

MECHANIZATION IN PAKISTAN
FOCUS ON
CEREAL GRAIN HARVESTING METHODS AND EQUIPMENT

BY

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CHAPTER

TABLE OF CONTENTS

| CHAPTER | PAGE |
|---|------|
| I INTRODUCTION | 1 |
| II REVIEW OF LITERATURE | 5 |
| III OVERVIEW OF PAKISTAN | 17 |
| IV PRESENT HARVESTING METHODS | 23 |
| 1. CONVENTIONAL METHOD | 23 |
| 2. CONVENTIONAL + MECHANICAL METHOD | 32 |
| 3. MECHANICAL METHOD | 35 |
| A. REAPER BINDER + STATIONARY THRESHER | |
| B. COMBINE HARVESTER | |
| V POTENTIALS FOR MECHANIZATION | 37 |
| VI SITUATION/POSITION AT PRESENT | 41 |
| VII HARVESTING CONDITIONS | 44 |
| VIII CONCEPTUAL DESIGN OF COMBINE HARVESTER | 48 |
| SUITABLE FOR PAKISTAN | |
| 1. SPECIFICATIONS OF THE BASIC MACHINE | 48 |
| 2. DISCRIPTIONS OF MACHINE SYSTEMS AND COMPONENTS | 54 |
| A. HEADER | 54 |
| B. CONVEYING MECHANISM | 61 |
| C. THRESHING MECHANISM | 61 |
| D. SEPARATING MECHANISM | 69 |
| E. CLEANING MECHANISM | 75 |

| | |
|-----------------------|----|
| (F) STRAW SAVER | 78 |
| (1) COMPRESSION BOX | 82 |
| (11) CHOPPER BLOWER | 84 |
| XI LIST OF REFERENCES | 86 |

**THIS BOOK
CONTAINS
NUMEROUS
PICTURES THAT
ARE ATTACHED
TO DOCUMENTS
CROOKED.**

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LIST OF TABLES

| TABLES | PAGE |
|--|------|
| 1 RELATIVE POSITION OF AGRICULTURE SECTOR IN THE GROSS NATIONAL PRODUCT OF PAKISTAN | 18 |
| 2 AREA CULTIVATED AND MAJOR CROPS PRODUCED (in 1980-81) | 20 |
| 3 NUMBER AND AREA OF FARMS BY SIZE OF FARM | 21 |
| 4 FAMILY WORKER AND PERMANENT HIRED AGRICULTURAL LABOR BY SIZE OF FARM | 22 |
| 5 COMPARATIVE PERFORMANCE OF DIFFERENT (LOCALLY MANUFACTURED) THRESHERS AT 600 RPM | 33 |
| 6 ESTIMATES OF AVAILABLE HORSEPOWER PER HECTARE | 39 |
| 7 HARVESTING-THRESHING EFFICIENCY OF DIFFERENT METHODS- EXPERIMENT No 4 CROP WHEAT USDA/PARC PROJECT PK - ARS 8 SIND AGRICULTURAL UNIVERSITY TANDO JAM | 43 |
| 8 SIZE RELATION FOR 1977 MODELS OF SELF PROPELLED COMBINES MANUFACTURED IN THE UNITED STATES OF AMERICA SUMMARIZED FOR FOUR CYLINDER RANGES | 55 |

LIST OF FIGURES

| FIGURES | PAGE |
|--|------|
| 1 SICKLE | 24 |
| 2 PHOTOGRAPH OF FARM LABOR HARVESTING WHEAT CROP WITH SICKLE | 25 |
| 3 PHOTOGRAPH OF FARM LABOR MAKING BUNDLES OF THE HARVESTED CROP AND CARRYING THE BUNDLES TO THE THRESHING FLOOR | 27 |
| 4 THRESHING OPERATION (Photograph) | 28 |
| 5 WINNOWING OPERATION (Photograph) | 30 |
| 6 BAGGING OPERATION (Photograph) | 31 |
| 7 TRACTOR DRAWN STATIONARY THRESHER AT WORK (Photograph) | 34 |
| 8 REAPER BINDER AT WORK IN A RICE FIELD | 36 |
| 9 PLAN OF COMBINE AND TRACTOR | 58 |
| 10 SIDE VIEW OF COMBINE | 59 |
| 11 PICK - UP REEL | 60 |
| 12 SPIKE TOOTH CYLINDER | 63 |
| 13 AXIAL - FLOW RASP - BAR CYLINDER | 66 |
| 14 CROSS - FLOW RASP - BAR CYLINDER | 67 |
| 15 OPEN GRATE CONCAVE FOR CROSS - FLOW RASP - BAR CYLINDER | 68 |
| 16 AXAIL - FLOW CYLINDER | 70 |
| 17 DUAL (Twine) ROTARY AXIAL - FLOW CYLINDER | 71 |
| 18 SEPARATION CYLINDER | 73 |
| 19 SEPARATION CONCAVE | 74 |
| 20 STRAW SAVER -- COMPRESSION BOX | 83 |
| 21 STRAW SAVER -- CHOPPER BLOWER | 85 |

INTRODUCTION

The word " mechanization " is some what misleading. It conjers up a picture of sophisticated machines increasingly engaged in the replacement of human and animal labor. Mechanization in many advanced/developed countries has been occasioned by acute shortages of labor rather than abundance of labor waiting. This situation can be readily distinguished from that of the developing countries, where the need of mechanization goes back to the original context in which tools were made for achieving better production from the tillage of the earth. In other words mechanization in the developing countries is more in the nature of a means of increasing production in a given situation.

Farm mechanizatiion in general has a somewhat wider meaning than indicated, it is comprised of not only highly mechanized and relatively modern equipment, but also conventional or even traditional tools of an improved variety wherher animal drawn or manually used.

Farm mechanization is an important factor for agricultural development in Pakistan. Additional water permits more intensive cultivation, but this is possible only if the land can be cleared of the first crop (standing crop) and prepared for the second crop (next crop) within a few weeks. In the areas with sufficient water, further extension of intensive cultivation has been limited by the lack of sufficient labor and draught power.

The peak periods for labor are those relating to harvesting and threshing of cereal grain crops. It is in this context that mechanization, such as the use of combine harvesters, helps to reduce the peak demand and even bring down

wages for the time being. A point to be remembered is that mechanization in agriculture creates significant employment in industry. Thus it enlarges the industrial base by promoting growth of industrial units for the manufacture of agricultural implements and machinery. In addition, employment opportunities arise for maintenance and services.

Some arguments in favor of mechanization have been forcefully put forward by economists Gotsh [1971] and Falcon [1970].

The basic arguments on which there is general agreement are, presented below.

1. Power and equipment facilitate an increase in crop yields through more timely and effective farm operations. Optimum yields of the new high-yielding varieties depend on correct seed-bed preparation, proper seeding dates, precise fertilizer placement, and the uniform and timely distribution of water and chemicals. All of these can be better provided through mechanization.
2. The possibilities for multiple cropping put a premium on speedy harvesting and land preparation so that the next crop can be planted. This gives rise to peak season labor shortages when demand for human labor exceeds the supply. Mechanization helps output by supplementing labor during peak periods and getting the standing crop harvested and the next crop planted more quickly.
3. Mechanization reduces the dependence on the draught animals, which have low productivity and high costs. These animals require feed (fodder) which utilizes land that would otherwise be available for growing food for human consumption.
4. Mechanization increases the productivity of labor in the agricultural sector of the economy. If standards of living are to rise, this must be the ultimate concern of the developing countries.

5. Mechanization lowers the cost of production by allowing more efficient utilization of land, labor, irrigation, and other inputs. This is important for overall growth of the economy because it permits the generation of savings for investment. It is also important for those countries hoping to lower costs in order to export goods in the world markets.

On the other hand several arguments are made against mechanization, but there is little general agreement. Some of these arguments and the controversy surrounding them are discussed below.

1. In countries where labor is plentiful but capital is in short supply, the scarce resources should not be diverted into agriculture where labor-intensive alternatives are available. The same argument holds for the foreign exchange to purchase tractors, and other farm machinery, which has an even higher cost.
2. Mechanization displaces labor and since no other sector of the economy can readily absorb this labor, substantial social and economic dislocation will occur.
3. Mechanization can accentuate the disparity in income between larger land owners and other farmers by enabling farmers to lower their costs. This may encourage the concentration of land and other resources.

FAO, in a 1969 report, has estimated that 90 percent of the arable land resources in Pakistan will be under cultivation by 1985 and the only way it will be possible to increase output will be to increase productivity per acre. Under these circumstances, mechanization is essential for farming intensification.

Studies show that Pakistani farmers have been remarkably responsive to changes in input and technology. Adoption of improved varieties of seeds and

inputs such as fertilizers and farm machinery has amazed agricultural economists.

The key role mechanization plays in the economic development of countries like Pakistan can not be over emphasized. In fact, there is no way of solving rural development problems without technological change.

However, one must caution against the adverse effect of introducing technological changes indiscriminately.

It has been argued that while scientific principles are universally applicable and transferable, many technologies, particularly those based upon biological technologies, are invariably affected by both:

1. Prevailing physical environments
2. Socio economic environment

Consequently, biologically based technologies which embrace virtually all post-harvest technologies must be elaborated from basic principles, at the place where they are to function and in close cooperation with those who are to use and benefit from these technologies.

To meet current and future food requirements, several lines of action can be taken, such as:

1. An increase in production of food through
 - a) Extension of cultivated land areas.
 - b) Increase in production per unit of land.

2. The prevention and or reduction in the loss of food after production by introducing better, more efficient, economical harvesting and processing methods/techniques.

REVIEW OF LITERATURE

Mechanization

An FAO Publication [FAO,1969] estimates the increase in productivity to be around 20 percent with the introduction of mechanization.

Bose and Clark [1969] reported that a series of experiments undertaken in Pakistan showed about a 30 percent average increase in yields for corn and wheat with the use of mechanization over the traditional methods of farming with bullocks.

Gill [1962] reported an increase of yield from 16 percent to 33 percent as a use of mechanical cultivation over conventional methods.

An FAO study [FAO,1969] emphasizes the desirability for increasing the farm power availability in the developing countries to at least 0.5 horsepower per hectare (0.2 hp per acre).

Giles [1967] concluded that the optimum power inputs are between 0.49 and 0.74 horsepower per hectare [0.2 to 0.3 hp per acre].

CRCFM [1979] concluded that the demand for tractors in Asian countries can be expected to grow at an annual rate of around 12.5 percent till 1985 as opposed to 5 to 9 percent in the rest of the world.

IBRD [1969] an IBRD study regarding cropping intensity showed that on the irrigated farms in the Punjab Province of Pakistan, production increased from 120 percent to 200 percent after the introduction of mechanical draught power.

An IBRD [1968] study showed that the financial return on mechanization resulting from increased intensity of cultivation alone could be expected to be 55 percent.

Government of Pakistan [1970] found that the average utilization of tractors in Pakistan to be around 500 hours per year.

An FAO Publication [FAO,1969] has estimated that in Pakistan, 90 percent of the arable land resources will be under cultivation by 1985 and if such is the case, the only way to increase output will be by increasing productivity per acre.

M. Toaha Qureshi [1978] reported that the future progress in agriculture depends on raising per acre productivity rather than on expansion of area under cultivation, because of limited resources.

M. Toaha Qureshi [1978] reported that the labor is becoming increasingly scarce, especially in peak work load seasons. During harvesting season, labor demand increases (due to high demand) wages rise sharply.

Suri, M. M. [1978] reported that if agricultural mechanization is undertaken for intensive multi-cropping to increase farm productivity, it may appear that labor is displaced on the individual farm. But the area taken as a whole would show that employment has been created and the whole society is elevated to a higher level of education, skills and wage earning thus eliminating the low-paid menial labor force.

S. B. Bukhari [1982] reported that wheat suffers 4 to 6 percent reduction in the yield for each week delay in planting.

Hunt, D. R. [1974] reported that in the northern corn belt of Pakistan it is estimated that each day of delay in planting after May 15th can decrease yield by 60 kg/ha.

UNIDO-PARC [1981] reported the need for promotion of manufacturing of various agricultural machines which have potential for local development and manufacturing in Pakistan. Combine harvester was also among the machines suggested.

A. Tongal [1977] reported that the overall poor performance of livestock in Pakistan is primarily due to over stocking. He suggested that Pakistan should reduce its number of animals especially cattle in the next five years.

W. Van Gilst (FAO) [1977] reported that increasing the power availability at the farm level to improve cultural practices (quality of work) as well as to achieve higher cropping intensity, by increasing the number of animals, especially timeliness of soil preparation and harvesting seems doubtful. It would require additional land for feeding animals.

Harvesting methods/grain losses

The United Nations Economic Commission of Europe [1957], in a comparative study of the methods of harvesting the more common cereals, suggested that the grain losses with the combine harvester were estimated at 1 to 5 percent, as opposed to 8 to 10 percent with the reaper-binder (sp) and 10 to 15 percent when the crop reaped and bound by hand.

Boyace and Rutherford [1972] reported that the total cost of combine harvesting operation could be considered as the sum of machine costs and the value of the grain lost.

Carpenter, et al., [1972] presented a simulation model to analyze costs associated with harvesting, drying, and storing systems for shelled corn. The model gave the means of providing information to evaluate the effect of the size and type of equipment used in the system.

Sanders and Lolor [1972] modified the inventory-cost model of Churhman, et, al., and tried to optimize the machine-size, crop-area relationship. They assumed the machine-crop-weather complex was an inventory model in which the harvesting capacity constituted an inventory for which weather conditions indirectly created a demand. In seasons of bad weather, the number of usable

hours was small and the demand for harvesting capacity was higher than in a good-weather season.

Constain [1973] evaluated a farm machinery system in terms of machine capacity and days available for field work. He was mainly concerned with plowing operations and availability of time corresponding to good working days.

Nyborg, McColly and Hinckle [1969] reported that the walker losses generally accounts for the major portion of total losses with cereal grains.

Madhu, S. Singh [1981] reported that the manual harvesting is tedious and requires about 150 to 175 man-animal-hours/hectare to harvest wheat crop.

Ghulam, S. S, M. Iqbal, and J. K. Sail [1979] concluded that mechanical harvesting and threshing required 4 hours compared to 48 man-bullock hours with conventional methods. The time required with mechanical threshing was 1/8 of the time required for threshing with bullocks and flail.

G. S. Sheikh [1979] reported that harvesting losses with manual operations increased linearly with time, ranging from 3 percent in first week to 7 percent in the third week after ripening of the crop, indicating that the delay of two weeks in harvesting can seriously affect the crop yield.

Threshing/separating.

Lamp and Buchele [1960] defined threshing action as the force applied on the grain in such a manner that the applied force exceeds the force restraining it.

There are three general methods of threshing grain, as stated by Lamp,

(a) Mechanical method applied such as rubbing and stripping.

(b) Impact or impulsive acceleration, as occurs when a cylinder bar strikes unthreshed grain.

(c) Non impulsive acceleration which would result if a head of grain were suddenly accelerated.

Cylinder-concave threshing is accomplished principally by the use of the first two methods.

Lamp and Buchele [1960] stated that wheat kernel can be removed from the heads by holding the stalks in a rotating clamp and applying centrifugal force.

Klein, and Harmond [1966] found that rubber-covered flat bars employed on cylinder and concave for harvesting small-seed legumes, such as Crimson clover, give less damage and less unthreshed loss than conventional cylinders.

Walker, and Schertz [1970] in laboratory tests with small quantities of soybeans, indicated that this crop (like seed grasses and legumes) could be threshed effectively between two belts moving in the same direction at different speeds, with practically no damage to the seeds.

Lalor, and Buchele [1963] designed and tested a truncated-cone threshing unit. One of their objectives was to obtain adequate seed separation with the threshing unit so no additional separating unit (eg: walker's) would be required.

Buchaman, and Johnson [1964] utilized centrifugal threshing and rubbing principles, their objective was to obtain adequate seed separation with the threshing unit so no additional separating unit (eg: straw walker) would be required.

Ettore, Marcello and Atonio [1977] stated that the grains and even stalks of the same field differ from one another in their physical and biological properties. This situation influences the threshing process as the completed ripe grains are attached to their ears less firmly than the less ripe ones, thus requiring a less mechanical action for removal. On the other

hand, the applied forces cause more damage to the riper grains because of higher fragility.

Goss and Kepner [1958] found that the ratio of reel speed to forward speed (reel speed index) should be 1.25 to 1.58 under most conditions in upright crops.

Arnold [1964] conducted extensive laboratory tests. In these tests he found that increasing the concave length increased the seed separation efficiency, but at a diminishing rate. With wheat, the first 169mm (6.67 inch) section removed 52 to 58 percent of the grain and each successive 169mm section, up to a total length of 678mm (26.7 inch), removed about 40 percent of the grain on to that section.

