

Department of Mechanical Engineering
Cavitation and Multiphase Flow Laboratory
The University of Michigan

Dr

Report No. UMICH 014571-3-I (Internal)

WET STEAM TUNNEL: TRAILING EDGE OBSERVED

by Sander Diome

(submitted in partial fulfillment of ME 490)

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

THE UNIVERSITY OF MICHIGAN
ENGINEERING LIBRARY

Supported by NSF Grant No. ENG 75-2315

30 June 1977

enqn
UMIC 0494

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 disintegration 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 $V_{GL} = 308 \text{ ft/sec}$

MAXIMUM DROP DIA. (cm.)	$\dot{Q} = 5 \text{ cc/min}$		$\dot{Q} = 10 \text{ cc/min}$		$\dot{Q} = 20 \text{ cc/min}$		$\dot{Q} = 40 \text{ cc/min}$	
	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

TABLE 2 DROP DISTRIBUTION TOP $V_{ST} = 522 \text{ ft/sec}$

Maximum Drop Dia (cm.)	Q = 5A $\frac{cc}{min}$		Q = 10A $\frac{cc}{min}$		Q = 10B $\frac{cc}{min}$		Q = 15A $\frac{cc}{min}$		Q = 15B $\frac{cc}{min}$		Q = 20 $\frac{cc}{min}$		Q = 30 $\frac{cc}{min}$		Q = 50 $\frac{cc}{min}$	
	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
.180	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

TABLE 3 DROP DISTRIBUTION FOR VST = 826 μ sec

Maximum Drop Dia (μ m.)	$\dot{Q} = 5A$ cc/min		$\dot{Q} = 5B$ cc/min		$\dot{Q} = 10A$ cc/min		$\dot{Q} = 10B$ cc/min		$\dot{Q} = 15H$ cc/min		$\dot{Q} = 15B$ cc/min		$\dot{Q} = 20$ cc/min		$\dot{Q} = 30$ 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

TABLE A 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)	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	5A	8	1.20	.150
10	16	1.32	.082	10A	13	1.32	.102	5B	5	1.20	.240	5B	5	1.20	.240
20	14	1.30	.092	10B	15	1.44	.096	10A	5	1.20	.240	10A	5	1.20	.240
40	17	1.44	.085	15A	16	1.32	.088	10B	10	1.12	.112	10B	10	1.12	.112
-	-	-	-	15B	19	1.52	.080	15A	11	1.44	.131	15A	11	1.44	.131
-	-	-	-	20	18	1.44	.080	15B	18	1.40	.078	15B	18	1.40	.078
-	-	-	-	30	16	1.20	.075	20	11	1.32	.120	20	11	1.32	.120
-	-	-	-	50	19	1.32	.069	30	10	1.28	.128	30	10	1.28	.128

TABLE 5 TRAILING EDGE DISINTEGRATION PERIODICITY

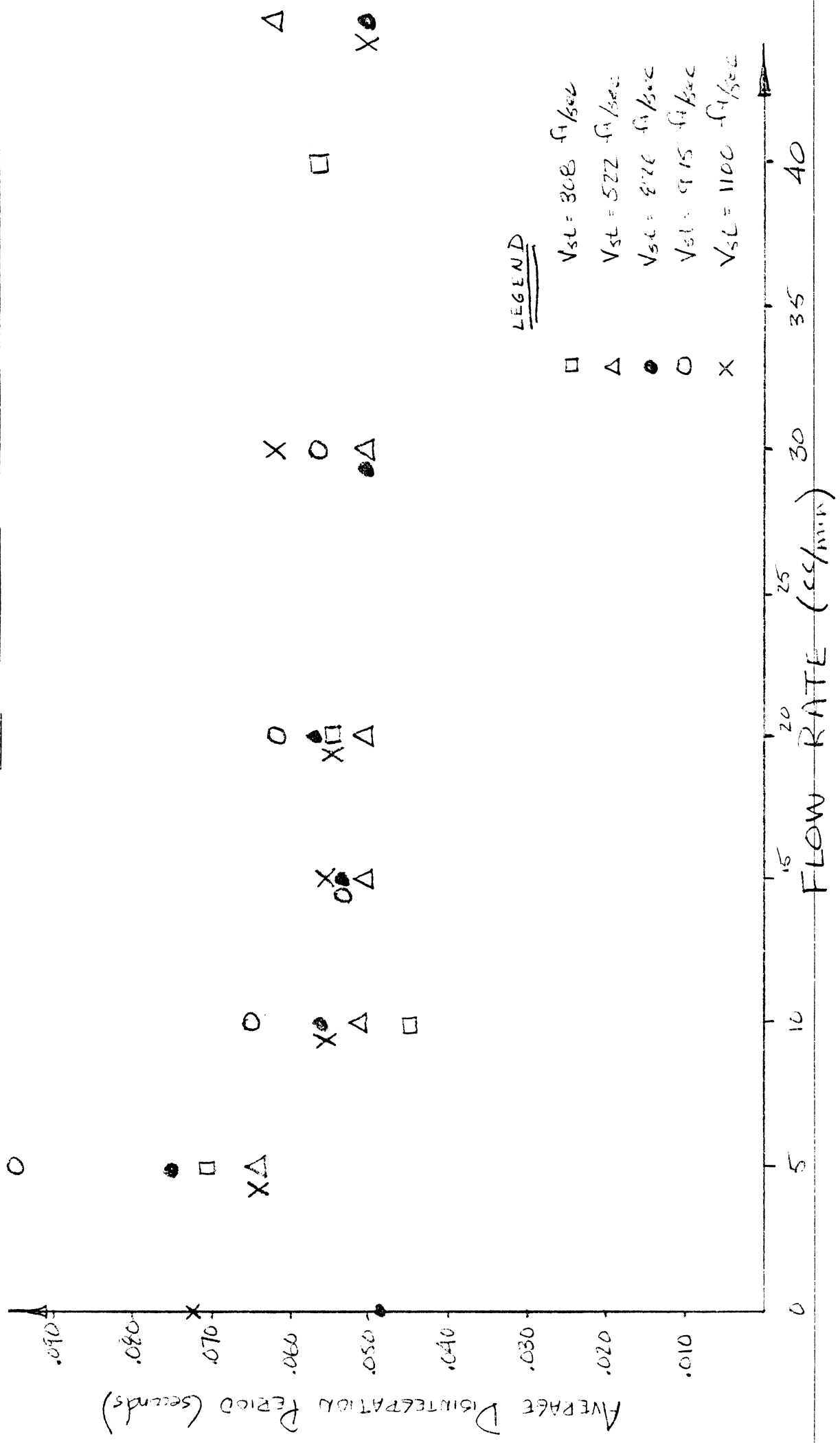
VSL = 308 ft/sec				VSL = 522 ft/sec				VSL = 826 ft/sec			
Q (cc/min)	NUMBER OF PLANKS	TOTAL TIME (sec)	Average Period (sec)	Q (cc/min)	NUMBER OF PLANKS	Total time (sec)	Average Period (sec)	Q (cc/min)	NUMBER OF PLANKS	Total Time (sec)	Average Period (sec)
5	17	1.20	.071	0	-	-	-	0	3	1.44	.048
10	22	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	.046	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
				50	21	1.32	.063	50	25	1.28	.051

TABLE 5 (cont'd) TRAILING EDGE DISINTEGRATION FREQUENCY

$V_{SL} = 975 \text{ ft/sec}$				$V_{SL} = 1100 \text{ ft/sec}$			
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	24	1.30	.054
20B	25	1.52	.061	20A	28	1.52	.054
30A	31	1.52	.049	30A	24	1.52	.063
50B	26	1.52	.058	50A	30	1.52	.051

FIGURE 1: FLOW RATE VS. AVERAGE DISINTEGRATION PERIOD

FOR VARIOUS STEAM VELOCITIES



LEGEND

- V_{st} = 308 ft/sec
- △ V_{st} = 522 ft/sec
- V_{st} = 876 ft/sec
- V_{st} = 915 ft/sec
- X V_{st} = 1100 ft/sec

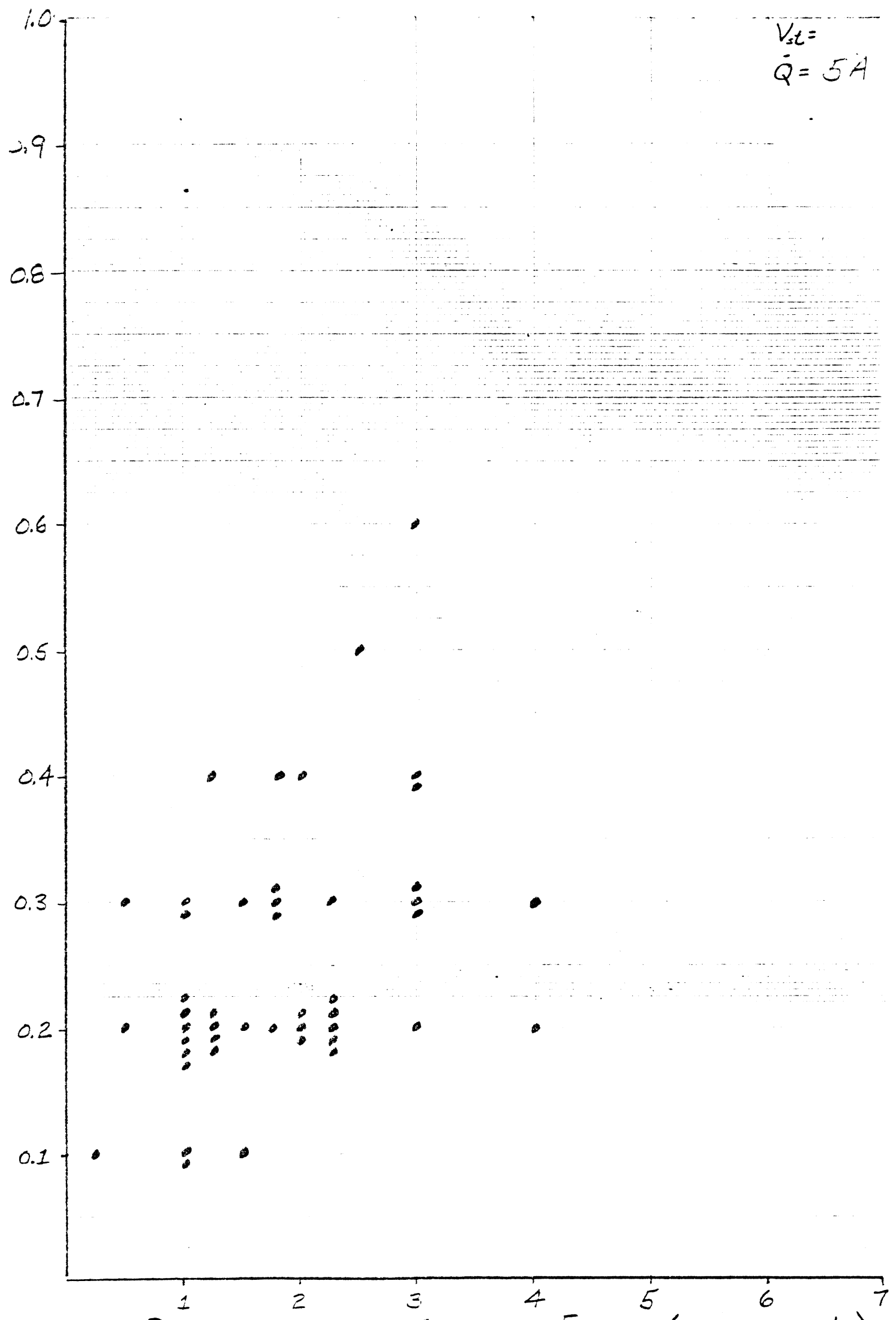
APPENDIX A

MAXIMUM DROP DIAMETER VS. DISTANCE

DROP DIAMETER VS. DISTANCE

$V_{sl} =$
 $\dot{Q} = 5A$

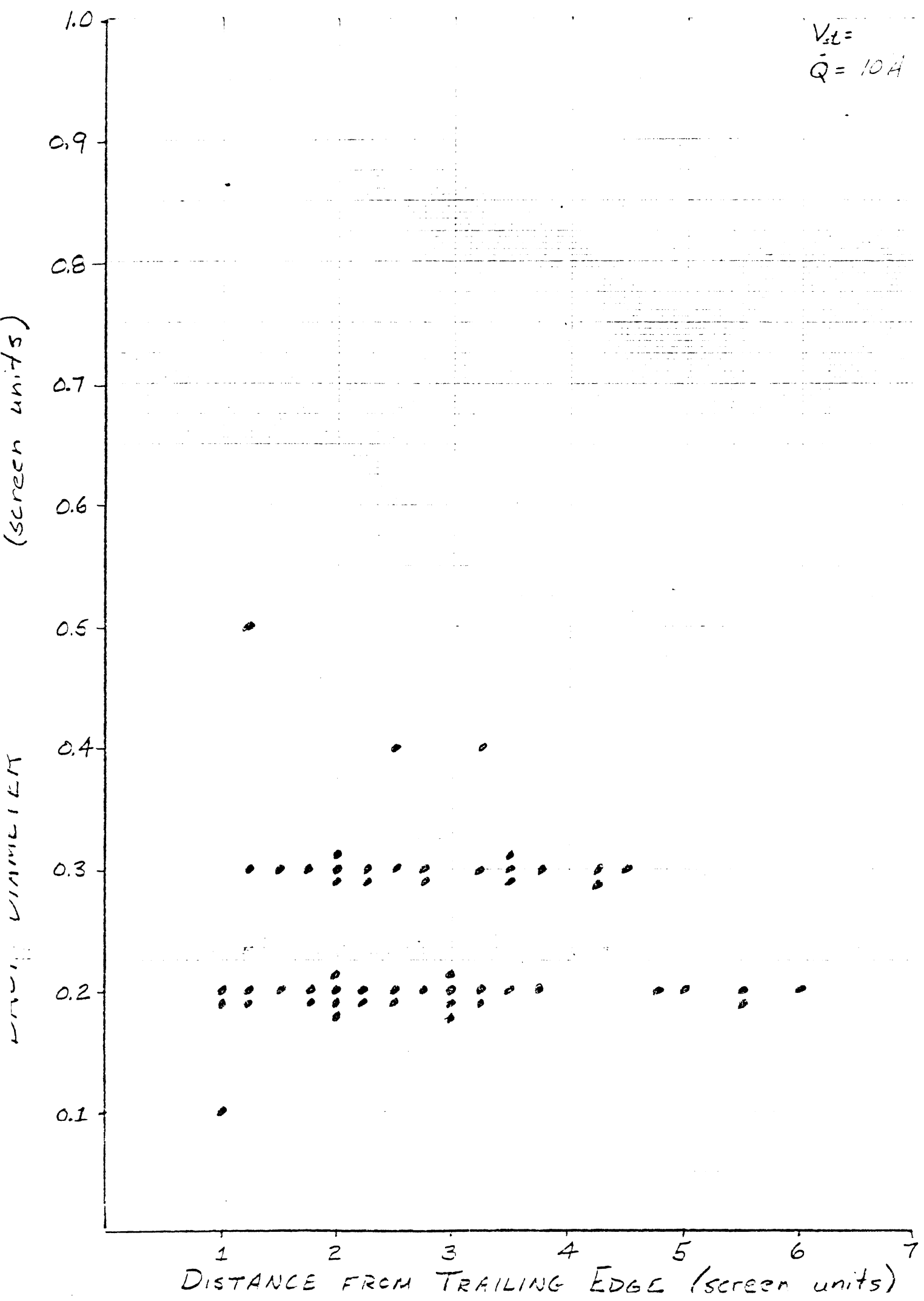
DROP DIAMETER
(screen units)



DROP DIAMETER VS. DISTANCE

2x4

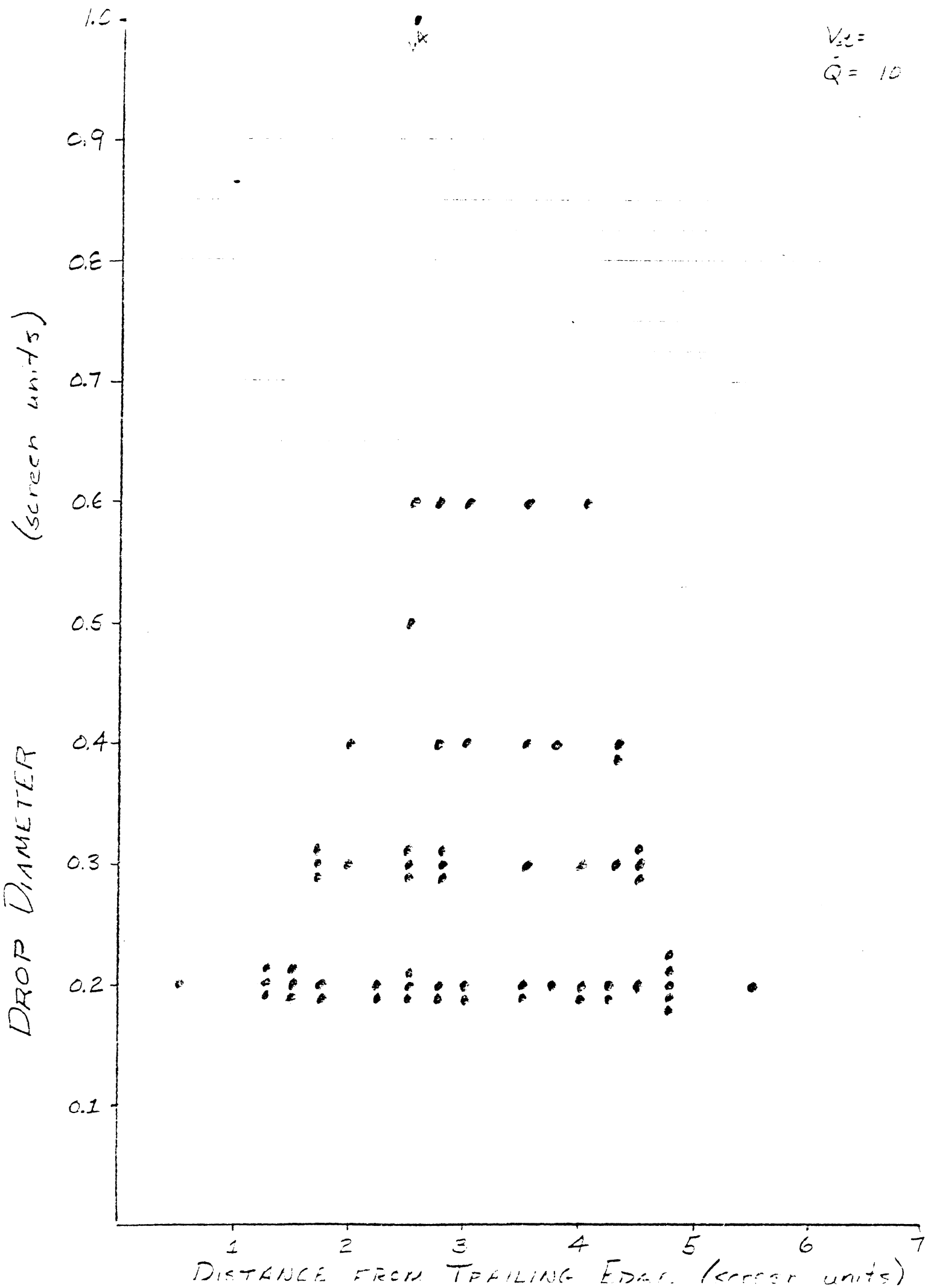
$V_{st} =$ ft
 $\bar{Q} = 10A$ %



DROP DIAMETER VS. DISTANCE

2/13/5

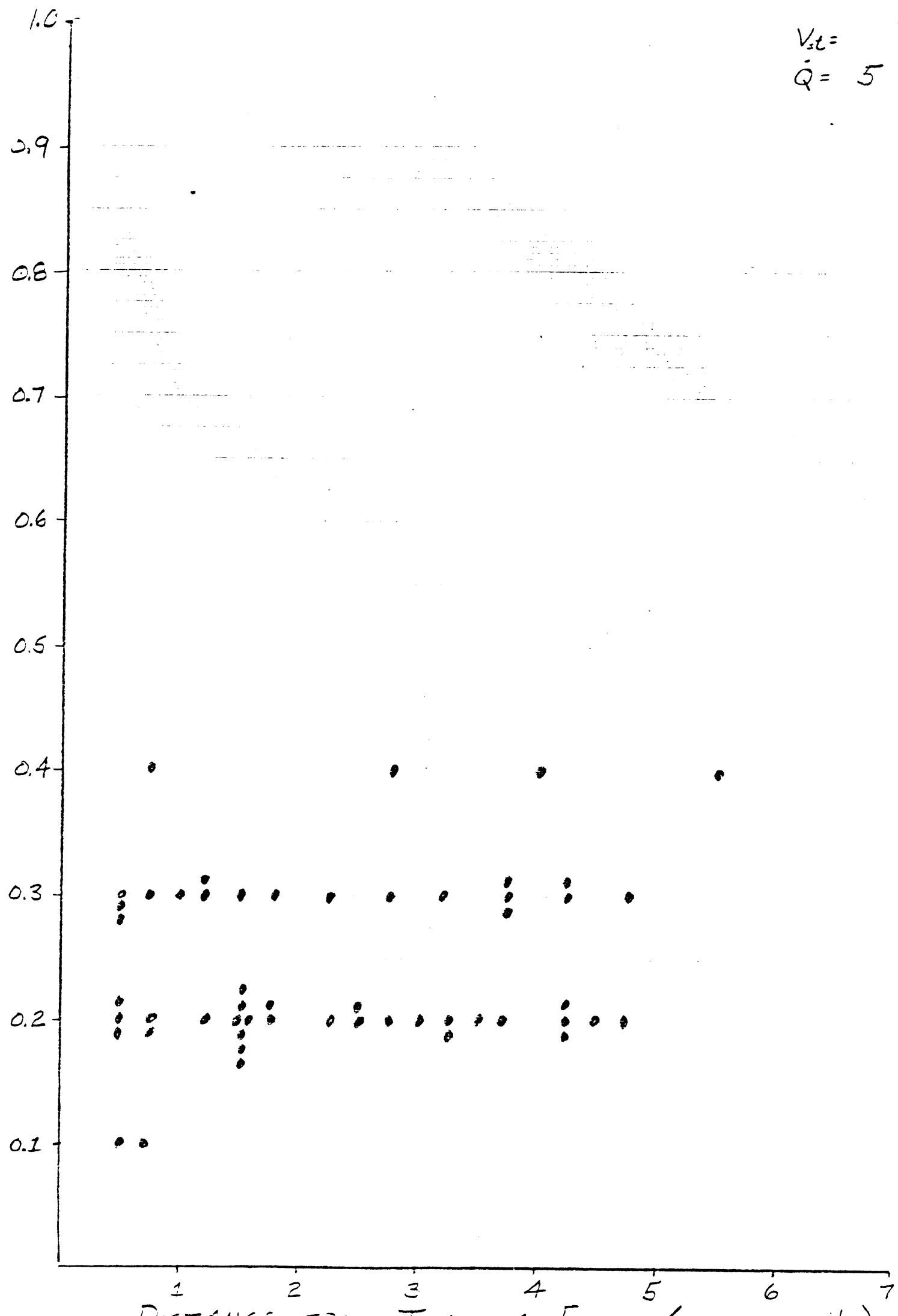
$V_{rel} =$
 $\bar{Q} = 10$



DROP DIAMETER VS. DISTANCE

$V_{sl} =$
 $\dot{Q} = 5$

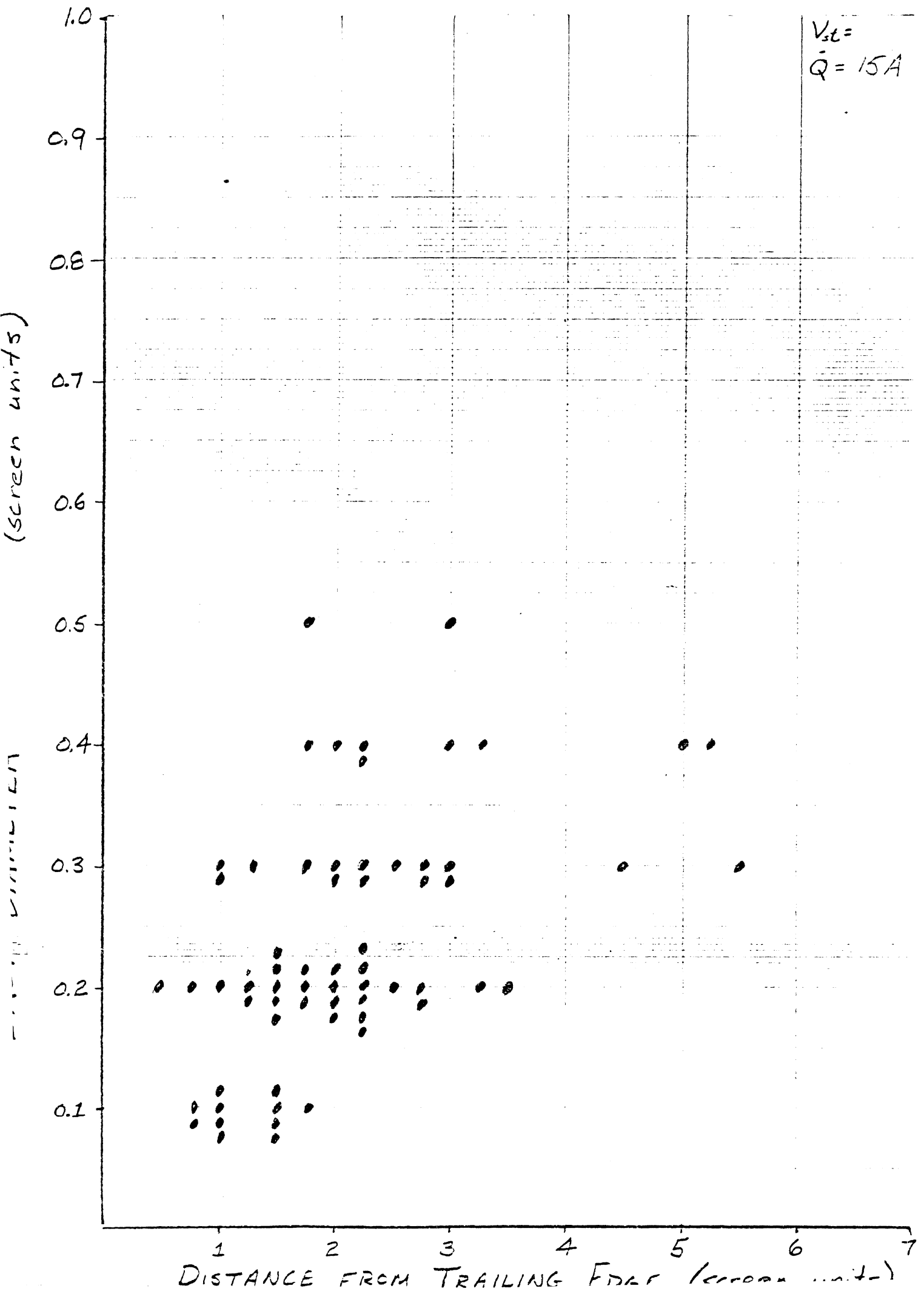
DROP DIAMETER
(screen units)



DROP DIAMETER VS. DISTANCE

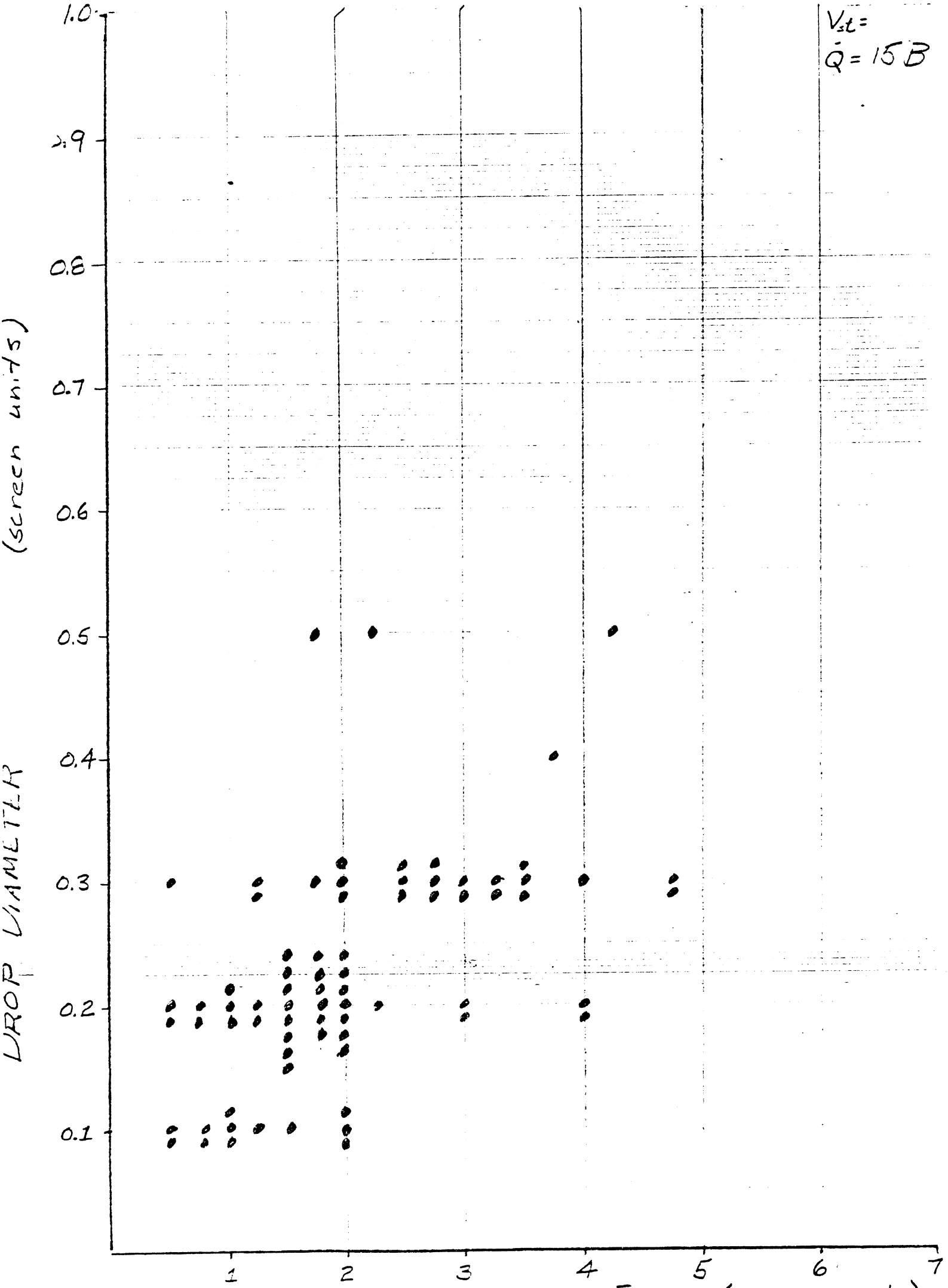
2x4

$V_{st} =$ A.
 $\dot{Q} = 15A$ %



DROP DIAMETER vs. DISTANCE

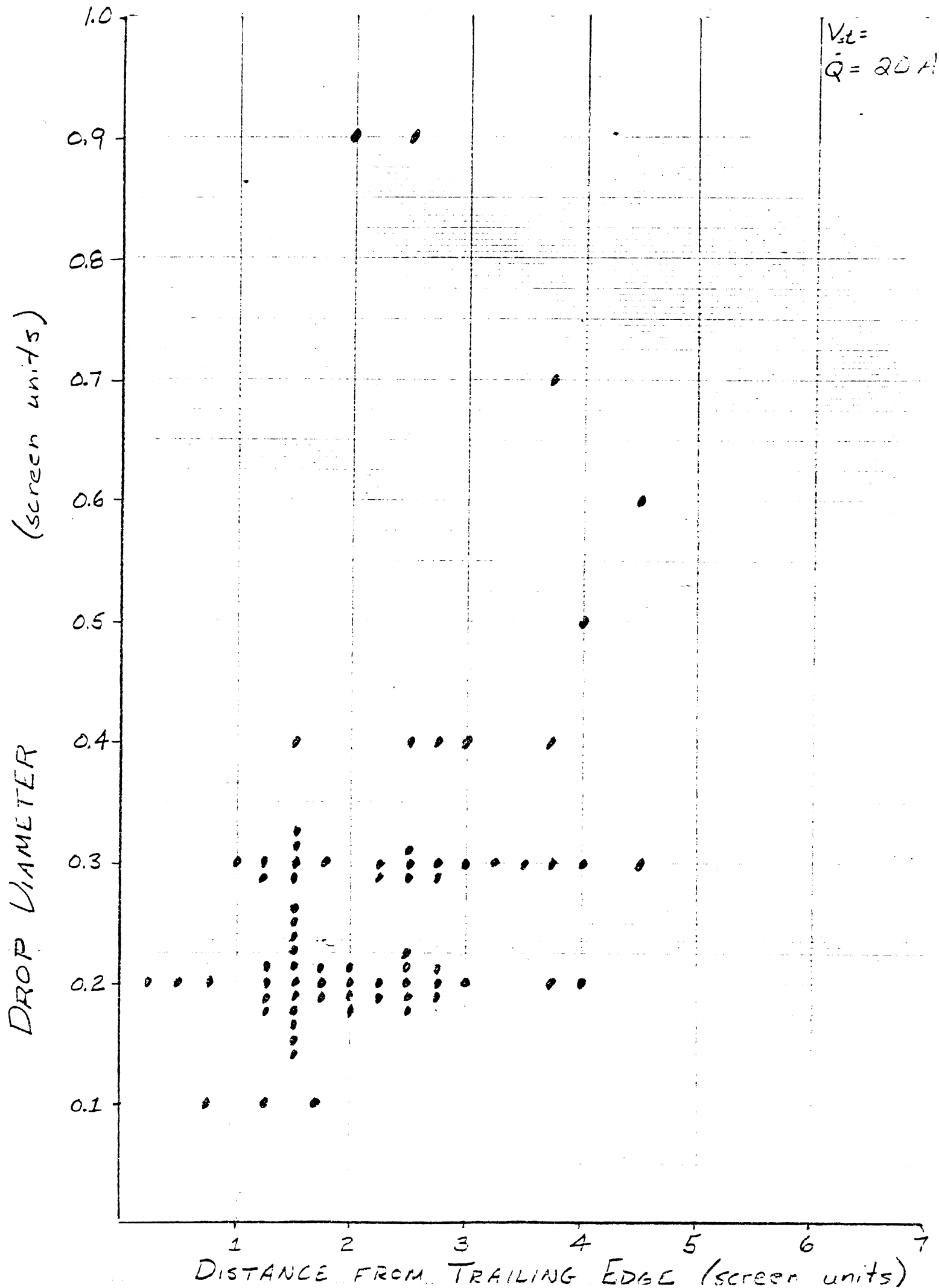
$V_{st} =$
 $\bar{Q} = 15B$



DROP DIAMETER VS. DISTANCE

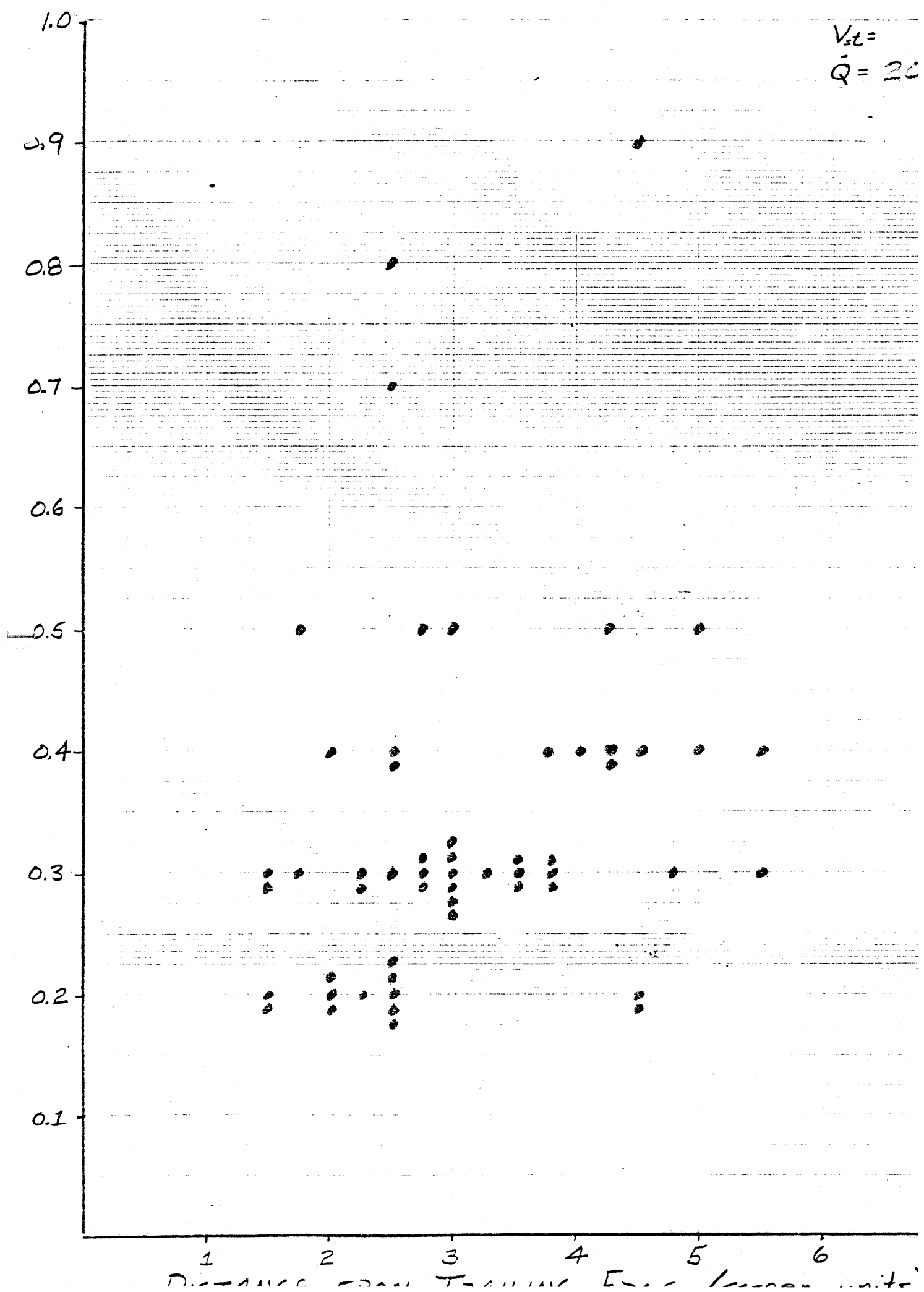
.2x4.

$V_{st} =$
 $\dot{Q} = 20 A$



DROP DIAMETER VS. DISTANCE

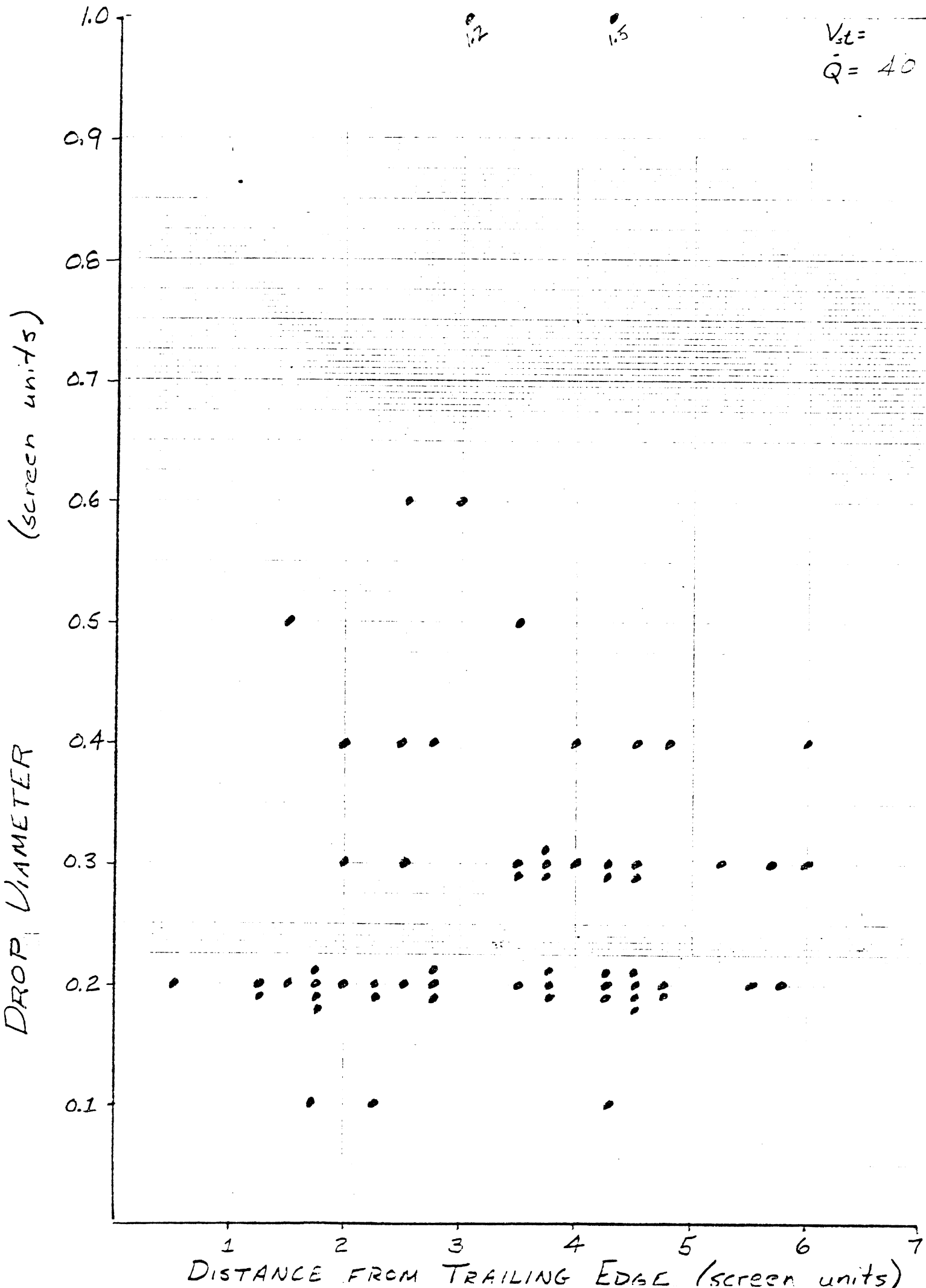
$V_{st} =$
 $\bar{Q} = 20$



DROP DIAMETER VS. DISTANCE

2495

$V_{st} =$
 $\dot{Q} = 40$



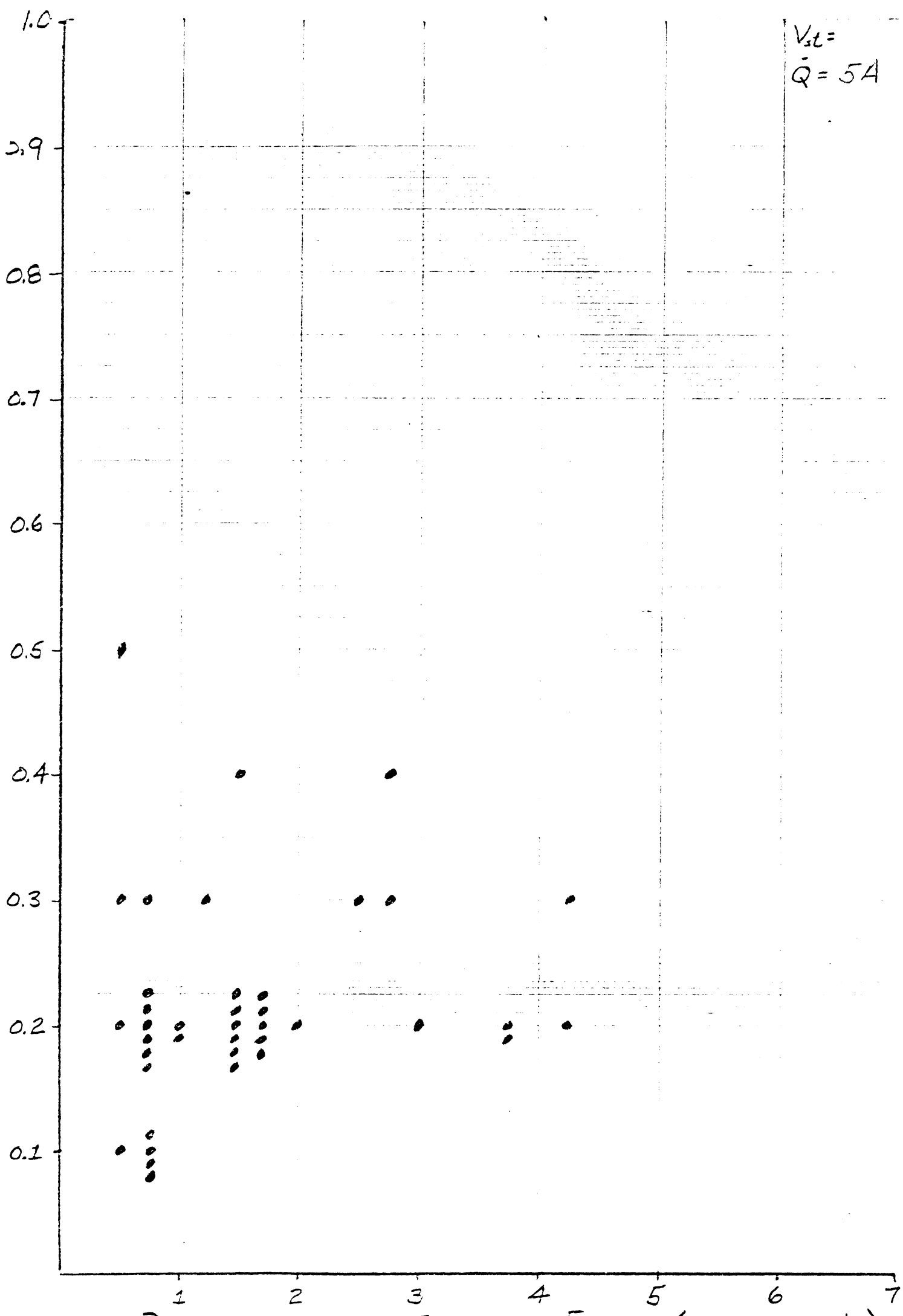
APPENDIX B

MAXIMUM DROP DIAMETER VS. TIME

DROP DIAMETER VS. DISTANCE

$V_{st} =$
 $\bar{Q} = 5A$

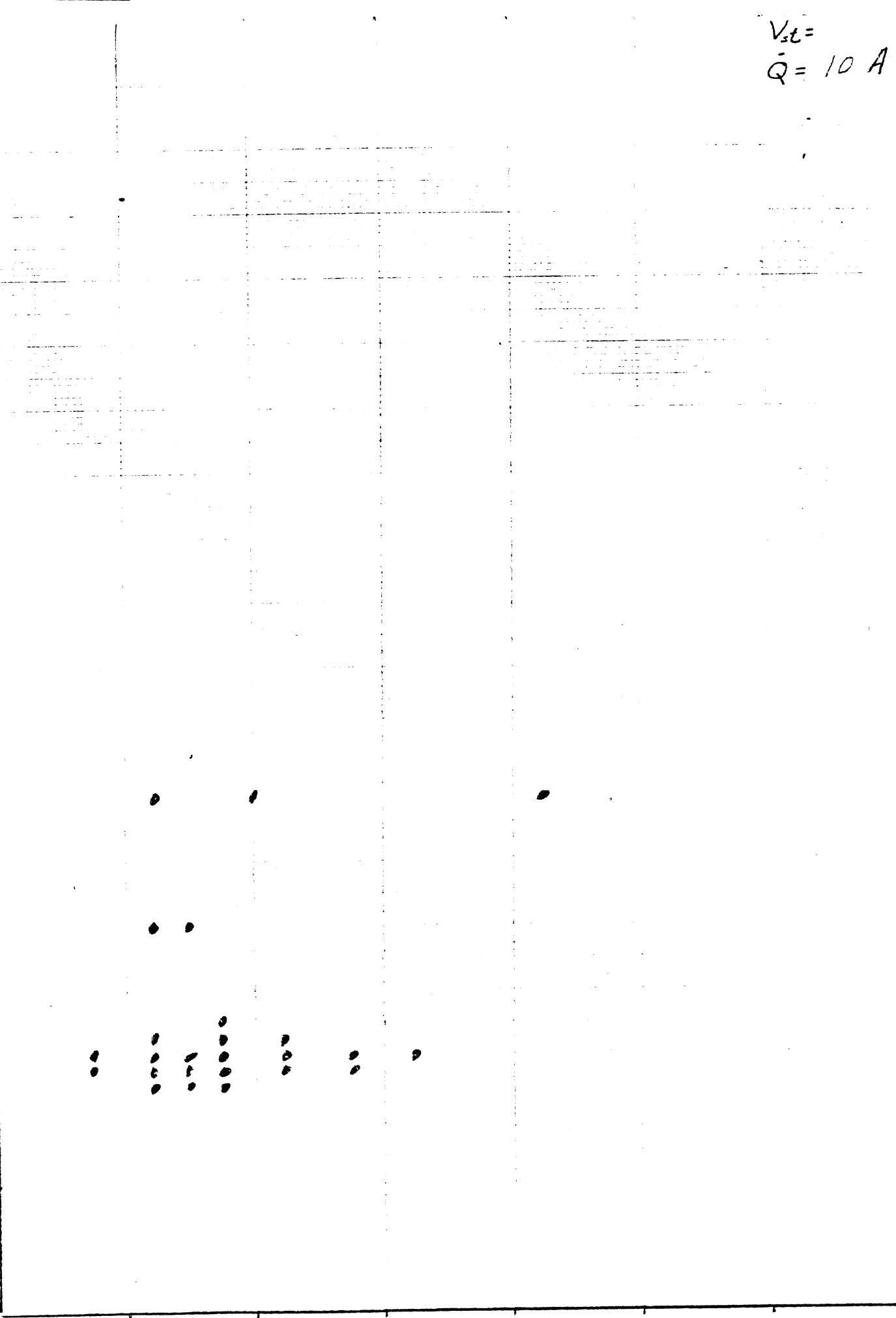
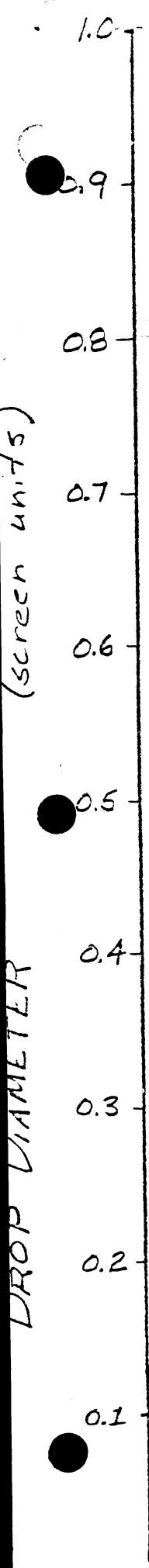
DROP DIAMETER
(screen units)



