12-1963

The Effect of Thrust on the Development of Strength with the Mead Refiner

G. Hayward
Western Michigan University

The Effect of Thrust on the Development of Strength With the Mead Refiner

ABSTRACT

Several different thrust pressures were exerted on the plates of the Mead Laboratory Refiner and pulp samples were refined over a wide freeness range for each of the several pressures. The strength characteristics developed were measured and it was found that maximum burst and tensile strength was developed by a thrust pressure of 31.22 pounds. Maximum tearing strength was developed at a thrust pressure of 25.94 pounds.

The refining time required to reach a given freeness increased as the thrust was reduced, but reached a maximum at 20.66 pounds and remained constant for lesser pressures.

Some General Aspects of Beating

The terms beating and refining are used in the paper industry to describe the operation of mechanically treating pulp fibers. Refining refers, in the usual sense, to fiber separation and fiber cutting, whereas beating action may include these two effects, and also a fibrillating or bruising effect on the fibers.

Caskey (1) states that beating in its broadest sense includes a wide range of effects from:

1. Cutting without wet beating, i.e., blotting paper.
2. Wet beating without cutting, i.e., grease proof or glassine paper.
3. The range between these two extremes in which most mills operate their beaters.

The following things are listed as effects of beating or refining on wood pulp by Casey (2):

1. Increased freeness
2. Increased viscosity
3. Decreased tear
4. Increased burst
5. Increased tensile
6. Fiber swelling and increased flexibility
7. Breaking of the primary wall
8. Cutting the fiber

Beating and refining are primarily mechanical processes resulting in physical changes in the fibrous structure and colloidal nature of the pulp. No major chemical changes may occur as a result of the great increase in surface activity of the fiber.

The Effect of Mechanical Action on the Cellulose Fiber

In July, 1943, James d'AClark (3) published a theory of beating which explains the effect of mechanical treatment on fibers. He maintains that mechanical or chemical treatment of fibers causes the primary wall to be partly cracked, rubbed loose or removed from the fiber.

This primary wall, although consisting of carbohydrates, is not true cellulose, and is not capable of adhering to adjacent fibers through secondary valences. The primary wall is completely insoluble in water and forms an elastic protective layer or sheath around the outside of the fibers.

Further beating causes this primary wall to be rubbed or sheared off as the fibers become wetted and swell in the water medium. Besides rubbing off most of the primary wall, a coarse fibrillation also occurs. This exposes the inner cellulose material and a surface colloidal solution forms on the new surfaces.

As beating proceeds still further, the fibers become mashed up and reticulated, as well as being further shortened. The additional strengthening causes are, in general, almost completely offset by the shortening and weakening of the mashed fibers. After this point, therefore, little further strength can be developed by beating and because of progressive shortening of the fiber length the strength of the sheet may actually decrease.

The exposed surfaces of the fibers are strongly hydrophilic and form a surface colloidal solution with water. The layers of water form what is termed "hydration" in the papermaking sense. As the fiber dries, the hydroxyl groups are freed from water and their residual valencies are mutually satisfied by adjacent cellulose molecules, thus causing secondary valence bonds to form.

Cutting and Fibrillation

Nadleman (4) states that these are two basic actions of stock preparation equipment: (1) the fibers may be cut and (2) the fibers may be split and unraveled.

Long fibers provide more area of contact for bonding than do short fibers and therefore should produce a stronger sheet of paper. It would seem that a high degree of cutting action should be avoided in any type of refining operation. Short fibers provide "bridges" for gaps between longer

fibers and thereby improve formation and optical qualities, and cannot be eliminated from the sheet.

Abbott (5) found that maximum fibrillation leads to maximum folding strength. A slight amount of cutting increases pulp tensile strength, but with larger amounts of cut stock the tensile strength decreases rapidly. Fibrillation was found to be the prime requisite for maximum burst, while cutting exerts an adverse effect if it is extreme. As with tensile a slight amount of cut stock appears to be beneficial to burst strength development. Fibrillation seems to be of the utmost importance for optimum tear development, but limited cutting is also required. Highly fibrillated stock gave greater opacity values than did highly cut stock and fibrillation appears to play the dominant role.

The freeness of a pulp does not distinguish between slowness due to short fibers and slowness due to fibrillation, since both reduce the average size of the passages in the wet mat (2).

Because of this indefinite nature, the freeness value does not always correlate with the strength of the pulp. For example, Sutermister (6) reports that the tear factor on a Draft pulp varied from 1.5 to 2.75, even though the pulp was beaten to the same freeness value. In order to obtain more complete information on a given

pulp, it is desirable to run a fiber classification according to length, in addition to the freeness test.

Variables in Beating and Refining

Thus far, this paper has been limited to a discussion of what happens to pulp when it is placed under mechanical stress in an instrument designed for the preparation of fibers for paper production. It has been stated that there are two basic actions of stock preparation equipment, i.e., cutting and fibrillation. The discussion will now be turned to the aspect of what can be done to control the action of the stock preparation equipment to get the desired results.

Caskey's theory (1) is that when speaking of beaters when the roll bar meets the bedplate, the cutting edges have completed their tasks the moment they touch one another, while the wet beating surfaces have not come into action at all. The cutting effect is dependent only on the number of bars. Wet beating occurs as the surface of the bar passes over that of the plate. The wet beating power of any beater depends solely on the total thickness of the bars in the roll and the total thickness of the bars in the bedplate.

The above theory has to do with design of equipment. Equipment with many narrow bars will give primarily

cutting action while those providing a large amount of contact area will give good wet beating action.

The choice of equipment then, is of great importance in determining the action on the pulp. Jordans and other types of conical refiners are noted for cutting the fibers while the conventional Hollander beater will give a higher degree of fibrillation.

In order to obtain the maximum refining treatment and yet secure some jordaning characteristics, many mills have installed jordans having three-eighths inch duplex plug and shell bar structures.(7). This arrangement gives contact area and prevents the operator from setting the jordan up to bar to bar metal contact. This treatment provides reasonable tear development and good mullen and tensile development.

Clark (3) maintains that it is probable that the efficiency of removal of the primary layer by rubbing in the tub and under the roll accounts for the superiority of beating results with the old-fashioned Hollander. The delay necessary before setting down the roll hard on the stuff for the best results and also the advantages of high consistency in beating fit in very nicely with this conception.

The difference between the refiner and the jordan is that the refiner utilizes wide bar (1/2 to 3/4 inch

tackle) operating at high speed and relatively high stock consistency (5-6%). The high speed and large areas of bar prevent close intimacy of the bar structure at the relatively low horsepower connected. Any attempt to bring it into cutting intimacy or comparable intimacy of the jordan would tend to stall the unit. Jordaning comprises the use of narrow bar tackle, low peripheral speed, high horsepower for the low spped, and relatively low consistency. The large amount of horsepower connected permits the operator to place the jordan in close intimacy or in bar to bar metal contact without stalling the connected motor. Fiber length reduction is an important function of jordan treatment (7).

Certain things can be done to change the action of the beater. Baxter (8) maintains that if a slowness of stock due to cutting of the fiber is wanted, the flybar edges must be sharp. Also, the flybars preferably should have narrow edges and the wood spaces between bars should be well under cut. "Hydration" and the production of long slow stuff is promoted by long, continued beating with very light pressure of the roll on the bedplate, and with dull and wide edge flybars and smooth bedplates. The action is that of bruising and mashing rather than cutting.

With the disk refiner, Brown (9) maintained that with pulps of high alpha cellulose content, high bar-

pressures can be used because they are not only tough but pliant, and they do not cut readily when well designed equipment is used for stock preparation. Only extremely light pressures may be exerted between the bars of the refiner when ground-wood is used, otherwise, the pulp is reduced to fines and flour, by breaking, by cutting, and by grinding. Though higher bar pressures may be used with semi chemical pulps than with groundwood, the amount of such pressure is relative to the degree to which the lignin residues are present. When refining regular chemical pulps we are dealing with pliant tough fibers which require and will stand up under heavy loadings.

