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The Effect of Machine Draw Tensions on Sheet Properties

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THE EFFECT OF MACHINE DRAW TENSIONS ON SHEET PROPERTIES

BY

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ABSTRACT

A machine run was made on 75% softwood, 25% hardwood bleached kraft. All variables were kept constant except for the draw between dryer sections. This was varied between -0.2 fpm and 2.0 fpm at approximately 90 fpm wire speed. Samples were taken at eighteen points between -0.2 fpm and 2.0 fpm and tested for moisture content, basis weight, tensile, elongation and tensile energy absorption. Moisture content was found to vary from 59.5% to 63.2% dryness while the basis weight varied from 39.2 to 41.1 lb. (25x38-500) ream. The basis weight showed no effect on percent dryness. Both the percent elongation and TEA values were shown to decrease with increased draw in both machine and cross machine direction. With an increased draw the machine direction tensile factor was shown to increase 12% followed by a 6% decrease. In this experiment percent elongation was shown to have more effect on TEA than did the tensile.

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INTRODUCTION

Although there are a number of variables involved in the drying process on the paper machine, it is generally recognized that the degree of tension under which paper is dried will greatly affect the properties of the finished sheet. This research project was designed to investigate the effect of increasing tension during drying on the percent elongation, tensile and TEA of the finished sheet.

Very little work relating to this area of research has been reported in the literature. Of the reported work that was related to this area of research, only the work which was performed by J. E. Sapp and W. F. Gillespie (2) was very analagous to the present research project. Their work was a comparison of the effects of wet straining on a pilot machine run and on laboratory hand sheets. The part of interest in their report was the statement that as the wet straining was increased, the tensile would increase 5-10% and then decrease to slightly lower that the starting tensile. Another work which was related to the research area was the work of A. P. Arlov and B. Ivarsson (1) who reported on their pilot machine run which dealt mainly with the effect of changing felt and draw tensions. The portion of interest in their report dealt with their finding that the percent elongation would decrease in the cross machine direction as the tension during drying was increased.

While the report of Sapp and Gillespie (2) contained the interesting statement about the effect of wet straining on tensile, another statement was made about the effect of wet straining on the percent elongation which contradicted the work of Arlov and Ivarsson[(1)]. Sapp and Gillespie[(2)] made the statement that as wet straining increased the cross machine direction percent elongation would increase. This contradiction with Arlov and Ivarsson[1] was supported by the report of H. F. Rance[4] who compiled a report of the effects of many different variables on the sheet properties. Another contradiction was encountered when the work reported by W. J. Carter[3] was reviewed. Carter's[3] report dealt with a pilot machine run was concerned with the effect of tension during drying on tensile. His conclusion was that the tensile increased with increased tension.

The difference of whether cross machine direction percent elongation increased or decreased with increased tension during was considered important when a sheet is being formed. Also whether the machine direction tensile will increase or increase to a maximum followed by a decrease is likewise considered important when the sheet is being formed. Because of these disagreements in the areas of tensile and percent elongation, it was considered that research was needed.

The method used to study these areas of disagreement was a machine run on a pilot fourdrinier paper machine. All variables except the tension between dryer sections were held as constant as possible while running the paper. Tension between dryer sections was increased in set steps and the paper obtained was tested for tensile, percent elongation, TEA and basis weight. During the machine run moisture samples were obtained to determine percent dryness.

EXPERIMENTAL

The experiment was run on a pilot fourdrinier paper machine running 89 fpm. The pulp used was 75% bleached softwood and 25% bleached hardwood kraft pulp with no additives. It was beaten in a hollander beater to a Canadian Standard Freeness of 477 as tested by TAPPI Standard T-227 m-58. After the couch roll, the paper was put through one press at moderate pressure followed by a second reverse press with just roll weight applied. It then went into the first dryer section which was adjusted to give approximately 60% dryness. The size press between the first and second dryer sections was bypassed and tne paper left the second dryer section at approximately 95% dryness. It was then run through the bottom nip of the calender which was running at roll weight and wound on a pope-type reel. After the sheet had been brought to approximately 40 lb. (25x38-500) and the dryness between the dryer sections was approximately 60% dryness, the draw between dryer sections was set at -0.2 fpm and the first set was run. The draw was then increased by 0.2 fpm for each set until 2.0 fpm was reached, then it was reset at 0.5 fpm and increased by 0.2 fpm for each set until 1.5 fpm was reached. At the start of each set that was run a moisture sample was put in a bag and the moisture of the sheet was determined from it.

After the machine run, the roll was cut down to obtain the samples required for each set. These samples were placed in a humidity room to be conditioned at 50% relative humidity and 73^{o} F according to TAPPI standard T402m-49. After conditioning was complete, the samples were cut into strips to be used on an Instron to test elongation and tensile. Strips were cut 1 inch width and the jaw span used was 10 cm. with a 20%/minute rate of percent elongation. Also standard circles were cut to be used for basis weight determination according to standard T-410m-45.