DROP DIAMETER VS. DISTANCE

$V_{st} =$
 $\bar{Q} = 10 A$

DROP DIAMETER
(screen units)

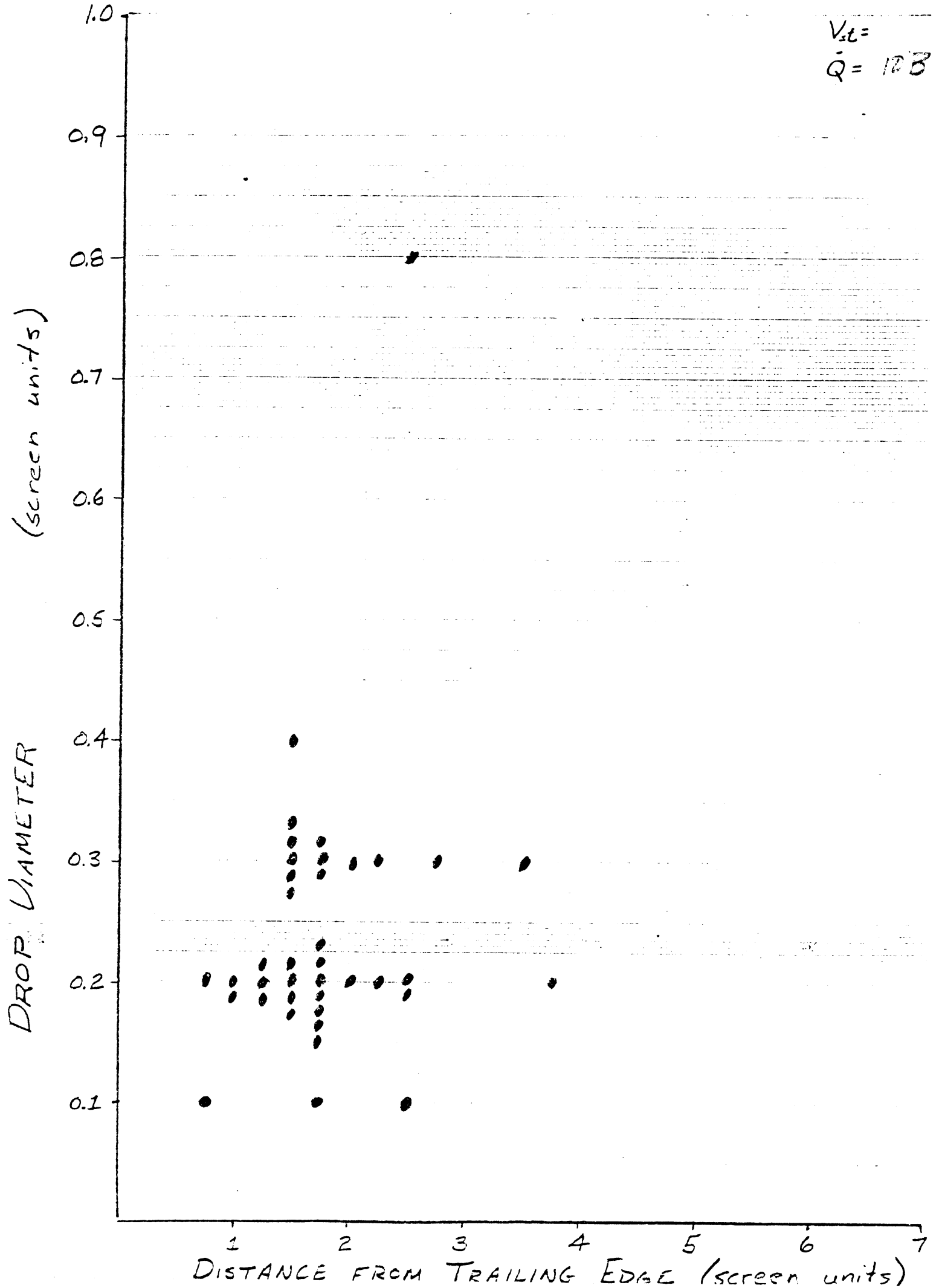


DISTANCE FROM TRAILING EDGE (screen units)

DROP DIAMETER VS. DISTANCE

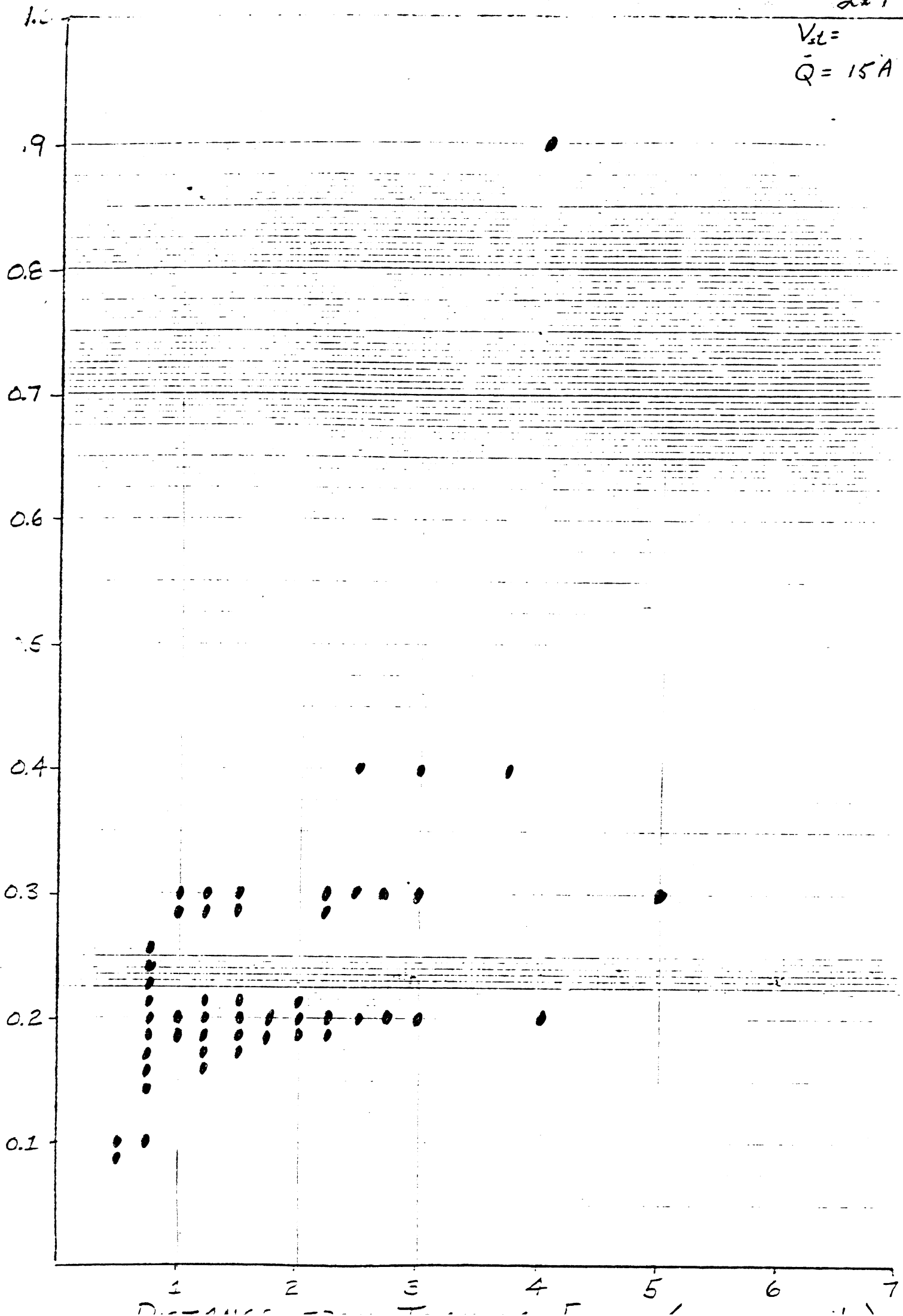
2-7

$V_{sl} =$
 $\dot{Q} = 108$



$V_{sl} =$
 $\bar{Q} = 15A$

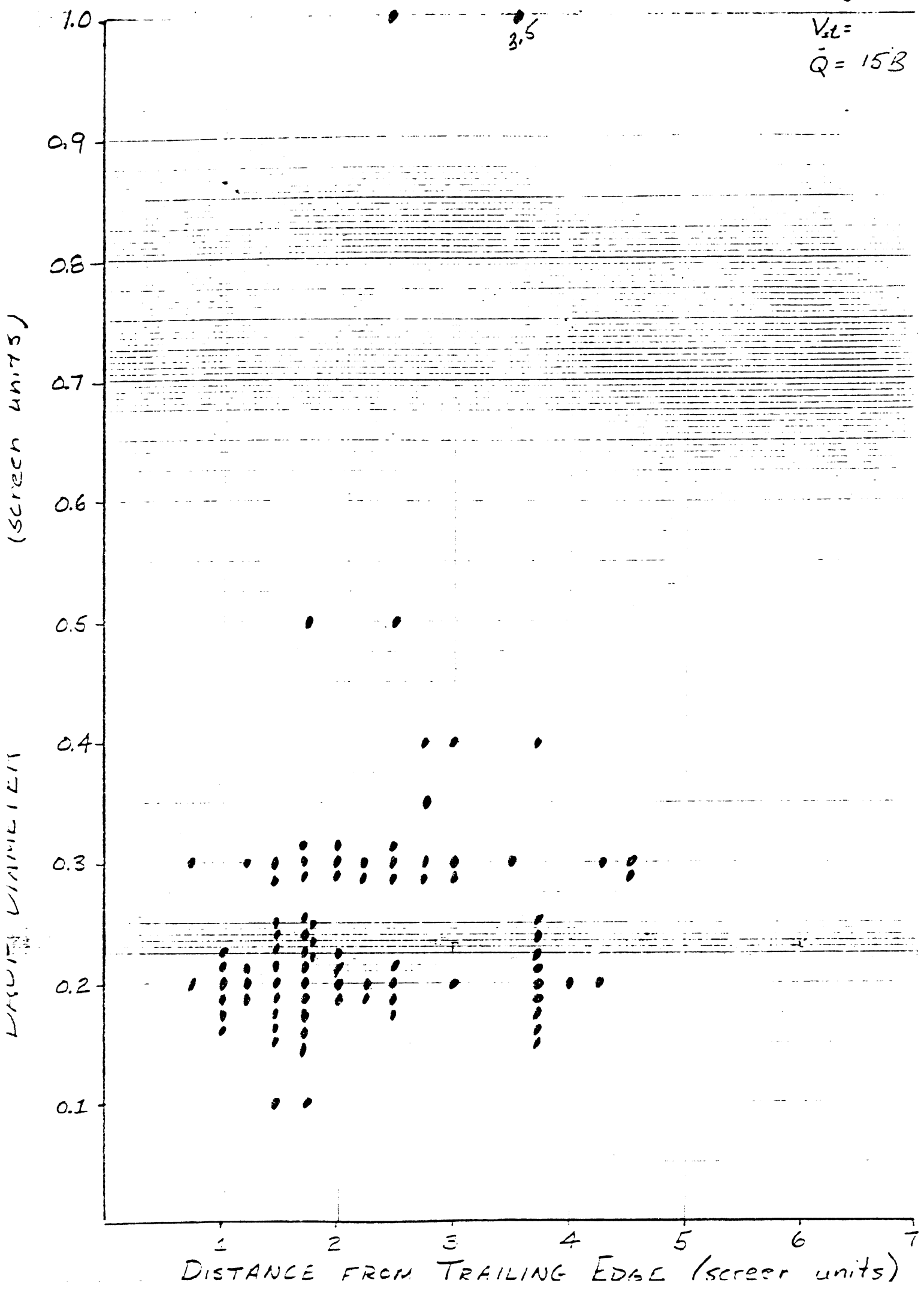
(Vertical axis label, partially cut off)

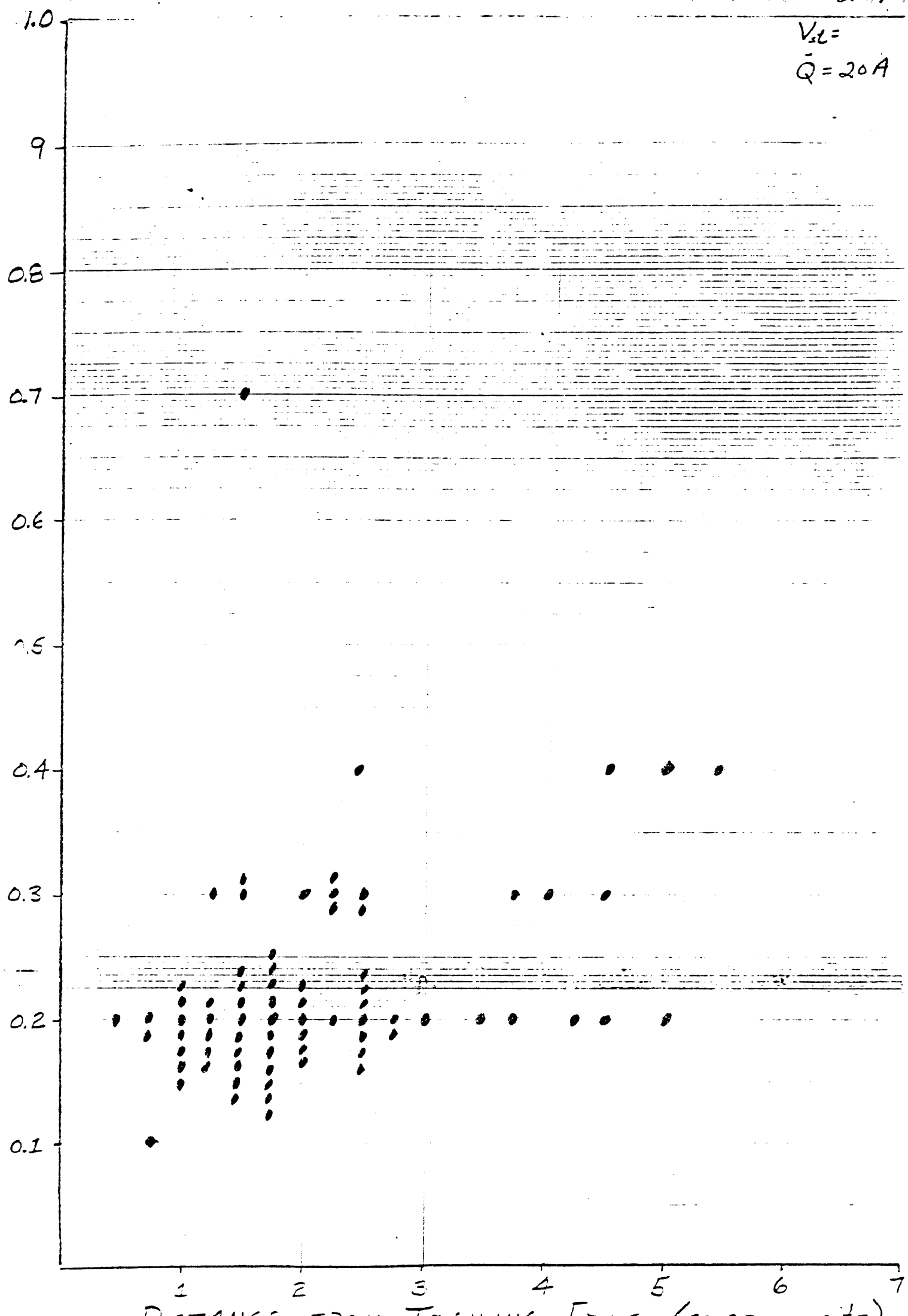


DROP DIAMETER vs. DISTANCE

2x7

$V_{SL} =$
 $\bar{Q} = 15B$



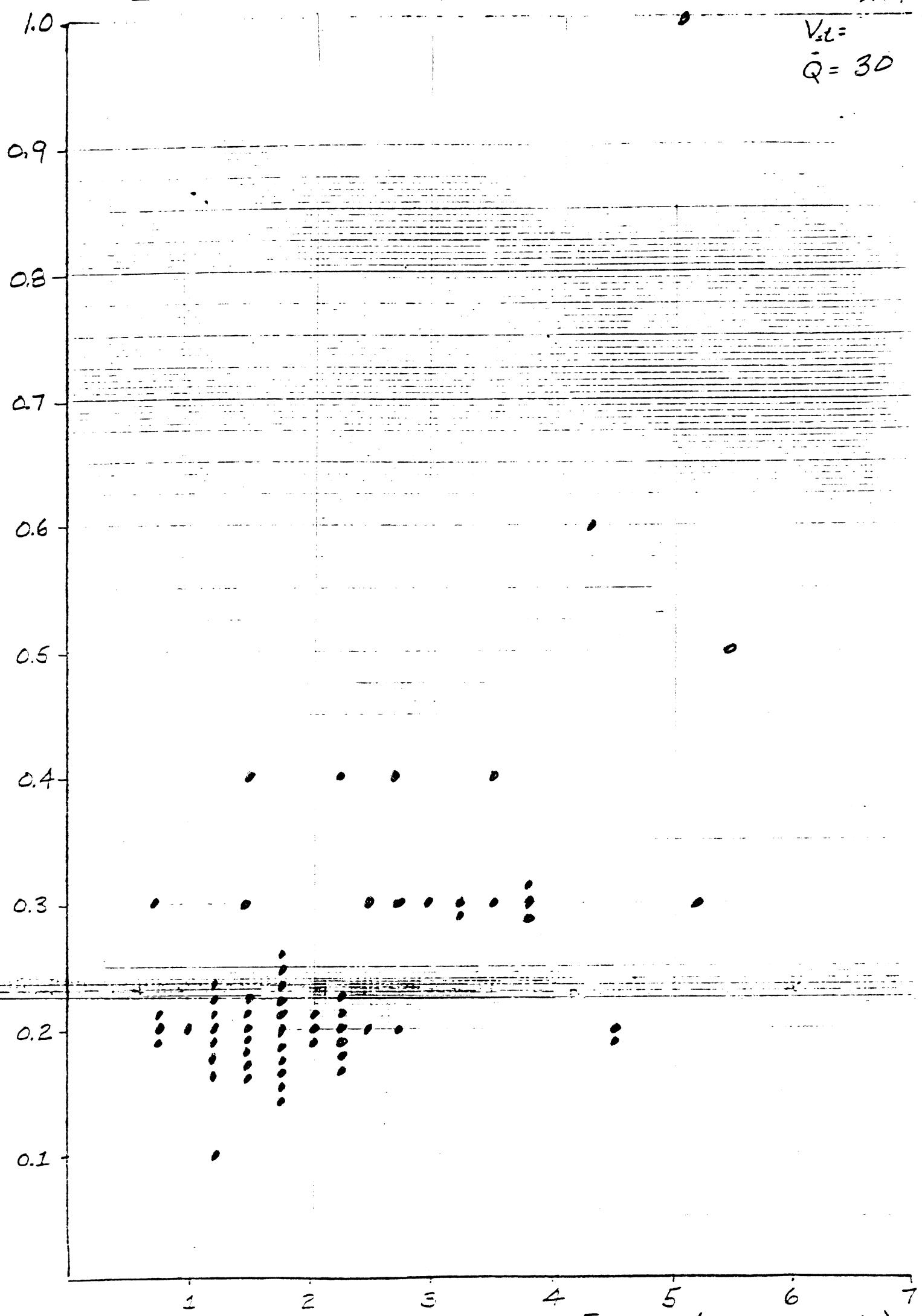


DROP DIAMETER vs. DISTANCE

2x7

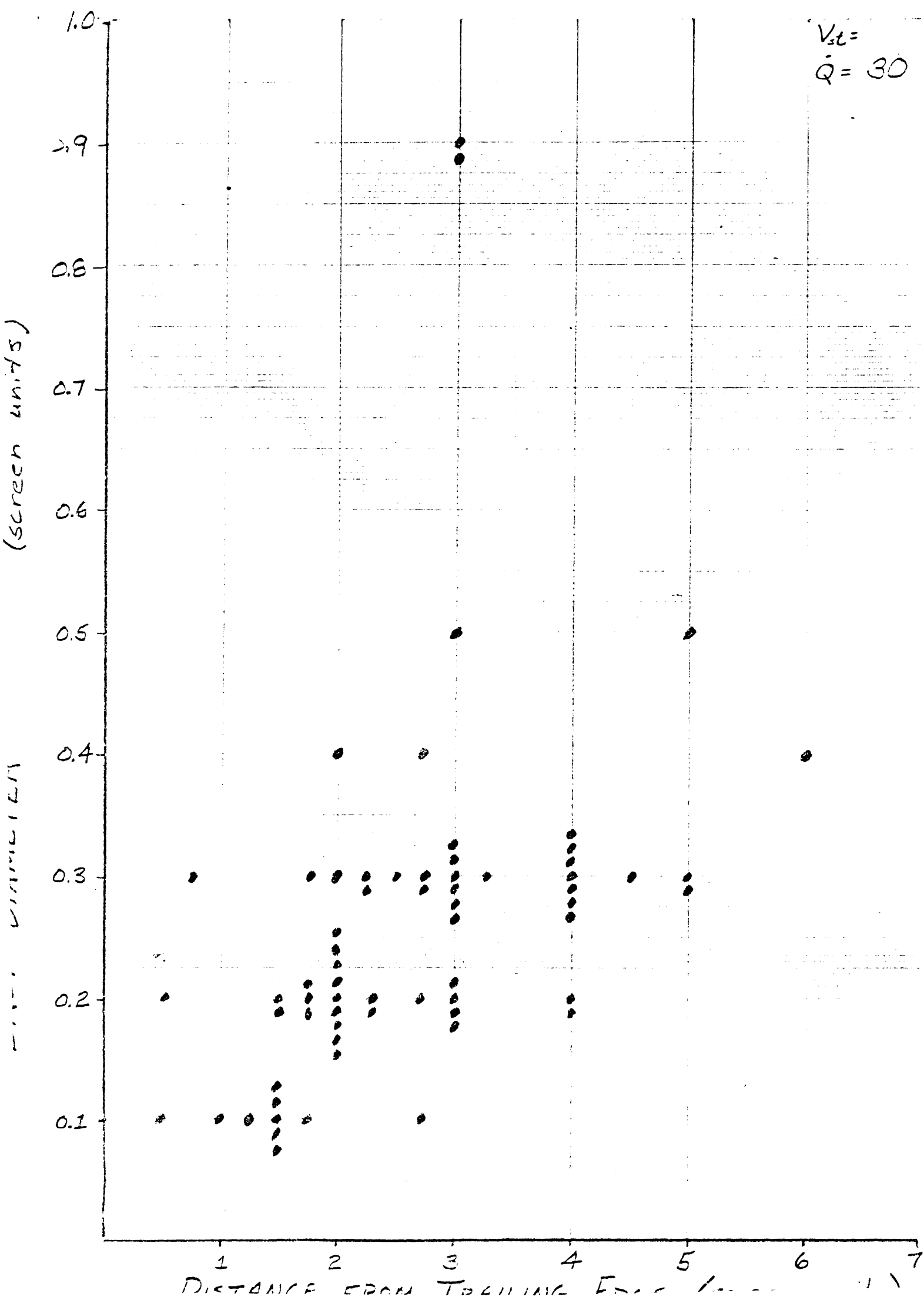
$V_{sl} =$
 $\bar{Q} = 30$

(SCREEN UNITS)



DISTANCE FROM TAPPING POINT (SCREEN UNITS)

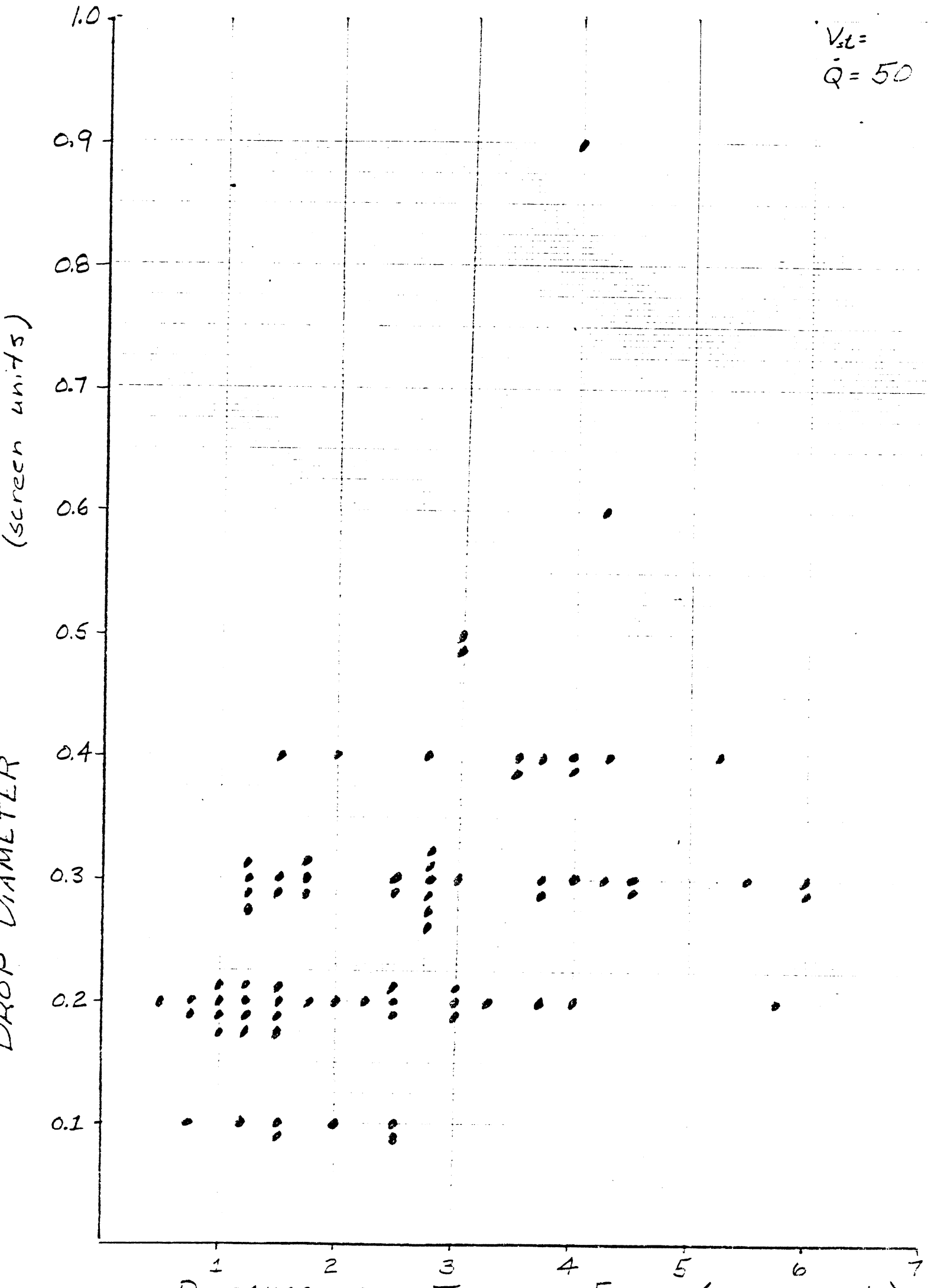
$V_{st} =$
 $\dot{Q} = 30$



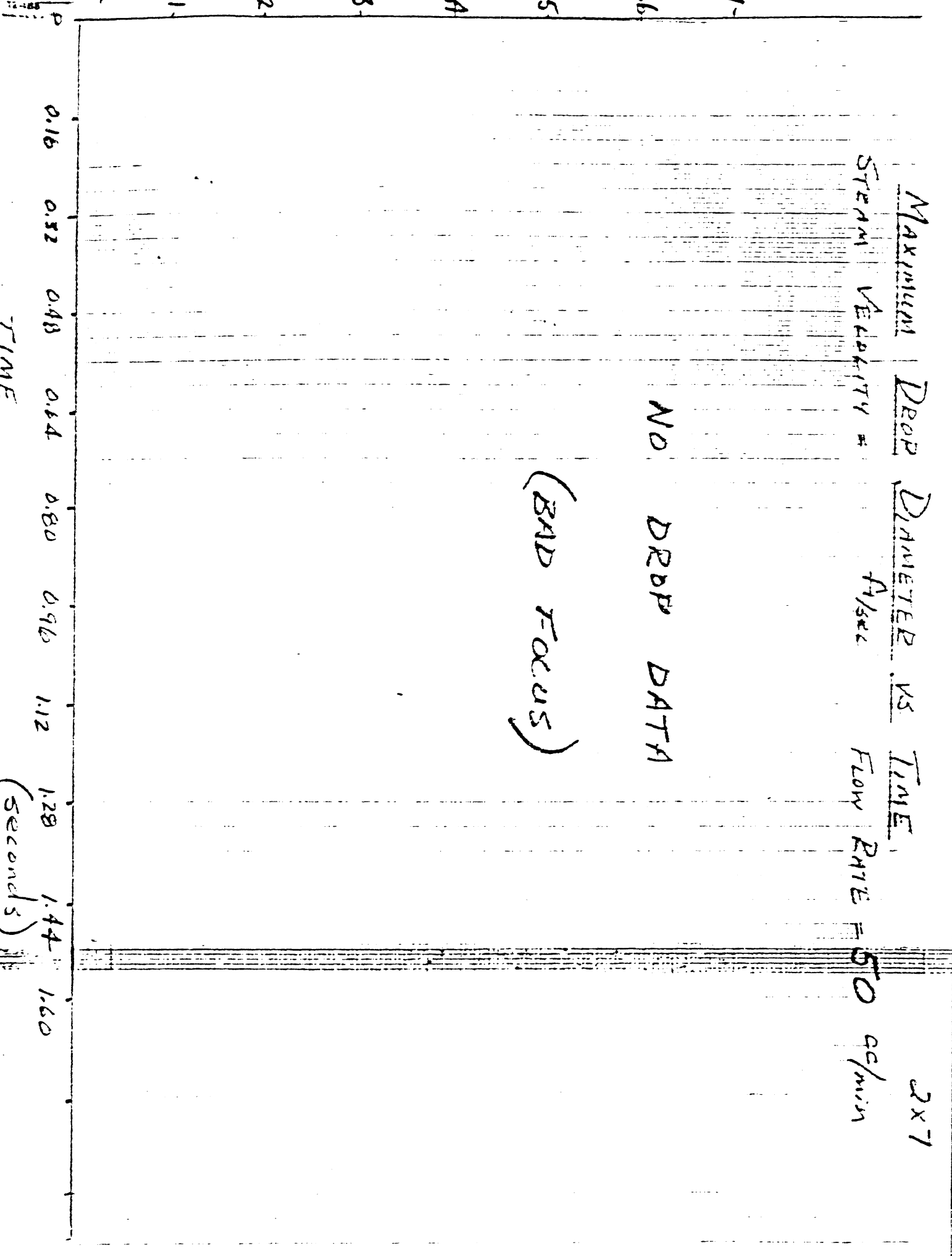
DROP DIAMETER VS. DISTANCE

2x4

$V_{st} =$
 $\dot{Q} = 50$



MAX. DROP DIAMETER (screen units)



Maximum Drop Diameter vs Time
Stream Velocity # Flow Rate = 50 cc/min
 # Flow Rate = 50 cc/min

NO DROP DATA

(BAD FOCUS)

2x7

TIME

(seconds)

0.16 0.52 0.88 0.64 0.80 0.96 1.12 1.28 1.44 1.60

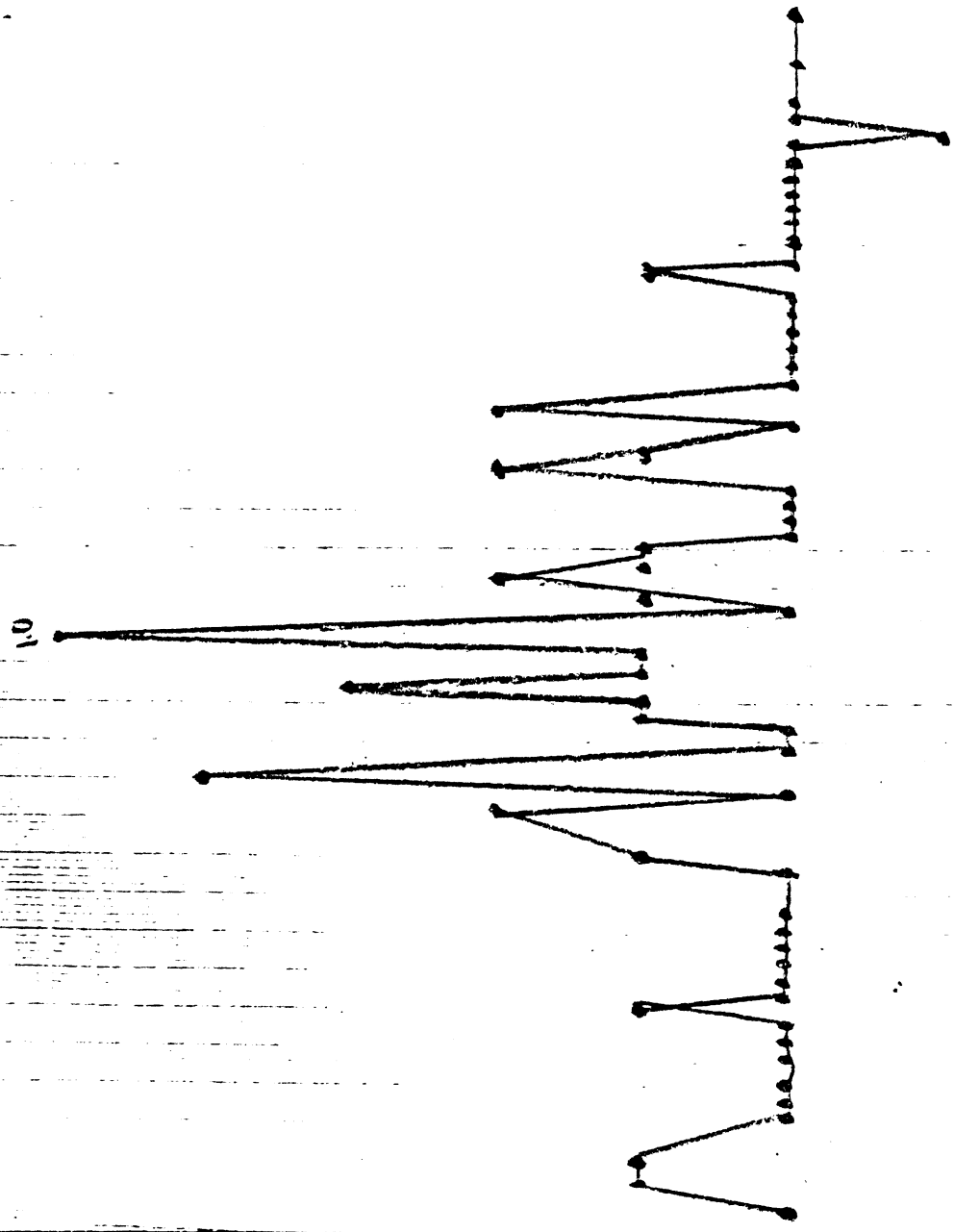
MAXIMUM VELOCITY =

DIAMET. VS. TIME

FLOW RATE = 30 cc/min

STREAM VELOCITY =

MAX. DROP DIAMETER (Screen units)

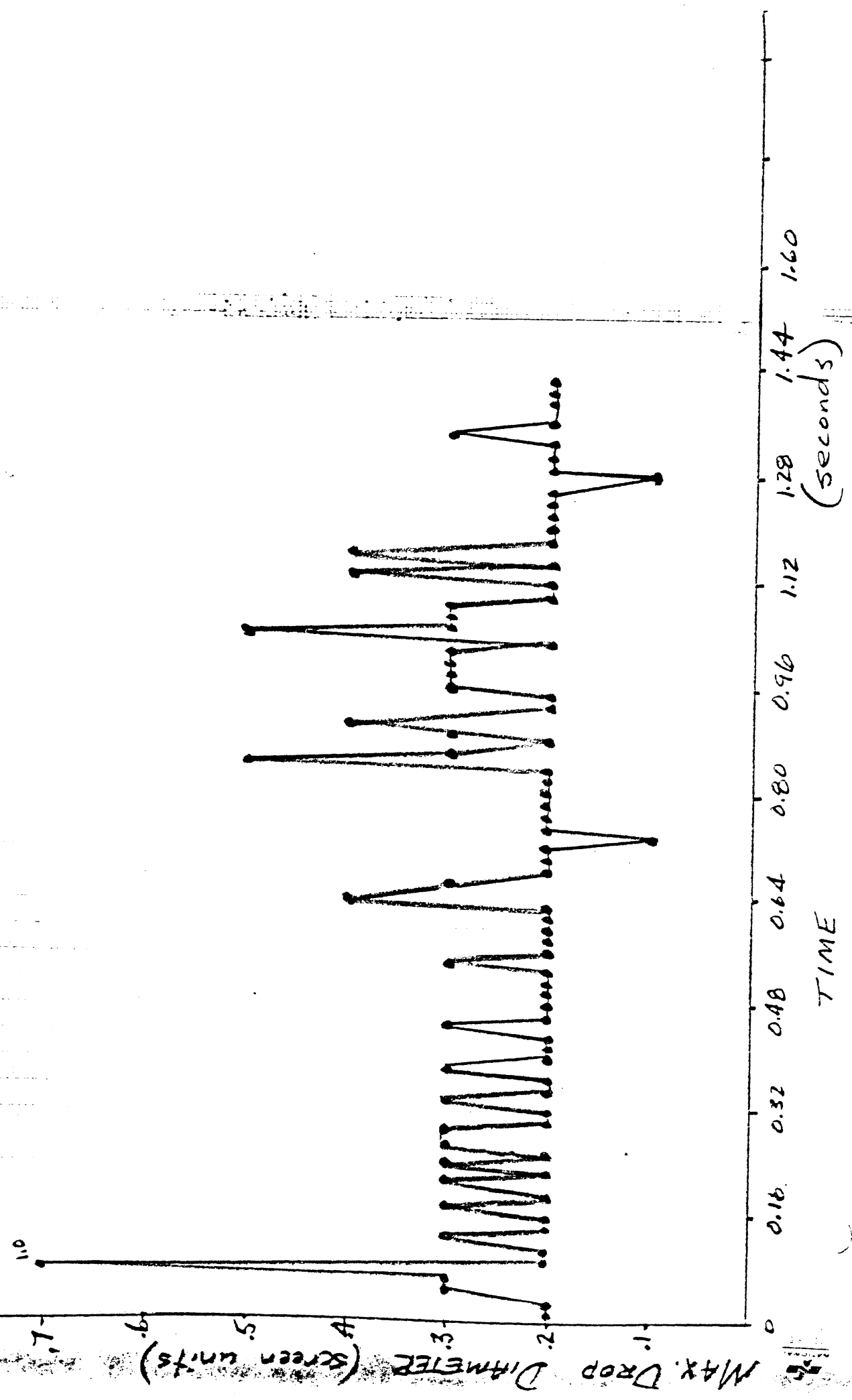


0.16 0.32 0.48 0.64 0.80 0.96 1.12 1.28 1.44 1.60
TIME (seconds)

MAXIMUM DROP DIAMETER VS TIME

STEAM VELOCITY = f /sec

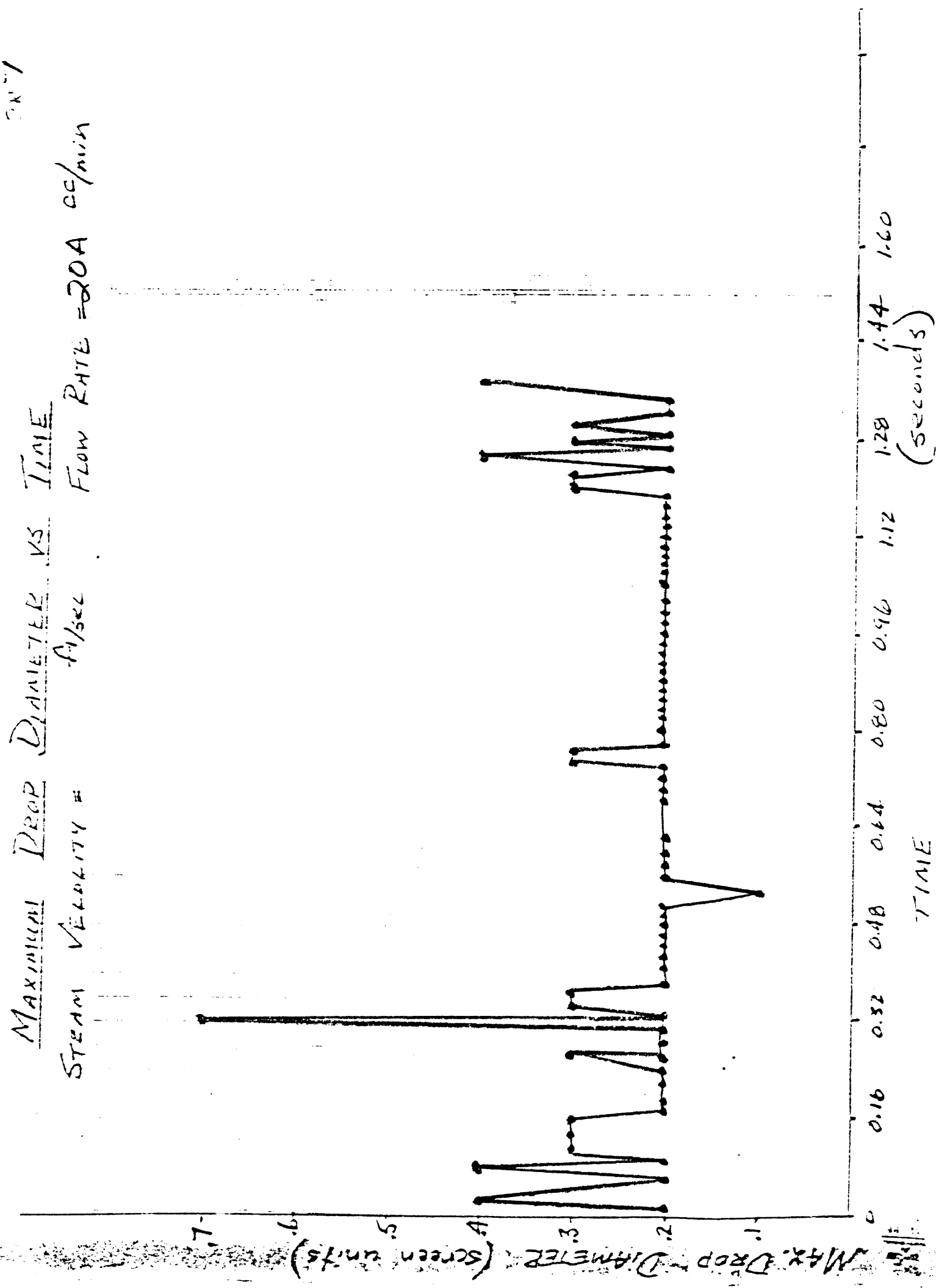
FLOW RATE = 15 B cc/min



2071

MAXIMUM DROP DIAMETER VS TIME

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

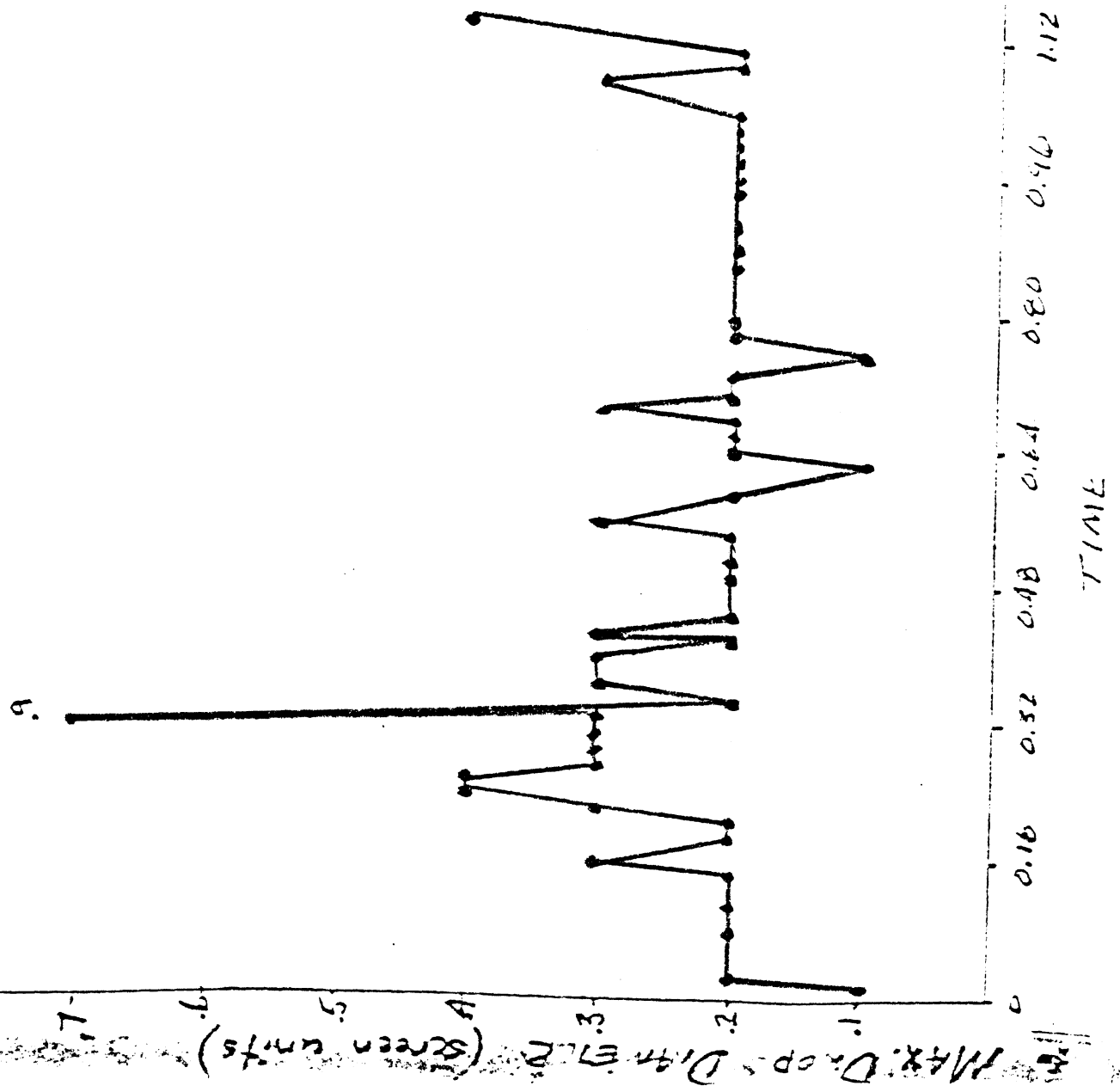


201

STEAM VELOCITY = 15A cc/min

VS TIME

FLOW RATE = 15A cc/min



TIME

(Seconds)

2x7

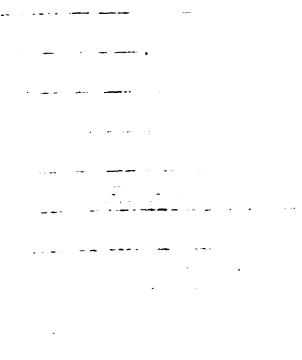
MAXIMUM DROP DIAMETER VS TIME

Flow Rate = 108 cc/min

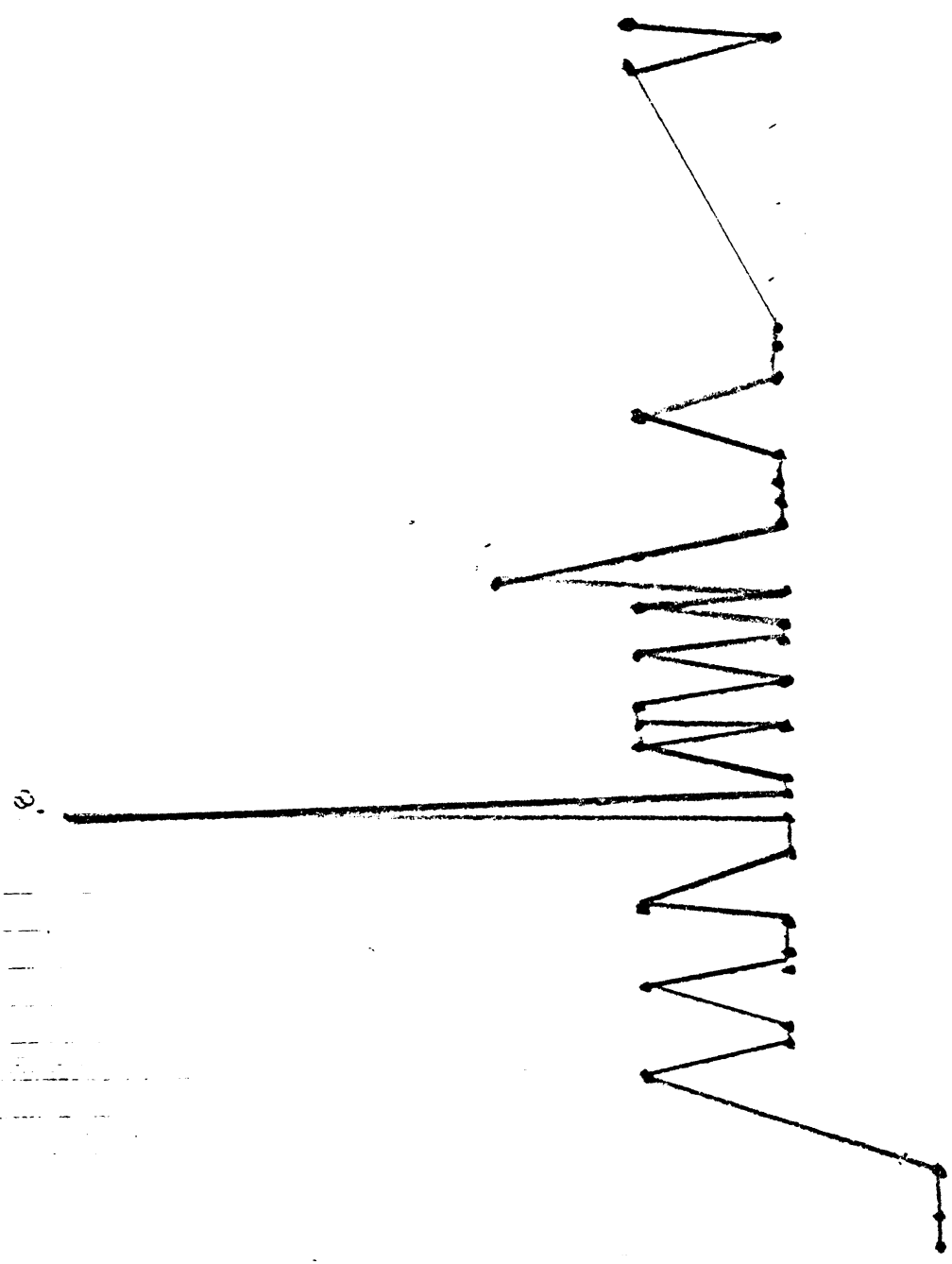
A/sec

Flow Rate = 108

Stream Velocity =



e.

