STEADY STATE SIFTING OF FIRST BREAK WHEAT STOCK

by

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INTRODUCTION

In a general flour milling process, stocks with different compositions are classified according to particle size. After the roller mill, which does the grinding work in the mill, the sifter is the machine that has most influence on the performance of a mill.

Due to increasing costs, the milling industry is constantly looking for higher capacity, efficiency and economy in its operations. Shortened systems make possible substantial economic benefits, thru higher rates of feed to the rolls and more efficient sifting machines.

Improved designs depend on a better understanding of the factors that govern the sifting process. The large number of variables involved account for the difficulty in developing a satisfactory theory of sieving.

Sieving studies can be made using two different approaches. The first one is the steady state condition found in most industrial processes; the material is fed continuously at a steady rate into the sifting machine and the relative amounts and quality of the thrus and overs are studied.

The second approach is the non-steady state condition in which a given quantity of material is placed on a screen and sieved in a certain device. In this case the amount and quality of the thrus and overs are studied as a function of time.

Most studies of sieving have been made by non-steady state condition since the equipment is far simpler and the amount of material required is much less than for a steady state study.

The objective of this work was to determine relationships among important parameters of a sieving process such as the nature of the stock, feed rate, thruput, traveling speed of the stock, sifter motion and the granulation of the thrus.

This experiment was carried out using stock from first break under steady state conditions.

LITERATURE REVIEW

A general definition considers sifting as a mechanical separation of a mixture according to the thickness or cross section of its particles (3). Sifting is the most widely applied method of separation in the milling process. Scalping, grading, dusting, flouring, rebolting are all sifting operations, though their purposes and the means by which they may be carried out are different (2,4).

The effectiveness of a separation of a mixture depends on the operating conditions of the separator, which in turn are determined in general by the following parameters:

- Initial feed
- Exposure to separation
- Physical properties and separability of the initial mixture (3).

Another factor to be considered in the effectiveness of a sifting operation is the accuracy or completeness of separation required. The rate of sifting or thruput (amount of product which passes through one unit of screen surface per unit time) is the only criterion of the effectiveness in a sifting operation, since the percentage extraction of potential thrus is different according to the requirements of a particular milling process (2). For example in scalping, all the potential thrus should be removed, but in flour dressing a certain percentage must be allowed to overtail in order to prevent the inclusion of specks due to overexposure of the overs to the sieve surface.

Factors affecting thruput rate can be divided as those depending on:

1- Nature of the stock

- Geometrical characteristics:

  -particle size distribution

  -potential thrus

  -particle shape

- Physiochemical characteristics

  -density

  -moisture

  -oilness

2- Feed rate, as determining the thickness of the layer of stock

3- Sifting surface

- Percentage open area

- Size and shape of perforation

- Material of the screen

4- Sieve design

- Shape (square, rectangular) and general dimensions

- Dimensions of thrus and overs outlets

- Presence of pitch

- Cleaning devices

5- Sifter motion

- Circle and speed of rotation

- Direction of rotation (CW or CCW)

Other conditions being equal, the effect of these factors on the rate of sifting is determined mainly by:

a - The self-sorting or stratification of the stock.

b - The rate at which potential thrus can penetrate the sifting surface (2,3).

In all forms of sifting carried out by means of sieves, stratification of the product is all important. The resting friction existing among particles in a layer of stock is neutralized when the sieving surface is started in motion (13). Stratification is mainly determined by size and density of the particles; the finer and more dense particles are sifted through the coarser ones and become concentrated in the lower parts of the layer. Since grain products consist of particles of almost uniform density, segregation by size predominates during the sifting process (3). Stratification is particularly important when the principle of deep stock flow is applied in sifting. Sifter feeds are deliberately spread thickly on to the sieve so particles stratify at the same time as others are being sifted and a much higher rate of sifting is obtained (11,6,5,21). The greater vertical weight attained by the stock also helps to improve the sifting effect (10).

Stratification can be accelerated by using flat screens with high frequency oscillation. This will cause the layers of stock to become very loose and the friction between individual particles will be decreased (3).

To obtain a maximum degree of stratification, three forces must be brought to bear upon the stock: Gravitational, Centrifugal, and Frictional (13). The velocity of the particles passing through the screen opening is affected by the sieve motion (2). Comparing both reciprocating and rotary motions, Speight affirms that maximum capacity and efficiency can be best secured by a form of rotary motion for the following reasons:

- In the case of rotary motion, stratification is obtained more effectively by reason of a constant pressing force of the product on the sieve surface.
- Centrifugal force being exerted continuously allows for a more rapid displacement of the product resulting in increased capacity (13). The capacity of a sifting machine is limited by the speed at which it can convey the stock, irrespective of the rate at which it can make the required separations (2). According to Scott, the maximum feed is restricted to the conveying capacity of the upper or coarse scalping sieves (21).

Conclusions from experiments made by Jones have shown that:

- The rate of thruput per unit of sifting surface varies with the percentage of thrus in the feed up to some fixed value, above which the thruput remains roughly constant.
- The thruput varies also with the rate of feed (that is the thickness of the stock on the sieve) with the rate of increase gradually falling off until it reaches a constant value (25).

Since the thruput depends on the load and on the dimensions of the thrus, it is not uniform on various parts along the sieve. At the head of the sieve, thruput increases as a result of the increase in concentration of undersized particles directly in contact with the surface and also due to stratification of the stock. As the period of sifting increases, the thruput decreases since the concentration of thrus is lowered making the sifting operation more difficult (3).

A complete study of this phenomenon is carried out by Whitby using a non-steady state approach. A sieving process can be broken down into two distinctly different regions. Region 1 exists as long as there are particles having a size much less than the sieve mesh opening on top of the sieve. Region 2 begins when all particles much less than the sieve opening have passed the sieve. Formulas for the sieving mechanism on both regions are developed in this study. One of the important conclusions is that non-steady state sieving analysis could be used to predict the performance of steady state equipment provided only that the traveling speed of the stock along the sieves is known (as a constant value or as a function of the distance) and that sieve material and sieve motion were identical (1).

An important thing to note is that even a small increase in the amount that is desired to pass the sieve during region 2 will require a large increase in sieve length. For this reason it is not practical to carry steady state sieving very far into region 2. If in order to get a complete separation it has to be carried into region 2, it appears that the region 1 and 2 sieving should be set up on different sieves so that the velocity of travel on the sieve could be reduced during the later portion of the transition region.

By working with break stocks it was found that the maximum output of sifting and the best quality sorting is achieved when the stock enters the three frames of the first group of sieves in parallel (3). By working with first midds stock, Grieg found several advantages in splitting the stock. Two of these were reduced load and friction at the head of the group of sieves and a lower probability that the coarsest and more fibrous material would pass through in the flour dressing operation (7).

Another advantage pointed out by Whitby in a split sieve arrangement is the possibility of using a larger size mesh for the first group of sieves, since in region 1 there are very few near mesh size particles coming thru the sieve. Considering that the sieving rate (thruput) in region 1 is proportional to the cube of the mesh opening, it might be possible to reduce the sieve area required by one half with such an arrangement (1).

Given a certain stock and other conditions being equal, the thruput is affected by the throw and rotational speed of the sieving surface.

Different settings for optimum combinations of speed and throw are used in commercial applications. Some of them were developed by experimentation and others simply by experience (4,8).

The two most important factors to be considered in choosing the right combination of kinematic parameters are sifting efficiency and mechanical strength of the sifter (4,9). Curves for optimum settings in these references have in common an approximate constant lineal cloth speed (π x Throw x RPM) starting with a combination of 180 RPM, 4 in. throw (2260 in/min). Assumptions that speeding up of sifter and reducing throw helps increase capacity are not firmly established for all the different stocks (18,19). When this is done, it should be noted that centrifugal forces are significantly increased causing the sifter to be subjected to higher mechanical stresses (4,20). Centrifugal force curves for different combinations of speed and throw are shown in these two references.

Sifting efficiency and economy when applied to modern machinery construction have resulted in an almost universally applied kind of machine to treat flour milling stocks: the square sieve sifter.

Used for many years in America, it has been adopted by all European manufacturers in their most recent designs. It has numerous advantages over earlier types of rectangular sieve plansifters, among which are:

- Fewer sifter sections are required for each passage due to the increased sieving efficiency. Considerable space saving is a consequence of this.
- Because the sieves are square and interchangeable, the flow of the sifter can be changed very easily.
- More separations are possible due to the greater number of superimposed sieves in each section.
- Considerable savings in time in cleaning and changing damaged cloths.
- Pad type cleaners are far more efficient than the old brush type.
- Large size delivery channels avoid bottlenecks which are common in earlier machines (5,12,14,15,16).

MATERIALS AND METHODS

Description of the Equipment

The installation used for this experiment is located in the Pilot Flour Mill building, Department of Grain Science and Industries, Shellenberger Hall, Kansas State University. Its flow diagram is illustrated in Figure 1.

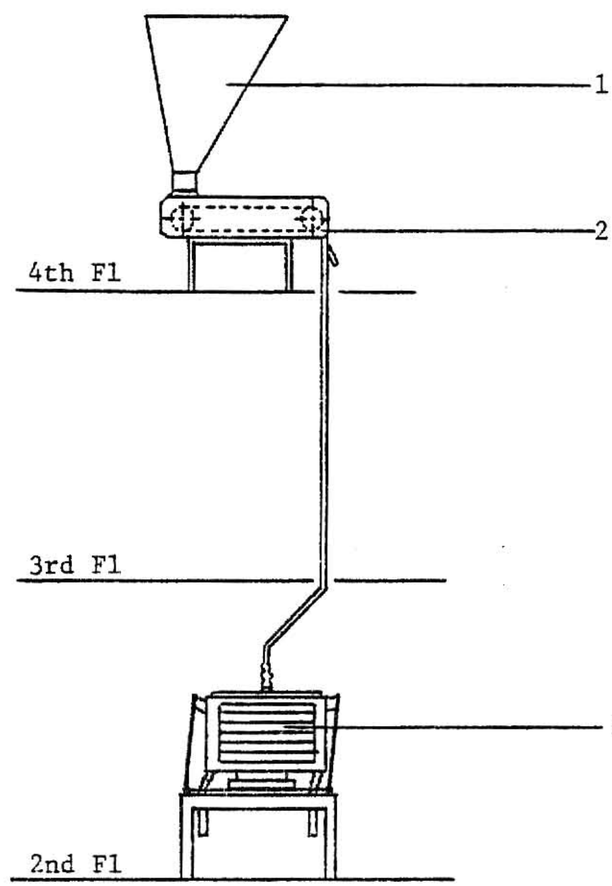


FIGURE 1: Flow diagram of the experimental installation.

1 - Hopper. Approximate capacity 21 cu ft

2 - Belt Feeder. Belt width: 9 inches

Belt speed: 9 feet/min

Maximum feed rate: 50 lb/min with first break stock (Approx.)

3 - Norvell Experimental Sifter. It operates with a circular motion in horizontal plane through a crankhandle mechanism.

Sieves: N&M commercial size. Frame-square: 24 11/16 inches

Cloth-free bolting area: 2.6 FT^2

Continuous adjustment of circle of gyration. Range: 0 to 4"

A small Great Western laboratory sifter and a Wenger batch mixer were also used during experimentation.

Figures 2 through 9 illustrate the equipment used in this study.

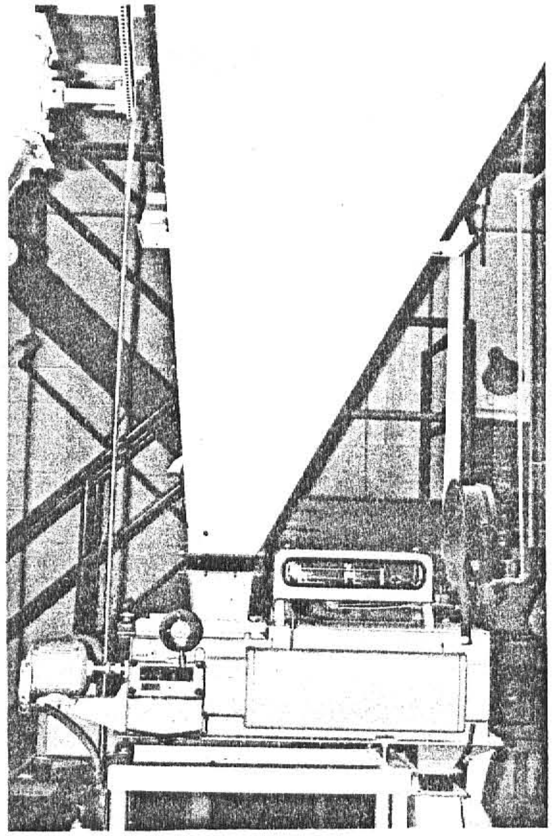


FIGURE 2: Hopper and belt feeder.

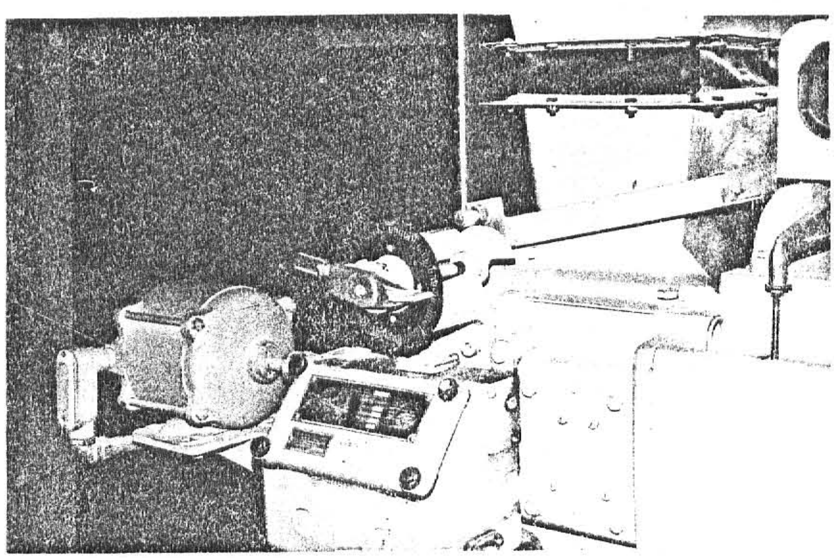


FIGURE 3: Feed rate regulation system.

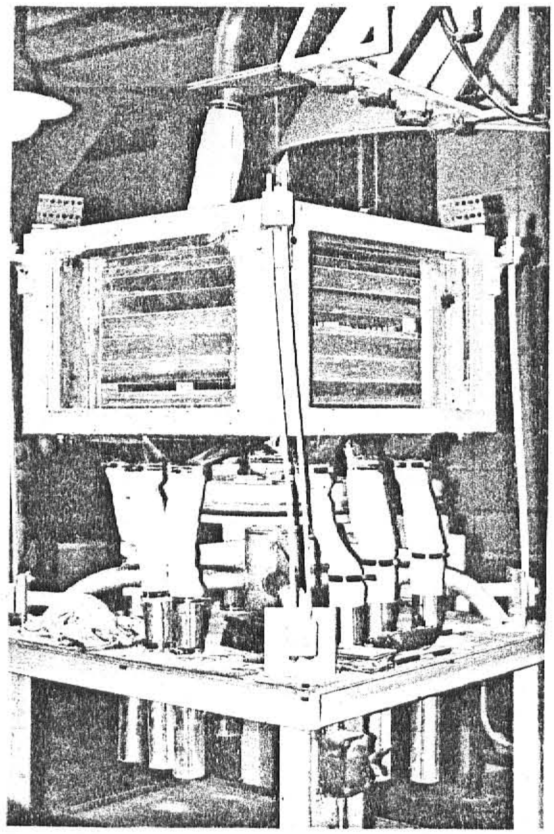


FIGURE 4: Norvell experimental sifter.

