UNIVERSITY OF MICHIGAN

DEPARTMENT OF MECHANICAL ENGINEERING AND APPLIED MECHANICS
CAVITATION AND MULTIPHASE FLOW LABORATORY

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THE EFFECTS OF CAVITATION USING THE VIBRATORY SYSTEM

by

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INTRODUCTION

Cavitation in its broadest sense is the formation of vapor or gas filled cavities in liquids by mechanical forces. In engineering, the term cavitation is used to describe the formation of vapor filled cavities in the interior or on the solid boundaries of vaporizable liquids when the pressure is reduced to a critical value without a change in the ambient temperature.

This report deals with cavitation in a vibratory system in which the liquid is water which is static. Two types of materials are analyzed, these are: 1100 Al and cast iron (3% carbon). The effects of cavitation on these materials are analyzed and a description of the testing facility explained.

PROCEDURE

The testing procedure is as follows. A test specimen is first cleaned of any impurities using isopropyl alcohol, then dried and weighed. The specimen is then ready to be placed on the vibratory system. A schematic of this is shown in fig. 1. The is threaded onto the horn and the assembly placed into the test fluid, which is a water bath. The vessel top plate is bolted onto the bottom plate securely. The water temperature is kept at a desired temperature, either 80°F or 160°F in the case of the test specimens being analyzed here. This accomplished by placing the water bath inside a oil bath, since oil has a high heat capacity. The oil temperature is maintained uniform by mixing it with an agitator.

The next step is to set the pressure which is to be used with the corresponding temperature. This is accomplished using the pressure that is supplied through a valve connected to the water tank. In this way the pressure is held constant over the water. Both the temperature and pressure being used can be measured from their corresponding meters. Thermocouples are used and appropriately placed and attached to the temperature meter. The temperature meter has a specific calibration for reading the temperature of the water and oil bath.

The appropriate amplitude of vibration is chosen through the use of the power supply. The power supply is also calibrated for various dial settings ranging from 0 to 80 in increas-order of magnitude of vibration amplitude. For example, a dial setting of 15 corresponds to an amplitude of vibration of 1.78 mils.

The panel switch is then placed in the on position and the vibratory system is in the operation mode. The switch is then placed in the off position after the time interval for the first run is completed. The time interval for different materials varies. For example, aluminum was run at 1 minute intervals up to 3 minutes, while cast iron specimens were run at time intervals of 30 to 60 minutes. The reasoning behind this is that aluminum is eroded away quicker than is a much harder material such as cast iron at the same temperature, pressure, and amplitude setting. The test specimen is then removed from the horn, cleaned, dried and weighed in order to determine the weight loss incurred. This completes one run and the entire process is repeated and the recorded.

With this data, graphs of Average Depth of Penetration vs. Cumulative Time and Cumulative Weight Loss vs. Cumulative Time can be made and the results interpreted.

The entire process discussed above is done with two test specimens of the same material. For the materials which are included in this report, two specimens of 1100 Al and two of cast iron were each tested at a dial setting of 15 (1.78 mils), a pressure of 19.5 psia, and a water temperature of 160° F. Also two specimens of 1100 Al were tested at a dial setting of 8 (1.38 mils), a pressure of 1 atmosphere, and a water tempera ture of 80° F. This is shown on the Material Damage Sheets at the end of this report.

DISCUSSION AND CONCLUSION

There were only two major problems incurred throughout the runs that were made. The first dealt with the water bath thermocouples. The connection was broken and the temperature of the water could not be read. This was repaired immediately and the runs were continued with no loss in time. The second problem was that the power supply which controlled the level of the amplitudes was intermittent, it would go off and on during the runs. This also was due to a faulty connection in the cable. The power supply was still functionable, however the cable had to be maneuvered into position by hand in order to keep the system operating.

The calculations for the Average MDPR were made by use of the equation:

$$\text{Avg. MDPR} = \frac{\text{Cumulative Wt. Loss}}{\text{Cumulative Time}} \times C$$

where

Cumulative Wt. Loss is in mg
Cumulative Time is in hours
C is in mils/mg
and Avg. MDPR is in mils/hr.

It can readily be seen that 1100 Al has a larger Avg. MDPR as compared with cast iron at the same amplitude setting, pressure and temperature. This is due to the fact that 1100 Al is not as hard as cast iron. The Brinell Hardness number for 1100 Al is 41 while for cast iron it is 184.

It can also be seen from the graphs of Cumulative Wt. Loss vs. Cumulative Time that cast iron has a smaller cumulative weight loss as compared to 1100 Al. This again can be attributed to the fact that 1100 Al is a softer material.

One additional remark concerning the graph of Avg. MDPR vs. Cumulative Time for cast iron on specimen #5 is that 2 peaks are observed. This can possibly be attributed to an inaccuracy in the reading of the weight loss for this specimen

Although this report contains no data on the effect of temperature on the erosion of a material due to cavitation when amplitude and pressure are held constant, it was observed from other students graphs that an increase in temperature with all other parameters held constant led to an increase in the Avg. MDPR and Cumulative Wt. Loss.

In summation, the data turned out well with results that were consistent throughout.

[EQUIPMENT]:

The equipment used here is somehow different from the standard issued by ASTM (G32-72) for more practical purpose.