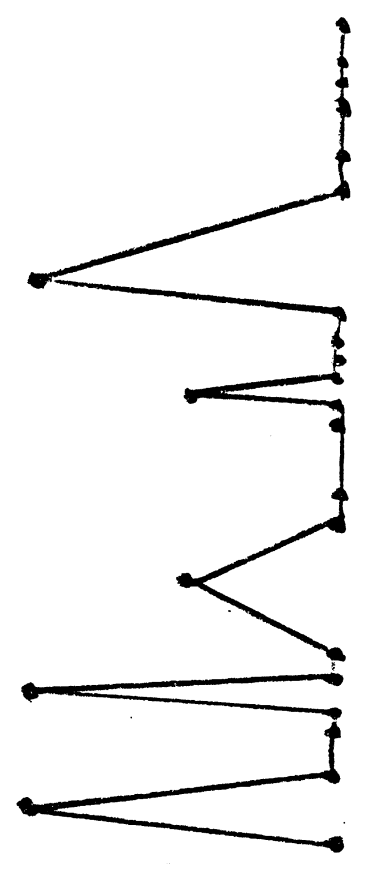


0.16 0.32 0.48 0.64 0.80 0.96 1.12 1.28 1.44 1.60
 (seconds)

TIME

MAXIMUM PROP DIAMETER VS TIME 2x7
 STREAM VELOCITY = f/sec FLOW RATE = 10A cc/min

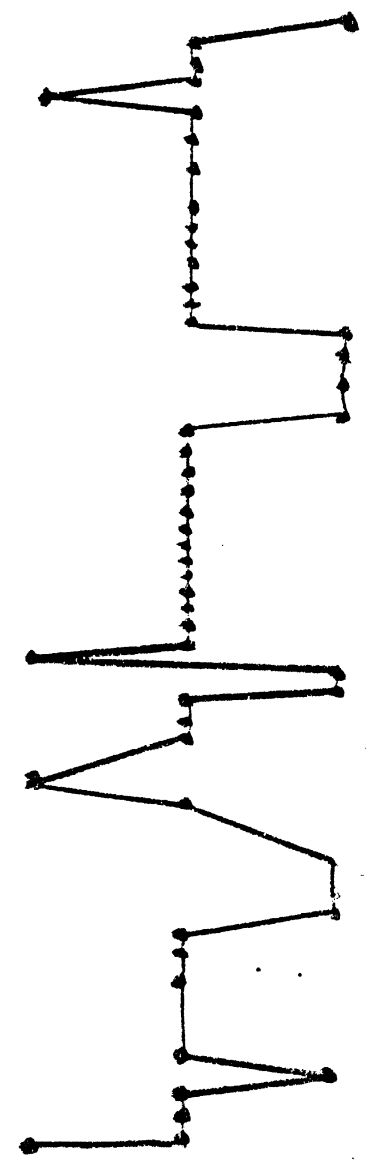
MAX. DROP DIAMETER (screen units)



0.16 0.32 0.48 0.64 0.80 0.96 1.12 1.28 1.44 1.60
 TIME (seconds)

MAXIMUM PROP DIAMETER VS TIME
 STREAM VELOCITY = ft/sec
 FLOW RATE = 58 cc/min

MAX. PROP. DIAMETER (SCREEN IN.)

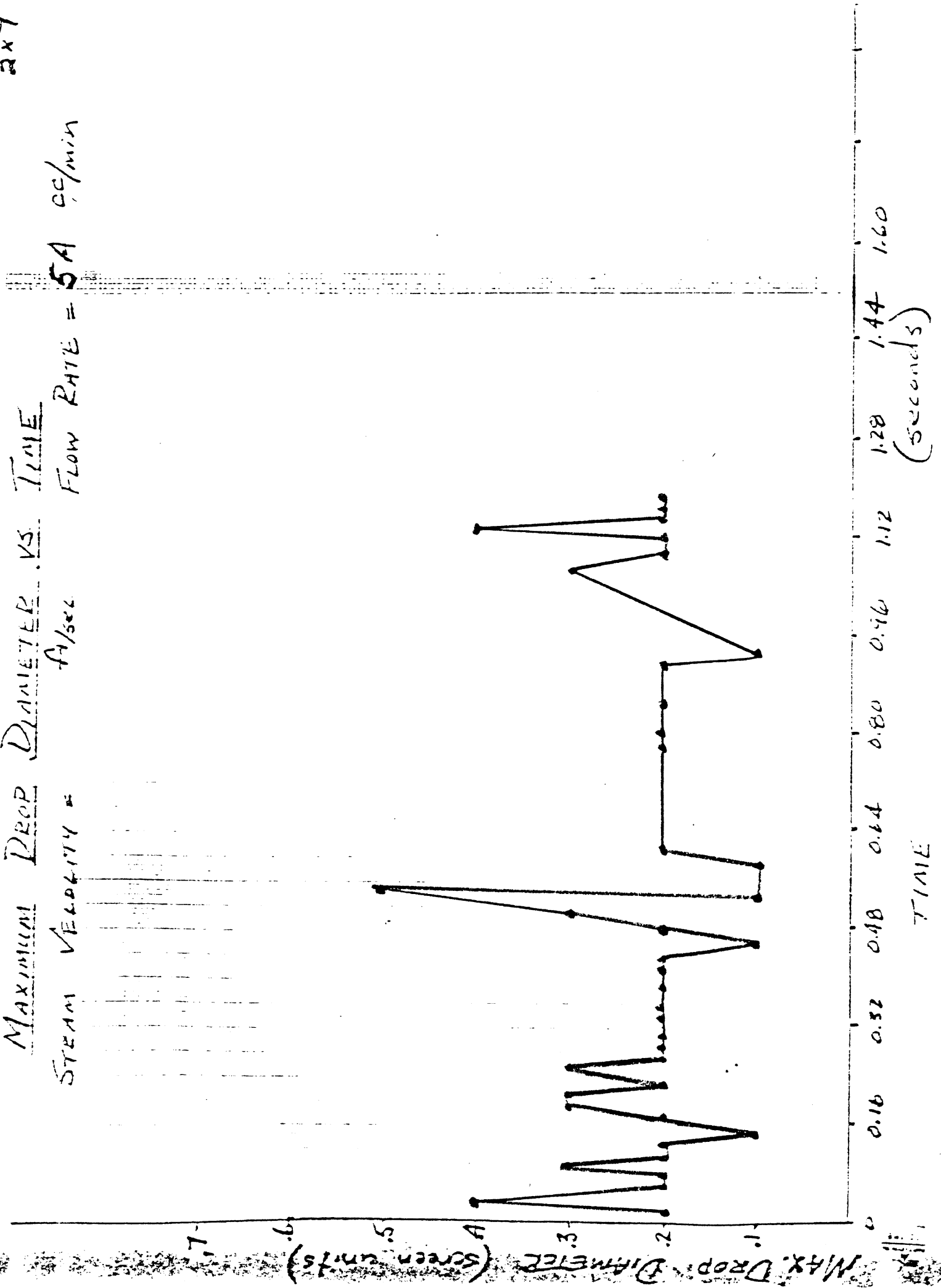


TIME (seconds)

2x7

MAXIMUM DROP DIAMETER VS. TIME

STREAM VELOCITY = f/sec FLOW RATE = 5A cc/min



2 x 10

cc/min

FLOW RATE = 0

DIAMETER VS. TIME

MAXIMUM DROP VELOCITY #

(NO DROPS)

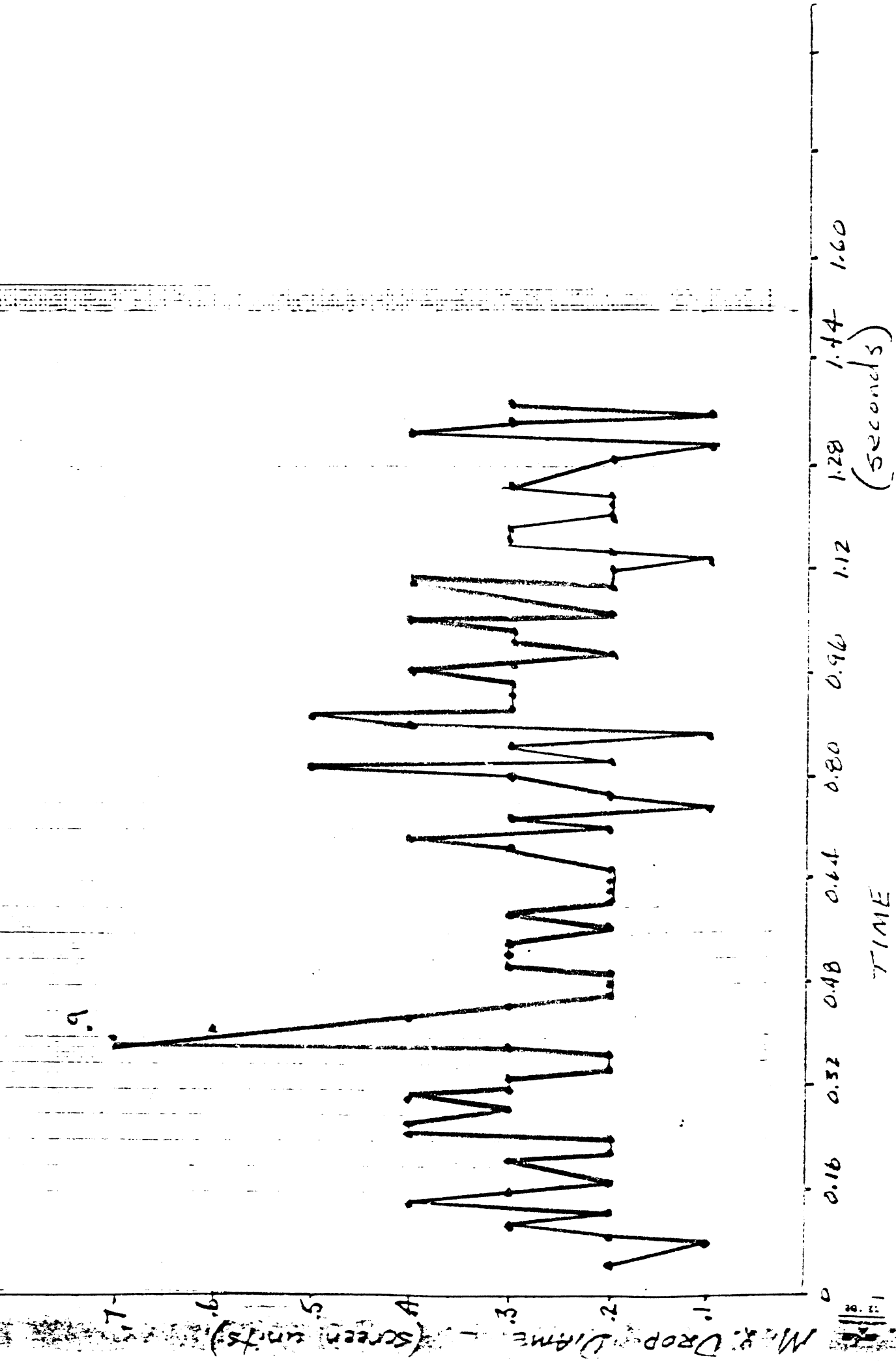
0.32	0.48	0.64	0.80	0.96	1.12	1.28	1.44	1.60
TIME (seconds)								

11

2x4

MAXIMUM DROP DIAMETER VS TIME

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

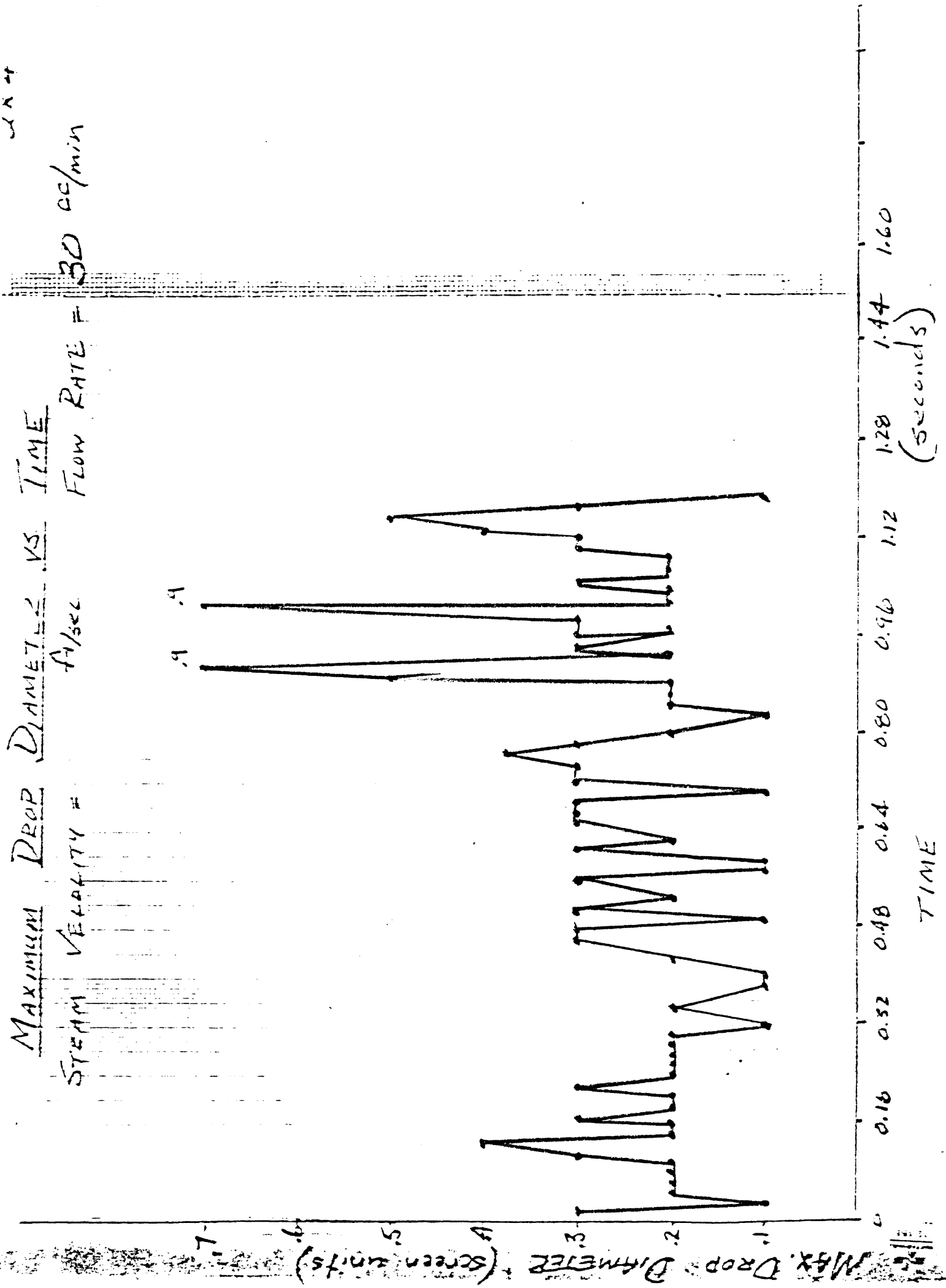


LN-4

MAXIMUM DROP DIAMETER VS TIME

FLOW RATE = 30 cc/min

STEAM VELOCITY = f/sec

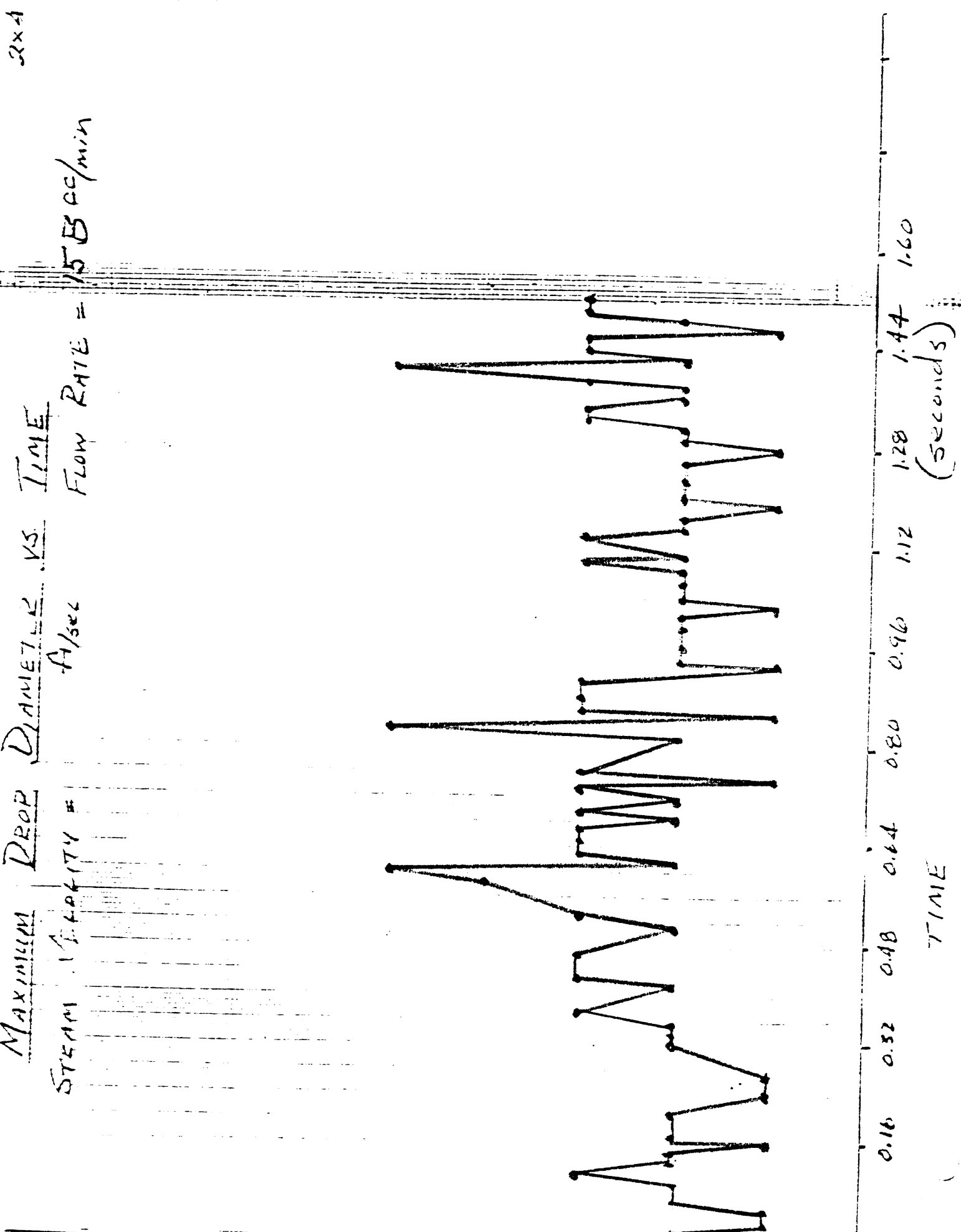


MAXIMUM DROP DIAMETER VS. TIME
STEAM VELOCITY = 1500 ft/min

MAXIMUM DROP DIAMETER VS. TIME
FLOW RATE = 1500 cc/min

MAXIMUM DROP DIAMETER VS. TIME
STEAM VELOCITY #

MAX. DROP DIAMETER (SCREEN UNITS)



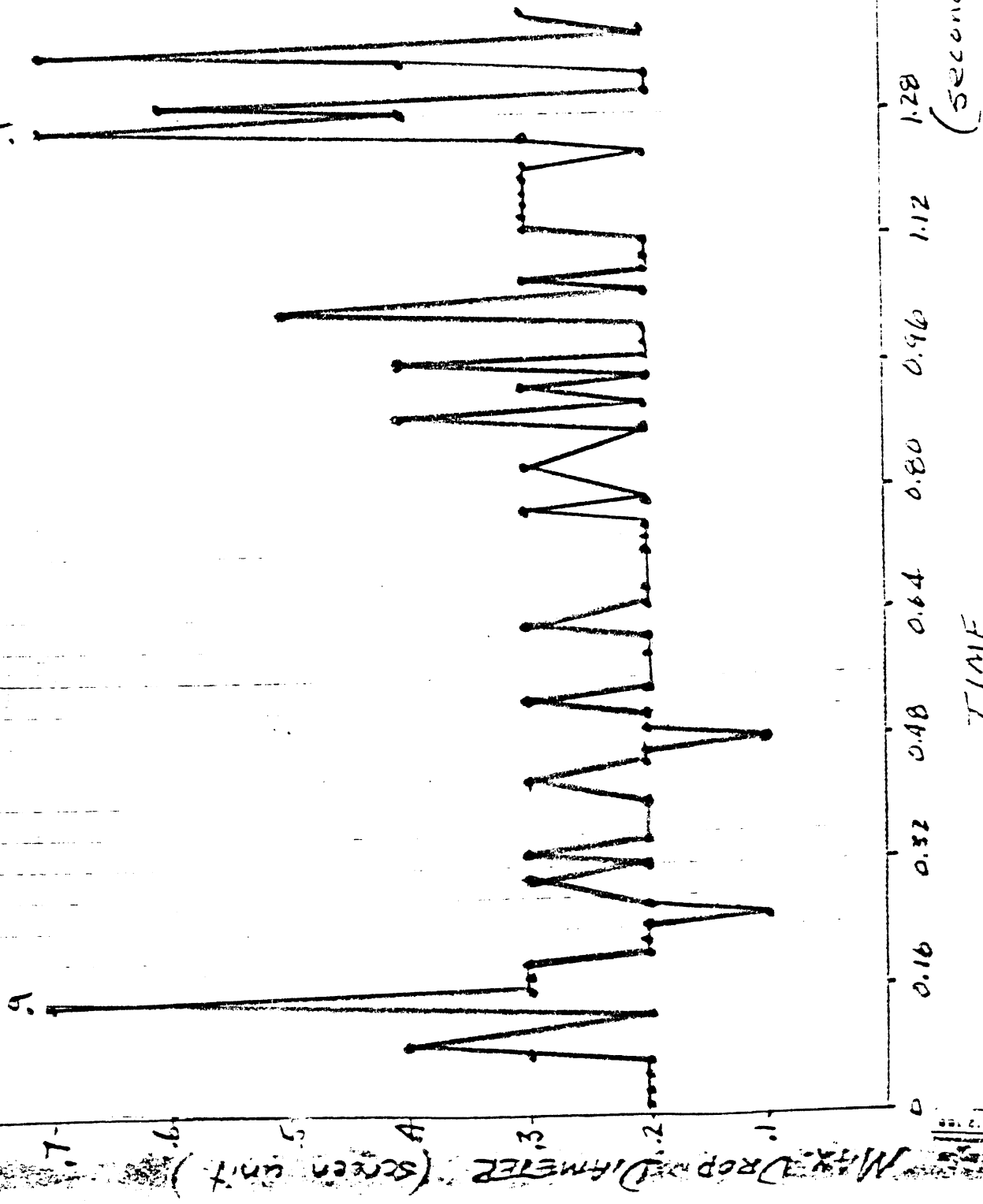
2x1

MAXIMUM DROP DIAMETER VS. TIME

STEAM VELOCITY =

f/sec

FLOW RATE = 20A cc/min



2x4

MAXIMUM DROP DIAMETER VS. TIME

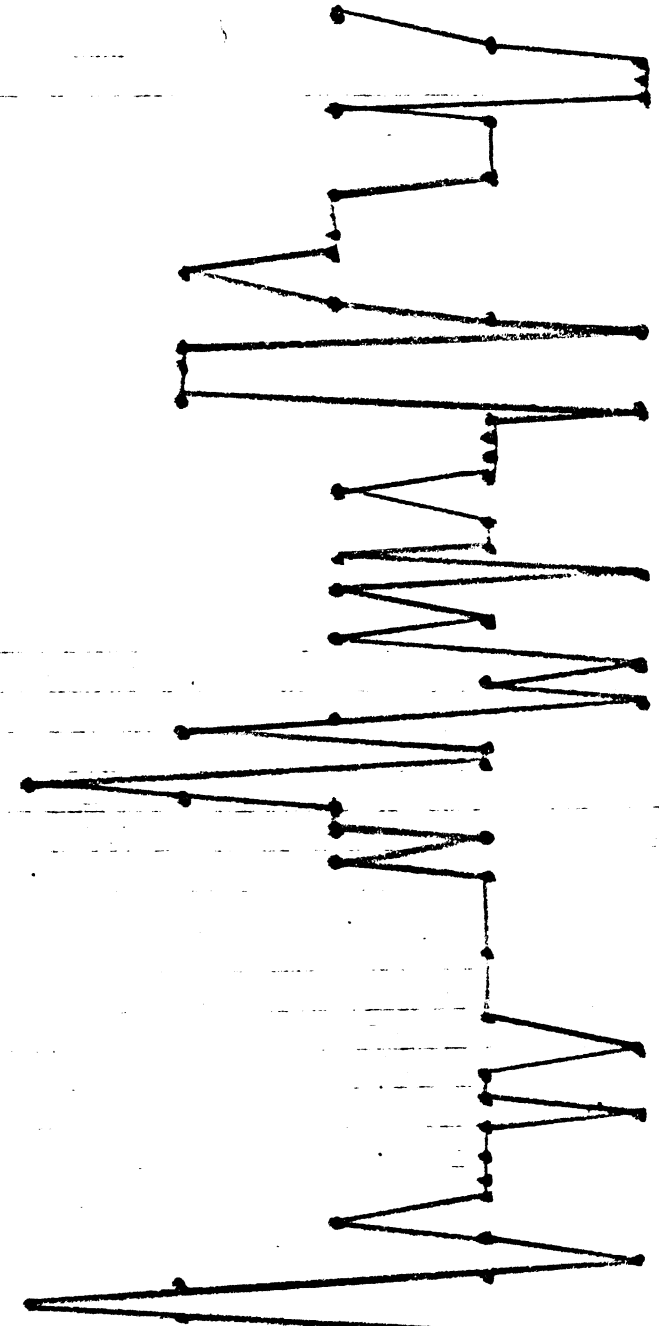
STREAM VELOCITY #

f/sec

FLOW RATE =

15A cc/min

MAX. DROP - DIAMETER (SCREEN UNIT) 5 4 3 2 1 0

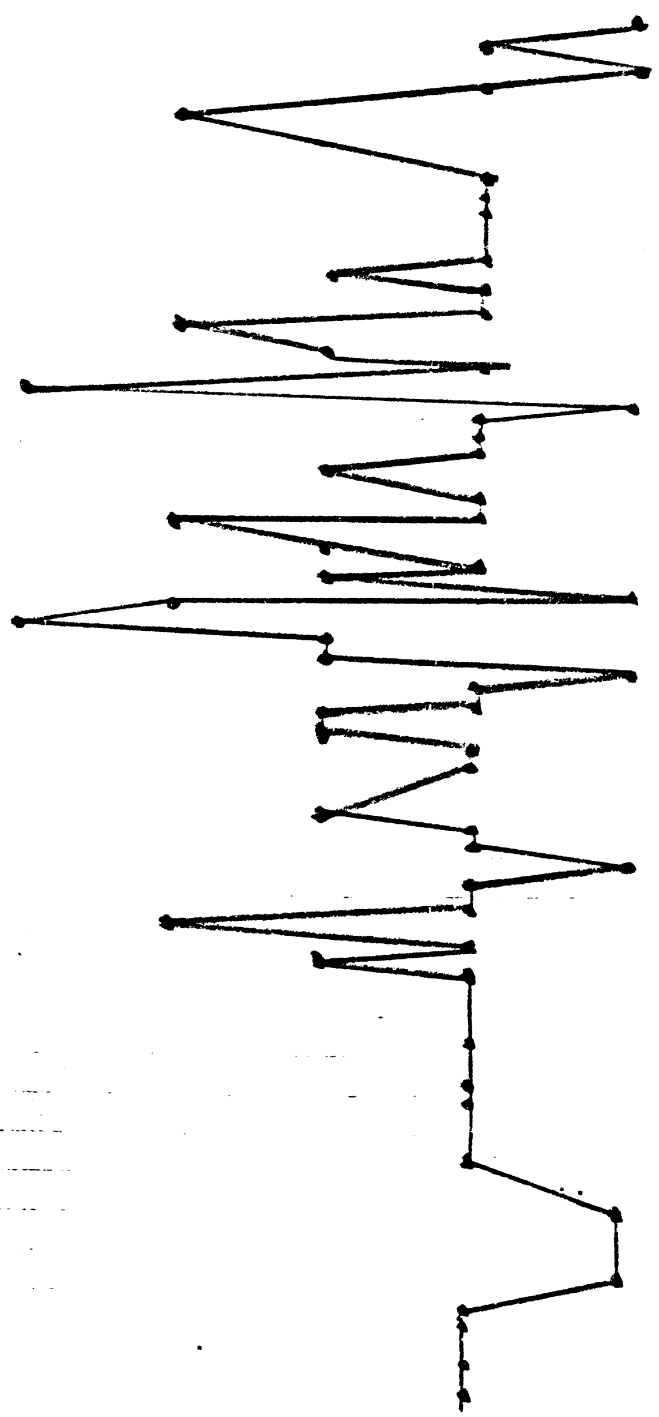


1.28 1.44 1.60
(seconds)

TIME

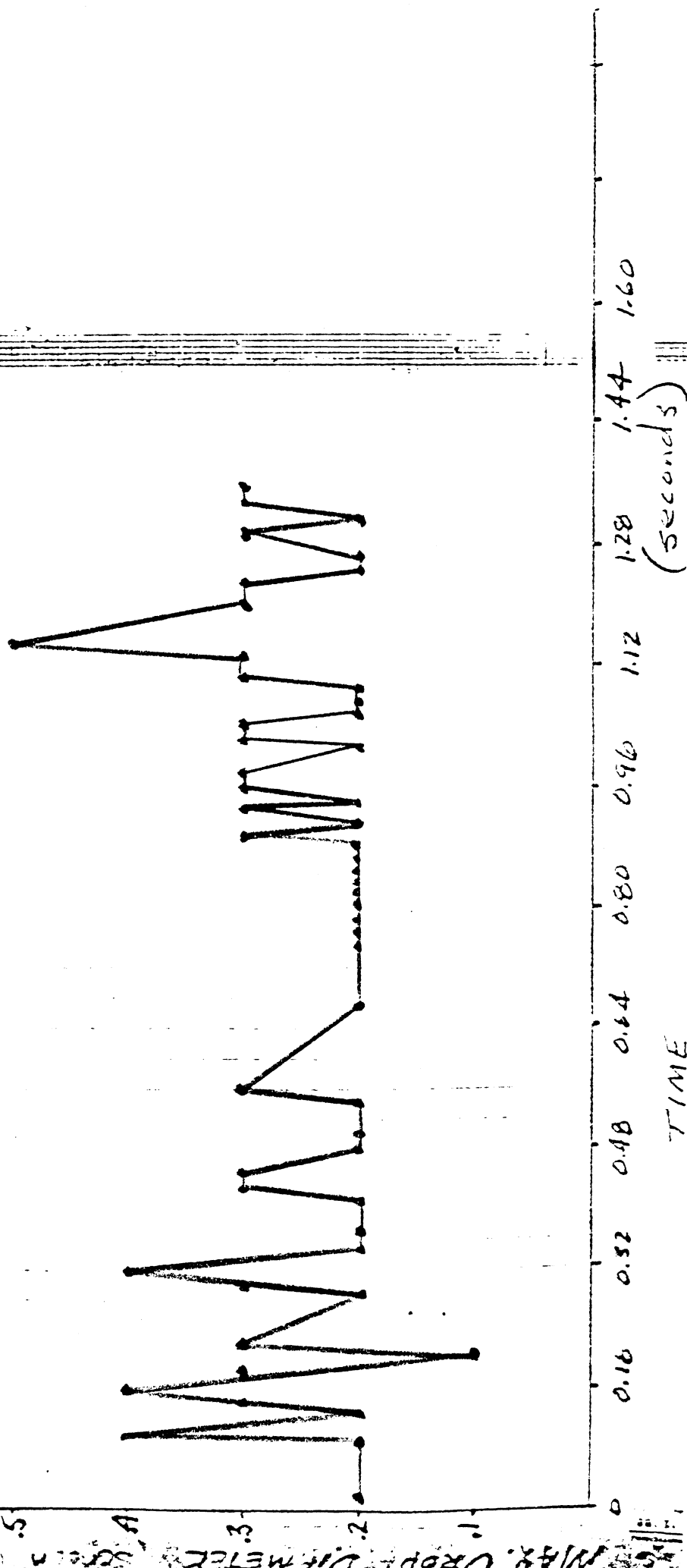
MAXIMUM PROP DIAMETER VS TIME
 2x4
 STREAM VELOCITY = ft/sec
 FLOW RATE = 108 cc/min

1
 2
 3
 4
 5
 6
 7
 8
 9
 10
 11
 12
 13
 14
 15
 16
 17
 18
 19
 20
 21
 22
 23
 24
 25
 26
 27
 28
 29
 30
 31
 32
 33
 34
 35
 36
 37
 38
 39
 40
 41
 42
 43
 44
 45
 46
 47
 48
 49
 50
 51
 52
 53
 54
 55
 56
 57
 58
 59
 60
 61
 62
 63
 64
 65
 66
 67
 68
 69
 70
 71
 72
 73
 74
 75
 76
 77
 78
 79
 80
 81
 82
 83
 84
 85
 86
 87
 88
 89
 90
 91
 92
 93
 94
 95
 96
 97
 98
 99
 100



TIME (seconds)

MAXIMUM DROP DIAMETER VS. TIME
 STEAM VELOCITY = f/sec
 FLOW RATE = 10 A cc/min
 2 x 4



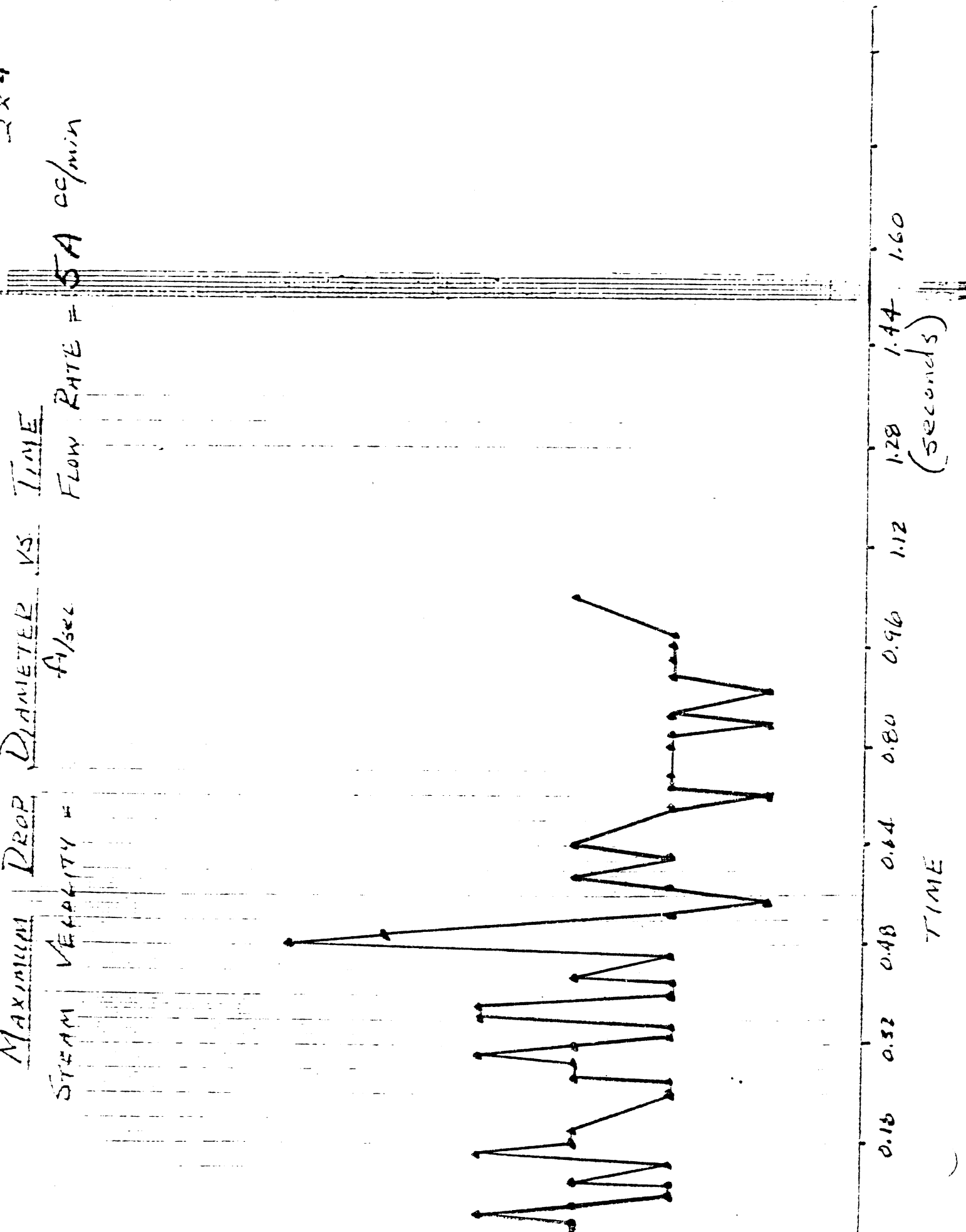
2x4

MAXIMUM DROP DIAMETER VS. TIME

FLOW RATE = 5A cc/min

STREAM VELOCITY = f/sec

MAX. DROP DIAMETER (Screen. units)



TIME

(seconds)

2x4

MAXIMUM DROP DIAMETER VS TIME

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

(NO DROPS)

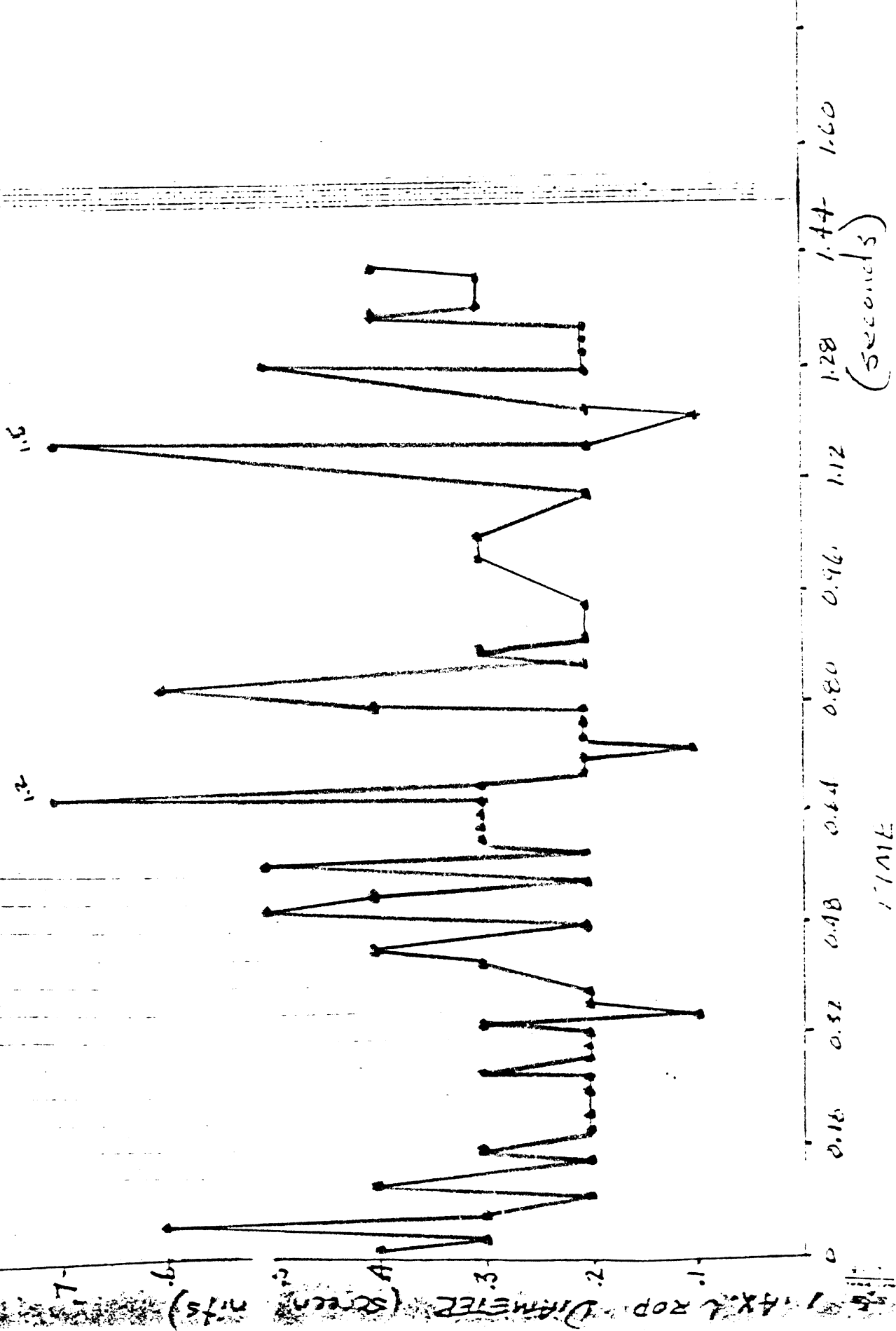
0.16	0.32	0.48	0.64	0.80	0.96	1.12	1.28	1.44	1.60
TIME (seconds)									

MAX. DROP DIAMETER IN cm (microns)

MAXIMUM DROP DIAMETER VS. TIME

FLOW RATE = 40 cc/min

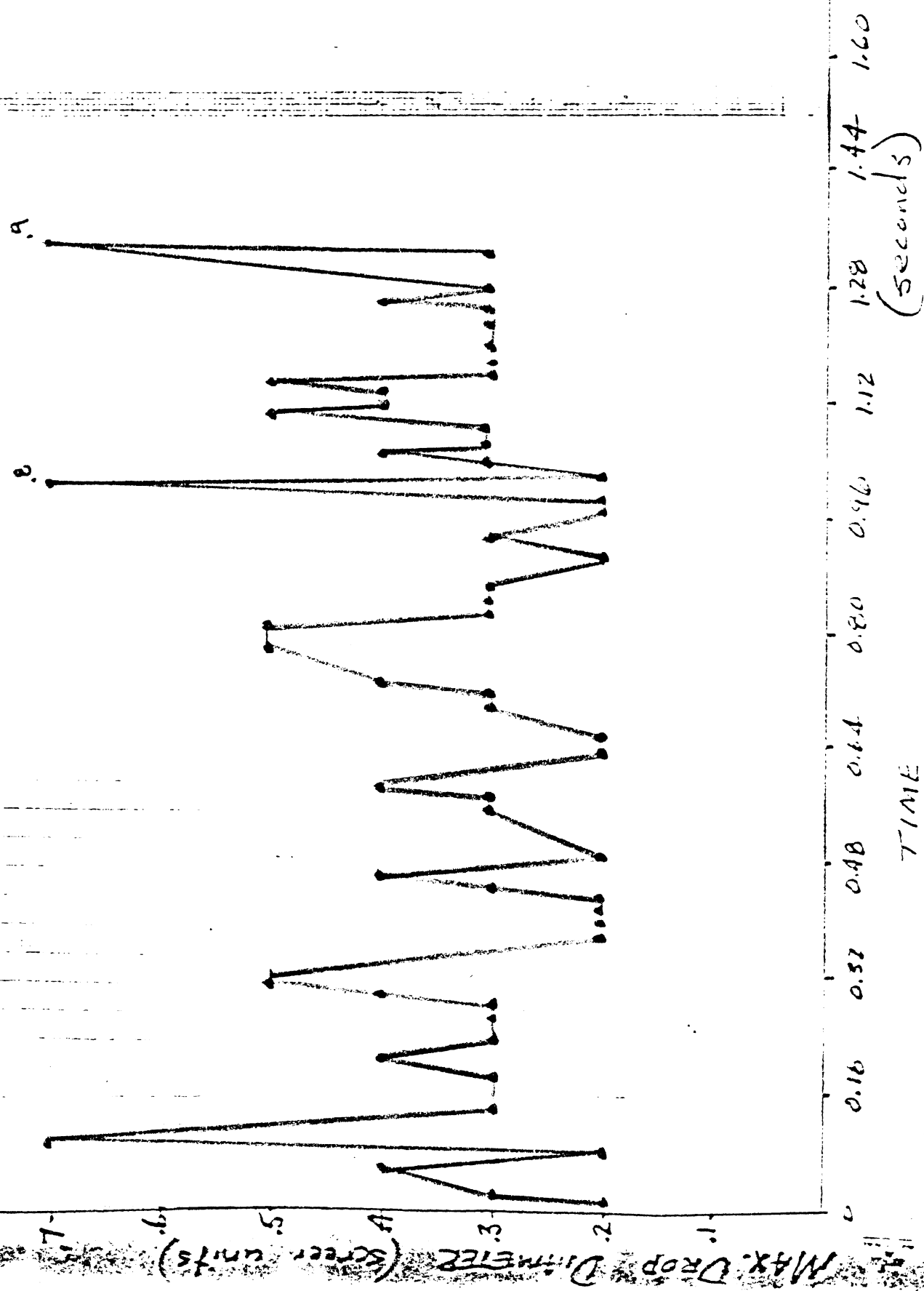
STREAM VELOCITY = 1.5 sec



TIME

MAXIMUM PROP DIAMETER VS TIME

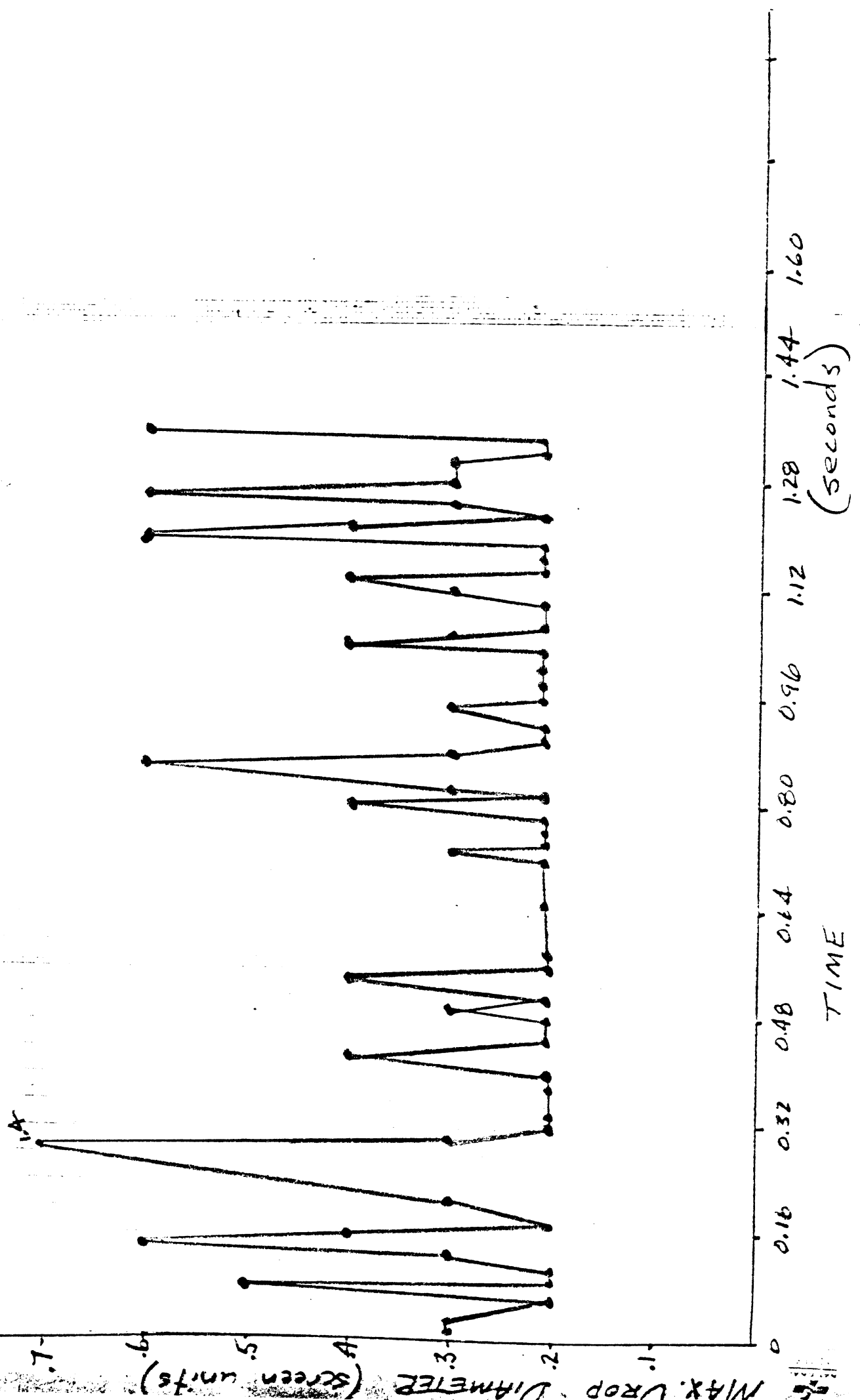
STEAM VELOCITY = ft/sec FLOW RATE = 20 cc/min



222'S

MAXIMUM DROP DIAMETER VS. TIME

STEAM VELOCITY = f/sec FLOW RATE = 10 cc/min

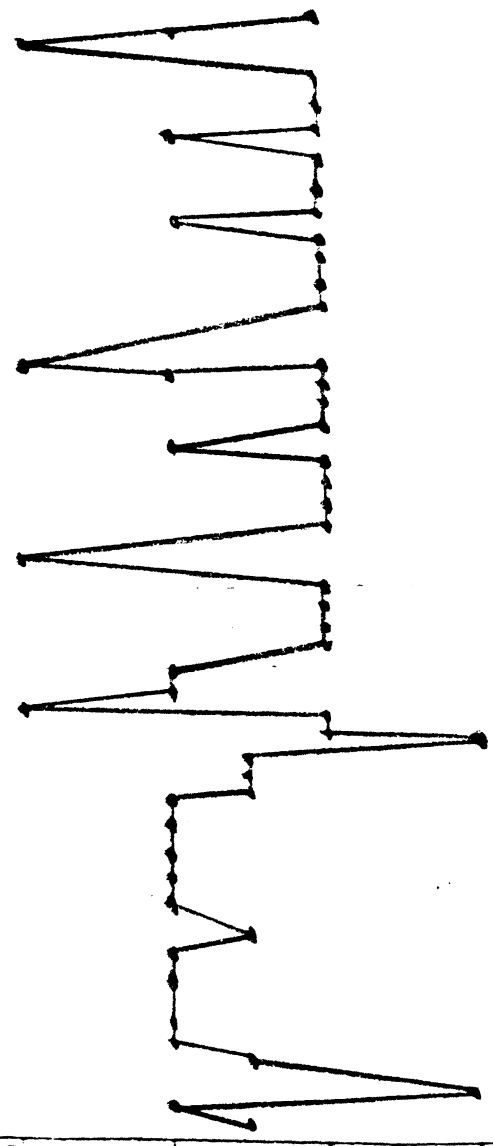


MAXIMUM PROP DIAMETER VS TIME

FLOW RATE = 5 cc/min

STREAM VELOCITY = 1/3 sec

MAX. DROP DIAMETER
Drops cm.



