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The Influence of Fiber Length and Fiber Length Distribution on Some Strength Characteristics of a Commercial Pulp

David Kraske
Western Michigan College

THE INFLUENCE OF FIBER LENGTH AND FIBER LENGTH DISTRIBUTION ON SOME STRENGTH CHARACTERISTICS OF A COMMERCIAL PULP.

Submitted to Dr.A.H.Nadelman in partial fulfillment of the requirements of the course, Senior Thesis, of the Pulp and Paper Technology Curriculum.

Signed,

David J. Kraske

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ABSTRACT

In this thesis, four groups of fibers with varying average fiber lengths have been separated from a coniferous bleached kraft pulp which had been beaten to different levels of freeness. The fractionation of the pulp was accomplished with a Bauer-McNett fiber classifier. The groups of fibers were analyzed for average fiber length, fiber length distribution and for their strength characteristics.

The results of this survey show interesting and significant trends, particularly with regard to the apparent density, tensile strength and the tearing resistance of the various fractions. The contributions of the various fractions to the strength characteristics of the whole pulp have been illustrated.

INTRODUCTION

In the past two decades numerous investigations have been made into the influence of various mechanical pulp treatment methods on the fiber length and fiber length distribution of commercial pulps. In conjunction with these studies the possibility of developing relationships between the fiber length and physical characteristics of pulp such as burst, tear, fold, tensile strength, bulk and opacity has been investigated. It is easy to see the number of benefits that would result if such relationships could be definitely established.

The biggest obstacle to the successful completion of this work lies in the fact that the fiber length classes obtained by present fractionation techniques overlap each other. In other words, the range of fiber lengths in any one fraction is relatively wide. It must also be considered that the fiber length distribution will vary for different types of pulps so that any strength-fiber length relationships will vary from pulp to pulp.

It is the objective of this thesis to attempt to develop a more exact technique for the fractionation of pulp fibers and to attempt to investigate further some of the strength-fiber length relationships.

THE THEORY OF FRACTIONATION AND ITS APPLICATION TO THE BAUER-McNETT FIBER CLASSIFIER

There are several makes of fiber classifiers available at the present time,all of which operate on the same general principle. Among these the most popular are the Clark and the Bauer-McNett. Since the experimental work in connection with this thesis will be done on the Bauer-McNett, a short description of this machine is in order.

The Bauer-McNett classifier consists of a series of four elliptical tanks, each of which is equipped with a removable screen of progressively diminishing mesh. In each tank there is an agitator and a mid-feather parallel to the screen which help to maintain a high,uniform velocity of stock across the surface of the screen.

Mechanical segregation of fibers into classes of fiber length by means of the Bauer-McNett is based on the following facts(3,5,9,18): a dilute suspension of fibers in water flowing transversely past a screen at a high velocity aligns the fibers in the suspension so that their axes are parallel to the surface of the screen. This aligned flow theoretically allows only a few of the shorter fibers to pass through the screen per cycle. Any fiber whose length is more than twice the diameter of the screen mesh will not pass through the screen unless it approaches the screen at an angle or unless it catches on a wire and is pulled through.Any fiber whose length is less than the diameter of the screen mesh will, of course, pass through the screen unless it becomes entangled in the fibrillae of longer fibers.

There are many variables connected with the operation of this classifier some of which can affect the results obtained to a considerable degree. The most important of these variables are listed below.

A. It is important that a uniform rate of flow of water -- to avoid pullsation-pull-through or slippage -- be maintained throughout the run. It is equally important that the same rate of flow is used throughout a series of comparative fractionating runs.

B. The elimination of eddies which interfere with the correct alignment of the fibers and uniform agitation are also important.

C. The time or duration of a run has a significant bearing on the results. As the time of fractionation is increased an increasingly larger amount of the long fiber fractions are displaced into the shorter fraction tanks. As yet no optimum running time has been determined and evidence seems to indicate that this time varies with the type of pulp used.

LITERATURE SURVEY

Of the large number of investigators who have worked in this field, F.W.Brainerd(2), J.d'A Clark(7), G.Haywood(10), and M.Steinschneider(21) are outstanding. Many others, however, have contributed a good deal of supplementary facts to the field and have, in addition, helped in the development of better techniques.

The experimental procedure followed in the majority of the studies reviewed by the author was along the same general lines. Modifications were introduced in some of the later works in an attempt to overcome difficulties experienced in previous work. In general form, the procedure is outlined below.

A. A particular pulp or pulps were fractionated, before mechanical treatment, by one of the many devices available for this segregation. In general the theory of the fractionating devices was the same. This gave an indication of the fiber length distribution of the pulp.

B. Samples of the pulps so fractionated were subjected to mechanical treatment in a Valley laboratory beater, a Kollergang or a ball mill. Pulp samples were fractionated at various degrees of slowness to determine the effect of beating on the fiber length distribution.

C. The average fiber length of the pulp fractions from the classifier was determined by either the deMontigny grid method for Fiber Length Index, and/or the current microscopic method. It is interesting to note that there exist certain relationships between the Fiber Length Index and some physical characteristics of pulp.

C. (cont.)

$B(\text{bulk}) = 0.19L - 1.20$ $\qquad$ L = Fiber Length Index

$T(\text{tear}) = 0.475L - 0.65$ $\qquad$ $B(\text{burst}) = 40L - 30\log(S - 16.5)$

$M(\text{breaking length}) = 3400L - 1970\log(S - 18.5) - 3280$

S = Schopper-Riegler slowness

The value of these relationships is somewhat limited due to the fact that they were derived from data supplied by deMontigny and Zborowski(15) who worked with only one pulp and who intended only to show that the Fiber Length Index is related to the papermaking properties of pulp.

D. Several of the investigators (11,14,15,17) studied the strength contributions of the individual fractions to the whole pulp. None of these investigations proved too successful due to difficulties encountered in obtaining distinct fiber length fractions. Clark(8) related some physical characteristics of pulp to the density of the sheet and the weighted average fiber length of the pulp.

$$\text{Rigidity factor} = k_1 d^{\frac{1}{2}} L^{\frac{1}{2}}$$

$$\text{Burst factor} = k_2 d\, L$$

$$\text{Tensile strength} = k_3 d\, L^{\frac{1}{2}}$$

$$\text{Tear factor} = k_4 L^{\frac{3}{2}}/d$$

Clark's work was done largely with density as the variable— that is, he was not primarily and specifically concerned about the various fiber length fractions of the pulp. It is obvious that the proportionality constant k allows for such factors as bonding, formation, etc..

E. Kress and Brainerd(14) and Haywood(10) also investigated the chemical properties of the untreated pulps.

In brief,the results of the work performed indicates that with progressive mechanical treatment of pulp, the percentage(by weight) of fibers in the longest fraction decreases, the percentage of fibers in the intermediate fractions remains the same or very nearly so,and the weight percentage of the shortest fibers increases. As far as strength relationships are concerned, it appears that the burst,tear, fold and tensile strength decrease with decreasing average fiber length. These strength relations or trends are characteristic of chemical pulps. In direct contrast, the burst and tear of groundwood pulps are higher in the shorter fiber fractions. This is so because the chemical nature of groundwood fines is not appreciably different from that of the longer fibers,resulting in better bonding of the fibers without decreased strength properties of the fibers. In chemical pulps it was found that the chemical ptoperties such as copper number, vicosity, lignin content, and resin content became increasingly poorer as the average fiber length of the fractions of untreated pulp decreased. Haywood(9) is of the opinion that this is due to the larger number of ray cells that have been found in this fraction.

There are several theories that must be considered when one attempts to understand the difficulties involved in arriving at the above conclusions.

A. According to Steinschneider, Kross, andImgrund(21) screen fractionation does not separate fibers according to their actual length only. This applies especially to beaten pulps, the authors are of the opinion that because of roughened sidewalls and fibril entanglement the fractionation results will not be completely indic-

A.(cont)
ative ofthe actual fiber length distribution. They do maintain, however, that fractionation can be adapted for use in stock preparation control through its ability to measure a degree of roughness and fibrillation.

B. Other investigators, notably Reed and Clark(18) and Brainerd(2), have observed that in each fraction of pulp from the classifier there is a wide range of fiber lengths. This phenomena seems to be related to:

1. The flexibility of the fibers being fractionated.
2. The entanglement of the short fibers in the fibrillae of the longer fibers in the first fractions.
3. The length of time that the classifier is run on each sample.

In the case of 1. it appears that if a flexible fiber of the long fraction should be deposited across an opening of one of the coarser screens its ability to bend under the force of the water flowing through the screen would result in its being drawn through the screen into the next shorter fraction. A more rigid fiber would resist this pull-through effect of the water flow.

C. The proportion of the fibers of a coniferous pulp (long fibered) sample that were caught on the coarsest screen was abnormally large. Schmut(19) tried many screen combinations in an effort to reduce the size of this fraction. He found, however, that a ten(10) mesh screen

C.(cont.)

would retain little or none of this fraction while a screen of finer mesh would again retain an overly large amount. Haywood(10) effectively solved the problem when he reclassified the large portion of fibers that were retained on the twenty(20) mesh screen over a series of ten(10), fourteen(14), sixteen(16) and twenty(20) mesh screens. Since Haywood was not primarily concerned with the strength contributions of the individual fractions, the strength characteristics of these very long fibered groups that he obtained by re-fractionation have yet to be evaluated.

There are ,of course, many other variables encountered in work of this type but those related to the actual fractionation of the pulp are by far the most important. The variables encountered in the treatment of the stock and those connected with the evaluation of handsheets are controllable to a large degree provided the experimental work is carried out with a great deal of care.