Caskey (1) states that "dull beater roll bars, high consistency of stock, and low temperature favor the rubbing or bruising action. On the other hand, if the consistency is low, the knives sharp, and the beater roll is put down hard on the bedplate, the action becomes predominantly of a cutting nature. In general, beaters with dull bars produce papers with higher bursting, tensile, and tearing strengths than beaters with sharp bars."

From the above discussion it can be seen that there are many things which affect the performance of a beater or refining instrument. The type and sharpness of the tackle, the space between the bars, width of the bars,

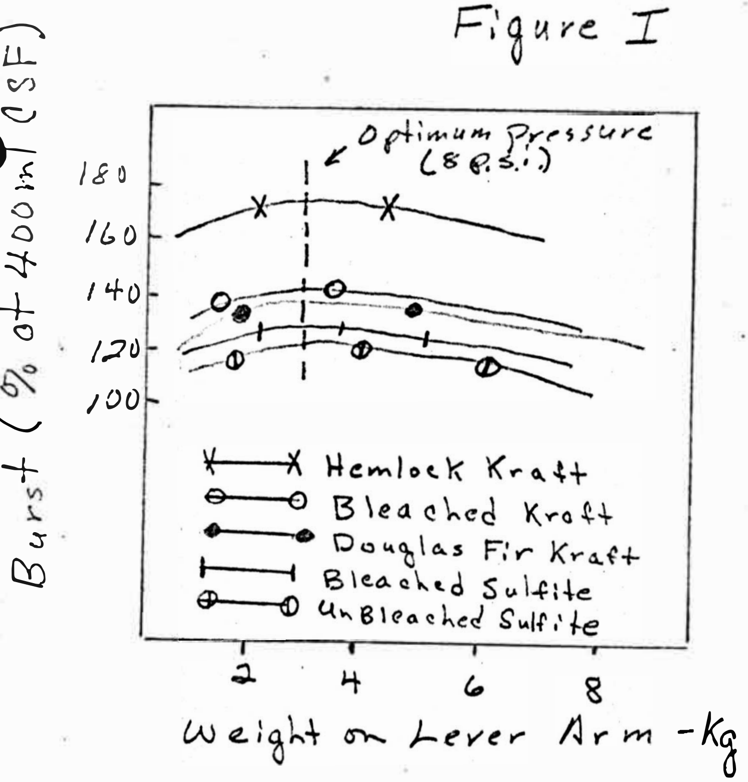
temperature, horsepower attached, etc. cannot be changed readily by the operator of the machine and are inherent qualities of the machine. The operator can, however, regulate the pressure applied to the plates, bedplate, plug or disk to change the refining pressure. Thus, in practical beating operation the best that can be done is to regulate the clearance and pressure to obtain the desired beating action.

In general, light mechanical action gives maximum length of fibers with good opportunity for bonding and maximum strength. It seems obvious that low pressure would be more conducive to fibrillation than to cutting.

Strength Development As Influenced By Contact Pressure

In an article written for Tappi, Caskey (1) found that when less pressure is applied to the beater roll by the bedplate, more time is required to reduce the freeness to a given level (in the one and one-half pound laboratory beater). However, at the same freeness levels, the bursting strength developed by the beater with the lower applied contact pressure is greater than that developed under standard conditions. He obtained the following curve (Figure 1) by plotting the bursting strength at a given freeness against the contact pressure applied to the roll by the bedplate.

Figure I



The effect of Contact Pressure on Burst Development

Figure III

The Effect of Contact Pressure on on the Development of Tensile

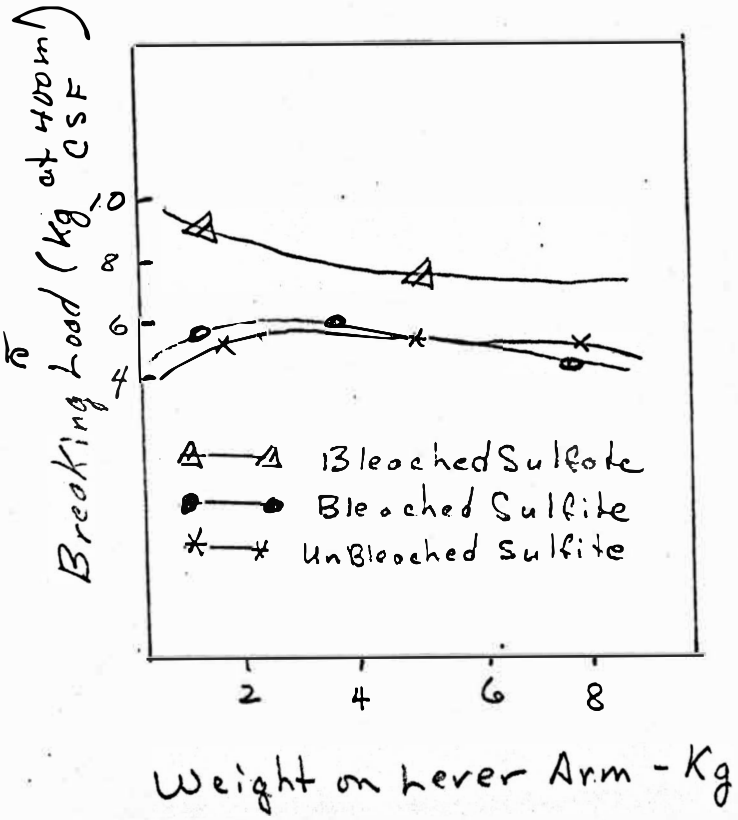
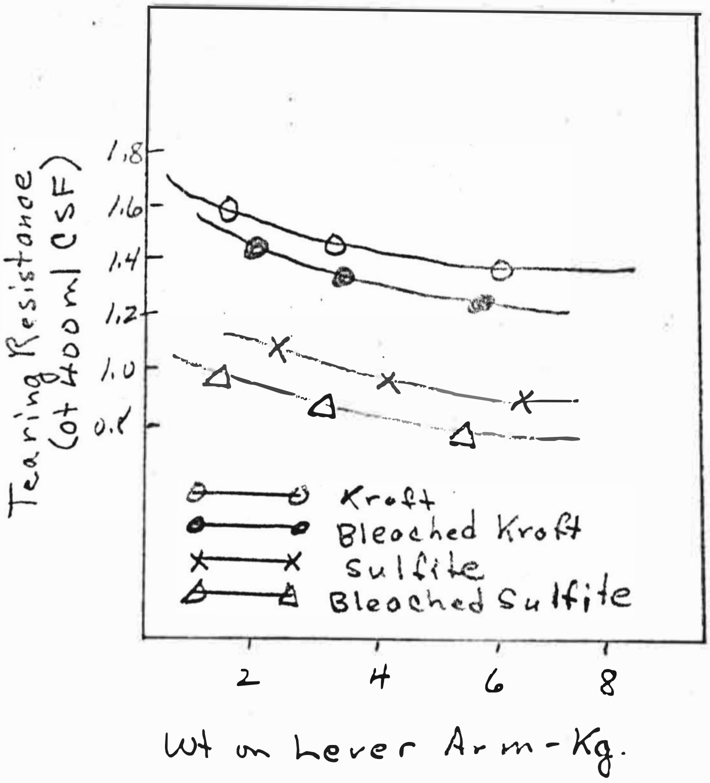


Figure II



The effect of Contact Pressure on Tear Retention

In all tests on the several pulps the maximum burst was developed at a contact pressure of approximately 8 p.s.i. (2.5 kg. on the bedplate lever).

It was also shown that the tearing residue at a given freeness level is increased by reducing the contact pressure as shown in Figure III.

Studies made in Great Britain substantiated these results. Glover (10), using the one and one-half pound laboratory beater obtained data indicated in Figure II.