Time (seconds)	Max. Drop Diameter (cm)
0	1.0
0.16	2.5
0.32	1.5
0.48	2.5
0.64	1.5
0.80	3.5
0.96	1.5
1.12	2.5
1.28	1.5
1.44	2.5
1.60	1.5

APPENDIX C

MAXIMUM LENGTH VS. TIME

FEYS 111

YR: 11ME

DATA FROM 1/77

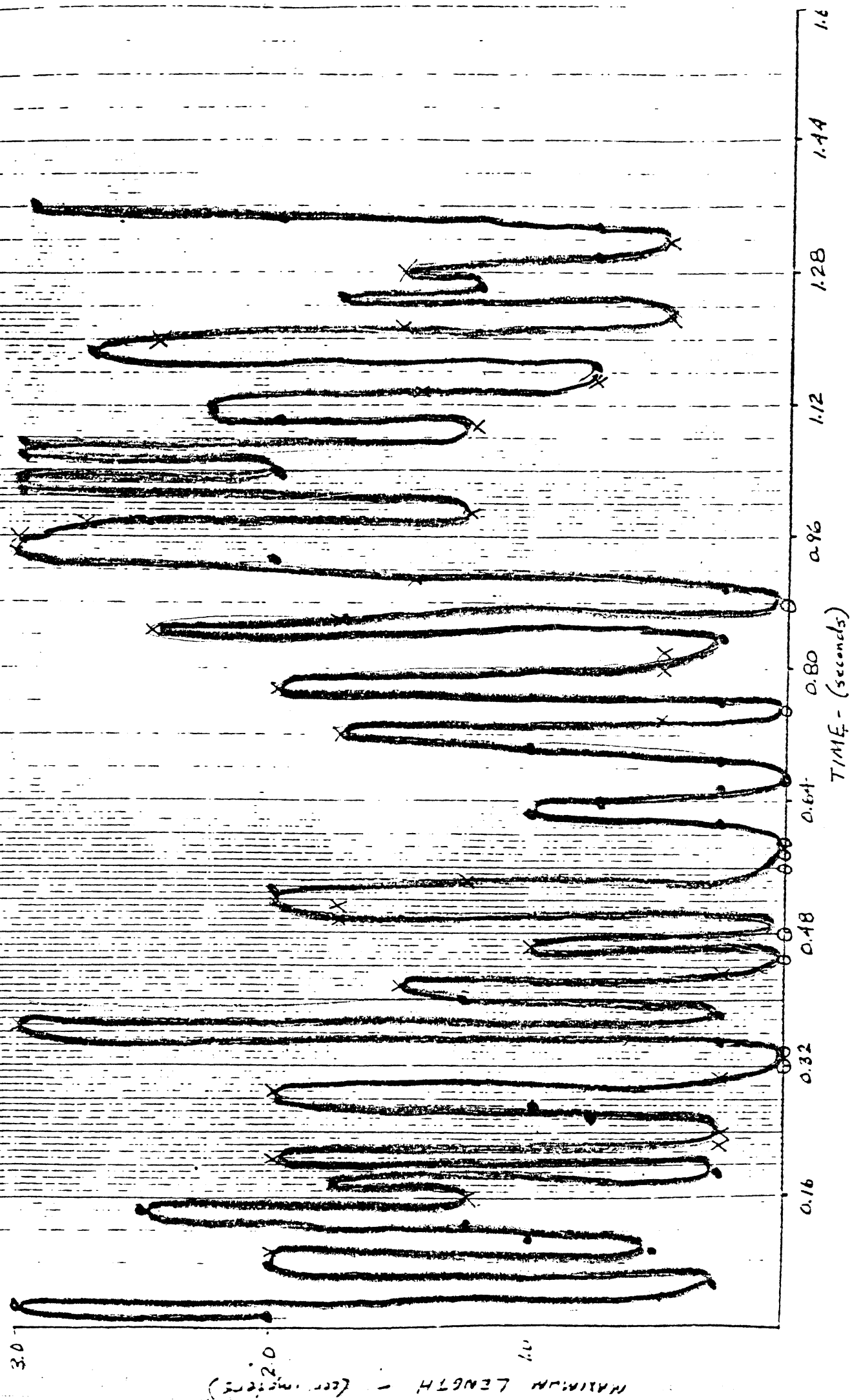
STEAM VELOCITY # ft/sec

FLOW RATE # 10 54/min

○ - NEGLIGIBLE

x - FINGERS

○ - FILM



REVISIONS
LENGTH

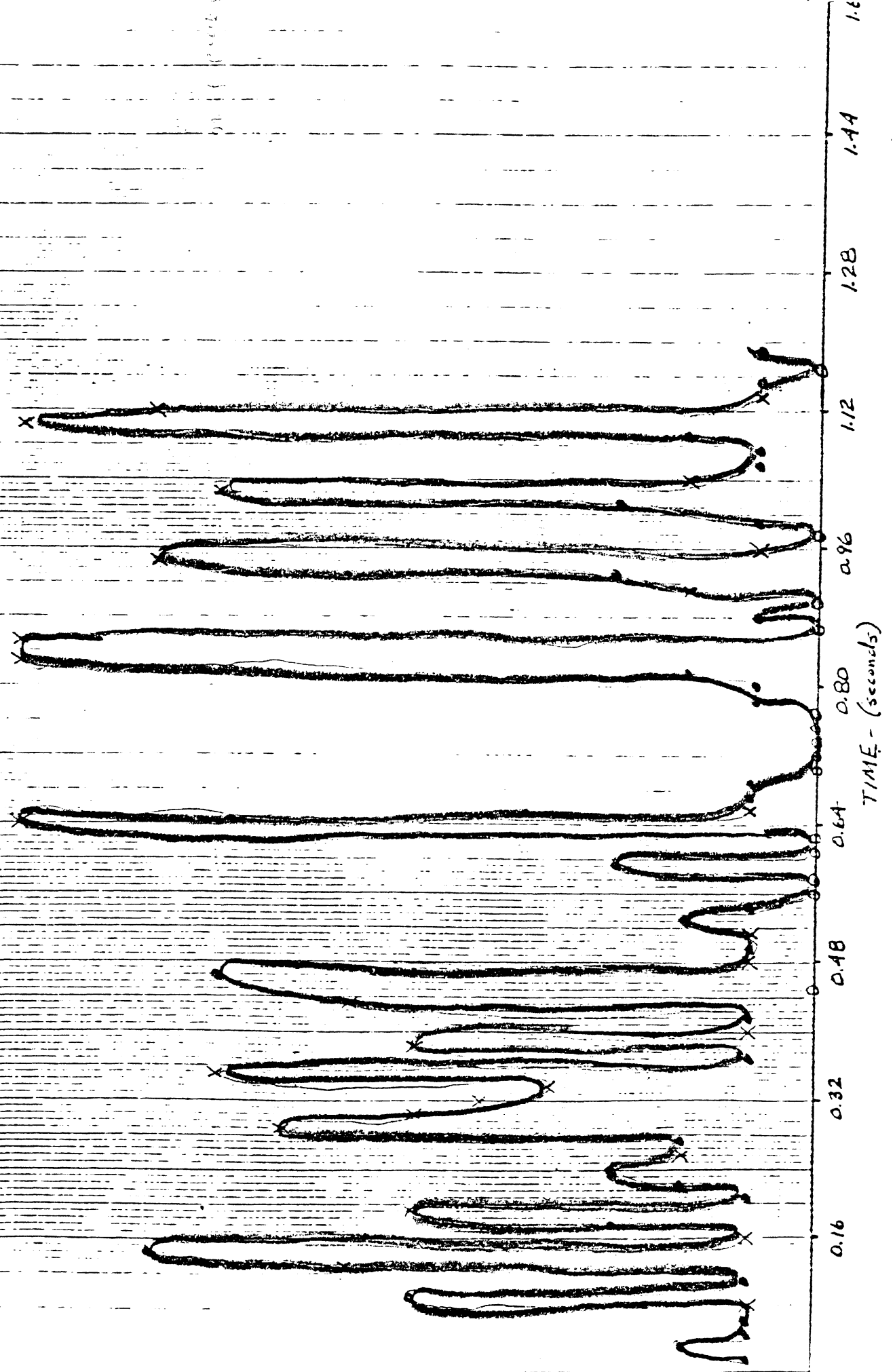
VS. TIME

DATA FROM 1/1/77

STEAM VELOCITY A
FT/SEC
O - NEGLIGIBLE

XT FINGERS
X

FLOW RATE A
5 99/min
• FILM



30

20

10

0.16

0.32

0.48

0.64

0.80

0.96

1.12

1.28

1.44

1.6

2 x 2.5

FILM/FINGER LENGTH VS. TIME

FILM/FINGER LENGTH

MAXIMUM

DATA FROM 1/77

ft/sec

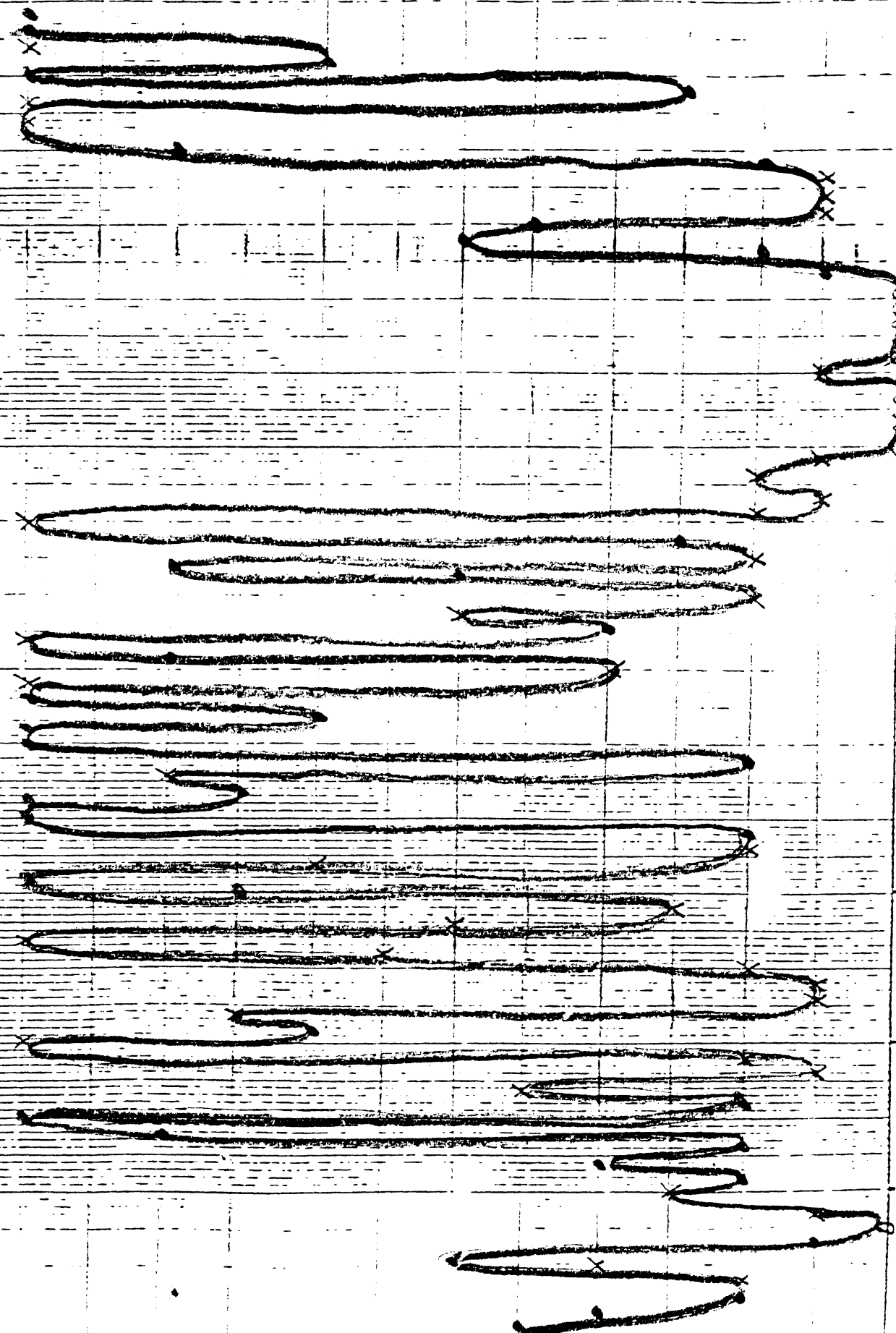
STEAM VELOCITY #

FLOW RATE # 1000/min

○ NEGLIGIBLE

× 1 FINGERS

○ FILM



1.6
1.44
1.28
1.12
0.96
0.80
0.64
0.48
0.32
0.16

TIME (seconds)

30

20

MAXIMUM LENGTH - (CENTIMETERS)

28225

VS: TIME

DATA FROM 1/77

FILM / FINGER LENGTH

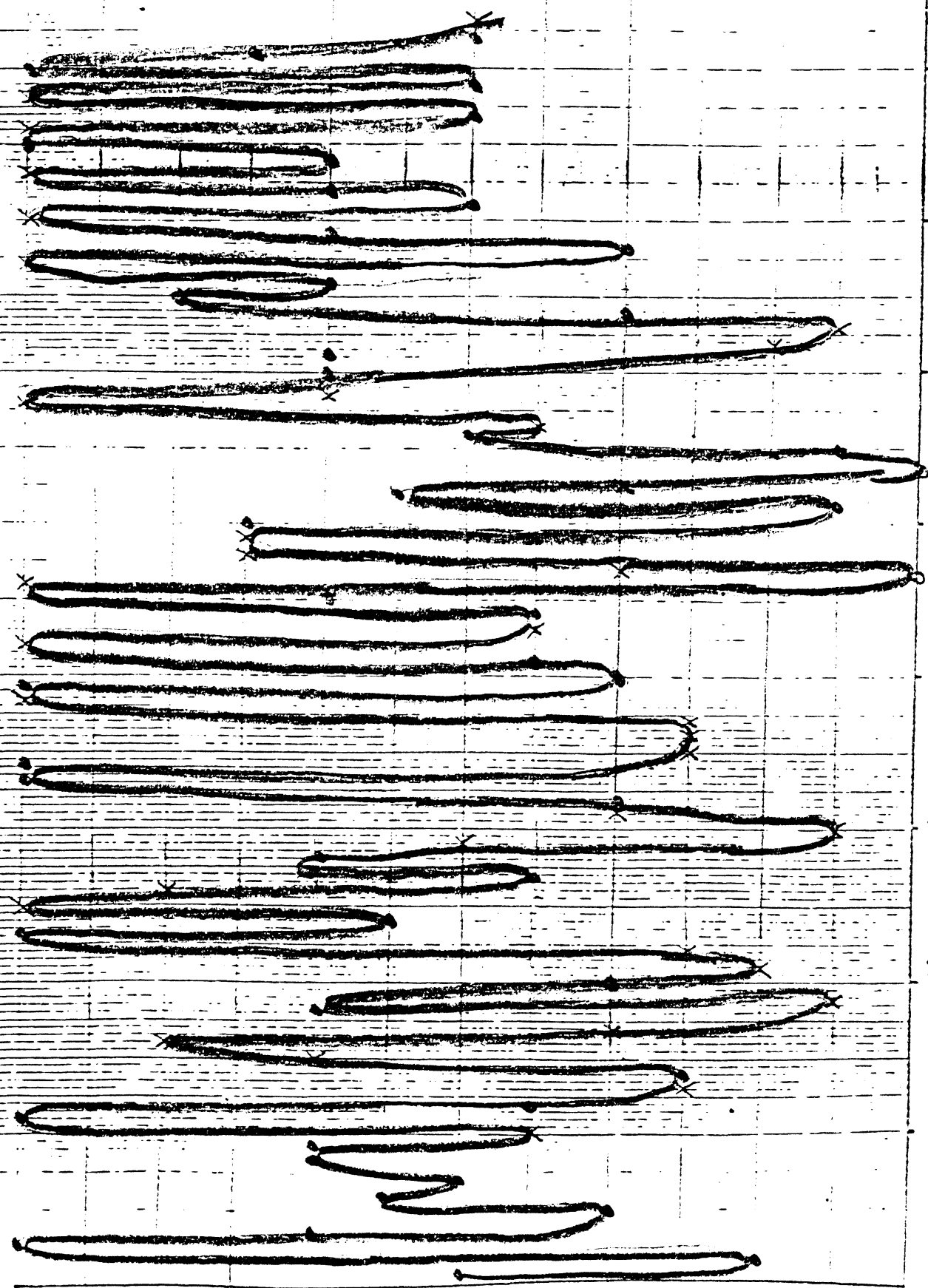
STEAM VELOCITY #

X T FINGERS

MAXIMUM

FLOW RATE # 20 54/min

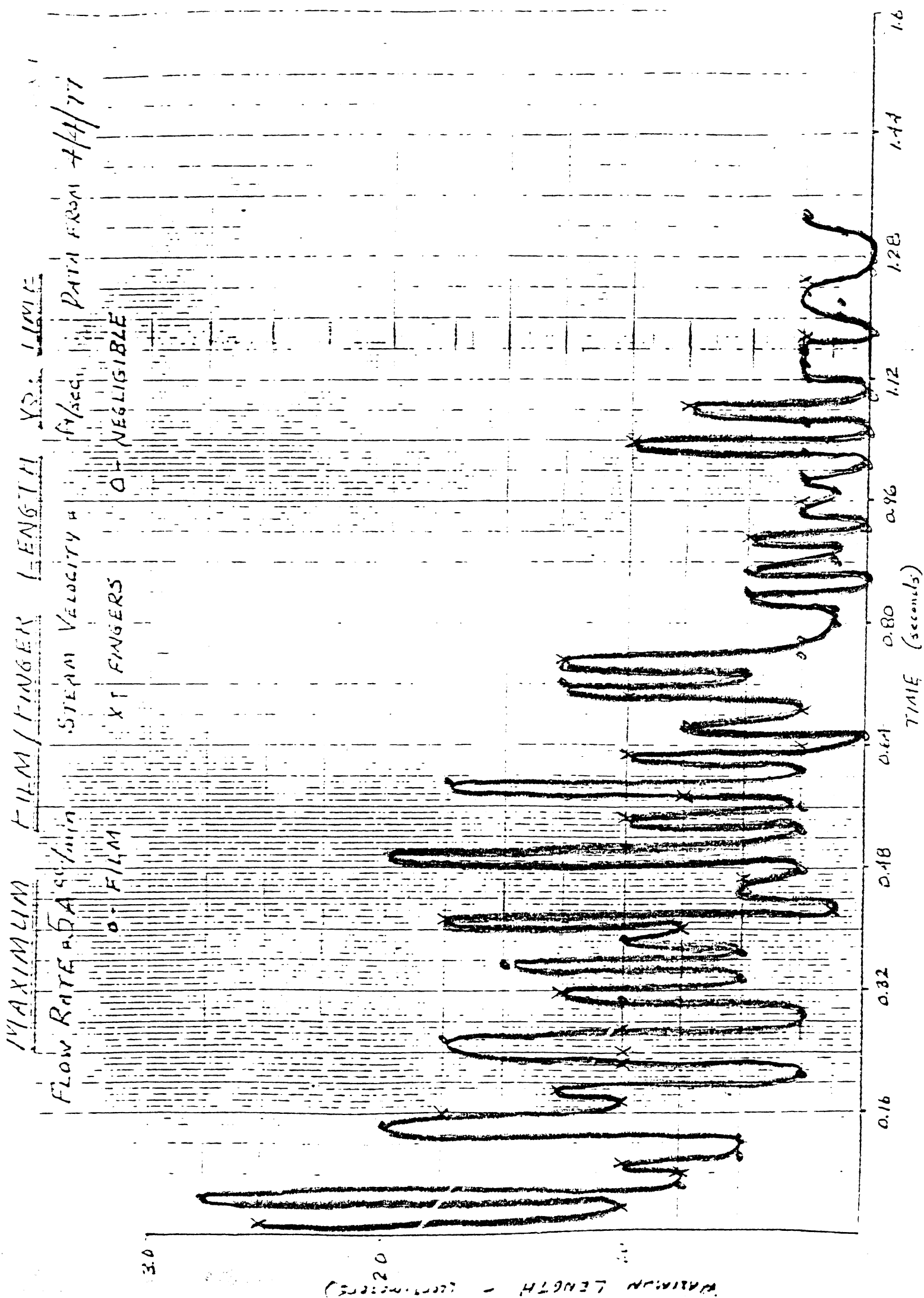
O FILM



0.16 0.32 0.48 0.64 0.80 0.96 1.12 1.28 1.44 1.6

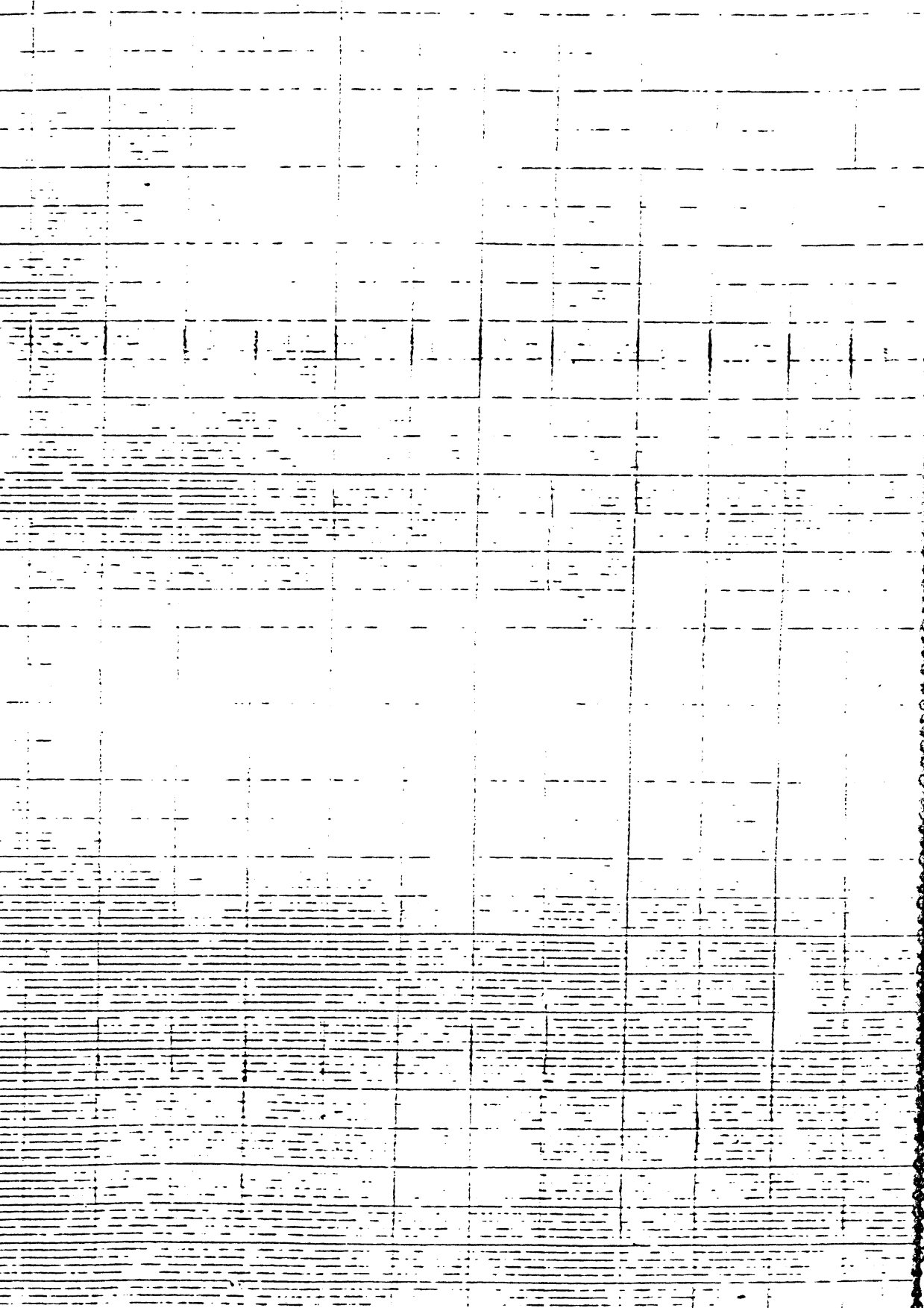
TIME - (seconds)

30
20
10
MAXIMUM LENGTH - (centimeters)



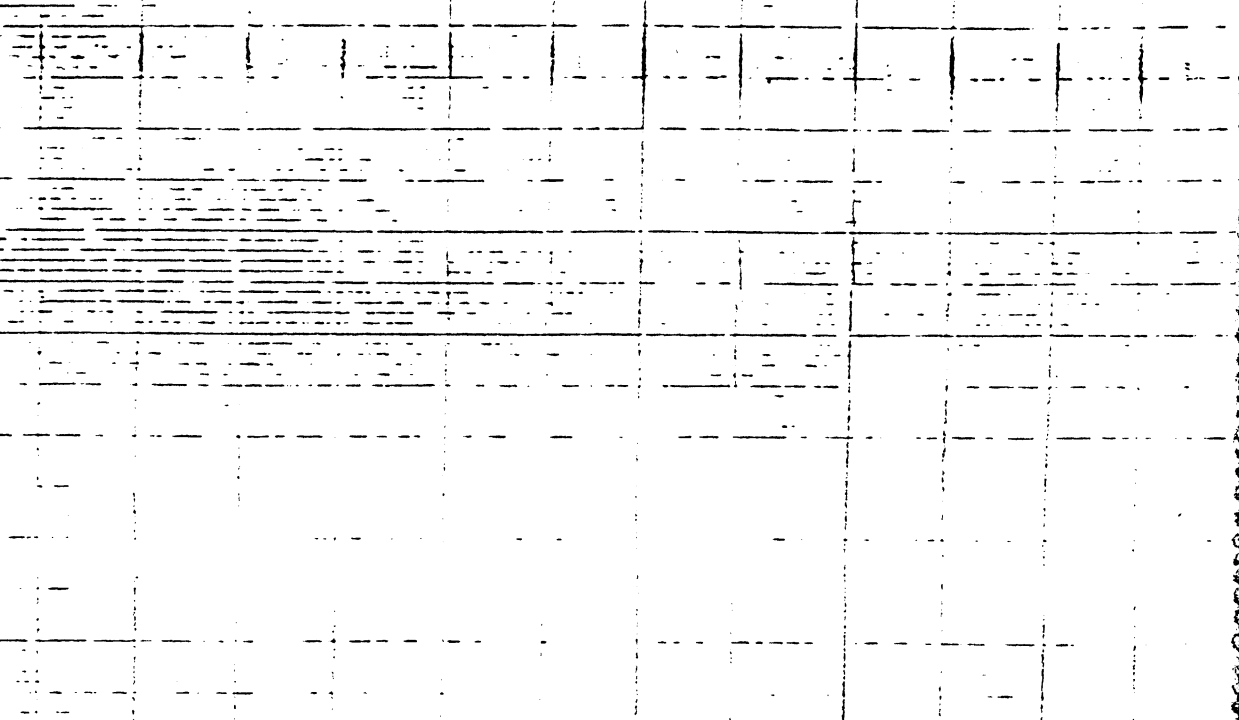
MAXIMUM FLOW RATE VS. TIME

DATA FROM 4/4/77
 FLOW RATE \dot{Q} (cc/min)
 0.16 0.32 0.48 0.64 0.80 0.96 1.12 1.28 1.44 1.6



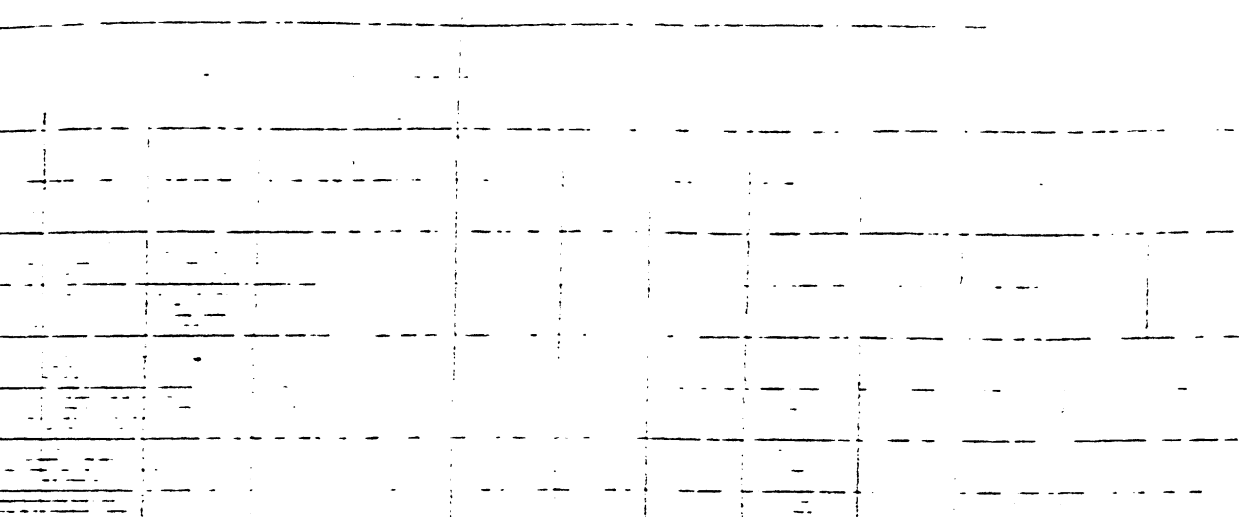
STEAM VELOCITY VS. TIME

DATA FROM 4/4/77
 STEAM VELOCITY V (ft/sec)
 0.16 0.32 0.48 0.64 0.80 0.96 1.12 1.28 1.44 1.6



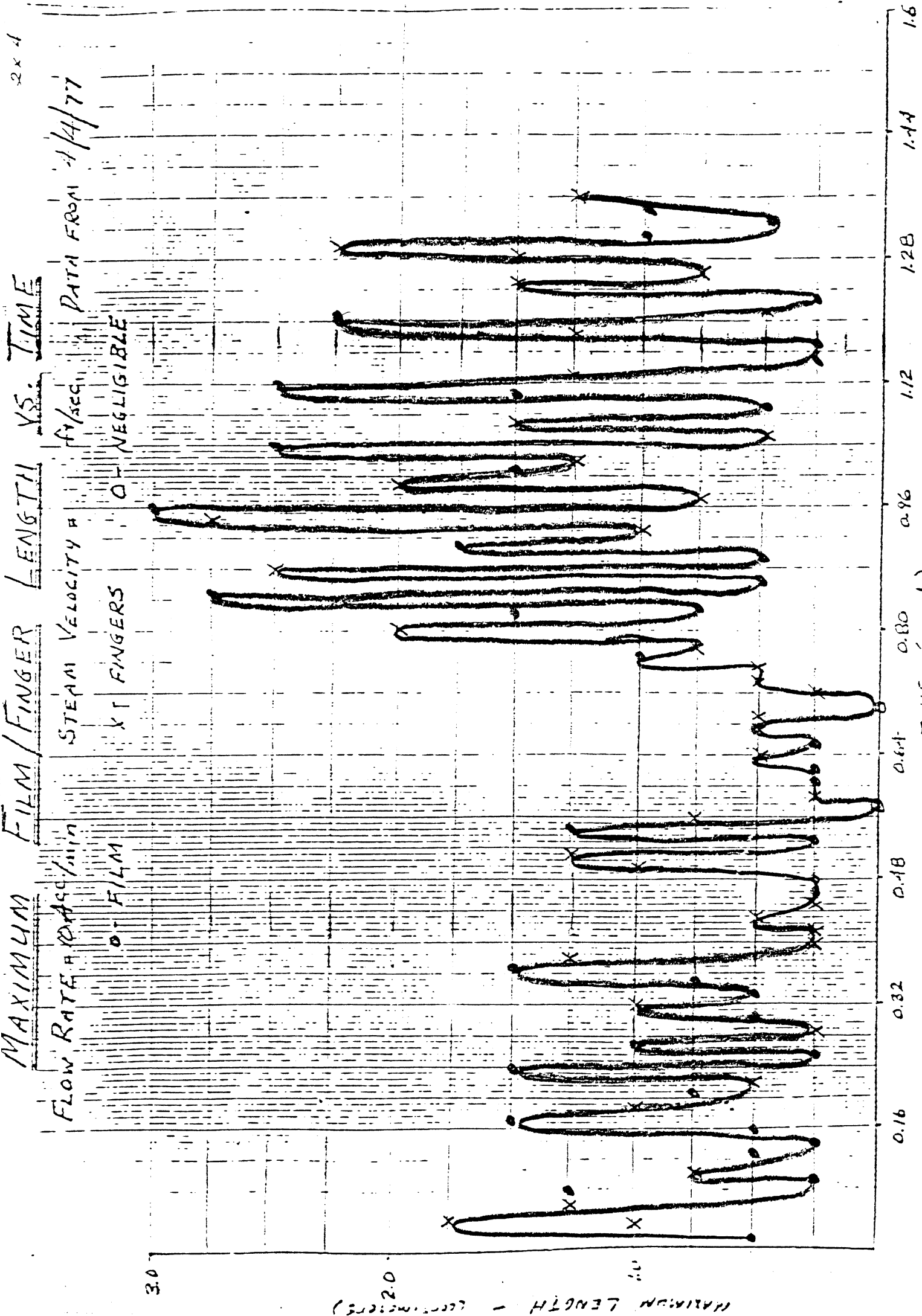
MAXIMUM LENGTH VS. TIME

DATA FROM 4/4/77
 MAXIMUM LENGTH - (centimeters)
 0.16 0.32 0.48 0.64 0.80 0.96 1.12 1.28 1.44 1.6



30

MAXIMUM LENGTH - (centimeters)

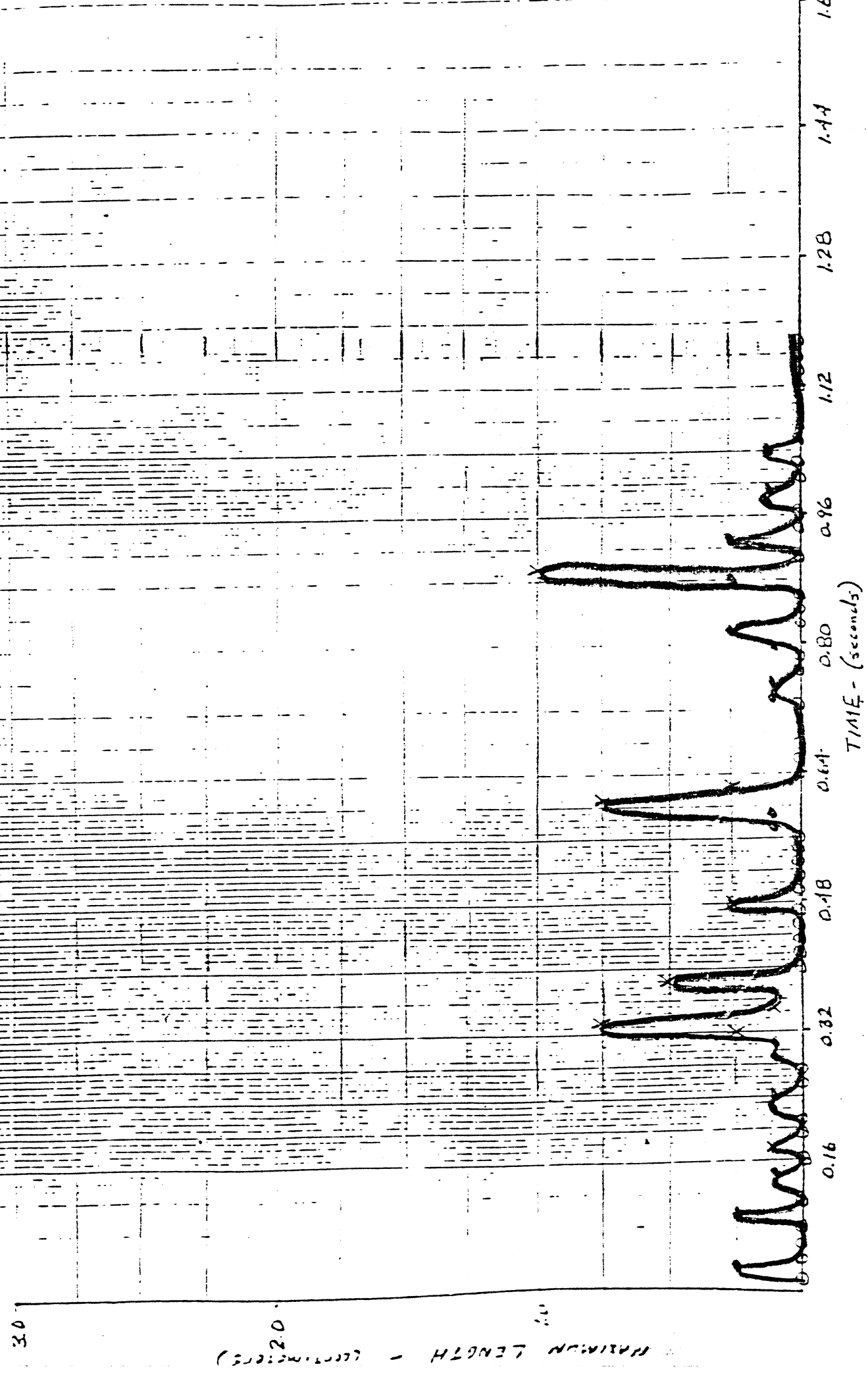


MAXIMUM FILM / FINGER LENGTH VS. TIME

DATA FROM 4/4/77

FLOW RATE 0.589 / MIN
0.1 FILM

STEAM VELOCITY 4 FT FINGERS
0.1 NEGLIGIBLE



FLIM / FINGER LENGTH VS. TIME

DATA FROM 4/4/77

ft/sec

STEAM VELOCITY #

FLOW RATE #

15 ft/min

O - NEGLECTIBLE

X - FINGERS

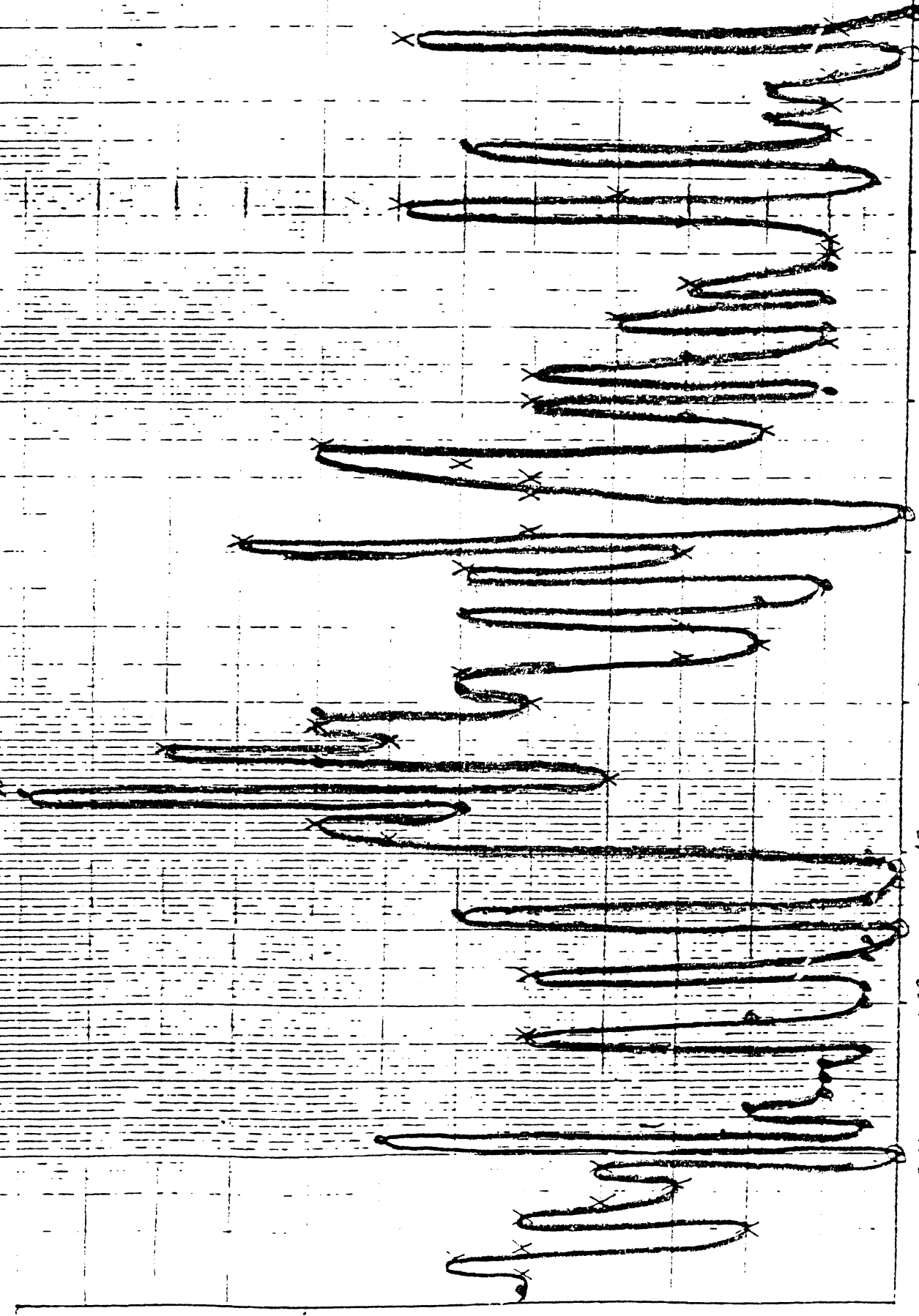
O - FILM

30

20

10

MAXIMUM LENGTH - (centimeters)



0.16

0.32

0.48

0.64

0.80

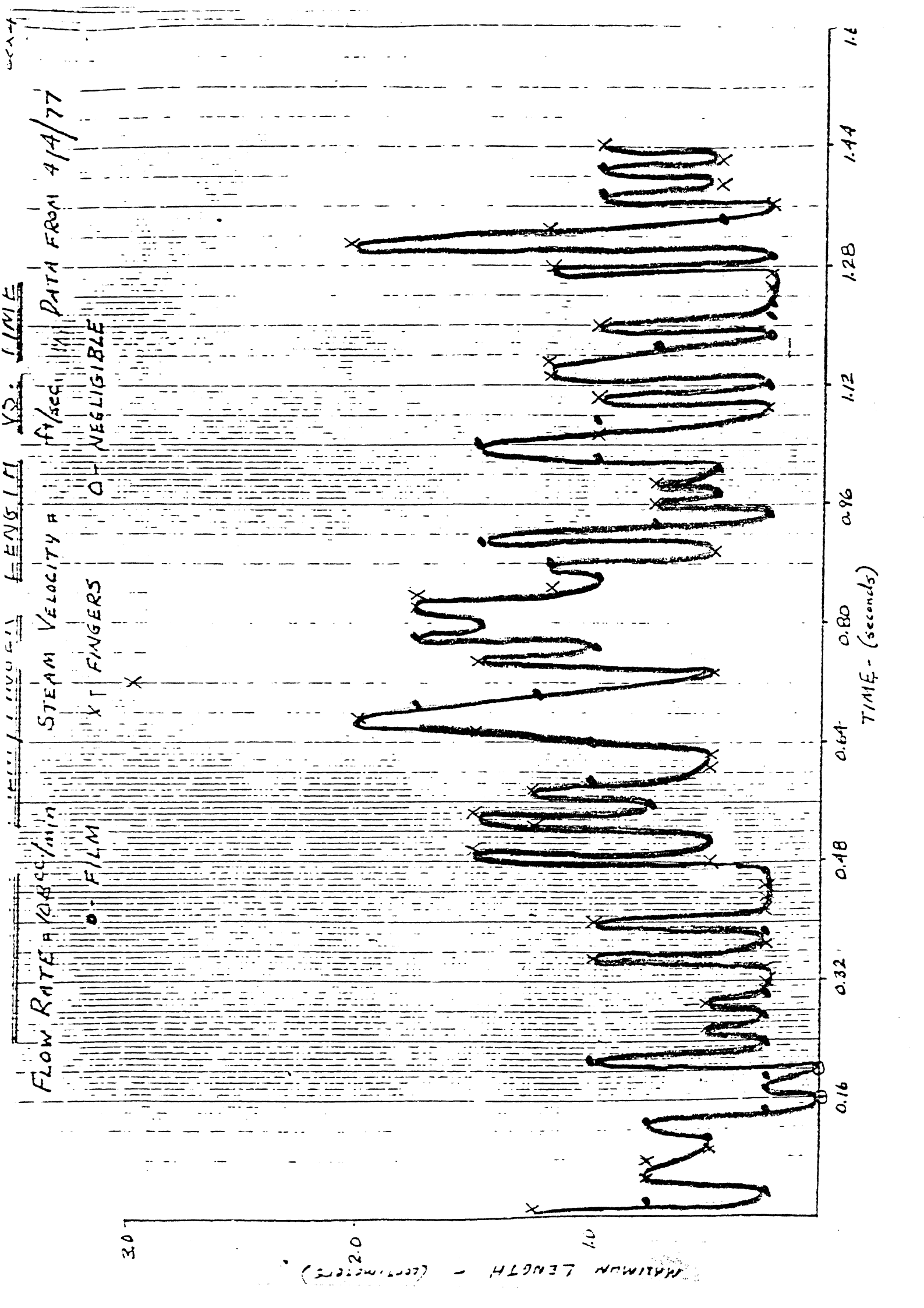
0.96

1.12

1.28

1.44

TIME (seconds)