FIGURE 5: Sifter RPM regulation system.

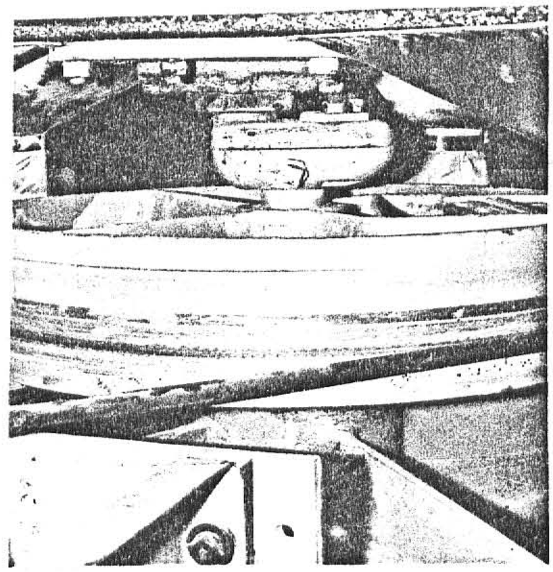


FIGURE 6: Sifter circle regulation system.

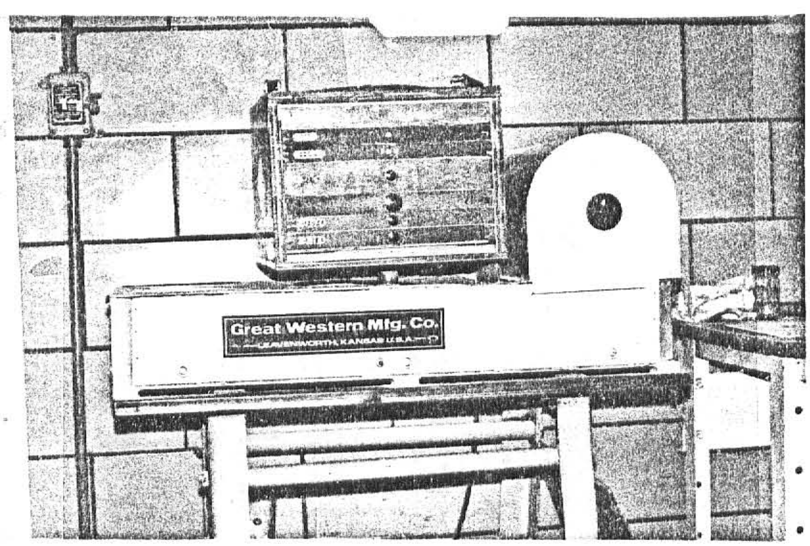


FIGURE 7: Great Western laboratory sifter.

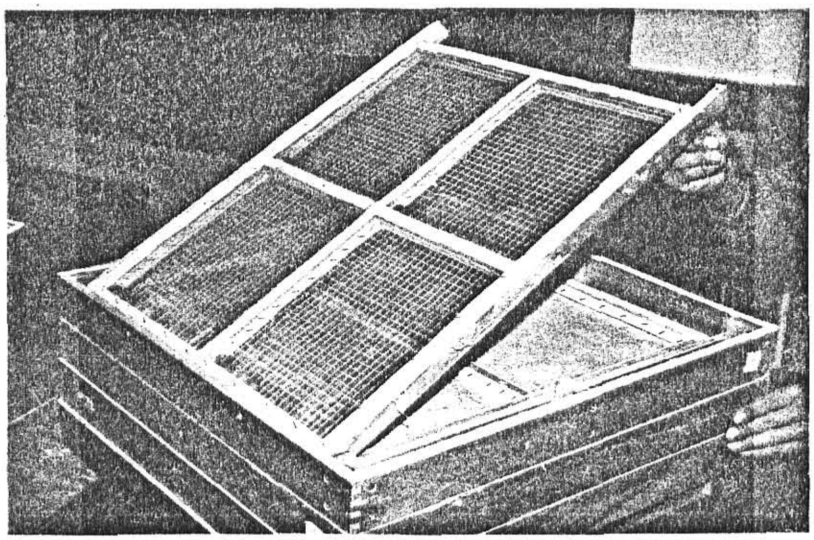


FIGURE 8: Demountable tray.

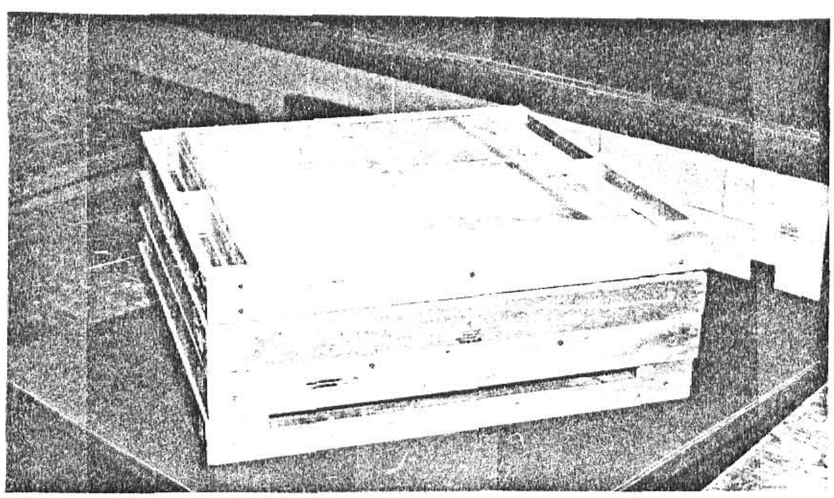


FIGURE 9: Sieve frames.

Characteristics of the Stock Used

A sample of 20 bushels of Hard Red winter wheat was cleaned, tempered and milled by the first break rolls of the pilot mill.

Characteristics of this process are:

Tempering: Original Moisture Content: 13.7%

Test Weight: 59.1 lb/bu

Moisture Content to 1st Bk.: 16.0%

Tempering Time: 24 hrs.

Milling: Rolls: 10" Diameter x 24" Long Roll Chills

Corrugations: 10/12 Getchell, Dull to Dull,

¼" spiral/foot of roll length.

Adjustment: 36% break release (-20 Light Wire).

For the particle size distribution of the original sample, see Figure 27. Part of the sample of the first break stock was introduced into the hopper and the rest was left in moisture proof containers.

Flow Sheet

Figure 10 shows the clothing arrangement used for the classification of first break stock in this particular study.

4 - 20 SS (1041 mµ)	scalp →
4 - 38 SS (503 mµ)	coarse sizings →
4 - 62 SS (308 mµ)	fine sizings →
4 - 135 SS (130 mµ)	midds →
Flour ↓	

SS = Stainless Steel Cloth; mµ = micrometer aperature opening.

FIGURE 10: Flow sheet used for the classification of first break stock.

Each test set used four cloths having the same aperature opening. Figure 11 shows the flow arrangement so that four different thrus plus the overs could be obtained on each test. (Example shown is for scalp sieves). Sieves used are all standard right hand sieves.

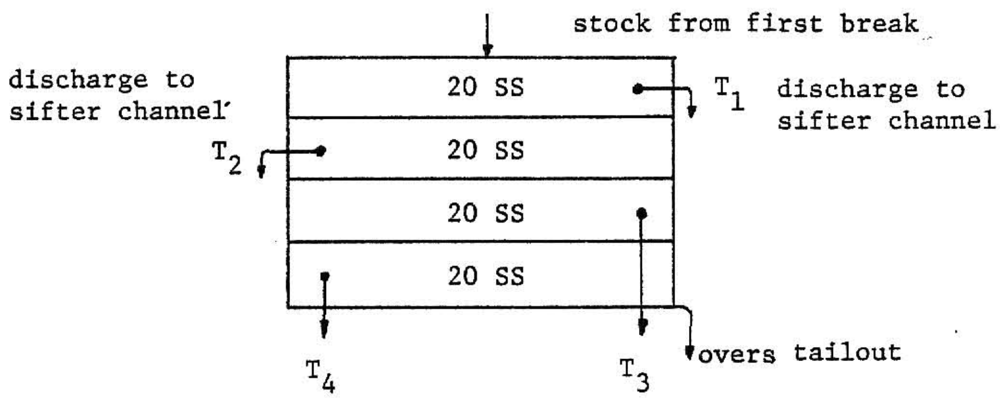


FIGURE 11: Flow arrangement for each test set.

After the test for scalp sieves is completed, the overs are discarded and the thrus become the new feed stock for the next test set, in this case coarse sizing sieves (38 SS).

In the same way, thrus from 38 SS and 62 SS sieves are used as feed stocks for the fine sizings and midds tests, respectively.

Rubber balls were used as cloth cleaners in all cases. Each sieve has 4 compartments.

20 SS	5 balls/compartment
38 SS	8 balls/compartment
62 SS	10 balls/compartment
135 SS	12 balls/compartment

Experimental Procedure

Four different feed rates, RPMs and throws were tested for each set of sieves. In order to get the most useful points in all the curves, ten combinations between these three parameters are needed. (See Appendix Table 1).

For each test, the sequence of operation is:

1 - Set RPM, throw and feed rate required.

2 - Take sample of the incoming stock and run particle size distribution test. (Through this test it is possible to have a control of uniformity of the sample being tested. No significant variations were observed when the different stocks were remixed and recirculated).

3 - Start empty sifter with selected RPM and throw (all tests are made clockwise).

4 - Start feeder with selected feed rate.

5 - After 3 sec. (that is the time it takes the stock to reach the sifter from the feeder), start the time control.

6 - Check the outlet on the last sieve and stop the time when a full load of overs is coming out.

7 - Let the system run for about 15 more sec., shut down the feeder and after 3 sec. shut down the sifter.

8 - Dispose the products obtained and set the empty cans for thruput test.

9 - Start feeder and after 3 sec., start the sifter.

10 - Allow 1 or 2 min. sifting time depending on the feed rate being used.

11 - After sifting time is completed, shut down sifter and feeder simultaneously.

12 - Weigh overs and the four different thrus.

13 - Empty the sifter by running it 4 min. at 185 RPM, 4 in. throw (repetition of thruput tests under identical conditions are made before emptying the sifter).

14 - Weigh overs and thrus.

15 - Check the amount of stock inside the hopper.

Note: Take samples for particle size distribution of the different thrus when the test with maximum feed rate and 185 RPM, 4 in. throw is being made.

Adjustment of Feed Rate, RPM, and Throw

Different feed rates are set by moving a gate up and down with a continuous regulation operated by a cam device (see Figure 3). Feed rate was fixed before each test using a butterfly valve located just after the feeder and checked afterwards by weighing all the products obtained from the sifting operation. The sifter is fully loaded and working under steady conditions when both feed rates are practically equal. It was observed for first break stock and its products that feeding under these conditions is very uniform. No flow stoppages were produced inside the hopper, in the feeder, or in the spouts going to the sifter.

The rotational speed, measured in RPMs, can be regulated in a stopless way by adjusting the diameter of the motor pulley (see

Figure 5). Variations of up to 5 RPMs are observed whether the sifter is working loaded or unloaded.

The throw is adjusted by means of a stopless excentric mechanism. If the throw is changed, the sifter must be rebalanced by adding or taking out the required counterweights. This is done according to the following formula:

$$W_1 \times D/2 = \sum w_i r_i$$

where W_1 = total weight of the sifter box (about 200 lb without stock)

D = throw (inches)

w_i = weight of a given counterweight (lb)

r_i = distance at which a given counterweight is placed from the center of gyration (inches).

The next diagram (Figure 12) shows the forces involved in this type of sifter (crankhandled) when it is running at a certain speed and with a given throw:

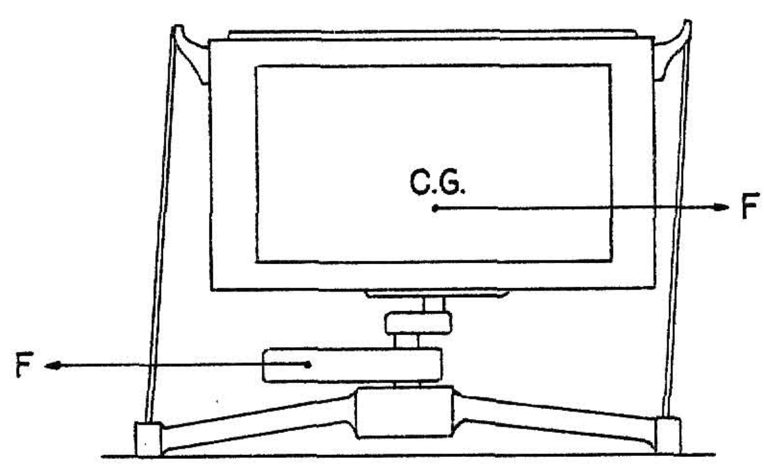


FIGURE 12: Diagram of forces in a crankhandled sifter.

The centrifugal forces produced by the sifter box and the counterweights may be equal (if the system is well balanced) but the center of gravity of those two bodies are located at different heights. This produces a constant torque that must be supported by the structure of the system. In order to avoid increasing this natural unbalanced situation, special care must be taken in using the right amount of counterweights when the throw is changed.

Remixing of Stocks

Considering the large amount of stock handled it was necessary to recirculate it several times. A horizontal Wenger batch mixer was used in order to retain the original properties of the stock. Appropriate amounts of overs and thrus were mixed for four minutes and carried back to the hopper.

RESULTS AND DISCUSSION

Traveling Speed of the Stock (S)

The index used in order to know the approximate traveling speed is the time "t", in seconds, necessary to get a full load of overs at the outlet of the bottom sieve, starting with an empty sifter.

An average speed in inches/sec. can be calculated by the formula:

$$s = \frac{90}{t} \quad \text{where} \quad 90 = \text{length of 4 sieves (inches)}, \quad t = \text{time in seconds}$$

For S_1 (20 SS), S_2 (38 SS), and S_3 (62 SS), this calculation is quite exact considering that a full load of overs comes out in a short period of time (1 to 4 seconds).

In the case of S_4 (135 SS), the overs load increases more slowly so the estimation of the time t is not as accurate and the speed calculated from it will be approximate.

