GRAIN SORGHUM THRESHABILITY PARAMETERS

by

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INTRODUCTION

The combine threshing cylinder has been the object of much research since it is one of the most important parts of the machine. It has been shown that cylinder losses are one of the major losses in the combine.

Most of the work has been with small grain crops like wheat, barley, oats, rye, etc., but there has been more work done with some types of grain than others. Grain sorghum is one in which the work done has been very limited.

The importance of knowing combine performance for all different types of grains has increased very rapidly because of the energy crisis. We need to know these performances in order to get the most benefit out of the combine with the minimum use of energy.

Since this work is related to the threshing cylinder of the combine, the results are related to the best cylinder conditions for minimizing the use of energy and grain losses. However, it should be understood that with cylinder performance we cannot conclude what is the best for the entire machine. Instead we need to put together all component performances to see what is the best for combine.

A field test of the combine could give us the best information about its overall performance, but to do this we need to make use of highly sophisticated expensive equipment. The lab study is easier to control and cheaper to work with. Since in the lab we can control the variables to a certain degree, we can see the influence of one parameter over the others. These results can help us to plan and conduct a better and more complete experiment when we test the combine in the field.

Another important factor is the rapid development of new machinery, which is larger, more complex and more expensive. If we want to make the maximum contribution to agricultural production, it is necessary to use equipment more efficiently. Renoll (1970) tells us that the design of the agricultural machine is still more of an art than a science because sufficient basic, quantitative knowledge of the relation of machinery design factors to the performance of the machine is not available. Agricultural machinery designers must rely heavily on experience and intuition to design a new machine or improve an existing one. Knowledge of the relation of design factors to machine performance will permit designing for optimum performance.

The present threshing practice in Nicaragua results in a very high amount of grain loss. Also since there is a substantial area increase of small grain grown in recent years, the development of a new type of thresher or the adaption of modern machines will be required. More people can be fed by cutting down on the excessive loss and at the same time use a minimum of energy.

REVIEW OF LITERATURE

The ease with which seed is separated from the florets is the definition that Long (1951) gave to threshability. Later, Lamp and Buchele (1960) defined this action as the applied force on a kernel which exceeds the sum of the forces which restrain it. Long (1951) also tells us about the three general methods for obtaining the threshing forces. They are as follows: a) mechanical method such as rubbing and stripping, b) impact or impulsive acceleration that occurs when a cylinder bar strikes unthreshed grain, and c) non-impulsive acceleration which would result if a head of grain were suddenly accelerated without impact. Threshing is accomplished principally in conventional cylinder-concave mechanisms by the use of the first two methods.

Thresher studies have been going on since invention of the cylinder mainly because of the grain damage and grain losses it produces. Grain marketing regulations, concerning grain conditions when the grain is to be shipped, have motivated many researchers to determine the best combine conditions for every crop it harvests. The objective is to obtain the least grain damage possible, because threshing is a higher source of grain damage than grain transportation and grain storage together. Also, this grain damage study is being conducted on grain losses because farmers want to eliminate, or at least reduce, grain loss as much as possible. The obvious reason is that grain losses mean money losses for them.

It has been shown in past research that grain damage and grain losses are mainly the result of grain moisture content and cylinder adjustment (cylinder speed and cylinder-concave clearance).

Long (1951), in his work with ladino clover, observed that the relative humidity of the air affects the percent of free seed obtained during threshing. That is, a high moisture content sample results in low threshability, whereas the reverse is true for one of low moisture content. With the moisture content between 10-18% (dry basis) the decrease in amount of seed obtained was significant, but from 6-9% (dry basis) it was not significantly affected. Johnson (1959) reported that the cylinder loss increases as the moisture content increases; although the combine has the capability of threshing the grain. The highest machine efficiency occurred between 15 and 20% grain moisture (wet basis), and further it appears in terms of combine functioning that 20% grain moisture should be the maximum. Arnold (1964), working with Koga 2 and Capelle Desprez wheat and Proctor barley, found that grain condition depended on grain moisture content, and efficiency of threshing on straw moisture content. The type of damage, incurred by cereal grains during combine-harvesting, is controlled by its moisture content. The condition of both Koga 2 and Capelle Desprez wheat was consistently superior when threshing was carried out in the "safe" zone between grain moisture levels of approximately 17.5-22% (wet basis). Proctor barley was shown to be much less susceptible to all forms of damage than either variety of wheat, particularly at low moisture content. In general, an increase from 15 to 25% (wet basis) m. c. doubled average drum losses. In both varieties of wheat this tendency could be overcome by appropriate drum adjustment, but could not be overcome in Proctor barley. Neal and Cooper (1968) pointed out that grain and straw absorb moisture at a diminishing rate, and this moisture, though unnatural, increases the crop's resistance to threshing. Waelti, et. al. (1971) observed that the cylinder loss in grain sorghum was high at high moisture, but decreased as grain matured. Schwantes (1940) indicated that moisture content is one of the factors responsible for grain harvesting damage in barley. King and Riddolls (1962), and Arnold and Jones (1963) reported that moisture content was the factor which damages the grain when it is harvested. The first work was done with wheat and peas, and the second with Cappelle Desprez wheat and barley.

According to Fenton (1941), sorghum is easy to thresh when it is dry, but it cracks easily. The drier it is, the more easily it cracks in threshing; although it is possible, by proper machine adjustment, to reduce the amount of cracked grain to 5% or less. The cylinder speed should be reduced to two-thirds or three-fourths of the rate for threshing wheat. Goss, et. al., (1958) reported that when the threshing effect was increased by either increasing the cylinder speed or decreasing the clearance, there was a substantial reduction in walker free-seed loss, and in total seed loss from the rear of the machine. Under the warm, dry condition of these tests, only 65 to 75% of the total straw-and-chaff input was carried over the walkers, the balance going onto the cleaning shoe. Increasing the threshing effect decreased the percentage of material carried over the walkers, primarily because more straw and chaff were forced through the concave grate. For harvesting barley under warm, dry, weather conditions, the cylinder-concave clearance should be relatively small (¼ inch), and the cylinder peripherial speed should be relatively high, (5000 to 5500 fpm). However, the cylinder speed should not be high enough to cause objectionable damage to the seed. Arnold (1964) reported that cylinder speed was one of the most important factors influencing drum losses. A reduction in losses with increasing cylinder speed occurred in all cases, but perfection was never achieved; although it was approached very closely in dry wheat. It follows that the more difficult a crop is to thresh, the greater the reduction in losses that result from a given increase in cylinder speed. Experiments performed by Bunnelle, et. al., (1954) on small seed legumes showed that cylinder speed is the most critical factor in causing seed damage, but could be reduced if the cylinder load was increased. Park (1954) observed, in crimson clover, that cylinder speed and clearance are very important. He also found that under the humid conditions usually present in South Carolina area, cylinder speed should be as high as possible and clearance as small as possible without causing excessive damage to the seed.

Fenton (1941), who studied the rasp bar and the angle bar, reported that both gave good results in threshing sorghum, but that the rasp bar cylinder cracked a large part of the grain if set too close and run at high speed. DeLong and Schwantes (1942) experimented with three different types of cylinder bars: spike-toothed, rasp bar, and rubber-faced bar. They worked with barley and found that the speed at which the cylinders do their best work is from 5,000 to 6,000 fpm. for all three types of cylinders. Slower speeds leave unthreshed heads and higher speeds result in too much cracking and skinning. The best clearance for the rasp bar cylinder was 3/8 to 1/2 inch as measured to the tips of the bar serrations. He concluded that all three types of cylinders 1) can be adjusted to thresh properly, 2) can be set to let heads go through unthreshed, or 3) can be set to thresh too severely and cause much mechanical injury to the kernels. Park (1954) observed that threshing loss is a major problem and angle-bar cylinders have been preferable to other types in harvesting crimson clover. Klein and Harmond (1966) in their experiment with crimson clover observed that for the spike-tooth cylinder, 5070 fpm peripherial speed and 5/32 inch clearance concave was the optimum combination; for the rubber-covered angle bar cylinder, 4110 fpm and 5/32 inch; and for rubber-covered flat bar cylinder, 4830 fpm and 1/32 inch to 1/8 inch. In addition, the rubber-covered, flat bar cylinder recovered about 10% more crimson clover seed than either of the other two cylinders and unthreshed seed loss was reduced to about 5% in the process.

Silver and McCuen (1935) working with wheat reported in a study of power division in a thresher indicated that about 50% of the total power requirement was consumed in the cylinder. Silver (1942) observed that a variety of wheat with a stiff straw will not be broken up as much by the cylinder, and therefore, the grain will sift through more quickly. The hardest threshing variety he found was Trumbull wheat. The cylinder loss was slightly greater at practically all heights of stubble. Thorne variety showed the lowest cylinder loss. According to Carroll (1948) the power to operate the threshing and cutting mechanism varies more nearly in proportion to the width of cut. A 16 ft cut will require up to 40 hp in a self-propelled combine. Burrough (1954) reported in wheat that the cylinder power requirements represented approximately 50% of the total combine power when it was operated under normal conditions. The cylinder is very responsive to the rate of material flow. In open-sowed crops the power requirements increase rapidly as the flow rate increases. This does not appear to be the case in sowed crops such as soybeans. In soybeans, the power required for the cylinder is higher than in wheat at the same rate of material flow. The flail or rub-bar cylinder required considerably more power than the rasp-bar cylinder at the no load condition for both types of crops. Bigsby (1959) observed in wheat the horsepower requirements showed 20 to 25% more power being required at the cylinder when threshing solid-stemmed wheat than that required to thresh hollow-stemmed wheat at the same rate. Lamp and Buchele (1960) observed in wheat that a centrifugal force of .30 lb is sufficient to thresh 98% or more of the mature grain independent of method of holding the head. A force of .20 lb is sufficient to thresh 98% of the grain under all typical harvesting conditions. Applying the centrifugal force so that the kernels must bend the attachment resulted in up to 50% less required threshing force as compared to a case when bending does not occur. Arnold and Lake (1964) found, in general, the fluctuations in torque requirements increased as moisture content increased. The average power requirement decreased, as cylinder diameter increased, by .25-.60 hp per 3 inches. This rate was not linear, and depended on the conditions prevailing in the particular experiment. Increasing the length of the concave increased the power requirement under all conditions. The rate of power increase as cylinder speed increased depended on the conditions pertaining to the particular experiments, but power was consistently higher at higher moisture contents.

Zaidi (1974) found a mean concave clearance of 5/16 inch to be best. He used a lab-type rasp-bar thresher and 13 different varieties of wheat. The speeds (4272, 4649 fpm) he used did not produce a significant difference in total unthreshed material. He indicated there is a relationship between the percentage of threshed material obtained at the front of the concave and unthreshed material discharged at the back of the concave.

INVESTIGATION

Research Objectives

1. To investigate the effects of : a) cylinder speed

   b) cylinder-concave clearance

   c) number of cylinder bars
2. To find the best combination of these design factors for each variety to be threshed.
3. To find the differences, if any, in the ease of threshing various varieties.

Experimental Unit

The threshing unit designed and described by Zaidi (1974) was used to make this study: (Figs. 1, 2, 3 and 4).

In general, the unit consists of a 12-inch diameter aluminum disc cylinder and uses conventional rasp-bars. These bars are 7.25 inches long. The shaft of the cylinder is supported at each end by a four-bolt flange bearing which is mounted on a plate. The unit has a vertical and horizontal adjustment made possible by the movement of two screws, one for each direction. These screws are joined to a series of small shafts which go through linear ball bearings. The ends of these shafts are supported by blocks mounted on the frame of the unit. The cylinder is powered by a 3 hp. capacitor start motor via a variable speed V-belt drive.