DATA DISCUSSION

Although an attempt was made to hold everything constant except the draw between the two dryer sections, the basis weight and percent dryness were of great importance and were therefore watched closely. The basis weight of the sheet was desired to be about 40 lb. (25x38-500) and was maintained as close as possible throughout the machine run. It was found that throughout the machine run, the maximum range in basis weight was 1.9 lb. (25x38-500) between 39.2 and 41.1 lb. (25x38-500) with the general trend during the run appearing to be toward slightly lower basis weights as shown in figure 1. Considering the maximum range as being such a small value, the variations in basis weight were well within the acceptable experimental limits. The values that were obtained from the percent dryness checks on the individual sets were also considered to be very good and well within the experimental limits. Figure 2 shows that the maximum moisture range was only 3.7% between 59.5 and 63.2%. These values were very close to the 60% dryness desired, although there was a trend for the percent dryness to decrease as the run progressed. While both basis weight and percent dryness decreased as the machine run progressed, figures 3 and 4 show that only basis weight can be correlated with the amount of draw during the machine run. This relationship can be derived from the definition of basis weight by considering that as the sheet is stretched it becomes thinner and therefore has less weight per unit area. As is shown by figure 4, the percent dryness has no apparent correlation with the amount of draw applied during the machine run and should be considered as a machine variable. One of the effects of increasing the draw is to decrease the percent elongation as can be seen in figure 5. This is due to the effect of prestretching the fibers and alligning them while the sheet is still wet. It seems likely that part of the bonding which should occur during the remainder of the drying process is destroyed by wet straining. Because of the decreased bonding, the stretch that will be tolerated, when the paper is dry, is decreased. At the same time, the effect of increasing the draw has a two-fold effect on the tensile factors as shown by figure 6. It decreased the tensile factor in the cross machine direction as well as increasing the tensile factors to a maximum and then decreasing them in the machine direction. The decrease in the cross machine direction would be expected if the wet straining destroyed some of the conforming action of the wet pressing. It could be asserted that some of the coherence of the sheet that is produced by wet pressing is destroyed by wet straining and is then less well bonded. The change occuring in the machine direction is a little more complex. The tensile factor increased 12% to a maximum value and then decreased 6% with increased draw. It can be theorized that a mechanism which is yet inknown acts to increase the tensile breaking stress up to a maximum and then becomes less effective as wet straining continues, where upon decreased bonding decreases the tensile breaking stress.

Because the increase in draw effects the percent elongation and the tensile factors of a sheet, it must also effect the tensile energy absorption which is a function of percent elongation and tensile. Its effect on the TEA is shown in figure 7 to decrease TEA with increasing draw. To facilitate the verification that this should happen, it is necessary to refer to figures 8 and 9. By comparison of the machine direction graphs of percent elongation and tensile factors with the machine direction graph of TEA in figure 7 it can be observed that the percent elongation has a closer relationship to TEA then does the tensile factor. Because the percent elongation plays a larger part in TEA than does the tensile factor, when the draw increases, the TEA values should decrease due to the decrease in the percent elongation. When an observation is made of the cross machine direction graphs of the relationship of percent elongation and tensile with TEA as shown in figures 8 and 9, the tensile factor appears to be more important than percent elongation. Yet, this seems to be refuted by looking at the similarity of the cross machine direction graphs for percent elongation and TEA in figures 5 and 7. This discrepency can possibly be eliminated by observing that the absolute difference being delt with in percent elongation is tenths while the absolute difference being delt with in tensile factors is hundredths. Therefore, in this particular instance the apparent importance of percent elongation over tensile is due to the degree of magnitude in the numbers rather than an actual closer relationship.

The only relationship between basis weight and the other three variables being studied is due to the inverse relationship between basis weight and draw. For this reason there are no graphs comparing basis weight to the three variables. Because there did not appear to be any relationship between the draw and the dryness, any graphs portraying the relationship between dryness and the three variables being studied would not be of any benefit to this research.

SUMMARY AND CONCLUSIONS

From this research it has been shown that as the tension is increased during drying, the basis weight of the sheet would decrease. It was also shown that percent elongation decreased in both machine and cross machine directions as the tension increased during drying. When the tension is increased during the drying process it has two effects on tensile. The first effect is to decrease the tensile in the machine direction. The second effect is that in the machin direction the tensile increases to a maximum and then decreasing slightly. It was stated that the percent elongation appeared to have more of an effect on TEA than did the tensile facto during this experiment.

It was shown that all of the statements in the research proposal were substantiated from the findings of the research. Further research could be done in the field of finding the effect of percent elongation and tensile on TEA and also possible effects of dryness during the period of stretching on the paper properties.