By observing Figures 13 through 16, several conclusions can be reported:

- For a given stock in the range analyzed, there is no traveling speed variation when feed rate is changed. The tests indicate that traveling speed is dependent only upon the characteristics of the stock and the sifter dynamic action. For example, considering similar feed rates, scalp stock travels faster than coarse sizing stock (see Figures 13

FIGURE 13: *Traveling speed of stock S(in/sec) over 20 SS sieve covering*

Total First Break Stock

LCS: lineal cloth speed (in/sec)

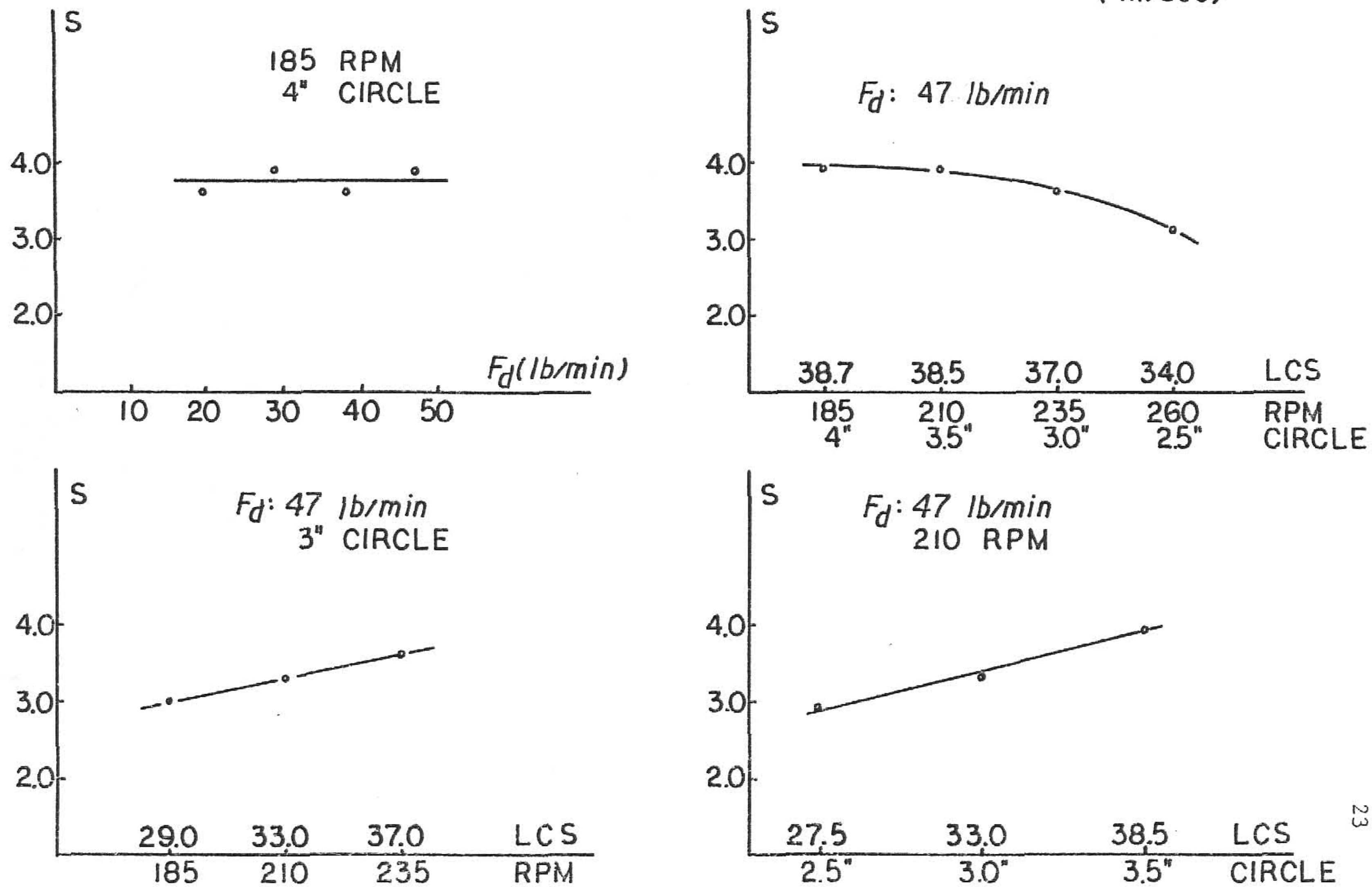


FIGURE 14: *Traveling speed of stock S(in/sec) over 38 SS sieve covering First Break Stock less overs of 20 SS.* *LCS: lineal cloth speed (in/sec)*

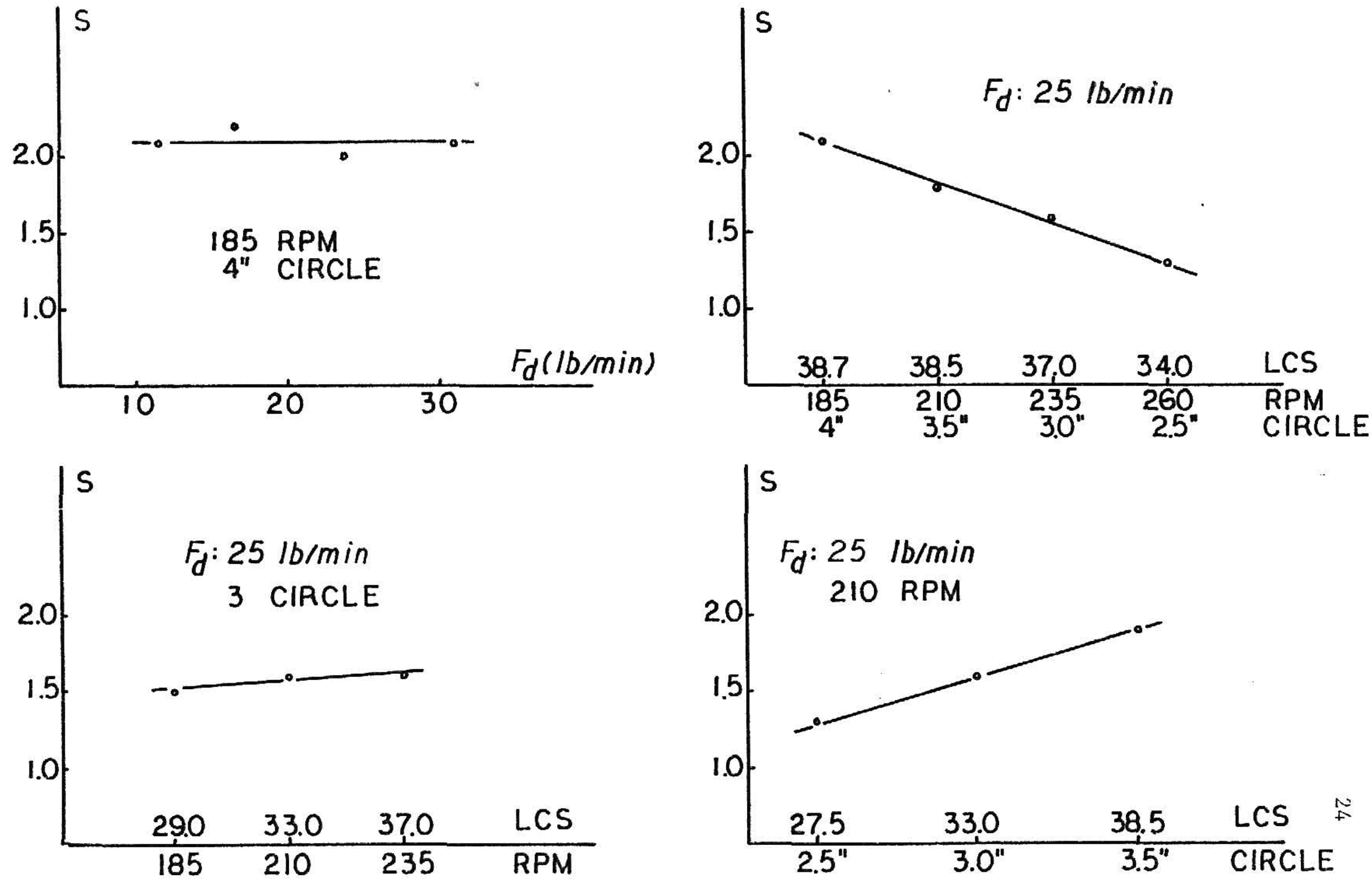


FIGURE 15: *Traveling speed of stock S(in/sec) over 62 SS sieve covering First Break Stock less overs of 38 SS.* *LCS: lineal cloth speed (in/sec)*

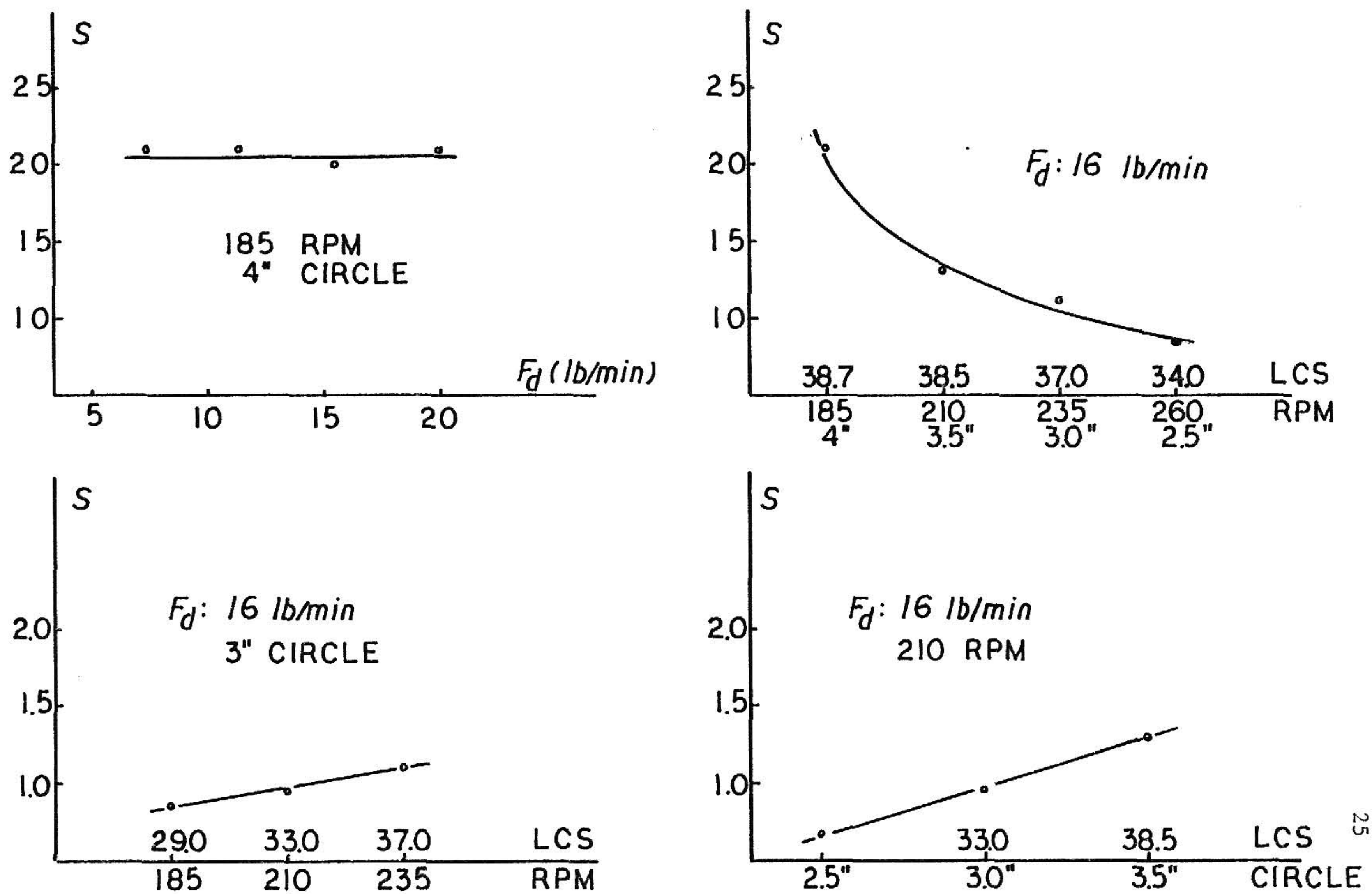
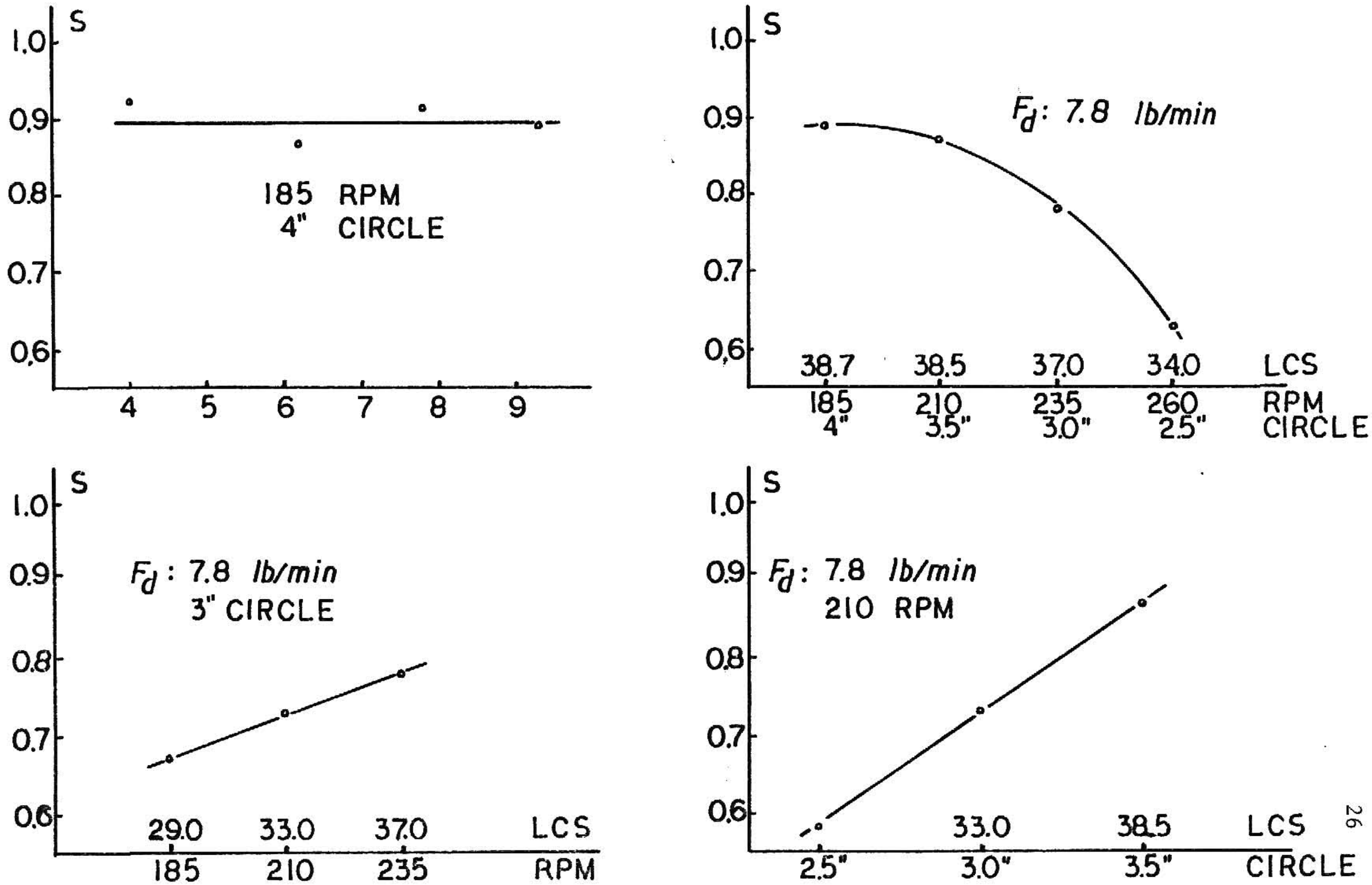


FIGURE 16: *Traveling speed of stock S(in/sec) over 135 SS sieve covering First Break Stock less overs of 62 SS. LCS: lineal cloth speed (in sec)*



and 14); the same is true between fine sizings and midds (figures 15 and 16). The finer the stock, the lower the speed. Floury stocks (135 SS) travel much slower than granular stocks. Considering both coarse and fine sizings coming from +38 SS and +62 SS, it can be seen that their traveling speeds are fairly similar. This factor indicates that not only particle size, but also particle shape is important in the friction of the stock against the sieve, this friction increasing with finer and more floury stocks.

The tests indicate that:

1 - Traveling speed increases with increasing RPM at constant feed rate.

2 - Traveling speed increases with increasing circle at constant feed rate.