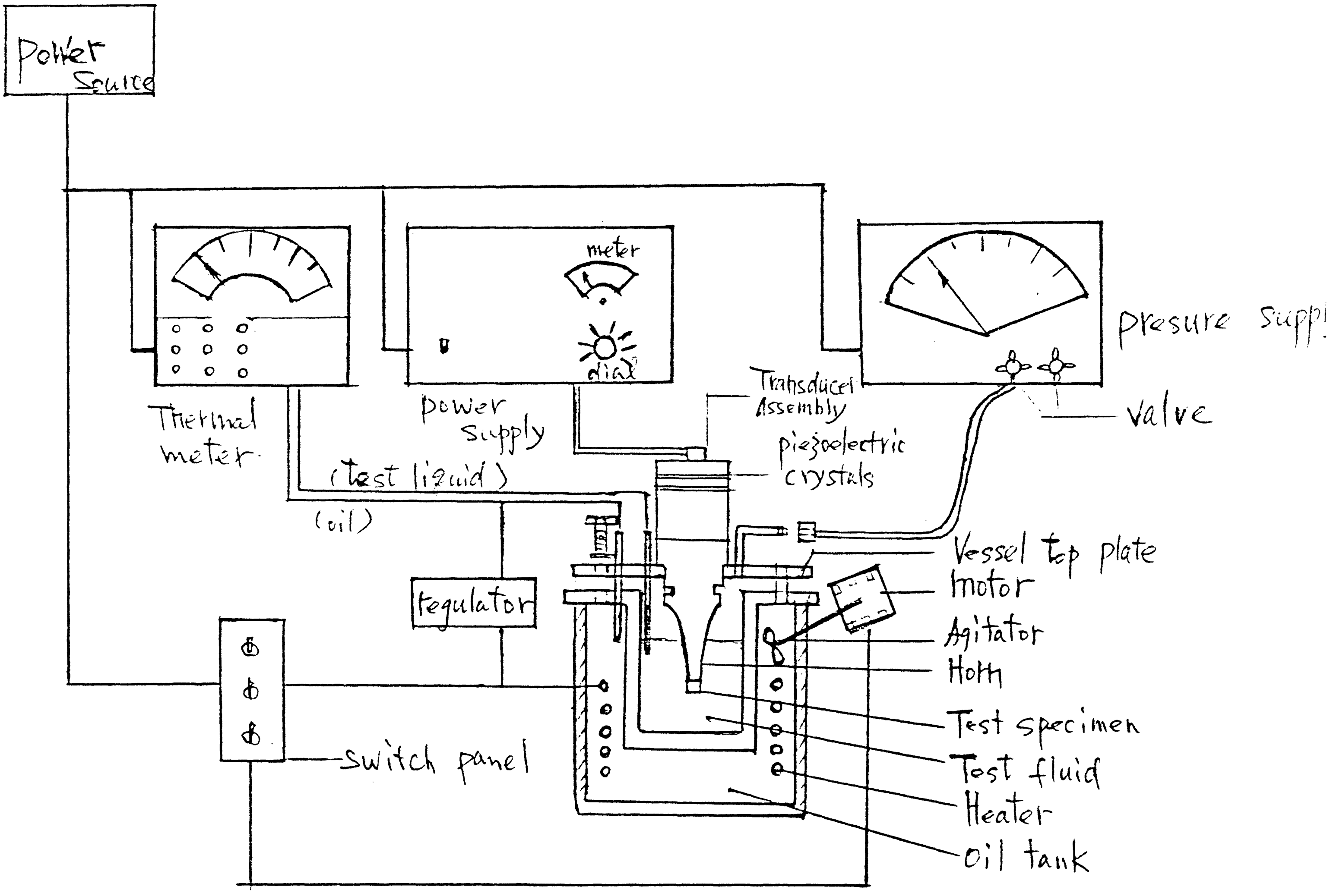


Fig. 1

MATERIAL DAMAGE SHEET

HORN: Ti

AMPLITUDE: 1.38 mil

WATER: TAP

TEMPERATURE: 80°F

PRESSURE: 1 bar

TORQUE:

PRE-RUN:

MATERIAL: AL 1100-0

NUMBER: # 4

APPROX. DATE: MAY 80

DENSITY: 2.69 gm/cm³

AREA: .248 in²

M.D.P. FACTOR: .09146 mil/mg

COMMENTS: Dial Setting = 8

C = [illegible]