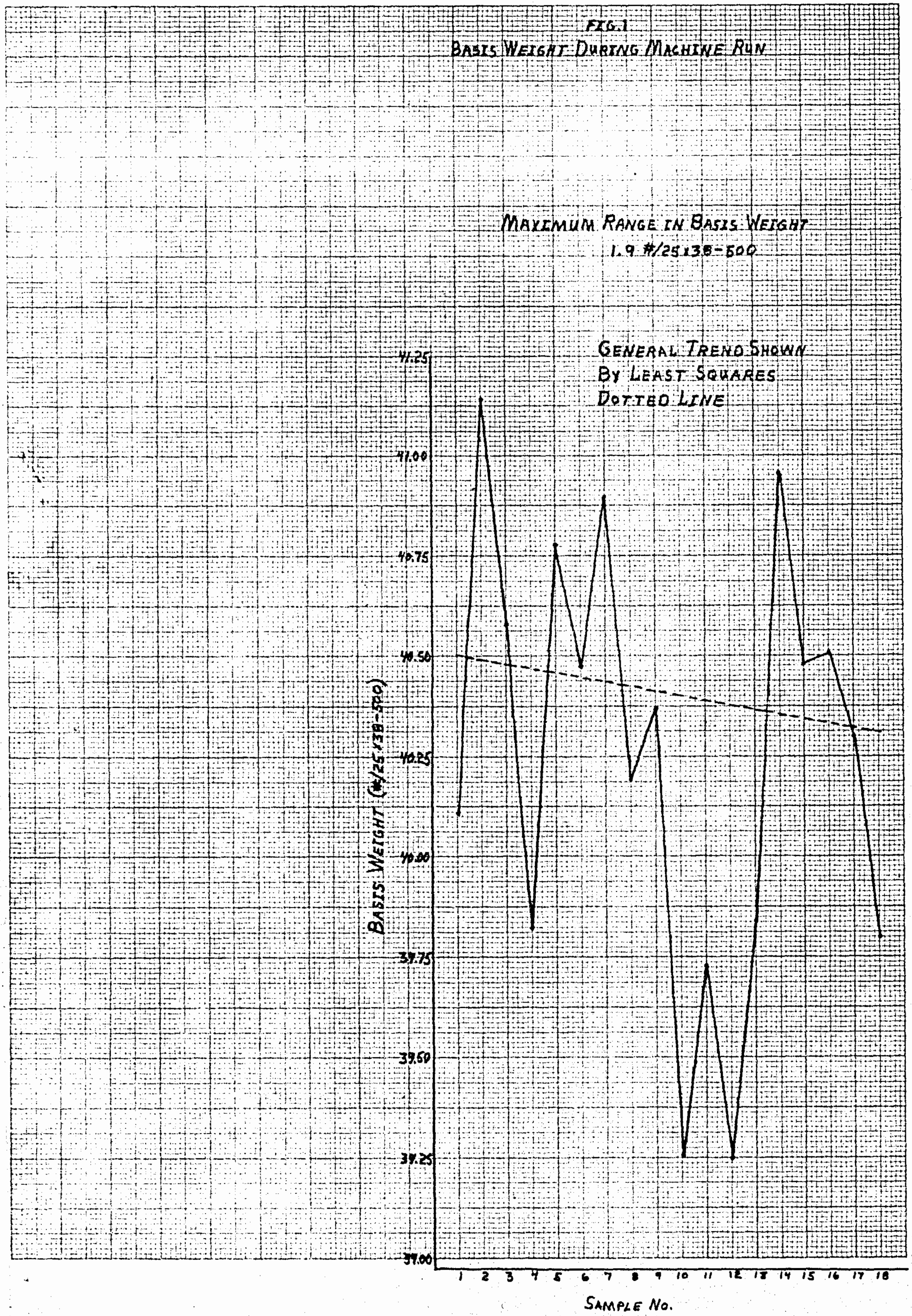


FIG. 1
BASIS WEIGHT DURING MACHINE RUN
MAXIMUM RANGE IN BASIS WEIGHT
1.9 #/25x38-500
GENERAL TREND SHOWN
BY LEAST SQUARES
DOTTED LINE
BASIS WEIGHT (#/25x38-500)
41.25
41.00
40.75