3 - If lineal cloth speed in inches/second calculated as (π x Circle x $\frac{RPM}{60}$) is considered as a measurement of the sifting dynamic action, it is possible to compare the effects of variations in RPMs with the effects of variations in Circles. In Figures 13 through 25, the abscissa of the two bottom graphs represent variation in RPMs and variations in Circle. If those variations are converted to lineal cloth speed and both graphs use the same scale, the slope of the curve obtained for variations in RPM can be compared with the slope of the curve obtained for variations in Circle.

Using the above criteria the results indicate that the increasing trends of traveling speed for increasing RPM and Circle are higher for variations in Circles than they are for variations in RPMs when using coarse sizings (38 SS), fine sizings (62 SS) and midds (135 SS) stocks.

4 - The effect of the variables on traveling speed is more pronounced as the stock becomes finer.

Amount of Stock in the Sifter at Any Given Time (S_t)

The amount of stock in the sifter at any given time varies depending on the stock being sifted, feed rate and motion of the sifter. This variable is directly related to the depth of the layer of stock on top of the sieve set.

In order to evaluate the amount of stock, the sifter is completely emptied of a certain stock after it has been operating with a given feed rate, RPM and Circle. The feeder is shut down and the sifter is run at 185 RPM, 4" Circle during 4 minutes. Overs and thrus obtained are weighed and the results plotted as shown in Figures 17 through 20.

The tests indicate that the amount of stock:

1 - Increases with increasing feed rate at constant RPM and Circle.

2 - Decreases with increasing RPM at constant feed rate and Circle.

3 - Decreases with increasing Circle at constant feed rate and RPM.

The two bottom graphs of Figures 17 through 20 show that equal variations in lineal cloth speed have different effects on the amount of stock when originated from either RPM or Circle changes. The decreasing trends are higher for variations in Circle than they are for variations in RPM.

Finally, the total amount of stock (thrus plus overs) is greater for floury than for granular stocks.

FIGURE 17: Amount of stock in the sifter S_t(Kg) at any given time. 20 SS sieve covering. Total First Break Stock.

∘ amount of overs
▵ amount of thrus
LCS: lineal cloth speed (in/sec)

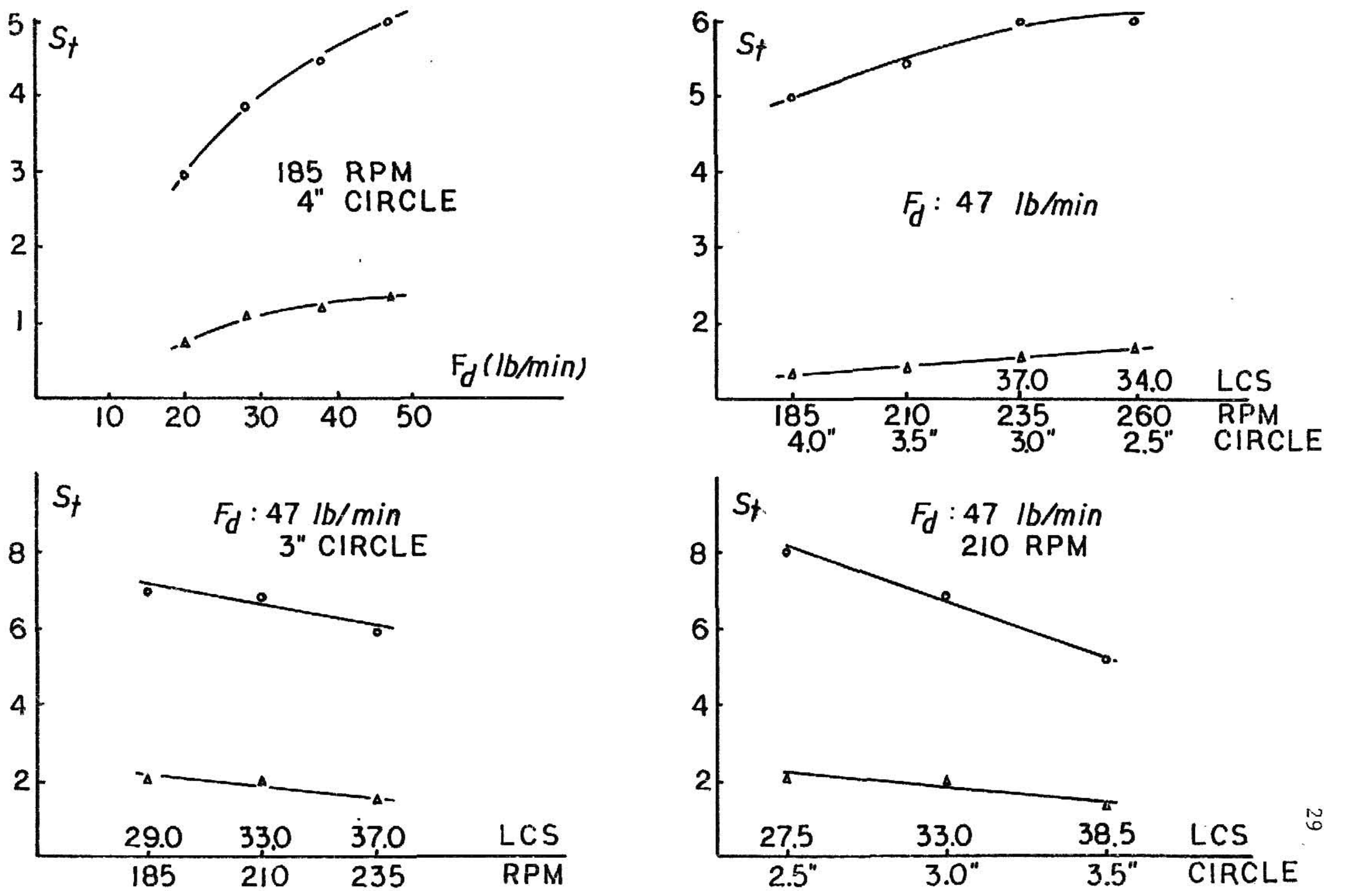


FIGURE 18: *Amount of stock in the sifter $S_t(Kg)$ at any given time.*

• *amount of overs*
▲ *amount of thrus*

First Break Stock less overs of 20 SS. LCS: lineal cloth speed (in/sec)
38 SS sieve covering

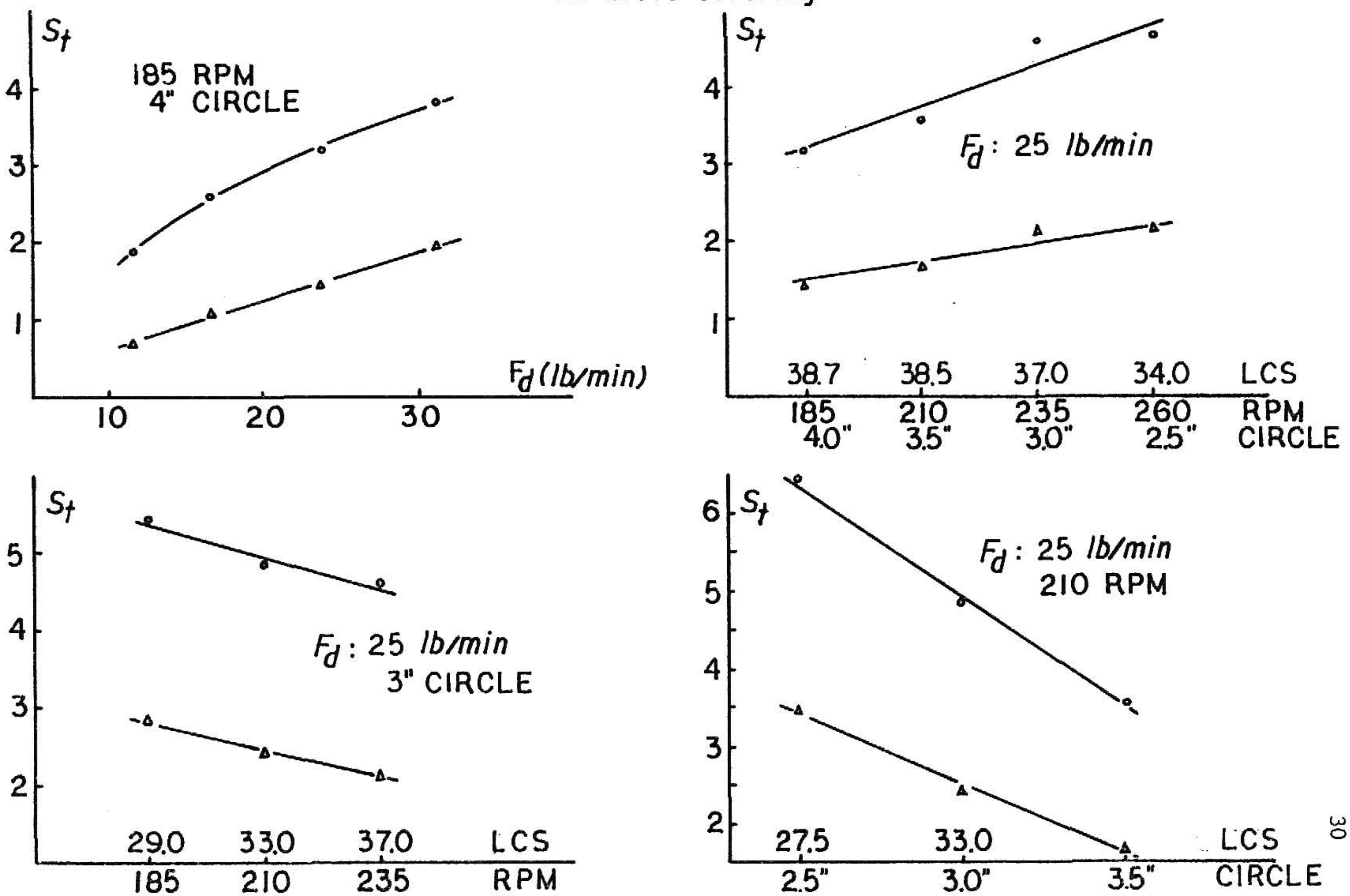


FIGURE 19: *Amount of stock in the sifter $S_t(Kg)$ at any given time.*

First Break Stock less overs of 38 SS. LCS: lineal cloth speed (in/sec)

62 SS sieve covering

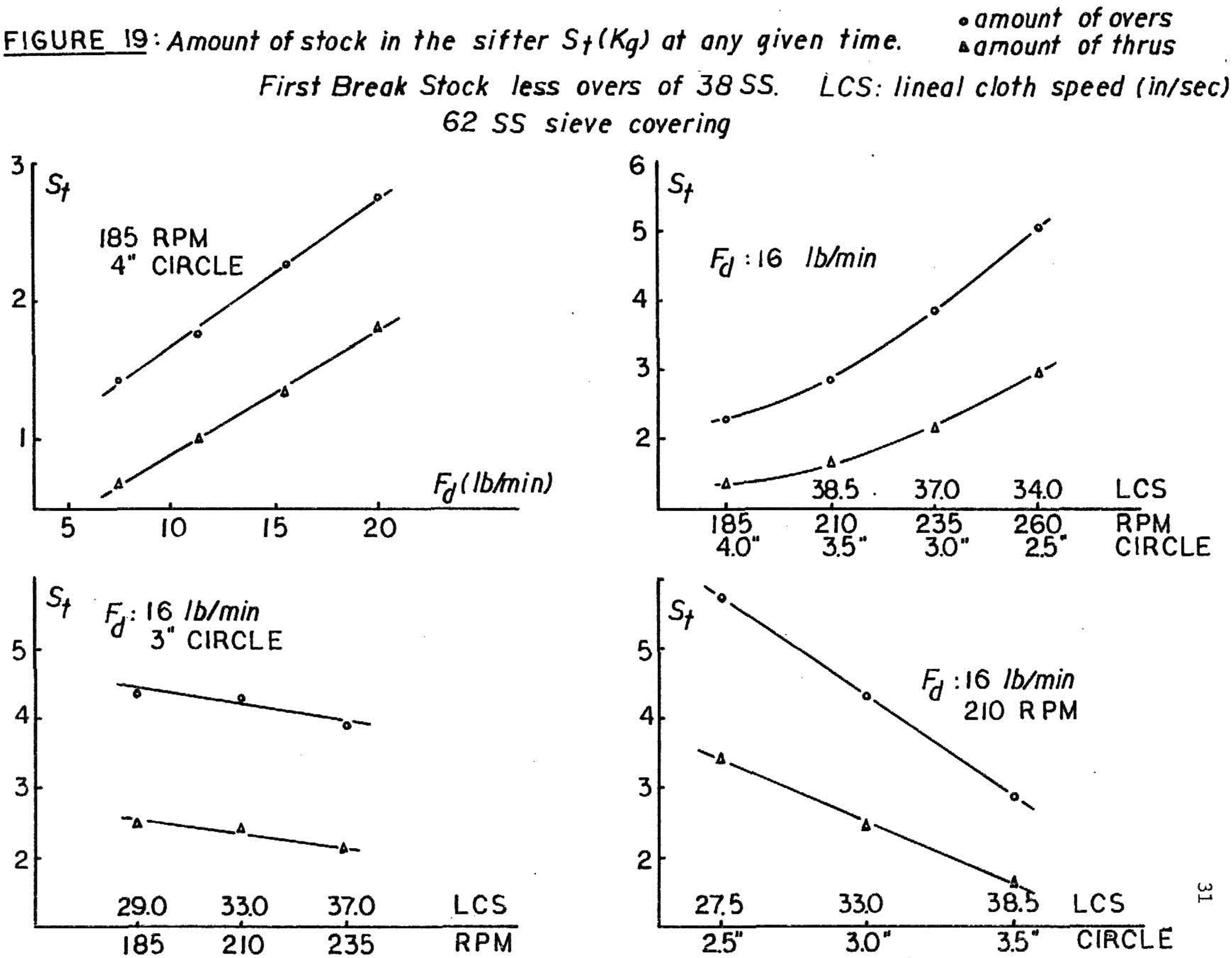
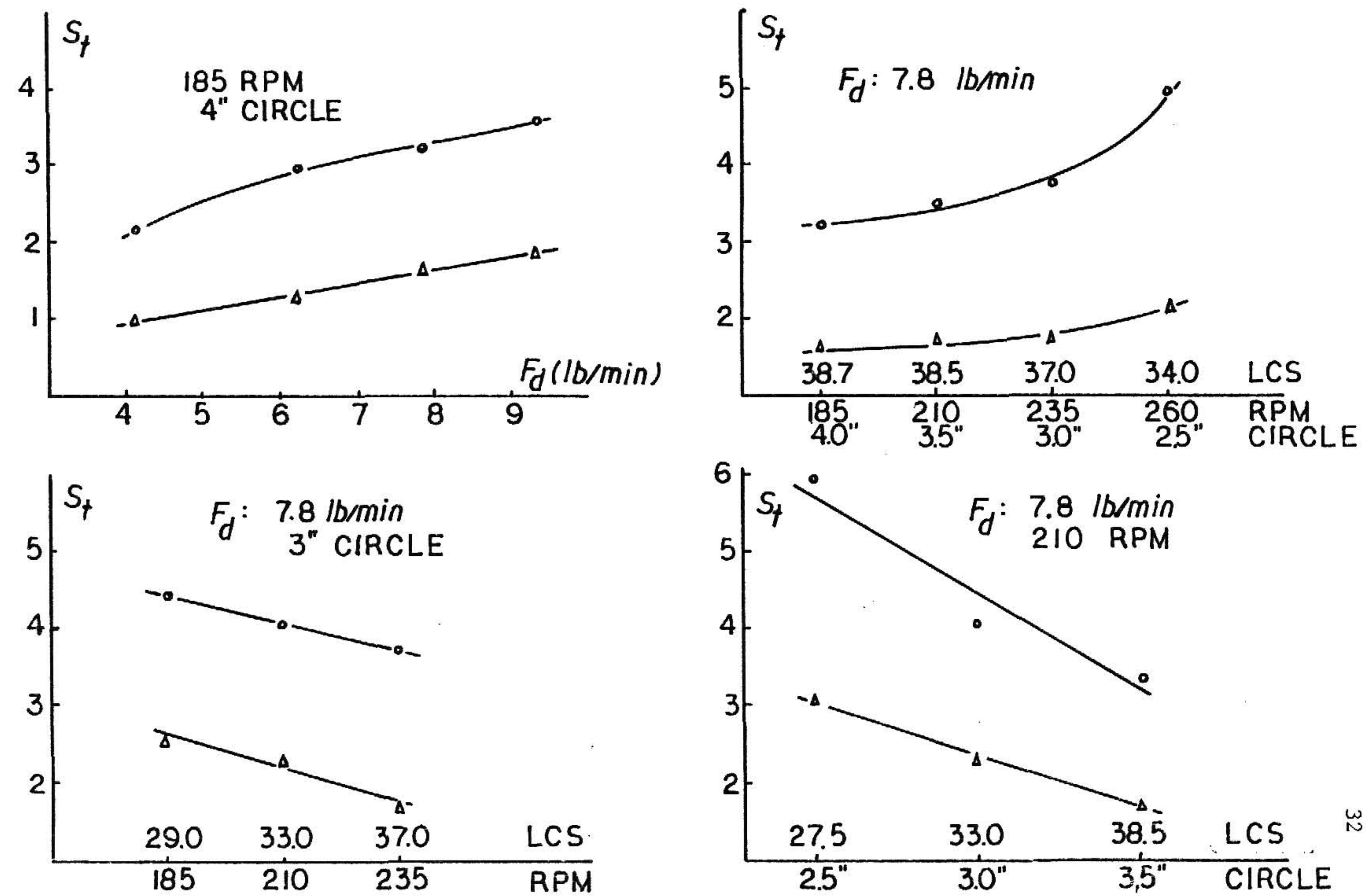