A beater-bar is mounted behind the cylinder to prevent material

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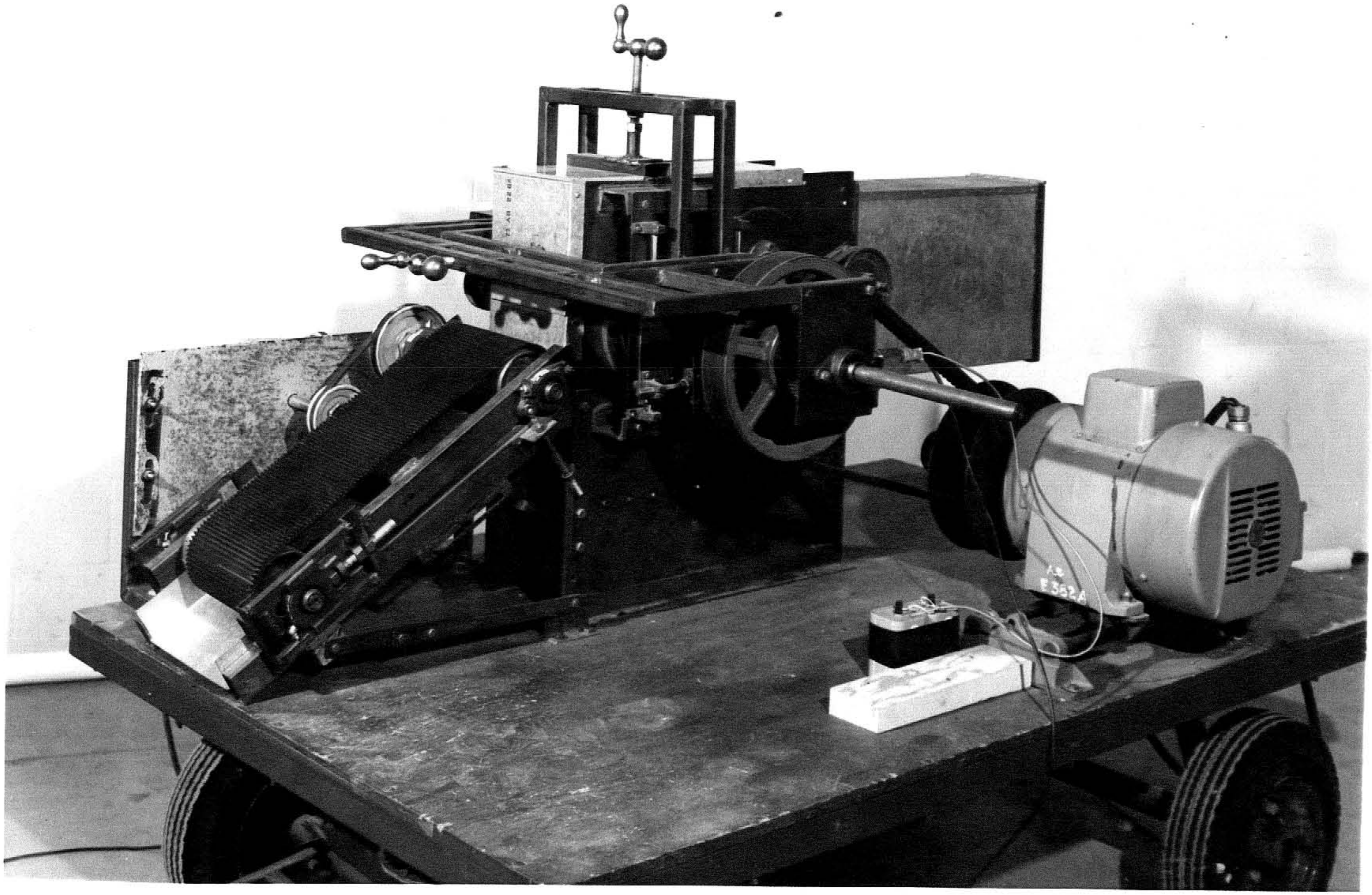

Fig. 1. Front and Right Side View of the Threshing Unit.

Fig. 2. Back and Right Side View of the Threshing Unit.

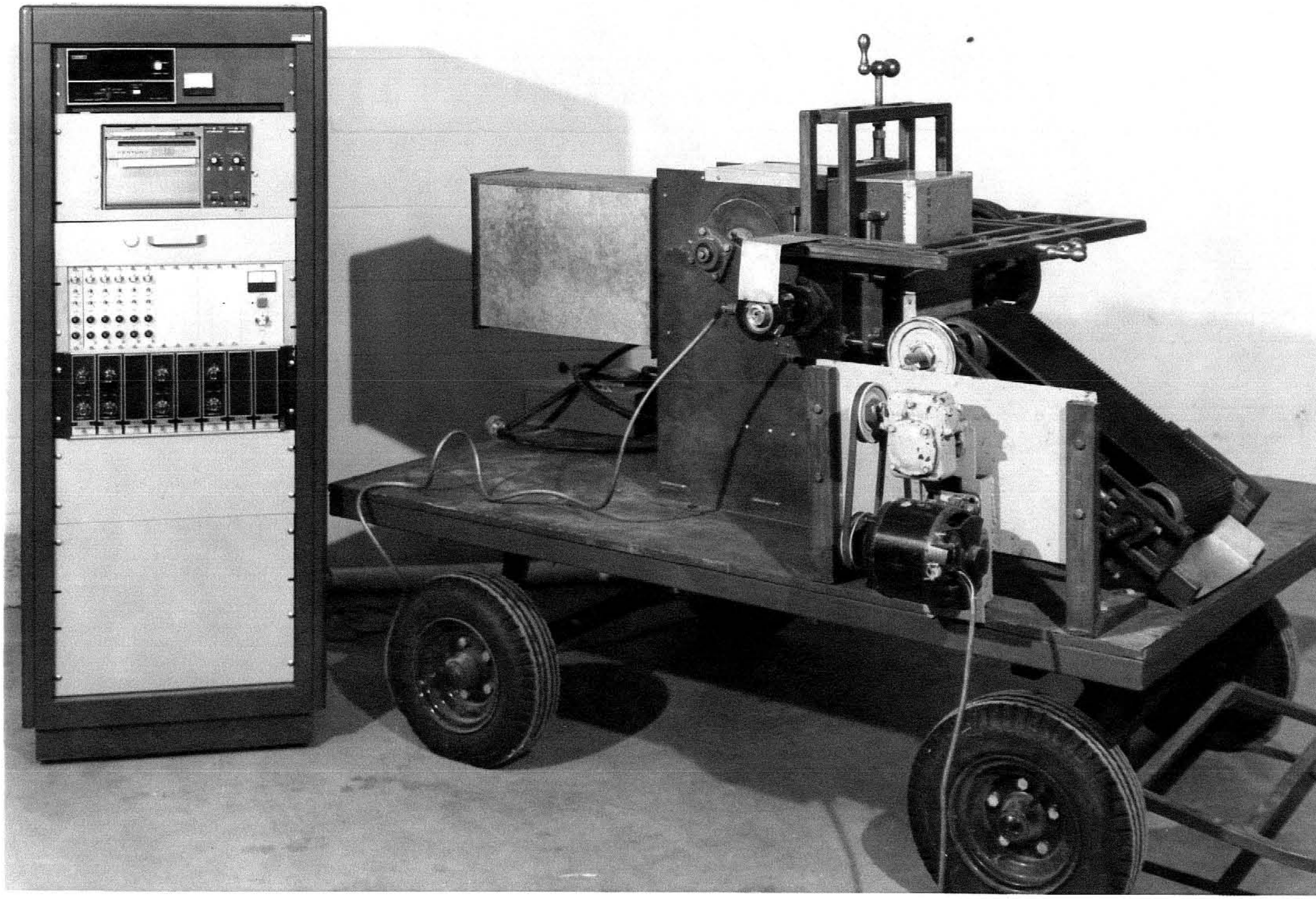

Fig. 3. Oscillograph and Left Side View of the Threshing Unit.

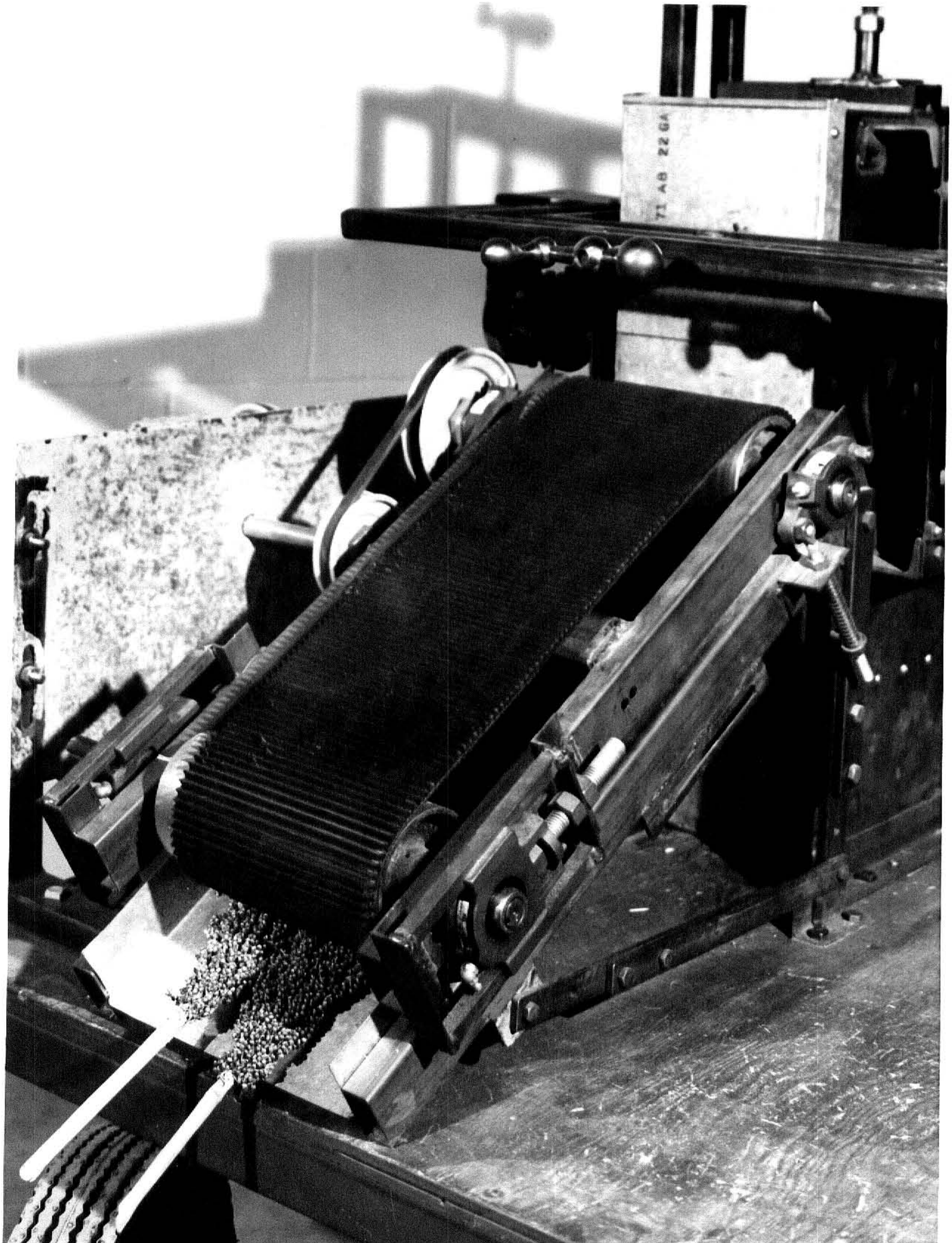

Fig. 4. Conveyor Belt Cylinder Feeder.

recirculation. The concave is divided into six sections. A tray with the same number of sections is placed below the concave to collect the material passing through it. There is also a box at the back of the unit to collect all the material discharged by the beater-bar. The material is fed to the cylinder by means of a motor-driver conveyor unit.

Recording System

To sense the torque, the unit uses a set of 45° rosette strain-gage bridge (Fig. 6), mounted on the cylinder shaft as shown in fig. 5. There is a two-inch diameter tube placed over the square cylinder shaft as a protection for the square section from permanent deformation that could be caused by high starting torque.

The strain gages are mounted 45° with respect to the shaft axis and at the center of the small square section. The strain gage in tension is diametrically opposite to the gage in compression. The wires, which are connected to these strain gages, run through a pilot hole in the main shaft to a slip ring unit located at one of the ends of the cylinder shaft. They then go to a filter which feeds the amplifier-oscillograph read-out system.