40.50
40.25
40.00
39.75
39.50
39.25
39.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
SAMPLE NO.

FIG. 2
% DRYNESS DURING MACHINE RUN

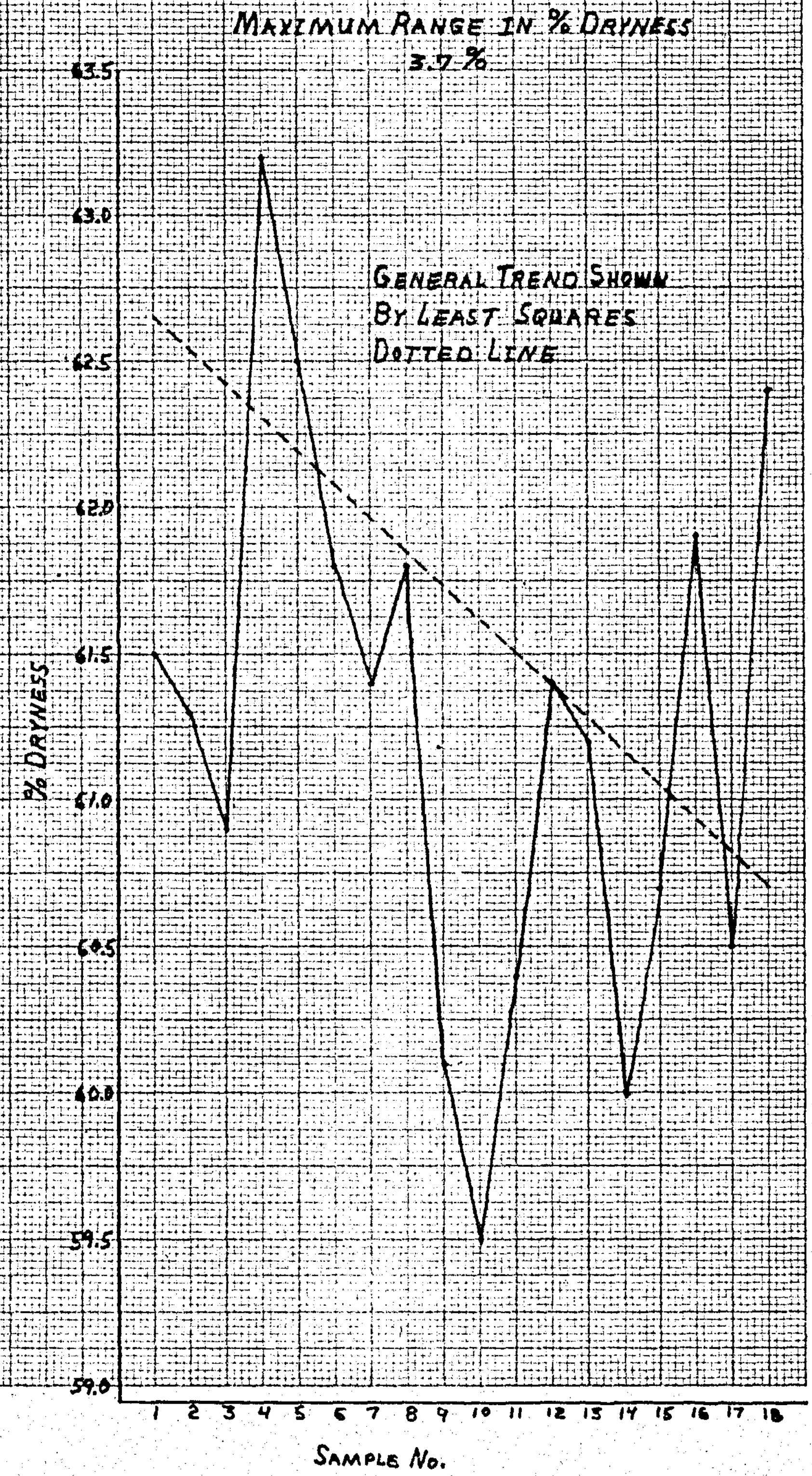
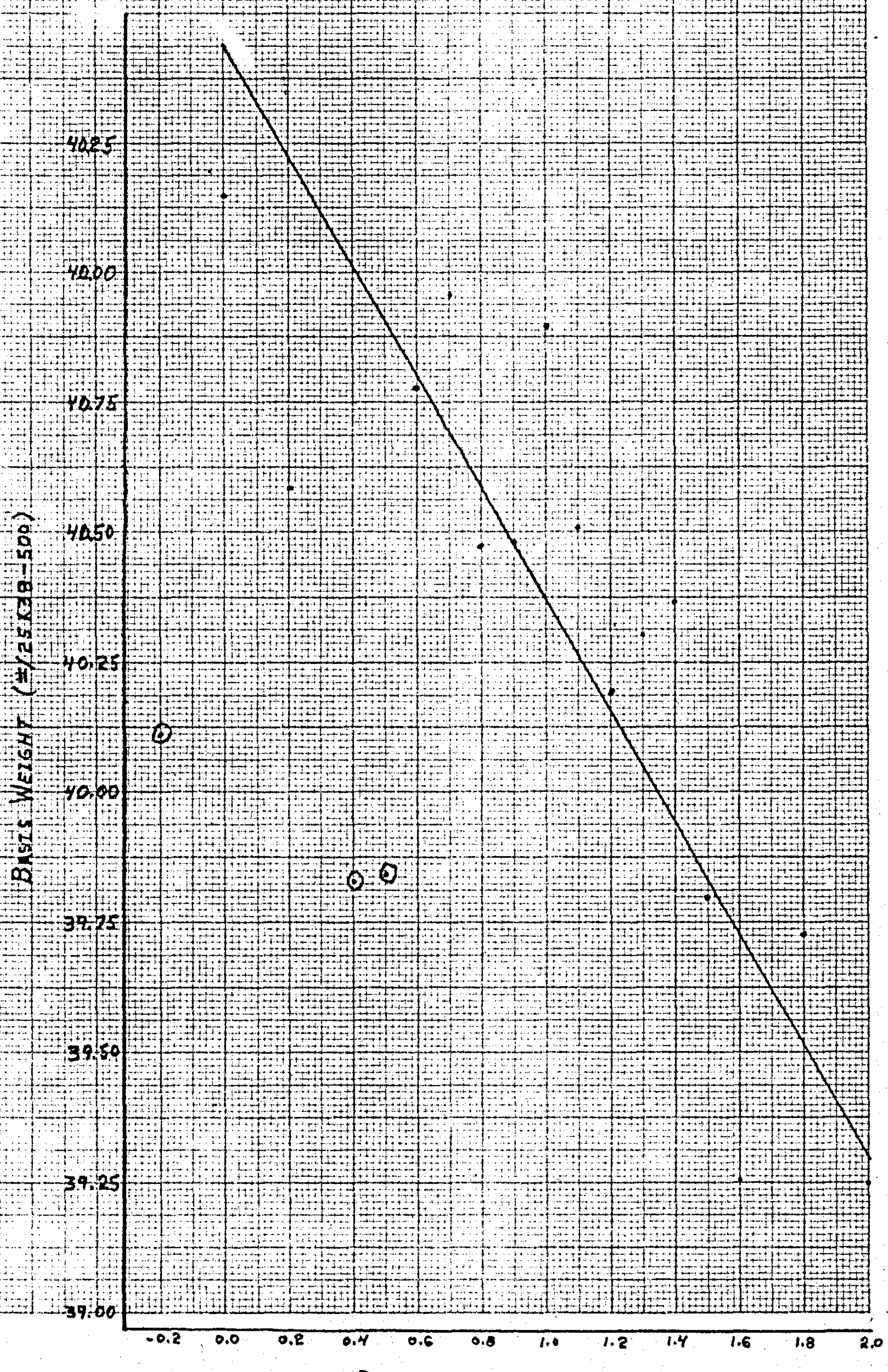


