOW RATE = 30 cc/min.

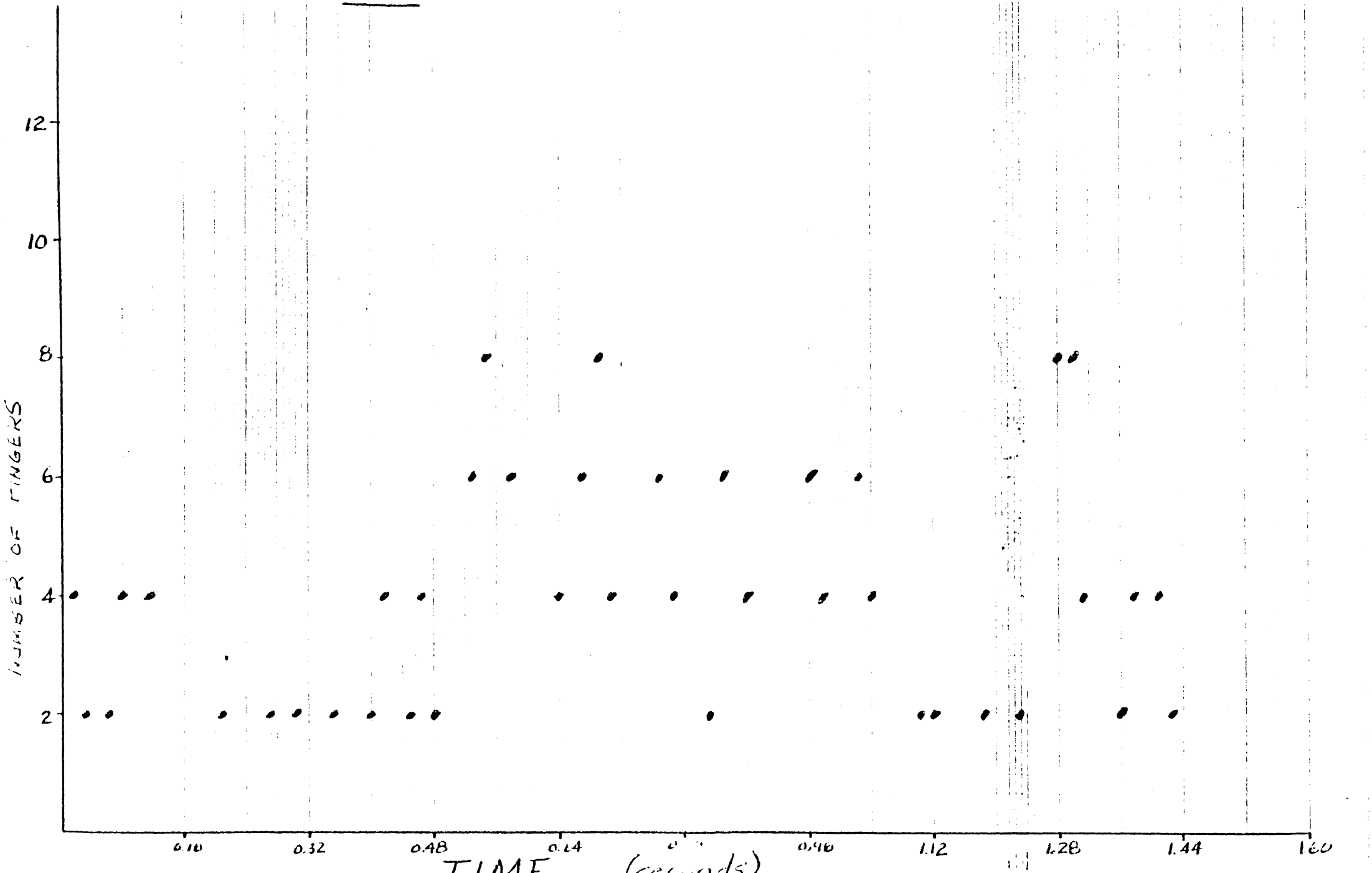



NUMBER OF FINGERS
VS.
TIME
STEAM VELOCITY = Ft./sec.
FLOW RATE = 20 A cc/min.
NUMBER OF FINGERS
12
10
8
6
4
2
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.60
TIME (seconds)

NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = Ft./sec.