MAXIMUM

FILM/FINGER

LENGTH

VS. TIME

2x4

FLOW RATE 200 cc/min

STEAM VELOCITY #

ft/sec

PATH FROM 4/4/77

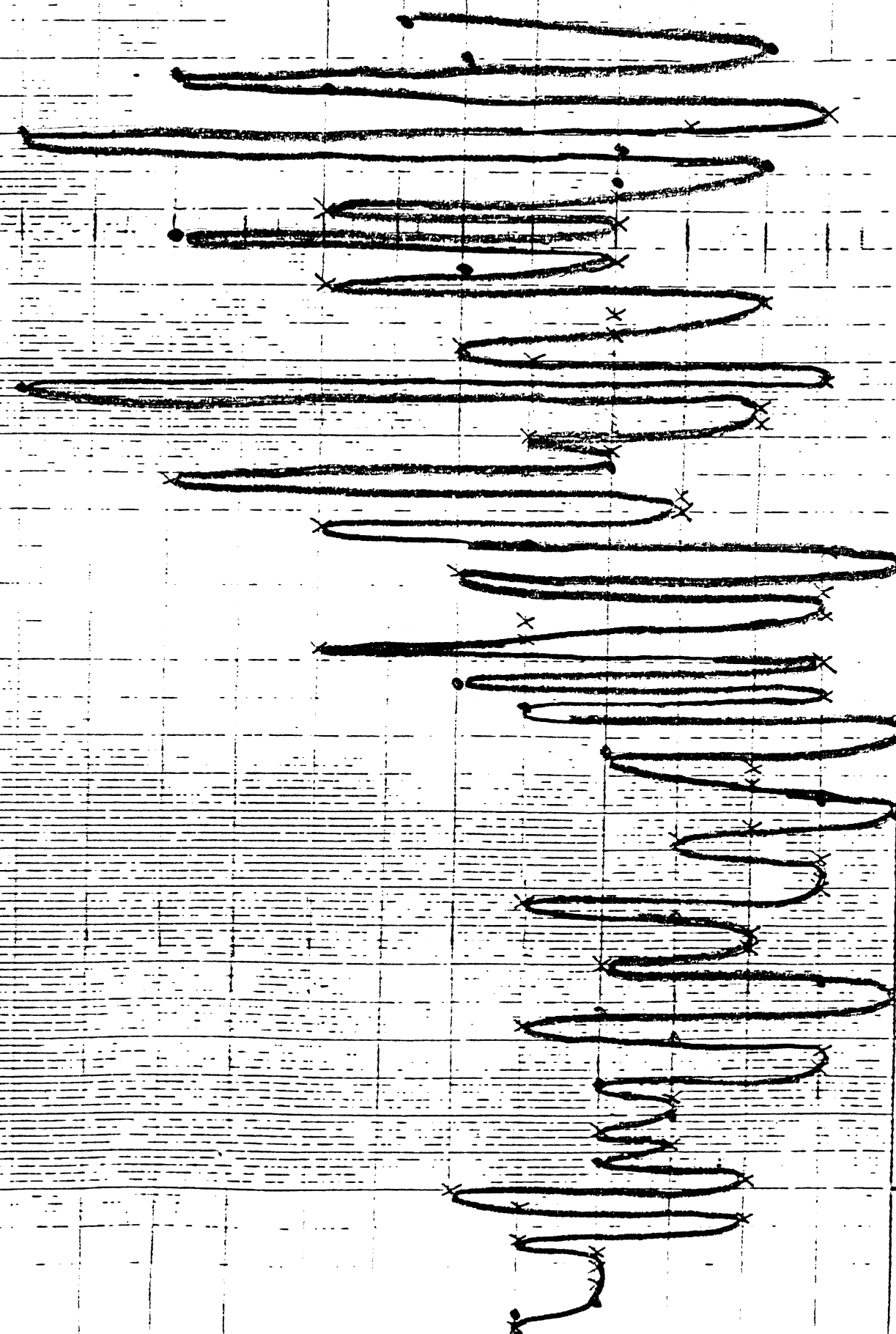
○ FILM

x 1 FINGERS

○ NEGLIGIBLE

30

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

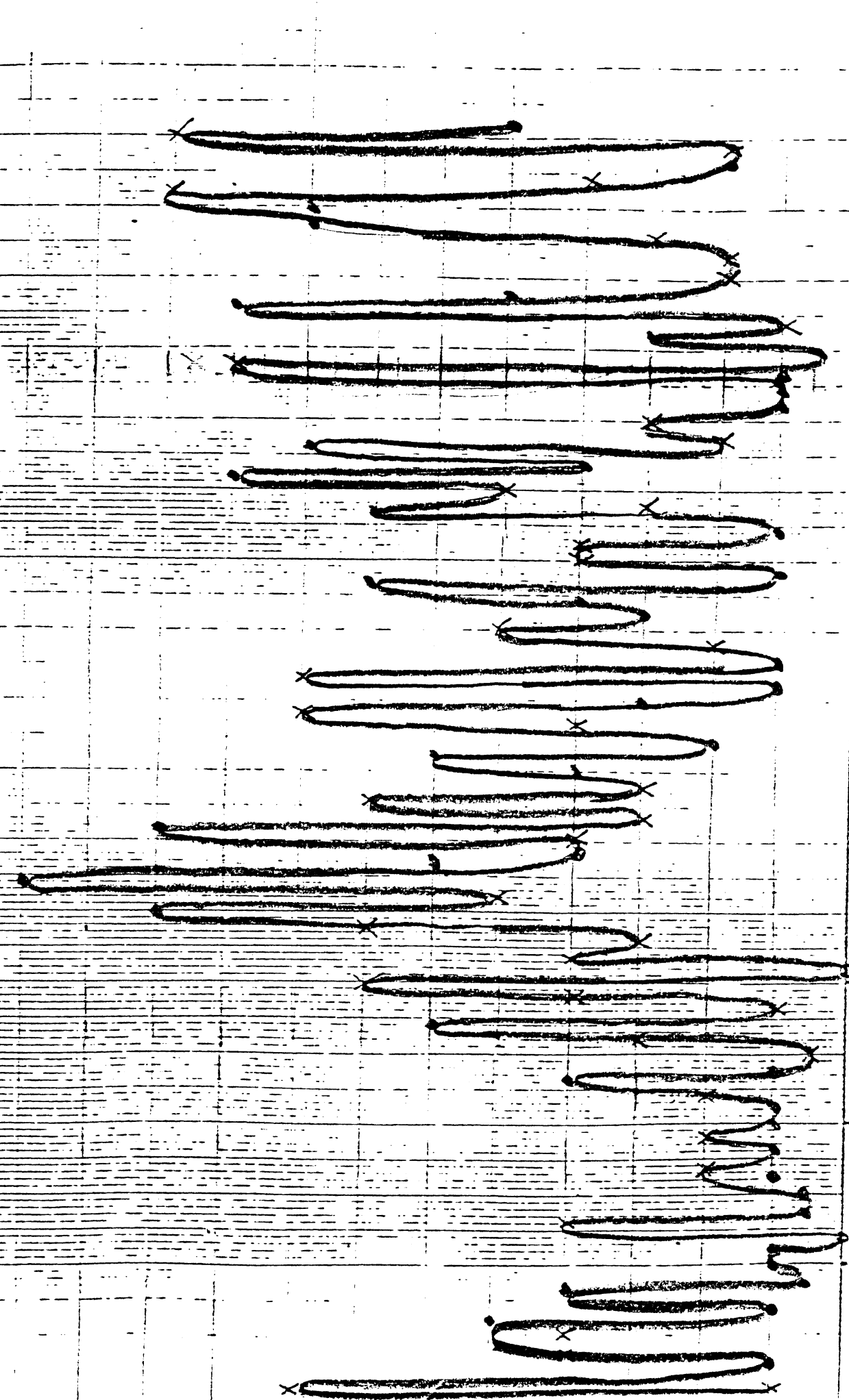
VS. TIME

FLOW RATE = 15.8 cc/min
O FILM

STEAM VELOCITY =
X 1 FINGERS

ft/sec
O NEGLIGIBLE

DATA FROM 4/4/77



3.0

2.0

1.0

MAXIMUM LENGTH - (CENTIMETERS)

0.16

0.32

0.48

0.64

0.80

0.96

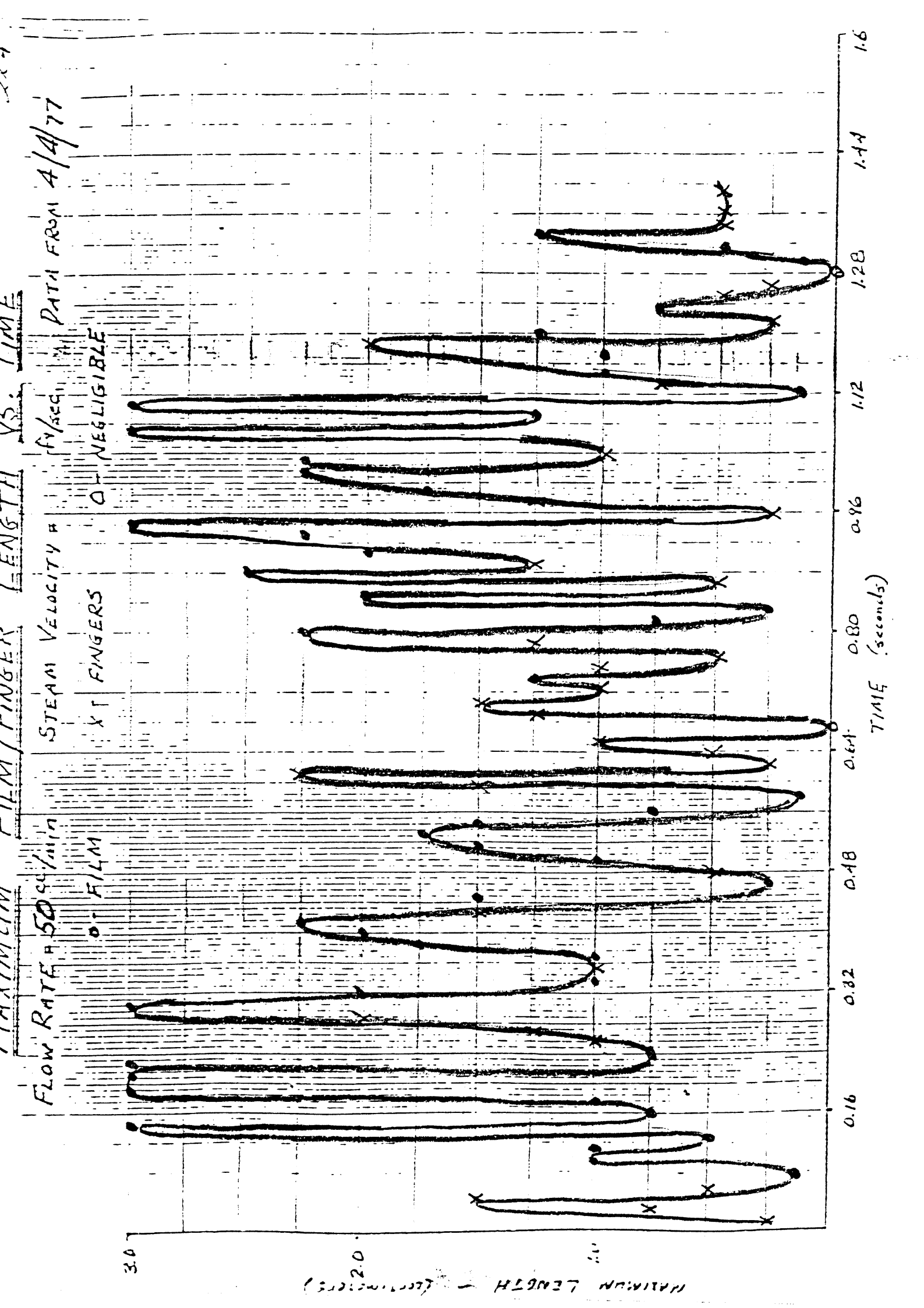
1.12

1.28

1.44

1.6

TIME - (seconds)

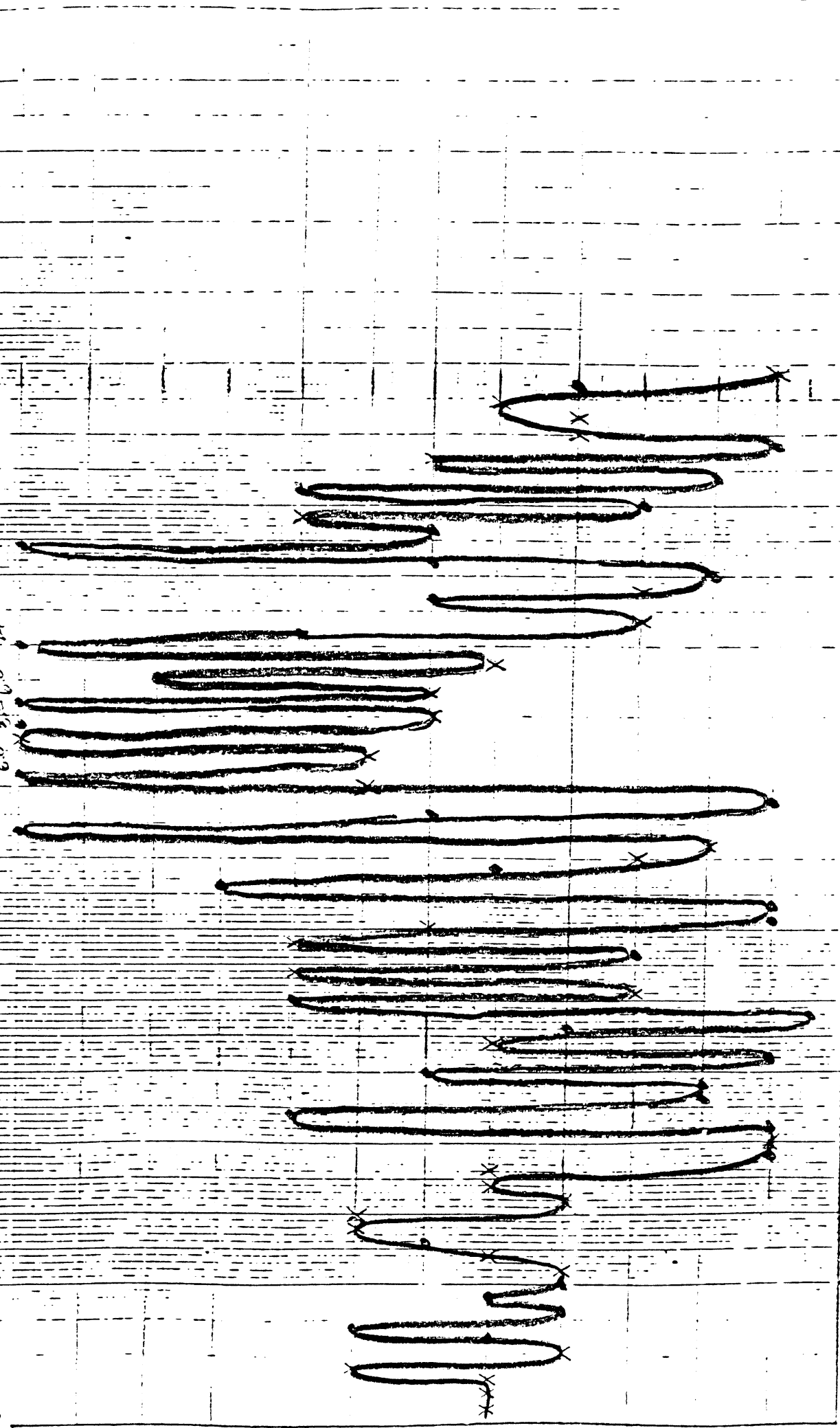


MAXIMUM FILM / FINGER R. LENGTH VS. TIME

FLOW RATE = 30 cc/min
0. FILM

STEAM VELOCITY =
X 1 FINGERS
6.0 3.0 0.0 IN.
O NEGLIGIBLE

PATH FROM 4/4/77



0.16 0.20 0.24 0.28 0.32 0.36 0.40 0.44 0.48 0.52 0.56 0.60 0.64 0.68 0.72 0.76 0.80 0.84 0.88 0.92 0.96 1.00 1.04 1.08 1.12 1.16 1.20 1.24 1.28 1.32 1.36 1.40 1.44 1.48 1.52 1.56 1.60

MAXIMUM LENGTH - (inches)

TIME - (seconds)

MAXIMUM

FILM / FINGER LENGTH

VS. TIME

FLOW RATE # 10 sec/min DATA FROM 1/4/77

STEAM VELOCITY #

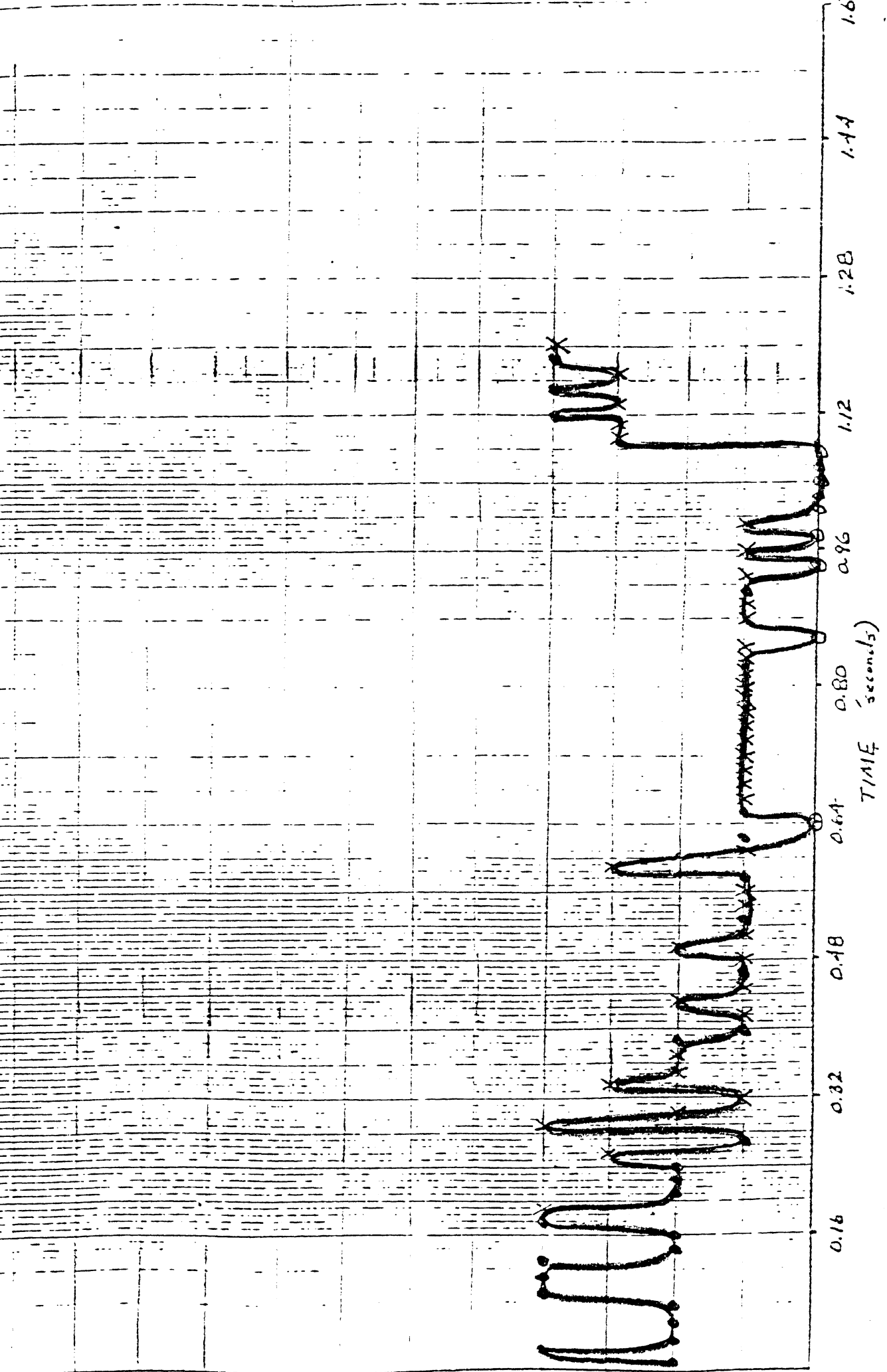
ft/sec

XT FINGERS

0 - NEGLIGIBLE

MAXIMUM FLOW RATE # 10 sec/min

0 - FILM



MAXIMUM LENGTH - (centimeters)

MAXIMUM FILM LENGTH VS. TIME

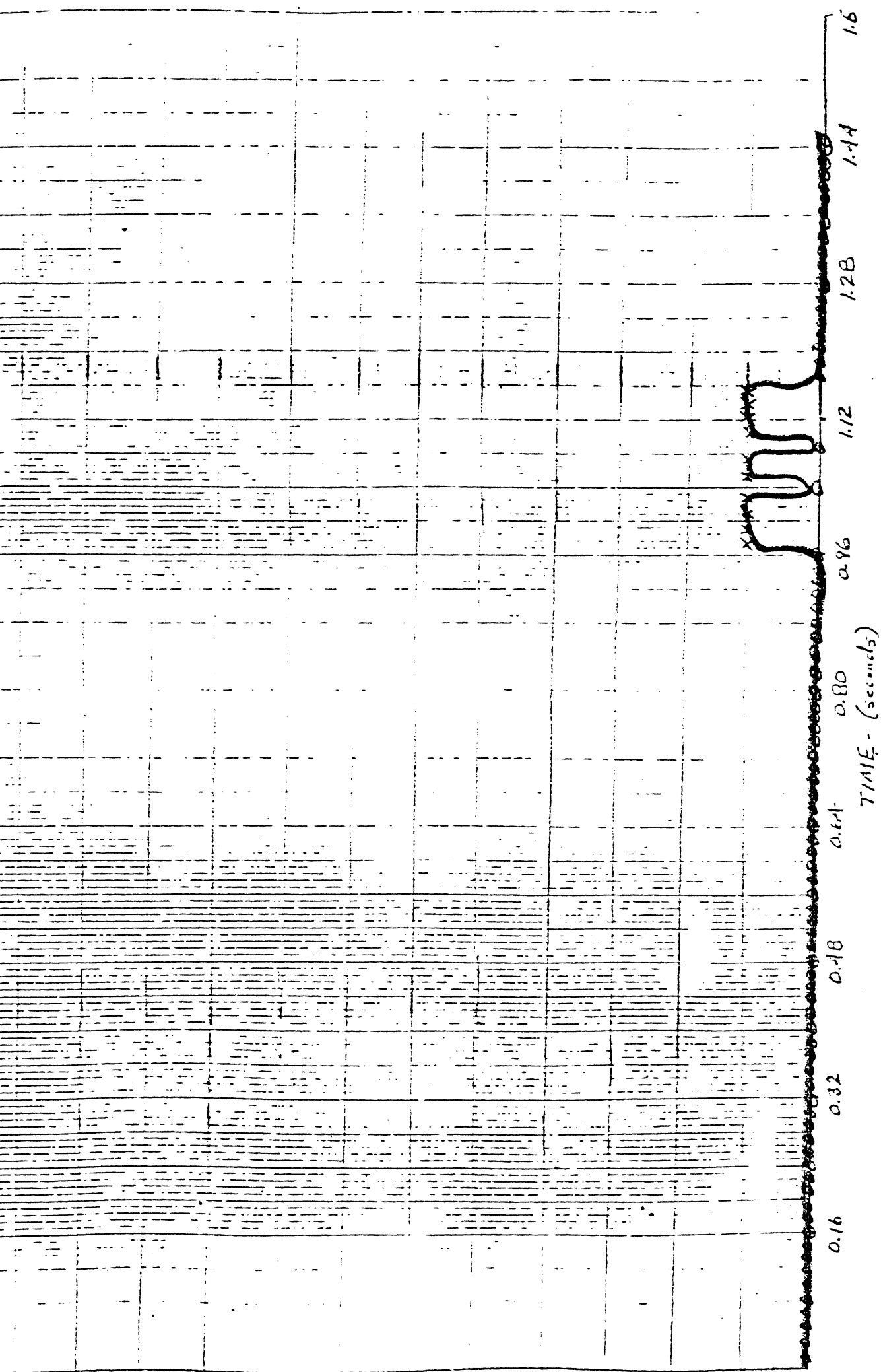
2x7

DATA FROM 4/4/77

FT/SEC
NEGLIGIBLE

STEAM VELOCITY #
XT FINGERS

FLOW RATE #
FILM



30

MAXIMUM LENGTH - (INCHES) - 2.0

10

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 cc/min

STEAM VELOCITY =

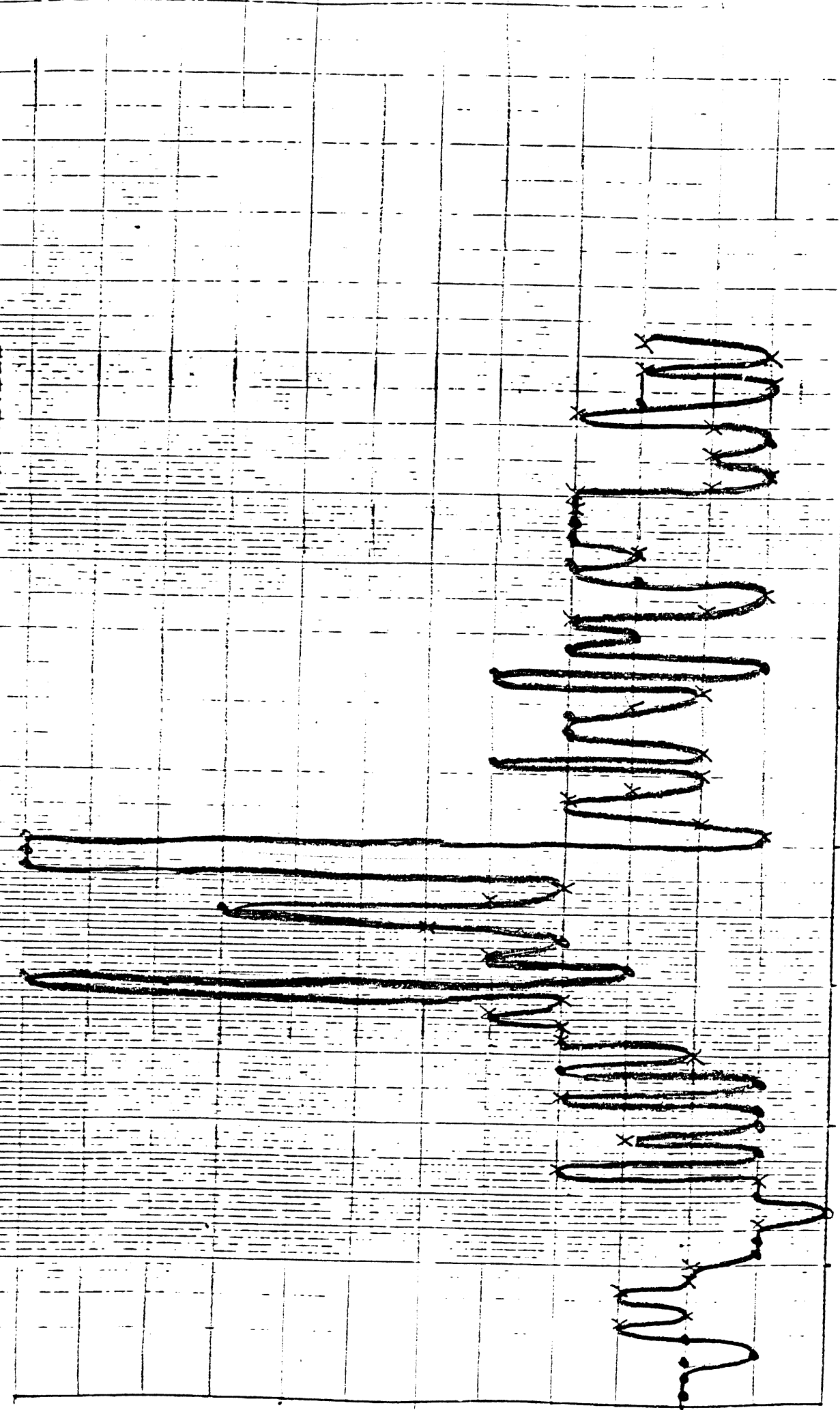
ft/sec

DATA FROM 4/4/77

● FILM

x FINGERS

○ NEGLIGIBLE



MAXIMUM LENGTH - (centimeters)

TIME - (seconds)

MAXIMUM

FILM / FINGER

FINGERS

ft/sec

DATA FROM

FLOW RATE # 58/min

STEAM VELOCITY #

DATA FROM 4/4/77

FILM

FINGERS

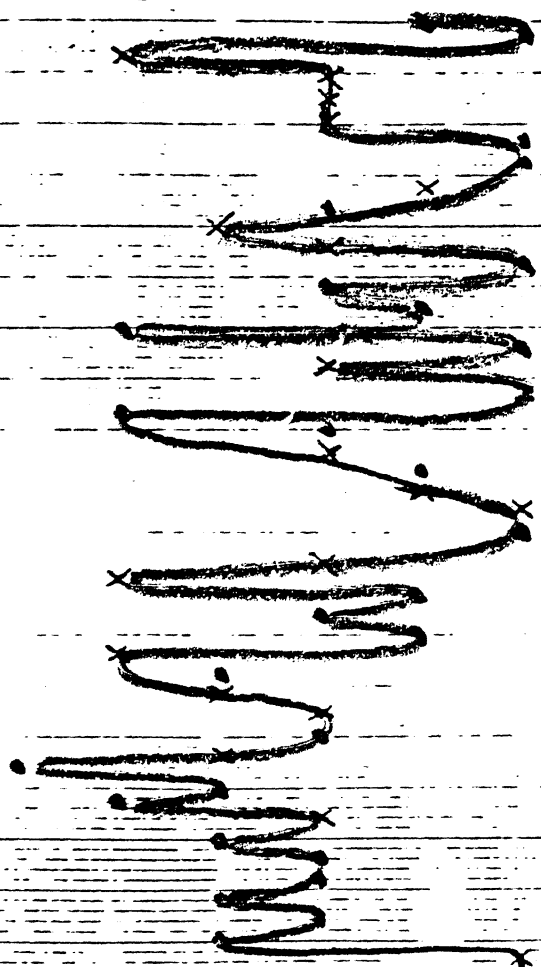
NEGLIGIBLE

30

20

10

MAXIMUM LENGTH - (CENTIMETERS)



0.16

0.32

0.48

0.64

0.80

0.96

1.12

1.28

1.44

1.6

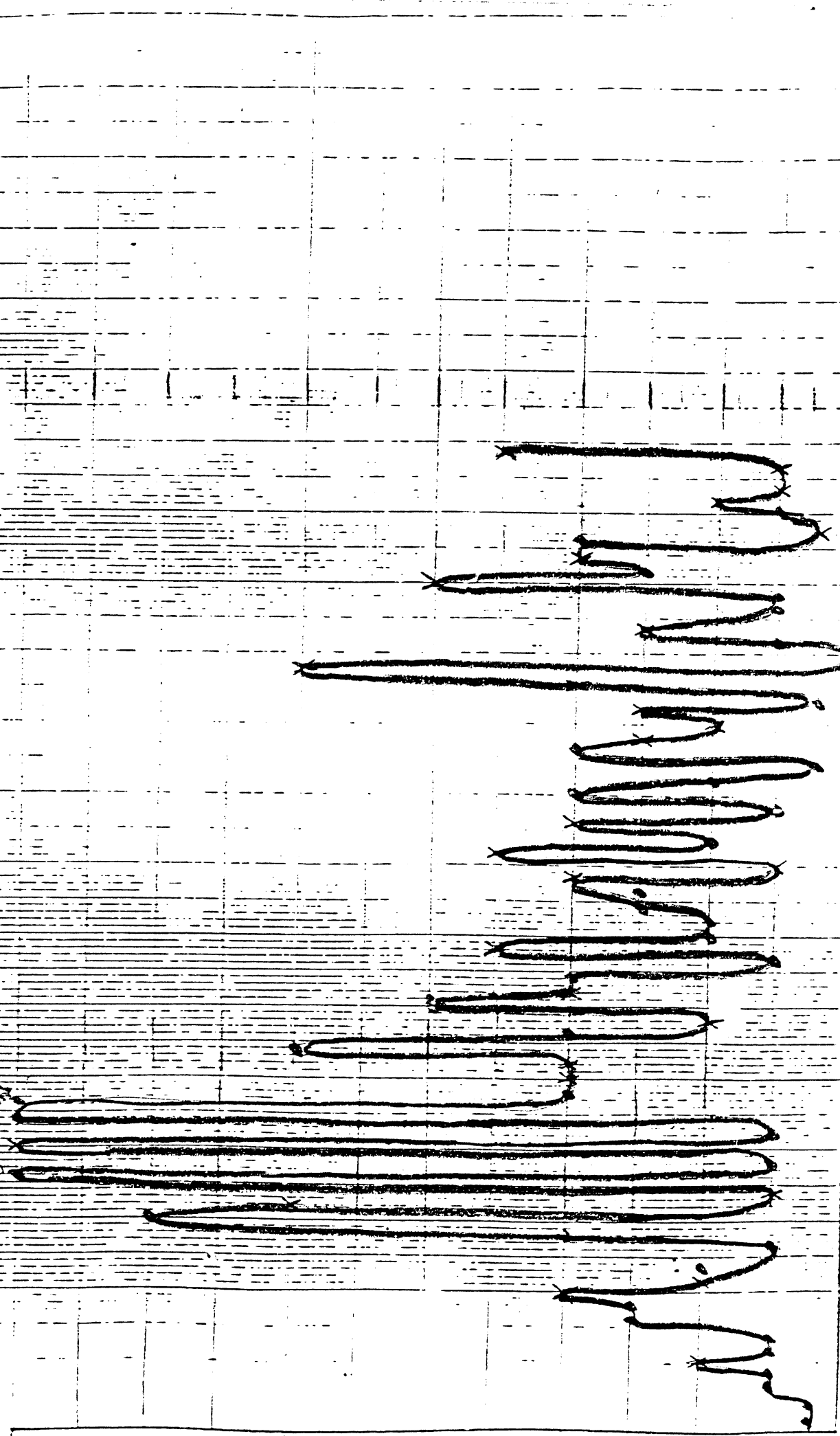
TIME - (seconds)

MAXIMUM FILM / FINGER LENGTH VS. TIME

FLOW RATE = 5 A⁹⁵ / MIN
#13
#12
#11
#10
#9
#8
#7
#6
#5
#4
#3
#2
#1
F/LM

STEAM VELOCITY =
X 1 FINGERS
O - NEGLIGIBLE

DATA FROM 4/4/77



TIME (seconds)

MAXIMUM LENGTH - (CENTIMETERS)

SEMI LOG X LENGTH VS. TIME

FLOW RATE (GPM) vs. TIME
0 - FILM

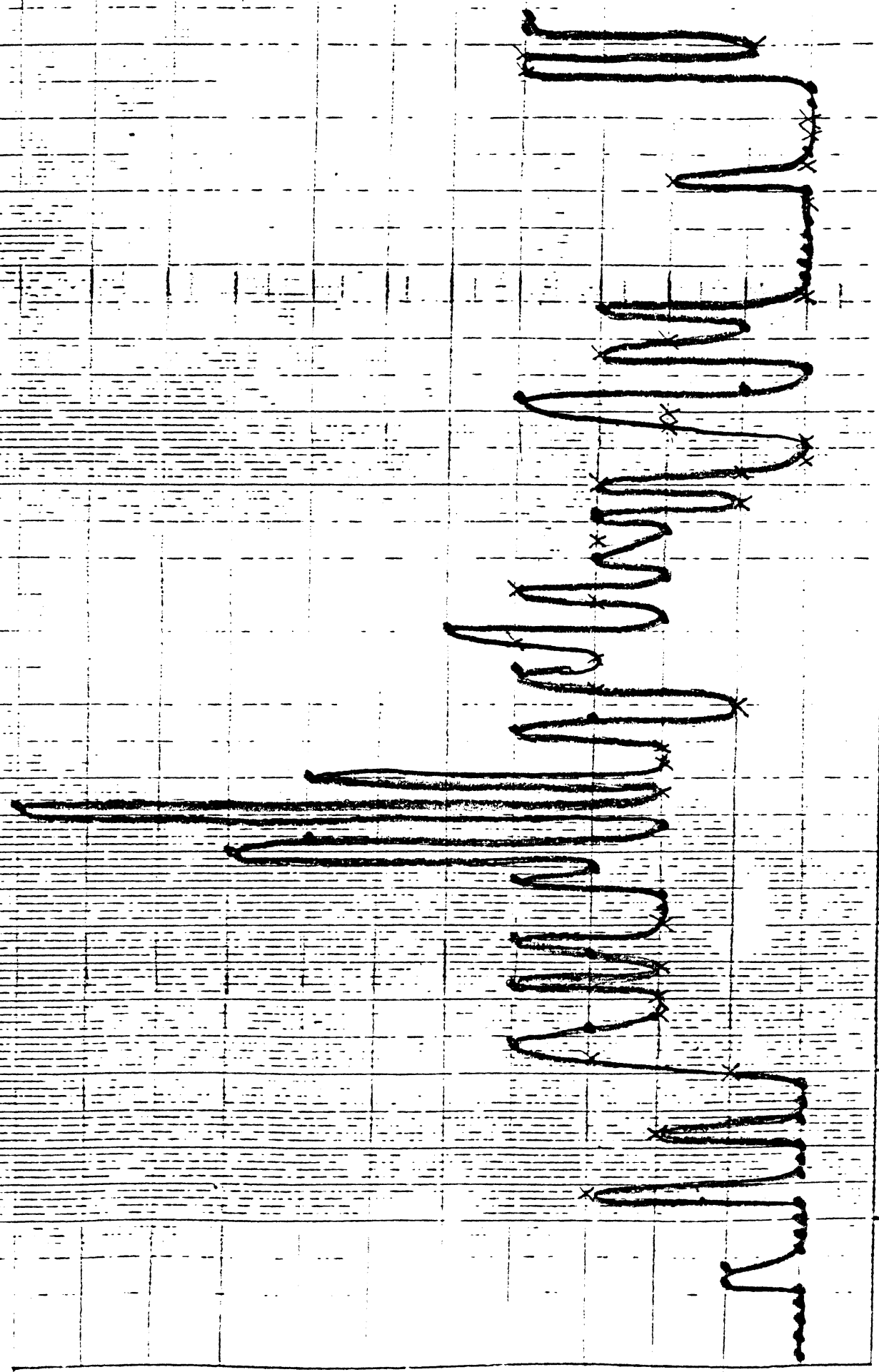
STEAM VELOCITY (FT/SEC) vs. TIME
0 - NEGLIGIBLE

STEAM VELOCITY (FT/SEC) vs. TIME
X - FINGERS

STEAM VELOCITY (FT/SEC) vs. TIME
0 - NEGLIGIBLE

3.0

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 VS. TIME

-X7

DATA FROM 4/4/77

ft/SEC

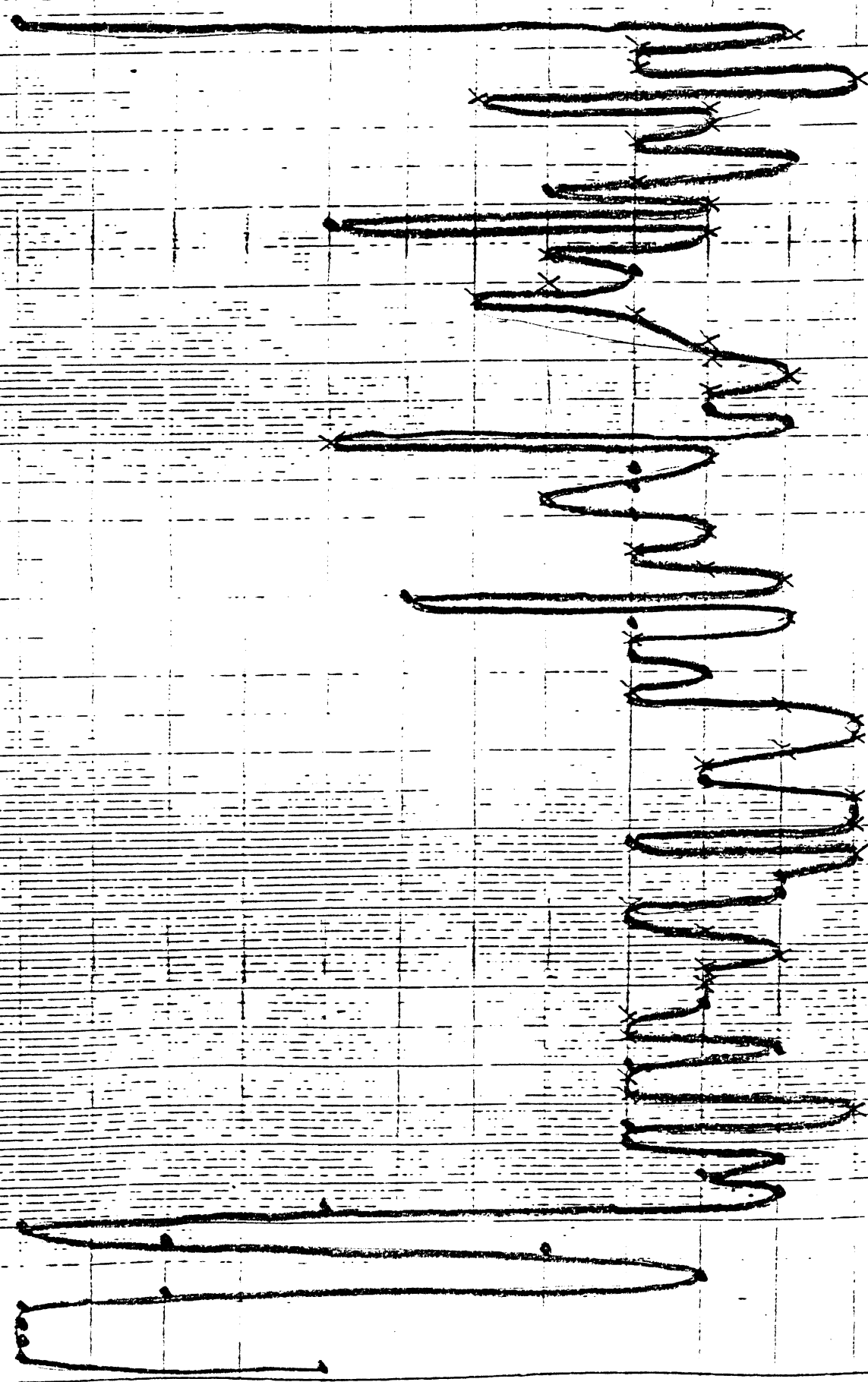
STEAM VELOCITY #

FLOW RATE # ROARS / MIN

O - NEGLIGIBLE

X - FINGERS

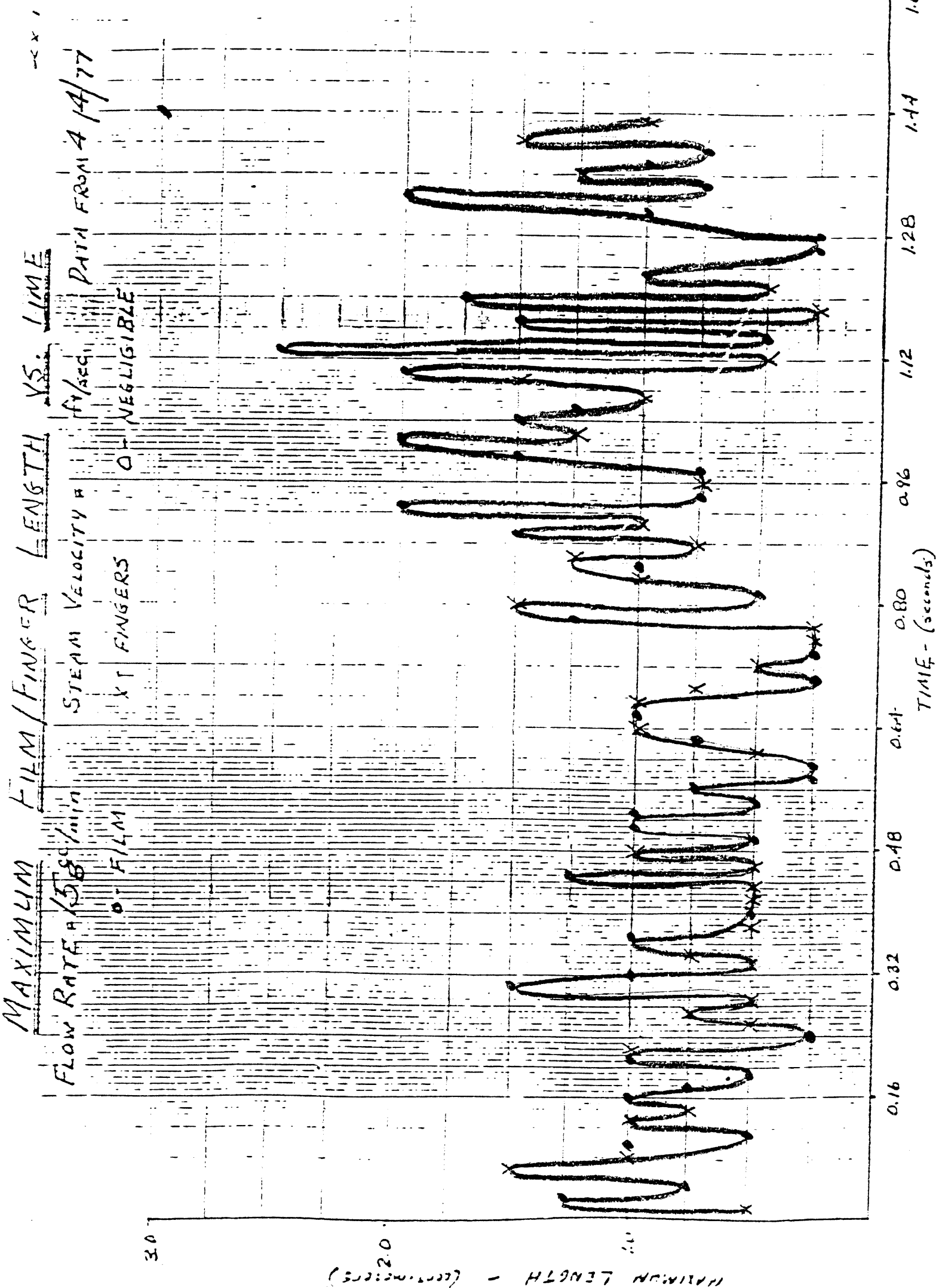
O - FILM



MAXIMUM LENGTH - (centimeters)