FIG. 3
THE EFFECT OF DRAW ON BASIS WEIGHT



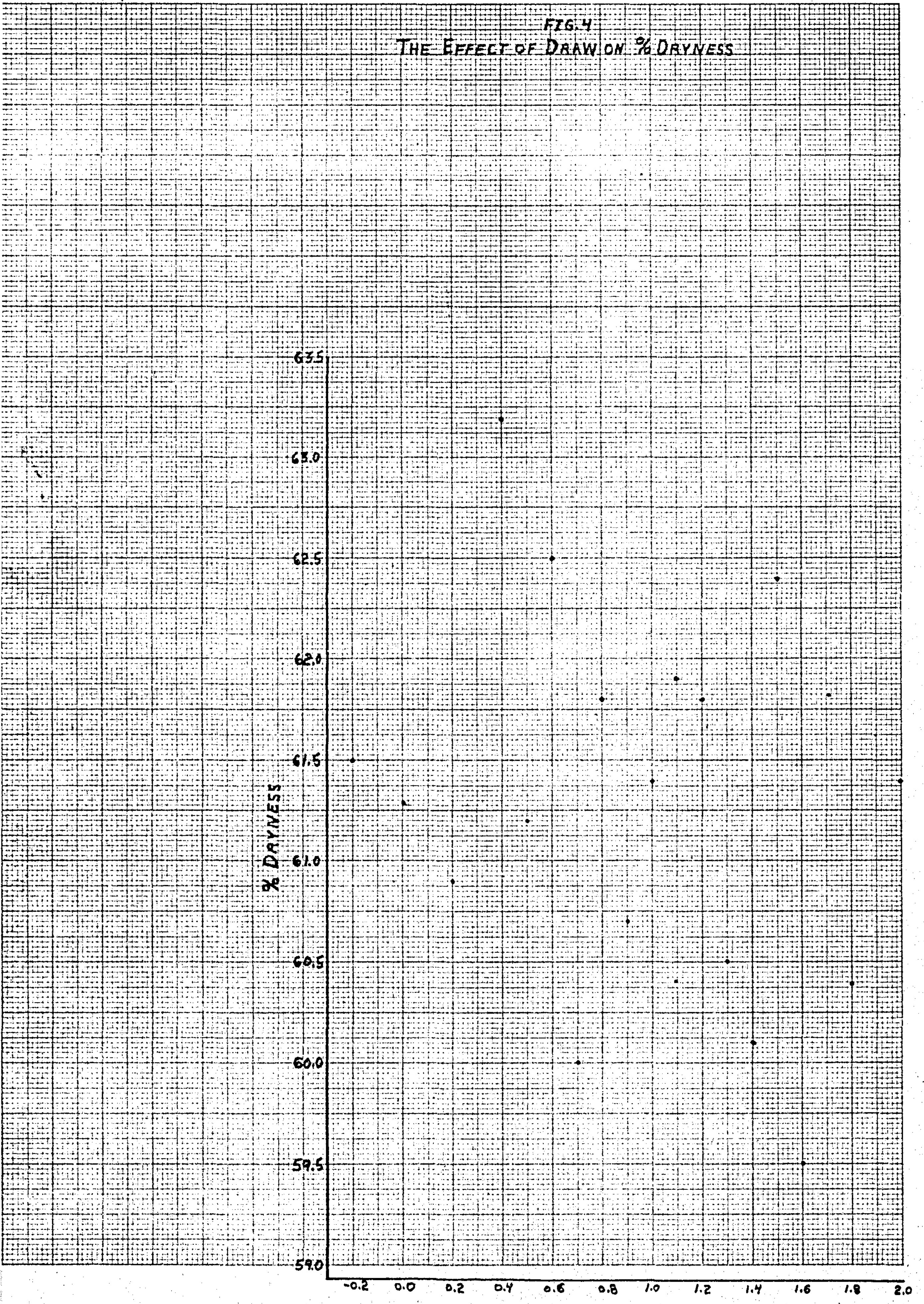


FIG. 4
THE EFFECT OF DRAW ON % DRYNESS
% DRYNESS
63.5
63.0
62.5
62.0
61.5
61.0
60.5
60.0
59.5
59.0
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
DRAW (FPM)

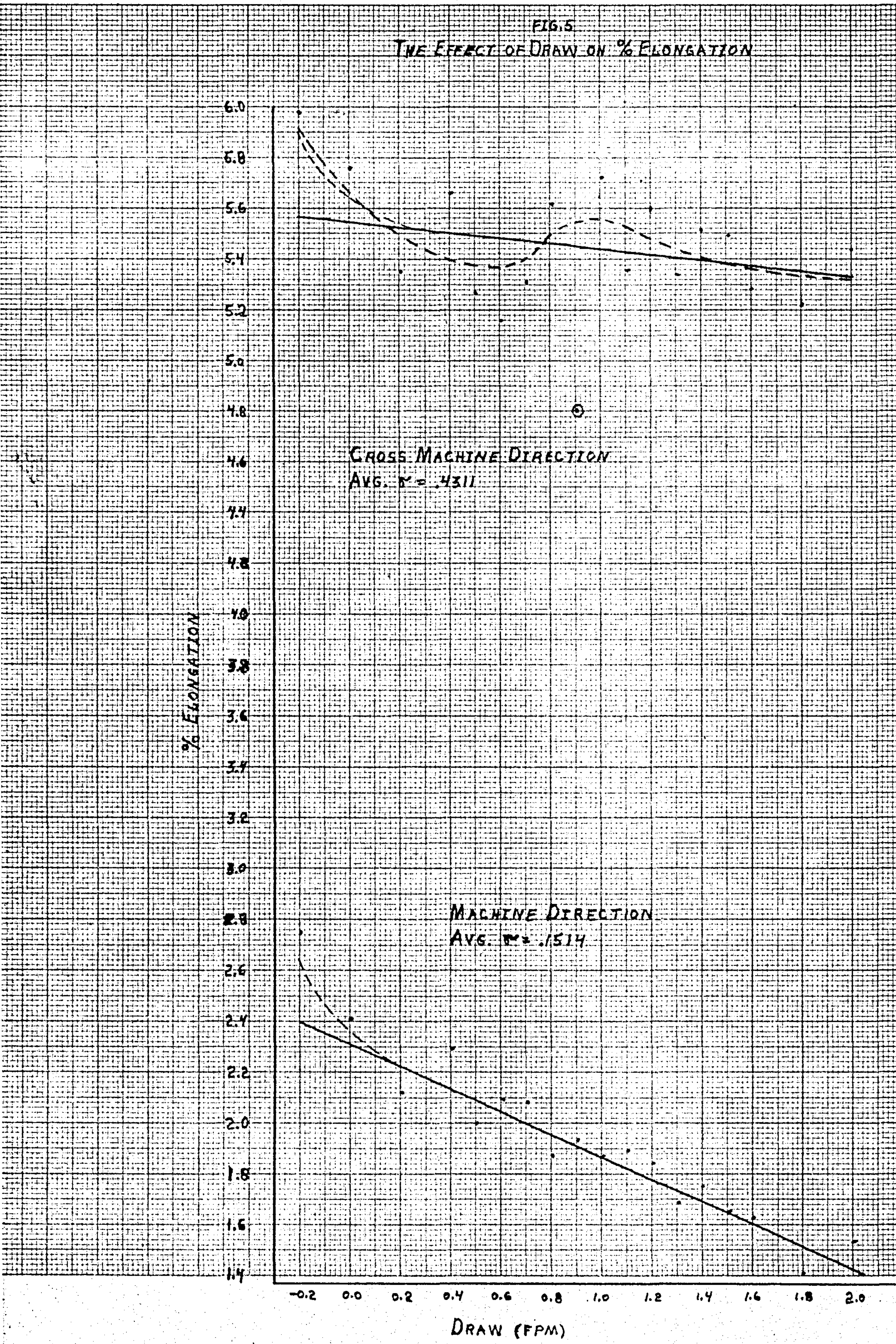
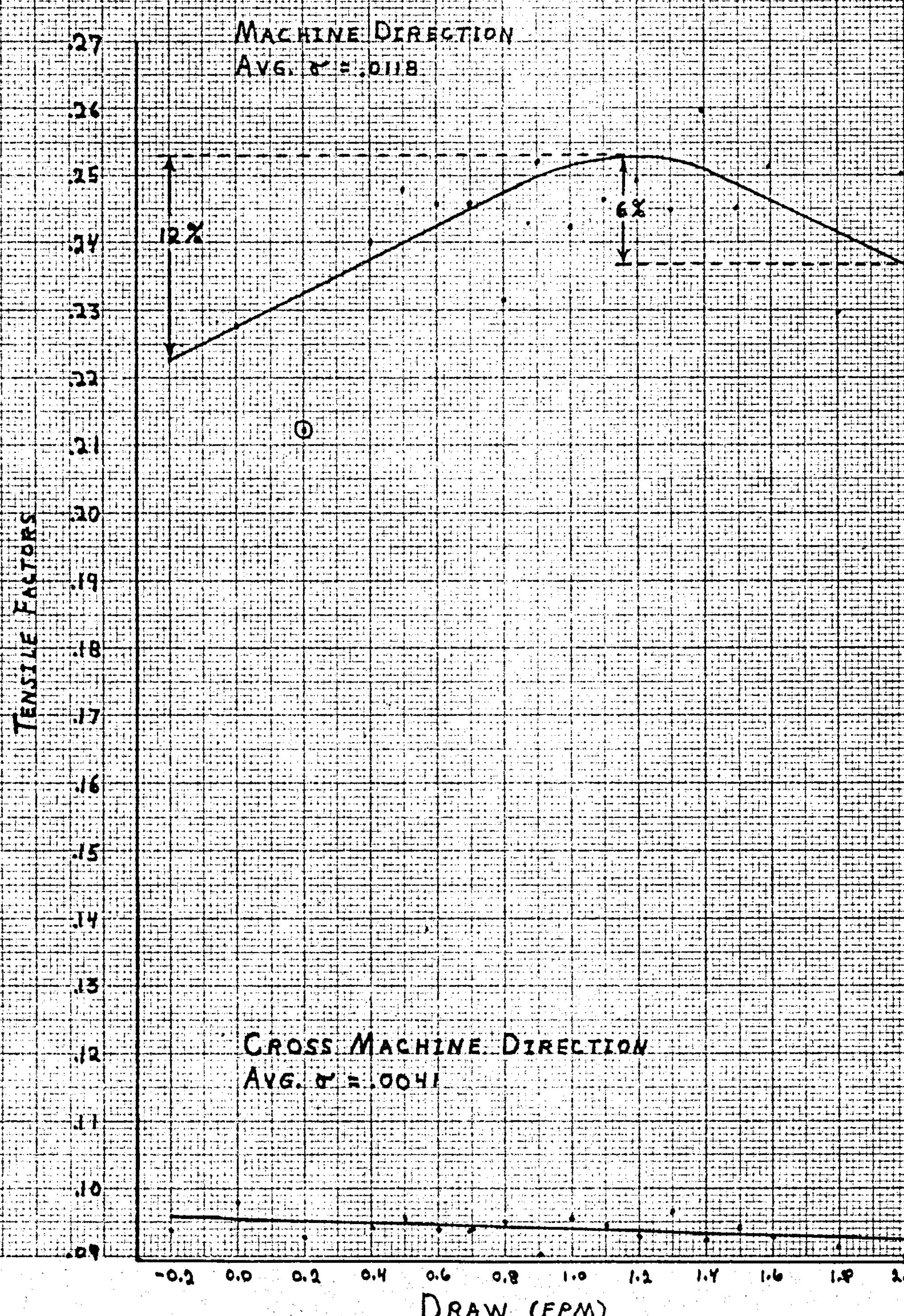


