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ENERGY CONSUMPTION AND PERFORMANCE MODELS
OF SMALL PHILIPPINE-BUILT RICE MILLS

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ANACIETO SAWAL PARAS, JR.

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Merle L Esmay
Major professor

Merle L. Esmay

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ENERGY CONSUMPTION AND PERFORMANCE MODELS OF SMALL PHILIPPINE-BUILT RICE MILLS

By

Anacleto Sawal Paras, Jr.

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ABSTRACT

ENERGY CONSUMPTION AND PERFORMANCE MODELS
OF SMALL PHILIPPINE-BUILT RICE MILLS

By

Anacleto Sawal Paras, Jr.

Two simulation models were developed for small rice mills of the conventional disc-cone and rubber-roll equipped designs which range from 0.3 to 1.8 tons-per-hour capacity. These sizes comprise a large proportion of the rice mills in the Philippines.

The first, a computer model, evaluated these two types of mills with regard to energy consumption, total and head grain recovery and processing time. Field and laboratory data taken by UPLB research workers and direct measurements by the author were compiled and employed in the development of equations and distribution functions for the variables that make up the subroutines for the models. The results indicated that the energy consumption of small rice mills in the Philippines could be reduced by five to nineteen percent, depending on size, without loss of quality in good performance mills by using one bigger

Anacleto Sawal Paras, Jr.

huller and an adjustable separator, and that the output quality of poor performance mills could be improved with just a four percent increase in energy consumption by adding a second-stage whitener.

The second model estimated the cost of milled rice by utilizing Kirchoff's current and voltage laws and energy conservation principles to derive a cost equation involving the material energy and processing cost. The results indicated that the cost of milling rice in 1978 was approximately P1.20 per kilogram of milled rice after crediting for by-product cost (P0.05) with the conventional disc-cone mill being less expensive than the rubber-roll type by about P0.02 (1.7 percent).

Approved ______________
Major Professor

Approved ______________
Department Chairman

To my late Father

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CHAPTER I

INTRODUCTION

The introduction of high yielding varieties (HYV's) of rice into Southeast Asia in the late 1960's created the potential for the Philippines to become self-sufficient for this vital crop and even to become a substantial exporter. However, "second generation" problems - those associated with storage, processing and marketing - confounded this potential.

When HYV's were first planted in 1967-68 on twenty-two percent of the lowland rice area, an eleven percent increase in total yield resulted (Mears, 1974). The peak rate of growth was attained in 1969-70 with annual increased yield of seventeen percent. Although the following year attention was prematurely turned to other crops and a rice crop failure occurred, the increased production experienced the previous years was sufficient to demonstrate the inadequacies of the traditional post-harvest operations. Indeed, post-harvest losses were as high as thirty-six percent (Araullo, et al., 1976).

The National Grains Authority (NGA) initiated an extensive effort to ameliorate the situation utilizing the facilities of the International Rice Research Institute (IRRI), the University of the Philippines at Los Banos (UPLB) and related government agencies.

Substantial progress was made in selected phases of processing and storage through the introduction of locally produced farm dryers and locally made and imported drying plants. Renovation of USAID-purchased grain elevator and storage facilities was also undertaken.

Rice milling, however, experienced the least technological improvement in the rice marketing system, although losses using the traditional mills had been among the most substantial, from two to ten percent of the grain processing operation (Timmer, 1974).

Efforts to improve mills were limited both by a lack of research into the problems involved and the comparably high cost of changes in these operations.

1.1 Purpose of the Study

Decisions regarding rice mill construction and alteration involve a number of variables and trade-offs reflecting the costs of construction, the costs of operation and the quality and quantity of the output. When the scope of the "second generation" problems became apparent in the early 1970's not enough information regarding rice milling operations in the Philippines was available to make informed decisions. There followed four significant studies. Three of these (Andales, et al., 1976; Camacho, et al., 1977; and Sison, et al., 1976) were made on commercial milling equipment processes under typical conditions, and the fourth was based on measurements made under controlled laboratory conditions (Manalabe et al., 1978). While these studies provided valuable theoretical and actual data about milling operations, they failed to provide a sufficiently complete picture for decision making because they were limited by the number, sizes and types of mills available in the field for monitoring. Some important variables such as energy consumption and time delays in milling were also unavailable.

With the field measurements of these missing variables made by the author in this study it was possible to construct a systems model validated by actual experience in the mills. This model provides a tool for evaluating at greatly reduced cost and in minimal time the effects of altering the variables involved (Seshu, et al., 1959), such as: the use of single versus double hullers, one-stage versus two-stage whitening, and energy use versus quality of output.

The Camacho, et al. study was a joint effort by the Agricultural Engineering Departments of the International Rice Research Institute and the University of the Philippines at Los Banos. This was conducted in the Bicol River Basin which is under development by the Bicol River Basin Development Program with funds from a USAID grant (Bicol Project Agreement No. 75-09, Sub-agreement No. 15). About 334,410 hectares[1/] in the Bicol Region was planted to rice in 1977. This represented about ten percent of the area planted to rice in the Philippines. This area is typical of about forty percent of the rice producing areas in this country, particularly the eastern seaboard areas of Cagayan Valley, Southern Tagalog and Eastern Visayas. These areas are subjected to the seasonal typhoons prevalent in the South Pacific Islands during the month of September. This particular characteristic makes it an area where special attention must be provided to minimize damage to crops during harvesting and processing. Table 1.1 summarizes data from the eleven representative rice mills monitored during the study period of 1976-77.

Small rice mills of the kind analyzed in this study processed almost all of the rice in the Philippines in

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1/See Appendix Table R.

Table 1.1 Comparative milling performance of mills included in the monitoring schedule, Bicol River Basin area, 1976-77

Milling system	Capacity tons/hr.	No. of observations	Commercial milling yield: Milled rice recovery[a/]	Commercial milling yield: Head rice recovery[b/]	Laboratory milling yield: Milled rice recovery[c/]	Laboratory milling yield: Head rice recovery	Difference bet. commercial & laboratory milling yield: Milled rice recovery	Difference bet. commercial & laboratory milling yield: Head rice recovery
					percent			
Steel huller (av.)		4	(61.8)	(48.3)	(67.1)	(78.8)	(5.3)	(30.5)
Dycoco RM	0.390	1	61.1	50.2	67.2	77.5	6.1	27.3
Torres RM	0.520	1	65.2	40.0	67.1	74.9	1.9	34.9
Olaño	0.280	1	61.5	38.3	67.5	77.9	6.0	39.6
Rayala RM	0.270	1	59.5	64.5	66.6	84.9	7.1	20.4
Cone type (av.)		3	(66.8)	(75.6)	(66.8)	(81.5)	(0.0)	(5.9)
Libmanan RM	0.830	1	65.9	77.0	66.5	84.1	0.6	7.1
Concina RM	0.600	1	67.5	76.25	67.7	81.6	0.2	5.4
Nazarrea RM	0.240	1	66.9	73.1	66.1	78.8	0.8[d/]	5.7
Rubber roll single pass	0.245	1	67.6	70.5	67.7	84.4	0.1	13.9
Rubber roll steel huller combination	0.315	1	68.5	70.9	67.2	81.3	1.3[d/]	10.4
Stone disc-steel huller combination	0.405	1	63.3	59.8	65.4	85.1	2.1	25.3
Centrifugal huller	0.600	1	63.7	66.7	67.8	84.1	4.1	17.4

a/ Based on daily records.

b/ Based on laboratory analysis of milled rice samples collected.

c/ Milling potential of collected paddy samples.

d/ Commercial milled rice recovery is higher than the laboratory.

1984. Less than one percent of the rice was processed by the three large-capacity (6 to 25 tons per hour) rice mills in the country.

The two most important types of small mills, which accounted for ninety-five percent of the milling operations, were equipped with steel hullers (forty percent) and the conventional disc-cone (fifty-five percent).1/ The miscellaneous types of mills which processed the remaining approximately five percent of the rice included a newly introduced rice mill with rubber rolls. This is a portable unit and favored by some as a replacement for the steel hullers. However, the rubber rollers are expensive and require replacement after every 15 tons of paddy (see Appendix Table Q2). Another portable mill is the centrifugal huller with a performance very similar to that of the steel huller mills.

The NGA estimated that in 1979 the steel huller mills numbered approximately eighteen thousand, eight thousand of which were unregistered. These mills were one-quarter to one-half ton per hour capacity. The conventional disc-cone mills were unofficially estimated by the NGA to number approximately three thousand, indicating

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1/See Appendix Table S for a survey of the number of steel hullers and conventional disc-cone mills in use in 1973.

increased popularity of steel huller mills compared with the 1973 survey estimate.

1.2 Specific Objectives

The specific objects of this study are to:

1. Develop a rice mill performance model that will realistically simulate selected milling technologies and provide a basis for the evaluation of performance and energy consumption over a wide range of input and output capacities.

2. Develop a linear network economic model of rice milling systems for evaluating milling costs over a range of capacities within a selected set of technologies.

3. Conduct simulation runs to show how information may be generated to help in the decision- and policy-making processes of planning, design and operation of milling facilities.

1.3 Description of the Models

1.3.1. Rice Mill Performance

All of the available information on rice mill performance was from rice mill tests. These data were limited by the high cost of monitoring mills and by the unavailability of the different types of mills in the field. The capacities of Philippine manufactured mills

range from 0.3 to 2.0 tons per hour. The two main technologies were from Europe (i.e., Germany and Italy) and Japan. Philippine mills which were based on German design were known as conventional disc-cone mills while the Japanese mills were known as rubber roll mills. In order to evaluate the mills on the basis of their technical and economic performance, it was decided to develop two models that would evaluate commercial rice milling systems over a range of capacities for a selected set of technologies.

Data that were readily available from other researchers included input paddy factors such as: maturity or moisture content at harvest and at milling, drying delay and purity of grain. Milling factors included machinery adjustments and ambient temperature and relative humidity. Data on grain rigidity or grain pressure during milling, grain shape, grain moisture content and purity were available but were not readily usable due to the lack of analyses of their relationship to rice milling. Unavailable information which was measured by this author was on energy consumption of individual rice mill component machinery, and time measurements of the different delays in the rice milling operation.

Modeling provides a convenient and low-cost means of evaluation. The first consideration in modeling is to choose between a dynamic and a static model. Static

models are incapable of providing information about the future consequences of current decisions. They are constructed with equations which do not contain past values or rates of change of system variables. A dynamic model is useful for analyzing the operation of an individual system for peak labor usage and the effect of a disturbance, such as bad weather, on the system (Tummala, et al., 1973). This study, however, was designed for comparison of a number of systems. Static models proved simpler and more suitable for the desired comparisons.

The development of the computer model involved the understanding of the rice grain, the rice milling process and gathering of data related to the model. Rice grain processing is uniquely different from the processing of other grains such as wheat, rye, barley and corn. Rice is marketed in whole-grain form rather than in a processed powdered form; thus, the processing stage is more critical than for other grains. However, all grains are living and respiring biological products and as such are affected by whatever previous treatment they experienced in the growing, field handling, drying and storage stages. The variables that affect the rice grain quality and milling yield were incorporated in the computer model. The physical properties of the grain such as grain shape, hardness and length are another set of variables that were analyzed and included in the model.

The rice milling process was also studied. The stages in the process were observed and measurements made on bin capacities, time delays and energy consumption. To collect data on energy consumption and time delays during rice mill operation, three mills of sizes 1.0, 2.5 and 6.25 tons per hour capacity were monitored during operation. One observer was posted at each machine component and the rice mill was started at a predetermined time. Time of entry and exit of paddy or rice, as the case may be, was noted. Figures L1 and L2 in Appendix L show the results of time measurements. Voltages, amperages, power factors and efficiencies were noted at each electric motor at three different times during the milling run (Figures 3.14 and 3.15). The average of the three readings for each machine component is shown in Appendix Table A1. Bin capacities were obtained from manufacturers' plans. Material reduction data were derived from the work of Manalabe, et al., (1978), and machine capacities were from Jose Bernabe and Co., Inc. These measurements were expressed in terms of equations and graphs which are discussed in more detail in Sections 3.2 through 3.5.

The computer model was patterned after the different steps in the rice milling process. Time delays in the process were due to the operator's practice of waiting until the bins were half full before opening the feed shutters of the machine. The measurements of the delays were obtained by dividing the bin capacities by the handling or processing rate of the machine immediately preceding the bin. Processing time of each machine was obtained from a graph or from the input grain mass divided by the machine handling rate. The power requirement which was obtained from a graph was then multiplied by the processing time to obtain the energy consumption. The grain quality was expressed in terms of the mass percentage of the whole grains and of discolored grains over the total milled rice. These two quantities were obtained from a quality factor which is the product of four variables obtained from the graph of grain factors affecting quality. This process is explained in more detail in Chapter Three.

The efficiency of the rice mill was measured by the milling recovery which was defined as the mass percentage of the milled rice over the pre-cleaned input paddy. The amount of milled rice was obtained by the use of reduction factors at each milling stage.

Input variables were of two types: first, the rice itself, and second, the mill studied.

The first category included such factors as grain shape (the length-width ratio), growing season (wet or dry) and drying method (solar or mechanical) which were determined by observation. Other grain factors such as harvesting delay, moisture content at milling and grain purity were generated internally by a random number generator employing normal distribution functions. Drying delay, by which is meant the number of days delay between harvesting the rice and the beginning of the drying process, was derived by employing a third order gamma distribution function. The second set of variables required were: the capacities of the different bins in cubic meters; the number and capacity of the precleaner; type, number and capacity of the whitener; type, number and capacity of hullers; type and capacity of separators and the mass of paddy processed.

The output provided the milling time in hours, output in hours, total recovery, head grain recovery and percent discolored kernels as well as the total energy consumed in kilowatt-hours.

1.3.2 Linear Network Economic Model

The system's cost of operation was evaluated over a range of capacities using a modeling technique in which the system was analyzed as a set of components which were described in terms of their mass and energy characteristics. The components of the rice mill were classified

into those that perform material transformations and those involving transportation. A material transformation involved conversion of the input material into an output product while transportation components included transport energy cost.

The model is in the form of an equation for the cost of output milled rice in terms of input variables and technical coefficients. The technical coefficients are dimensionless numbers that express the ratio of output over input or vice-versa for a particular process. A more involved discussion of the method is in Chapter Four.

CHAPTER II

REVIEW OF LITERATURE

In order to carry out the objectives of this research it was necessary to develop an understanding of the complete rice milling process and the previous work done by other researchers.

2.1 Nomenclature

The following terms are commonly encountered in rice milling literature. Terminologies sometimes vary depending on milling practices. Milling in Japan, for example, does not include the husking process, and their definition of recovery or yield is based on brown rice rather than paddy or rough rice. The definitions found here are those used in the Philippines.

a. Rough Rice (Paddy) is unhulled grain.

b. Rice Milling includes the process of removing the husk from the rough (whole) rice kernel and bran (pericarp, testa and aleurone layers) from the brown rice kernel.

c. *Husking or Hulling* is the operation of removing the husks from rough rice.

d. *Brown Rice* consists of rice after the husks have been removed and separated from the whole kernels.

e. *Whitening* is the process of removing the bran layer from the brown rice.

f. *Milled Rice* consists of the resulting white rice after the bran layer has been removed from the brown rice.

g. *Milling Degree* refers to the extent the bran layer has been removed and is expressed in percentage of the original rough rice.

h. *Polishing or Refining* is the process of removing the powdered bran adhering to the milled rice after the whitening process.

i. *Broken Rice* includes kernels broken into pieces that range in size from 1/4 to 3/4 of whole grain.

j. *Brewer's Rice or Points* include broken pieces after milling that will pass through a 1/16 inch sieve.

k. *Head Rice* includes kernels that are from 3/4 to whole kernel size.

l. *Foreign Matter or Dockage* pertains to impurities in rice such as: weed seeds, stones, sand and dirt.

m. Chalky Kernels include milled rice kernels which are at least half non-translucent. It may be caused by the harvest of immature rice or also may be genetically related.

n. Damaged Kernels includes milled rice kernels damaged by insects or mechanical means.

o. Discolored Kernels includes yellowish milled rice kernels damaged by fermentation or heat.

p. Total Milling Recovery consists of the weight of milled rice from the milling operation expressed as a percentage of the original rough rice (clean and dry) weight.

q. Head Rice Recovery consists of the weight of head rice obtained from the milling operation expressed as a percentage of the total milled rice weight.

r. Coefficient of Hulling is the proportion of brown rice by mass produced by a huller as percentage of the total amount of paddy fed into the huller.

s. Coefficient of Wholeness is the proportion of whole brown rice by mass as a percentage of total amount of brown rice produced by a huller.

t. Hulling Efficiency is the product of the coefficient of hulling and coefficient of wholeness of grains.