Arnold and Lake [1964] determined that when threshing wheat at 15 percent and 24 percent moisture content, seed damage was substantially greater with the openings of a 356mm [14-inch long] concave covered than with them open, but there was no appreciable effect upon cylinder loss or straw breakup.

Arnold [1964] found that increasing the concave length increased the straw breakup and tended to increase seed damage, especially with low moisture content and high cylinder speeds.

Neal and Cooper [1970] compared a cross-flow rasp-bar cylinder and open grate concave with a spike tooth cylinder and a concave in regard to seed separation through the concave grate, using rice in laboratory tests.

At a non-grain feed rate of 90 Kg/min [200 lbs/min], approximately 72 percent of the grain was separated by the rasp-bar concave grate, but only 50 percent by the spike tooth grate. A spike-tooth concave grate inherently has considerably less open area than the rasp-bar grate.

Arnold [1964] concluded that cylinder diameter was not of major importance in regard to performance and that the diameter should be chosen to suit

the desired concave length.

Bainer and H. A. Brothwick [1934] feel that cylinder speed is the most important operating parameter in regard to cylinder loss and also in regard to seed damage. Increasing the speed reduces the cylinder loss, but substantially increases seed damage. Susceptibility to damage varies greatly among different crops. The seeds of some dicotyledonous plants, such as beans, may be damaged excessively at peripheral speeds as low as 7.6 m/sec [1500 ft/min].

Bunnelle and Jones [1954] concluded that Lindo clover can withstand cylinder speeds of over 36m/sec [7000 ft/min] without appreciable damage.

Arnold [1964] concluded that threshability varies widely with different crops and conditions.

Klein and Harmond [1966] concluded that in determining the best cylinder speed for a field operation, the effect of cylinder speed upon walker loss and shoe loss also need to be considered.

Arnold [1964] compared front/rear clearance ratio of 3 to 1 and 1 to 1 and found very little difference in cylinder loss, visible damage, or germination of Barley or wheat for any given mean clearance. Front-to-rear clearance convergence is generally desirable because the wider front opening tends to improve the feeding characteristics of a cylinder.

Nyborg [1964] concluded that increasing the non-grain feed rate increases cylinder losses. Field tests have indicated that the relation is often about linear.

Nyborg, McColly and Hinkle [1969] reported that the field tests with barley, wheat, oats and rye have indicated that increasing the grain/non-grain ratio usually decreases the percent of cylinder loss at a given non-grain feed rate.

Vas and Harrison [1969] reported that increasing the feed rate tends to

reduce seed damage, although the effect is usually small. The greater density of the layer of material passing between the cylinder and the concave bars at a high feed rates apparently provides more protection for the seeds, thereby reducing the probability of repeated impacts by the cylinder bars.

Arnold [1964] concluded that when harvesting cereal grain crops with combine having rasp-bar-cylinder and open grate concave, 60 to 90 percent of the seed is usually separated through the concave grate.

Neel and Cooper [1970] found in laboratory tests with rice (which generally has tough, high moisture straw) that the percent of separation through the concave grate with the crossflow rasp-bar cylinder was reduced from 72 to 63 percent when the non grain feed rate was doubled.

Reed, Zoerb, and Bigsby [1974] in an analysis of their data in laboratory tests with wheat having a straw moisture content of 9 to 10 percent indicated that increasing the grain/non-grain ratio from 0.7 to 1.00 had no effect upon the separating efficiency at a given non-grain feed rate.

Power requirement/feed rate

Arnold and Lake [1964] found that the power requirement decreased substantially as the cylinder diameter was increased from 305mm to 533mm [12 to 21 inches]. They conducted laboratory tests with a 610mm [24inches] wide rasp-bar cylinder to determine the effects of various factors upon cylinder power requirements.

Arnold and Lake [1964] concluded that a closed concave required about 25 percent more power than an open grate concave at cylinder speeds of 23 to 33 m/sec [4500 to 6500 ft/min].

In the same tests, they found out that increasing the length of open

concave from 338mm to 508mm [13.3 to 20 inches] increased the power requirement by about 10 percent.

Arnold and Lake [1964] found that at a high feed rate, much less power was required to thresh a thin, fast moving input stream of material than to thresh a thick, slow moving stream.

Arnold and Lake [1964] reported that the power requirements tended to increase linearly with cylinder speed, the rate of increase depending upon the operating conditions. In three experiments, the power at 33m/sec [6500 ft/min] averaged 65 % greater than the power at 18m/sec [3500 ft/min]

Arnold and Lake [1964] reported that the cylinder concave clearance had no great effect on power requirement with wheat and barley.

Dodds [1968] reported that main-shaft power requirement for a non-grain feed rate of 90 Kg/min [200 lbs/min], calculated from regression equations for a rasp-bar cylinder, were as follows:

| | GRAIN/NON GRAIN RATIO | MAIN SHAFT POWER, KW [HP] | |
|-------------------|--------------------------|---------------------------|-------------|
| | | DIRECT CUT | WINDROWED |
| HOLLOW-STEM WHEAT | 0.78 | 19.7 [26.4] | 18.5 [24.8] |
| SOLID-STEM WHEAT | 0.66 | 20.6 [27.6] | 19.2 [25.8] |
| BARLEY | 1.13 | — | 15.4 [20.7] |
| OATS | 1.22 | — | 17.5 [23.4] |

Dodds [1968] found that the power requirements when harvesting wheat were 75 to 85 percent as great with the spike-tooth cylinder as with the rasp-bar cylinder.

Arnold [1964] reported that the cylinder generally accounts for a substantial portion of the total power required by a combine harvester.

NIAE [1962] tested three 3.7m [12ft] self-propelled combines in wheat having a grain moisture content of 16 to 18 percent and a grain non-grain

ratio of 0.63. They reported that the total power requirements, including propulsion, were 28 to 41 kw [37 to 55 HP] at a normal non-grain feed rate of .13 to .15 kg/min per millimeter of cylinder width [7 to 8.5 lb/min per inch of cylinder width]. At these feed rates, total energy requirements were 3.5 to 4.4 kwh per megagram of non-grain material [4.2 to 5.4 hph per ton of non-grain material].

Burrough [1954] reported that the power requirements for the separating and cleaning units are small and relatively independent of feed rate.

Dodds [1968] reported that the short-time peak power requirements for the cylinder may be 2 to 3 times as great as the average requirement.

Burrough, D. E. and J. A. Graham [1953] determined the power inputs to various components of an automatic twin-tying baler over wide range of conditions, and found that total power requirements increase less rapidly than the feed rate.

With the dry wheat the plunger power requirements were about double when the bale density increased by only 25 percent from 135 to 168 kilogram per meter cube [8.4 to 10.5 pounds per feet cube].

M. Feldman and E-Z. Jan [1977] investigated the use of wheat straw and chaff as feed source for cow-calf operations and concluded that the advantage in the feed quality is when sufficient chaff is included. The main contributing factor however may be the combine grain loss retained with the straw and chaff.

Burrough, D. E. and J. A. Graham [1953] reported that the peak plunger forces as high as 76KN [17000 lbf] were encountered when baling wheat straw at 5 percent moisture content.

Burrough, D. E. and J. A. Graham [1954] reported that the peak power requirements during the compression part of the stroke were about 8 to 12

times the average plunger power, when baling wheat straw at 5 percent moisture content.

Priepke, E. H. and H. D. Bruhn [1970] reported results of laboratory tests on various mechanical, chemical, thermal and electrical treatments applied to alfalfa. Their results indicated that crushing the stems to increase the amount exposed surface is one of the most effective ways to increase the drying rate.

Nation, H. J. [1961] reported that maintaining a constant hydraulic pressure while baling a clover-rye grass mixture at moisture content from 15 to 49 percent resulted in dry matter densities that were fairly constant [at about 96 kilogram per meter cube (6 pounds per foot cube)]. These results suggest that the coefficient of friction did not change much with particular kind of hay.

W. F. Buchelle, and S. J. Marley [1977] reported that there is inverse relationship between the bulk density of a material and its economic hauling distance. The bulk density of large round balers varies from 64 to 160 kilograms per meter cube (4 to 10 pounds per foot cube).

John B. Dobie [1982] reported that the normal level harvest fallowed by swathing and windrowing has a major disadvantage, in that about 40 percent of the stubble remaining after the harvest can not be collected due to tracts. This reduces the amount of straw that can be collected by about 20 percent.

John B. Dobie [1982] reported that there was a difference in rate of harvest when tall saturated rice was harvested at ground level compared to normal level. The operating time for the harvester and grain bankout wagons for ground level harvest totaled 1.45 hrs/ha (0.5 hr/acre) compared to 1.16 hrs/ha (0.47 hr/acre) for rice harvested at normal level. This was 27 percent increase in time of harvest.

John B. Dobie [1982] concluded that the ground level harvest of rice straw by the grain harvester produces more straw than normal harvest followed by a swather-windrower to collect stubble. Ground level harvest is also effective in leaving the least straw in the field for potential increase in stem rot, but the cost of collection is higher for tall varieties.

John B.Dobie [1982] concluded that the short saturated rice varieties make ground level harvest more practical, since the grain harvester can handle the full straw crop with minimal loss of operating speed. These studies indicated minimal grain losses with ground level harvest compared to normal height of cut.

OVERVIEW OF PAKISTAN

This section is devoted to very brief presentation of Pakistan in general which may assist in understanding the position of the farmer in Pakistan and how he relates to the present labor situation, his access to capital, and his many other agricultural needs.

Present population estimates report that Pakistan has a population of about 80 million inhabitants and a land area of 794,786 square kilometers (307,000 sq. miles), about 25 percent of which is in the fertile plains of Indus valley. In general, the climate is considered to be sub-tropical and semi-arid. According to information published in 1974, of the approximately 79.94 million hectares of land in the country, some 30.76 million hectares are suitable for cultivation (38 percent of the land). Of these 19.43 million hectares (24 percent of the total land) are presently being cultivated.

Of the approximately 19.43 million hectares under cultivation, about 12.95 million hectares, or 67 percent is irrigated, some of which double cropped.

Major crops grown in Pakistan are:

Wheat,
Rice,
Cotton,
Sugercane, and
Corn (maize).

Table 1, presents in summary the relative position of the agricultural sector in the Gross National Product of Pakistan as reported for 1973-74.

Table 1. Relative position of agricultural sector in the gross national product of Pakistan 1973 - 74.

| SECTOR | CONTRIBUTIONS | PERCENT OF TOTAL |
|--------------------------|-------------------|------------------|
| | RUPEES (MILLIONS) | |
| AGRICULTURE | 13.515 | 36.4 |
| MANUFACTURING | 5.808 | 15.6 |
| SERVICES | 2.650 | 7.1 |
| WHOLESALES, RETAIL TRADE | 4.965 | 13.4 |
| ALL OTHERS | 10.227 | 27.5 |
| TOTAL GROSS DOMESTIC | 37.65 | 100.0 |

SOURCE: Pakistan Economic Survey 1973-74, Finance Division Government of Pakistan, Islamabad, Pakistan:1975.

USAID: Pakistan economic development data, June 1975, chapter 4.

NOTE: One U. S. Dollar equal, approximately 10 PAK: Rupees.

Land area and major crop production as of 1980-81 are shown in Table 2. Wheat and rice cropped areas occupies nearly 9 million hectares.

Table 3 presents the number and area of farms classified according to size as of 1972.

The size distribution of farms is also of great importance in view of the fact that the combine, the conceptual design of which is being discussed here, is oriented to the medium and large size farm. Medium and large size farms constitute about 44 percent of the total cultivated area or (8.54 million hectares). In this report medium and large size farms, are farms ranging in size from 10.12 hectares to above 60.72 hectares. Small farms with 5.06 to 10.12 hectares constitute 5.28 million hectares of the total cultivated area, or 27 percent of the total cultivated area.

It is also of interest to consider in this overview, background information of the employment situation in the agricultural sector. Table 4 presents a classification of farms by number of family workers and permanently hired agricultural workers. It is apparent from the information presented in Table 4 that on the small farms, the bulk of the labor force is provided by the family. Many of these may be tenant-farmers (peasents), but the labor is still provided by the families.

It may be seen from Table 4 that out of 11.877 million people engaged in labor only 2.09 million (about 17.6 percent) are engaged on the medium and large size farms (10.12 to 60.72 and over farms). Of this 17.6 percent (2.09 million) 15.45 percent (1.83 million) is family labor and only 2.18 percent (.25 million) is hired labor.

Table 2. Area cultivated and major crops produced in 1980-81.

| CROP | AREA IN MILLION HECTARES | PRODUCTION IN MILLION | YIELD IN |
|---------------|--------------------------|-----------------------|----------|
| | | TONS | KG/HA |
| WHEAT | 6.914 | 11.340 | 1640 |
| RICE | 1.919 | 3.074 | 1602 |
| COTTON (LINT) | 2.000 | 0.934 | 467 |
| SUGAR CANE | 0.823 | 32.140 | 39052 |
| CORN | 0.745 | 0.947 | 1271 |

SOURCE: Pakistan economist, March 20, 1982. Statistical survey of Pakistan's economy Table 1. Area, production and yield of major agricultural crops, PP 39.

Table 3. Number and area of farms by size of farm.

| FARM SIZE (HECTARES) | NUMBER OF | | FARMS AREA | | AVERAGE FARM (HECTARES) |
|----------------------|-----------|-------|------------|-------|----------------------------|
| | FARMS | % | HECTARES | % | |
| UNDER 2.02 | 1,095,038 | 28.15 | 1.0375 | 5.22 | 1.00 |
| 2.02 TO UNDER 5.06 | 1,500,772 | 39.90 | 4.9949 | 25.14 | 3.32 |
| 5.06 TO UNDER 10.12 | 793,928 | 21.11 | 5.2878 | 26.63 | 6.65 |
| 10.12 TO UNDER 20.24 | 289,146 | 7.68 | 3.7308 | 18.78 | 12.90 |
| 20.24 TO UNDER 60.72 | 102,641 | 2.73 | 2.9967 | 15.08 | 39.19 |
| OVER 60.72 | 16,163 | 0.43 | 1.8144 | 9.15 | 112.28 |

SOURCE: Pakistan census of agriculture, 1972 agricultural census organization ministry of food and agriculture, Lahore, Pakistan. 1975 pp 1-5.

Table 4. Family workers and permanent hired agricultural labor by size of farm

| AGRICULTURAL LABOR | | | | | |
|----------------------|------------|-------|----------|-------|------------|
| FARM SIZE (HECTARES) | FAMILY | | HIRED | | TOTAL |
| | ABSOLUTE | % | ABSOLUTE | % | |
| UNDER 2.02 | 2,369,149 | 98.99 | 24,080 | 1.01 | 2,393,229 |
| 2.02 TO UNDER 5.06 | 4,337,397 | 98.17 | 80,499 | 1.83 | 4,417,892 |
| 5.06 TO UNDER 10.12 | 2,865,868 | 96.45 | 105,465 | 3.55 | 2,971,333 |
| 10.12 TO UNDER 20.24 | 1,273,111 | 92.49 | 103,383 | 7.51 | 1,376,494 |
| 20.24 TO UNDER 60.72 | 489,571 | 82.46 | 104,111 | 17.54 | 593,682 |
| OVER 60.72 | 71,843 | 57.43 | 52,380 | 42.17 | 124,223 |
| TOTAL | 11,406,935 | 96.04 | 469,912 | 3.96 | 11,876,853 |

SOURCE: Pakistan census of agriculture, 1972,

Agricultural census organization, ministry of food and agriculture, Lahore,

Pakistan 1975, PP. 22-24.

PRESENT HARVESTING METHODS

Wheat and rice are staple crops in Pakistan. These crops are grown on an area of 8.83 million hectares, representing 45.5 percent of the total cropped area, Table 2 .

HARVESTING AND THRESHING METHODS USED IN PAKISTAN.

1. Manual/conventional method.
2. Conventional + mechanical method.
3. Mechanical method
 - A. Reaper binder + stationary thresher.
 - B. Combine harvester.

1. CONVENTIONAL METHODS

The conventional method is a traditional practice of harvesting cereal grain crops by using sickle (figure 1) with a serrated blade and a wooden handle. The harvesting, collecting, bundling, transporting/conveying, threshing, winnowing and bagging operations are performed by manual-animal power as stated below.

A. HARVESTING OPERATION:

The tool used in this operation is a sickle (figure 1); it is a hand held tool, permitting the worker to grasp the stalk with one hand and simultaneously cut the stalk with the serrated blade, held in the other hand of the harvester (figure 2). It is a very slow and laborious process. About 40 to 50 man hours are required to harvest one hectare with the sickle. Harvesting losses with this method range from 4 to 6 percent.