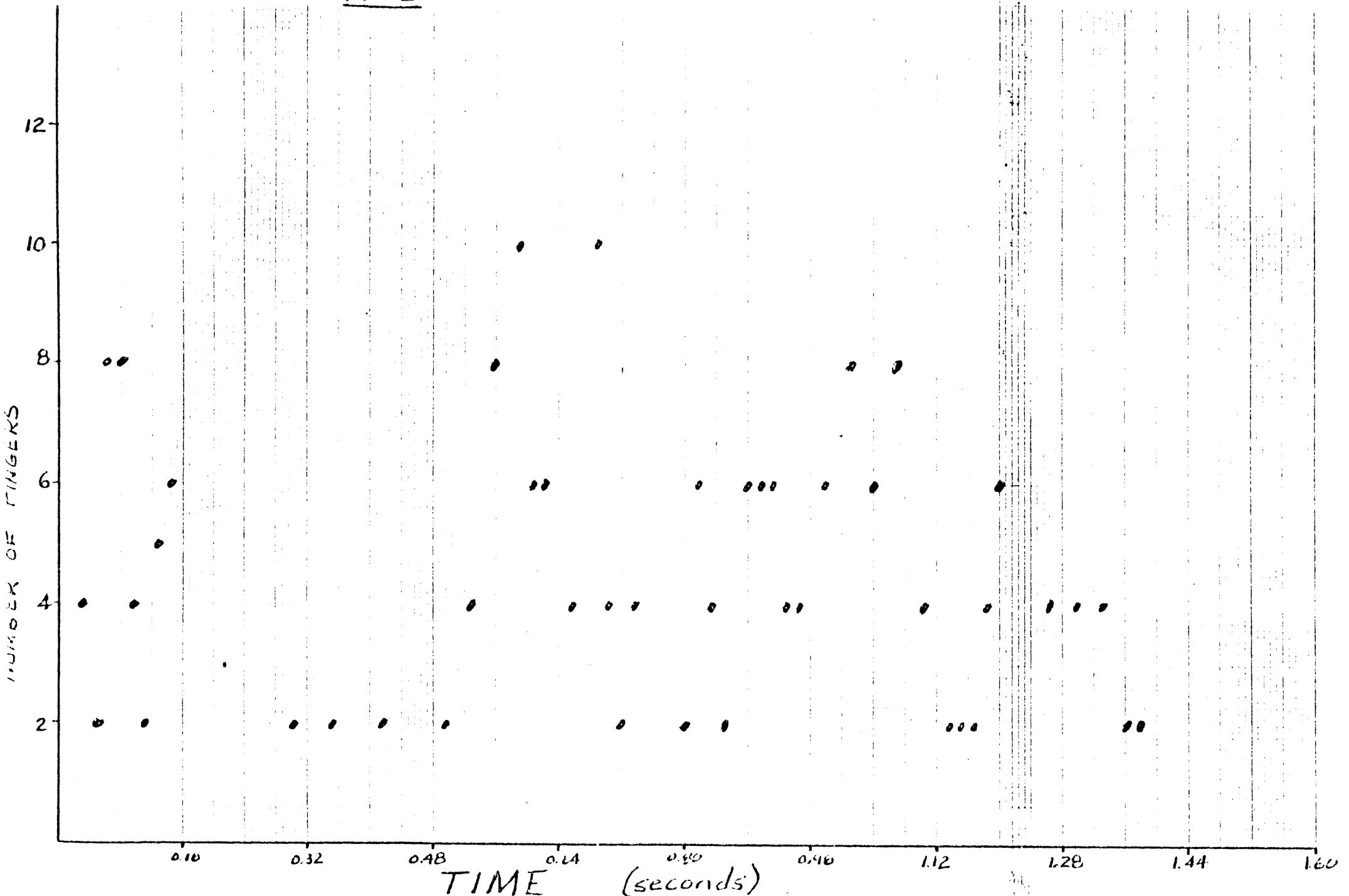
FLOW RATE = 15 B cc/min.



NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = Ft./sec.

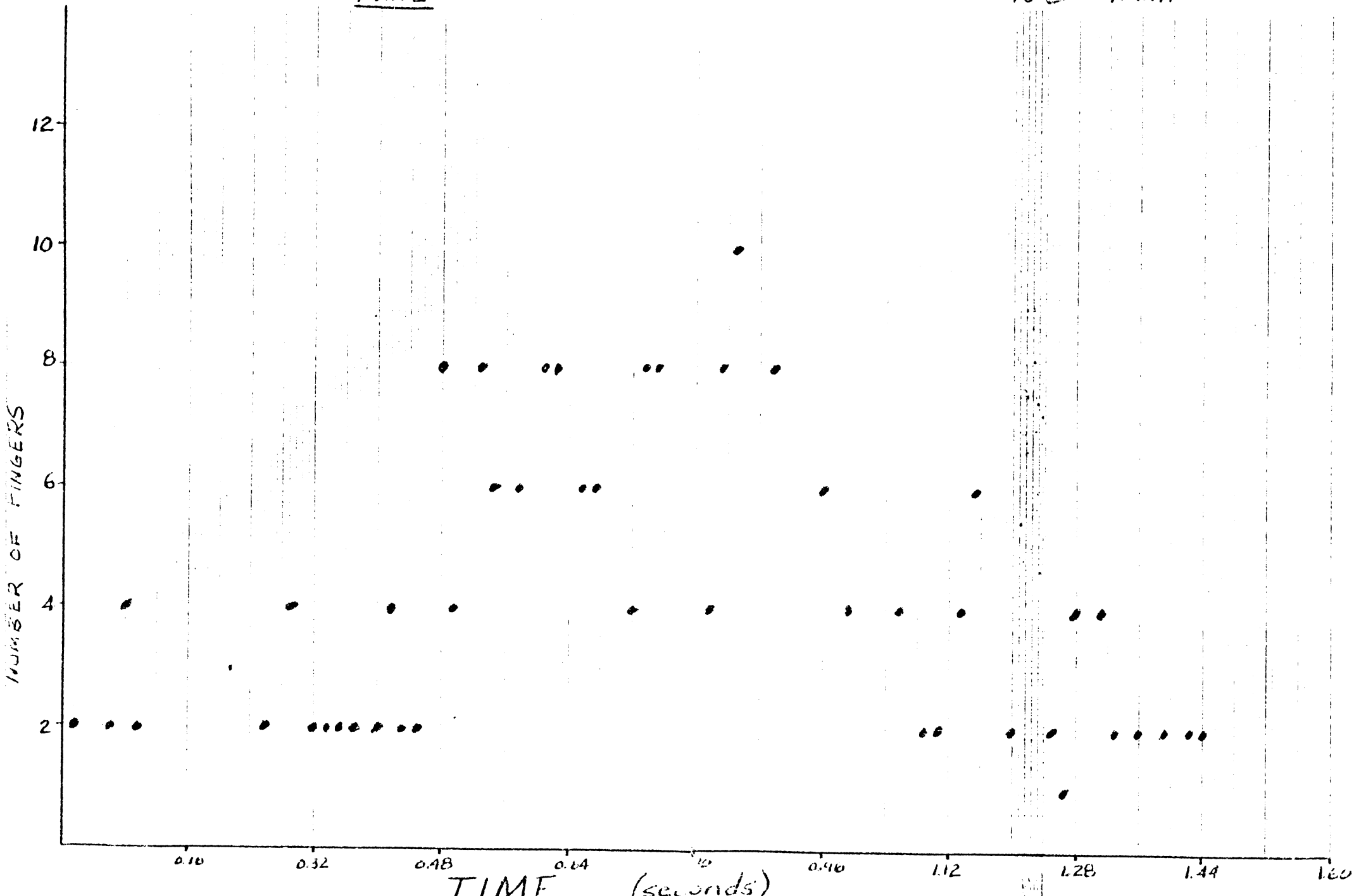
FLOW RATE = 15A cc/min.



NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = Ft./sec.

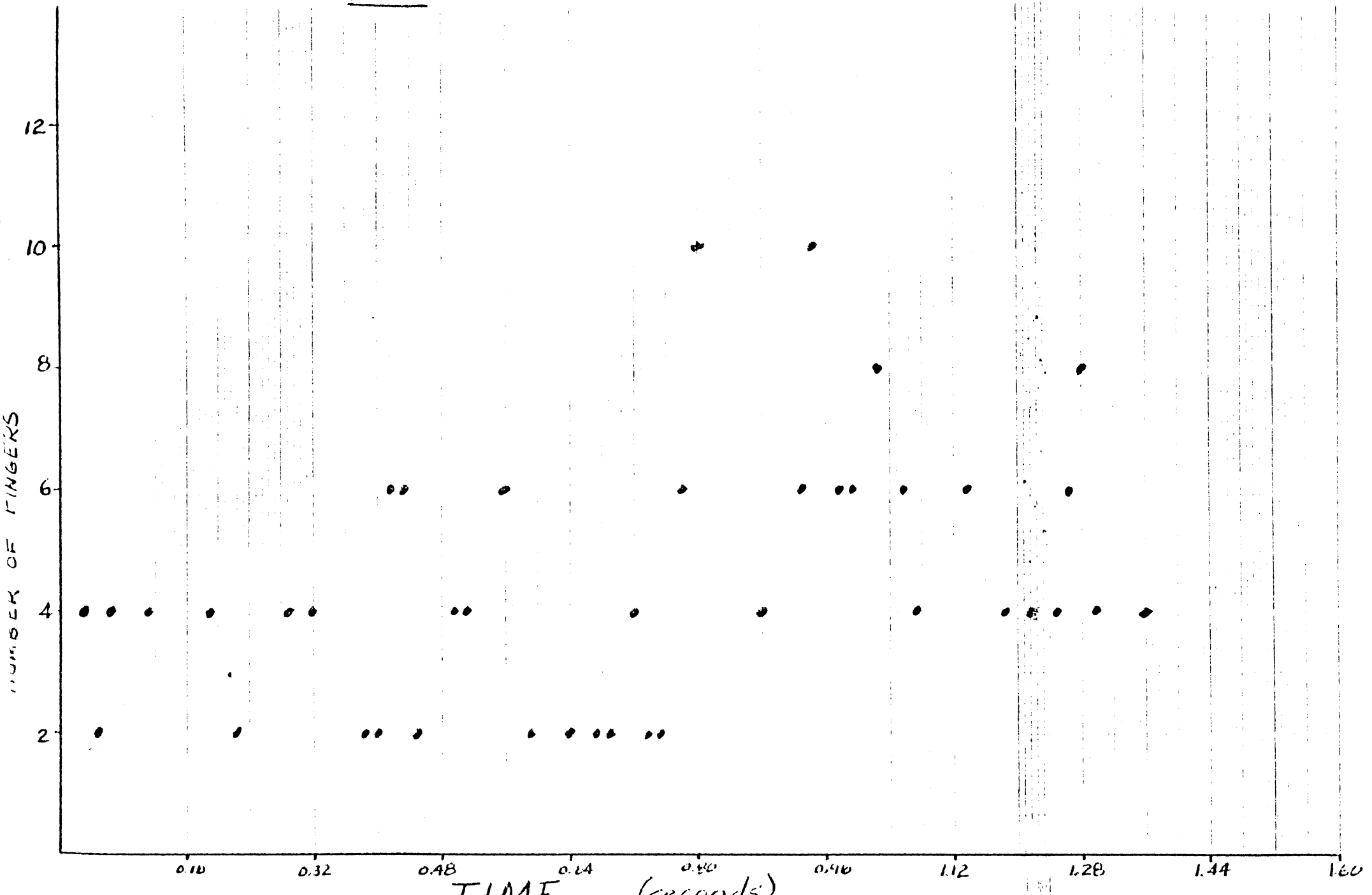
FLOW RATE = 108 cc/min.



NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = Ft/sec.

FLOW RATE = 10 M cc/min.