2.2 Anatomy of the Rice Grain and Its Significance

The anatomy of a rough rice kernel is shown in Figure 2.1 and a rice mill diagram in Figure 2.2. The following description is from Araullo, et al. (1976):

> The outermost tissue of the grain is commonly known as the husk and is formed from two specialized leaves, the lemma covering the dorsal part of the seed and the palea covering the ventral portion.
>
> The palea and lemma are very loosely joined together longitudinally by means of an interlocking fold on each side of the seed and they are consequently very easily separated. The husk is formed mostly of cellulosic and fibrous tissue and is covered with very hard glass like spines. In the dry seed there is a distinct space between the husk and the cryopsis (kernel).
>
> The outermost layer of tissue of the cryopsis is a thin sheet of fibrous cells, the pericarp. This is sometimes called the silver skin because of its very flimsy and fibrous appearance when it is dissected from the grain. The thin pericarp layer is a very hard tissue that is highly impermeable to the movement of oxygen, carbon dioxide and water vapour. When it is intact it provides very good protection against mold attack and oxidative and enzymatic deterioration of the underlying tissues. Beneath the pericarp is the tegmen, which is a layer several cells in thickness. These cells are also a part of the seed coat but are less fibrous than the pericarp layer. They are rich in oil and protein but contain little starch. Beneath the tegmen is a layer of tissue several cells in thickness commonly known as the

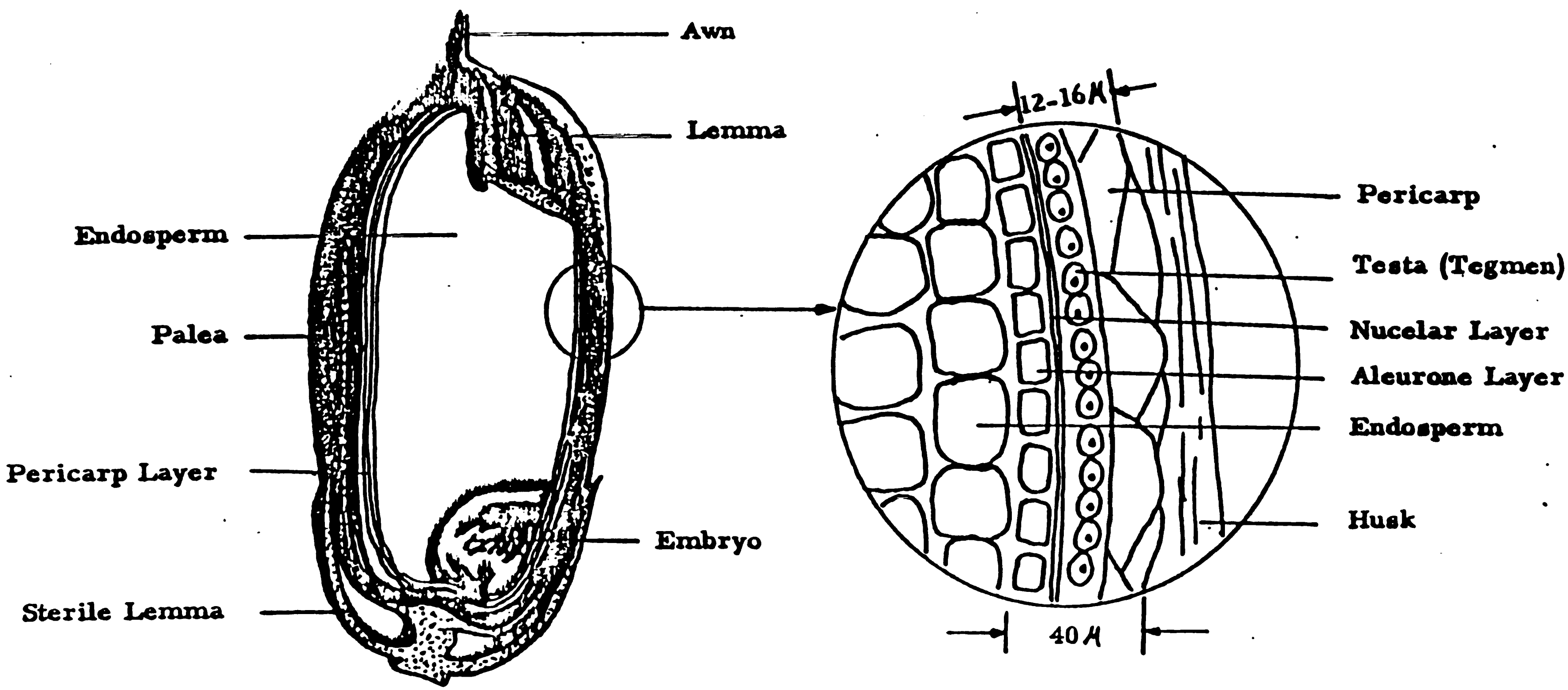

Figure 2.1 Anatomy of Paddy

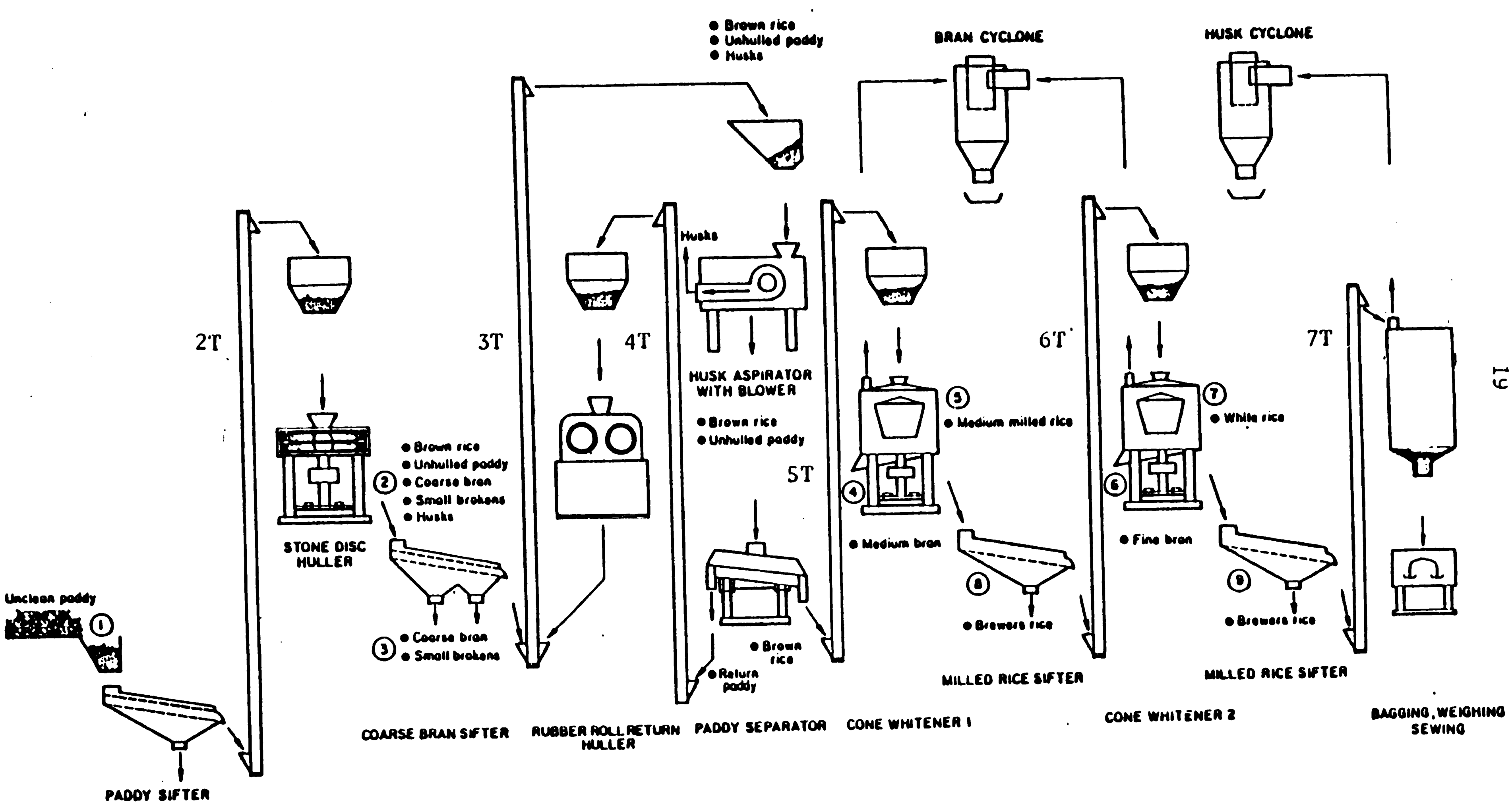

Figure 2.2 Schematic Diagram of a Disc-Cone (Conventional) Rice Mill

aleurone layer or bran. This layer of cells is very rich in protein, oil and vitamins with a relatively small amount of starch. The shape of the cells is somewhat hexagonal to spherical. The innermost tissue of the caryopsis is the starchy endosperm which contains only a very small percentage of protein. In the central core of the grain, the starchy cells are somewhat hexagonal in shape, but between the center and the outside they are elongated with the long walls radiating outwards from the center. It is the radial walls of the starchy cells that form thousands of potential cleavage planes that may result in breakage of the grain as a result of mechanical impact or thermal or moisture stress during processing.

In cross-section the total caryopsis has an undulating shape, the undulations corresponding with those of the husk. The undulating form is important in the whitening process because the bran layer can only be removed entirely when the undulations have been completely levelled.

The paddy grain husk, which is very fibrous and covered with spines, is very abrasive and easily causes wear and tear in mild steel conveying ducts. For this reason, bucket eleators and belt conveyors are preferable.

The distinct space between the husk and the caryopsis in dried grain allows the grain to be dehusked without any or with very little abrasion to the pericarp. Provided the clearance between the shearing surfaces of the hulling machinery is precisely adjusted, the palea and the lemma can be separated from the caryopsis with only a minimal mechanical stress against the surface of the caryopsis. Dehusking between rubber rollers can generally be done without scratching the pericarp. On the other hand, with the emery disc type of hulling, even if very well adjusted, it is difficult to avoid at least some abrasion of the pericarp. When such abrasion does occur, it usually results in damage to the oily layers beneath the pericarp that release lipase enzyme during storage, which results in enzymatic hydrolysis of the oil to produce free fatty acids, that are commonly manifested as rancidity. If the grain is to be stored in the form of brown rice, it is extremely important that the pericarp of the caryopsis is not damaged during the dehusking process. In contrast to this limitation, there are a number of advantages to be gained from storing the grain as brown rice; principally, the fact that brown rice occupies about half the volume of an equivalent quantity of paddy. It may also be useful when the grain is stored as brown rice in large milling centrals because they are equipped to dispose of the large quantities of husk created. Large centrals are equipped with husk grinders and have outlets for selling husks as filler feed for swine and cattle.

The radial configuration of the outer cells of the endosperm allows easy breakage of the grain kernels. It has been observed by researchers at IRRI in 1969[1] that breakage during threshing by manual beating of the grain, even at a moisture content of about 20%, is much greater than in certain types of mechanical threshing where the force is applied to the ends of the grain like in spike-tooth threshers. This indicates that breakage is greater when impact is exerted along the side of the grain rather than at the end. The alignment of the longitudinal walls of the starch cells (see Figure 2.1) across the body of the grain makes it very friable during the drying process and when the temperature of the grain reaches 48°C, thermal stress checks may be the cause of grain breakage during conveying and milling.

It is very important to avoid breakage of the rice because in the whitening stage of the milling process, the surface area of the broken grain exposed to abrasion is

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[1] See the report of Khan (1969)

much greater than whole grain and not only bran is lost but starch as well. This results in a low total recovery and low recovery of whole grain.

2.3 Rice Milling Process

Rice transformation through several stages of the milling operation are here defined. The milling process is generally carried out in several distinct stages with individual and separate machines doing specific operations. The transformation stages as shown in Figure 2.3 are as follows:

a. Precleaning to remove foreign matter with the use of sieves and air blasts.

b. Detachment of hulls from kernels with abrasive discs (or rubber rollers).

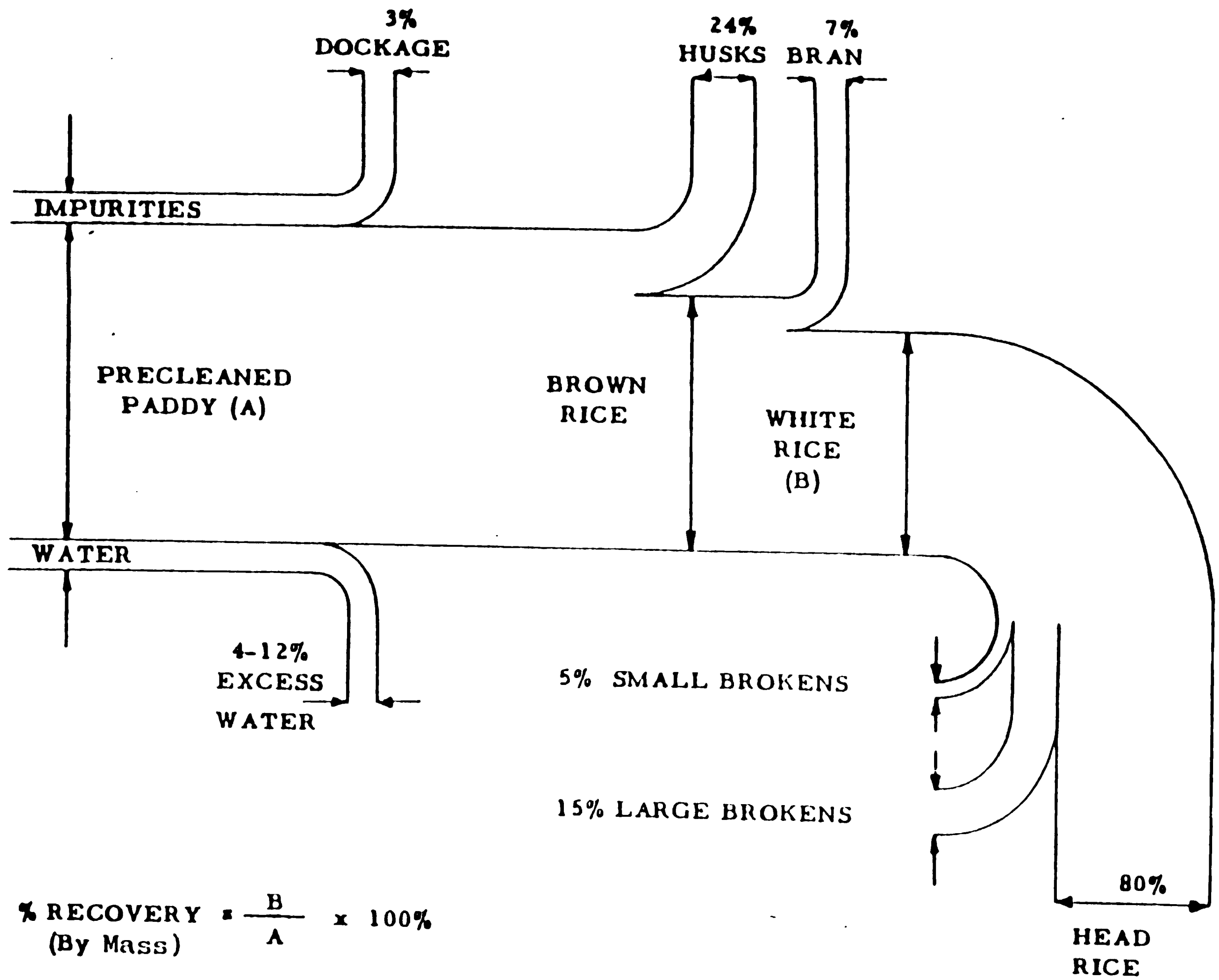
c. Separation of small brokens and coarse bran (pericarp or silver skin) by screening.

d. Separation of unhulled rice from hulled (brown) rice by paddy separator.

e. Whitening of rice by removing bran with abrasive stones (and/or a steel grinder).

f. Refining or polishing rice with leather strips or brush.

g. Grading of rice with sieves (and/or indented cylinders).



$$\% \text{ RECOVERY (By Mass)} = \frac{B}{A} \times 100\%$$

Figure 2.3. Rice Processing

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2.4 Input Paddy Factors

Nangju and De Datta (1970) found that irrespective of variety or nitrogen level, the optimum time of harvest of transplanted rice for obtaining maximum grain and head rice yields and highest germination percentage was between 28 and 34 days after initial heading in the dry season and between 32 and 38 days in the wet season. These periods correspond to moisture contents of between 22 and 19 percent and between 21 and 18 percent, respectively.

Rapusas, et al. (1978) reported that in the dry season, in Los Banos, Philippines[1/] the non-aerated paddy held in sacks before drying maintained its grade quality up to 3 days. In the wet season experiment, the non-aerated paddy held in sacks showed a loss in grade with a one day drying delay.

Ongkingco, et al. (1964) found that the highest milling recovery was obtained from grain dried to a moisture content ranging from 13.0 to 14.5 percent wet basis, with milling yields ranging from 68.2 to 69.9 percent and the highest percentages of whole grain (head rice) ranging from 58.3 to 58.8 percent. Much lower

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[1/] The dry and wet season average temperature and relative humidity in Los Banos are 26.8°C and 80.0 percent and 26.1°C and 85.4 percent, respectively.

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recoveries were obtained from grain dried to a moisture content of 15.0 to 16.5 percent. Lower percentages of whole grains were also obtained, which may have been due to damage caused by overheating caused by respiratory heat during storage.

2.5 Milling Factors

Manalabe, et al. (1978) reported that the quantity as well as the quality of brown rice recovered from single pass hulling varies significantly with the huller clearance. The indica rice variety has an average brown rice kernel length, width and thickness of 7.13 mm., 2.18 mm. and 1.66 mm., respectively. At 14 percent moisture content wet basis, the clearance adjustment for optimum hulling efficiency should range from 3.0 mm. to 4.0 mm. for the stone disc huller and from 0.75 to 1.0 mm. for the rubber roll huller. Hulling efficiency on these settings ranges from 55.1 to 57.8 percent for the disc huller and 82.1 to 83.3 percent for the rubber roll huller. Between the two huller types, the rubber roll huller had a higher total outturn of brown rice from paddy of 75.2 as compared to 72.8 percent for the stone disc huller. There was partial scouring of brown rice and brokens are blown away with the husks in the stone disc huller.

Manalabe, et al. (1978) concluded that the milling system used did not have a significant effect on the recovery. The recovery percentage for the milling systems using a stone disc huller ranged from 63.2 to 64.87 percent, while that for the milling systems using a rubber roll huller was higher, though not significantly so, ranging from 66.5 to 67.7 percent.

Researchers at the University of Arkansas[1/] found that the relative humidity of the mill room affects the yield of head rice. Optimum yields were obtained when the relative humidity was between 70 and 80 percent. The mill room temperature did not affect the yields of head rice when the temperature of the rough rice entering the mill was approximately the same as that of the mill room air. The mill room relative humidity ranged between 70 and 80 percent.

2.6 Ambient Relative Humidity and Temperature

Rice milling researchers at the University of Arkansas presented results of the effects of mill room humidity on milling efficiency as well as in some portion of the milling process. The effect of rice temperature

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[1/] See undated Reference entitled Rice Milling Research Terminal Report of the Institute of Science and Technology, University of Arkansas, Fayetteville, Arkansas.

relative to room temperature on milling efficiency was also studied. The relationship of air humidity and rice moisture content has been discussed in several published reports (Hall, C.W., 1963) concerned with hygroscopic equilibrium. Rice with a moisture content of 12.5 to 14 percent is in equilibrium with the atmosphere at approximately 70 percent relative humidity, which would indicate that rice milled under such conditions would neither gain nor lose moisture.

Rough rice samples of approximately 1,200 lb each were collected from representative lots from Southern Arkansas commercial mills for each series of test runs. The 1,200 lb samples were divided into six 200 lb mill samples and stored in airtight containers for three weeks preparatory to milling. The mill room temperature was held constant at 80°F plus or minus 2°F during all runs. An attempt was made to mill all runs at relative humidities of 30, 50, 60, 80 or 90 percent with a duplicate run at each of these humidities. Determination of moisture was made and the fat content of bran layers was measured in order to determine whether bran was being removed to a uniform degree in a specific series of runs. Figures 2.4 and 2.5 show, respectively, the average deviation from maximum yield with changes in humidity and the effect of temperature on Zenith and Rexark Rice.