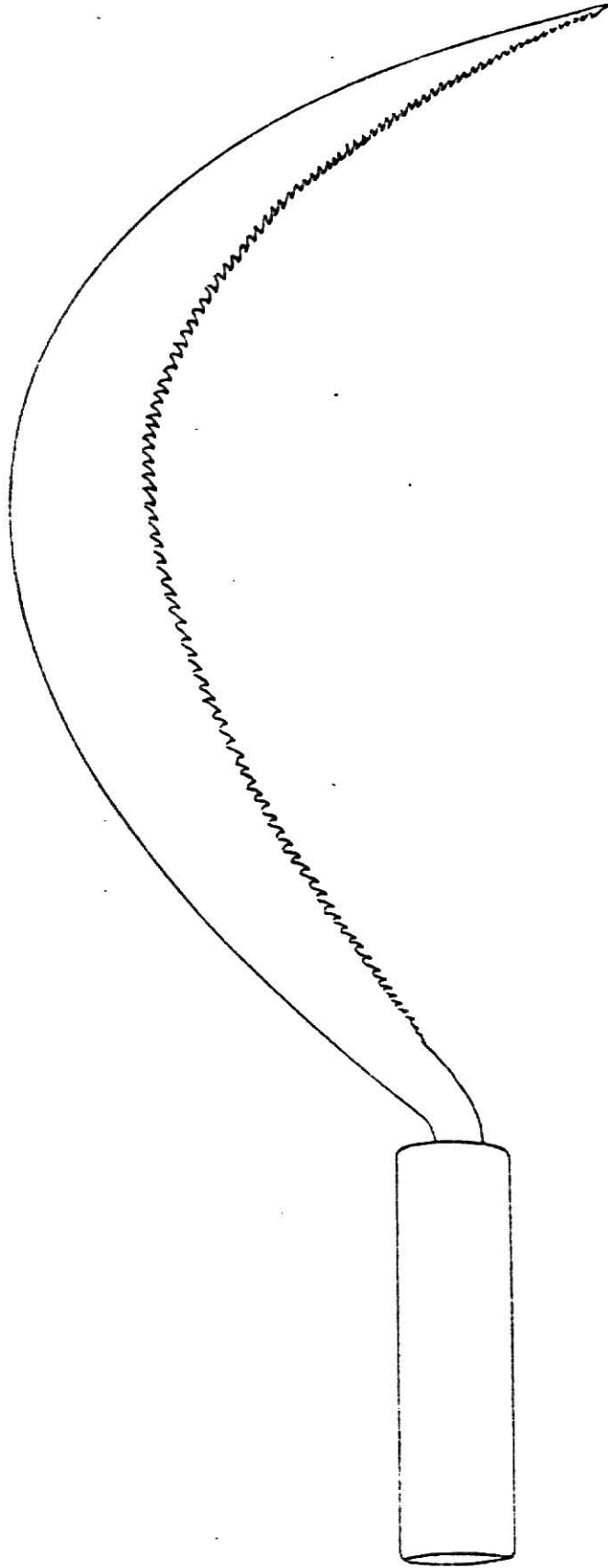


Figure 1. Sickle.



Figure 2. Harvesting Operation

B. BUNDLING/CONVEYING OPERATION:

The harvested crop is collected, bundled and tied with a rope or in piece of cloth measuring 2 by 2.5 meter size (figure 3). Each bundle weighs approximately 25 to 30 kilograms. This operation takes about 20 to 25 man hours/hectare. Grain losses in this operation ranges from 2 to 3 percent.

C. THRESHING OPERATION :

The harvested crop is placed on the threshing floor in a cone shaped heap and threshed by moving large twigs of a thorny tree interwoven with straw around and through it (this local implement is commonly known as a "Phala"). The phala is driven around the heap by the bullocks at the edge of the heap and slowly moved towards the center of the heap by bringing the material, bit by bit, under the "phala" (figure 4). This threshing operation is very time consuming and tedious, it takes about 45 to 55 man-bullock hours per hectare. Grain loss with this threshing operation ranges from 5 to 8 percent/hectare.

D. WINNOWING OPERATION:

The threshed material is placed in a pan (2 by 2.5 ft in size, made from sticks or tin sheet) and dropped at man's arm raised length (about 7 to 8 feet height) by vibrating and lowering the front portion of the pan. (figure 5). The operation is dependent on the direction and velocity of the wind currents as the operation can only be performed when the wind is blowing across/away from the threshed heap of the material. In this manner the light straw and chaff are blown away from the place and the grain falls to the ground. The operation is repeated several times, until all the grain is completely separated from the MOG, (material other than grain).

This also is a very tedious and time consuming operation. It takes about 20 to 30 hours/hectare to separate the grain from the MOG. The operation may



Figure 3. Bundling/Conveying Operation



Figure 4. Threshing Operation

be completed in two consecutive days or within a few days, depending upon the weather conditions. Grain losses for the winnowing operation range from 4 to 8 percent.

E. BAGGING OPERATION :

Clean grain is weighed and poured into jute bags; each bag has a capacity of 100 kilograms of wheat. Bagging takes about 5 hours/hectare (figure 6).

Harvesting and threshing of one hectare of cereal grain crop (wheat) by conventional method takes about 130 to 165 man-bullock hours/hectare. (Harvesting, bundling/tying and conveying/transporting operations are performed manual labor for 85 to 110 man hours/hectare, and the for threshing operation bullocks are driven on the crop for 45 to 55 man-bullock hours/hectare).



Figure 5. Winnowing Operation



Figure 6. Bagging Operation

2. CONVENTIONAL + MECHANICAL METHOD

A. CONVENTIONAL PORTION:

The harvesting, bundling/tying and conveying/transporting operations are performed as discussed earlier. All the operations performed in the conventional portion of this method take about 85 to 110 man hours/hectare and the grain loss ranges from 10 to 17 percent per hectare.

B. MECHANICAL PORTION (Threshing Operation)

The grain bearing straw is fed into the stationary thresher manually (figure 7). Six men feed the stationary thresher for 5 to 7 hours to thresh an average yield of one hectare, depending upon the capacity of the thresher and the variety of crop being threshed. Thresher which are locally manufactured in Pakistan are given in table 5.

Table 5. Comparative performance of different threshers at 600 rpm.

| MAKE OF THRESHERS | OUT PUT KG/HR | PERCENT PURITY | PERCENT BREAKAGE | PERCENT "GHUNDI" LOSS (UNTHRESHED) |
|-----------------------------|------------------|-------------------|---------------------|--|
| 1 MUGHAL (FAISALABAD) | 451 | 96 | 0.41 | 3.58 |
| 2 CHAZI & Co (MAIN CHUNNUN) | 352 | 95 | 4.17 | 0.83 |
| 3 SUN LIGHT (BUREWALA) | 354 | 94 | 6.00 | — |
| 4 L.E.F.O (LAHORE) | 294 | 96 | 3.00 | 0.41 |
| 5 ITEFAQ | 415 | 98 | 2.00 | ---- |

SOURCE: Agricultural mechanization in Asia Summer 1980. Harvesting and threshing losses of wheat with mechanical and conventional methods, PP: 66-70.



Figure 7. Stationary Thresher in operation

3. MECHANICAL METHOD

A. Reaper binder + stationary thresher:

(a) Harvesting and binding operation:

The harvesting and binding operation is performed by tractor drawn reaper binder. The reaper binders are imported in Pakistan. The commonly used width of cut of the reaper binder is 1.5 meters. A synthetic fiber twine used is expensive and increases the cost of the harvesting operation substantially. To overcome the problem of high cost and unavailability of the synthetic twine at the peak required time, a jute fiber twine treated with wax is in the trial stage.

The necessity of hand harvesting the crop at the corners of the field before getting the machine into the field is an obstacle to the acceptance of the machine. This reaper binder takes 4 to 5 hours to harvest one hectare.

(b) Conveying/transporting operation is performed manually as discussed earlier.

(c) Threshing and cleaning operation is performed by a tractor/electric motor driven stationary thresher, as discussed previously.

(d) Bagging operation is performed manually, as discussed earlier.



Figure 8. A reaper binder operating in field

POTENTIALS FOR MECHANIZATION

Most nation have been endeavouring to achieve economic prosperity through the exploitation of resources to optimum use. The increasing demand for food and fiber makes agriculture the most important sector of the national economy. However, in Pakistan agriculture's share of the gross national product is about 36.4 percent, while employing about 72 percent of the population, which results in a very low per capita income.

Extremely low productivity of farm labor using ineffective, primitive methods of cultivation, with inadequate and uneconomic capital investments on farms, makes the introduction of technological improvements imperative.

The change from man-animal labor to tractor power [mechanization] is essential to free the land used to grow fodder to feed the animals, for growing other crops of higher priority. One bullock's fodder requirement takes away the equivalent of land required for feeding two humans. Farms in Pakistan have employed about 10.55 million draft animals, therefore taking away the equivalent of land required for feeding 21.10 million people. It is urgent to use such land for raising milk and meat animals in order to produce more food.

The replacement of draft animals by power machines and the use of agricultural machines, supplemented by bio-hydro-chemical technologies, should increase agricultural production in Pakistan. The increase in industrialization and educational facilities, is shifting labor from farm to towns, seriously reducing the availability of farm labor. Moreover, scarce labor and land relatively abundant, make farm mechanization an important growth factor.

The present level of power input in Pakistan's agriculture has been estimated as follows:

| | Horse power per hectare |
|---|-------------------------|
| 1. Human power | 0.041 |
| 2. Animal power | 0.180 |
| 3. Mechanical power (exclusive of tube wells) | 0.231 |
| | ----- |
| [see table 6] | 0.452 |

By the end of 1978, about 90,000 tractors of various makes and models had been imported into Pakistan. The present the tractor population is estimated to be over 100,000 units. It has been estimated that a minimum of 0.5 horse power per hectare is necessary in developing countries for agricultural development and for obtaining adequate crop yields. Pakistan is barely meeting this minimum requirement of power, i.e, 0.5 horse power per hectare, as can be observed from the present power availability/requirements and estimated units of tractors available by the end of 1982. In fact, the present situation is such that four tractor manufacturing plants are under construction and within 2 to 3 years, increased manufacturing by these four companies in the horse power range of 45 to 65 will begin.

The tractors presently being used in Pakistan are in the 45 to 65 horse power range and use hours range from 400 to 800 hours per year. Tractors and other agricultural machinery have not been utilized enough in Pakistan. This is because tractor use has been confined mainly to preparatory tillage, pre-sowing operations and transportation.

Some of the major reasons for the under utilization of tractors are:

1. High initial cost of machines.
2. Lack of advisory service for the farmers.

Table 6. Estimates of available horse power per hectare for agriculture in Pakistan.

| POWER SOURCE | NUMBER IN MILLIONS | TOTAL POWER AVAILABLE IN MILLION HORSE POWER | HORSE POWER PER HECTARE |
|--------------|--------------------|---|----------------------------|
| HUMAN | 12.00 | 0.800 | 0.041 |
| WORK ANIMAL | 10.55 | 5.43 | 0.1808 |
| TRACTORS | 0.10 | 4.5 | 0.231 |
| TOTAL | | | 0.452 |

1. Exclusive of irrigation pumps. Power value used for human, work animals, and tractors are 1/5, 1/3, and 45 horse power respectively.

2. Based on 19.43 million hectares of cultivated land.

3. A population of 100,000 tractors was used on the basis that 90,000 tractors were in operation in late 1978. (Cumulative report Pakistan tractors corporation limited June 30, 1978). According to demand projection worked out for agricultural machines and tractors (Estimated 162,000 by end 1982). But an adjustment was made so we take a approximate figure of 100,000 tractor units working at present.

3. Lack of service facilities.
4. Imported machines not giving best results due to difference of biological, environmental, field, and socio-economic conditions between the place of manufacture and the place where the machine is used, resulting in discouragement of the farmers.
5. Unavailability of locally manufactured machines.

SITUATION/POSITION AT PRESENT

At present, the demand for preparatory tillage and cultivating equipment is fulfilled by locally manufactured implements. Sowing, fertilizer and spraying equipment is manufactured in some quantity and the rest of the demand is partially filled by importing these machines.

EQUIPMENT AVAILABLE:

1. Combine harvester:

A small number of imported combines [self-propelled and tractor drawn] is used on the progressive farms and some machines are run on custom hire basis.

2. Reaper binder :

Limited numbers of imported [self-propelled and tractor drawn] reaper binders are used on medium and large farms.

3. Threshers:

About 20,000 to 30,000 locally manufactured threshers are being operated on medium and large farms and on custom hire basis. Present estimates show that there is a great demand in Pakistan for agricultural implements, ranging from sowing to harvesting and threshing machines. This is confirmed by the number of implements being used and by project demand survey. This demand will increase rapidly when assembly lines of the four tractor manufacturers begin production.

In summary the need of agricultural machines and implements will continue increase because of the following factors.

1. Local manufacturing of the tractors will further increase the demand for agricultural machines/implements.
2. Increase in industrialization and education will cause agricultural labor to shift from farms to towns
3. There is need to improve crop yields.
4. Millions of hectares used for fodder for draft animals must be converted to production of human food.
5. Timeliness of operations must be improved.
6. Losses of all agricultural products, including food and fiber must be reduced.

An experiment was performed in which harvesting and threshing losses of wheat were measured using different methods of harvesting. The time required, cost, efficiency and grain losses in each of operational method are reported in table 7.

Table 7. Time required, efficiency, cost, grain lost, total cost [operational-cost + value of grain lost] per hectare. For harvesting and threshing of one hectare of wheat [1640 kilogram yield per hectare] by different methods.

| METHOD | TIME REQUIRED Hrs/Ha | EFFICIENCY % | OPERATIONAL COST US \$/Ha | GRAIN LOSS % | TOTAL COST COST+VALUE OF THE GRAIN LOST US \$ /Ha |
|----------------------------|----------------------------|-----------------|---------------------------------|--------------------|---|
| MANUAL/CONVENTIONAL | 140 | 84.41 | 81.46 | 15.59 | 122.24 |
| CONVENTIONAL+MECHANICAL | 100 | 87.56 | 64.58 | 12.44 | 94.76 |
| MECHANICAL | | | | | |
| (1) REAPER BINDER+THRESHER | 37 | 90.71 | 49.86 | 9.29 | 72.40 |
| (11) COMBINE HARVESTER | 3 | 96.95 | 37.06 | 3.05 | 45.55 |

SOURCE: Harvesting and threshing of wheat by different methods, experiment number 4 crop wheat USDA/PARC project PIC-ARS 8 Sind Agricultural University Tando Jam, Sind, Pakistan.

Pakistan Tractors Corporation Limited 1978 Combine harvester model MS-70 trials.

Harvesting and threshing losses of wheat with mechanical and conventional method University of agriculture Faisalabad Pakistan.

HARVESTING CONDITIONS

1. Major cereal grain crops :

- A. The major cereal grain crops are wheat and rice.
- B. Area cropped under each of these crops is 6.9 and 1.9 million hectares, respectively. About 45 percent of the total cultivated million hectares are cropped under both crops.
- C. The average yield of these crops is 1.64 ton per hectare and 1.6 ton per hectare, respectively.

2. Harvesting and threshing methods presently used are:

- A . Conventional method.
- B . Conventional + mechanical method.
- C . Mechanical method.
 - a. Reaper binder + thresher.
 - b. combine harvester.

3. Field formation and layout :

About 12.95 million hectares, or about 67 percent of the cultivated area, are irrigated. Irrigation practices commonly used are:

- A. Flooding.
 - a. wild flooding.
 - b. controlled flooding.
- B. Furrow irrigation.

Ditches are used for irrigation water conveyence to the land and on the farm. Due to the topography of the farms and lower initial cost of operation of the above mentioned irrigation practices, and in effort to increase

irrigation efficiency, the farmer uses small plots and makes on farm irrigation facilities such as borders, checks, basins, and levees. Thus he loses 10 to 15 percent of good crop land. Small size plots also make it difficult for the farmer to use larger machines 20 to 30 feet long, 15 to 20 feet wide.

4. Climate:

Climate and weather are most important factors in the agricultural productivity. The climate in Pakistan is variable and unpredictable. The monsoon rains are scanty and do not adequately supplement irrigation. However, occasional unexpected rains cause floods and damage the standing crop. Due to lack of communication regarding weather information and time delays due to ineffective, primitive methods used for harvesting and threshing of cereal grain crops, huge quantity (millions of kilograms) of cereal grain are lost every year.

5. Labor:

There has not been sufficient available labor to harvest the entire major cereal grain crops. Consequently, substantial quantities of cereal grain are lost due to delay in harvesting operations, use of ineffective, primitive methods, ineffective labor.

At the peak of harvest, the scarcity and unavailability of labor increases the labor cost. This results in the farmers having to pay 250 to 300 rupees [about 19 to 27 U. S. dollars] per hectare, just for the harvesting of the crop.