SUMMARY OF THE LITERATURE SURVEY

A review of the available literature seems to indicate:

1. The longest fibers in a commercial pulp are shortened during mechanical pulp treatment. The percentage by weight of fibers in the intermediate length ranges remains about the same during beating. The weight percentage of fines in a given pulp increases as treatment time increases.
2. Bursting strength, tensile strength, folding endurance, and tearing resistance tend to decrease as average fiber length decreases, at least in the case of chemical pulps. O'Leary and co-workers(17) noted, while working with glass fibers which do not have the same bonding characteristics as cellulose fibers(in fact the bonding of glass fibers is solely dependent on friction between fibers), that in no case does the strength of the individual fractions exceed that of the mixture of the long and short fibers. This fact is especially important when one considers that with glass fibers all effects of fiber bonding are removed and one arrives at the very core, the essence, of the strength contributions of long and short fractions. Unfortunately, it must still be proven that this same fact applies to cellulose fibers.
3. Chemical properties of the original, untreated pulp have been shown to be poorer in successively shorter fractions of the pulp.
4. No means of mechanically separating the fibers into sufficiently distinct fractions covering a narrow range of fiber lengths has yet been found. Until the time when such a means is developed, fiber length -strength relationships will have to be based on work with groups of fibers whose average length has been determined.

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OUTLINE OF EXPERIMENTAL PROCEDURE

As stated in the introduction to this thesis (page 1), the objective of this study is two fold:

[1]

1. An attempt will be made, using re-fractionation techniques to obtain fiber length fractions whose range is considerably narrower than the ranges obtained by previous investigators In drawing up the tentative schedule of re-fractionation the author has assumed that nothing is to be gained by re-fractionating the finest fraction obtained from the initial run, that is the fraction deposited on the 150 mesh screen. This assumption is based on the fact that the fibers and debris of this fraction have been shown to contribute little to the strength of the pulp, at least, as a unit. The proposed schedule of re-fractionation is present~~at~~ed as a diagram in Fig. 1. The numbers within the symbols represent ~~represent~~ the fraction of fibers retained on the screen whose mesh size corresponds to the number.

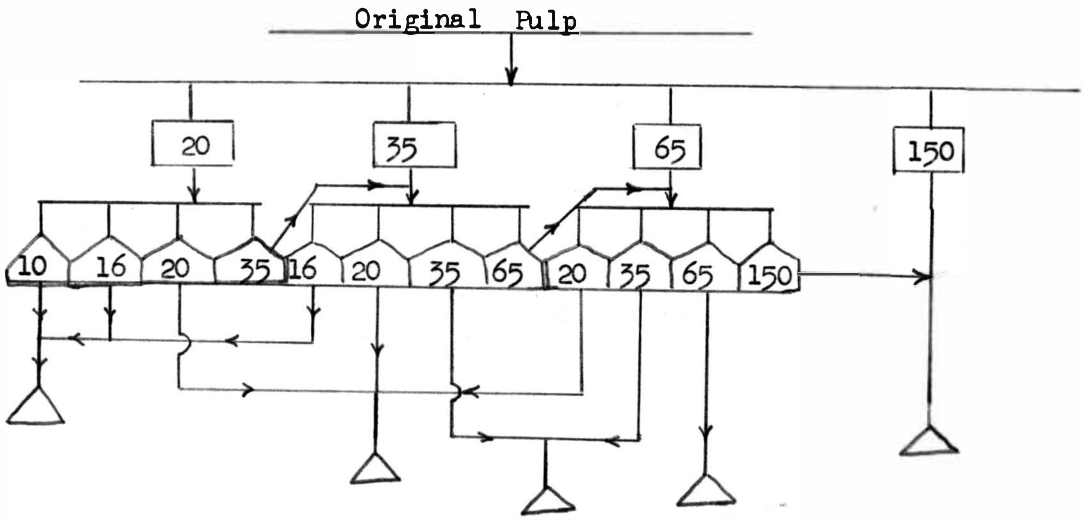

Fig. 1

As diagrammed in Fig.1, the original pulp will first be separated into the four fractions (shown as ) 20,35, 65, and 150 mesh. The next step will be to refractionate the pulp from the 20 mesh screen into fractions of 10 , 16, 20, and 35 mesh. This second fractionation is indicated by the  . The pulp retained on the 10 and16 mesh screens will be set aside for microscopical analysis and sheet making. The pulp retained on the 35 mesh screen will be added to that from the first fractionation and the entire quantity will be refractionated. This procedure will be continued until sufficient distinction of fiber length ranges has been attained. When this point is reached the fibers will be collected according to mesh retention, mixed, and each fraction will be examined for determination of numerical average fiber length. Hansheets will be made of the various fractions for determination of strength characteristics.

In an attempt to determine whether or not this fractionation is feasible, the first step in experimental work will be a trial run as outlined in Fig.1 using an unbeaten pulp. It is not expected that this fractionation will produce fractions of as narrow a range as could be desired, however, even a reduction of 25% in range will make the large amount of extra work worthwhile.

2. The second part of the experimental work of this thesis cocerns the strength contributions of the individual fractions to the strength of the pulp as a whole and the development, through beating, of the strength of the individual fractions.

2. cont.

The procedure in general will be as outlined in Fig.2. If the results of the fractionation schedule in Fig.1 seem to warrant it, all fractionations will be done as listed. There is the possibility that the results of the fractionation will indicate that the re-fractionation should be carried even further. If this is the case, the re-fractionation will be carried out until microscopic examination shows that minimum fiber length ranges have been reached. On the other hand, if re-fractionation does not produce a reduction in range of fiber length of 25% or more, just one fraction of the original pulp will be made.

TAPPI std. Beater Run	1. Unbeaten Pulp Fractionation
↓	↓
	2. 500 C.S.F. Pulp Fractionation
↓	↓
	3. 400 C.S.F. Pulp Fractionation
↓	↓
	4. 300 C.S.F. Pulp Fractionation
↓	↓
TAPPI std. Beater Run	5. 200 C.S.F. Pulp Fractionation

Fig. 2.

C.S.F. Canadian Standard Freeness

Strength sheets will be made in all cases. In steps 1, 2, 3, 4, 5, strength sheets will be made of the un-fractionated pulp in order to establish comparison figures against which the strength values of the individual fractions can be graphed.

2. cont.

The two TAPPI standard beater runs, one at the beginning and one at the end of the experimental work, will serve to showw whether or not the beating conditions have changed beyond the limits of normal variability.

At each of the steps 1, 2, 3, 4, 5, adetermination of the numerical average fiber length will be made by Mr. Russell I. Larson of the un-fractionated pulp and the individual fractions from which sheets are to be made. A determination of the Fiber Length Index (grid method) will be made of the unfractionated pulp in each of steps 1, 2, 3, 4, 5. A sample of the fibers retained on the grid will be submitted to Mr. Larson for determination of the average fiber length.

All beating, sheetmaking, and testing will be carried out in accordance with TAPPI standard procedures.

The physical characteristics of the handsheets that will be evaluated are as follows:

1. Caliper
2. Apparent Density
3. Burst Factor (Perkins Mullen Tester)
4. Tear Factor (Elmendorf tear Tester)
5. Tensile Strength (Schopper Tensile Tester)
6. Folding Endurance (M.I.T. Fold Tester)

The results of the evaluations will be plotted against Canadian Standard Freeness and against the Fiber Length. However, if the standard beater runs made at the beginning and the end of the experimental work indicat that neither the beating action nor the pulp itself have changed, it may become possible to plot some of the results against beating time.

Certain arguments have been advanced by Clark for the advantages of plotting physical characteristics against the apparent density. These arguments appear, at least to the author, to be based on solid grounds. I t is quite possible that this method might have the advantage of eliminating some of the variables of sheet forming. It will be interesting to see the result of plotting the physical characteristics of the handsheets of the various fractions against their apparent density.

EXPERIMENTAL PROCEDURE

As was stated in the experimental outline of this thesis, one of the first objectives was to establish a satisfactory method of fractionation. Experimental work was confined to a bleached coniferous west coast kraft pulp which has an average numerical fiber length of approximately 2.9 millimeters. Reference is made to the thesis of R. I. Larson (unpublished, Western Michigan College, 1953) for details concerning this pulp.

Initially, the method of fractionation presented in the experimental outline of this thesis was followed. The technique, as illustrated, proved inadequate with respect to the time involved and the yields of the various fractions.

The following method was adopted as a practical compromise. Ten grams of a pulp sample were fractionated in a Bauer-McNett fiber classifier over a series of screens of 10, 16, 20, and 35 mesh. All effluent water was passed through a 200 mesh screen to remove remaining"useful" fibrous material. The 16 and 20 mesh fractions were then combined and re-fractionated over asseries of 16, 20, 35, and 65 mesh screens. Again, all effluent water was passed through a 200 mesh screen. Running time was extended to thirty minutes in all cases. It was expected that two relatively narrow range fractions could be obtained through the use of this method. The fractions referred to are the ten mesh group and the fraction retained on the 200 mesh screen. It was assumed that the long running time would effectively wash the shorter fibers out of the ten mesh fraction. Secondly, it was assumed that, since most fibers of this particular pulp were over two millimeters in length and since fibers of this length are retained on a 35 mesh screen, the fraction of pulp retained on the 200 mesh screen would be relatively free of long fibers.

Following the adoption of the above technique, experimental work evaluating the strength characteristics of the fractions was initiated.

In order to ascertain the characteristics of the pulp used in the experimental work, a beater run was made according to TAPPI standard procedures. The results of this evaluation were useful in establishing the level of beating of subsequent runs. The results, in terms of freeness and strength development, are summarized in Table 1A and graphed in Figure 1.