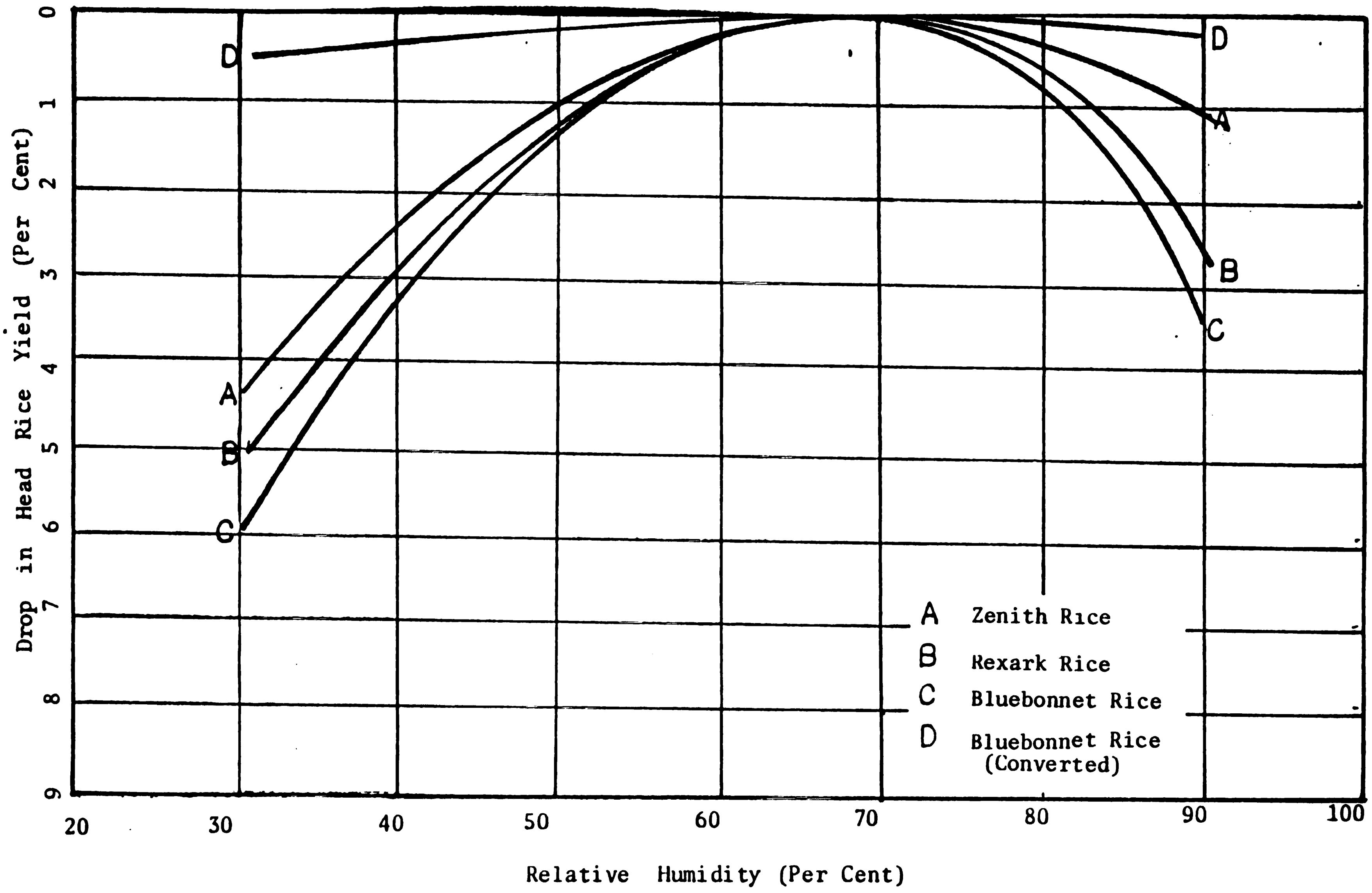

Figure 2.4. Average deviation from maximum yield with changes in humidity from Rice Milling Research Terminal Report (Anonymous and Undated) University of Arkansas, Fayettevile, Arkansas

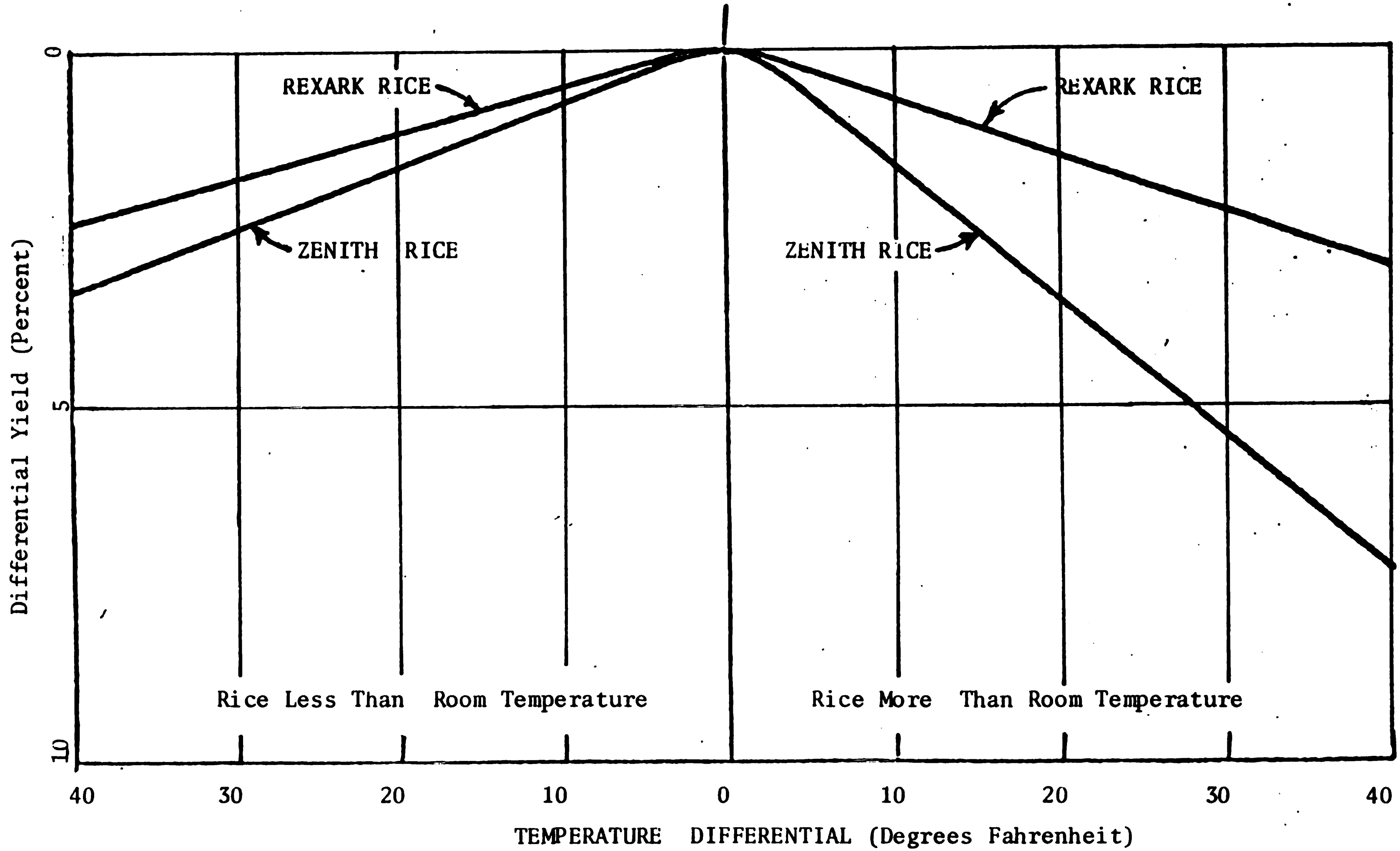

Figure 2.5. Effect of temperature on Zenith and Rexark rice from Rice Milling Research Terminal Report (Anonymous and Undated). University of Arkansas, Fayetteville, Arkansas

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Table O1 in Appendix O shows the normal weather data for Southern Luzon (Philippines) as recorded by the College Weather Station. The relative humidity varies from 78 to 86 percent with a mean of 83 percent. This corresponds to a hygroscopic equilibrium of 15 to 16 percent. The variation is negligible on a day-to-day basis but it is pronounced on a seasonal basis. Figure 2.4 shows that the head rice was reduced under this condition from 0 to 1.2 percent depending on the actual relative humidity and rice variety. It was found that the conditioning of first and second stage hullers was not of prime importance. It is apparent from the data that the operations in which the rice comes into contact with large volumes of air, such as aspirators and elevators, are the critical points where humidity affects yield of head rice. Due to lack of data on the effect of humidity on Philippine grown varieties, this variable was not considered in the modeling.

2.7 Economic Factors

Shelby, et al. (1974) modeled three rice mills with capacities of 11.0, 22.0 and 36.8 tons per hour. Capital requirements and operating costs were analyzed to develop average cost curves. The importance of maintaining high levels of mill utilization is shown by the fact that costs

decreased 30 to 40 percent when the mill operating time was increased from a 5-day, 40-hour week to a 7-day, 168-hour week.

The 11-ton-per-hour mill had the highest operating cost at any given level of time utilization. However, this relative cost disadvantage narrowed as the operating time increased. Bagtas and Lizardo (1970) reported that the benefits to the investor from rubber roll rice mills are insufficient to make them attractive. Such studies indicate the need to increase the hours of daily operation of the mills approximately fifty percent to cope with the increased harvests derived from HYV's and new farming technology.

2.8 Systems Technique Used in the Modeling

Manetsch and Park (1977) identified three major ways in which models can go wrong. The first is at the "problem definition" level where a model must obviously address the correct set of problems. It must adopt the right variables as policy inputs and include the correct variables for enabling decision-makers to evaluate alternative possibilities. Secondly, a "good" model must in its mathematical structure produce close approximation of actual experience. This requirement introduces such complexity as to require that the system be expressed in terms of a computer program in order to be efficiently handled. This means that it is necessary to produce a mathematical model that approximates the real world. Finally, a "good" model must incorporate a computer model that closely approximates the mathematical model.

Models can be classified according to the view they take of the real world: microscopic or macroscopic. Microscopic models take a very detailed view of reality and represent, explicitly, individual entities moving through, or being processed by, the system. For example, a detailed model of the operation of a grain storage system would represent each individual shipment of grain as it was loaded or unloaded at the storage facility. A macroscopic (or aggregative) model, on the other hand, deals with aggregative flows of goods or services; for example, aggregated birth and death rates in a population or total production of a commodity in a geographical region. A good "problem definition" will help decide which type of model to build. Some problems require a microscopic point of view; for others, a macroscopic model is clearly more appropriate.

A second important way to classify models is whether or not they represent dynamic phenomena in the real world. A good test to determine whether a given system or situation is dynamic or not is to pose the question, "Will actions taken today influence the future in some important ways?" If the answer to this question is "yes," the system is dynamic. Static models are incapable of providing information about the future consequences of current decisions. Static models can, however, be useful in addressing decision problems in agricultural development. For example, a static model may provide information to a farmer on how many acres of various crops he should produce this year, given particular assumptions about prices and yields per acre.

A third important way of classifying models is according to whether they are deterministic or stochastic (random). A stochastic model contains random elements which will simulate outcomes of an uncertain nature, while deterministic models do not. Deterministic models are appropriate when the effect of stochastic elements are small or negligible.

Stochastic models approximate the impacts of random factors and provide decision-makers with some idea of the range of outcomes that are possible from a particular decision, given the random factors that are present in the given situation. In order to do this, models are operated repetitively in a so-called "Monte Carlo" mode. In each "Monte Carlo" run of the model, the random factors involved are allowed to take on a different set of values that are

consistent with the randomness inherent in the real world. The average value obtained from the "Monte Carlo" simulation is considered the most likely value to be encountered in real life situations.

With the broad outlines of the system model established as a result of sound problem definition and given selection of the most appropriate model type, two major approaches to model-building can be employed singly or in combination. These are the so-called "black box" and "structural" approaches. Essentially the "black box" approach seeks to identify a system model from data describing the past behavior of the real-world system. Through various statistical and mathematical techniques, a model is derived which in some sense is a best fit to the historical data.

The "structural" approach to building a model attempts to represent or simulate the detailed system structure that causes the total system to behave as it does. This approach decomposes a system into its component parts, builds mathematical models that approximate the behavior of those component parts, and then interconnects the component models to obtain a model of the overall system. Many, if not most, large-scale decision models are developed using this approach aided by the "black box" approach to fill certain parts of the structure.

In system simulation there are significant decisions to be made in the choice of computational techniques used in the computer model. Proper choice here can lead to substantial savings in model development time and cost.

In almost every model simulation there is a need to represent the relationship between two variables or quantities in language a digital computer can understand. A very common and efficient means of doing this is the so-called "straight-line approximation" method. In some cases the functional relationship between two variables can be implemented with functions built into a programming language such as FORTRAN (examples are logarithmic, exponential and trigonometric functions). Programming using "built-in" functions is easier, but they almost always use more computer time than the straight-line approximation method. Another method of function representation, polynomial approximation, can be extended to functions of more than one variable but is less common than the two methods cited.

Differential equations are solved on a digital computer by the process of numerical integration; and there are several ways to do this. The simplest and most common numerical integration technique in agricultural models is the so-called "Euler" integration.

Holtman, et al. (1972) discussed that the primary function of systems analysis is the determination of performance characteristics of a system of interaction components operating in a specified environment. The engineer's basic interest is to study system performance utilizing various component configurations. In some situations there may exist a fixed set of components from which those to be utilized are selected. Alternatively, the primary emphasis may be the design of a particular component which is suitable for use in the system. In either case, the systems methodology will be enhanced if component manipulation capability exists.

A second feature of engineering models is the description of mass and energy flows among components. The system is viewed as a collection of components which interact with each other and their environment via mass and energy exchanges. The law of continuity is involved at every exchange point.

Finally, a level of energy is associated with each material. The energy level is an intensive attribute which reflects the energy required (per unit of material) to place this material in its current form and location.

Koenig and Tummala (1972) discussed the components of an ecosystem into three general classes: material transformation processes, material transport processes and material storage processes. All production processes in industry and agriculture can be defined as transformation of materials to achieve a well defined change in their physical, chemical, technological or biological structure, through the application of energy in one or more of the three forms: solar, human and/or physical. The transformation processes are organized in technical units called plants, a plant being a technically coordinated aggregate of fixed capital under common management. The term "process" is used in a semi-abstract sense as distinct from the total productive activity of the plant. It specifically excludes the technological treatment to which materials are subjected to bring them further toward their completed state as products useful to man.

Transport processes in the ecosystem can be viewed as a special class of material transformation processes wherein the process simply moves the material form from one geographic location to another at a cost.

Storage processes can also be viewed as a special class of material transformation processes wherein the input and output materials are identical in form. The accumulation of material and energy (or monetary value of inventory) depend upon the flow rates ingoing and outgoing in the storage process.

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A model of the physical and economic characteristics of any given or proposed system is obtained by constraining the free-body models of the system components according to the laws of material and energy balance imposed by the interconnections between the material transformation, transportation and storage processes and the components of the natural environment.

Various literature on grain and food handling were reviewed to find out if there was previous work on modeling grain processing facilities. This author did not come across any technical model of grain-handling facilities similar to the proposed model. However, an economic model by Shelby, et al. (1974) was discussed earlier in Section 2.7.

2.9 Summary of Review of Literature

From the preceding review of literature sufficient information on rice grain parameters was obtained to build a rice mill systems model. Important grain parameters include input paddy factors such as: moisture content at milling, maturity, purity and drying delay. Environmental input variables such as relative humidity and ambient temperature are fairly constant on a day-to-day basis; and were assumed constant in this modeling.

The parameters which are controllable in rice mill design include type and size of component for each process stage. Additional data were needed on the rice mill parameters to successfully simulate a rice mill operation including consumption and time analysis of various components. A more detailed discussion of this is presented in Sections 3.3, 3.4 and 3.5. Other parameters such as material reduction rate, conversion efficiencies and machine capacities are available and were discussed in Section 2.5. Two management input variables are non-controllable: the operator's skill and dedication and the condition (state of repair) of the mill, hence these variables are unpredictable for a simulation model. It was decided by this author to assume that good maintenance is performed and that proper training and conditioning of mill operators takes place (which is highly desirable). The Philippine government through the National Grains Authority in connection with the University of the Philippines at Los Banos has been conducting training on rice milling for rice millers and operators since 1972. The training consists of lectures and laboratory work in the Grain Processing Laboratory in Los Banos and on-site training in NGA leased commercial mills. The training emphasizes the importance of well maintained equipment and its proper adjustment.

CHAPTER III

RICE MILL PERFORMANCE MODEL

This chapter covers the development of the rice mill performance model and its implementation with a computer. Based on the specific objectives of this study as presented in Section 1.2 and the discussion of systems technique in Section 2.8, it was decided to develop a stochastic static model. This model incorporated grain variables such as: harvesting and drying delay, moisture content and purity of paddy. It was decided to employ a microscopic view of the rice mill to study precisely what occurs as a batch of grain goes through the stages of the rice milling process. A "structural" approach was utilized to enable the model user to manipulate components for purposes of simulating various combinations and capacities of machinery.

3.1 Model Definition

Primary considerations for rice mill output performance evaluation were the milling yield and rice quality. The parameters that affect these variables were analyzed. A causal diagram was developed and is shown in Figure 3.1. The system was identified based on this diagram.

Energy consumption, which is another performance criterion, is discussed separately in Section 3.4.

Desired Outputs are:

a. High milling yield and high proportion of head grain (unbroken kernels).

b. High quality of grain (no discolored and checked kernels).

c. Clean grain kernels.

Designer Controllable Input Variables are:

a. Type and size of component for each process stage.

b. Mill capacity (tons per hour).

c. Optimum combination of locally produced and imported equipment.

Management Non-controllable Input Variables are:

a. Operator's skill and dedication.

b. Condition (state of repair) of mill.

Non-controllable Environmental Input Variables are:

a. Relative humidity.

b. Ambient Temperature.

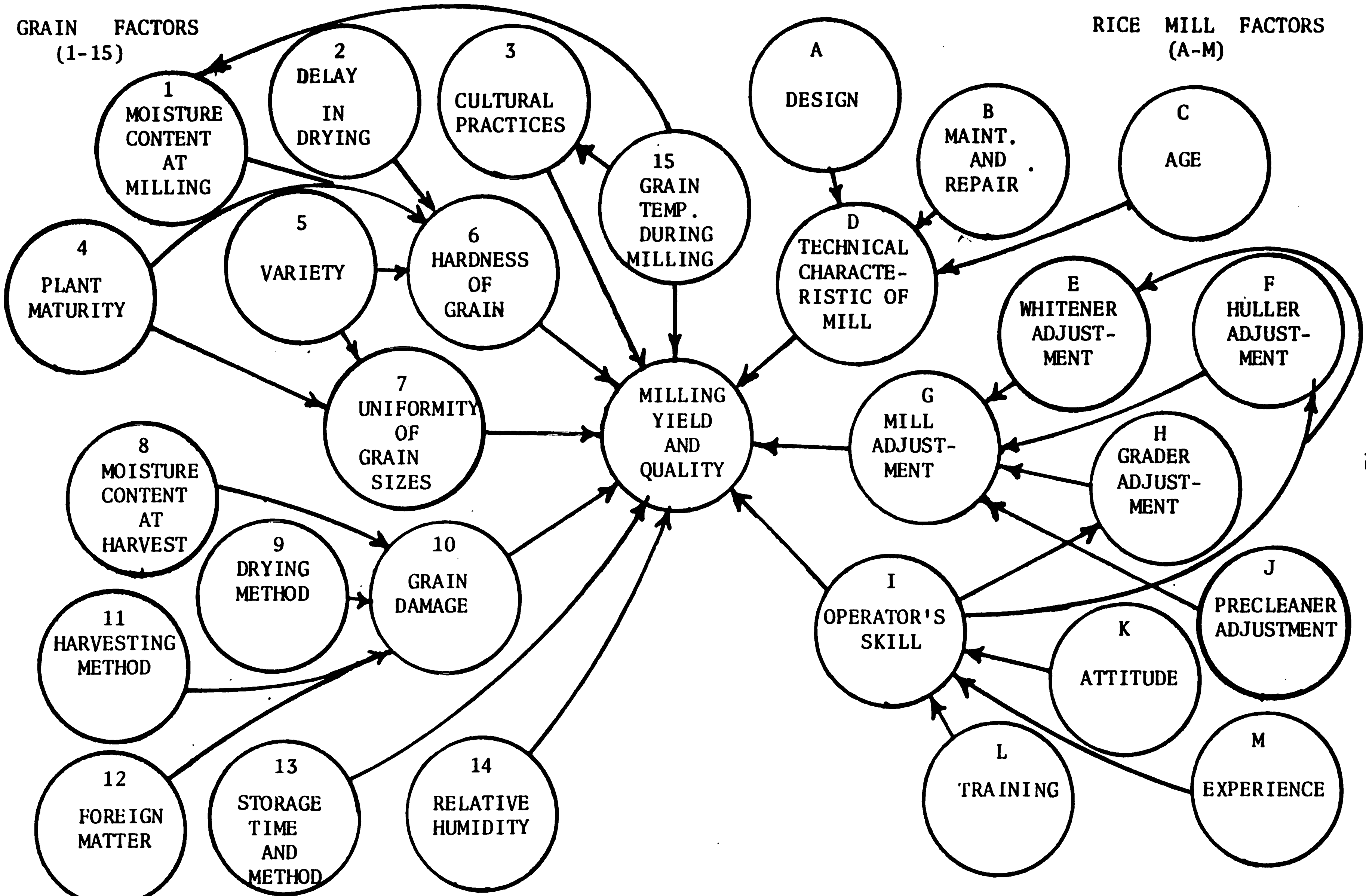

Figure 3.1 Idealized Causal Diagram of Rice Mill System's Yield and Rice Quality Characteristics.