0.16 0.32 0.48 0.64 0.80 0.96 1.12 1.28 1.44 1.60

TIME



MAXIMUM FILM / FINGER LENGTH VS. TIME

DATA FROM 4/4/77

ft/sec

NEGLIGIBLE

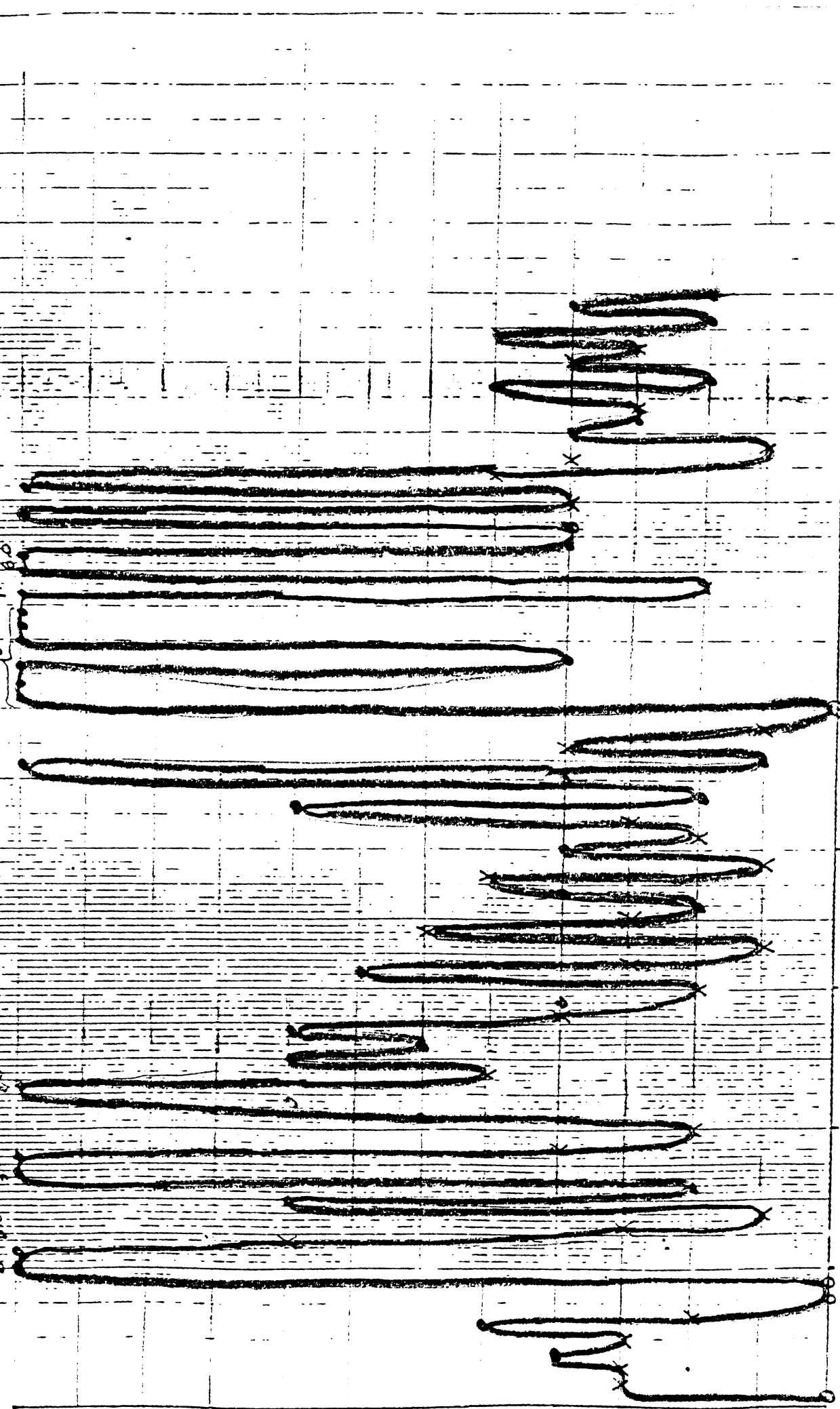
STEAM VELOCITY #

60 40 80

FINGERS

FLOW RATE 50 cc/min

DOT FILM



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

DATA FROM 4/4/77

ft/sec

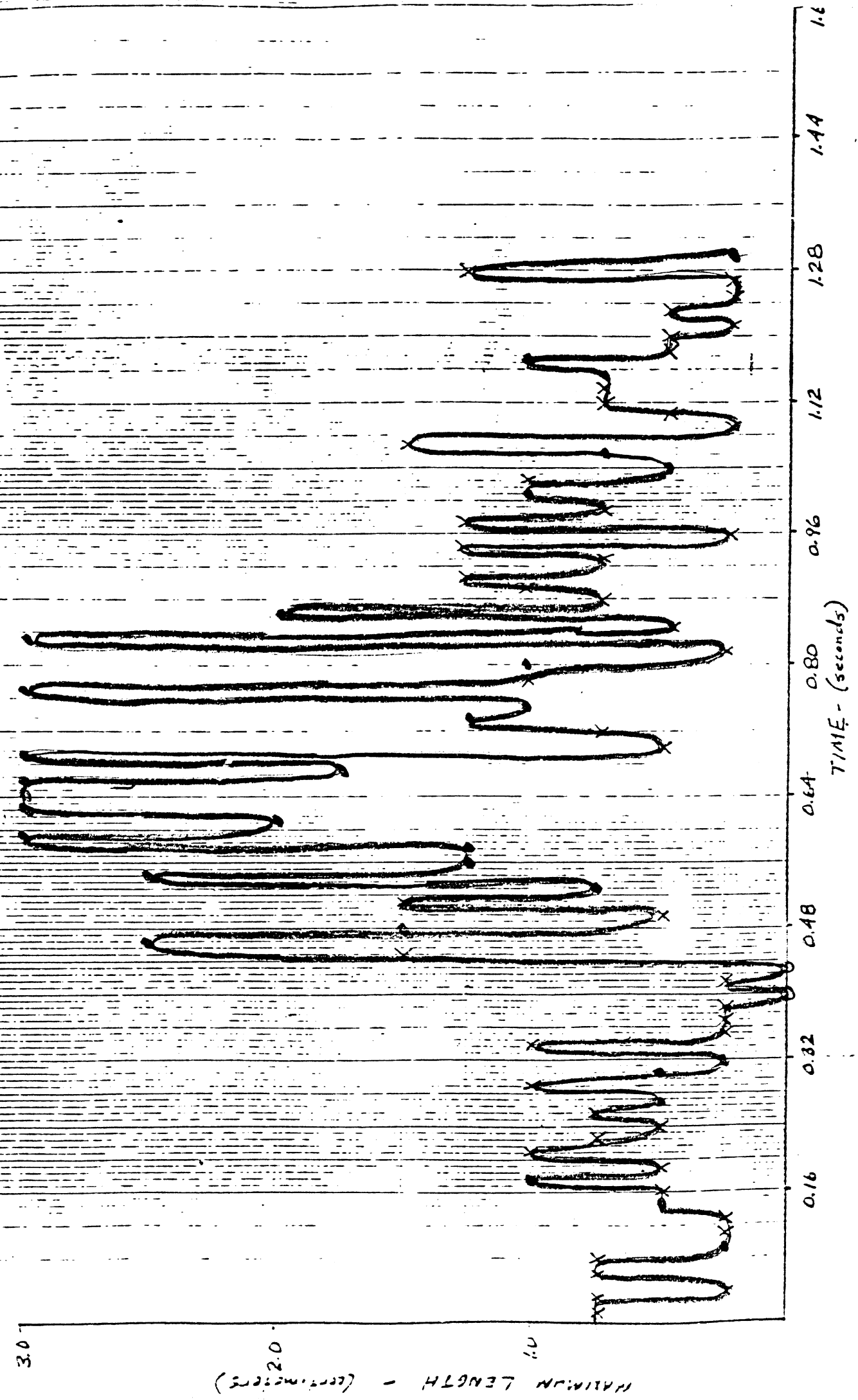
STEAM VELOCITY #

FLOW RATE # 30 cc/min

○ - NEGLIGIBLE

× | FINGERS

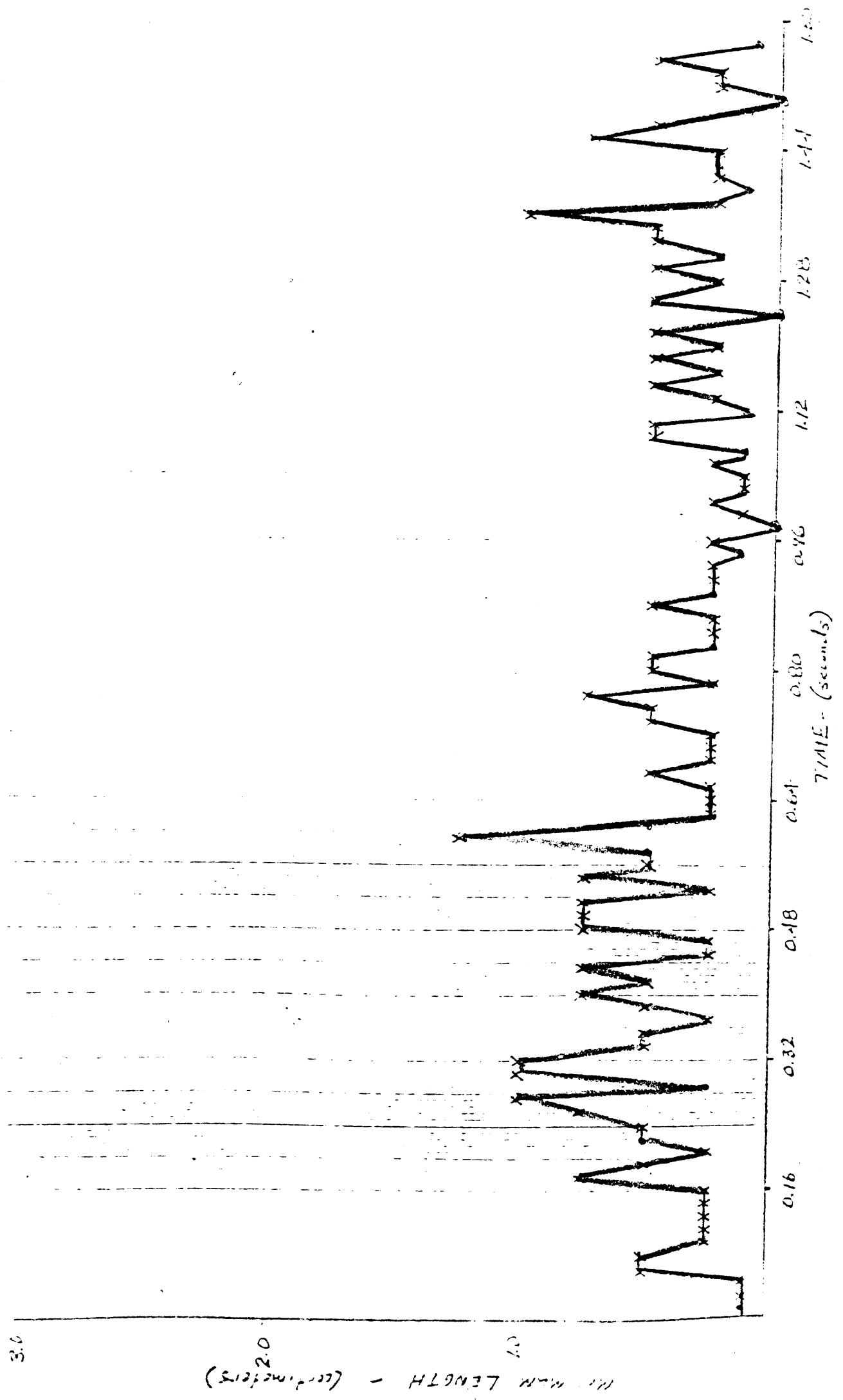
● - FILM



MAXIMUM FILM THICKNESS LENGTH VS. TIME

Flow Rate = 10 cc/min (A) Steam Velocity = 975 ft/sec. Data from 3/24/77

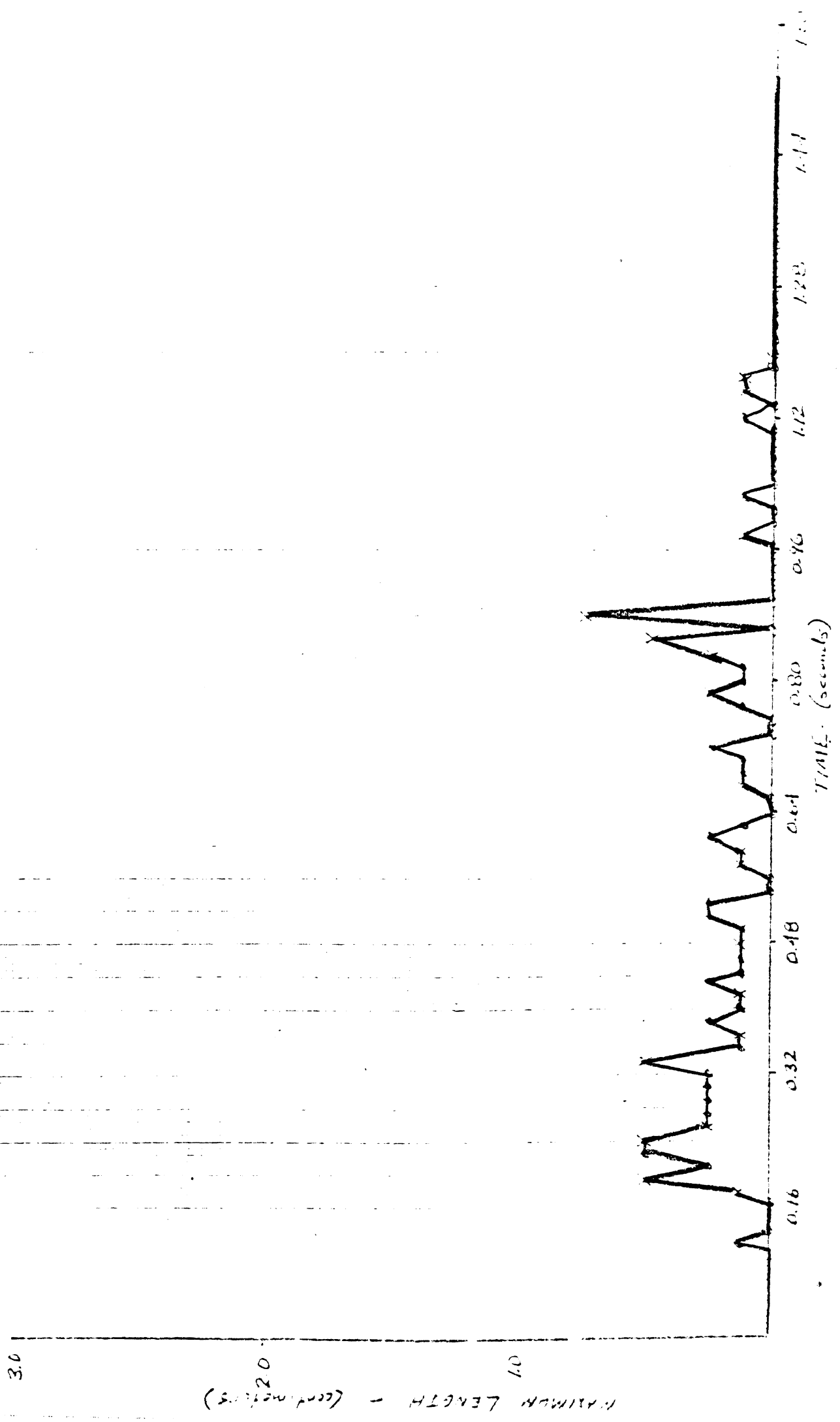
o - FILM x - FINGERS o - NEGLIGIBLE



MAXIMUM FILM/FINGR LENGTH VS. TIME

Flow Rate = 5 cc/min (1) Steam Velocity = 774 ft/sec. Data from 1/11

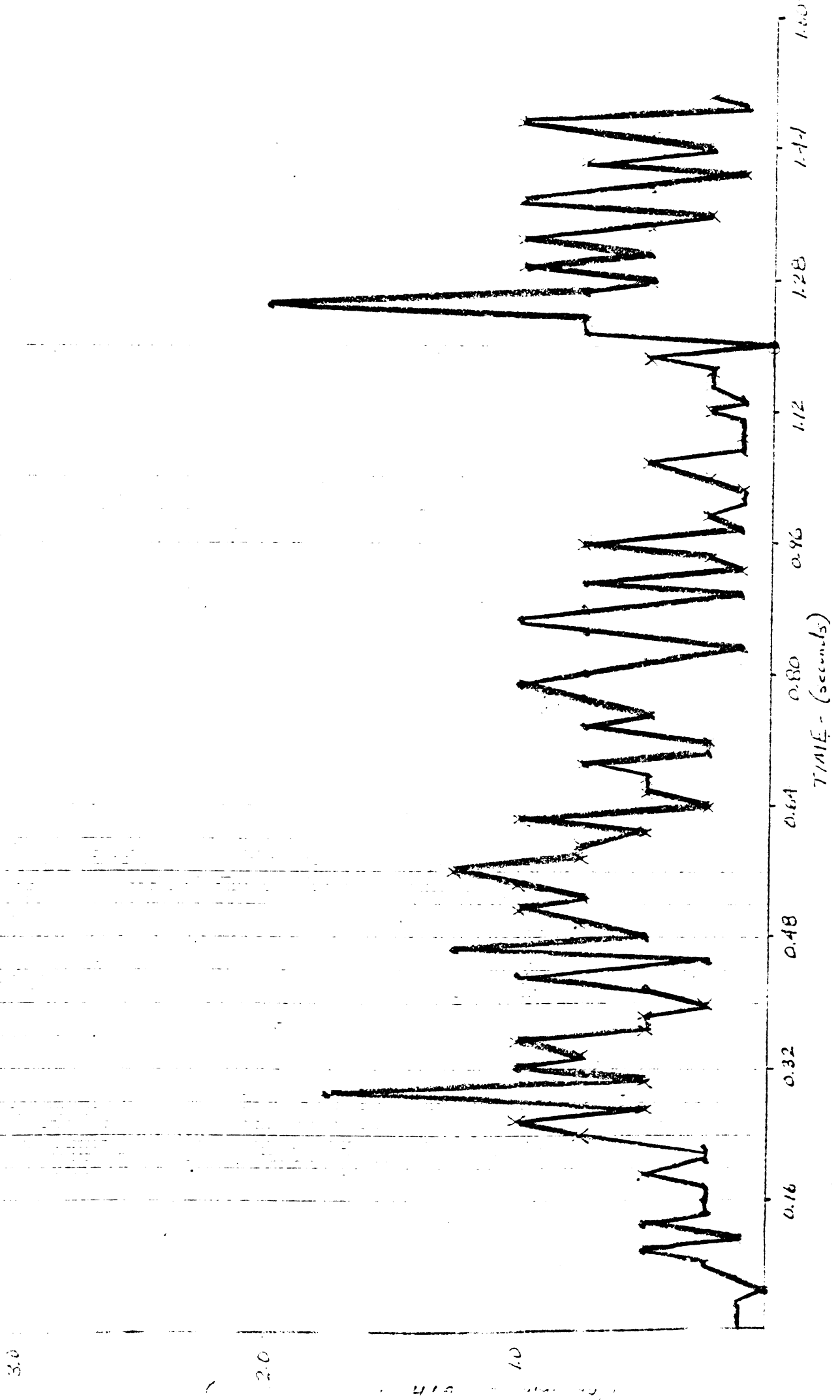
● - FILM x - FINGERS ○ - NEGLIGIBLE



MAXIMUM FILM/FINGER LENGTH VS. TIME

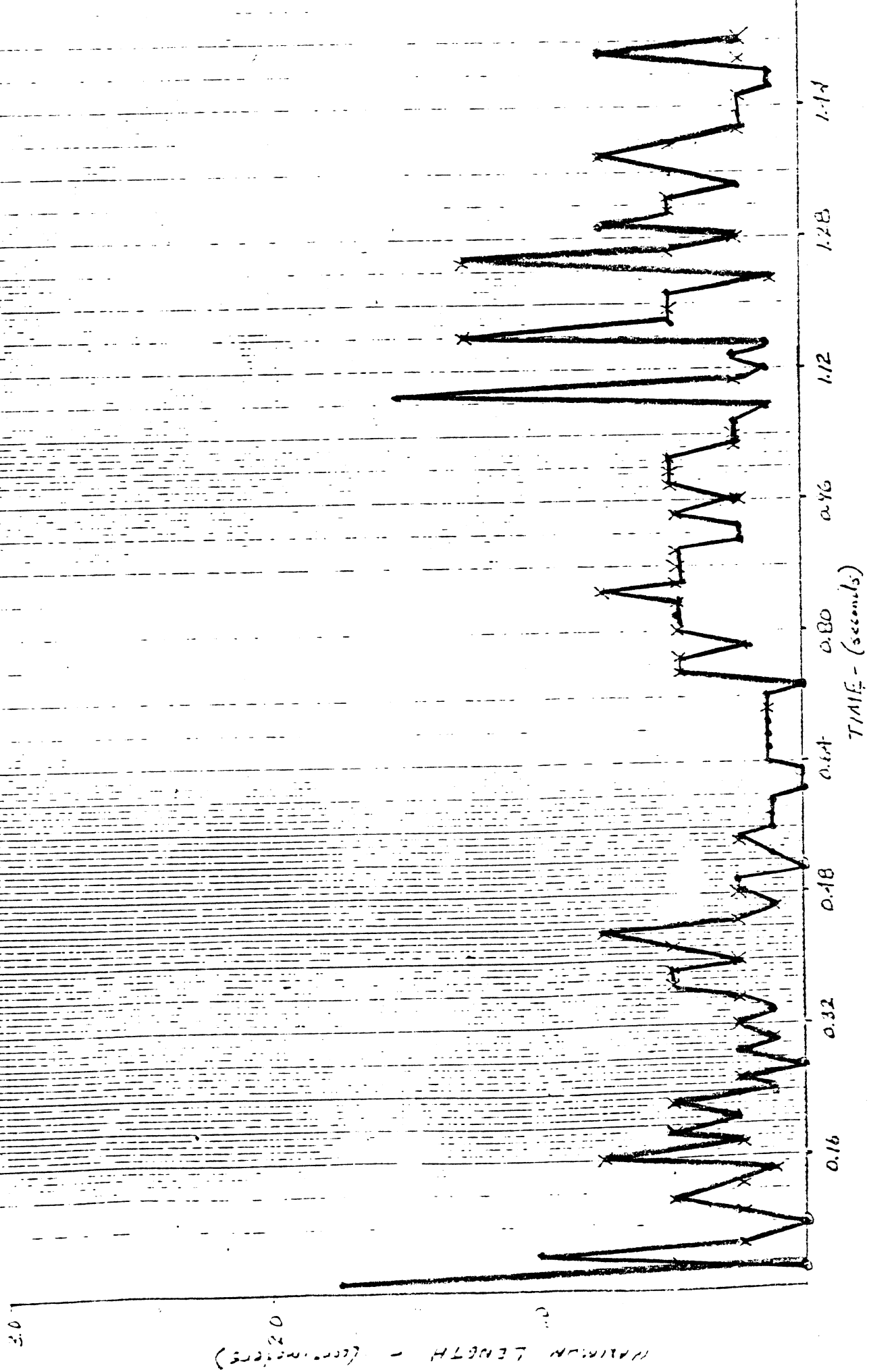
FLOW RATE = 15 cc/min (1) STEAM VELOCITY = 175 ft/sec. DATA FROM 1/77

o - FILM x - FINGERS 0 - NEGLIGIBLE



FILM / FINGERS LENGTH / FT. V.D. 110111

Flow Rate (0.55/min (B)) STERN VELOCITY # 975 (1/2 sec.) PAIR FROM 1/3/77
0 - FILM XT FINGERS 0 - NEGLIGIBLE



MAXIMUM FILM/FINNER LENGTH VS. TIME

FLOW RATE = 5 cc/min (A) STEAM VELOCITY = 1100 ft/sec. DATA FROM 5/14/77

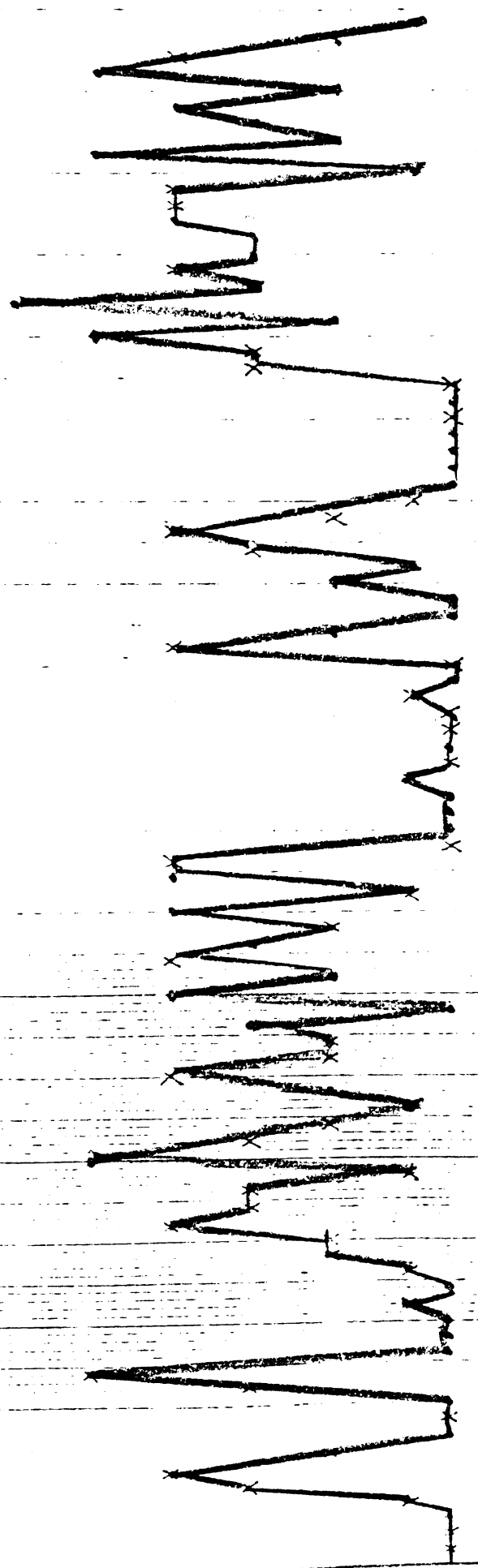
0.1 FINGERS 0 - NEGLIGIBLE

0.1 FINGERS

0.1 FINGERS

R

MAXIMUM LENGTH - (centimeters)



MAXIMUM LENGTH - (CENTIMETERS)

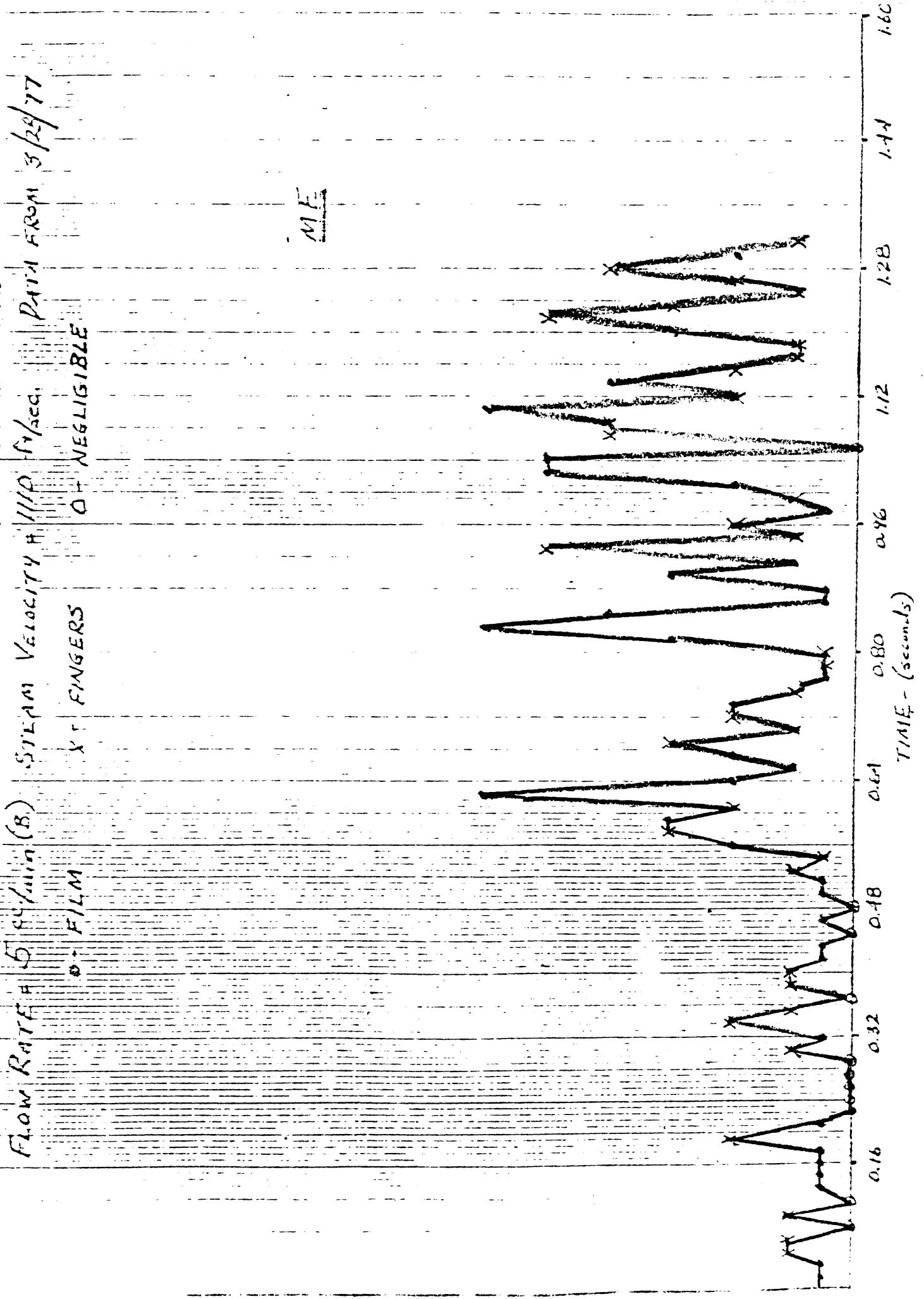
MAXIMUM FILM/FINGER LENGTH VS. TIME

FLOW RATE # 5
 40/min (B.)
 0 - FILM

STREAM VELOCITY # 1110
 ft/sec.
 0 - NEGLIGIBLE

PAIR FROM 3/29/77

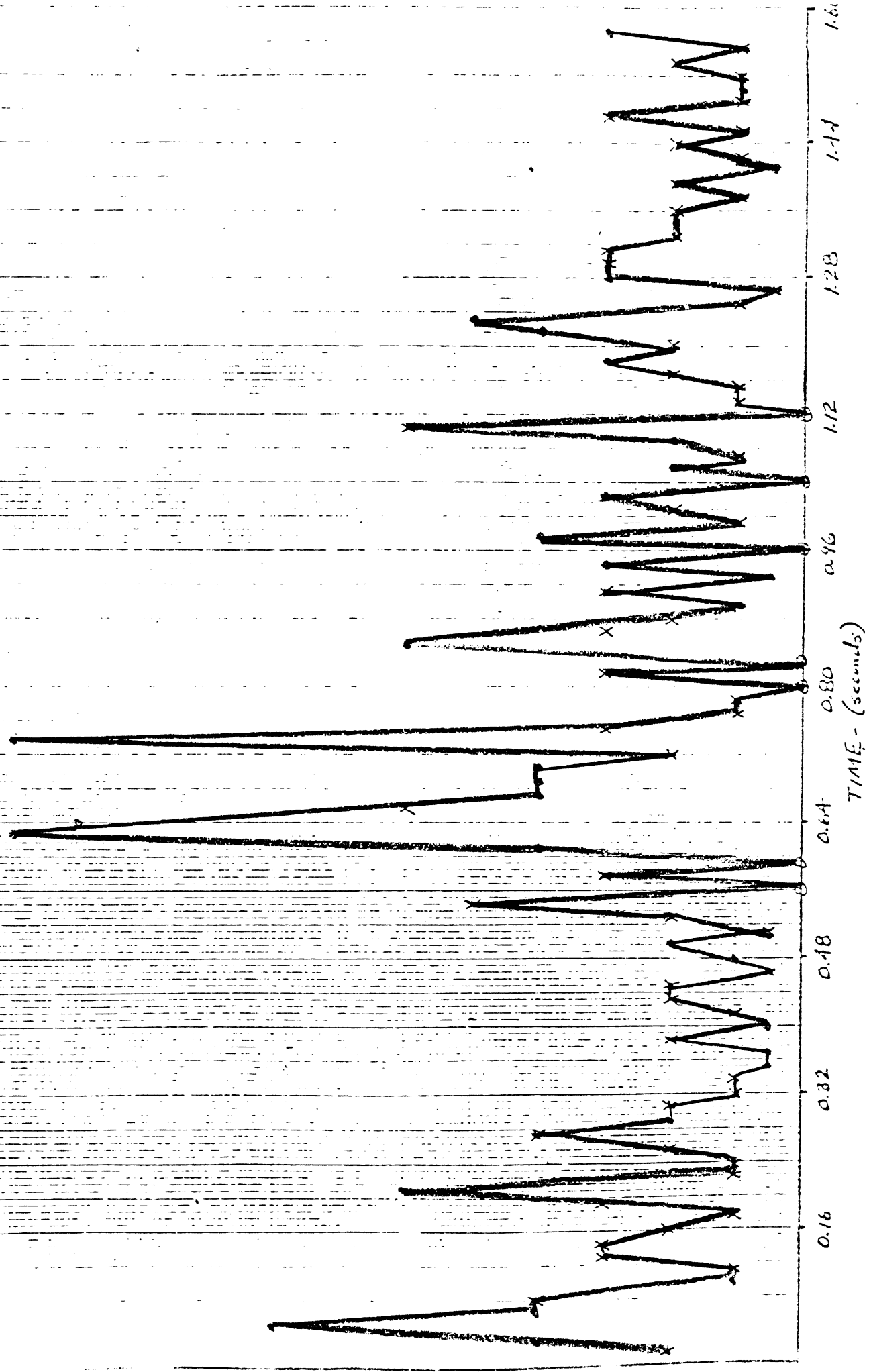
ME



MAXIMUM FILM/FIN²R LENGTH VS. TIME

FLOW RATE = 30 cc/min (B) STEAM VELOCITY = 975 ft/sec. DATA FROM 15/14/77
 0 - FILM X - FINGERS 0 - NEGLIGIBLE

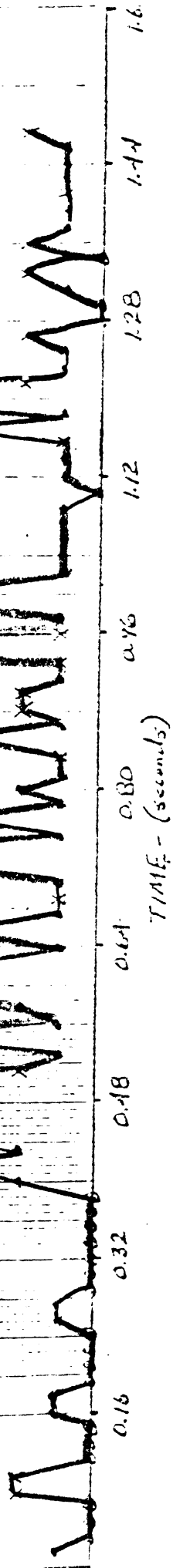
MAXIMUM LENGTH - (centimeters)
 20
 10



FLOW RATE = 0.55/min
OF FILM

STEAM VELOCITY = 1100 ft/sec.
XT FINGERS
OF NEGLIGIBLE

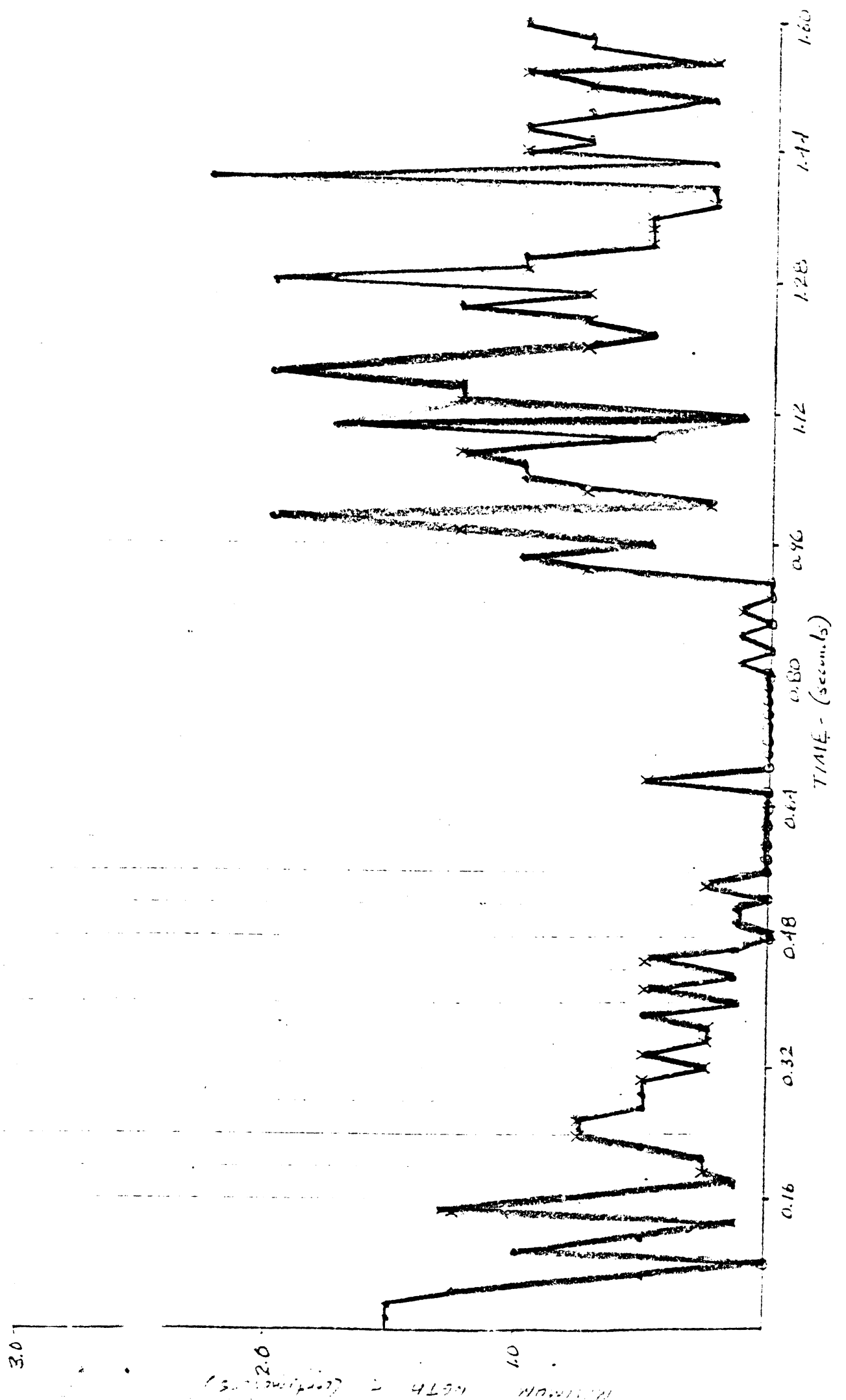
DATA FROM 5/23/77



MAXIMUM FILM / FINGER LENGTH VS. TIME

FLOW RATE = 20 cc/min (B) STREAM VELOCITY = 175 ft/sec. DATA FROM 3/2/71

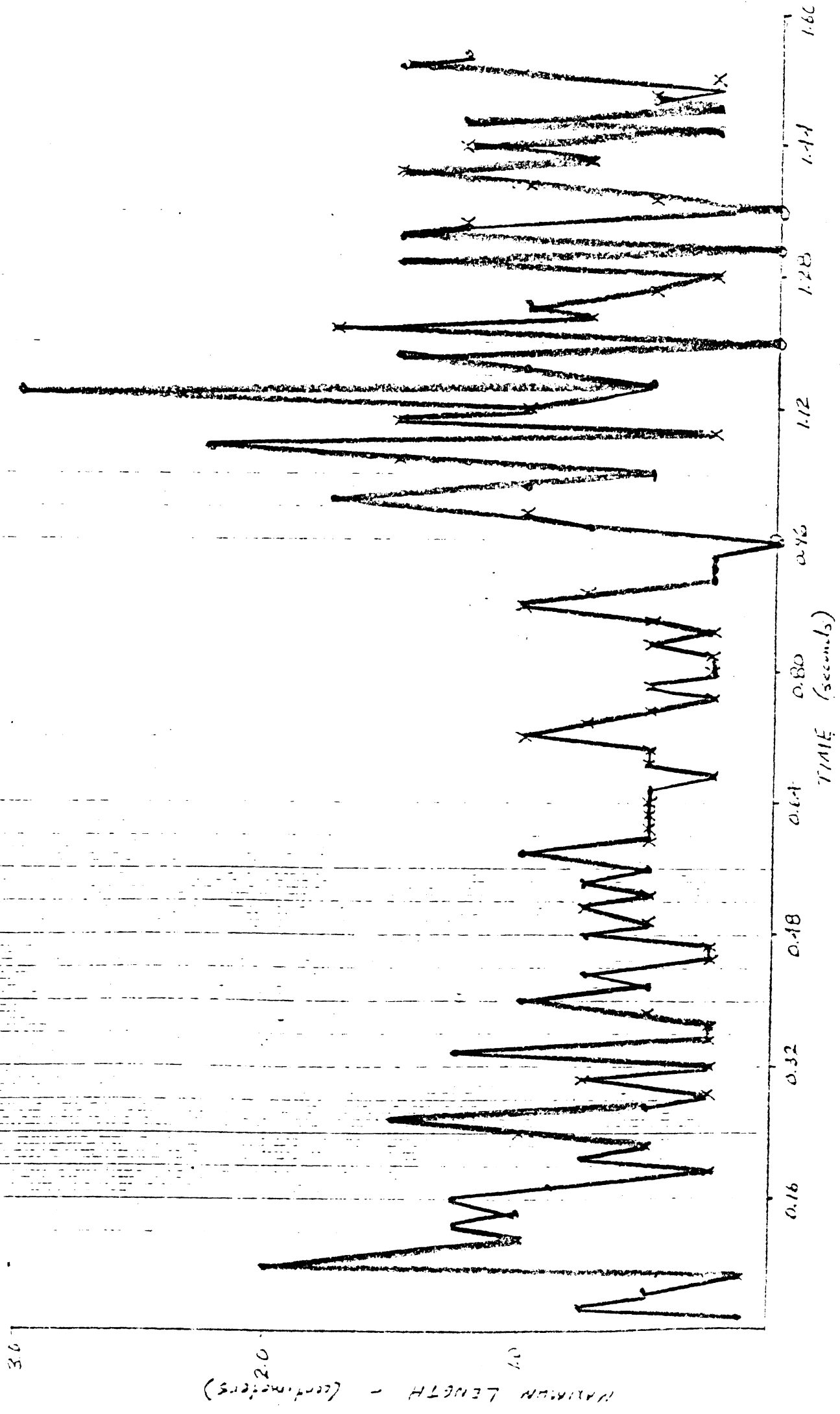
● - FILM x - FINGERS 0 - NEGLIGIBLE



MAXIMUM FILM / FINGER LENGTH VS. TIME

FLOW RATE = 30 cc/min (A) STEAM VELOCITY = 915 ft/sec. DATA FROM 3/13/77
 X - FINGERS O - NEGLIGIBLE

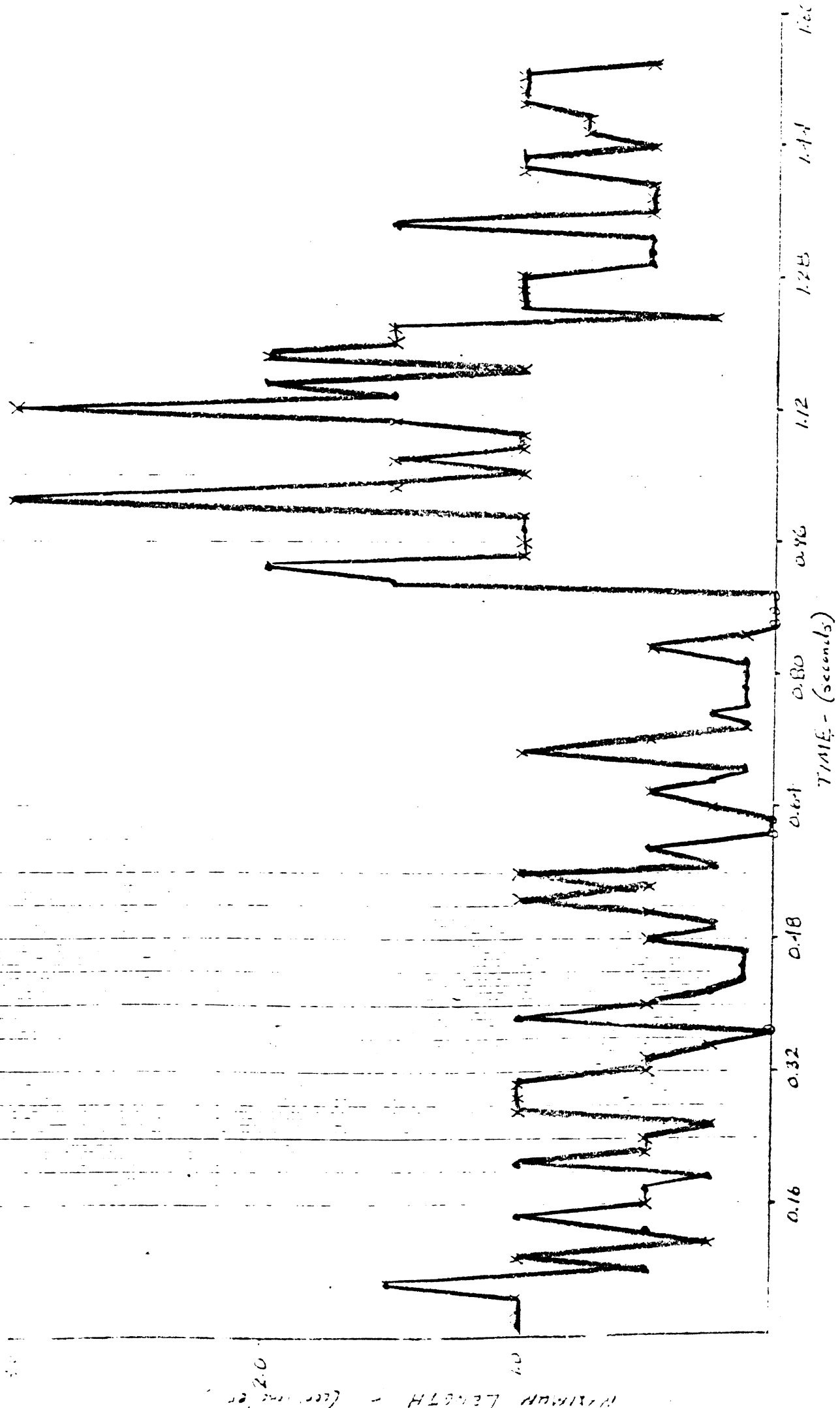
FILM



MAXIMUM FILM/FINGER LENGTH VS. TIME

Flow Rate = 20 cc/min. (A) Stream Velocity = 915 ft/sec. Data from 3/2/77

o - FILM x - FINGERS 0 - NEGLIGIBLE



MAXIMUM

FILM / FINGER LENGTH

VS. TIME

FLOW RATE # 15 cc/min (F)

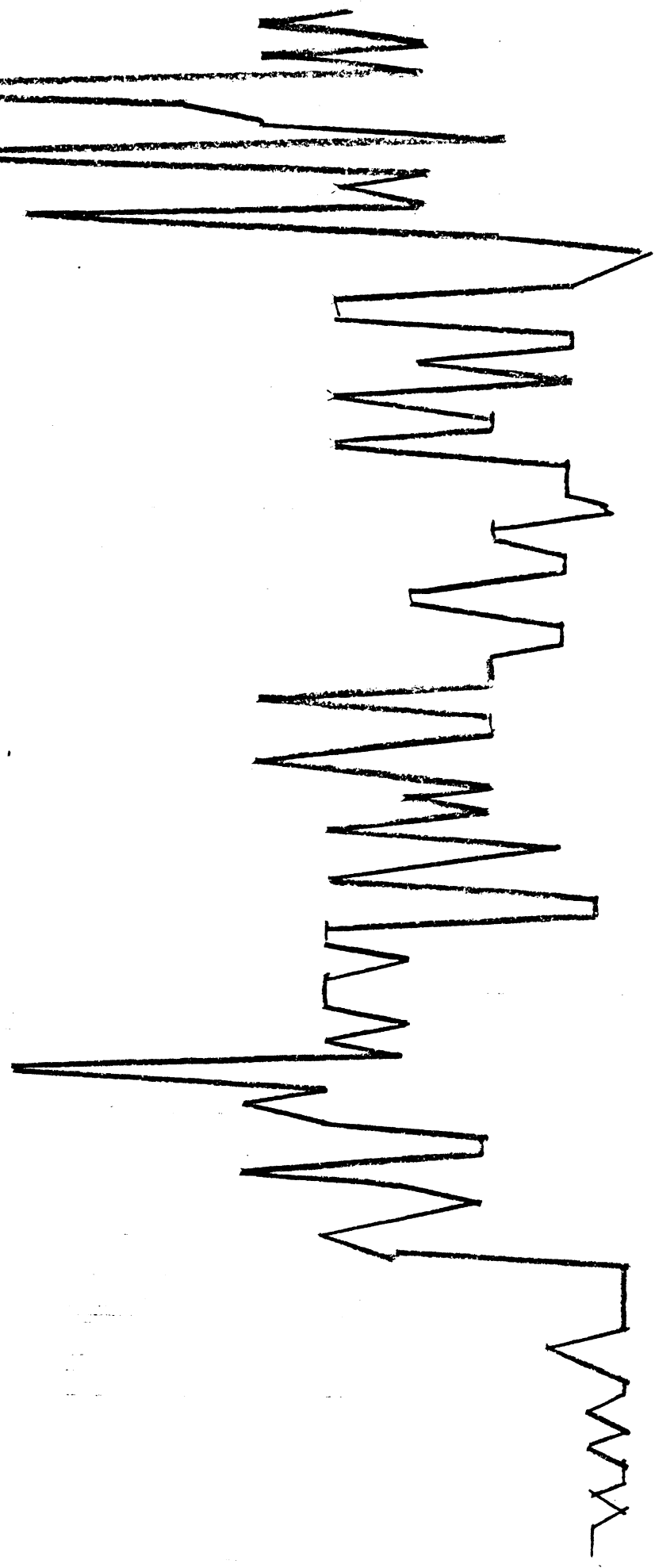
STEAM VELOCITY # 975 ft/sec

DATA FROM 3/13/77

OT FILM

X FINGERS

OT NEGLIGIBLE



MAXIMUM LENGTH VS. TIME

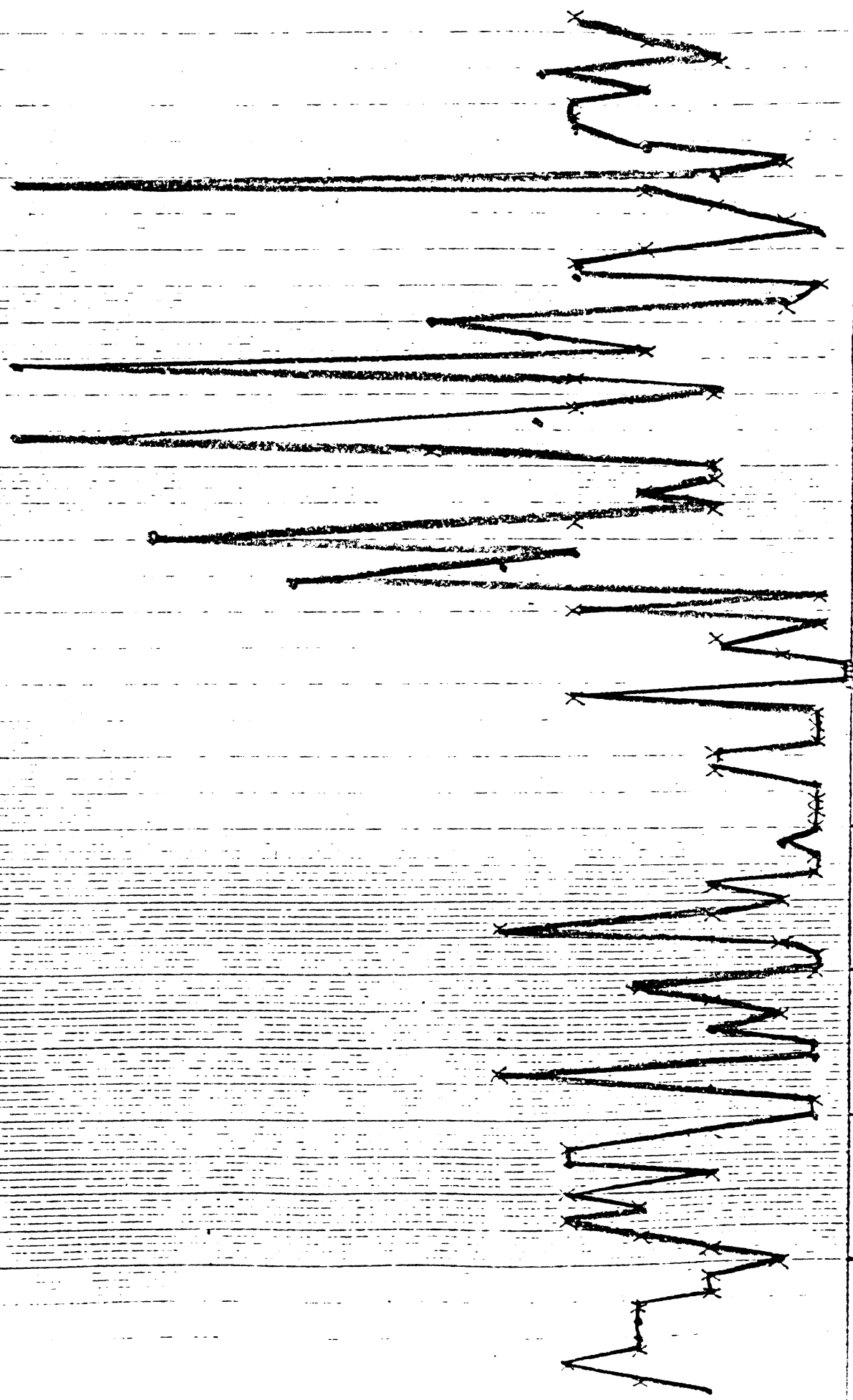
FLOW RATE = 10 cc/min (8) STEAM VELOCITY = 1100 ft/sec. DATA FROM 5/18/77

0 - FILM

X - FINGERS

O - NEGLIGIBLE

MAXIMUM LENGTH - (centimeters)



0.16 0.20 0.24 0.28 0.32 0.36 0.40 0.44 0.48 0.52 0.56 0.60 0.64 0.68 0.72 0.76 0.80 0.84 0.88 0.92 0.96 1.00 1.04 1.08 1.12 1.16 1.20 1.24 1.28 1.32 1.36 1.40 1.44 1.48 1.52 1.56 1.60 1.64 1.68 1.72 1.76 1.80

TIME - (seconds)

MAXIMUM LENGTH - (centimeters)

FLOW RATE 10 cc/min (A)

0 - FILM

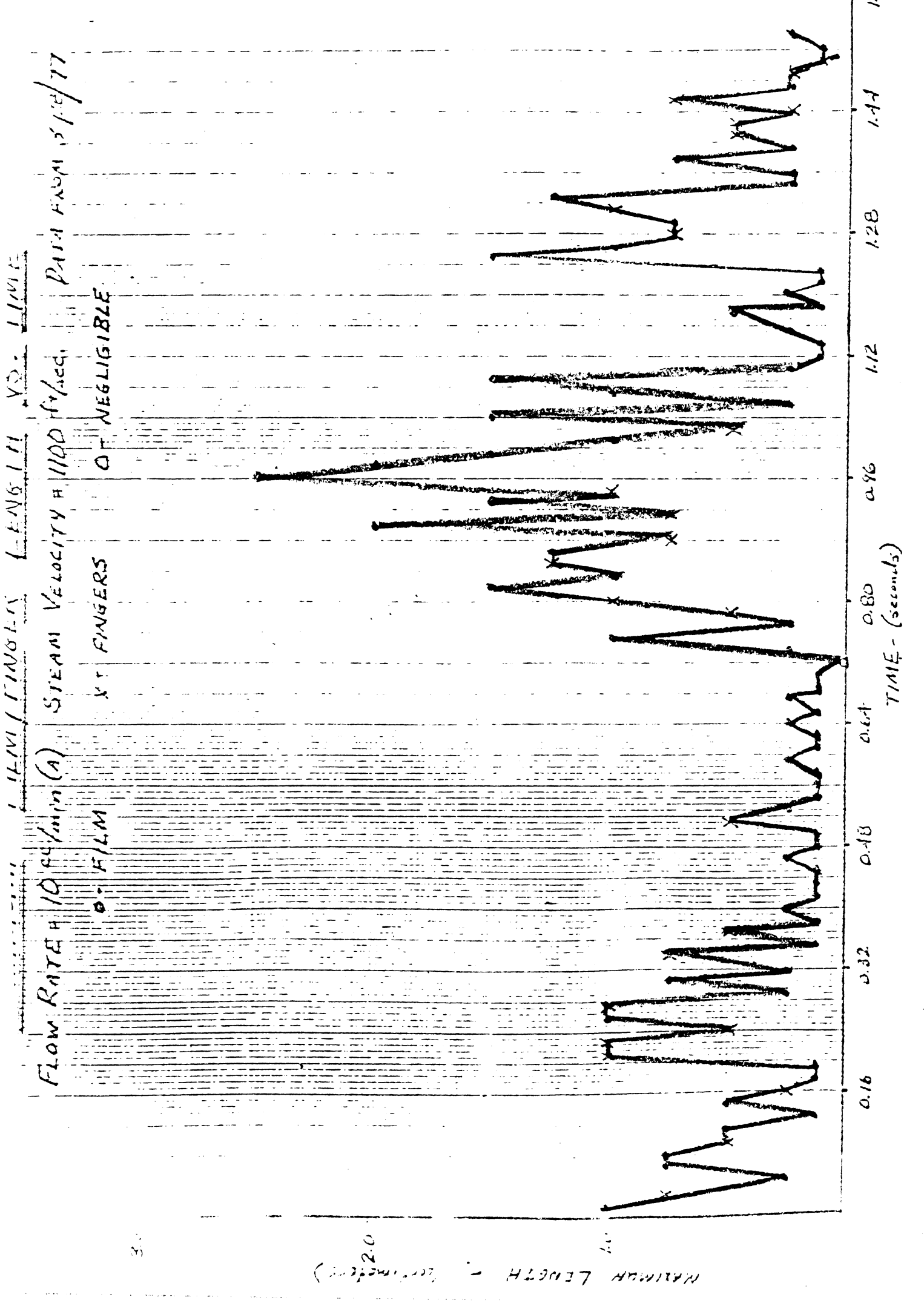
X - FINGERS

STEAM VELOCITY 1100 ft/sec.