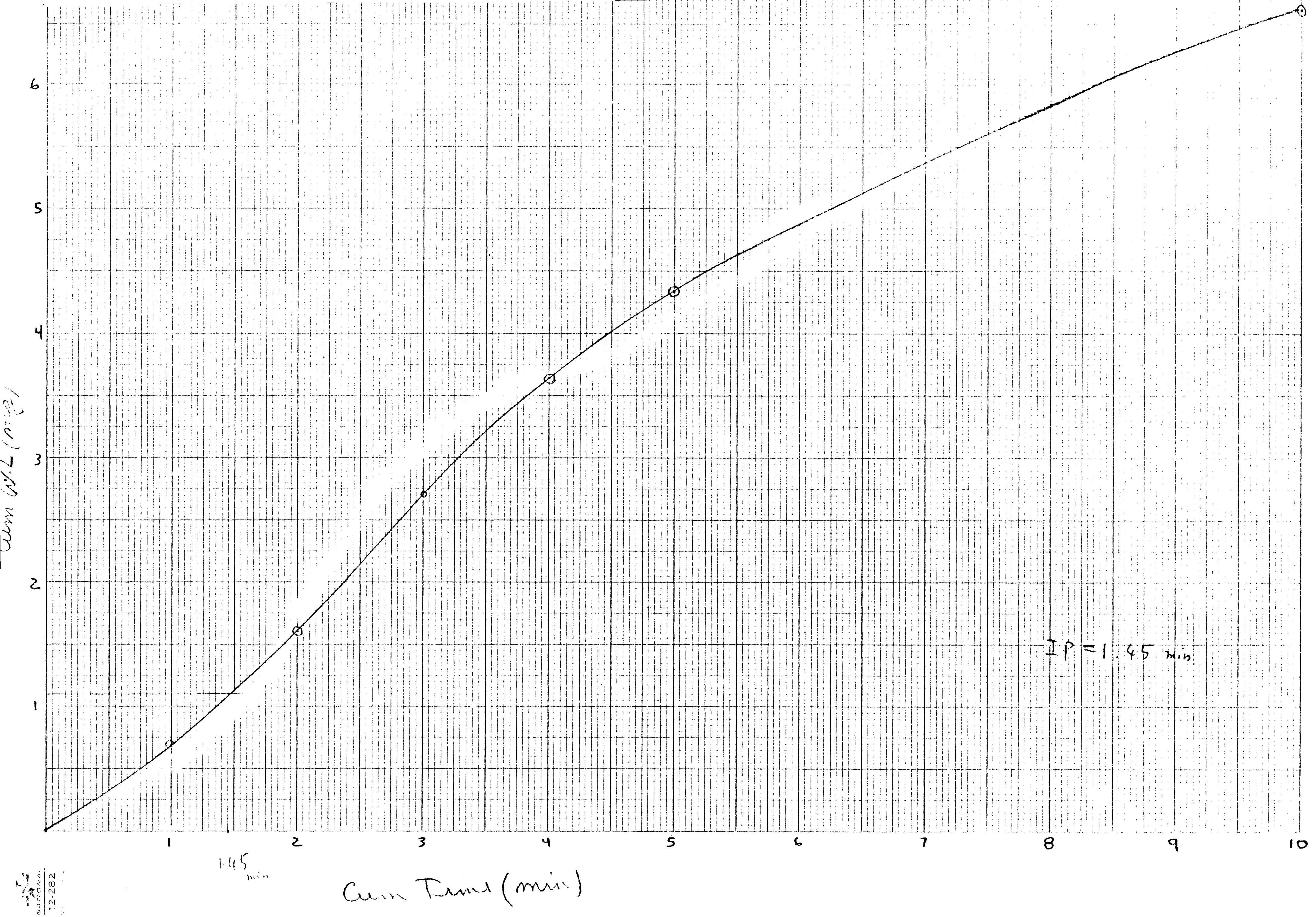
MDPR$_{max}$ = 8.3[illegible] mil/hr

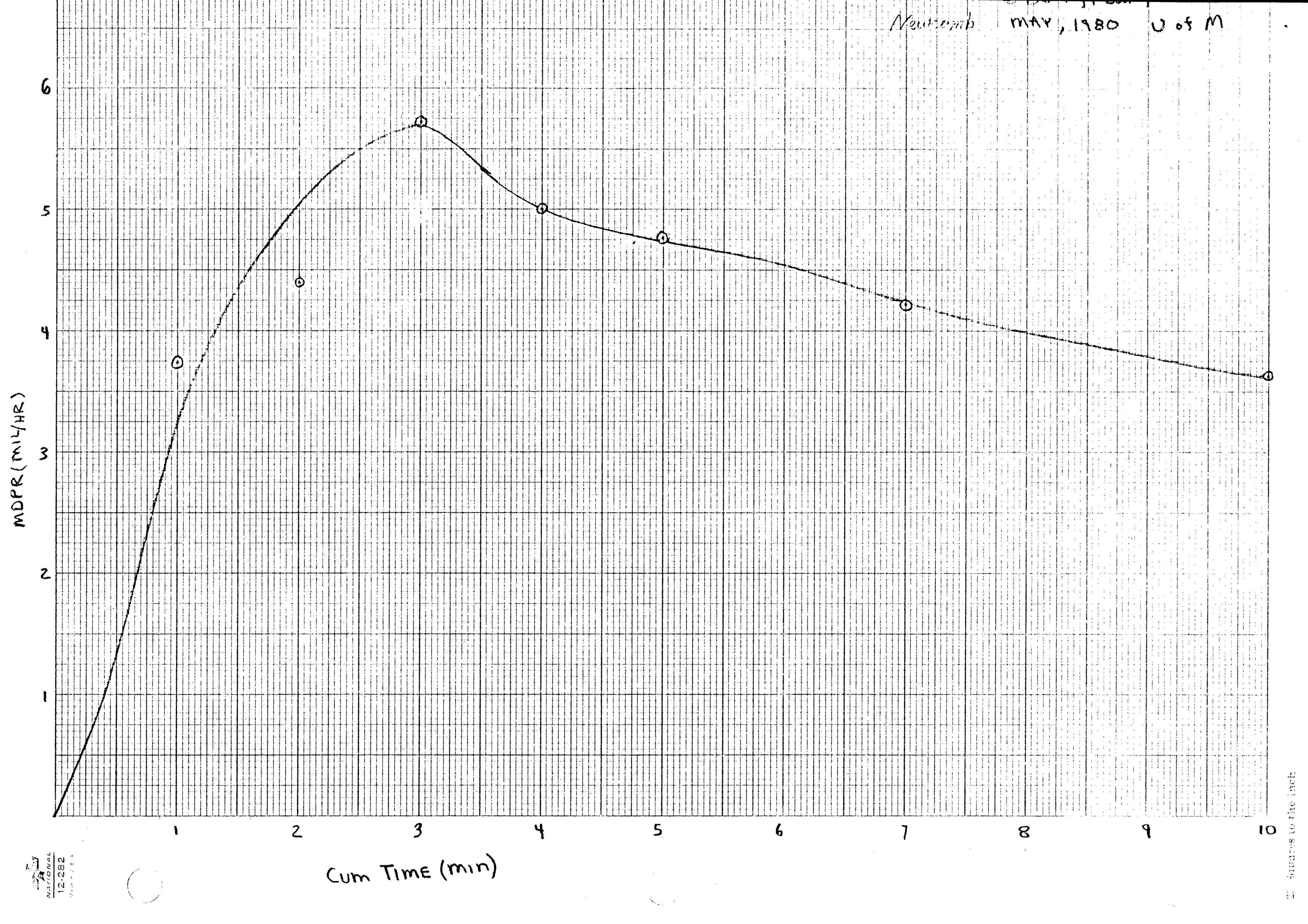
Ip = 1.05 min

Operator: Newcomb

DATA

TIME INTERVAL min	CUMULATIVE TIME min	WEIGHT LOSS mg	CUM. WT. LOSS mg	M.D.P.	M.D.P.R. mil/hr
0	0	0	0		0
1	1	.68	.68		3.732
1	2	.92	1.60		4.390
1	3	1.53	3.13		5.735
1	4	.51	3.64		4.994
1	5	.70	4.34		4.763
2	7	1.04	5.38		4.218
3	10	1.23	6.61		3.627


6
5
4
3
2
1
1
2
3
4
5
6
7
8
9
10
1.45 min
IP = 1.45 min
Cum Time (min)


Newcomb MAY, 1980 U of M
MDPR (MIL/HR)
6
5
4
3
2
1
1
2
3
4
5
6
7
8
9
10
Cum Time (min)
NATIONAL
12-282

MATERIAL [illegible]MAGE SHEET

HORN: Ti | MATERIAL: AL 1100
AMPLITUDE: 1.38 mil | NUMBER: # 7
WATER: TAP | APPROX. DATE: MAY 30
TEMPERATURE: 80°F | DENSITY: 2.69 gm/cm³
PRESSURE: 1 bar | AREA: .248 in²
TORQUE: | M.D.P. FACTOR: .09146 mil/mg
PRE-RUN:

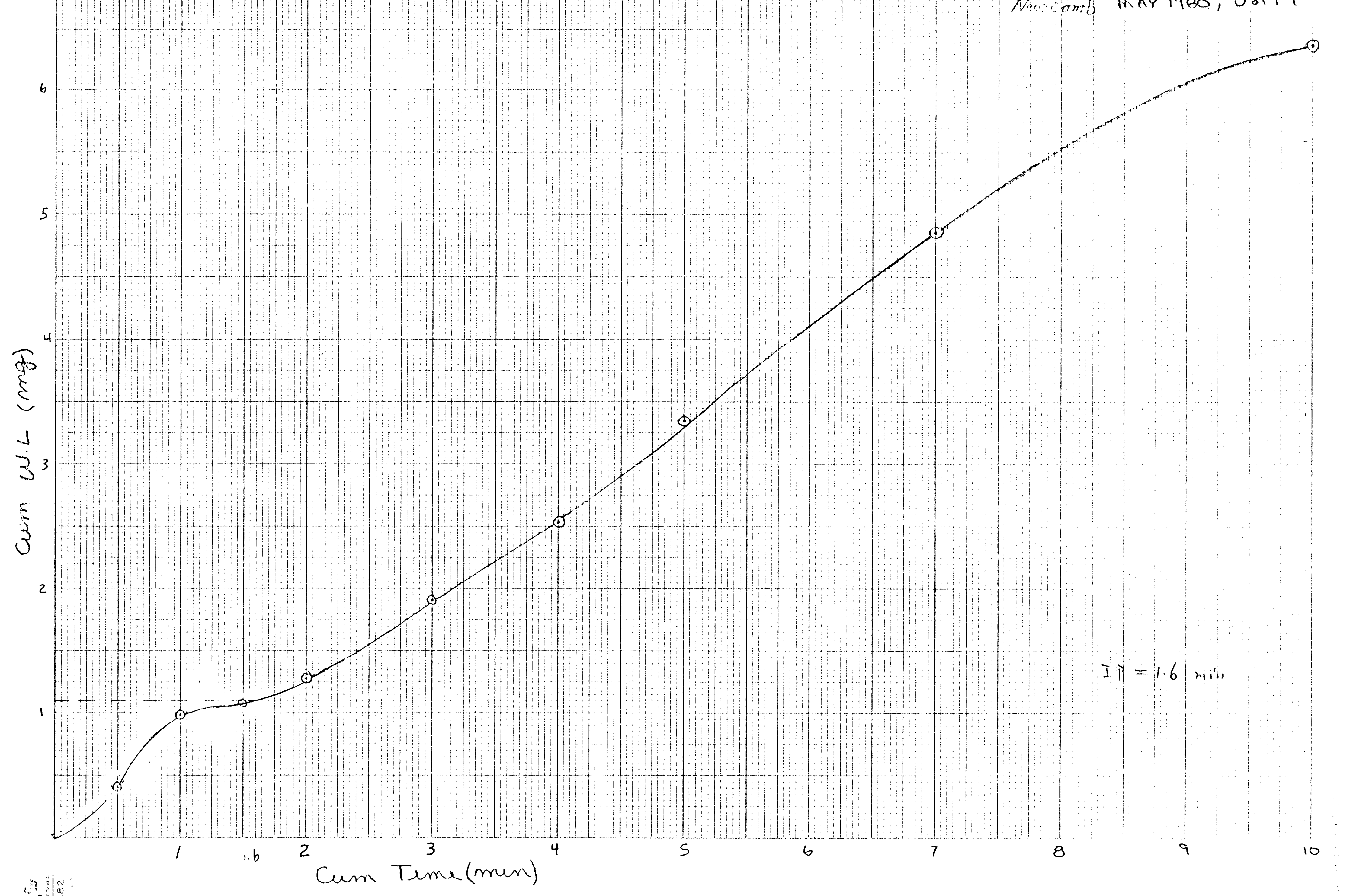
COMMENTS: Dial Setting = 8

I.P = 1.6 mins

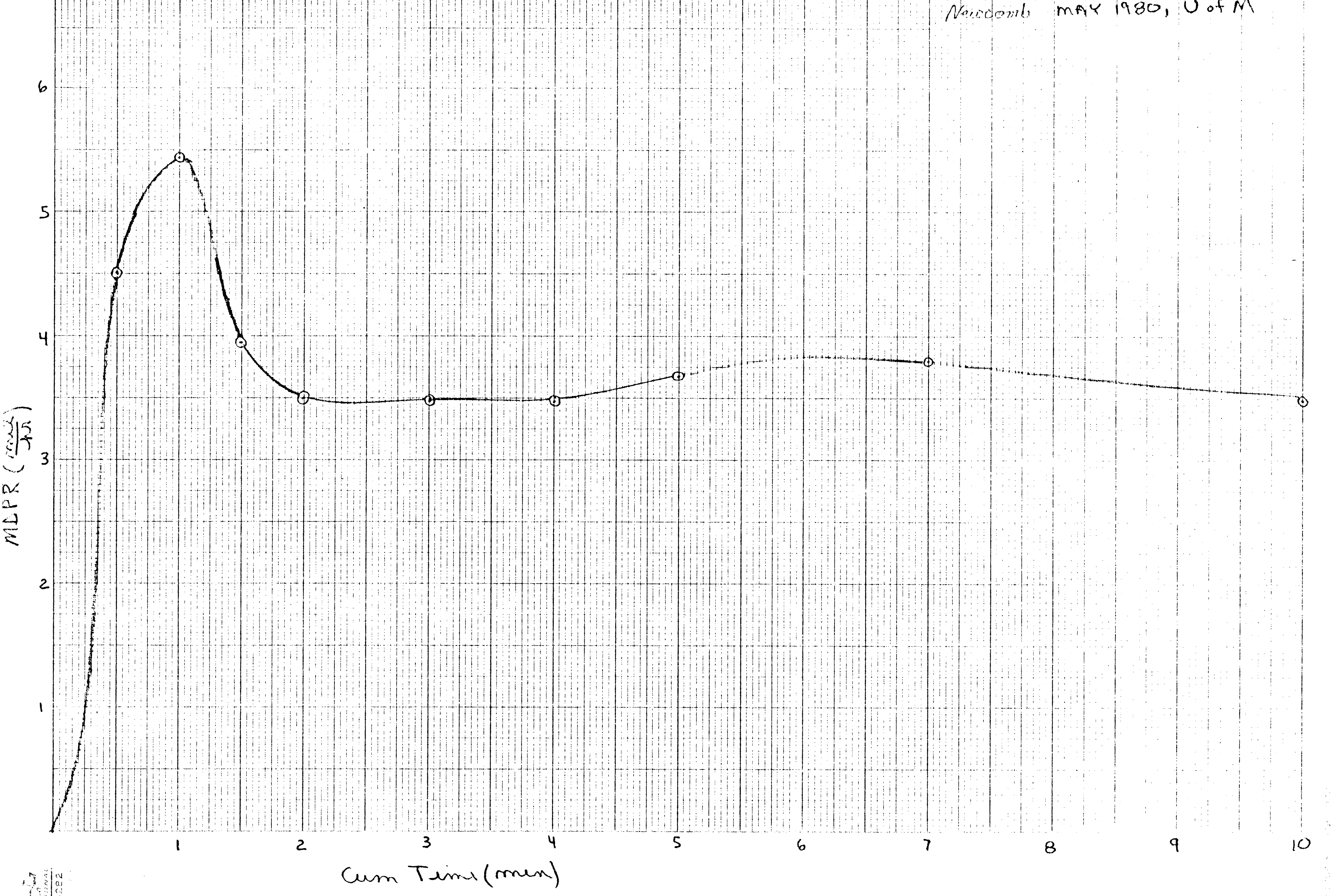
Operator : Newcomb

DATA

TIME INTERVAL min	CUMULATIVE TIME min	WEIGHT LOSS mg	CUM. WT. LOSS mg	M.D.P.	M.D.P.R. mil/hr
0	0	0	0		0
1/2	1/2	.41	.41		4.500
1/2	1	.58	.99		5.433
1/2	1 1/2	.09	1.08		3.951
1/2	2	.19	1.27		3.504
1	3	.63	1.90		3.475
1	4	.63	2.53		3.491
1	5	.82	3.35		3.677
2	7	1.50	4.85		3.802
3	10	1.52	6.37		3.496



Newcomb MAY 1980
IP = 1.6 min
Cum W.L (mg)
Cum Time (min)
1
2
3
4
5
6
1
1.6
2
3
4
5
6
7
8
9
10



Newcomb MAY 1980, U of M
MLPR (mi/hr)
6
5
4
3
2
1
1
2
3
4
5
6
7
8
9
10
Cum Time (min)

MATERIAL DAMAGE SHEET

ORN: Ti

MPLITUDE: 1.5 mil

ATER: TAP

EMPERATURE: 160°F

RESSURE: 19.5 psi

ORQUE:

RE-RUN:

MATERIAL: AL 1100

NUMBER: 7

APPROX. DATE: 4/80

DENSITY: 2.69 gm/cm³

AREA: .248 in²

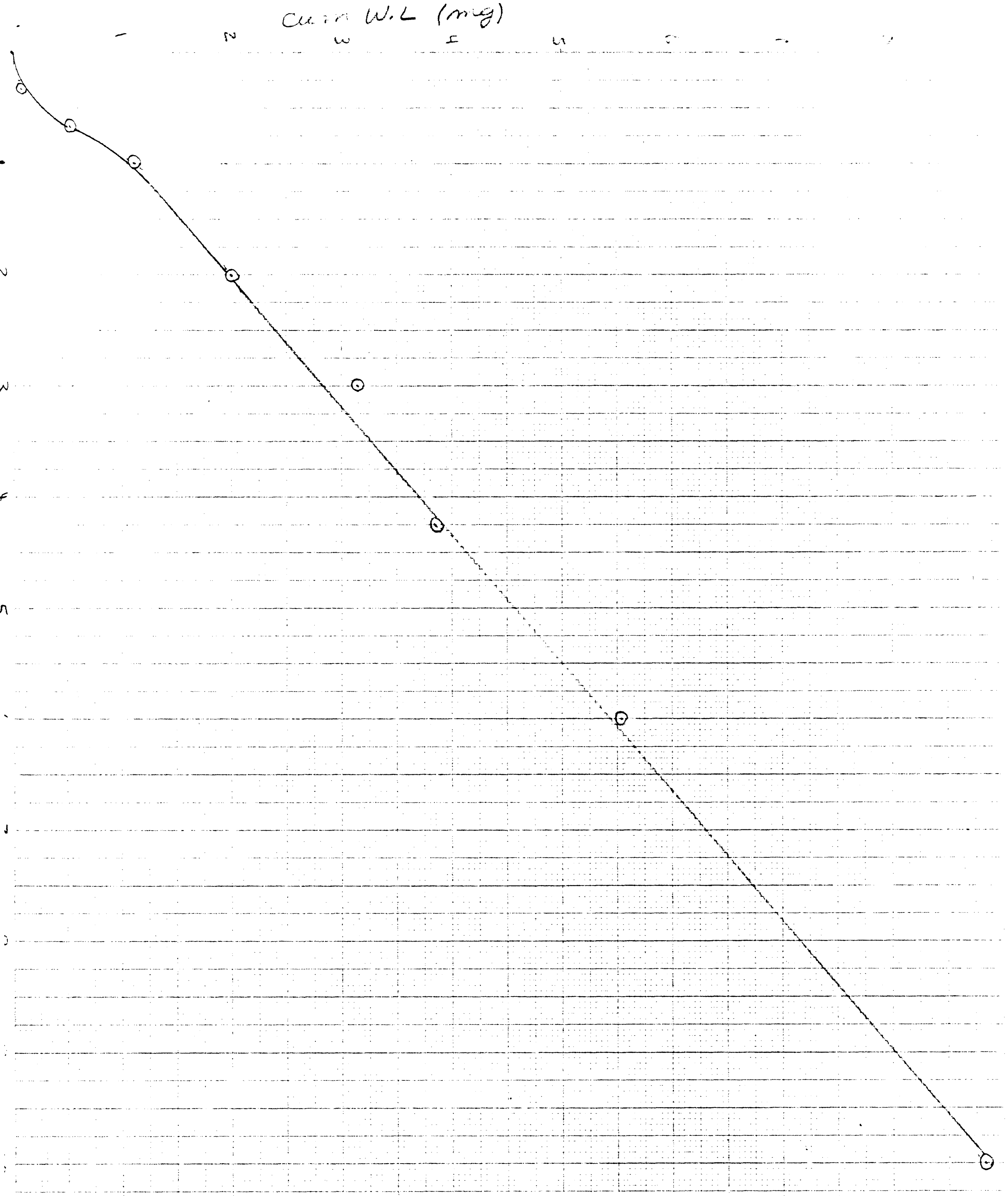
M.D.P. FACTOR: .09146 mil/mg

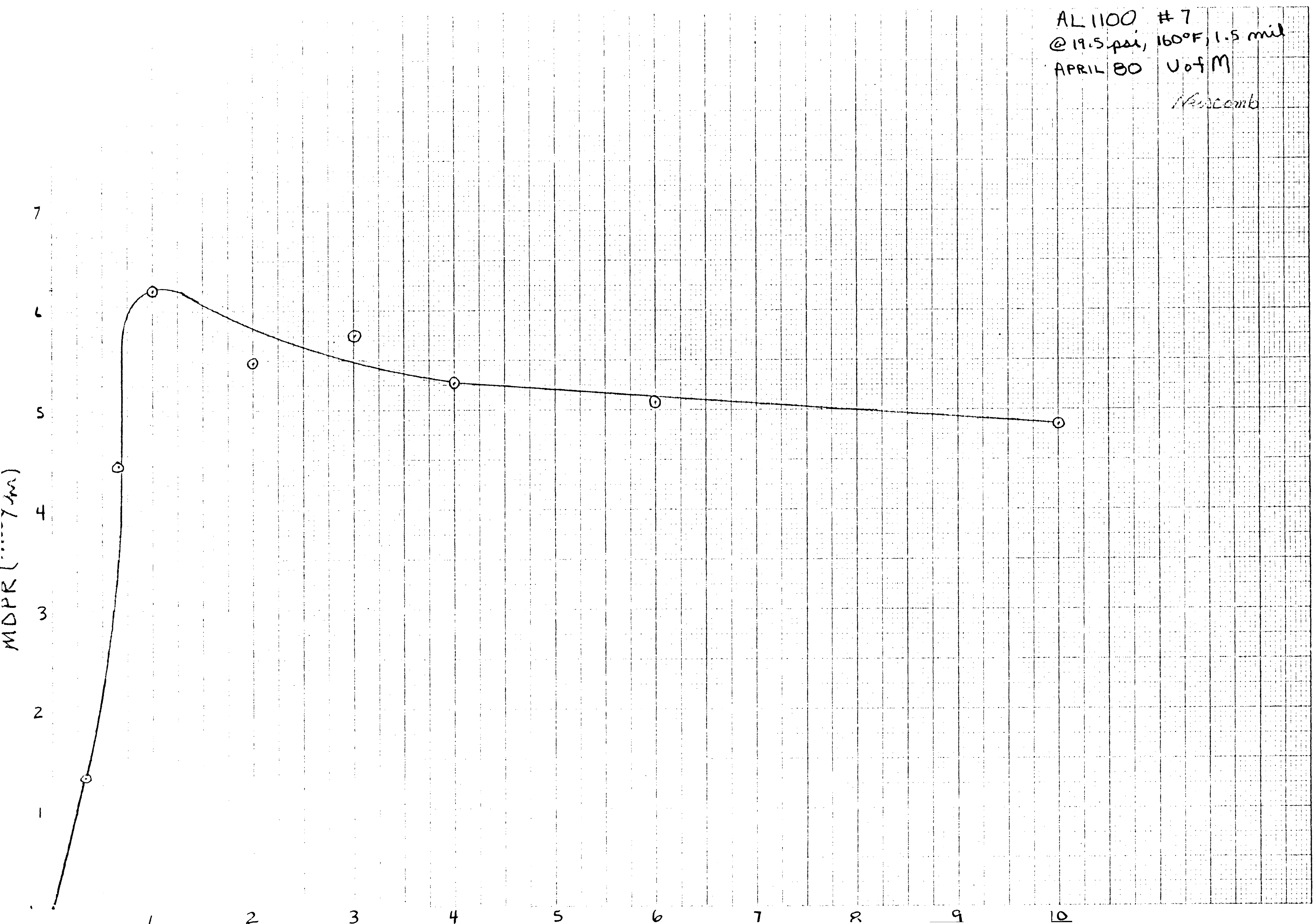
OMMENTS: Dual setting = 10

Operator:
Newcomb

DATA

ME ERVAL min	CUMULATIVE TIME min	WEIGHT LOSS mg	CUM. WT. LOSS mg	M.D.P.	M.D.P.R. mils/hr
0	0	0	0		0
⅓	⅓	.08	.08		1.317
⅓	⅔	.46	.54		4.445
⅓	1	.59	1.13		6.201
	2	.87	2.00		5.488