Non-controllable Inputs are:

a. Input grain parameters.

b. Total grain input per batch (tons).

3.2 Grain Variables

Data on the grain variables that affect milling quality (maturity, moisture content at harvest and at milling, drying delay, purity and grain-shape) were obtained from several studies by other researchers.[1/] These studies were done under controlled conditions to isolate the effect of each variable. The value of each (loss or yield) variable was expressed as a percentage of the maximum value attained in the experiment. These percentages were then multiplied to obtain an index similar to Steele's multiplier (Steel, et al., 1969). These reflect the extent of damage due to adverse conditions. If grain was produced and processed under ideal conditions, its milling yield and quality index would be at a maximum value for that particular grain-shape. The use of grain shape[2/] instead of variety has the advantage of eliminating model obsolescence as new varieties are developed.

[1/] See the works of Camacho, et al.; Eriyatno; Nangju and De Datta; and Rapusas, et al.

[2/] See Appendix J, Figure 3.15 and Section 3.3 for more details.

3.2.1. Input Paddy Factors

Grain is a living and respiring biological product and its treatment prior to milling has a direct bearing on the quality of the final product. These include production treatments such as fertilization, solar radiation and irrigation; and post-harvest conditioning such as harvest maturity, drying method, duration of storage and delays in the various processing operations. It was not possible to include the effect of all these factors due to non-availability of data. However, the variables that have the greatest known effect on the quality of the final rice product were included. These were maturity at harvest, drying delay, moisture content at milling and grain-shape.

3.2.1.1 Maturity at Harvest

Nangju and De Datta (1970) reported the effect of time of harvest on the grain yields of four varieties in the dry season. When the varieties were first harvested at 16 days after initial heading (DAH), the kernels had just turned from the milk stage to the soft dough stage, the kernels were thus under-developed, mostly green and partly filled. The mean moisture contents of the mature grain, unfilled grain and green kernel at 16 DAH (average of four varieties at three nitrogen levels) were 33, 36 and 89 percent, respectively. As the harvesting was delayed, more of the kernels were fully filled and had turned from green to yellow. Consequently, the percentage of unfilled grains and of moisture content of the grain decreased and the 100 grain weight[1/] increased in grain yield during the early ripening period. The 100-grain weight sample from filled grains was highest at about 22 DAH. The further increase of grain yield after 22 DAH apparently resulted from a decrease in unfilled grains, which was lowest at about 30 DAH.

For the wet season, the mean moisture content percentages for the mature, unfilled and green kernels at 16 DAH (average of four varieties and nitrogen levels) were 34, 44 and 89, respectively. As the moisture content of the grain decreased and the 100-grain weight increased, the grain yields of the four varieties increased.

Data showing the effect of time of harvest on percentage of total milled rice and head rice for the four varieties during the dry and wet seasons are presented in Figure 3.2. In both seasons, total milled rice and head rice yields increased to maximum values until the moisture content decreased to the point of optimum yield. Thereafter, total milled rice yields remained fairly constant, whereas head rice yields dropped off with a further

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1/A 100-grain weight is the weight in grams of 100 grains of rice.

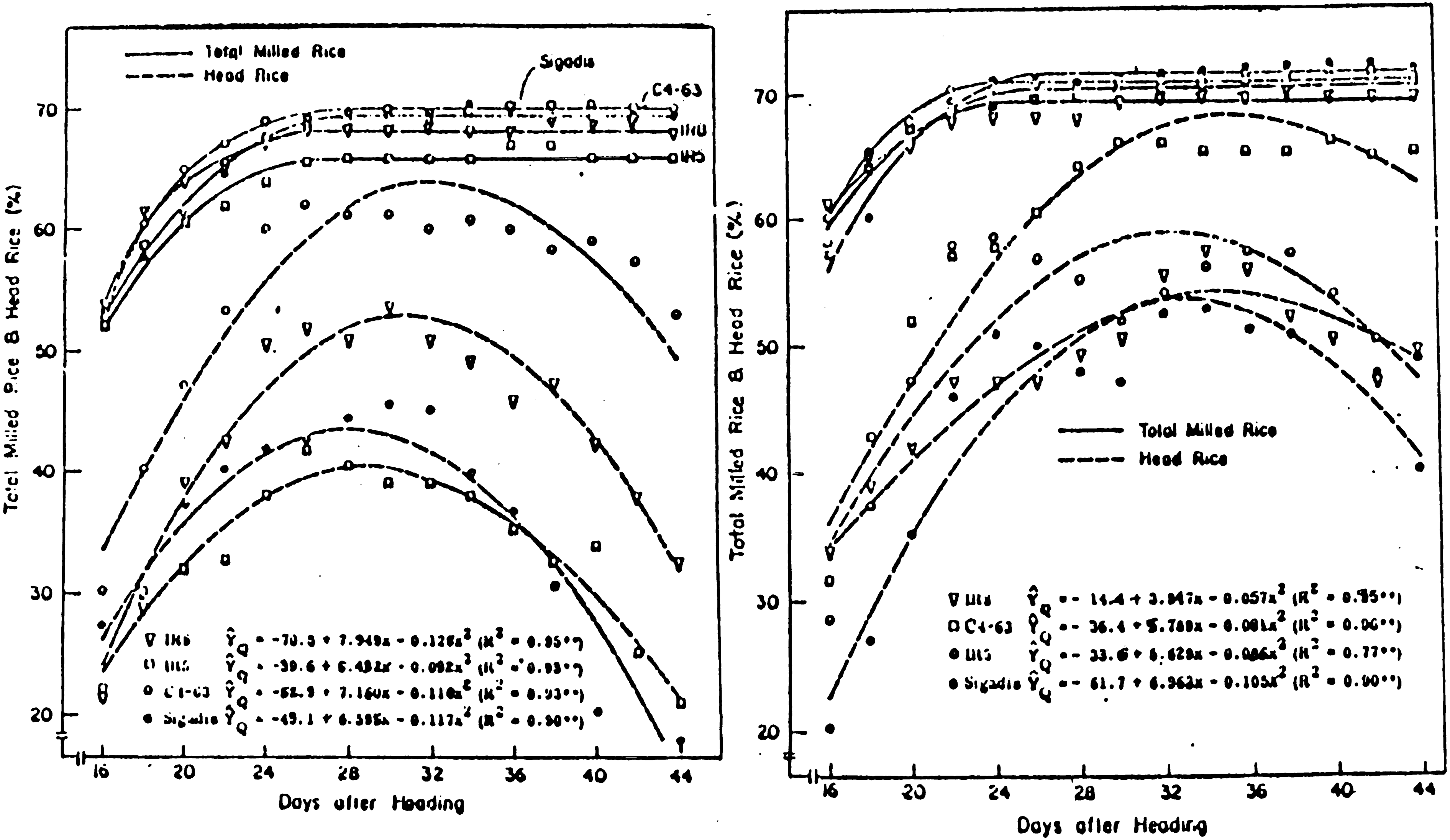

Figure 3.2 Effect of time of harvest on percentages of total milled rice and head rice in IR8, IR5, C4-63 and Sigadis. IRRI, 1968 Dry(Left) and Wet(Right) seasons. (Average of three nitrogen levels). From Nangju and De Datta (1970).

decrease in moisture content. A combined graph as discussed in Section 2.4 is shown in Figure 3.3.

The low levels of head rice for the four varieties at early harvest were primarily due to the presence of many immature, green and chalky grains, which were easily broken during hulling and polishing. As the level of these low-quality kernels decreased, the head rice yield increased. After reaching the maximum value of head rice yields, the head rice yield at later dates was caused by the alternate wetting and drying of the grains, which caused sun-checking.

When variability arising from varieties and nitrogen levels was ignored, the maximum head rice level occurred between 24 and 34 DAH in the dry season and between 32 and 38 DAH in the wet seasons. Harvesting before or after these optimum periods resulted in significant head rice decreases due either to under-ripening or over-ripening of the kernels. The corresponding moisture contents of grain during these optimum stages were between 19 and 25 percent for the wet season and between 18 and 21 percent for the dry season.

Camacho, et al. (1978) reported that farmers used several methods which could be categorized as follows: twenty-one percent used maturity date, eight percent used a percentage of 50-69 ripe grains, eleven percent used a

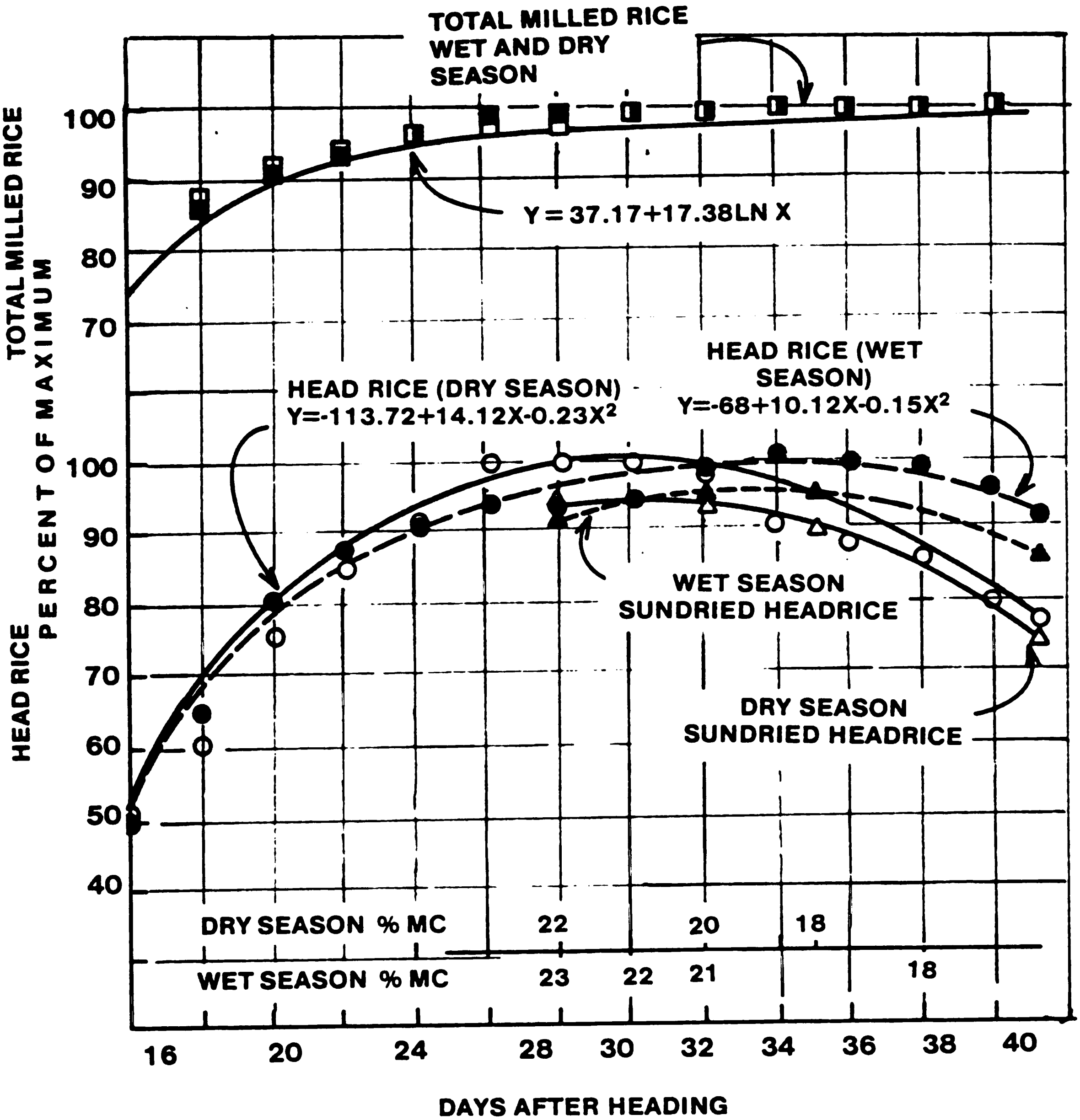

FIGURE 3.3 RELATIONSHIP BETWEEN DAYS AFTER HEADING AND HEAD-RICE PERCENTAGE FROM NANGJU AND DE DETTA (1970)

percentage of 70-89 ripe grains and sixty percent used a percentage of 90-100 ripe grains. Although most harvested at maturity, 5 percent delayed up to 10 days after maturity and a few advanced the harvest 1 to 10 days before maturity. In the simulation normal distribution was used with the mean being the optimum harvest date.

3.2.1.2. Delay in Drying

Rapusas, et al. (1978) found that the quality of paddy deteriorated with delays in drying. This study was conducted during both the dry and wet harvesting seasons of 1976 and 1977 in the Grain Processing Laboratory of the University of the Philippines at Los Banos. The three study methods of handling paddy were: sack handling with 28 m^3/min.-ton aeration, bulk handling with 35m^3/min.-ton aeration, and sack handling without aeration treatment. The three rice varieties tested for both seasons included IR-26, IR-32 and IR-38.

Dry Season Results

Based on the percentage of damaged kernels in milled rice as the controlling factor, non-aerated paddy was stored from 1 to 3 days before drying without loss in grade. However, when delay in drying was prolonged to 15 days, the recovered milled rice had deteriorated to sample grade. The paddy in sacks aerated at an airflow rate of $28m^3$/min.-ton was held after threshing up to 9 days prior to drying. At an airflow rate of $35m^3$/min.-ton applied on paddy handled in bulk, the safe period of drying delay was extended up to 2 weeks.

Laboratory milling of paddy samples from all the handling treatments revealed a slight decrease in milling recovery because of drying delay, although paddy held without aeration (Figures 3.4 and 3.5) showed a faster rate of deterioration as delay increased. Aerated paddy in bulk and in sacks gave an almost uniform milling recovery after 26 days of drying delay. At the same time a drop of less than 1 percent from the initial milling recovery was evident for paddy held without aeration treatment.

Head rice yields of aerated paddy in bulk and in sacks were higher than those obtained from non-aerated paddy at any period of drying delay. This can be attributed to the presence of being fewer damaged kernels which break easily during milling. Paddy aerated at an airflow rate of $35m^3$/min.-ton gave better head rice yields than those aerated at $28m^3$/min.-ton. Neither airflow rate maintained the initial head rice yield obtained when paddy was dried immediately, however.

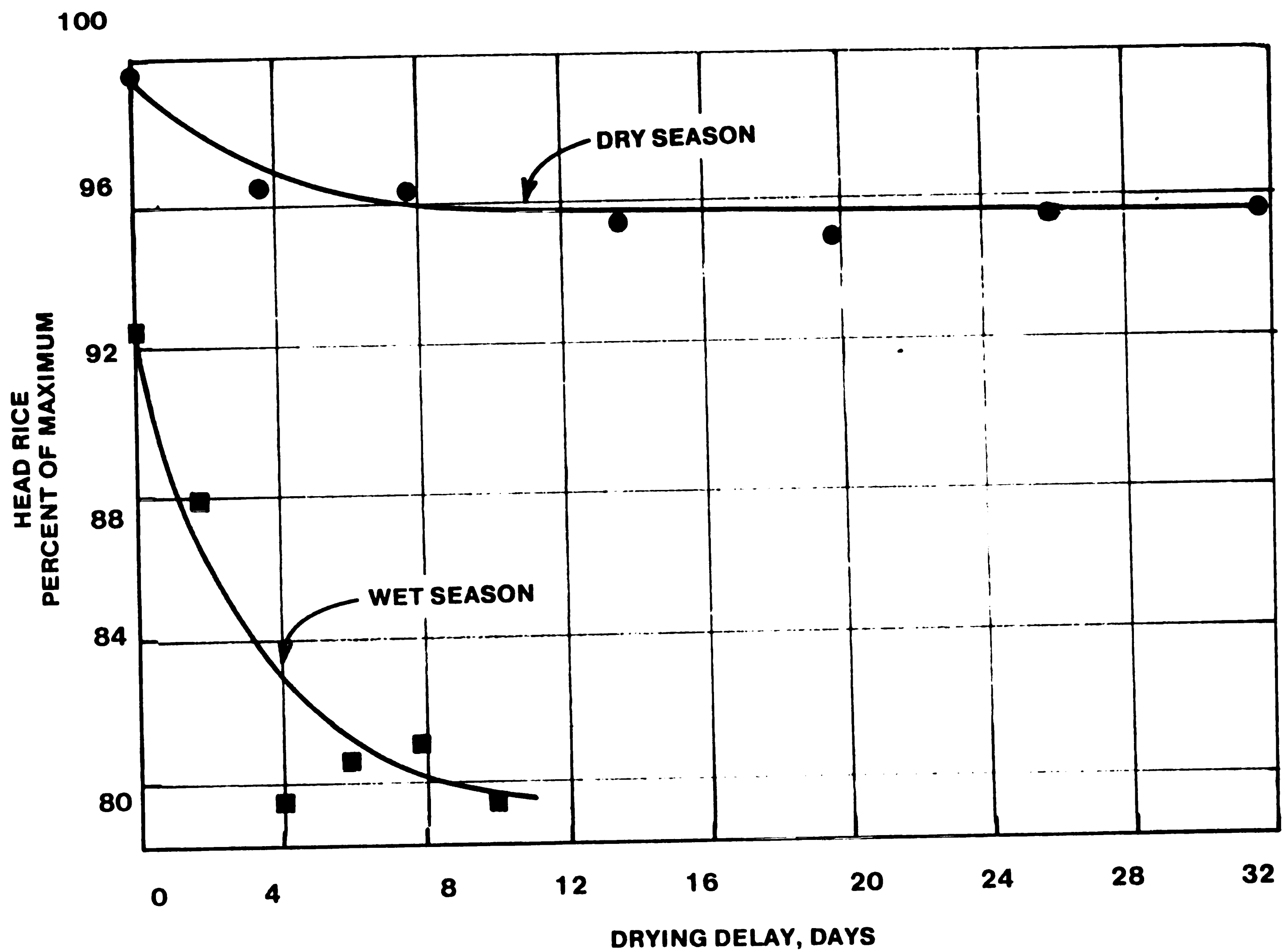

FIGURE 3.4 DRYING DELAY AND HEAD RICE RELATIONSHIP
from Rapusas, de Padua and Lozada (1978).