FIGURE 20: *Amount of stock in the sifter S_t (Kg) at any given time.* ∘ *amount of overs* ▵ *amount of thrus*

First Break Stock less overs of 62 SS. LCS: lineal cloth speed (in/sec)

135 SS sieve covering



Percentage of Total Thrus Coming Out of the First Sieve of the Test Set

Table 5 shows the amount of thrus coming out of the different sieves of the test set as percentages of the total thrus obtained.

It can be observed that by far, the largest percentage obtained corresponds to the thrus coming out of the first sieve (thrus 1). According to this, most of the sifting work is carried out by the first sieve, and the sifting performance of the sieves No. 2, 3, and 4 becomes very inefficient in terms of thruput value.

The relative amounts of thrus coming out of the different sieves was observed to vary depending on different feed rates and sifting motion tested.

Figures 21 through 24 show variations of such relative amounts as a function of feed rate and sifting motion for the different stocks. The percentage of thrus obtained from the first sieve (T_1) is used as an index since variations in such percentage originate changes in the percentages of thrus coming out of sieves 2, 3, and 4.

The results indicate that:

1 - For all different stocks, percentages of thrus 1 decrease with increasing feed rates.

2 - For the thrus of the 20 SS, 38 SS, and 62 SS sieve sets, percentages of thrus 1 decrease with higher RPMs and higher Circles. For the 135 SS sieve set, the trend is different mainly because of low dynamic actions. This is especially true when using low Circles. These conditions produce a blinding effect on the first sieve, sending more stock to be sifted on the others.

FIGURE 21: % of total thrus coming out of sieve No. 1 (T_1). LCS: lineal cloth speed (in/sec)

20 SS sieve covering

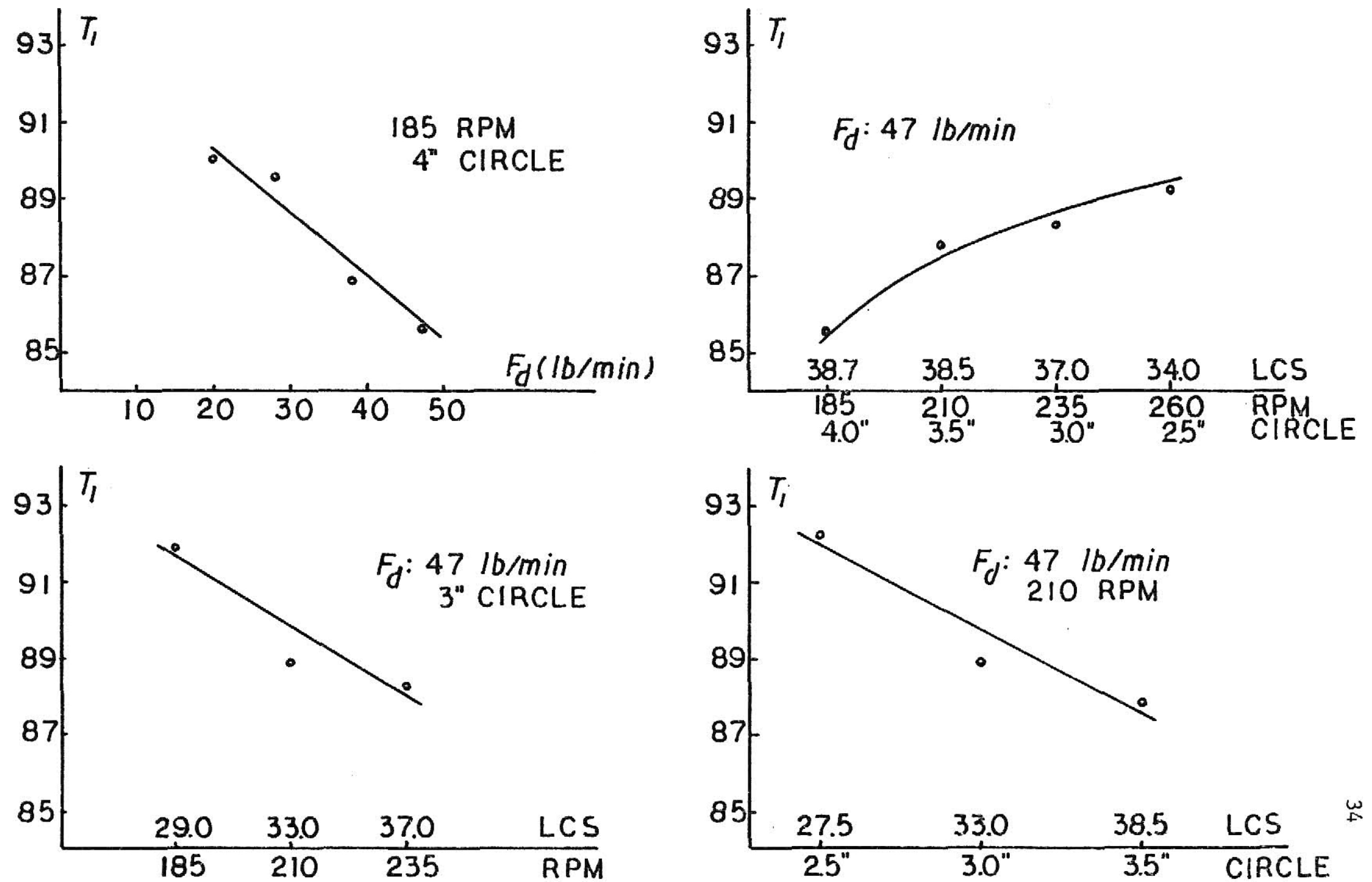


FIGURE 22: % of total thrus coming of sieve No 1 (T_1). LCS: lineal cloth speed (in/sec)

38 SS sieve covering

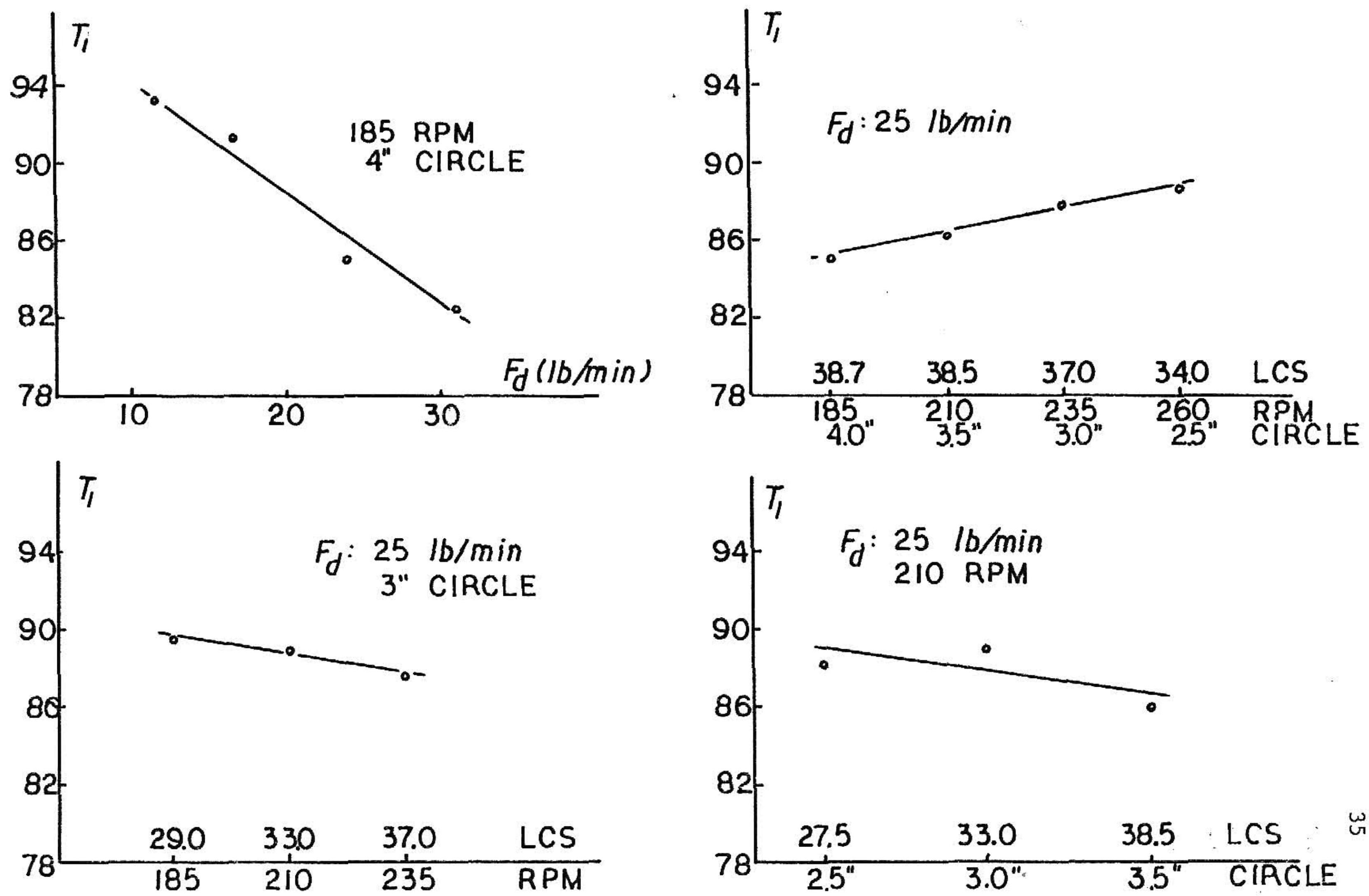


FIGURE 23: % of total thrus coming out of sieve No 1 (T_1) LCS: lineal cloth speed (in/sec)

