AN EVALUATION OF THE CUSHIONING PROPERTIES OF CORRUGATED PAPERBOARD

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
Gerald L. Palmreuter
1968

THESIS

ABSTRACT

AN EVALUATION OF THE CUSHIONING PROPERTIES
OF CORRUGATED PAPERBOARD

by Gerald L. Palmreuter

This study was undertaken in order to determine the shock absorbing characteristics of built up corrugated material. Test cushions varying in thickness, basis weight, and flute size were evaluated with a Vertical Dynamic Drop Tester. The data obtained was used in evaluating cushioning properties and predicting the shock experienced by an article packaged in corrugated.

On the basis of the data, the following conclusions were drawn:

1) Unstressed corrugated is a very inconsistent material and its performance inside a package cannot be steadily predicted after the initial drop.

2) Prestressed corrugated cushioning is a relatively consistent cushioning material and it performs quite well inside a package. However, its cushioning ability cannot be predicted with the use of cushion curves.

3) The basis weight of the corrugated medium is a more important factor in determining cushion effectiveness than the basis weight of the liner.

4) As the flute size increases, the first impact effectiveness increases but the multidrop effectiveness decreases.

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By

Gerald L. Palmreuter

A THESIS

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INTRODUCTION

In our competitive society, the search for potential areas of cost reduction is a never ending battle. Consequently, many companies which previously regarded packaging as a "liability" are being forced into realizing that packaging is a frontier which, if conquered, could give them the edge on their competitor. With this increased interest, a movement is beginning which is aimed at changing packaging from an art into a science. In this respect, the cushion curve--peak g vs static stress curve--has been a very useful tool. With the help of such curves it is possible to compare the merits of various cushioning materials for a certain given application. The School of Packaging at Michigan State University has derived such curves for many materials. However, prior to the time of this study, no cushion curve work had been done with corrugated material.

This study then is designed to use cushion curves to investigate the effects of various variables associated with corrugated board--basis weight of liners, basis weight of corrugated medium, flute size, cushion thickness, etc.--upon cushioning properties. In addition, a comparison between corrugated and other commercially available materials will also be included.

BACKGROUND

Until World War II there was little interest in package cushion testing. However, during the war the Forest Products Laboratory in Madison, Wisconsin, began studies on cushions used in packages. These early studies were based on static tests and they were aimed at finding some way of predicting a cushion's performance inside a package. The static method involves placing a series of weights on the cushioning material and measuring the amount of compression of the material as each weight is added. The greatest drawback to this method lies in the fact that the forces are not applied to the cushioning material at the same rate as they are when the cushioned article is dropped. Because of this, dynamic testing, which more closely simulates the action of a cushion in an actual drop, became the accepted method for evaluating cushion performance.[1]

All dynamic tests in package cushioning operate on the same basic principle. A cushion of known thickness and area is impacted by a mass of known weight. The deceleration of the falling body as well as the deflection of the cushion and the drop distance--based on impact velocity--can then be measured. Several methods have been tried. Of these, the one making use of the Vertical Dynamic Drop Tester is most common because of the ease with which impact velocity is controlled. This method makes use of a variable weight platen that is dropped on a sample cushion.[2]

The main purpose in using a dynamic tester is to derive a cushion curve. All such curves are of the basic form shown in Figure 1. They have g's deceleration plotted against static stress and are used to evaluate the merits of a particular package cushioning material for certain given applications. Figure 1 is a first drop - 24" free fall cushion curve for 2" ZZ-A Flute. The ZZ indicates that the basis weight of both the corrugated medium and the liner is 17 lbs/1000 sq ft. (Appendix 1)

The way in which a drop tester is used to derive the curves is the static stress, which is measured in lbs/sq", is varied by changing weights on the dynamic dropping head which impacts a cushion 8 inches square. The g's experienced in the drop for a certain static stress are measured by an accelerometer and recorded on an oscilloscope. From Figure 1 it is easy to see that:

1) Under a load of .19 lbs/sq" a shock of 50 g's was experienced.

2) Under a load of .40 lbs/sq" a shock of 30 g's was experienced.

3) Under a load of .50 lbs/sq" a shock of 50 g's was experienced.

Knowing that the area impacted was 64 sq" and that static stress (ss) = pounds loading of the drop platen (lbs)/square inches impacted by the platen (sq"), it is easy to determine the number of pounds which impacted the cushion at each of the above static stresses.

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ZZ-A FLUTE

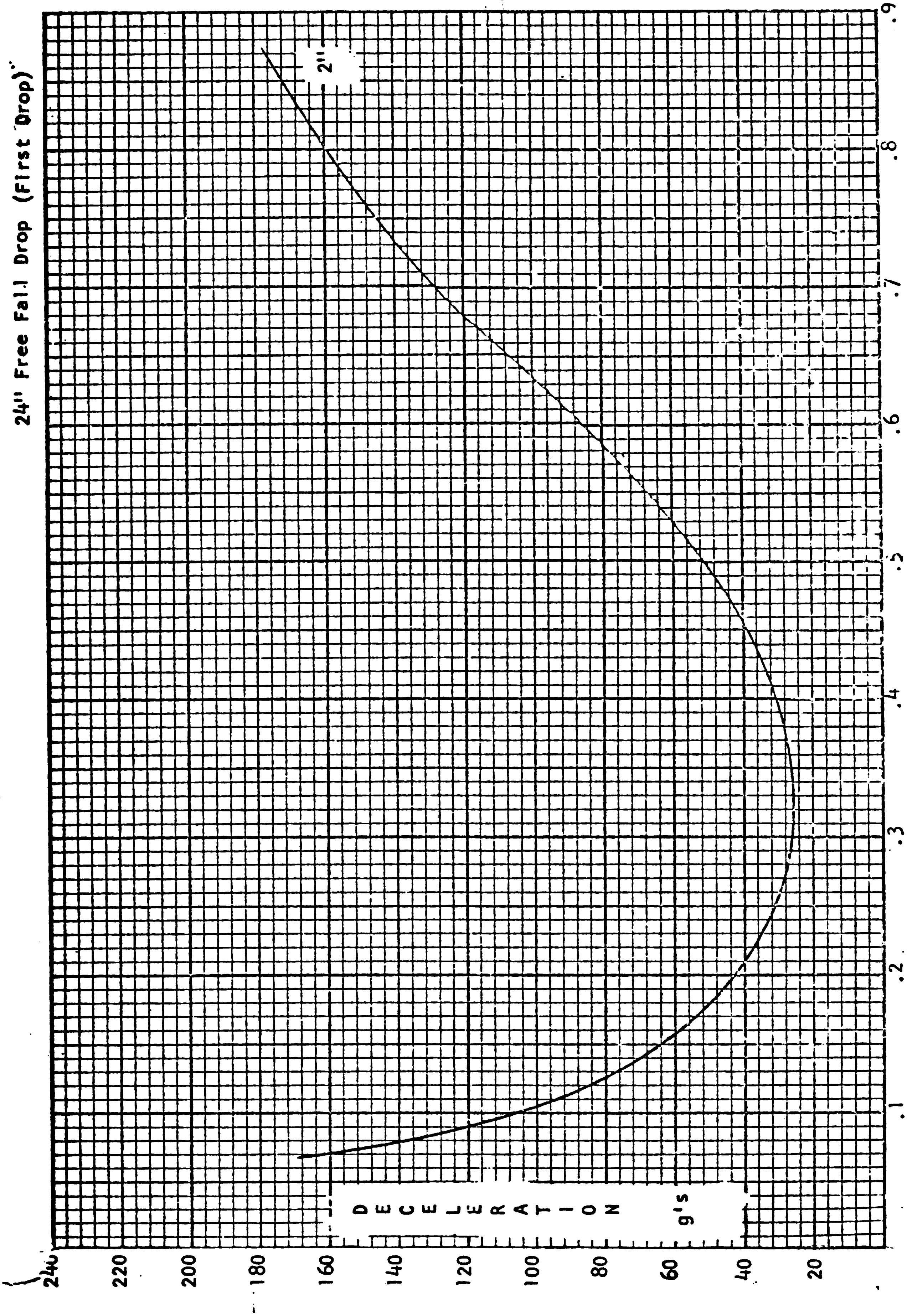

Figure 1

ss = lbs/sq"

where ss = .19 lbs/sq" and sq" = 64 sq"

therefore .19 lbs/sq" = lbs/64 sq"

or lbs = .19 lbs/sq" X 64 sq" = 12.16 lbs

Similarly at .4 lbs/sq", 25.6 lbs impacted the sample and at .5 lbs/sq", 32 lbs impacted the sample.

From this one can see that 64 sq" of this cushion offers 24" first drop protection to an article which has a fragility of 50 g's if this article weighs inbetween 12.8 and 32.0 lbs. Above and below this weight range the cushion will not give the desired protection if 64 sq" of cushioning is used on the side of the package which is to be impacted. However, by deviating from the 64 sq" it is possible to protect an article with a 50 g fragility which has a weight outside the 12.8 to 32.0 lb range. This is beyond the purpose of my study. If, however, you are interested in this aspect of cushion design, the Cushion Design Method and an example of this method appear in Appendix 2 of this study.

As a result of the previous discussion concerning cushion curves, it should now be relatively easy to compare cushioning properties with the use of cushion curves. Figure 2 gives 24" free fall cushion curves derived for two hypothetical cushioning materials. From these curves it is obvious that both materials protect throughout the same loading range. However, material A is better to protect a low fragility item. (It offers protection to an article with a fragility of 32 g's at

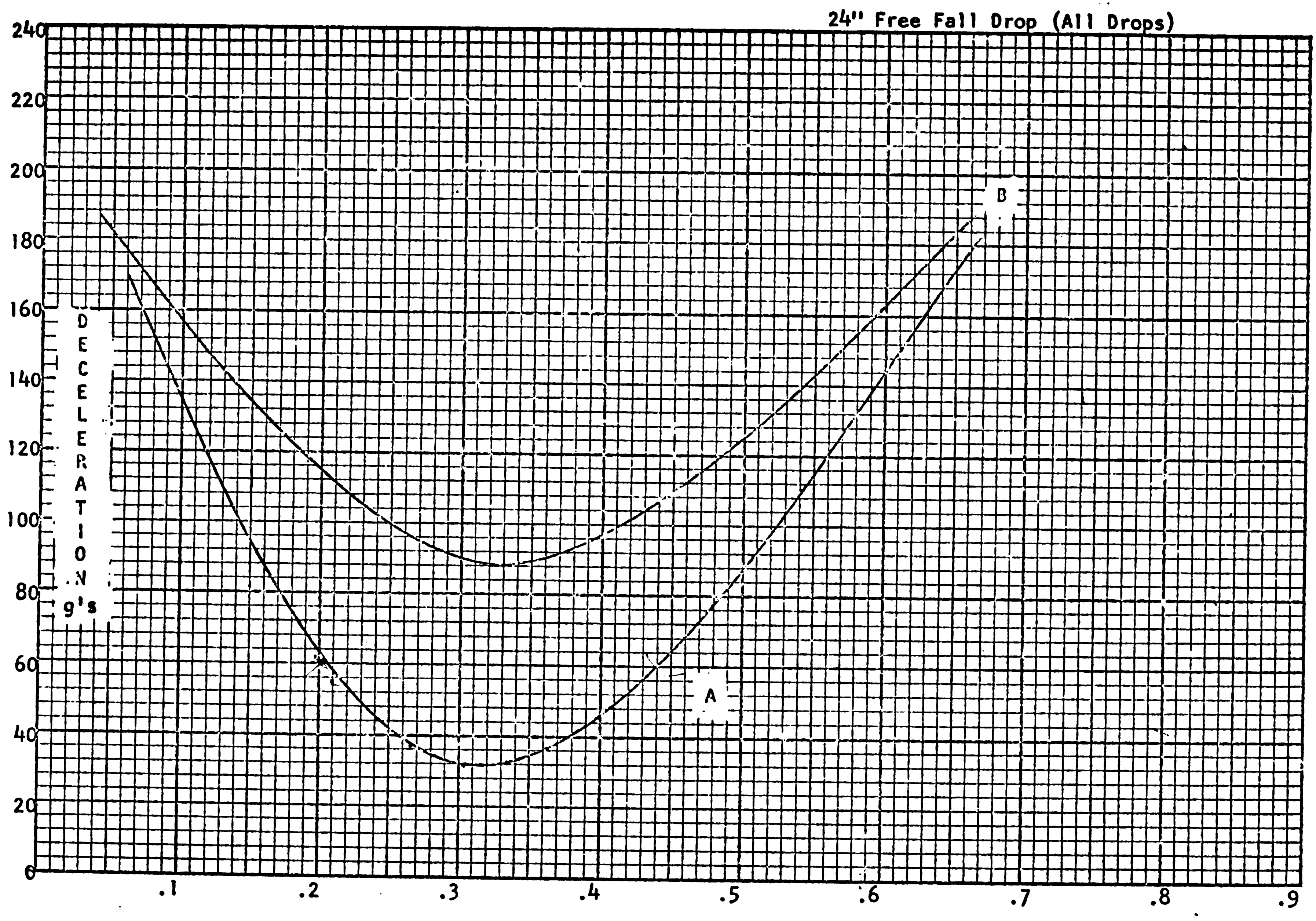
24" Free Fall Drop (All Drops)
DECELERATION g's
240
220
200
180
160
140
120
100
80
60
40
20
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
A
B
STATIC STRESS - PSI

Figure 2

a static stress of .31 lbs/sq"). The best protection material B can offer is 88 g's at a static stress of .325 lbs/sq". Thus if a packaging engineer had only materials A and B available and he had to protect an article with a fragility of 60 g's; his only choice would be material A between a static stress of .2 lbs/sq" and .435 lbs/sq".

Figure 3 represents two more hypothetical cushion curves derived for a 24" free fall. It can be seen that material C is only good at light loadings. (At .185 lbs/sq" it protects down to 28 g's). Material D is good over a wide loading range but it offers best protection at .5 lbs/sq" (32 g's). If a packaging engineer were faced with a choice between materials C and D in protecting an article with a fragility of 40 g's, the major consideration would be the weight of the product. Material C would be used for a light product and material D would be used for a heavy product.

From the previous discussion it is obvious that cushion curves can be very useful to a packaging engineer. For this reason some companies have had such curves derived for their package cushioning material.[3] However, as far as could be determined, no cushion curves have been made available for built up corrugated cushioning.

Mr. R. K. Stern who is a technologist for the Forest Products Laboratory in Madison, Wisconsin did some work concerning the cushioning ability of freely ventilated corrugated pads. However this work was concerned with only single loading

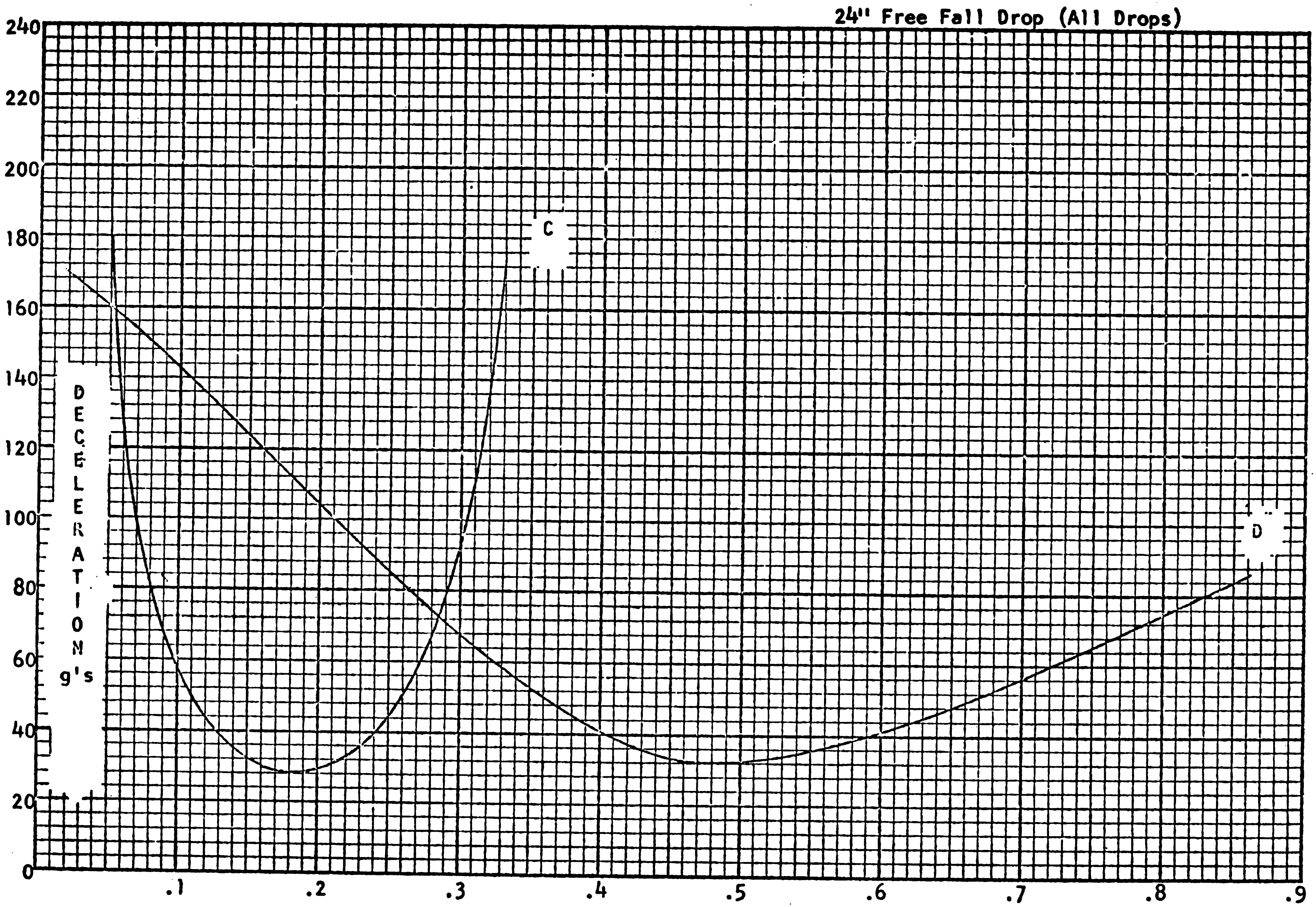
24" Free Fall Drop (All Drops)
240
220
200
180
160
140
120
100
80
60
40
20
0
DECELERATION g's
C
D
.1
.2
.3
.4
.5
.6
.7
.8
.9
STATIC STRESS - PSI

Figure 3

--one impact--of one to five layers of corrugated. On the basis of this work he concluded:[4]

1) For a single impact, the larger the corrugation size --flute size--the greater the cushion effectiveness.

2) For a single impact, an even number of layers--2 or 4 --is more effective than an odd number of layers--1, 3 or 5.

As an extension of Mr. Stern's work, this study is concerned with using cushion curves to:

1) Compare corrugated cushioning to a few selected foamed plastics (polyethylene and polystyrene) in order to see if corrugated has any distinct cushioning advantages.

2) Compare the various types of corrugated cushioning to one another in order to evaluate the effects of such variables as flute size, basis weight, and cushion thickness.

3) Evaluate the accuracy of predicting shock experienced by a product packaged in corrugated.

4) Evaluate the effects of prestressing corrugated pads.

TEST EQUIPMENT AND INSTRUMENTATION

The equipment and instrumentation section will be divided into the following three parts:

1) The dynamic drop tester and the associated instrumentation used to derive cushion curves.

2) The package drop tester, the dummy load, and the instrumentation used to evaluate the shock predicting ability of corrugated cushion curves.

3) The compression tester used to prestress corrugated cushioning.

Dynamic Drop Tester

The testing apparatus consisted of a dynamic drop tester plus the associated electronic instrumentation. A dynamic drop tester is a machine having a dropping head and a massive anvil. A Kistler Model 818 accelerometer was mounted on the dropping head. This accelerometer, together with a Kistler Model 548 B piezotron coupler and a Tektronix Type 564 storage oscilloscope, gave a complete deceleration vs time curve for any given drop. Selected traces were photographed using a Tektronix Model C-12 oscilloscope camera and Polaroid Type 47 high speed (3000 ASA equivalent) black and white film. A Krohn-Hite Model 330M band pass filter was used to purify the deceleration vs time pulse because the Kistler Model 818 accelerometer has such a high natural frequency that it picked up undesirable noise from the movement of the bearings on the shafts. The filter was properly adjusted so that it filtered out only the noise and not part of the fundamental shock which was being measured. A justification for the filter setting is shown in Appendix 3.

All of the data in this study is based on "equivalent free fall height" rather than actual drop height. This free fall height is based on impact velocity. In order to measure this impact velocity a Sanborn 3LVI-N linear velocity transducer was employed. This transducer has a calibration in terms of mv/in/sec and it was set up such that the velocity was measured one inch before the actual impact. (For a 24" free fall the impact velocity which had to be read 1" before impact is 133.5"/sec).[5] This was done to avoid the effects of an air cushion which existed between the test sample and the dropping head when they were less than one inch apart. Remembering now that the transducer has a calibration in terms of mv/in/sec, its voltage output was recorded on a Tektronix Type 502 dual beam oscilloscope and converted to in/sec which is velocity. The dynamic drop tester and all of the associated instrumentation is shown in Figure 4.

Package Drop Tester

This part covers the items used in the package drop test. The three principal items were (1) the corrugated containers, (2) the dummy load used in the packages and (3) the package drop tester itself.

The containers were constructed of 200 pound test A flute

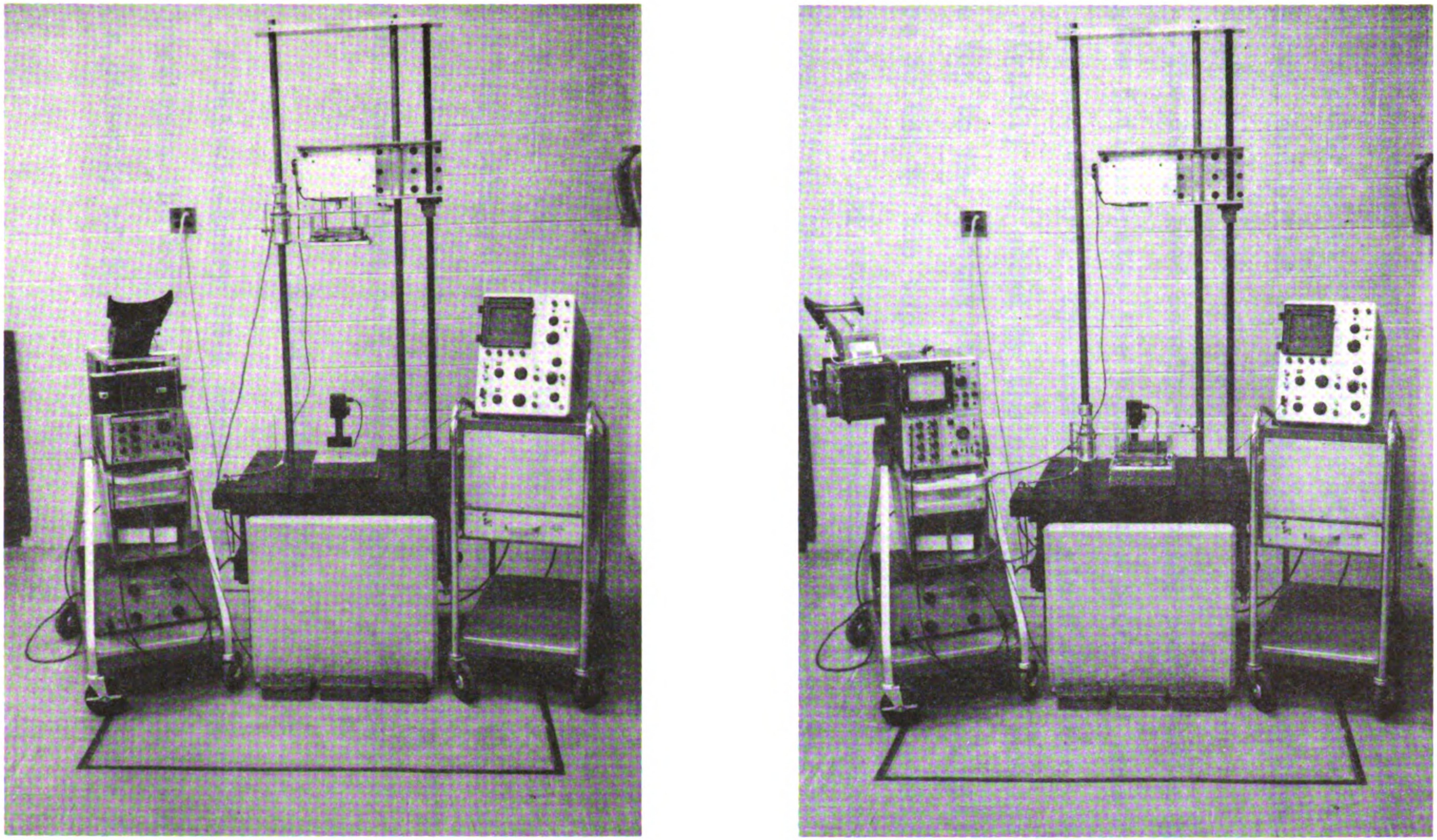

Figure 4 DYNAMIC DROP TESTER & THE ASSOCIATED INSTRUMENTATION

board. They had inside dimensions of 8 X 8 X 11 inches. All were regular slotted containers with the manufacturers' joint, the top, and bottom sealed with glass reinforced asphalt laminated kraft backed tape.

The dummy load consisted of an 11½ pound wooden block. Figure 5 illustrates the block. This block was constructed of maple dieboard. The layers were glued together. Additional rigidity was added by the use of 3/8" bolts running from the top to the bottom at all four corners. Steel plates were bolted to the top and bottom to increase the weight of the block to 18½ pounds. A Kistler Model 818 accelerometer was mounted in the center of the block (see Figure 5). The output of this accelerometer was fed into a Tektronix Type 564 storage oscilloscope through a Kistler Model 548 B piezotron coupler.

The package drop tester used was a L.A.B. Model 5D-100 drop tester. The base plate which held the drop tester and which the packages impacted was one-half inch steel plate grouted onto an eight-inch concrete floor resting on tamped earth. The package drop tester is shown in Figure 6.

Compression Tester

A Baldwin-Emery SR-4 compression testing machine was used to prestress the corrugated samples. This compression tester has a capacity of 50,000 lbs. It is shown in Figure 7.

DUMMY LOAD FOR THE PACKAGE DROP TEST

DUMMY LOAD FOR THE PACKAGE DROP TEST

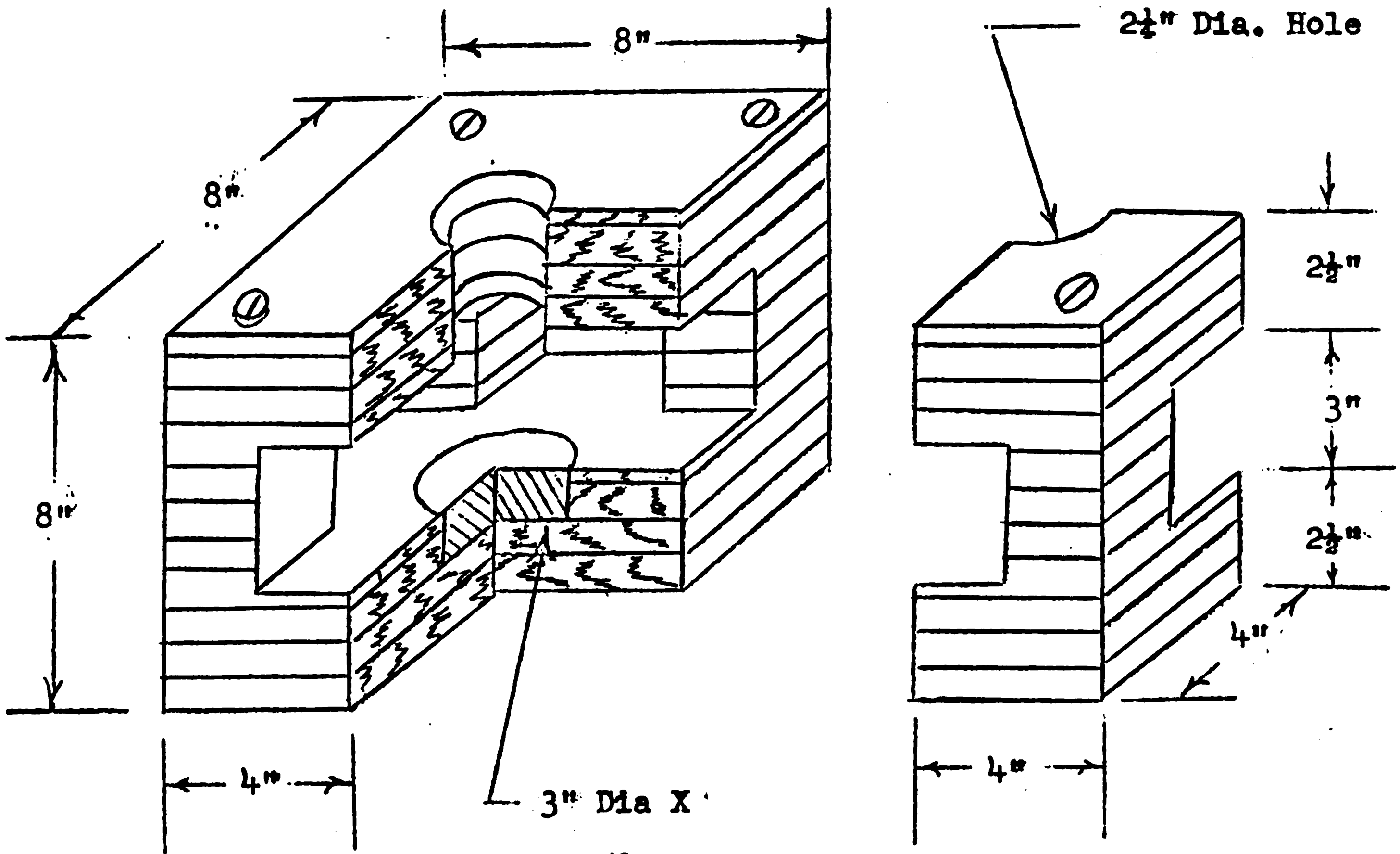

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Figure 5

L.A.B. MODEL 5D-100 PACKAGE DROP TESTER

Figure 6

BALDWIN-EMERY SR-4 COMPRESSION TESTER

• SEP • 68

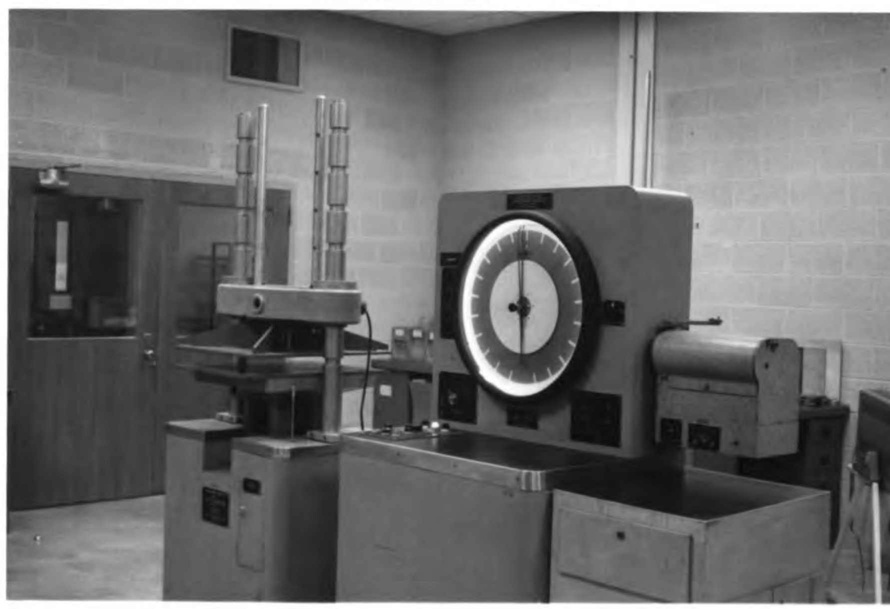

Figure 7

EXPERIMENTAL PROCEDURE

This section will be broken up into three parts corresponding to the three parts found in the equipment and instrumentation section. They are (1) the dynamic drop tester (2) the package drop tester and (3) the compression tester.

Dynamic Drop Tester

In order to derive the cushion curves used for this study, a modified version of ASTM D 1596-64--Standard Method of Test for the Shock Absorbing Characteristics of Package Cushioning Materials--was used. According to this method, drop height is specified as "equivalent free fall height" rather than actual drop height. This is because all dynamic dropping heads are influenced by friction. This friction may be due to the air and/or the shafts which guide the dropping head. The significance of this effect varies not only with the type of apparatus, but also with the various weights used in a given apparatus. For this reason a velocity transducer was used to measure impact velocity.

The test specimens consisted of 8 X 8 inch built up corrugated pads which varied in (1) flute size (2) specimen thickness (3) basis weight of the liners and (4) basis weight of the corrugated medium.

All specimens were preconditioned at 50 ± 2% relative humidity and 73.4 ± 3.6 degrees Fahrenheit for at least 24 hrs.

The test procedure consisted of the following four basic steps:

1) Adjust the impact velocity for a 24" free fall--a few curves were also derived for 18" and 30" free falls. This was done by varying the height that the platen dropped until the readout from the oscilloscope indicated the impact velocity desired. (Our Sanborn velocity transducer was calibrated so that a readout of 5.3 volts was needed one inch above the cushion in order to achieve an impact velocity of 136"/sec).

2) Measure the original thickness. An accurate ruler was used to determine the thickness of the specimen at its four corners. An average of these four readings was taken and recorded as the original thickness.

3) Impact the specimen. The test specimen was placed in position on the anvil and impacted by the dropping head with a series of five drops at a predetermined static stress--the lowest for which the material was to be evaluated. (Static stress is a function of the weight of the dropping head). A minimum of one minute elapsed between drops. After each drop (1) a complete deceleration vs time record was taken from the oscilloscope and (2) the specimen thickness was again measured. If the thickness of the specimen had decreased for any given drop, the drop height had to be changed in order to retain the proper

impact velocity for the next drop. The last of the five thicknesses was recorded as the final thickness.

4) Obtain a new sample, change the weight of the dropping head and repeat steps 1 through 3 until the upper loading--static stress--for which the cushion is to be evaluated has been reached.

The data obtained by this procedure is found in Appendix 4 and the first and second drop cushion curves derived by the use of this data can be found in the results section of this study.

Package Drop Tester

Once the test cushion had been selected, three test packages were assembled and sealed. Figure 8 illustrates the cross-section of a typical package ready for testing.

The test procedure used consisted of 5 impacts on the bottom surface of the instrumented package. A drop height of 24" was used and approximately one minute was allowed to elapse between drops.

The package drop test data can be found in the results section of this study.

Compression Tester

The procedure for prestressing the corrugated material consisted of the following:

1) Placing a sample between the platens of the compression tester.

A TYPICAL PACKAGE READY FOR THE PACKAGE DROP TEST

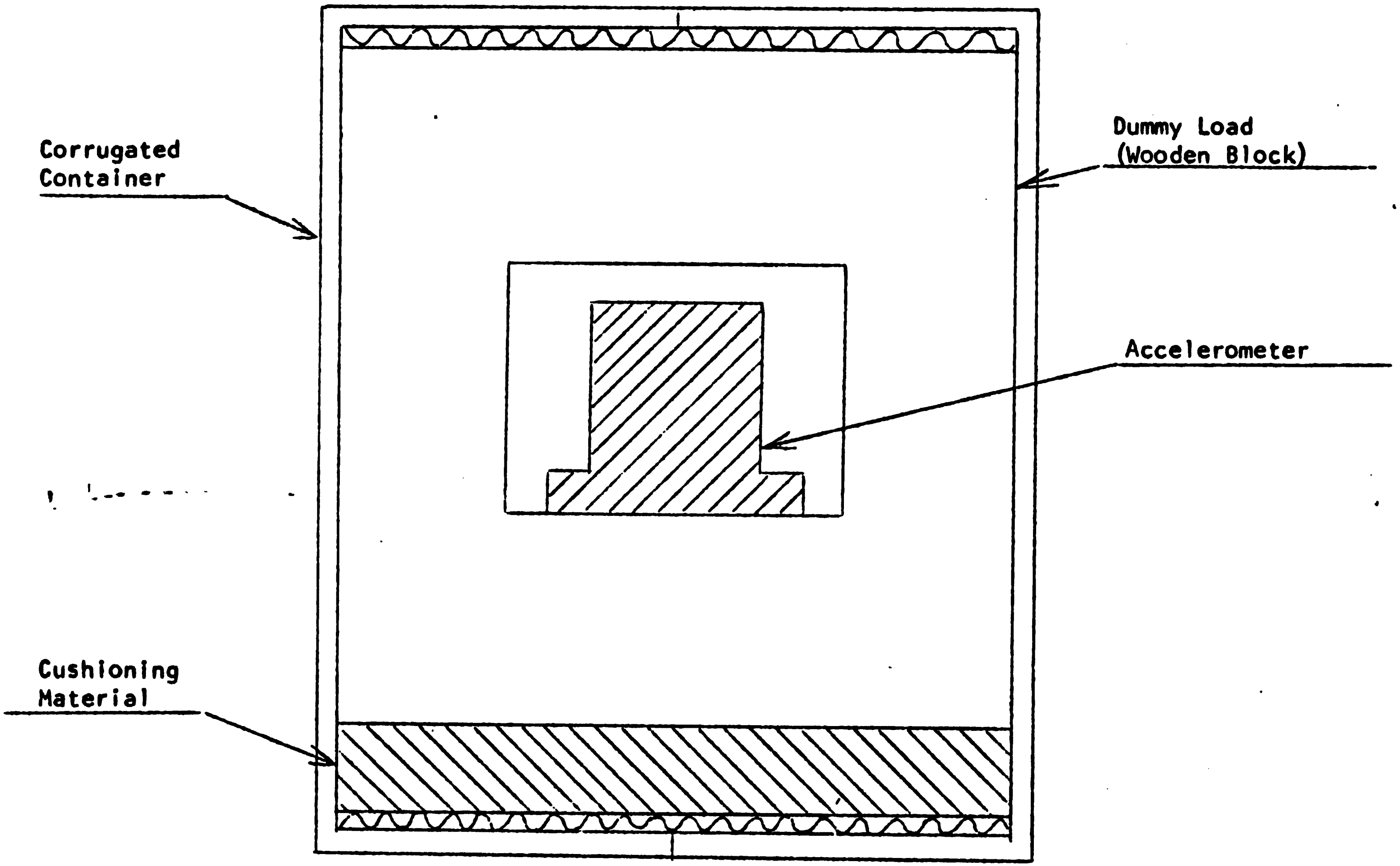

Figure 8

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2) Adjusting the machine to automatically shut off when the sample experienced a load of 1,250 pounds.