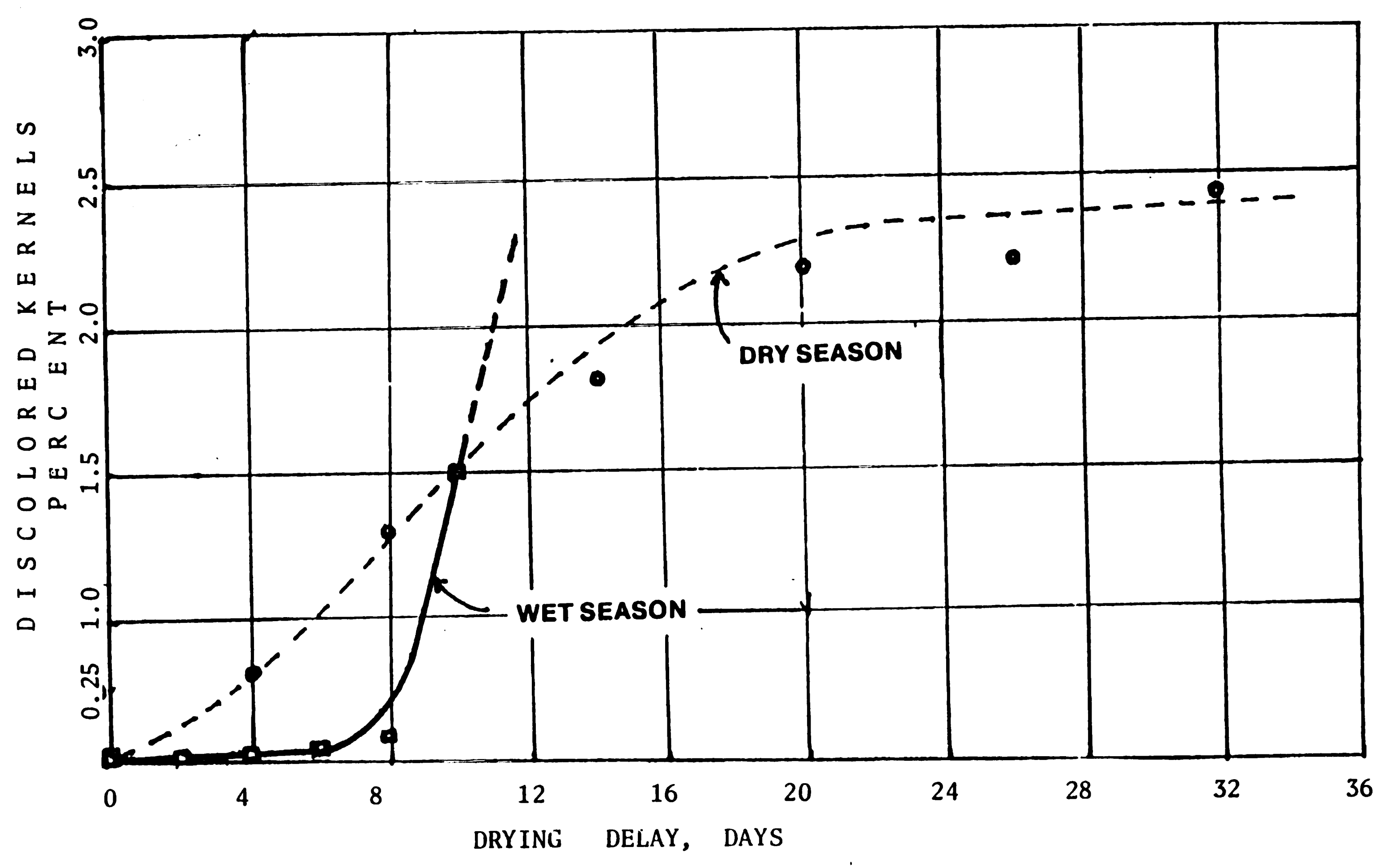

Figure 3.5 Drying delay and discolored kernels relationship.
from Rapusas et al.(1978)

Wet Season Results

Aerated paddy held in sacks and in bulk showed no lowering of grade based on the percentage of kernels for a drying delay of 2 or 3 days after wet season harvests. After ten days, however, a decrease in milling recovery was experienced in paddy no matter how stored. With aeration, however, smaller reduction in milling recovery was experienced. Paddy stored without aeration for the ten-day period yielded a four percent decrease in milling recovery as compared to aerated paddy. Smaller decrease of milling recovery was observed for paddy aerated with $28m^3$/min.-ton, followed by the paddy with $35m^3$/min.-ton. For 10 days drying delay, there was a 4 percent drop in milling recovery of paddy stored without aeration as compared to the initial milling recovery of aerated paddy that was dried immediately after threshing. The milling recovery of aerated paddy either in sacks or in bulk dropped by about 2 percent from the initial milling recovery of 66.8 percent for a 10-day drying delay.

With non-aerated paddy there was a rapid decrease in head rice yield as drying was delayed 10 days. This reflected the rapid increase in damaged kernels which are prone to break during milling. After a two-day delay in drying there was already a drop in head rice of 4.6 percent from the initial head rice recovery of 84.6 percent.

The graphs on Figures 3.3, 3.4 and 3.5 were incorporated in the simulation by the use of a "straight-line approximation" method discussed in Section 2.8. The drying delay was generated by the computer in accordance with the probability distribution shown in Figure 3.40.

3.2.1.3 Moisture Content at Milling

Ongkingco, et al. (1964) reported that there was a direct correlation between moisture content and milling recovery. Tables K1 to K8 in Appendix K show the milling recovery of samples milled one day after drying and at storage periods of one month, two months and three months after drying. The milling recovery for rice stored at moisture contents of 13 to 14.5 percent was the highest at the one-month milling date. After this there was a gradual decrease in milling recovery. In the fourth and last milling, the recovery increased again but to a lower value than in the first milling. This variation in milling recovery was attributed to variation in moisture content of the grain at milling which in turn was attributed to prevailing weather conditions.

Eriyatno (1979) presented a mill conversion curve (Figure 3.6) which has a mathematical relationship between rough rice moisture content and mill conversion as follows:

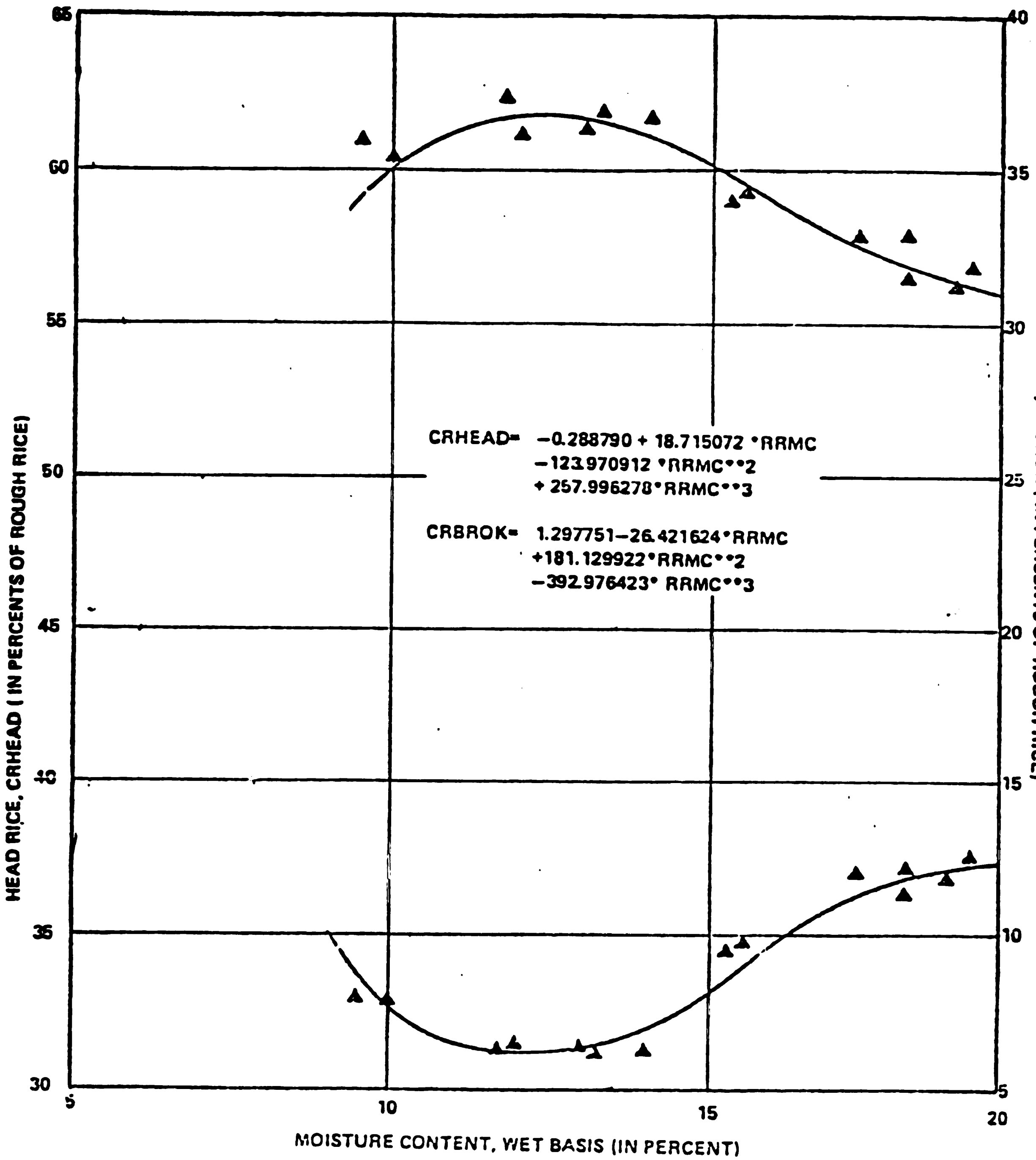

Figure 3.6 Milling Yield Curve from Eriyatno (1979)

$$CRHEAD = -0.28879 + 18.715072 \times RRMC - 123.970912 \times RRMC^2 + 257.996278 \times RRMC^3$$

where CRHEAD = percentage of head rice, in percent of rough rice

RRMC = rough rice moisture content, percent wet basis

Paras (1976) measured grain rigidity1/ at different moisture contents (Figures 3.7, 3.8, 3.9 and 3.10). A graph of the relationship is presented in Figure 3.11. Rigidity may be converted to pressure by dividing the rigidity in kilograms by the cross-sectional area of the plunger on the rigidity tester.

Sang Ha No (1976) presented a characteristic curve for a whitening machine showing the relationship between head rice recovery and radial pressure (Figure 3.12). In this figure, the capacity scale of the lower horizontal axis was developed using the linear relationship which exists between average grain radial pressure and machine capacity. The head rice recovery-radial pressure (H-Pr) curve constitutes the upper scale of the horizontal axis showing radial pressure and the left-hand vertical axis showing head rice recovery. The capacity-electric power consumption (C-EC) curve involves the horizontal axis

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1/Rigidity is the hardness in kilograms of a grain kernel measured by a tester consisting of a plunger with a 5 mm. diameter.

Figure 3.7. Rough rice at different moisture contents was collected during a drying run using a flatbed mechanical drier.

Figure 3.8. Moisture content of samples were measured using a capacitance moisture meter.

Figure 3.9. The rough rice grain sample was dehulled by hand.

Figure 3.10. Pressure was applied on the grain until it cracked and the force and pressure recorded. A total of 50 grains at each moisture content level was tested.

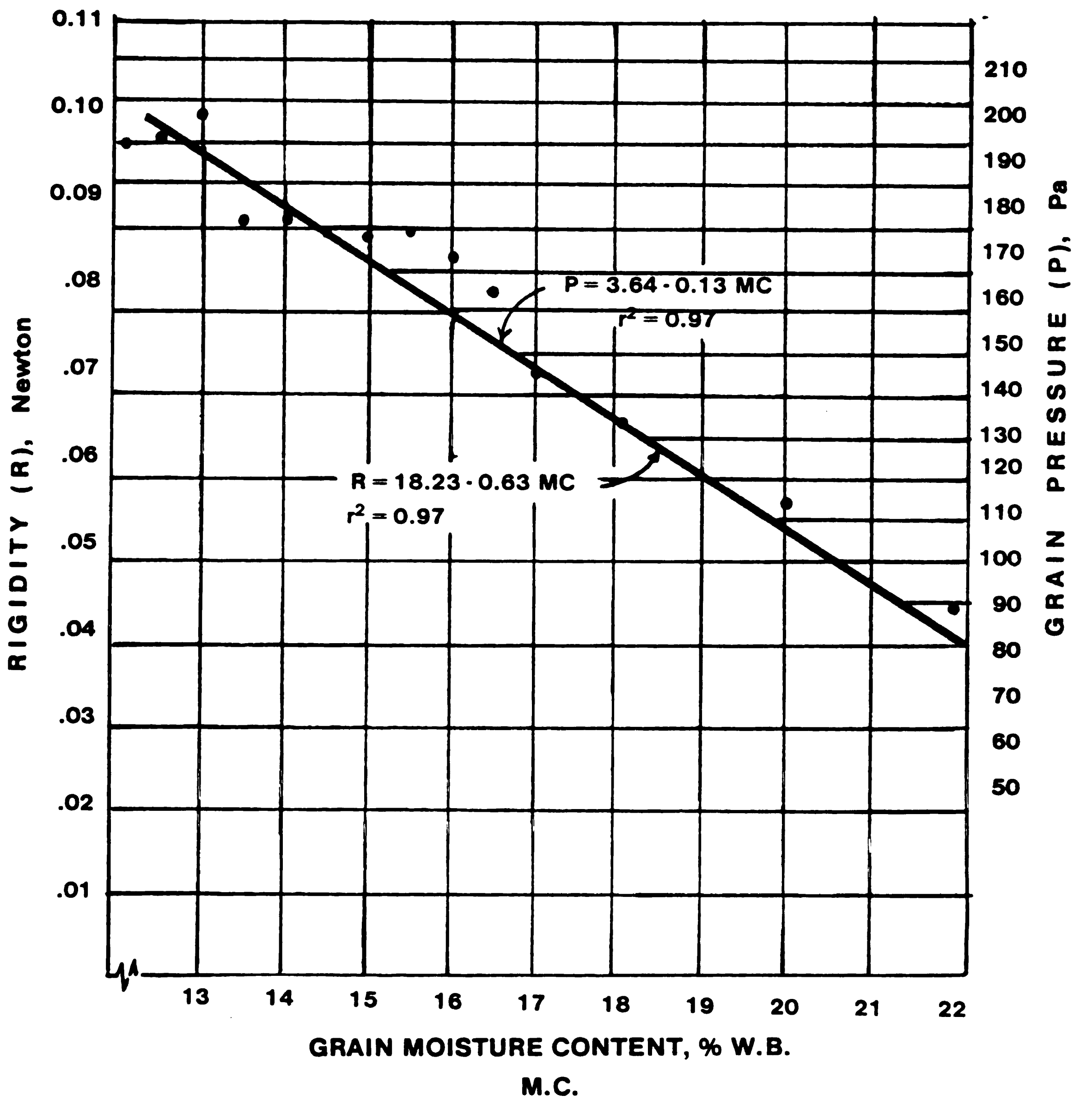

Figure 3.11 Grain Moisture Content VS Rigidity
All information where the source is not noted were gathered by the author for this dissertation.

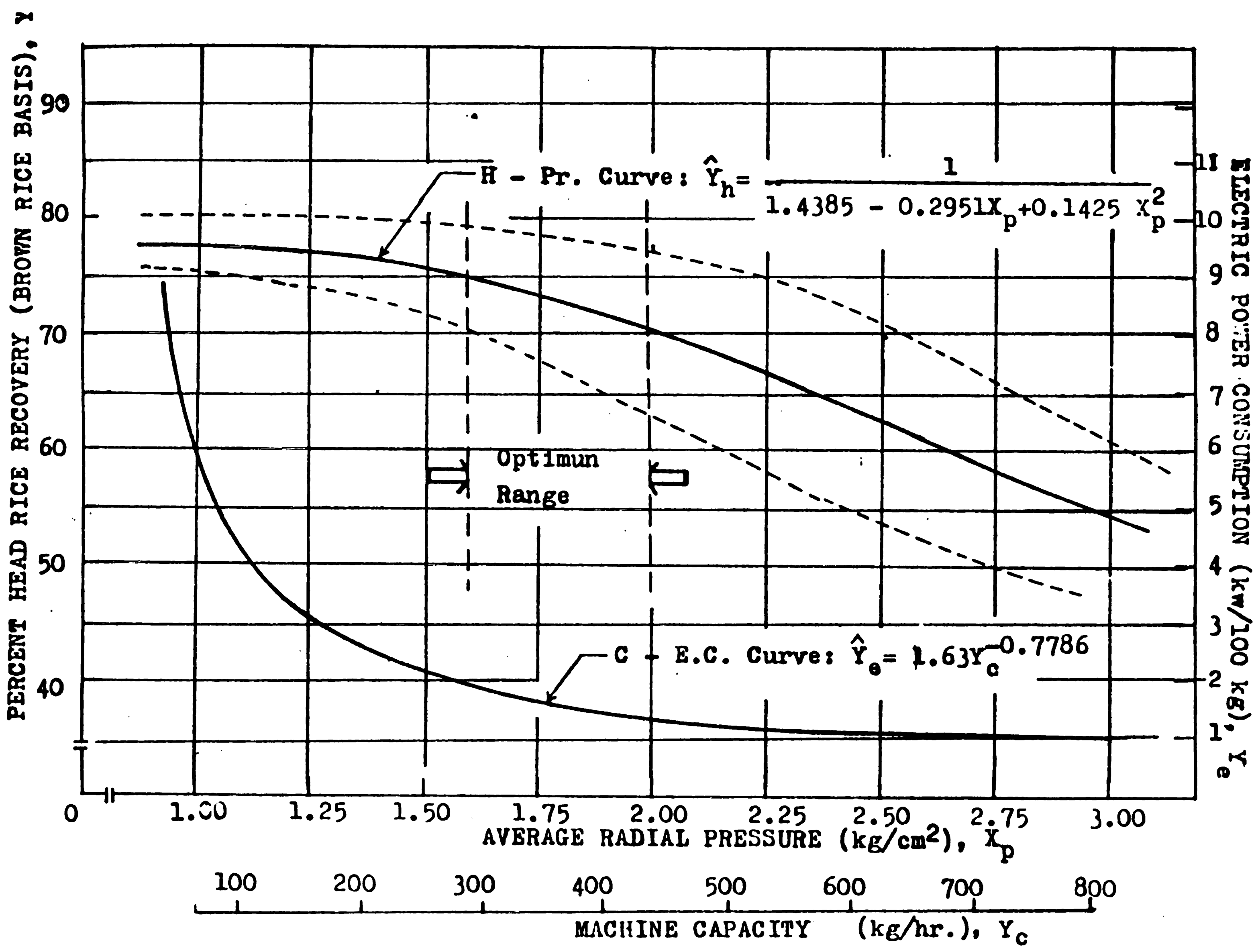

Figure 3.12 An empirical characteristic curve for rice whitening machine. From Sang Ha No (1976).

(capacity) and the right hand vertical axis (power consumption). The dotted lines along the H-Pr curve show the variation caused by differences in cylinder speed, screen type and counterpressure.

The general characteristic curve shows that when internal radial pressure is maintained at a low level, head rice recovery will be high but machine capacity will be limited and energy consumption per unit of output will be high.

In contrast, if radial pressure increases beyond the optimal range noted on the chart, a sharp decrease in head rice recovery occurs without any significant increase in power consumption efficiency or machine efficiency. Therefore, to ensure high machine and milling efficiency, it is important to maintain the pressure inside the whitening chamber within the optimal range by controlling the feed rate and the counterpressure during milling operation.

The four relationships presented by Ongkingco, Eriyatno, Paras and Sang Ha No are in close agreement with each other in that they show that as the grain moisture content reaches 15 percent or a pressure of 1.75 kg. per $cm.^2$, the head rice recovery starts decreasing.

