THE EFFECT OF DISK SPEED ON THE PERFORMANCE OF AN EXPERIMENTAL CASTOR BEAN HULLER

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Stillwater, Oklahoma

1951

Submitted to the Faculty of the Graduate School of
the Oklahoma Agricultural and Mechanical College
in Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE
May, 1952

THE EFFECT OF DISK SPEED ON THE PERFORMANCE OF AN

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PREFACE

This study was undertaken to supply additional information on the subject of castor bean hulling so that the domestic production of castor beans can become economically practicable and feasible. At present castor beans are being produced to supply castor oil which is primarily needed for defense purposes.

The effectiveness and efficiency of the castor bean huller depends upon many factors, such as variety, maturity, and moisture content of the beans, disk speed, spacing between disks, width of disk, and hardness of rubber. The effect of these factors on the performance of the castor bean huller can be determined only through relentless research and experimentation. The author felt that there was a need for determining the effect of disk speed on the percent hulled beans and various other performance characteristics of the castor bean huller. No attempt was made to determine what effect the other factors have on the performance.

The author wishes to express his deepest appreciation to Professors E. C. Baker and J. G. Porterfield, under whose supervision this study was carried out. Professor Porterfield has given much of his time as guidance and has offered invaluable suggestions in the writing of this paper. He is also indebted to Dr. D. L. Vanhorn, agronomist for the United States Department of Agriculture and Oklahoma Agricultural Experiment station, who gave helpful advice and criticisms for the various problems involved and to Professor C. E. Marshall, Head of Statistics, who gave excellent advice in the sampling technique used in this thesis. The author is especially grateful to Professor E. W. Schroeder, Head of the Department of Agricultural Engineering, who made special efforts to provide the necessary facilities to carry out this study. The author would also like to thank all those who assisted him in performing the laboratory tests as it would have been impossible by himself to have obtained the data.

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I. INTRODUCTION

Castor bean production, which was sizable in the United States during the last century, is being revived on a completely new basis of management. Public and private research, experimentation, and development is making this possible. Castor oil is listed as a strategic material and is needed in large quantities for both civilian and defense purposes.

Research by the agronomist, plant breeder, agricultural engineer, and the chemist has revolutionized production methods and decreased cultural costs to the point where domestic production is again practical. The agronomist made his contribution by finding where the plant preferred to be grown and what methods should be used in its culture. The plant breeder was charged with developing varieties of castor beans which would be suitable for commercial culture here. The breeder now has furnished types which are early-blooming, small-stemmed, short, high-yielding, and resistant to both shattering and dehiscence; therefore making them more suitable for mechanical harvesting. The agricultural engineer has aided in the development of satisfactory harvesting equipment and the design and manufacture of efficient hulling equipment, which put the hulling costs within range of economic practicability. Many of these machines are now in commercial production and are being used on the present domestic crop. The chemist has brought about the many uses of castor oil. These combinations of developments have now made possible the economic production of castor beans in this country.

The demand for castor beans as a major crop in the shifting pattern of wheat, cotton, grass, grain sorghum and other crops is becoming popular in Oklahoma. This study was undertaken because it was felt that the need existed for new developments or modifications of farm machinery necessary for castor bean production and that the agricultural engineer should be increasingly responsible to any effort that looks to new discoveries to meet these needs.

II. OBJECTIVE

The objective of this study was to determine the effect of disk speed of a horizontal disk type castor bean huller on the following factors:

1. The per cent hulled beans.
2. The per cent beans in unhulled segments.
3. The per cent attached hulls in unhulled segments.
4. The per cent unhulled segments (beans plus attached hulls).
5. The per cent cracked and broken beans.
6. The capacity of hulled beans.
7. The per cent losses.
8. And to compare the above performance factors with three different materials, bulk or harvested, whole capsules, and segments, which were obtained from the same variety of castor beans.

III. REVIEW OF LITERATURE

A. HISTORY OF CASTOR BEAN PRODUCTION

The castor bean (Ricinus communis), seed of the castor plant, is not a true bean, nor a legume, but a member of the spurge family, a group of plants such as the rubber and tung oil trees. The name Ricinus is a Latin term meaning dog-tick which the seed was thought to resemble.

Tropical in its origin and native either to Africa or India, the castor plant has been carried by the many migrations of men in the course of ages to all parts of the tropical and subtropical world. In the tropics, the castor plant is a perennial that grows to a height of thirty or forty feet, but acclimated in cooler zones it becomes an annual, and attains a height of only from eight to twelve feet. In most areas of the United States they are grown as annuals.

Castor bean production is not new to American agriculture; however no records exist as to the exact date the first castor beans were produced in the United States. In the early 1800's[19], limited production was reported in parts of the states of Illinois, Missouri, Kansas, and the territory of Oklahoma. Within the period 1825-1850[19] there are occasional references that castor beans were produced in the coastal states from Virginia to Georgia and in Kentucky, Texas and California.

In 1850[19] the first comprehensive data was recorded that indicated the extent of the crop. There were twenty-three castor oil mills in the

United States in 1850. St. Louis was the commercial center in the west and seventy per cent of the domestic production of castor oil was produced there. In 1857[19] a mill, the largest of its kind, was built in Jersey City, New Jersey. This mill processed some of the domestic production, but soon became the center for imported seed. Production became spasmodic and areas of production shifted and by 1870[19] there were only six mills left in operation.

From about 1860 to 1916 Crooks[5] and Sievers mention that extensive production occurred in southeastern Kansas and adjacent parts of Missouri and Oklahoma. Production to a lesser extent occurred in other parts of the United States mostly in the cotton belt.

During the first World War the production of castor beans was stimulated by the need for oil for special purposes, such as the lubrication of airplane engines. The castor bean industry did not survive after the war due to the economic factor of laborious and expensive hand-harvesting practices that limited production. During this period until 1940 no commercial acreage is reported in the United States and the United States was wholly dependent upon importations from the tropical countries. The earliest importations of castor beans used in the United States was supplied by India. During World War II imports were entirely from Brazil and Mexico, where castor beans have been grown under cultivation for at least fifty years. By 1939[4] the United States was importing 150 million pounds of castor beans, of which almost the entire supply came from Brazil. World War II boosted the consumption to about double the peacetime level. A higher level of use carried over into peacetime and it appears now that the use of between 200 or 300 million pounds of beans per year will be normal. At the present the United States depends entirely on Brazil, taking about 80 per cent of her output.

In 1940[5] castor bean production was again undertaken in the United States on a limited scale, particularly in the vicinity of Dallas, Texas. In June 1941[15] the United States Department of Agriculture started an emergency castor bean program to furnish a supply of adapted seed stock for 1942. In the spring of 1942 this program was instituted through Texas, north to Kansas, east to Kentucky, and south to Tennessee. Out of scores of strains in hundreds of experimental plantings, the seed of two or three varieties, having more or less the desired characteristics as to plant growth and non-shattering factors were accepted, and one of them, called Conner, turned out to be well adapted to the region around Texas, Oklahoma, and Arkansas. It grew four to eight feet high and the hulls were reasonably resistant to shattering. The need for domestic castor beans did not materialize and this government work was virtually discontinued in 1944[4]. Some state agricultural colleges went on with the work and eventually came up with improvements; however the big push after the war came from the Baker Castor Oil Company[4], one of the oldest and largest companies processing the oil.

Since 1947[4] the Baker Castor Oil Company have brought about the development of several new varieties of castor beans of the low growing type of around four feet high, with vastly increased yields and more shatter-resistant hulls. The Baker Castor Oil Company also recognized that economic production required proper machinery and they have assisted greatly in the development of harvesting and hulling machinery. The entire commercial castor bean acreage in the United States from 1947 to 1950 was grown under contract with the Baker Castor Oil Company. That acreage increased during that period from zero to about nine thousand acres in 1950.

In 1951[13], after the outbreak of the Korean war, the Munitions Board realized the importance of castor oil as a strategic commodity which was in demand for military purposes and at their request, the Department of Agriculture was authorized to install a program for the domestic production of castor beans to be carried out by the Commodity Credit Corporation by a commitment of funds by the Defense Production Administration. The program was made available to farmers who enter into contracts either with Commodity Credit Corporation or with private companies under contract with Commodity Credit Corporation, in areas within Oklahoma, Texas, California and Arizona for which adapted seed is available. Harvesting machinery and technical guidance was made available to contracting farmers. The seed supply was the major limiting factor on the acreage planted.

In 1952[4] a program similar to that of 1951 to assure increased supplies for the national defense was authorized by the Secretary of Agriculture. At the present both the Baker Castor Oil Company and the Department of Agriculture are coordinating their efforts to carry on the now important crop of castor beans and the improvement of implements necessary to handle the crop.

B. CASTOR BEANS AND THEIR USES

Castor beans have shiny brittle coats of black, brown, tan and all sorts of mottled effects varying according to different varieties. The size of castor bean seeds is variable; however those measuring about one-half inch long and about one-fourth inch in diameter are preferable, and uniformity of seed size facilitates the removal of hulls by mechanical means. On early varieties seed production begins about 120 days after planting. The seed occurs in clusters made up of capsules each containing three seeds. The plants which grow wild have capsules that split open very readily at maturity;

however improved varieties have been developed that are resistant to shattering. Castor bean yields of 500 pounds per acre are average in the non-irrigated land of the midwest and with irrigation, various varieties of beans yield from three to four times as much. Localities with the longer growing seasons can produce better yields because seed formation goes on until frost kills the plant. Castor bean plants are not affected by plant diseases or insect pests.

A bushel of castor beans weighs 46 pounds and good varieties of castor beans analyze by weight approximately as follows: oil--50 per cent, shells--23 per cent, and pomace--27 per cent. Pomace is the cake or remnant of the bean after oil extraction. The chemical structure of castor oil differs from other domestic vegetable oils in that its fatty acids contain a hydrozyl group. This gives castor oil a chemical versatility over all other oils. Chemists have found many ways that castor oils can be used. It is in demand for military purposes mainly for use in lubricating oil for jet planes, a fluid in control equipment, such as hydraulic brakes, shock absorbers, and retractable landing gears on planes and special plastics. In addition dehydrated castor oil is a quick-drying oil that is used in protective coatings. Some other essential uses of castor oil are: paints, varnishes, lacquers, medicinal oil, nylon, linoleum, rubber substitutes, ink, cosmetics, electrical insulations, fungicides, soaps, artificial leather and for many other purposes. Pomace contains 73 per cent protein but it also contains a poisonous substance that renders it unsuitable for cattle feed, but because of its high nitrogen value it is an excellent fertilizer, especially where ground insects are troublesome, since it serves the dual purpose of a fertilizer and destruction of some insects. The shells have no value as far as is known.

All plant parts of castor beans are poisonous to humans and to livestock. Pomace contains a very toxic albumin called ricin and the other parts of the plant as well as the seed contain a poisonous substance called ricinine, which is of an alkaloidal nature.

C. DEVELOPMENT OF CASTOR BEAN HULLING EQUIPMENT

When the beans, or more correctly capsules, have been harvested a hulling machine is necessary to separate the beans from the hulls. Several machines have been built which do a successful job with little damage to the beans. These will be discussed briefly in the following paragraphs.

In 1942 Arnold[1] and Sharp developed a vertical disk type huller at the agricultural experiment station of the University of Tennessee. The machine consisted of two rubber disks, one being stationary and the other rotated at a peripheral speed of about 1,570 feet per minute, or approximately 1,000 revolutions per minute for the 6-inch diameter disk. The rubber used on the faces of the disks was 3/8 inch thick, black, soft, abrasive-resistant sheet rubber, with a specific gravity of 1.15. The disks were spaced about 1/2 inch apart and adjusted so the beans would just fit endwise between them without being crushed. A cleaning duct connected to a suction fan was provided for the removal of the cleanings. This 6 inch machine hulled 95 to 98 per cent of the beans without injury to them at a capacity of about one bushel per hour, and has proven to be very satisfactory for experimental plot work. Arnold and Sharp found that the capacity was proportional to the area of the disks and later in 1942[17] they constructed a similar machine with 12 inch diameter rubber-faced disks and vacuum-type cleaner. Rotating the rotor at 525 rpm gave a capacity of six bushels of hulled beans per hour and over 99 per cent hulled. At that time this machine was considered adequate for individual farm use.

In 1942 Clay[3] built a homemade castor bean thresher. The threshing device consisted of a 32 x 6:00 10-ply truck tire slightly inflated and rotated at 50 to 100 rpm inside approximately 1/5 of a 9:00 x 36 tractor tire casing, with bead cut-off, mounted on a wood frame. An air blast was used to clean the chaff from the beans. The capacity of the hulling element was over 200 lb/hr and around 99 per cent of perfect beans were hulled with proper adjustments.

Late in 1943 Arnold[2] designed an improved castor-bean huller similar to the one in 1942. This machine had 24-inch-diameter rubber-faced hulling disks and an hourly capacity of 900 to 1,400 pounds of shelled beans. Because of its capacity it became known as the "commercial size". A suction fan was employed to remove the hulls and trash from the clean beans. Under ordinary conditions, the machine hulled from 95 to 98 per cent of the beans and cracked less than 2 per cent.

In the Great Plains of Texas in 1941 Gordon[10] tried out several types of experimental hullers to devise a method of hulling which would do a good job without excessive damage to the beans.

A machine, developed previous to 1940, was tried. Its hulling element consisted of a horizontal cylinder, 12 inches in diameter and studded with steel spikes, 3/8 inch in diameter and 2 inches long, was rotated between a feeding hopper and a curved metal grate at about 250 rpm. The chaff was separated from the beans by the use of a screen and an air blast. This huller worked satisfactorily with some varieties of castor beans; however excessive breakage occurred with the Conner variety.

A small experimental model was tried which consisted of an inverted conical rotor, mounted vertically and covered with rubber matting. The rotor turned inside a funnel-shaped housing, lined with a smooth rubberized fabric underlain with a coating of sponge rubber 3/4 inch thick, at a close distance which diminished toward the small end. No cleaning device was provided for this experimental unit. Rotating the rotor at speeds ranging from 125 to 150 rpm cracked less than 1 per cent and hulled about 94 per cent, however the capacity of this unit was very low.

Gordon[10] built a small huller of the double belt type in which two belts traveled parallel, close to each other, in the same direction. The top belt traveled 38 per cent slower than the bottom one whose surface speed was computed to be 1,200 fpm. The abrasive action of the belt surfaces traveling at different speeds removed the hulls from the beans and tests showed that about 72 per cent were hulled and 2 per cent were cracked and broken. The belt type huller had a capacity of 650 to 700 pounds of hulled beans per hour per foot of belt width.

Gordon[10] investigated the possibility of using a small combine, Allis Chalmers 40 all crop Harvestor, equipped with a cylinder covered with heavy rubber matting having a slightly grooved pattern. The cylinder was rotated at about 400 rpm and results showed that 85 to 90 per cent or more beans of the US varieties were hulled and 1 to 5 per cent were cracked and broken, however the Conner variety was badly damaged by the cylinder action. The machine had a capacity of 2,400 lb/hr.

A small huller, Cardwell-Gordon[10] unit, was built during the winter of 1941-42. The hulling element consisted of a rubber covered cylinder 8 inches in diameter and 24 inches long, and a rubber covered concave. Results showed that with the Conner and Kentucky 38 varieties less than 5 per cent were cracked and broken; however capacity was very low. A paddle wheel type fan and rotary screens were used for cleaning and separation.

This principle of cylinder-concave hulling resulted in the revision of the Cardwell-Gordon machine into a larger machine with greater capacity and it became known as the "USDA Castor Bean Huller". The hulling unit consisted of a wooden cylinder, eight inches in diameter and twenty-four inches long, and a concave facing, which were covered with abrasion resistant rubber matting, Type A, Durometer No. 70. Separation and cleaning was accomplished by a vibrating screen and suction type fan. The vibrating screen was equipped with a reciprocating wiping device to prevent clogging and to aid separation of unhulled beans from hulled beans. The hulling cylinder had a capacity of 1,200 lb/hr with Conner or Kentucky thirty-eight varieties. Five of these machines, designed by the Bureau of Agricultural Chemistry and Engineering for the Commodity Credit Corporation, were built for use during the 1942-43 hulling season.

This huller was later improved by development work at the Tillage machinery Laboratory[16] of the United States Department of Agriculture, at Auburn, Alabama. Simplification of this unit resulted in an improved USDA Castor Bean Huller which has a capacity between 1,600 and 1,850 pound per hour and under normal conditions cracks less than two per cent and hulls above ninety-eight per cent.

It should be recognized that no research has been recorded on a castor bean huller with horizontal disks and it is believed that the research in this study will bring out the merits of a horizontal disk type huller comparable to the above hullers.

IV. APPARATUS AND EQUIPMENT

The castor bean huller tested is shown in Figures 1, 2, 3, and 4. It is mounted on a trailer to facilitate transportation and to accommodate it for quick service as soon as it is pulled to the job. The complete unit consists essentially of the huller engine, a hopper and elevator unit with electric motor, a rotating drum feeder, a hulling element consisting of two horizontal adjacent rubber-faced disks, and a cleaning unit made up of a section fan powered by a gasoline engine. Any one of these parts can be adjusted independently of the others, thereby making it possible to adapt the huller to various conditions to get maximum effectiveness and efficiency under any conditions.

The huller engine is a four cycle, single cylinder air cooled gasoline engine, type PAC 184, Serial Number 7-41394, rated hp 4.3, and manufactured by the Lauson Company, New Holstein, Wisconsin. The engine speed is controlled by changing the setting of the governor and after the governor is set for a particular speed the engine operates at approximately constant speed and has good governing for any range of speed. The engine is connected by V-belts to the vertical shaft which drives the rotating disk.