62 SS sieve covering

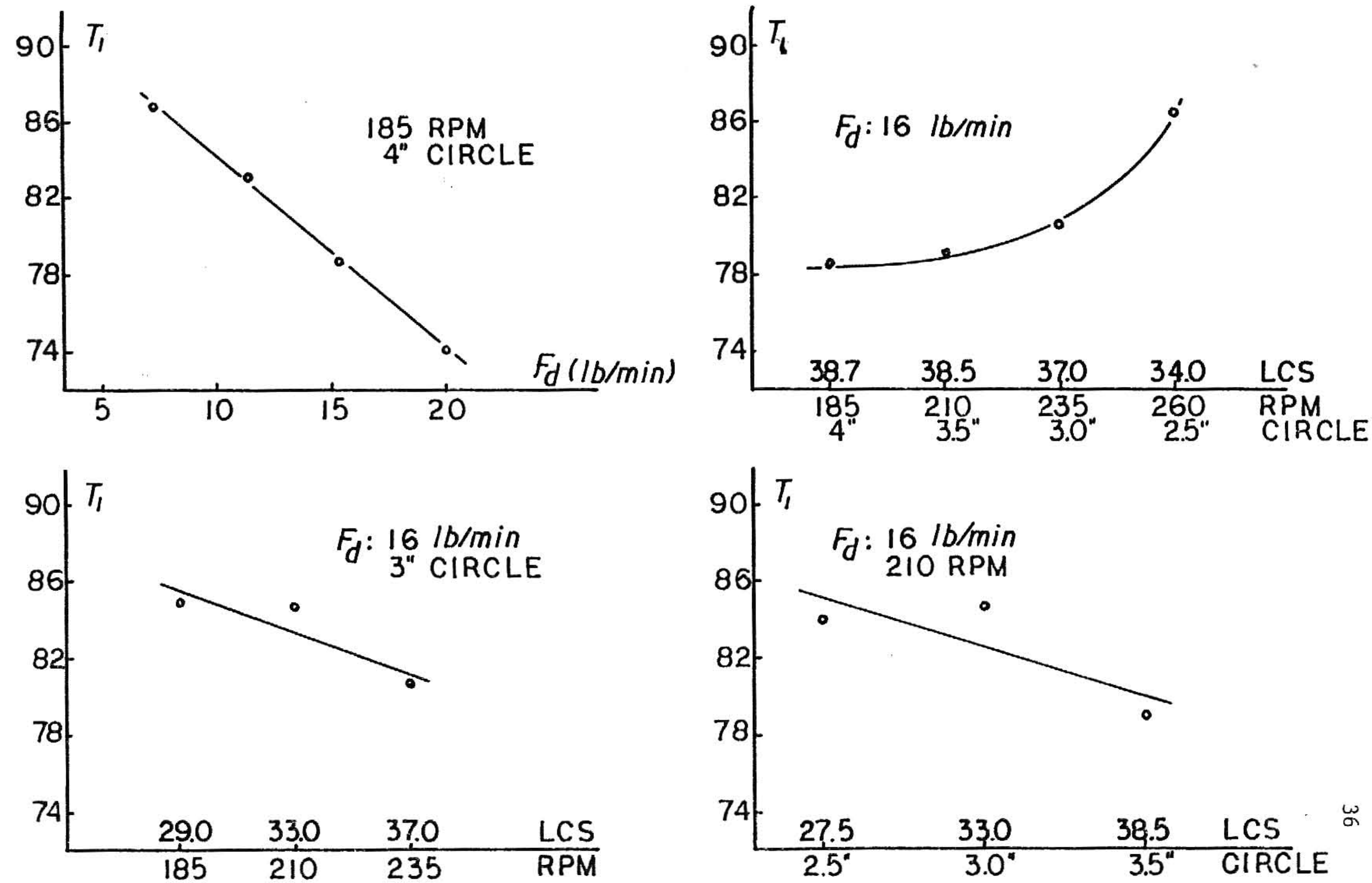
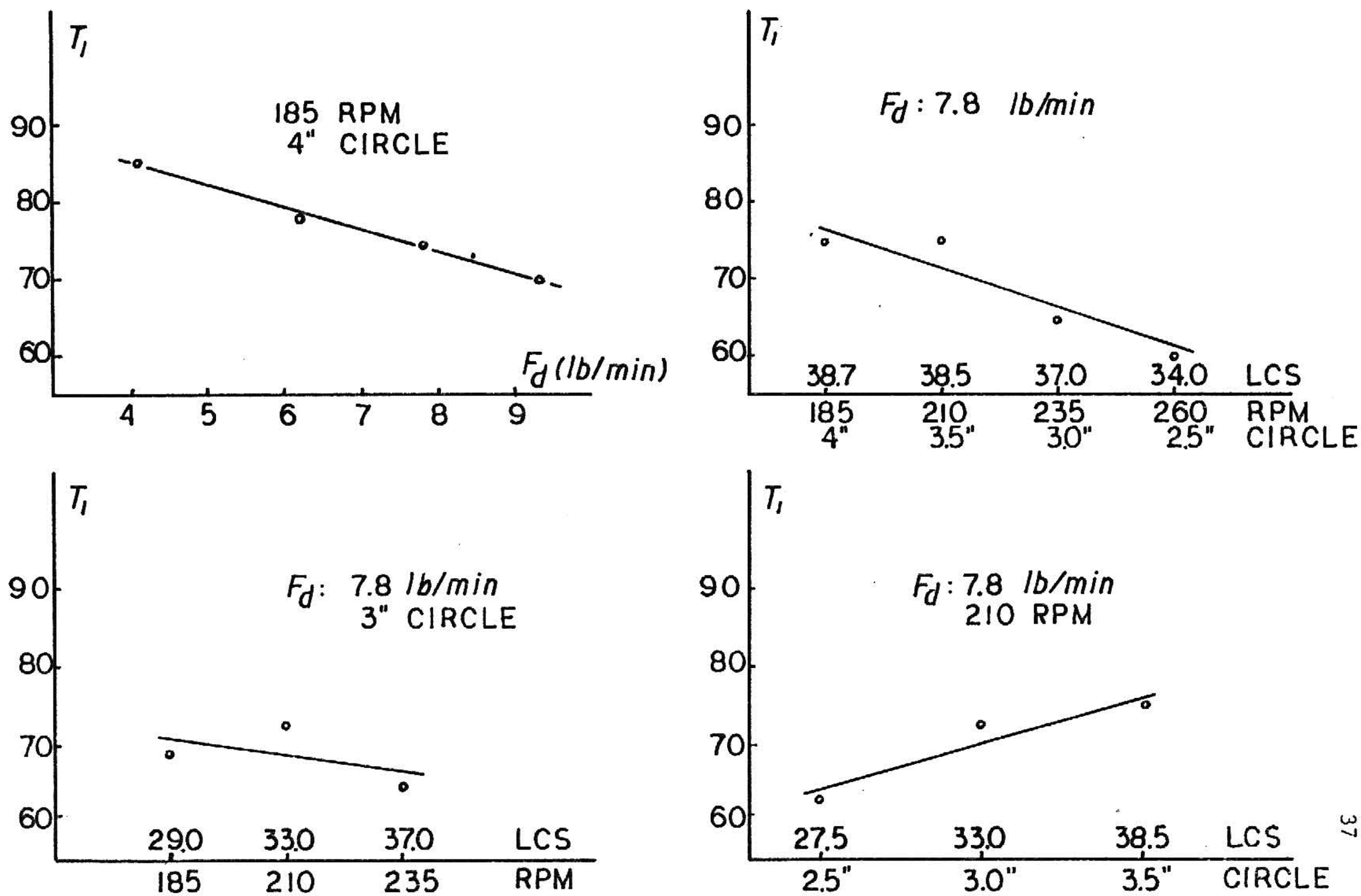


FIGURE 24 % of total thrus coming out of sieve No. 1 (T_1). LCS: lineal cloth speed (in/sec)
135 sieve covering



It would be interesting in a future study to determine curves like those indicated in Figure 25.

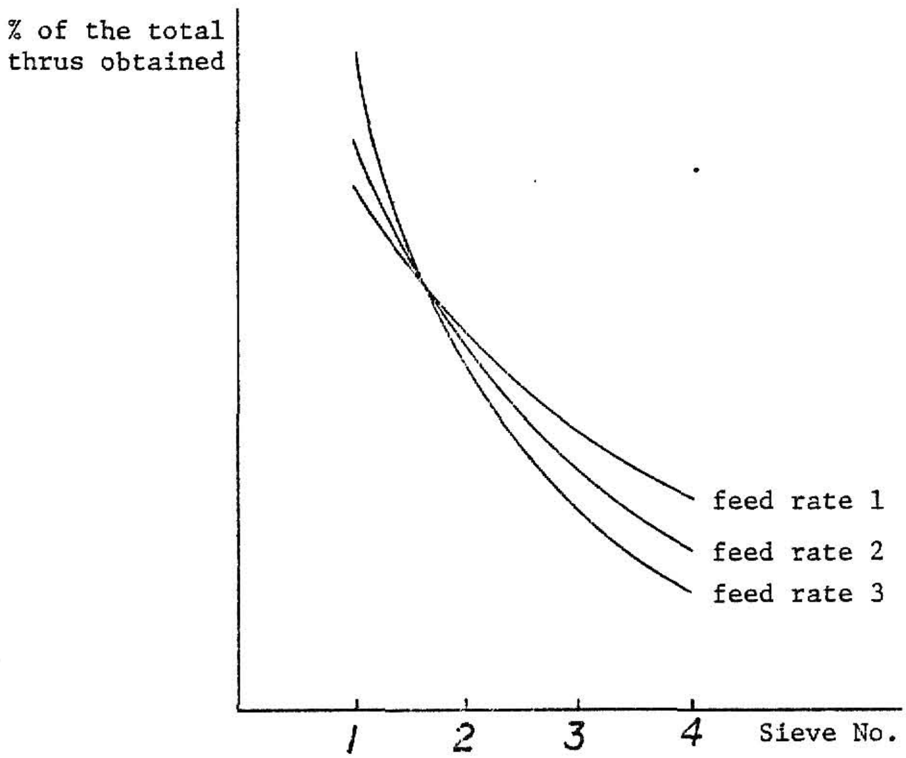


FIGURE 25: Curves of percentages of thrus obtained from the different sieves.

These curves indicate the percentage of thrus obtained from the different sieves of a given test set as a function of feed rate. They could be plotted also as a function of different sifting motions.

A fairly accurate estimation of the capacity of a sifter could be obtained by having maximum thruput values and these curves for a given stock being handled on a certain cloth number.

Thruput as a Function of Feed Rate

Thruput is the amount of product which passes through one unit of cloth surface per unit time.

Figure 26 shows the variation of thruput for different feed rates on the first sieve of each set of sieves. Maximum values of thruput were not arrived at due to limitations of the feeding system.

No differences in the total thruput were observed for different sifting motions in the range of feed rates analyzed.

Particle Size Distribution of Thrus

Granulation curves are made with thrus taken from each of the four sieves of the set. The size of the samples is indicated on Table 8 (see Appendix).

The sample is sifted for two minutes in a Great Western laboratory sifter and overs left on the different screens and the pan are weighed.

The cumulative percentage of overs (Σ over as indicated in the last column of Table 8) is plotted against the screen opening in micrometers so that the particle size distribution of the different samples can be compared.

Granulation curves from Figures 27 through 30 clearly illustrate the principle that the finer particles go through first. Most of the particles having a size much less than the cloth opening are sifted on the first sieve. The thrus coming out of the last two sieves have a greater percentage of particles with sizes nearer that of the cloth opening.

FIGURE 26: *Thruput of the first sieve on the test set (lb/hr/ft^2 of cloth)*

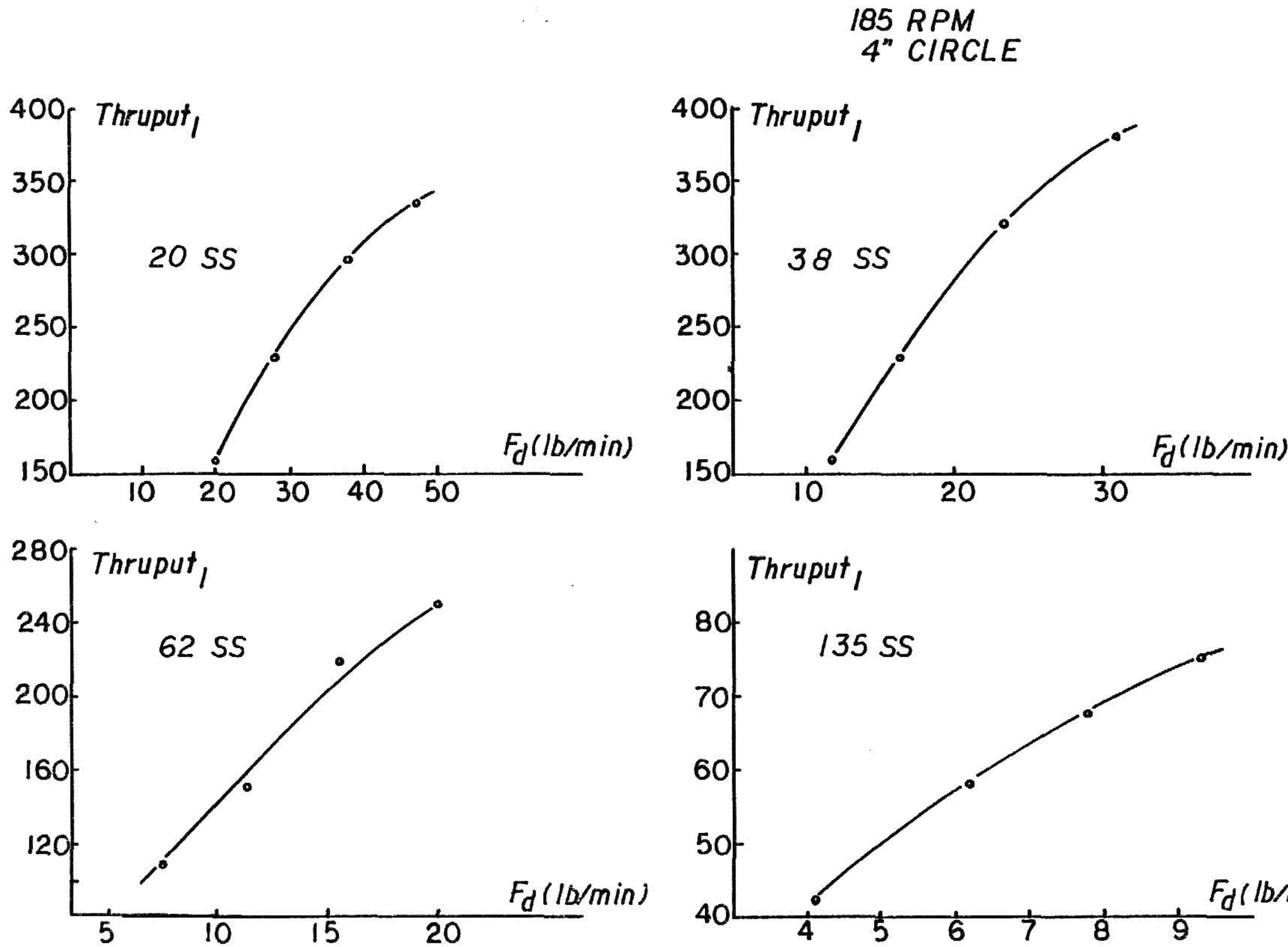


FIGURE 27: PARTICLE SIZE DISTRIBUTION
(20 SS *sieve covering*)

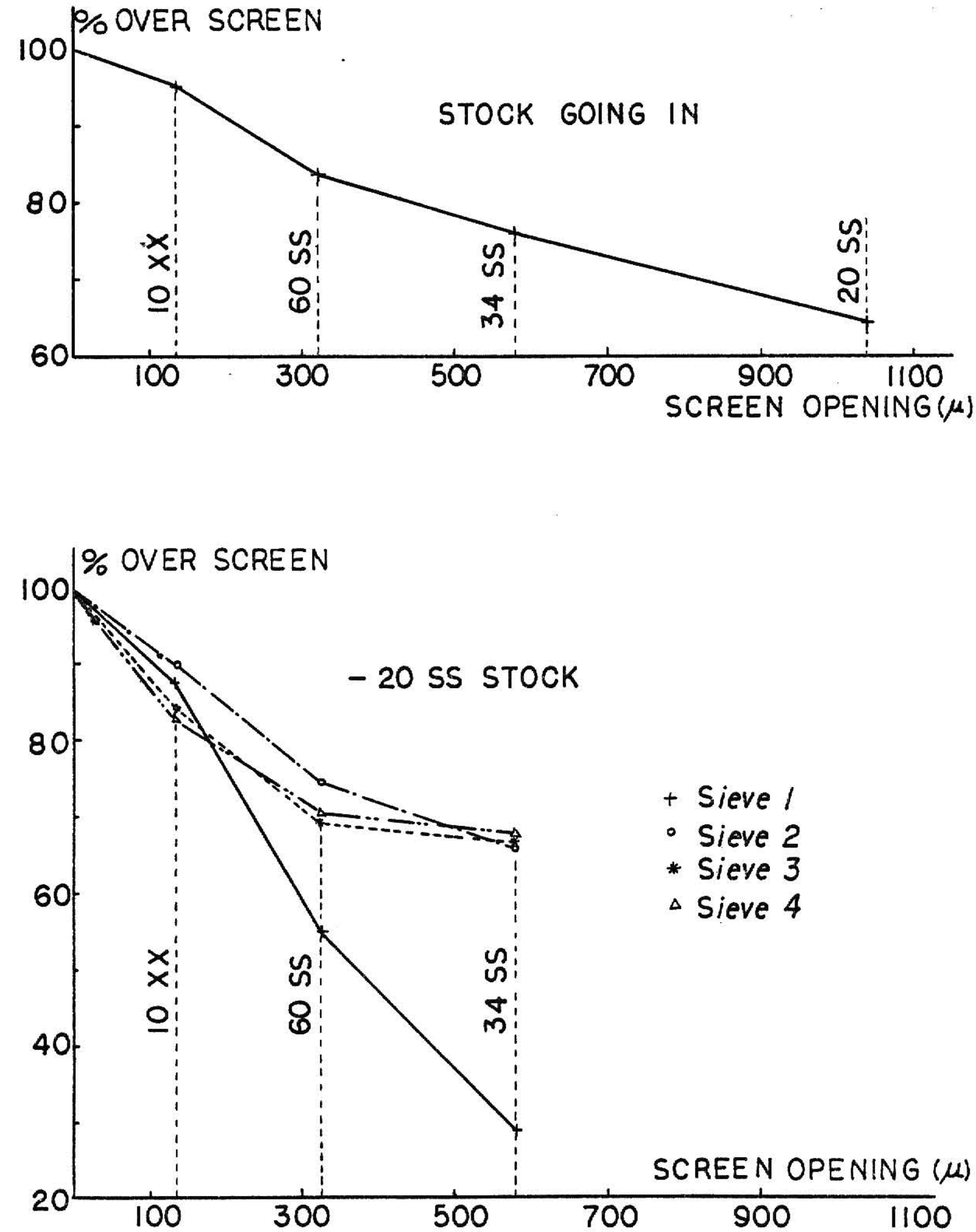


FIGURE 28: PARTICLE SIZE DISTRIBUTION (38 SS *sieve covering*)