3) Setting the bottom platen to move up at a rate of .5"/minute. This rate of movement continued until the sample experienced a load of 1,250 pounds.

4) Removing the 1,250 pound load from the sample as soon as possible.

RESULTS

This section is divided into two parts. Part I--Figures 9 to 60--contains the cushion curves which were drawn using the dynamic drop test data found in Appendix IV. For reasons presented in the introductory comments to this appendix, five drop average cushion curves, as specified by ASTM D 1596-64, were only drawn for the prestressed materials. (Prestressed curves appear in Figures 57 & 58). All other figures in this section represent either first or second drop cushion curves for one of the materials tested. Third, fourth, and fifth drop cushion curves were also drawn, but they were not included in this report.

Part II consists of a table comparing the shock predicted via corrugated cushion curves and the shock actually experienced by an article packaged in corrugated cushioning.

ZR-A Flute

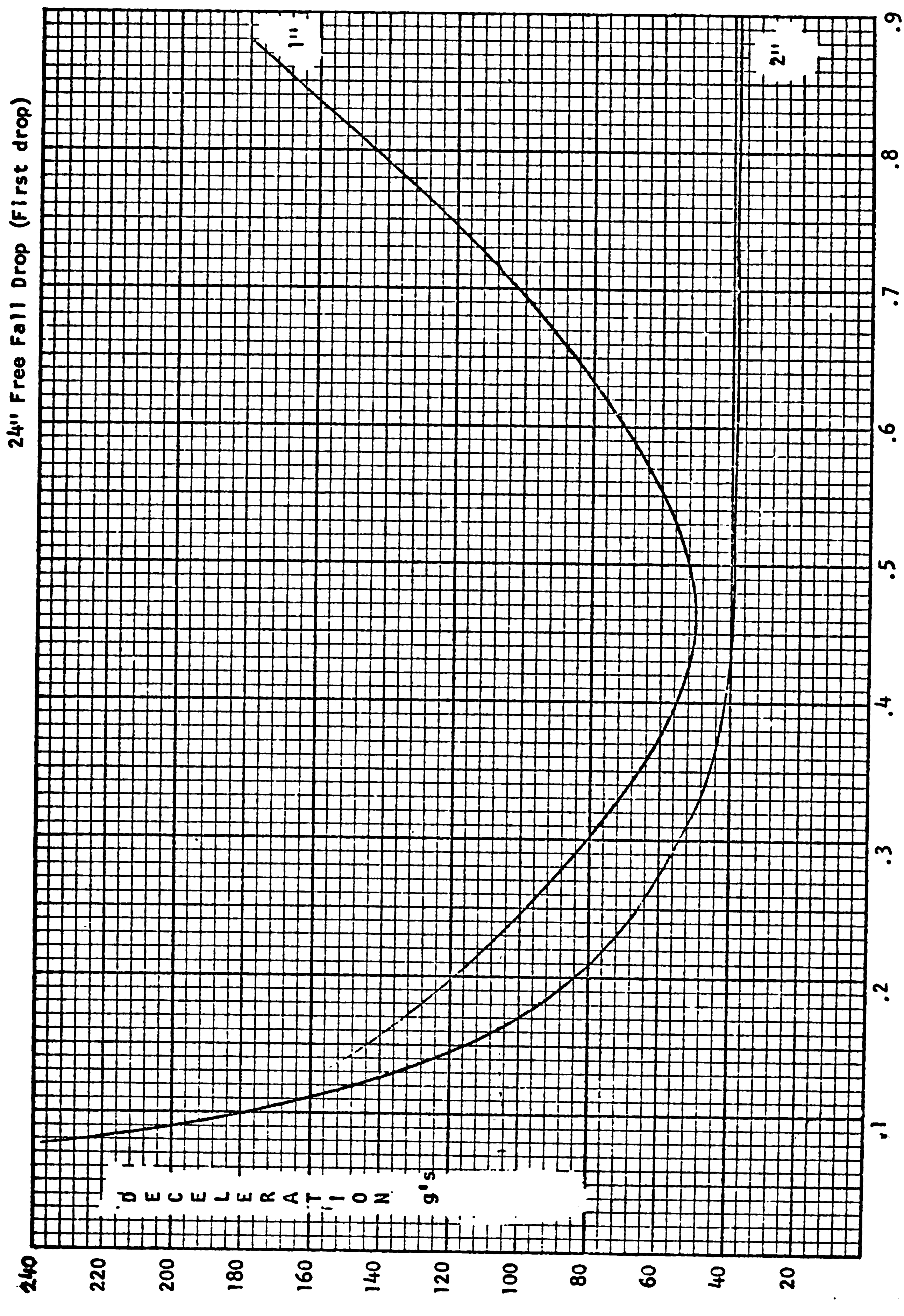


Figure 2

W. Va. Pulp & Paper H & D Div. (Sandusky)

ZR-A Flute

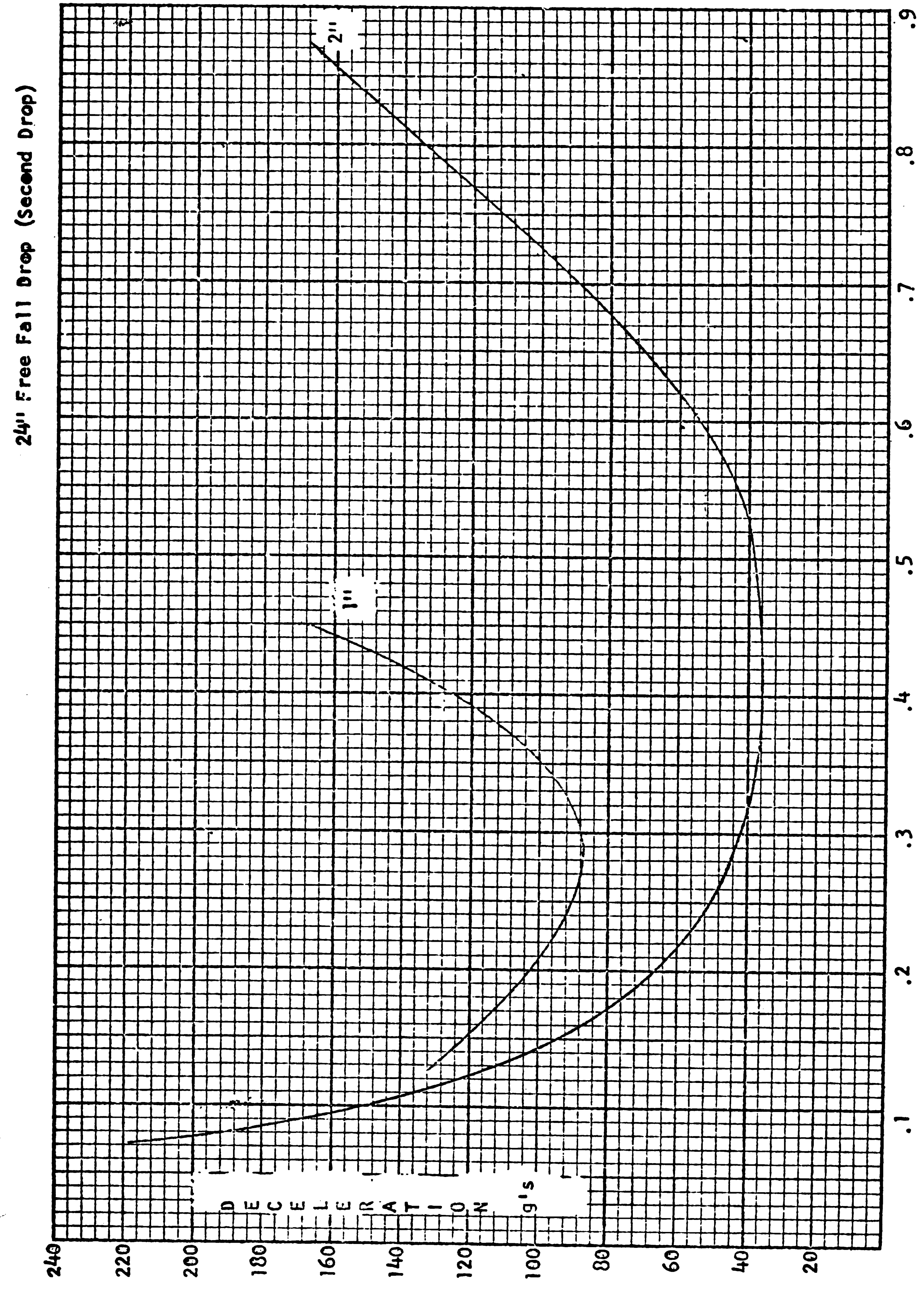


Figure 10

W. Va. Pulp & Paper H & D Div. (Sandusky)

ZR-A Flute

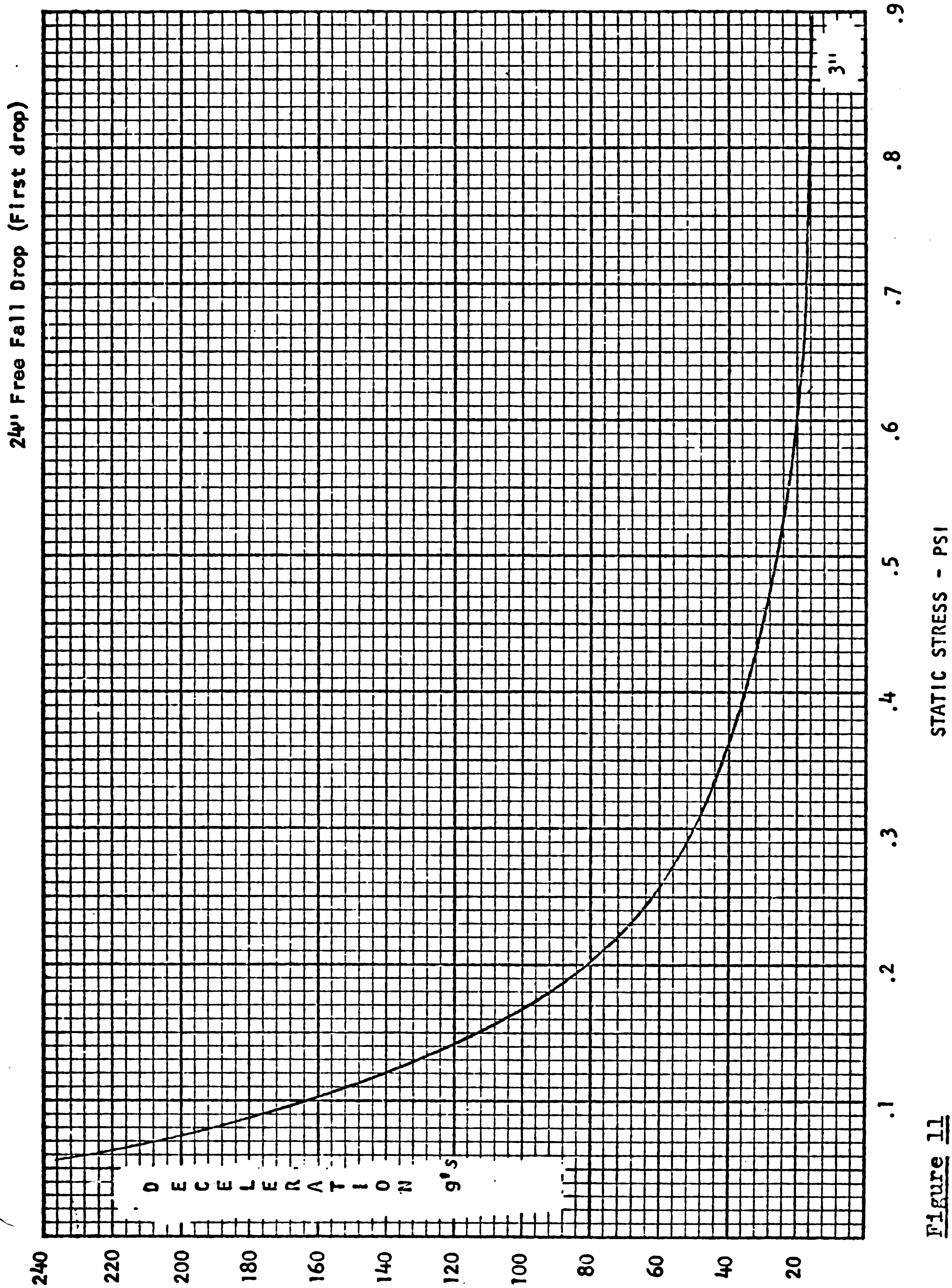


Figure 11

W. Va. Pulp & Paper H & D Div. (Sandusky)
ZR-A Flute

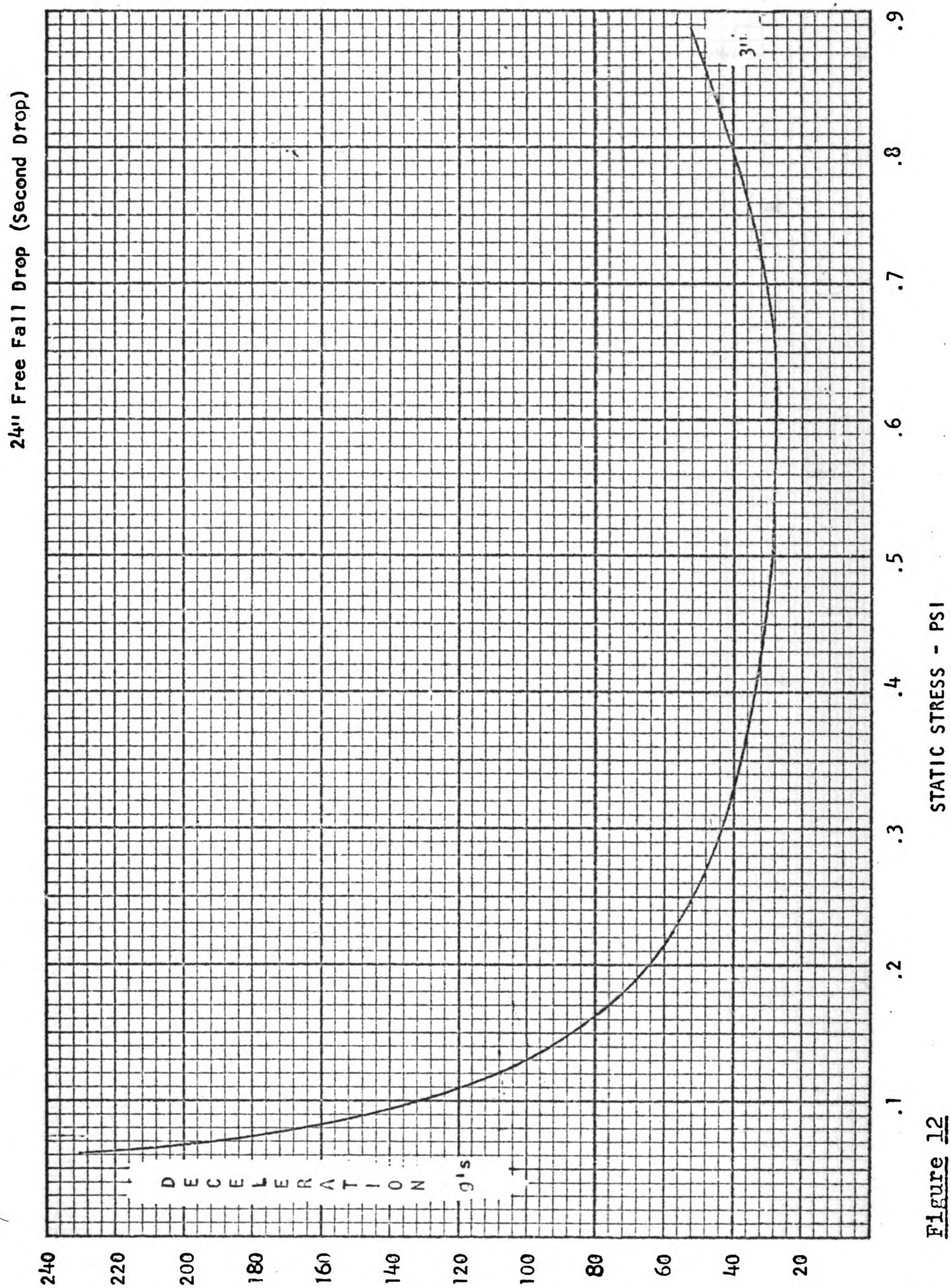


Figure 12

W. Va. Pulp & Paper H & D Div. (Sandusky)

AV-A Flute

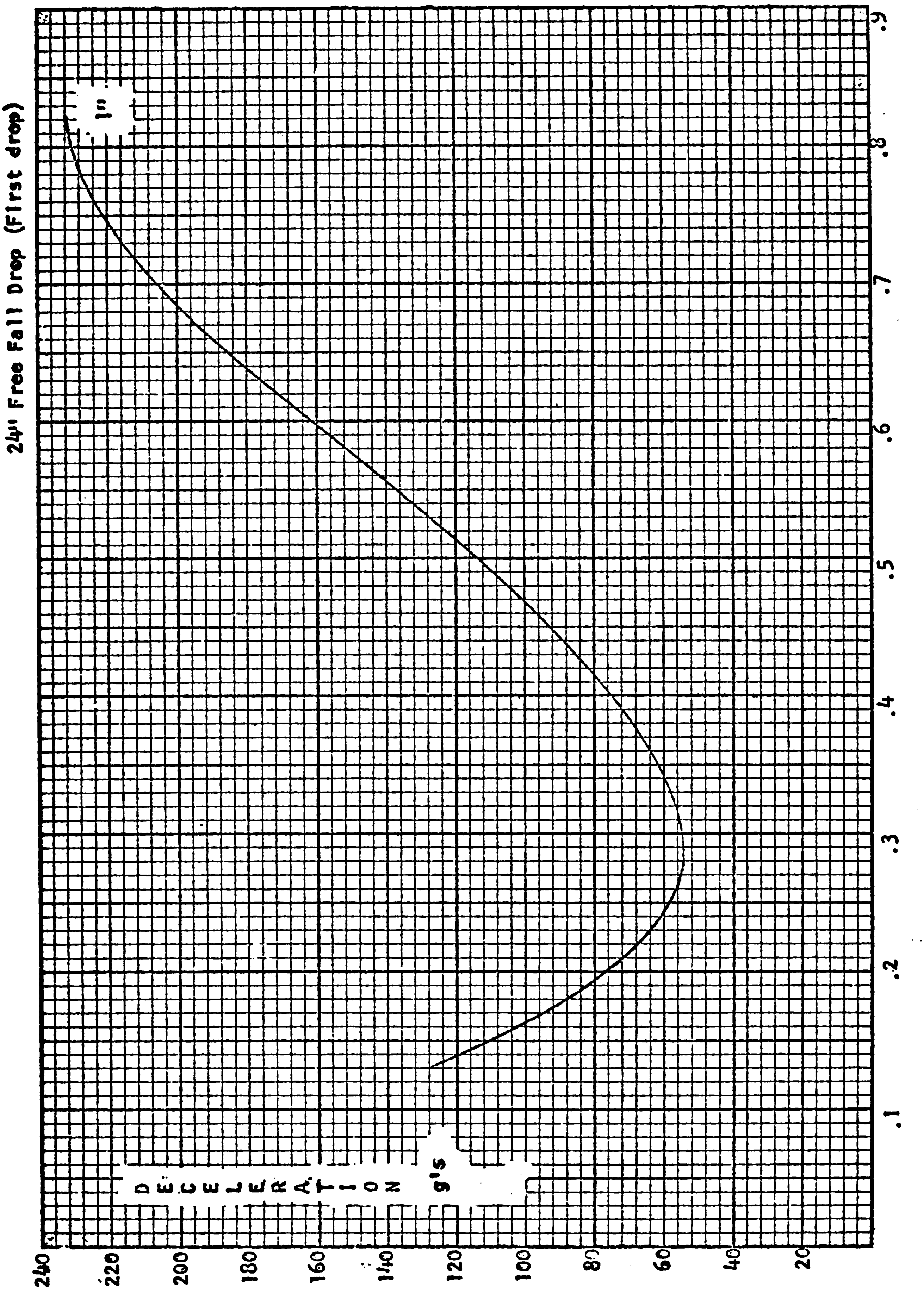


Figure 13

W. Va. Pulp & Paper H & D Div. (Sandusky)

AV-A Flute

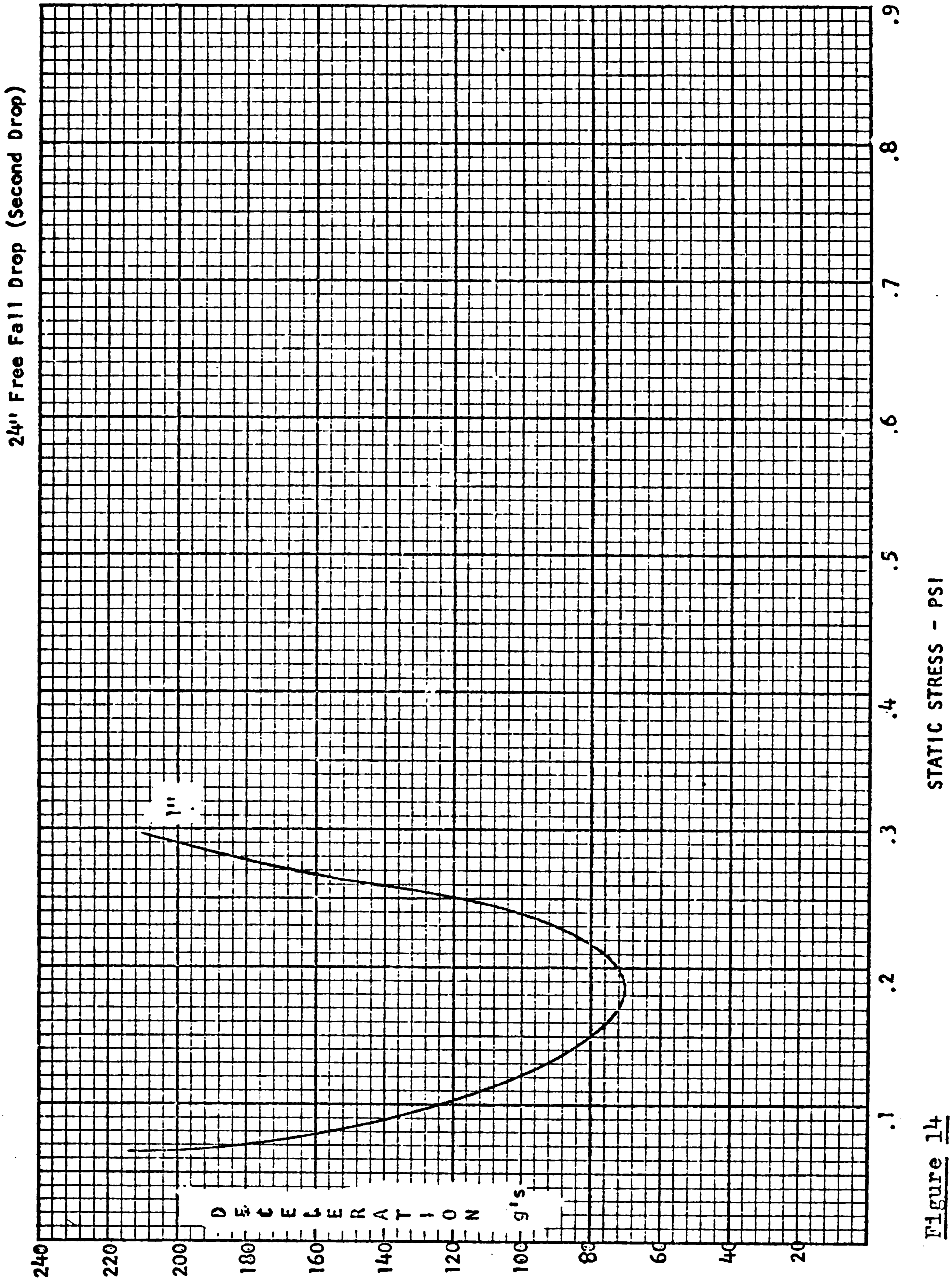


Figure 14

W. Va Pulp & Paper H & D Div. (Sandusky)

AV-A Flute

24" Free Fall Drop (First Drop)

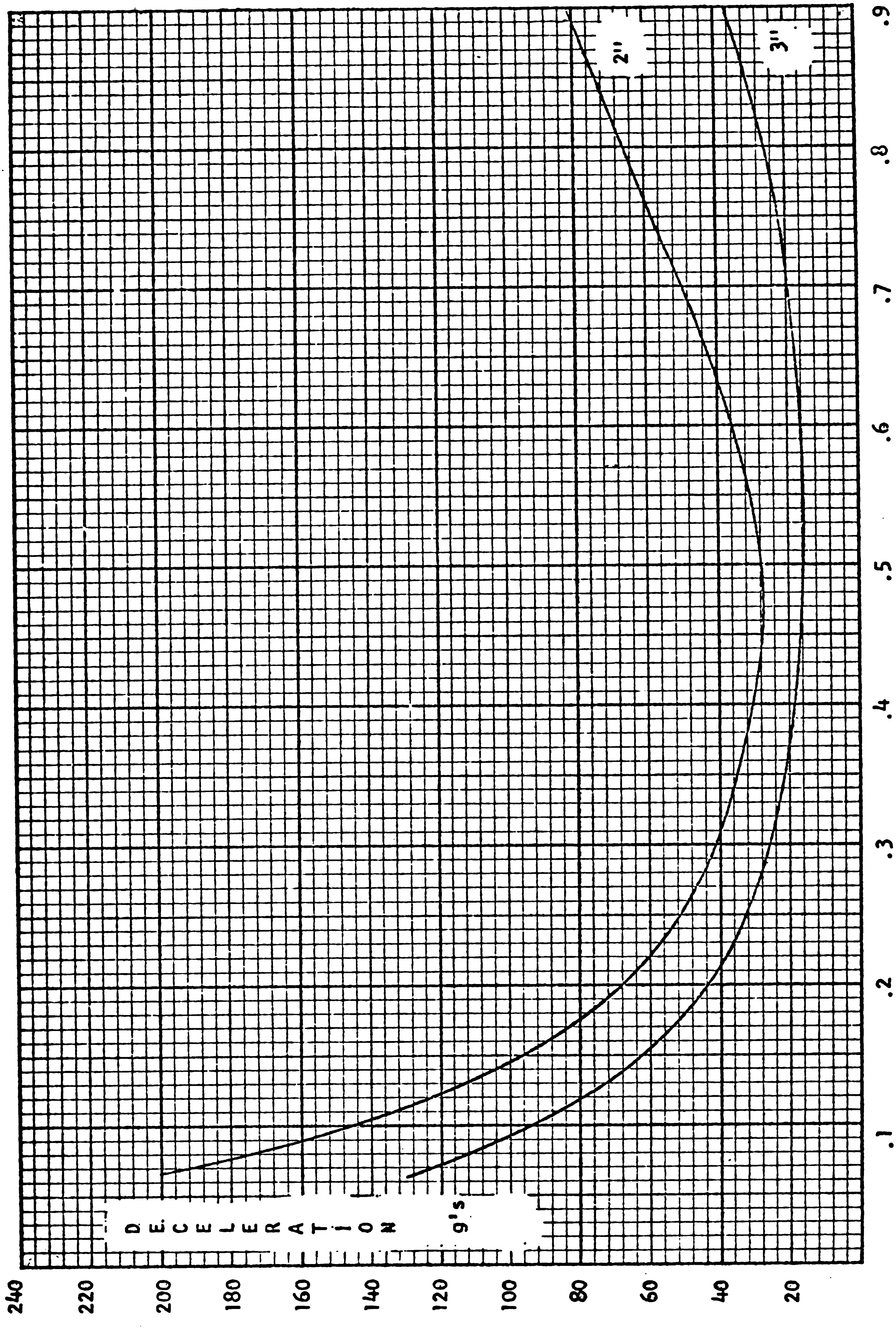


Figure 15

W. Va. Pulp & Paper H & D Div. (Sandusky)

AV-A Flute

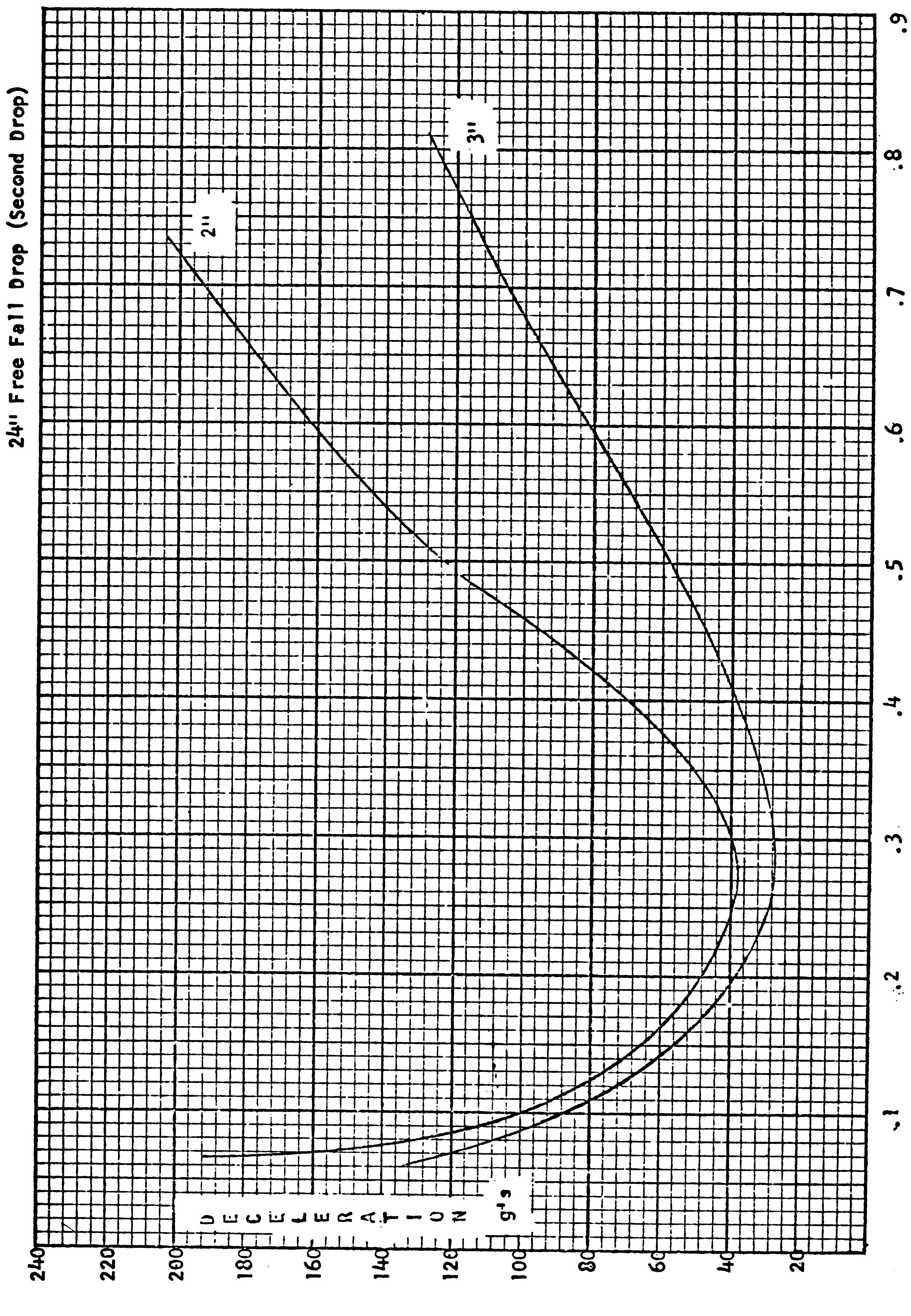


Figure 16

W. Va. Pulp & Paper H & D Div. (Sandusky)

RR-A Flute

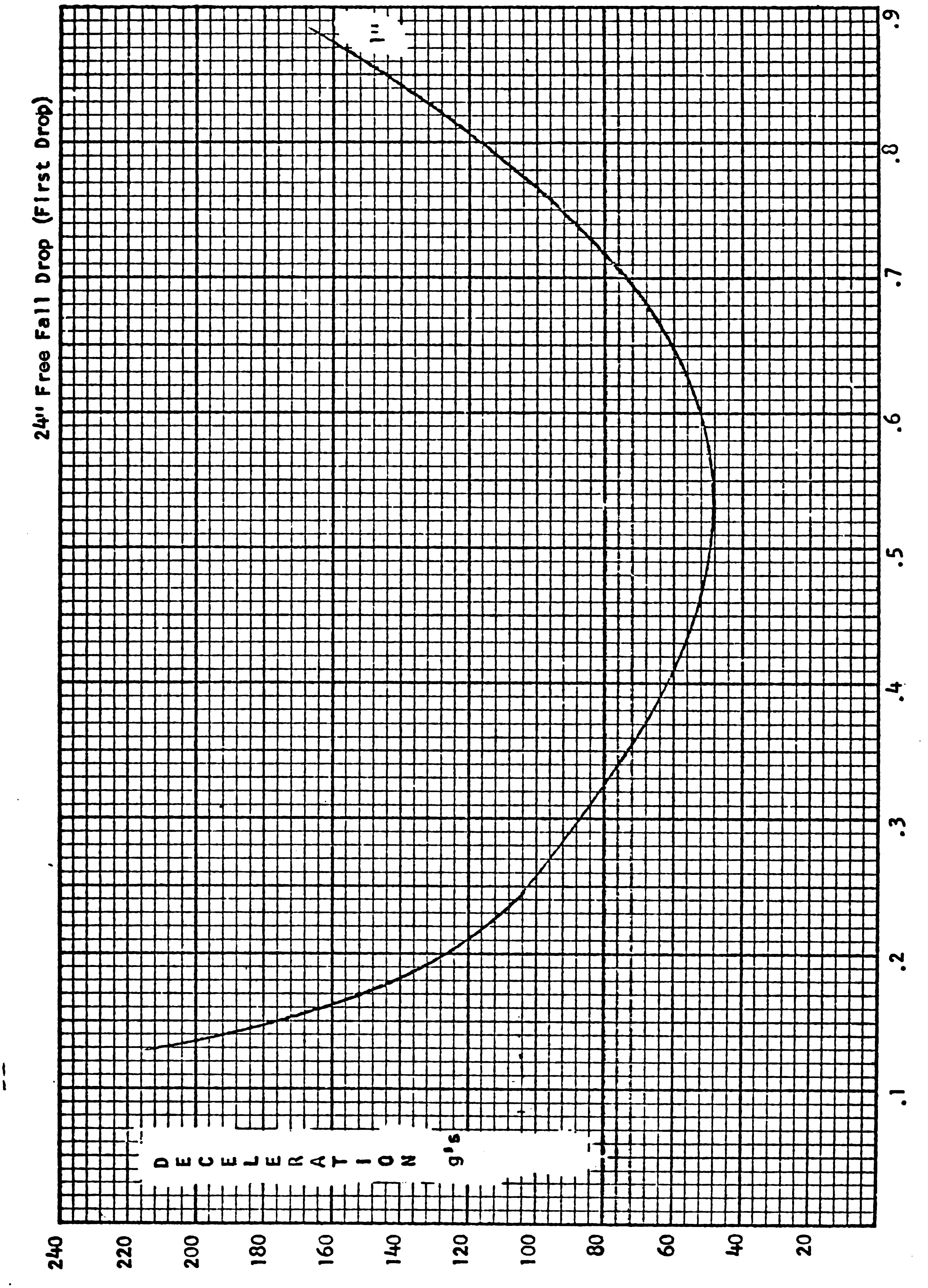


Figure 17

W. Va. Pulp & Paper H & D Div. (Sandusky)

RR-A Flute

24" Free Fall Drop (Second Drop)