Calibration of the Unit

A static calibration was performed on the torque meter from 0 to 60 in-lbs (Fig. 7). The different loads on the shaft were obtained by placing weights at different arm lengths from the center of the cylinder, on an arm which was attached to the threshing cylinder. All other types of inputs were kept constant during the calibration. The frictional forces in the cylinder, for all meter values below

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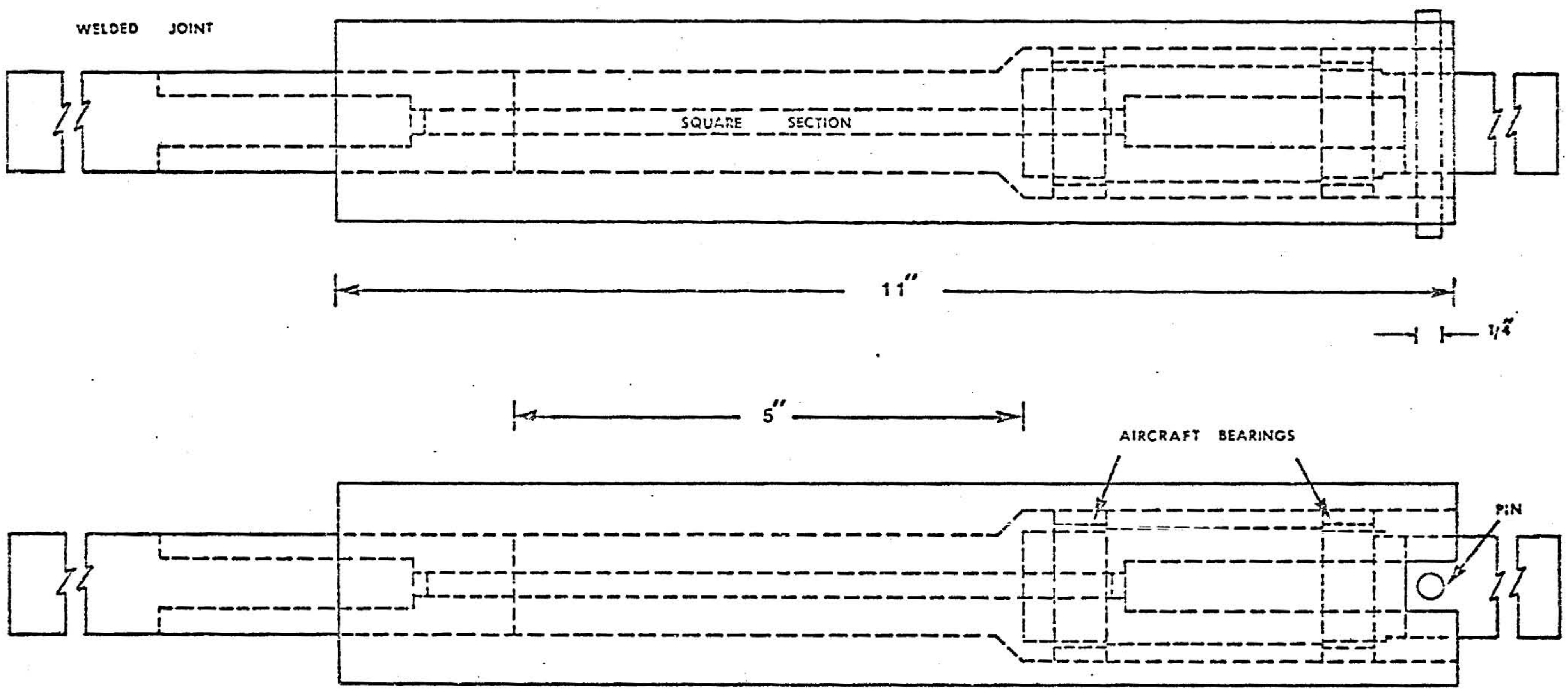


Fig. 5. Small Square Strain Sensing Section of Cylinder Shaft. Zaidi (1974).

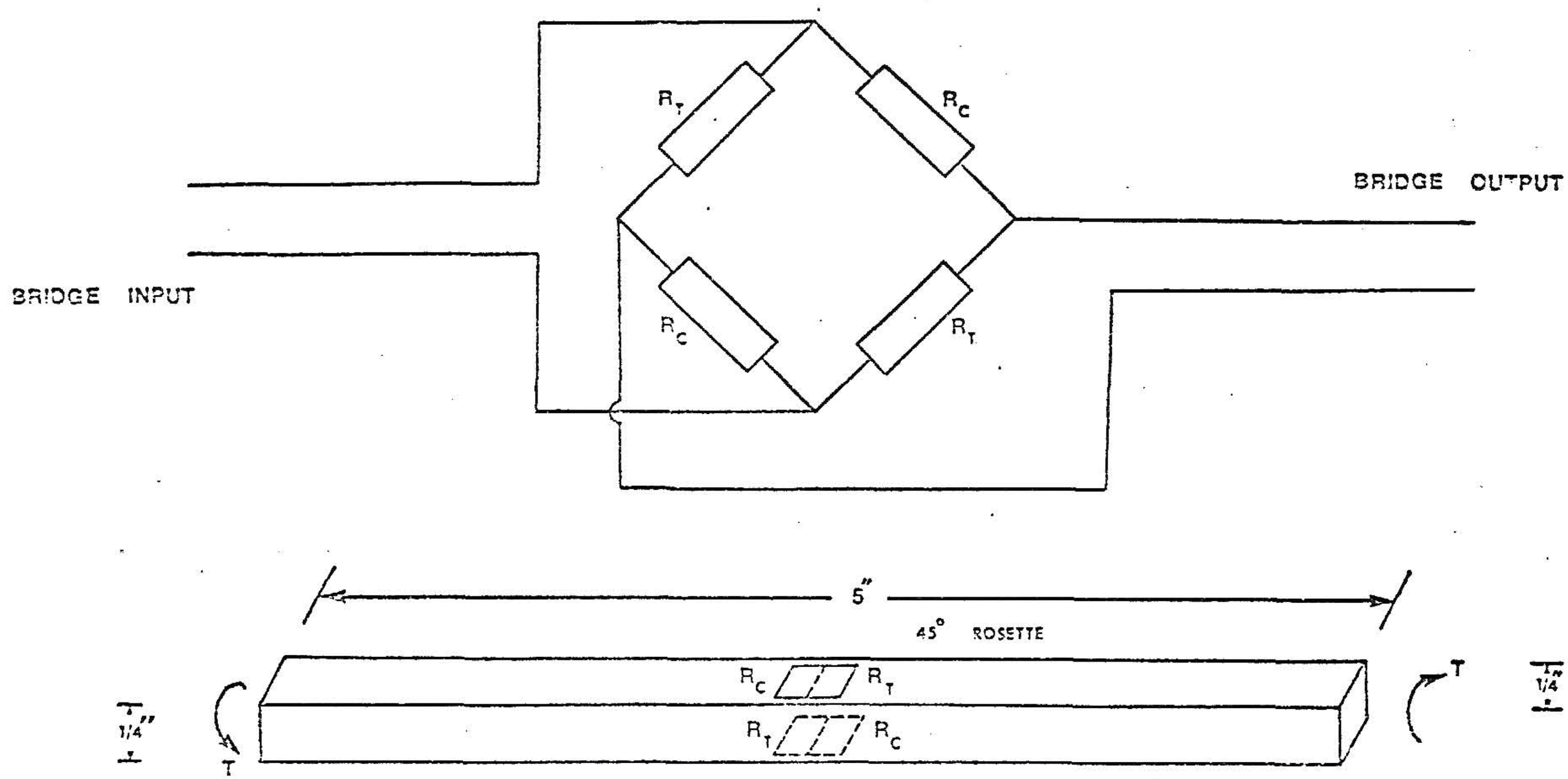


Fig. 6. Strain Gage Location on Strain Sensing Section of the Cylinder Shaft and a Wiring Diagram to Show How They Were Connected in the Bridge Circuit. Zaidi (1974).

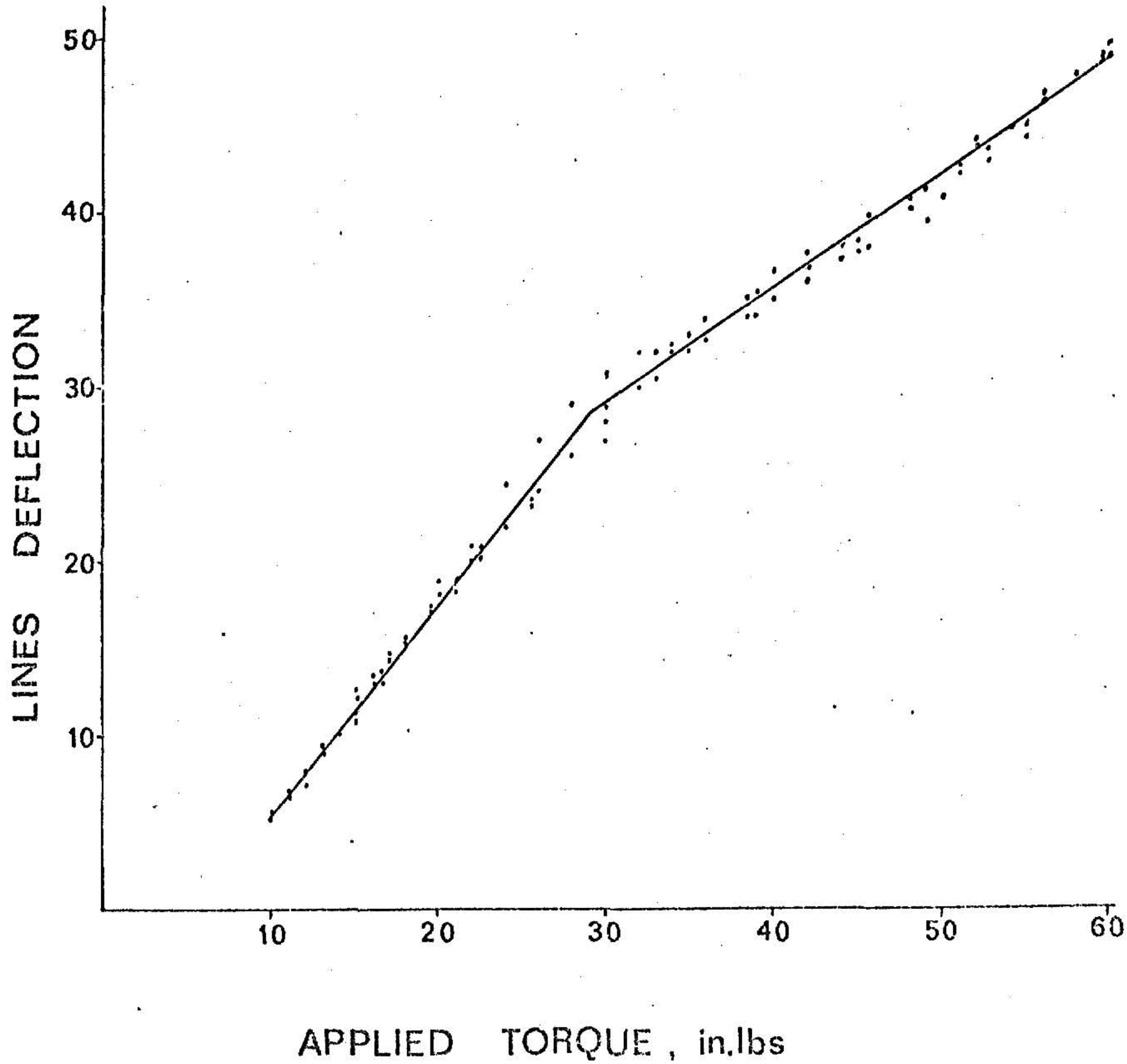


Fig. 7. Calibration Curve for the Torque-meter

10 in-lbs., were too high to give an accurate read-out; however they do not influence anything in this work so it was decided not to take them into consideration when the least square equation was found. By plotting the remaining points, it was noticed that from 10 to 30 in-lbs. all these points fall on a single-slope curve, but from 30 to 60 in-lbs. they follow another trend. It was decided to statistically fit two different lines; one line going from 10 to 30 in-lbs., and the other from 30 to 60 in-lbs. The method outlined by Doeblin (1966) was used to establish these two curves. The relationship between the cylinder torque and the recorder-chart deflection was given by the following least square equations.

$$T_1 = \frac{d_1+6.4630}{1.1927} \qquad (1)$$

$$T_2 = \frac{d_2-9.4471}{0.6506} \qquad (2)$$

Where

T_1 and T_2 are the true torque in in-lbs.

d_1 and d_2 are the number of lines deflection from zero in the recorder chart.

The standard error for these equations, at the 99.7 percent limit and assuming normal distributions, are ±1.6414 and ±3.708 in-lbs. for equation 1 and 2 respectively.