The milling yield by Eriyatno was adopted by the author for predicting head rice yields in the simulation model.

3.3 Grain Shape Measurements

The various rice varieties differ in their grain shape (length-width ratio) and hardness. The first property could be easily measured using the FAO recommended method. The second property is affected by other variables such as: moisture content, fertilization and delay in drying.[1/] Due to lack of information and also the difficulty involved in segregating these effects, this author decided not to include variation of grain hardness (due to variety) in the analysis.

Figure 3.13 shows the relationship between grain shape and head rice. The grain shape ratio was obtained by dividing the length of a brown rice kernel by the width.[2/] Grains with a ratio of 1 to 2 are classified as round shape, those with a ratio of 2.1 to 3 are bold and those with a ratio of 3.1 to 4 are slender. The varieties grown in the Philippines are either bold or slender. Two

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[1/] See works of Eriyatno (1979), Nangju and De Datta (1970) and Ongkingco, et al. (1964).

[2/] See Appendix J for actual values.

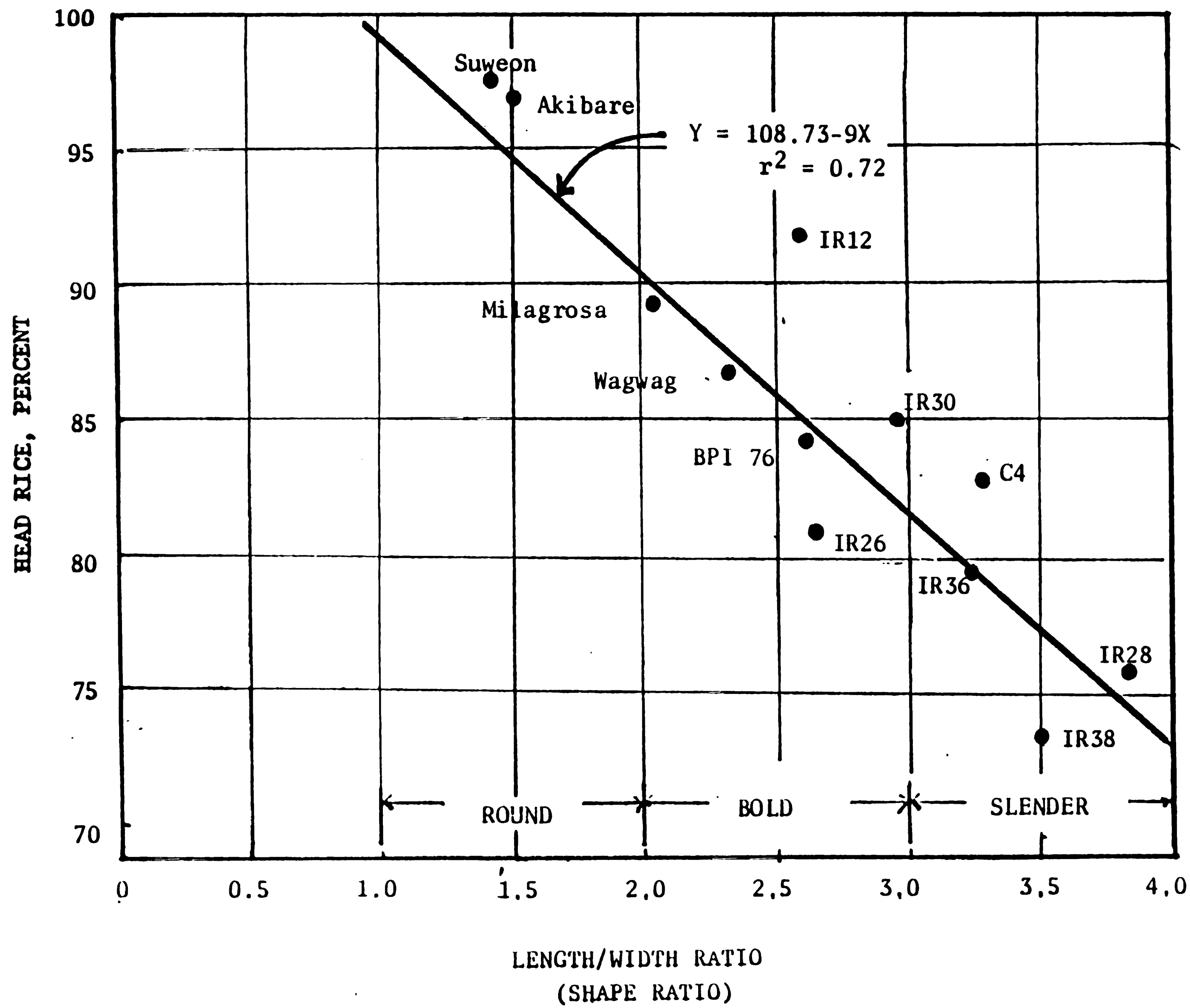

FIGURE 3.13. GRAIN SHAPE RATIO AND HEAD RICE RELATIONSHIP

Japonica (round shape) varieties grown in Korea were plotted on the graph for comparison purposes.

3.4 Measurements of Energy Consumption and Milling Time

Energy consumption and milling time were the two other performance criteria measured for the model. To measure energy consumption and milling time, it was necessary to monitor the following electrically driven conventional disc-cone mills:

1. Mindanao Progress Corporation, Quezon City (6.25 tons per hour).
2. Tobacco Industries of the Philippines, Valenzuela, Bulacan (2.5 tons per hours).
3. U.P.L.B., Los Banos, Laguna (1.0 ton per hour).

3.4.1 Methodology

The input paddy which was supplied by the National Grains Authority (NGA) was first weighed in bags. The weight of the empty bags was then subtracted from this gross weight to get the net weight of paddy. One observer was then posted at each machine component and at a predetermined time, the rice mill was started. The observers (whose watches were synchronized) then noted the time of entry and exit of paddy or rice as the case may be. Voltages, amperages, power factors and efficiencies were noted at each electric motor at three different times using clamp-on (induction) testers during the milling operation (Figure 3.14). The time at which each component was shut down was also noted by the observers.

3.4.2 Analysis of Results

The total milling time then was the time from the start-up of the mill to the shut-down of the last component. This was equivalent to the operating time of the last machine component plus the delays before the paddy reached the last machine component. In the computer model, the total milling time was obtained by adding all the different delays plus the operating time of the last machine component. The delays were calculated by dividing one-half of the capacity of the feeder bins by the handling rate of the machine component immediately ahead of it. The time measurement data obtained in the milling operation in the three rice mills were used for validating the computer results. Figures L1 and L2 in Appendix L show the results of the time measurements. It was learned that the practice of waiting for the feeder bins to be half-full increases the time delay between two batches of paddy. It took almost an hour (53 minutes) for the rice to travel from the intake to the output in the 2.5 ton-per-hour locally made mill. It took only seven minutes for the imported 6.25-ton-per-hour mill because of the smaller bins.

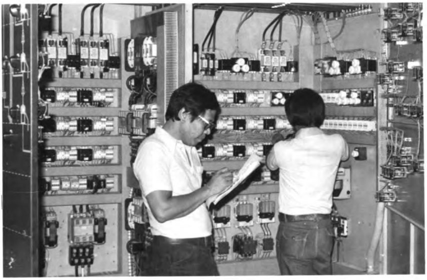

Figure 3.14 Measurement of voltage and current of motors during a milling run. Some motors were inaccessible and must be measured at the control panel.

Figure 3.15. Motor nameplate data were noted as to the power factor and efficiency ratings.

The energy consumption was computed by the following formulas:

Power (kw) = Current (I) x Voltage (V) x Power Factor[1] x Efficiency[2]

Energy Consumed (kw-hr) = Power (kw) x Processing Time (hr)

Current, voltage, power factor, efficiency and time came from measurements on each machine component. The total energy was the sum of the energy consumption of each individual machine component. Appendix Table A1 shows the results of these measurements and computations.

3.4.3 Discussion of the Different Machine Components

Figure 3.16 shows a double-sieve precleaner which is commonly used in Philippine rice mills. The large-mesh upper sieve performs a "scalping" operation which is the removal of straws and other large impurities by allowing the smaller grains to pass through. The lower fine-mesh sieve performs a "screening" action which is the removal of smaller impurities such as sand by allowing them to pass through the sieve opening. The sieve assembly was mounted

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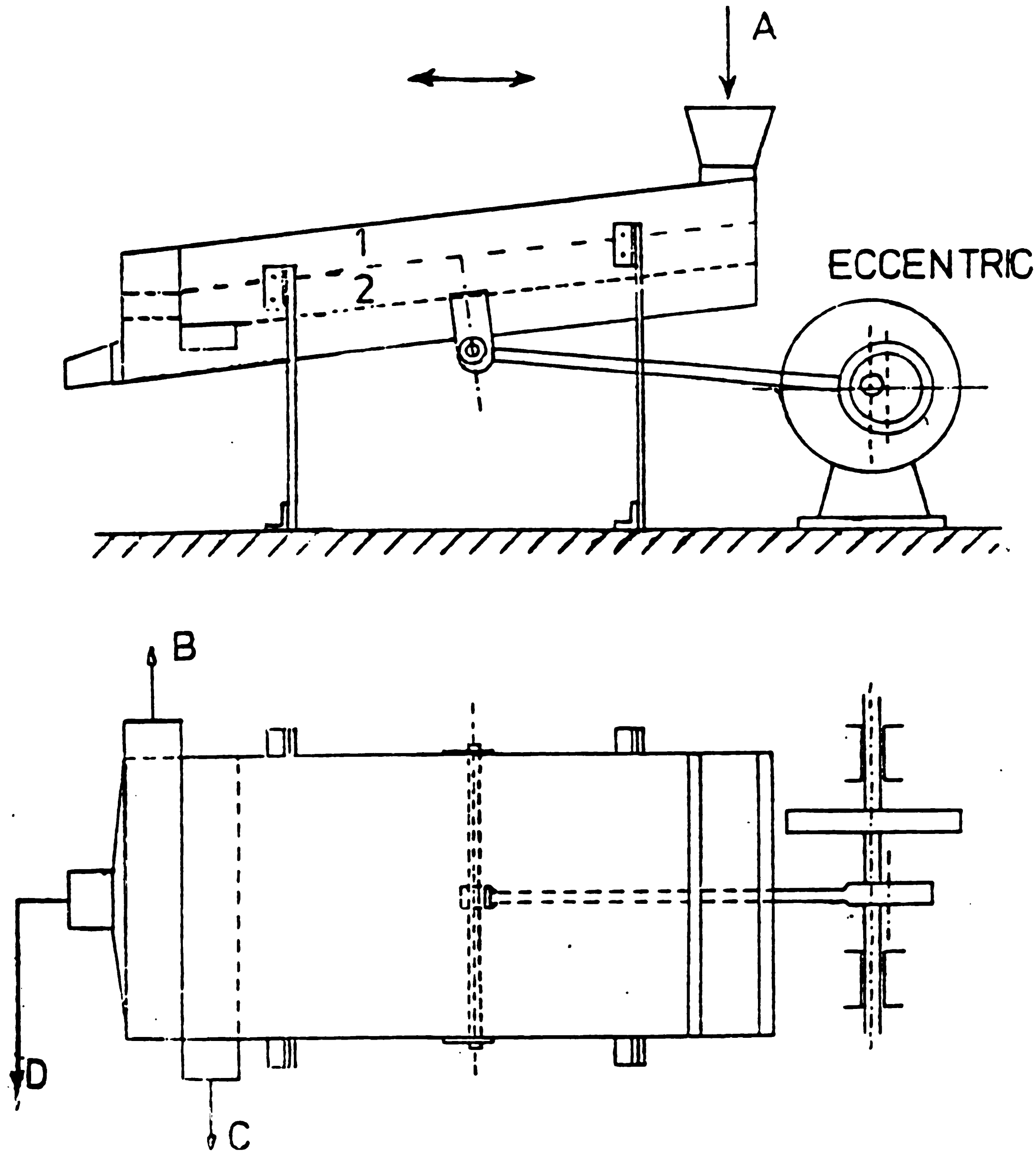
1/Power factor of the electric motor is the cosine function of the phase angle or the ratio of resistance to impedance.

2/Efficiency of the electric motor in converting electrical energy into mechanical energy.



1 - Large mesh sieve
2 - Fine mesh sieve
A - Input paddy

B - Large impurities
C - Fine impurities
D - Clean paddy

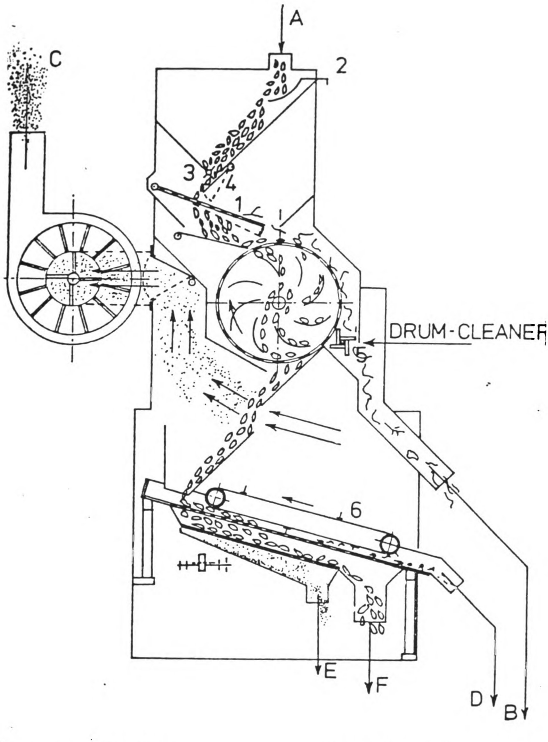
Figure 3.16 Double sieve precleaner

on flexible wooden legs and driven in a reciprocating motion by an eccentric mechanism. Figure 3.17 shows a single-drum precleaner used in Japanese mills. It operates on principles similar to the double sieve except for the addition of a suction blower which eliminates fine dust and a scalping drum which eliminates large impurities.

The power requirements of these two types of precleaners are shown in Figure 3.18. The double-sieve precleaner has a lower power consumption but has the disadvantage of creating a very dusty operating condition. The single-drum precleaner eliminates this problem by blowing the dust through exhaust pipes and out of the mill building.

The disc huller (Figure 3.19) consists of two cast-iron discs partly coated with an abrasive emery layer. The top disc is fixed in the frame housing while the bottom disc is driven by a belt pulley. The paddy is driven centrifugally between the discs and approximately sixty percent of the paddy is dehulled by the friction and pressure between the discs and grains.

The rubber-roll huller was developed in order to provide a huller that does not damage the second protective layer (pericarp) of the kernel (Figure 3.20). This is advantageous in that transporting and storage of brown rice greatly reduces the space requirement. The rubber-roll



1 - Vibrating comb
2 - Dispersing plate
3 - Feeding roll
4 - Regulating valve
5 - Rotating rubber wing
6 - Moving rubber brush

A - Input paddy
B - Large impurities
C - Dust
D - Medium size impurities
E - Sand, soil, etc.
F - Clean paddy

Figure 3.17 Single drum precleaner

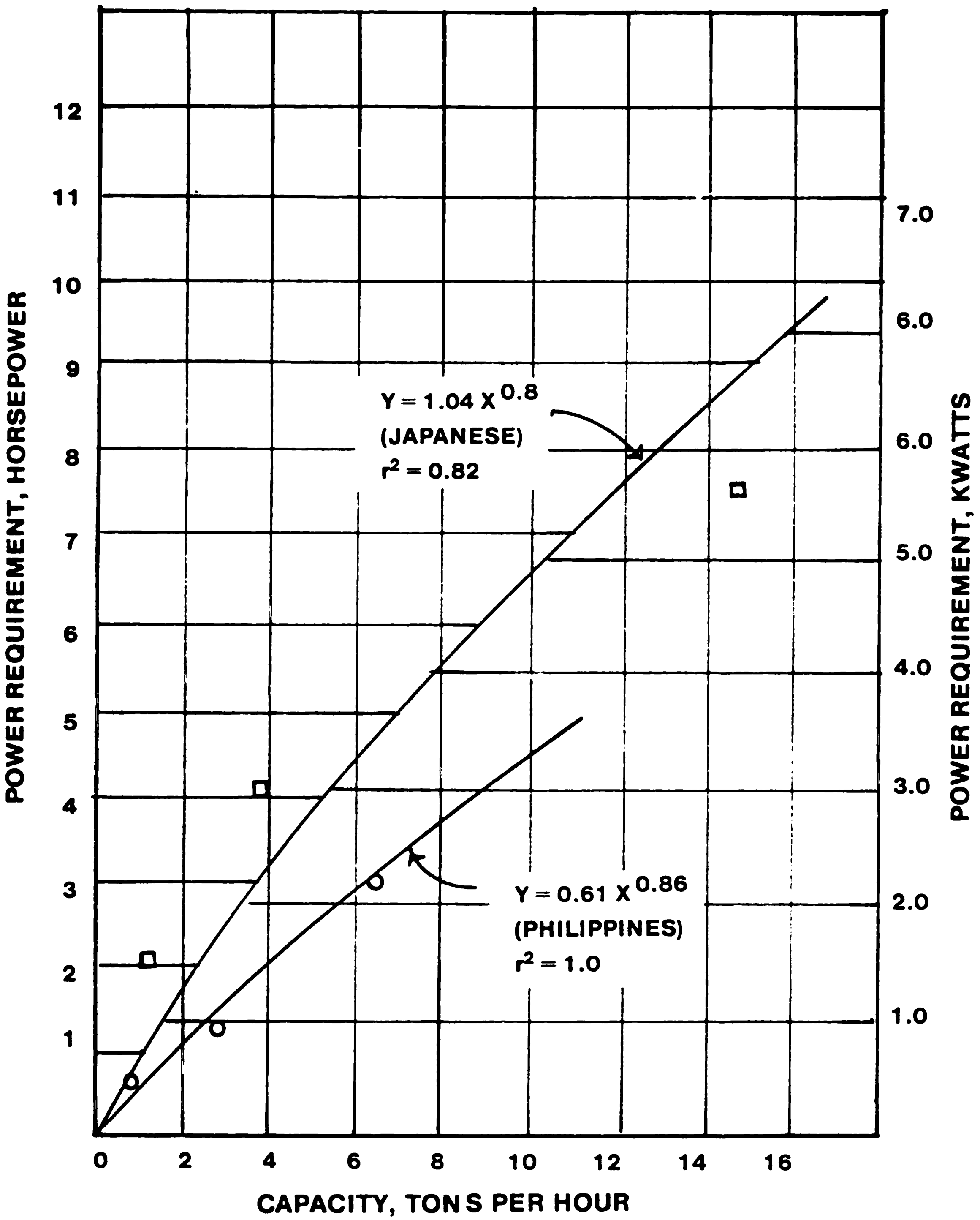
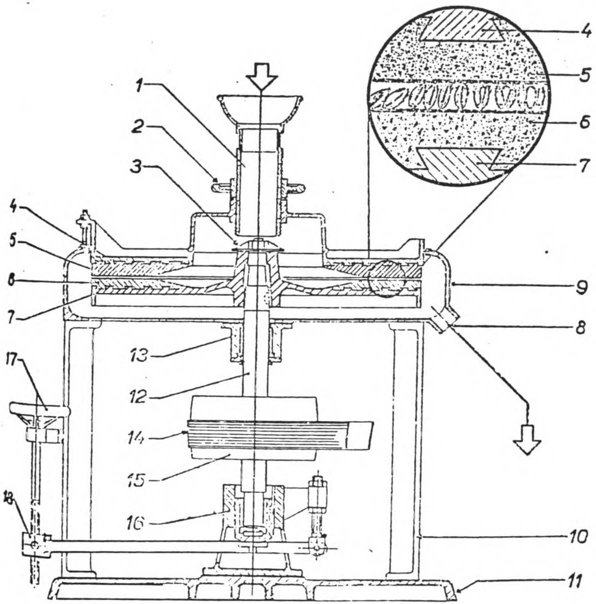
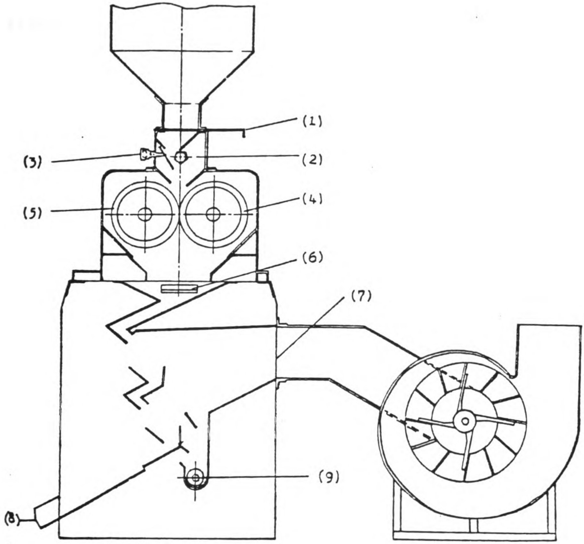


FIGURE 3.18 PRECLEANER CAPACITY AND POWER REQUIREMENT.