The hopper was built large enough to hold several sacks of unhulled beans and it was equipped with a sliding gate and a rod mechanism for operating the gate opening so as to control the rate of feeding the unhulled material.

The belt-conveyor, flight-type-elevator, feed mechanism is a Porta-Loader Serial No. 260, manufactured by the Boardman Company, Oklahoma City,

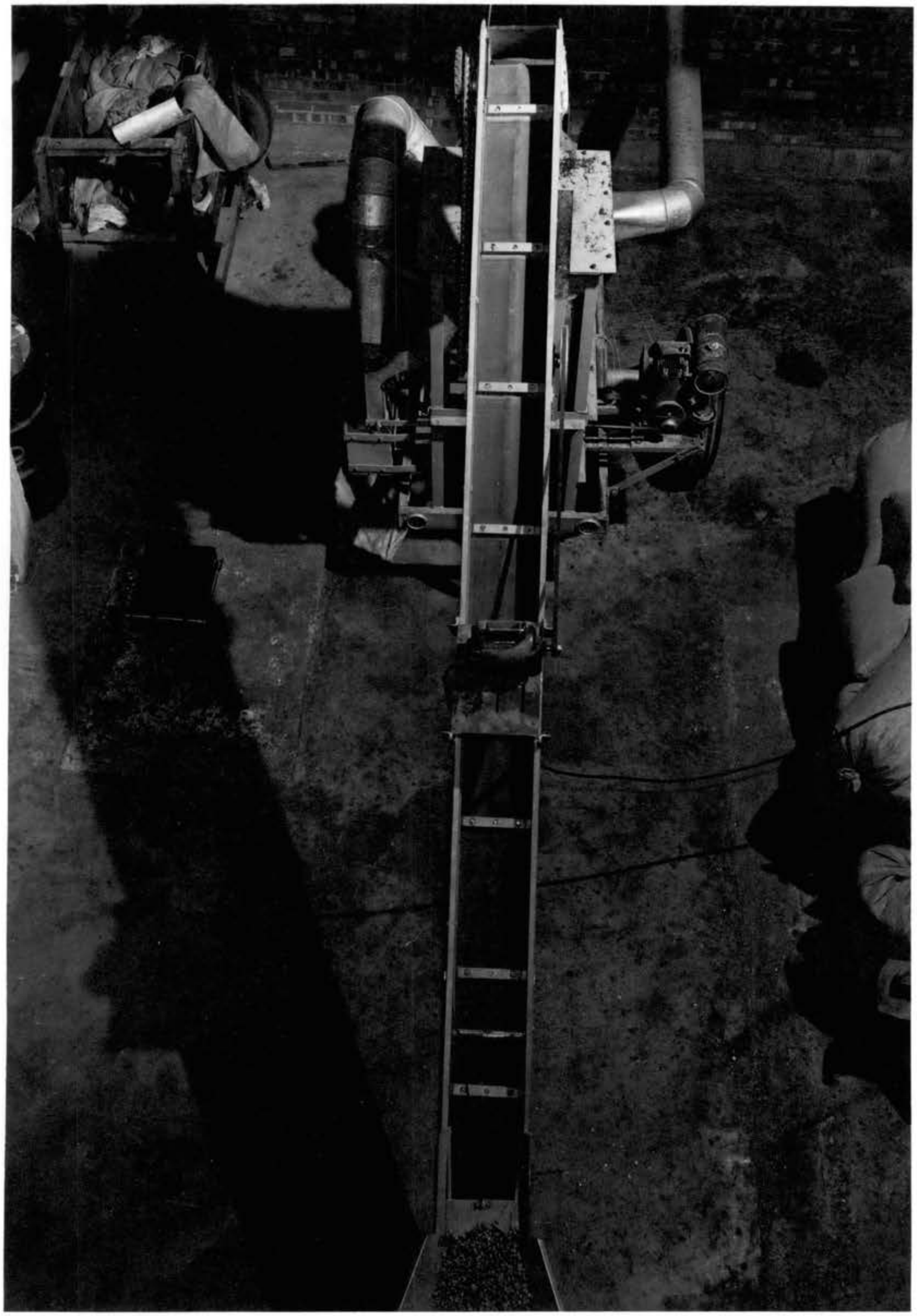

Figure 1. Top View of Complete Castor Bean Huller Unit Showing Position of Elevator as Used in Tests.

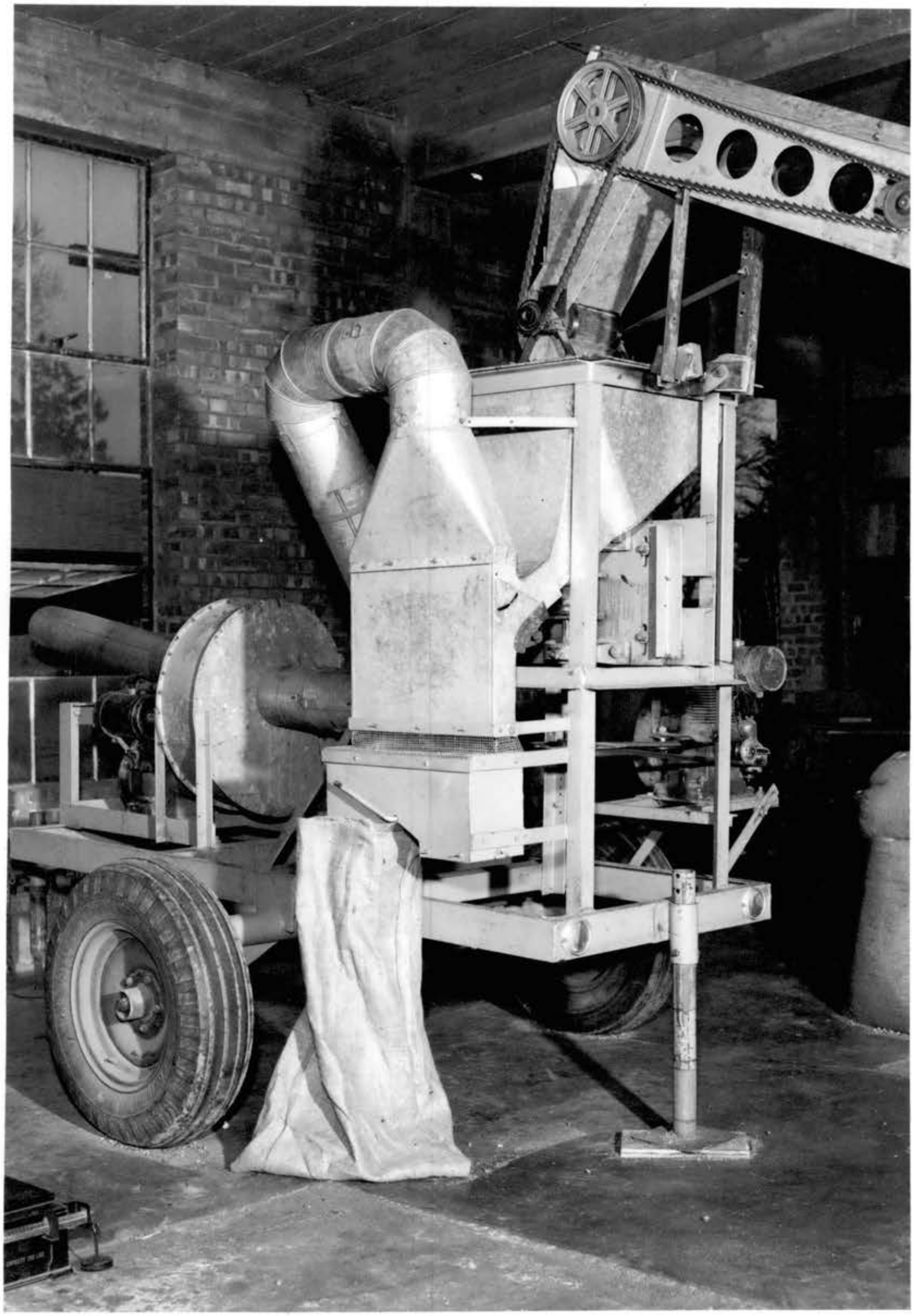

Figure 2. Right Side View of Castor Bean Huller Showing Arrangement of Rotating Drum Feeder, Cleaning Unit and Two Way Discharge Valve for Sacking.

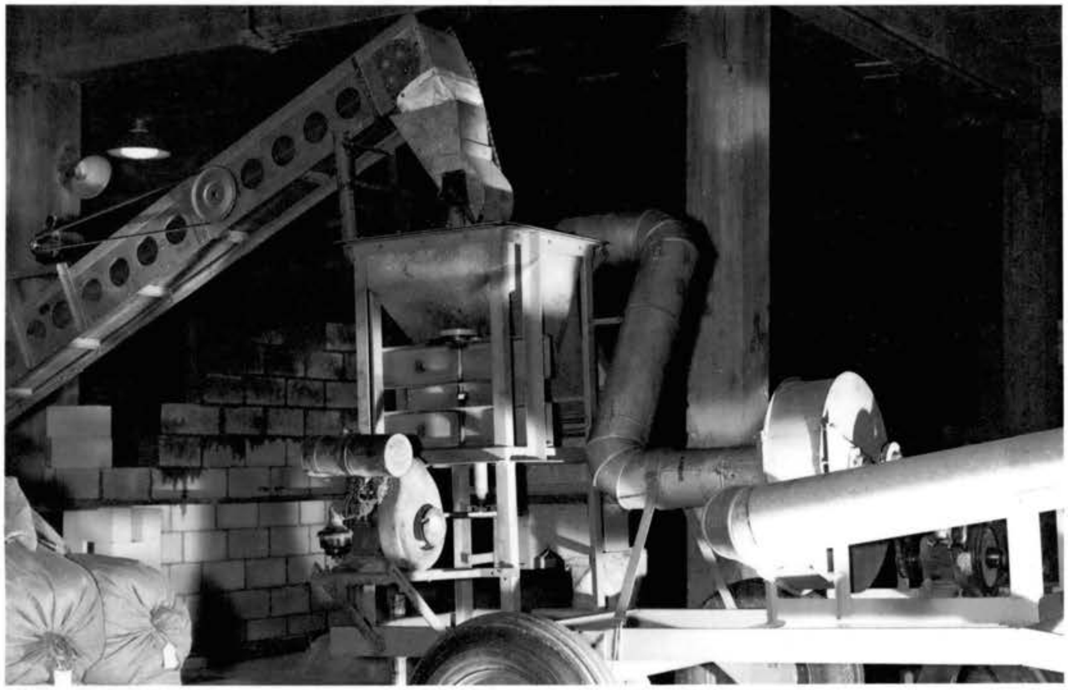

Figure 3. Left Side View of Castor Bean Huller Showing Position of Huller Engine and Handwheel Used to Adjust Spacing Between the Disks.

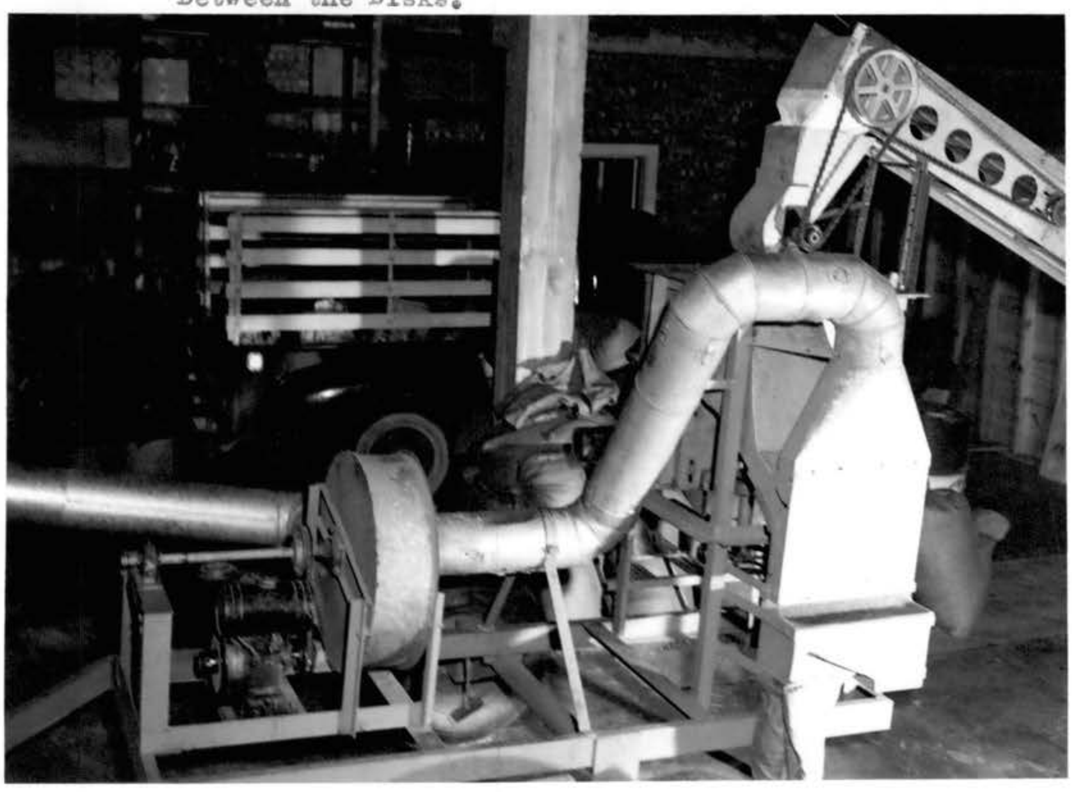

Figure 4. Right Side View of Castor Bean Huller Showing Position of Fan and Motor.

Oklahoma. The elevator is approximately 16 feet in length and has a channel width of 9 inches. The elevator belt runs at a peripheral velocity of about 5 fps and is driven by the top roller shaft which is powered by pulleys and V-belts connected to a 1/3 hp electric motor, integrally mounted on the elevator. The unhulled beans are conveyed to the rotating drum feeder by boards one inch by nine inches equally spaced on the belt.

The huller element consists essentially of two adjacent rubber-faced disks. One of the disks is stationary and the other rotates. The rotor is shown in Figure 5 and is attached on the end of the vertical shaft driven by the huller engine. This shaft is mounted in ball bearings and provided with large lubricant reservoirs. The rotor has an outside diameter of 18 inches and is faced with a 1-inch thickness of soft abrasive-resistant rubber with durometer hardness of 40, as based on company specifications and not on actual tests of rubber hardness. The rubber was cemented to a 1/4 inch steel plate with a good grade of rubber cement. The hulling surface of the rotor lies between a 14 inch diameter and the outside diameter of 18 inches. It consists of an area of around 100 square inches. The rubber disk facing on the rotor is provided with a 1-inch bevel at the center opening. The inner edge of the bevel is protected from being torn loose by a 1/16 inch steel plate fastened to the 1/4 inch plate by machine screws. This bevel is essential to break up the whole capsules into single segments small enough to enter the hulling space, to guide the beans between the disk, and to increase the capacity of the machine. Careful consideration should be taken in selecting the proper bevel since too much bevel will overload the disks, increase seed crackage, and permit large stones or other objects to go between the disks.

The stationary disk shown in Figure 6 is attached on the lower side of the top plate of the huller housing. The fixed disk has an outside diameter

diameter of 18 inches and is faced with a 1/4 inch thickness of abrasive-resistant rubber with durometer hardness of 55, as based on company specifications and not on actual tests of rubber hardness. The rubber was cemented to a 1/4 inch steel plate which is fastened by four bolts to the top plate. No bevel is provided on the fixed rubber disk. A sheet-metal bank is fastened around the inside and outside diameters of the fixed disk housing to prevent the material from wedging and passing between the top plate and fixed disk.

The spacing or clearance between disks is adjusted by moving the rotor disk and vertical shaft assembly by means of a small threaded hand wheel on the front of the huller. Turning the threaded hand wheel slides the assembly up or down on four supporting bolts; however once the spacing is set it remains fixed since no provision was made on this machine to prevent damage to the disks whenever a large object enters the disk. This might be provided for by having the stationary disk spring tensioned to the top plate to permit large objects to go between the disks without damaging them.

Alignment of the disks is provided on the fixed disk by means of four adjustable screws equally spaced on a square centered on the mean diameter of the fixed disk. The screws may be raised or lowered by turning them inside the four hexagon nuts welded to the top plate. See Figure 7. By raising and lowering the screws and tightening the four bolts fastened to the fixed disk, the proper disk alignment is obtained.

The rotating drum feeder shown in Figure 7 is essentially a wooden roller 5 inches in diameter. The feeder and its housing are fastened over the central opening on the top plate. Its primary function is to facilitate uniform feeding of the beans to the huller disks. The unhulled beans flow through the opening and against the rotary disk. Then the rotation of the

Figure 5. View of 18 Inch Diameter Rotating Disk Equipped With 1-inch Thick Rubber Facing of Durometer Hardness No. 40 as Based on Company Specifications.

Figure 6. View of 18 Inch Diameter Stationary Disk Equipped With 1/4 Inch Thick Rubber Facing of Durometer Hardness No. 55 as Based on Company Specifications.

Figure 7. View of Rotating Drum Feeder and Two of the Four Adjusting Screws Used to Align the Disks.

rotor automatically feeds and circumfuses the beans between the disk faces, breaks up the capsules, removes the hulls and discharges the hulls and beans at the periphery. The feeding of the beans centrally between the disks causes the layer to spread or become thin as the beans move outward, thus reducing the chances of wedging.