Samples of the pulp were then treated in a Valley laboratory beater to freeness* of approximately 750, 600, 500, 400, 300, and 200 milliliters (Canadian Standard). Fractionations were made at each of these levels of beating. Handsheets were made on the British sheet mold from each of the fractions so obtained and from samples of the whole pulp of the same beater run. Samples of each fraction and of the whole pulp were analyzed as to average fiber length and fiber length distribution by R. I. Larson.

The handsheets were conditioned at 73° Fahrenheit and 50% relative humidity and tested for basis weight, caliper, bursting strength, tearing resistance, tensile strength and folding endurance (M.I.T.). A summary of the test results is presented in Table 11. Figures 11 through X represent a graphical presentation of this data.

Further work was carried out in evaluation of the shifting of the fiber length distribution caused by increasing degrees of mechanical treatment. The work was done by screen analysis only. The results of this survey are presented in Table 111.

Finally, the change in the fiber length index (deMontigny grid method) with increasing degree of beating was determined. Samples of the pulp retained on the grid of pulp beaten to 750, 400, and 200 ml. freeness were analyzed for fiber length distribution by R. I. Larson. The results are presented in Table IV.

It was mentioned in the experimental outline that it might be revealing to plot the results of strength tests against apparent density. A quick survey of the results obtained shows that this method of graphical presentation is not feasible.

DISCUSSION AND INTERPRETATION

OF EXPERIMENTAL DATA

As shown by Figure I, the bleached kraft pulp used throughout the experimental program developed strength characteristics uniformly and relatively rapidly upon beating. The course of the curves is to be considered normal in so far as the strength development is concerned.

TableIII represents the quantitative results of determinations of fractionation yields at different levels of beating. These data indicate that there is not a consistent decrease in the relative number of long fibers in the pulp but rather, there are intervals of sharp decrease and periods of relative stability of the percentage of fibers retained on the 10 mesh screen. Likewise, the increase in the weight percentage of fibers retained on the 20 mesh screen is not consistent. It is significant that the percentage increase of the 200 mesh fraction is not as great as that of the 20 mesh fraction. This indicates that the greater part of the fiber cutting was performed on the longest fibers of the pulp and that the region of the cut must be near the end of the fiber.

The average numerical fiber length and the range of fiber distribution of the groups of fibers retained on any one screen varies slightly from run to run. There is no correlation between this variation and the extent of mechanical treatment. This points to the fact that these variations are caused by imperfections in experimental technique. The extent of this variation may be seen in Table II.

Figure II, a plot of the apparent density of the sheets of the various fractions vs. the freeness of the whole pulp, shows that all fractions have their lowest density in the case of the unbeaten stock. However,

the apparent density of the fractions increases to the point of 600 ml. freeness whereupon it levels off to a constant value regardless of the degree of beating. Each fraction then, assumes a characteristic value,which lies within a very narrow range, after a certain preliminary amount of mechanical treatment. With allowances for experimental error, this narrow range of densities may be assumed to be constant. In comparing the curves shown in the graph, it is noticed that the 10 mesh fraction has the lowest density. The densites of the remaining fractions increase with decreasing average fiber length but they fall within a relatively narrow range. It is interesting to note that the density of the whole pulp increases with a uniform slope throughout the investigated range of beating. The various fractions however, early attain their characteristic value which exceeds that of the whole pulp only in the early stages of beating. Therefore,it may be concluded that the density of the whole pulp, in the stages where it has a higher value than that of any of the fractions, is due to the shifting of the relative quantities of the fibers in the various fractions and to the effect of the fibrillae which provide greater surface area and fiber to fiber contact. As a result,more fiber bonds are formed which tends to pull the fibers into even closer matting.

The phenomenon of a constant value for a specified fraction, (one that has been extracted from a pulp beaten to any point past 600 ml. freeness, that was evident in the data accumulated for the apparent density is prominent again in the curves for bursting development that are shown in Figure 111. In accordance with Clark's equation for bursting strength, the low density, the exceptionally long fiber length and the wild formation (accounted for by the constant k) of the handsheets of the 10 mesh fraction combine to produce a low bursting strength. It is noted that the strength characteristics of the various

fractions do not consistently exceed the strength characteristics of the whole pulp. O'leary and coworkers (17) found a similiar situation while working with glass fibers which are not expected to show bonding, at least, not the type of bonding commonly associated with cellulosic fibers. Therefore one may surmise that the steady increase in the bursting strength of the whole pulp may be attributed to the fact that as the degree of mechanical treatment increases, the percentage of the fines increases. Thus,the formation of the sheet improves, the actual area of contact between the fibers increases (increasing the probability of fiber bonding) and yet a sufficient quantity of long fibers remain to provide for a distribution of applied force throughout a larger area. The last part of the previous statement can be explained through entanglement of the long fiber with other fibers or their fibrillae.

The figures obtained for breaking length show fair uniformity, however, once again the attainment of a maximum strength is noted in the case of the individual fractions. The similiarity between the curves for apparent density and the breaking length is striking, showing clearly that Clark's statement on the relatively small influence of the fiber length on tensile strength has been confirmed.

Folding endurance is known to be a property of unusual variability particularly when one deals with folds of high numerical value. As can be seen in Figure V, the results obtained in this investigation are erratic. The only consistent values are those of the fraction of fibers retained on the 200 mesh screen which, since they are relatively low, seem to indicate that the folding endurance is somewhat dependent on fiber length.

As illustrated by Figure Vl, the tearing resistances obtained conform empirically to the statement made by Clark in this regard. The longest fibered fraction (that retained on the 10 mesh screen) has a high initial tearing strength. After sufficient beating to rupture the fiber wall, the tearing resistance of this fraction improves about 50% over that of the unbeaten pulp. After this preliminary beating, the tearing resistance does not increase significantly with further mechanical treatment. It should be noted that this particular case is the only instance where the strength of the fraction consistently exceeded that of the whole pulp. In direct contrast to the case of the long fibered fraction and still in accordance with Clark's theory is the tearing resistance of the 200 mesh fraction. This fraction's initial tearing resistance was low but it went still lower during the preliminary beating period discussed above. The presence of a larger quantity of fiber debris would account for this peculiar behavior as would the presence of a group of shorter fibers. However, either of these explanations would be reflected in an increased density. Such was not observed.

Throughout this discussion, nothing has been said about the effects of fibrillation. The number of fibrillae produced increases, of course, with increasing beating. Therefore, it is logical to assume that all the long fibers in a pulp will be fibrillated to a certain extent when a freeness of 200 ml. has been attained. Certainly, the increase in the strength characteristics, between the freeness' of 747 and 600 ml., of the long fibered pulp proves conclusively that at least the primary wall has been ruptured. If fibrillation occurs, which it must, why is it that there is no increase in strength characteristics of the 10 mesh fraction of pulp beaten past a freeness of 600 ml.? Fibrillae, if present,

increase the surface area of the fiber, providing opportunity for more intimate contact between the fibers and enhancing the probability of fiber bonding. This increased degree of fiber bonding would result in both an increase in the apparent density and in the bursting and the tensile strength. Obviously, since fibrillation most occur, the only plausible explanation of the phenomena is that the fibrillae are not, or atleast, not strongly attached to the body of the fiber. As a result, they are washed out of the stock during the fractionation run. Assuming that this hypothesis is correct, if samples of pulp were beaten to a freeness or freeness' lower than those allready investigated and then fractionated, the sheets of the fractions would show the same characteristics strength constants presented in this thesis. Eventually, a point would be reached where the extremely high degree of beating would bring about a rupturing of intrafiber bonds which , in turn, would cause a decrease in the total strength characteristics of the sheets.

It seems logical to assume then that the constant strength values that have appeared in this work may be a measure of the bonding strength of the fibers that is due to the removal of the primary fiber wall and the resulting exposure of the secondary wall with its " more available " hydroxyl groups.

SUMMARY

The evaluation of the data obtained during this investigation indicates:

1. The percentage of long fibers in a pulp decreases with increasing beating time. The percentage (by weight) of the fines does not increase as rapidly as the percentage of fibers retained on the This shows clearly that the cutting of the fibers must take place near the ends of the longer fibers thus bringing them down into the intermediate ranges.
2. There is a characteristic maximum density for each fraction extracted from a pulp. This maximum is attained in the interval of beating from 750 to 600 milliliters Canadian Standard freeness, This maximum constant value is a result of the rupture of the primary wall of the fiber and of the removal of the fibrillae by the fractionation process. Furthermore, in the later stages of beating the density of the whole pulp surpasses that of the fractions.
3. A constant maximum value for the strength characteristics of specified fractions obtained by the prescribed fractionation technique seems to be evident. This was found to be the case with bursting strength, tensile strength and tearing resistance. Some evidence is presented which indicates that folding endurance gains by fiber lengths greater than that found in the shortest fraction.
4. The dependence of tearing resistance on fiber length has been profoundly demonstrated. The low density, the wild formatiom and the long fibers of the ten mesh fraction yield a tearing resistance greater than that of the whole pulp, regardless of the degree of beating.

5. The phenomenon of the constant value of strength characteristics of the fractions must be due to the washing out of fibrillae during the fractionation operation. Therefore, it may be concluded that the results comprising these constant values do not the effects of bonding caused by the additional surfaces ordinarily presented by fibrillae.

6. If the results of the Fiber length Index determinations were to be plotted against freeness they would present a curve approaching that of a parabola.

7. Finally, the strength characteristics of the whole pulp consistently exceed the strengths of the individual fractions.