1 - Input paddy tube
2 - Paddy tube adjustment
3 - Paddy spreader
4 - Fixed disc level adjusting screw
5 - Fixed disc emery
6 - Revolving disc emery
7 - Fixed disc cast iron frame
8 - Outlet tube
9 - Huller frame
10 - Huller stand
11 - Huller base
12 - Revolving disc drive shaft
13 - Upper bearing
14 - Drive belt
15 - Drive pulley
16 - Lower thrust bearing
17 - Disc clearance adjusting wheel
18 - Adjustment bar

Figure 3.19 Disc huller



1 - Feed shutter
2 - Feeding roll
3 - Regulating valve
4 - Stationary roll
6 - Rubber plate
7 - Aspirator
8 - Outlet for rice
9 - Screw conveyor for unripe grain

Figure 3.20 Schematic diagram of a rubber roll huller

huller consists of two rubber rolls, one of which has a fixed position and the other has an adjustable position that enables the desired clearance between the two rolls to be fixed. The rolls are mechanically driven in opposite directions. The adjustable roller turns at a speed 25 percent lower than the fixed roller. The paddy passes through the gap between the rolls and is twisted and dehulled. The resiliency of the rubber roll provides some tolerance for variation in grain sizes and its smoothness eliminates abrasion to the pericarp. The relationship between hulling capacity and hulling time is shown in Figure 3.21. Different grain types, i.e., short, medium and long, have different hulling times. The power requirement for these hullers is shown in Figure 3.22.

The separation of broken brown rice and coarse bran (damaged pericarp) after hulling provides additional income to the rice mill. Otherwise, the broken brown rice would be blown out of the mill in the husk aspiration process. Figure 3.23 shows a V-type sifter commonly employed in Philippine mills for this purpose. It operates on the "screening" principle and is oscillated by an eccentric drive. The power requirement is shown in Figure 3.24.

Due to the lack of individually driven and electrically powered machines in the Philippines, there are only three actual data points available. However, the

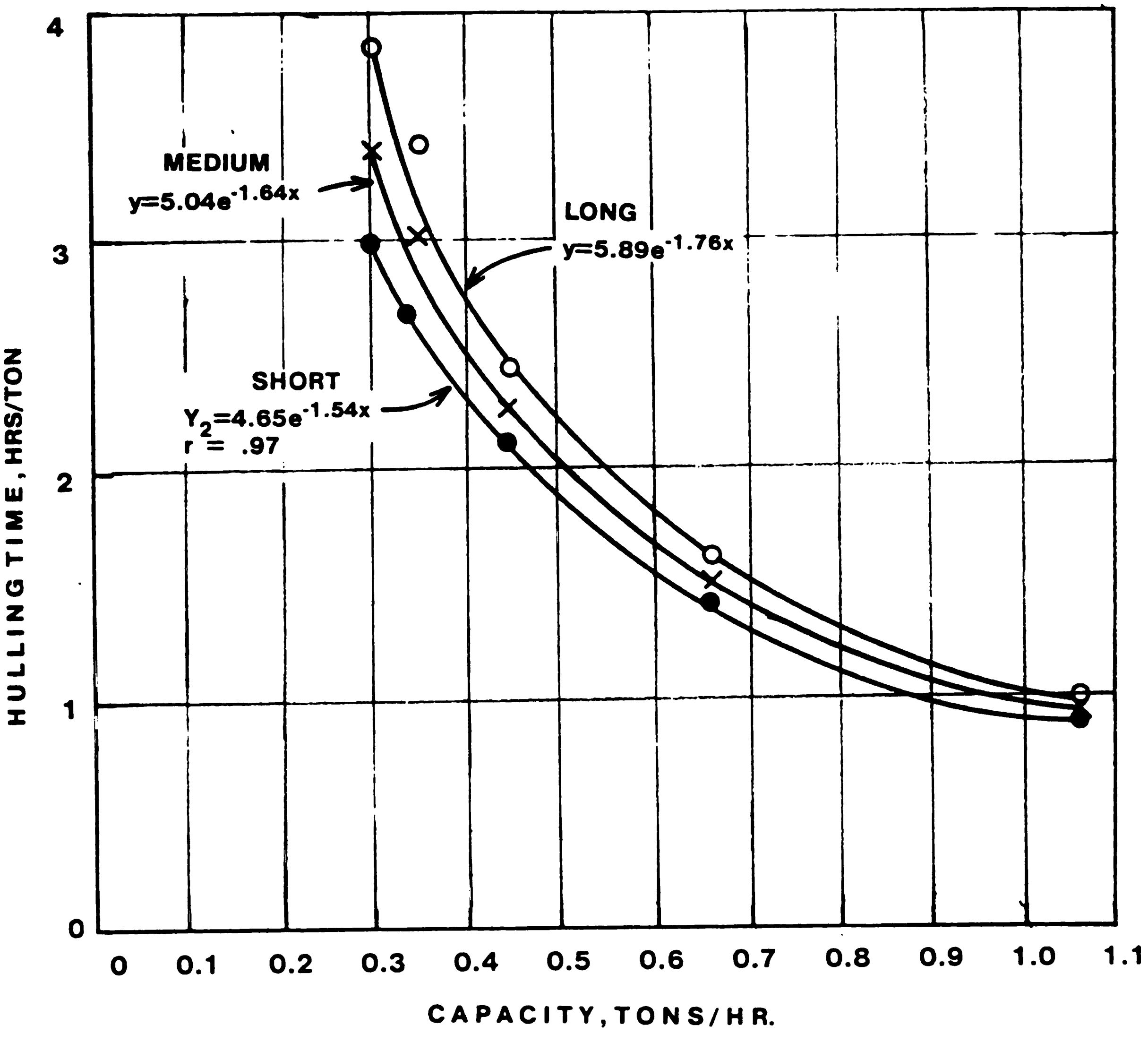


Figure 3.21 Huller Capacity VS Hulling Time

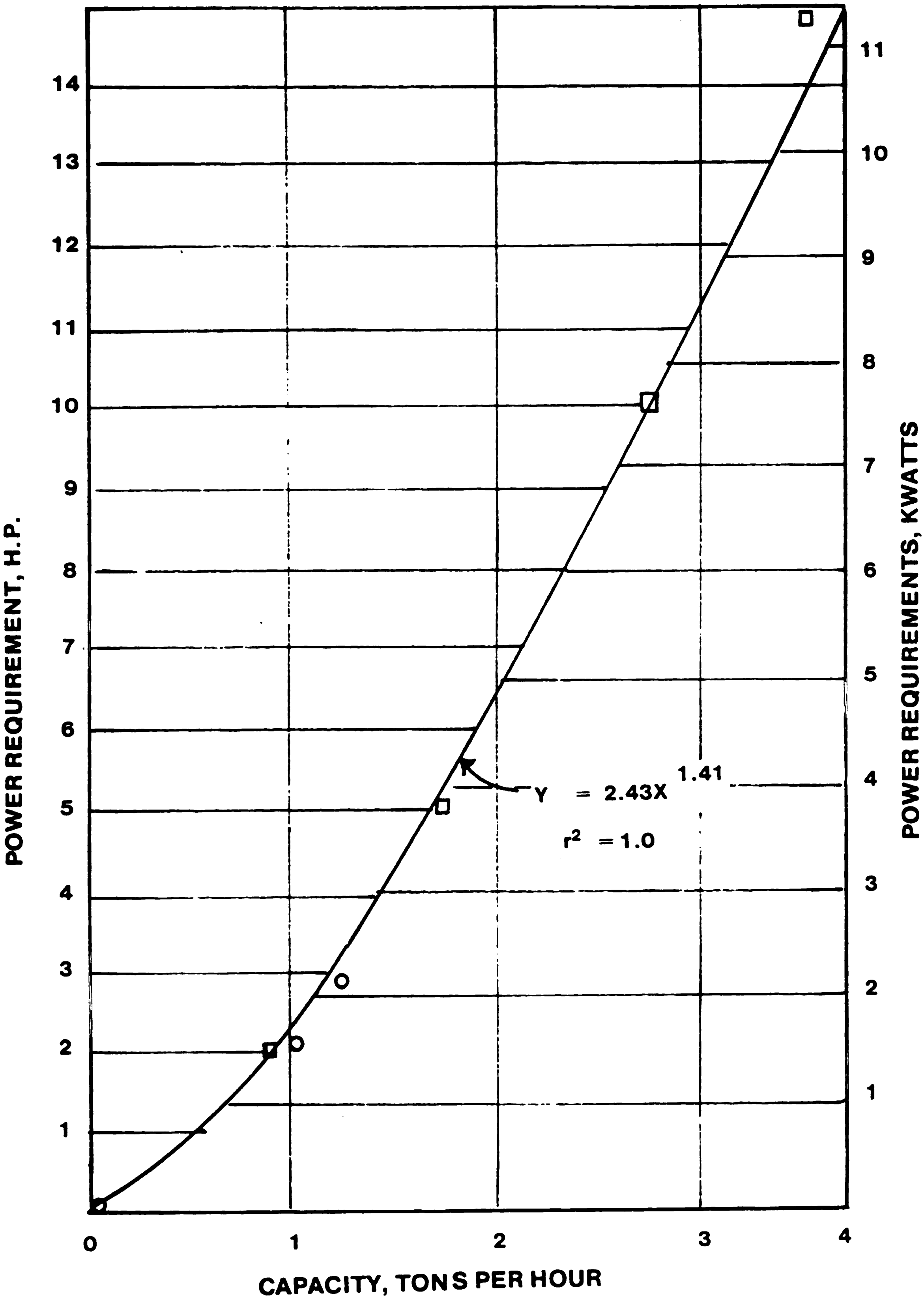


FIGURE 3.22 HULLER CAPACITY AND POWER REQUIREMENT RELATIONSHIP

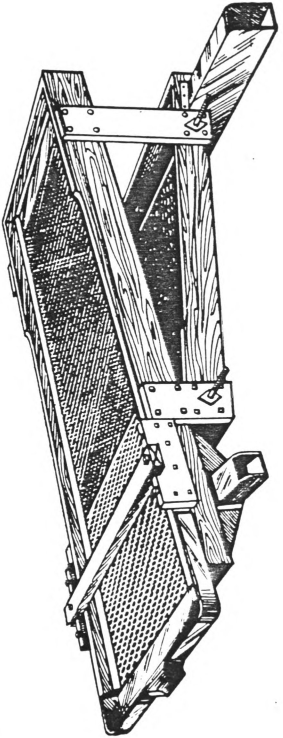


Figure 3.23 V-type Sifter

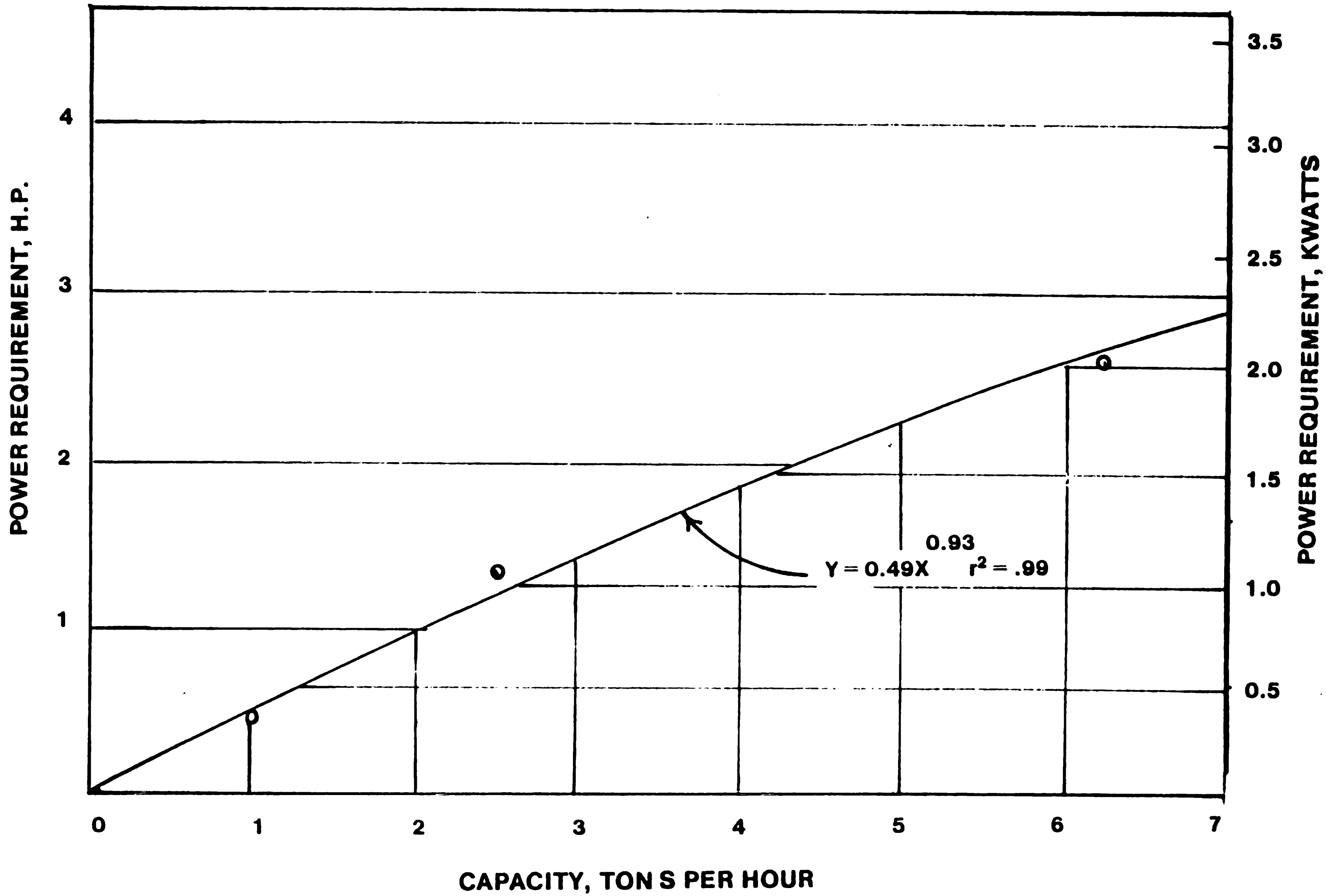
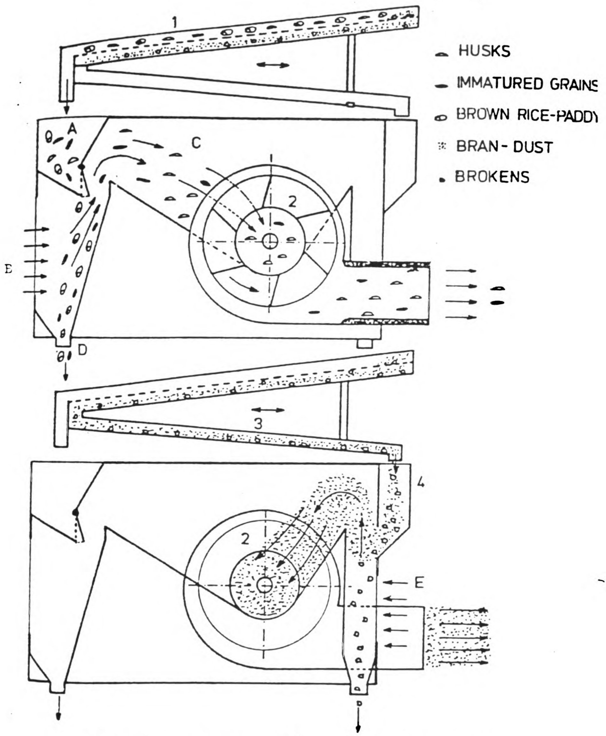


FIGURE 3.24 V-TYPE RICE SIFTER CAPACITY AND POWER REQUIREMENT

curve must pass through the origin as an initial condition that the power requirement is zero when the capacity is zero. The values obtained in the measurement show that for this machine, the power requirement goes down as the capacity increases which rules out the use of linear relationship between capacity and power requirement. In view of these considerations in addition to the fact that the other machines used power curves, the relationship used for the power sifter was a power curve. The next machine used in the processing of rice is the husk aspirator shown in Figure 3.25. The operation is based on screening and aspiration. The mixture of husks, brown rice, brokens, bran and dust is discharged on an oscillating sieve which separates the brokens, bran and dust. The mixture of husks, paddy and brown rice is then passed through the husk aspirator which separates out the husks and dust. The power requirement of this machine is shown in Figure 3.26.

For the husk aspirator, there are only two actual data points available and there is no indication that the power requirement goes down as the capacity increases. Another machine which is constructed similar to the husk aspirator but not included in conventional cone-type rice mills is the aspirator plus stoner for use in removing impurities from paddy in rubber-roll mills. There are three actual data points for this machine and the power



1 - Oscillating fine mesh sieve
2 - Suction blower
3 - Feeding trough
4 - Separating chambers

A - rice and husk
B - airblast
C - husks
D - rice
E - airblast

Figure 3.25 Double action husk aspirator.