The cleaning unit consists of a centrifugal type fan manufactured by the Belle City Manufacturing Company, Racine, Wisconsin. The fan is approximately 22 inches in diameter and is connected with 8 inch suction and discharge pipes at its housing. The 8 inch suction line is connected to the Y-cleaning duct, 3 inches by 20 inches in cross-sectional area which reduces the air velocity in the suction pipe. The Y-cleaning duct is equipped with an adjustable damper at the upper end which further restricts the air inlet but permits sound hulled beans to drop down through the throat area against the upward air stream and then into the sack. The damper permitted varying the throat cross-sectional area from 0 to 2 inches in width. Additional air inlet is provided by a screen area of 4 inches x 20 inches which may be adjusted by 4 shutters, each 1 inch x 20 inches, so as to provide additional air velocity to carry off the hulls. By closing one or more shutters it may be equally effective without requiring an increase in fan speed.

The mixture of hulls, beans and unhulled beans slides down a short incline to the Y-cleaning duct. The hulls, dust, and light undeveloped beans are carried up with the air through the fan which discharges them to the outside. The clean whole beans drop through the throat area and are sacked at the discharge spout which is equipped with a two way valve to facilitate the sacking operations.

The fan is driven by a 4 cycle single cylinder air cooled gasoline engine, rated 2 hp and manufactured by the Briggs and Stratton Corporation.

The engine speed is governed by changing the governor setting and maintains approximately constant speed after once set.

The number 16 cleaner shown in Figure 8 was used to separate the bulk or harvested material into whole capsules and segments. The cleaner was equipped with two screens, a top screen No. 28 with 7/16 inch oval perforations and a bottom screen No. 20 with 5/16 inch oval perforations. A wiping device of reciprocating brushes on the cleaner completely eliminated clogging the screen with hulls and segments. By proper adjustment of the fan practically all of the foreign material and light beans were removed by this cleaner. The cleaner removed all the cracked and broken, and hulled beans from the whole capsules; however part of the cracked and broken, and hulled beans were carried over with the segments. This is shown in Table 1.

The instruments used in testing the castor bean huller were a tachometer and stop watch, manufactured by M. DuCommun Company, New York. The hand tachometer, Type 25A Metron, Serial No. 1156, manufactured by Metron Instrument Company, Denver, Colorado, was very sensitive and was equipped with an adjustment for zeroing it before each run. Its smallest scale division was 20 rpm; however with careful observation it could be read accurately to increments of 5 rpm. A more precision instrument for obtaining the disk speed would have been by the use of a revolutions counter; however none was available.

The apparatus used in sampling is illustrated in Figure 9. The balance is a Model 4021Y, Serial No. 697, manufactured by Toledo Scale Company, Toledo, Ohio, and has a capacity of 5 kilogram with the smallest graduations of 1 gram. The balance was very sensitive and was read to within an accuracy of 1/2 gram for the measurements recorded during the sampling of the products.

The small hand operated clipper was used to separate the oil bearing

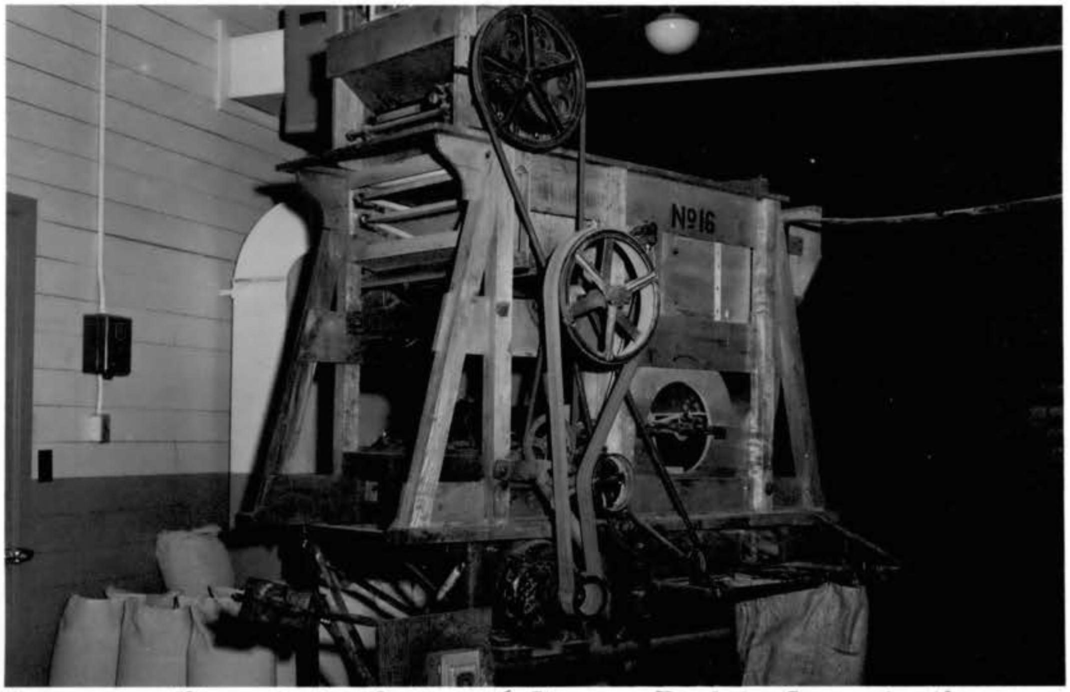

Figure 8. View of the Number 16 Cleaner Used to Separate the Bulk or Harvested Material of US 74 Castor Beans Into Whole Capsules, and Segments.

Figure 9. Sampling Apparatus Consisting of Toledo Scale Balance, Small Hand Clipper and 3 Separating Screens Used to Evaluate the Products in the Sack and in the Cleanings.

material from the hulls and chaff, or cleanings. This small cleaner did a good job of separating the oil bearing material from the products of the cleanings.

The three screens shown in the foreground of Figure 9 were used in sampling the products from the sack. The top screen with holes 17/64 x 3/4 inch separated the unhulled segments, the middle screen with 12/64 x 3/4 inch holes separated the clean whole beans, cracked and broken, and the bottom screen or blank was used to collect the light undeveloped beans and the foreign material.

In Figure 10 is shown a small hand huller which was used to obtain the weight of the beans in the samples taken from the materials. Its hulling element consisted of a wooden drum faced with a 1/4 inch grooved rubber matting that turns close to another grooved rubber facing.

V. METHOD OF MAKING TESTS AND OBSERVATIONS

The technical aspects of making tests and observations to determine the effect of disk speed on the performance of the castor bean huller were considered in order that the results obtained would be reliable and acceptable. Such considerations included an understanding of the theory, precision, and accuracy of methods and measurements, and the practical limitations imposed by testing the castor bean huller.

A. PRELIMINARY INVESTIGATIONS

Preliminary investigations were made to find the best operating conditions for the different disk speeds so as to obtain data with as much accuracy as possible. These investigations were made with the bulk or harvested material of US 74 castor beans.

These investigations showed the following:

1. The minimum and maximum disk speeds that could be obtained with the Lauson engine were 150 and 750 rpm when the disk was loaded. Excessive heating of the disks occurred at the maximum disk speed of 750 rpm and this heating ruined the rubber and loosened the rubber cement so that it caused the rubber to peel from the disk plates. It was found that the top speed to prevent excessive heating was in the neighborhood of 650 rpm. The approximate setting of the disk speeds at intervals of 100 rpm are given in the results of preliminary investigations found in the appendix.
2. The proper adjustments of fan speed, damper opening, and position

of shutters to obtain the best cleaning performance for the different disk speeds were established by the following analysis. If the fan ran too slow it would not elevate the hulls and chaff, if too fast it would carry the good beans over with the hulls and chaff. When the removal of the hulls and light beans was not accomplished, even with the damper properly adjusted, the shutters could be closed over the screen area at the upper part of the Y-cleaner duct to provide additional air velocity to carry off the hulls. Making the cross-section area of the screen area smaller by closing one or more of the 1 inch x 20 inch shutters increases the air velocity in the duct so that it may be equally effective without requiring an increase in fan speed.

Additional air inlet into the cleaner duct is adjusted by raising or lowering the damper in the Y-duct. This opening should be as small as possible without letting light beans and hulls come down with the sound beans. Too much air entering through the screen area and damper causes poor elevation of the hulls and foreign material unless the fan speed is high.

The fan speed, position of shutters and position of damper are given in the results of preliminary investigations found in the appendix.

3. The selection of the proper spacing of the disks for good hulling of the variety of castor beans used was found to be 5/16 inch. This was determined by observing the number of beans remaining in the hulls and the number cracked and broken. If too many beans remained in the hulls the spacing was decreased by turning the hand wheel clockwise and if too many beans were cracked and broken the spacing

was increased by turning the hand wheel counterclockwise.

4. If the machine, after adjusting the spacing for 5/16 inch, failed to hull the material without crackage, the disks required checking for alignment. This was done by means of a round rod or dowel, with a diameter of 5/16 inch and 9 inches long, placed radially between the disks through the feed inlet, or opening. The disks were adjusted by changing the effective length of the four screws between the top plate of huller housing and the fixed disk so that both disks barely touched the dowel at all points.

B. TEST CONDITIONS

The testing conditions for determining the effect of disk speed upon the per cent hulled with the castor bean huller were controlled such that all variables except speed were held constant.

The variety of castor beans used in this study was US 74. US 74 are medium in height and is a recommended variety of castor beans for Oklahoma. The castor beans used were harvested with a combine modified to do a satisfactory job. The castor beans were stored in a bin and no preliminary drying was employed in testing the effect of speed on the per cent hulled.

Two other types of material in addition to the bulk or harvested material were obtained from the bulk material by the use of the No. 16 cleaner. The three materials are shown in Figure 10 and consist of the following: (1) The original harvested or bulk material taken from the bin, (2) Whole capsules or all material separated by the cleaner that contained only a small percentage of segments and (3) Segments or all material consisting of 1/3 of a capsule. All three of these materials were used to determine what effect they had upon the per cent hulled with different disk speeds.

In order to correct for the deviations from the test operating conditions of the per cent hulled and the per cent cracked and broken in the materials before they were run through the huller, five one quart samples were taken at random during the sacking of each material tested. Correction factors, C_s (Pounds of sound hulled beans in test weight) and C_{cb} (Pounds of cracked and broken beans in the test weight) were determined from the data obtained from these five samples. Since a 100 pound test weight was used, C_s and C_{cb} are numerically equal to their percentages as found in the test weight. For bulk or harvested material, C_s = 4.06 lbs. and C_{cb} = 0.57 lbs.. This data is recorded in Table 1.

It should be recognized that there is a wide variation within the five samples taken from the bulk material and to arrive at a more accurate estimation of the per cent hulled and the per cent cracked and broken in the bulk material, more samples should have been taken until a smaller deviation was obtained. The variation obtained with the whole capsules and segments have less deviation from the mean and give a more approximate estimation of the corrections to be applied to the total population. These corrections are used in computing the test results for the actual conditions at which the machine performed.

The intended test conditions for each material were as follows:

1. The test weight of the different materials used in each run was 100 pounds and this established the duration of operation under test conditions for the different disk speeds.
2. Disk spacing to be held at 5/16 inch for all runs and disks checked for alignment.
3. Six different disk speeds with increments to be held as close as possible to 100 rpm so as to cover the speed range determined in

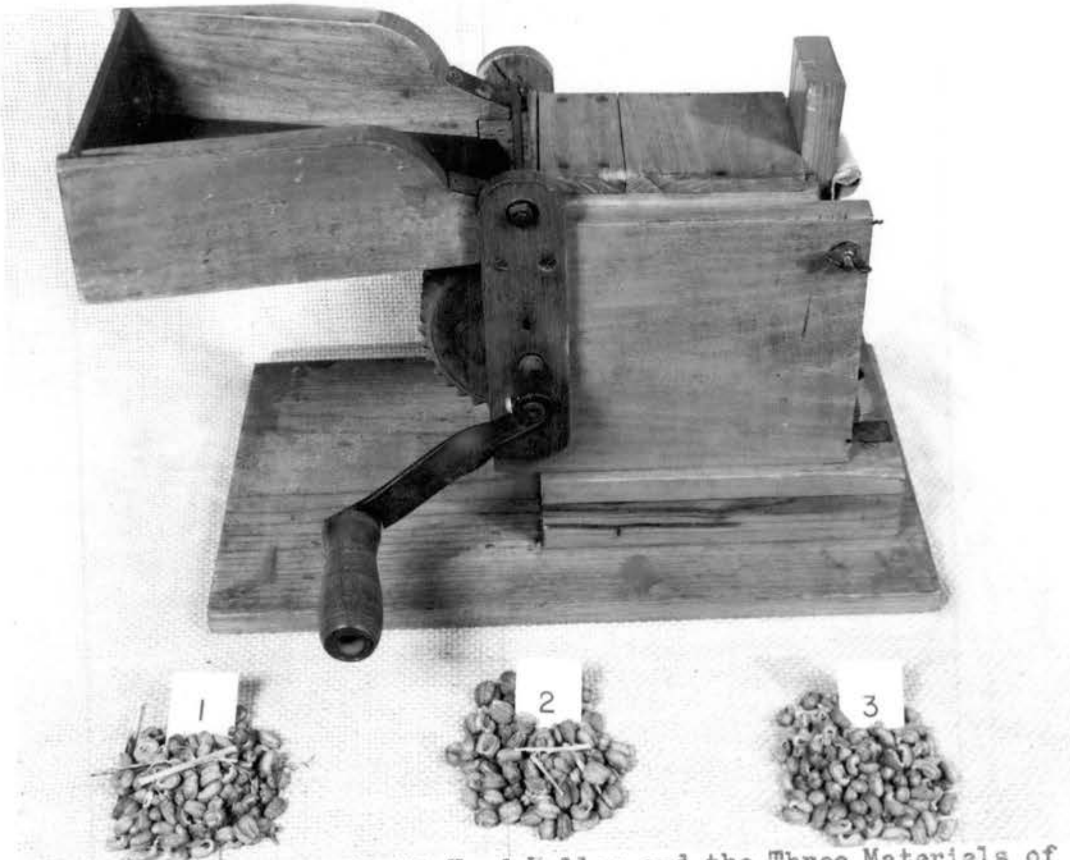

Figure 10. View of Small Hand Huller and the Three Materials of US 74 Castor Beans Used in Tests.
1. Bulk or Harvested Material
2. Whole Capsules Material
3. Segments Material

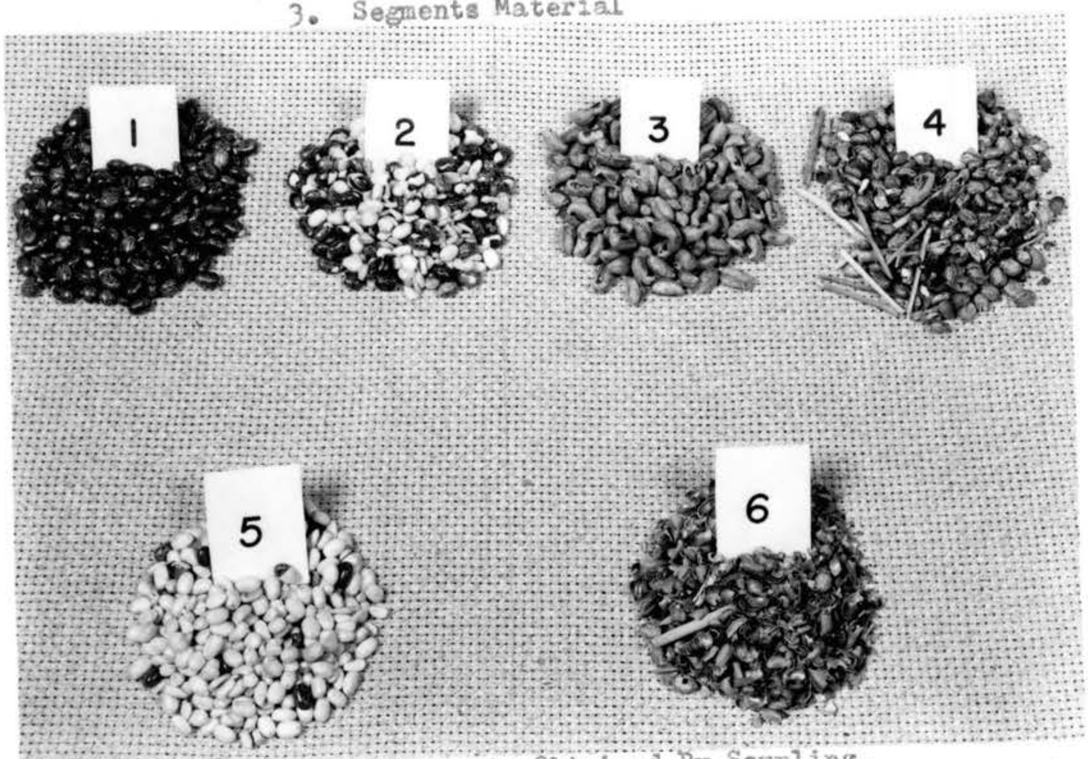

Figure 11. View of Products Obtained By Sampling.

Products in Sack
1. Clean Whole Beans
2. Cracked and Broken Beans
3. Unhulled Segments
4. Foreign Materials, Hulls, Sticks, Light Beans, etc.

Products in Cleanings
5. Oil Bearing Material
6. Hulls, Chaff, Light Beans, Trash.