For the three pulps teated, two of them developed a maximum tensile at 8 p.s.i. This contact pressure was equal to the pressure optimum for burst found by Caskey using a similar beater.

Caskey found that in a series of tests on a given pulp, the beater test using the 2.5 kg. weight on the bedplate lever arm (contact pressure, 8 p.s.i.) developed the highest burst at any freeness level, not only at 400 ml Canadian Standard Freeness.

In an earlier paper (11) Caskey considered consistency, materials used in tackle, peripheral speed, contact pressure of the bedplate on the beater roll, and the ratio of cutting edge to wet beating surface, as variables worthy of consideration in a study of the beating process. Several trials were made varying the pressure from 10 p.s.i. to 121 p.s.i. in the five pound

laboratory beater. At a consistency of 2.25% a maximum burst was obtained for all bedplates tested at a pressure ranging from 30 to 50 p.s.i. Its tearing strength for all types of tackle dropped quite sharply until its contact pressure of 50 p.s.i. was reached where it leveled off. Thsi contact pressure figure of 30 p.s.i. is nearly four times as great as that shown previously for the smaller beater. This discrepancy indicates the need for determining a contact pressure for each piece of equipment.

Caskey compared the burst developed by the jordan equipped with 1/4 inch tackle with that developed by the TAPPI laboratory beater. At the normal setting of 300 to 350 kw relatively low values for burst ratio were obtained because the contact pressure in these cases was excessive. On a few cases when tests were made at lower jordan settings, high burst ratios were obtained. At an unusually low setting of 210 kw, the jordan developed a higher burst than did the laboratory beater for the same freeness level. Caskey attributed this to the fact that this high burst resulted at a low contact pressure in a manner similar to that of the laboratory beater. In a similar manner the trend of tear tests indicated an improvement in the tearing resistance, but this was not as apparent as in the case of the burst.

Effect of Jordan Settings on Burst Development

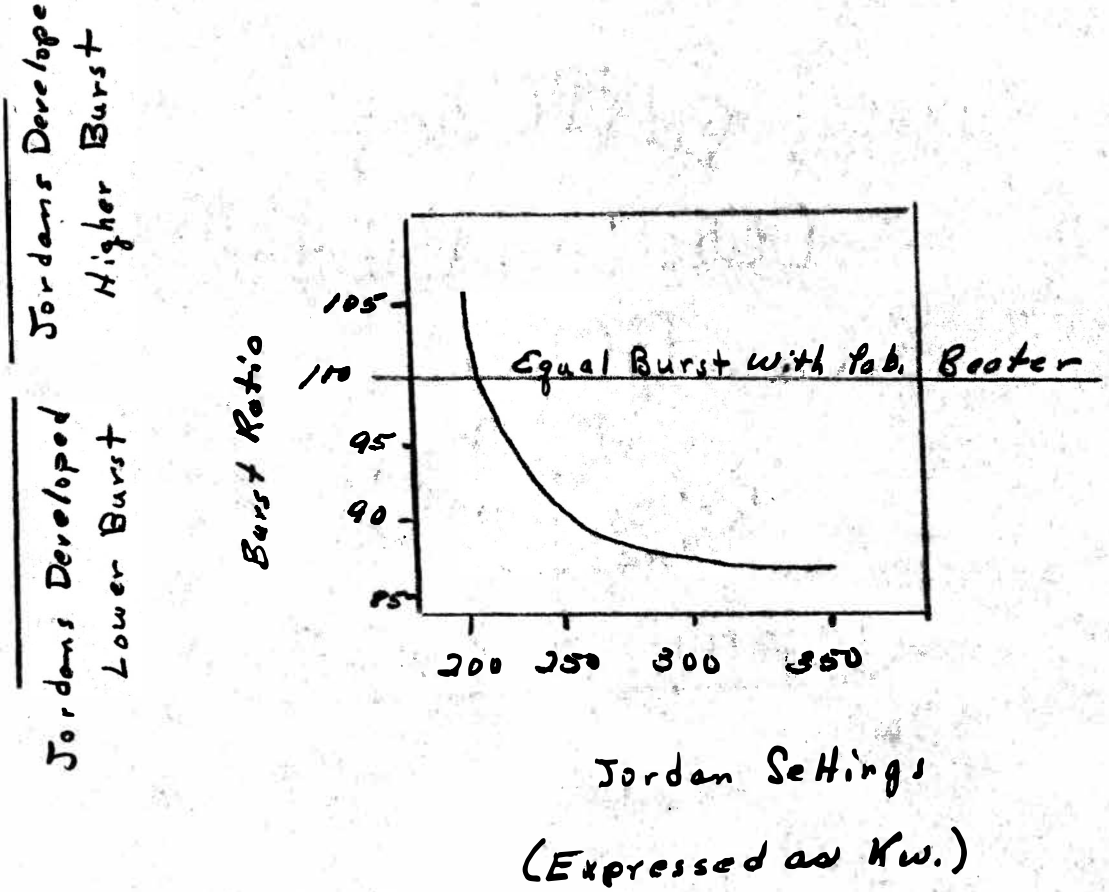
Burst Ratio	Jordan Settings kw	Burst Developed at Same Freeness Jordan	Lab Beater
102	182	83	81
104	205	86	83
105	210	78	74
94	245	76	81
90	249	78	87
90	270	97	108
87	313	92	106
87	330	98	113

In the above table, the "burst ratio" is the ratio of the burst developed by the jordan to that developed by the lab beater. A ratio over 100 indicates that the jordan developed higher burst than did the laboratory beater.

In an investigation of the Escher-Wyss refiner as an instrument for stock testing, Wultsch (12) found because of its adjustable beating pressures and changeable beater tackle.

Figure IV

Effect of Jordon Settings on Burst Development



Casey (2) reports that at 500 ml. S-R freeness, burst and tear factor drop when the applied load increases, and that at low pressure there is better fibrillation and less cutting in most stock preparation apparatus.

He presents the following table:

Effect of Refining Load on Douglas Fir

Kraft Pulp

Hp Load	Burst %	Tear Factor	Fiber Length mm.
		Hydration Type Wide-Bar Refiner (Morden Stockmaker)	
110	127	2.35	2.35
128	123	2.30	2.16
164	117	2.20	2.13
		Jordan-type Narrow-bar Refiner (Morden Stuff Maker)	
110	136	2.50	-
128	129	2.30	2.1
164	114	2.15	1.80
		Laboratory Beater	
	164	2.35	2.68

The Mead Refiner

The Mead Refiner is a disk-type refiner, where one set of slots set in a disk remain stationary while the other disk containing slots revolves.

A force is exerted on the stationary disk by applying a force of 5 pounds on an 18 inch lever arm against the rotating disk. Eighty grams of dry pulp, at a consistency of 2% is required for each refiner load. Pulp requires approximately 5 - 8 minutes for refining to