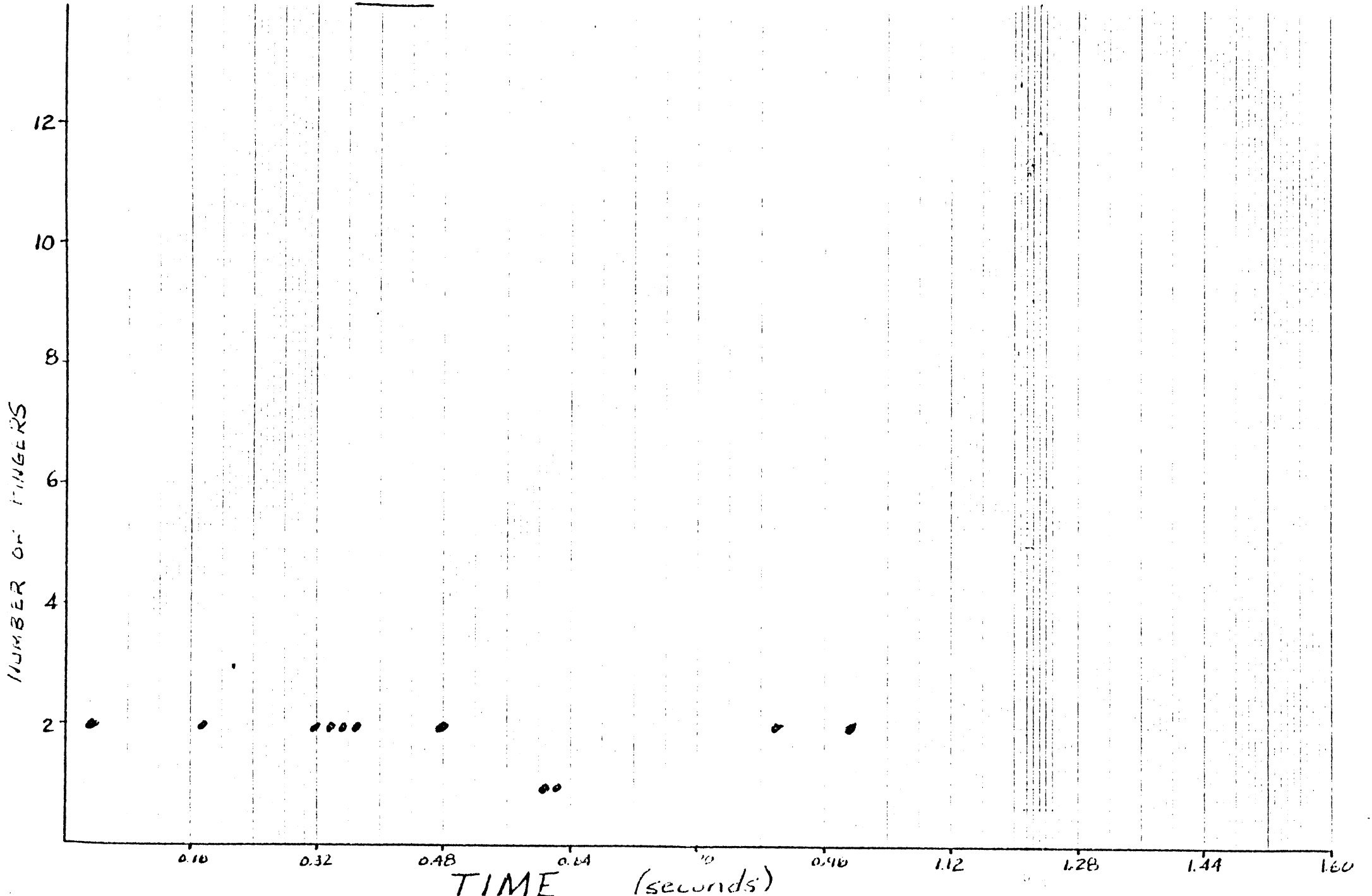


2×4

NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = Ft./sec.

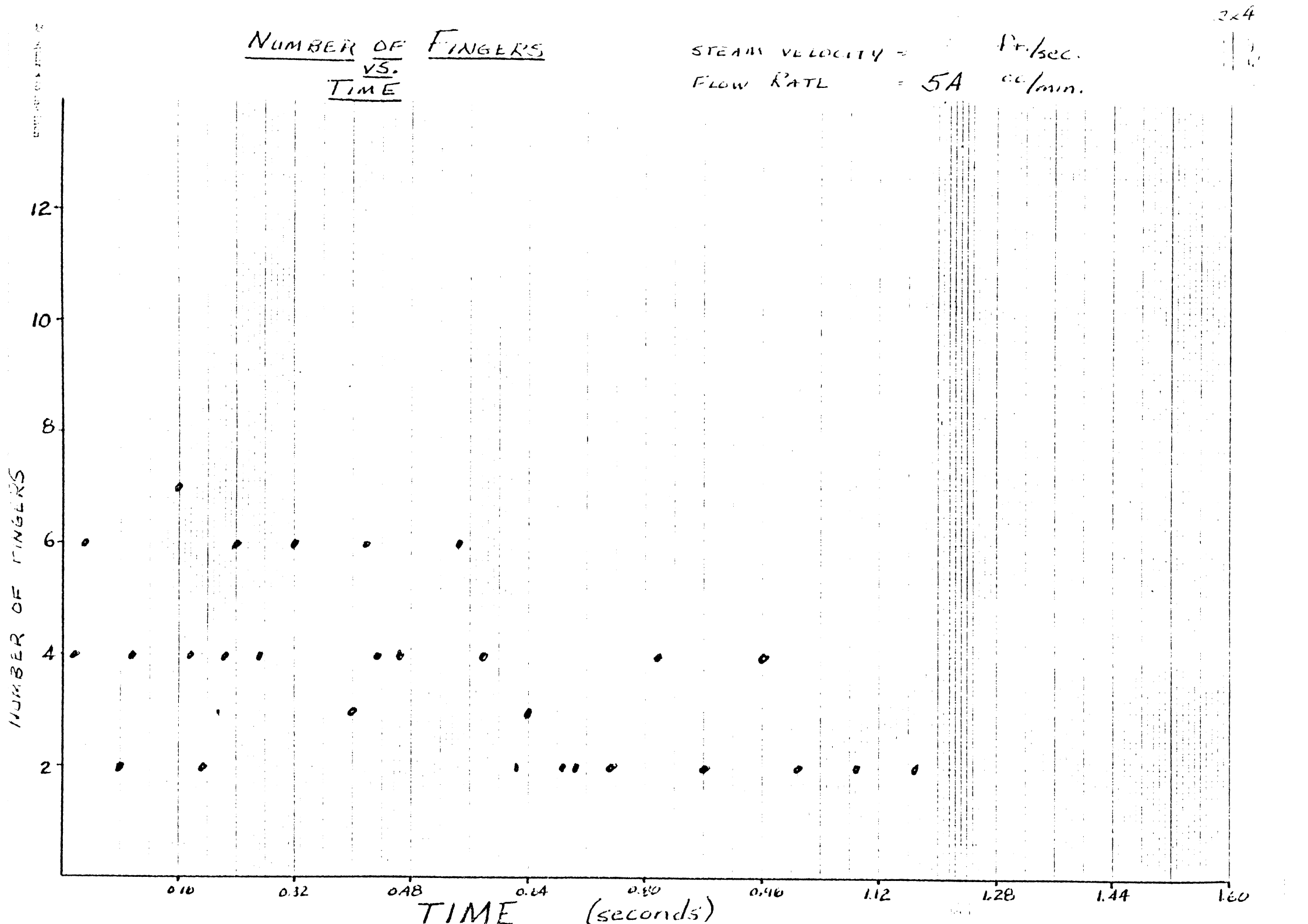
FLOW RATE = 5.B cc/min.