TABLE 1

Determination of Correction Factors, C_s and C_{cb}, In Materials Tested

From US 74 Castor Beans.

Sample No.	Weight	Weight Whole Capsules	Weight Two Segments	Weight Single Segments	Shelled Beans		Cracked and Broken Beans		Foreign Material	Weight Beans
	grams	grams	grams	grams	wt. grams	no.	wt. grams	no.	grams	grams
1. Bulk or Harvested Material										
1	255	32.0	17.0	172	8.0	35	2.0	9	24	172
2	285.5	40.0	28.0	167	4.5	19	1.0	4	18	177
3	280	13.5	9.5	182	21.0	90	2.0	8	52	175
4	260.5	18.5	27.0	180.5	13.0	47	1.5	7	20	180.5
5	263	38.5	26.5	161	7.0	29	1.0	5	29	170
Total	1317.0	142.5	108.0	862.5	53.5		7.5		143	874.5
Per Cent	100	10.8	8.2	65.52	4.06		0.57		10.85	66.4
2. Whole Capsules										
1	219	93	87.5	35.5	-	-	-	1	3.0	149
2	225	94	78.0	50.0	-	1	-	-	3.0	156
3	222	95	87.5	37.5	-	-	-	1	2.0	152
4	223	90	92.0	38.0	-	1	-	-	3.0	150
5	212.5	81	87.5	41.0	-	-	-	-	3.0	142.5
Total	1101.5	453	432.5	202.0	-		-		14.0	749.5
Per Cent	100	41.1	39.3	18.33	0		0		1.27	68.0
3. Segments										
1	299	-	-	284	13	53	1	4	1.5	233
2	299	-	-	290	7	28	-	-	2.0	229
3	257	-	-	249	6	24	-	-	2.0	195
4	280	-	-	266	11	43	1	3	1.5	216.5
5	309	-	-	296	11	44	1	3	1.0	239
Total	1444	-	-	1385	48		3		8.0	1112.5
Per Cent	100			95.92	3.32		0.21		0.55	77.0

the preliminary investigations.

4. The fan speed, damper opening and position of shutters set as found in the preliminary investigations.

5. The feed regulated manually by means of the rod mechanism that controls the gate opening in the hopper; thereby operating the disks at loaded conditions for all runs.

Every effort was made to carry out the tests as nearly as possible to the above conditions and thus reduce to a minimum any deviations from the specified conditions.

C. TECHNIQUE USED

The huller engine was regulated to give the desired disk speed under operating conditions and the fan speed, damper opening and position of shutters adjusted according to the preliminary investigations to give good performance at this disk speed. One hundred pounds of unhulled material was dumped into the hopper and the elevator started. The feed was regulated manually by the gate opening in the hopper on the elevator, so that there was always an adequate supply of unhulled material to keep the disks at loaded conditions throughout each run. The gate was opened and the beans conveyed to the rotating drum feeder. When the first beans dropped down on the disks the stop watch was started. During each run at various intervals five samples of the products in the sack were taken at random by means of the two-way valve at the discharge spout and three samples were taken at random from the products in the cleanings at the discharge side of the fan. Three readings of disk speed were taken with the tachometer and the average value recorded for each run. After all the one hundred pounds of unhulled material had passed through the disks, the stop watch was stopped and the length of time was recorded. Three runs or similar observations were made for each disk speed tested except where there was variation in the desired disk speed, an extra run was made.

D. SAMPLING TECHNIQUE

The sampling technique was planned so that the data obtained could be analyzed on a statistical basis. The equipment used in obtaining data by sampling is shown in Figure 9 and the products obtained by sampling are shown in Figure 11.

The technique employed consisted of inspecting five samples, each one a 200 gram sample, taken from the products in the sack during each run. The procedure in inspecting the samples from the products in the sack was to separate and weigh the clean whole beans and the cracked and broken beans from each sample and to save the unhulled segments and foreign material from each individual sample until all five samples were inspected and then weigh them. Measurements of these products were recorded to the nearest 1/2 gram weight. From these five samples the mean percentages of clean whole beans, cracked and broken beans, unhulled segments, and foreign material were found. With these mean percentages the weight in pounds of each product was found by multiplying its mean percentage times the weight of products in the sack.

The same technique was used in sampling the three samples, each a 300 gram sample, taken from the cleanings. The mean percentages of oil bearing material, hulls, light beans, and foreign material were found and from these the weight in pounds was computed from the weight of the products in the cleanings. The oil bearing material was used to designate what few beans were whole and those cracked and broken that contained oil and were pulled over by the fan. This term was used since the fan tends to crack the largest percentage of whole beans passing through it; therefore making it impossible to separate the whole beans and cracked and broken beans in the products of the cleanings. Corrections for this could have been found by making a device to catch samples before they entered the fan.

VI. ANALYSIS OF DATA

The method of analyzing the data obtained was to select the bean weight basis as the standard for computation of all results. Correction factors, resulting from deviations in the materials from the test operating conditions specified, were applied in computing the results. The method employed in computing the results from the observed data was to compute all values for each individual run. Calculations of these values were rounded off to two decimal places. The results obtained from the three different materials are summarized in Tables 2, 3, and 4. These values were then plotted graphically and curves constructed through the averages of the three points obtained for each speed.

A. DETERMINATION OF PERFORMANCE CHARACTERISTICS

The procedure followed in calculating these values from the observed data is explained in detail in the succeeding paragraphs. In order to simplify this analysis a flow diagram of the products, symbols for terms, and values of constants are employed. In reference to the flow diagram, the number of light beans left in the sack will depend upon the adjustment of the damper opening, position of shutters over screen area and fan speed.

The products and the symbols used in the following analysis are the weight in pounds found from the mean percentages obtained from the sampling data.

Let R = Total Weight in pounds of beans that went through huller.

Then $R = A + B + KC + E$, where K is the ratio of the weight of beans in the unhulled segments to the total weight of beans plus the hulls in

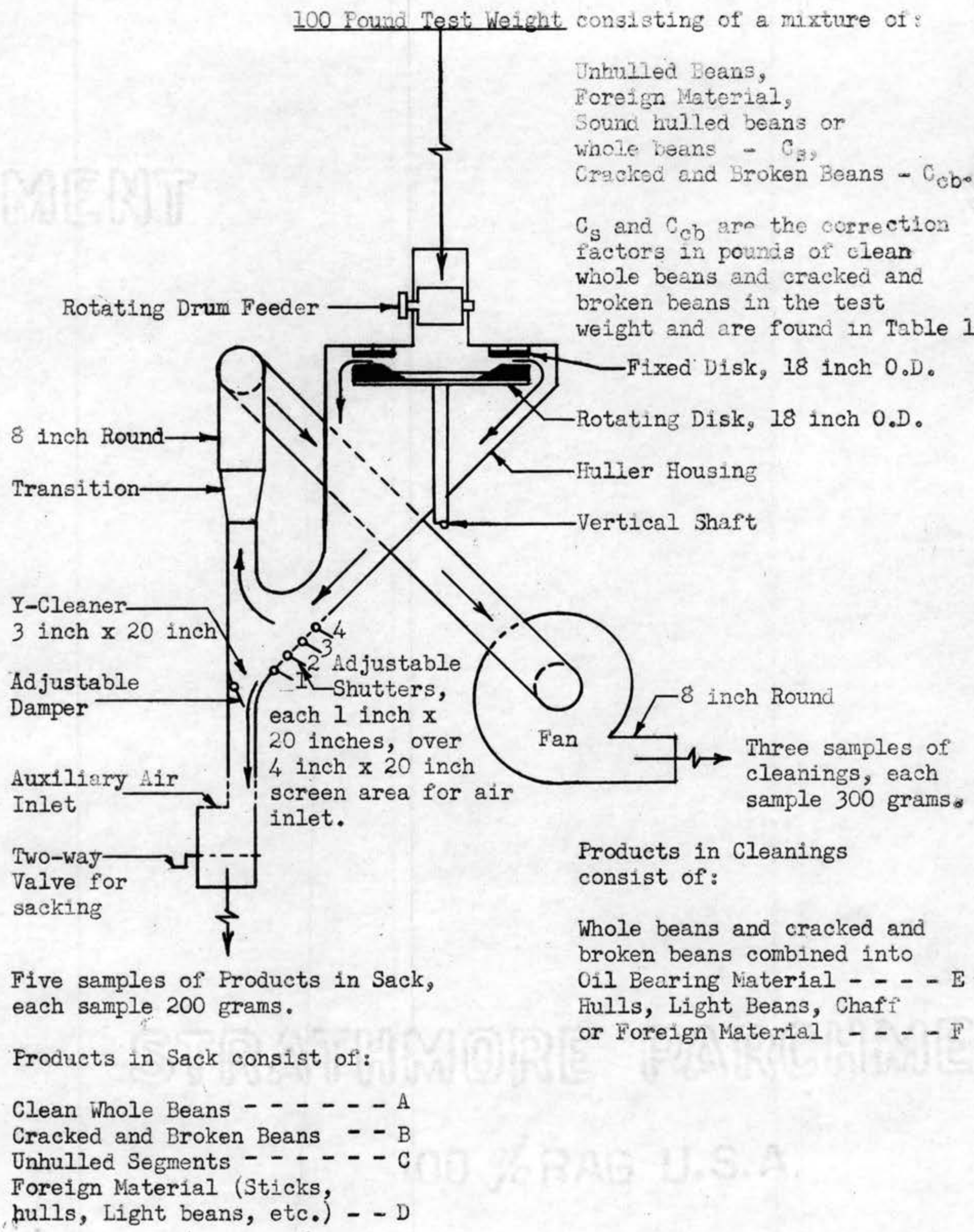

FIGURE 12. Flow Diagram of Products through Huller.

TABLE 2

Effect of Disk Speed and Spacing of 5/16 Inch on Bulk or Harvested

Material of US 74 Castor Beans.

Run No.	Time	Average Disk Speed	Fan Speed	Weight Of Beans	Per Cent Hulled Beans	Per Cent Beans In Unhulled Segments	Per Cent Attached Hulls in Unhulled Segments	Per Cent Unhulled Segments	Per Cent Cracked and Broken Beans	Per Cent Losses	Capacity of Hulled Beans
	Seconds	RPM	RPM	Lbs.	%	%	%	%	%	%	Lb/Hr
1A	493	185	900	68.06	99.79	0.21	0.06	0.27	0.46	0.84	497
1B	512	180	900	67.99	99.87	0.13	0.04	0.17	0.41	0.51	478
1C	528	175	900	68.79	99.83	0.17	0.05	0.22	0.36	0.79	469
2A	356	255	900	67.51	99.61	0.39	0.10	0.49	0.62	0.55	683
2B	325	260	900	67.19	99.61	0.39	0.11	0.50	0.72	0.61	744
2C	361	255	900	67.54	99.66	0.34	0.09	0.43	0.45	0.55	674
3A	210	355	960	66.12	99.56	0.44	0.11	0.55	0.83	0.80	1133
3B	211	355	940	67.92	99.44	0.56	0.15	0.71	0.96	0.60	1159
3C	214	355	940	67.64	99.57	0.43	0.11	0.54	1.00	0.52	1138
4A	147	455	980	68.01	99.40	0.60	0.16	0.76	1.50	0.87	1666
4B	147	455	980	66.19	99.32	0.68	0.18	0.86	1.12	2.19*	1621
4C	135	460	980	67.57	99.22	0.78	0.21	0.99	1.49	0.77	1802
5A	100	550	1010	68.59	98.75	1.25	0.33	1.58	2.16	0.83	2469
5B	103	550	1010	67.93	99.00	1.00	0.26	1.26	2.12	0.80	2374
5C	109	545	1010	67.61	98.70	1.30	0.35	1.65	2.24	0.81	2233
6A	79	635	1200	67.98	98.53	1.47	0.39	1.86	3.70	1.06	3098
6B	70	640	1200	67.89	98.54	1.46	0.39	1.85	4.17	1.12	3492
6C	73	640	1200	68.29	98.58	1.42	0.35	1.79	4.04	1.22	3368

* Screen area for air inlet clogged with trash.

DATA SHEET 1.

Mean Percentages and Pounds of Products Evaluated From Samples

Taken From Bulk or Harvested Material

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
1A	68.69	1	194	2.5		
		2	192	3.0		
		3	193	2.5		
		4	195	2.0		
		5	194	2.5		
		Total	968	12.5	2.5	17.0
		Mean Per Cent	96.8	1.25	0.25	1.70
		Lbs.	66.49	0.86	0.17	1.17
1B	69.09	1	195	2.0		
		2	190	3.5		
		3	194	2.0		
		4	195	2.0		
		5	192	2.5		
		Total	966	12.0	1.5	20.5
		Mean Per Cent	96.6	1.20	0.15	2.05
		Lbs.	66.74	0.83	0.10	1.42
1C	69.31	1	193	3.0		
		2	195	2.0		
		3	193	3.0		
		4	194	2.0		
		5	196.5	1.5		
		Total	971.5	11.5	2.0	15.0
		Mean Per Cent	97.15	1.15	0.20	1.50
		Lbs.	67.33	0.80	0.14	1.04

Products in Cleanings
Sample Weight - 300 Gram

Run No.	Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
	Lbs.		Grams	Grams
1A	31.31	1	6.5	293.5
		2	4.5	295.5
		3	5.5	294.5
		Total	16.5	883.5
		Mean Per Cent	1.83	98.17
		Lbs.	0.57	30.74
1B	30.91	1	3.0	297
		2	4.0	296
		3	3.0	297
		Total	10.0	890
		Mean Per Cent	1.11	98.89
		Lbs.	0.34	30.57
1C	30.69	1	4.0	296
		2	7.0	293
		3	5.0	295
		Total	16.0	884
		Mean Per Cent	1.78	98.22
		Lbs.	0.55	30.14

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
2A	68.46	1	191	4.0		
		2	193	3.0		
		3	194	2.0		
		4	191	3.0		
		5	194	2.0		
		Total	963	14.0	4.5	18.5
		Mean Per Cent	96.3	1.40	0.45	1.85
		Lbs.	65.93	0.96	0.31	1.27
2B	68.24	1	191	3.5		
		2	192	3.0		
		3	192	3.0		
		4	192	3.0		
		5	193	2.5		
		Total	960	15.0	4.5	20.5
		Mean Per Cent	96.0	1.50	0.45	2.05
		Lbs.	65.51	1.02	0.31	1.40
2C	68.36	1	194	2.0		
		2	193	3.0		
		3	194	2.0		
		4	193	2.5		
		5	193	3.0		
		Total	967	12.5	4.0	16.5
		Mean Per Cent	96.7	1.25	0.40	1.65
		Lbs.	66.10	0.86	0.27	1.13

Products in Cleanings
Sample Weight - 300 Gram

Run No.	Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
	Lbs.		Grams	Grams
2A	31.54	1	4.5	295.5
		2	3.0	297
		3	3.0	297
		Total	10.5	889.5
		Mean Per Cent	1.17	98.83
		Lbs.	0.37	31.17
2B	31.76	1	2.5	297.5
		2	5.0	295.0
		3	4.0	296.0
		Total	11.5	888.5
		Mean Per Cent	1.28	98.72
		Lbs.	0.41	31.35
2C	31.64	1	3.5	296.5
		2	3.0	297
		3	4.0	296
		Total	10.5	889.5
		Mean Per Cent	1.17	98.83
		Lbs.	0.37	31.27

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
			Products in Sack Sample Weight - 200 Gram			
	Lbs.		Grams	Grams	Grams	Grams
3A	67.27	1	194	2.5		
		2	191	3.0		
		3	189	3.5		
		4	189	3.5		
		5	192	3.5		
		Total	955	16.0	5.0	24
		Mean Per Cent	95.5	1.60	0.50	2.40
		Lbs.	64.24	1.08	0.34	1.61
3B	69.22	1	191	3.0		
		2	191	3.0		
		3	191	4.0		
		4	190	4.0		
		5	190	3.0		
		Total	953	17.0	6.5	23.5
		Mean Per Cent	95.3	1.70	0.65	2.35
		Lbs.	65.97	1.18	0.45	1.63
3C	68.63	1	192	4.0		
		2	192	3.0		
		3	193	3.5		
		4	192	3.0		
		5	190	4.0		
		Total	959	17.5	5.0	18.5
		Mean Per Cent	95.9	1.75	0.50	1.85
		Lbs.	65.82	1.20	0.34	1.27

Run No.	Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans Foreign Material
			Products in Cleanings Sample Weight - 300 Gram	
	Lbs.		Grams	Grams
3A	32.73	1	5.0	295
		2	4.5	295.5
		3	5.0	295
		Total	14.5	885.5
		Mean Per Cent	1.61	98.39
		Lbs.	0.53	32.20
3B	30.78	1	3.5	296.5
		2	3.5	296.5
		3	5.0	295.0
		Total	12.0	888.0
		Mean Per Cent	1.33	98.67
		Lbs.	0.41	30.37
3C	31.37	1	4.0	296
		2	2.0	298
		3	4.0	296
		Total	10.0	890
		Mean Per Cent	1.11	98.89
		Lbs.	0.35	31.02