SUMMARY OF TEST RESULTS

TABLE IA

TAPPI STANDARD BEATER RUN ON WEST COAST KRAFT

BEATING INTERVAL MIN.	FREENESS ML. CANADIAN	BASIS WT. G/M²	APPARENT DENSITY	BURST FACTOR	TEAR FACTOR	BREAKING LENGTH	M.I.T. FOLDING ENDURANCE
0	745	63.5	.500	11.4	202	2000	6
5	725	64.5	.515	22.6	273	3330	39
10	667	63.5	.535	33.1	241	4675	141
20	565	64.0	.572	47.6	168	5950	567
30	383	63.5	.633	54.8	139	6860	876
40	225	64.5	.664	57.6	120	7740	1082
50	156	66.5	.690	59.6	116	7700	925

SUMMARY OF TEST RESULTS

TABLE IB

EVALUATION OF HANDSHEETS FROM PULP BEFORE FRACTIONATION

FREENESS ML. CANADIAN	AVERAGE NUMERICAL FIBER LENGTH mm	BASIS WT G/M²	APPARENT DENSITY	BURST FACTOR	TEAR FACTOR	BREAKING LENGTH meters	M.I.T. FOLDING ENDURANCE
747	2.74	67.0	.498	12.5	193	2135	8.[illegible]
600	2.54	59.0	.595	46.5	151	6050	497
485	2.66	64.5	.648	49.5	142	6660	1015
400	2.84	65.5	.636	50.7	138	6790	1033
310	2.51	62.5	.651	56.1	129	6920	794
200	1.99	65.0	.712	60.2	110	7700	1268

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SUMMARY OF TEST RESULTS — TABLE II

STRENGTH CHARACTERISTICS OF HANDSHEETS FROM VARIOUS FRACTIONS

FRACTION MESH	AVERAGE NUMERICAL FIBER LENGTH	RANGE OF FIBER LENGTHS	FREENESS ML. CANADIAN STANDARD	APPARENT DENSITY	BURST FACTOR	TEAR FACTOR	BREAKING LENGTH meters	FOLDING ENDURANCE M.I.T.
10	5.44	2.5 — 6.0 mm	747	.444	8.25	195	1412	2 ~~2.4~~
10	3.99	2.0 – 6.5	600	.568	39.2	282	4895	551
10	4.38	2.5 – 6.25	485	.546	37.5	291	4940	624
10	4.23	2.0 – 6.5	400	.555	36.5	293	4920	716
10	4.23	2.5 — 6.25	310	.538	39.4	325	4900	408
10	3.98	2.25 – 6.25	200	.552	37.8	304	4500	726
16	3.78	1.25 – 4.5	747	.562	11.4	178	1880	10 ~~9.6~~
16	3.12	1.0 – 5.0	600	.620	47.6	154	5870	672
16	3.28	1.5 – 5.25	485	.622	52.7	151	6650	999
16	3.37	1.75 – 5.25	400		NO YIELD			
16	3.54	2.0 – 5.5	310	.588	47.4	164	6100	503
16			200		NO YIELD			
20	3.02	1.7 – 5.5	747	.507	14.2	240	2245	16.4
20	2.82	1.5 – 4.5	600	.631	45.7	133	6240	818
20	2.52	1.25 – 4.00	485	.654	56.7	99	7200	569
20	3.21	1.5 — 5.00	400	.624	49.6	137	6230	767
20	3.00	1.5 – 5.25	310	.620	51.2	153	6780	574
20	3.00	1.5 — 5.5	200	.648	52.5	133	6890	1222
200	1.1	0 – 2.5	747	.578	14.5	115	2535	14
200	1.1	0 – 2.5	600	.652	36.2	80	5490	171
200	1.2	0 – 2.25	485	.642	35.8	82	5800	179
200	1.3	0 – 2.75	400	.641	38.3	78	6010	194
200	1.0	0 – 2.1	310	.592	39.2	68	6070	153
200	1.4	0 – 2.25	200	.658	40.9	68	6820	733

THESIS DATA — D. J. KRASKE
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MAY 29, 1953

TABLE 111

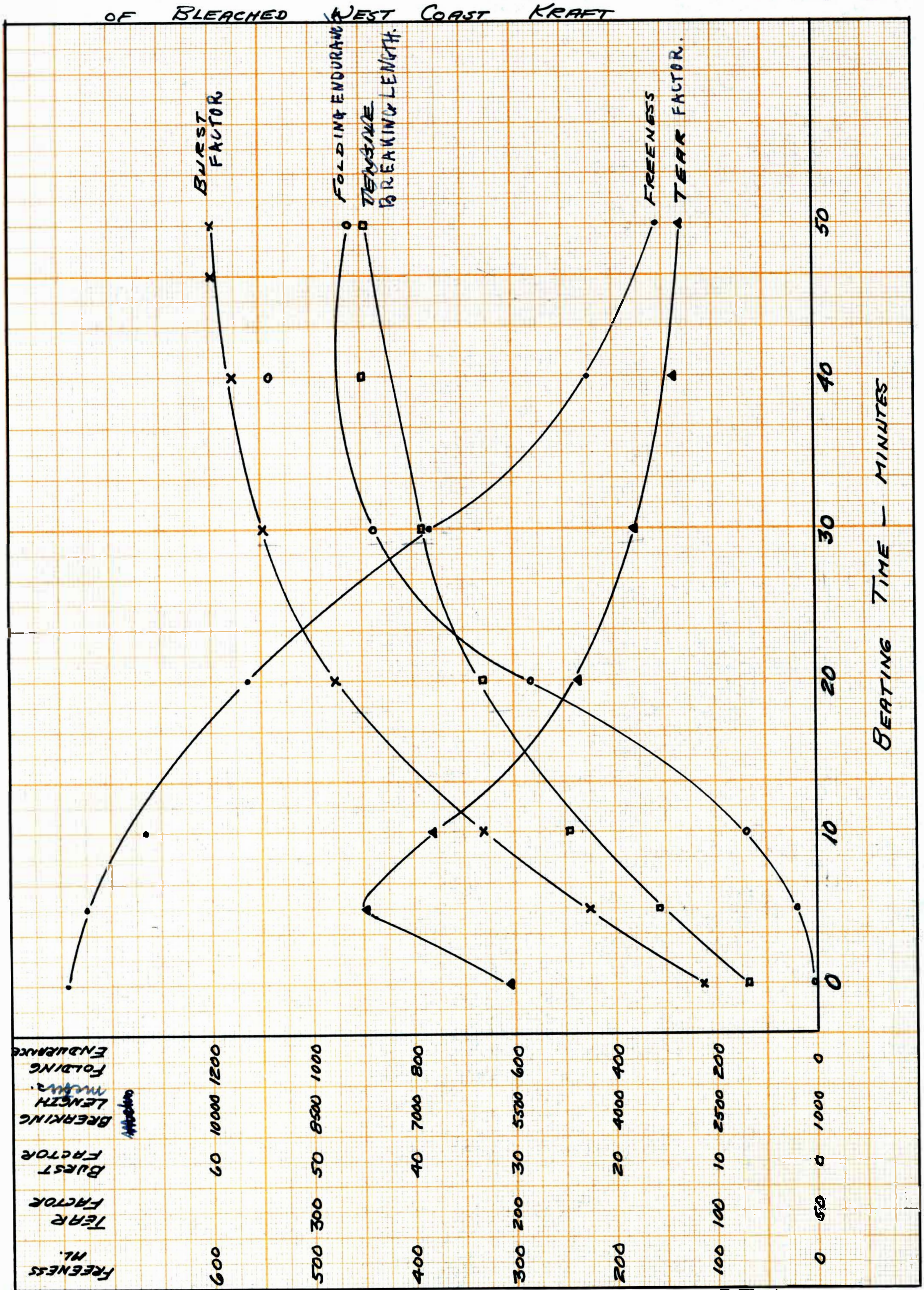
CHANGES IN THE FIBER LENGTH DISTRIBUTION AND THE

FIBER LENGTH INDEX ~~CAUSED~~ BY MECHANICAL TREATMENT.

Beating Time	Freeness C.S.F.	Fiber Length Index	Percent by Weight retained on Classification Screens					Total Wt. Acc't for	
min.	ml.	grams	10 mesh	16 mesh	20 mesh	35 mesh	200 mesh.	~~grams~~ percent	
0	750	5.65	57.5	0.1	23.7	4.4	13.3	~~9.27~~	92.7
15	570	3.33	57.7	1.0	23.2	4.6	13.5	~~9.7~~	97.0
19	500	3.00	54.7	1.1	25.7	5.0	13.5	~~8.95~~	89.5
24	395	2.67	40.8	1.2	37.3	5.2	15.5	~~8.7~~	87.0
28	300	2.40	38.9	1.1	39.4	5.0	15.6	~~9.0~~	90.0
33	200	2.14	28.4	2.4	43.8	7.7	17.7	~~8.45~~	84.5.