FIG. 5
THE EFFECT OF DRAW ON % ELONGATION
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
% ELONGATION
CROSS MACHINE DIRECTION
AVG. r = .4311
MACHINE DIRECTION
AVG. r = .1514
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
DRAW (FPM)

FIG. 6
THE EFFECT OF DRAW ON TENSILE FACTORS



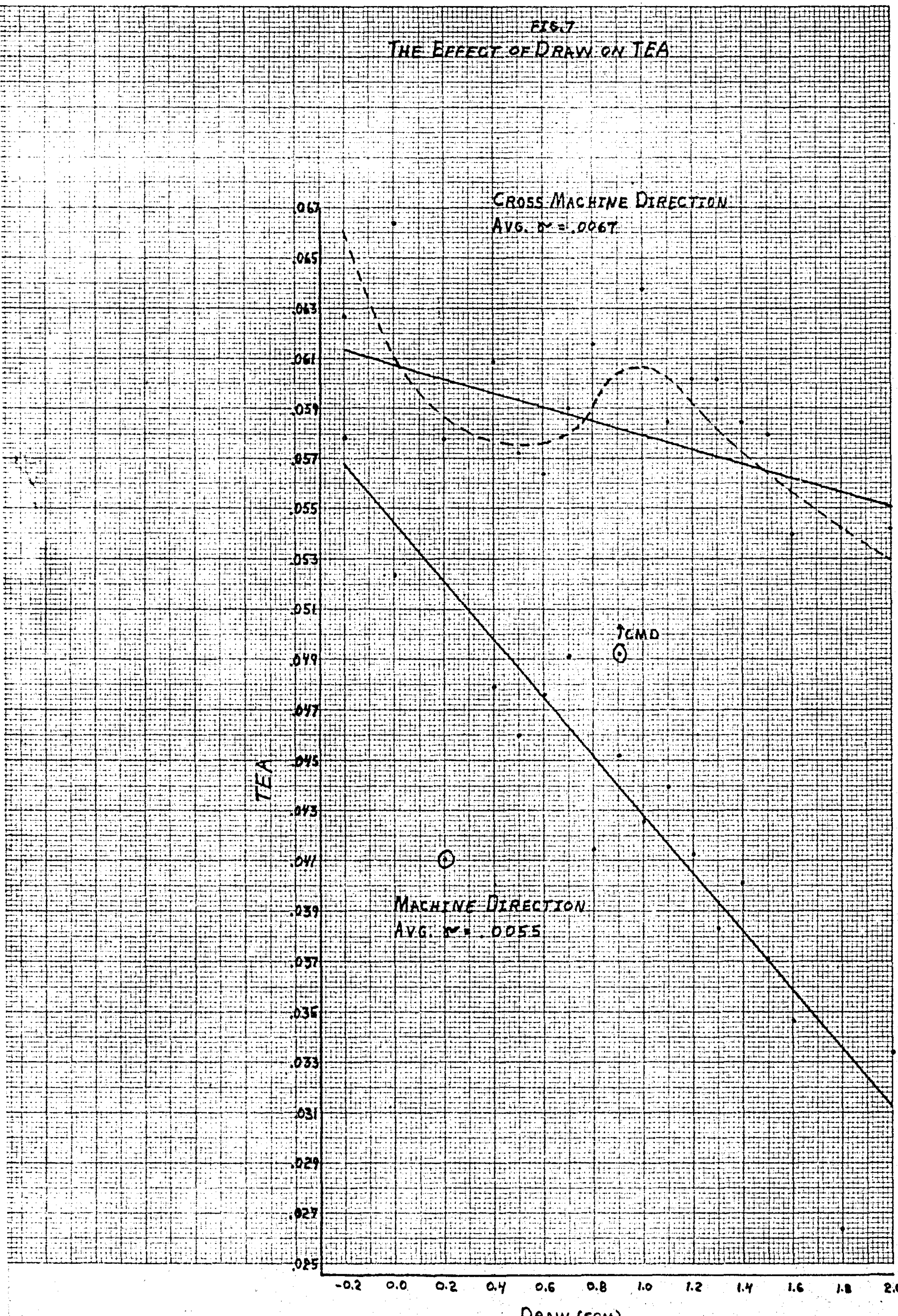


FIG. 7
THE EFFECT OF DRAW ON TEA