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
4A	68.97	1	192	4.5		
		2	193	3.0		
		3	189	4.5		
		4	190	4.0		
		5	186	6.0		
		Total	950	22.0	7.0	21.0
		Mean Per Cent	95.0	2.20	0.70	2.10
		Lbs.	65.52	1.52	0.48	1.45
4B	66.24	1	190	4.0		
		2	190	4.0		
		3	191	3.5		
		4	190	4.0		
		5	191	3.5		
		Total	952	19.0	8.0	21.0
		Mean Per Cent	95.2	1.90	0.80	2.10
		Lbs.	63.06	1.26	0.53	1.39
4C	68.84	1	186	5.5		
		2	190	4.0		
		3	190	4.0		
		4	189	4.5		
		5	190	4.0		
		Total	945	22.0	9.0	24.0
		Mean Per Cent	94.5	2.20	0.90	2.40
		Lbs.	65.05	1.51	0.62	1.65

Products in Cleanings
Sample Weight - 300 Gram

Run No.	Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
	Lbs.		Grams	Grams
4A	31.03	1	6.0	294
		2	4.5	295.5
		3	6.5	293.5
		Total	17.0	883.0
		Mean Per Cent	1.89	98.11
		Lbs.	0.59	30.44
4B	33.76	1	5.0	295
		2	5.5	294.5
		3	28.0	272.0
		Total	38.5	861.5
		Mean Per Cent	4.28	95.72
		Lbs.	1.45	32.31
4C	31.16	1	5.0	295
		2	5.0	295
		3	5.0	295
		Total	15.0	885
		Mean Per Cent	1.67	98.33
		Lbs.	0.52	30.64

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
5A	69.73	1	189	5.0		
		2	187	5.5		
		3	185	7.0		
		4	187	5.5		
		5	188	5.0		
		Total	936	28.0	14.5	21.5
		Mean Per Cent	93.6	2.80	1.45	2.15
		Lbs.	65.27	1.95	1.01	1.50
5B	69.58	1	185	5.5		
		2	191	5.0		
		3	183	7.0		
		4	186	5.0		
		5	187	5.0		
		Total	932	27.5	11.5	29.0
		Mean Per Cent	93.2	2.75	1.15	2.90
		Lbs.	64.85	1.91	0.80	2.02
5C	69.38	1	182	6.5		
		2	187	5.5		
		3	190	5.0		
		4	188	5.0		
		5	179	6.5		
		Total	926	28.5	15.0	30.5
		Mean Per Cent	92.6	2.85	1.50	3.05
		Lbs.	64.26	1.98	1.04	2.12

Products in Cleanings
Sample Weight - 300 Gram

Run No.	Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
	Lbs.		Grams	Grams
5A	30.27	1	6.0	294
		2	5.0	295
		3	6.0	294
		Total	17.0	883
		Mean Per Cent	1.89	98.11
		Lbs.	0.57	29.70
5B	30.42	1	5.5	294.5
		2	5.5	294.5
		3	5.0	295.0
		Total	16.0	884.0
		Mean Per Cent	1.78	98.22
		Lbs.	0.54	29.88
5C	30.62	1	6.0	294
		2	4.0	296
		3	6.0	294
		Total	16.0	884
		Mean Per Cent	1.78	98.22
		Lbs.	0.55	30.07

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
6A	69.20	1	182	8.0		
		2	177	11.0		
		3	186.5	7.0		
		4	185.0	8.5		
		5	186	7.5		
		Total	916.5	42.0	17.0	24.5
		Mean Per Cent	91.65	4.20	1.70	2.45
		Lbs.	63.42	2.91	1.18	1.69
6B	69.00	1	186	10.0		
		2	187	7.5		
		3	184	7.0		
		4	176	10.0		
		5	180	12.0		
		Total	913	46.5	17.0	23.5
		Mean Per Cent	91.3	4.65	1.70	2.35
		Lbs.	63.00	3.21	1.17	1.62
6C	68.94	1	185	8.5		
		2	185	8.5		
		3	184	9.0		
		4	183	10.5		
		5	183	9.0		
		Total	920	45.5	16.5	18.0
		Mean Per Cent	92.0	4.55	1.65	1.80
		Lbs.	63.42	3.14	1.14	1.24

Products in Cleanings
Sample Weight - 300 Gram

Run No.	Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
	Lbs.		Grams	Grams
6A	30.80	1	7.0	293
		2	6.0	294
		3	8.0	292
		Total	21.0	879
		Mean Per Cent	2.34	97.66
		Lbs.	0.72	30.08
6B	31.00	1	7.0	293
		2	8.0	292
		3	7.0	293
		Total	22.0	878
		Mean Per Cent	2.45	97.55
		Lbs.	0.76	30.24
6C	31.06	1	9.5	290.5
		2	7.5	292.5
		3	7.0	293
		Total	24.0	876
		Mean Per Cent	2.67	97.33
		Lbs.	0.83	30.23

TABLE 3

Effect of Disk Speed and Spacing of 5/16 Inch on Whole Capsule

Material of US 74 Castor Beans.

Run No.	Time	Average Disk Speed	Fan Speed	Weight Of Beans	Per Cent Hulled Beans	Per Cent Beans In Unhulled Segments	Per Cent Attached Hulls in Unhulled Segments	Per Cent Unhulled Segments	Per Cent Cracked and Broken Beans	Per Cent Losses	Capacity of Hulled Beans
	Seconds	RPM	RPM	Lbs.	%	%	%	%	%	%	Lb/Hr
1AC	722	180	900	65.16	99.88	0.12	0.03	0.15	0.45	0.38	325
1BC	726	180	900	66.30	99.88	0.12	0.03	0.15	0.60	0.33	329
1CC	724	180	900	65.54	99.92	0.08	0.02	0.10	0.50	0.35	326
2AC	450	270	900	65.46	99.92	0.08	0.02	0.10	0.71	0.49	524
2BC	503	250	900	65.70	99.92	0.08	0.02	0.10	0.66	0.49	470
2CC	504	250	900	66.01	99.92	0.08	0.02	0.10	0.61	0.46	471
3AC	305	370	960	65.07	99.76	0.24	0.06	0.30	0.86	0.52	768
3BC	374	340	960	64.81	99.84	0.16	0.04	0.20	0.66	0.63	624
3CC	300	370	960	65.34	99.84	0.16	0.04	0.20	0.66	0.58	784
4AC	158	500	1000	65.23	99.68	0.32	0.08	0.40	1.66	1.20	1486
4BC	229	440	1000	64.33	99.80	0.20	0.05	0.24	1.25	1.97	1011
4CC	215	450	1000	63.87	99.84	0.16	0.04	0.20	1.25	1.78	1069
4DC	210	450	980	64.66	99.72	0.28	0.07	0.35	1.46	0.93	1108
5AC	132	560	1000	65.93	99.60	0.40	0.11	0.51	2.71	0.71*	1798
5BC	134	560	1000	65.20	99.64	0.36	0.10	0.46	2.38	1.49*	1752
5CC	133	560	1000	66.69	99.52	0.48	0.12	0.60	2.71	1.39	1805
6AC	85	680	1150	64.76	98.79	1.21	0.32	1.53	6.22	1.12	2740
6BC	83	680	1150	66.42	99.00	1.00	0.26	1.26	6.26	1.43	2880
6CC	84	680	1150	66.30	98.97	1.03	0.28	1.31	6.08	1.84	2842

* No. 4 Shutter over screen area of air inlet partially closed.
* No. 4 Shutter over screen area of air inlet closed.

DATA SHEET 2.

Mean Percentages and Pounds of Products Evaluated From Samples

Taken From Whole Capsules Material

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
1AC	65.39	1	197	1.0		
		2	197	1.0		
		3	198	0.5		
		4	198	1.0		
		5	197	1.0		
		Total	987	4.5	1.5	7.0
	Mean Per Cent		98.7	0.45	0.15	0.70
		Lbs.	64.54	0.29	0.10	0.46
1BC	66.94	1	196.5	1.0		
		2	195.5	1.0		
		3	196.5	1.0		
		4	194.5	1.5		
		5	197.0	1.5		
		Total	980.0	6.0	1.5	12.5
	Mean Per Cent		98.0	0.60	0.15	1.25
		Lbs.	65.60	0.40	0.10	0.84
1CC	66.05	1	196	1.0		
		2	197	1.0		
		3	196	1.5		
		4	197	0.5		
		5	197	1.0		
		Total	983	5.0	1.0	11.0
	Mean Per Cent		98.3	0.50	0.10	1.10
		Lbs.	64.93	0.33	0.07	0.73

Run No.	Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
	Lbs.		Grams	Grams
1AC	34.61	1	2.5	297.5
		2	1.5	298.5
		3	2.5	297.5
		Total	6.5	893.5
	Mean Per Cent		0.72	99.28
		Lbs.	0.25	34.36
1BC	33.06	1	2.5	297.5
		2	2.0	298.0
		3	1.5	298.5
		Total	6.0	894.0
	Mean Per Cent		0.67	99.33
		Lbs.	0.22	32.84
1CC	33.95	1	2.0	298
		2	2.5	297.5
		3	1.5	298.5
		Total	6.0	894.0
	Mean Per Cent		0.67	99.33
		Lbs.	0.23	33.72

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
2AC	66.15	1	195.5	1.5		
		2	196.0	1.5		
		3	194.0	1.0		
		4	195.5	1.5		
		5	196.0	1.5		
		Total	977.0	7.0	1.0	15.0
	Mean Per Cent		97.7	0.70	0.10	1.50
		Lbs.	64.63	0.46	0.07	0.99
2BC	66.23	1	196	1.0		
		2	196	1.5		
		3	197	1.0		
		4	195	1.5		
		5	196	1.5		
		Total	980	6.5	1.0	12.5
	Mean Per Cent		98.0	0.65	0.10	1.25
		Lbs.	64.90	0.43	0.07	0.83
2CC	66.59	1	195	1.5		
		2	196	1.0		
		3	197	1.0		
		4	197	1.0		
		5	195	1.5		
		Total	980	6.0	1.0	13.0
	Mean Per Cent		98.0	0.60	0.10	1.30
		Lbs.	65.26	0.40	0.07	0.87

Products in Cleanings
Sample Weight - 300 Gram

Run No.	Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
	Lbs.		Grams	Grams
2AC	33.85	1	3.5	296.5
		2	3.0	297.0
		3	2.0	298.0
		Total	8.5	891.5
	Mean Per Cent		0.94	99.06
		Lbs.	0.32	33.53
2BC	33.77	1	2.5	297.5
		2	3.0	297.0
		3	3.0	297.0
		Total	8.5	891.5
	Mean Per Cent		0.94	99.06
		Lbs.	0.32	33.45
2CC	33.41	1	3.0	297
		2	2.0	298
		3	3.0	297
		Total	8.0	892
	Mean Per Cent		0.89	99.11
		Lbs.	0.30	33.11

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
3AC	65.62	1	194	1.5		
		2	196	1.0		
		3	195	2.5		
		4	195	2.0		
		5	195.5	1.5		
		Total	975.5	8.5	3.0	13.0
		Mean Per Cent	97.55	0.85	0.30	1.30
		Lbs.	64.01	0.56	0.20	0.85
3BC	65.31	1	196	1.5		
		2	193	1.5		
		3	197	1.0		
		4	196	1.5		
		5	196	1.0		
		Total	978	6.5	2.0	13.5
		Mean Per Cent	97.8	0.65	0.20	1.35
		Lbs.	63.87	0.43	0.13	0.88
3CC	65.95	1	196	0.5		
		2	196	1.5		
		3	195	1.0		
		4	196	1.5		
		5	194	2.0		
		Total	977	6.5	2.0	14.5
		Mean Per Cent	97.7	0.65	0.20	1.45
		Lbs.	64.43	0.43	0.13	0.96

Products in Cleanings
Sample Weight - 300 Gram

Run No.	Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
	Lbs.		Grams	Grams
3AC	34.38	1	2.5	297.5
		2	3.5	296.5
		3	3.0	297.0
		Total	9.0	891.0
		Mean Per Cent	1.00	99.00
		Lbs.	0.34	34.04
3BC	34.69	1	5.0	295
		2	3.0	297
		3	2.5	297.5
		Total	10.5	889.5
		Mean Per Cent	1.17	98.83
		Lbs.	0.41	34.28
3CC	34.05	1	3.5	296.5
		2	2.5	297.5
		3	4.0	296.0
		Total	10.0	890.0
		Mean Per Cent	1.11	98.89
		Lbs.	0.38	33.67

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
4AC	65.72	1	191	4.0		
		2	192	3.0		
		3	192	4.0		
		4	192	2.0		
		5	194	3.5		
		Total	961	16.5	4.0	18.5
	Mean Per Cent		96.10	1.65	0.40	1.85
		Lbs.	63.16	1.08	0.26	1.22
4BC	64.31	1	195	2.5		
		2	193	2.5		
		3	192	3.0		
		4	193	2.5		
		5	193	2.0		
		Total	966	12.5	2.5	19.0
	Mean Per Cent		96.6	1.25	0.25	1.90
		Lbs.	62.12	0.81	0.16	1.22
4CC	64.01	1	193	2.5		
		2	192	3.0		
		3	193	2.5		
		4	195	2.0		
		5	193	2.5		
		Total	966	12.5	2.0	19.5
	Mean Per Cent5		96.6	1.25	0.20	1.95
		Lbs.	61.83	0.80	0.13	1.25
4DC	65.09	1	194	2.5		
		2	193	3.0		
		3	193	3.0		
		4	193.5	3.0		
		5	193.5	3.0		
		Total	967.0	14.5	3.5	15.0
	Mean Per Cent		96.7	1.45	0.35	1.50
		Lbs.	62.94	0.94	0.23	0.98

Products in Cleanings
Sample Weight - 300 Gram

Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
Lbs.		Grams	Grams
34.28	1	6.5	293.5
	2	7.0	293.0
	3	7.0	293.0
	Total	20.5	879.5
Mean Per Cent		2.28	97.72
	Lbs.	0.78	33.50
35.69	1	12.0	288
	2	9.5	290.5
	3	10.5	289.5
	Total	32.0	868.0
Mean Per Cent		3.56	96.44
	Lbs.	1.27	34.42
35.99	1	11.0	289.0
	2	9.5	290.5
	3	8.0	292.0
	Total	28.5	871.5
Mean Per Cent		3.17	96.83
	Lbs.	1.14	34.85
34.91	1	4.0	296
	2	5.0	295
	3	6.5	293.5
	Total	15.5	884.5
Mean Per Cent		1.72	98.28
	Lbs.	0.60	34.31

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
5AC	67.38	1	189	5.5		
		2	189	5.0		
		3	190	4.5		
		4	187	5.5		
		5	186	6.0		
		Total	941	26.5	5.0	27.5
		Mean Per Cent	94.1	2.65	0.50	2.75
		Lbs.	63.40	1.79	0.34	1.85
5BC	65.88	1	190	5.0		
		2	189	4.0		
		3	190	5.0		
		4	189	5.0		
		5	190	4.5		
		Total	948	23.5	4.5	24.0
		Mean Per Cent	94.8	2.35	0.45	2.40
		Lbs.	62.45	1.55	0.30	1.58
5CC	67.05	1	190	5.5		
		2	188	7.0		
		3	191	4.0		
		4	190	4.5		
		5	190	6.0		
		Total	949	27.0	6.0	18.0
		Mean Per Cent	94.9	2.70	0.60	1.80
		Lbs.	63.63	1.81	0.40	1.21

Products in Cleanings
Sample Weight - 300 Gram

Run No.	Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
	Lbs.		Grams	Grams
5AC	32.62	1	5.0	295
		2	4.5	295.5
		3	3.5	296.5
		Total	13.0	887.0
		Mean Per Cent	1.44	98.56
		Lbs.	0.47	32.15
5BC	34.12	1	9.0	291.0
		2	7.5	292.5
		3	9.0	291.0
		Total	25.5	874.5
		Mean Per Cent	2.83	97.17
		Lbs.	0.97	33.15
5CC	32.95	1	7.5	292.5
		2	10.0	290.0
		3	8.0	292.0
		Total	25.5	874.5
		Mean Per Cent	2.83	97.17
		Lbs.	0.93	32.02

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
6AC	65.82	1	177	15		
		2	178	13		
		3	184	10.5		
		4	176	13.5		
		5	185	9.0		
		Total	900	61.0	15.0	24
	Mean Per Cent		90.0	6.10	1.50	2.40
		Lbs.	59.24	4.02	0.99	1.58
6BC	67.02	1	183	11.0		
		2	181	12.5		
		3	179	14.0		
		4	179	13.5		
		5	183	11.0		
		Total	905	62.0	12.5	20.5
	Mean Per Cent		90.5	6.20	1.25	2.05
		Lbs.	60.65	4.16	0.84	1.37
6CC	66.63	1	183	11.0		
		2	178	15.0		
		3	180	12.5		
		4	185	9.5		
		5	180	12.5		
		Total	906	60.5	13.0	20.5
	Mean Per Cent		90.6	6.05	1.30	2.05
		Lbs.	60.37	4.03	0.87	1.37

Products in Cleanings
Sample Weight - 300 Gram

Run No.	Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
	Lbs.		Grams	Grams
6AC	34.18	1	7.0	293
		2	6.0	294
		3	6.0	294
		Total	19.0	881
	Mean Per Cent		2.11	97.89
		Lbs.	0.72	33.46
6BC	32.98	1	8.0	292
		2	11.0	289
		3	7.0	293
		Total	26.0	874
	Mean Per Cent		2.89	97.11
		Lbs.	0.95	32.03
6CC	33.37	1	7.0	293
		2	12.0	288
		3	14.0	286
		Total	33.0	867
	Mean Per Cent		3.67	96.33
		Lbs.	1.22	32.15

TABLE 4

Effect of Disk Speed and Spacing of 5/16 Inch on

Segment Material of US 74 Castor Beans.