Approximately 50 percent of the harvest labor is not normally occupied in agriculture, so if the harvest labor is reduced to 50 percent, it need not

affect the income of those who are normally engaged in farm labor, it may be noted from Table number 4 that out of the total labor force of 11.87 million, only 2.09 million (representing 17.6 percent) are engaged on the medium and large size farms, which constitute 43 percent of the total cultivated area. Since the first phase of mechanization of harvesting and threshing of cereal grain crops starts with medium and large size farms, it is clear that there will not be a large displacement of labor. Unemployment would not be a factor in inhibiting the introduction of mechanization in the harvesting and threshing of cereal grain crops.

6. Duration of harvesting period

The harvesting period ranges from 1 to 1.5 months, e.g, harvesting of wheat starts at the end of March and ends in mid of May.

7. Grain losses

The U. N. general assembly adopted a resolution in 1975, urging all countries and international agencies to cooperate in an effort to achieve a 50 percent reduction in food loss by 1985.

In Pakistan harvesting and threshing losses vary from 3 to 15 percent [see table 7] depending upon the method of harvesting and threshing used.

When the crop is allowed to remain in the field after the physiological maturity, the dry weight and quality of the grain decreases. The combined effect of variations in temperature, relative humidity, percent sunshine, wind velocity and rainfall causes variation in vapor-pressure difference between the grain and the atmosphere. This difference causes the grain to lose or gain moisture depending on which pressure is greater.

The intermittent wetting and drying of grain, during the daily cycle of evaporation and condensation weakens the grain attachment making it more susceptible to shattering. Because weather is beyond the control of humans, an attempt to harvest during favorable weather condition is desirable, but this generally is possible only by using faster, mechanized means of harvesting and threshing of cereal grain crops.

CONCEPTUAL DESIGN OF COMBINE HARVESTER SUITABLE FOR PAKISTAN

1. SPECIFICATIONS OF THE BASIC MACHINE

DIMENSIONS

| | |
|---|------------------|
| OVER ALL WIDTH | 2.32 M (7.60 FT) |
| OVER ALL WIDTH (Combine mounted on tractor) | 2.87 M (9.40 FT) |
| OVER ALL LENGTH | 5.70 M (18.7 FT) |
| OVER ALL LENGTH LESS HEADER | 4.48 M (14.7 FT) |
| OVER ALL LENGTH LESS HEADER AND STRAW SAVER | 3.57 M (11.7 FT) |
| HEIGHT | 2.00 M (6.5 FT) |
| WHEEL BASE | 2.66 M (8.7 FT) |
| POWER REQUIREMENT (At 540 rpm of tractor p.t.o) | 22 Kw (30.0 HP) |

2. SPECIFICATIONS OF THE MACHINE MECHANISMS

A. HEADER:

| | | |
|-----|---------------------------|---------------------------------------|
| (a) | CUTTING WIDTH | 1.828 M (6 FT) |
| (b) | CUTTING HEIGHT | 40 TO 400 mm |
| (c) | CUTTING HEIGHT ADJUSTMENT | HYDRAULIC |
| (d) | CUTTER-BAR FLOATATION | RELIEF SPRING |
| (e) | DIVIDER | 5 (2 ADJUSTABLE) (2 SIDE DIVIDERS) |
| (f) | GRAIN LIFTERS (No's) | 6 |
| (g) | STEEL FINGERS (No's) | 20 |

| | | |
|-----|--------------------------------------|--|
| (h) | DOUBLE STEEL FINGERS (No's) | 2 |
| (i) | CUTTER BAR | 1 |
| (j) | KNIFE SPEED | 477 CYCLES/min. |
| (k) | PICK UP REEL | FOUR SECTION SPRING TIME |
| (l) | PICK UP REEL HEIGHT ADJUSTMENT | HYDRAULIC |
| (m) | PICK UP REEL FLOATATION | RELIEF SPRING |
| (n) | PICK UP REEL FOR AND AFT MOVEMENT | LEVER (MANUALLY) |
| (o) | PICK UP REAL SPEED | 15 TO 40 RPM. |
| (p) | AUGER | END FEED |
| (q) | AUGER HEIGHT | ADJUSTABLE |
| (r) | QUICK CLUTCH | INSTANT STOP FOR ENGAGING AND DISENGAGING CUTTING PLAT FORM. |

B. CONVEYING MECHANISM:

| | | |
|-----|------------------------|---|
| (a) | FEEDER CONVEYOR | 2 CHAINS ON SPROCKET 14 SLATS BOLTED ON CHAIN |
| (b) | FEEDER CONVEYOR HEIGHT | ADJUSTABLE |
| (c) | STONE TRAP | FRONT EMPTYING |

C. THRESHING MECHANISM:

| | | |
|-----|-----------------------|---------------------|
| (a) | DRUM TYPE | CROSS-FLOW RASP-BAR |
| (b) | DRUM (CYLINDER) WIDTH | 675mm [26.6 in] |
| (c) | DRUM DIAMETER | 450mm [17.71 in] |
| (d) | DRUM SPEED RANGE | 460 - 1460 rpm |

| | | |
|-----|--------------------|--|
| (e) | RASP BAR No's | 6 |
| (f) | DRUM PLATES No's | 4 |
| (g) | CONCAVE TYPE | OPEN GRATE |
| (h) | CONCAVE LENGTH | 350mm |
| (i) | CONCAVE AREA | 0.236 sq. meter [2.54 sq. ft] |
| (j) | CONCAVE RADIUS | 225mm [8.85 in] |
| (k) | CONCAVE BAR No's | 9 (varies with crops) |
| (l) | CONCAVE WIRES No's | 48 |
| (m) | CONCAVE ADJUSTMENT | ECCENTRIC ONE LEVER ENTRY AND EXIT TOGETHER |

D. SEPARATING MECHANISM:

| | | |
|-----|-------------------------------------|--|
| (a) | TYPE | MULTI-SERRATED CYLINDER AND OPEN GRATE CONCAVES |
| (b) | SEPARATION CYLINDERS No's | 3 |
| (c) | WIDTH OF SEP:CLY: | 675mm [26.6 in] |
| (d) | DIAMETER OF SEP:CLY: | 450mm [17.71 in] |
| (e) | SERRATED BARS No's | 6 |
| (f) | SEPARATION CYLINDERS SPEED RANGE | 430 - 810 rpm |
| (g) | CONCAVE No's | 3 |
| (h) | CONCAVE BAR No's | 9 (varies with crops) |
| (i) | CONCAVE WIRES No's | 48 |
| (j) | CONCAVE ADJUSTMENT | CENTRALLY (collectively) ADJUSTABLE |

| | | |
|-----|-----------------------|----------------------------------|
| (k) | CONCAVE LENGTH | 400mm [15.74 in] |
| (l) | CONCAVE AREA | 0.27 sq. meter [2.91 sq. ft] |
| (m) | CONCAVE RADIUS | 225mm [8.85 in] |
| (n) | TOTAL SEPARATION AREA | 0.912 sq. meter [9.817 sq ft] |

E. CLEANING MECHANISM:

| | | |
|-----|---|---|
| (a) | TYPE | ROTARY CLEANING |
| (b) | FAN | high performane |
| (c) | FAN BLAST | Adjustable via a variator |
| (d) | DIRECTION OF BLAST | Adjustable externally |
| (e) | CYLINDRICAL SIEVES No's | 2 |
| (f) | INNER CLY:SIEVE DIA: | 457mm [18.0 in] |
| (g) | INNER CLY:SIEVE LENGTH | 915mm [36.0 in] |
| (h) | INNER CLY:SIEVE HOLE CONFIGURATION | ROUND (varies with crops) |
| (i) | INNER CLY: SIEVE HOLE DIA | 8mm [.314 in] Vareies with crop |
| (j) | INNER CLY: SIEVE AREA | 1.64 sq. meter [17.7 sq. ft] |
| (k) | INNER CLY: SIEVE VOLUME | 0.15 meter cube [5.30 feet cube] |
| (l) | INNER CLY: SIEVE SPEED | |
| (m) | INNER CLY: SIEVE AREA PER mm OF CYLINDER WIDTH | 24.3 sq. cm/mm [95.66 sq. inches/inch] |
| (n) | OUTER CLY: SIEVE DIA: | 610 mm [24 inch] |
| (o) | OUTER CLY: SIEVE LENGTH | 915 mm [36 in] |

| | | |
|-----|---|---|
| (p) | OUTER CLY: SIEVE HOLE CONFIGURATION | ROUND (varies with crop) |
| (q) | OUTER CLY: SIEVE HOLE DIA: | 6 mm [0.236 in] |
| (r) | OUTER CLY: SIEVE AREA | 2.33 sq. meter [25.1 sq. ft] |
| (s) | OUTER CLY: SIEVE VOLUME | 0.266 meter cube [9.42 feet cube] |
| (t) | OUTER CLY: SIEVE SPEED | |
| (u) | OUTER CLY: SIEVE AREA PER mm OF CLY: WIDTH | 34.63 sq. cm/mm [136.1 sq. inch/ in] |
| | TOTAL CLEANING AREA | 3.98 sq. meter [42.8 sq. ft] |
| | TOTAL CLEANING VOLUME | 0.416 meter cube [14.72 feet cube] |
| | TOTAL CLEANING AREA PER mm OF CLY: WIDTH | 58.95 sq. cm/mm [231.76 sq. inch/inch] |

F. SECOND CLEANING AND BAGGING:

| | | |
|-----|--------------------------|---|
| (a) | TYPE | ROTARY WITH CYLINDRICAL, GRADED SIEVE AND CARRIER. |
| (b) | INLET | |
| (c) | AUGER | |
| (d) | CARRIER | |
| (e) | CYLINDRICAL SIEVE DIA: | 304mm [12 in] |
| (f) | CYLINDRICAL SIEVE LENGTH | 915mm [36 in] |

| | | |
|-----|--|--|
| (g) | CYLINDRICAL SIEVE HOLE CONFIGURATION. | ROUND (varies with crop) |
| (h) | CYLINDRICAL SIEVE HOLE SIZE | 6mm [0.236 in] (varies with crop) |
| (i) | CYLINDRICAL SIEVE AREA | 1.02 sq. meter [11 sq. ft] |
| (j) | CYLINDRICAL SIEVE VOLUME | 0.067 meter cube [2.355 feet cube] |
| (k) | SPOUTS (outlets) No's | 3 |
| (l) | CLIPS FOR BAGS No's | 3 (2 For grade A and B grain) (1 For dust, weed seeds and chaff pieces etc.) |
| (m) | SPEED OF CARRIER | |

DESCRIPTION OF MACHINE SYSTEMS AND COMPONENTS

A. HEADER :

The header is the portion of combine comprising the mechanisms for gathering the crop. The header is a complete assembly which embodies the components cutter bar, the reel, the auger, and the feed conveyor.

Determining the most desirable and economical combination of capacities of the different functional units in a multi-crop combine harvester presents a problem which necessitates compromise.

The header width requirements are related to the capacities of the threshing, separating, and cleaning units, crop yields, plot size, and the range of forward speeds desired.

Size relation for 1977 models of self-propelled combines manufactured in the United States of America are summarized in table number 8 for four cylinder width ranges.

(a) CUTTER BAR:

The cutter bar is a device on the header for severing the plant stalk by reciprocating action. A knife 1.828 meter [6 ft] long, comprised of 24 (3inch) blades is driven by a crank in a reciprocating action.

The cutting width of 1.828 meter [6 ft] has been selected because of general field/road conditions, and the size of the fields on which the cereal grain crops are grown in Pakistan.

The plot sizes for cereal grain crops adopted by farmers in Pakistan range from 0.202 to 3.24 hectares [0.5 to 8 acres]. Generally a 0.404 hectare [1 acre] plot size is used by medium and large size farmers.

Cutter bar floating action, i.e. height above ground, is obtained by a relief spring tightened to the degree required, by the use of a turn buckle [See Side/section view figure 10 pos: 15].

Table 8. Size relation for 1977 models of self propelled combines manufactured in the United States of America summarized for four cylinder ranges.

| RANGE | CYLINDER WIDTH | | HEADER WIDTH | | AVERAGE AREA | |
|-----------|----------------|-------|--------------|-------------|--------------------------------|----------------------------------|
| | MILLIMETERS | INCH | METERS | (FEET) | CM SQ: PER MM OF CLY: WIDTH | IN SQ: PER INCH OF CLY: WIDTH |
| | AVG: | RANGE | AGE: | AVG: MIN: | AVG: MAX: | WALKER SHOE SIEVE |
| 685-840 | 757 | 27-33 | 29.8 | 3.35 (11.0) | 4.51 (14.8) | 30.2 (119) 22.1 (87) |
| 915-1015 | 983 | 36-40 | 38.7 | 3.87 (12.7) | 6.16 (20.2) | 30.5 (120) 23.6 (93) |
| 1120-1320 | 1212 | 44-52 | 47.7 | 4.02 (23.2) | 6.95 (22.8) | 36.3 (143) 25.4 (100) |
| 1395-1525 | 1461 | 55-60 | 57.5 | 3.96 (13.0) | 7.32 (24.0) | 34.5 (136) 25.9 (102) |

SOURCE: IMPLEMENT AND TRACTOR RED BOOK, JANUARY, 31, 1977.

NUMBER OF MODLES LISTED IN THE FOUR CYLINDER SIZE GROUPS,

FROM TOP TO BOTTOM 4, 9, 15, 2.

(b) DIVIDERS:

Dividers part the crop and determine the effective cutting width of the machine. [figure number 9 pos: 6] The divider has the effect that the crop on the right side is laid in front of the pickup reel.

(i) FOR STIFF-STRAWED AND UPRIGHT CROPS: There are two easily adjustable side dividers which help in separating the standing crop and define the swath to be cut.

(ii) FOR LODGED CROPS: A big steel rod loop, when mounted on the right side divider helps in lifting the lodged crop.

(c) CROP LIFTERS:

Spring-steel crop lifters which are part of the standard equipment, lift the low-lying (lodged) straw out of the green growth. The number of spring-steel lifters to be fitted depends on the field and crop conditions and the kind of crop.

(d) REEL: [Figure number 11 and figure number 10 position 3]

The reel is positioned above the knife, where it rotates and gathers the crop into the machine as the cut is made.

Although fixed bat-reels are less expensive and simpler than pickup reels and work well in upright crops, the pickup reel is more effective in lodged (down) crops such as rice. The pickup reel operates ahead of the cutter bar and also works satisfactorily in upright crops.

The pickup reel is equiped with cam operated, adjustable spring tines. The pickup reel is adjustable both vertically and horizontally, with respect to cutter bar. (Figure number 11 pos: 2 and 3). A hydraulic height adjustment,

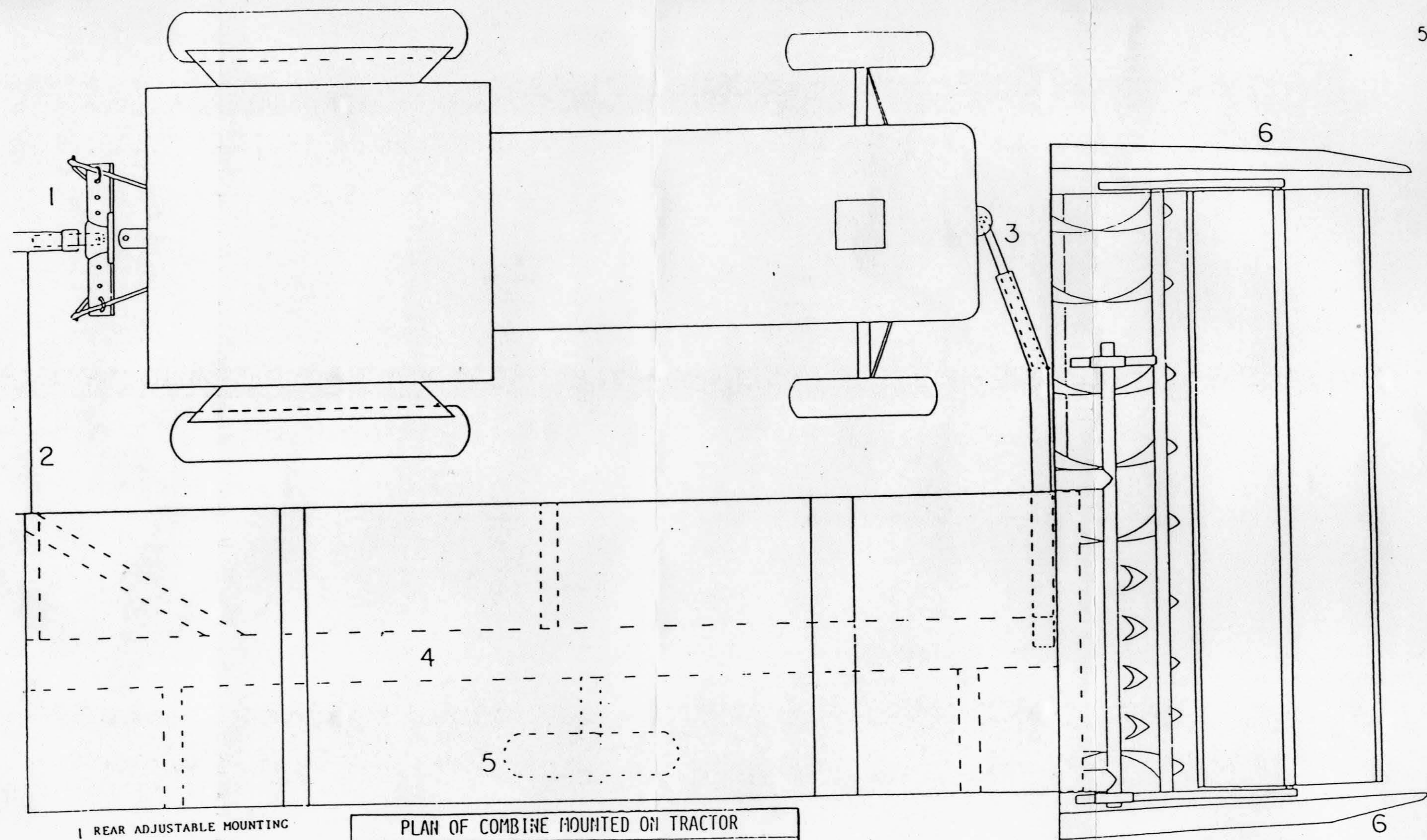
controllable from the operator's platform, is provided.