Figure V

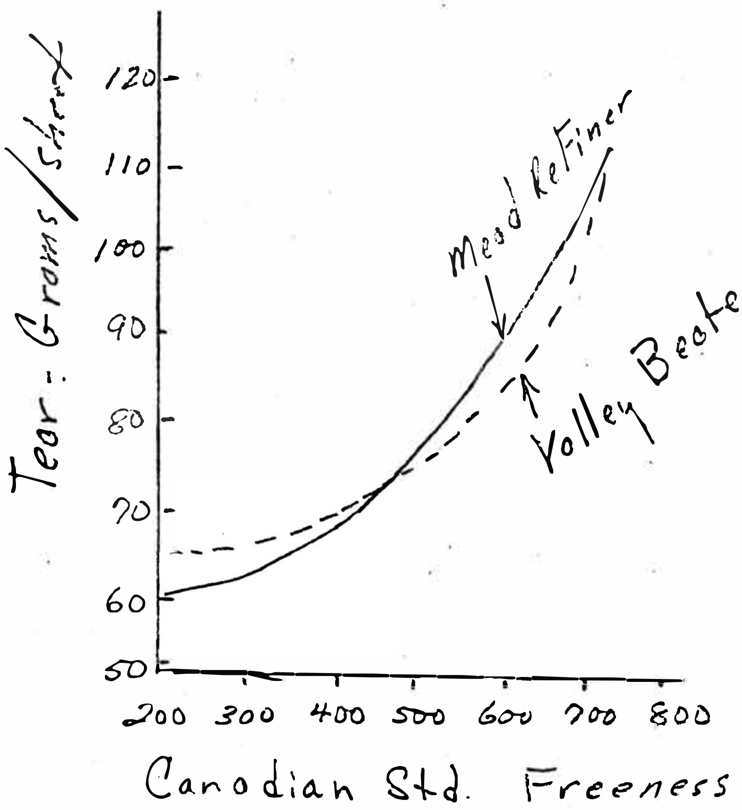


Figure VI

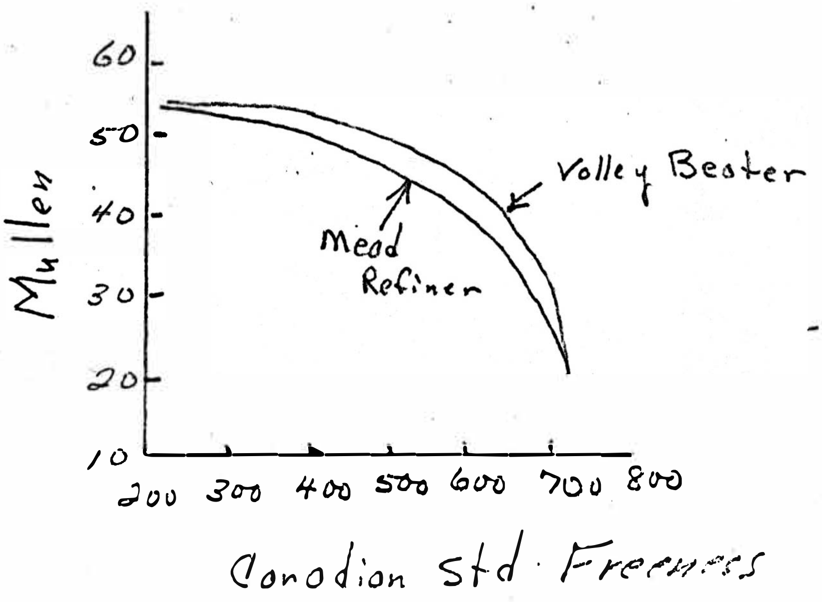
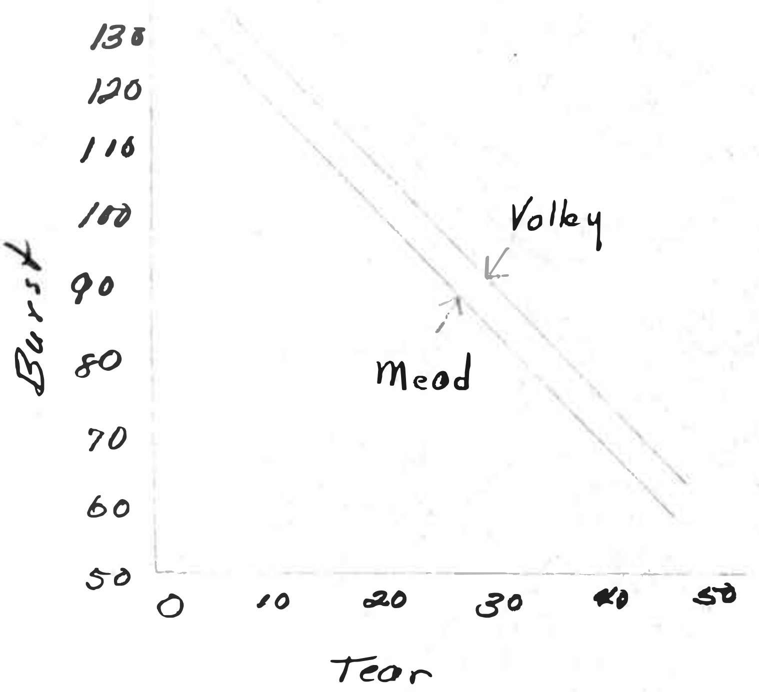


Figure VII


130
120
110
100
90
80
70
60
50
Burst
0
10
20
30
40
50
Tear
Volley
Mead

200 - 300 freeness.

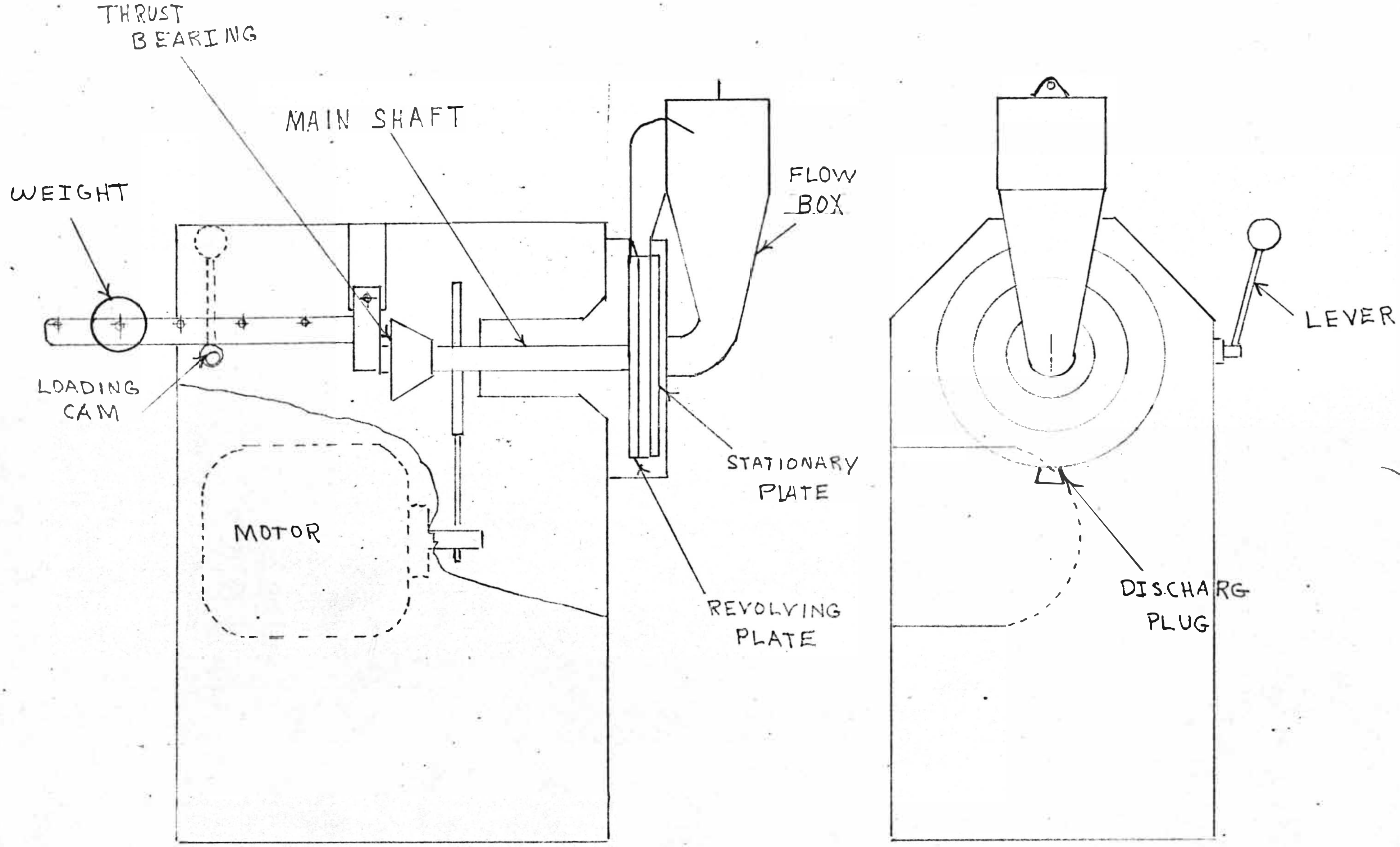
Wright (13) found that the Mead refiner compares quite well with the Valley beater and that it is possible to substitute a Mead refiner curve for a Valley beater curve for a particular pulp and vice versa with only a small error.