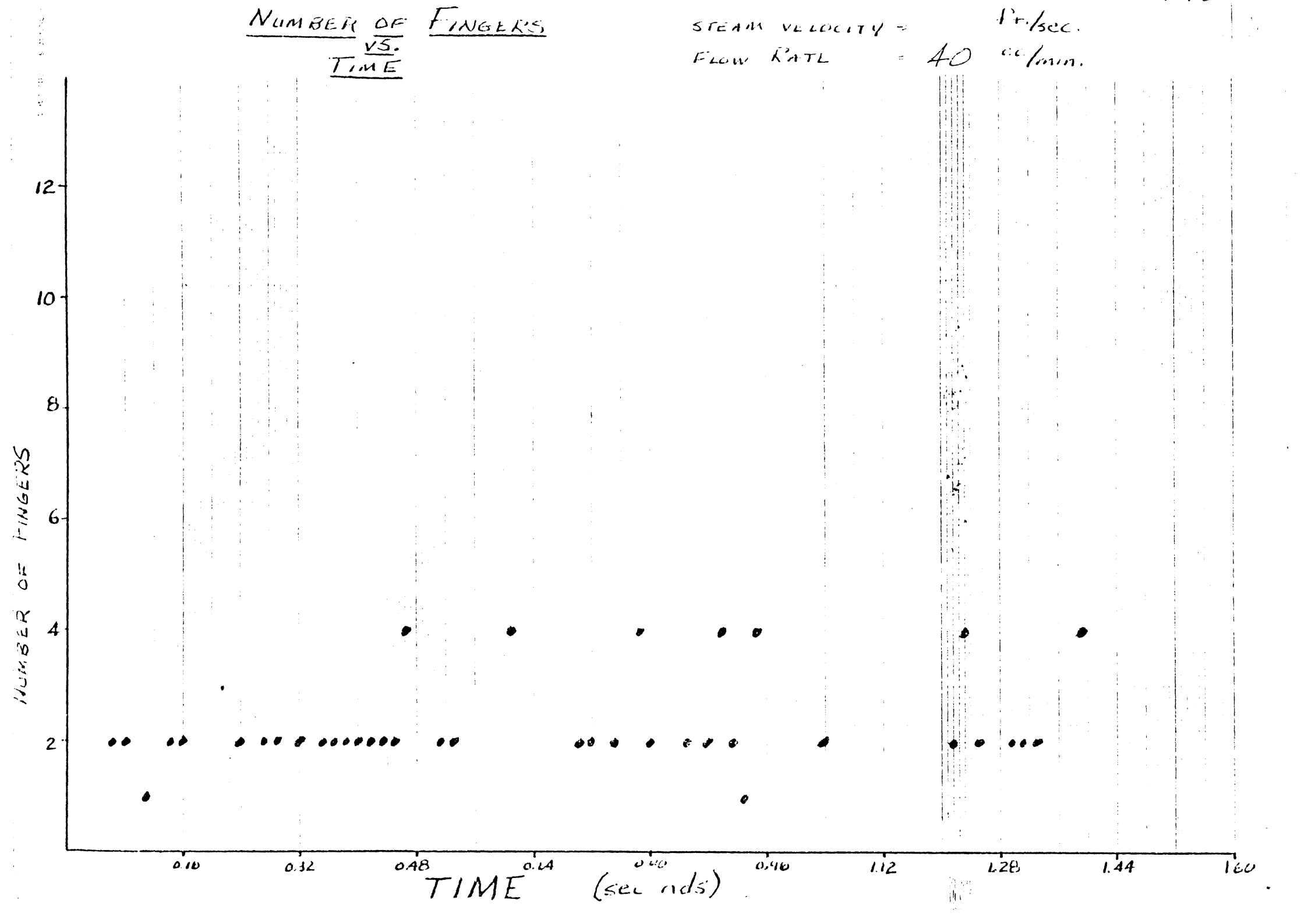
NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = Ft./sec.

FLOW RATE = 5A cc/min.