Run No.	Time	Average Disk Speed	Fan Speed	Weight Of Beans	Per Cent Hulled Beans	Per Cent Beans in Unhulled Segments	Per Cent Attached Hulls in Unhulled Segments	Per Cent Unhulled Segments	Per Cent Cracked and Broken Beans	Per Cent Losses	Capacity of Hulled Beans
	Seconds	RPM	RPM	Lbs.	%	%	%	%	%	%	Lb/Hr
1AS	410	180	900	76.59	99.75	0.25	0.06	0.31	0.55	0.34	672
1BS	450	160	900	76.84	99.83	0.17	0.04	0.21	0.97	0.57	615
1CS	423	175	900	76.48	99.79	0.21	0.05	0.26	0.66	0.30	650
2AS	249	285	920	76.41	99.67	0.33	0.09	0.42	0.77	0.24	1105
2BS	302	240	920	76.37	99.75	0.25	0.07	0.32	0.66	0.24	910
2CS	331	220	920	76.48	99.75	0.25	0.07	0.32	0.60	0.31	832
2DS	263	260	920	76.84	99.71	0.29	0.08	0.37	0.66	0.29	1052
3AS	177	360	960	76.68	99.59	0.41	0.11	0.52	1.08	0.31	1560
3BS	174	365	960	76.54	99.58	0.42	0.11	0.53	1.08	0.34	1584
3CS	170	370	960	76.31	99.58	0.42	0.11	0.53	1.18	0.33	1616
4AS	114	440	1000	76.70	99.50	0.50	0.13	0.63	1.28	0.81	2422
4BS	114	440	1000	76.24	99.42	0.58	0.15	0.73	1.44	0.96	2407
4CS	124	430	1000	76.20	99.55	0.45	0.13	0.58	1.28	0.92	2212
5AS	72	550	1000	76.12	99.21	0.79	0.21	1.00	2.45	0.55	3806
5BS	72	550	1000	76.71	99.17	0.83	0.22	1.05	2.08	0.61	3836
5CS	72	550	1000	76.33	99.18	0.82	0.22	1.04	2.34	0.79	3816
6AS	62	650	1150	76.87	98.92	1.08	0.28	1.36	5.64	1.08	4463
6BS	62	650	1150	76.46	98.76	1.24	0.33	1.57	4.26	1.11	4440
6CS	62	650	1150	76.06	98.92	1.08	0.29	1.37	5.91	1.22	4417

DATA SHEET 3.

Mean Percentages and Pounds of Products Evaluated From Samples

Taken From Segment Material

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
1AS	76.54	1	197	1.5		
		2	197	2.5		
		3	198	1.0		
		4	198	1.0		
		5	197	2.0		
		Total	987	8.0	3.0	2.0
		Mean Per Cent	98.7	0.80	0.30	0.20
		Lbs.	75.54	0.61	0.23	0.16
1BS	76.74	1	196	2.0		
		2	197	2.0		
		3	196	3.0		
		4	197	2.0		
		5	196	3.0		
		Total	982	12.0	2.0	4.0
		Mean Per Cent	98.2	1.20	0.20	0.40
		Lbs.	75.36	0.92	0.15	0.31
1CS	76.56	1	197	1.5		
		2	197	2.0		
		3	196	2.5		
		4	197	1.5		
		5	198	1.5		
		Total	985	9.0	2.5	3.5
		Mean Per Cent	98.5	0.90	0.25	0.35
		Lbs.	75.41	0.69	0.19	0.27

Products in Cleanings
Sample Weight - 300 Gram

Run No.	Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
	Lbs.		Grams	Grams
1AS	23.46	1	3.5	296.5
		2	3.0	297
		3	3.5	296.5
		Total	10.0	890.0
		Mean Per Cent	1.11	98.89
		Lbs.	0.26	23.20
1BS	23.26	1	5.0	295
		2	3.0	297
		3	9.0	291
		Total	17.0	883
		Mean Per Cent	1.89	98.11
		Lbs.	0.44	22.82
1CS	23.44	1	3.0	297
		2	3.0	297
		3	3.0	297
		Total	9.0	891
		Mean Per Cent	1.00	99.00
		Lbs.	0.23	23.21

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
2AS	76.76	1	196	1.5		
		2	195	3.0		
		3	197	1.5		
		4	197	1.5		
		5	195	2.5		
		Total	980	10.0	4.0	6.0
		Mean Per Cent	98.0	1.00	0.40	0.60
		Lbs.	75.22	0.77	0.31	0.46
2BS	76.55	1	196	2.0		
		2	196	1.5		
		3	198	1.0		
		4	197	2.0		
		5	197	1.5		
		Total	984	9.0	3.0	4.0
		Mean Per Cent	98.4	0.9	0.30	0.40
		Lbs.	75.32	0.69	0.23	0.31
2CS	76.52	1	197	2.0		
		2	196	2.0		
		3	197	2.0		
		4	197.5	1.5		
		5	198	1.0		
		Total	985.5	8.5	3.0	3.0
		Mean Per Cent	98.55	0.85	0.30	0.30
		Lbs.	75.41	0.65	0.23	0.23
2DS	76.87	1	197	2.0		
		2	197	1.5		
		3	196	2.5		
		4	199	1.0		
		5	196	2.0		
		Total	985	9.0	3.5	2.5
		Mean Per Cent	98.5	0.90	0.35	0.25
		Lbs.	75.72	0.69	0.27	0.19

Products in Cleanings
Sample Weight - 300 Gram

Run No.	Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
	Lbs.		Grams	Grams
2AS	23.24	1	2.0	298
		2	2.5	297.5
		3	2.5	297.5
		Total	7.0	893.0
		Mean Per Cent	0.78	99.22
		Lbs.	0.18	23.06
2BS	23.45	1	2.5	297.5
		2	2.0	298.0
		3	2.5	297.5
		Total	7.0	893.0
		Mean Per Cent	0.78	99.22
		Lbs.	0.18	23.27
2CS	23.48	1	3.0	297
		2	3.5	296.5
		3	2.5	297.5
		Total	9.0	891
		Mean Per Cent	1.00	99.00
		Lbs.	0.24	23.24
2DS	24.13	1	3.5	296.5
		2	2.5	297.5
		3	2.0	298.0
		Total	8.0	892.0
		Mean Per Cent	0.89	99.11
		Lbs.	0.22	23.91

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
3AS	76.91	1	196	2.5		
		2	196	2.0		
		3	194	3.5		
		4	196	2.5		
		5	195	2.5		
		Total	977	13.0	5.0	5.0
		Mean Per Cent	97.7	1.30	0.50	0.50
		Lbs.	75.14	1.00	0.38	0.38
3BS	76.86	1	193	3.5		
		2	194.5	3.0		
		3	196	2.0		
		4	196	2.0		
		5	196	2.5		
		Total	975.5	13.0	5.0	6.5
		Mean Per Cent	97.55	1.30	0.50	0.65
		Lbs.	74.98	1.00	0.38	0.50
3CS	76.61	1	195	3.5		
		2	196.5	2.0		
		3	195	3.0		
		4	194.5	3.0		
		5	194	2.5		
		Total	975	14.0	5.0	6.0
		Mean Per Cent	97.5	1.40	0.50	0.60
		Lbs.	74.69	1.07	0.38	0.46

Products in Cleanings
Sample Weight - 300 Gram

Run No.	Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
	Lbs.		Grams	Grams
3AS	23.09	1	3.0	297
		2	4.0	296
		3	2.5	297.5
		Total	9.5	890.5
		Mean Per Cent	1.06	98.94
		Lbs.	0.24	22.85
3BS	23.14	1	2.5	297.5
		2	4.0	296
		3	3.5	296.5
		Total	10.0	890
		Mean Per Cent	1.11	98.89
		Lbs.	0.26	22.88
3CS	23.39	1	4.5	295.5
		2	2.5	297.5
		3	2.5	297.5
		Total	9.5	890.5
		Mean Per Cent	1.06	98.44
		Lbs.	0.25	23.14

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
4AS	76.64	1	193	4.0		
		2	195	3.5		
		3	195	2.5		
		4	196	2.5		
		5	194	2.5		
		Total	973	15.0	6.0	6.0
		Mean Per Cent	97.3	1.50	0.60	0.60
		Lbs.	74.57	1.15	0.46	0.46
4BS	76.19	1	194	3.0		
		2	194	3.5		
		3	193	4.0		
		4	195	2.5		
		5	193	3.5		
		Total	969	16.5	7.0	7.5
		Mean Per Cent	96.9	1.65	0.70	0.75
		Lbs.	73.83	1.26	0.53	0.57
4CS	76.09	1	194	3.0		
		2	195	4.0		
		3	195	2.5		
		4	194	3.0		
		5	195	2.5		
		Total	973	15.0	5.5	6.5
		Mean Per Cent	97.3	1.50	0.55	0.65
		Lbs.	74.03	1.14	0.42	0.49

Products in Cleanings
Sample Weight - 300 Gram

Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
Lbs.		Grams	Grams
23.36	1	8.0	292
	2	7.0	293
	3	9.0	291
	Total	24.0	876
	Mean Per Cent	2.67	97.33
	Lbs.	0.62	22.74
23.81	1	9.0	291
	2	10.0	290
	3	8.5	291.5
	Total	27.5	872.5
	Mean Per Cent	3.06	96.94
	Lbs.	0.73	23.08
23.91	1	11.5	288.5
	2	7.0	293
	3	8.0	292
	Total	26.5	873.5
	Mean Per Cent	2.94	97.06
	Lbs.	0.70	23.21

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
5AS	76.51	1	192	5.0		
		2	193	4.5		
		3	191	5.0		
		4	190	6.5		
		5	190	5.0		
		Total	956	26.0	9.5	8.5
	Mean Per Cent		95.6	2.60	0.95	0.85
		Lbs.	73.14	1.99	0.73	0.65
5BS	77.06	1	192	4.0		
		2	193	4.5		
		3	190	5.0		
		4	192	4.5		
		5	192	4.5		
		Total	959	22.5	10.0	8.5
	Mean Per Cent		95.9	2.25	1.00	0.85
		Lbs.	73.90	1.73	0.77	0.65
5CS	76.43	1	191	5.5		
		2	191	5.0		
		3	193	4.5		
		4	190	5.5		
		5	193	4.5		
		Total	958	25.0	10.0	7.0
	Mean Per Cent		95.8	2.50	1.00	0.70
		Lbs.	73.22	1.91	0.76	0.54

Products in Cleanings
Sample Weight - 300 Gram

Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
Lbs.		Grams	Grams
23.49	1	4.5	295.5
	2	5.5	294.5
	3	6.0	294
	Total	16.0	884
Mean Per Cent		1.78	98.22
	Lbs.	0.42	23.07
22.94	1	5.0	295
	2	6.0	294
	3	7.5	292.5
	Total	18.5	881.5
Mean Per Cent		2.06	97.94
	Lbs.	0.47	22.47
23.57	1	8.5	291.5
	2	8.0	292
	3	6.5	293.5
	Total	23.0	877
Mean Per Cent		2.56	97.44
	Lbs.	0.60	22.97

Products in Sack
Sample Weight - 200 Gram

Run No.	Wt. of Products in Sack	Sample No.	Clean Whole Beans	Cracked and Broken Beans	Unhulled Segments	Foreign Material
	Lbs.		Grams	Grams	Grams	Grams
6AS	76.90	1	180	15.0		
		2	185	11.5		
		3	188	8.0		
		4	187	8.0		
		5	182	14.0		
		Total	922	56.5	13.0	8.5
		Mean Per Cent	92.2	5.65	1.30	0.85
		Lbs.	70.90	4.35	1.00	0.65
6BS	76.20	1	189	7.5		
		2	186	10.0		
		3	187	9.5		
		4	190	7.5		
		5	185	9.0		
		Total	937	43.5	15.0	8.5
		Mean Per Cent	93.7	4.35	1.50	0.85
		Lbs.	71.40	3.31	1.14	0.65
6CS	76.18	1	188	9.0		
		2	179	16.5		
		3	180	15.0		
		4	188	8.0		
		5	182	10.5		
		Total	917	59.0	13.0	11.0
		Mean Per Cent	91.7	5.90	1.30	1.10
		Lbs.	69.86	4.49	0.99	0.84

Products in Cleanings
Sample Weight - 300 Gram

Run No.	Wt. of Products in Cleanings	Sample No.	Oil Bearing Material	Hulls, Light Beans, Foreign Material
	Lbs.		Grams	Grams
6AS	23.10	1	10.5	289.5
		2	11.0	289
		3	11.0	289
		Total	32.5	867.5
		Mean Per Cent	3.61	96.39
		Lbs.	0.83	22.27
6BS	23.80	1	9.0	291
		2	15.0	285
		3	8.0	292
		Total	32.0	868
		Mean Per Cent	3.56	96.44
		Lbs.	0.85	22.95
6CS	23.82	1	14.0	286
		2	7.0	293
		3	14.0	286
		Total	35.0	865
		Mean Per Cent	3.89	96.11
		Lbs.	0.93	22.89

the unhulled segments. K is the term commonly referred to as the hulling percentage of the material or variety of beans. The value of K was found from an actual population of unhulled segments that were saved during the sampling of the products. A sample of 300 grams of unhulled segments was used in which the actual weight of beans found by hulling with the small hand huller was 237 grams. This gave a value of $K = 237/300 = 0.79$, which was used in all computations.

Let R = Actual weight in pounds of beans in test weight that were unhulled. Then $R' = R - (C_s + C_{cb})$.

Let H = Actual weight in pounds of beans hulled by the disks in machine.

$$H = A + B + E - (C_s + C_{cb})$$

Then PER CENT HULLED BEANS $= H/R' \times 100$ Also the PER CENT HULLED BEANS $= (1 - KC/R') \times 100$, where $KC/R' \times 100$ equals PER CENT BEANS IN UNHULLED SEGMENTS, which is also equal to $(1 - H/R') \times 100$. Both the above values, per cent hulled beans and per cent beans in unhulled segments give the same relationship on the effect of disk speed except that one expresses the performance on a high percentage level (per cent hulled beans) and the other on a low percentage level (per cent beans in unhulled segments). Since they are generally found expressed either way, both values were included in this study.

PER CENT ATTACHED HULLS IN UNHULLED SEGMENTS $= (C - KC/R') \times 100$. This value was included in the results because after the foreign material has been removed the attached hulls are the only material remaining which tend to lower the quantity of oil obtained from the beans. This per cent should be kept as low as possible.

PER CENT UNHULLED SEGMENTS (beans plus attached hulls) = $C/R' \times 100$.

PER CENT CRACKED AND BROKEN BEANS = $\frac{B - C_{cb}}{R'} \times 100$.

It should be recognized that this per cent cracked and broken neglects the small percentage that is cracked and broken which may have been pulled off in the cleanings by the air velocity. This small percentage is included in the oil bearing material.

CAPACITY OF HULLED BEANS (LB/HR) = $\frac{R \times 3600}{\text{Time(Sec)}}$

The capacity is computed on the total weight in pounds of beans that went through the huller without correcting for the beans hulled in the test weight.

PER CENT LOSSES OR PER CENT OIL BEARING = $E/R \times 100$.

This value was included to show the overall performance of the machine cycle for the various settings of disk speed, fan speed, shutter and damper openings, because even though the disks may be doing a good job of hulling the complete unit may be performing very poorly.

An example of the calculation of these values is taken from Run 1A.

From Data Sheet 1 : Clean whole beans - A = 66.49 lbs.
Cracked and broken beans - B = 0.86 lbs.
Unhulled segments - C = 0.17 lbs.
Oil bearing material - E = 0.57 lbs.

From Table 1: C_s = 4.06 lbs.
C_{cb} = 0.57 lbs.

$R = A + B + KC + E = 66.49 + 0.86 + (0.79)(0.17) + 0.57 = 68.06$ lbs.

$R' = R - (C_s + C_{cb}) = 68.06 - (4.06 + 0.57) = 63.43$ lbs.

$H = A + B + E - (C_s + C_{cb}) = 66.49 + 0.86 + 0.57 - (4.06 + 0.57) = 63.29$ lbs.