BEATER EVALUATION OF BLEACHED WEST COAST KRAFT

FIGURE I



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A COMPARISON OF THE APPARENT DENSITIES OF THE VARIOUS FRACTIONS

FIGURE II

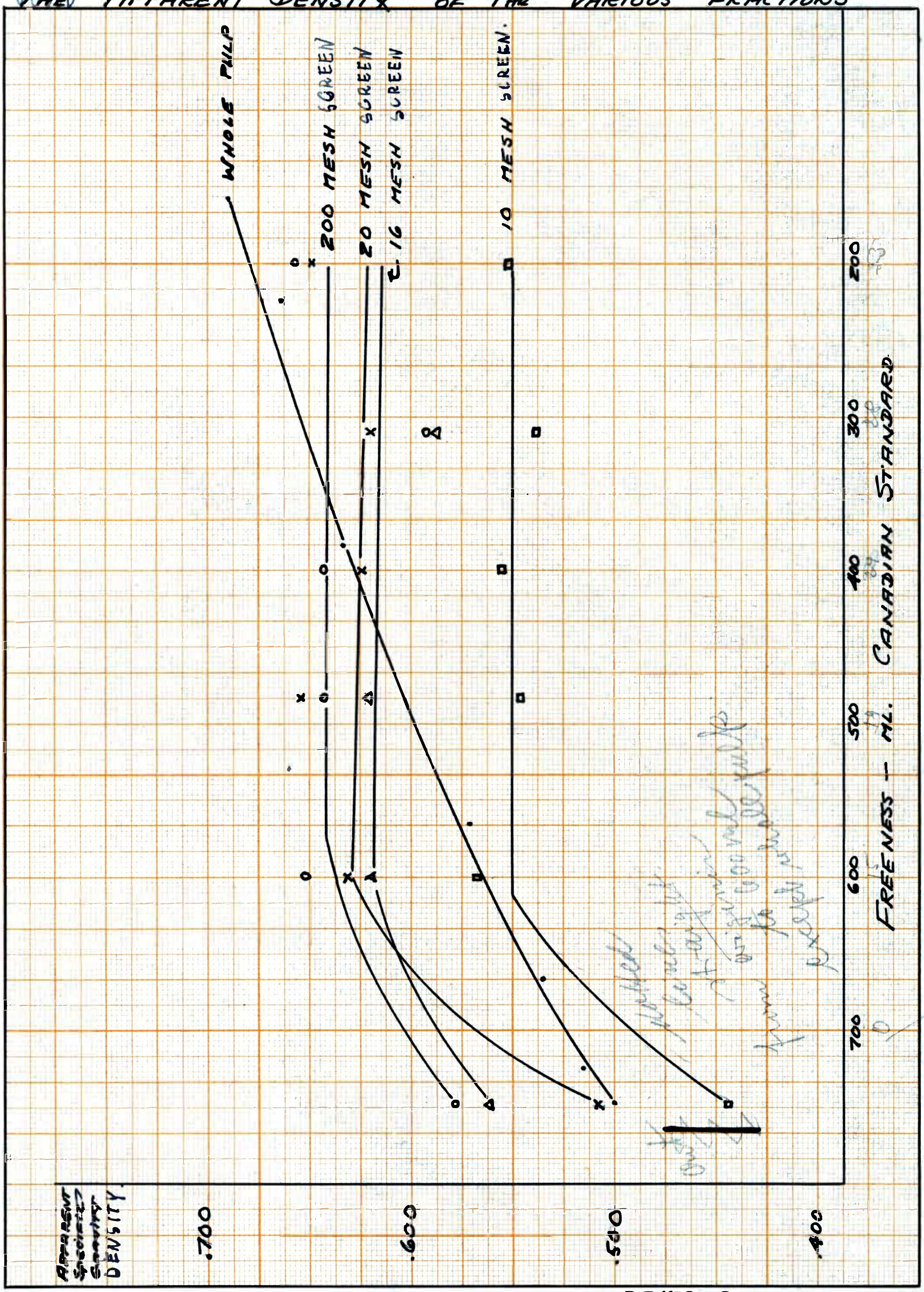

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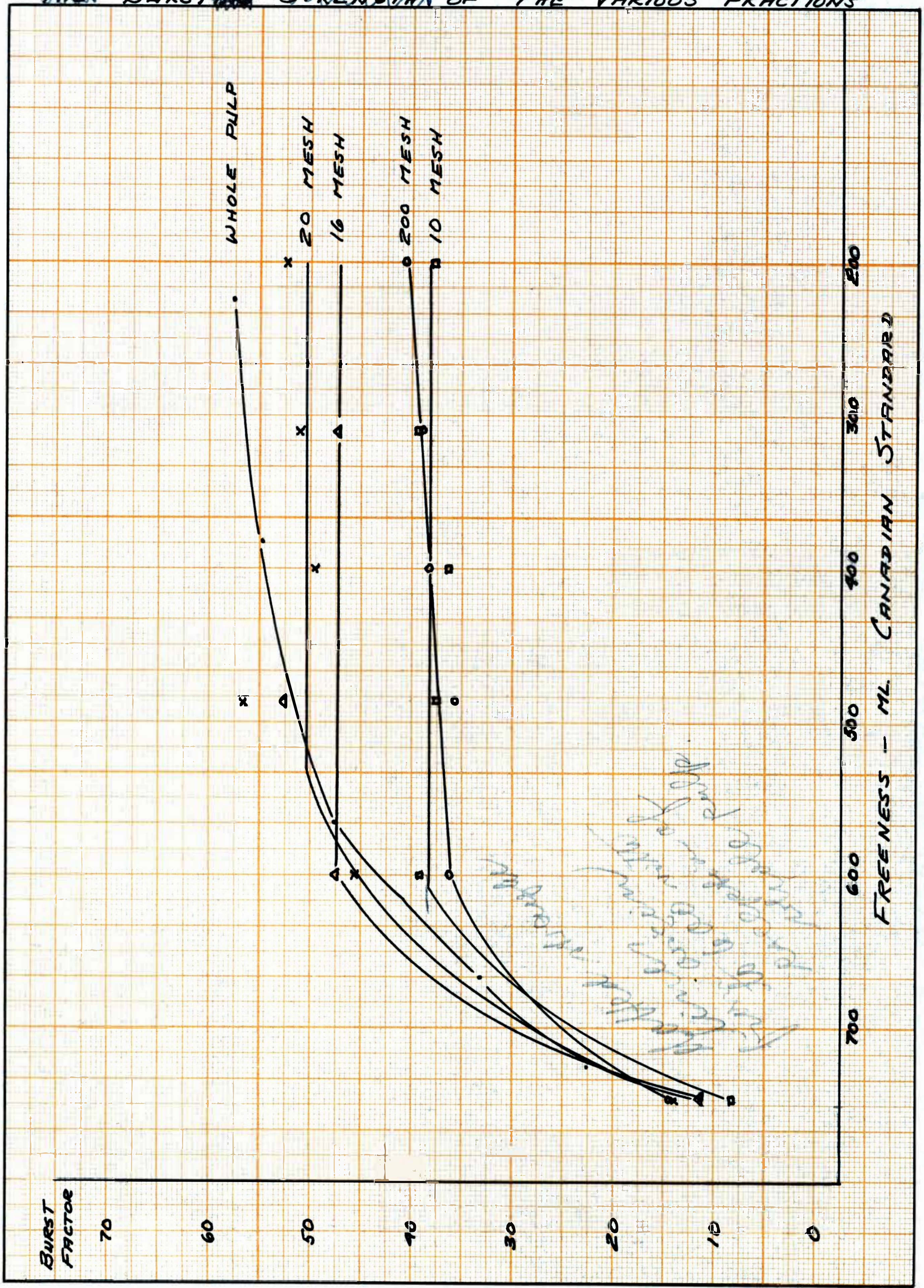
FIGURE III

A COMPARISON OF
factors
~~THE~~ BURST~~ING~~ STRENGTH OF THE VARIOUS FRACTIONS



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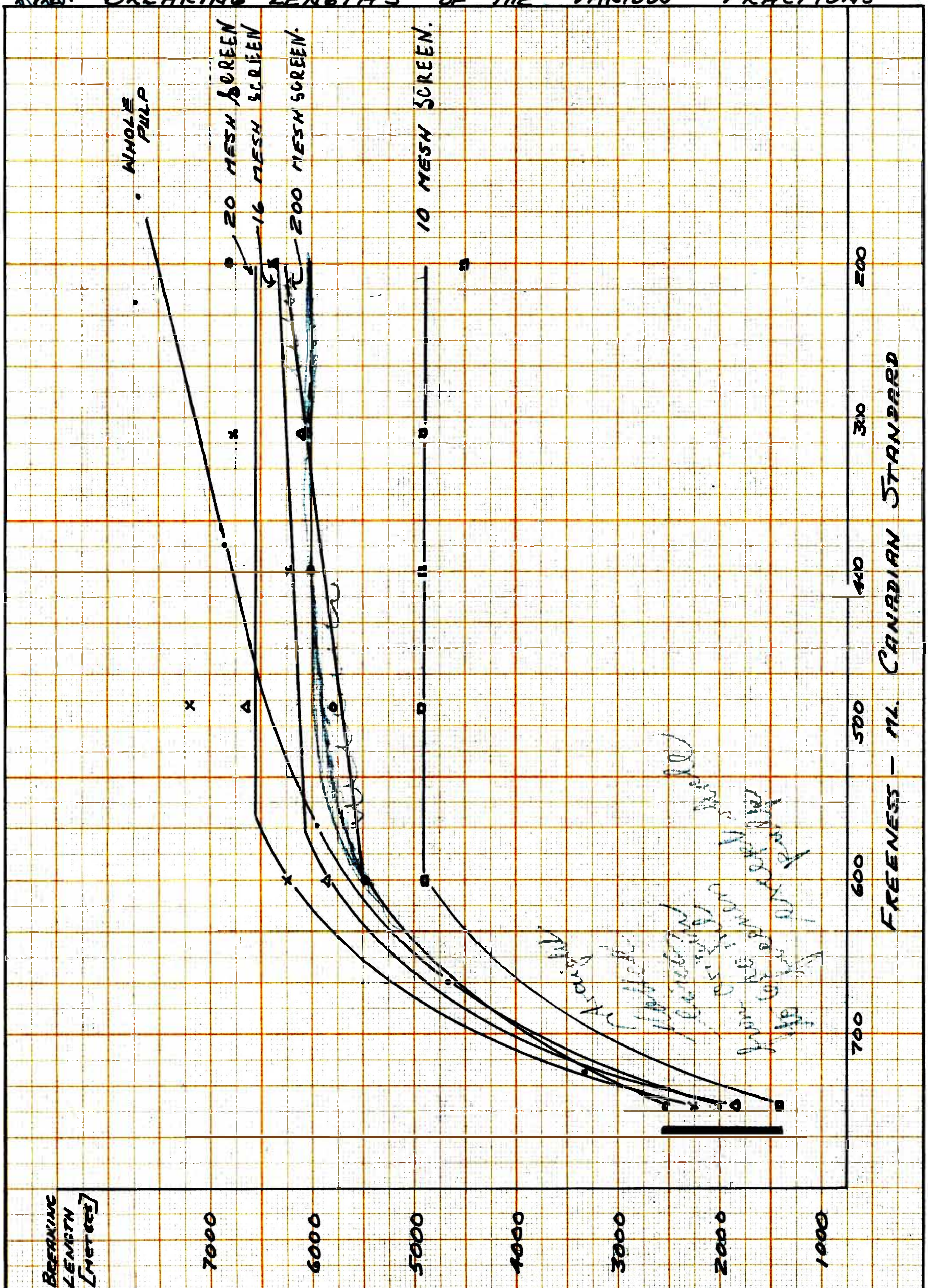
Breaking Lengths of the Various Fractions