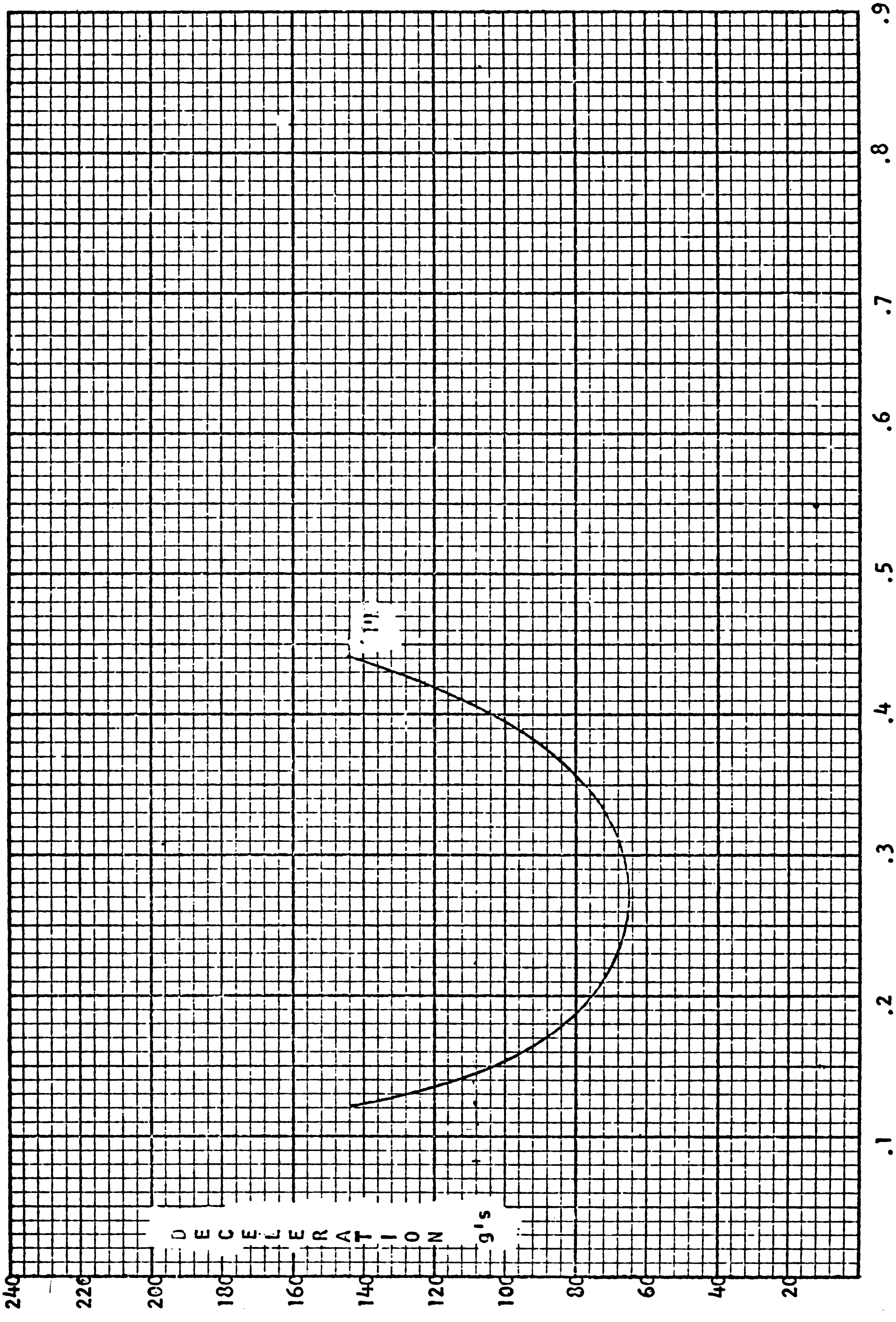


Figure 18

W. Va. Pulp & Paper H & D Div. (Sandusky)

RR-A Flute

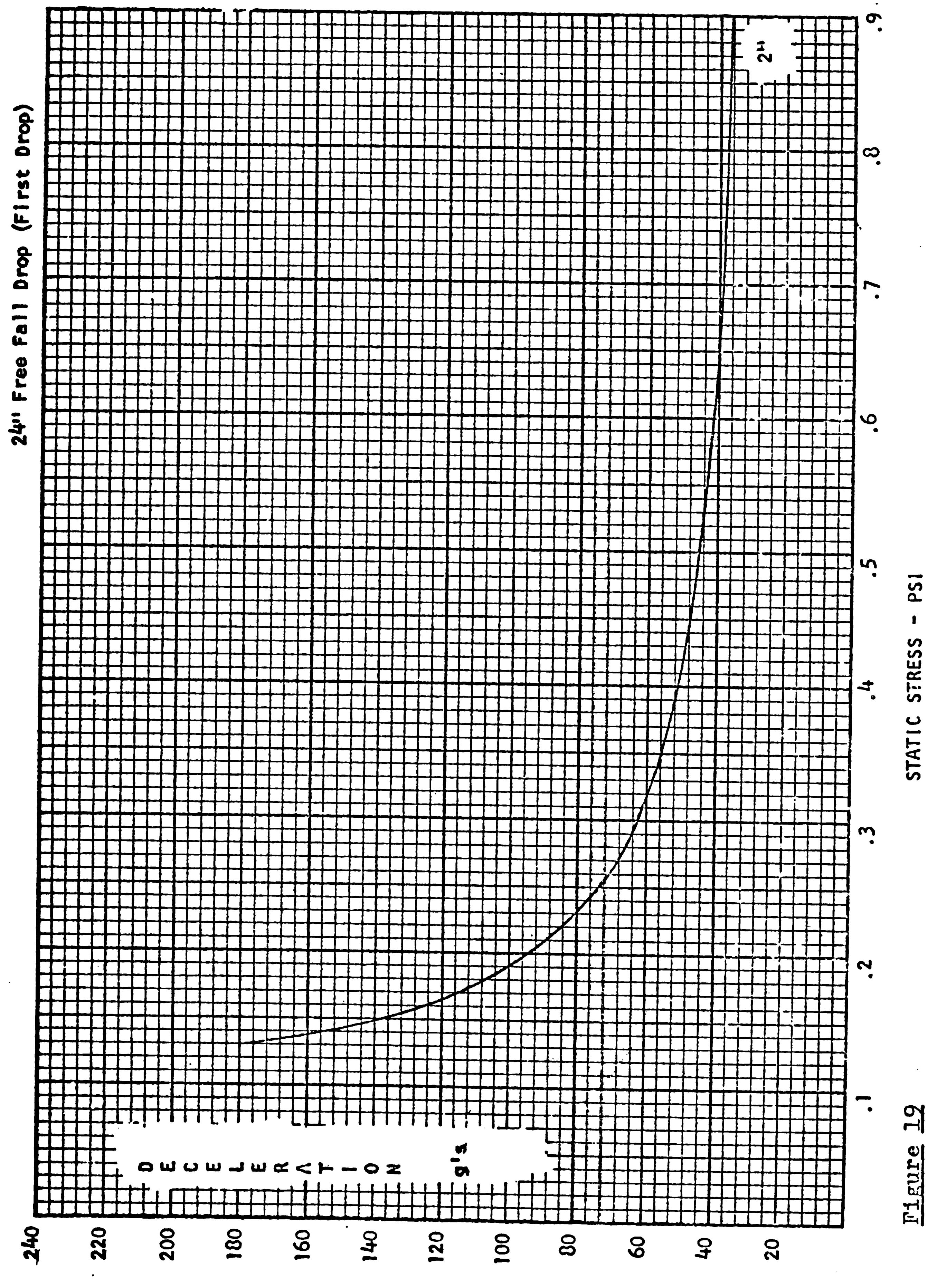


Figure 19

W. Va. Pulp & Paper H & D Div. (Sandusky)

RR-A Flute

24" Free Fall Drop (Second Drop)

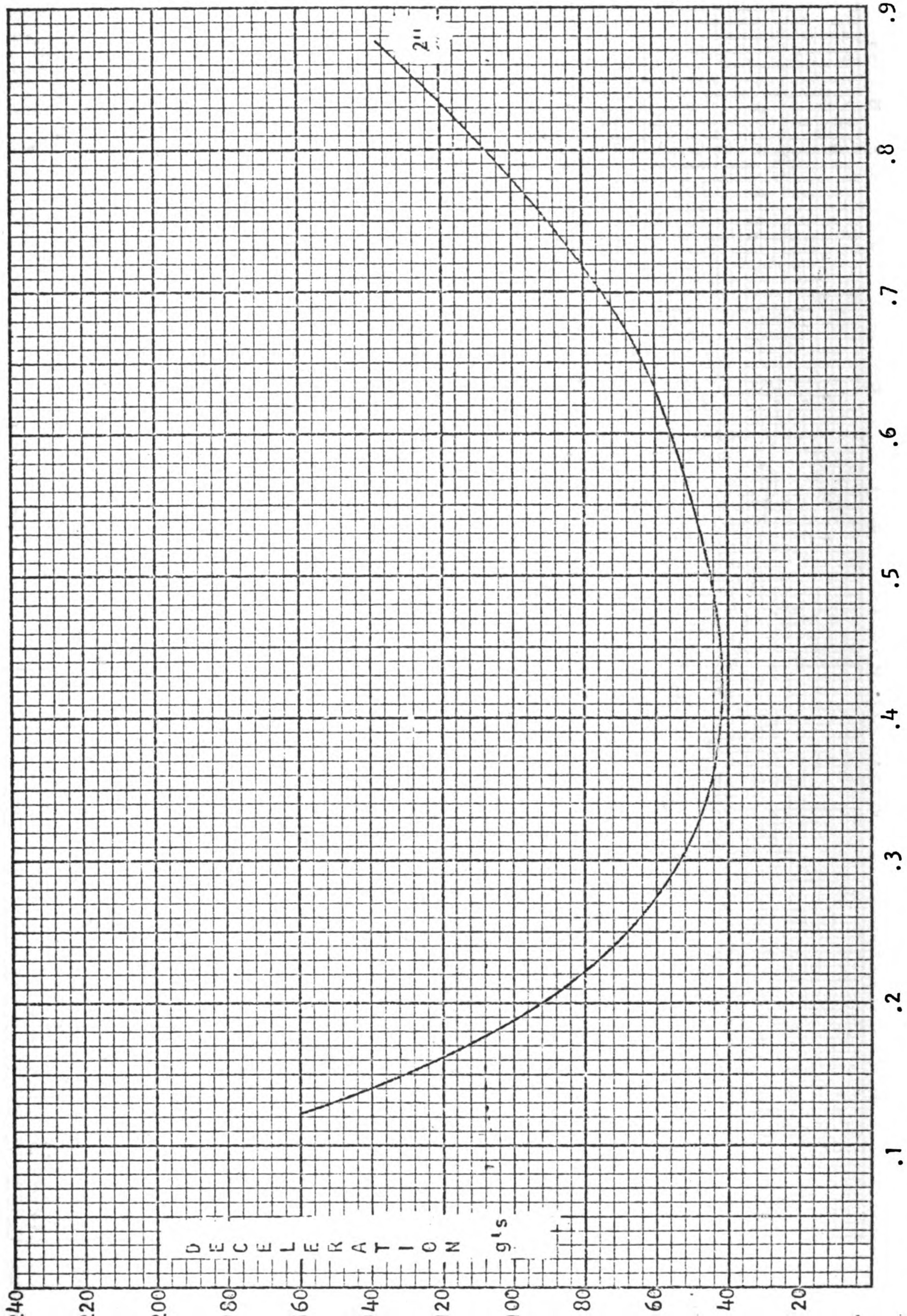


Figure 20

W. Va. Pulp & Paper H & D Div. (Sandusky)

RR-A Fulte

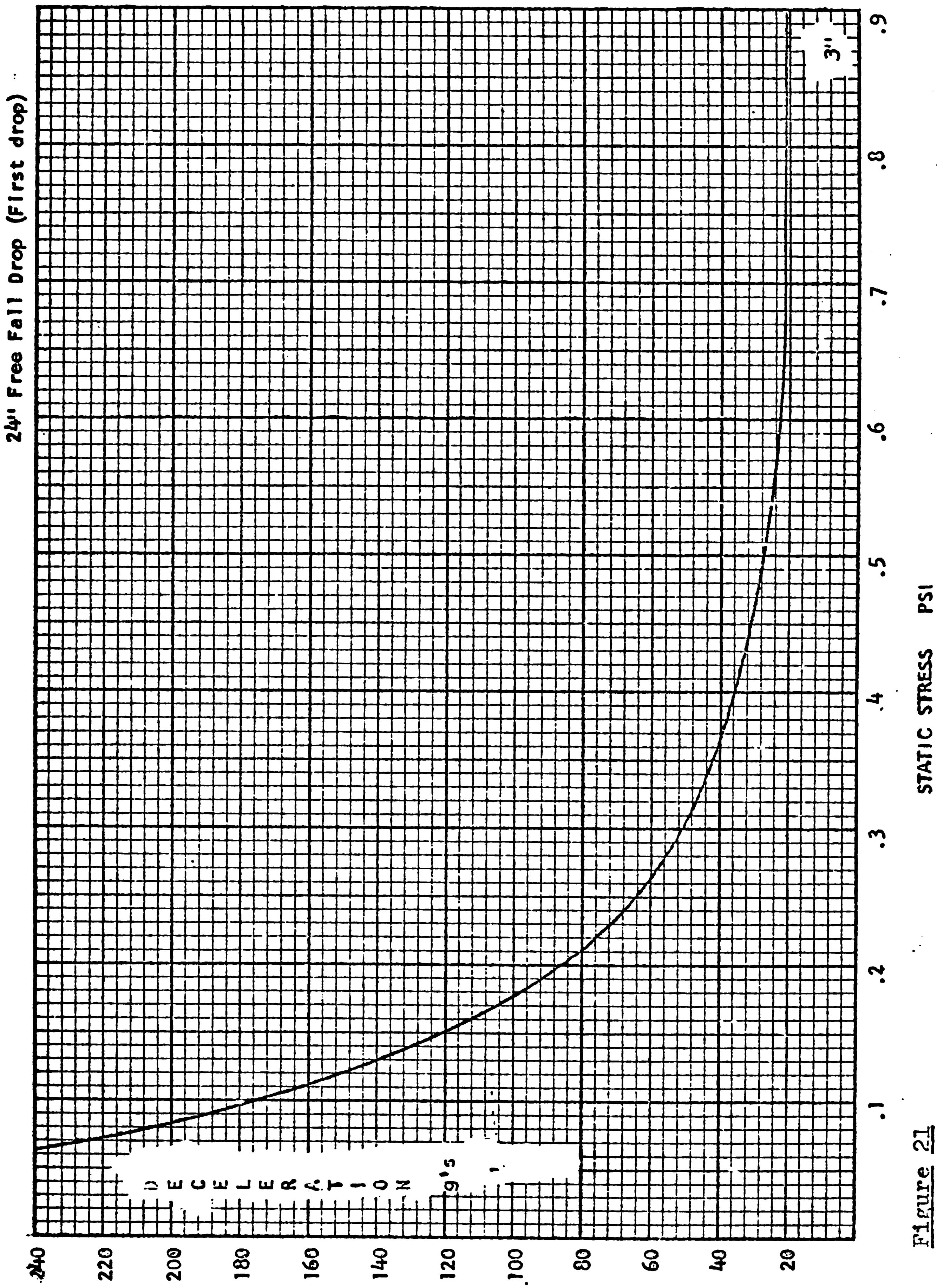


Figure 21

W. Va. Pulp & Paper H & D Div. (Sandusky)

RR-A Flute

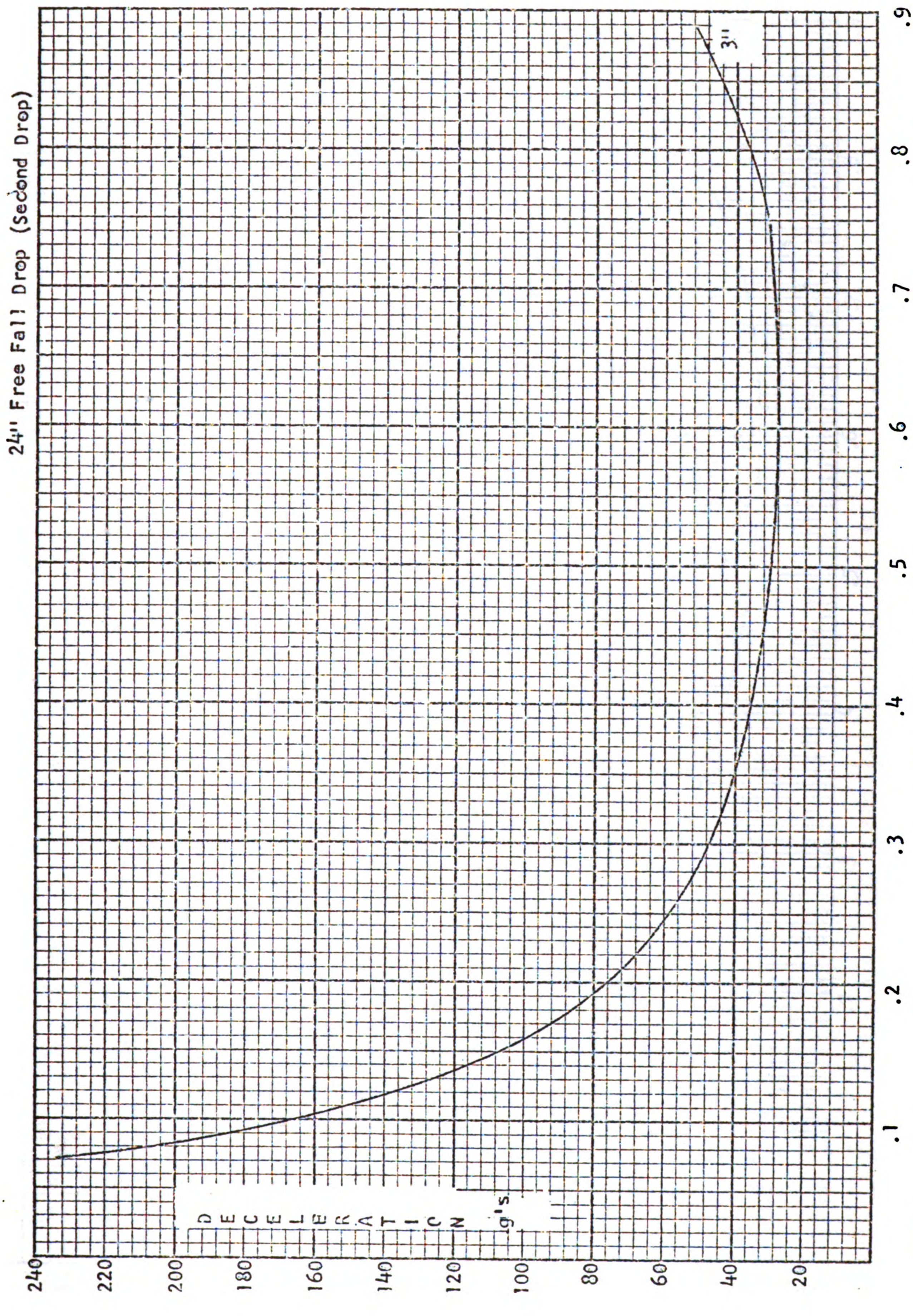


Figure 22

W. Va. Pulp & Paper H & D Div. (Sandusky)

FR-Q Flute

24" Free Fall Drop (first drop)

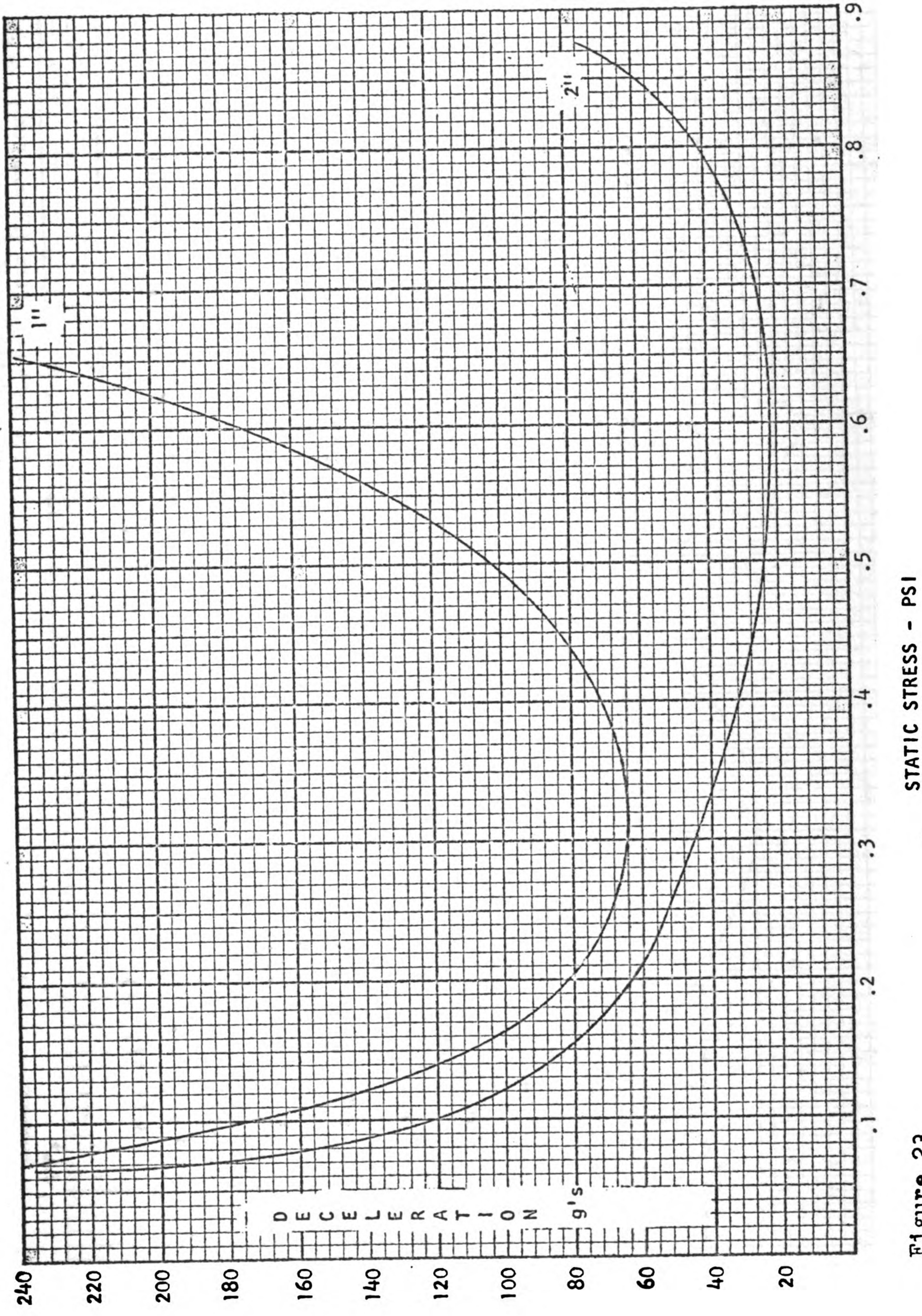


Figure 23

W. Va. Pulp & Paper H & D Div. (Sandusky)

FR-Q Flute

24' Free Fall Drop (Second Drop)