0 - NEGLIGIBLE

DATA FROM 5/18/77

INCHES LENGTH VS. TIME

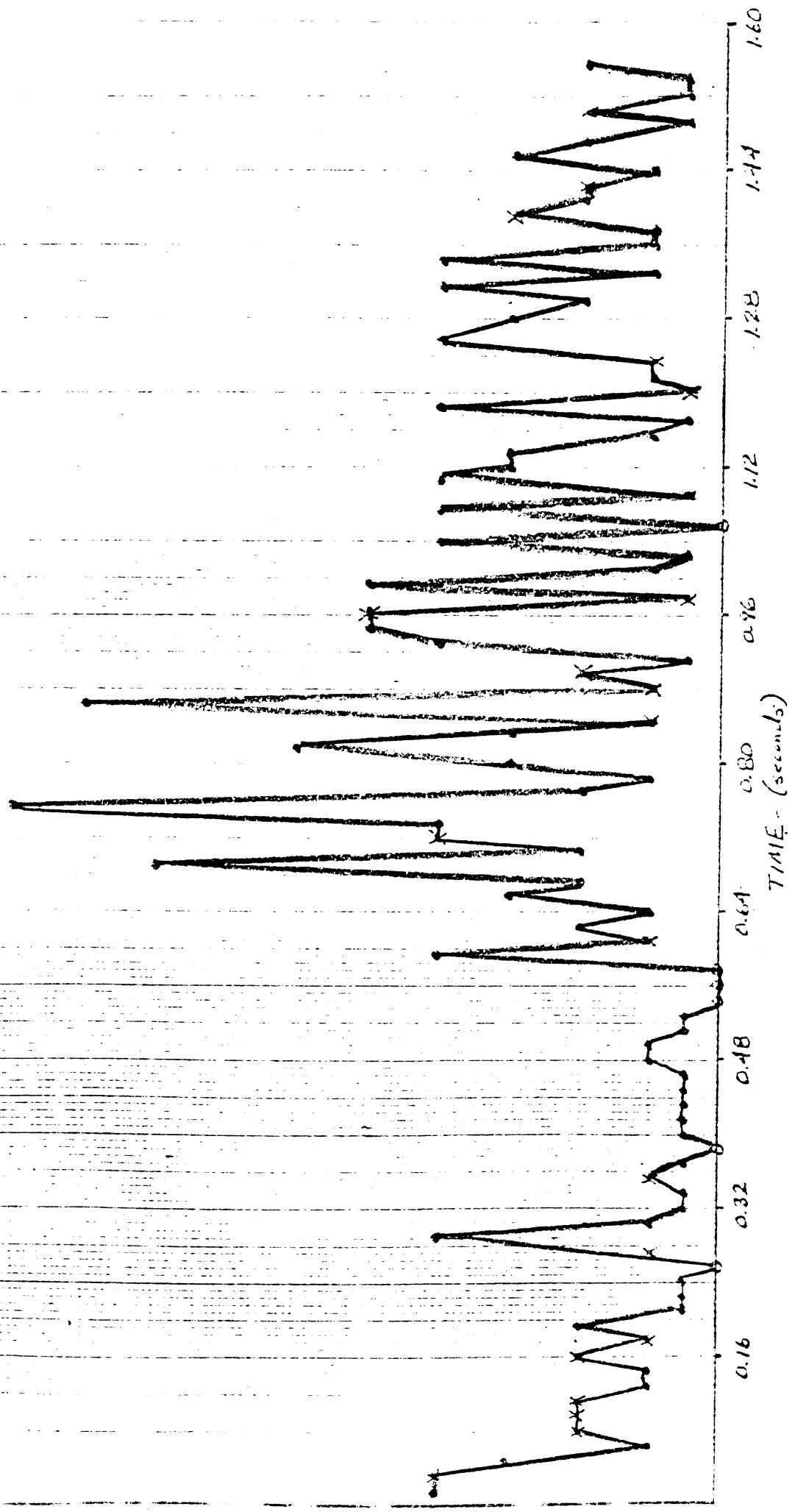


MAXIMUM FILM LENGTH VS. TIME

FLOW RATE = 15 cc/min (A) STEAM VELOCITY = 1100 ft/sec. DATA FROM 5/1/77

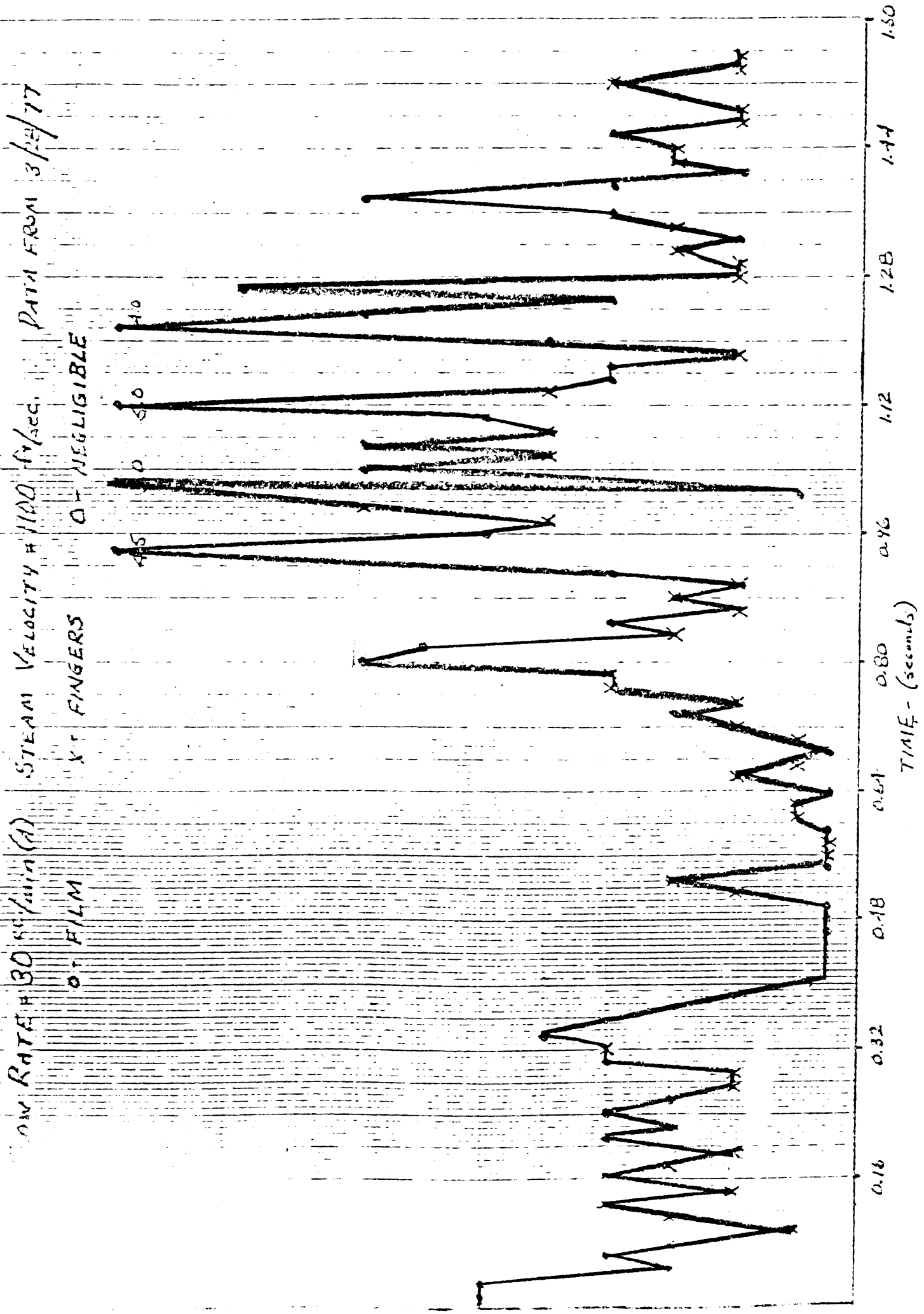
o - FILM x - FINGERS o - NEGLIGIBLE

MAXIMUM LENGTH - (centimeters)



WAVELENGTH VS. TIME

FLOW RATE = 30 cc/min (A)
 STEAM VELOCITY = 1100 ft/sec.
 PATH FROM 3/22/77
 X = FINGERS
 O = NEGLIGIBLE



WAVELENGTH - (cm)

TIME - (seconds)

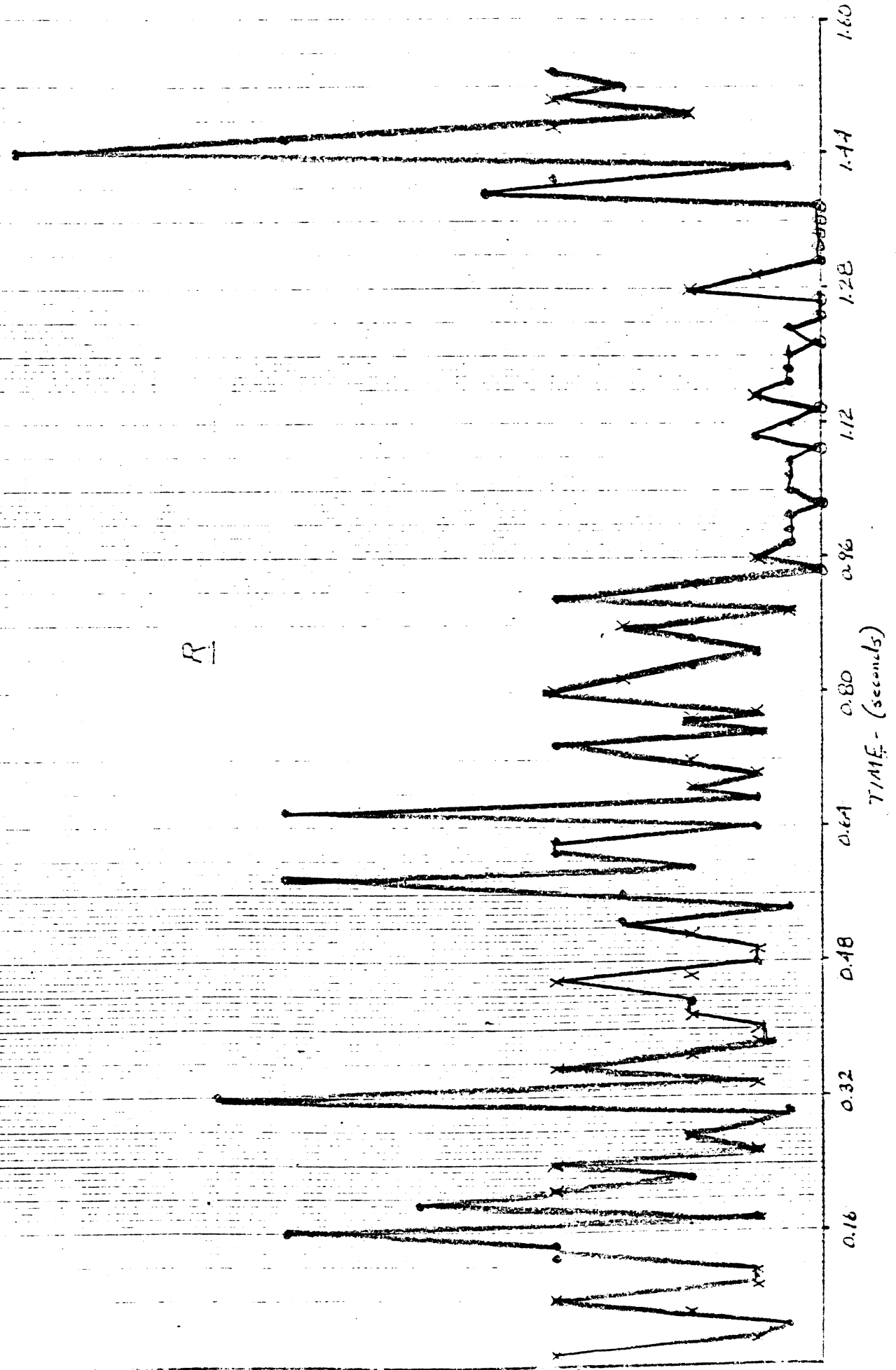
MAXIMUM FILM/ FINGER LENGTH VS. TIME

Flow Rate = 20 cc/min (A) Steam Velocity = 100 ft/sec. DATA FROM 3/3/77

X - FINGERS
O - NEGLIGIBLE

R

MINIMUM LENGTH - (centimeters)

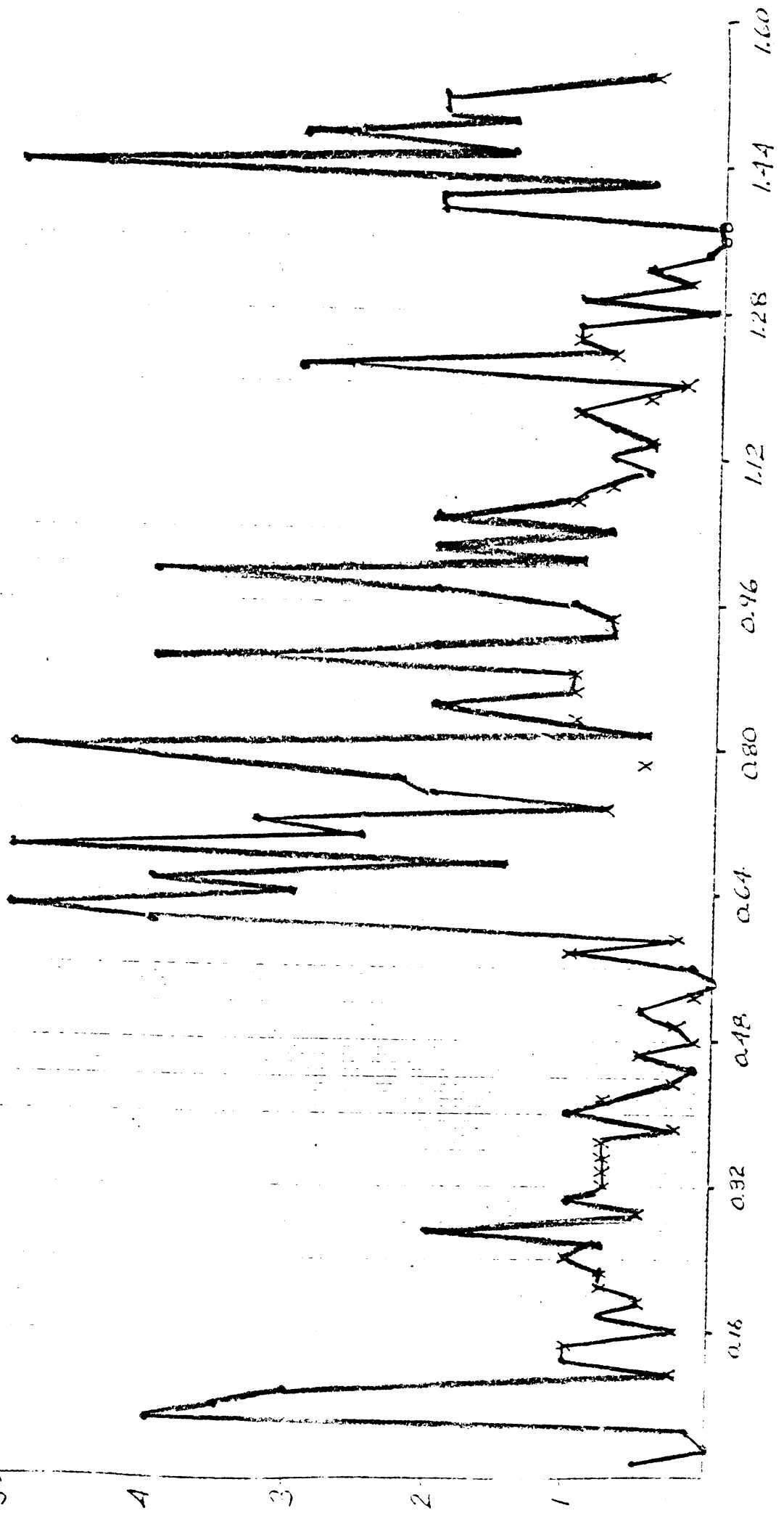


MAXIMUM FILM / FINGER LENGTH VS. TIME

FLOW RATE = 50 cc./min. (A) STEAM VELOCITY = $975 \frac{ft.}{sec.}$

DATA FROM 3/23/77

- O - FILM
- X - FINGERS
- o - NEGLIGIBLE



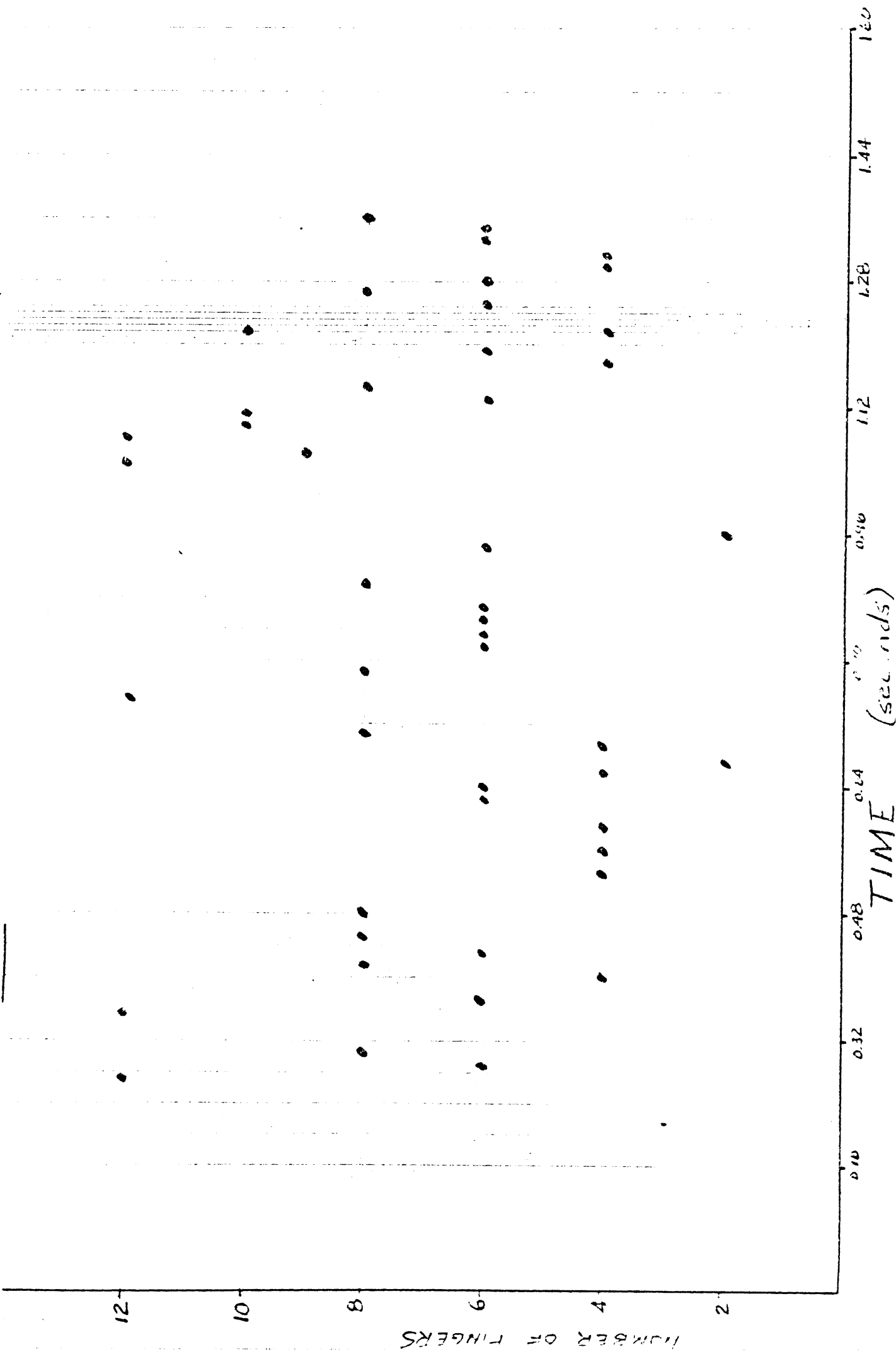
TIME (sec.)

APPENDIX D

NUMBER OF FINGERS VS. TIME

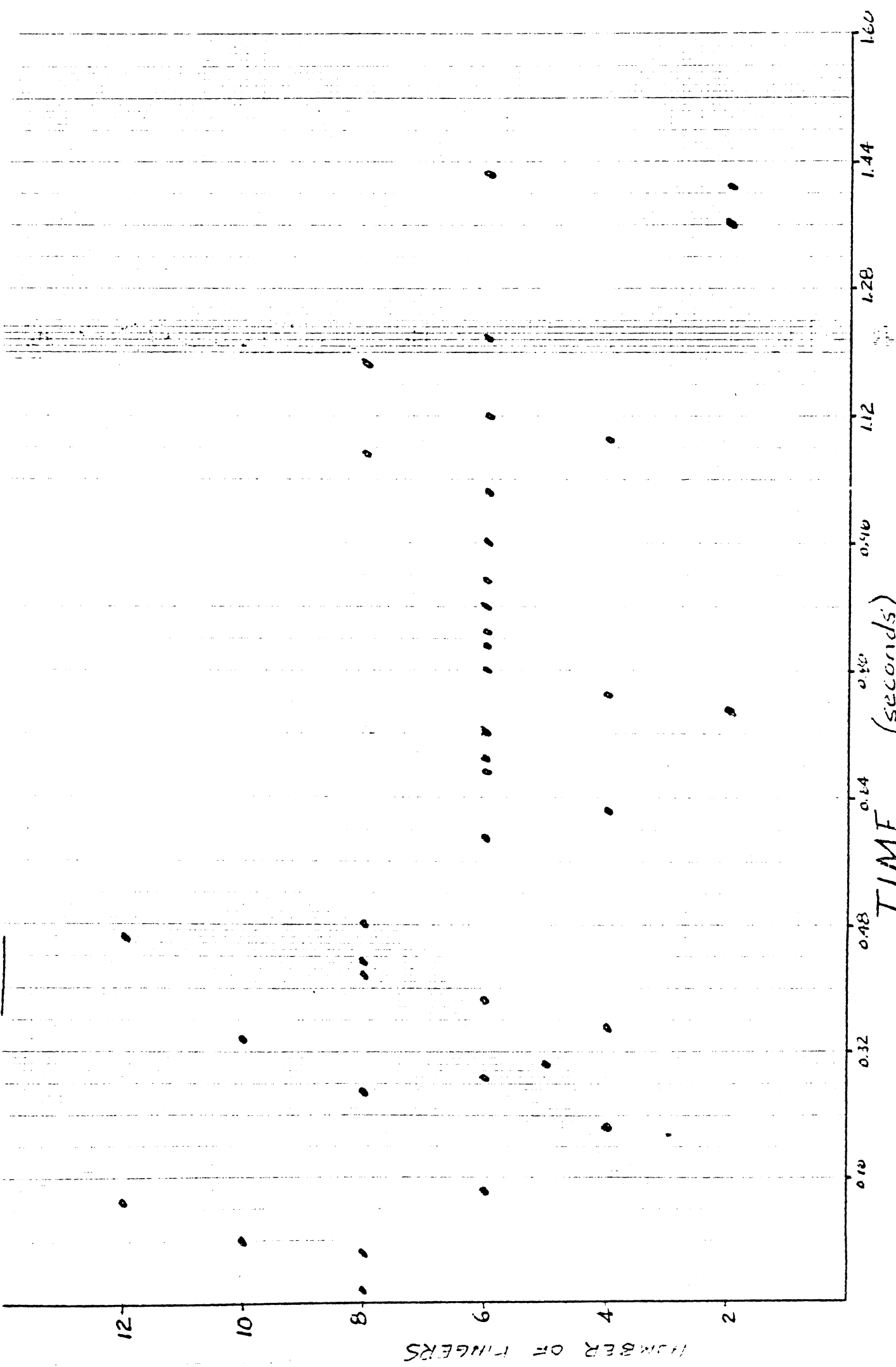
NUMBER OF FINGERS
VS.
TIME

STEAM VELOCITY = Ft./sec.
FLOW RATE = 20 A cc/min.



NUMBER OF FINGERS
VS.
TIME

STEAM VELOCITY = Ft./sec.
FLOW RATE = 15 B cc/min.

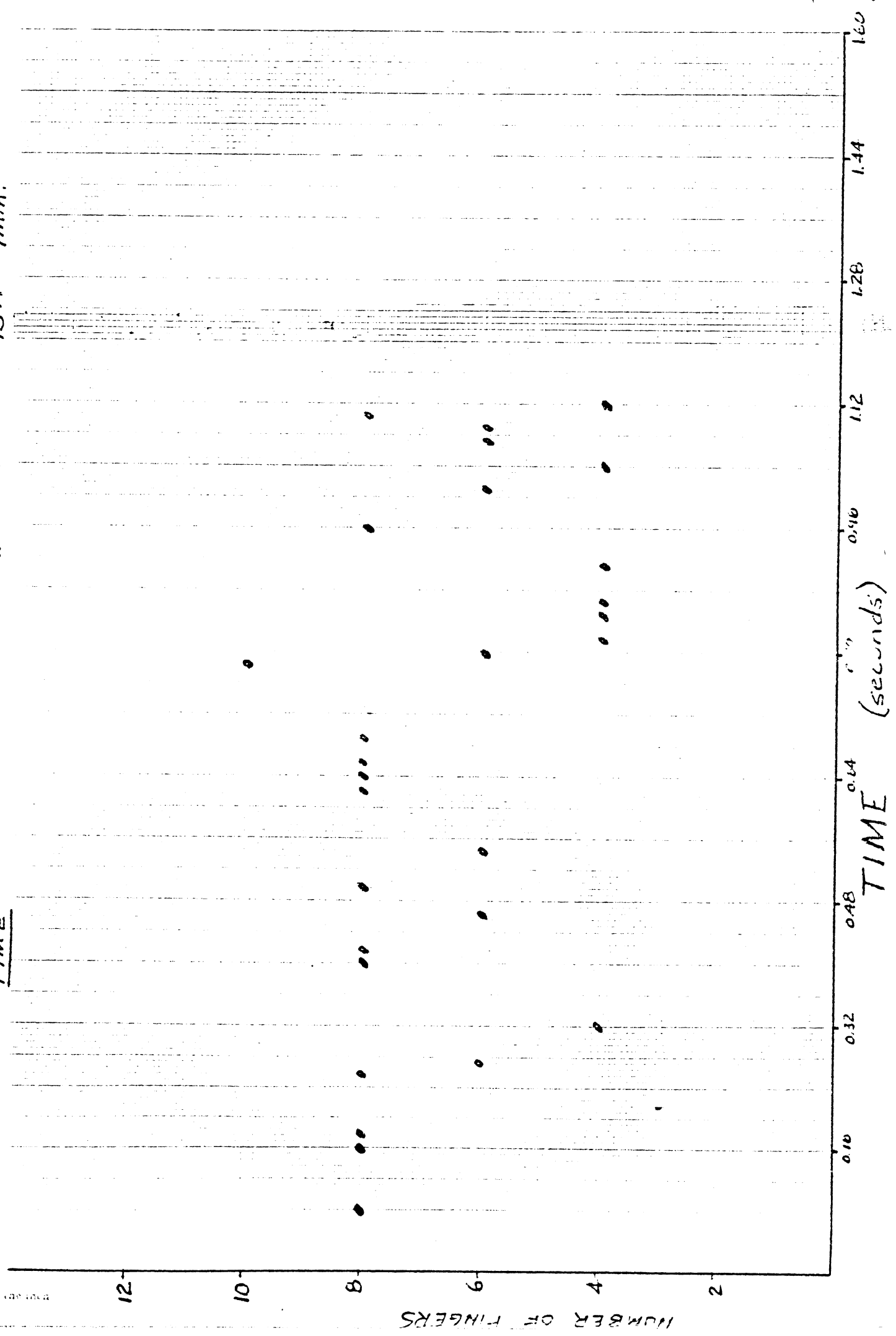


221

STEAM VELOCITY = 17.5 sec.
FLOW RATE = 15A cc/min.

NUMBER OF FINGERS
VS.
TIME

SCALE TO THE LEFT



NUMBER OF FINGERS

TIME (seconds)

12

10

8

6

4

2

0.10

0.32

0.48

0.64

0.80

0.96

1.12

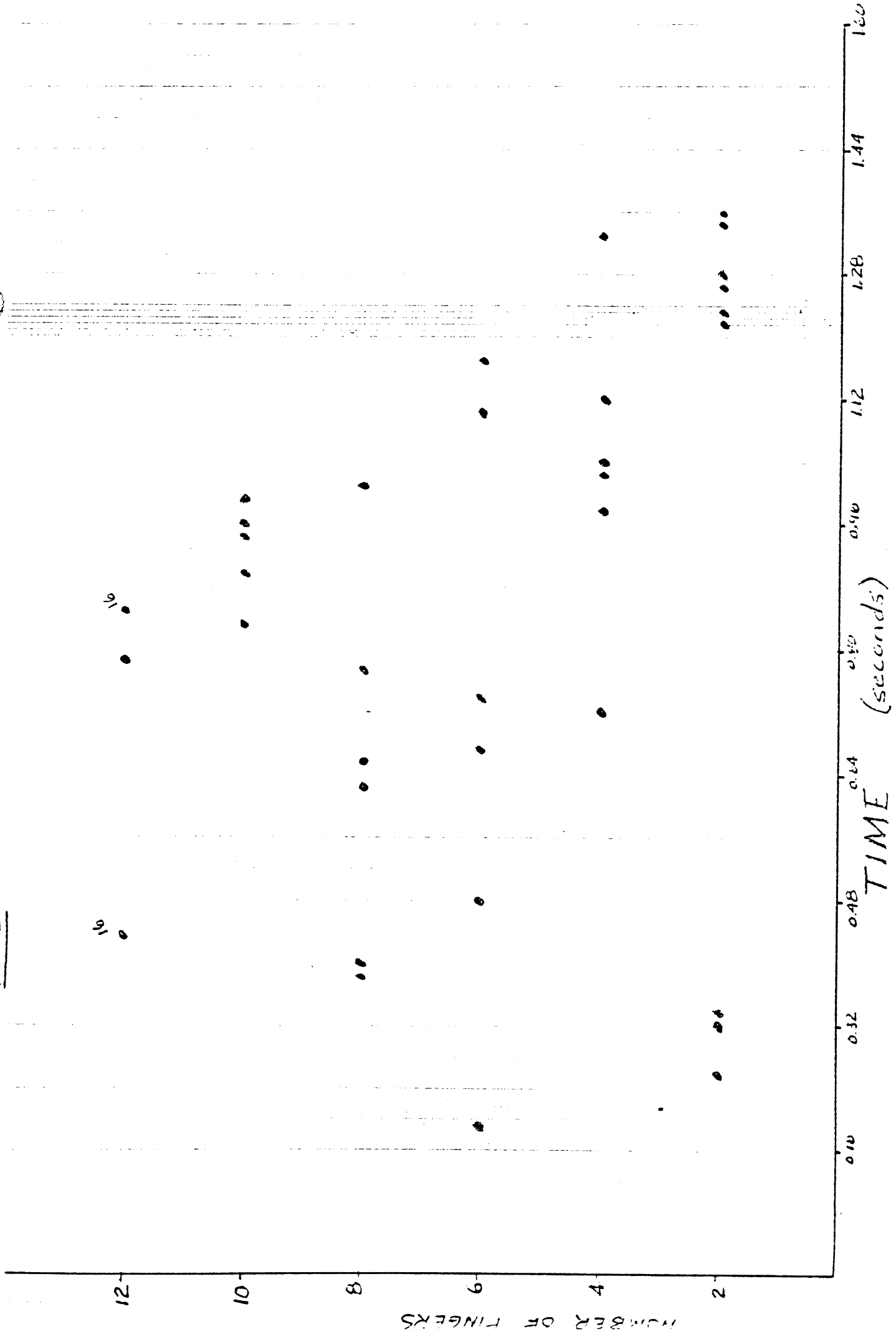
1.28

1.44

1.60

NUMBER OF FINGERS
VS.
TIME

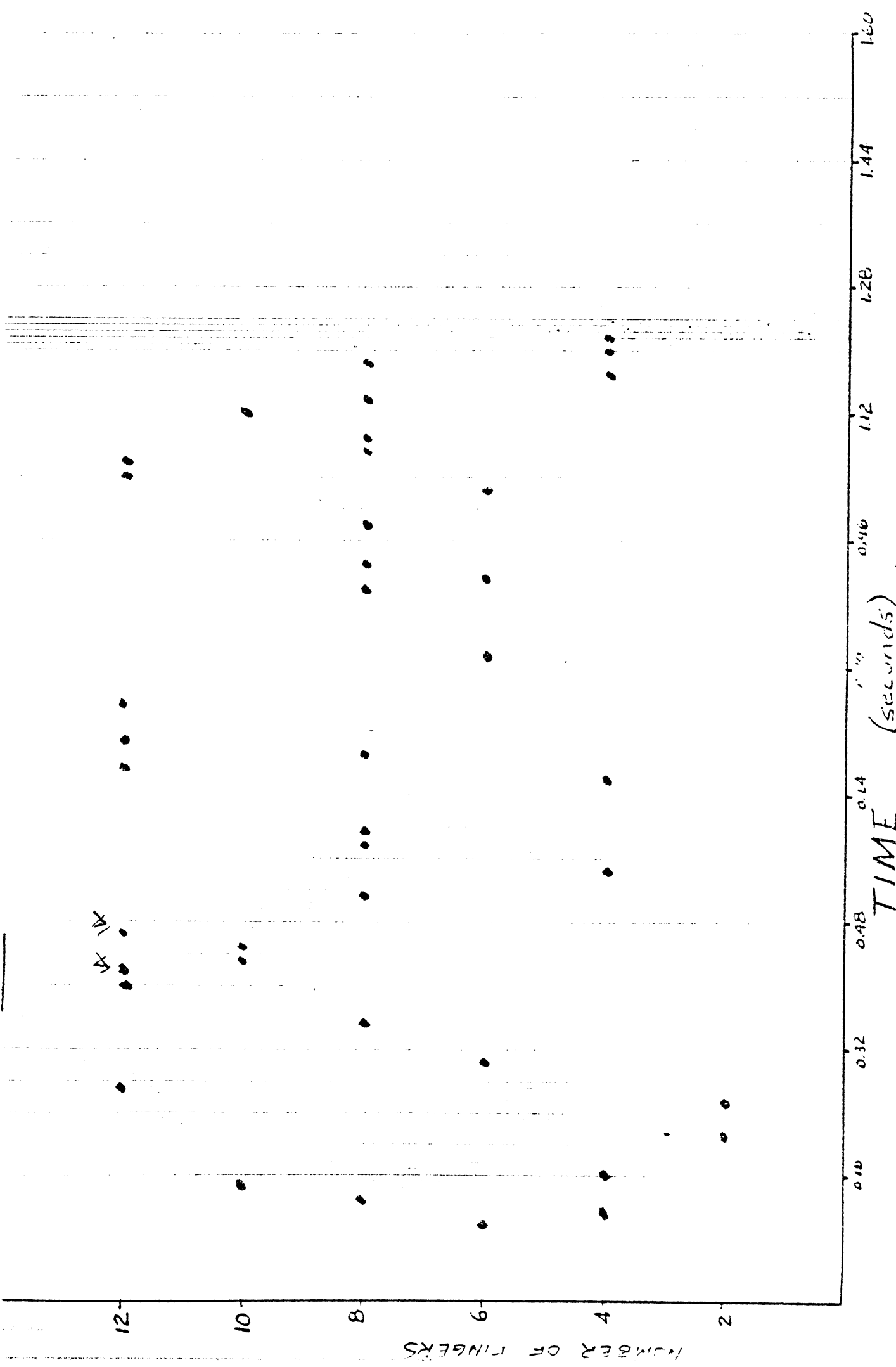
STEAM VELOCITY = Ft./sec.
FLOW RATE = 105 cc/min.



2x7

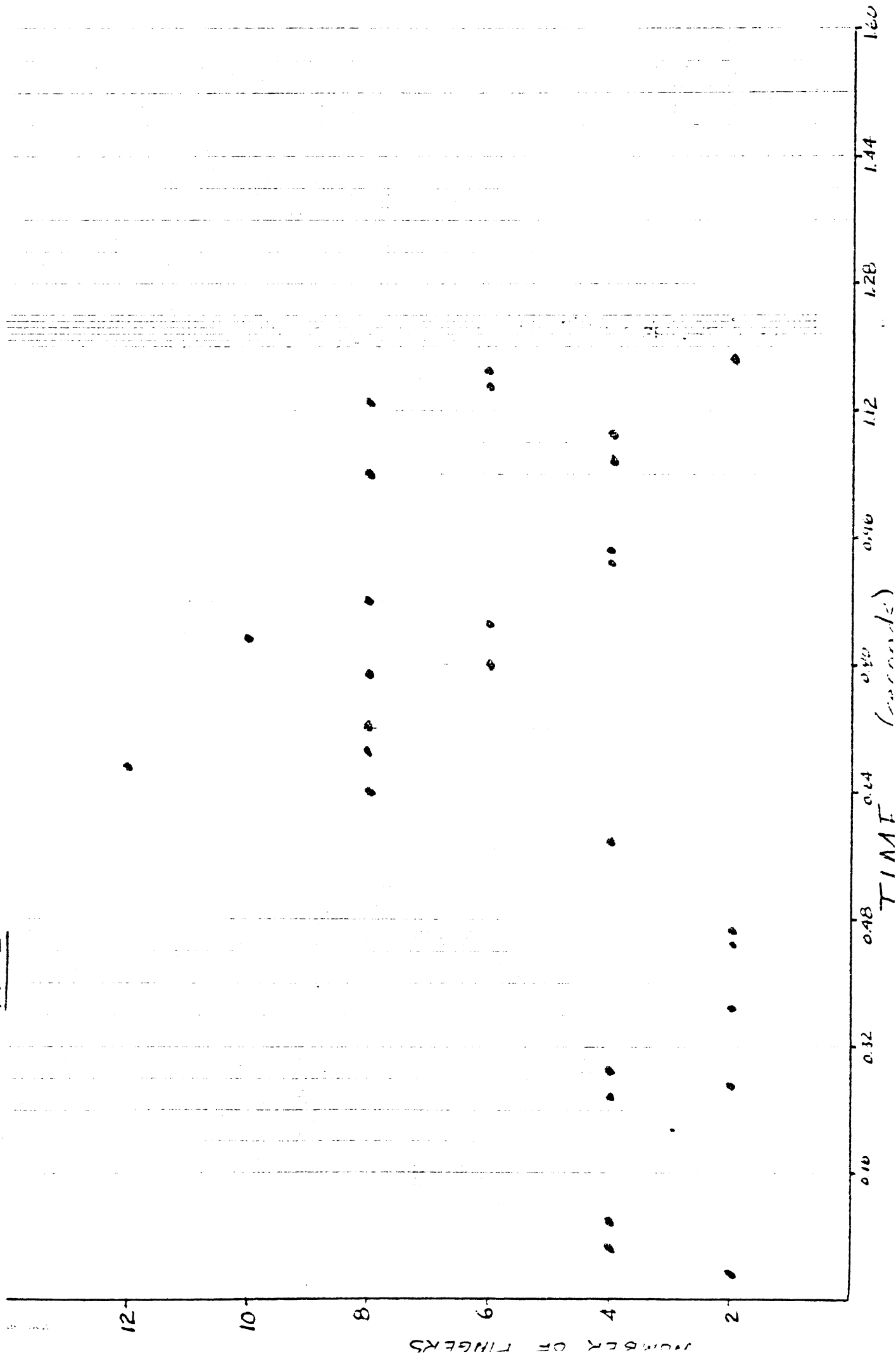
STEAM VELOCITY = Ft./sec.
FLOW RATE = 10 A cc/min.

NUMBER OF FINGERS
VS.
TIME



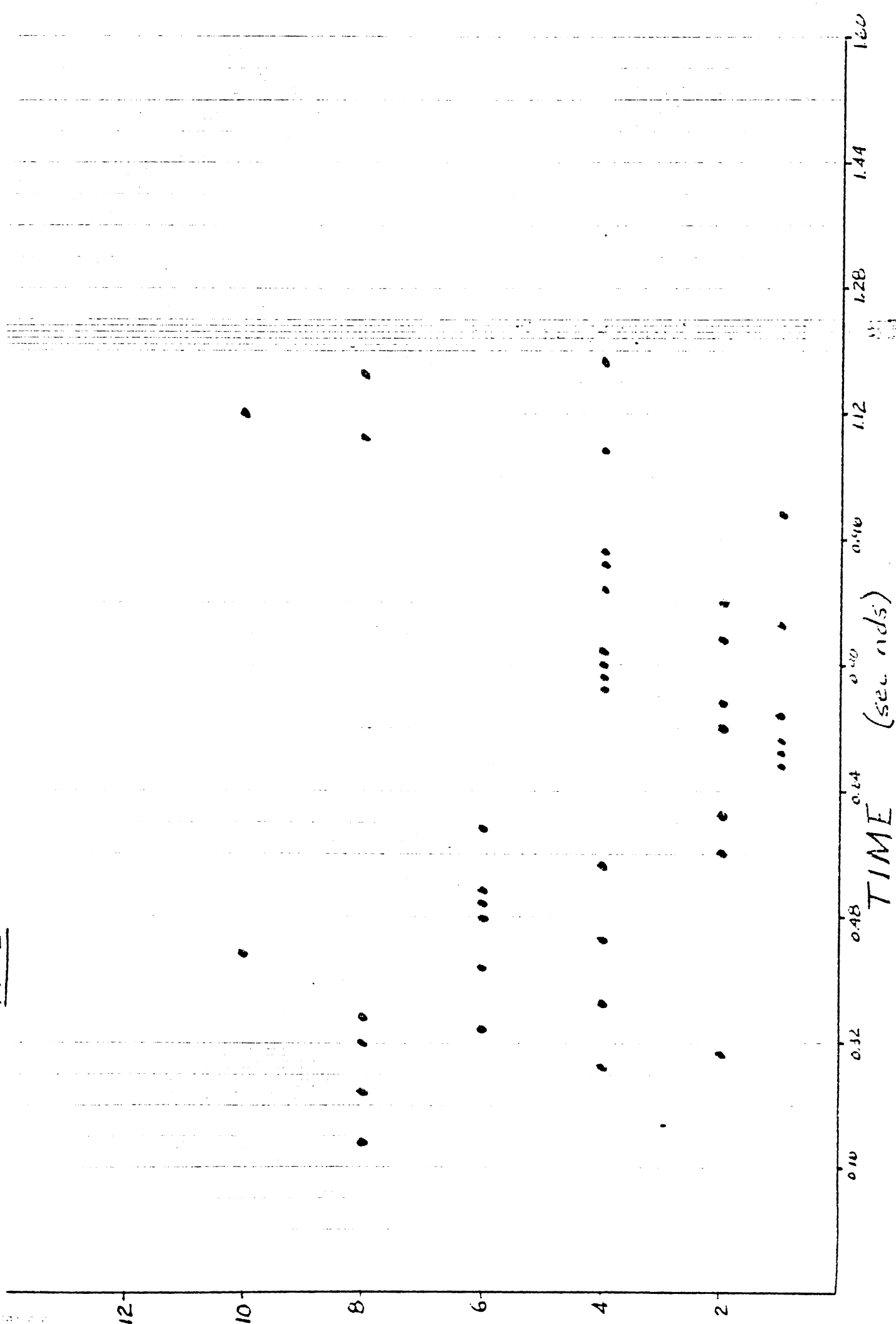
NUMBER OF FINGERS
VS.
TIME

STEAM VELOCITY = Ft/sec.
FLOW RATE = 5B cc/min.



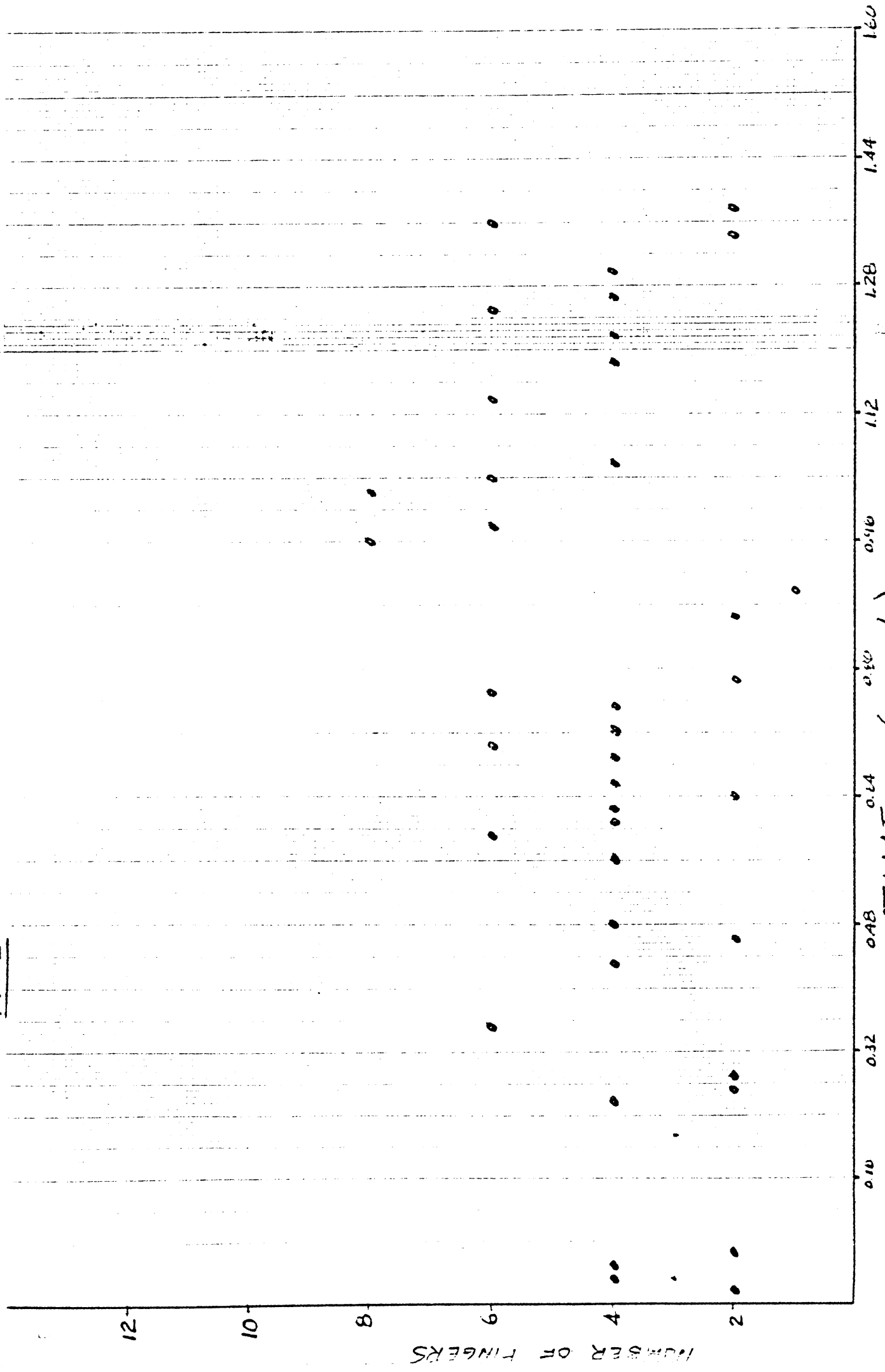
NUMBER OF FINGERS
VS.
TIME

STEAM VELOCITY = 1 ft./sec.
FLOW RATE = 5A cc/min.