The for and aft movement of the pickup reel is adjusted manually by shifting the hole on the guide (Figure 11 pos: 3) on the reel frame, thereby moving the reel (figure 11) forward or backward with the lever as required. The pickup reel speed needs to be easily adjustable to accommodate different crop conditions and different crops, and to compensate for different forward speeds.

The speed of the pickup reel can be adjusted by the handle (Figure 11 pos: 1). The adjustment must be made so that the speed of the reel corresponds to the ground speed of the combine. In moist, green crops and lodged crops, it is advantageous to increase the reel speed.

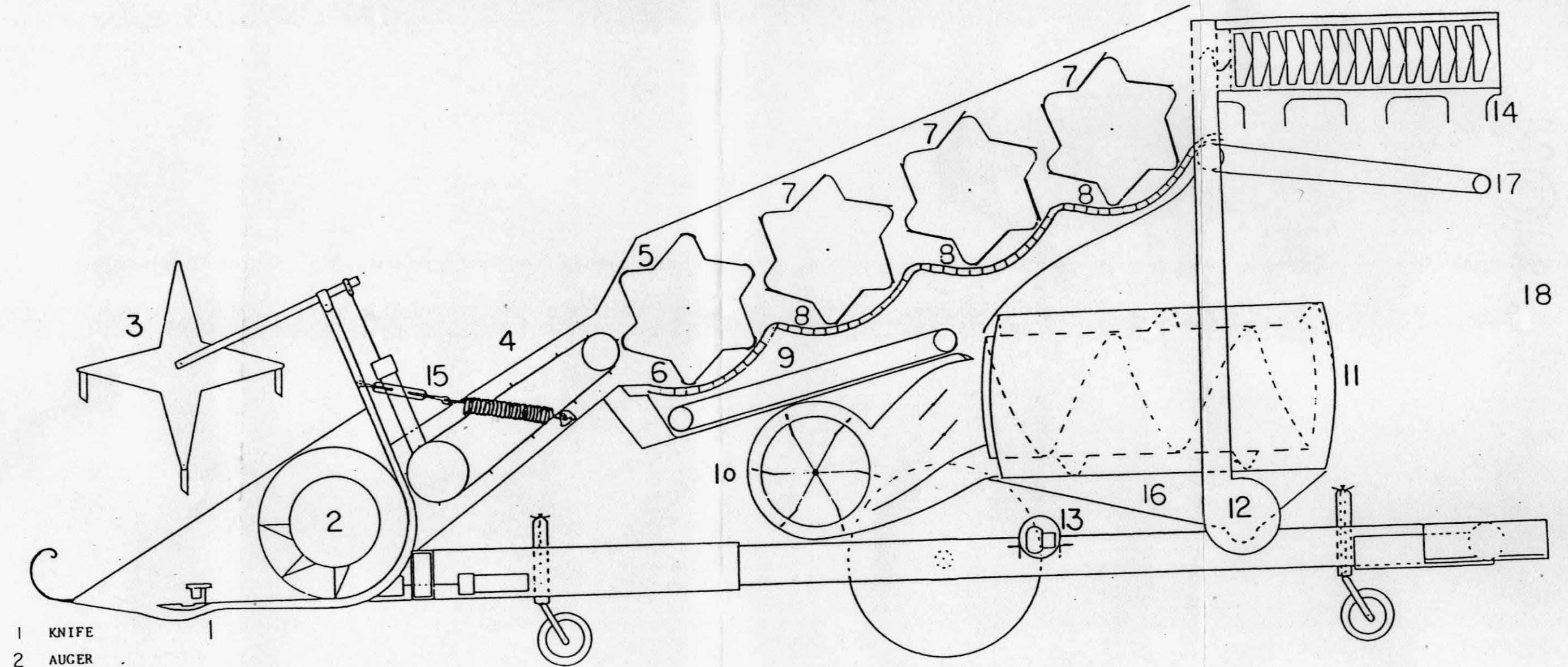
(e) AUGER: [Figure number 10 position 2]

The auger has left hand spiral vanes. These gather the crop from the extreme of the cutter bar and discharge it on to an end feed conveyor by means of retracting fingers. The auger can be moved vertically by means of an adjusting bolt.



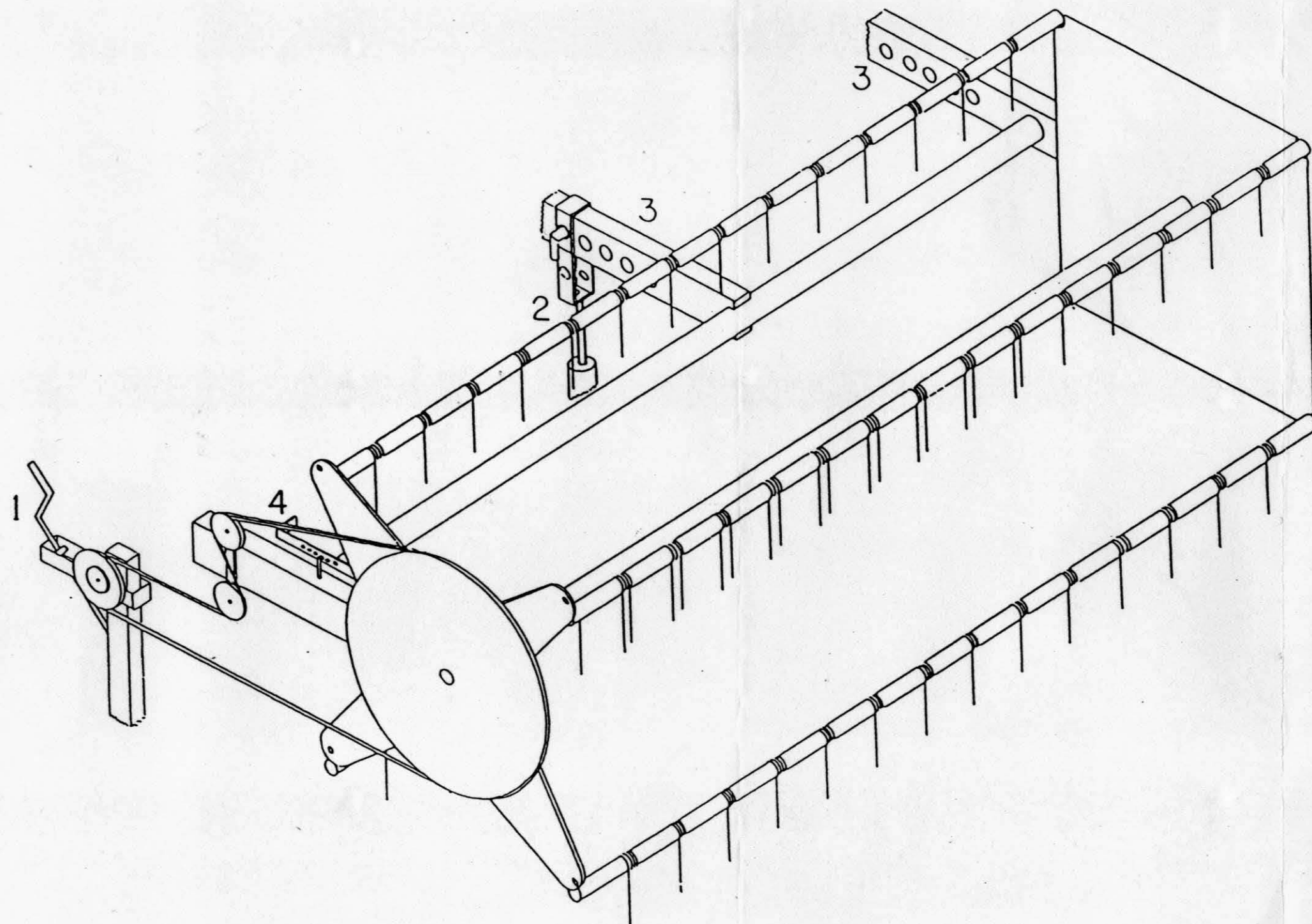
- 1 REAR ADJUSTABLE MOUNTING
- 2 ADJUSTABLE MOUNTING BAR
- 3 FRONT ADJUSTABLE MOUNTING
- 4 MAIN BASE FRAME
- 5 WHEEL
- 6 DIVIDER

| PLAN OF COMBINE MOUNTED ON TRACTOR | | |
|------------------------------------|-------------|----------|
| SCALE | APPROVED BY | DRAWN BY |
| 1/12 | | A S A |
| KANSAS STATE UNIVERSITY | | |
| DATE | FIGURE 9 | |



- 1 KNIFE
- 2 AUGER
- 3 PICKUP REEL
- 4 CONVEYOR CHAIN SLAT UNIT
- 5 THRESHING DRUM
- 6 THRESHING CONCAVE
- 7 SEPARATING CYLINDER
- 8 SEPARATING CONCAVE
- 9 CONVEYOR
- 10 FAN
- 11 CLEANING CYLINDRICAL SIEVES
- 12 GRAIN THROWER
- 13 HYDRAULIC PUMP
- 14 BAGGING MACHINE

| SIDE/SECTION VIEW OF COMBINE | | |
|------------------------------|-------------|----------|
| SCALE | APPROVED BY | DRAWN BY |
| 1/13 | | ASA |
| KANSAS STATE UNIVERSITY | | |
| DATE | FIGURE 10 | |



- 1 SPEED ADJUSTMENT HANDLE
- 2 HEIGHT ADJUSTMENT (HYDRAULIC)
- 3 FORE & AFT ADJUSTMENT (HOLES)
- 4 TINE ANGLE ADJUSTMENT

| PICKUP REEL | | |
|-------------------------|-------------|----------|
| SCALE | APPROVED BY | DRAWN BY |
| 1/13 | | A S A |
| KANSAS STATE UNIVERSITY | | |
| DATE | FIGURE II | |

B. CONVEYING MECHANISM

The feeder conveyor is a chain slat unit, of the same width as the drum. The roller chain runs on two sprockets, the upper feeder sprocket travelling faster than the lower. (figure 10 pos:4) It combs and straightens the grain and feeds it into the cylinder. Conveyor slats (12) [Figure 10 pos:4] are on the chain, which moves the crop uniformly towards the threshing mechanism.

The orientation of the material as it enters a cross-flow rasp bar cylinder has a considerable effect upon cylinder and concave performance and uniform feed is important for efficient threshing.

C. THRESHING MECHANISM:

Threshing of cereal grain crops has received much attention by many researchers during the past several decades. However, the threshing principles applied many years ago are not much different from present day techniques. In principal, introducing the grain between the concave and cylinder is the same as applying force to the grain on the floor. [See figure 4]

The primary performance parameters of a threshing unit are the percent of seed detached from the non-grain parts of the plant (threshing effectiveness) and the percent of seed that is damaged. Two additional parameters that are of importance, because they affect the performance of the separating and cleaning units, are the percent of seed separated through the concave grate (separating efficiency) and the degree of break up of the straw. Power requirement is not a functional performance parameter, but is of concern in evaluating a threshing unit.

Threshing may be accomplished by:

- (a) Impact of fast moving member upon the material.
- (b) Rubbing
- (c) Squeezing pods.
- (d) A combination of two or more of these actions.

OR

- (e) Some other method of applying force.

As stated above, many different types and configurations of threshing devices have been devised, but very few have reached the stage of even limited use.

Three types generally employed in present day combines and threshers are:

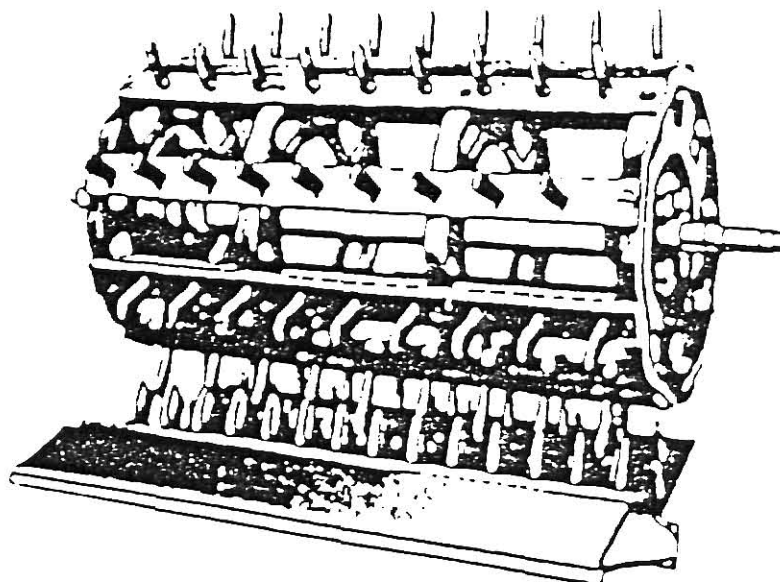
- (a) SPIKE-TOOTH CYLINDER.
- (b) AXIAL-FLOW RASP-BAR CYLINDER.
- (c) CROSS-FLOW RASP BAR CYLINDER.

- (a) Spike tooth cylinder, Figure 12.

Were used almost exclusively in both combines and stationary threshers in the developed (originating) countries prior to about 1930. They are still used on stationary threshers manufactured in Pakistan because this is the only threshing drum design the thresher manufacturers have.

Performance of locally manufactured threshers in Pakistan is summerized in table number 5.

A Spike-tooth cylinder has a more positive feeding action than the rasp-bar cylinder and it does not plug as easily.



SPIKE - TOOTH CYLINDER

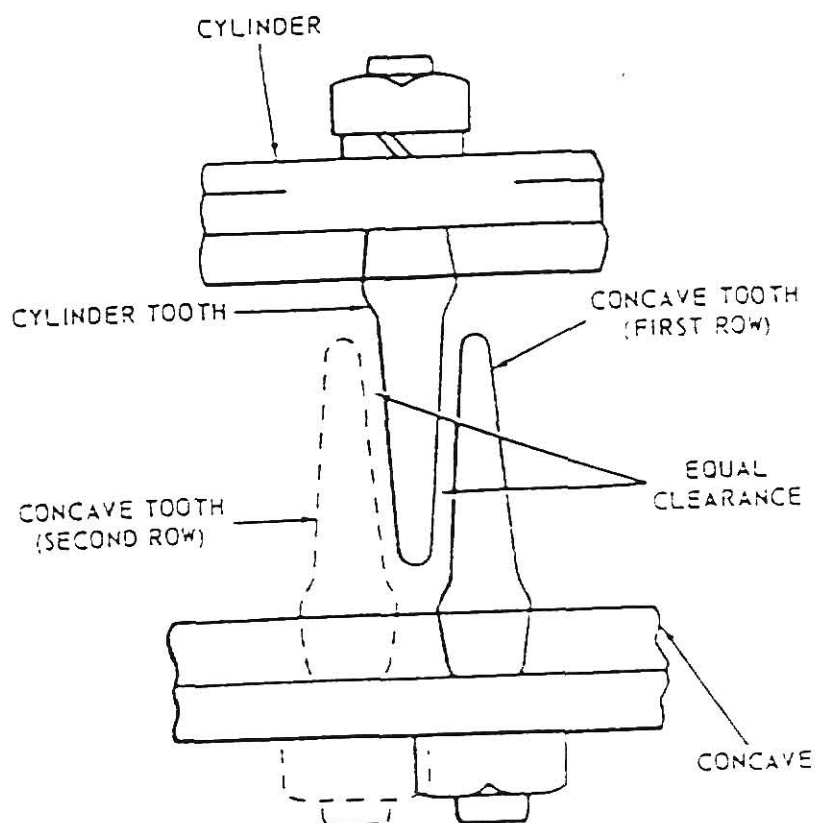


Figure 12. Spike - Tooth Cylinder

(b) Axial-flow (helical flow) rasp bar cylinder (figure 13).