Wright obtained the following curves for burst vs. freeness and tear vs. freeness: (see figures V and VI).

The curves obtained with the Mead Refiner for burst vs. tear are similar in shape to those obtained with the Valley beater. The Mead refiner curve is slightly under the Valley beater curve. The difference is small, indicating that there is little or no degradation of pulp when refining with a disk refiner as compared to a beater-type refiner. (see figure VII).

The following is a diagram of the Mead Refiner showing important parts.

MEAD REFINER



Bibliography

1. Caskey, Frank E., Tappi 37, No. 4: 155-157 (April, 1954).

2. Casey, (Vol. 2).

3. Clark, James d'A., Paper Industry and Paper World 25, 382-507 (1943).

4. Nadelman, A. H., Tappi 38, No. 5: 151A-153A (May, 1955).

5. Abbott, Thesis, W.M.U. (1960) Effect of Cutting and Fibrillation.

6. Sutermister, E., Paper Industry 29, No. 24: 542-547 (July, 1947).

7. Felton, H. J., Tappi 41, No. 4: 186A. (June, 1953).

8. Baxter, B. M., Paper Industry and Paper World 28, No. 9: 1308-1311 (January, 1941).

9. Brown, J. P., Paper Trade Journal 142, No. 40: 48-52 (1958).

10. Glover, G. F., Proc. Tech. Section, British Paper and Board Makers Assoc. 32, No. 2: 335-359, 371-413 (May, 1951).

11. Caskey, Frank E. Pulp and Paper 21, No. 13: 66-68 (1947).

12. Wultsch, F., Das Papier 12, 334-42 (1958).

13. Wright, Tappi 42, No. 7: 123-126A (July, 1959).

Experimental Design

The objective of this work was to compare the strength development (mullen, tensile, and tear) as influenced by contact pressure or thrust on the plates of the Mead refiner. Variations in thrust on the plates can be obtained by placing the five-pound weight on one of five different positions provided along the load bar at different distances from the fulcrum or thrust bearing.

Equipment required:

1. Mead Laboratory Refiner
2. TAPPI Disintegrator
3. Stop Watch
4. Canadian Standard Freeness Tester
5. Noble and Wood Sheet Machine
6. Conditioning Room (50% RH, 72°F)
7. Balance, Testing Equipment for Tear (Elemendorf), Tensile, and Mullen

The investigation was carried out as follows:

1. Eighty grams of oven dry Wheyhouser sulphite pulp was placed in the TAPPI disintegrator for 1500 revolutions.
2. The weight on the lever arm was placed in the desired position.
3. The motor was started with the plates disengaged and the eighty gram sample was added

into the flow box with a total volume of four liters.

4. The plates were then engaged and the stop watch started. At the end of the desired refining time the plates were disengaged and the pulp drained out. The refiner was then rinsed with about two and one-half liters of water.
5. Three grams of the pulp sample were then taken for a Canadian Standard Freeness determination.
6. For each weight position on the lever arm, four pulp samples were prepared. The freeness of these samples was approximately 150, 240, 325 and 500 ml.
7. A portion of each pulp sample was then placed into the mixing chamber of the Noble and Wood sheet machine, and the machine was adjusted to make handsheets of 2.5 grams. Six handsheets were made for each refining condition.
8. The sheets were conditioned for at least 48 hours at 72°F. and 50% R.H. prior to testing.
9. The handsheets were then tested for basis weight, mullen, tensile, and tearing strength according to TAPPI Standard - (T-220, m-46). The strength tests were corrected to 2.505 oven dry grams common denominator in weight.

Discussion of Results

The results of the work done are represented in the following graphs. The profile over the entire freeness range covered is given for tensile, burst and tearing strength in figures I, II and III. The position of the weight on the load bar is denoted by the number one, two, three, four, five and six respectively, on the graphs. The number one position is the last hole from the fulcrum and the number five position is nearest the fulcrum. The number six position is the load bar with the five pound weight left off. The bursting strength of 300 and 150 ml. C.S.F. is plotted against the weight position or thrust in figure IV. Figure V represents the same data for tearing strength. In figure VI the tensile developed at 300 ml. C.S.F. is plotted against weight position.

The time of rrfining varied from four to six minutes for refining to a freeness of approximately 240. The refining time for each position (freeness 240) is given on the following page:

Position	Time (Minutes)
1.	4
2.	5
3.	5.5
4.	6
5.	6
6.	6

The constant refining time for the last three positions may indicate that there was little difference in the action on the pulp between these three positions, and may account for the fact that maximum burst and tensile was reached at positions 2 and 3. The maximum mullen was developed by a thrust pressure given by the second weight position on the load bar. This is consistent for most of the freeness range covered.

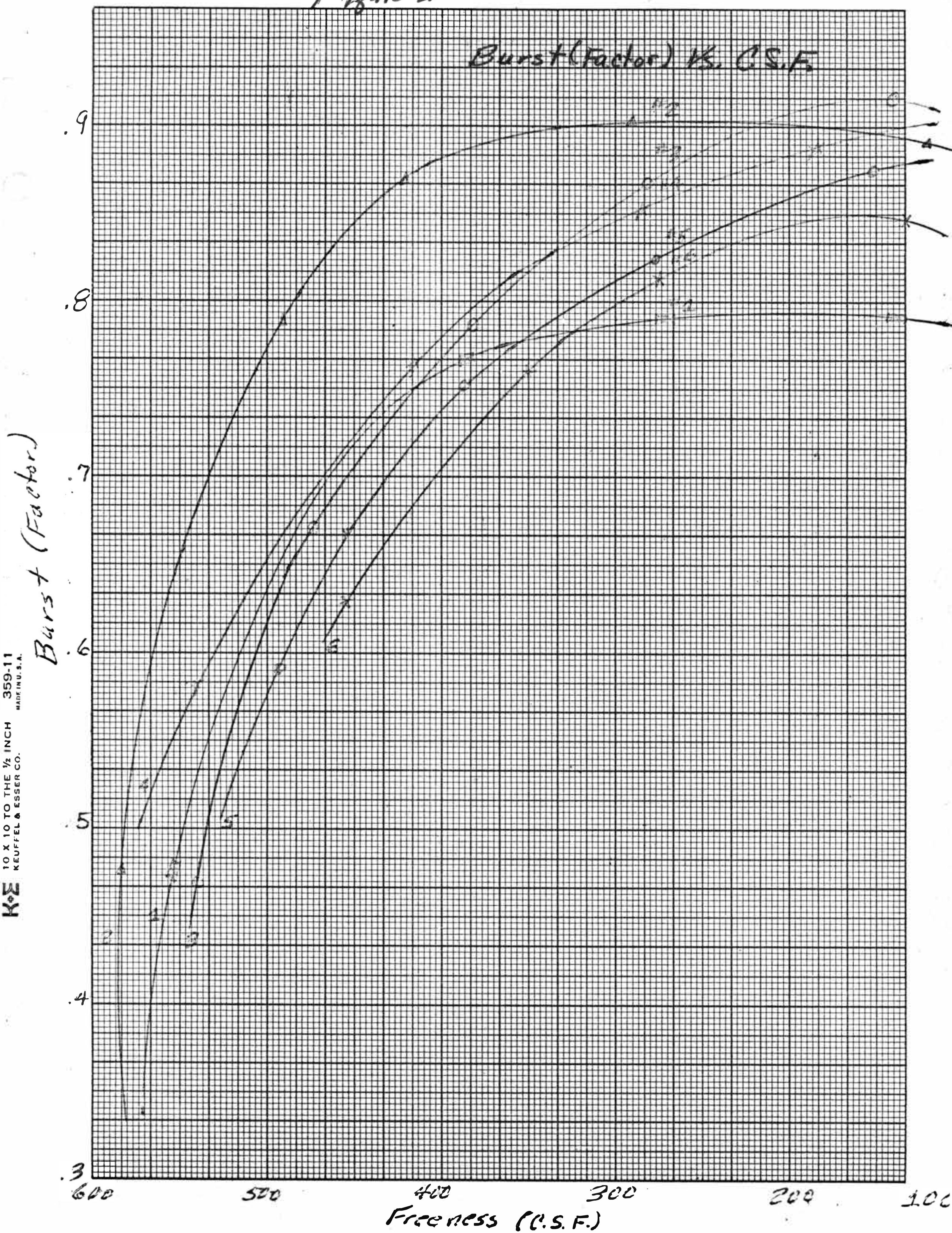
It was found that tensile strength followed fairly closely the pattern set by mullen. The maximum tensile was developed with the five pound weight in the second position over most of the freeness range.