CROSS MACHINE DIRECTION
AVG. σ = .0067
MACHINE DIRECTION
AVG. σ = .0055
↑CMD
TEA
.067
.065
.063
.061
.059
.057
.055
.053
.051
.049
.047
.045
.043
.041
.039
.037
.035
.033
.031
.029
.027
.025
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
DRAW (FPM)

FIG 8
THE RELATIONSHIP BETWEEN % ELONGATION AND TEA

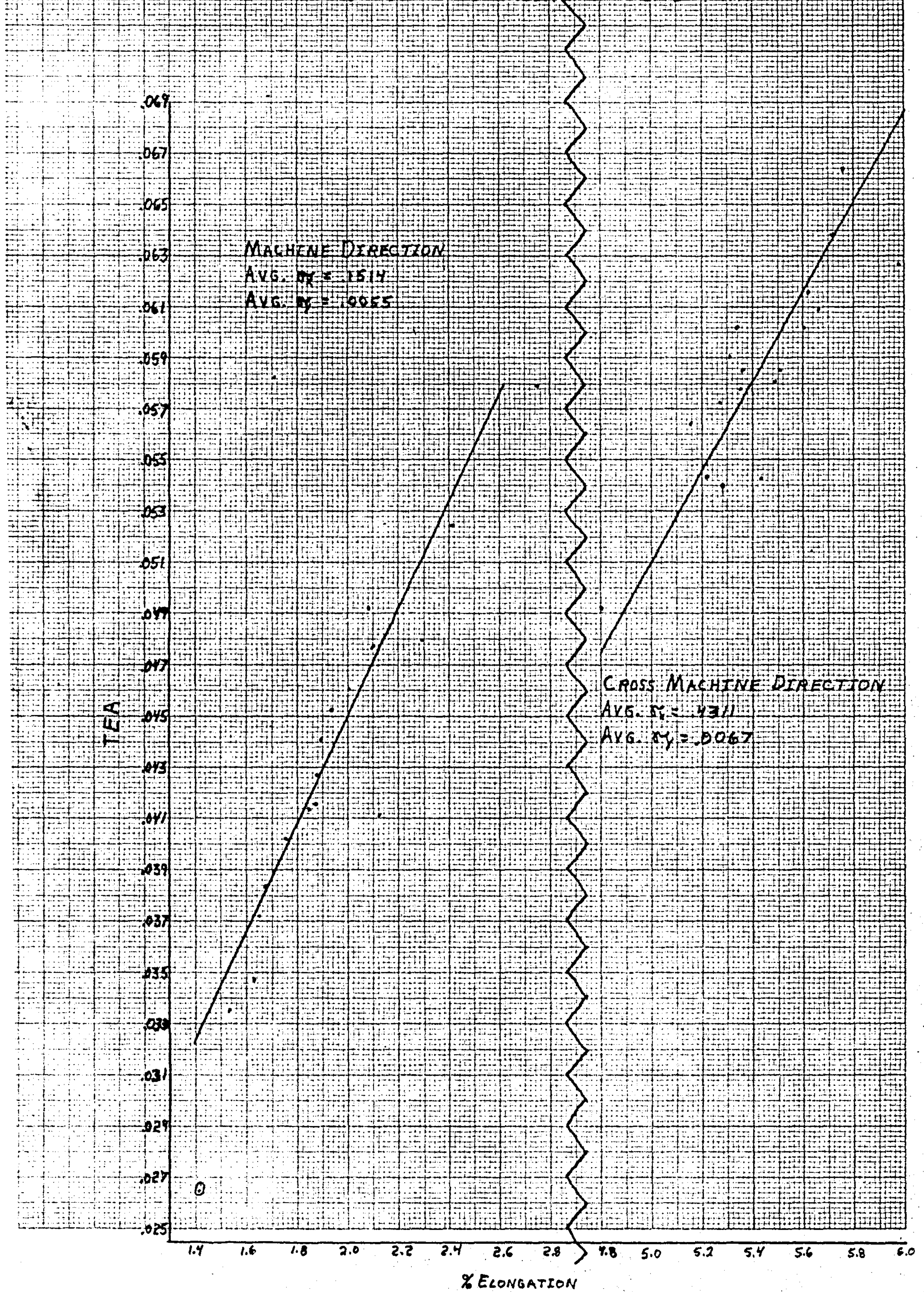
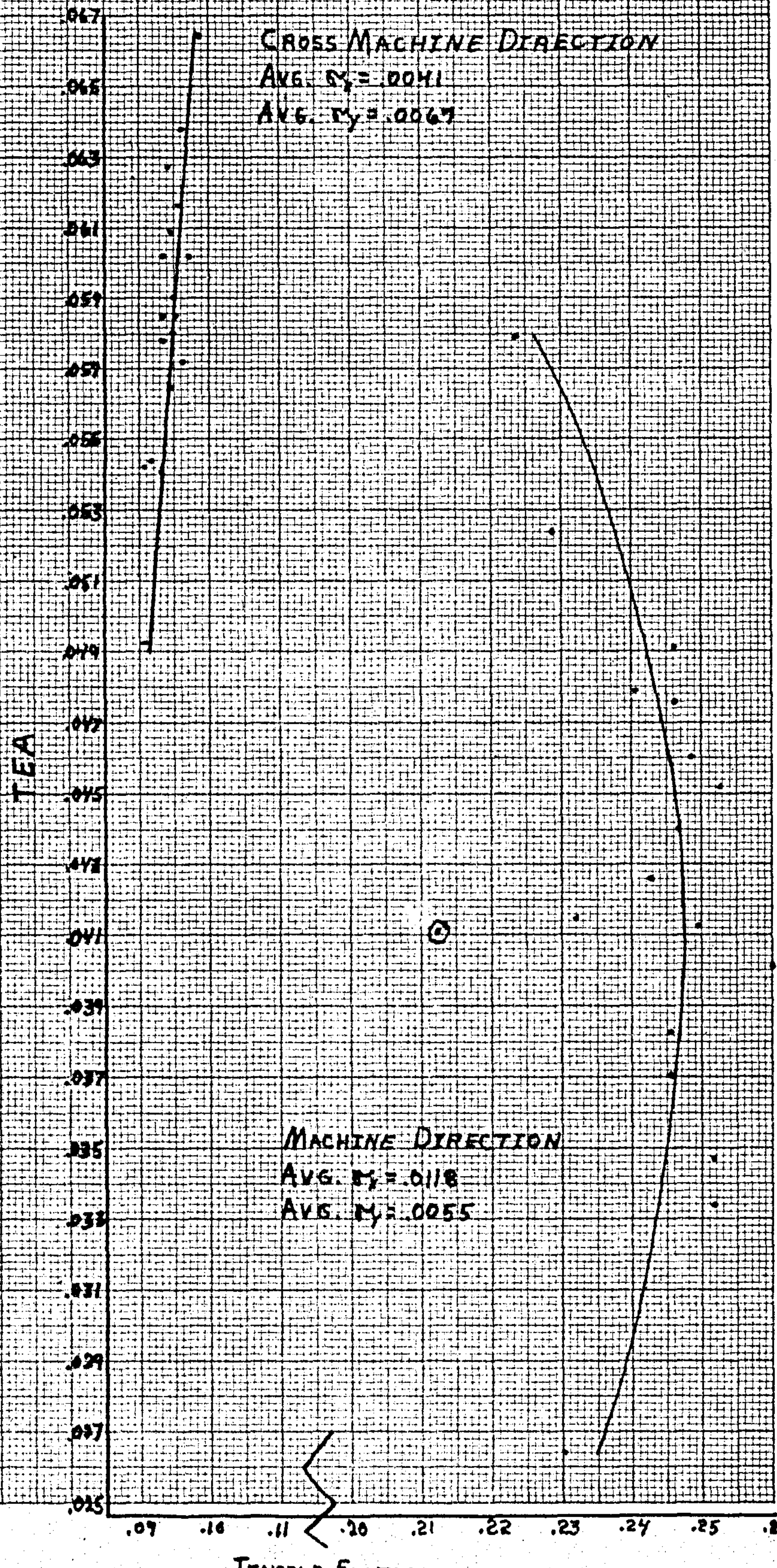