Are similar to cross-flow rasp-bar cylinders except for the number and arrangement of rasp bars on the rotor. Axial flow simply means that the material is threshed and separated by rotating around the cylinder/rotor axis. A major functional difference is that the material passes through the threshing zone between the axial flow cylinder and concave several times as it moves rearward in a helical path, rather than making a single pass as with the cross-flow rasp-bar cylinder.

There are several advantages of the axial-flow rasp-bar cylinder over the cross-flow rasp-bar cylinder which makes them worth the extra investment in some situations.

One advantage is increased harvest capacity; another is that the grain is exposed to more threshing area, which improves threshing efficiency. Farmers with experience using both cross-flow and axial-flow combines, indicate that a combine with axial-flow cylinder accommodates a wider range of crop conditions than cross-flow combines. However, others indicate that under normal conditions, cross-flow combines can be just as efficient.

(c) Cross-flow rasp-bar cylinders, Figure number 14.

Most combines now being produced have cross-flow rasp-bar cylinder. Rasp-bar cylinders are readily adoptable to wide variety of crop conditions. They are easy to adjust and maintain; they are relatively simple, durable, and less expensive. A cross-flow rasp-bar cylinder with an open grate concave has a greater seed separation capacity and requires less power than a spike tooth cylinder.

Generally, there are two major advantages of cross-flow rasp-bar cylin-

ders over the axial-flow. They are smaller in physical size; power requirement is less; and the price per unit capacity is lower.

The cross-flow rasp-bar cylinder is durable, simple, and low in cost. It is easy to adjust and maintain. When consideration is given to these advantages and results of laboratory tests conducted by various researchers in the last two decades, it seems apparent that this cylinder is more suitable for this combine in the areas where the cost, size and performance of the combine are of major importance.

Therefore a cross-flow rasp-bar cylinder of 675mm [26.6inches] width and 450mm [17.71 in] diameter (see figure 14) and a open grate concave of same width and 350mm [14 in] length (figure 15) was selected for the threshing unit of the proposed combine. The concave has one point adjustment (figure 15 pos: 1) the relation between the distance at rear and front will always be correct. The adjustment for increasing the concave drum clearance is done by turning the eccentric (Figure 15 Pos:1) to the right and then properly rest the concave stop screws (Figure 15 pos:2) in the groove on both eccenters left and right.

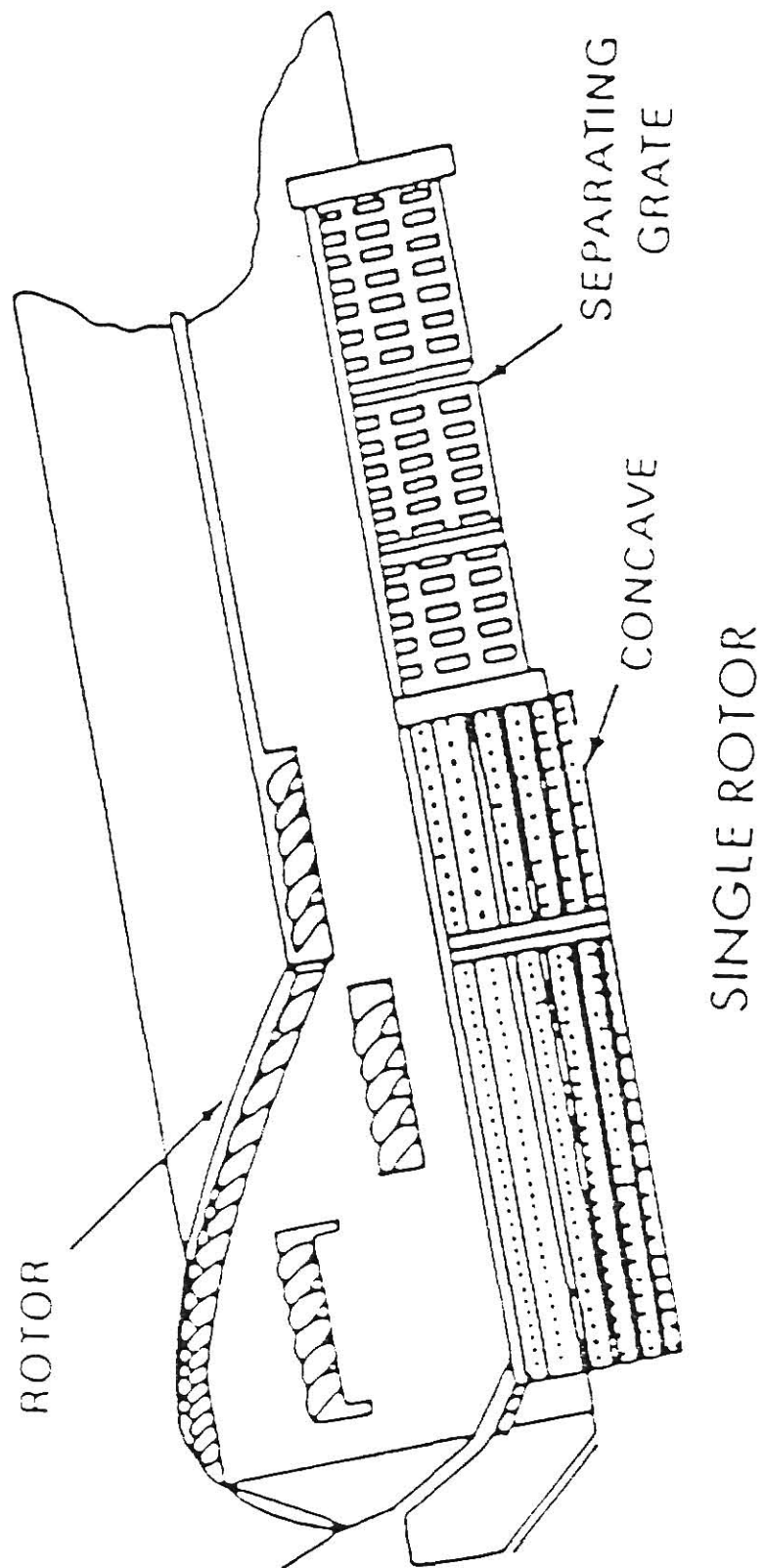
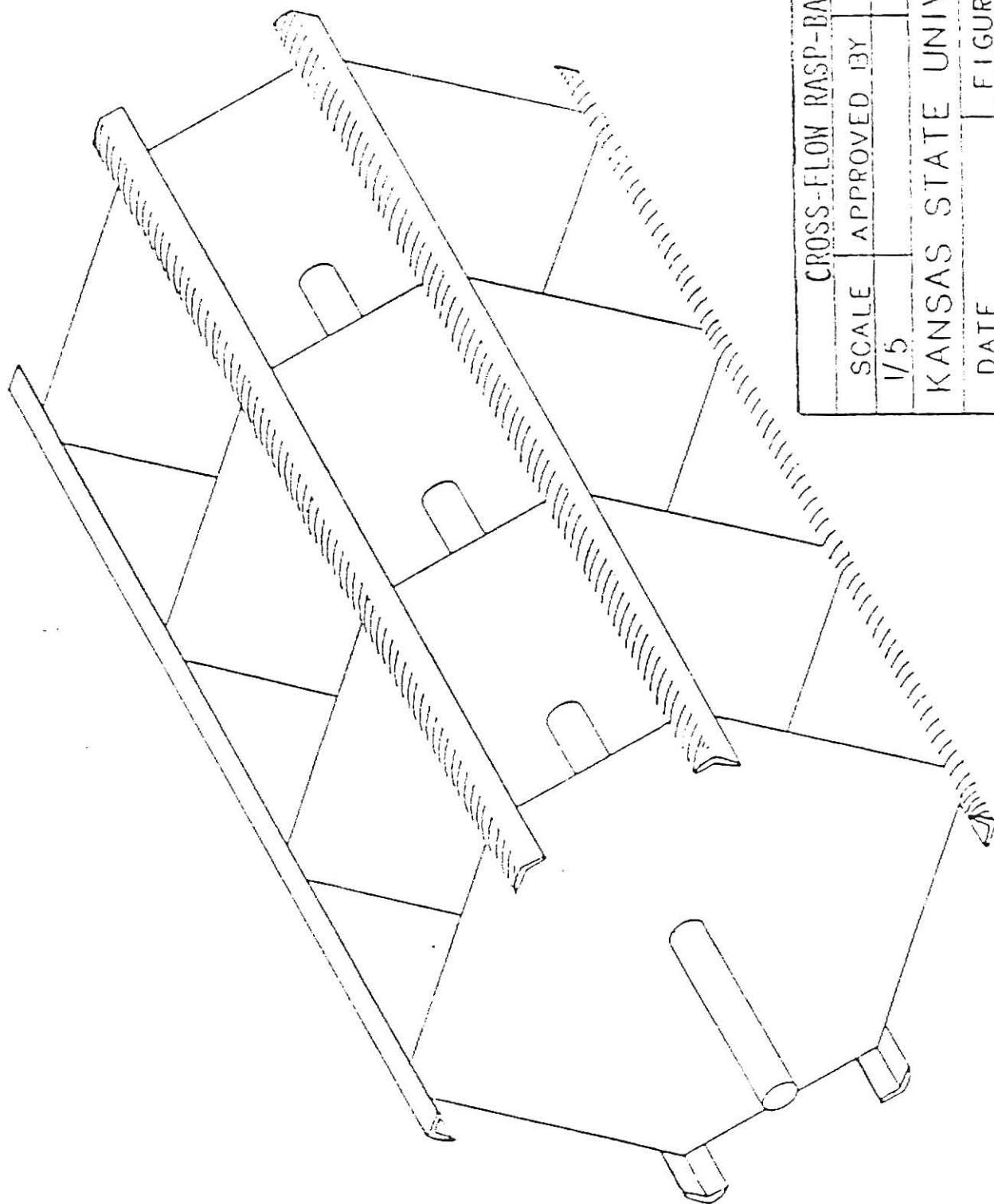
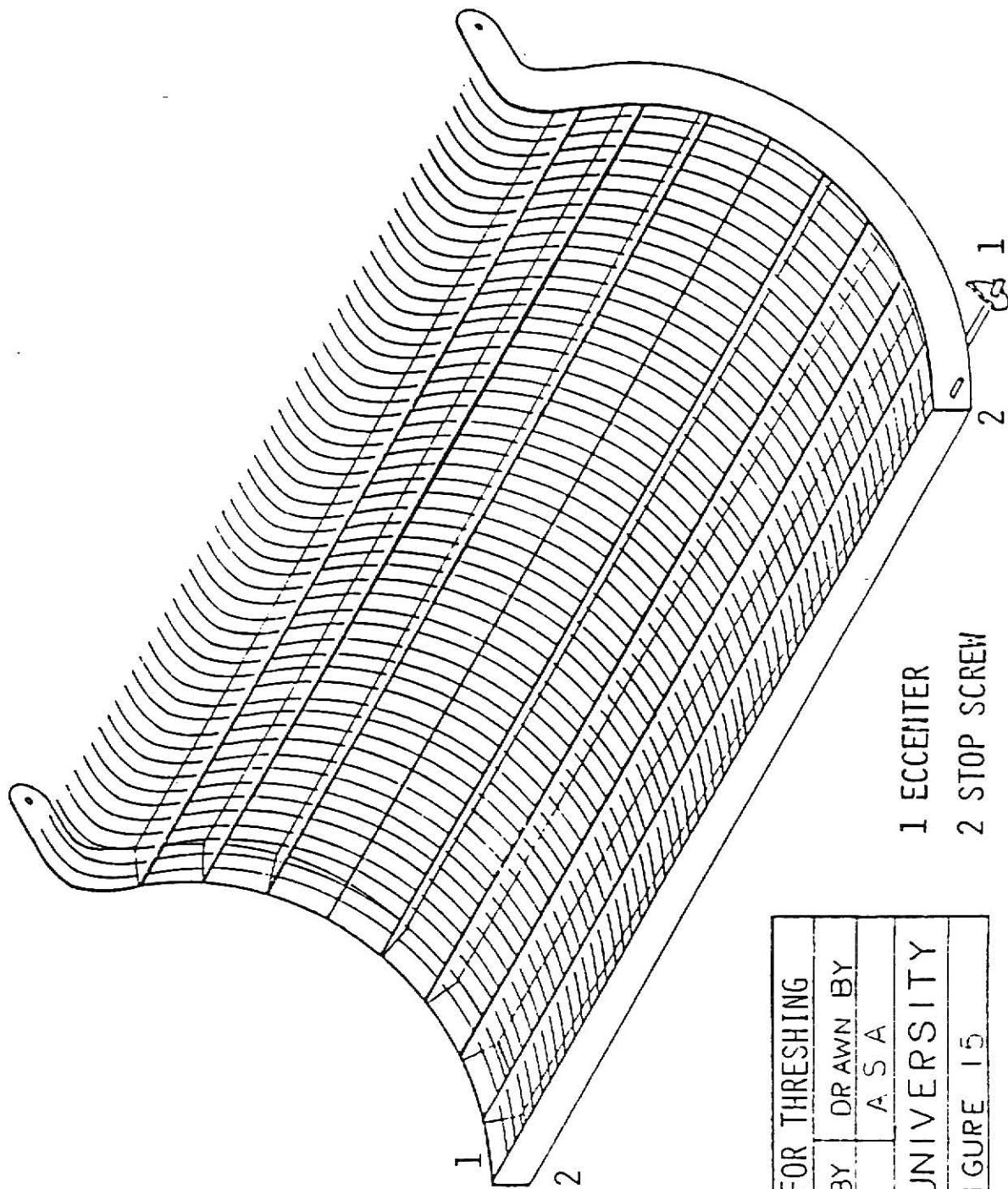


Figure 13. Axail - Flow Rasp - Bar Cylinder.



| CROSS-FLOW RASP-BAR CYLINDER | | | |
|------------------------------|-------------|----------|--|
| SCALE | APPROVED BY | DRAWN BY | |
| 1/5 | | A S A | |
| KANSAS STATE UNIVERSITY | | | |
| DATE | FIGURE 14 | | |



| | | | |
|----------------------------------|-------------|----------|--|
| OPEN-GRATE CONCAVE FOR THRESHING | | | |
| SCALE | APPROVED BY | DRAWN BY | |
| | | A S A | |
| KANSAS STATE UNIVERSITY | | | |
| DATE | FIGURE 15 | | |

D. SEPARATING MECHANISM:

A rotary separation device [(Figure 10 pos:7 & 8) CYLINDER & CONCAVE] is fitted to promote separation. The possibilities of utilizing rotary separation devices instead of straw walker have been under consideration for many years.

Combine harvester models having three distinctly different types of rotary separation devices became commercially available in the 1970's. One of these (Figure 16 & 17) has stationary grates and one or more vented rotors which are axial extensions of the rasp-bar threshing units. The crop material rubs against the separating grate as it is rotated and moved rearward. Centrifugal force causes the seed to move outward through the straw and grate openings.

The other model has a rotating, perforated drum into which the material is fed from a conventional rasp-bar cylinder. A parallel auger located close to the inner surface of the drum near the top, strips the grain straw mixture from the drum surface and, with the assistance of a blower, gradually moves the material towards the discharge end.

The major performance parameter of straw walkers and other separating devices is the percentage of seed and unthreshed heads or pods separated from straw and chaff. However, the percentage of non-grain material that passes through the separating device is also of concern, since this material contributes to the shoe load. Both factors are affected by the kind and condition of the crop, and by the separating device design.