Experimental Material

Three sorghum varieties, DeKalb F-61A, NC$^+$55X, and NC$^+$80X, were used in this experiment. They were harvested on November 9, 1973 at the Scandia Irrigation Field, Kansas State University. Samples were brought to the lab and dried at ambient room conditions for two weeks, then they were weighed and the stems were measured. Samples were separated into two-head units keeping the weight of heads more or less equal and typical for the variety. After this they were stored in sealed cans until they were used.

TABLE 1. Average Weight per Experimental Unit (Two Heads)

Variety	Weight (gm.)
DeKalb F61-A	155.49
NC^+80X	161.62
NC^+55X	114.03

TABLE 2. Average Stem Length Per Head

Variety	Length (inches)
DeKalb F61-A	4.66
NC^+80X	3.93
NC^+55X	3.85

The moisture content was checked before storage and several times throughout the experiment. The main purpose of taking these moisture contents was to see if there would be any major variance from test to test.

Method of Procedure

It was mentioned before that the material was separated into samples of two heads each, weighed, and stored. Then for each test,

TABLE 3. Moisture Content Throughout the Experiment

Variety	1(%)*	2(5)	3(5)	4(5)	5(%)	6(%)
DeKalb 61-A	10.24	9.91	10.35	10.06	10.41	10.89
NC+80X	10.16	10.06	9.99	9.98	10.62	11.21
NC+55X	9.87	9.90	11.04	11.25	10.03	11.36

*Percents are wet basis.

one sample was taken at a time from the storage cans and placed on the lower conveyor belt by raising the upper belt (Fig. 4). The cylinder speed and concave clearance were checked in order to have the right settings for each test. Next, the oscillograph recorder was zeroed before the test was run. When everything was ready, the conveyor belt was started and material was fed into the cylinder. During the test, torque-time curves were recorded on the oscillograph chart. After threshing was completed, and material was deposited in the tray and box the material was placed in paper bags for further cleaning. Finally, the weight of the threshed and unthreshed material was taken. For complete data see Appendixes A and B. The same procedure was used for each variety and each of the two replications.

Preliminary Tests

Since the sorghum heads were quite dry, some preliminary tests were performed to find the maximum cylinder speed and the minimum concave clearance at which the thresher unit could be run to have no more than the normal combine crackage. Because of the dry grain condition, the maximum cylinder speed was not as high as expected.

(Table 4). Two other cylinder speeds were selected, one was the minimum speed that the V-belt drive could give, and the last one was an average of these two extremes. In the concave-clearance case, a minimum was found (Table 4), and the other two were established by increasing the clearance by 1/8 inch increments. The decision concerning number of cylinder bars was made to be compatible with the way that the holes on the cylinder disc were drilled when it was constructed. The conveyor belt speed was set by watching which speed was adequate to feed the cylinder.

Two heads of sorghum were used as an experimental sample to give an adequate torque output. By so doing, the amplifier gain could be lowered to reduce the noise-level output produced by the thresher. Samples of more than two heads were not feasible because they resulted in too much material for the width of the conveyor belt.

The conveyor belt speed was set from the optimum point by adjusting pulleys. This gave a suitable way to feed the cylinder of the thresher unit. The final ranges of these speeds are given in Table 4.

TABLE 4. Range of the Variables Used in the Experiment

Variable	Range
Feed rate	2 heads/run
Conveyor speed	22 ft./min.
Number of cylinder bars	4, 8 bar/trial
Cylinder speed	2356,2827,3298 ft./min.
Cylinder-concave clearance	3/8,1/2,5/8 inch

RESULTS AND DISCUSSION

The threshability factors for each of three grain sorghums were analyzed in eighteen treatments. These treatments were combinations of three cylinder speeds, three cylinder-concave clearances, and two sets of cylinder bars. Each experiment was replicated twice, and a split-plot design analysis of variance was used to analyze the data. The tables included in this section reflect those results.

The basis for each experiment was the selection of a set of either four or eight cylinder bars, and the other factors of the experiment were chosen at random. The experiment was duplicated by using the other set of cylinder bars, the other factors being chosen at random. The analysis of variance table shows the sources of variation, the degrees of freedom, their respective mean squares, and the "F" statistic. Each "F" value was computed by using $ERROR_1$ and $ERROR_2$ mean squares as the denominator of a division where the mean squares of the variables, above each ERROR, was the numerator. The asterick(s) (*) beside some "F" values show that the source was significant at the 10, 5 or 1% level of alpha hat.

The analysis of variance (Table 5-A) is the total threshed kernels along the entire concave. All the results are expressed on a weight basis. Among the factors studied, none were significant for the variety DeKalb F61-A, but for NC^+80X, the speed of the cylinder was significant at the 0.10 alpha level. For NC^+55X, the replication factor and the set of cylinder bar parameters were found to be significant at

TABLE 5-A. Analysis of Variance for the Total Weight of Threshed Kernels in Grams for Three Grain Sorghum Varieties

		DeKalb F61-A		NC^+80X		NC^+55X	
Source of Variation	DF	Mean Squares	F	Mean Squares	F	Mean Squares	F
Replication (R)	1	83.874	3.317	281.908	1.779	4.906	73.542*
Bars (B)	1	109.025	4.312	2.879	0.018	9.933	148.890*
$ERROR_1$	1	25.285		158.507		0.067	
Speed (S)	2	4.457	0.090	69.047	2.849*	11.570	0.213
Clearance (C)	2	25.557	0.514	11.598	0.479	20.672	0.381
B x S	2	17.035	0.342	7.066	0.292	5.071	0.094
B x C	2	90.810	1.825	61.044	2.519	22.373	0.413
S x C	4	23.726	0.477	6.500	0.268	9.493	0.175
B x S x C	4	14.885	0.299	44.430	1.833	15.787	0.291
$ERROR_2$	16	49.753		24.238		54.196	

*Significant at 0.10 alpha level.

TABLE 5-B. Analysis of Variance for the Total Weight of Unthreshed Kernels in Grams for Three Grain Sorghum Varieties

			DeKalb F61-A		NC+80X		NC+55X	
Source of Variation		DF	Mean Squares	F	Mean Squares	F	Mean Squares	F
Replication	(R)	1	1.174	4.025	95.160	3.459	6.961	0.985
Bars	(B)	1	462.821	1587.181**	602.784	21.911	259.478	36.718
ERROR1		1	0.292		27.510		7.067	
Speed	(S)	2	26.448	1.571	141.360	9.953***	81.765	6.184**
Clearance	(C)	2	40.646	2.415	215.707	15.187***	35.643	2.696*
B x S		2	12.803	0.761	16.392	1.154	26.013	1.967
B x C		2	15.810	0.939	28.253	1.989	32.056	2.424
S x C		4	5.906	0.351	4.044	0.285	2.304	0.174
B x S x C		4	9.877	0.587	18.162	1.279	5.596	0.423
ERROR2		16	16.832		14.203		13.223	

*Significant at 0.10 alpha level.
**Significant at 0.05 alpha level.
***Significant at 0.01 alpha level.

TABLE 6-A. Analysis of Variance for the Ratio of Threshed Kernels to Total Input Material for Three Sorghum Varieties

Source of Variation		DF	DeKalb F61-A Mean Squares	DeKalb F61-A F	$NC^{+}80X$ Mean Squares	$NC^{+}80X$ F	$NC^{+}55X$ Mean Squares	$NC^{+}55X$ F
Replication	(R)	1	0.003469	3.317	0.010792	1.779	0.000377	73.553*
Bars	(B)	1	0.004510	4.312	0.000110	0.018	0.000764	148.910*
$ERROR_1$		1	0.001046		0.006068		0.000005	
Speed	(S)	2	0.000184	0.090	0.002643	2.849*	0.000890	0.213
Clearance	(C)	2	0.001057	0.514	0.000444	0.479	0.001590	0.381
B x S		2	0.000705	0.342	0.000271	0.292	0.000390	0.094
B x C		2	0.003756	1.825	0.002337	2.518	0.001721	0.413
S x C		4	0.000981	0.477	0.000249	0.268	0.000730	0.175
B x S x C		4	0.000616	0.299	0.001701	1.833	0.001214	0.291
$ERROR_2$		16	0.002058		0.000928		0.004168	

*Significant at 0.10 alpha level.

TABLE 6-B. Analysis of Variance for the Ratio of Unthreshed Kernels to Total Input Material for Three Sorghum Varieties

Source of Variation		DF	DeKalb F61-A		NC^+80X		NC^+55X	
			Mean Squares	F	Mean Squares	F	Mean Squares	F
Replication	(R)	1	0.000049	4.024	0.003643	3.459	0.000535	0.985
Bars	(B)	1	0.019143	1587.181**	0.023077	21.912	0.019955	36.718
$ERROR_1$		1	0.000012		0.001053		0.000543	
Speed	(S)	2	0.001094	1.571	0.005412	9.953***	0.006288	6.184**
Clearance	(C)	2	0.001681	2.415	0.008258	15.187***	0.002741	2.696*
B x S		2	0.000530	0.761	0.000628	1.154	0.002000	1.967
B x C		2	0.000654	0.939	0.001082	1.989	0.002465	2.424
S x C		4	0.000244	0.351	0.000155	0.285	0.000177	0.174
B x S x C		4	0.000409	0.587	0.000695	1.279	0.000430	0.423
$ERROR_2$		16	0.000696		0.000544		0.001017	

*Significant at 0.10 alpha level.
**Significant at 0.05 alpha level.
***Significant at 0.01 alpha level.

the 0.10 alpha level. Table 5-B shows the analysis for the total unthreshed kernels along the entire concave, and, as in Table 5-A, the analysis was done on a weight basis. The set of cylinder bar parameter for DeKalb F61-A was found to be significant at the 0.05 alpha level. At this level (0.05 alpha), the speed parameter for NC+55X was significant; the cylinder-concave clearance was also significant but at the 0.10 alpha level speed of the cylinder and cylinder-concave clearance had an effect (0.01 alpha) on the weight of unthreshed kernels for NC+80X variety.

The results in Table 6 are similar to the results in Table 5. The data, as summarized in Table 6-A, is the ratio of the weight of threshed kernels to total weight of the input material (two sorghum heads) and Table 6-B is the ratio of the weight of unthreshed kernels to total weight of the input material.

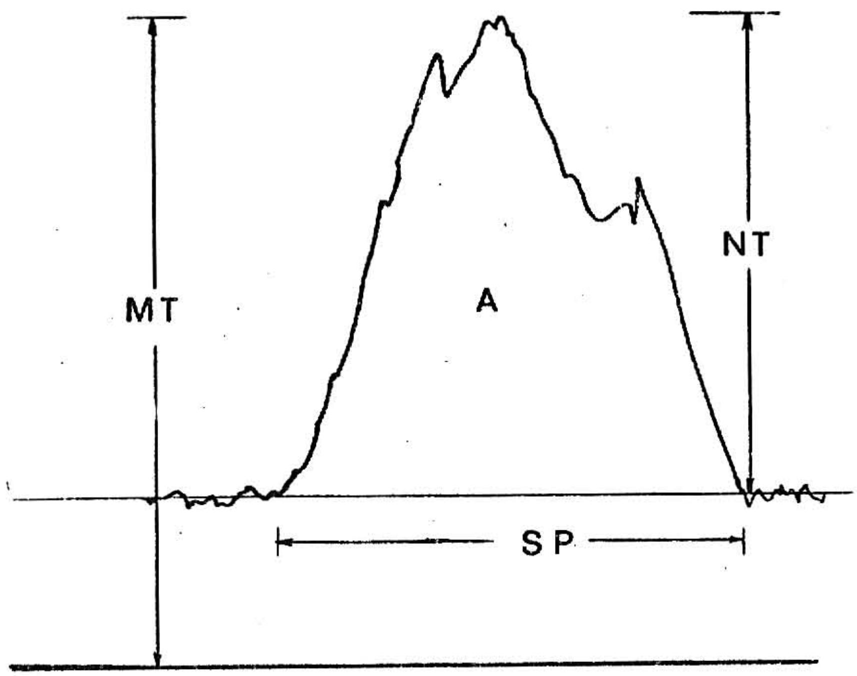
Table 7 shows the treatment means which were significant in Tables 5-A and 5-B for the varieties studied. These means show that the set of 4 cylinder bars for DeKalb F61-A gave the minimum amount of unthreshed kernels. The speed of 2827 fpm for NC+80X gave the maximum amount of threshed kernels, but the speed of 3298 fpm was the one which gave the minimum of unthreshed kernels. The minimum amount of unthreshed kernels was also obtained with a cylinder-concave clearance of 3/8 inch. It also shows that a speed of 3298 fpm and a cylinder-concave clearance of 3/8 inch for NC+55X resulted in a minimum amount of unthreshed kernels, and that the set of 8 cylinder bars gave the maximum amount of threshed kernels.