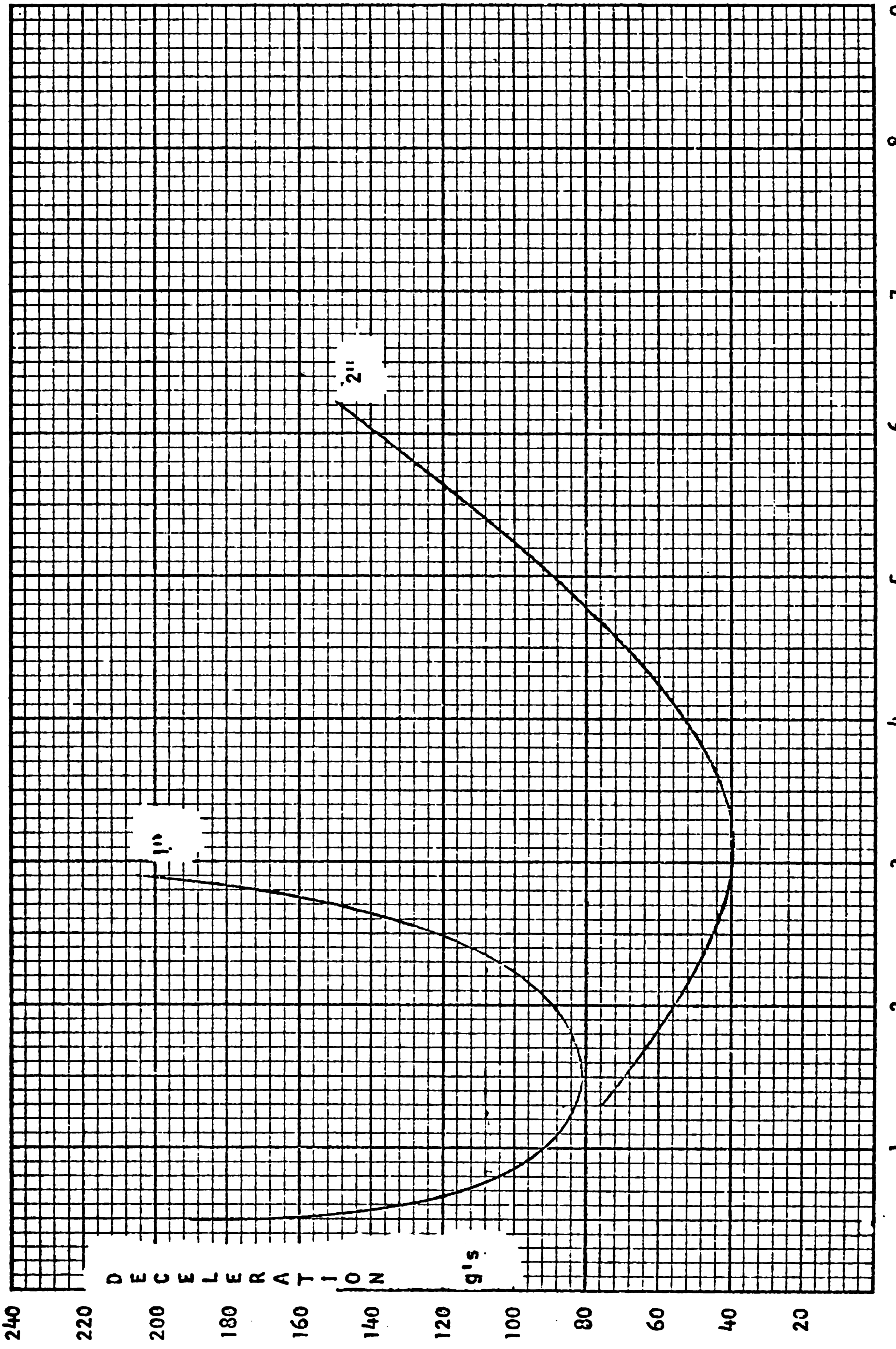


Figure 24

W. Va. Pulp & Paper H & D Div. (Sandusky)

FR-Q Flute

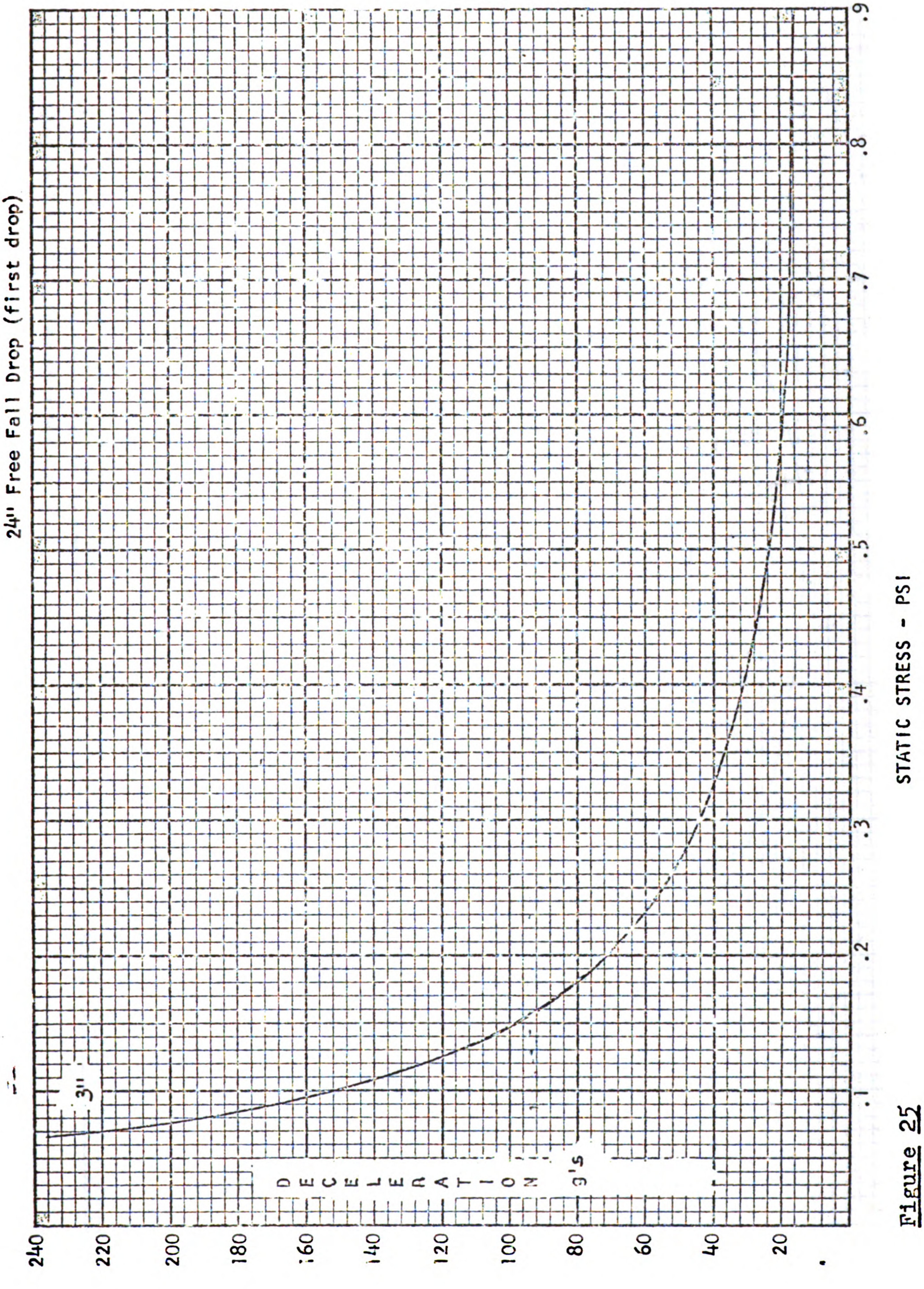


Figure 25

W. Va. Pulp & Paper H & D Div. (Sandusky)

FR-Q Flute

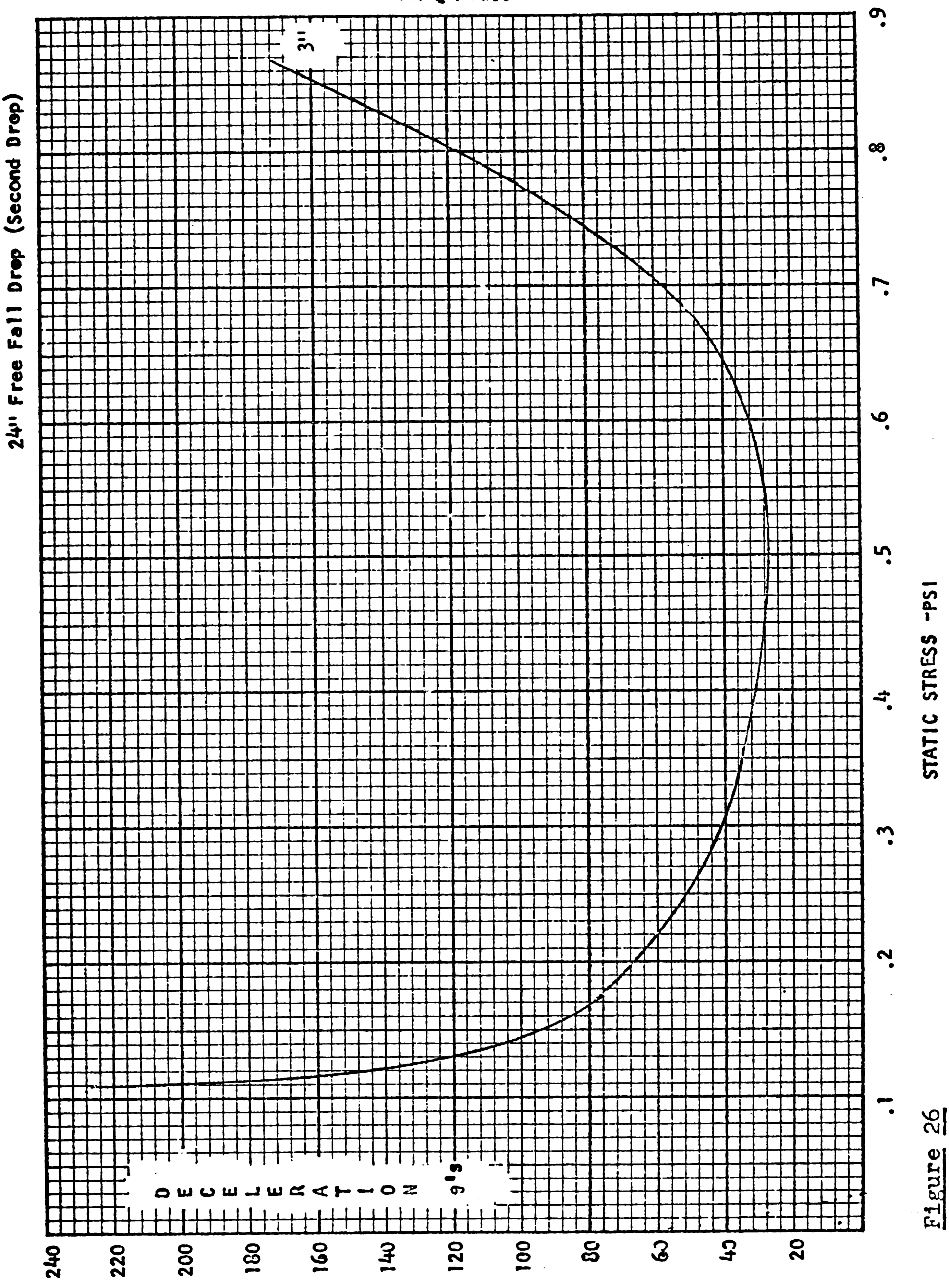


Figure 26

AR-Q Flute

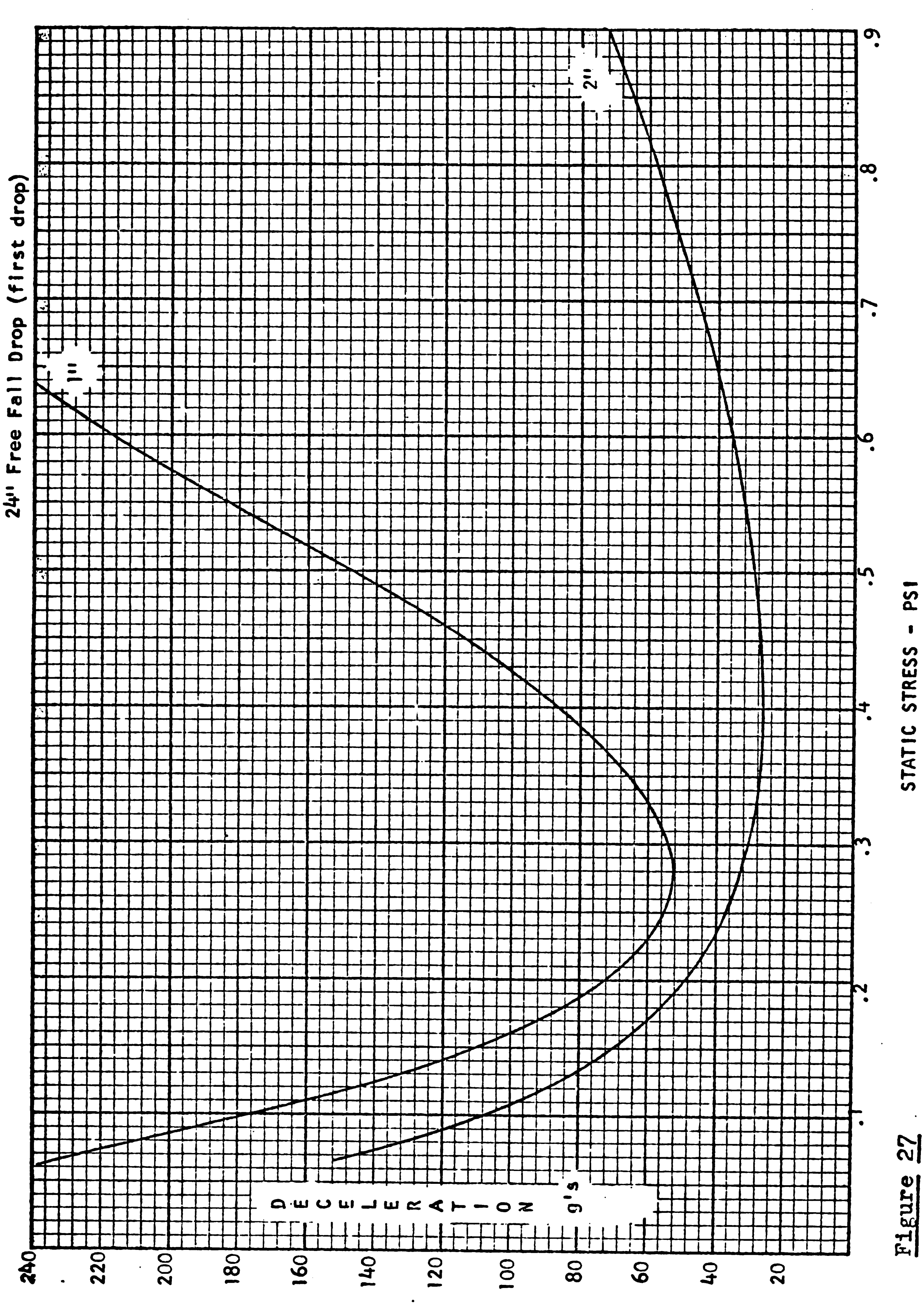


Figure 27

W. Va. Pulp & Paper H & D Div. (Sandusky)
AR-Q Flute

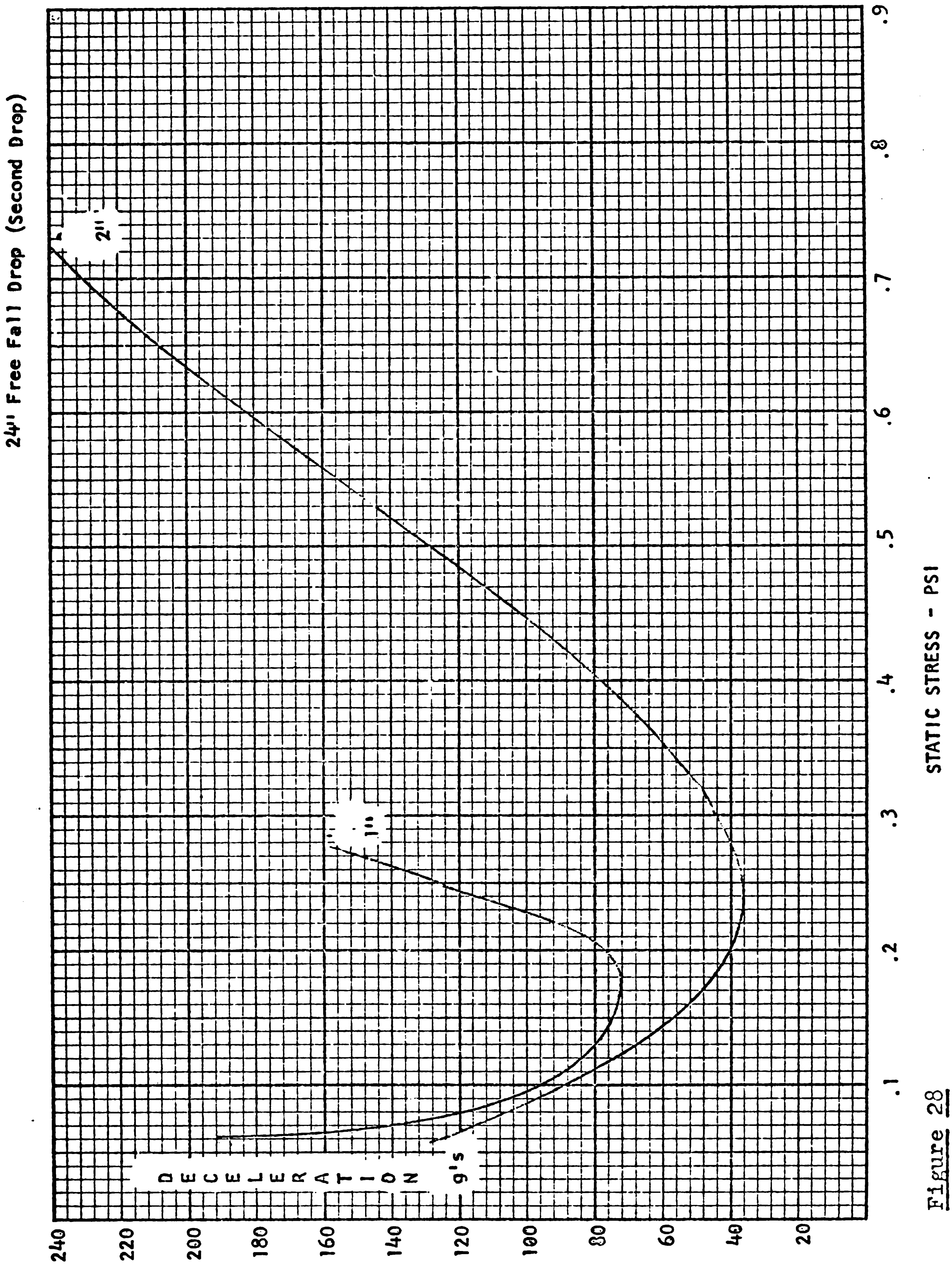


Figure 28

W. Va. Pulp & Paper H & D Div. (Sandusky)

AR-Q Flute

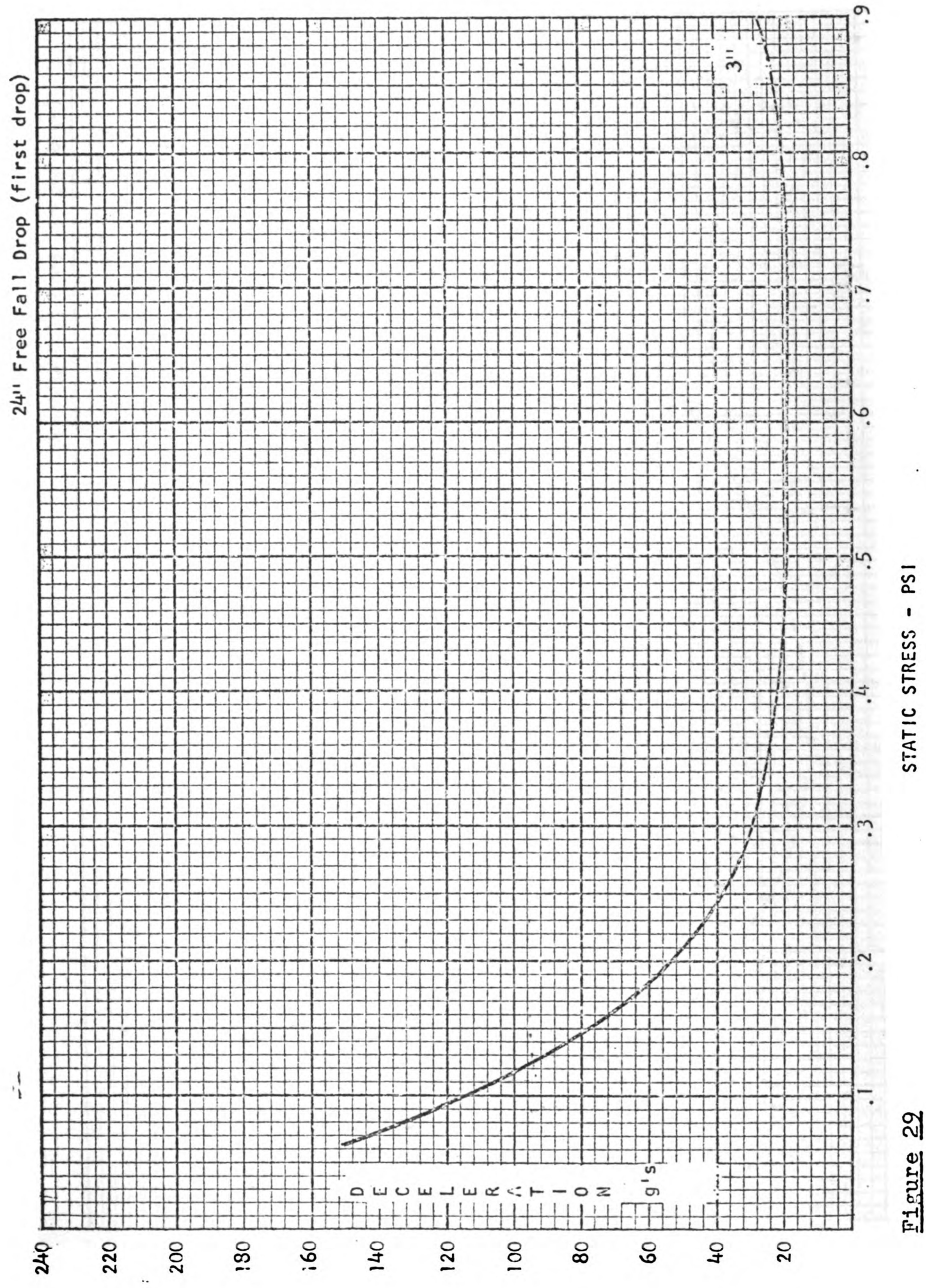


Figure 29

W. Va. Pulp & Paper H & D Div. (Sandusky)

AR-Q Flute

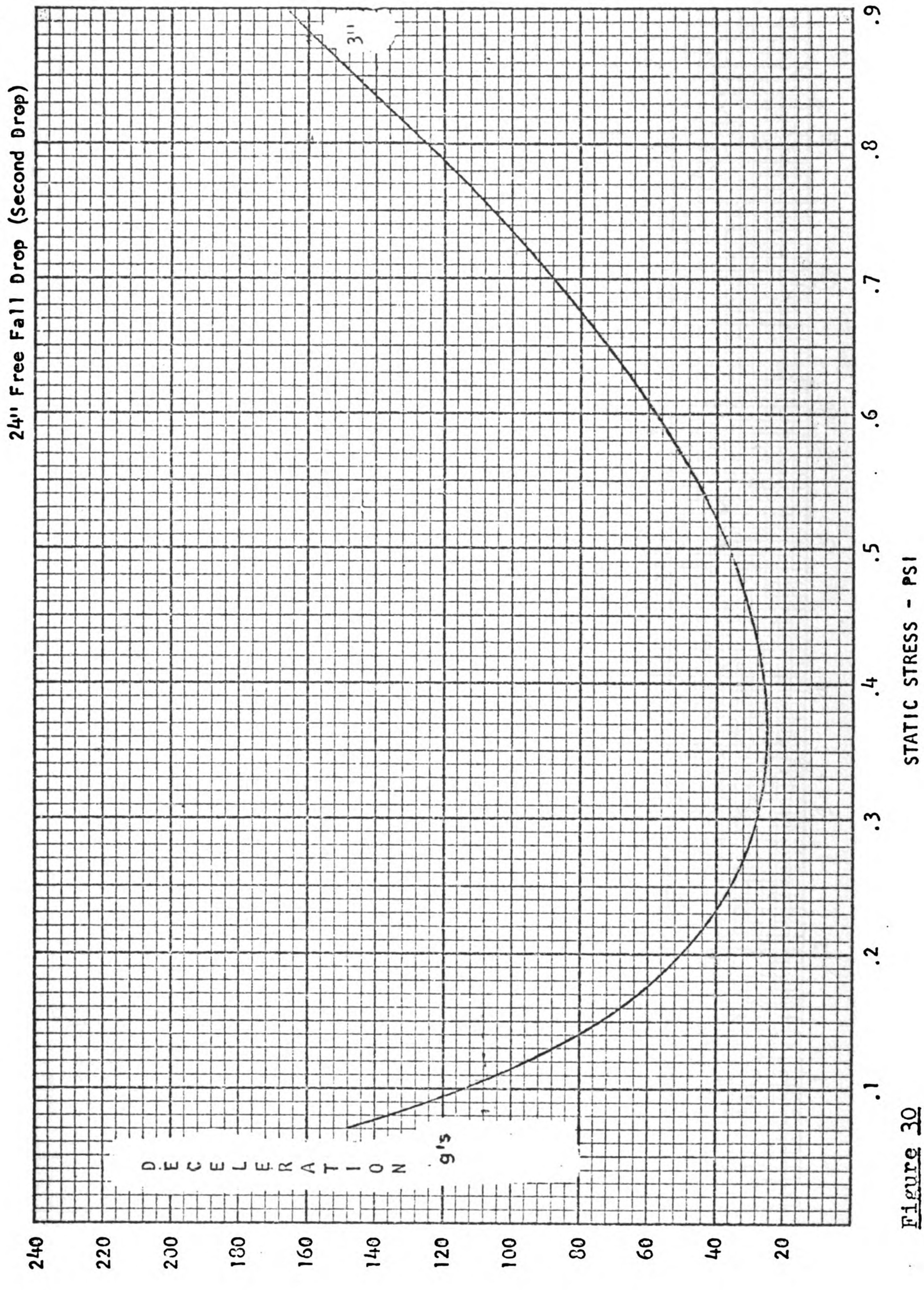


Figure 30

W. Va. Pulp & Paper H & D Div. (Sandusky)

AR-A Flute

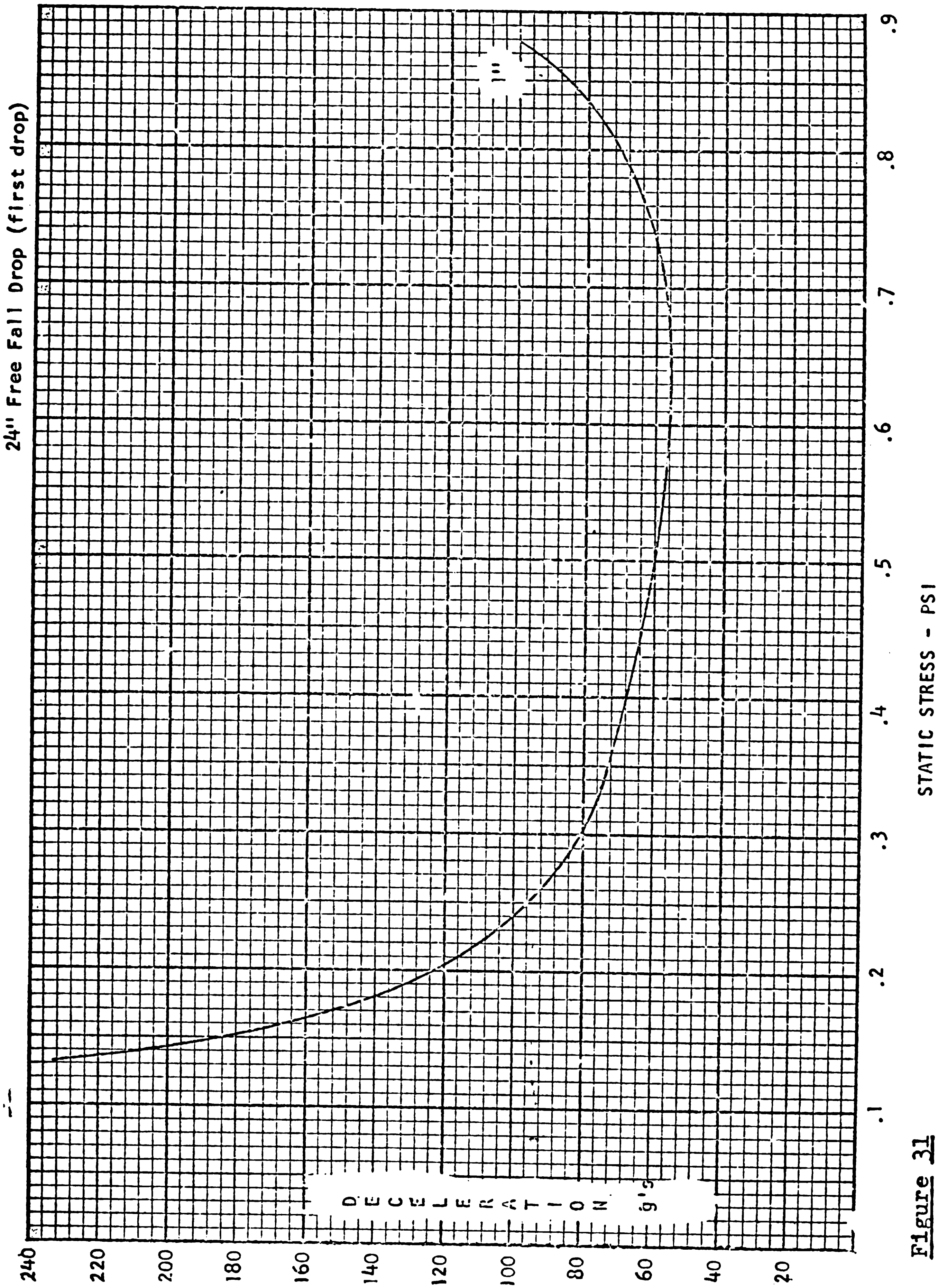


Figure 31

W. Va. Pulp & Paper H & D Div. (Sandusky)
AR-A Flute

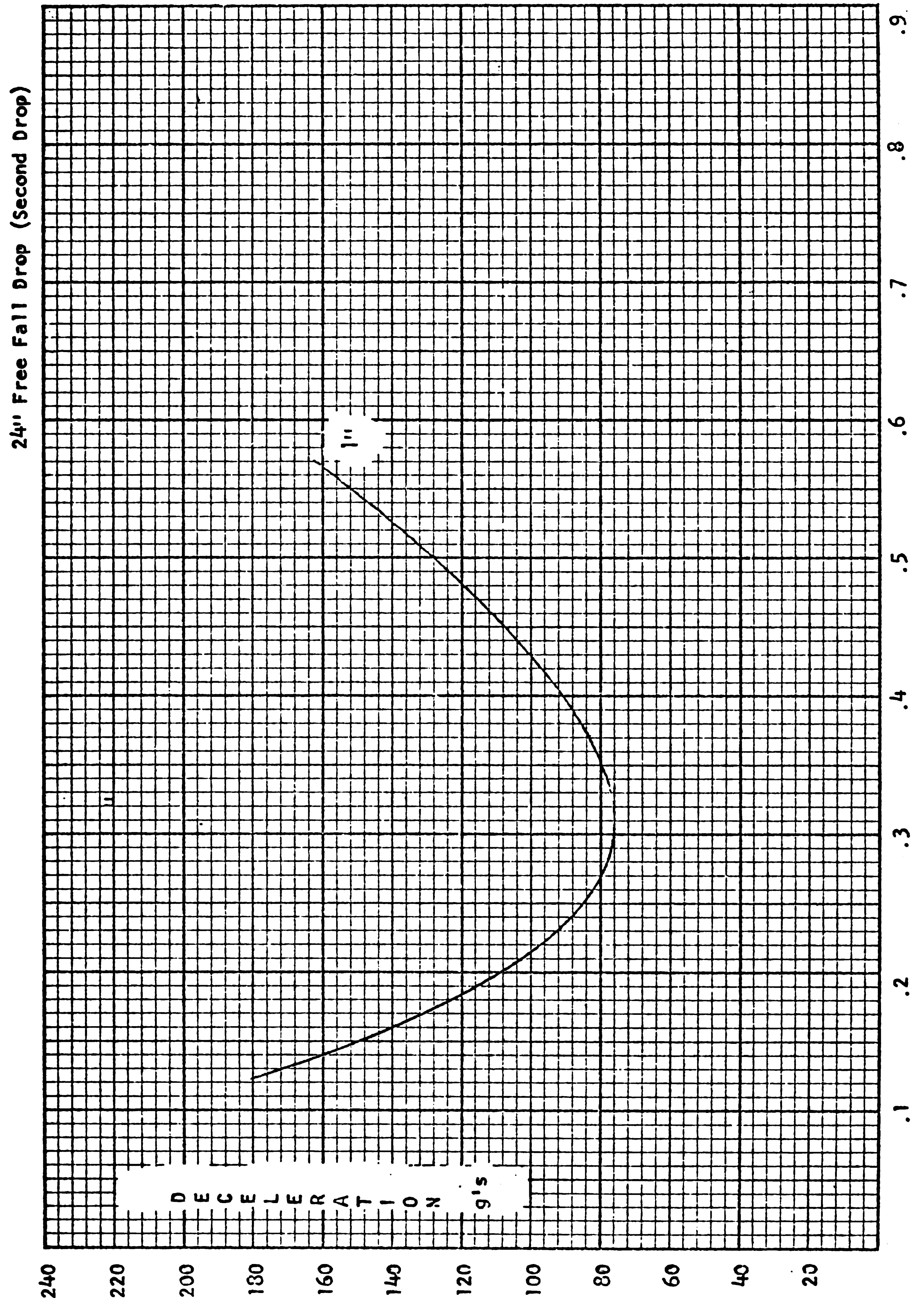


Figure 32

W. Va. Pulp & Paper H & D Div. (Sandusky)

AR-A Flute

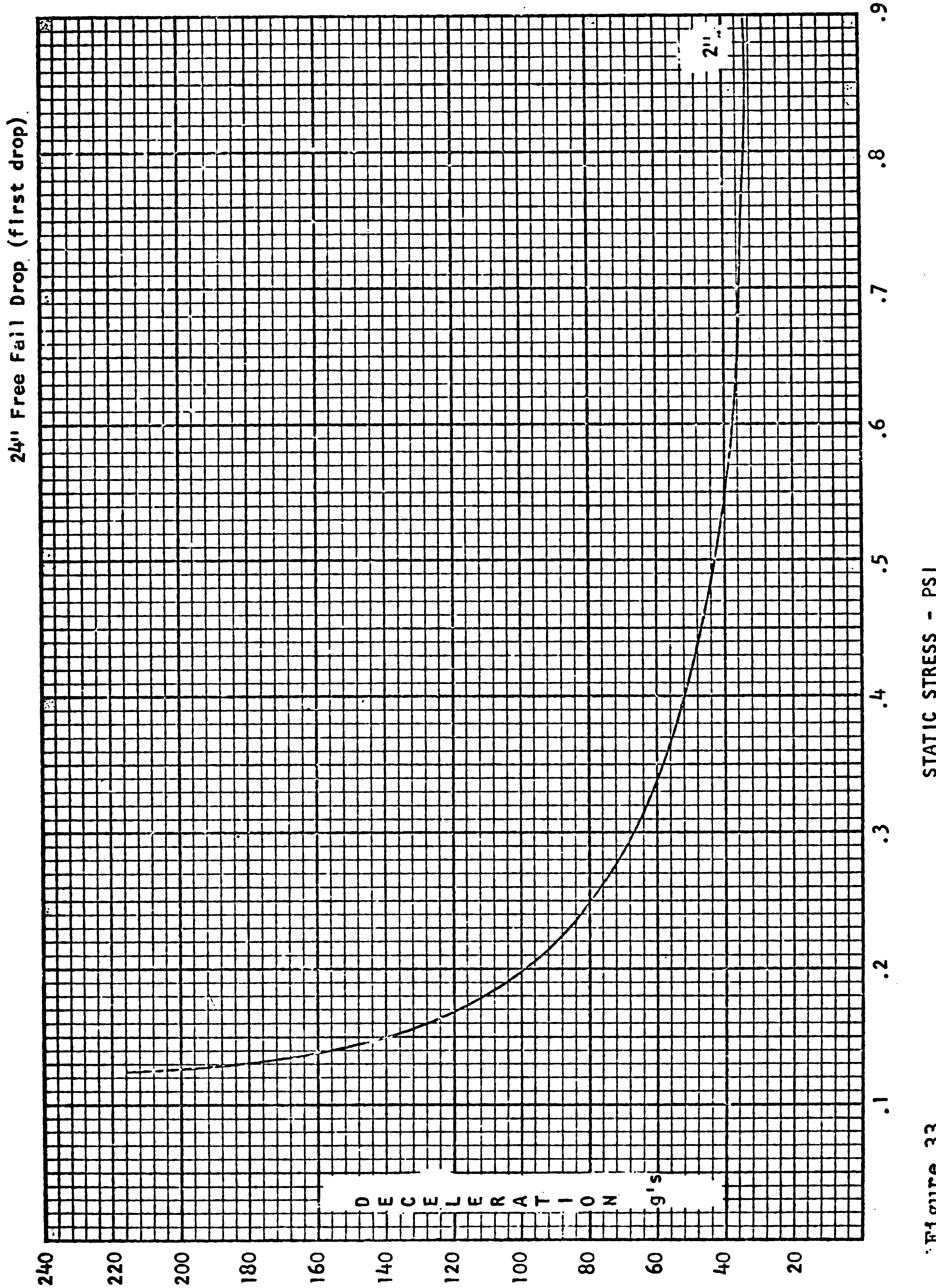


Figure 33

W. Va. Pulp & Paper H & D Div. (Sandusky)

AR-A Flute

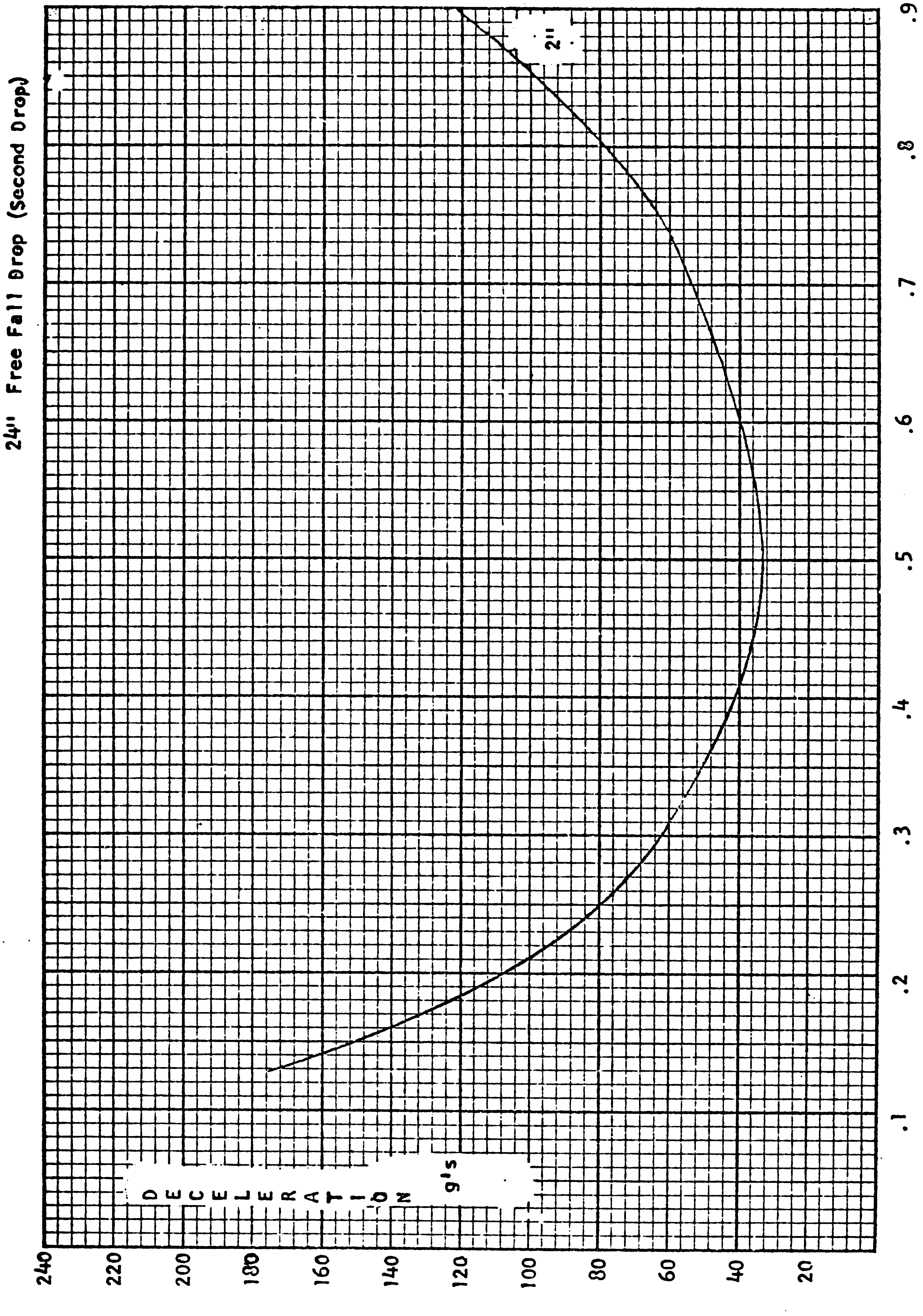


Figure 34

W. Va. Pulp & Paper H & D Div. (Sandusky)

AR-A Flute

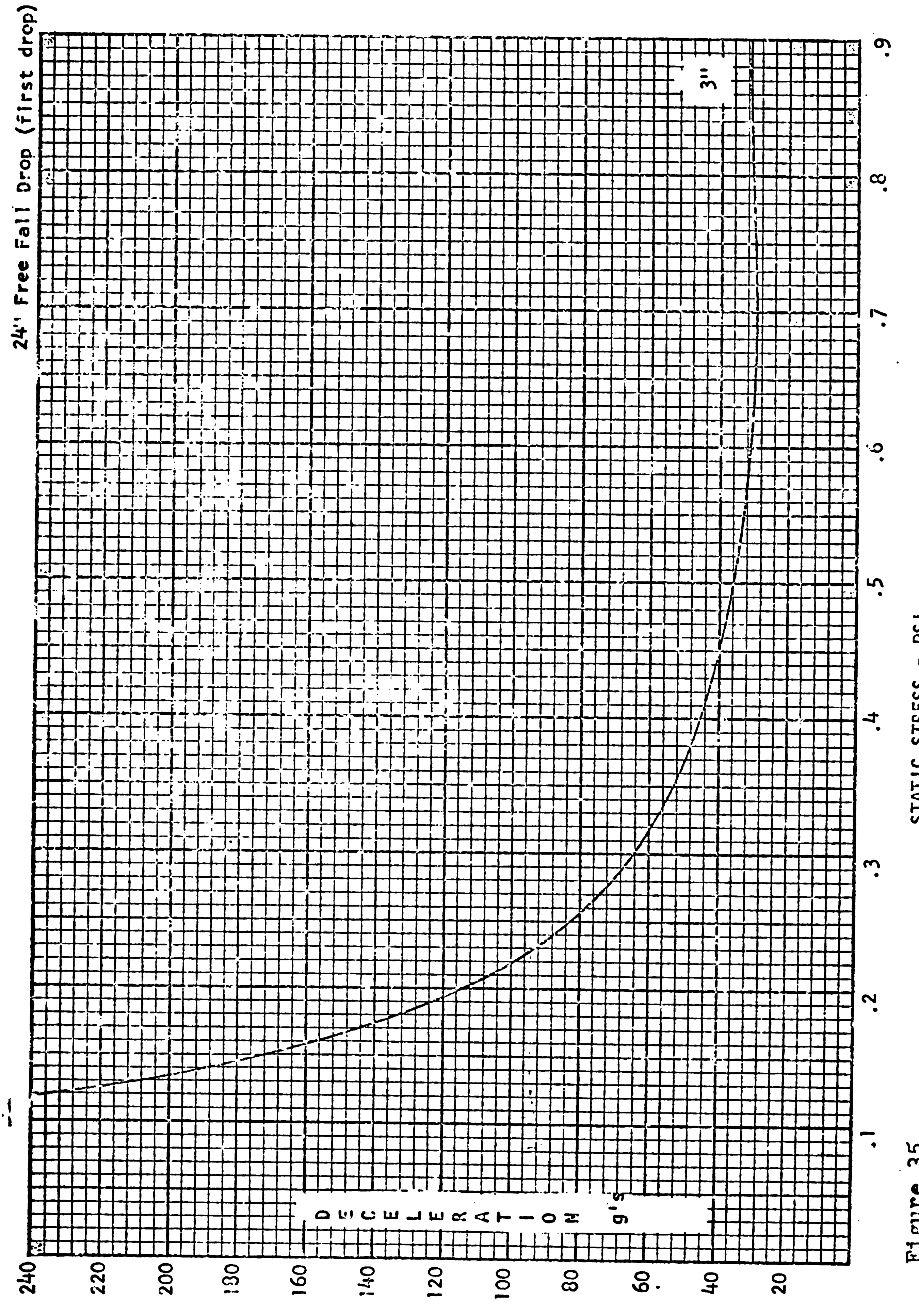


Figure 35

W. Va. Pulp & Paper H & D Div. (Sandusky)
AR-A Flute

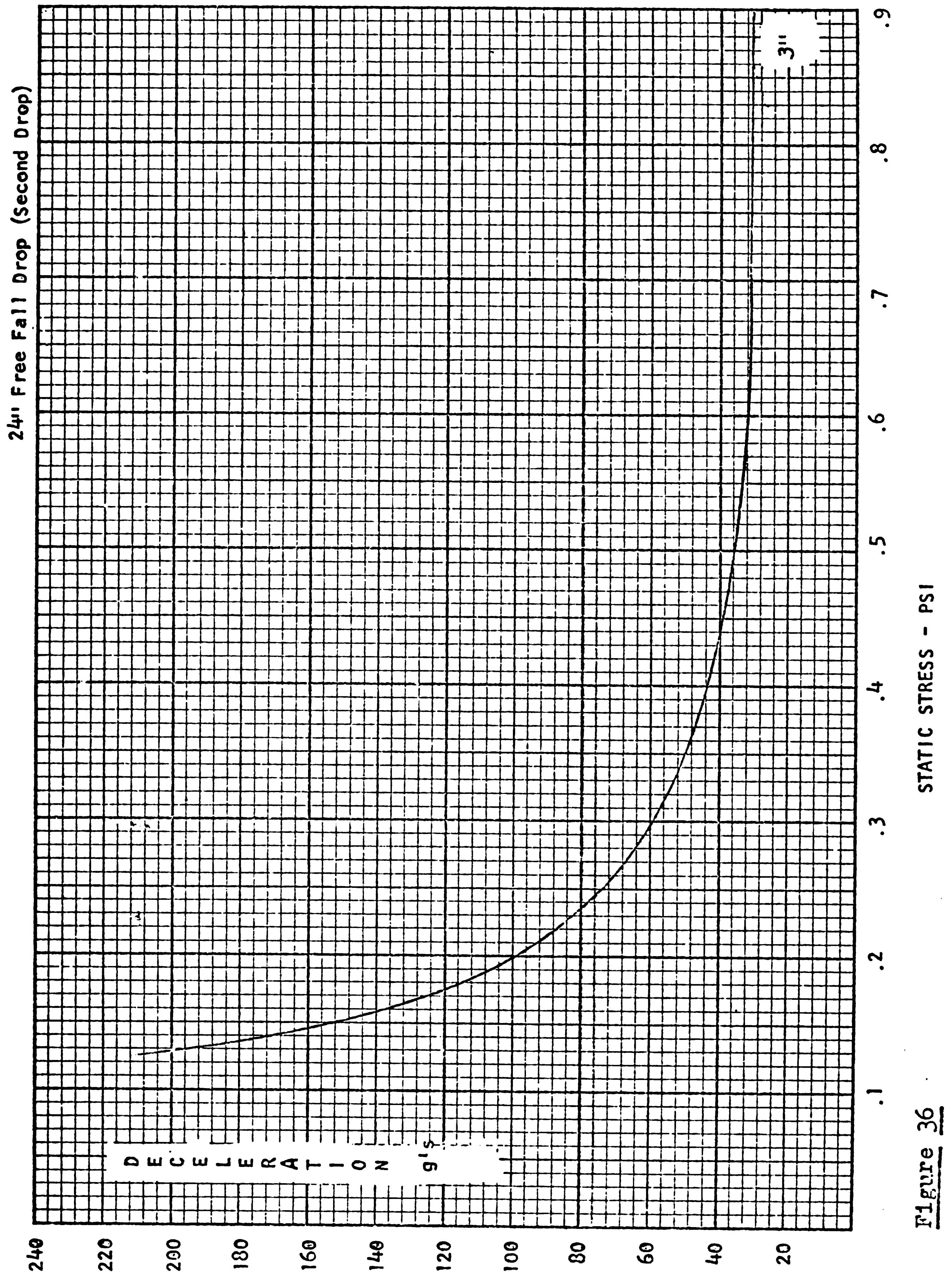
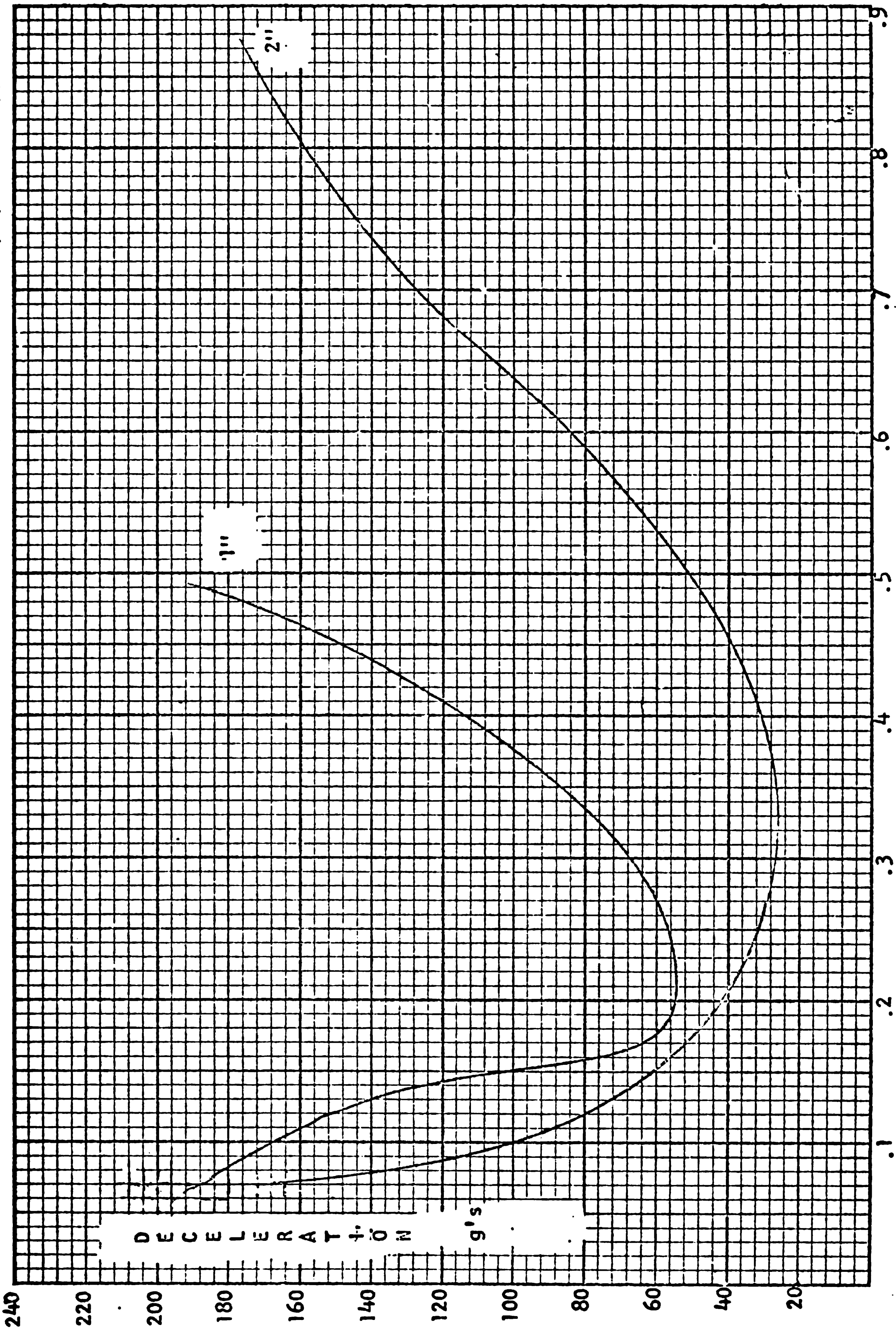


Figure 36

ZZ-A Flute

24" Free Fall Drop (First Drop)