The tearing residue of most freeness levels reached a maximum when the weight was placed in the third position.

The Bauer Bros. Co. reported the following information with reference to the amount of thrust exerted at various setting along the load bar:

Position	Thrust (Pounds)
1)	36.50
2)	31.22
3)	25.94
4)	20.66
5)	15.38

Figure I



Burst (Factor) Vs. C.S.F.
.9
.8
.7
.6
.5
.4
.3
Burst (Factor)
600
500
400
300
200
100
Freeness (C.S.F.)
K+E 10 X 10 TO THE ½ INCH 359-11
KEUFFEL & ESSER CO. MADE IN U.S.A.

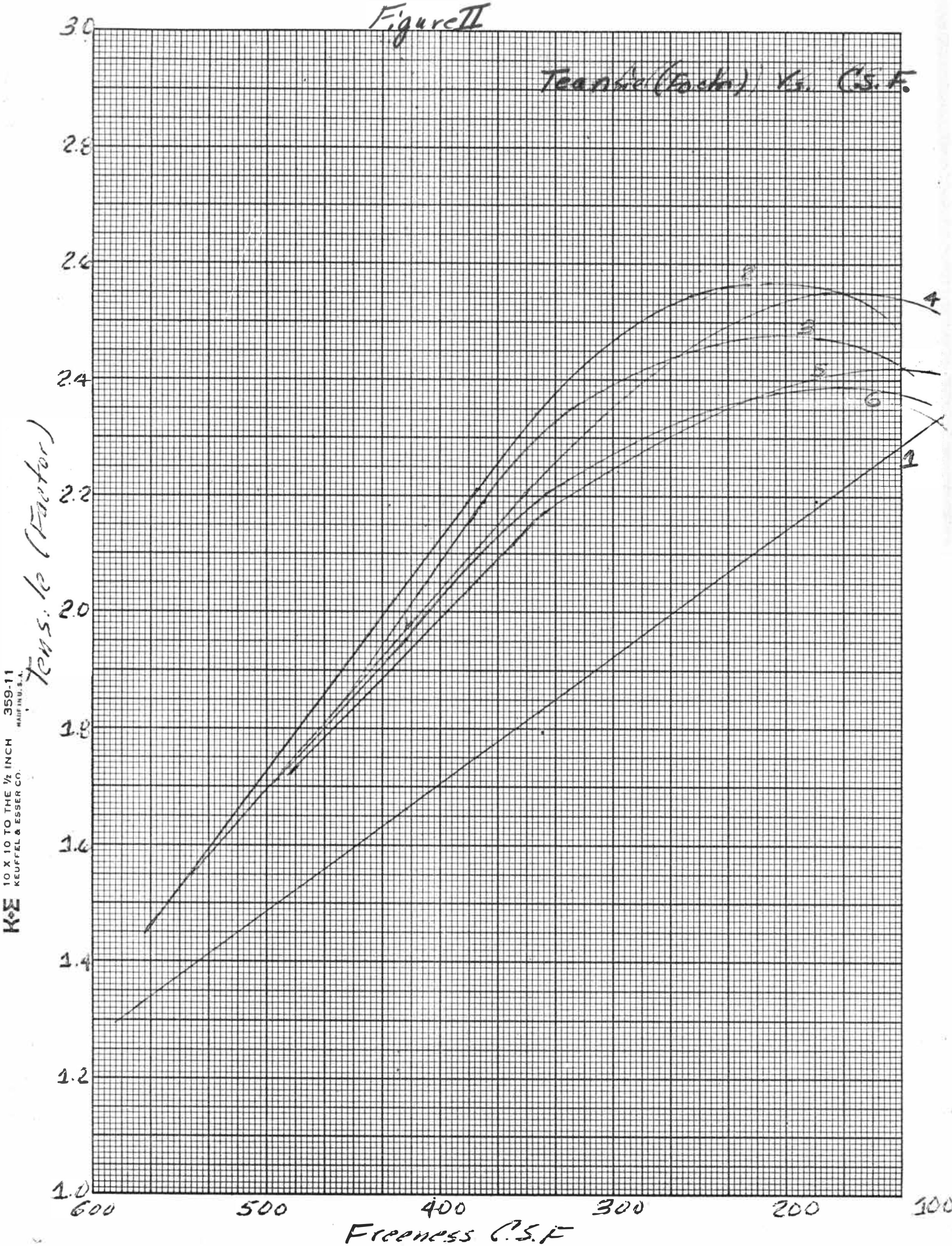


Figure II
Tensile (Factor) Vs. C.S.F.
Tensile (Factor)
Freeness C.S.F
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
600
500
400
300
200
100
1
2
3
4
5
6
K+E 10 X 10 TO THE ½ INCH 359-11
KEUFFEL & ESSER CO. MADE IN U.S.A.