Table 8 shows the torque-time curve analysis. This table is divided into four different sections, each one represented in Figure 8.

TABLE 7. Comparison of Means (weight in grams) for Each of Three Sorghum Varieties which Were Significant in Tables 5-A and 5-B

		Variables							
		Number of Cylinder Bars		Speed (fpm)			Concave-clearance (inch)		
Source	Variety	4	8	2356	2827	3298	3/8	1/2	5/8
Threshed	DeKalb F61-A								
kernels	NC+80X			100.161	104.731*	103.710			
analysis	NC+55X	73.398	74.449*						
Unthreshed	DeKalb F61-A	4.272*	11.443						
kernels	NC+80X			15.201	10.912	8.422*	8.409*	9.787	16.344
analysis	NC+55X			8.077	4.518	2.989*	3.518*	5.104	6.962

*Best condition for the comparisons made.



Where

MT is the height from "O" to the peak

NT is the height from the average torque to run the cylinder without load to the peak

SP is the span length while threshing

A is the area below the path left by the electric beam of the recorder and above the average torque to run the cylinder without load while threshing was being performed.

Fig. 8. Torque-time Curve Parameters.

For the maximum torque (MT) analysis, the replication factor for $NC^{+}55X$ was significant at the 0.05 alpha level, the set of cylinder bars at the 0.01 level, and the cylinder speed at the 0.01 level. For DeKalb F61-A, the interaction of the set of cylinder bars and cylinder speed was

TABLE 8. Analysis of Variance for the Torque-Time Curves Data for Threshing Three Varieties of Grain Sorghum

A. Maximum Torque

Source of Variation		DF	DeKalb F61-A Mean Squares	DeKalb F61-A F	NC^+80X Mean Squares	NC^+80X F	NC^+55X Mean Squares	NC^+55X F
Replication	(R)	1	134.174	1.277	78.618	3.274	62.938	3540.791**
Bars	(B)	1	429.179	4.085	366.084	15.247	137.672	7745.147***
$ERROR_1$		1	105.063		24.010		0.018	
Speed	(S)	2	4.327	0.163	29.116	2.180	8.585	1.102
Clearance	(C)	2	39.941	1.505	52.578	3.937**	28.285	3.631*
B x S		2	1.704	0.064	0.072	0.005	6.969	0.894
B x C		2	100.668	3.793**	21.354	1.599	19.981	2.565
S x C		4	13.732	0.517	20.408	1.528	8.294	1.065
B x S x C		4	14.479	0.546	27.383	2.050	1.069	0.137
$ERROR_2$		16	26.537		13.355		7.791	

*Significant at 0.10 alpha level.
**Significant at 0.05 alpha level.
***Significant at 0.01 alpha level.

TABLE 8. (continued)

B. Normal Torque

Source of Variation		DF	DeKalb F61-A		$NC^{+}80X$		$NC^{+}55X$	
			Mean Squares	F	Mean Squares	F	Mean Squares	F
Replication	(R)	1	265.146	3.463	153.760	36.000	154.174	213.388**
Bars	(B)	1	103.023	1.346	50.410	11.803	0.002	0.003
$ERROR_1$		1	76.563		4.271		0.722	
Speed	(S)	2	4.850	0.210	63.286	12.330***	6.003	0.821
Clearance	(C)	2	40.921	1.774	36.790	7.168***	36.413	4.981**
B x S		2	7.682	0.333	1.266	0.247	5.250	0.718
B x C		2	113.663	4.928**	35.003	6.819***	19.443	2.659
S x C		4	16.942	0.735	25.277	4.925***	5.908	0.808
B x S x C		4	18.429	0.799	14.125	2.752*	1.020	0.139
$ERROR_2$		16	23.063		5.125		7.311	

*Significant at 0.10 alpha level.
**Significant at 0.05 alpha level.
***Significant at 0.01 alpha level.

TABLE 8. (continued)

C. Span

Source of Variation		DF	DeKalb F61-A		NC^+80X		NC^+55X	
			Mean Squares	F	Mean Squares	F	Mean Squares	F
Replication	(R)	1	1.791	11.877	0.637	4.017	0.017	0.310
Bars	(B)	1	0.006	0.037	0.358	2.256	1.007	18.490
$ERROR_1$		1	0.151		0.159		0.054	
Speed	(S)	2	0.168	0.574	0.466	1.708	0.149	0.369
Clearance	(C)	2	0.628	2.149	0.489	1.792	1.604	3.976**
B x S		2	0.324	1.108	0.246	0.904	0.038	0.095
B x C		2	0.341	1.168	0.230	0.844	0.298	0.738
S x C		4	0.673	2.302	0.152	0.556	0.660	1.637
B x S x C		4	0.355	1.216	0.146	0.535	0.264	0.654
$ERROR_2$		16	0.292		0.273		0.403	

**Significant at 0.05 alpha level.

TABLE 8. (continued)

D. Area

Source of Variation		DF	DeKalb F61-A Mean Squares	DeKalb F61-A F	$NC^{+}80X$ Mean Squares	$NC^{+}80X$ F	$NC^{+}55X$ Mean Squares	$NC^{+}55X$ F
Replication	(R)	1	29.088	8.029	9.394	4.562	4.326	32.180
Bars	(B)	1	4.608	1.272	1.184	0.575	0.002	0.016
$ERROR_1$		1	3.623		2.059		0.134	
Speed	(S)	2	0.128	0.127	0.566	1.352	0.013	0.120
Clearance	(C)	2	1.631	1.622	0.506	1.209	1.576	14.197***
B x S		2	0.196	0.195	0.329	0.786	0.212	1.908
B x C		2	4.616	4.592**	0.333	0.796	0.738	6.643***
S x C		4	0.863	0.858	0.650	1.553	0.382	3.436**
B x S x C		4	0.270	0.269	0.478	1.144	0.324	2.917*
$ERROR_2$		16	1.005		0.418		0.111	

*Significant at 0.10 alpha level.
**Significant at 0.05 alpha level.
***Significant at 0.01 alpha level.

significant at the 0.05 alpha level. For NC^+80X, the cylinder-concave clearance was significant at the 0.05 alpha level.

In the normal torque (NT) analysis, the set of cylinder bars and cylinder speed interaction for DeKalb F61-A was significant at the 0.05 alpha level. The replication factor and the cylinder-concave clearance for NC^+55X were significant at the 0.05 alpha level. For NC^+80X the significance level was 0.01 for cylinder speed, cylinder-concave clearance, the interactions of cylinder speed with cylinder-concave clearance, and set of cylinder bars by cylinder-concave clearance. The interaction of set of cylinder bars and cylinder speed by cylinder-concave clearance was significant at the 0.10 alpha level.

In the span (SP) analysis, the only significance was the cylinder-concave clearance of NC^+55X at the 0.05 alpha level.

In the area (A) analysis, the DeKalb F61-A set of cylinder bars and cylinder concave clearance interaction was significant at the 0.05 alpha level. For NC^+55X, the cylinder-concave clearance and the interaction set of cylinder bars by cylinder-concave clearance were significant at the 0.01 alpha level. Cylinder speed by cylinder-concave clearance interaction was significant at 0.05, and the set of cylinder bars by cylinder speed by cylinder-concave clearance interaction was significant at the 0.10 alpha level.

Table 9 shows the mean squares of the variables which were significant in Table 8, for the varieties studied. For NC^+80X, the cylinder-concave clearance of 5/8 inch gave the minimum peak in the MT and NT analysis. The speed for 3298 fpm also gave a minimum peak in the NT analysis. For NC^+55X, the set of four cylinder bars gave the minimum peak in the MT analysis, the cylinder-concave clearance of

TABLE 9. Comparison of Means for Each of the Three Sorghum Varieties which Were Significant in Table 8

		Variables							
		Number of Cylinder Bars		Speed (fpm)			Concave-clearance (inch)		
Source	Variety	4	8	2356	2827	3298	3/8	1/2	5/8
MT analysis	DeKalb F61-A								
	$NC^{+}80X$						27.750	24.625	23.775*
	$NC^{+}55X$	21.589*	25.500				25.033	21.697*	23.633
NT analysis	DeKalb F61-A								
	$NC^{+}80X$			13.867	15.725	11.158*	15.300	13.650	11.800*
	$NC^{+}55X$						13.792	10.325*	11.758
Span analysis	DeKalb F61-A								
	$NC^{+}80X$								
	$NC^{+}55X$						3.274	3.620	2.899*
Area analysis	DeKalb F61-A								
	$NC^{+}80X$								
	$NC^{+}55X$						2.344	1.775	1.671*

*Best condition for the comparisons made.

5/8 inch gave the minimum span and area for their respective analysis, and cylinder-concave clearance of 1/2 inch was the minimum for the MT and NT analysis.

All tables from 5 to 9 indicate that for DeKalb F61-A, threshing by 4 cylinder bars is the best; however, comparisons with cylinder speeds and cylinder-concave clearances did not reveal any significant differences. For NC^+80X, no difference was found in the set of cylinder bars, but a speed of 3298 fpm gave less unthreshed material and the minimum NT peak. Concerning the cylinder-concave clearance, it is a matter of economics to find the best, because the 3/8 inch clearance gave the minimum of unthreshed material, but the 5/8 inch gave the minimum MT and NT peak. However, this study does not show any performance about the amount of unthreshed material that is going to be recirculated. Therefore, it will be a choice between having less unthreshed material and higher use of energy, or vice versa. For NC^+55X, the highest cylinder speed (3298 fpm) used in the experiment was the best, but in the set of cylinder bars and cylinder-concave clearance comparisons, we have the same economic problem as for NC^+80X.

Table 10 shows the analysis of the data for the ease of threshing, which is measured by comparing the amount of grain collected in the first concave position. For the four cylinder bars analysis, the varieties factor was significant at the 0.10 alpha level. For the eight cylinder bars analysis, the cylinder-concave clearance and the interaction cylinder speed by cylinder-concave clearance were significant at 0.05 alpha level.

Table 11 shows the mean squares of the variables which were significant in Table 10, and the set of cylinder bars. For the set of

TABLE 10. Analysis of Variance for the Ease of Threshing with Four and Eight Cylinder Bars

A. First Concave Position

			Four Bars		Eight Bars	
Source of Variation		DF	Mean Squares	F	Mean Squares	F
Replication	(R)	1	0.000368	3.265	0.002670	6.000
Variety	(V)	2	0.001025	9.103*	0.002505	5.630
$ERROR_1$		2	0.000113		0.000445	
Speed	(S)	2	0.000253	2.192	0.000204	1.827
Clearance	(C)	2	0.000175	1.512	0.000430	3.859**
V x S		4	0.000093	0.805	0.000142	1.274
V x C		4	0.000195	1.693	0.000088	0.793
S x C		4	0.000147	1.272	0.000329	2.951**
V x S x C		8	0.000048	0.415	0.000207	1.858
$ERROR_2$		24	0.000115		0.000111	

*Significant at 0.10 alpha level.
**Significant at 0.05 alpha level.

TABLE 11. Comparison of Means for Each Set of Bars which Were Significant in Table 10

Number of Cylinder Bars	Variety			Speed (fpm)			Concave-clearance (inch)		
	DeKalb F61-A	$NC^{+}80X$	$NC^{+}55X$	2356	2827	3298	3/8	1/2	5/8
4	0.010	0.024*	0.012						
8							0.020	0.029*	0.028

*Best condition for the comparisons made.

four cylinder bars, the variety NC^+80X gave the maximum amount of kernels in the first concave position, and for the set of eight cylinder bars, the 1/2 inch cylinder-concave clearance produced more material in the first concave clearance position.

Table 12 is the analysis of the ratio of the material in the back box to the total material along the concave. For NC^+80X, the replication factor and the set of cylinder bars were significant at the 0.05 alpha level, and the interaction set of cylinder bars by cylinder speed of NC^+55X was significant at 0.10 alpha level.

Table 13 shows the analysis of the ratio of the material in the first concave position and the total material along the concave. For NC^+80X, the cylinder speed and the cylinder-concave clearance were significant at the 0.10 alpha level. For NC^+55X, the replication factor, the cylinder-concave clearance and the cylinder speed by cylinder-concave clearance interaction were significant at the 0.10 alpha level, and at the 0.05 alpha level the set of cylinder bars and the set of cylinder bars by cylinder-concave clearance interaction were significant.