STATIC STRESS - PSI

Figure 37

W. Va. Pulp & Paper H·& D Div. (Sandusky)

ZZ-A Flute

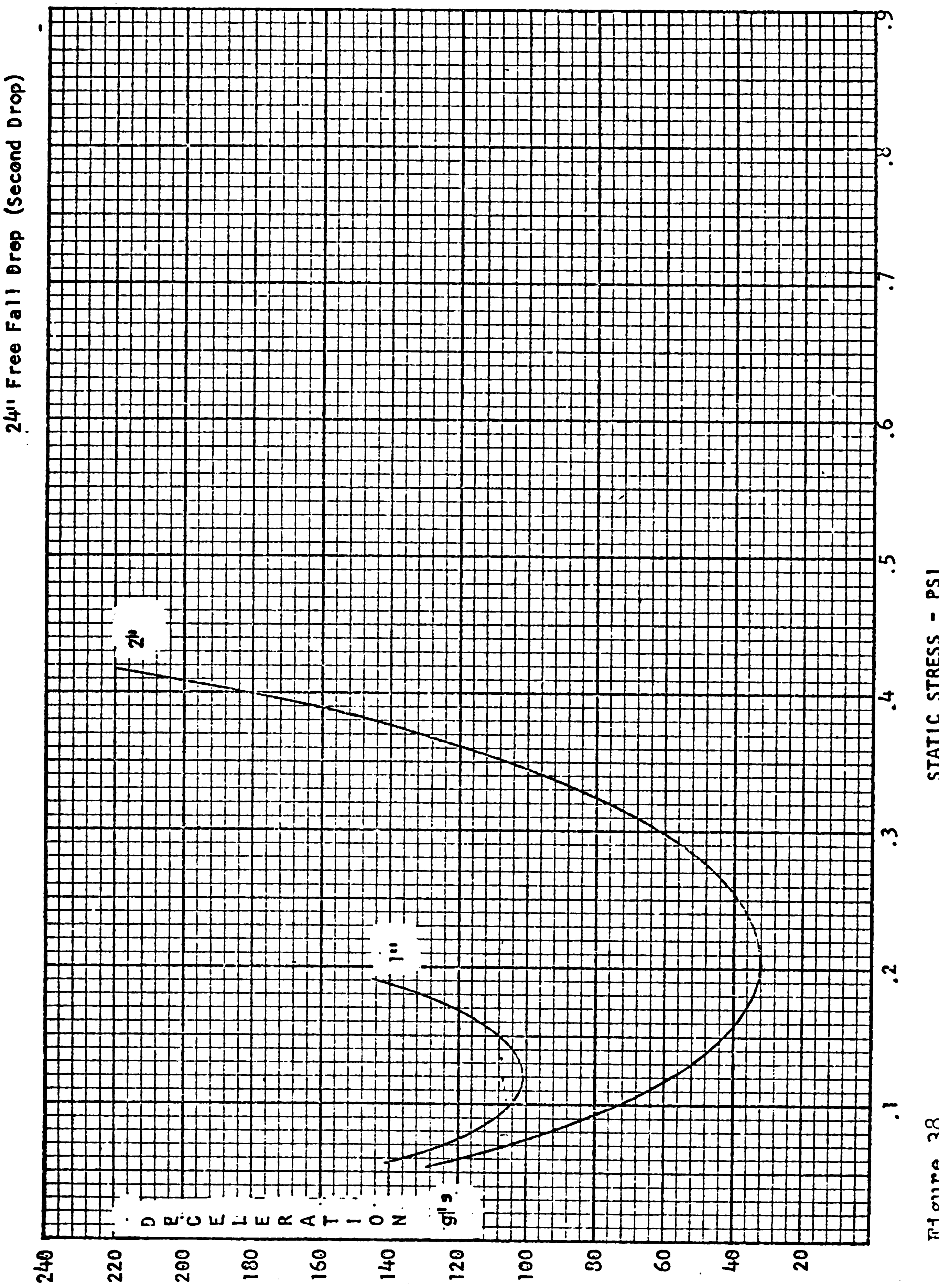


Figure 38

W. Va. Pulp & Paper H & D Div. (Sandusky)

ZZ-A Flute

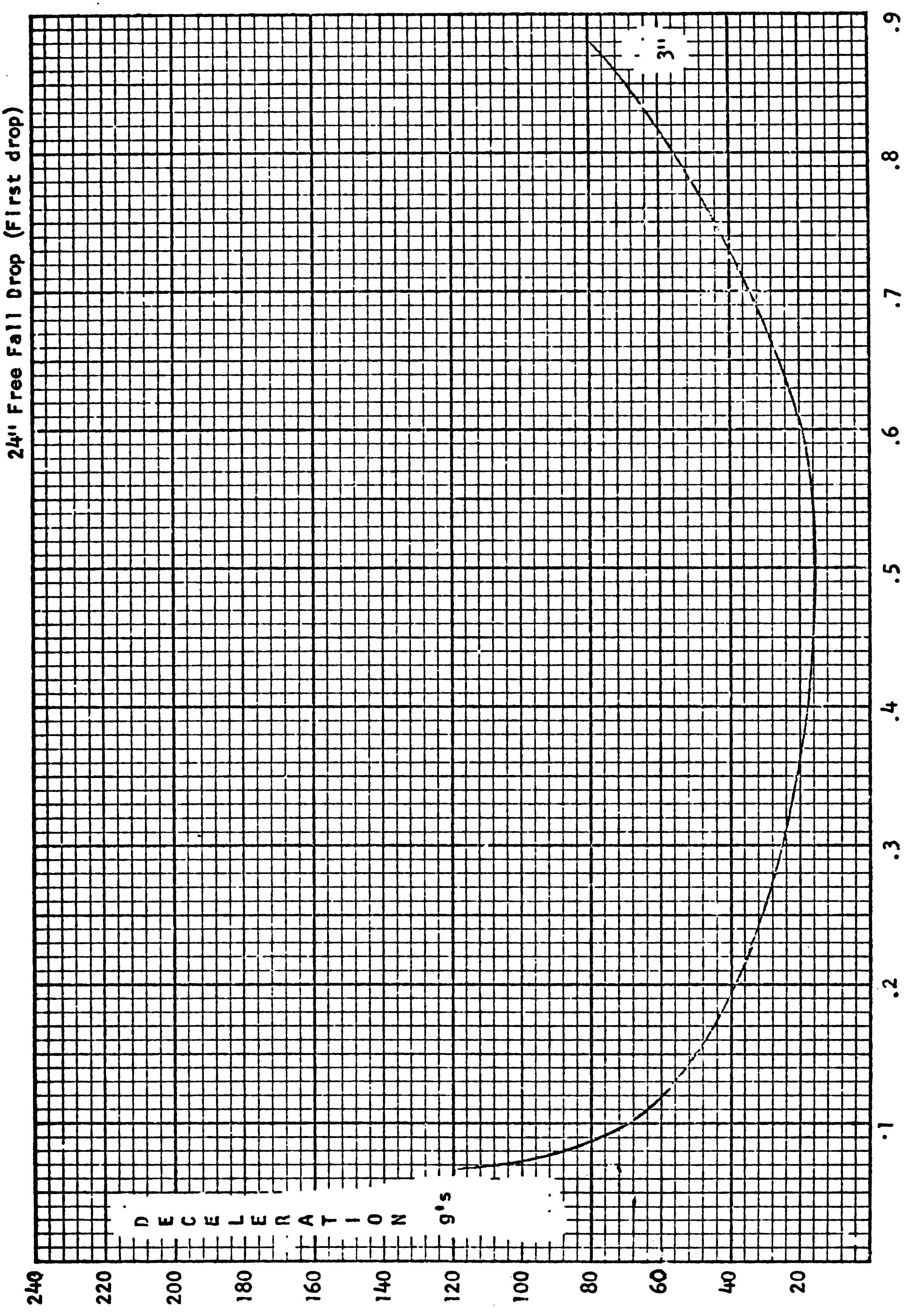


Figure 39

W. Va. Pulp & Paper H & D Div. (Sandusky)
ZZ-A Flute

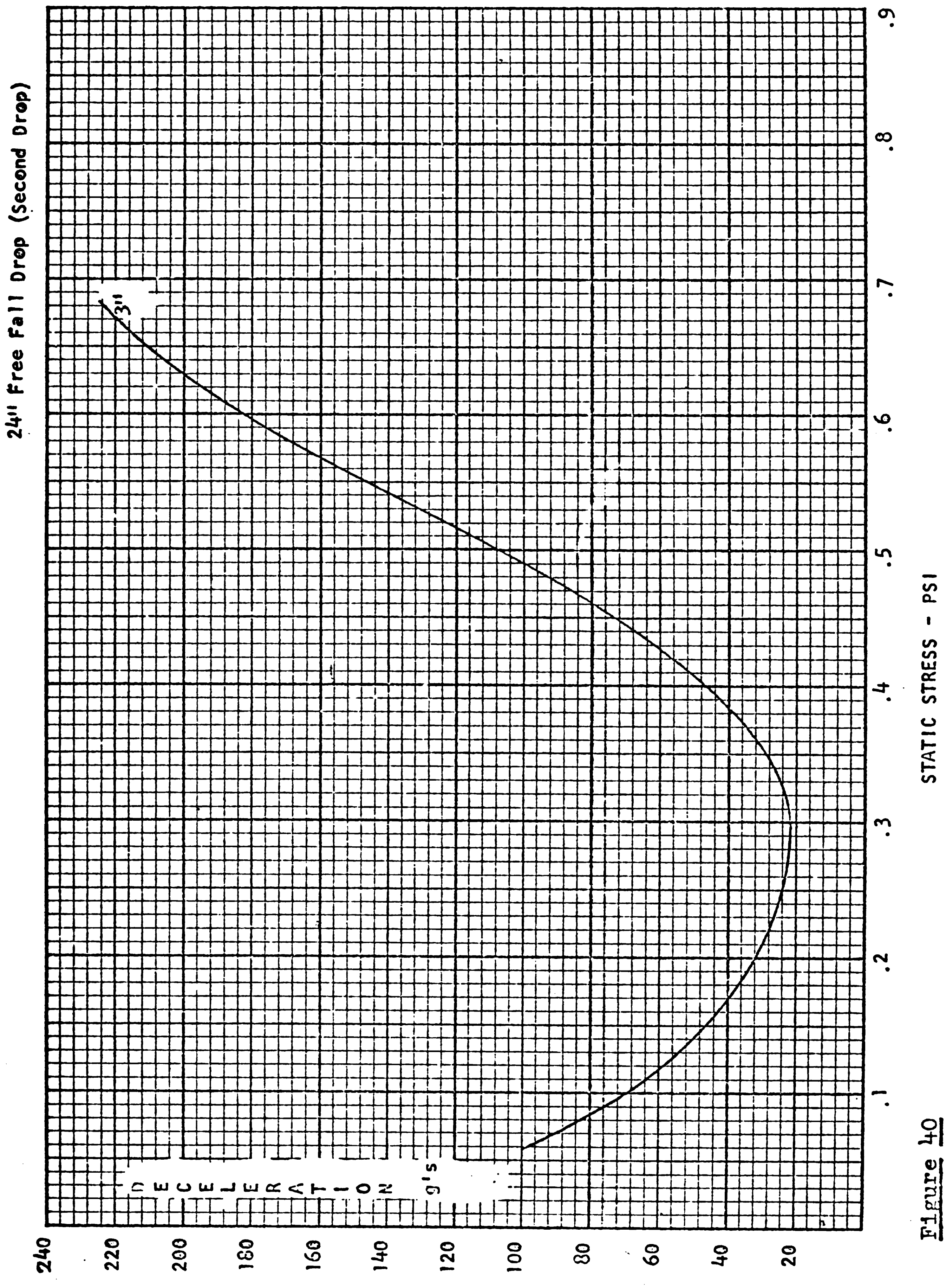


Figure 40

W. Va. Pulp & Paper H & D Div. (Sandusky)

AS-A Flute

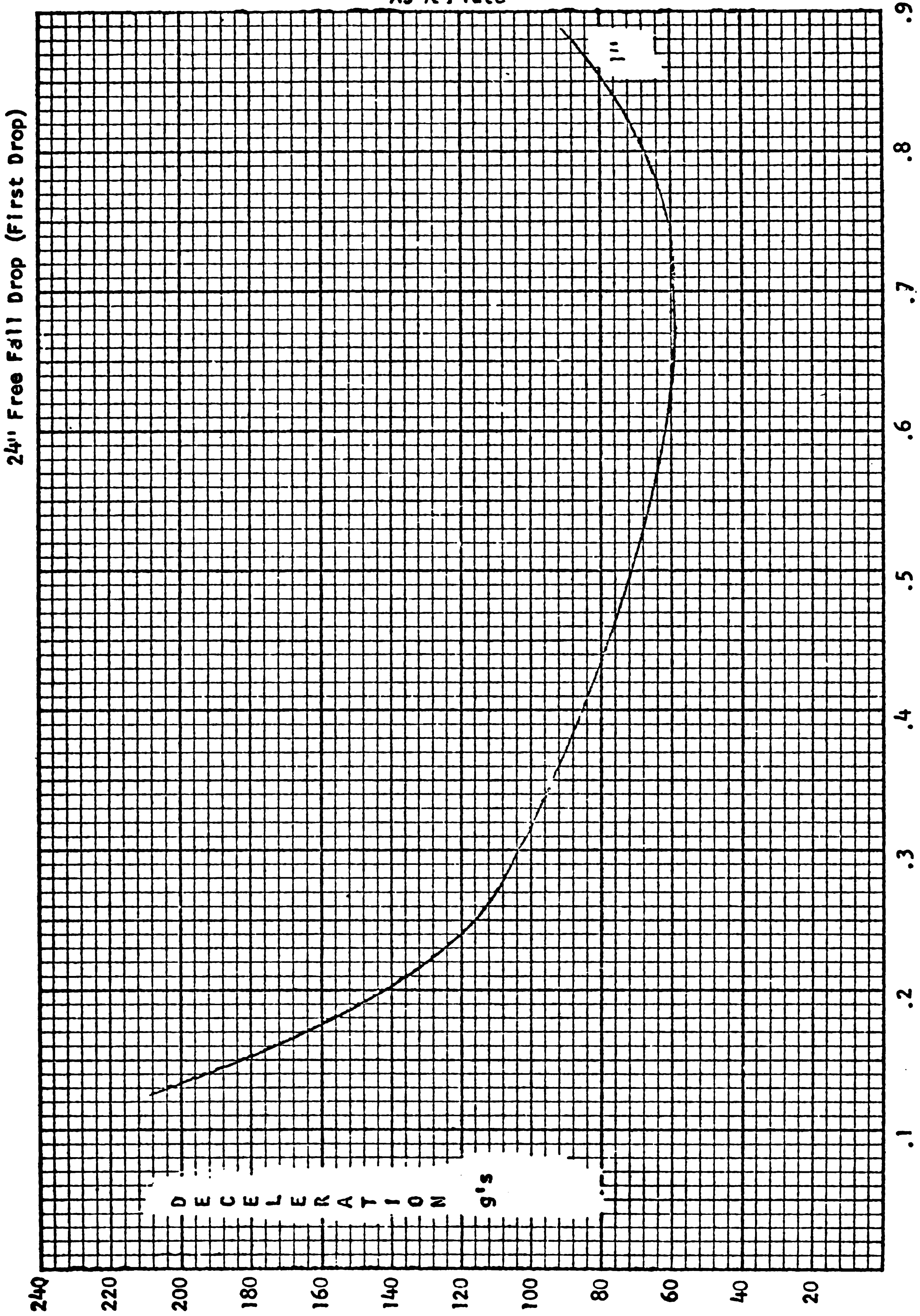


Figure 41

W. Va. Pulp & Paper H & D Div. (Sandusky)

AS-A Flute

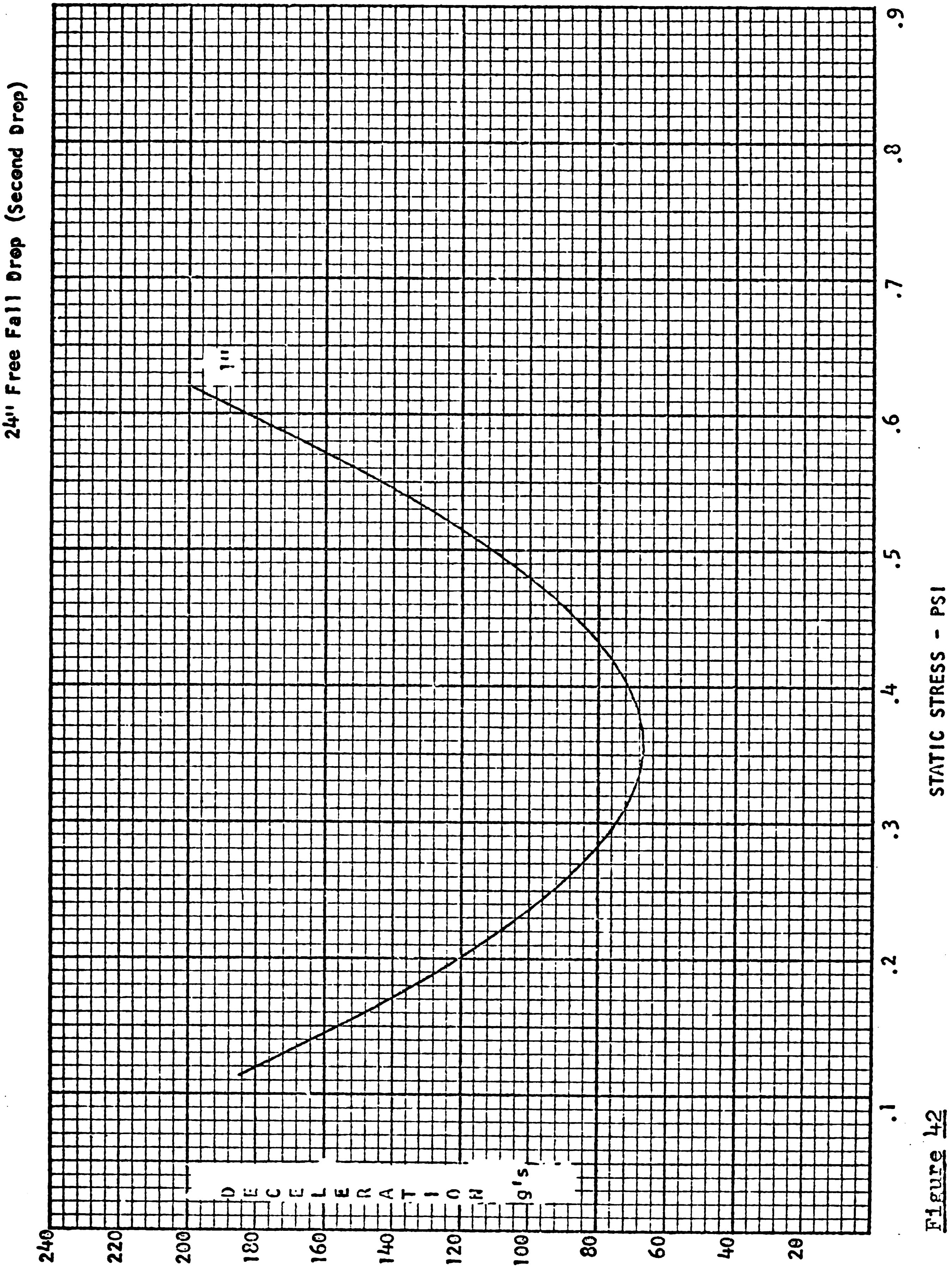


Figure 42

W. Va. Pulp & Paper H & D Div. (Sandusky)

AS-A Flute

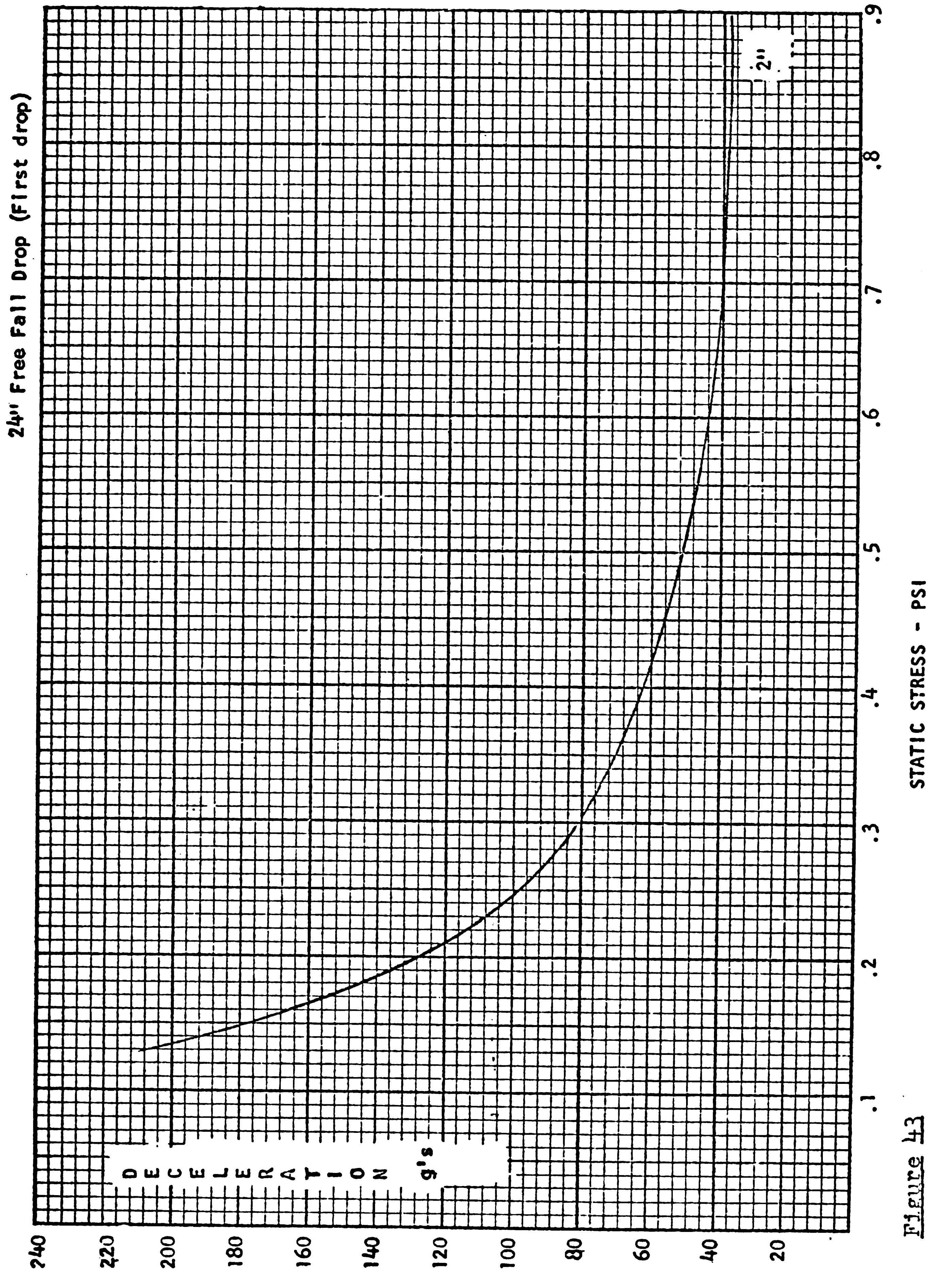


Figure 43

W. Va. Pulp & Paper H & D Div. (Sandusky)
AS-A Flute

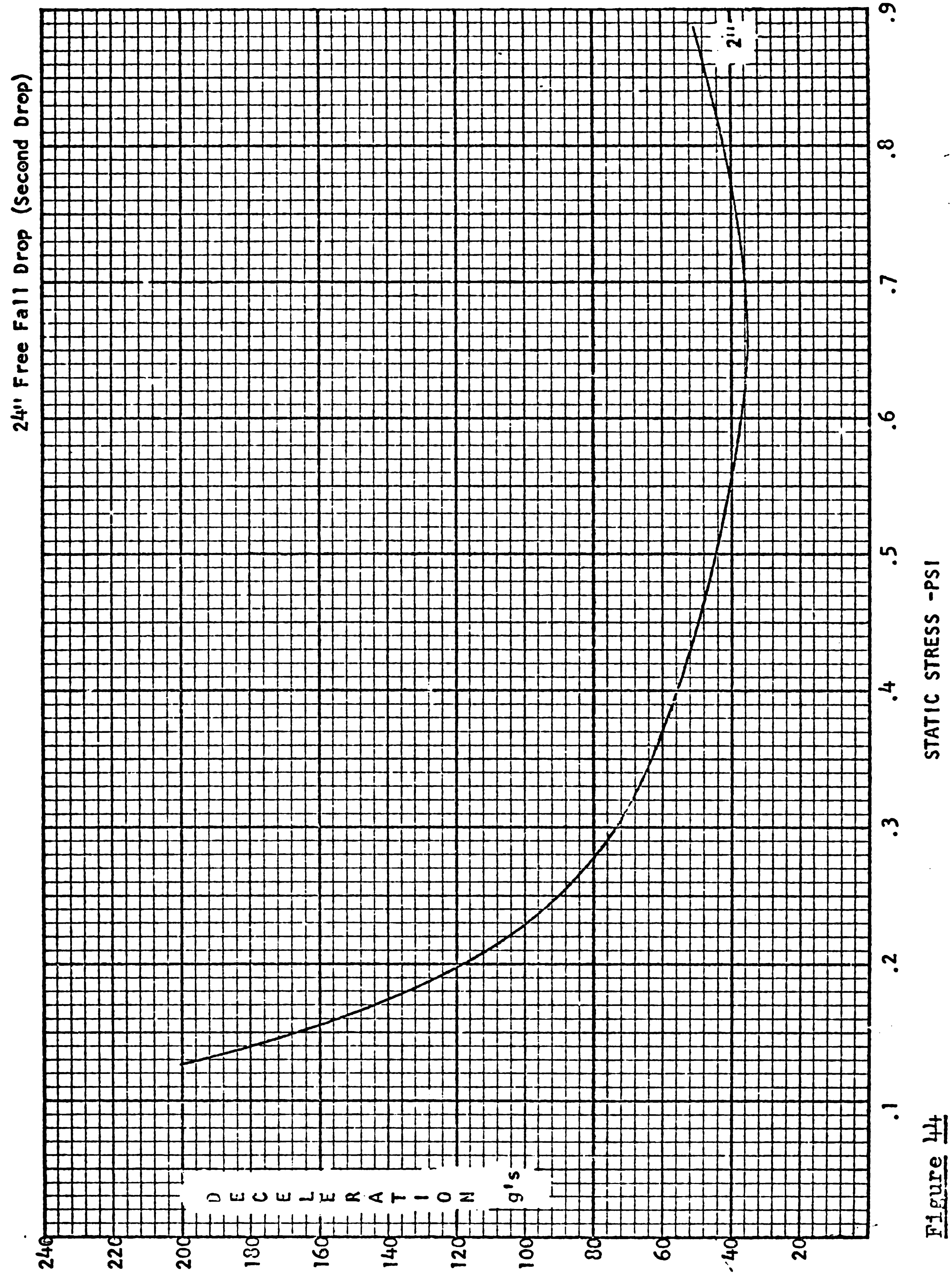


Figure 44

W.Va. Pulp & Paper H & D Div. (Sandusky)