Figure IV



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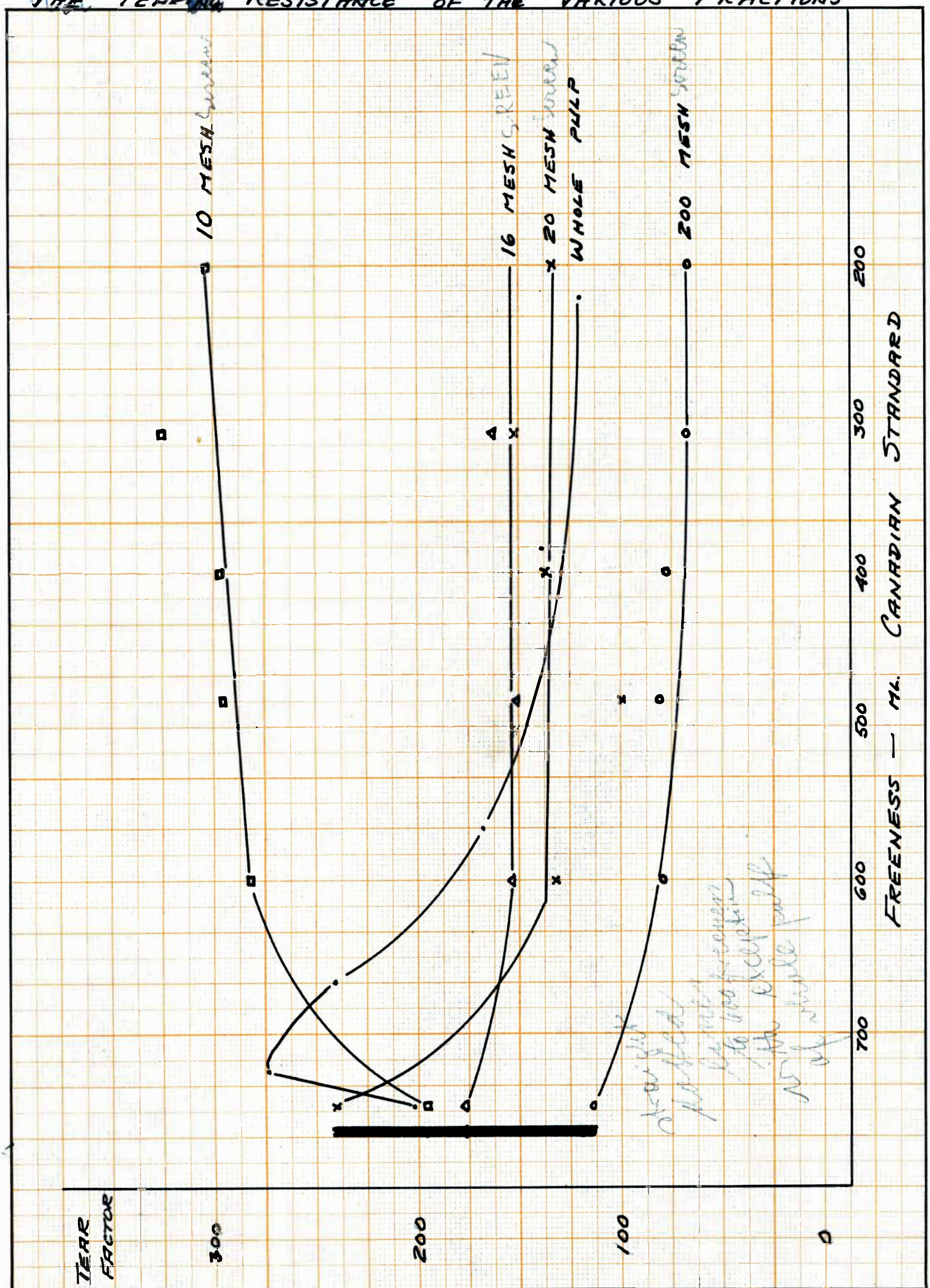
Western Michigan College
5/22/53

FIGURE VI

A COMPARISON OF FACTORS OF THE TEARING RESISTANCE OF THE VARIOUS FRACTIONS



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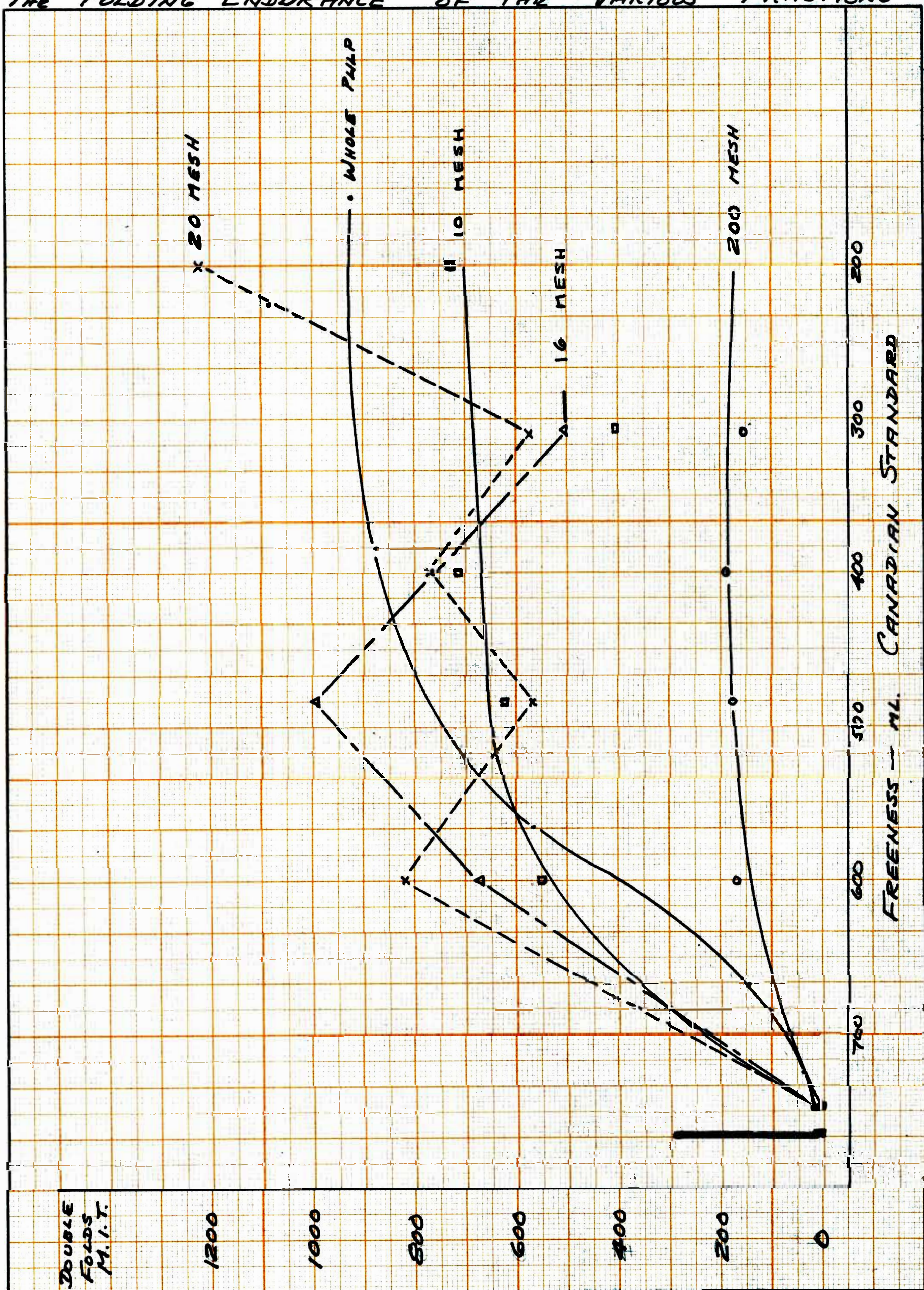
A COMPARISON OF THE FOLDING ENDURANCE OF THE VARIOUS FRACTIONS