Per cent Hulled Beans = $H/R' \times 100 = 63.29/63.43 \times 100 = 99.79\%$

$= (1 - KC/R') \times 100 = \left(1 - \frac{0.79 \times 0.17}{63.43}\right) \times 100 = 99.79\%$

Per cent Beans in Unhulled Segments = $KC/R' \times 100$

$$= \frac{(0.79)(0.17)}{63.43} \times 100 = 0.21\%$$

Or

$$= (1 - H/R') \times 100$$

$$= (1 - 0.9979) \times 100 = 0.21\%$$

Per cent Attached Hulls in Unhulled Segments = $(C - KC/R') \times 100$

$$= \left(0.17 - \frac{0.79 \times 0.17}{63.43}\right) \times 100 = 0.06\%$$

Per cent Unhulled Segments = $C/R' \times 100 = 0.17/63.43 \times 100 = 0.27\%$

Per cent Cracked and Broken Beans = $\frac{B - C_{cb}}{R'} \times 100 = \frac{0.86 - 0.57}{63.43} \times 100 = 0.46\%$

Capacity of Hulled Beans (lb/hr) = $\frac{R \times 3600}{\text{Time (Sec)}} = \frac{68.06 \times 3600}{493} = 497$ lb/hr

Per cent Losses = $E/R \times 100 = 0.57/68.06 \times 100 = 0.84\%$

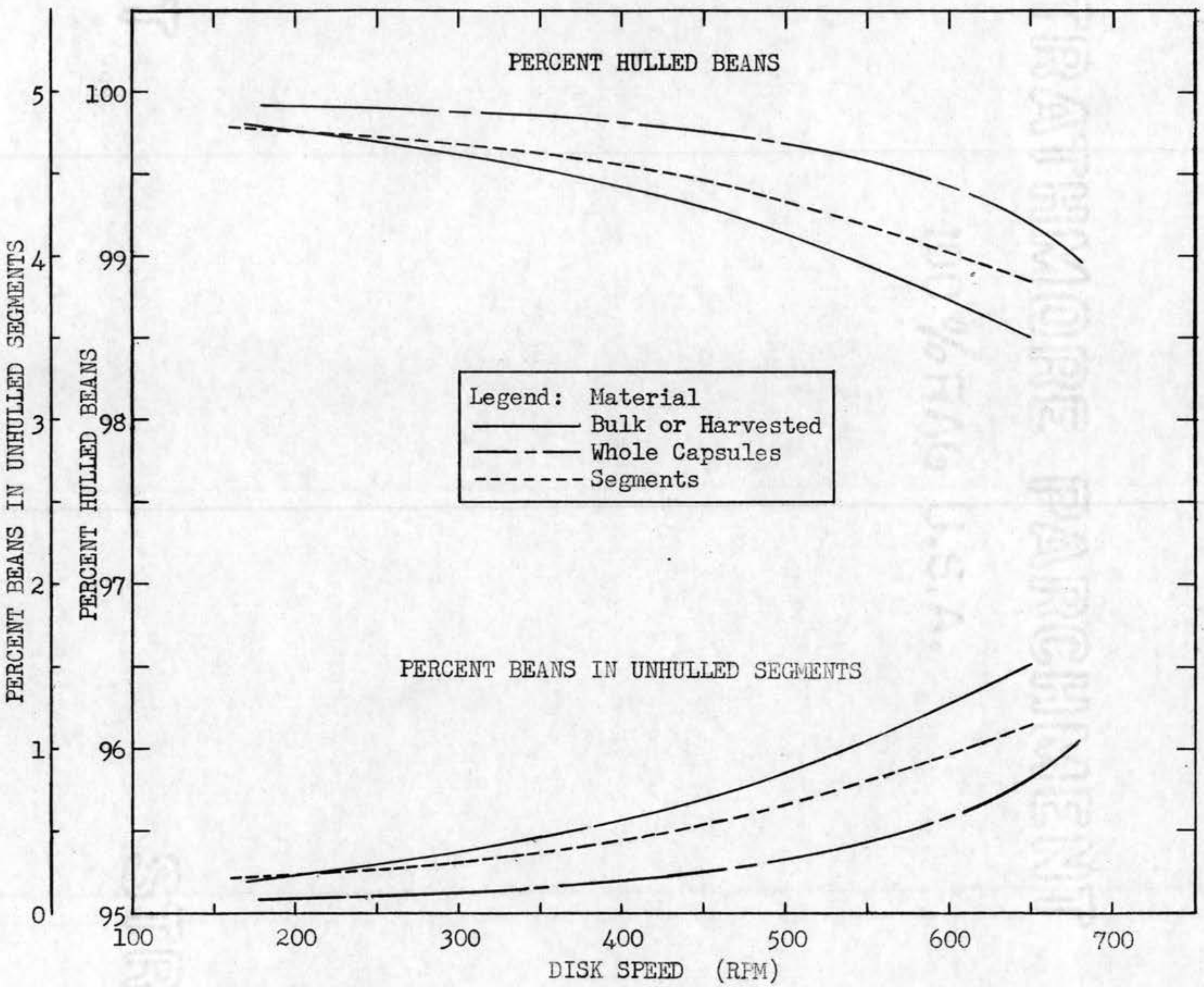

Figure 13. Effect of Disk Speed and Spacing of 5/16 inch on Percent Beans In Unhulled Segments and Percent Hulled Beans.

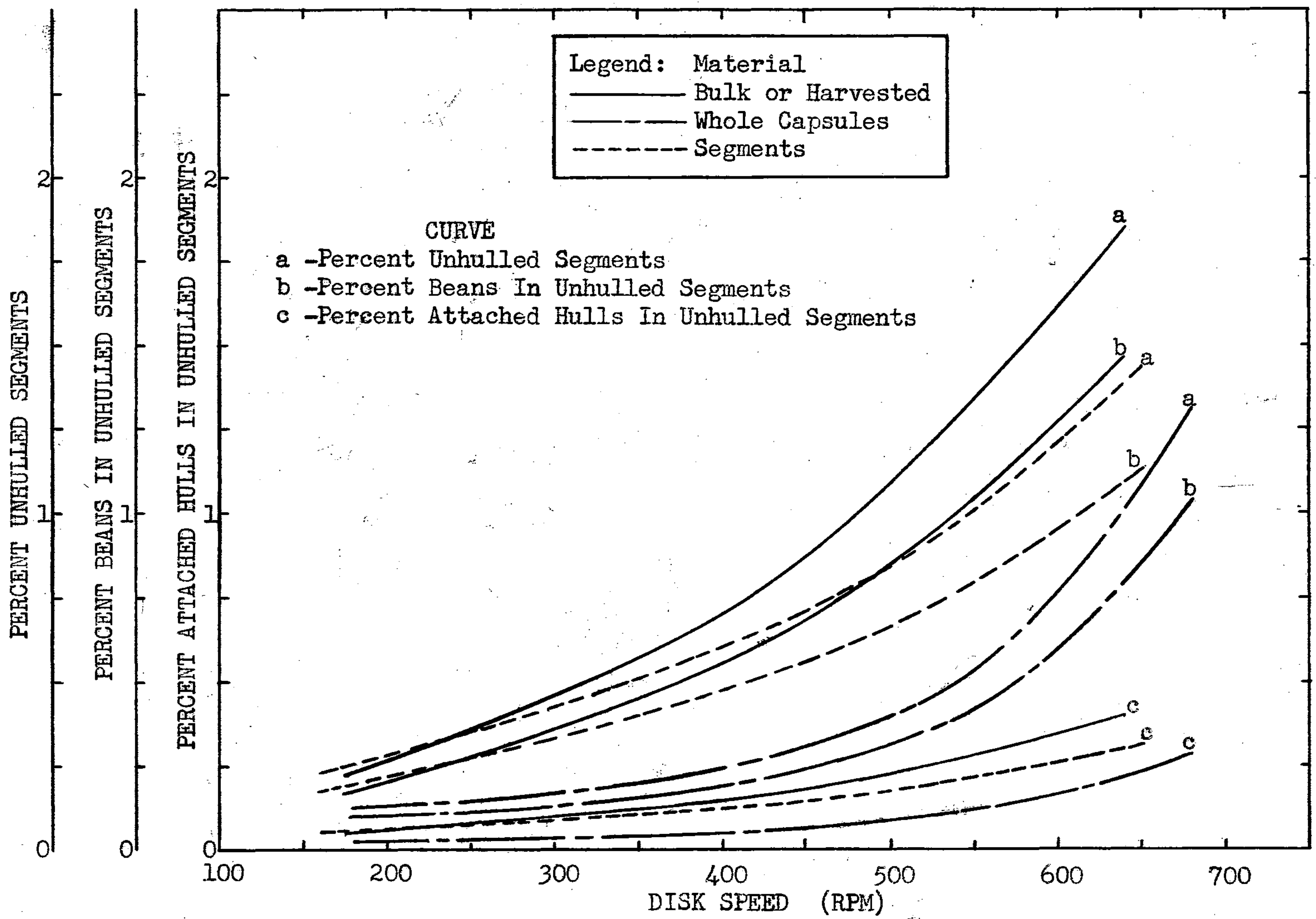

Figure 14. Effect of Disk Speed and Spacing of 5/16 inch on Percent Unhulled Segments, Percent Beans in Unhulled Segments, and Percent Attached Hulls in Unhulled Segments.

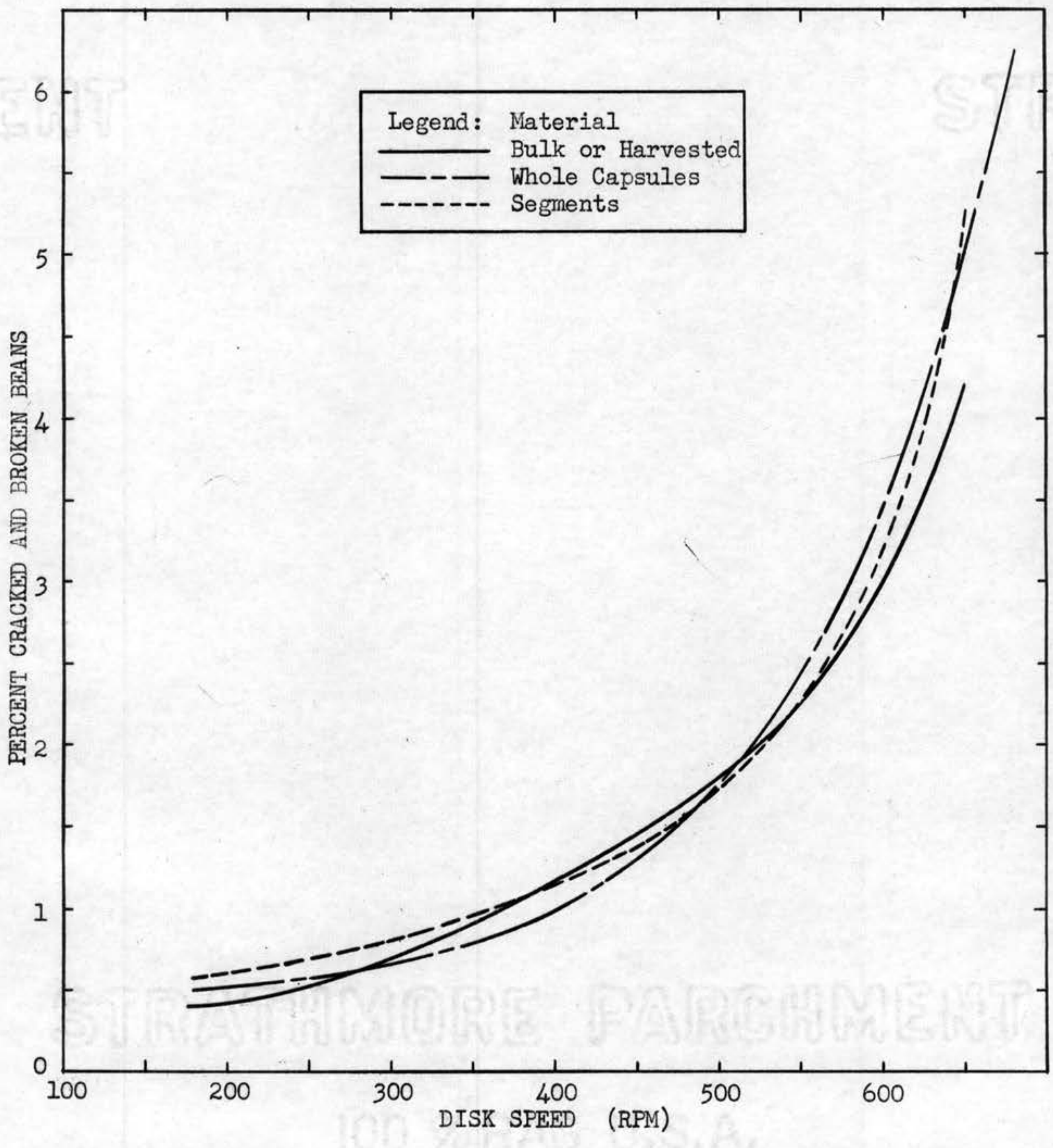

Figure 15. Effect of Disk Speed and Spacing of 5/16 inch on Percent Cracked and Broken Beans.

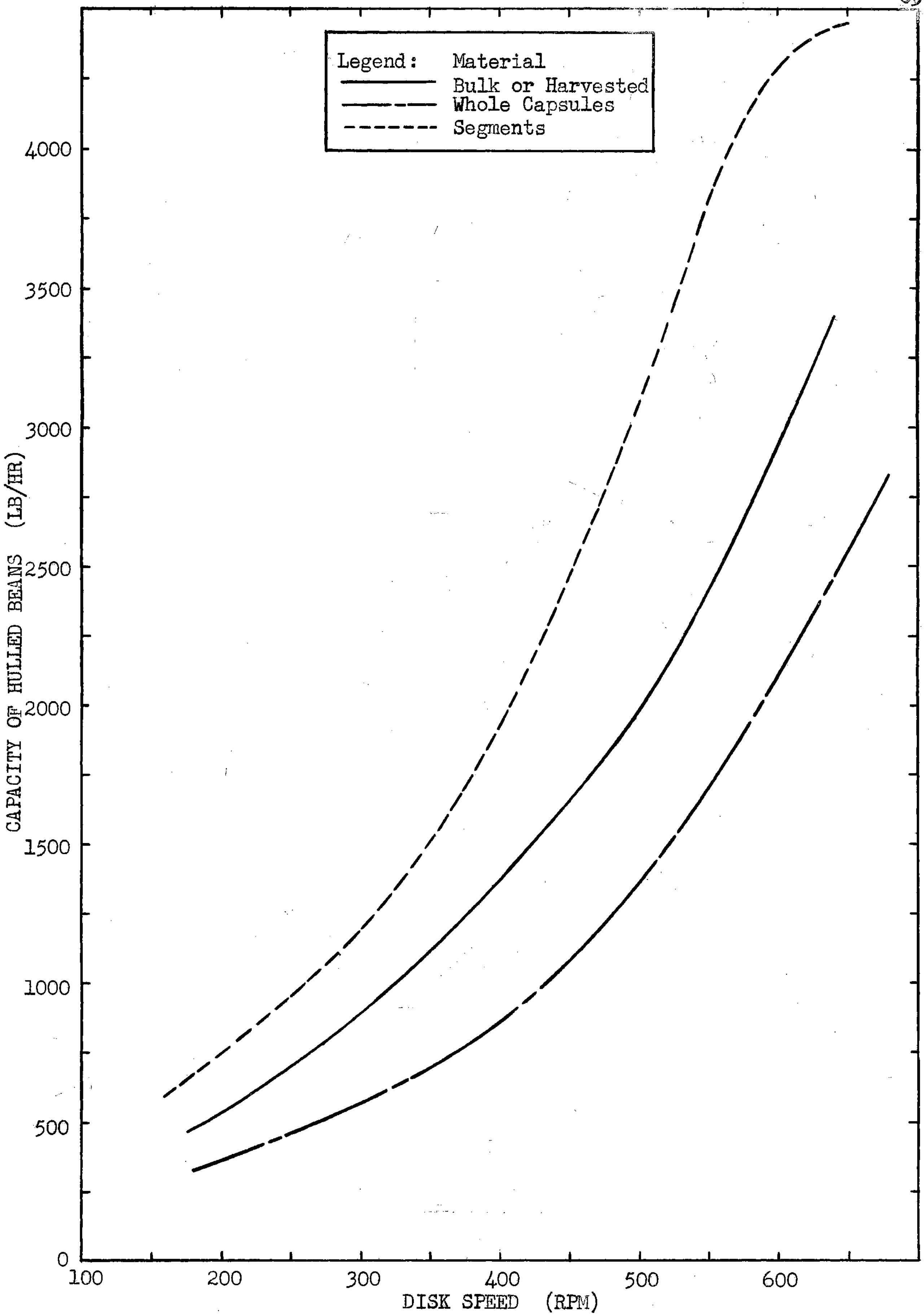

Figure 16. Effect of Disk Speed and Spacing of 5/16 inch on Capacity of Hulled Beans.

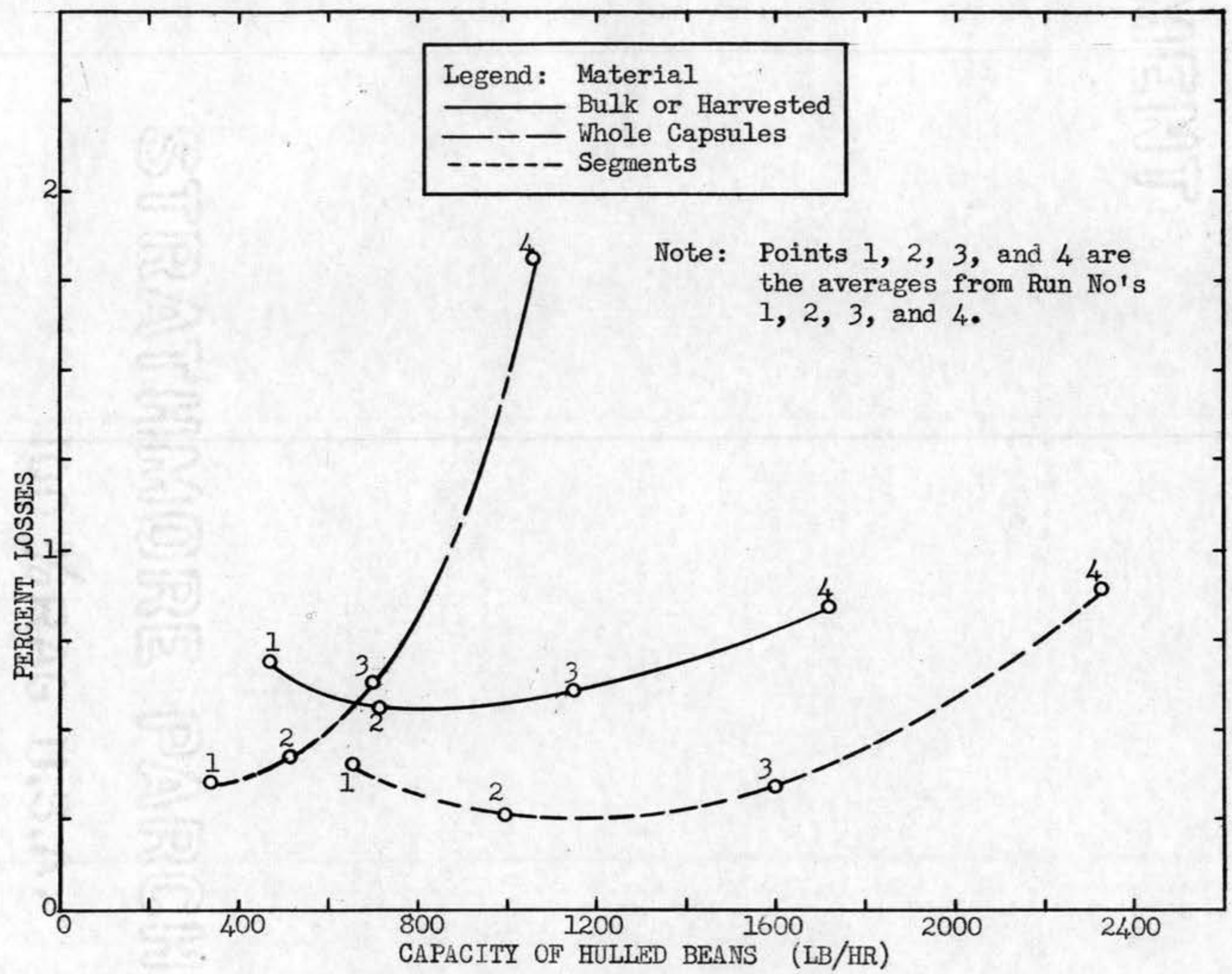

Figure 17. Effect of Capacity on Percent Losses obtained with Settings of Fan Speed, Shutter Openings, and Damper Opening for Runs 1, 2, 3, and 4.