Figure III

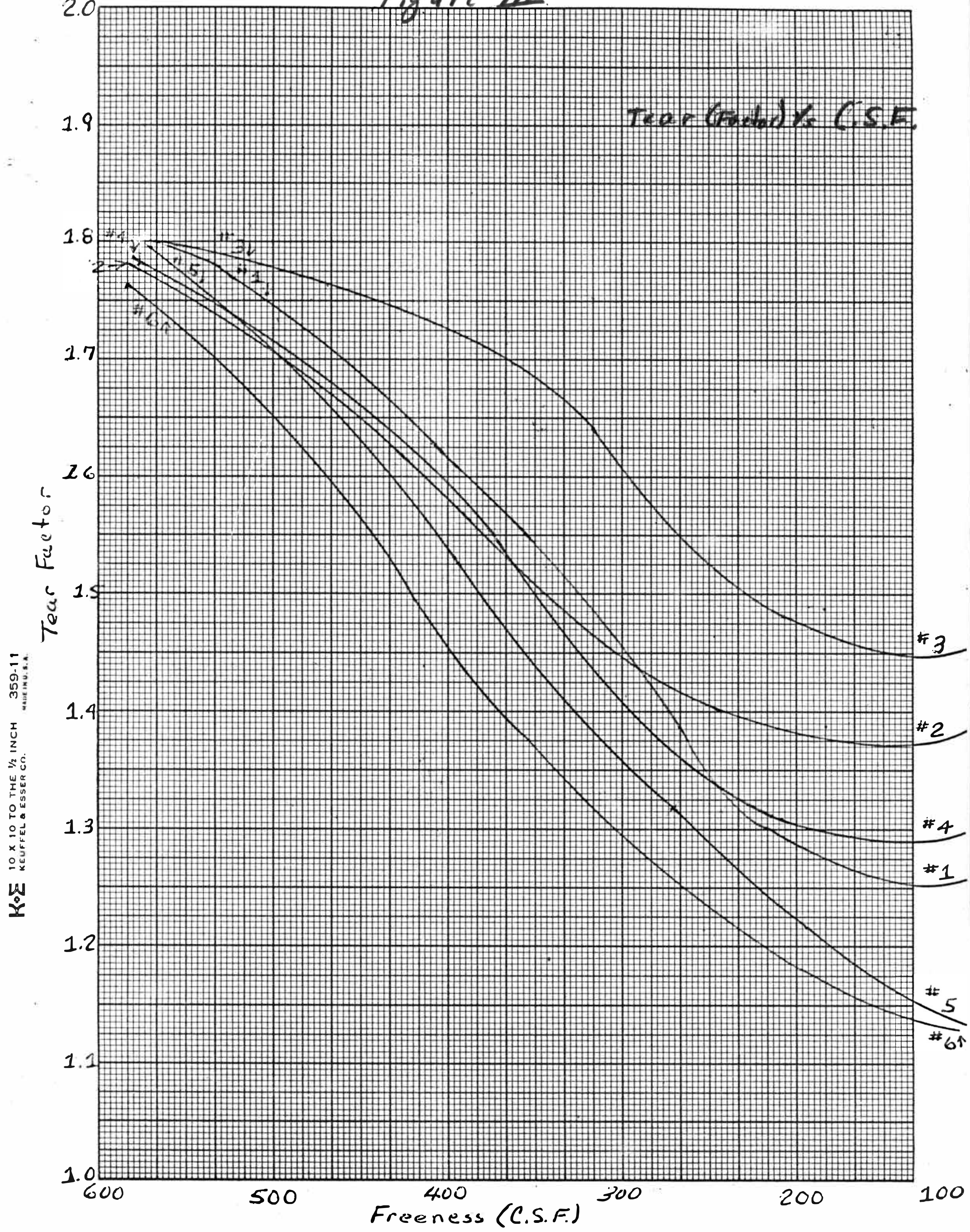
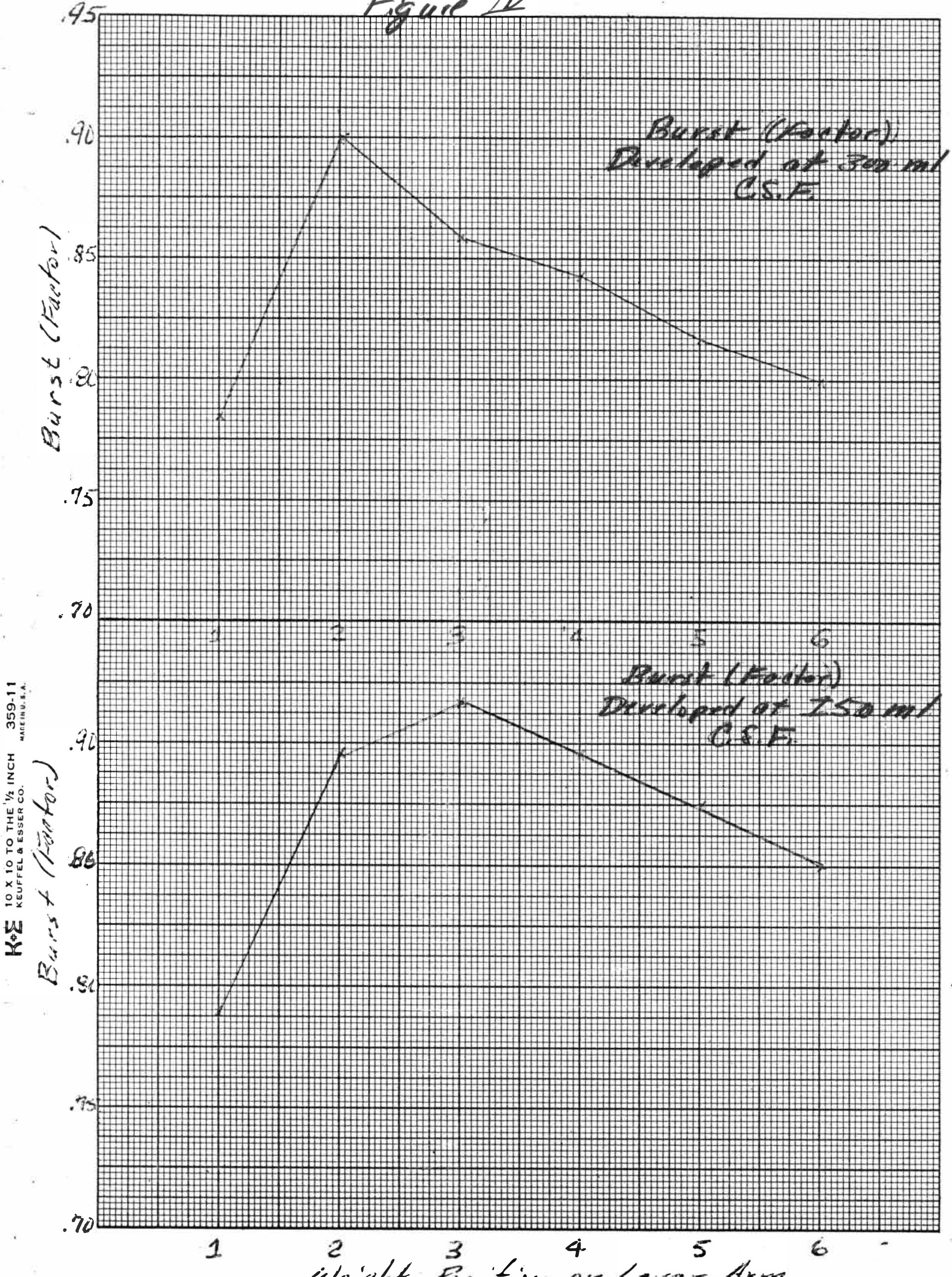

Tear (Factor) Vs C.S.F.
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
Tear Factor
600
500
400
300
200
100
Freeness (C.S.F.)
#3
#2
#4
#1
#5
#6
K&E 10 X 10 TO THE ½ INCH KEUFFEL & ESSER CO. 359-11 MADE IN U.S.A.

Figure IV


Burst (Factor)
Developed at 300 ml
C.S.F.
Burst (Factor)
Developed at 150 ml
C.S.F.
Burst (Factor)
Burst (Factor)
.95
.90
.85
.80
.75
.70
1
2
3
4
5
6
K+E 10 X 10 TO THE ½ INCH 359-11
KEUFFEL & ESSER CO.