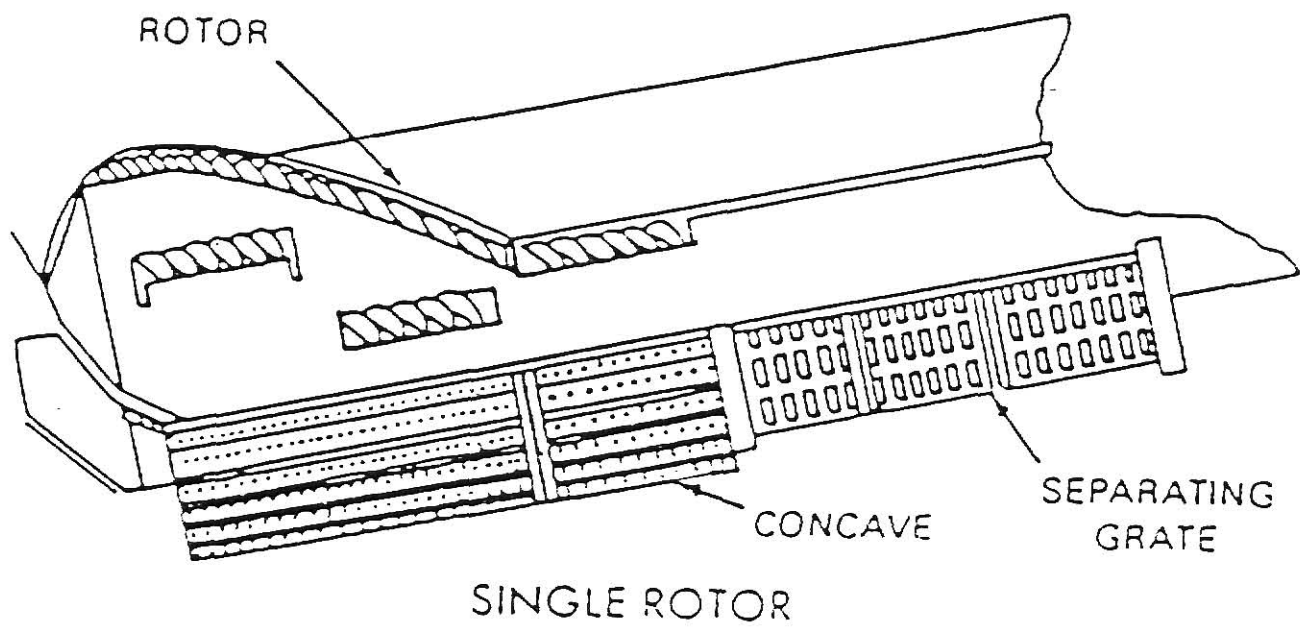


Figure 16. Single Rotor Axial - Flow Cylinder.

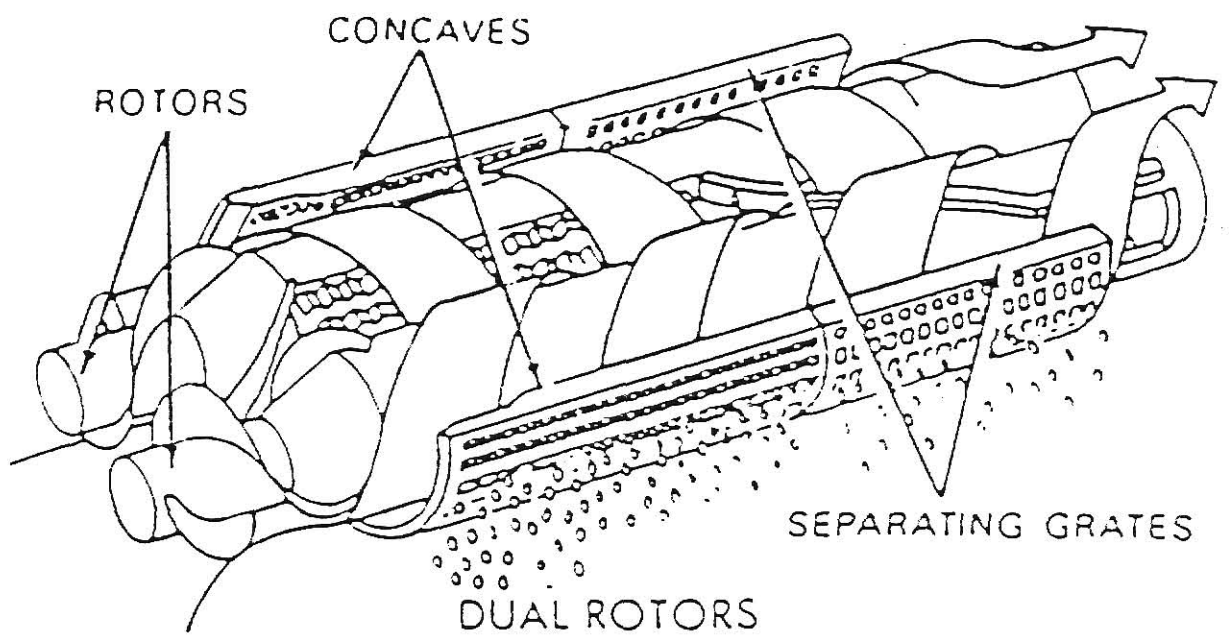


Figure 17. Dual (Twine) Rotary Axial - Flow Cylinder.

As indicated in the preceding discussion, the major portion of the seed is separated from the straw at the threshing drum as the combine is equipped with a rasp-bar cylinder and has an open grate concave. The remaining seed and unthreshed heads or pods, as well as considerable amount of chaff and other small debris, are separated by means of multi cylinder separation system with which the combine is equipped in order to promote separation.

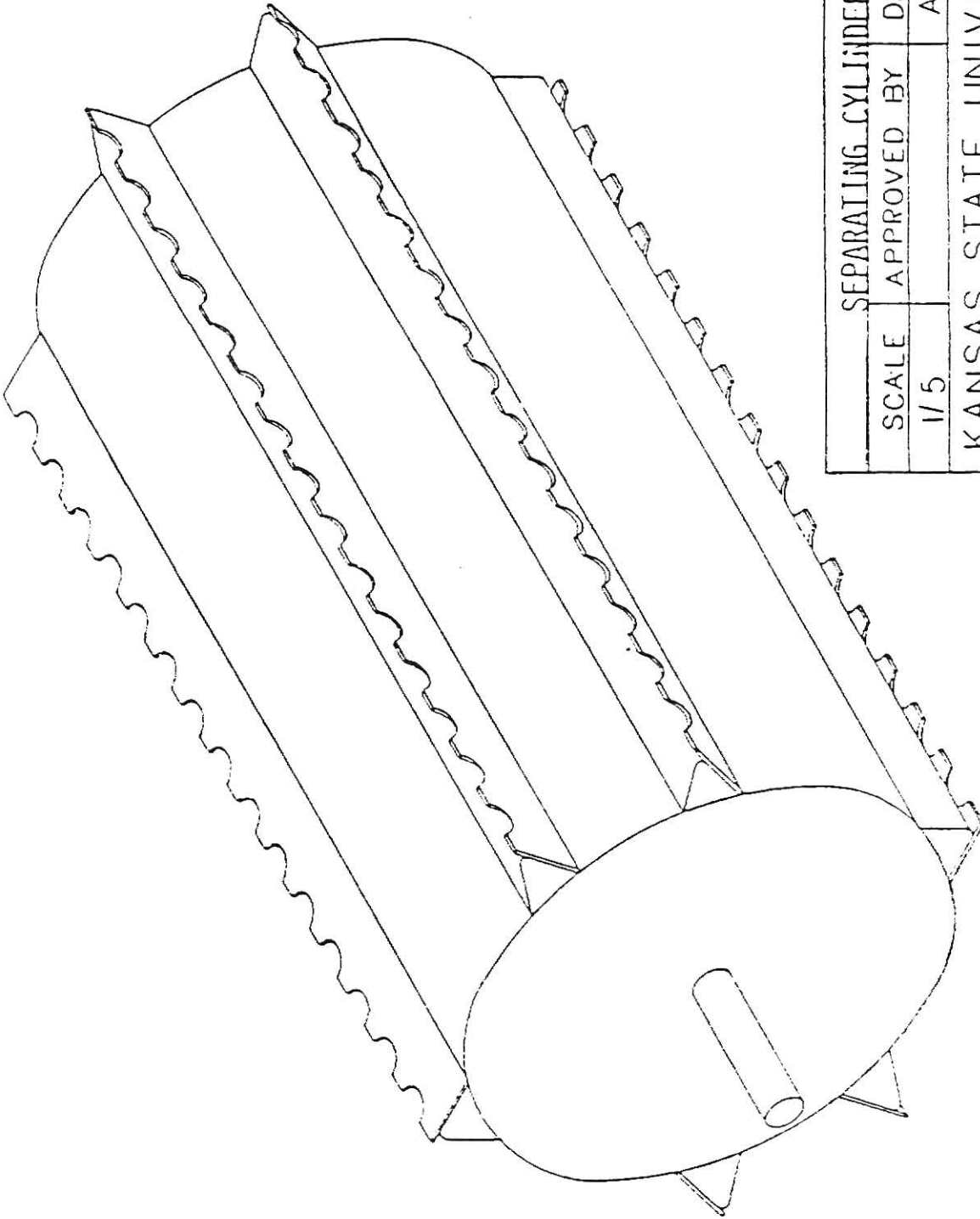
This system [Figure 10 pos: 7 & 8] operates upon centrifugal separation with only a thin carpet of straw in conjunction with a powered positive straw transportation.

After the crop has passed through the threshing system, the straw is forced through a series of separation cylinders [Figure 18] and separation concaves [Figure] fitted beneath the cylinders.

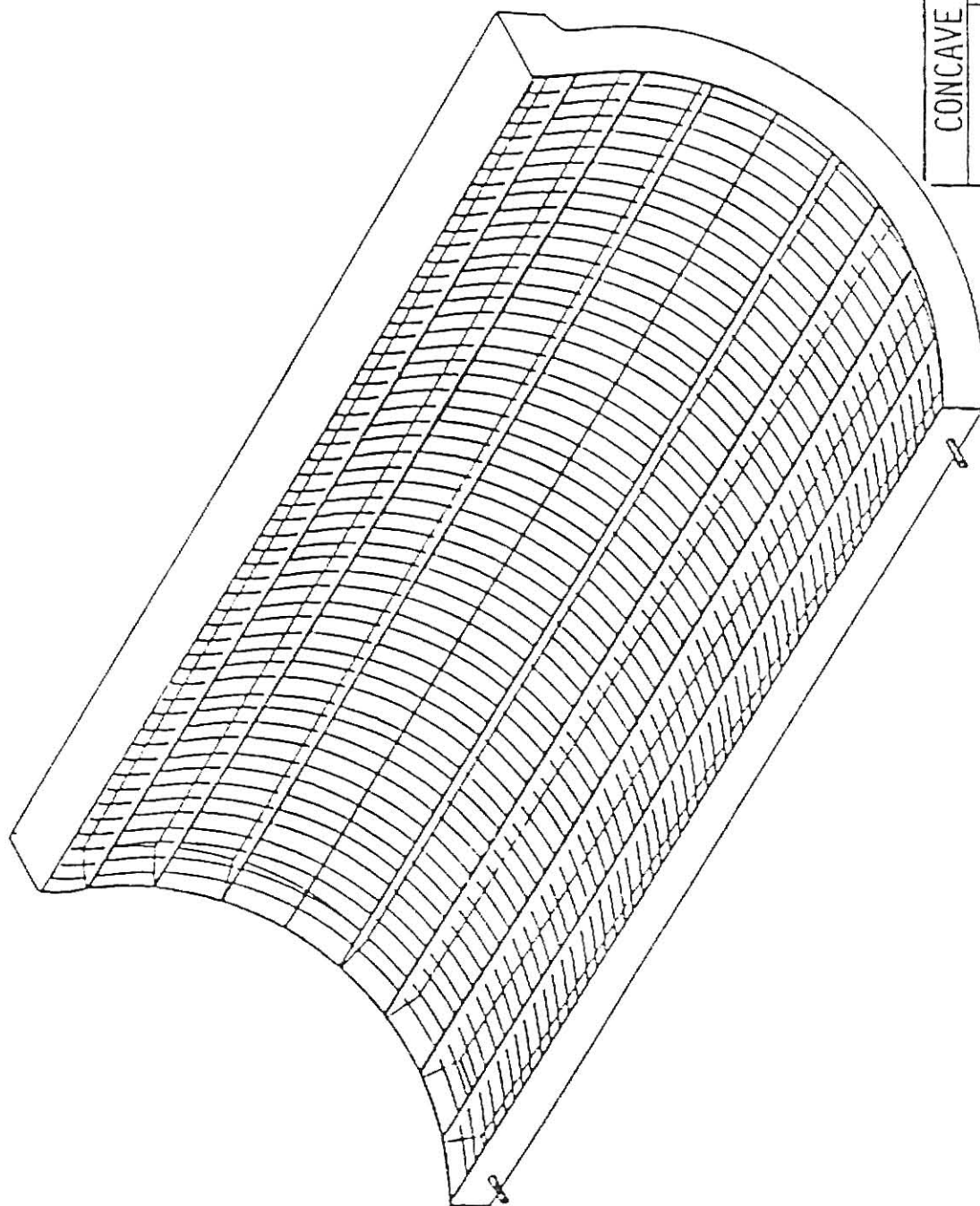
Serrated bars fitted to the separation cylinders loosen the straw carpet and pull apart and transport the straw between the cylinder and concave positively in the direction of straw saver [Figure 10 pos: 18].

The straw flow has to go through a total of three cylinders and concaves. With this system, the last grain is separated from the straw with the grain falling through the separation concaves onto the conveyor [Figure 10 pos: 9] and to the preparation floor/rotary cleaning system [Figure 10 pos:11]. At the end of the process, the straw with all the grain removed is laid on to the straw saver.

The separation concaves are held in position in channels on either side of the machine and can be removed individually. The distance between the separation cylinders and concaves is adjustable over a single adjustment point.



| SEPARATING CYLINDER | | |
|-------------------------|-------------|----------|
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| DATE | FIGURE 18 | |



| | | |
|------------------------------------|-------------|----------|
| CONCAVE FOR SEPARATING MECIIANISIM | | |
| SCALE | APPROVED BY | DRAWN BY |
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| KANSAS STATE UNIVERSITY | | |
| DATE | FIGURE 19 | |

E. CLEANING MECHANISM.

Cleaning is accomplished by a rotary mechanism in which the material passes through the cleaning zone several times as it moves rearward in a helical path. The cleaning unit consists of two cylindrical sieves and of a high performance fan (Figure 10, pos: 11 & 10 respectively). The functions of the cleaning unit are to separate the threshed seed from the chaff and other plant residue that have passed through the openings in the concave grates and transition grates of the threshing and separating units, and dispose of the unwanted material.

Three types of separation occur in the cleaning unit, i.e. aerodynamic, mechanical (by rotating, agitating or shifting), and a combination of aerodynamic and mechanical.

Aerodynamic separation depends on the existence of a differential between the suspension velocities (air velocity required to support the pieces of material against the action of gravity in a vertical air stream) of the components to be separated. Nearly complete aerodynamic separation of some crops can be obtained with vertical air streams. However, the air flow through the sieves is usually at an angle less than 45 degrees above horizontal, so only the lightest material can be separated entirely by aerodynamic action.

A portion of air stream, directed through the falling material, provides initial separation of much of the chaff and increases dispersion of the material on to the inner cylindrical sieve. These actions leave the blanket of material more open so that the seed can more readily escape downward through the material. If air is not blown through the falling material, the velocity of the air directed at the front of the sieve should be great enough to penetrate and loosen the material.

The cleaning unit must be able to handle with a wide variety of crop conditions. The quantity and nature of material that must be processed by the cleaning unit (sieves) is influenced by the performances of the cylinder and concave assembly, and the separating mechanism, as well as by crop characteristics and conditions.

Cleaning unit performance is affected by a number of factors, among which are cleaning unit design, the type and condition of the crop, the cleaning unit non-grain feed rate, the cleaning unit grain/non grain ratio, cleaning unit adjustments, and slope of the machine. Performance parameters are seed lost, cleanliness of seed, and amount of tailings.

The areas of chaffer sieves and chaffer extension on the conventional models with two sieves shoes average 11.4 to 14.7 sq. cm/mm of cylinder width [45 to 58 sq. inch/inch] for four group size shown in table 8. These values indicate a relative increase in sieve length as the size of the combine is increased.

As mentioned eariler, with this rotary cleaning mechanism the material passes through the cleaning zone several times as it moves rearward in a helical path in the cylindrical sieves.

The outer cylindrical sieve is 610mm (24 inch) in diameter, 915mm (36 inch) length, and is fitted over the inner cylindrical sieve which is 457mm (18 inch) diameter, and 915mm (36 inch) length; which makes a total cleaning area of 58.95 sq. cm/mm (231.71 sq. inch/inch) of cylinder width. The total cleaning area of the rotary cleaning mechanism is much higher then the cleaning area given for the conventional combines [11.4 to 14.7 sq. cm/mm (45 to 58 sq. in/inch) of cylinder width] see table 8.

The existence of differential between the suspension velocities hold the small pieces of chaff/MOG, and let the grain pass through the holes of inner cylindrical sieve on to the outer cylindrical sieve, which rotates in the opposite direction to the rotation (direction) of inner cylindrical sieve. This further helps in the cleaning process, the clean grain passes through the holes of the outer cylindrical sieve into the grain pan (Figure 10 pos:16) which is fitted underneath the cleaning unit, and the MOG falls into the straw saver compression box (Figure 10 pos:18). The cleaning grain is then conveyed by the grain thrower (Figure 10 pos: 12) to the bagging machine (Figure 10 pos: 14) and the straw separated at the end of the separating mechanism is conveyed on the conveyor (Figure 10 pos: 17) to the straw saver.