FIGURE V



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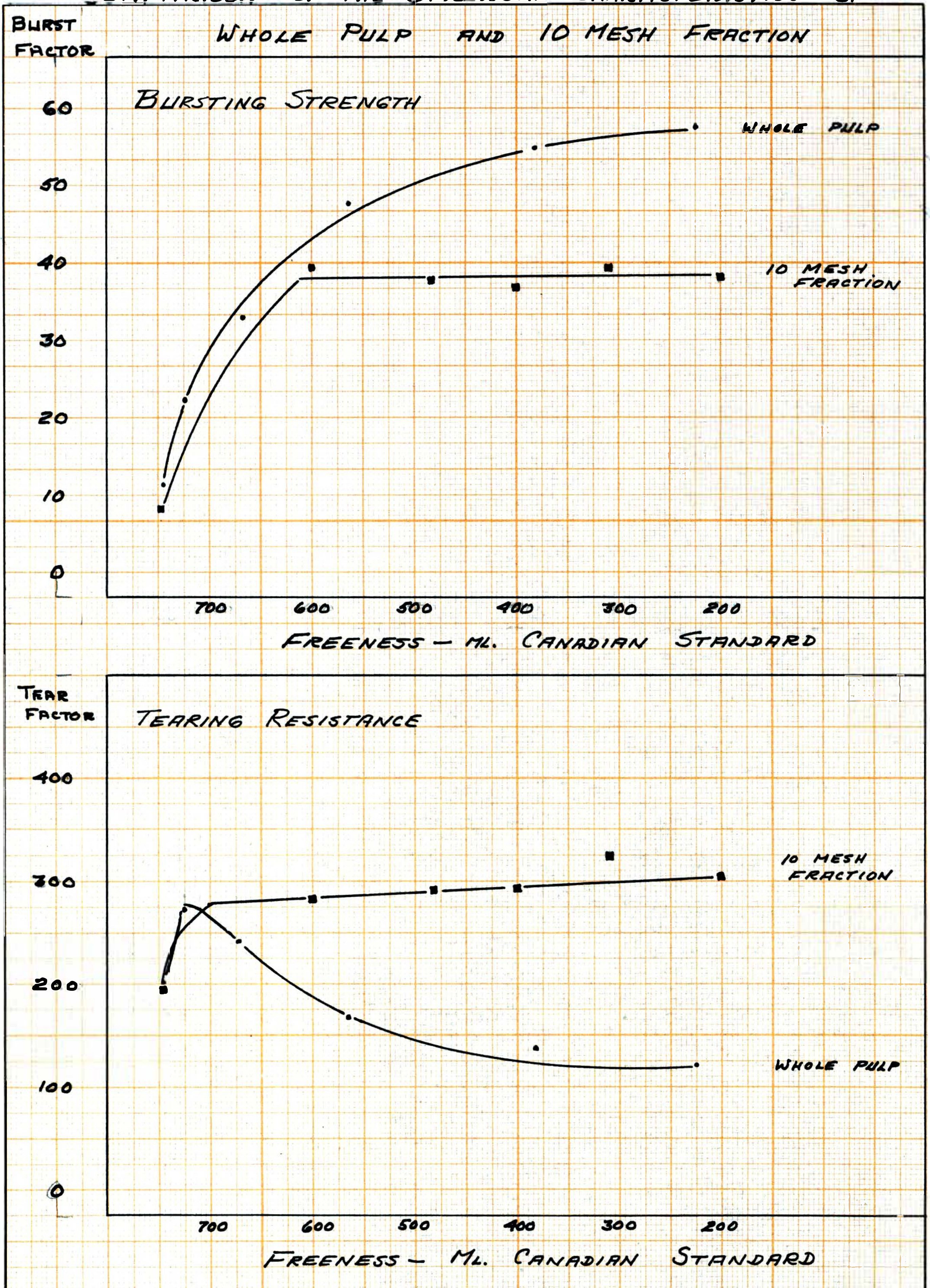
COMPARISON OF THE STRENGTH CHARACTERISTICS OF WHOLE PULP AND 10 MESH FRACTION



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COMPARISON OF THE STRENGTH CHARACTERISTICS OF WHOLE PULP AND THE 10 MESH FRACTION