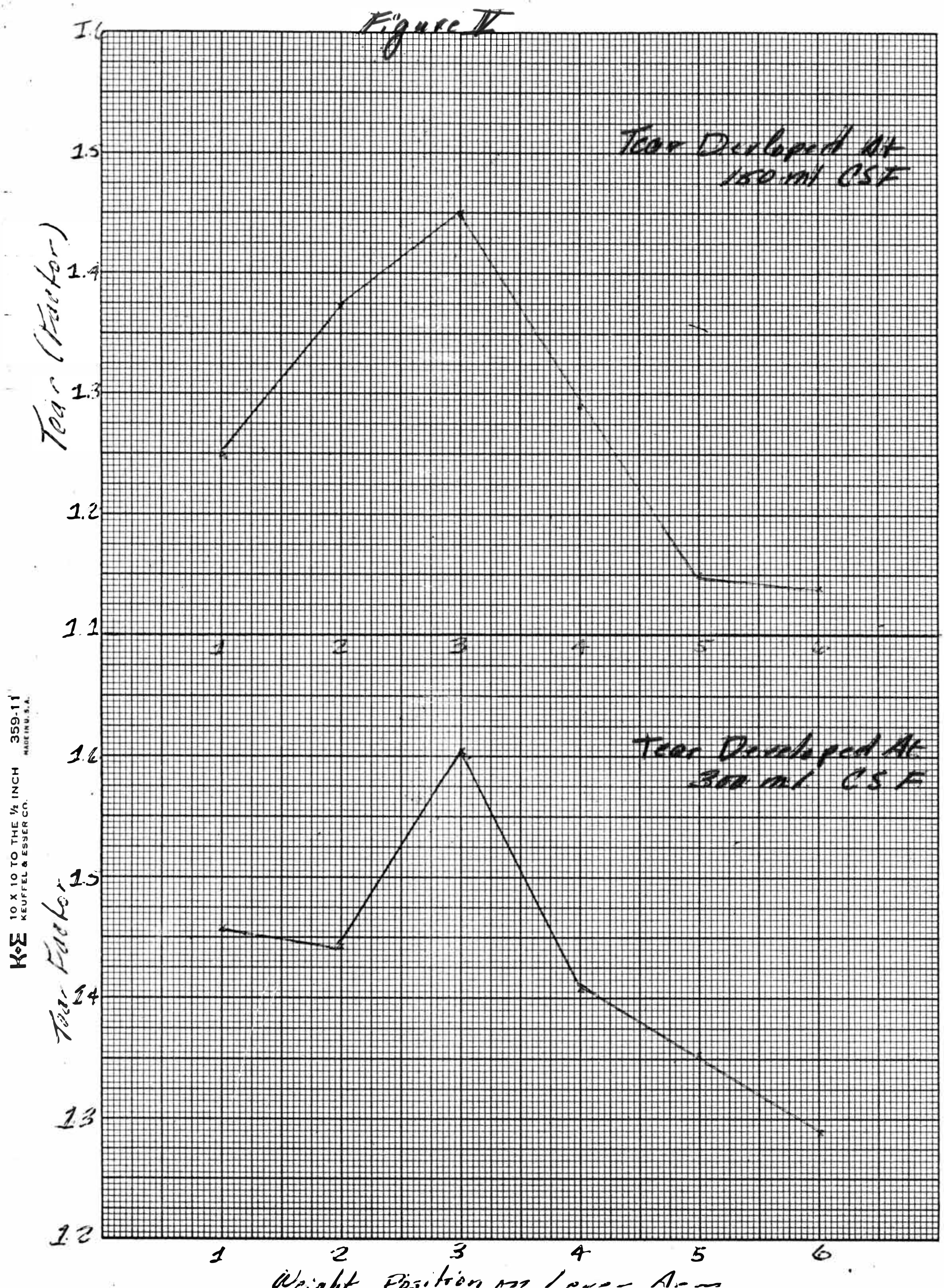
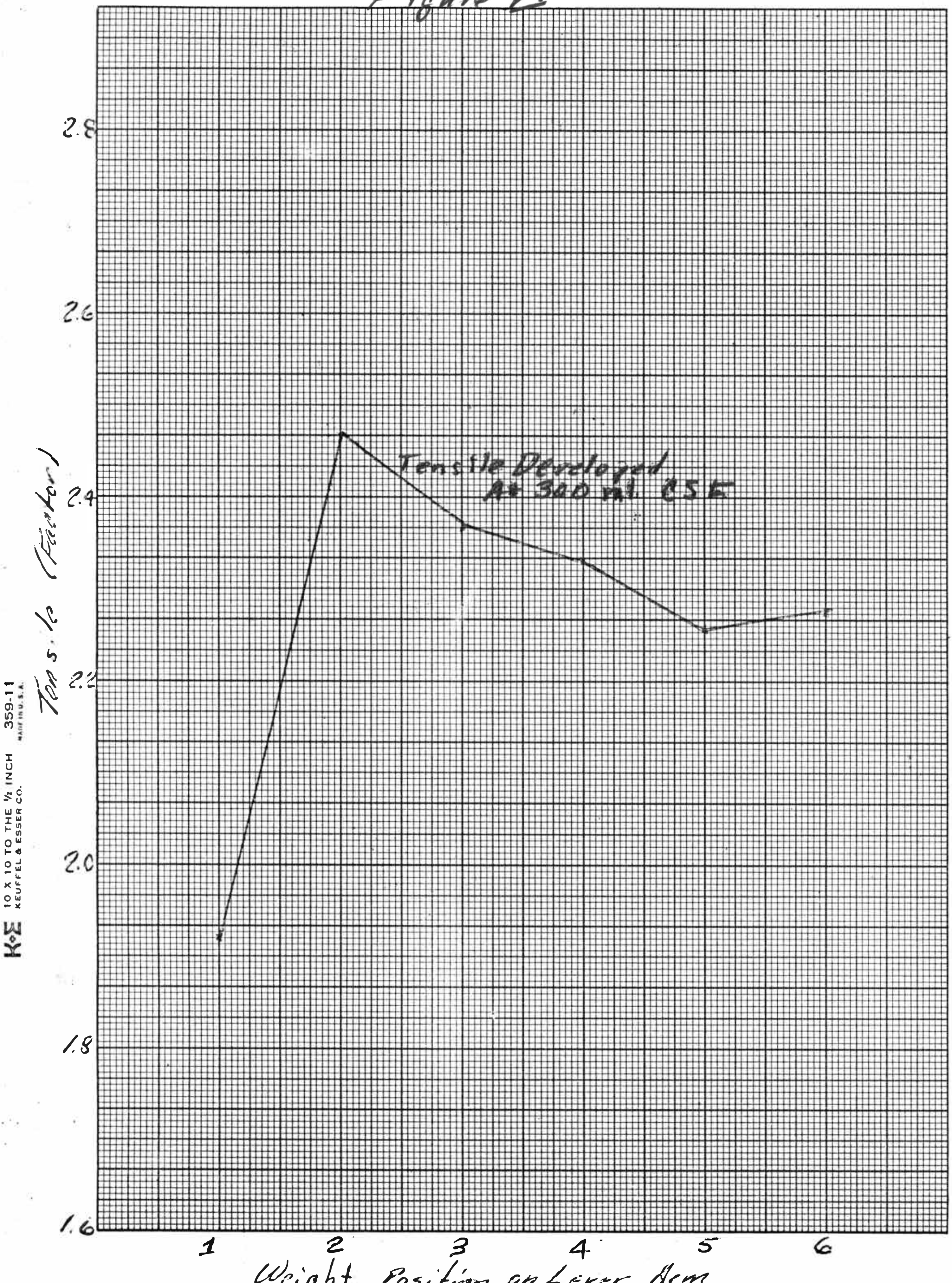


Figure V
Tear Developed At
150 ml CSF
Tear Developed At
300 ml CSF
Tear (Factor)
Tear Factor
1.6
1.5
1.4
1.3
1.2
1.1
1.6
1.5
1.4
1.3
1.2
1
2
3
4
5
6
1
2
3
4
5
6
10 X 10 TO THE ½ INCH
KEUFFEL & ESSER CO.
359-11
MADE IN U.S.A.

Figure VI



Tensile Developed
At 340 ml. CSF
2.8
2.6
2.4
2.2
2.0
1.8
1.6
Tensile (Factor)
1
2
3
4
5
6
Weight Position on Lever Arm
10 X 10 TO THE ½ INCH
KEUFFEL & ESSER CO.
359-11
MADE IN U.S.A.

Conclusions

1. Maximum burst was developed by a thrust pressure of approximately 31.22 pounds on the plates of the refiner.
2. The maximum tensile strength was developed at a pressure of 31.22 pounds.
3. Maximum tearing strength was developed at 25.94 pounds pressure on the plates.
4. The refining time to obtain 240 freeness varied from four to six minutes, remaining constant at six minutes after the thrust was reduced below 20.66 pounds.