AS-A Flute

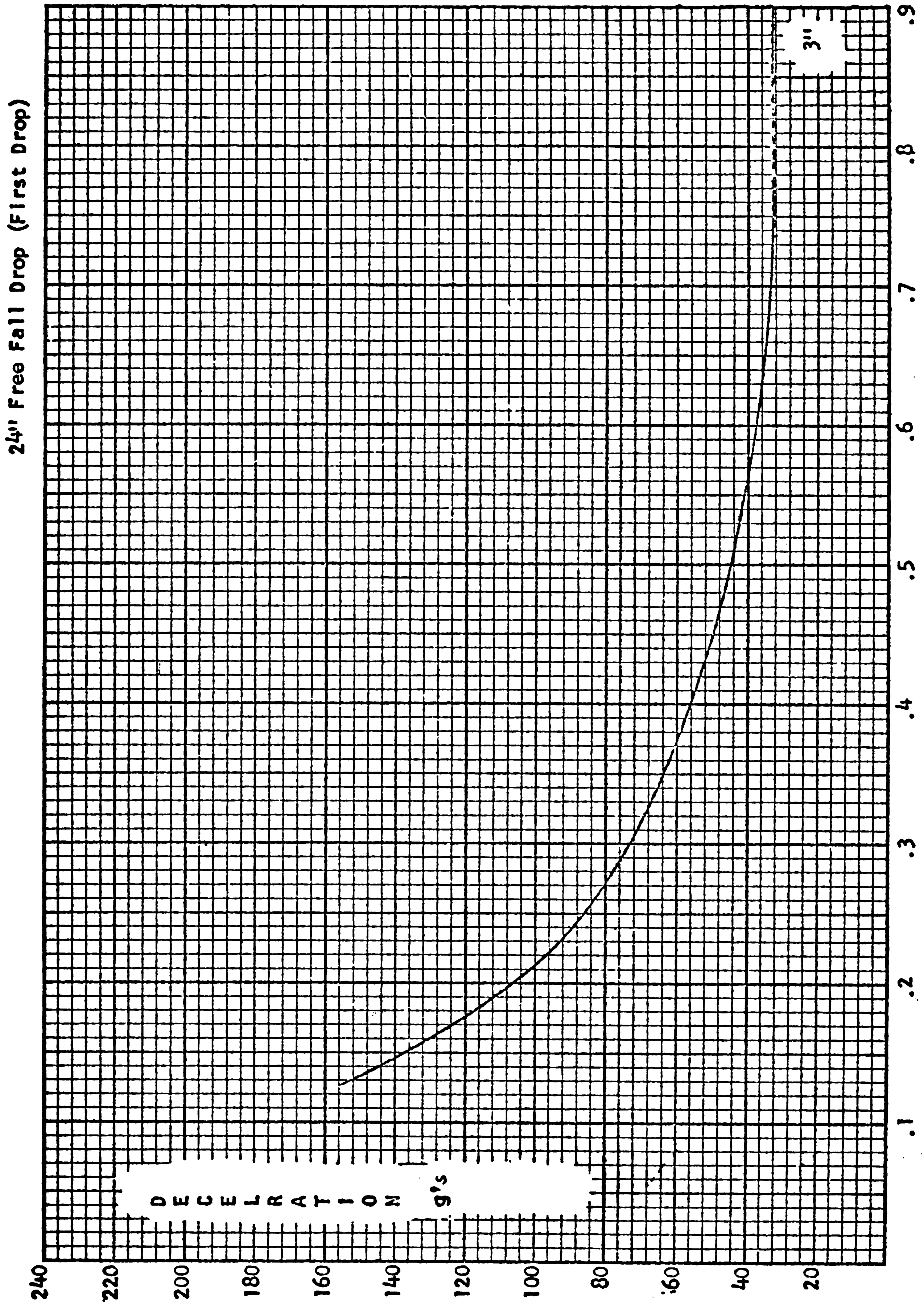


Figure 45

W. Va. Pulp & Paper H & D Div. (Sandusky)

AS-A Flute

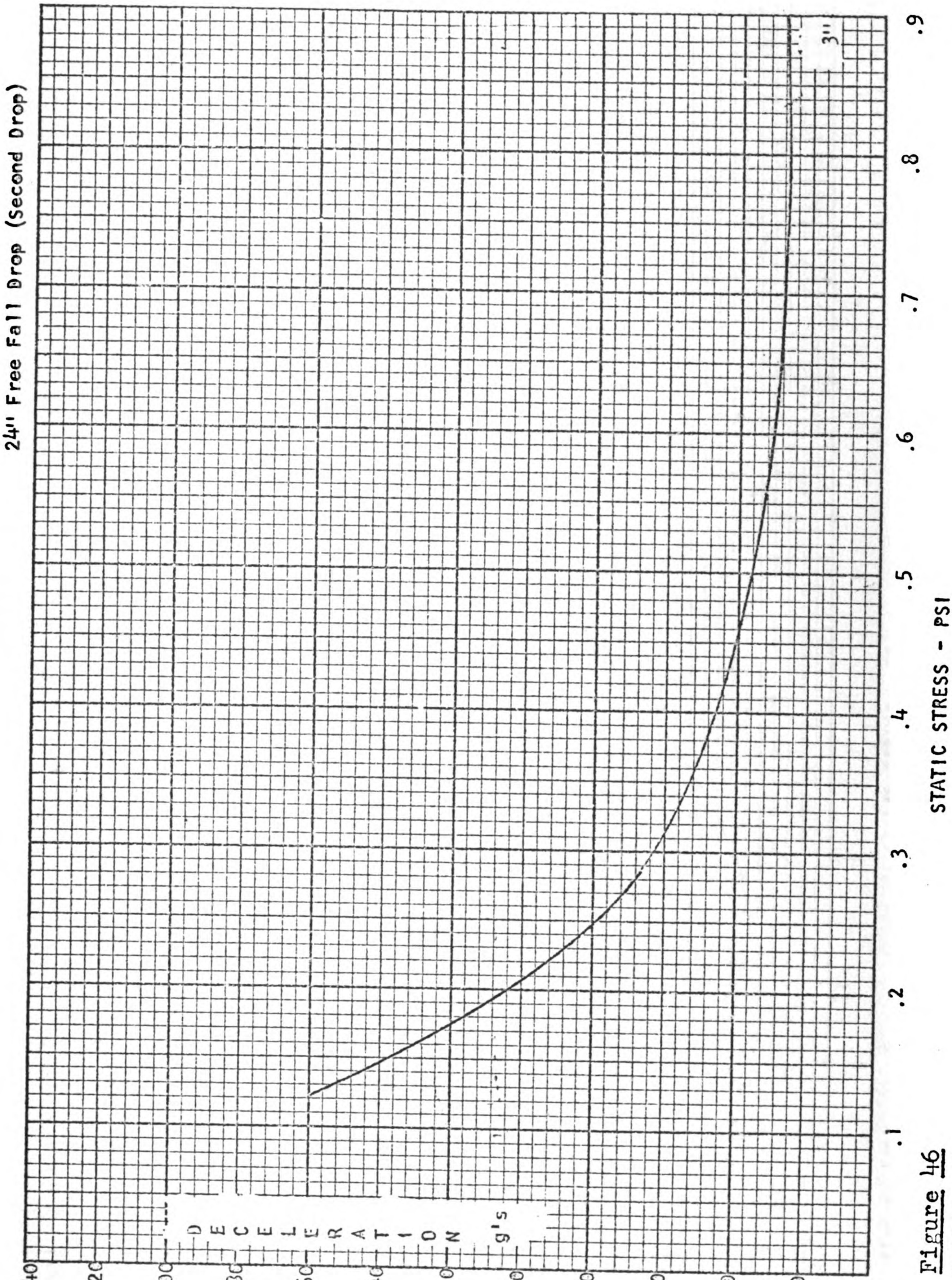


Figure 46

W. Va. Pulp & Paper H & D Div. (Sandusky)

PLY PAC A-Flute

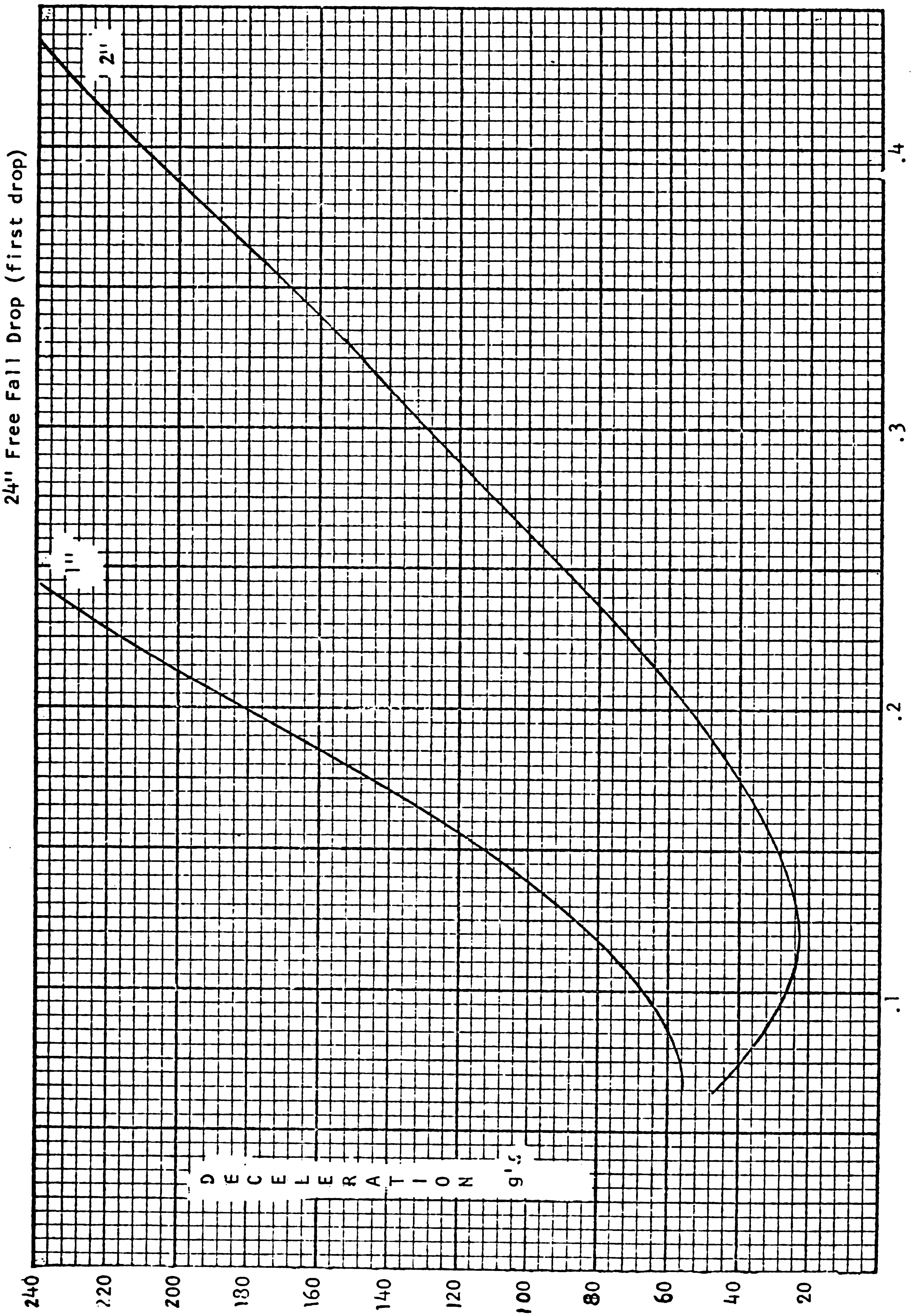


Figure 47

W. Va Pulp & Paper H & D Div. (Sandusky)

PLY PAC A-Flute

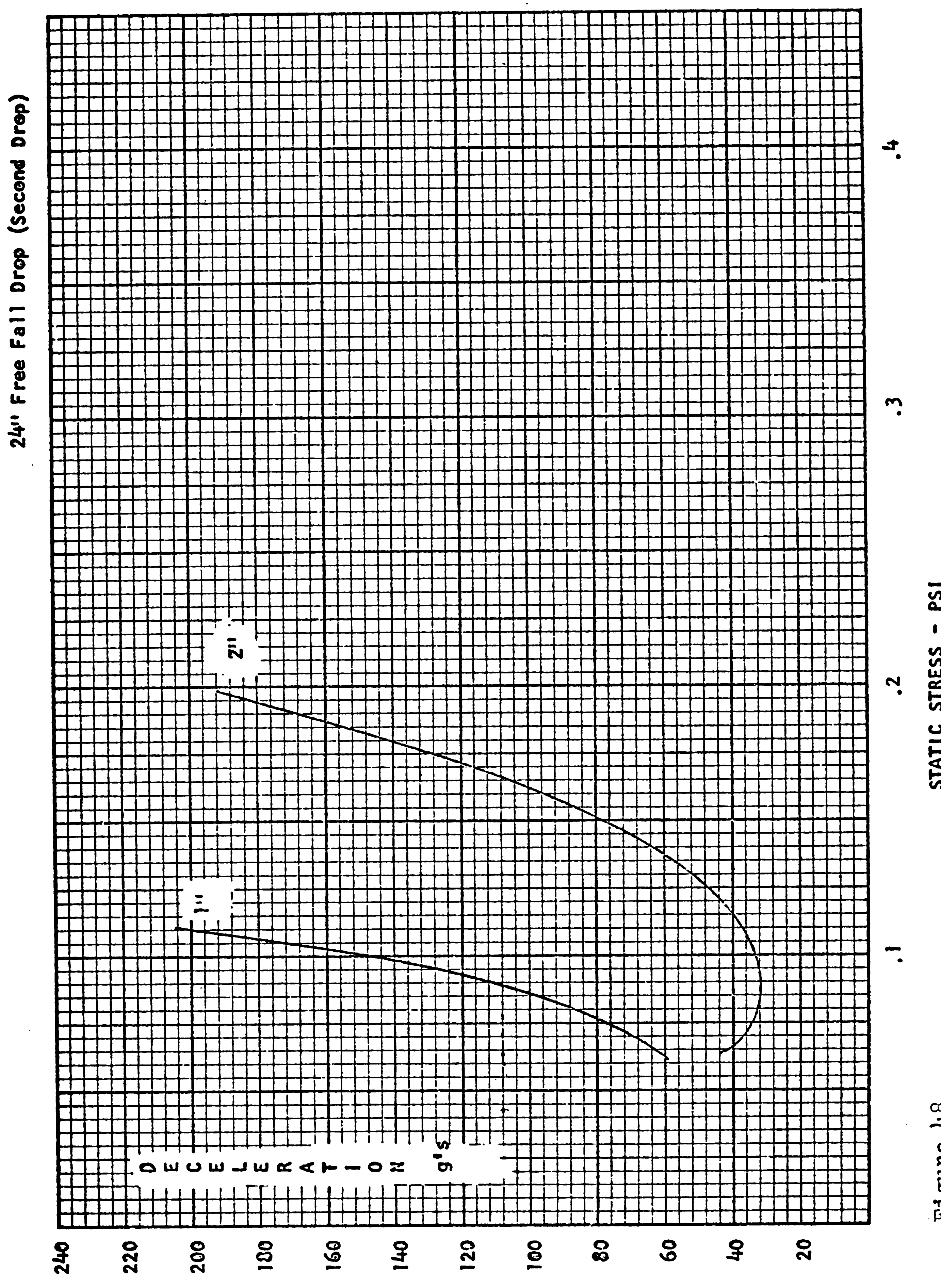


Figure 48

W. Va. Pulp & Paper H & D Div. (Sandusky)

PLY PAC A-Flute

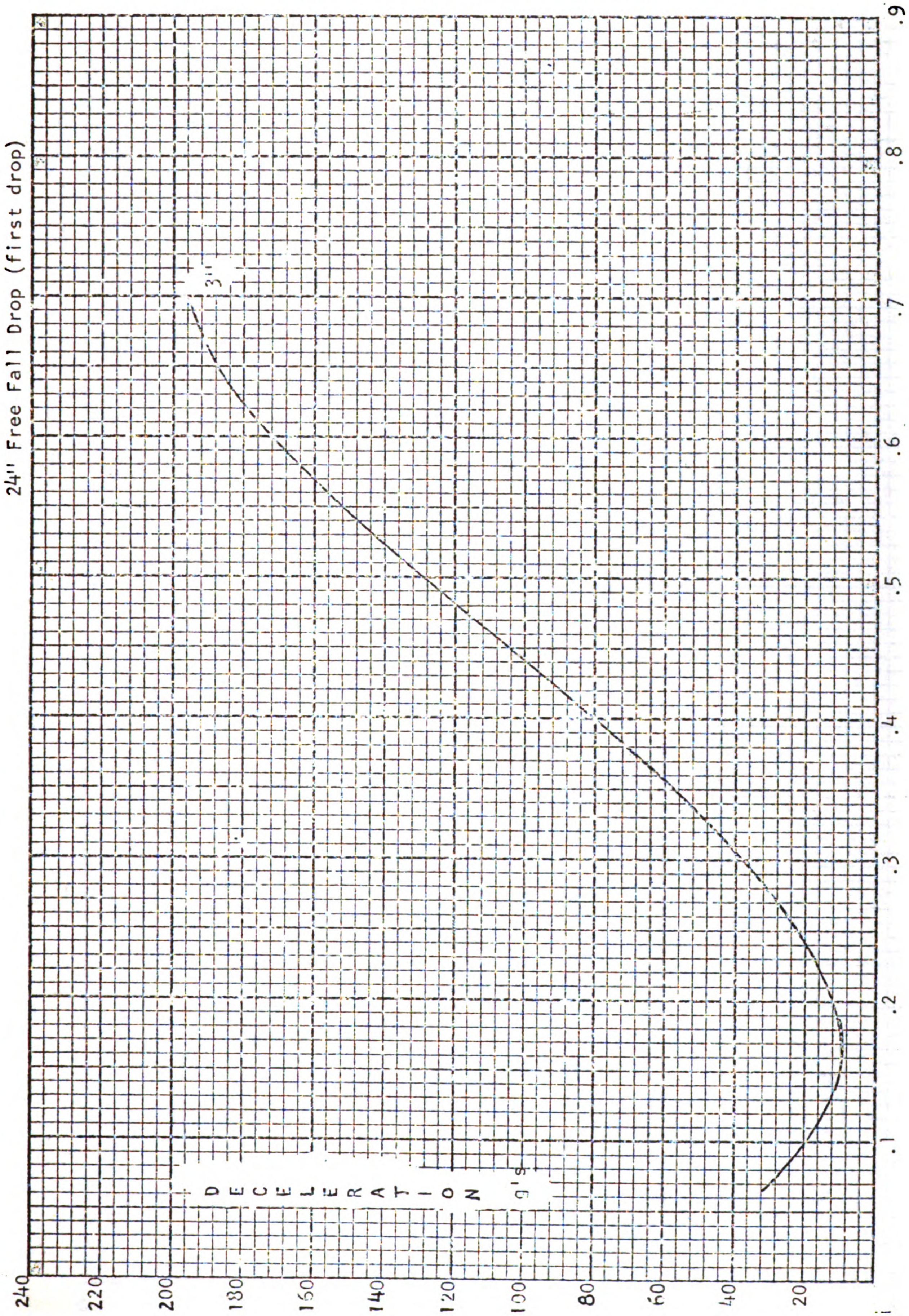


Figure 49

W. Va Pulp & Paper H & D Div. (Sandusky

PLY PAC A-Flute

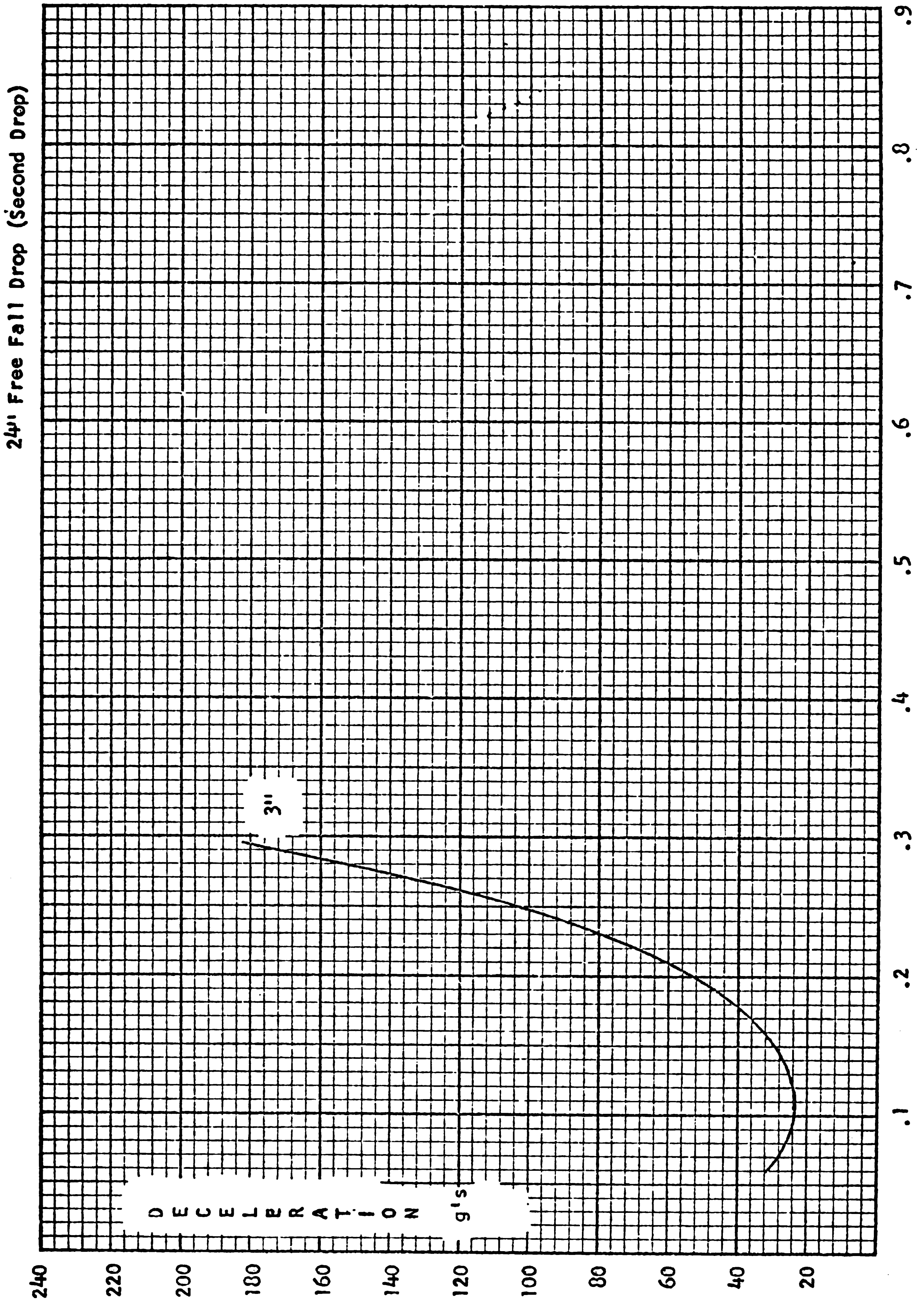


Figure 50

W. Va. Pulp & Paper H & D Div. (Gloucester)

PLY PAC A-Flute

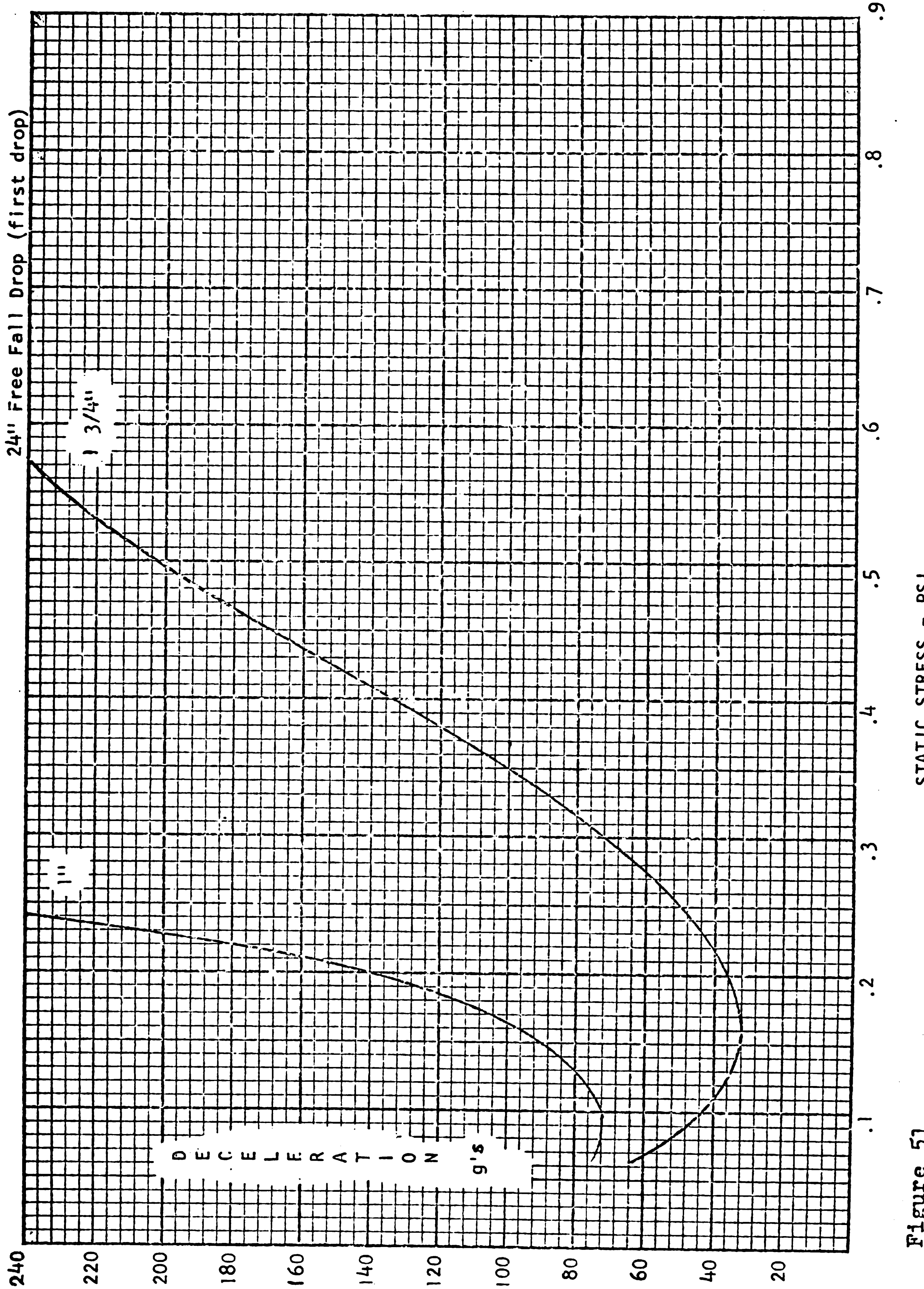


Figure 51

W. Va. Pulp & Paper H & D Div. (Gloucester)
PLY PAC A-Flute

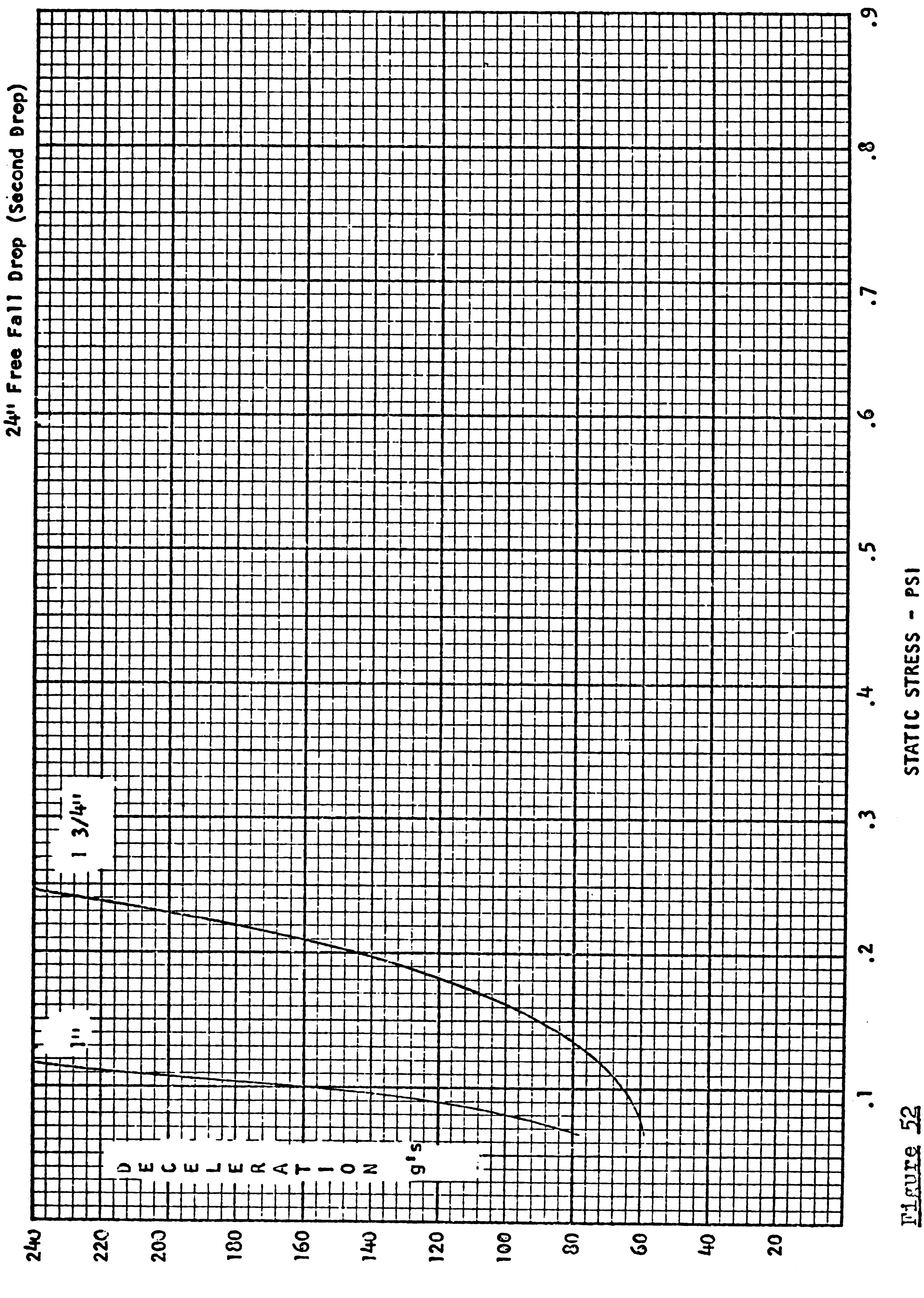


Figure 52

W. Va. Pulp & Paper H & D Div. (Sandusky)

PLY PAC-Q Flute

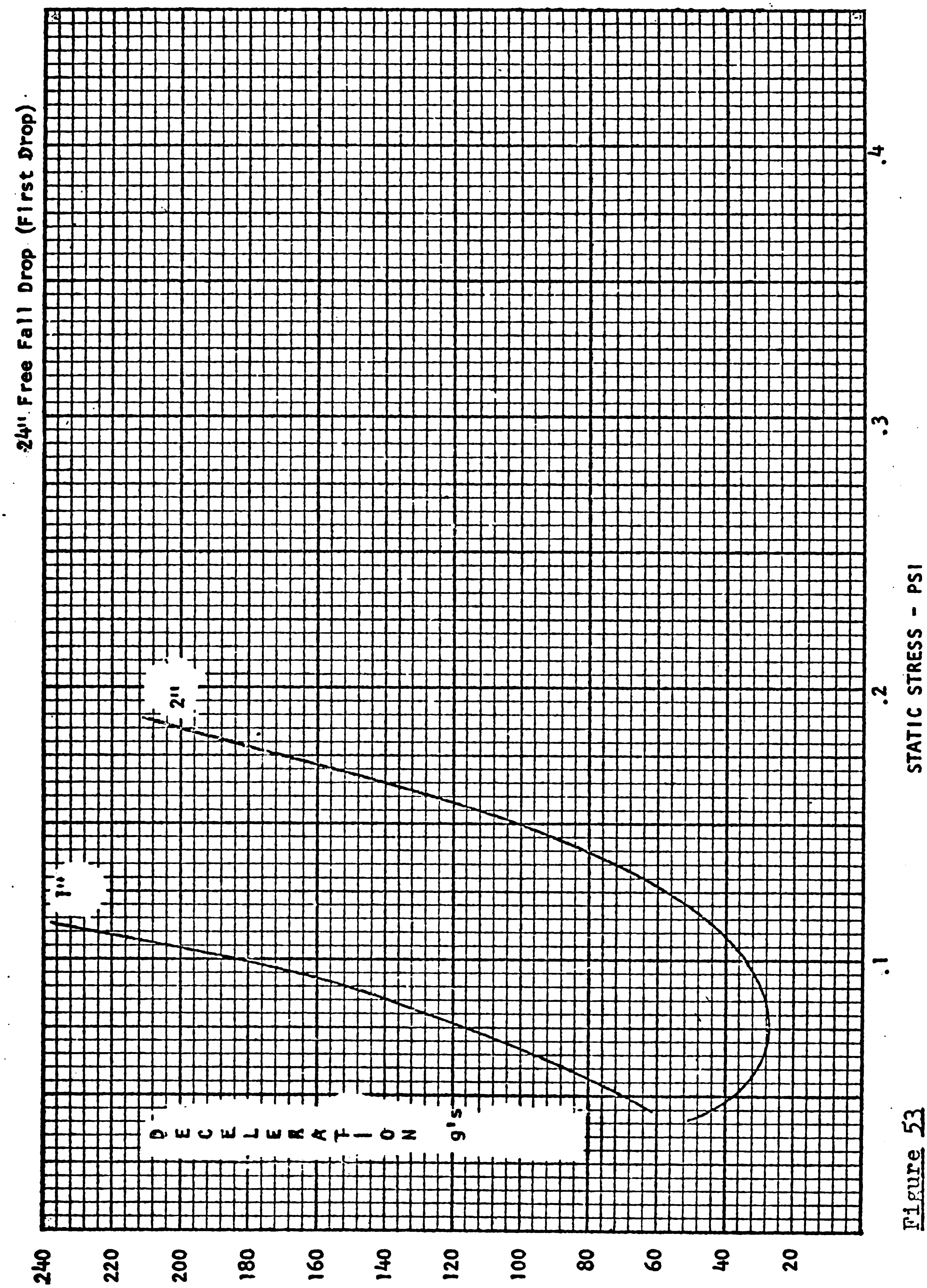


Figure 53

W. Va. Pulp & Paper H & D Div. (Sandusky)

PLY PAC-Q Flute

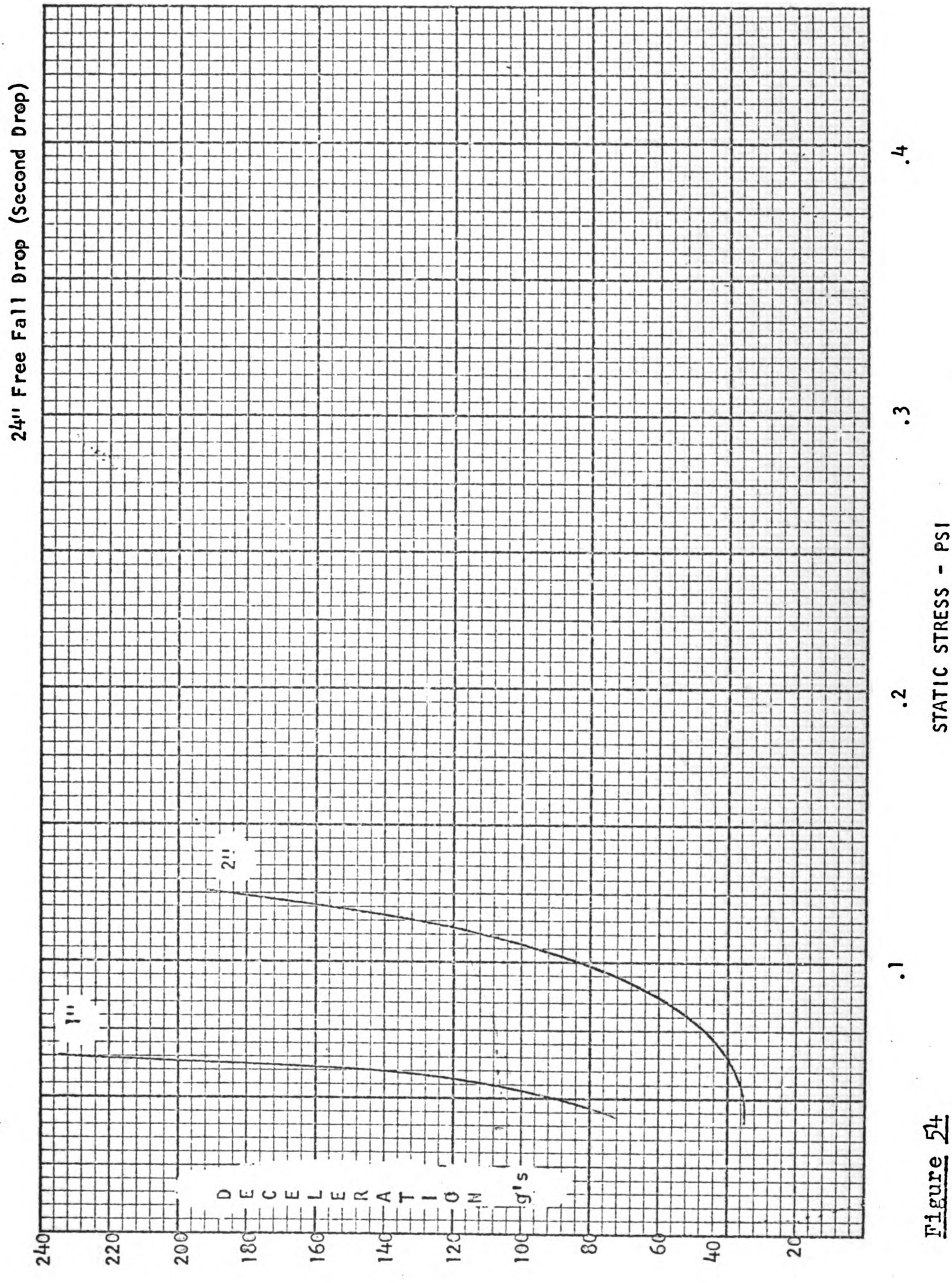


Figure 54

W. Va. Pulp & Paper H & D Div. (Sandusky)

PLY PAC-Q Flute

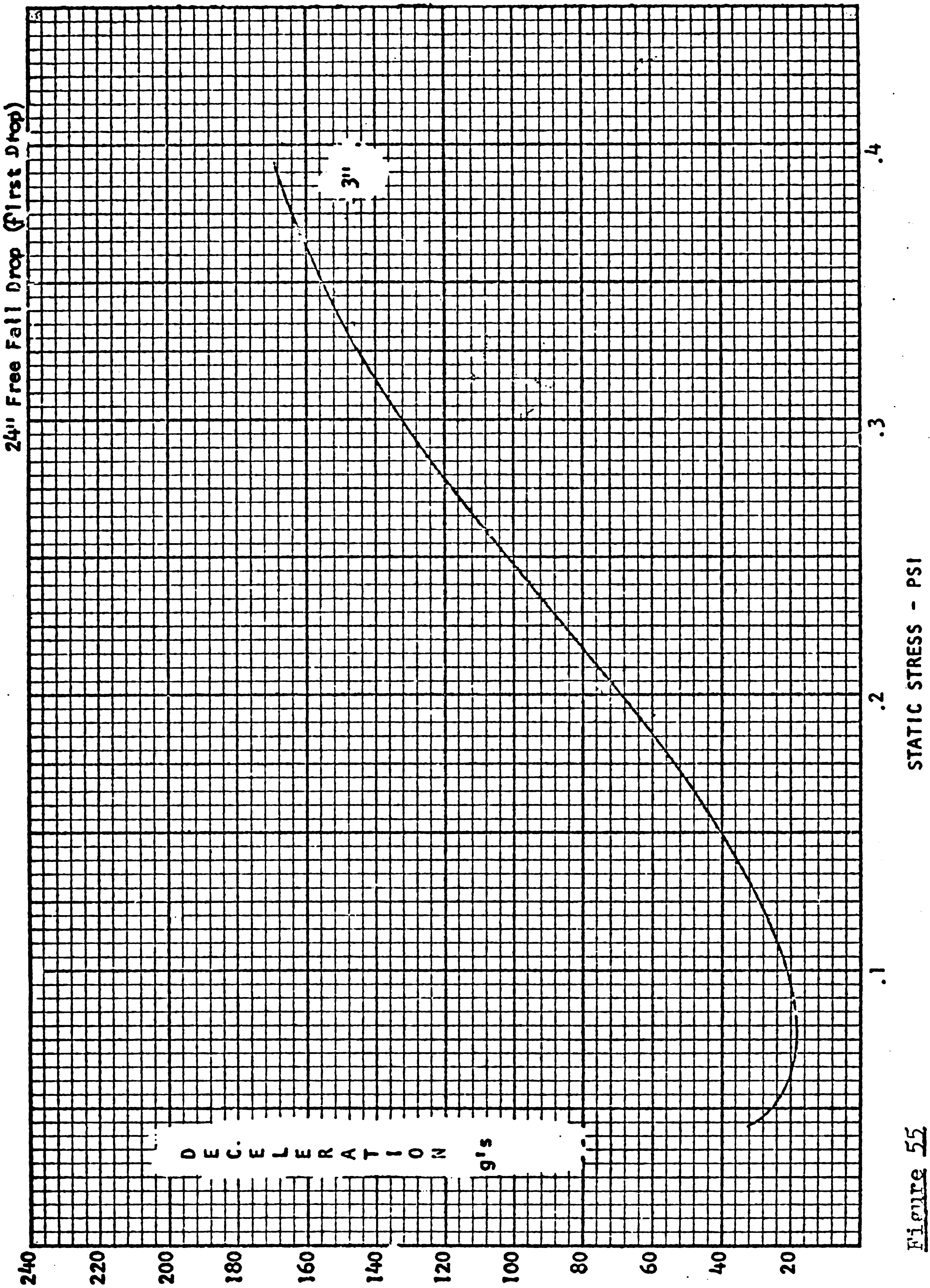


Figure 55

W. Va. Pulp & Paper H & D Div. (Sandusky)

PLY PAC Q-Flute

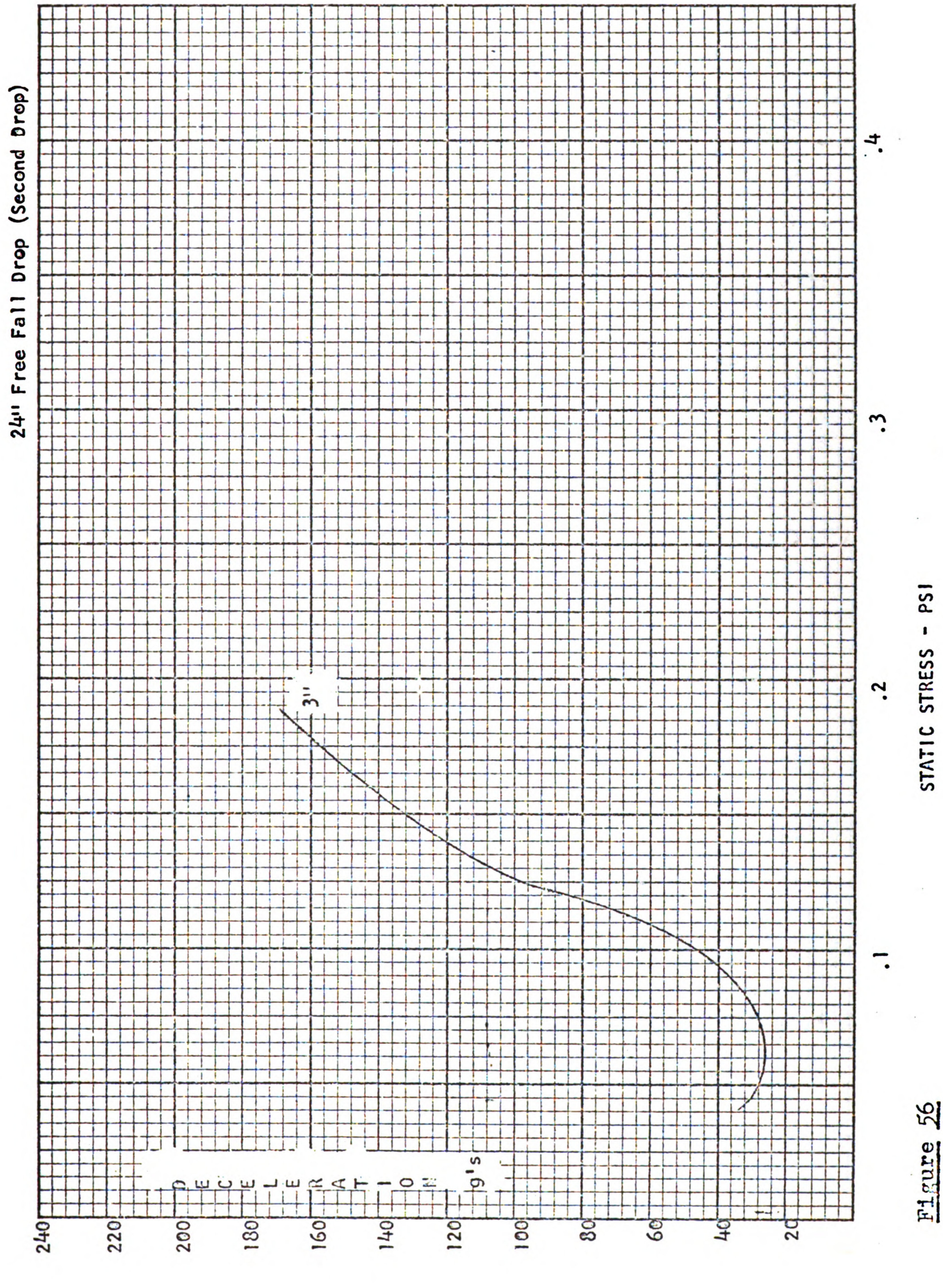


Figure 56

West Virginia Pulp & Paper H & D Div. (Sandusky)
Prestressed ZR-A Flute

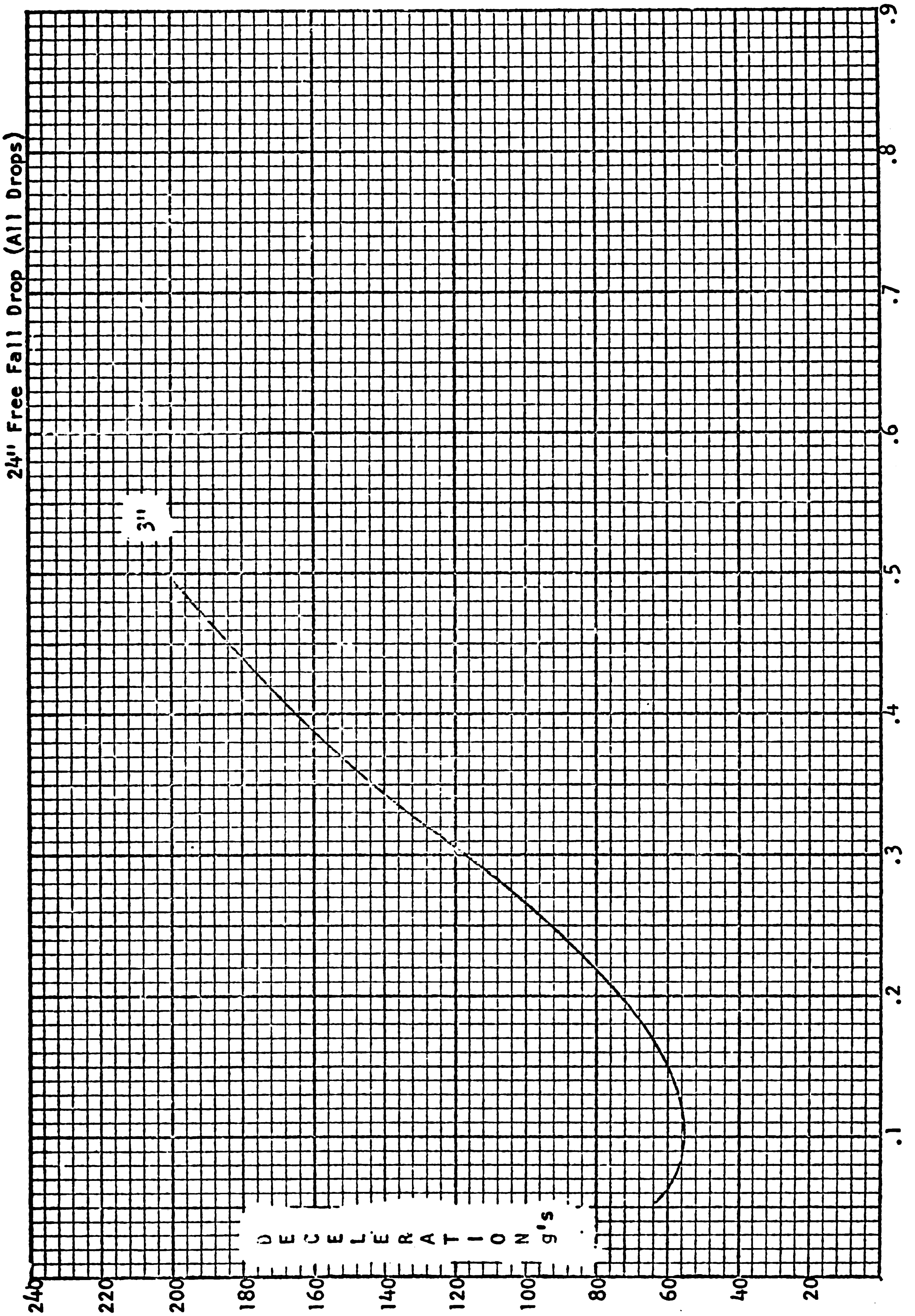


Figure 52

West Virginia Pulp & Paper H & D Div. (Sandusky)
Prestressed AV-A Flute

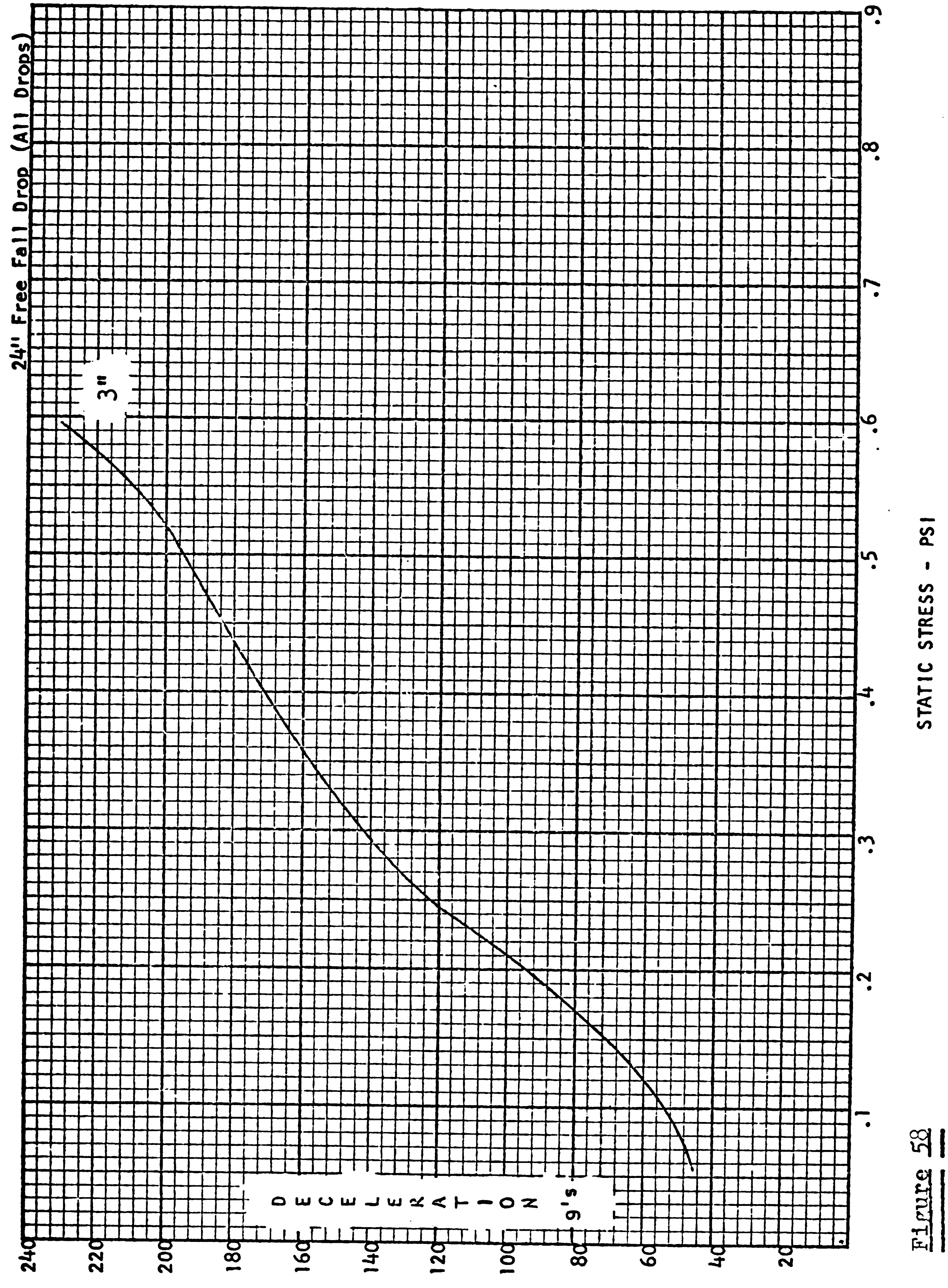


Figure 58

W. Va. Pulp & Paper H & D Div. (Sandusky)

PLY PAC A-Flute

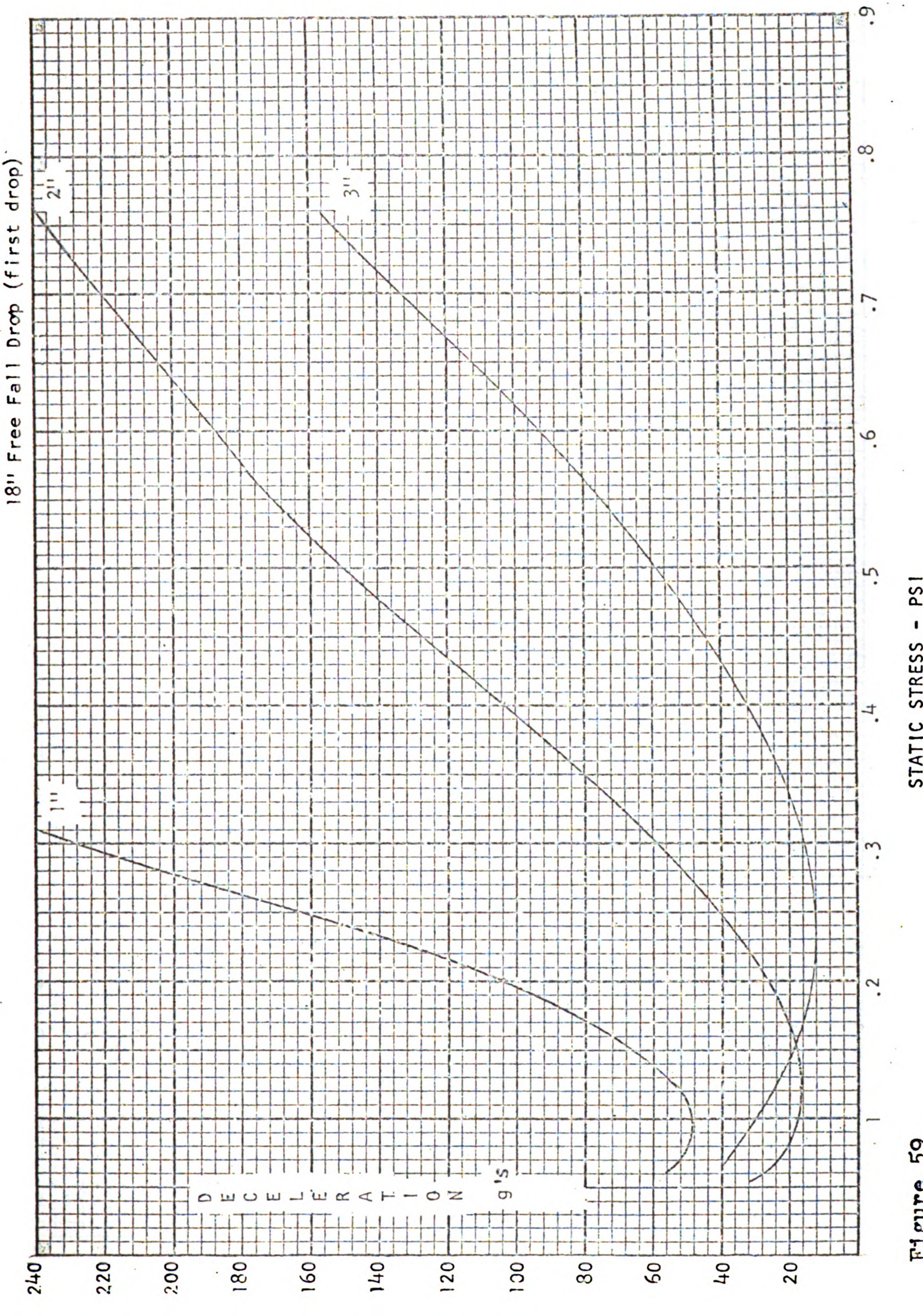


Figure 59

W. Va. Pulp & Paper H & D Div. (Sandusky)

PLY PAC A-Flute

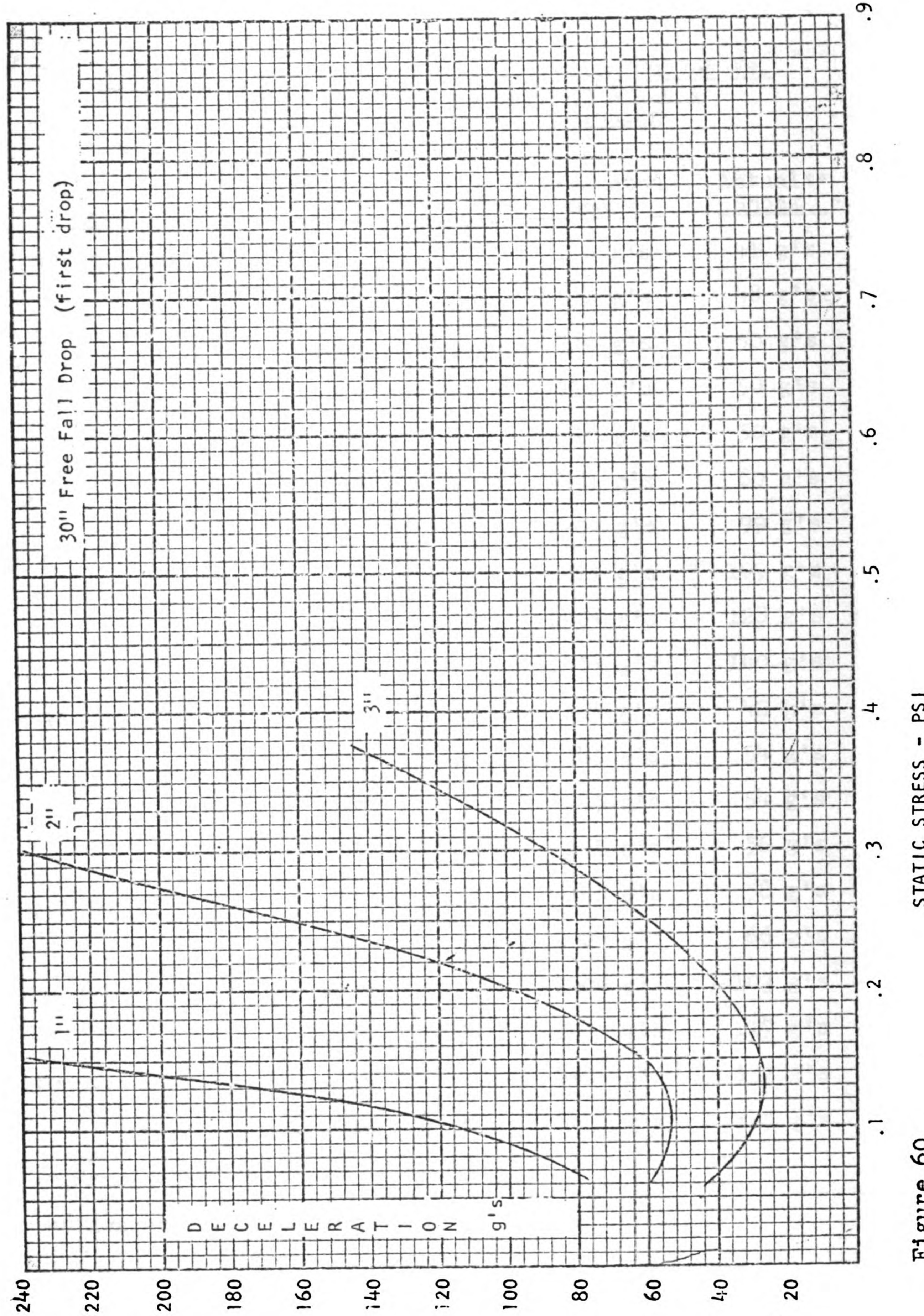


Figure 60

TABLE I

Shock Predicted Via Corrugated Cushion Curves Vs. Shock Actually Experienced By An Article Packaged In Corrugated Cushioning

Material	Static Stress	Drop No.	Predicted Shock	Actual** Shock
3" ZR-A Flute*	.289	1	110 g's	41 g's
	.289	2	110 g's	48 g's
	.289	3	110 g's	50 g's
	.289	4	110 g's	50 g's
	.289	5	110 g's	50 g's
	.616	1	240+ g's	60 g's
	.616	2	240+ g's	99 g's
	.616	3	240+ g's	109 g's
	.616	4	240+ g's	128 g's
	.616	5	240+ g's	140 g's
3" AV-A Flute*	.289	1	145 g's	42 g's
	.289	2	145 g's	54 g's
	.289	3	145 g's	54 g's
	.289	4	145 g's	56 g's
	.289	5	145 g's	58 g's
	.616	1	240+ g's	66 g's
	.616	2	240+ g's	103 g's
	.616	3	240+ g's	117 g's
	.616	4	240+ g's	132 g's
	.616	5	240+ g's	145 g's

* Prestressed Material

** Average Of Three Tests

Material	Static Stress	Drop No.	Predicted Shock	Actual** Shock
3" RR-A Flute	.289	1	52 g's	52 g's
	.289	2	49 g's	48 g's
	.289	3	58 g's	49 g's
	.289	4	54 g's	50 g's
	.289	5	52 g's	51 g's
	.616	1	22 g's	26 g's
	.616	2	28 g's	31 g's
	.616	3	36 g's	34 g's
	.616	4	99 g's	42 g's
	.616	5	158 g's	66 g's
3" FR-Q Flute	.289	1	46 g's	42 g's
	.289	2	44 g's	37 g's
	.289	3	46 g's	40 g's
	.289	4	50 g's	48 g's
	.289	5	56 g's	48 g's
	.616	1	19 g's	20 g's
	.616	2	34 g's	30 g's
	.616	3	98 g's	62 g's
	.616	4	200 g's	124 g's
	.616	5	240 g's	161 g's
3" AR-Q Flute	.289	1	31 g's	33 g's
	.289	2	29 g's	35 g's
	.289	3	36 g's	33 g's
	.289	4	42 g's	34 g's
	.289	5	58 g's	36 g's

** Average Of Three Tests

Material	Static Stress	Drop No.	Predicted Shock	Actual** Shock
3" AR-Q Flute	.616	1	19 g's	18 g's
	.616	2	62 g's	39 g's
	.616	3	135 g's	108 g's
	.616	4	235 g's	161 g's
	.616	5	240+ g's	215 g's
3" AR-A Flute	.289	1	68 g's	72 g's
	.289	2	61 g's	66 g's
	.289	3	54 g's	61 g's
	.289	4	51 g's	61 g's
	.289	5	51 g's	63 g's
	.616	1	31 g's	34 g's
	.616	2	32 g's	42 g's
	.616	3	29 g's	45 g's
	.616	4	54 g's	44 g's
	.616	5	84 g's	51 g's
3" ZZ-A Flute	.289	1	26 g's	28 g's
	.289	2	22 g's	30 g's
	.289	3	54 g's	35 g's
	.289	4	115 g's	39 g's
	.289	5	175 g's	46 g's
	.616	1	22 g's	21 g's
	.616	2	190 g's	44 g's
	.616	3	240+ g's	68 g's
	.616	4	240+ g's	76 g's
	.616	5	240+ g's	88 g's

** Average Of Three Tests

Material	Static Stress	Drop No.	Predicted Shock	Actual** Shock
3" AV-A Flute	.289	1	27 g's	32 g's
	.289	2	27 g's	38 g's
	.289	3	34 g's	39 g's
	.289	4	56 g's	42 g's
	.289	5	72 g's	47 g's
	.616	1	16 g's	18 g's
	.616	2	86 g's	30 g's
	.616	3	135 g's	38 g's
	.616	4	175 g's	49 g's
	.616	5	200 g's	64 g's
3" AS-A Flute	.289	1	76 g's	80 g's
	.289	2	66 g's	71 g's
	.289	3	68 g's	74 g's
	.289	4	65 g's	74 g's
	.289	5	64 g's	68 g's
	.616	1	37 g's	35 g's
	.616	2	30 g's	44 g's
	.616	3	37 g's	46 g's
	.616	4	46 g's	48 g's
	.616	5	57 g's	50 g's
3" ZR-A Flute	.289	1	52 g's	53 g's
	.289	2	45 g's	49 g's
	.289	3	44 g's	53 g's
	.289	4	47 g's	53 g's
	.289	5	46 g's	52 g's

** Average Of Three Tests

Material	Static Stress	Drop No.	Predicted Shock	Actual** Shock
3" ZR-A Flute	.616	1	19 g's	20 g's
	.616	2	28 g's	30 g's
	.616	3	54 g's	33 g's
	.616	4	120 g's	40 g's
	.616	5	180 g's	58 g's
3" PP-A Flute	.289	1	34 g's	31 g's
	.289	2	168 g's	37 g's
	.289	3	240+ g's	72 g's
	.289	4	240+ g's	91 g's
	.289	5	240+ g's	111 g's
	.616	1	176 g's	164 g's
	.616	2	240+ g's	190 g's
	.616	3	240+ g's	240+ g's
	.616	4	240+ g's	240+ g's
	.616	5	240+ g's	240+ g's
3" PP-Q Flute	.289	1	127 g's	100 g's
	.289	2	240+ g's	140 g's
	.289	3	240+ g's	148 g's
	.289	4	240+ g's	154 g's
	.289	5	240+ g's	160 g's
	.616	1	240+ g's	200 g's
	.616	2	240+ g's	230 g's
	.616	3	240+ g's	240 g's
	.616	4	240+ g's	240+ g's
	.616	5	240+ g's	240+ g's

** Average Of Three Tests

DISCUSSION OF RESULTS

The graphs and tables found in the results section of this study form the basis for several statements regarding corrugated cushioning. These statements are as follows:

1) Unstressed corrugated is a very inconsistent material when compared to foamed polyethylene. i.e. The g's vary drastically between drops. (See Appendix IV).

2) Compared to foamed polyethylene, corrugated is better on the first drop but worse on successive drops. Figure 61 illustrates that 2" AV-A flute corrugated protects to a lower "g" level on the first drop than does 2" foamed polyethylene. However, when 2nd drop protection is required, the useful range of the corrugated becomes limited to the crosshatched area while the useful range of foamed polyethylene remains unchanged.

3) Prestressed corrugated cushioning is a relatively consistent cushioning material and it performs quite well inside a package. (See Table I and Appendix IV).

4) C flute protects to the same or a lower "g" level than A flute on the first drop. However, if multiple drop protection is required, the range of static stresses through which C flute is useful becomes limited. (See Figure 62).

5) An increase in the basis weight of the liner will

cause a shift to the right of the <u>peak</u> <u>g</u> vs <u>static</u> <u>stress</u> curve. However, the level and range of protection remain approximately equal. (See Figure 63).

6) Decreasing the basis weight of the corrugated medium will give better first drop protection. However, when second drop protection is required, the range of useful static stresses becomes extremely limited. (See Figure 64).