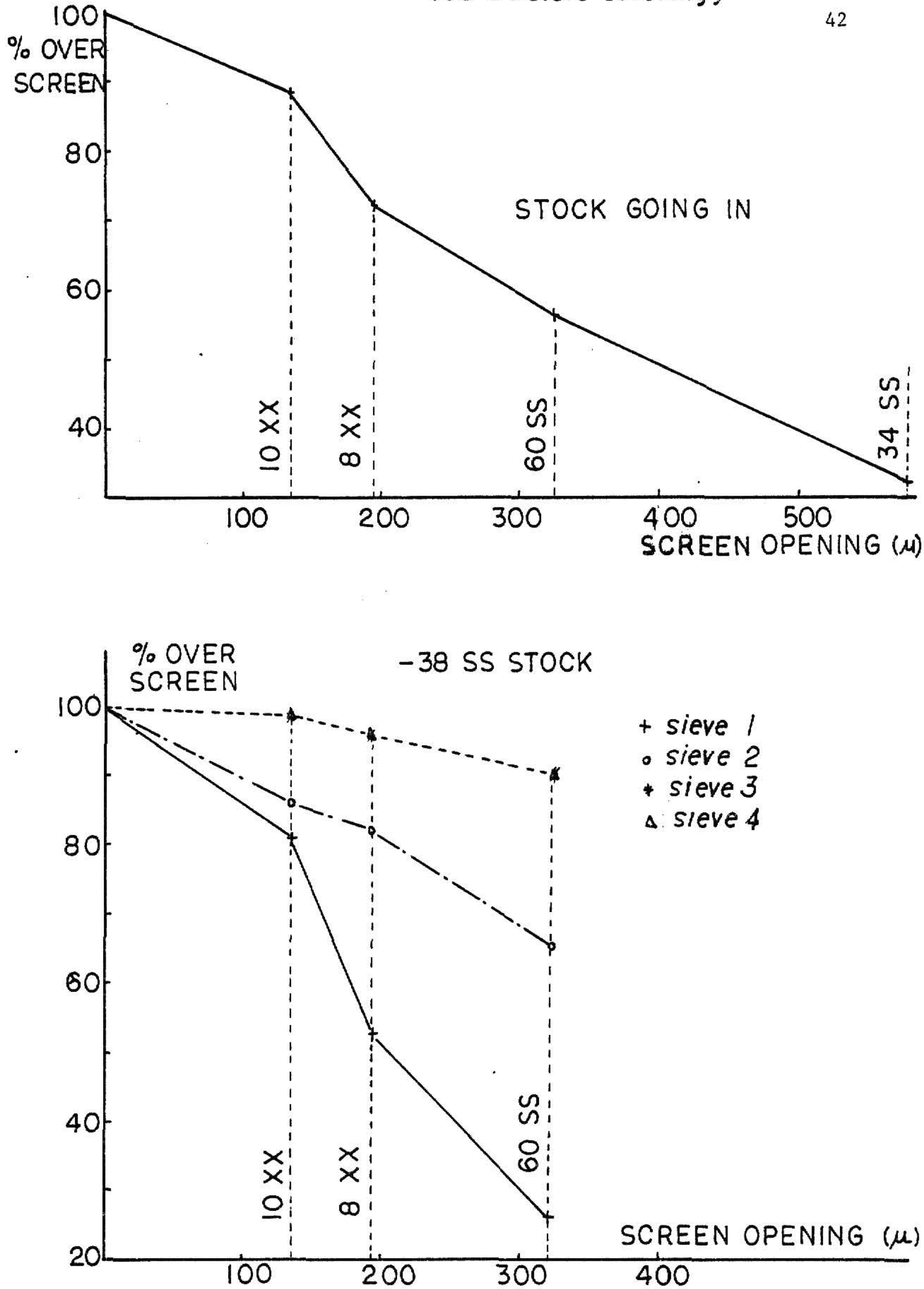
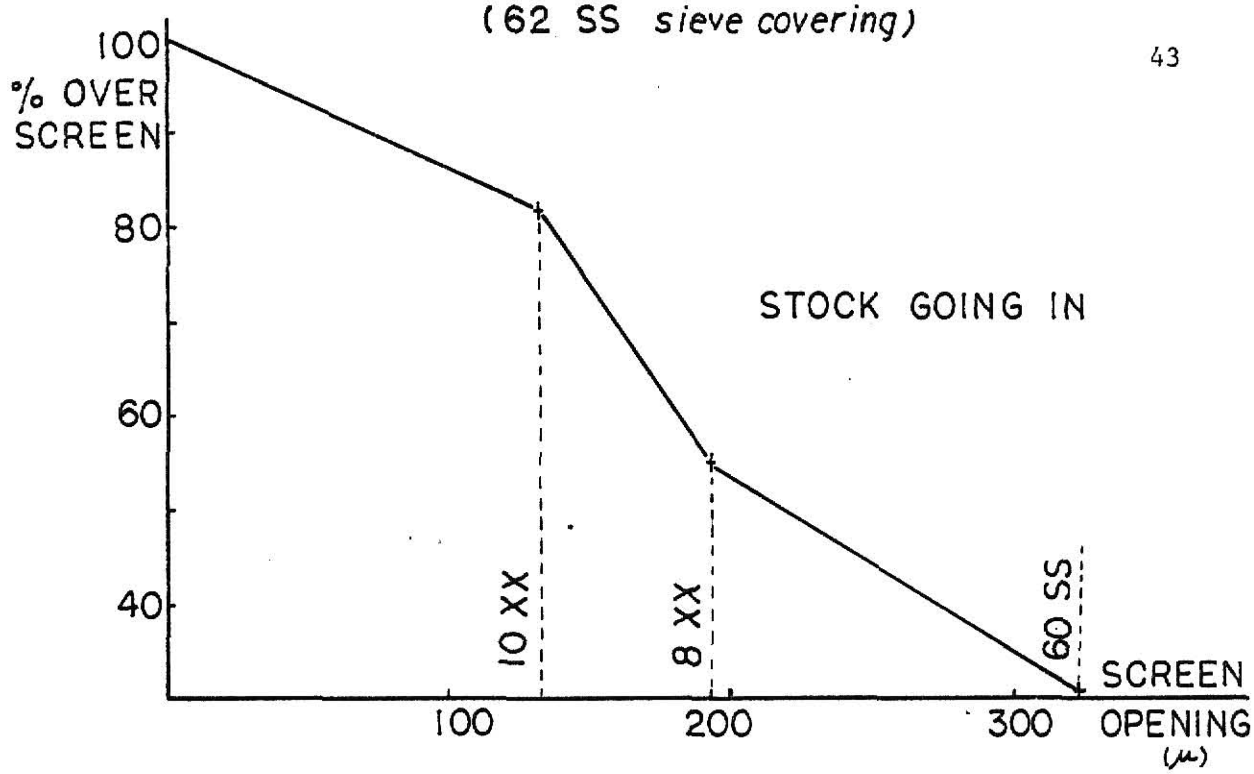


FIGURE 29: PARTICLE SIZE DISTRIBUTION
(62 SS *sieve covering)*



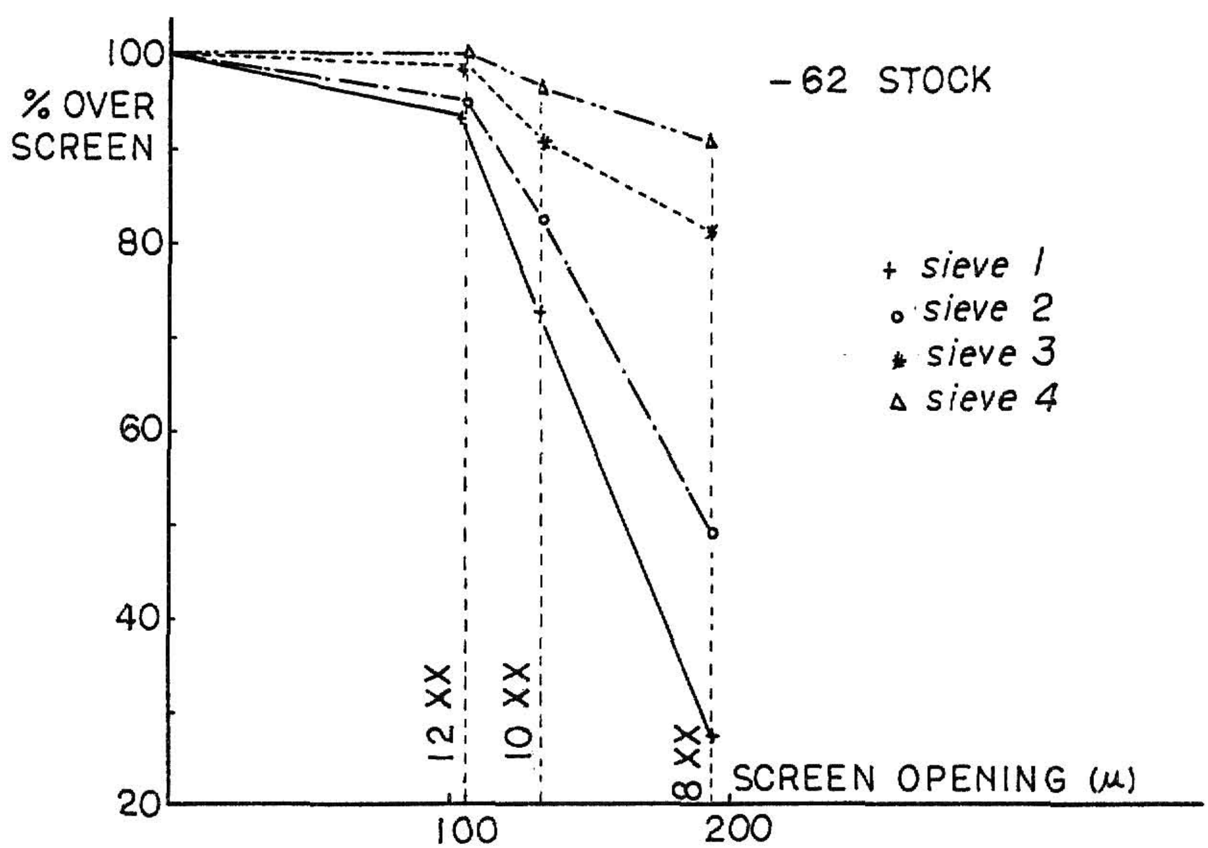
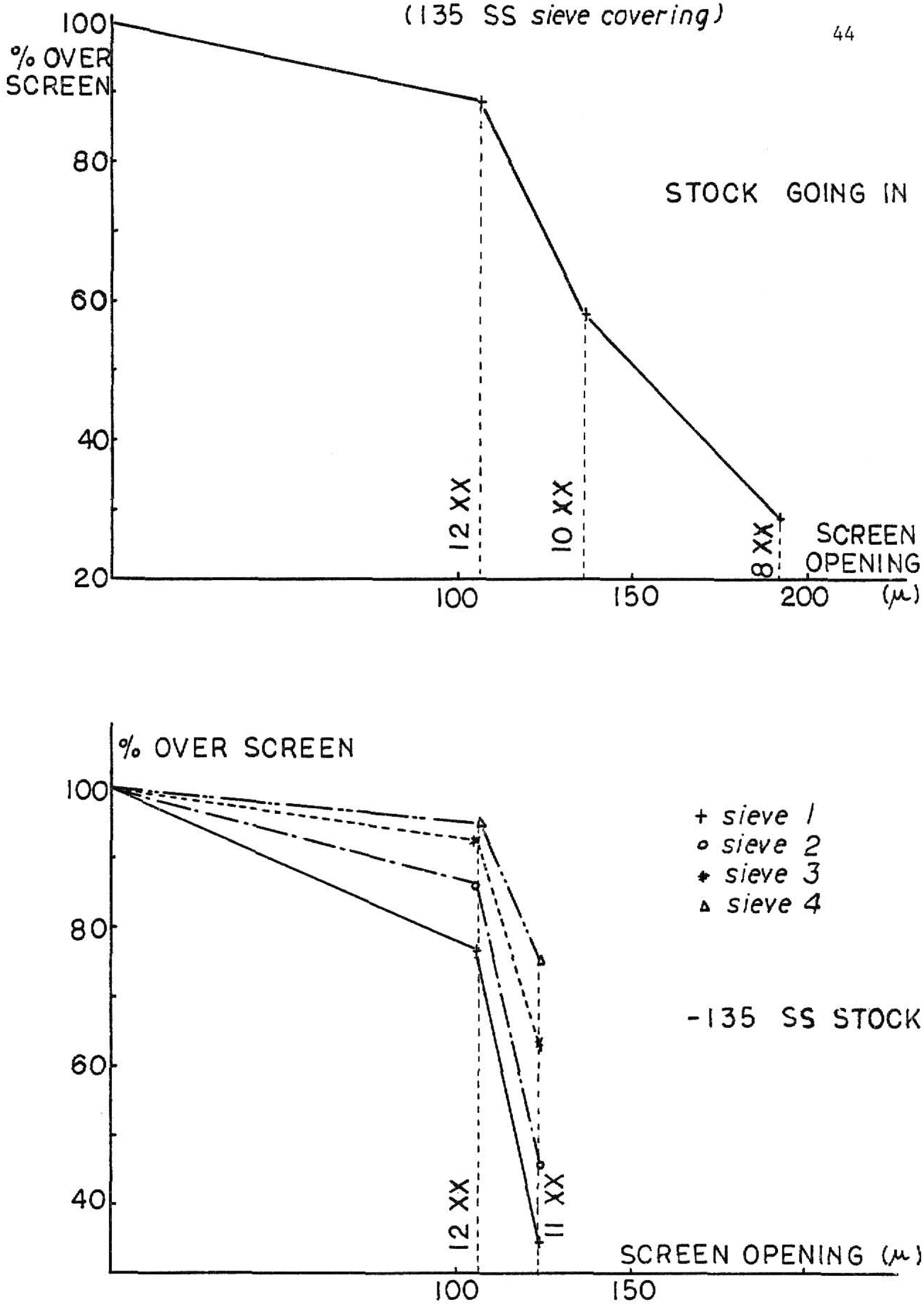


FIGURE 30: PARTICLE SIZE DISTRIBUTION
(135 SS *sieve covering*)



This phenomenon could be used to make multiple separations by particle size within a set of sieves having identical mesh numbers. Normally this procedure would also give a classification by degree of bran contamination of the thrus. Another approach, as indicated previously in the literature review, would be to increase the capacity by using a slightly coarser mesh for the top sieves of a set, considering that stratification will keep the larger particles from being sifted at this point.

Statistical Analysis

Mathematical expressions for the most significant curves obtained are found by using the least square method (24).

The next general expression for continuous functions with scattered empirical values is used:

$$y = f(x) = a_o + a_1x + a_2x^2 + a_3x^3 +....+ a_nx^n$$

In this work, two different kinds of curves are observed: straight lines and quadratic curves. Coefficients a_o and a_1 for straight lines, and a_o, a_1 and a_2 for quadratic curves are determined.