Table 14 shows the mean squares of the variables which were significant in Tables 12 and 13, and the varieties studied. For NC^+80X, the set of four cylinder bars gave the minimum amount of material in the back box, but the cylinder speed of 2356 fpm and the cylinder-concave clearance of 5/8 inch gave the maximum amount of material in the first concave position. For NC^+55X, the set of eight bars and the cylinder-concave clearance of 1/2 inch gave the maximum amount of material in the first concave position.

Table 11 shows that the easiest variety to thresh with a set of four cylinder bars was NC^+80X, and the hardest was DeKalb F61-A. It

TABLE 12. Analysis of Variance for the Ratio of Material in the Back Box and the Total Material Along the Concave

Source of Variation		DF	DeKalb F61-A		NC^+80X		NC^+55X	
			Mean Squares	F	Mean Squares	F	Mean Squares	F
Replication	(R)	1	0.012061	2.804	0.001029	250.347**	0.000145	0.416
Bars	(B)	1	0.009871	2.294	0.001704	414.667**	0.000093	0.267
$ERROR_1$		1	0.004302		0.000004		0.000348	
Speed	(S)	2	0.000339	0.248	0.000937	0.773	0.003365	1.760
Clearance	(C)	2	0.001364	0.998	0.002825	2.329	0.000982	0.514
B x S		2	0.000397	0.290	0.002039	1.681	0.005385	2.817*
B x C		2	0.000768	0.562	0.001939	1.599	0.001132	0.592
S x C		4	0.000222	0.162	0.000070	0.057	0.000692	0.362
B x S x C		4	0.001469	1.075	0.000381	0.314	0.000286	0.149
$ERROR_2$		16	0.001366		0.001213		0.001911	

*Significant at 0.10 alpha level.
**Significant at 0.05 alpha level.

TABLE 13. Analysis of Variance for the Ratio of Material in the First Concave Position and the Total Material Along the Concave

			DeKalb F61-A		$NC^{+}80X$		$NC^{+}55X$	
Source of Variation		DF	Mean Squares	F	Mean Squares	F	Mean Squares	F
Replication	(R)	1	0.000939	1.695	0.002359	9.714	0.000057	124.702*
Bars	(B)	1	0.000884	1.595	0.002135	8.791	0.000350	765.665**
ERROR1		1	0.000554		0.000243		0.0000005	
Speed	(S)	2	0.000002	0.041	0.000780	2.896*	0.000030	1.159
Clearance	(C)	2	0.000048	1.059	0.000855	3.174*	0.000079	3.086*
B x S		2	0.000033	0.741	0.000013	0.047	0.000068	2.655
B x C		2	0.000045	1.001	0.000025	0.094	0.000119	4.636**
S x C		4	0.000003	0.068	0.000259	0.960	0.000063	2.450*
B x S x C		4	0.000024	0.531	0.000591	2.193	0.000046	1.784
ERROR2		16	0.000045		0.000269		0.000026	

*Significant at 0.10 alpha level
**Significant at 0.05 alpha level

TABLE 14. Comparison of Means for Each of the Three Sorghum Varieties which Were Significant in Tables 12 and 13.

		Variables							
		Number of Cylinder Bars		Speed (fpm)			Concave-clearance (inch)		
Source	Variety	4	8	2356	2827	3298	3/8	1/2	5/8
	DeKalb F61-A								
Table 12	NC+80X	0.184*	0.198						
	NC+55X								
	DeKalb F61-A								
Table 13	NC+80X			0.041*	0.029	0.025	0.023	0.032	0.040*
	NC+55X	0.012	0.018*				0.012	0.017*	0.016

*Best condition for the comparisons made.

also shows that for a set of eight bars, it is easiest to thresh with a cylinder-concave clearance of 1/2 inch. Table 14 shows that for NC+80X, a set of four cylinder bars, cylinder speed of 2356 fpm, and a cylinder-concave clearance of 5/8 inch is the easiest way to thresh. For NC+55X, the easiest way was a set of eight cylinder bars, and a cylinder-concave clearance of 1/2 inch. Cylinder speed did not make any difference.

SUMMARY AND CONCLUSIONS

The experiment has as a main objective the study of some threshing factors for grain sorghum. The work was accomplished by using a laboratory thresher which is described in Zaidi's MS thesis (1974). The grain sorghum varieties used were DeKalb F61-A, NC+80X and NC+55X. The cylinder factors studied were two sets of cylinder bars; 4 or 8 bars per trial, three cylinder speeds: 2356, 2827 and 3298 fpm, and three cylinder-concave clearances: 3/8, 1/2 and 5/8 inch.

Two groups of data were taken: the threshed and unthreshed material collected along the concave and the torque-time curve data for the cylinders. These data were maximum torque (MT), normal torque (NT), span (SP), and area (A). Each experiment was replicated twice. The analysis used on the data was the split-plot statistic design.

On the basis of the experimental results, the following conclusions can be drawn:

1. The set of 4 cylinder bars gave the minimum amount of unthreshed kernels for DeKalb F61-A, and the set of 8 cylinder bars gave the maximum amount of threshed kernels for NC+55X.
2. The cylinder speed was a significant factor in the total amount of threshed material for NC+80X. For the total amount of unthreshed material, it was significant for NC+55X but highly significant for NC+80X. For both NC+55X and NC+80X, the higher the speed, the less unthreshed kernels there were.
3. The cylinder-concave clearance influenced the total amount of

unthreshed material for NC^+80X and NC^+55X, with the 3/8 inch clearance being the best.

4. DeKalb F61-A did not show any significance in the torque-time results, but for NC^+80X, the cylinder speed and cylinder-concave clearance were an influential factor for the NT peak. The best combination was a cylinder speed of 3298 fpm and a cylinder-concave clearance of 5/8 inch. For NC^+55X, the MT and NT peaks were affected by the replication factor, so no conclusive results were drawn.
5. The easiest variety to thresh with a four-cylinder bar was NC^+80X and the hardest was DeKalb F61-A.
6. The total amount of kernels deposited in the first concave position with eight cylinder bars was affected by the cylinder-concave clearance, the 1/2 inch being the best.

SUGGESTIONS FOR FUTURE WORK

1. The torque-time curve could be improved by cutting down the vibration produced by the threshing unit, and also by checking the effectiveness of the strain gages' mounting because they should give more accurate results than they did.
2. Further studies could be made in this field, using different moisture content levels and higher cylinder speeds. This particular experiment was limited to a slower cylinder speed by the low moisture content of the samples used.
3. A study could be done using a continuous feed technique, to see if results differed from this experiment which used intermittant feeding.
4. An investigation should be made of the kernel damage done during the threshing operation.
5. Field tests should be carried out to see if the relationship between results of laboratory testing and actual field conditions are related.
6. Since some of the results obtained in the threshability study differ from those obtained in the torque-time study, an economic study should be made to determine what settings would be most advantageous in specific situations.

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APPENDICES

APPENDIX A. Weight Data of the Threshed and Unthreshed Kernels at Successive Positions Along the Cylinder-concave

Replication = 1 Set of Bars = 4 Cylinder Speed = 2356

Concave Clearance	Variety	1 *	1 **	2 *	2 **	3 *	3 **	4 *	4 **	5 *	5 **	6 *	6 **	7 *	7 **
	DeKalb F61-A	23.24	0.28	12.51	0.29	9.32	0.15	8.25	0.02	6.99	0.12	10.43	0.20	18.15	1.77
3/8	NC+80X	27.15	1.18	14.47	0.79	10.41	0.42	8.32	0.29	6.71	0.36	10.33	0.44	18.15	3.48
	NC+55X	18.20	0.78	10.30	0.41	7.12	0.07	6.04	0.20	5.31	0.29	7.25	0.16	13.17	0.42
	DeKalb F61-A	25.15	1.16	15.45	0.84	11.32	0.71	9.22	0.43	7.54	0.41	10.85	0.32	16.96	4.29
1/2	NC+80X	30.88	2.45	15.82	1.38	11.29	0.50	9.51	0.62	8.67	0.55	11.24	0.80	18.16	2.34
	NC+55X	30.99	0.58	11.42	0.00	7.99	0.52	5.96	0.04	5.22	0.09	7.75	0.30	14.21	0.93
	DeKalb F61-A	34.96	0.31	14.92	0.30	11.45	0.27	8.66	0.32	7.98	0.13	9.99	0.12	19.07	0.66
5/8	NC+80X	24.94	1.86	15.85	0.72	12.90	0.72	9.88	0.80	8.05	0.20	13.45	1.07	19.57	1.58
	NC+55X	21.78	1.10	12.09	0.68	7.78	0.19	7.80	0.54	5.21	0.39	7.78	0.48	12.88	0.90

Replication = 2 Set of Bars = 4 Cylinder Speed = 2356

Concave Clearance	Variety	1 *	1 **	2 *	2 **	3 *	3 **	4 *	4 **	5 *	5 **	6 *	6 **	7 *	7 **
	DeKalb F61-A	26.10	1.32	16.72	0.46	9.28	0.53	9.68	0.34	5.78	0.34	12.53	0.90	19.65	1.58
3/8	NC+80X	28.50	1.91	16.34	1.24	8.32	0.97	9.59	0.79	5.60	0.55	10.49	0.76	16.49	1.73
	NC+55X	26.82	1.42	12.86	0.96	8.06	0.00	7.77	0.26	5.01	0.46	9.46	0.37	14.06	1.88
	DeKalb F61-A	23.76	0.26	16.09	0.10	9.53	0.30	11.17	0.00	6.59	0.00	11.63	0.23	17.55	0.96
1/2	NC+80X	32.70	2.76	17.24	1.01	9.18	0.57	9.95	0.44	5.83	0.44	11.11	0.40	15.95	0.87
	NC+55X	18.60	0.46	11.82	0.11	7.87	0.13	5.95	0.48	5.22	0.15	7.29	0.08	12.28	1.14
	DeKalb F61-A	29.43	1.74	18.57	0.98	15.26	0.55	9.82	1.41	7.89	0.58	9.40	0.44	15.34	1.78
5/8	NC+80X	32.77	10.29	12.89	1.83	9.60	1.76	8.13	1.11	6.29	0.91	10.33	1.19	14.18	4.64
	NC+55X	20.62	1.61	10.95	1.12	7.90	0.50	6.05	0.53	5.12	1.00	7.20	0.31	13.47	1.75

*Grams of threshed kernels.
**Grams of unthreshed kernels.

APPENDIX A. (continued)

Replication = 1 Set of Bars = 4 Cylinder Speed = 2827

Concave Clearance	Variety	POSITION 1 *	1 **	2 *	2 **	3 *	3 **	4 *	4 **	5 *	5 **	6 *	6 **	7 *	7 **
	DeKalb F61-A	23.77	0.83	13.85	0.45	9.67	0.47	8.44	0.14	7.29	0.25	9.88	0.56	16.34	2.14
3/8	NC+80X	23.48	1.21	13.64	0.90	11.70	0.71	9.72	0.49	7.96	0.58	11.28	0.94	19.55	2.02
	NC+55X	17.30	0.90	9.93	0.22	7.35	0.21	6.14	0.04	4.75	0.29	6.29	0.30	11.52	1.30
	DeKalb F61-A	28.30	0.93	17.21	0.22	11.05	0.21	9.32	0.69	6.60	0.35	12.22	0.25	18.75	2.55
1/2	NC+80X	27.98	1.39	17.36	0.47	13.19	0.41	11.06	0.73	7.82	0.10	12.55	0.33	19.83	0.63
	NC+55X	19.53	0.33	11.20	0.25	9.49	0.18	7.18	0.07	5.67	0.05	7.58	0.08	15.52	0.52
	DeKalb F61-A	28.32	0.26	18.75	0.20	11.92	0.33	10.48	0.42	8.38	0.20	11.70	0.21	20.27	5.13
5/8	NC+80X	27.94	2.12	18.36	0.82	13.65	0.28	12.10	0.61	8.02	0.67	11.55	1.06	21.25	2.78
	NC+55X	21.53	0.37	11.66	0.18	8.02	0.14	6.35	0.13	5.80	0.09	7.67	0.19	13.98	1.25

Replication = 2 Set of Bars = 4 Cylinder Speed = 2827

Concave Clearance	Variety	POSITION 1 *	1 **	2 *	2 **	3 *	3 **	4 *	4 **	5 *	5 **	6 *	6 **	7 *	7 **
	DeKalb F61-A	28.68	0.75	15.85	0.31	11.24	0.18	8.74	0.21	7.20	0.10	11.38	0.25	15.58	1.07
3/8	NC+80X	26.43	2.08	18.27	1.09	10.93	0.41	9.77	0.44	7.27	0.32	11.43	0.73	19.86	1.25
	NC+55X	20.54	0.00	10.60	0.00	7.70	0.00	6.91	0.00	5.83	0.13	8.14	0.00	14.70	0.17
	DeKalb F61-A	25.72	0.53	16.72	0.29	9.52	0.03	9.00	0.00	6.16	0.05	10.13	0.00	16.73	0.19
1/2	NC+80X	29.38	1.98	16.54	1.59	11.23	0.40	9.75	0.33	6.57	0.39	12.38	0.32	18.57	0.57
	NC+55X	24.08	0.65	12.21	0.18	7.40	0.17	5.63	0.05	4.35	0.00	8.02	0.12	13.26	1.05
	DeKalb F61-A	23.20	0.60	16.66	0.27	8.00	0.18	8.68	0.25	5.80	0.16	9.44	0.42	16.39	4.18
5/8	NC+80X	30.02	3.84	16.67	1.80	11.13	0.90	8.98	0.64	7.30	0.63	10.97	0.78	18.52	3.92
	NC+55X	19.74	0.30	12.25	0.31	6.96	0.00	5.98	0.00	5.35	0.00	7.84	0.00	15.36	0.26

*Grams of threshed kernels.
**Grams of unthreshed kernels.