7) The inner package performance of prestressed corrugated cushioning and unstressed corrugated cushioning after the initial drop cannot be predicted consistently by the use of cushion curves. This may be due to the fact that the movement of air is restricted inside a package and not restricted when it is tested on the Vertical Dynamic Drop Tester. (See Table I).

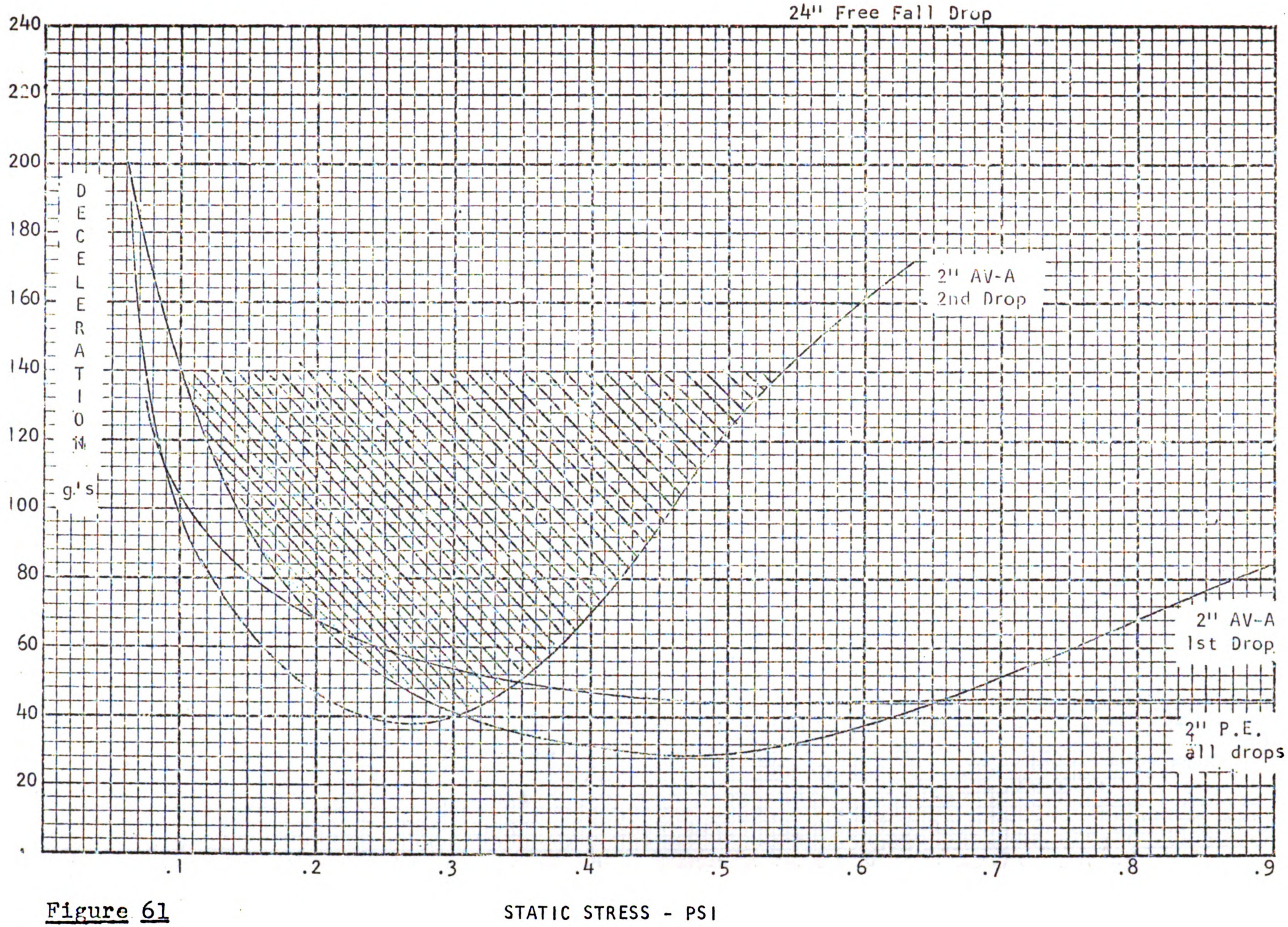

24" Free Fall Drop
240
220
200
180
160
140
120
100
80
60
40
20
DECELERATION g.'s
2" AV-A 2nd Drop
2" AV-A 1st Drop
2" P.E. all drops
.1
.2
.3
.4
.5
.6
.7
.8
.9
STATIC STRESS - PSI

Figure 61

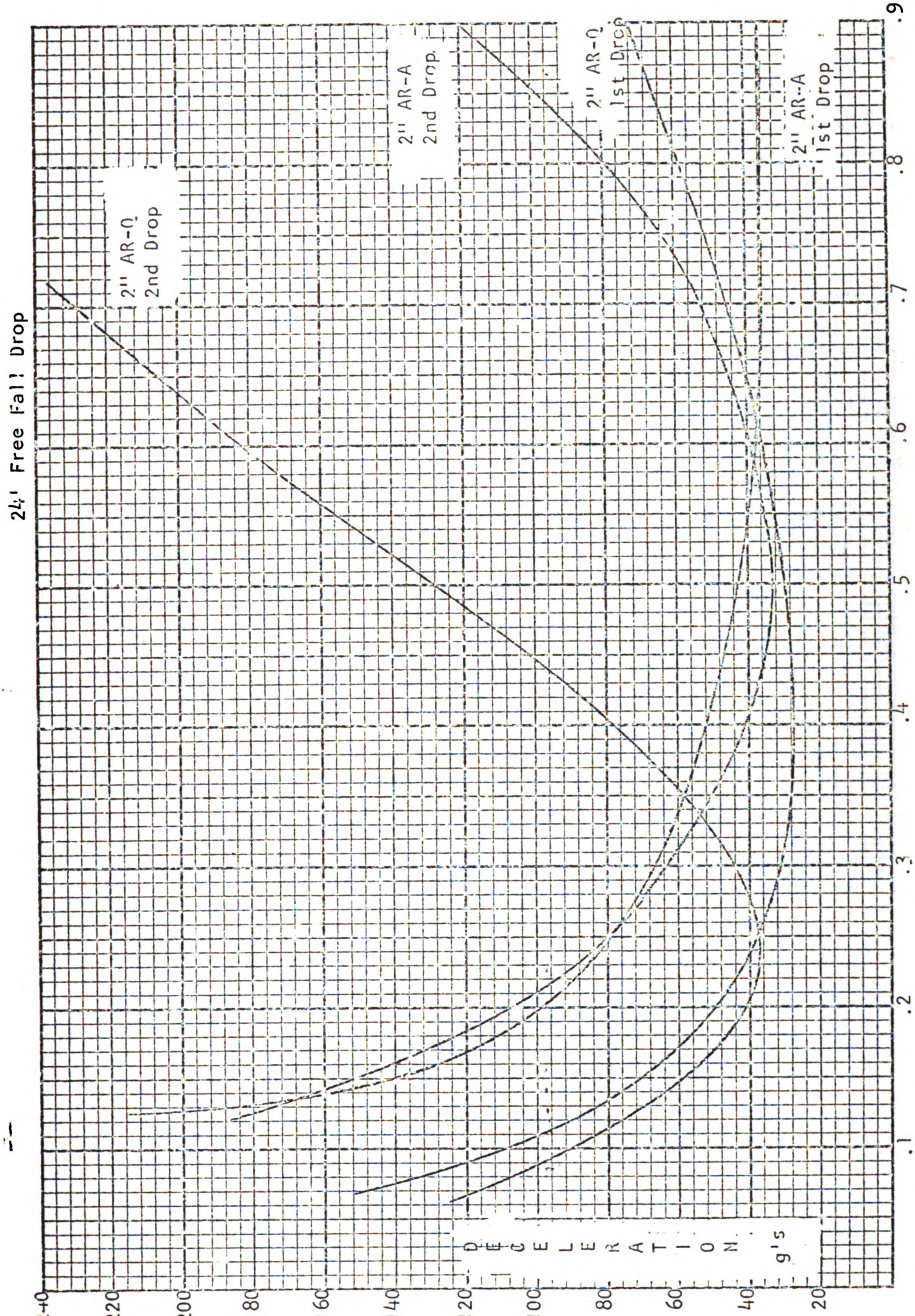

24' Free Fall Drop
2" AR-O 2nd Drop
2" AR-A 2nd Drop
2" AR-O 1st Drop
2" AR-A 1st Drop
DECELERATION g's
240
220
200
180
160
140
120
100
80
60
40
20
.1
.2
.3
.4
.5
.6
.7
.8
.9
STATIC STRESS - PSI

Figure 62

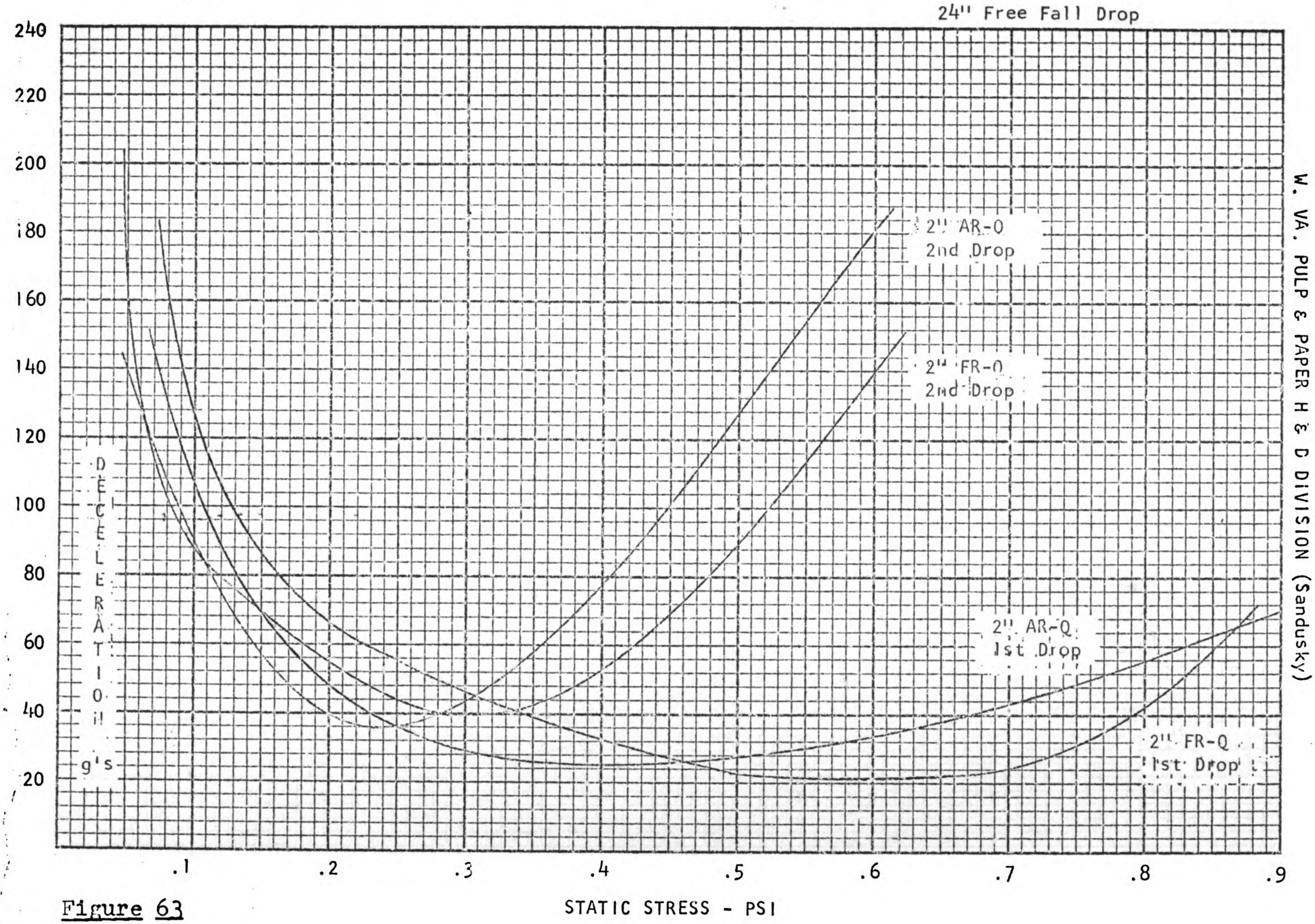

24" Free Fall Drop
W. VA. PULP & PAPER H & D DIVISION (Sandusky)
240
220
200
180
160
140
120
100
80
60
40
20
DECELERATION g's
2" AR-O 2nd Drop
2" FR-O 2nd Drop
2" AR-Q 1st Drop
2" FR-Q 1st Drop
.1
.2
.3
.4
.5
.6
.7
.8
.9
STATIC STRESS - PSI

Figure 63

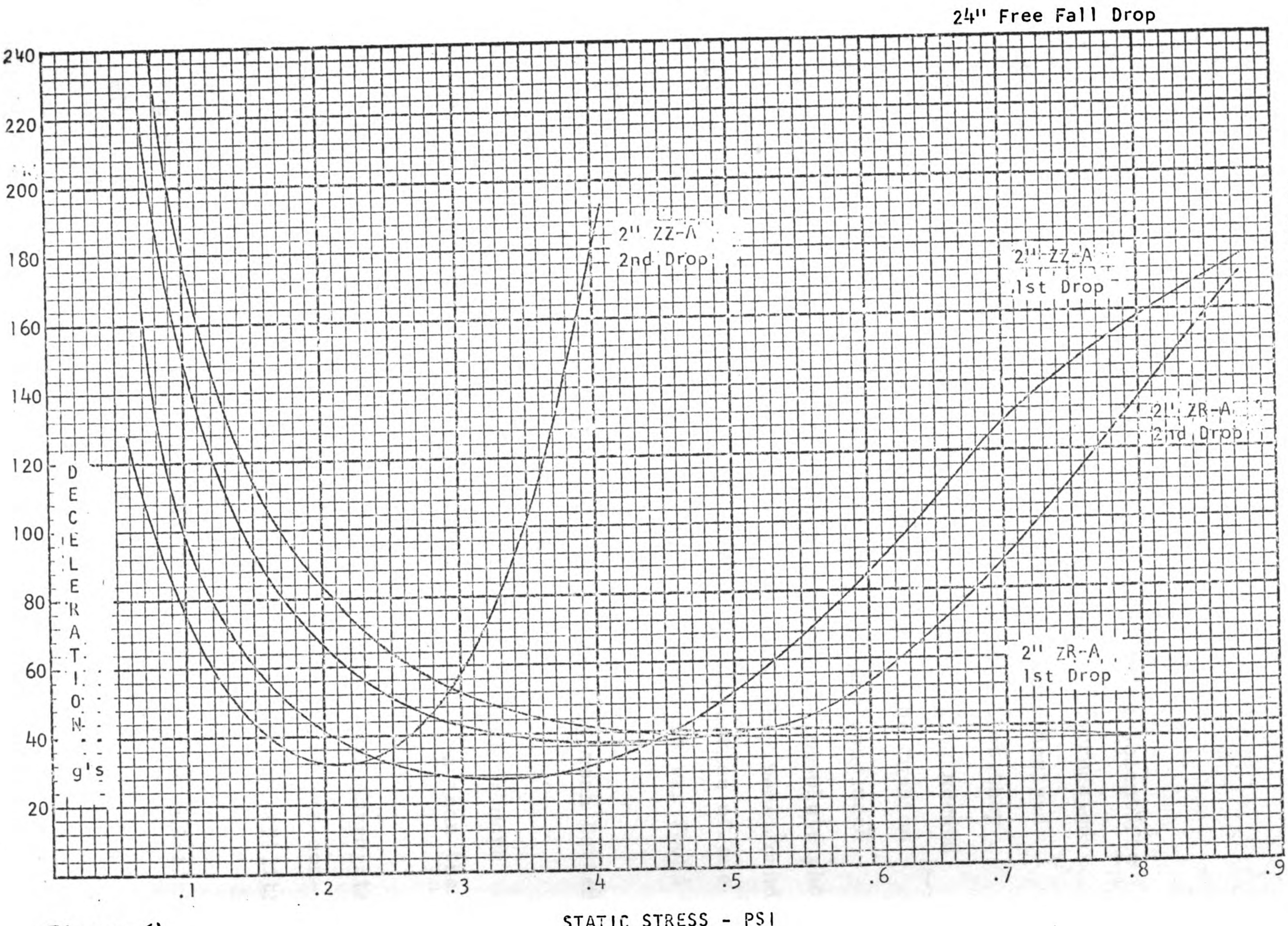

24" Free Fall Drop
W. VA. PULP & PAPER H & D DIVISION (Sandusky)
DECELERATION g's
240
220
200
180
160
140
120
100
80
60
40
20
.1
.2
.3
.4
.5
.6
.7
.8
.9
STATIC STRESS - PSI
2" ZZ-A 2nd Drop
2" ZZ-A 1st Drop
2" ZR-A 2nd Drop
2" ZR-A 1st Drop

Figure 64

CONCLUSIONS

This study has been an attempt at providing scientific information for present and potential users of corrugated cushioning. Peak g vs static stress curves were derived for unstressed corrugated material in the hope that they could be used to determine the amount of cushioning needed to protect an article of a known fragility. (The Cushion Design Method). After a series of tests it was concluded that these curves did not accurately predict the absolute shock experienced after the initial drop. However, they were found quite useful in determining the cushioning properties of one material in relation to another. On this basis it was found that;

1) A larger flute size does not necessarily mean better cushioning.

2) The basis weight of the corrugated medium is more important in determining cushion effectiveness than the basis weight of the liner.

As a result of the inconsistency of unstressed corrugated, some work was done with prestressed corrugated. It was concluded that prestressed corrugated has cushioning possibilities. However, it was still impossible to accurately predict the shock experienced by an article packaged in this material with the use of cushion curves.

BIBLIOGRAPHY

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3. Blake, Howard C. III, "24 Inch Drop Height Peak Deceleration - Static Stress Curves for Selected Cushioning Materials." School of Packaging, Michigan State University, Technical Report No. 5, Project No. 1, November 1, 1964.
4. Stern, R.K., "Tests Show Corrugated Pads' Performance As Cushioning." Package Engineering, Vol. 13, February, 1968, p.71.
5. "Standard Method of Test for the Shock Absorbing Characteristics of Package Cushioning Materials." ASTM Standards Part 15, April, 1968, p.568.
6. Blake, Howard C. III, "A Cushion Design Method and Static Stress - Peak Deceleration Curves For Selected Cushioning Materials." School of Packaging, Michigan State University, Technical Report No. 2, Project No. 1, March 25, 1963.

APPENDIX I.

A Key To West Virginia Pulp & Paper's Letter Designations

A Flute = Thirty-six - 3/16" flutes per foot.

Q Flute = Twenty-six - 3/16" flutes per foot.

A = 26 lb/1000 sq ft virgin kraft liner.

F = 42 lb/1000 sq ft virgin kraft liner.

P = 30 lb/3000 sq ft virgin kraft liner.

R = 26 lb/1000 sq ft semi-chemical corrugated medium.

S = 33 lb/1000 sq ft semi-chemical corrugated medium.

V = Off grade saturated kraft—cushion stock.

Z = 17 lb/1000 sq ft virgin kraft liner.

Examples

1. A material labelled as 2" ZR-A flute would indicate that the A flute corrugated material in question is 2 inches thick, has a kraft liner which weighs 17 lbs/1000 sq ft, and has a semi-chemical corrugated medium which weighs 26 lbs/1000 sq ft.
2. A material labelled as 1" AS-Q flute would indicate that the Q flute corrugated material in question is 1 inch thick, has a kraft liner which weighs 26 lbs/1000 sq ft, and has a semi-chemical corrugated medium which weighs 33 lbs/1000 sq ft.

APPENDIX II

The Cushion Design Method And An Example[6]

The basic steps to arriving at a cushion design for a given article are:

1. Weigh the article to be packaged.
2. Measure the length and width of each surface of the article on which the article could rest.
3. Compute the area of each of the surfaces measured.
4. Compute the static stress of each measured surface by dividing the article weight by the area of each surface.
5. Determine the maximum peak deceleration the article can safely undergo in g's. This maximum peak deceleration is often called fragility.*
6. Determine which materials could conceivably be used to package the article in question and obtain static stress vs. peak g curves for these materials.
7. Cushion selection.
   a. Examine the static stress vs. peak g curves to determine which of them have the static stress and peak deceleration levels needed.

*Obtain this information from the designer. If it cannot be obtained from this source it must be either estimated or measured. Precise means of measuring fragility are not available and estimating techniques rely heavily on the estimator.

b. Adjust cushion size. If desirable, from the standpoint of economy or the availability of particular cushioning materials, the static stress level may be raised by reducing the size of the cushion supporting the article. Similarly, the static stress level may be reduced by introducing a rigid load spreading member between the article and the cushion.

c. Final selection. This will be based on cost, weight, compatibility, etc.

Cushion Design Example

The article weight is 65# with dimensions of 12" x 12" x 20" and a maximum allowable peak deceleration of 44 g's. The problem is to protect this article in a 30" drop assuming that polyethylene is the only suitable material.

Design steps:

1. Weight - 65#
2. Load bearing surfaces
   a. 12" x 12"
   b. 12" x 20"
3. Load bearing surface areas
   a. 144 sq in
   b. 240 sq in
4. Static stress on surfaces

a. .452 psi

b. .271 psi

5. Maximum allowable peak deceleration - 44 g's

6. Polyethylene has been determined to be the only suitable packaging material. See Figure 65 for the applicable cushion curves.

7. Cushion selection

a. From the cushion curves it is obvious that 1" and 2" polyethylene do not give the desired protection. However, 3" and 4" polyethylene do protect to 44 g's.

b. Use 3" polyethylene for economy and realize that it only protects to 44 g's between a static stress of .46 and .74 psi. Decide to package to a static stress of .56 psi and take advantage of a 3 g safety factor. With this design

$$\frac{65\#}{.56\#/\text{sq in}} = \underline{\underline{116 \text{ sq in}}}$$

of cushioning will have to be used on all surfaces in order to get the desired protection.