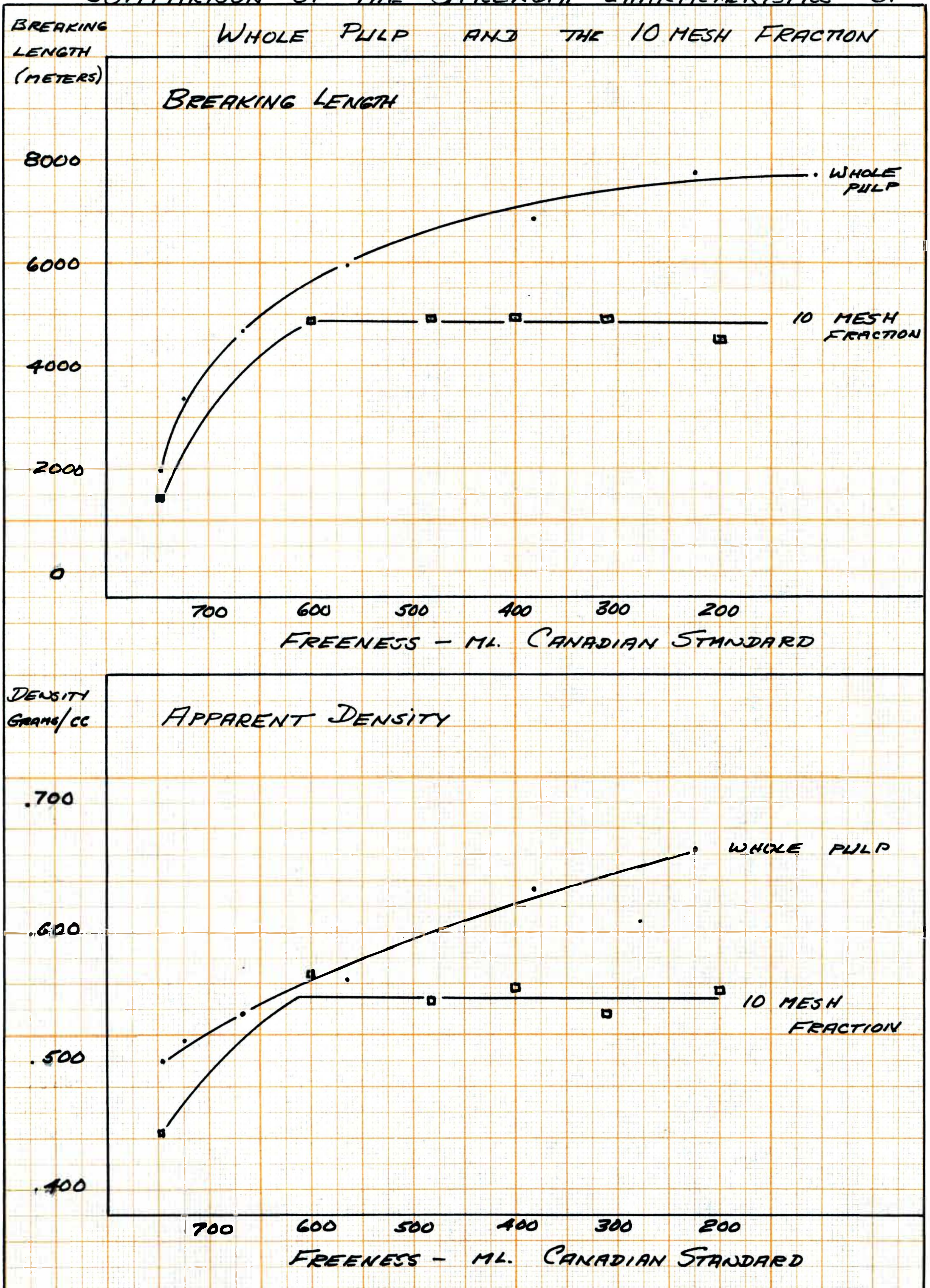

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FIGURE IX

COMPARISON OF THE STRENGTH CHARACTERISTICS OF WHOLE PULP AND 200 MESH FRACTION

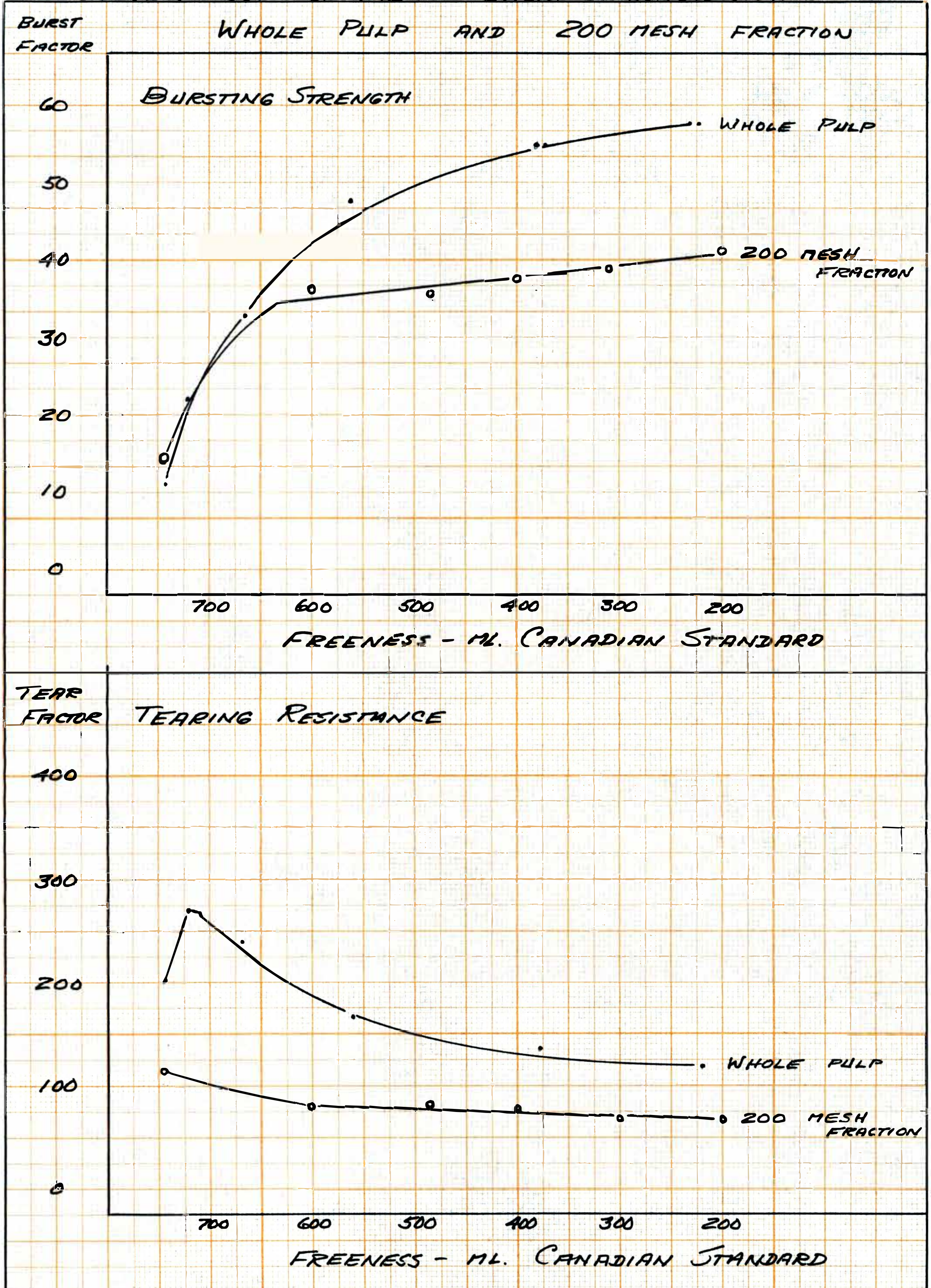

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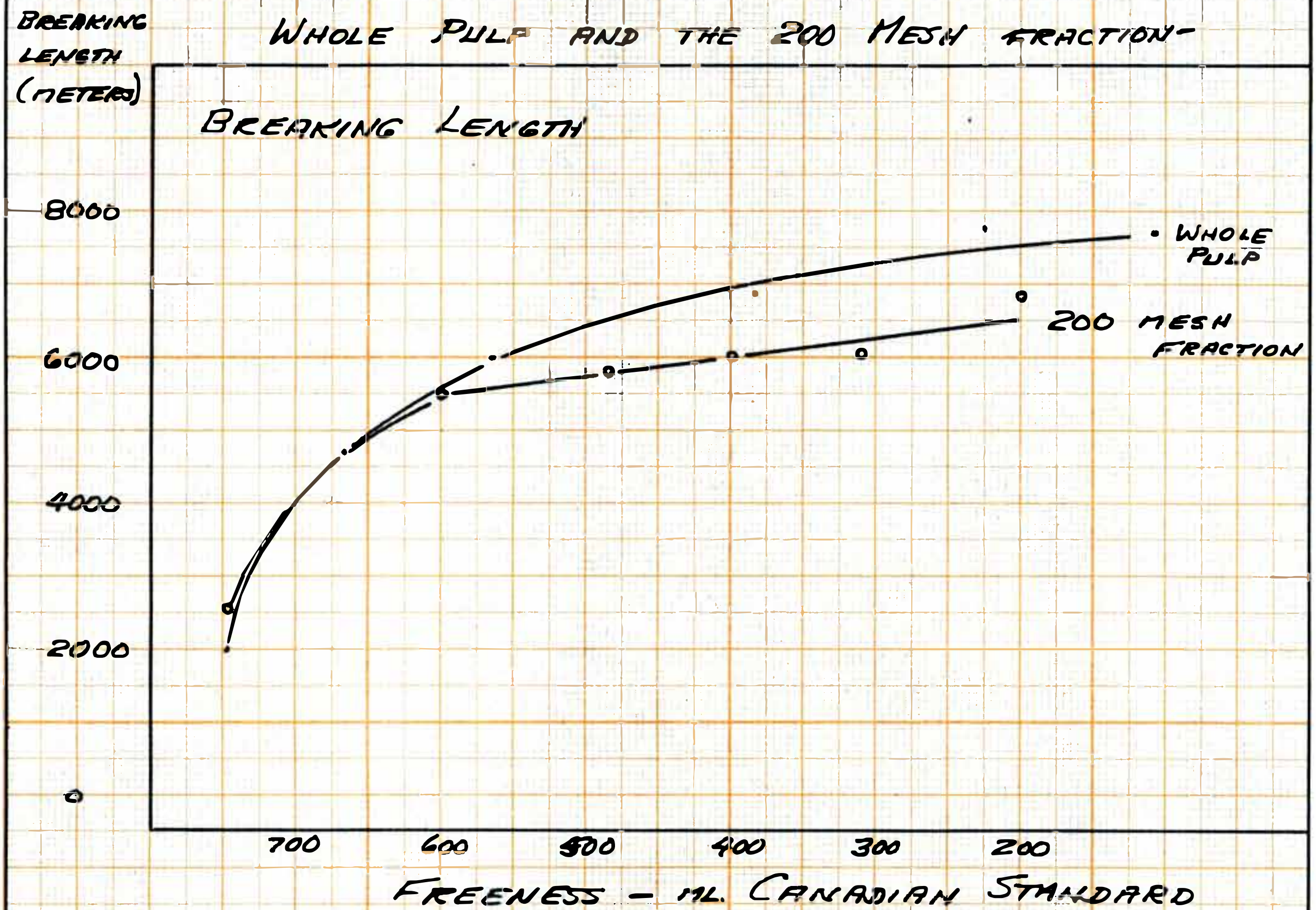
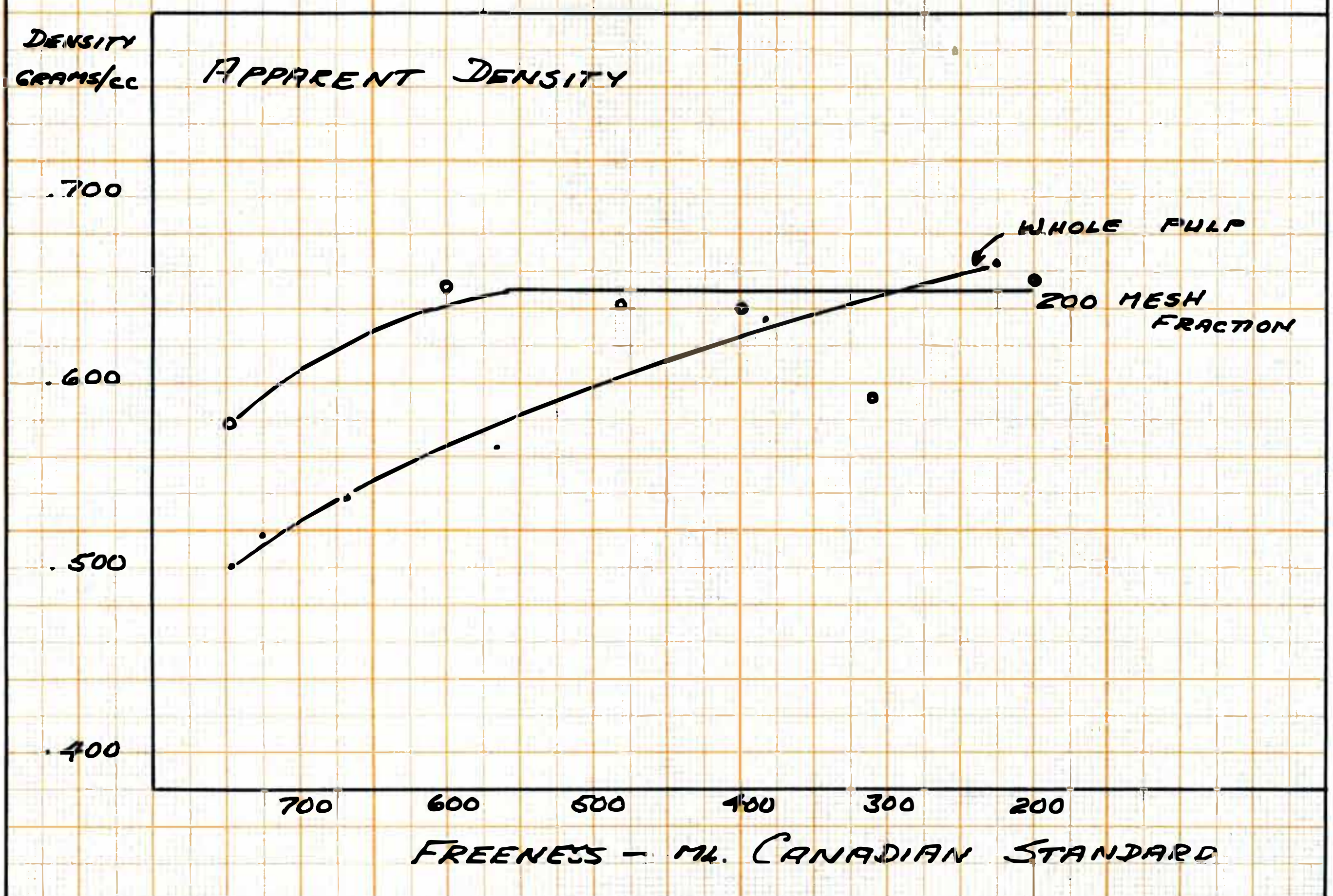
FIGURE X

COMPARISON OF THE STRENGTH CHARACTERISTICS OF WHOLE PULP AND THE 200 MESH FRACTION





D. J. KRASKE
WESTERN MICHIGAN COLL.
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