F. STRAW SAVER

Straw has been used as a feed throughout a long history of agriculture in cereal grain producing areas. Man's growing concern about the world's finite deposit of fossile fuel and raw materials, is changing his attitude towards the resources which can be renewed by photosynthesis. Cereal straw in particular is being used as a fuel, ruminant feed and industrial raw material.

In Pakistan fodder is the third crop after cereals and cotton, as area consumer, covering about 2 million hectares (11 percent) of the total cultivated area. Both food and feed crops compete for land, this hardly allows for an immediate diversification exclusively for feed and fodder production.

As the shortage of feed occurs when the (Rabi) winter fodder are finished and the (Khraif) summer fodder are not yet in full production, the conservation of crops for feeding, e.g, hay or silage should be investigated.

A low feeding value of straw per unit weight can not justify the equivalent expense of harvesting and transporting the regular forages. In this context the improvement of the collecting methods (agglomeration) and the feeding value of (bhusa) wheat and rice straw with or without concentrated supplementation, deserves study.

The nutritional evaluation of crop by products and the utilization of these products in various feeding systems will be of great importance for the production of meat and milk. One of the main disadvantages of the fibrous by-products of agriculture is their bulk density. As a result load densities are low and transportation costs are high.

Regular balers are not considered suitable for collection of straw. Aside from pickup losses i.e chaff and grain and other losses, the packages are not suitable for handling and feeding.

Mechanization of straw collection during combining encumbers the combine

to some extent. When straw alone to be harvested, the only requirement during combining is to disengage the straw spreader and/ or straw chopper, leaving the straw in the windrow for bailing. However, if the rotary cleaning effluent is to be collected, additional attachment is required. These systems must work in conjunction with the combine, and thereby possess certain restrictions to operations. But this straw collection method does not solve the problem since it involves extra equipment (Baler). The cost of the extra operation for the collection of straw is not justified for majority of farmers, considering agro-technical and socio-economic condition of Pakistani farmer.

The variation in need, place of use, purpose of utilization of straw, value of straw in the locality and cost of collection and transportation makes it difficult to go for one specific method of collection (agglomeration) of straw. Therefore two different combine harvester attachments are designed, which may fit into different situations, needs and cost considerations mentioned above.

The three combine harvester attachments for agglomeration of straw during combining are as follows:

1. CHOPPER BLOWER (Bagging in Burki)
2. PRESS ROLLER (Round Bales)
3. COMPRESSION BOX

The grain, straw and chaff proportion (percent) of cereal grain crops vary from one crop to another. The grain, straw and chaff proportion varies with the variety of the crop, locality where the crop is grown, and growing seasons.

M. Fledman (1977) used the average grain, straw and chaff proportion (percent) of wheat crop as 46.6 %, 39.7 % and 13.7 % respectively.

R. R. Allen and L. D. Holding Worth (December 1982) calculated the

average grain, straw, and chaff proportion of wheat crop as 40 %, 50 %, and 10 % respectively. They used hand harvesting (ground level) and small bundle thresher for threshing and machine harvesting at ground level and at normal level. The average grain yield of wheat and rice crops in Pakistan is about 1600 Kg/hectare, here the maximum average grain yield is estimated as 3200 Kg/hectare with the proportion of 40 %, 50 %, and 10 % for grain, straw and chaff respectively, that is 3200 kilograms grain, 4000 kilogram straw and 800 kilogram chaff per hectare [Total crop yield of 8000 kilograms per hectare].

It is generally accepted that a part of the straw is to be retained in the soil for its beneficial effects. Some return of the plant material to the soil is desirable to maintain organic content, but the root system and short stubble will probably suffice in soil where wheat and rice are grown every year.

It is expected that the general weather conditions in the wheat and rice growing area's of Pakistan, will not permit every year removal of the total straw crop in every field. There is no surplus residue in some western regions of Pakistan since it is needed for wind erosion protection.

Considering the above reasons for retaining of some crop material on the soil, the normal harvest level should be set at 8 cm to 13 cm (3 to 5 inch). It is estimated that for a whole plant crop yield of 7 to 10 metric tons per hectare, each one-inch difference in height of cut from ground level makes a difference in straw yield of about 160 to 250 kilogram per hectare. This means that when the height of cut is set at 8cm to 13cm (3 to 5 inch) above the ground level that reduces the intake into the combine by 600 to 1,100 kilogram per hectare.

For an estimated crop yield of 8 metric ton/ha a height of cut is set about 10 centimeter (4.16 inches), if it is assumed that the total intake

into the combine will be about 7 metric ton with grain, straw and chaff proportion of 45.71 %, 44.5 %, and 11 % respectively. The total MOG collected at the end of combine will be about 3.8 metric ton/hectare.

STRAW SAVER SPECIFICATIONS

For the reasons mentioned previously, specifications and figures of two (optional) equipments/methods of agglomeration of straw are given.

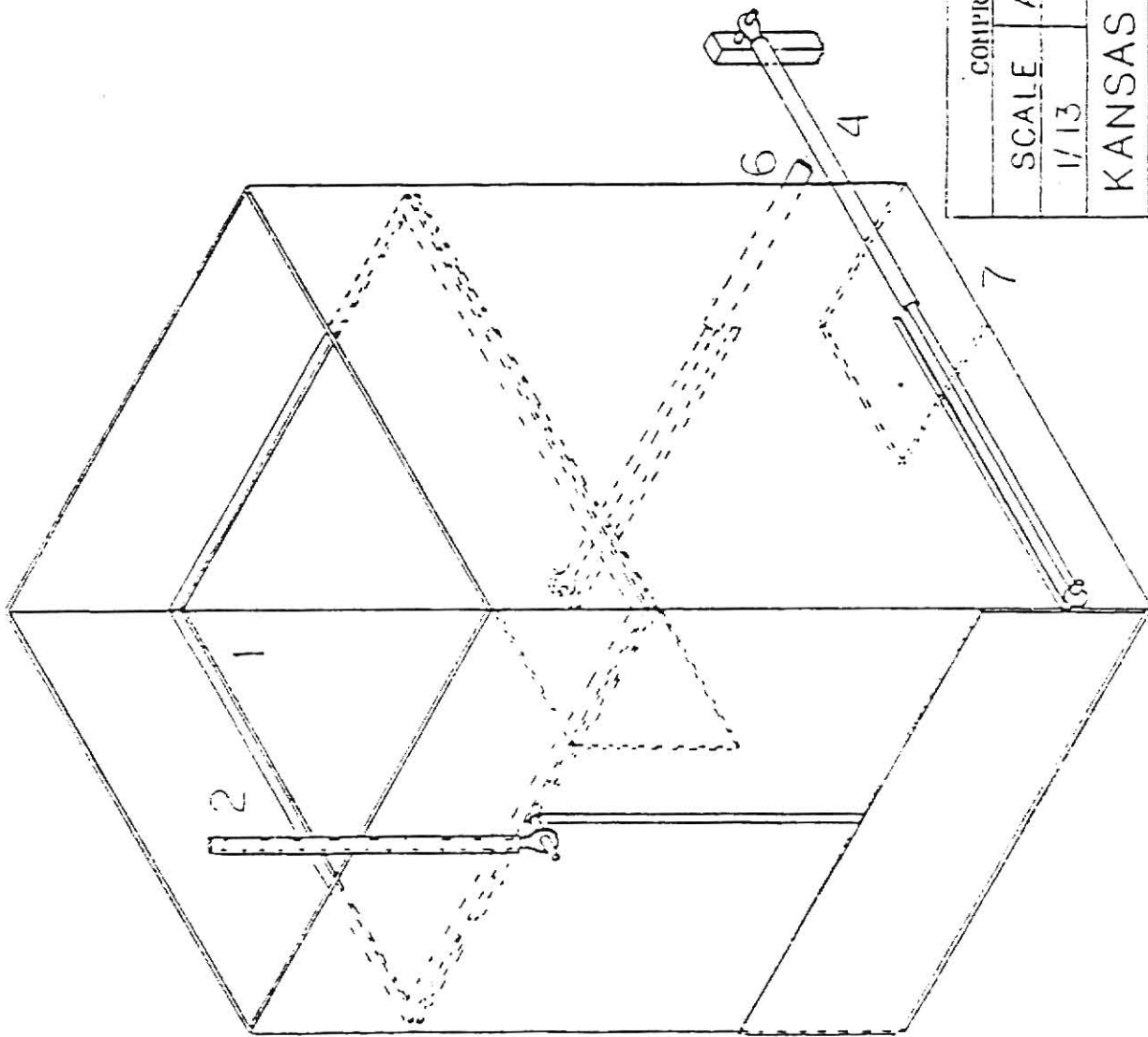
I COMPRESSION BOX.

II CHOPPER BLOWER.

COMPRESSION BOX

SPECIFICATION:

| | |
|--------------------------------|---|
| LENGTH | 1 meter (3.281 ft) |
| WIDTH | 1 meter (3.281 ft) |
| HEIGHT | 1 meter (3.281 ft) |
| VOLUME | 1 meter cube (35.3 ft:cube) |
| HYDRAULIC SYSTEM (Type) | constant flow, variable pressure |
| HYDRAULIC CYLINDER TYPE & No's | 2 Ram type single acting |
| | 3 Piston or Ram single & double acting |
| HYDRAULIC CYLINDER SIZE | ----- |
| COMPRESSION RATIO | 1 to 0.028 meter cube (35.5 to 1.307 ft cube). |



1 TOP COVER

2 CYLINDER

3 CYLINDER (not shown)

4 CYLINDER

5 CYLINDER (not shown)

6 CYLINDER

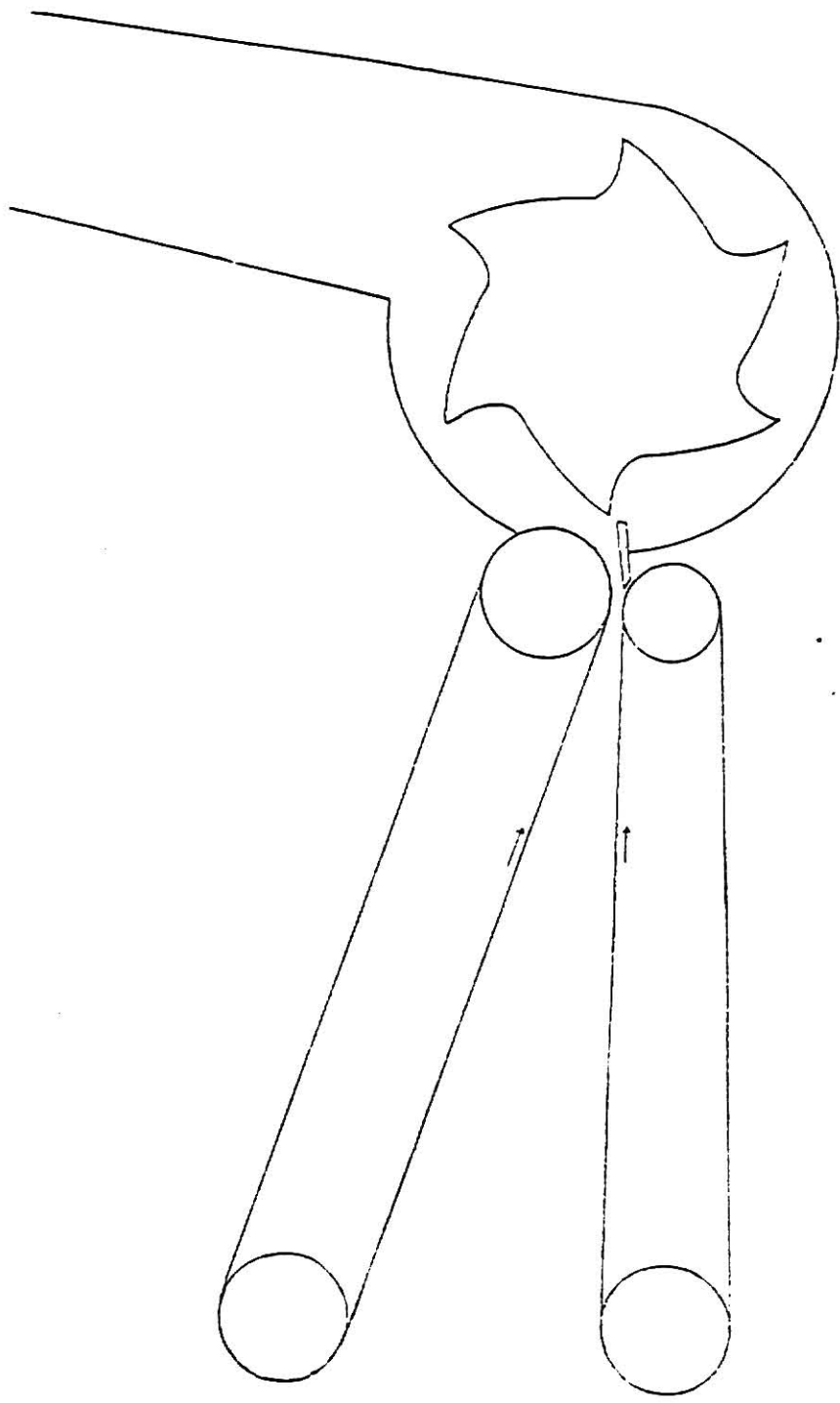
7 BOTTOM DOOR

| COMPRESSION BOX | | |
|-------------------------|-------------|----------|
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| KANSAS STATE UNIVERSITY | | |
| DATE | FIGURE 20 | |

CHOPPER BLOWER (BURKEE)

SPECIFICATION

| | |
|--|---|
| TYPE | 0.304 meter (1 ft) |
| CYLINDER DIAMETER | 0.914 METER (3 FT) |
| CUTTING EDGE No's ON CYLINDER | 6 |
| SHEAR PLATE/BAR | - - - - - |
| PRESSURE/FEED ROLLERS | same rollers on the conveyor are used for feeding the chopper. |
| DIAMETER OF PRESSURE ROLLER AND THE REAR ROLLER | 0.101 meter (4 inches) |
| DIAMETER OF FRONT FEED ROLLER | 0.0762 meter (3 inches) |
| DIAMETER OF REAR FEED ROLLER | 0.101 meter (4 inches) |
| CONVEYOR BELT TYPE | strip rubber conveyor belt |
| LENGTH OF CUT OF STRAW (pieces size) | adjustable |
| BURKEE (Jute bag) CAPACITY | 2 meter cube (70.6 ft cube) |
| BURKEE (Bag) ENGAGING OPERATION | manual. |



| | | | |
|-------------------------|-------------|----------|----|
| CHOPPER BLOWER | | | |
| SCALE | APPROVED BY | DRAWN BY | |
| 1/13 | | A S A | |
| KANSAS STATE UNIVERSITY | | | |
| DATE | | FIGURE | 21 |

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MECHANIZATION IN PAKISTAN
FOCUS ON
CEREAL GRAIN HARVESTING METHODS AND EQUIPMENT

BY

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ABSTRACT

Farm mechanization is an important factor for agricultural development in Pakistan. Due to limited arable land, and high cost for expansion, i.e. bringing new land under cultivation, the further extension of cultivation has been limited. This gives rise to the need of intensive cultivation, which is possible only if the land can be cleared of the previous crop (standing crop) and prepared for the next crop within a few weeks. Further the extension of intensive cultivation has been limited by the lack of labor and draught power.

The peak periods for labor are those relating to harvesting and threshing of cereal grain crops. On the other hand labor is becoming increasingly scarce during harvesting seasons, and dependence on the draught animals requires use of land for growing fodder which could otherwise be available for growing food for human consumption.

The conventional harvesting methods presently being used in Pakistan are time consuming, ineffective and primitive. Harvesting and threshing grain losses vary from 3 to 15 percent, depending on the method of harvesting and threshing used. The method generally used is the conventional method, which is primitive and time consuming, grain losses range from 10 to 15 percent.

When the crop is allowed to remain in the field after physiological maturity, dry weight and quality of the grain decreases. Intermittent wetting and drying of grain, during daily cycle of evaporation and condensation weakens the grain attachment making it more susceptible to shattering.

Mechanization, involving the use of a combine harvester should help to reduce labor costs. Millions of hectares required for growing fodder for draught animals could be reduced and millions of kilograms of grain lost due

to use of conventional methods for harvesting and threshing of cereal crops could be saved.

A conceptual design of combine harvester, considering the bio-agro-technical, and socio-economic conditions of Pakistani farmers in particular and of the country in general, was developed.

The separating mechanism on this combine is multi-serrated cylinder type, requiring much shorter length than the straw walker on conventional combines, This helped in minimizing the overall length of the combine.

The combine is designed with a rotary cleaning mechanism, which has a total cleaning area of 58.95 sq. cm/mm (231.71 sq. inch/inch) of cylinder width, which is much higher than the total cleaning area of conventional combines i.e. 11.4 to 14.7 sq. cm/mm (45 to 58 inch/inch) of cylinder width. This conceptual design is thought to be workable, but additional study, laboratory and field tests on the prototype of this are needed to prove the concept.