APPENDIX A. (continued)

Replication = 1 Set of Bars = 4 Cylinder Speed = 3298

Concave Clearance	Variety	POSITION 1		2		3		4		5		6		7	
		*	**	*	**	*	**	*	**	*	**	*	**	*	**
	DeKalb F61-A	29.88	1.04	16.78	0.49	9.36	0.15	8.88	0.16	4.95	0.07	11.12	0.14	19.49	0.57
3/8	NC+80X	22.44	0.70	15.84	0.37	12.64	0.17	9.40	0.06	7.13	0.15	12.83	0.25	18.70	0.35
	NC+55X	16.72	0.46	11.51	0.52	8.43	0.14	6.01	0.26	5.18	0.15	9.54	0.37	15.68	1.55
	DeKalb F61-A	24.27	0.57	14.96	0.19	10.45	0.06	9.08	0.10	7.13	0.22	11.05	0.13	18.00	0.27
1/2	NC+80X	29.66	2.80	16.23	1.25	11.35	0.57	9.32	0.23	7.15	0.10	10.80	0.42	17.27	1.09
	NC+55X	20.74	0.24	11.71	0.23	9.74	0.23	7.19	0.11	5.72	0.07	8.42	0.00	13.25	0.43
	DeKalb F61-A	19.65	0.72	16.31	0.09	11.66	0.15	8.04	0.00	7.59	0.11	10.80	0.20	17.69	0.69
5/8	NC+80X	26.13	2.72	18.18	2.41	14.02	1.18	8.84	0.54	7.08	0.36	10.22	0.55	18.59	1.96
	NC+55X	16.40	0.12	12.23	0.19	9.02	0.48	7.02	0.11	5.90	0.31	8.35	0.12	14.05	0.37

Replication = 2 Set of Bars = 4 Cylinder Speed = 3298

Concave Cylinder	Variety	POSITION 1		2		3		4		5		6		7	
		*	**	*	**	*	**	*	**	*	**	*	**	*	**
	DeKalb F61-A	23.17	0.54	13.92	0.16	10.10	0.44	9.00	0.50	6.81	0.23	10.73	0.53	16.00	2.00
3/8	NC+80X	29.93	0.93	19.20	0.61	10.03	0.17	10.15	0.21	6.20	0.12	12.25	0.48	19.97	1.19
	NC+55X	18.66	0.50	11.11	0.27	7.52	0.00	7.38	0.00	5.06	0.08	8.22	0.00	13.90	0.13
	DeKalb F61-A	24.79	1.45	17.21	0.67	10.48	0.30	9.39	0.28	11.37	0.59	6.91	0.38	16.58	1.18
1/2	NC+80X	28.69	2.43	16.34	0.42	12.29	0.59	10.29	0.50	6.87	0.21	13.20	0.00	20.20	0.95
	NC+55X	22.06	1.07	11.70	0.25	6.73	0.12	6.13	0.26	4.05	0.00	7.09	0.20	12.58	0.55
	DeKalb F61-A	29.96	1.24	17.30	0.64	10.46	0.36	8.51	0.15	7.10	0.15	10.87	0.18	16.42	4.09
5/8	NC+80X	25.63	1.27	17.43	1.12	10.82	0.37	8.99	0.42	7.12	0.00	10.91	0.28	17.00	0.71
	NC+55X	17.56	0.48	12.49	0.21	6.65	0.07	6.95	0.00	3.56	0.00	7.22	0.20	12.80	0.06

*Grams of threshed kernels.
**Grams of unthreshed kernels.

APPENDIX A. (continued)

Replication = 1 Set of Bars = 8 Cylinder Speed = 2356

Concave Clearance	Variety	POSITION 1 *	1 **	2 *	2 **	3 *	3 **	4 *	4 **	5 *	5 **	6 *	6 **	7 *	7 **
	DeKalb F61-A	30.63	0.85	13.08	0.16	7.66	0.05	8.40	0.00	5.90	0.00	15.08	0.15	22.57	10.88
3/8	NC+80X	36.37	3.20	17.97	0.67	10.19	0.19	10.54	0.44	6.32	0.17	12.56	0.41	20.92	4.69
	NC+55X	29.29	0.57	11.60	0.00	7.22	0.04	6.64	0.00	4.78	0.00	4.28	0.00	12.82	5.23
	DeKalb F61-A	38.61	2.81	15.59	0.34	9.64	0.34	7.78	0.52	6.60	0.00	10.89	0.23	17.71	4.08
1/2	NC+80X	33.20	6.76	14.15	3.08	9.37	1.30	8.32	0.62	5.46	0.96	10.55	0.97	18.77	9.09
	NC+55X	35.00	1.35	15.07	0.46	6.80	0.09	5.87	0.25	3.86	0.00	7.75	0.08	12.31	3.80
	DeKalb F61-A	29.91	0.72	14.69	0.41	8.11	0.54	8.11	0.04	5.61	0.07	12.57	0.97	17.96	20.64
5/8	NC+80X	39.55	5.18	16.30	2.28	12.04	0.85	8.72	0.42	6.07	0.00	8.63	0.13	13.16	10.60
	NC+55X	37.95	1.24	11.06	0.41	6.46	0.10	5.81	0.00	3.75	0.00	5.64	0.00	8.62	11.45

Replication = 2 Set of Bars = 8 Cylinder Speed = 2356

Concave Cylinder	Variety	POSITION 1 *	1 **	2 *	2 **	3 *	3 **	4 *	4 **	5 *	5 **	6 *	6 **	7 *	7 **
	DeKalb F61-A	32.30	3.10	16.35	1.46	8.48	0.37	8.80	0.30	6.47	0.21	9.43	0.85	16.84	2.95
3/8	NC+80X	35.05	5.85	14.65	2.28	8.31	1.03	9.55	0.49	5.81	0.20	9.00	0.76	12.45	12.79
	NC+55X	20.50	1.98	12.57	1.47	10.40	0.68	7.80	1.00	5.59	1.26	7.34	1.21	12.20	3.87
	DeKalb F61-A	27.36	2.44	14.17	1.61	9.08	1.71	7.28	1.08	5.82	0.64	10.86	2.51	15.97	7.48
1/2	NC+80X	31.83	8.62	14.10	2.64	8.91	1.45	7.86	1.11	6.36	0.00	8.91	1.33	14.02	5.26
	NC+55X	26.71	0.97	7.17	0.00	4.78	0.00	4.77	0.44	3.65	0.21	5.06	0.14	6.75	19.64
	DeKalb F61-A	32.55	2.60	17.28	0.94	10.91	0.57	8.59	0.30	8.27	0.14	11.95	0.00	17.08	9.55
5/8	NC+80X	38.66	3.82	11.98	0.00	6.98	0.63	7.70	0.00	5.80	0.00	9.37	0.64	18.24	22.85
	NC+55X	31.96	0.86	9.63	0.00	6.19	0.15	5.67	0.00	3.78	0.00	4.70	0.00	10.20	14.18

*Grams of threshed kernels.
**Grams of unthreshed kernels.

APPENDIX A. (continued)

Replication = 1 Set of Bars = 8 Cylinder Speed = 2827

Concave Clearance	Variety	1		2		3		4		5		6		7	
		*	**	*	**	*	**	*	**	*	**	*	**	*	**
	DeKalb F61-A	35.78	1.24	15.52	0.00	9.07	0.00	7.50	0.00	6.32	0.00	11.35	0.00	23.56	4.65
3/8	NC+80X	46.86	2.44	17.97	0.13	9.86	0.00	7.81	0.00	5.55	0.00	9.49	0.00	16.95	3.50
	NC+55X	29.54	0.00	10.82	0.06	7.83	0.00	5.72	0.00	4.35	0.00	6.95	0.00	11.28	1.82
	DeKalb F61-A	31.10	0.60	13.64	0.60	8.50	0.12	8.73	0.07	5.26	0.00	11.17	0.21	18.52	17.05
1/2	NC+80X	41.28	1.33	18.01	0.42	10.62	0.15	9.45	0.33	5.44	0.04	11.06	0.00	16.24	9.25
	NC+55X	26.30	1.45	12.55	0.51	7.57	0.04	5.92	0.00	6.35	0.30	4.48	0.20	9.05	6.98
	DeKalb F61-A	31.19	1.02	15.36	0.50	9.96	0.40	8.16	0.31	6.12	0.00	10.93	0.19	17.13	11.89
5/8	NC+80X	42.50	3.75	15.09	0.76	9.86	0.00	7.47	0.00	5.93	0.00	9.33	0.13	16.81	15.10
	NC+55X	23.52	1.50	10.18	0.65	6.46	0.00	5.83	0.12	3.77	0.00	5.57	0.07	9.94	14.91

Replication = 2 Set of Bars = 8 Cylinder Speed = 2827

Concave Clearance	Variety	1		2		3		4		5		6		7	
		*	**	*	**	*	**	*	**	*	**	*	**	*	**
	DeKalb F61-A	33.12	1.77	17.33	0.96	8.88	0.22	9.24	0.27	5.27	0.00	10.25	0.34	20.68	2.80
3/8	NC+80X	35.50	3.70	16.19	1.56	9.26	0.46	8.20	0.69	5.75	0.32	11.61	0.74	16.07	5.56
	NC+55X	26.36	0.74	10.72	0.00	6.95	0.00	6.59	0.00	4.53	0.00	7.44	0.15	13.24	2.02
	DeKalb F61-A	36.07	4.27	16.01	1.00	8.59	0.44	7.74	0.56	4.90	0.40	8.19	0.37	11.75	1.90
1/2	NC+80X	32.54	2.84	17.43	3.17	9.97	0.76	9.17	0.80	4.95	0.37	10.17	0.76	12.90	2.80
	NC+55X	31.20	1.91	11.76	0.76	7.17	0.00	8.20	0.22	4.81	0.00	6.40	0.00	10.67	2.22
	DeKalb F61-A	36.33	3.61	14.57	1.14	10.98	0.77	8.51	0.75	5.93	0.22	8.05	0.33	13.31	5.66
5/8	NC+80X	36.50	10.66	16.70	3.70	8.15	1.24	7.45	1.84	5.01	0.00	7.58	0.71	10.13	7.28
	NC+55X	27.50	2.21	11.23	1.17	7.45	0.40	7.00	0.34	4.53	0.15	6.37	0.22	9.00	2.62

*Grams of threshed kernels.
**Grams of unthreshed kernels.