VII. DISCUSSION OF RESULTS

In discussing the effect of disk speed on the various factors recorded in the analysis of the data, it should be kept in mind that these values were obtained under the controlled testing conditions as listed in Part V, methods of making tests and observations.

The results obtained from the sampling data sheets are recorded in Tables 2, 3 and 4. As was mentioned previously the sampling technique for obtaining the sampling data was planned so that a statistical analysis could be made if it was considered necessary. It is believed that the values obtained from the three runs for each disk speed give as accurate an estimation of the actual population as is required in this study; hence no statistical analysis was made to determine whether or not a sufficient number of samples were taken from the products in the sack and in the cleanings for each run. A study of these results shows that perhaps the greatest error in the reported values would be from failure to obtain enough representative samples; however no relation as to the per cent of error in sampling was made on the recorded data.

A. PER CENT HULLED BEANS AND PER CENT BEANS IN UNHULLED SEGMENTS

The factors determined in the analysis of the data are presented graphically in Figures 13 through 17. Figure 13 shows the effect of disk speed on per cent hulled beans and per cent beans in unhulled segments and the effect the different materials have on these percentages. At low disk speeds the per cent hulled beans has a maximum value of 99.75 to 99.90% and it is obvious that the per cent unhulled beans will have a minimum value of 0.10 to 0.25% for any of the three materials tested. As the disk speed is increased the per cent hulled beans tends to decrease and the per cent beans in unhulled segments will increase. Whole capsules material had the highest per cent hulled, followed by segments and then the bulk or harvested materials. An important cause contributing to the fact that a higher per cent hulled is obtained with the whole capsules is that the capacity of hulled beans at a given disk speed is much lower than that of either the segments and bulk or harvested material. Referring to Tables 2, 3, and 4 or to Figure 16 and comparing the materials at the same capacity of hulled beans for different disk speeds, the per cent hulled beans obtained with the whole capsules is more nearly equal to that of the segments and the bulk or harvested material. Considering the lowest permissible per cent of hulled beans to be around 98%, none of the disk speeds used in this study are limited by this factor since the actual performance of the castor bean huller showed a minimum of 98.50% with the bulk or harvested material at the maximum disk speed of 650 rpm.

B. PER CENT UNHULLED SEGMENTS

Figure 14 shows the effect of disk speed on the per cent unhulled segments and its component parts, per cent beans in unhulled segments and per cent attached hulls in unhulled segments. Hence for any particular disk speed and material the ordinate of curve c plus the ordinate of curve b must equal the ordinate for curve a. The per cent unhulled segments was divided into these two parts for the purpose of illustrating how small the actual per cent of attached hulls are that the unhulled segments contain. At high disk speeds a maximum value of 0.40% of attached hulls was found with the bulk or harvested material. This percentage should be kept as low as possible as the attached hulls on the unhulled segments are the only foreign material which tend to lower the quantity of oil obtained at the extraction mills. These values are minimum at low disk speeds and gradually increase as the disk speed increases.

The poorest performance occurred with the bulk or harvested material and since it contained more trash and foreign material than the whole capsules and segments, it would seem that this additional trash may have influenced the values obtained with the bulk or harvested material. However, if 2% unhulled segments is considered as the maximum value acceptable for good performance with this type of huller, any disk speed with the speed range tested will give satisfactory results.

C. PER CENT CRACKED AND BROKEN BEANS

Figure 15 shows the relationship of disk speed on the per cent cracked and broken beans for the three types of material tested. It is evident that the different materials have very little effect on the per cent cracked and broken beans as the disk speed is varied. At the lowest disk speed between 0.40 to 0.60% was cracked and broken and at the highest disk speed between 4 to 6% was cracked and broken for the materials tested. At the higher disk speeds the capacity tends to increase and it is possible that there is a definite relation between the per cent cracked and broken to the capacity of the disks. Some evidence of this possibility is found by studying Tables 2, 3, and 4.

If 2% cracked and broken is arbitrarily selected as the maximum permissible value for satisfactory performance of the hulling disks, the maximum speed at which the disk should be operated is 525 rpm. The per cent cracked and broken should be kept as low as possible since whenever the seed coat is cracked rapid deterioration of the oil in the bean itself occurs before it reaches the extraction mill.

D. CAPACITY OF HULLED BEANS

Figure 16 shows the effect of disk speed on the capacity of hulled beans in pounds per hour and the effect of the different materials tested on the capacity of the disks. There is a difference between the various materials and from Figure 16 the order of materials of increasing capacities for a particular disk speed is whole capsules, bulk or harvested material, and segments. An important cause of the larger capacity with the segments is the fact that the segments will pass directly between the hulling surfaces where the bulk or harvested material and whole capsules require a time interval to break the material into segments before they can pass through the disks. In addition to this time required a higher degree of wedging action occurs that tends to lower the capacities of these materials below that obtained with segments. The whole capsules material had a lower capacity than the bulk or harvested material and by referring to Table 1 it is seen that the bulk or harvested material consisted primarily of segments; therefore causing the capacity of the bulk or harvested material to be greater than the whole capsules material. A capacity of 2825 lb/hr at a disk speed of 680 rpm was obtained with the whole capsules while a capacity of 3400 lb/hr at a disk speed of 640 rpm was obtained with the bulk or harvested material. The curve for the segments tends to level off at a disk speed around 550 rpm and at the maximum disk speed of 650 rpm a capacity of 4450 lb/hr was obtained. The leveling off of this curve may indicate that the hulling area of the disks is approaching its maximum capacity.

E. PER CENT LOSSES

Figure 17 shows the effect of capacity on per cent losses as obtained with the settings of fan speed, shutter openings over screen area, and damper opening for runs 1, 2, 3, and 4. The settings correspond to those that were determined from the results of the preliminary investigations with bulk or harvested material. The per cent losses is a function of the air velocity and the air velocity required is a function of the capacity. The air velocity is dependent upon the fan speed, shutter openings over screen area, and damper opening. The curves were plotted for only the first four runs since with these runs the fan speed alone was varied to try to maintain approximately constant per cent losses as the capacity increased. With runs 5 and 6 the position of shutters and damper opening as well as the fan speed were changed to provide the necessary air velocity for removal of the hulls and chaff.

These curves give the overall performance of the castor bean huller for each setting. By comparing the points corresponding to the same settings for each run number, the effect of air velocity on the per cent losses for the different capacities can be determined. For example by considering the points numbered 4 where the air velocity is the same for all three curves it is evident that for the whole capsules the air velocity was too high for the capacity obtained; thereby resulting in a higher per cent losses than with either the bulk or harvested and segment materials. This indicates that preliminary investigations should have been made separately with each material tested so as to obtain the proper air velocity corresponding to the capacity of the disk at the different disk speeds. A maximum of 1.85% losses was obtained at run number 4 for the whole capsules material.

The per cent losses for the segments follow a curve similar to that of the bulk or harvested material; however the per cent losses are some-what smaller than that obtained with the bulk or harvested material. A minimum of 0.25% losses was obtained with the segment material. Since smaller per cent losses were obtained with the segments it is evident that the fan speed for each setting was greater than was needed for the capacities of the bulk or harvested material.

Referring to Table 2, Run 4B shows the effect of decreasing the area of air inlet which increases the air velocity in the Y-cleaner and tends to pull over a higher percentage of material. The same effect occurred in Table 3 in Runs 5AC and 5BC.

Since the preliminary investigations were made with only the bulk or harvested material the per cent losses for this curve approached a straight line. With this evidence at hand it would seem that, regardless of the material tested, the air velocity could be maintained so that the per cent losses could be held approximately constant as the capacity increases. This air velocity can be obtained by correct settings of the fan speed shutter openings over screen area, and damper opening. The per cent losses with the bulk or harvested material were held under 1%.

VIII. SUMMARY AND CONCLUSIONS

In summarizing the information contained in this study it is evident that the effect of disk speed is an important cause on the per cent hulled, per cent cracked and broken, and the capacity of the machine; however these characteristics are also affected by other variables which were held constant in this study. These variables are: moisture content of the beans, spacing or clearance between the disks, width of disk and hardness of rubber used on the disks. Since these variables were kept constant the conclusions drawn from this study pertain only to the effect of disk speed. To facilitate arriving at conclusions for these other variables requires further research.

The conclusions made from the present investigation are as follows:

A. OPERATING DISK SPEED

1. The per cent hulled beans was above 98% and it is obvious that the per cent beans in unhulled segments was lower than 2% for any disk speed between the range investigated.

   The per cent attached hulls in the unhulled segments was low for all the disk speeds; therefore this factor will have very little effect on the quantity of oil obtained at the extraction mills.

   The per cent unhulled segments (beans plus attached hulls) was less than 2% for all speeds. Since 2% unhulled segments or 98% hulled is established commercially as the maximum and minimum permissible values, the selection of any disk speed within the range tested is acceptable.

2. The per cent cracked and broken beans varied from 0.50% to 6% as the disk speeds increase for the range of disk speeds used. The selection of the proper disk speed for a certain per cent cracked and broken is dependent upon an economic balance between the spoilage of the cracked and broken beans and the capacity of the disks. If a minimum amount of spoilage is desired this per cent should be kept as low as possible. On the other hand if capacity is desired additional spoilage of the cracked and broken beans will have to be sacrificed. If 2% cracked and broken beans is considered maximum to prevent excessive losses through spoilage, a maximum permissible disk speed should be around 500 rpm.

3. The capacity of the disks increased for the three materials tested as the speed increased. At a capacity of 4250 lb/hr the capacity of the hulling surfaces of the disks tend to approach a maximum value.

4. After selecting a desirable operating disk speed the relationship of per cent losses can be controlled by proper adjustments of the fan speed, shutter openings over screen area and damper opening so as to control the necessary air velocity to give good cleaning at the capacity at which the disks are operating.

B. TYPE OF MATERIAL

1. There is no important difference between the per cent hulled beans since 98% can be obtained with any of the materials. However it is seen that the whole capsules have the highest per cent hulled and an important cause is that the bevel on the rotating

disk tends to hull them before they pass through the disks.

2. There is no essential difference between the per cent cracked and broken beans with the different materials.

3. There is a difference between the capacities of the materials. The segments have a much greater capacity than either the whole capsules and bulk material; therefore it would be desirable to increase the bevel on the rotating disk so as to increase the capacity of these other materials.

4. There is no effect upon the per cent losses with different materials if the machine is properly adjusted.

C. PROPOSALS FOR FURTHER STUDY

Since in this study the performance of the castor bean huller dealt only with the effect of disk speed under the specified test conditions, it is obvious that further research is necessary to determine the performance of the castor bean huller when tested at different conditions. Much information is needed to determine the relationship of other factors on the performance of the castor bean huller.

The proposals for further work for determining the overall performance of the castor bean huller when operated at different conditions are as follows:

1. To determine the effect of the variety, maturity, and moisture content of the beans.
2. To determine the effect of spacing or clearance between the disks.
3. To determine the effect of the width of the rubber facing on the disks, amount of bevel, size and hulling area of the disks.
4. To determine the effect of rubber hardness used on the disks.
5. To determine the effect of the rate of feeding the unhulled beans.

6. To determine the size of cleaning unit to provide the proper air velocity to give minimum per cent losses at various capacities.

Any one of the above variables should be determined independently of the others, so as to make it possible to evaluate its effect on the performance of the castor bean huller.

BIBLIOGRAPHY

1. Arnold, H. A. and Sharp, M. A.; "Shelling Castor Beans"; Agricultural Engineering Journal; Volume 23: 11; January, 1942.

2. Arnold, H. A. and Sharp, M. A.; "The Improved Castor-Bean Sheller"; University of Tennessee Agricultural Experiment Station; Knoxville, Tennessee; Bulletin 187; January, 1944.

3. Clay, H. P.; "Homemade Castor Bean Thresher"; Agricultural Engineering Journal; Volume 23: 135; April, 1942.

4. Colbeth, I. M.; Castor Beans---Paying Crop for Peace or War; Chemurgic Digest; Volume 10 No. 12; 4-8; December, 1951

5. Crooks, D. M. and Sievers, A. F.; Castor Beans, U. S. Department of Agriculture, Bureau of Plant Industry, Division of Drug and Related Plants; Mimeographed Circular 1941.

6. Dexter, Wayne; Castor Beans-A New Cash Crop; The Agricultural Situation, U. S. Department of Agriculture; Volume 35 No. 4: 13; April, 1951.

7. Domingo, W. E.; Castor Seed An Old Crop With The New Look; Chemurgic Digest; Volume 7 No. 12; 12, 13; December, 1948.

8. Domingo, W. E.; Castor Beans; Chemurgic Digest; Volume 10 No. 3: 7,8; March, 1951

9. Engineering the Castor Bean; Agricultural Engineering Journal; Volume 27: 157; April, 1946.

10. Gordon, E. D.; "Castor Bean Hullers"; Agricultural Engineering Journal; Volume 24: 189, 190, 196; June, 1943.

11. Miller, H.; "Agricultural Engineering Aspects of Castor Bean Production"; Agricultural Engineering Journal; Volume 21: 391, 392; October, 1940.

12. Miller, H.; "Production and Processing of Castor Beans"; Agricultural Engineering Journal; Volume 24: 124; April, 1943.

13. More About Castor Beans; Chemurgic Digest; Volume 10 no. 3: 8; March, 1951.

14. More About Castor Beans; Chemurgic Digest; Volume 10 No. 12: 8; December, 1951

15. O. P. D. Washington Bureau, Castor Bean Growing Backed By the Government; Oil, Paint and Drug Reporter; Volume 139 No. 25: 45; June, 1941.

16. Reed, I. F. and Brown, O. A.; The USDA Castor Bean Hullers; Agricultural Engineering Journal; Volume 25: 290; August, 1944

17. Sharp, M. A.; "A Castor Bean Sheller"; Agricultural Engineering Journal; Volume 23: 188; June, 1942.

18. Sharp, M. A.; "It Shells Beans"; Agricultural Engineering Journal; Volume 24: 428; December, 1943.

19. Weibel, R. O. and Burlison, W. L.; A Review of the Experimental Work of Castor Beans in the United States; Chemurgic Reprint; Serial Number 46; 1946

20. Yerkes, A. P., McKibben, E., and Baker, Jr., E. J.; "New Farm Machinery Development Needed"; Agricultural Engineering Journal; Volume 25: 39; February, 1944.

APPENDIX

RESULTS OF PRELIMINARY INVESTIGATIONS WITH BULK OR HARVESTED MATERIAL

FOR DETERMINING OPERATING CONDITIONS.

See Flow Diagram of Products For Shutter Numbers

and Damper Opening

Run No.	Desired Disk Speed Under Operating Conditions	Approximate Setting Of Disk Speed When Empty	Approximate Fan Speed Under Operating Conditions	Position of Shutters	Approximate Damper Opening
	RPM	RPM	RPM		
1	150	180	900	All Open	1"
2	250	280	900	All Open	1"
3	350	380	960	All Open	1"
4	450	480	1000	All Open	1"
5	550	590	1000	4 Closed	1½"
6	650	740	1200	4 Closed	2"

It should be recognized that in order to obtain the desired disk speeds under operating conditions the approximate setting of disk speed when empty had to be set fast enough to account for the losses in belt friction, bearings, and the torque-speed characteristic of the huller engine.

THESIS TITLE: THE EFFECT OF DISK SPEED ON THE PERFORMANCE OF AN EXPERIMENTAL CASTOR BEAN HULLER

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The content and form have been checked and approved by the author and thesis adviser. Changes or corrections in the thesis are not made by the Graduate School office or by any committee. The copies are sent to the bindery just as they are approved by the author and faculty adviser.

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