FIG. 9
THE RELATIONSHIP BETWEEN TENSILE AND TEA



DATA TABLE – STANDARD DEVIATIONS

run #	Tensile factor machine Direction	Tensile factor cross-machine Direction	% Elongation machine Direction	% Elongation cross-machine Direction	Tensile energy absorption machine Direction	Tensile energy absorption cross-machine Direction
1	0.0173	0.0028	0.2872	0.5381	0.0102	0.0067
2	0.0090	0.0054	0.2343	0.5044	0.0079	0.0097
3	0.0160	0.0037	0.1887	0.4500	0.0070	0.0076
4	0.0065	0.0026	0.1868	0.4077	0.0033	0.0061
5	0.0095	0.0030	0.1446	0.4944	0.0046	0.0072
6	0.0094	0.0032	0.1616	0.5706	0.0108	0.0073
7	0.0199	0.0044	0.1792	0.3092	0.0059	0.0060
8	0.0168	0.0048	0.1428	0.4899	0.0069	0.0083
9	0.0053	0.0035	0.1204	0.2700	0.0032	0.0046
10	0.0084	0.0026	0.1166	0.4142	0.0036	0.0062
11	0.0082	0.0050	0.0700	0.4020	0.0014	0.0050
12	0.0171	0.0040	0.1005	0.3716	0.0042	0.0051
13	0.0103	0.0033	0.1000	0.3951	0.0039	0.0057
14	0.0128	0.0039	0.1077	0.2166	0.0047	0.0048
15	0.0136	0.0064	0.1487	0.6738	0.0060	0.0102
16	0.0087	0.0052	0.1221	0.4964	0.0044	0.0092
17	0.0139	0.0041	0.1778	0.2764	0.0059	0.0044
18	0.0102	0.0061	0.1360	0.4784	0.0050	0.0074
avg. value	0.0118	0.0041	0.1514	0.4311	0.0055	0.0067

DATA (MACHINE RUN)

Machine Conditions During Run

Position	Draw
between first press and smoother----------------	+1.4 fpm
between smoother and first dryer section--------	0.0
between first dryer section and second dryer section----	-0.2
between second dryer section and calender-------	-0.1

Wire speed = 88.8 fpm

Pressure on first press = 15 psi air pressure

Pressure on calander = roll weight

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