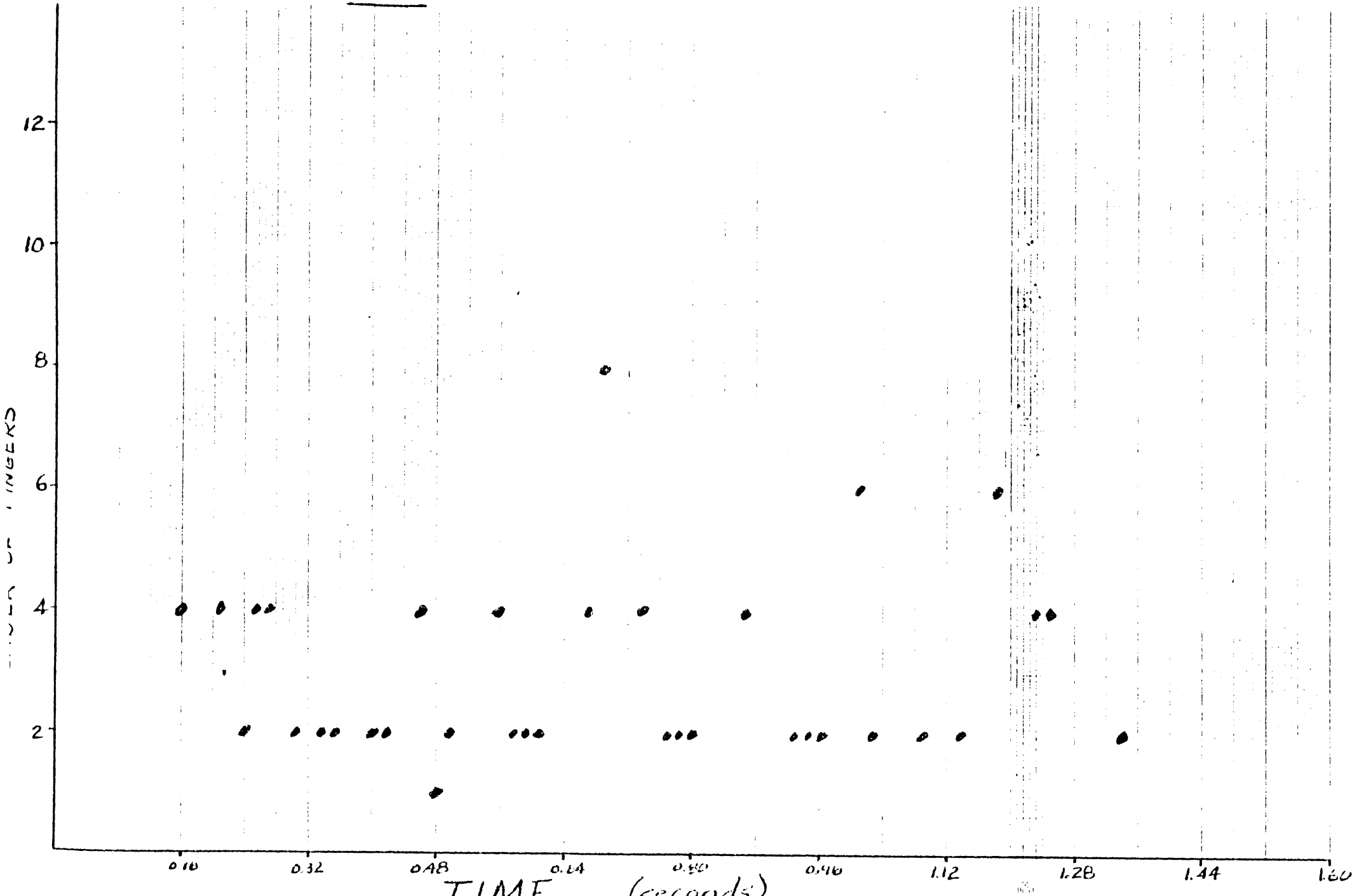
R E N C E L I S T I N G*****


NUMBER OF FINGERS VS. TIME
STEAM VELOCITY = Ft/sec.
FLOW RATE = 40 cc/min.
12
10
8
6
4
2
NUMBER OF FINGERS
0.16
0.32
0.48
0.64
0.80
0.96
1.12
1.28
1.44
1.60
TIME (seconds)

NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = Ft./sec.

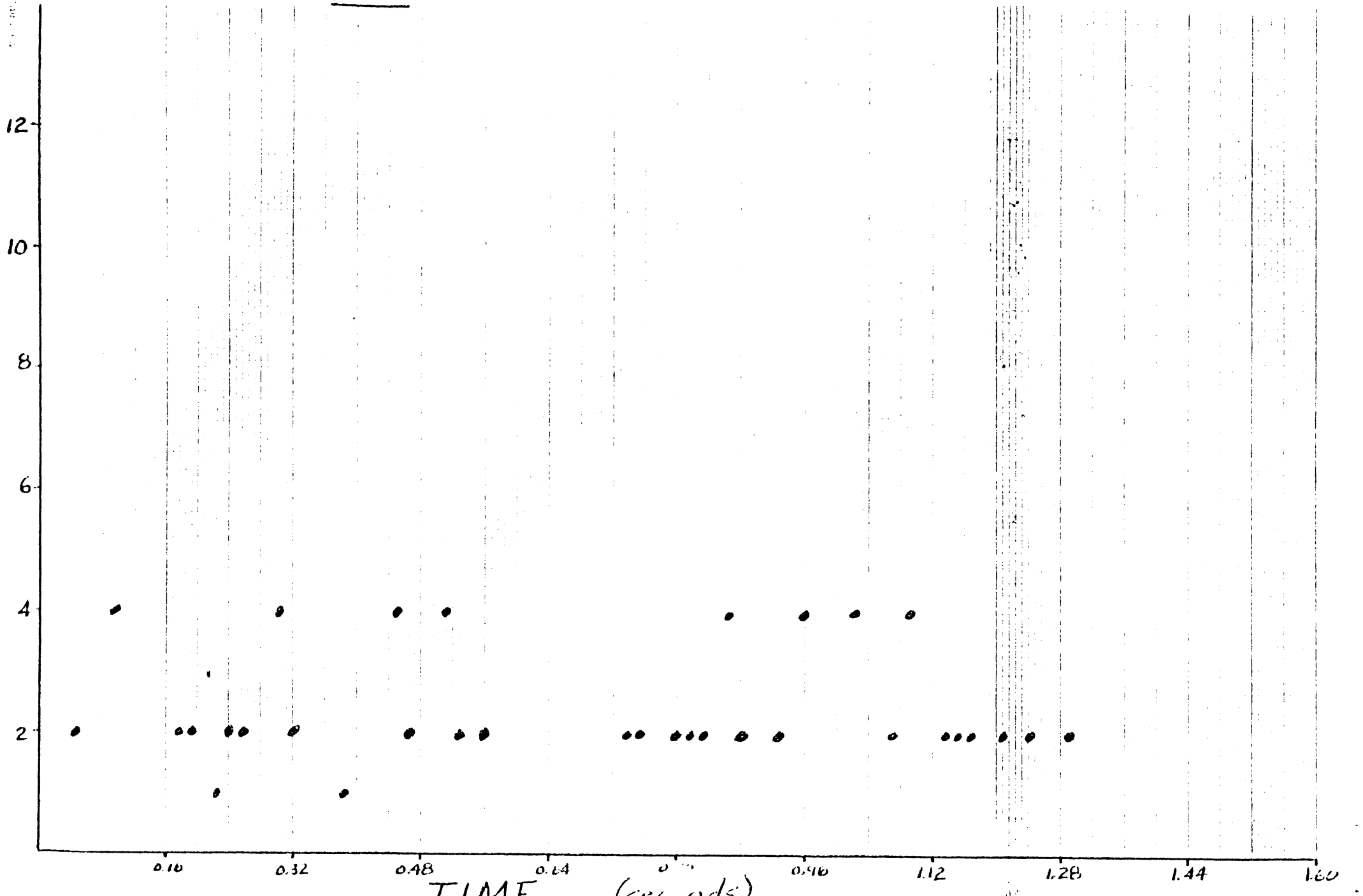
FLOW RATE = 20 cc/min.



NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = Ft./sec.

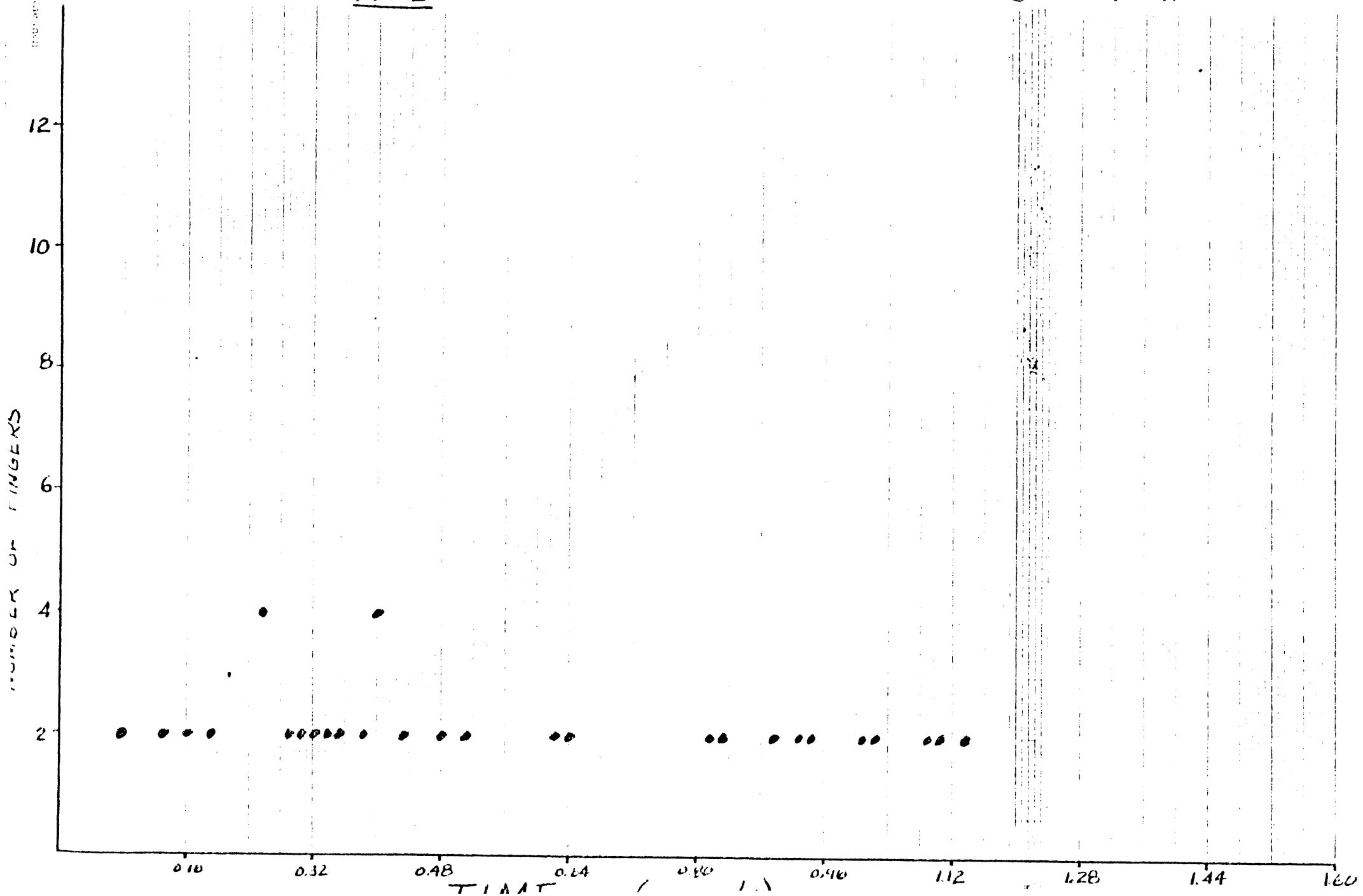
FLOW RATE = 10 cc/min.



NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = Ft./sec.

FLOW RATE = 5 cc/min.