	3	1.14	3.14		5.744
	4	.70	3.84		5.268
	6	1.70	5.54		5.067
	10	3.29	8.83		4.847


Cum W.L (mg)
AL 1100 #7
@19.5 psi, 160°F, 1.5mil
APRIL 80 U of M
Newcomb



ers to the Centimeter

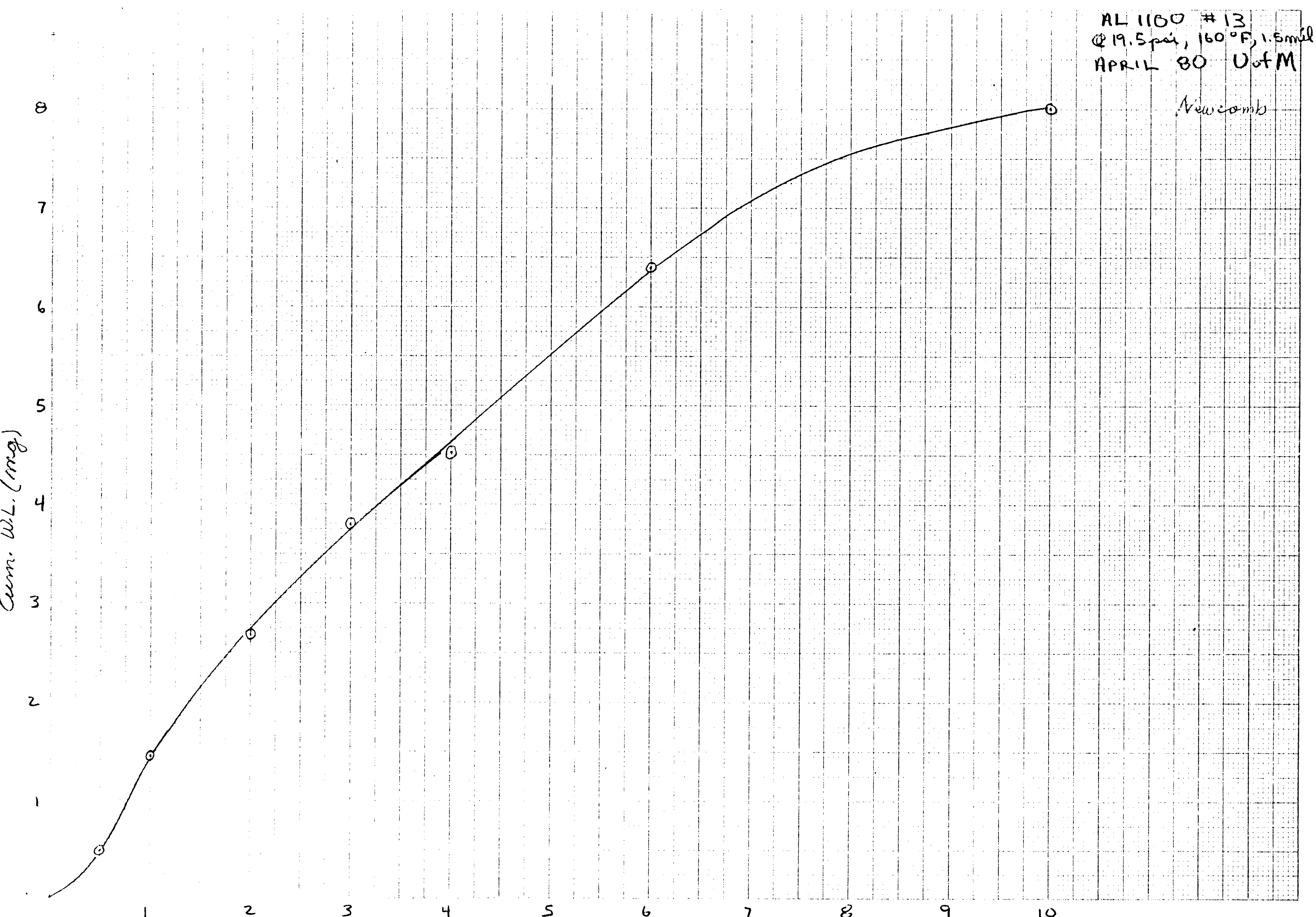
MATERIAL DAMAGE SHEET

N: Te | MATERIAL: AL 1100
PLITUDE: 1.5 mils | NUMBER: 13
ER: TAP | APPROX. DATE: 4/80
IPERATURE: 160°F | DENSITY: 2.69 gm/cm³
SSURE: 19.5 psi | AREA: .248 in²
QUE: | M.D.P. FACTOR: .09146 mil/mg
-RUN:

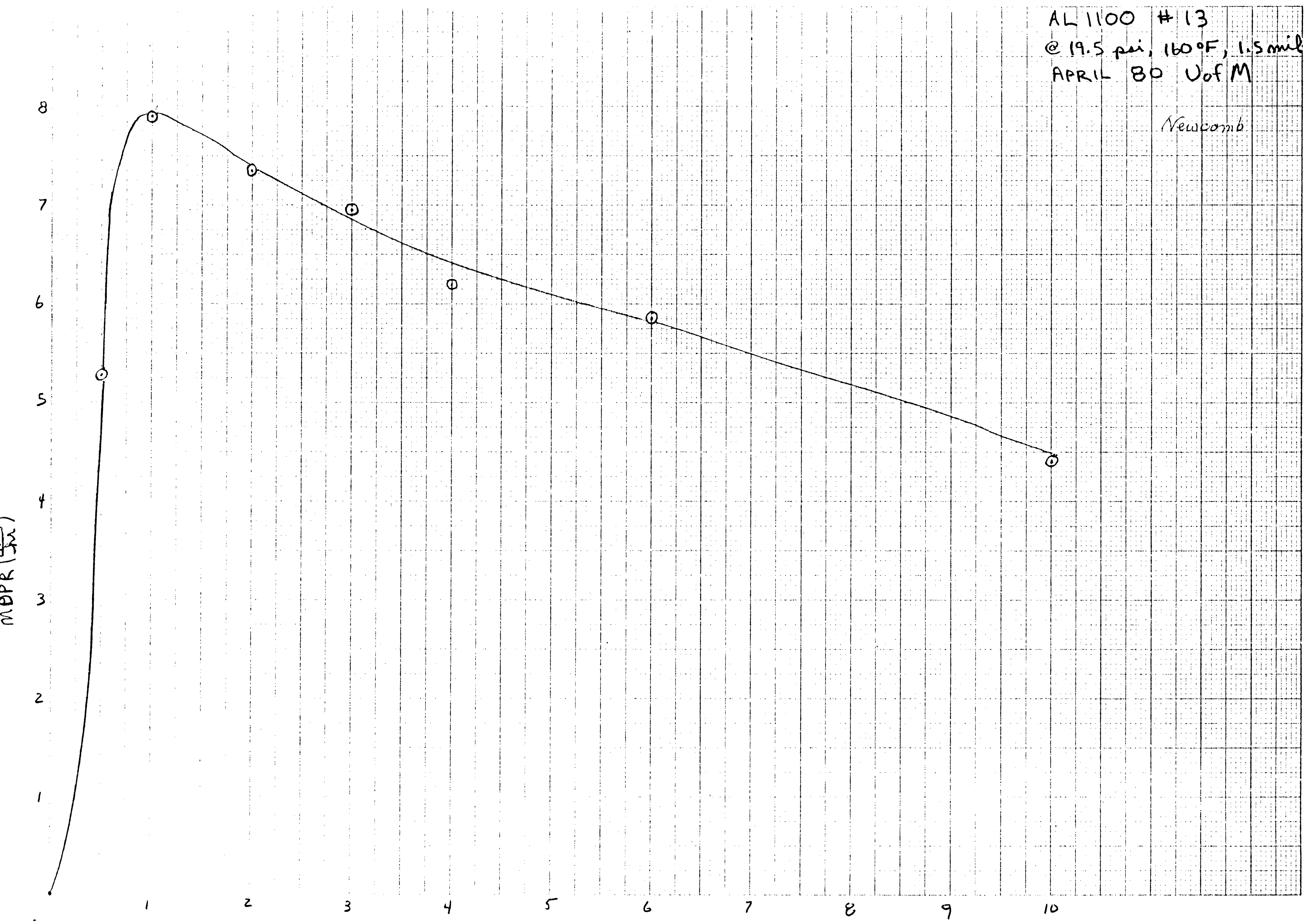
IMENTS: Dial setting = 10

Operator = Newcomb

DATA					
E ERVAL min	CUMULATIVE TIME min	WEIGHT LOSS	CUM. WT. LOSS	M.D.P.	M.D.P.R.
	0	0	0		0
	½	.48	.48		5.268
	1	.96	1.44	✓	7.902
	2	1.24	2.68	✓	7.353
	3	1.12	3.80	✓	6.951
	4	0.72	4.52	✓	6.201
	6	1.88	6.40	✓	5.853
	10	1.61	8.01		4.396



ters to the Centimeter



meters to the Centimeter

MATERIAL DAMAGE SHEET

HORN: Ti

AMPLITUDE: Dial Setting = 13 [illegible]

WATER: Fresh

TEMPERATURE: [illegible]

PRESSURE: 135 psig

TORQUE:

PRE-RUN:

MATERIAL: Cast Iron

NUMBER: # 6

APPROX. DATE: June 1985

DENSITY: 7.29 g/cc

AREA: 0.236 in^2

M.D.P. FACTOR: [illegible] = $\frac{1}{\rho A}$ = 0.0 [illegible]348

COMMENTS:

MDPR$_{max}$ = [illegible]

MDPR ACQ = [illegible]

I. P[illegible]

Donator:
Brian Szar

DATA

TIME INTERVAL (min)	CUMULATIVE TIME (min)	WEIGHT LOSS (grams)	CUM. WT. LOSS (grams)	M.D.P. (μm)	M.D.P.R. (mils/hr)
	0	0.0	0.0		0.0
	30	0.0122	0.0122		0.866
	60	0.0148	0.0268	26.7[illegible]	0.951 [illegible]
	90	0.008	0.0348		0.523
	150	0.0295	0.0643		0.913
	210	0.0182	0.0825	[illegible]	0.586
					[illegible]

MATERIAL DAMAGE SHEET

ORN: T1

MATERIAL: Cast Iron

MPLITUDE: [illegible]

NUMBER: #2

ATER: Fresh

APPROX. DATE: June 19[illegible]

EMPERATURE: 160 F

DENSITY: 7.29 g/cc

RESSURE: 14.5 psia

AREA: 0.236 in²

ORQUE:

M. D. P. FACTOR: $C = \frac{1}{\rho A} = 0.03548$

RE-RUN:

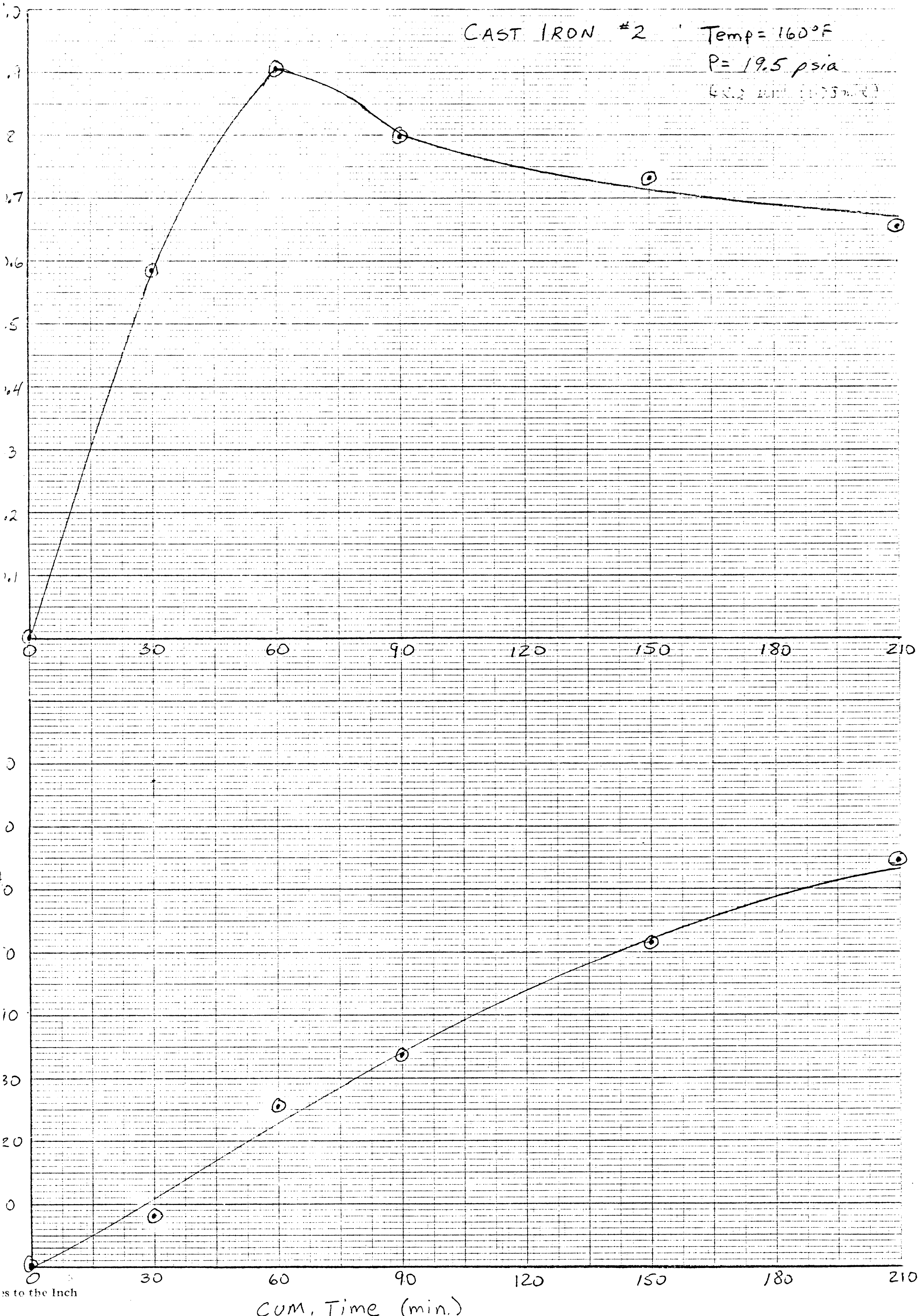
OMMENTS:

$MDPR_{max} =$ [illegible]

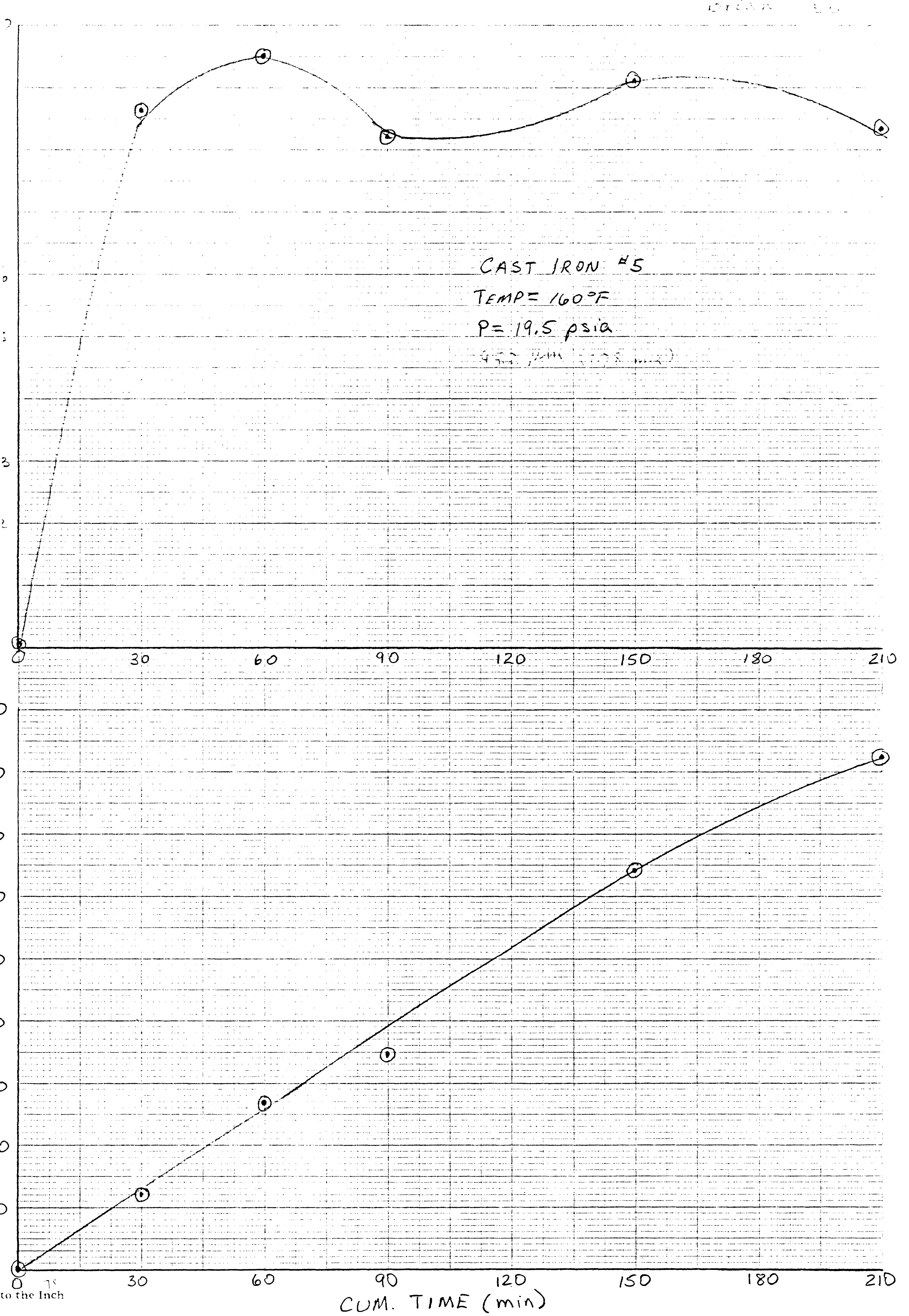
Operator: Brian Szal

DATA

ME ERVAL	CUMULATIVE TIME (min)	WEIGHT LOSS (grams)	CUM. WT. LOSS (grams)	M. D. P.	M. D. P. R. (mils/hr)
	0	0.0	0.0		0.0
	30	0.00825	0.00825		0.585
	60	0.0173	0.02555		0.807
	90	0.0082	0.03375		0.798
	150	0.01785	0.0516		0.732
	210	0.0131	0.0647		0.656



CAST IRON #2
Temp = 160°F
P = 19.5 psia
0
30
60
90
120
150
180
210
CUM. Time (min.)



CAST IRON #5
TEMP= 160°F
P= 19.5 psia
0
30
60
90
120
150
180
210
CUM. TIME (min)
to the Inch