APPENDIX A. (continued)

Replication = 1 Set of Bars = 8 Cylinder Speed = 3298

Concave Clearance	Variety	POSITION 1 *	1 **	2 *	2 **	3 *	3 **	4 *	4 **	5 *	5 **	6 *	6 **	7 *	7 **
	DeKalb F61-A	32.63	0.44	16.86	0.00	11.78	0.00	10.35	0.00	7.33	0.00	12.82	0.00	23.08	3.96
3/8	NC+80X	29.43	1.72	18.36	0.30	10.48	0.21	9.90	0.00	6.20	0.00	10.50	0.00	17.55	1.15
	NC+55X	23.21	0.20	11.94	0.16	8.83	0.00	6.39	0.15	5.38	0.00	7.35	0.00	9.27	0.88
	DeKalb F61-A	30.14	1.12	17.42	0.40	11.48	0.21	8.96	0.19	5.73	0.16	9.76	0.04	15.33	1.59
1/2	NC+80X	38.09	3.00	18.70	1.34	10.90	1.23	8.51	0.00	6.17	0.10	9.48	0.08	16.88	0.93
	NC+55X	29.31	1.67	12.55	0.20	6.57	0.12	5.95	0.00	3.80	0.00	6.76	0.00	9.52	1.18
	DeKalb F61-A	29.70	0.24	14.55	0.23	9.36	0.00	9.85	0.03	5.62	0.00	12.16	0.00	21.59	11.00
5/8	NC+80X	40.40	1.34	19.43	0.58	11.08	0.00	9.17	0.00	5.95	0.00	8.62	0.00	13.88	16.63
	NC+55X	25.81	1.25	14.05	0.00	7.25	0.19	4.88	0.00	3.96	0.00	5.77	0.14	8.64	3.15

Replication = 2 Set of Bars = 8 Cylinder Speed = 3298

Concave Clearance	Variety	POSITION 1 *	1 **	2 *	2 **	3 *	3 **	4 *	4 **	5 *	5 **	6 *	6 **	7 *	7 **
	DeKalb F61-A	22.15	2.68	16.14	2.13	9.17	0.90	10.65	1.18	6.08	0.40	11.01	0.82	19.55	5.34
3/8	NC+80X	30.58	3.66	18.30	2.05	11.24	0.00	8.88	0.58	5.45	0.25	10.78	0.68	18.84	4.20
	NC+55X	25.96	0.35	14.91	0.14	7.85	0.00	6.84	0.00	4.56	0.00	8.30	0.11	13.13	2.46
	DeKalb F61-A	29.48	3.12	17.04	0.93	10.83	0.16	9.77	0.14	6.33	0.00	10.12	0.58	17.88	5.69
1/2	NC+80X	33.14	3.72	18.18	1.19	12.11	0.78	8.80	0.60	6.23	0.37	12.14	0.66	15.41	0.91
	NC+55X	26.51	1.60	12.31	0.68	7.88	0.23	6.64	0.00	5.02	0.36	6.35	0.09	10.81	0.63
	DeKalb F61-A	29.63	2.74	18.88	1.30	9.65	0.44	8.75	0.36	6.52	0.46	10.24	0.49	14.50	5.35
5/8	NC+80X	33.00	7.09	19.37	2.30	7.68	0.85	8.10	0.50	5.58	1.28	8.70	0.67	15.00	8.90
	NC+55X	30.75	0.87	13.11	0.25	6.52	0.00	6.01	0.16	3.62	0.00	4.98	0.00	7.73	7.74

*Grams of threshed kernels.
**Grams of unthreshed kernels.

APPENDIX B. Torque Time Curve Data

Set of Bars = 4 Cylinder Speed = 2356

Concave Clearance	Variety	Replication 1				Replication 2			
		MT	NT	SP	A	MT	NT	SP	A
	DeKalb F61-A	23.0	14.2	4.10	2.90	21.0	10.0	3.72	1.64
3/8	NC+80X	21.0	12.4	3.70	2.58	22.5	10.5	3.50	1.78
	NC+55X	21.2	12.7	3.10	1.89	21.2	12.4	2.90	1.20
	DeKalb F61-A	32.5	24.3	3.00	3.91	28.5	19.5	2.70	2.85
1/2	NC+80X	25.7	17.5	3.40	2.84	22.0	13.5	3.00	2.13
	NC+55X	18.4	10.2	3.90	2.06	17.3	8.0	3.88	1.89
	DeKalb F61-A	29.1	20.3	3.50	3.73	21.0	12.5	2.90	1.34
5/8	NC+80X	22.6	15.0	3.08	2.41	18.0	8.3	2.60	1.04
	NC+55X	29.4	20.3	2.40	2.14	17.0	8.5	4.30	1.40

Set of Bars = 8 Cylinder Speed = 2356

Concave Clearance	Variety	Replication 1				Replication 2			
		MT	NT	SP	A	MT	NT	SP	A
	DeKalb F61-A	41.5	26.5	4.87	7.33	32.0	20.2	3.50	1.90
3/8	NC+80X	42.0	22.0	3.82	4.78	29.0	18.0	2.42	2.05
	NC+55X	29.0	17.0	3.70	3.10	27.5	15.5	2.70	2.15
	DeKalb F61-A	29.2	15.2	3.40	3.18	25.0	10.5	3.00	1.72
1/2	NC+80X	24.5	17.0	2.95	2.94	22.0	10.2	3.50	1.83
	NC+55X	28.3	16.0	2.80	2.16	23.6	8.1	3.00	1.16
	DeKalb F61-A	32.8	20.0	4.18	3.57	32.8	19.0	3.13	3.14
5/8	NC+80X	25.0	13.5	3.82	2.63	26.5	8.5	3.08	2.55
	NC+55X	28.0	16.0	3.00	2.40	21.6	8.6	2.80	1.22

MT in lines deflection.
NT in lines deflection.
SP in seconds.
A in square inches.

APPENDIX B. (continued)

Set of Bars = 4 Cylinder Speed = 2827

Concave Clearance	Variety	Replication 1				Replication 2			
		MT	NT	SP	A	MT	NT	SP	A
	DeKalb F61-A	20.9	11.8	3.60	1.81	32.0	19.0	3.30	2.97
3/8	NC+80X	24.1	14.8	3.40	1.89	26.5	16.0	4.50	3.50
	NC+55X	26.4	17.6	4.20	3.52	20.7	11.0	3.50	2.40
	DeKalb F61-A	29.4	20.1	4.20	3.86	25.8	15.0	3.75	2.53
1/2	NC+80X	27.9	18.6	4.32	2.99	19.0	11.5	4.50	2.50
	NC+55X	21.9	13.0	3.70	2.18	17.3	7.4	2.88	1.04
	DeKalb F61-A	26.0	13.8	4.00	3.31	24.0	12.5	3.50	2.21
5/8	NC+80X	22.6	15.0	3.10	2.60	23.0	12.5	3.46	2.55
	NC+55X	19.0	8.5	3.30	1.54	23.1	13.3	2.70	1.88

Set of Bars = 8 Cylinder Speed = 2827

Concave Clearance	Variety	Replication 1				Replication 2			
		MT	NT	SP	A	MT	NT	SP	A
	DeKalb F61-A	45.7	33.0	3.80	5.93	37.0	21.0	3.53	3.30
3/8	NC+80X	31.5	20.5	3.60	3.97	33.0	16.0	2.80	2.02
	NC+55X	28.6	14.6	3.40	2.74	27.5	14.0	3.00	2.46
	DeKalb F61-A	39.0	24.0	3.20	4.33	23.8	9.8	5.07	2.88
1/2	NC+80X	39.3	23.5	3.75	3.75	29.0	19.0	3.56	2.86
	NC+55X	23.0	15.0	2.90	2.35	22.0	7.0	3.50	1.16
	DeKalb F61-A	32.7	22.7	3.42	4.38	26.5	11.5	3.40	1.60
5/8	NC+80X	31.0	16.3	2.70	2.68	18.0	5.0	3.80	0.81
	NC+55X	24.3	11.5	2.12	1.38	18.6	5.8	3.05	0.92

MT in lines deflection.
NT in lines deflection.
SP in seconds.
A in square inches.

APPENDIX B. (continued)

Set of Bars = 4 Cylinder Speed = 3298

Concave Clearance	Variety	Replication 1				Replication 2			
		MT	NT	SP	A	MT	NT	SP	A
	DeKalb F61-A	21.9	12.3	4.60	2.86	32.2	20.3	2.80	2.82
3/8	NC^+80X	22.6	12.1	3.60	2.68	22.3	9.8	3.20	1.78
	NC^+55X	23.0	14.5	2.60	1.65	21.2	9.6	3.30	1.85
	DeKalb F61-A	27.9	17.3	4.00	3.55	22.0	7.5	3.80	1.19
1/2	NC^+80X	15.8	6.5	4.40	1.58	19.0	5.2	3.34	1.09
	NC^+55X	22.6	12.1	5.60	2.46	18.4	7.3	3.55	1.33
	DeKalb F61-A	26.8	18.6	4.15	4.36	27.0	13.8	3.50	2.27
5/8	NC^+80X	23.4	15.2	3.60	3.39	21.5	8.8	3.30	1.70
	NC^+55X	24.5	16.0	2.60	2.57	26.0	12.7	3.30	1.88

Set of Bars = 8 Cylinder Speed = 3298

Concave Clearance	Variety	Replication 1				Replication 2			
		MT	NT	SP	A	MT	NT	SP	A
	DeKalb F61-A	41.5	29.8	5.06	6.28	32.0	16.0	3.80	2.38
3/8	NC^+80X	28.0	14.5	3.70	2.95	30.5	17.0	3.33	2.20
	NC^+55X	28.0	14.5	3.59	3.14	26.1	12.1	3.30	2.03
	DeKalb F61-A	26.0	12.0	2.85	2.21	33.0	17.5	2.53	1.72
1/2	NC^+80X	27.0	13.0	3.68	3.03	24.3	8.3	3.44	1.56
	NC^+55X	24.0	11.0	3.68	2.12	26.8	8.8	4.05	1.39
	DeKalb F61-A	42.0	26.2	3.43	5.23	22.8	8.8	3.40	1.46
5/8	NC^+80X	29.5	14.3	3.98	3.80	24.2	9.2	2.48	1.15
	NC^+55X	28.0	12.0	2.50	1.58	24.1	7.9	2.60	1.14

MT in lines deflection.
NT in lines deflection.
SP in seconds.
A in square inches.

GRAIN SORGHUM THRESHABILITY PARAMETERS

by

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ABSTRACT

Since cylinder losses are one of the major harvesting losses of the combine, the study of these losses is very important because, knowing the right machine adjustment for every crop and each variety of the crop will help to reduce these losses. It is also important to study kernel damage and energy consumption and to try to reduce them to a minimum.

This work deals with three grain sorghum varieties. The major objectives are 1) to investigate the effect of the cylinder speed, cylinder-concave clearance and the number of cylinder bars, and 2) to find if there are significant differences in threshing characteristics of the three varieties.

A laboratory thresher was used to do the study. This threshing unit was designed by Zaidi (1974). The unit basically has a 12 inch diameter rasp bar type cylinder which is 7.25 inches long. This cylinder can be adjusted in the horizontal and the vertical direction to fit different settings of cylinder-concave clearance. It also has a strain gage bridge mounted on the main shaft to sense additional strain caused by resistance of the material being threshed.

The three grain sorghum varieties in the study were: DeKalb F61-A, NC+80X and NC+55X. Three factors were included in the study: two sets of cylinder bars (4 and 8 bars), three cylinder speeds (2356, 2827, and 3298 fpm), and three cylinder-concave clearances (3/8, 1/2 and 5/8 inch).

The data were analyzed for the amount of threshed and unthreshed kernels at regular increments from the front to the rear

of the concave and the torque time parameters for the maximum torque (MT), normal torque (NT), span (SP) and area (A).

The only factor which affected the DeKalb F61-A variety was the set of cylinder bars with the 4-bar set being the best. This variety was the hardest to thresh.

For the NC+80X variety, it was found that the higher the cylinder speed, the less unthreshed kernels there were. The 3/8 inch cylinder-concave clearance was found to be the best. From the torque-time curve it was found that the cylinder speed of 3298 fpm and the cylinder-concave clearance of 5/8 inch gave the smaller NT peak. This variety also was the easiest to thresh with four cylinder bars.

For NC+55X, the use of 8 cylinder bars gave the maximum amount of threshed kernels. The minimum amount of unthreshed kernels was obtained with a cylinder speed of 3298 fpm and a cylinder-concave clearance of 3/8 inch. Due to the significance (0.05 alpha level) of the replication factor, the torque-time results were not a good source of information for the best setting.

For the NC+80X and NC+55X varieties, where the best threshability factors do not agree with the best factor of energy use from the torque-time curve, an economic analysis should be done to determine the best setting for each specific situation.