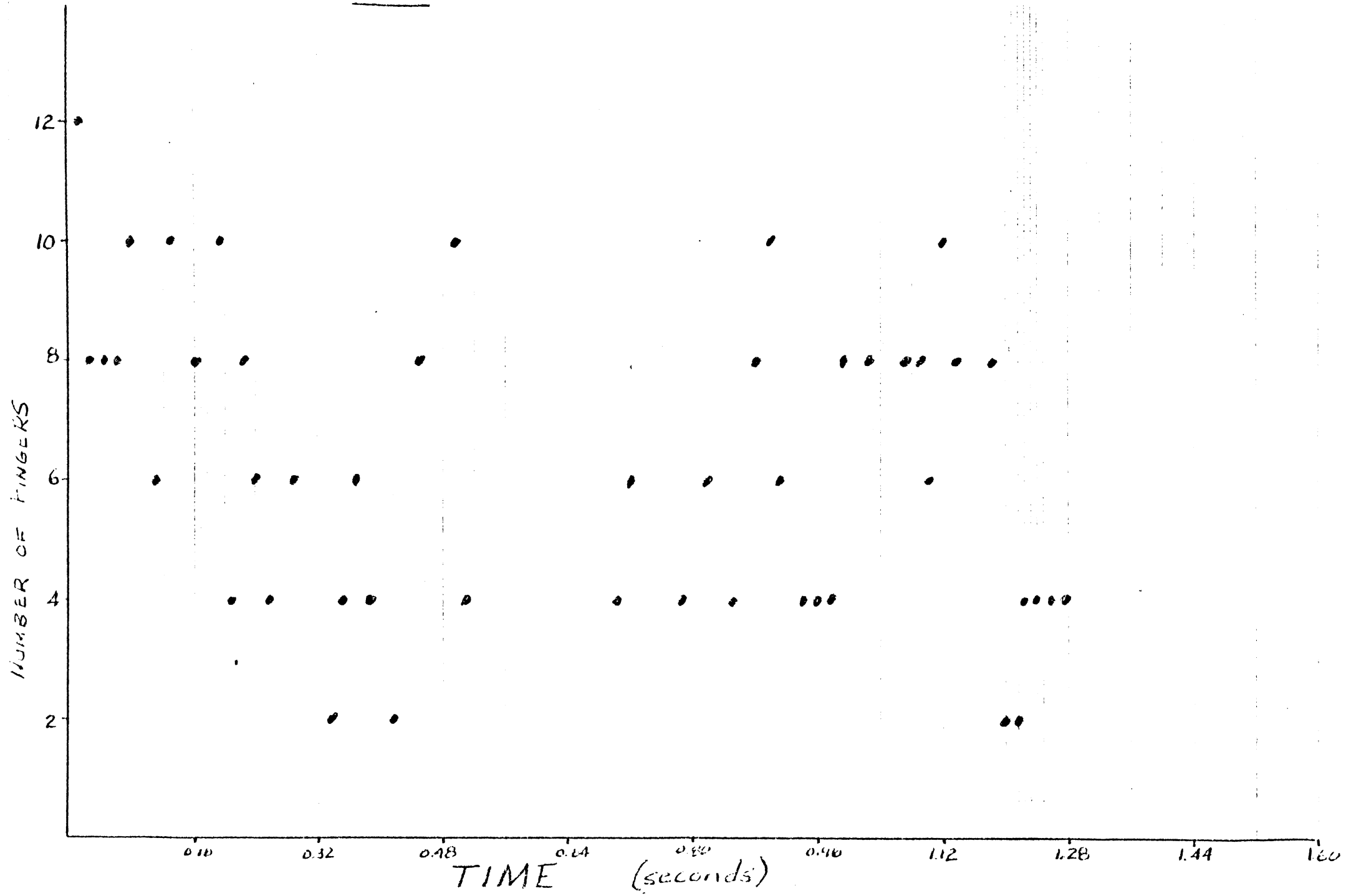


2 x 1

NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = ? ft/sec.

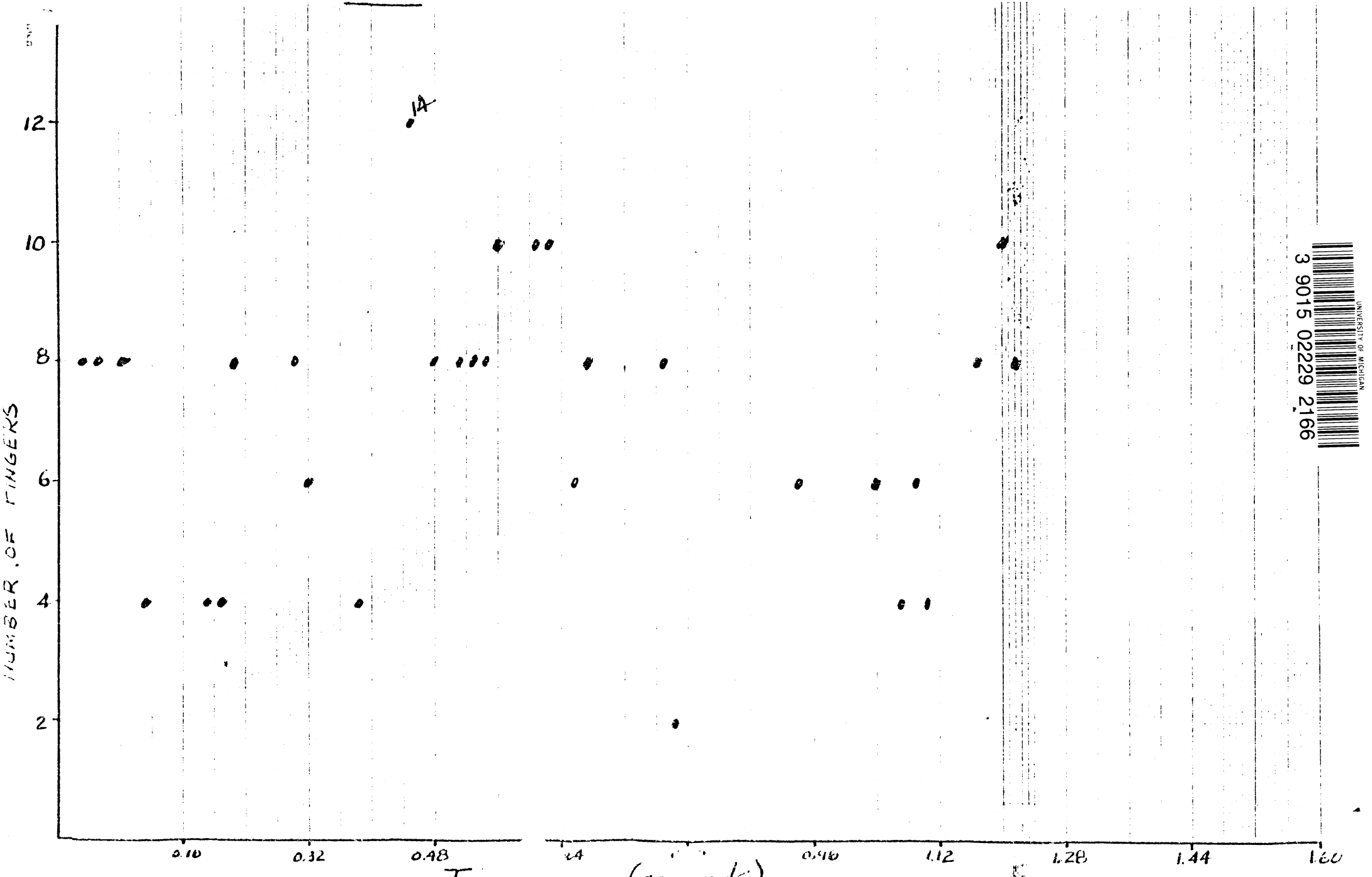
FLOW RATE = 30 cc/min.



NUMBER OF FINGERS VS. TIME

STEAM VELOCITY = Ft/sec.

FLOW RATE = 50 cc/min.



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