NUMBER OF FINGERS
VS.
TIME

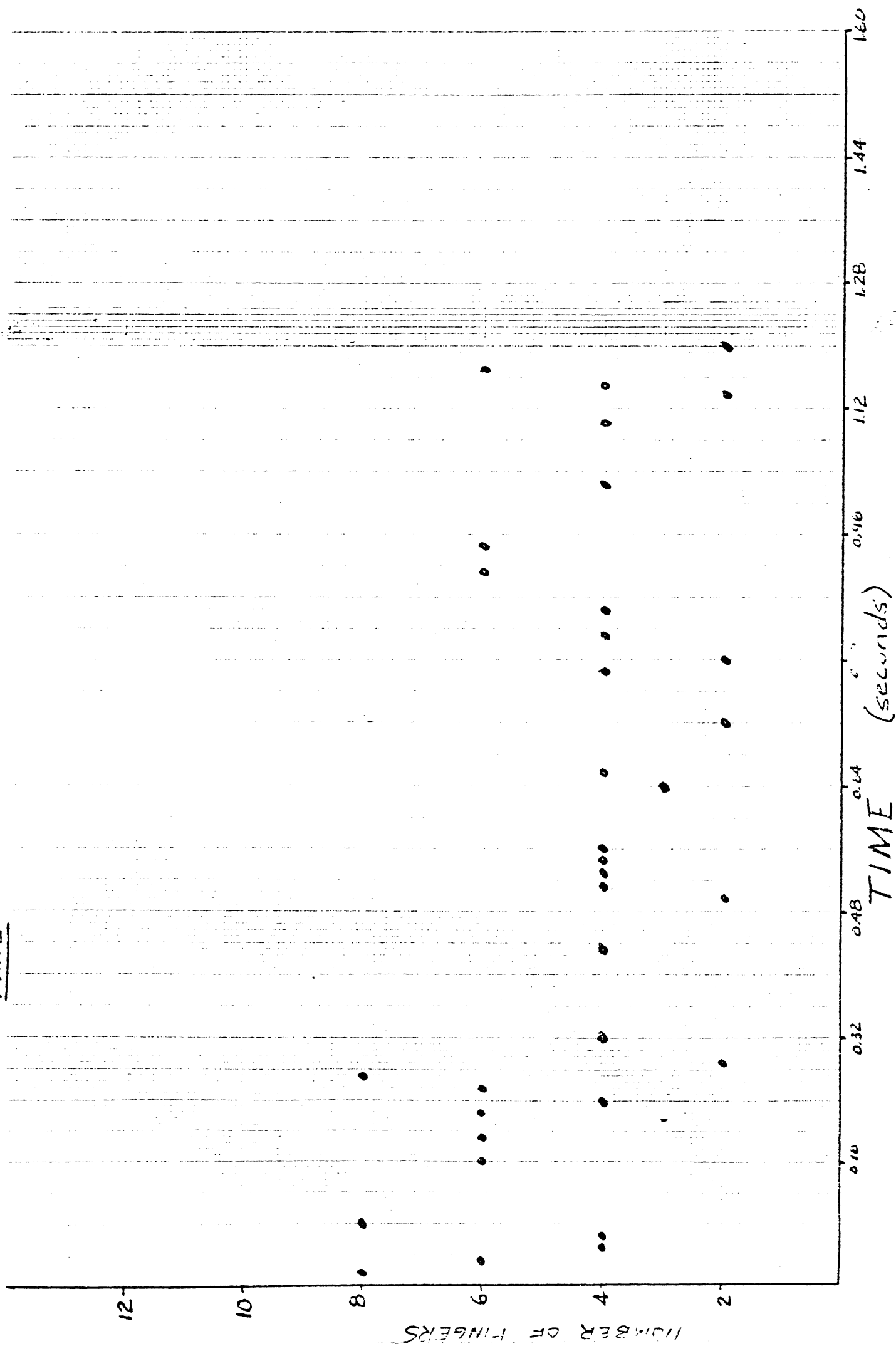
STEAM VELOCITY = Ft./sec.
FLOW RATE = 50 cc/min.



2x4

NUMBER OF FINGERS
VS.
TIME

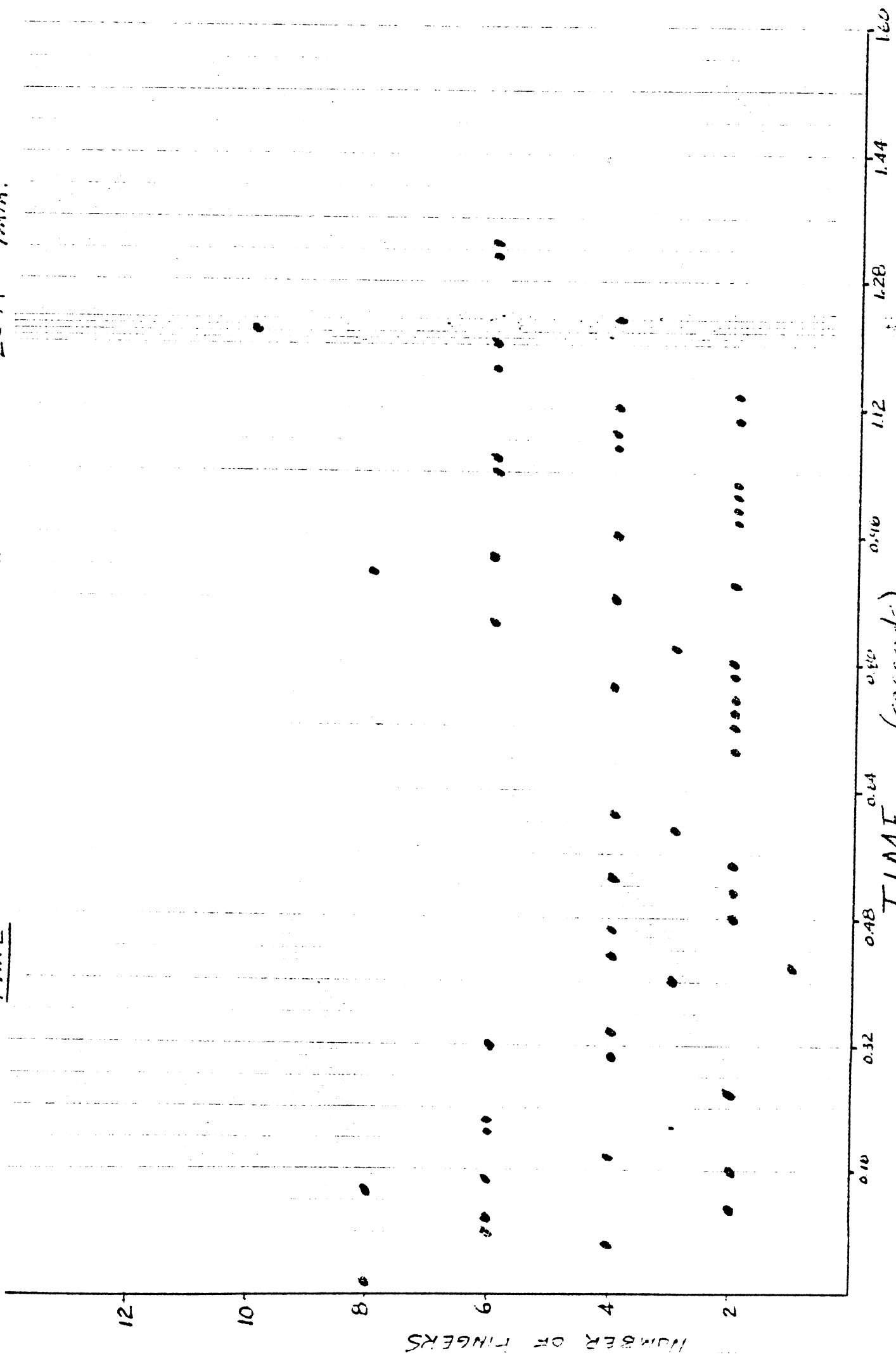
STEAM VELOCITY = Ft./sec.
FLOW RATE = 30 cc/min.



2507

NUMBER OF FINGERS
VS.
TIME

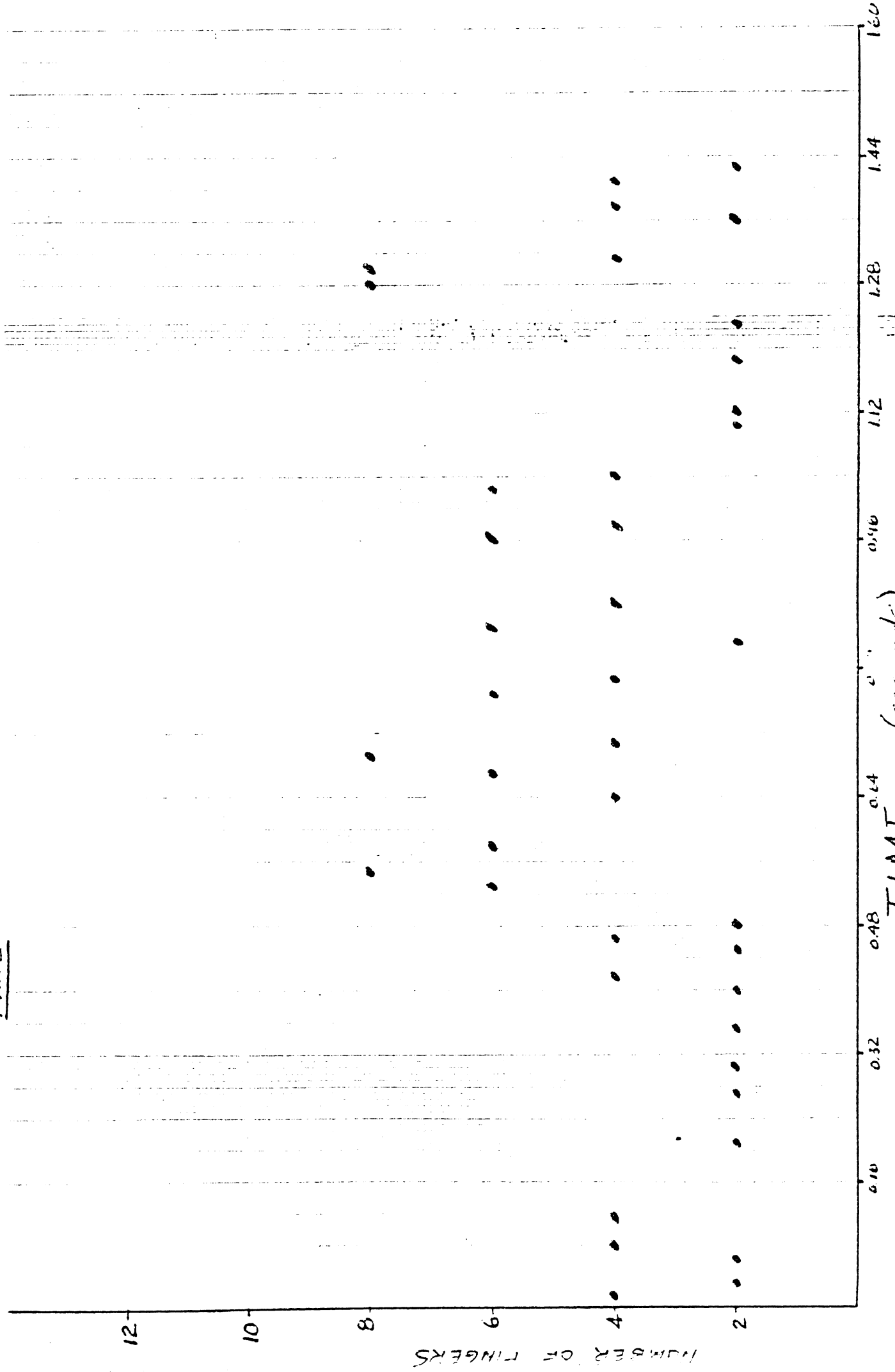
STEAM VELOCITY = Ft/sec.
FLOW RATE = 20A cc/min.



2K4

NUMBER OF FINGERS
VS.
TIME

STEAM VELOCITY = Ft./sec.
FLOW RATE = 15 B cc/min.



NUMBER OF FINGERS

TIME

(seconds)

12

10

8

6

4

2

0.10

0.32

0.48

0.64

0.80

0.96

1.12

1.28

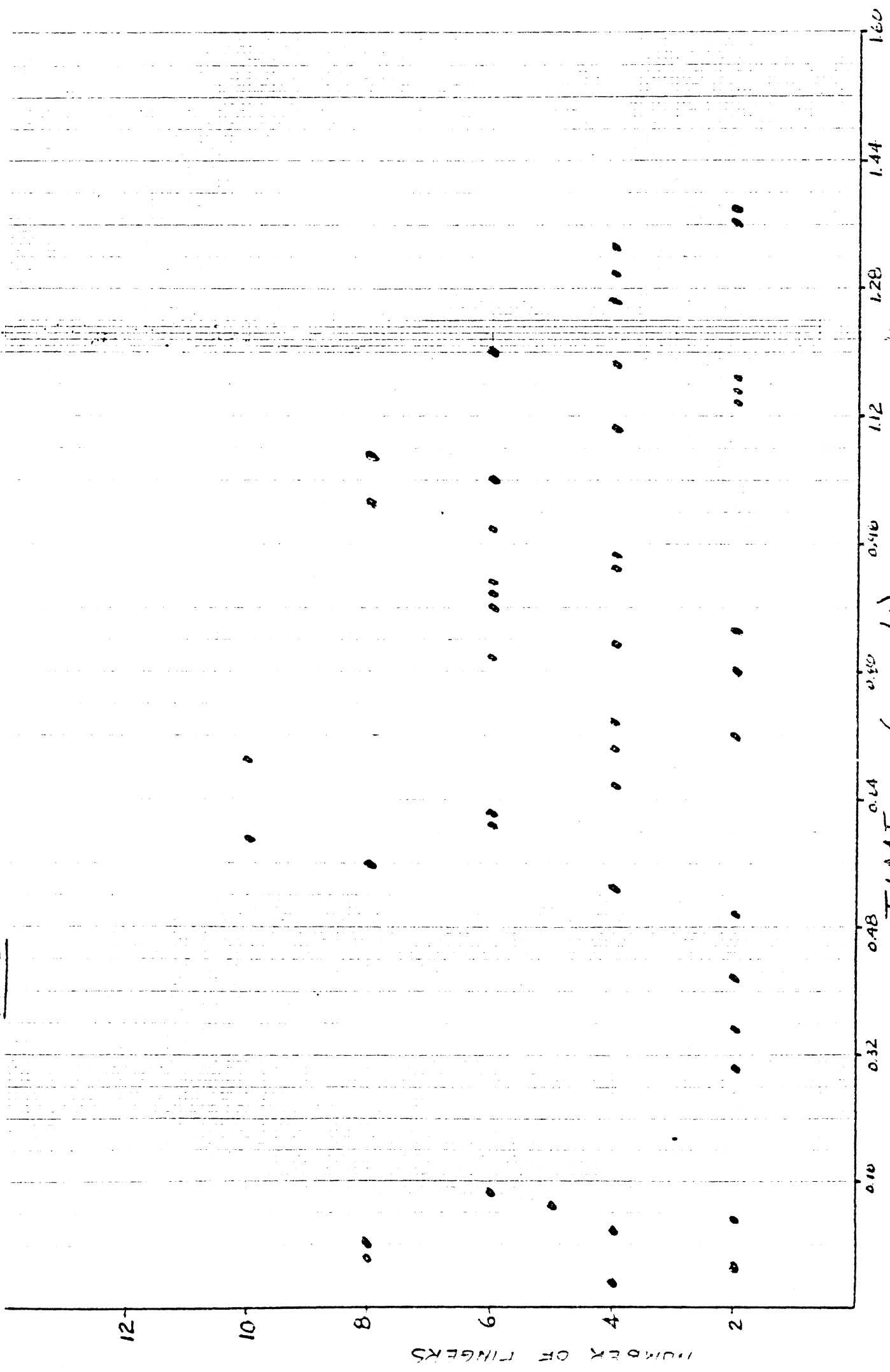
1.44

1.60

2x4

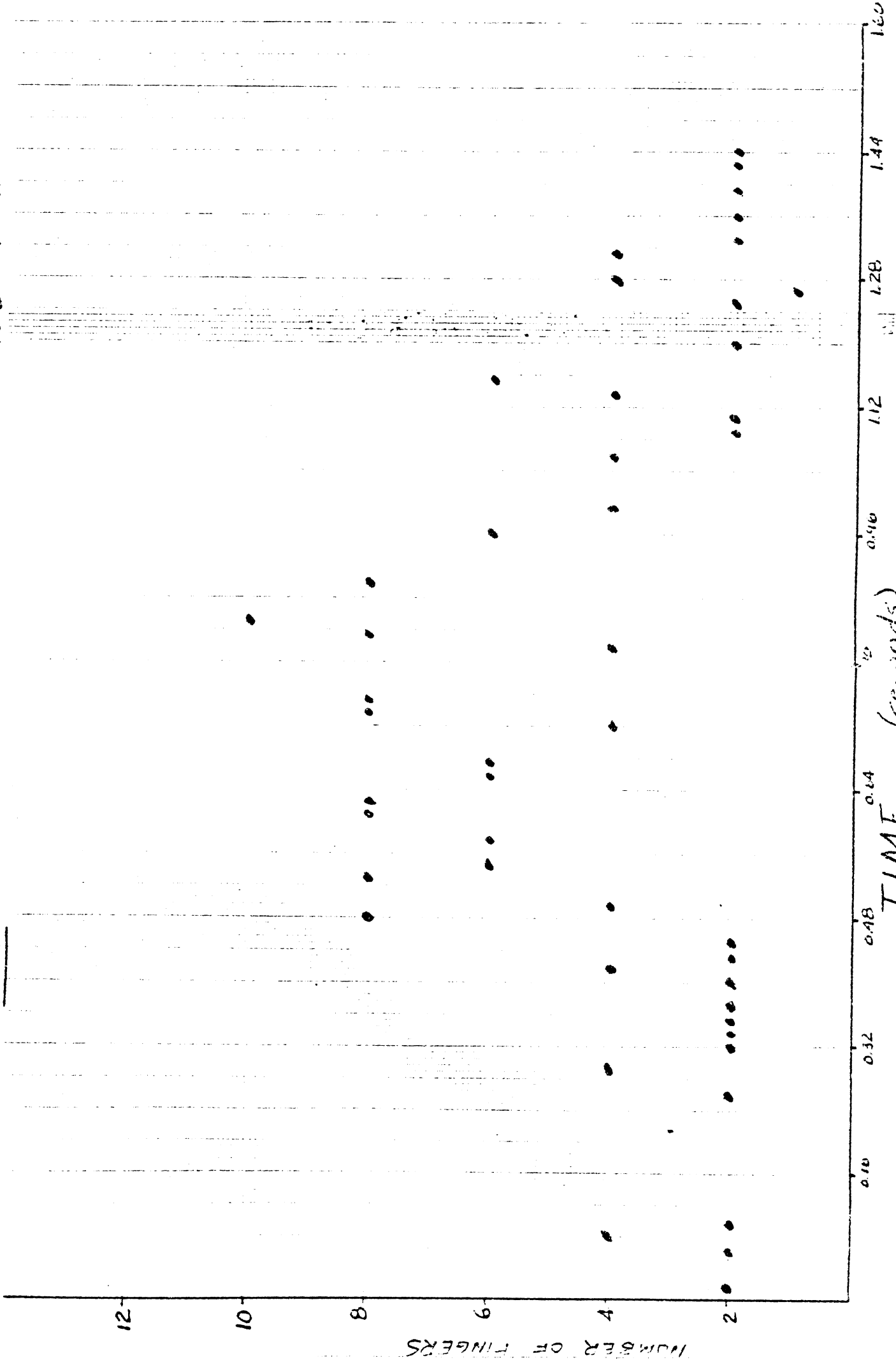
NUMBER OF FINGERS
VS.
TIME

STEAM VELOCITY = 17.5 sec.
FLOW RATE = 15 A cc/min.



NUMBER OF FINGERS
VS.
TIME

STEAM VELOCITY = Ft/sec.
FLOW RATE = 10 B cc/min.

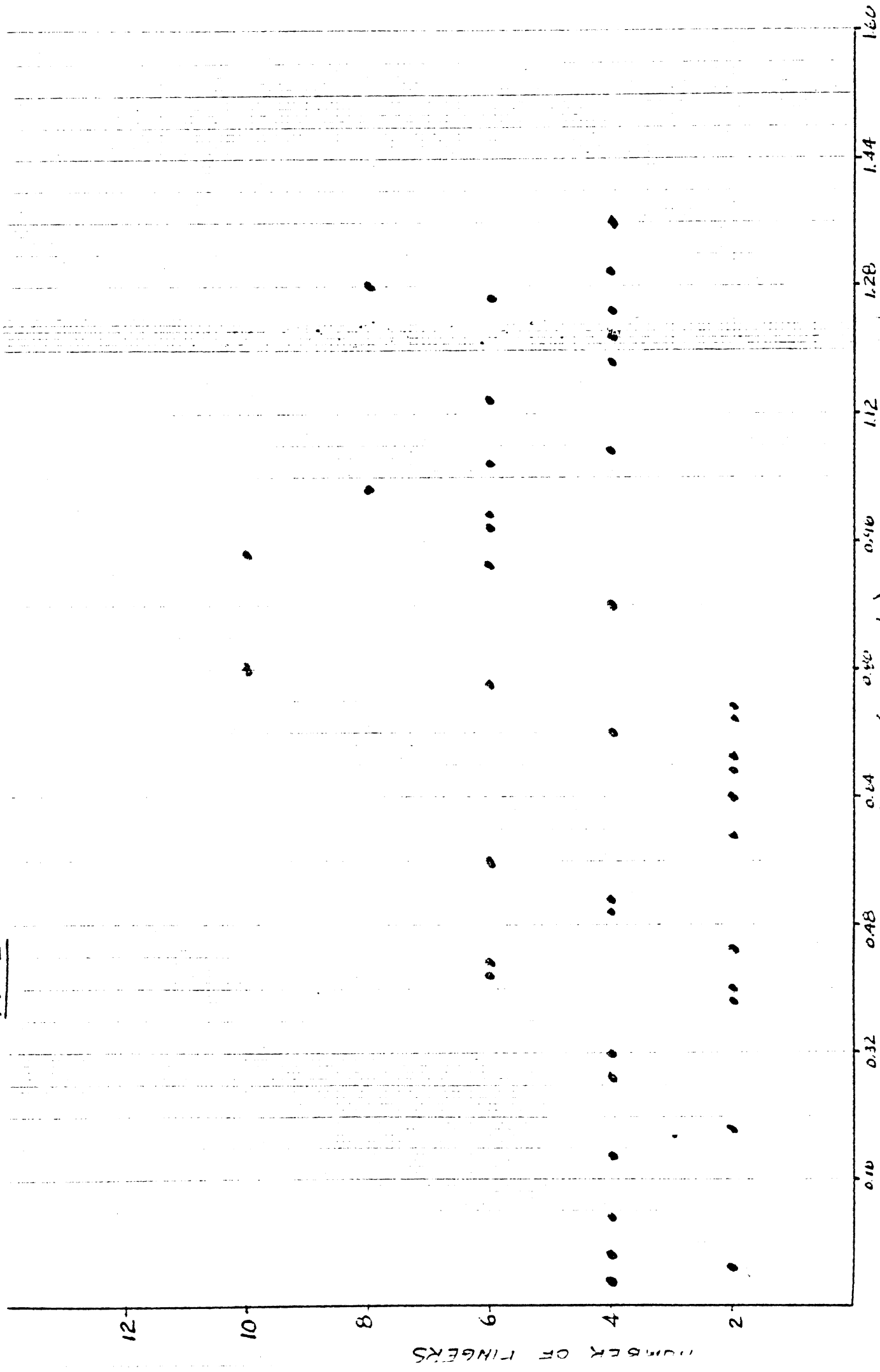


107

22-4

NUMBER OF FINGERS
VS.
TIME

STEAM VELOCITY = Ft/sec.
FLOW RATE = 10 A cc/min.



NUMBER OF FINGERS

TIME (seconds)

12

10

8

6

4

2

0.10

0.32

0.48

0.64

0.80

0.96

1.12

1.28

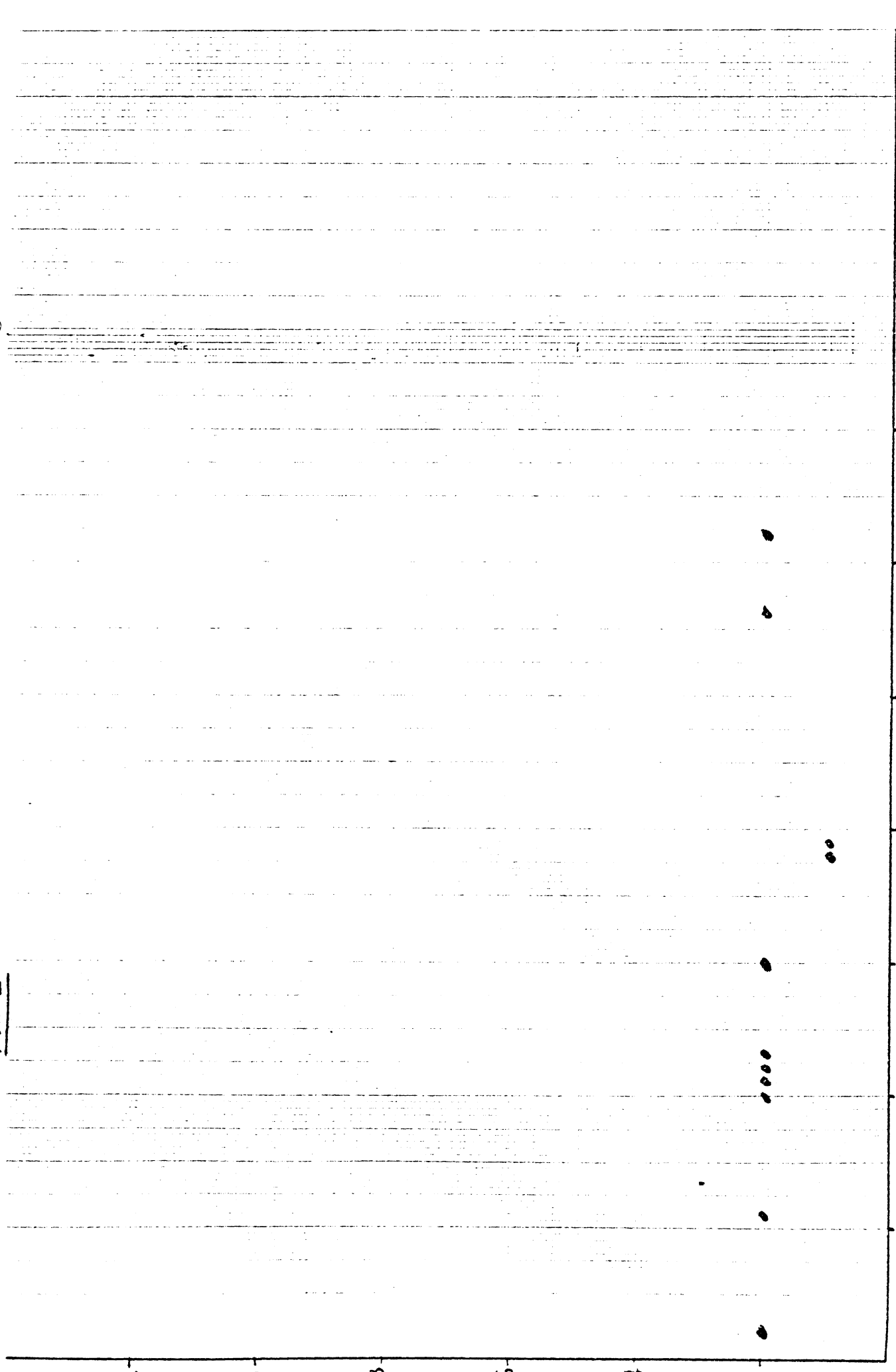
1.44

1.60

2x4

NUMBER OF FINGERS
VS.
TIME

STEAM VELOCITY = Ft./sec.
FLOW RATE = 5.8 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

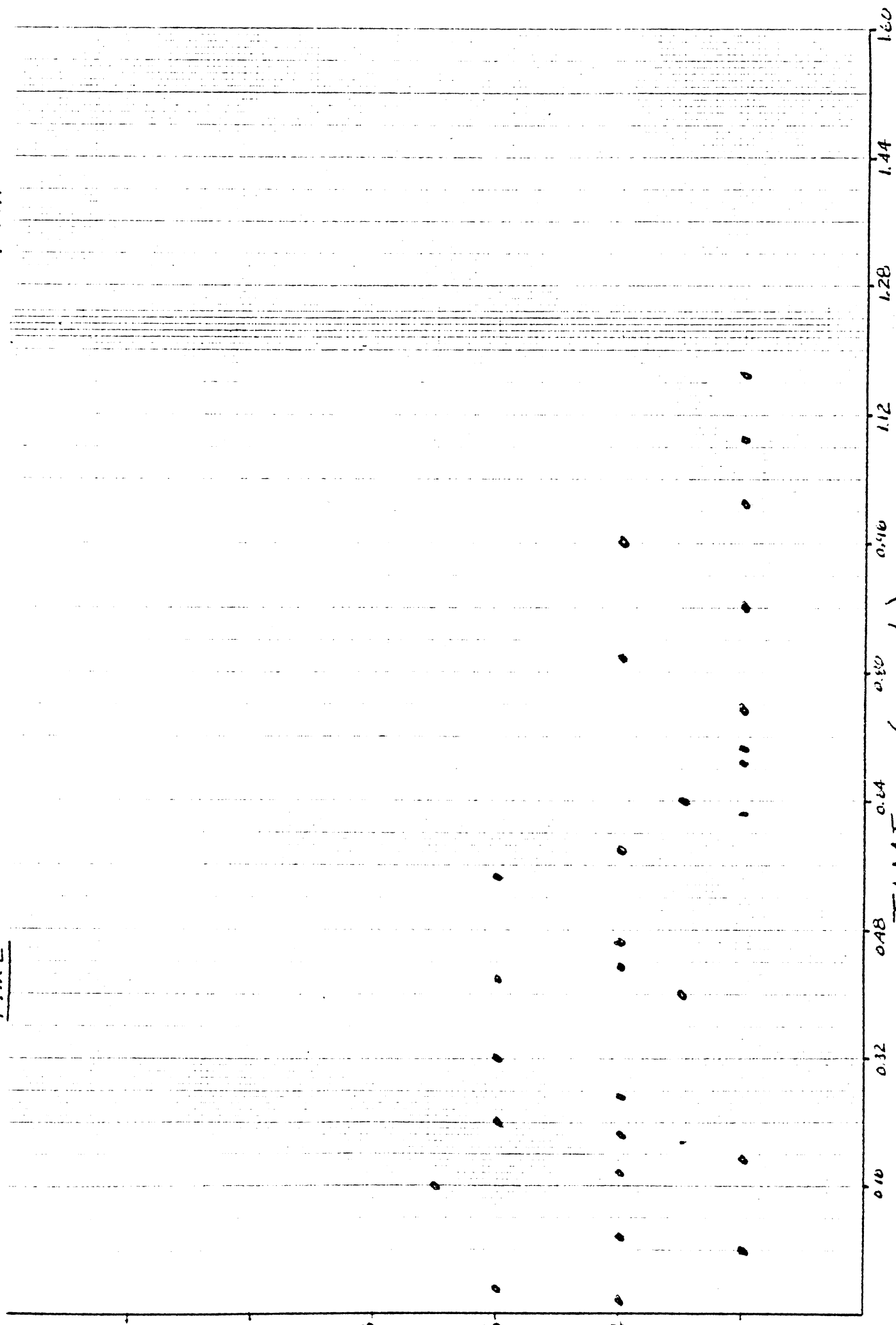
1.60

TIME (seconds)

2x4

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

NUMBER OF FINGERS
VS.
TIME

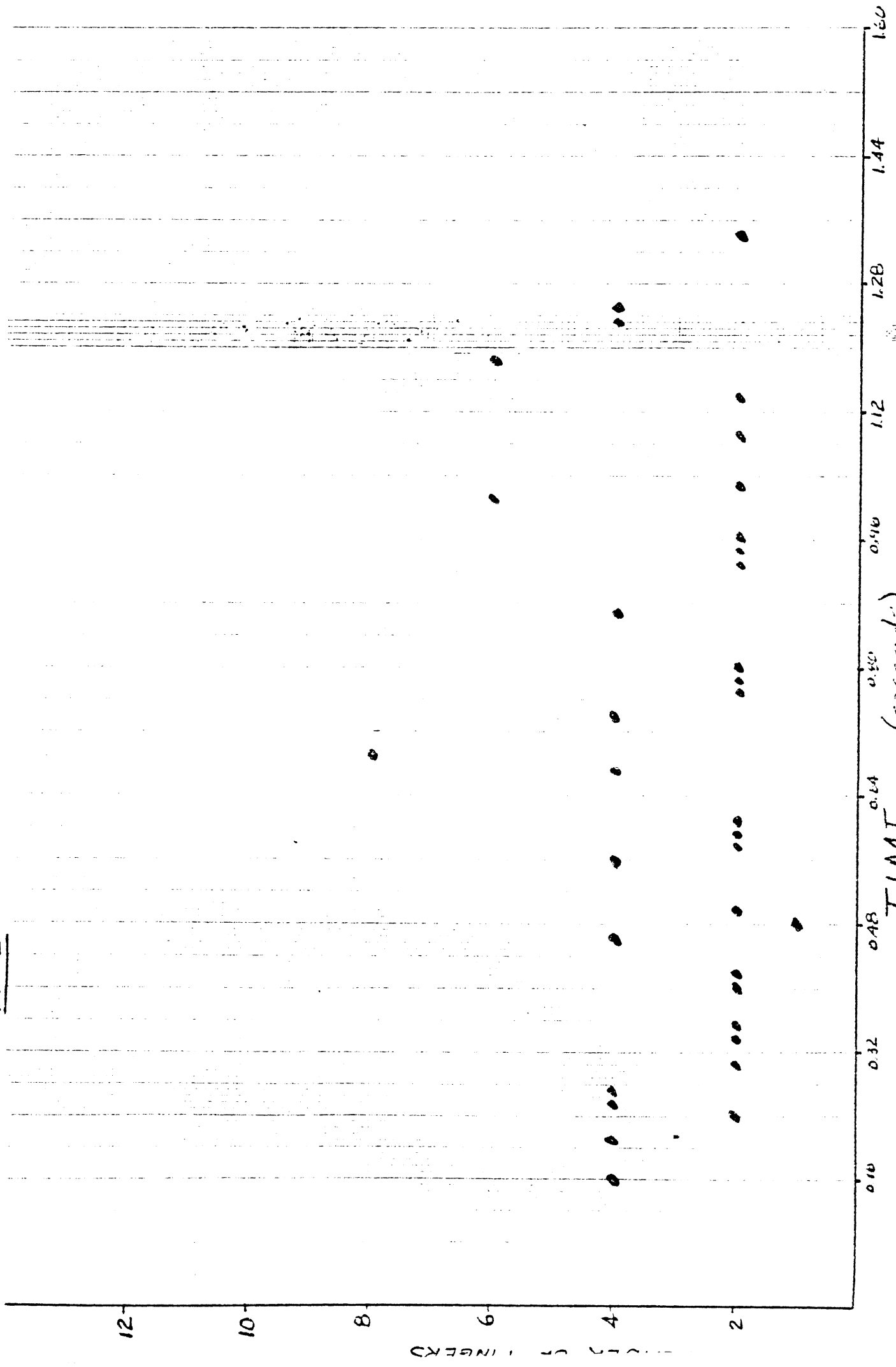


R E N C E L I S T I N G*****

2025

NUMBER OF FINGERS
VS.
TIME

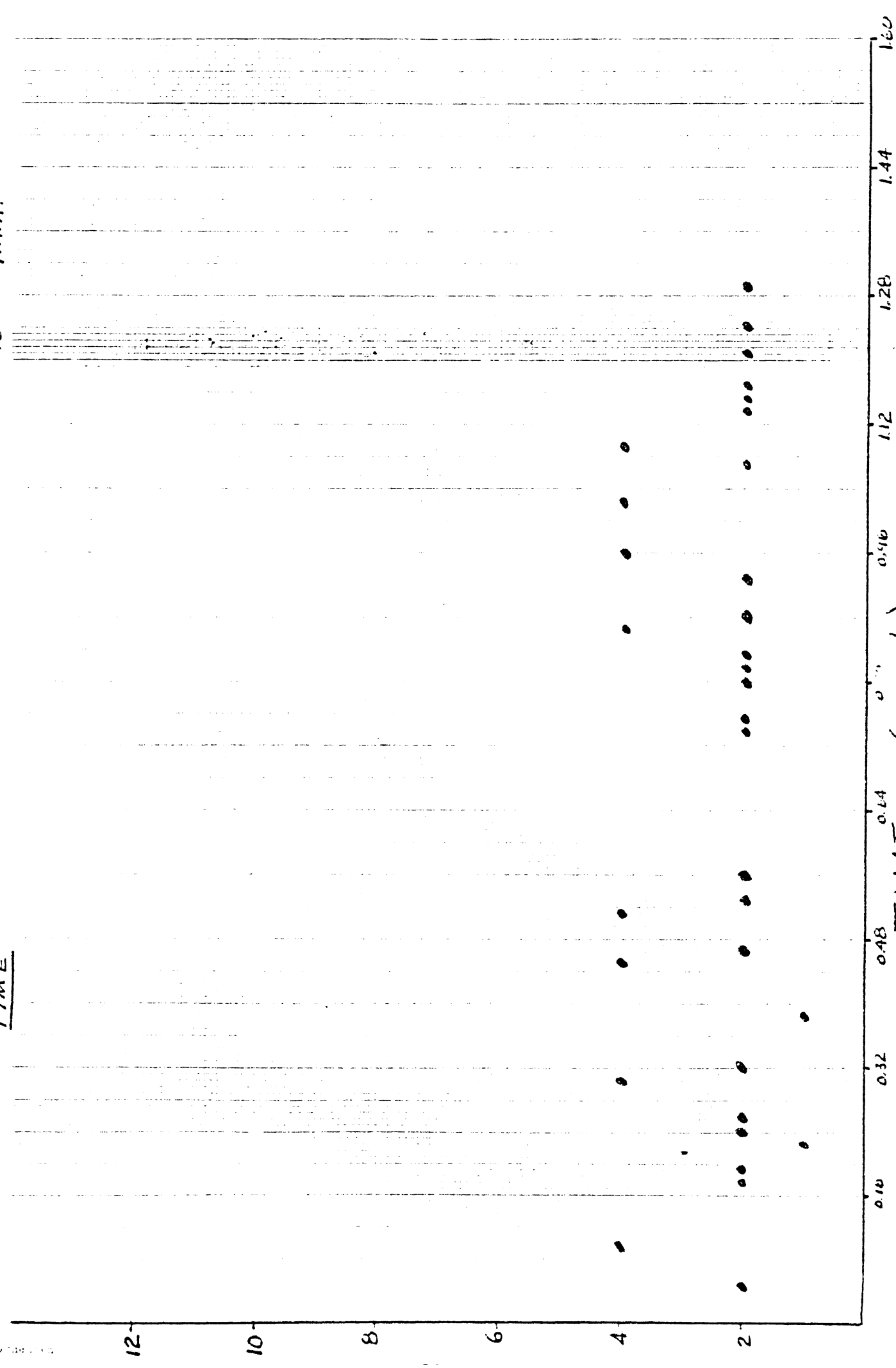
STEAM VELOCITY = Pr./sec.
FLOW RATE = 20 cc/min.



2005

NUMBER OF FINGERS
VS.
TIME

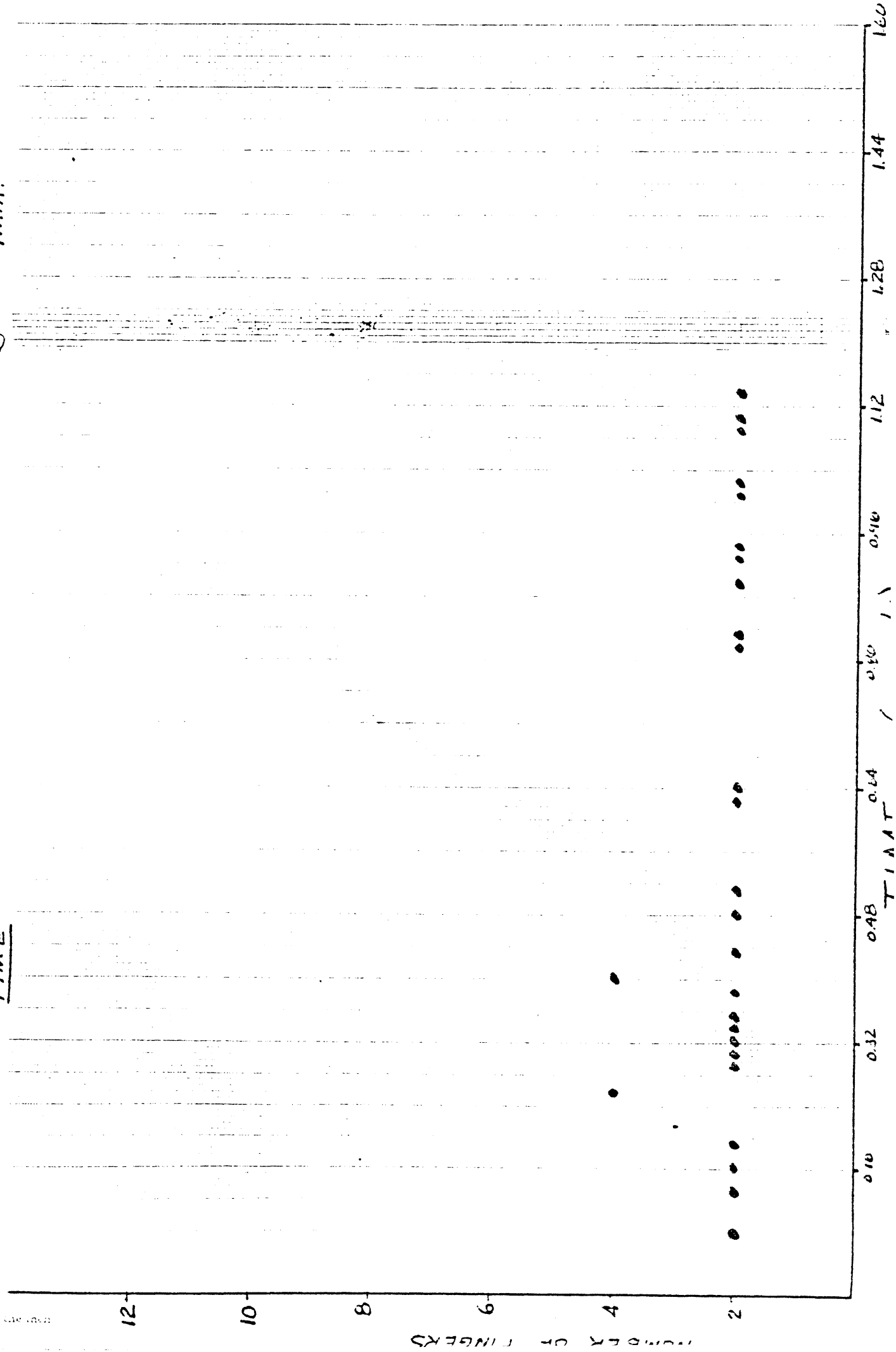
STEAM VELOCITY = 17.5 sec.
FLOW RATE = 10 cc/min.



2:25

NUMBER OF FINGERS
VS.
TIME

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

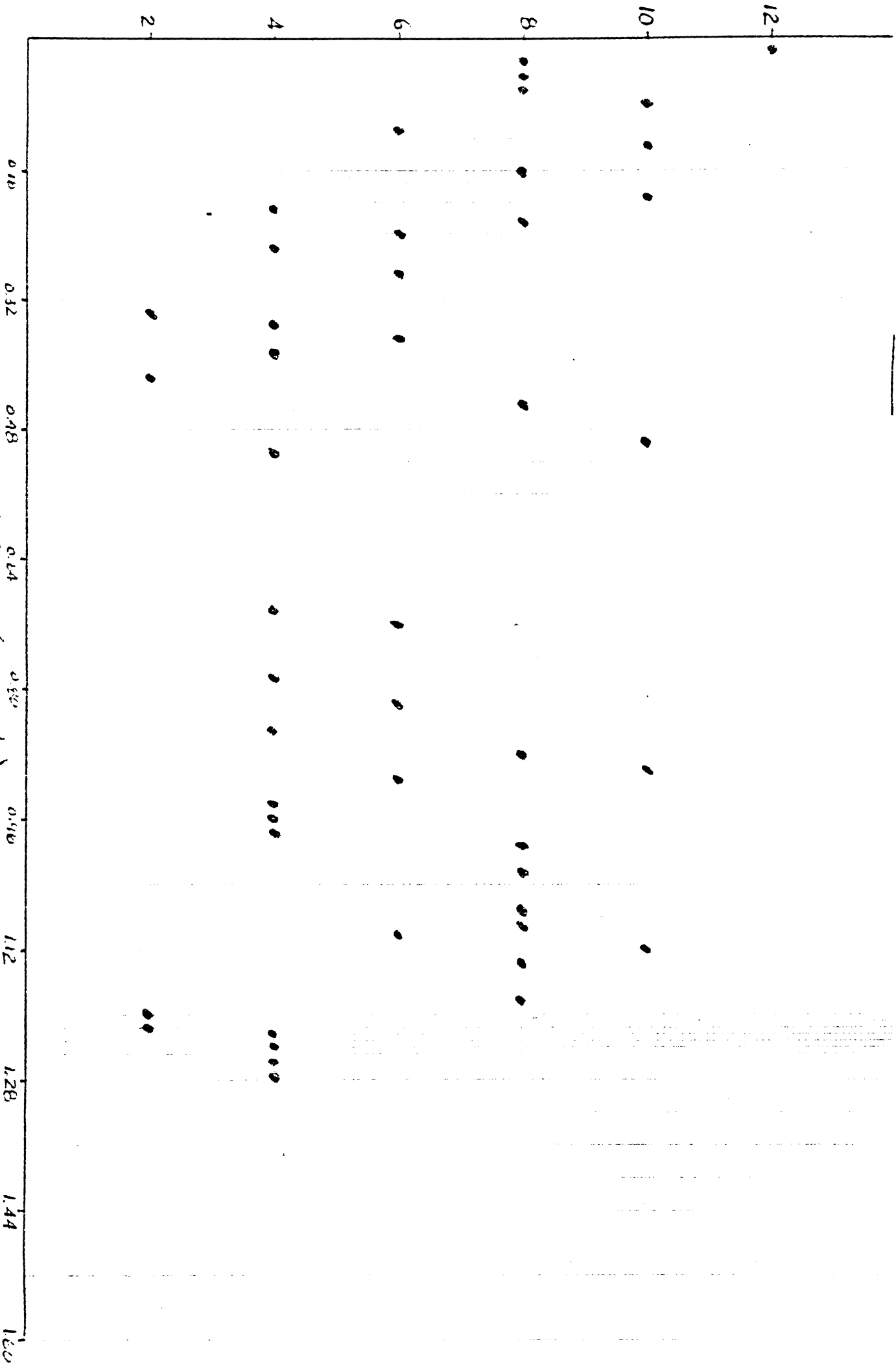


NUMBER OF FINGERS
VS.
TIME

STEAM VELOCITY =
FLOW RATE = 30 cc/min.
P./SEC.

2011

NUMBER OF FINGERS

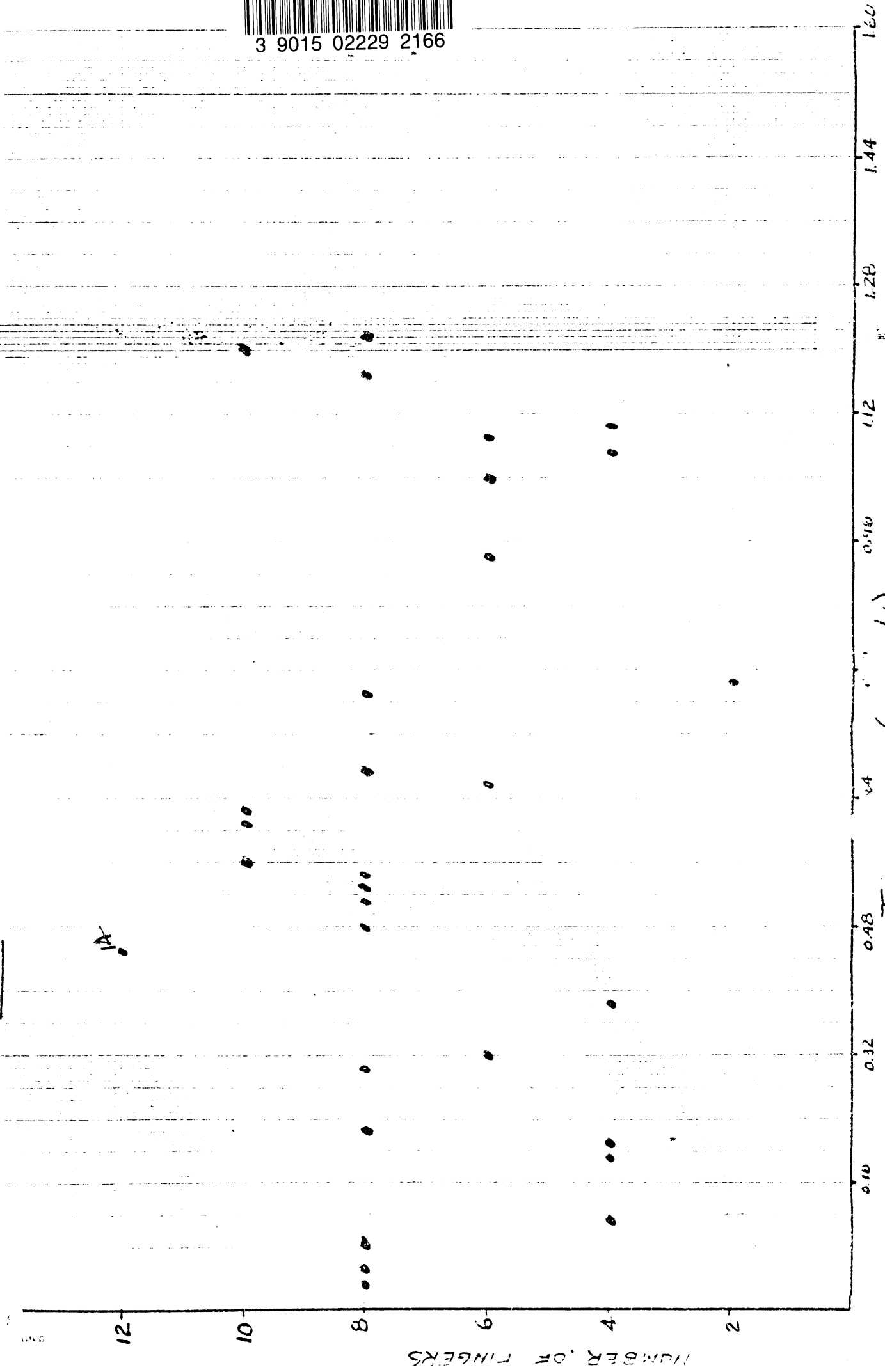


2x7



STEAM VELOCITY = Pr./sec.
FLOW RATE = 50 cc/min.

NUMBER OF FINGERS
VS.
TIME



NUMBER OF FINGERS