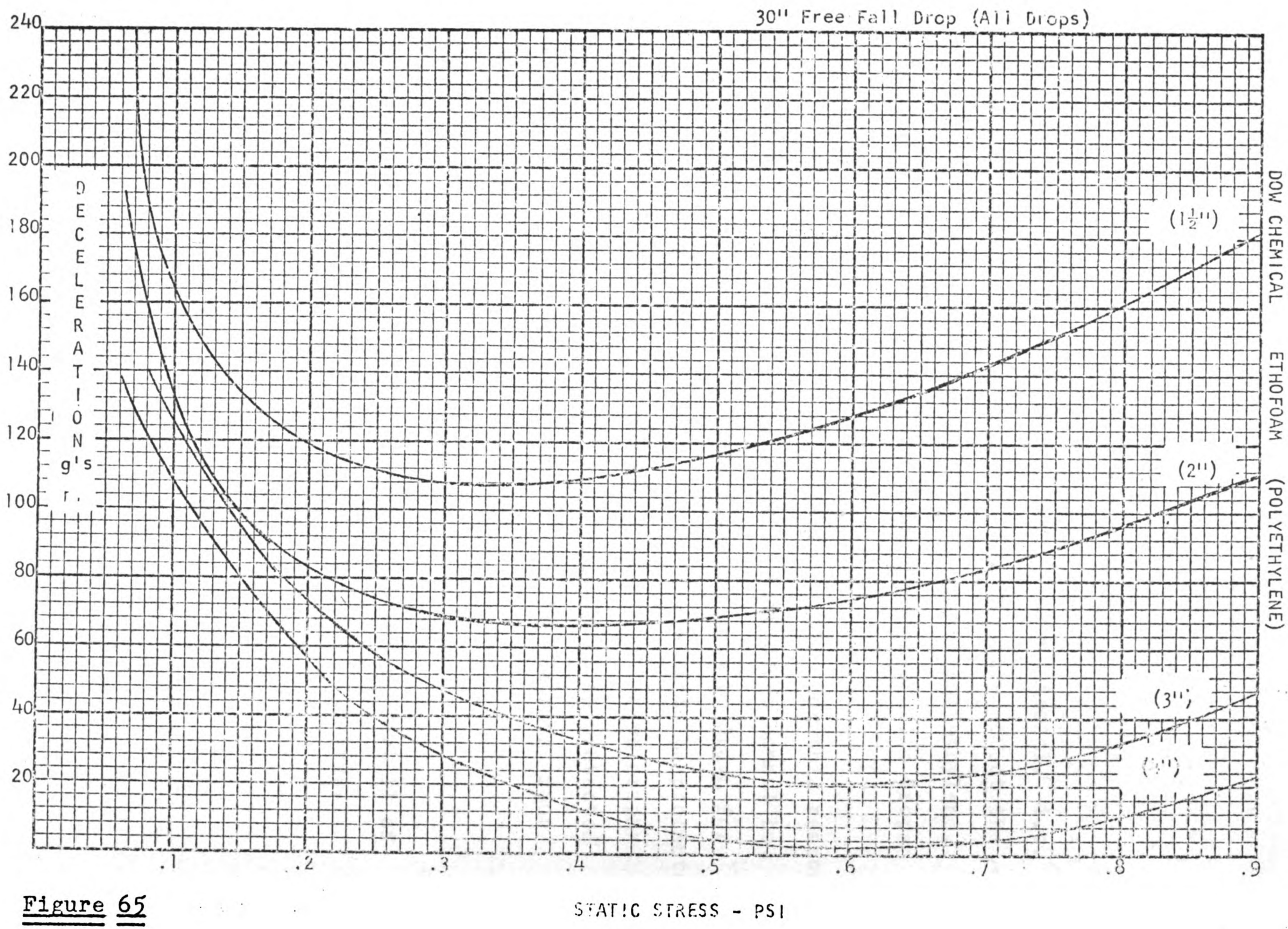

30" Free Fall Drop (All Drops)
DOW CHEMICAL ETHOFOAM (POLYETHYLENE)
DECELERATION g's
240
220
200
180
160
140
120
100
80
60
40
20
(1½")
(2")
(3")
.1
.2
.3
.4
.5
.6
.7
.8
.9
STATIC STRESS - PSI

Figure 65

Comments On Cushion Design

Polyethylene is a consistent cushioning material. i.e. successive loadings--drops--do not significantly effect the thickness or the cushioning ability of foamed polyethylene. Therefore a cushion curve based on an average of five drops can be used in the Cushion Design Method.

Corrugated paperboard is not consistent. For this reason a cushion curve based on an average of five drops cannot be used. Instead, individual cushion curves must be drawn for each of the five drops. Then, if an article is to be protected against five drops, only the area common to all five graphs could be used. Similarly, if an article is to be protected against four drops, only the area common to the first four cushion curves could be used.**

**Theoretically speaking this is true. However, Part II of the results section proves that it is not actually true.

APPENDIX III

A Justification For The Electric Filter Setting

Until 1955 it was necessary to use an accelerometer with a low frequency response or an electric filter in order to monitor the shock pulses generated by shock machines. This was because these early machines had fabricated steel carriages which, when struck by other steel members, created high frequency ringing of the carriage structure. Both of these methods--the filter and the low frequency response accelerometer--gave a readable acceleration vs time curve. However, this curve was not a true indication of the actual shock which was experienced because the "filtering affect" distorted the shape of the acceleration vs time curve by shifting different parts of the spectrum by varying amounts.

This study is concerned with a dynamic drop tester--not a shock machine. However, the same principle applies. A filter should not be used to merely obtain a "clean wave form." Instead, if one is to be used properly, it should be set so that a minimum amount of distortion occurs from the unfiltered signal. The question now becomes, "where is this ideal setting?" One of the most generally accepted theories is that advanced by Sandia Corporation. This group feels that a high frequency cutoff which is five times the basic frequency of a half sine signal does not produce undue distortion of that signal.

The filter used in this study was originally set on this basis. However, to be absolutely certain that the filter did not effect the results, a "margin of safety" was incorporated. This "margin of safety" is illustrated below:

The high frequency cutoff (f) must be <u>at least</u> five times the basic frequency of a half sine signal (F) which represents the shock pulse being measured.

Therefore $f = 5F$

The shocks in this study range from 3 ms to 50 ms in duration. Since the period of a shock pulse equals twice its duration, the periods of these two shock pulses are 6 ms and 100 ms respectively. Now, by knowing the period of these shock pulses, it is relatively easy to calculate F because F = 1/period.

1) The frequency (F) of the 3 ms shock pulse = 1/.006 sec
= <u>166.7 cps</u>

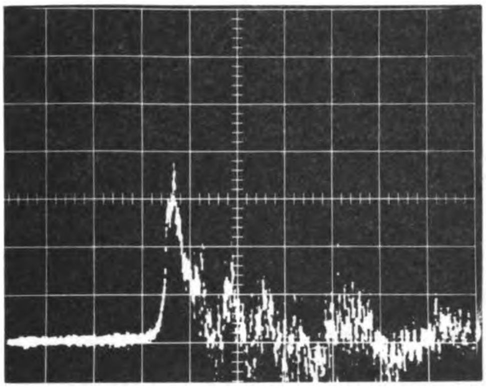
2) The frequency (F) of the 50 ms shock pulse = 1/.1 sec
= <u>10.0 cps</u>

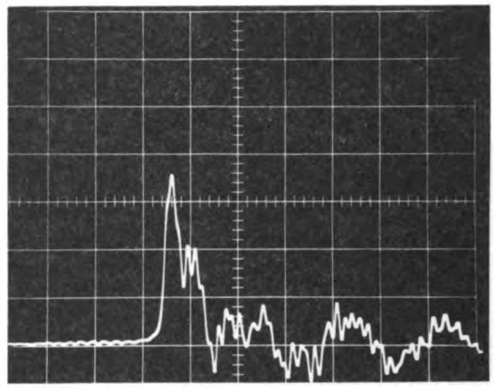
Five times the highest of these two frequencies should be the acceptable high frequency cutoff.

Therefore $f = 5F = 5(166.7) = 833.5$ cps

The filter was set at 1000 cps even though a setting of 833.5 would have been adequate. Thus the safety factor was (1000.0-833.5) 166.5 cps.

The following three pages contain diagrams which illustrate that the filter, which had a high frequency cutoff of 1000 cps, did not significantly affect the results.





Unfiltered

Filtered

Figure 66

Material: 2" ZZ-A Flute

Drop Number: 1

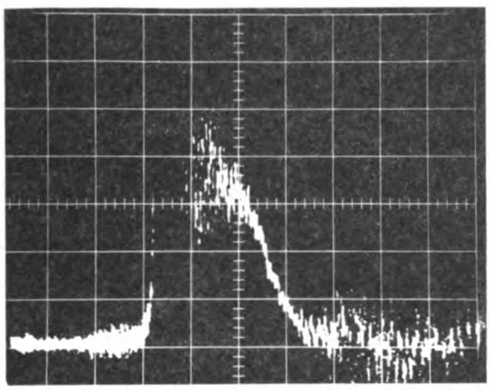
Static Stress: .0625 lbs/sq"

Vertical Sensitivity: .5 volt/division

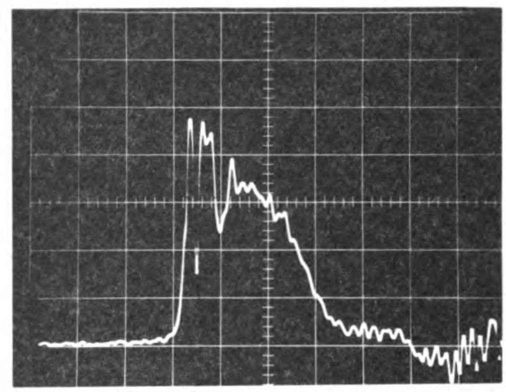
Horizontal Sensitivity: 5 msec/division

Accelerometer Sensitivity: 10.06 mv/g

From the sensitivities, it is obvious that both the filtered and the unfiltered pulse represent a shock of approximately 185 g's magnitude and 5 ms duration. These pictures also illustrate, as do those on the following two pages, that the error in reading the unfiltered pulse is more significant that the error due to filtering.



Unfiltered



Filtered

Figure 67

Material: 2" ZZ-A Flute

Drop Number: 1

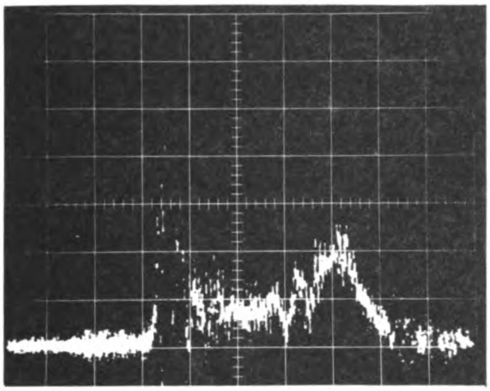
Static Stress: .1875 lbs/sq"

Vertical Sensitivity: .1 volt/division

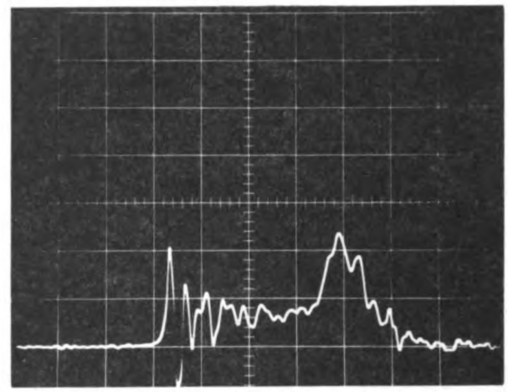
Horizontal Sensitivity: 5 msec/division

Accelerometer Sensitivity: 10.06 mv/g

Both the filtered and the unfiltered pulse represent a shock of approximately 48 g's magnitude and 20 ms duration.



Unfiltered



Filtered

Figure 68

Material:	2" ZZ-A Flute
Drop Number:	1
Static Stress:	.500 lbs/sq"
Vertical Sensitivity:	.2 volt/division
Horizontal Sensitivity:	5 msec/division
Accelerometer Sensitivity:	10.06 mv/g

Both the filtered and the unfiltered pulse represent a shock of approximately 50 g's magnitude and 25 ms duration.

APPENDIX IV

Dynamic Drop Test Data

This appendix contains a partial listing--magnitude only--of the acceleration vs time curves which the oscilloscope recorded for each drop. The durations of the shocks have been omitted because no conclusions regarding them were made. If, however, anyone is interested in these durations for future research, they are on permanent file at the School of Packaging which is located on the campus of Michigan State University.

From this data, it should be noted that five drop averages were only computed for the prestressed material These averages were used to draw cushion curves which are based on a five drop average. Without prestressing, the magnitude of the shock varied so much that a cushion curve based on an average would be useless. Therefore, individual cushion curves were drawn for each drop and the averages were not computed.

TABLE II

Material	Static* Stress	1st** Drop	2nd** Drop	3rd** Drop	4th** Drop	5th** Drop	5 Drop** Average	Drop*** Height
1" ZR-A Flute	.0625	325	300	275	255	240		24"
	.1250	155	130	135	140	135		24"
	.1875	120	116	108	114	130		24"
	.2500	110	90	125	160	175		24"
	.3125	80	90	175	305	350+		24"
	.3750	60	105	250	350+	350+		24"
	.4375	52	165	350+	350+	350+		24"
	.5000	52	330	350+	350+	350+		24"
	.5625	68	350+	350+	350+	350+		24"
	.6250	68	350+	350+	350+	350+		24"
	.6875	100	350+	350+	350+	350+		24"
	.7500	140	350+	350+	350+	350+		24"
	.8125	155	350+	350+	350+	350+		24"
	.8750	180	350+	350+	350+	350+		24"
	.9375	195	350+	350+	350+	350+		24"
	1.000	200	350+	350+	350+	350+		24"

* Units = lbs/sq"
** Units = g's
*** Drop Height Is Specified As "Equivalent Free Fall Height"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
2" ZR-A Flute	.0625	250	250	250	250	270		24"
	.1250	140	124	116	118	100		24"
	.1875	88	68	86	82	70		24"
	.2500	70	58	64	62	58		24"
	.3125	46	40	48	60	68		24"
	.3750	40	40	48	76	120		24"
	.4375	28	40	70	145	235		24"
	.5000	35	38	100	200	290		24"
	.5625	40	40	96	210	300		24"
	.6250	39	74	200	310	350+		24"
	.6875	34	60	200	320	350+		24"
	.7500	27	155	320	350+	350+		24"
	.8125	37	135	320	350+	350+		24"
	.8750	30	170	330	350+	350+		24"
	.9375	30	200	350	350+	350+		24"
	1.000	48	200	330	350+	350+		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
3" ZR-A Flute	.0625	235	230	230	220	220		24"
	.1250	120	95	95	95	105		24"
	.1875	88	72	72	68	68		24"
	.2500	62	56	54	54	54		24"
	.3125	54	44	40	44	48		24"
	.3750	38	40	40	44	48		24"
	.4375	32	36	38	46	60		24"
	.5000	29	29	33	54	106		24"
	.5625	22	27	44	80	120		24"
	.6250	25	24	56	135	200		24"
	.6875	21	29	90	175	225		24"
	.7500	16	38	128	195	250		24"
	.8125	16	38	115	195	245		24"
	.8750	16	52	150	230	280		24"
	.9375	15	52	150	225	275		24"
	1.000	14	76	175	250	295		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
1" AV-A Flute	.0625	280	215	170	165	185		24"
	.1250	125	95	78	84	118		24"
	.1875	86	70	150	200	245		24"
	.2500	54	145	240	320	350+		24"
	.3125	54	245	340	350+	350+		24"
	.3750	80	265	350+	350+	350+		24"
	.4375	100	280	350+	350+	350+		24"
	.5000	116	275	350+	350+	350+		24"
	.5625	150	340	350+	350+	350+		24"
	.6250	160	350+	350+	350+	350+		24"
	.6875	220	350+	350+	350+	350+		24"
	.7500	220	350+	350+	350+	350+		24"
	.8125	230	350+	350+	350+	350+		24"
	.8750	250	350+	350+	350+	350+		24"
	.9375	300	350+	350+	350+	350+		24"
	1.000	350+	350+	350+	350+	350+		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
2" AV-A Flute	.0625	200	190	160	135	145		24"
	.1250	105	78	84	60	85		24"
	.1875	78	50	58	64	76		24"
	.2500	50	38	68	110	135		24"
	.3125	41	40	104	155	190		24"
	.3750	42	80	150	180	200		24"
	.4375	30	112	185	230	270		24"
	.5000	30	126	190	250	290		24"
	.5625	35	150	220	280	320		24"
	.6250	43	155	230	290	310		24"
	.6875	56	200	255	350	350+		24"
	.7500	60	185	300	350+	350+		24"
	.8125	70	235	350	350+	350+		24"
	.8750	74	220	340	350+	350+		24"
	.9375	78	220	340	350+	350+		24"
	1.000	86	260	350	350+	350+		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
3" AV-A Flute	.0625	130	135	135	135	130		24"
	.1250	74	64	64	54	58		24"
	.1875	48	40	38	40	48		24"
	.2500	36	28	30	36	60		24"
	.3125	34	34	36	62	76		24"
	.3750	24	28	66	96	112		24"
	.4375	20	40	84	116	132		24"
	.5000	20	60	120	145	170		24"
	.5625	16	88	135	165	200		24"
	.6250	18	94	135	180	200		24"
	.6875	20	82	145	170	210		24"
	.7500	21	108	160	210	230		24"
	.8125	33	126	185	250	270		24"
	.8750	36	125	190	240	270		24"
	.9375	44	150	205	260	280		24"
	1.000	48	150	200	240	280		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
1" RR-A Flute	.0625	350	340	320	310	310		24"
	.1250	215	145	140	130	115		24"
	.1875	130	76	100	105	105		24"
	.2500	100	72	90	150	170		24"
	.3125	84	72	120	230	310		24"
	.3750	72	85	270	320	350+		24"
	.4375	58	145	340	350+	350+		24"
	.5000	52	250	350+	350+	350+		24"
	.5625	48	260	350+	350+	350+		24"
	.6250	60	350+	350+	350+	350+		24"
	.6875	68	350+	350+	350+	350+		24"
	.7500	98	350+	350+	350+	350+		24"
	.8125	120	350+	350+	350+	350+		24"
	.8750	170	350+	350+	350+	350+		24"
	.9375	350+	350+	350+	350+	350+		24"
	1.000	350+	350+	350+	350+	350+		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
2" RR-A Flute	.0625	300	310	310	300	310		24"
	.1250	180	160	150	140	130		24"
	.1875	90	80	86	88	76		24"
	.2500	72	72	58	70	60		24"
	.3125	60	50	52	60	72		24"
	.3750	58	48	48	52	100		24"
	.4375	56	48	48	78	155		24"
	.5000	54	42	56	170	250		24"
	.5625	44	40	130	245	340		24"
	.6250	48	54	140	240	340		24"
	.6875	36	88	250	300	350+		24"
	.7500	30	70	215	330	350+		24"
	.8125	36	128	300	350+	350+		24"
	.8750	30	145	320	350+	350+		24"
	.9375	26	170	340	350+	350+		24"
	1.000	28	200	340	350+	350+		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
3" RR-A Flute	.0625	240	240	240	240	240		24"
	.1250	130	120	125	110	100		24"
	.1875	100	80	74	72	72		24"
	.2500	70	58	54	54	54		24"
	.3125	50	59	59	55	50		24"
	.3750	42	36	41	40	38		24"
	.4375	36	38	38	38	44		24"
	.5000	34	29	29	38	96		24"
	.5625	32	28	32	52	112		24"
	.6250	25	24	38	110	175		24"
	.6875	23	26	66	140	200		24"
	.7500	20	28	108	195	260		24"
	.8125	20	34	125	210	275		24"
	.8750	19	54	175	260	290		24"
	.9375	16	58	175	260	290		24"
	1.000	17	56	175	240	280		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
1" FR-Q Flute	.0625	290	245	210	180	160		24"
	.1250	140	80	100	115	165		24"
	.1875	86	135	105	105	125		24"
	.2500	68	125	150	170	210		24"
	.3125	60	250	290	350+	350+		24"
	.3750	68	260	290	350+	350+		24"
	.4375	110	350+	350+	350+	350+		24"
	.5000	130	350+	350+	350+	350+		24"
	.5625	140	350+	350+	350+	350+		24"
	.6250	200	350+	350+	350+	350+		24"
	.6875	250	350+	350+	350+	350+		24"
	.7500	300	350+	350+	350+	350+		24"
	.8125	350+	350+	350+	350+	350+		24"
2" FR-Q Flute	.0625	260	255	245	235	225		24"
	.1250	96	78	84	84	82		24"
	.1875	74	52	52	60	66		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
2" FR-Q Flute	.2500	56	54	70	70	84		24"
	.3125	44	44	44	130	220		24"
	.3750	34	36	126	260	350+		24"
	.4375	32	78	235	350+	350+		24"
	.5000	24	92	280	350+	350+		24"
	.5625	28	126	350+	350+	350+		24"
	.6250	26	152	350+	350+	350+		24"
	.6875	24	260	350+	350+	350+		24"
	.7500	30	350+	350+	350+	350+		24"
	.8125	62	350+	350+	350+	350+		24"
	.8750	76	350+	350+	350+	350+		24"
	.9375	75	350+	350+	350+	350+		24"
	1.000	90	350+	350+	350+	350+		24"
3" FR-Q Flute	.0625	240	225	180	150	160		24"
	.1250	120	100	90	98	98		24"
	.1875	90	80	58	60	62		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
3" FR-Q Flute	.2500	60	52	50	54	54		24"
	.3125	44	38	44	48	58		24"
	.3750	38	32	34	48	72		24"
	.4375	30	26	64	140	200		24"
	.5000	25	35	65	115	190		24"
	.5625	24	42	80	200	290		24"
	.6250	19	30	102	200	280		24"
	.6875	20	34	144	250	350+		24"
	.7500	17	150	350+	350+	350+		24"
	.8125	15	130	350+	350+	350+		24"
	.8750	18	135	350+	350+	350+		24"
	.9375	12	105	350+	350+	350+		24"
	1.000	18	145	350+	350+	350+		24"
1" AR-Q Flute	.0625	230	190	160	150	150		24"
	.1250	160	80	100	115	120		24"
	.1875	94	72	148	270	350+		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
1" AR-Q Flute	.2500	52	120	250	350+	350+		24"
	.2813	52	155	275	350+	350+		24"
	.3125	56	280	350+	350+	350+		24"
	.3750	92	350+	350+	350+	350+		24"
	.4375	110	350+	350+	350+	350+		24"
	.5000	170	350+	350+	350+	350+		24"
	.5625	180	350+	350+	350+	350+		24"
	.6250	190	350+	350+	350+	350+		24"
	.6875	250	350+	350+	350+	350+		24"
	.7500	350+	350+	350+	350+	350+		24"
2" AR-Q Flute	.0625	150	130	130	130	130		24"
	.1250	84	70	72	68	72		24"
	.1875	52	42	48	68	92		24"
	.2500	42	40	60	100	140		24"
	.3125	36	44	84	142	180		24"
	.3750	28	84	170	250	350+		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
2" AR-Q Flute	.4375	24	90	220	350+	350+		24"
	.5000	28	114	260	350+	350+		24"
	.5625	38	170	290	350+	350+		24"
	.6250	42	225	350+	350+	350+		24"
	.6875	48	210	350+	350+	350+		24"
	.7500	54	230	350+	350+	350+		24"
	.8125	58	350+	350+	350+	350+		24"
	.8750	64	350+	350+	350+	350+		24"
	.9375	88	350+	350+	350+	350+		24"
	1.000	92	350+	350+	350+	350+		24"
3" AR-Q Flute	.0625	150	155	155	155	170		24"
	.1250	90	64	60	68	60		24"
	.1875	60	72	50	50	50		24"
	.2500	36	32	36	40	54		24"
	.3125	34	34	36	44	60		24"
	.3750	30	30	56	92	124		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
3" AR-Q Flute	.4375	26	26	50	96	160		24"
	.5000	18	32	56	116	205		24"
	.5625	18	56	130	215	285		24"
	.6250	22	44	128	245	350+		24"
	.6875	21	132	280	350+	350+		24"
	.7500	18	96	235	350+	350+		24"
	.8125	16	116	290	350+	350+		24"
	.8750	24	160	350+	350+	350+		24"
	.9375	29	160	350+	350+	350+		24"
	1.000	34	190	350+	350+	350+		24"
1" AR-A Flute	.0625	350	350	350+	350+	350+		24"
	.1250	250	180	160	150	125		24"
	.1875	125	110	118	104	120		24"
	.2500	105	90	88	114	180		24"
	.3125	76	76	118	180	240		24"
	.3750	72	92	230	350+	350+		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
1" AR-A Flute	.4375	70	96	270	350+	350+		24"
	.5000	68	112	290	350+	350+		24"
	.5625	72	160	350+	350+	350+		24"
	.6250	60	300	350+	350+	350+		24"
	.6875	60	350+	350+	350+	350+		24"
	.7500	60	350+	350+	350+	350+		24"
	.8125	68	350+	350+	350+	350+		24"
	.8750	100	350+	350+	350+	350+		24"
	.9375	135	350+	350+	350+	350+		24"
	1.000	175	350+	350+	350+	350+		24"
2" AR-A Flute	.0625	350	350+	350+	350+	350+		24"
	.1250	200	175	160	150	150		24"
	.1875	100	98	88	78	88		24"
	.2500	92	88	80	84	72		24"
	.3125	84	62	60	62	72		24"
	.3750	72	58	46	52	72		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
2" AR-A Flute	.4375	54	38	46	120	170		24"
	.5000	58	36	46	112	175		24"
	.5625	40	40	55	130	185		24"
	.6250	35	39	112	200	240		24"
	.6875	34	48	164	200	220		24"
	.7500	37	56	145	185	200		24"
	.8125	28	100	220	350+	350+		24"
	.8750	28	114	260	350+	350+		24"
	.9375	30	136	300	350+	350+		24"
	1.000	31	145	350+	350+	350+		24"
3" AR-A Flute	.0625	280	300	295	300	300		24"
	.1250	215	210	200	200	195		24"
	.1875	170	105	90	90	98		24"
	.2500	84	68	68	60	60		24"
	.3125	60	54	48	48	48		24"
	.3750	64	48	48	44	54		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
3" AR-A Flute	.4375	60	44	40	44	44		24"
	.5000	56	44	44	38	44		24"
	.5625	42	30	28	40	60		24"
	.6250	36	26	30	60	98		24"
	.6875	34	26	44	88	124		24"
	.7500	32	32	60	98	130		24"
	.8125	28	24	56	98	140		24"
	.8750	27	22	56	95	130		24"
	.9375	22	22	77	144	225		24"
	1.000	22	20	56	110	155		24"
1" ZZ-A Flute	.0625	190	140	120	130	125		24"
	.1250	150	100	96	150	185		24"
	.1875	54	145	300	350+	350+		24"
	.2500	70	300	350+	350+	350+		24"
	.3125	75	300	350+	350+	350+		24"
	.3750	105	350	350+	350+	350+		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
1" ZZ-A Flute	.4375	170	350+	350+	350+	350+		24"
	.5000	190	350+	350+	350+	350+		24"
	.5625	285	350+	350+	350+	350+		24"
	.6250	350+	350+	350+	350+	350+		24"
2" ZZ-A Flute	.0625	170	130	110	115	105		24"
	.1250	76	60	52	56	60		24"
	.1875	48	32	52	95	125		24"
	.2500	35	36	120	215	270		24"
	.3125	28	80	230	275	320		24"
	.3750	34	125	240	320	350+		24"
	.4375	32	250	350	350+	350+		24"
	.5000	54	260	330	350+	350+		24"
	.5625	72	330	350+	350+	350+		24"
	.6250	88	350	350+	350+	350+		24"
	.6875	130	350+	350+	350+	350+		24"
	.7500	150	350	350+	350+	350+		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
2" ZZ-A Flute	.8125	165	350+	350+	350+	350+		24"
	.8750	175	350+	350+	350+	350+		24"
	.9375	195	350+	350+	350+	350+		24"
	1.000	220	350+	350+	350+	350+		24"
3" ZZ-A Flute	.0625	120	100	100	100	92		24"
	.1250	58	52	54	52	52		24"
	.1875	42	40	38	40	38		24"
	.2500	34	28	30	55	104		24"
	.3125	25	28	64	130	190		24"
	.3750	19	28	124	195	240		24"
	.4375	19	72	175	260	300		24"
	.5000	17	120	240	320	350+		24"
	.5625	15	165	290	350	350+		24"
	.6250	24	175	320	350+	350+		24"
	.6875	38	230	350+	350+	350+		24"
	.7500	49	230	350+	350+	350+		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
3" ZZ-A Flute	.8125	58	280	350+	350+	350+		24"
	.8750	78	330	350+	350+	350+		24"
	.9375	80	350+	350+	350+	350+		24"
	1.000	88	350+	350+	350+	350+		24"
1" AS-A Flute	.0625	350+	350+	350+	350+	350+		24"
	.1250	210	175	175	175	175		24"
	.1875	150	125	114	126	110		24"
	.2500	118	98	96	86	106		24"
	.3125	108	74	90	100	190		24"
	.3750	108	76	124	200	265		24"
	.4375	104	68	245	350+	350+		24"
	.5000	78	130	325	350+	350+		24"
	.5625	76	175	350+	350+	350+		24"
	.6250	58	200	350+	350+	350+		24"
	.6875	60	275	350+	350+	350+		24"
	.7500	58	350+	350+	350+	350+		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
1" AS-A Flute	.8125	68	350+	350+	350+	350+		24"
	.8750	86	350+	350+	350+	350+		24"
	.9375	90	350+	350+	350+	350+		24"
	1.000	110	350+	350+	350+	350+		24"
2" AS-A Flute	.0625	290	290	290	290	290		24"
	.1250	210	200	220	190	130		24"
	.1875	134	120	104	98	102		24"
	.2500	100	90	78	80	80		24"
	.3125	76	72	72	72	68		24"
	.3750	72	58	58	58	70		24"
	.4375	53	52	58	60	72		24"
	.5000	58	44	52	66	100		24"
	.5625	44	38	56	104	180		24"
	.6250	42	36	54	150	240		24"
	.6875	40	36	94	190	260		24"
	.7500	36	40	134	240	290		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
2" AS-A Flute	.8125	42	48	165	255	310		24"
	.8750	34	50	180	270	320		24"
	.9375	36	65	200	290	330		24"
	1.000	36	100	230	320	350+		24"
3" AS-A Flute	.0625	285	285	285	285	285		24"
	.1250	155	160	155	160	165		24"
	.1875	135	105	100	100	95		24"
	.2500	84	76	76	76	76		24"
	.3125	76	60	64	60	58		24"
	.3750	58	58	56	56	56		24"
	.4375	52	52	54	48	50		24"
	.5000	46	40	40	40	48		24"
	.5625	40	36	40	42	46		24"
	.6250	36	32	36	48	62		24"
	.6875	30	28	32	54	92		24"
	.7500	34	30	36	60	112		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
3" ZZ-A Flute	.8125	58	280	350+	350+	350+		24"
	.8750	78	330	350+	350+	350+		24"
	.9375	80	350+	350+	350+	350+		24"
	1.000	88	350+	350+	350+	350+		24"
1" AS-A Flute	.0625	350+	350+	350+	350+	350+		24"
	.1250	210	175	175	175	175		24"
	.1875	150	125	114	126	110		24"
	.2500	118	98	96	86	106		24"
	.3125	108	74	90	100	190		24"
	.3750	108	76	124	200	265		24"
	.4375	104	68	245	350+	350+		24"
	.5000	78	130	325	350+	350+		24"
	.5625	76	175	350+	350+	350+		24"
	.6250	58	200	350+	350+	350+		24"
	.6875	60	275	350+	350+	350+		24"
	.7500	58	350+	350+	350+	350+		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
1" AS-A Flute	.8125	68	350+	350+	350+	350+		24"
	.8750	86	350+	350+	350+	350+		24"
	.9375	90	350+	350+	350+	350+		24"
	1.000	110	350+	350+	350+	350+		24"
2" AS-A Flute	.0625	290	290	290	290	290		24"
	.1250	210	200	220	190	130		24"
	.1875	134	120	104	98	102		24"
	.2500	100	90	78	80	80		24"
	.3125	76	72	72	72	68		24"
	.3750	72	58	58	58	70		24"
	.4375	53	52	58	60	72		24"
	.5000	58	44	52	66	100		24"
	.5625	44	38	56	104	180		24"
	.6250	42	36	54	150	240		24"
	.6875	40	36	94	190	260		24"
	.7500	36	40	134	240	290		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
2" AS-A Flute	.8125	42	48	165	255	310		24"
	.8750	34	50	180	270	320		24"
	.9375	36	65	200	290	330		24"
	1.000	36	100	230	320	350+		24"
3" AS-A Flute	.0625	285	285	285	285	285		24"
	.1250	155	160	155	160	165		24"
	.1875	135	105	100	100	95		24"
	.2500	84	76	76	76	76		24"
	.3125	76	60	64	60	58		24"
	.3750	58	58	56	56	56		24"
	.4375	52	52	54	48	50		24"
	.5000	46	40	40	40	48		24"
	.5625	40	36	40	42	46		24"
	.6250	36	32	36	48	62		24"
	.6875	30	28	32	54	92		24"
	.7500	34	30	36	60	112		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
3" AS-A Flute	.8125	38	28	32	76	136		24"
	.8750	34	22	44	100	150		24"
	.9375	34	28	60	140	180		24"
	1.000	26	32	88	155	210		24"
1" PP-A Flute (Sandusky)	.0625	55	58	96	130	145		24"
	.0937	61	126	290	350+	350+		24"
	.1250	85	265	270	350+	350+		24"
	.1560	160	350+	350+	350+	350+		24"
	.1875	190	350+	350+	350+	350+		24"
	.2190	190	350+	350+	350+	350+		24"
	.2500	290	350+	350+	350+	350+		24"
	.2810	300	350+	350+	350+	350+		24"
	.3125	350+	350+	350+	350+	350+		24"
2" PP-A Flute (Sandusky)	.0625	49	47	47	48	53		24"
	.0937	26	30	39	61	98		24"
	.1250	30	52	100	150	190		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
2" PP-A Flute (Sandusky)	.1562	30	85	160	190	230		24"
	.1880	55	200	240	275	285		24"
	.2500	80	245	350+	350+	350+		24"
	.3125	140	350+	350+	350+	350+		24"
	.3750	145	350+	350+	350+	350+		24"
	.4375	240	350+	350+	350+	350+		24"
	.5000	265	350+	350+	350+	350+		24"
	.5625	350+	350+	350+	350+	350+		24"
3" PP-A Flute (Sandusky)	.0625	32	32	28	27	28		24"
	.1250	16	20	45	74	88		24"
	.1880	12	65	116	148	180		24"
	.2500	35	140	205	265	350+		24"
	.3125	55	165	270	350+	350+		24"
	.3750	90	280	350+	350+	350+		24"
	.4375	106	260	350+	350+	350+		24"
	.5000	140	350+	350+	350+	350+		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
3" PP-A Flute (Sandusky)	.5625	148	350+	350+	350+	350+		24"
	.6250	180	350+	350+	350+	350+		24"
	.6875	190	350+	350+	350+	350+		24"
	.7500	200	350+	350+	350+	350+		24"
	.8125	260	350+	350+	350+	350+		24"
	.8750	350+	350+	350+	350+	350+		24"
1" PP-A Flute (Gloucester)	.0625	76	78					24"
	.0937	68	130					24"
	.1250	82	250					24"
	.1560	95	350+					24"
	.1875	160	350+					24"
	.2190	205	350+					24"
	.2500	255	350+					24"
	.2810	290	350+					24"
	.3130	300	350+					24"
	.3440	350+	350+					24"

Only Two Drops Made On The 1" Gloucester Material

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
1 3/4" PP-A Flute (Gloucester)	.0625	62	58	64	70	70		24"
	.1250	33	60	85	120	165		24"
	.1560	41	110	200	350+	350+		24"
	.1875	40	135	350+	350+	350+		24"
	.2190	42	165	350+	350+	350+		24"
	.2500	50	240	350+	350+	350+		24"
	.2810	66	280	350+	350+	350+		24"
	.3130	85	350+	350+	350+	350+		24"
	.3440	120	350+	350+	350+	350+		24"
	.3750	125	350+	350+	350+	350+		24"
	.4060	130	350+	350+	350+	350+		24"
	.4380	175	350+	350+	350+	350+		24"
	.4690	205	350+	350+	350+	350+		24"
	.5000	205	350+	350+	350+	350+		24"
	.5625	215	350+	350+	350+	350+		24"
	.6250	240	350+	350+	350+	350+		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
1 3/4" PP-A Flute (Gloucester)	.6875	290	350+	350+	350+	350+		24"
	.7500	350+	350+	350+	350+	350+		24"
1" PP-Q Flute	.0430	60	72	135	150	160		24"
	.0625	100	235	280	300	350+		24"
	.1250	235	350+	350+	350+	350+		24"
	.1875	350+	350+	350+	350+	350+		24"
2" PP-Q Flute	.0430	52	36	44	38	50		24"
	.0625	28	37	78	96	108		24"
	.1250	66	190	265	300	350+		24"
	.1875	210	350+	350+	350+	350+		24"
	.2500	240	350+	350+	350+	350+		24"
	.3125	320	350+	350+	350+	350+		24"
	.3750	350+	350+	350+	350+	350+		24"
3" PP-Q Flute	.0430	34	36	30	34	32		24"
	.0625	20	26	34	52	68		24"
	.1250	28	100	155	185	220		24"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
3" PP-Q Flute	.1875	58	170	280	340	350+		24"
	.2500	100	280	350+	350+	350+		24"
	.3125	140	350+	350+	350+	350+		24"
	.3750	150	350+	350+	350+	350+		24"
	.4375	210	350+	350+	350+	350+		24"
	.5000	350+	350+	350+	350+	350+		24"
3" ZR-A Flute*	.0625	60	64	64	62	63	63	24"
	.1250	54	52	54	56	58	55	24"
	.1875	68	70	76	76	78	75	24"
	.2500	84	100	116	125	120	115	24"
	.3125	85	100	120	130	140	123	24"
	.3750	85	125	160	185	200	168	24"
	.4375	90	120	150	170	185	156	24"
	.5000	100	155	190	230	250	206	24"
	.5625	110	180	235	280	310	251	24"
3" AV-A Flute*	.0625	44	48	48	46	48	48	24"

* Prestressed Material

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
3" AV-A Flute*	.1250	50	58	60	60	60	58	24"
	.1875	72	86	100	100	106	98	24"
	.2500	100	126	145	140	130	135	24"
	.3125	110	140	155	165	175	159	24"
	.3750	105	135	160	175	180	163	24"
	.4375	120	150	170	190	195	176	24"
	.5000	130	165	185	200	210	190	24"
	.5625	120	180	210	250	280	230	24"
1" PP-A Flute	.0625	56						18"
	.0938	47						18"
	.1250	56		Only One 18" Drop Made				18"
	.1875	100		On The PP-A Flute				18"
	.2500	175		Material				18"
	.3125	240						18"
	.3750	260						18"
	.4375	300						18"

* Prestressed Material

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
1" PP-A Flute	.5000	350+						18"
2" PP-A Flute	.0625	30						18"
	.1250	18						18"
	.1875	28						18"
	.2500	56						18"
	.3125	70						18"
	.3750	86			Only One 18" Drop Made			18"
	.4375	135			On The PP-A Flute			18"
	.5000	150			Material			18"
	.5625	160						18"
	.6250	185						18"
	.6875	220						18"
	.7500	230						18"
3" PP-A Flute	.0625	40						18"
	.1250	20						18"
	.1875	14						18"

Material	Static Stress	1st. Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
3" PP-A Flute	.2500	12						18"
	.3125	26						18"
	.3750	38						18"
	.4375	44		Only One 18" Drop Made				18"
	.5000	56		On The PP-A Flute				18"
	.5625	68		Material				18"
	.6250	92						18"
	.6875	100						18"
	.7500	155						18"
1" PP-A Flute	.0625	78		Only One 30" Drop Made				30"
	.1250	160		On The PP-A Flute				30"
	.1875	340		Material				30"
	.2500	350+						30"
2" PP-A Flute	.0625	60						30"
	.1250	50						30"
	.1875	100						30"

Material	Static Stress	1st Drop	2nd Drop	3rd Drop	4th Drop	5th Drop	5 Drop Average	Drop Height
2" PP-A Flute	.2500	170						30"
	.3125	250						30"
	.3750	290						30"
	.4375	350+						30"
3" PP-A Flute	.0625	44						30"
	.1250	24			Only One 30" Drop Made			30"
	.1875	40			On The PP-A Flute			30"
	.2500	80			Material			30"
	.3125	110						30"
	.3750	145						30"
	.4375	200						30"
	.5000	270						30"
	.5625	350+						30"