Notes:

a) In order to be able to set the relationships, the different combinations of RPM and Circle are represented by the sequence of numbers: 3(185 RPM-4"), 4(210 RPM-3.5"), 5(235 RPM-3"), 6(260 RPM-2.5").

b) When dealing with RPMs or Circles independently, lineal cloth speed (π x D x RPM) is used as the variable factor. Values for different combinations are shown in the next table:

RPM	CIRCLE in.	CLOTH SPEED in/sec
185	3	29.1
210	3	33.0
235	3	36.9
210	2.5	27.5
210	3.5	38.5

The coefficients obtained after evaluation of the least square method are:

I. Traveling speed of the stock (coefficients evaluated for the time "t").

	FEED RATE		COMB. OF RPM/CIRCLE			RPM		CIRCLE	
	a_0	a_1	a_0	a_1	a_2	a_0	a_1	a_0	a_1
20 SS	24	0	25.5	-2.5	.5	48	-.64	51	-.73
38 SS	41	0	39	-3	1.4	76	-.51	122	-1.9
62 SS	44	0	24	0	2.4	187	-2.8	267	-5.2
135 SS	100	0	119	-16	3.2	208	-2.6	283	-4.7

II. Amount of stock in the sifter at any given time (S_t).

OVERS

	RPM		CIRCLE	
	a_0	a_1	a_0	a_1
20 SS	10.8	-.13	14.3	-.23
38 SS	8.3	-.10	13.7	-.26
62 SS	6.2	-.06	12.9	-.26
135 SS	6.9	-.08	11.8	-.22

THRUS

	RPM		CIRCLE	
	a_0	a_1	a_0	a_1
20 SS	3.9	-.06	3.6	-.05
38 SS	5.4	-.09	7.8	-.16
62 SS	3.9	-.005	8.0	-.17
135 SS	6.0	-.11	6.5	-.13

III. Percentage of total thrus coming out of the first sieve of the test set.

	FEED RATE	
	a_0	a_1
20 SS	95	-.19
38 SS	100	-.56
62 SS	94	-1.04
135 SS	97	-2.9

IV. Thruput value as a function of feed rate.

	FEED RATE		
	a_0	a_1	a_2
20 SS	-94	15.2	-.13
38 SS	5	14.6	-.081
62 SS	11	13.1	-.057
135 SS	15	7.6	-.12

SUGGESTIONS FOR FUTURE WORK

The experimental installation used during this work lends itself for a lot of further experimentation on sifting performance.

Each of the main stocks from the milling process could receive particular attention.

Heavier loads especially when working with thruput determinations (thruput value and distribution) should be used in order to know maximum capacities.

The influence of different characteristics of the stock like potential thrus and moisture could be considered.

Taking advantage of the particle size distribution of the different thrus, experimentation can be done using a set of sieves with clothing having minor differences in opening size.

Other topics that could receive attention are:

- Inverse sifting for light loads. In some light streams, the normally used arrangement of cloth from coarse to fine can be inverted so that the finer cloths receive a heavier load of stock and a more efficient sifting operation can be performed.
- Comparison with other types of sifting machines, such as high speed centrifugals in handling difficult to sift stocks.
- Distribution of thrus when running the sifter clock or counterclockwise.

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Finally, thanks to Great Western Manufacturing Company for providing a new set of sieves to carry out this study.

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APPENDIX

TABLE 1

Conditions used in each trial.

Trial No.	Circle in.	RPM	Feed Rate (lb/min.) 20 SS	38 SS	62 SS	135 SS
1	4	185	19.9	11.4	7.6	4.1
2	4	185	28.2	16.6	11.3	6.2
3	4	185	38.0	24.1	15.6	7.8
4	4	185	46.9	31.2	20.0	9.3
5	3	185	47.1	25.0	15.6	7.8
6	3.5	210	47.0	25.0	16.6	7.8
7	3	210	47.1	24.7	15.6	7.8
8	2.5	210	46.7	24.9	15.5	7.8
9	3	235	46.1	24.5	16.3	8.2
10	2.5	260	46.8	23.8	15.5	7.8

TABLE 2

Traveling speed of the stock.

Trial No.	Traveling Speed of the Stock (in/sec)			
	20 SS	38 SS	62 SS	135 SS
1	3.6	2.1	2.1	.92
2	3.9	2.2	2.1	.86
3	3.6	2.0	2.0	.91
4	3.9	2.1	2.1	.89
5	3.0	1.5	.86	.67
6	3.9	1.8	1.3	.87
7	3.3	1.6	.95	.73
8	2.9	1.3	.72	.58
9	3.6	1.6	1.1	.78
10	3.1	1.3	.82	.63

TABLE 3

Amount of stock being sifted at any given time (S_t)

Trial No.	S_t (grams) 20 SS over	thrus	38 SS over	thrus	62 SS over	thrus	135 SS over	thrus
1	2951	725	1871	696	1431	682	2178	976
2	3859	1070	2557	1084	1767	1018	2950	1272
3	4449	1168	3180	1426	2275	1353	3222	1621
4	4994	1310	3835	1972	2770	1816	3577	1860
5	6983	2010	5433	2853	4348	2478	4412	2570
6	5421	1416	3524	1653	2840	1628	3471	1684
7	6810	2002	4844	2422	4308	2453	4050	2298
8	7945	2022	6444	3407	5706	3472	5915	3070
9	5993	1525	4625	2147	3867	2121	3743	1650
10	5942	1639	4660	2155	5055	2952	4982	2150

TABLE 4

Amount of Overs and Thrus (grams) from different sieves.

Trial No.	Thrus 1	Thrus 2	Thrus 3	Thrus 4	Total Thrus	Total Overs	Total Product
				20 SS			
1	2883	188	69	44	3184	5844	9028
2	4168	325	95	66	4654	8168	12822
3	5386	574	147	99	6206	11032	17238
4	6100	709	195	120	7124	14171	21296
5	6786	394	126	76	7382	13977	21359
6	6526	619	186	96	7427	13887	21314
7	6923	624	149	81	7786	13605	21390
8	7193	405	126	71	7795	13394	21189
9	6665	608	180	99	7552	13563	21115
10	7088	631	150	74	7943	13317	21260
				38 SS			
1	2881	109	64	33	3087	2084	5171
2	4154	232	87	67	4550	3009	7549
3	5641	676	163	86	6652	4297	10949
4	6928	1097	246	135	8406	5769	14175
5	6146	576	91	64	6877	4491	11368
6	5980	710	177	77	6944	4425	11369
7	6207	616	115	45	6983	4212	11195
8	5944	626	102	64	6736	4577	11313
9	5865	676	91	54	6686	4446	11132
10	6135	660	92	37	6924	3881	10805

TABLE 4 (Cont.)

Trial No.	Thrus 1	Thrus 2	Thrus 3	Thrus 4	Total Thrus	Total Overs	Total Product
				62 SS			
1	1954	214	64	19	2251	1180	3431
2	2814	444	95	39	3392	1743	5135
3	3673	734	185	73	4664	2339	7003
4	4538	1280	263	56	6137	2952	9089
5	4141	652	65	22	4880	2180	7060
6	3930	887	128	32	4977	2562	7539
7	4116	602	115	29	4862	2205	7067
8	4166	661	98	26	4951	2090	7041
9	3994	790	154	22	4960	2440	7400
10	4319	566	91	16	4992	2052	7044
				135 SS			
1	733	105	24	3	905	956	1861
2	1949	207	79	11	1345	1464	2809
3	1228	258	131	30	1647	1912	3559
4	1363	317	206	60	1946	2283	4229
5	1125	306	161	42	1634	1901	3535
6	1242	245	149	25	1661	1881	3542
7	1202	279	161	20	1662	1878	3540
8	1042	378	201	37	1658	1880	3538
9	1163	442	176	25	1806	1900	3703
10	1028	470	189	27	1714	1836	3550

TABLE 5

Distribution of thruput coming from different sieves.
(% of total thrus)

Trial No.	Thrus 1	Thrus 2	Thrus 3	Thrus 4
		20 SS		
1	90.5	5.6	2.2	1.4
2	89.6	7.0	2.0	1.4
3	86.8	9.2	2.4	1.6
4	85.6	10.0	2.7	1.7
5	91.9	5.3	1.7	1.0
6	87.9	8.3	2.5	1.3
7	88.9	8.0	1.9	1.0
8	92.3	5.2	1.6	0.9
9	88.3	8.1	2.4	1.3
10	89.2	7.9	1.9	0.9
		38 SS		
1	93.3	3.5	2.1	1.1
2	91.3	5.1	1.9	1.5
3	84.8	10.2	2.5	1.3
4	82.4	13.1	2.9	1.6
5	89.4	8.4	1.3	0.9
6	86.1	10.2	2.5	1.1
7	88.9	8.8	1.6	0.6
8	88.2	9.3	1.5	1.0
9	87.7	10.1	1.4	0.8
10	88.6	9.5	1.3	0.5

TABLE 5 (Cont.)

Trial No.	Thrus 1	Thrus 2	Thrus 3	Thrus 4
		62 SS		
1	86.8	9.5	2.8	0.8
2	83.0	13.1	2.8	1.1
3	78.7	15.7	3.9	1.6
4	73.9	20.9	4.3	0.9
5	84.9	13.4	1.3	0.5
6	79.0	17.8	2.6	0.6
7	84.7	12.4	2.4	0.6
8	84.1	13.4	2.0	0.5
9	80.5	15.9	3.1	0.4
10	86.5	11.3	1.8	0.3
		135 SS		
1	85.4	11.6	2.7	0.3
2	78.0	15.4	5.9	0.8
3	74.6	15.7	8.0	1.8
4	70.0	16.3	10.6	3.1
5	68.8	18.7	9.9	2.6
6	74.8	14.8	9.0	1.5
7	72.3	16.8	9.7	1.2
8	62.8	22.8	12.1	2.2
9	64.4	24.5	9.7	1.4
10	60.0	27.4	11.0	1.6

TABLE 6

Thruput of the first sieve of the series as a function of feed rate.

Trial No.	lb/hr/ft^2 of cloth			
	20 SS	38 SS	62 SS	135 SS
1	158.6	158.5	107.5	42.5
2	229.2	228.5	149.3	57.7
3	296.2	310.3	202.0	67.5
4	335.5	381.0	249.6	75.0

TABLE 7

Average particle size distribution of the sample going into the sifter.

Stock	Sieve	Opening	Over	% Over	Σ Over
		μ	gr.	%	%
From First Break	-10XX	0	22	4.5	100.0
	+10XX	136	58	11.9	95.5
	+60SS	323	37.5	7.7	83.6
	+34SS	581	55.4	11.4	75.9
	+20SS	1041	314.1	64.5	64.5
-20SS	-10XX	0	47.6	11.9	100.0
	+10XX	136	63.7	15.9	88.1
	+ 8XX	193	63.4	15.8	72.2
	+60SS	323	96.8	24.1	56.4
	+34SS	581	129.8	32.3	32.3
-38SS	-10XX	0	54.2	18.2	100.0
	+10XX	136	80.5	27.1	81.8
	+ 8XX	193	72.0	24.2	54.7
	+60SS	323	90.7	30.5	30.5
-62SS	-12XX	0	23.2	11.8	100.0
	+12XX	107	60.2	30.5	88.2
	+10XX	136	58.3	29.6	57.7
	+ 8XX	193	55.4	28.1	28.1

TABLE 8

Particle size distribution of thrus from different sieves.

			20 SS		
Stock	Sieve	Opening	Over	% Over	Σ Over
		μ	gr.	%	%
S_1	-10XX	0	37	12.5	100.0
	+10XX	136	96	32.5	87.5
	+60SS	323	77	25.7	55.0
	+34SS	581	85	28.3	29.3
S_2	-10XX	0	30	10.2	100.0
	+10XX	136	45	15.3	89.8
	+60SS	323	26	8.8	74.5
	+34SS	581	193	65.6	65.7
S_3	-10XX	0	47	15.8	100.0
	+10XX	136	45	15.2	84.2
	+60SS	323	7	2.4	69.0
	+34SS	581	198	66.7	66.6
S_4	-10XX	0	50	16.8	100.0
	+10XX	136	38	12.8	83.2
	+60SS	323	7	2.4	70.4
	+34SS	581	202	68.0	68.0

TABLE 8 (Cont.)

38 SS

Stock	Sieve	Opening	Over	% Over	Σ Over
		μ	gr.	%	%
S_1	-10XX	0	37	18.8	100.0
	+10XX	136	56	28.4	81.2
	+ 8XX	193	54	27.4	52.8
	+60SS	323	50	25.4	25.4
S_2	-10XX	0	8	4.0	100.0
	+10XX	136	27	13.6	96.0
	+ 8XX	193	34	17.1	82.4
	+60SS	323	130	65.3	65.3
S_3	-10XX	0	2	1.0	100.0
	+10XX	136	6	3.0	99.0
	+ 8XX	193	11	5.5	96.0
	+60SS	323	180	90.4	90.4
S_4	-10XX	0	2	1.0	100.0
	+10XX	136	7	3.5	99.0
	+ 8XX	193	10	5.0	95.5
	+60SS	323	180	90.4	90.4

TABLE 8 (Cont.)

62 SS

Stock	Sieve	Opening	Over	% Over	Σ Over
		μ	gr.	%	%
S_1	-12XX	0	13	6.5	100.0
	+12XX	107	42	21.0	93.5
	+10XX	136	92	46.0	72.5
	+ 8XX	193	53	26.5	26.5
S_2	-12XX	0	10	5.0	100.0
	+12XX	107	25	12.5	95.0
	+10XX	136	67	33.5	82.5
	+ 8XX	193	98	49.0	49.0
S_3	-12XX	0	2	1.0	100.0
	+12XX	107	16	8.0	99.0
	+10XX	136	20	10.0	91.0
	+ 8XX	193	161	89.0	81.0
S_4	-12XX	0	-	0	100.0
	+12XX	107	7	3.5	100.0
	+10XX	136	12	6.0	96.5
	+ 8XX	193	180	90.5	90.5

TABLE 8 (Cont.)

135 SS

Stock	Sieve	Opening	Over	% Over	Σ Over
		μ	gr.	%	%
S_1	-12XX	0	46	23.5	100.0
	+12XX	107	83	42.3	76.5
	+11XX	124	67	34.2	34.2
S_2	-12XX	0	27	13.7	100.0
	+12XX	107	81	41.1	86.3
	+11XX	124	89	45.2	45.2
S_3	-12XX	0	14	7.1	100.0
	+12XX	107	59	30.1	92.9
	+11XX	124	123	62.8	62.8
S_4	-12XX	0	10	5.1	100.0
	+13XX	107	40	20.5	94.9
	+11XX	124	145	74.4	74.4

STEADY STATE SIFTING OF FIRST BREAK WHEAT STOCK

by

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The objective of this work was to determine what effect certain variables--rate of feed, sifter speed and throw, type of stock--have on the sifting characteristics--thruput, stock traveling speed, granulation of thrus.

The study was carried out by testing first break stock under conditions that can be compared directly to commercial situations. This is possible because full scale sifting equipment was used under continuous flow conditions.

The experimental setting included a feeder and a small sifter adapted to hold commercial size sieves. A set of 4 sieves with independent outlets was used in order to analyze the quality and the quantity of the thrus on each sieve.

Traveling speed of the stock was determined as an average for the set of 4 sieves. It was found to be dependent on the nature of the stock handled and the sifter motion, and independent from the feed rate in the range analyzed.

The amount of stock in the sifter at any given time was observed to be a function of feed rate and different combinations of RPMs and circles. Variations in lineal cloth speed had different effects on the amount of stock depending on whether the cloth speed originated from changes in RPM or from changes in circle. For a given feed rate and sifter motion, the amount of stock in the sifter was greater for floury than for granular particles.

The relative amounts of thrus coming out of the different sieves of the test set were analyzed. It was found to be dependent on feed rate and sifter motion for a given stock.

Thruput values were obtained for different stocks, loads and sifting motions.

Finally, analysis of the particle size distribution of the thrus from the different sieves of the set is provided. The principle that finer particles go thru first is clearly illustrated.