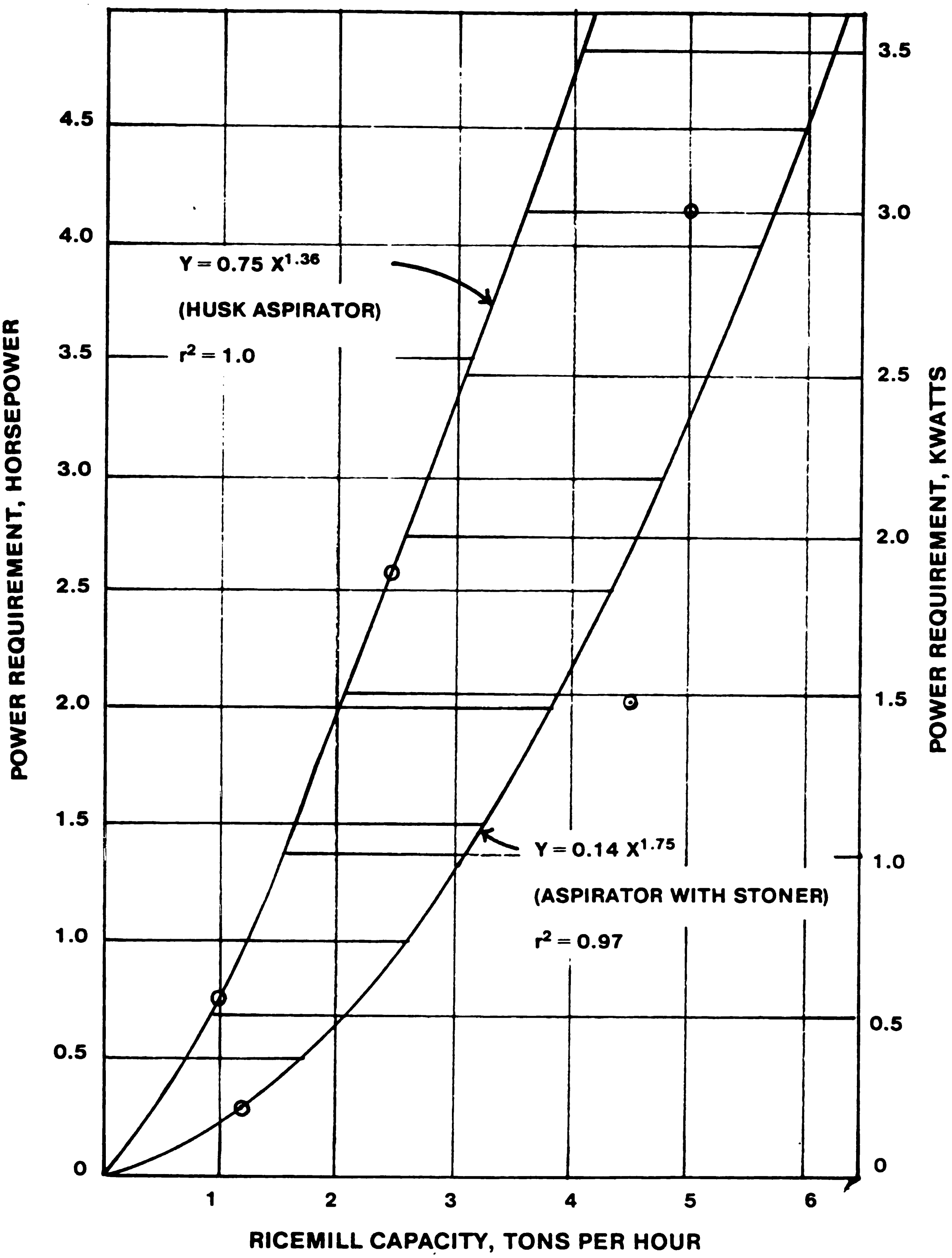


FIGURE 3.26 HUSK ASPIRATOR AND ASPIRATOR WITH STONER POWER REQUIREMENT.

curve is similar to the power curve for the husk aspirator. The efficiency of hullers varies between 60 and 95 percent which leaves from 5 to 40 percent unhulled. The compartment-type paddy separator is used in the Philippines for separating the paddy from the brown rice and it uses the differences in mass and coefficient of friction of the two grains. A newer machine, the tray-type separator, utilizes their differences in specific gravity but is not effective in countries where moisture content of paddy varies greatly. Figure 3.27 shows the operation of a compartment-type paddy separator. The mixture of paddy and brown rice is introduced into the center of a specially shaped passage (bottom diagram) which is steadily reciprocated in the direction of the arrows on the left. The paddy, because of its heavier mass and lower coefficient of friction, hits the walls harder causing it to bounce from wall to wall through the passages going up the inclined passage until it reaches the left-hand side.

The lighter and stickier brown rice hits the wall more softly and because of the downhill inclined surface it eventually reaches the right-hand side of the passage. The frequency of the oscillation is usually adjustable and some machines also have adjustable stroke length (Figure 3.28). Figures 3.29 and 3.30 show the hulling time and power requirement, respectively.

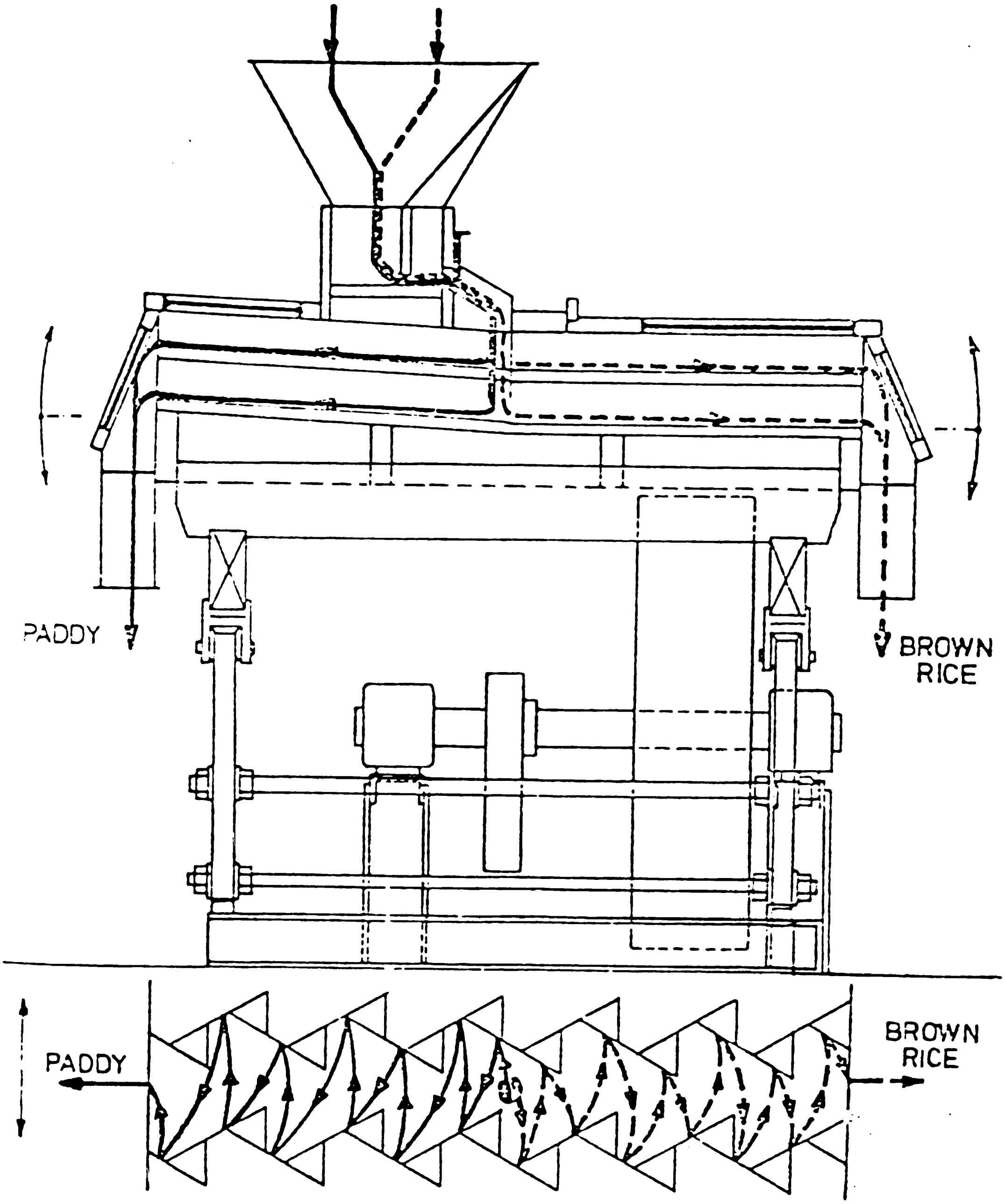
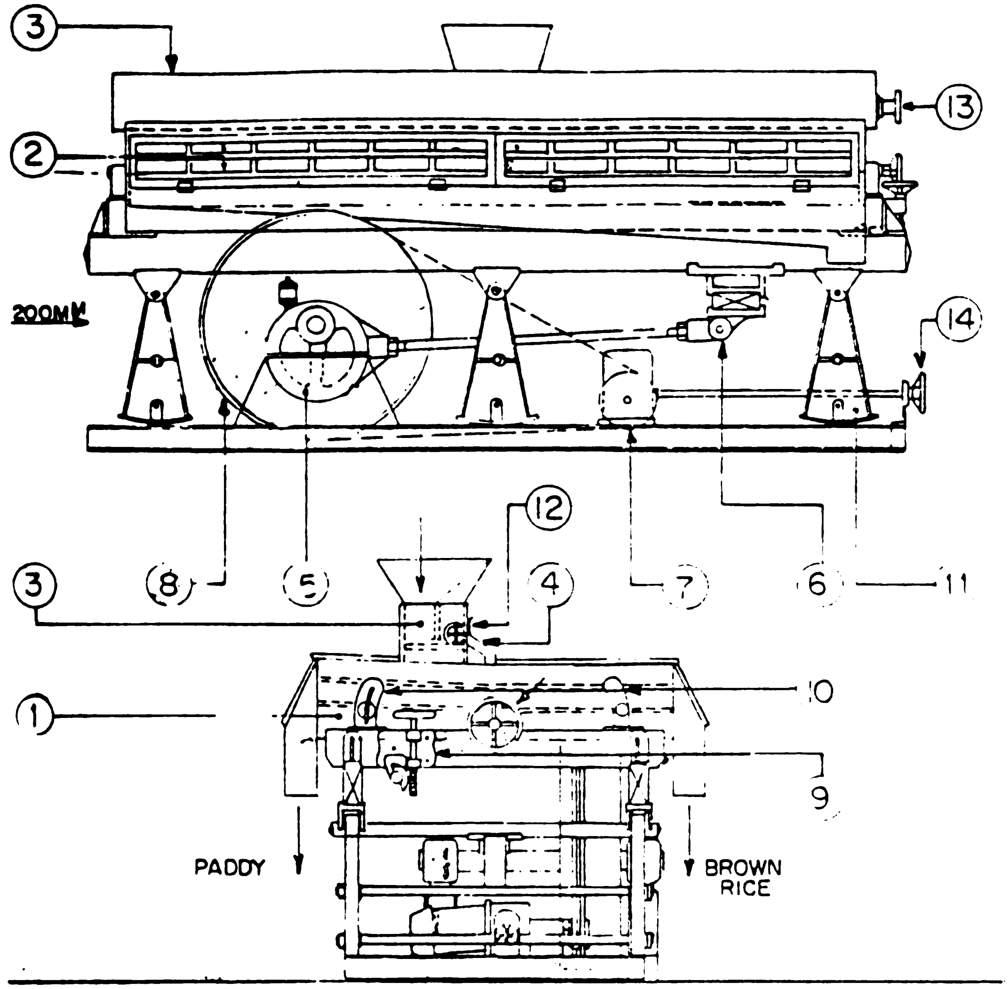


Figure 3.27 Grain Flow through the Paddy Separator



1 SEPARATOR TABLE
2 COMPARTMENT (24)
3 GRAIN DISTRIBUTION BOX
4 SPOUT FEEDING COMPARTMENT
5 ECCENTRIC DRIVE
6 SUSPENSION FOR ECCENTRIC ROD
7 ELECTRIC MOTOR WITH SPEED CONTROL
8 FLYWHEEL / DRIVEN PULLEY
9 INCLINATION ADJUSTMENT
10 TABLE LOCKING DEVICES
11 TABLE SUPPORT (SIX)
12 COMPARTMENT FEED CONTROL
13 CENTRAL FEED CONTROL
14 HANDWHEEL FOR SPEED CONTROL

Figure 3.28 Components of a Paddy Separator

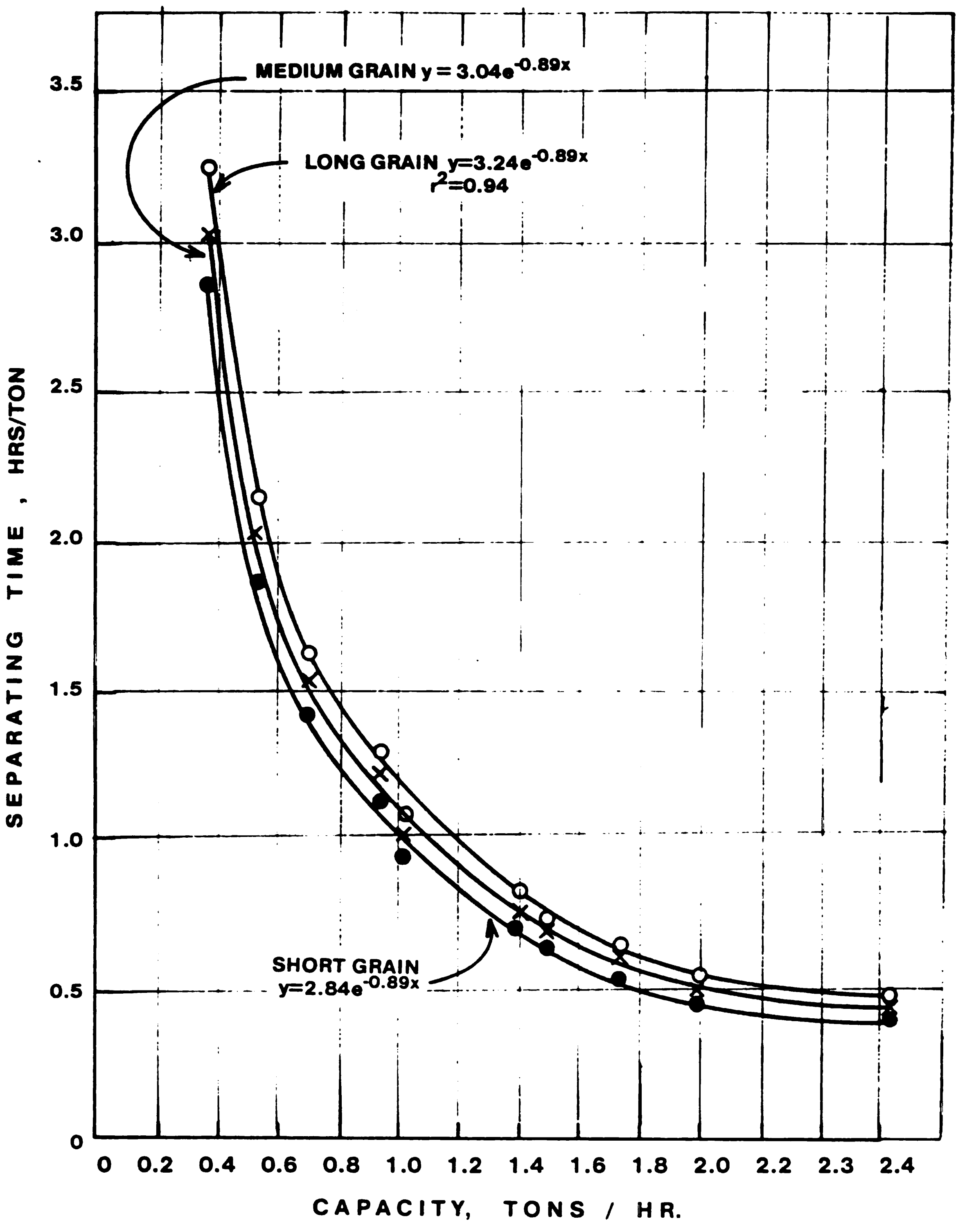


FIGURE 3.29 PADDY SEPARATOR CAPACITY VS SEPARATING TIME

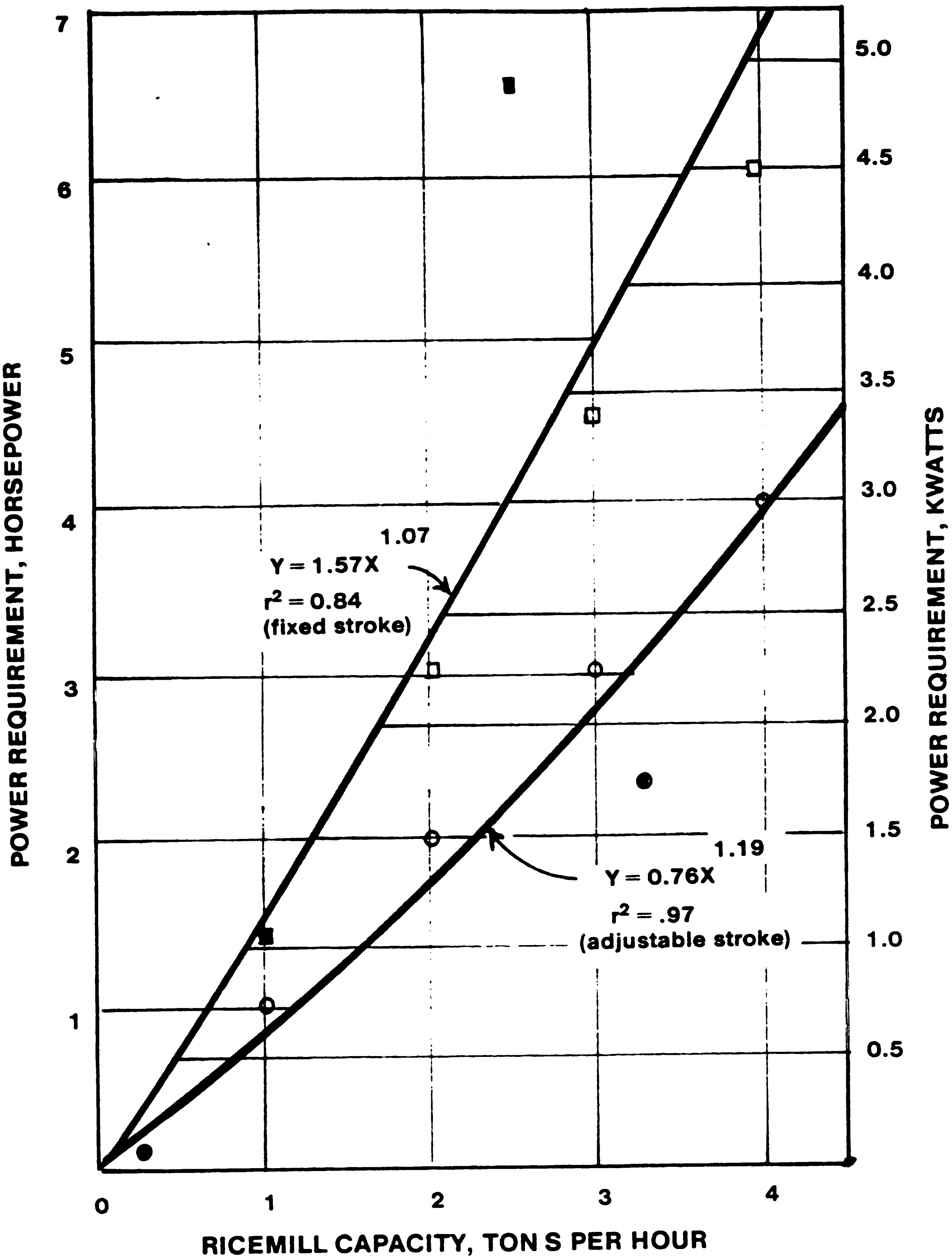


Figure 3.30 Paddy Separator Energy Requirement VS Capacity

The next operation is done by a whitening machine and involves the removal of the pericarp and the bran layer of the brown rice. Four kinds of whitening machines are widely used in the rice-processing industry, namely:

a. The vertical abrasive whitening cone,

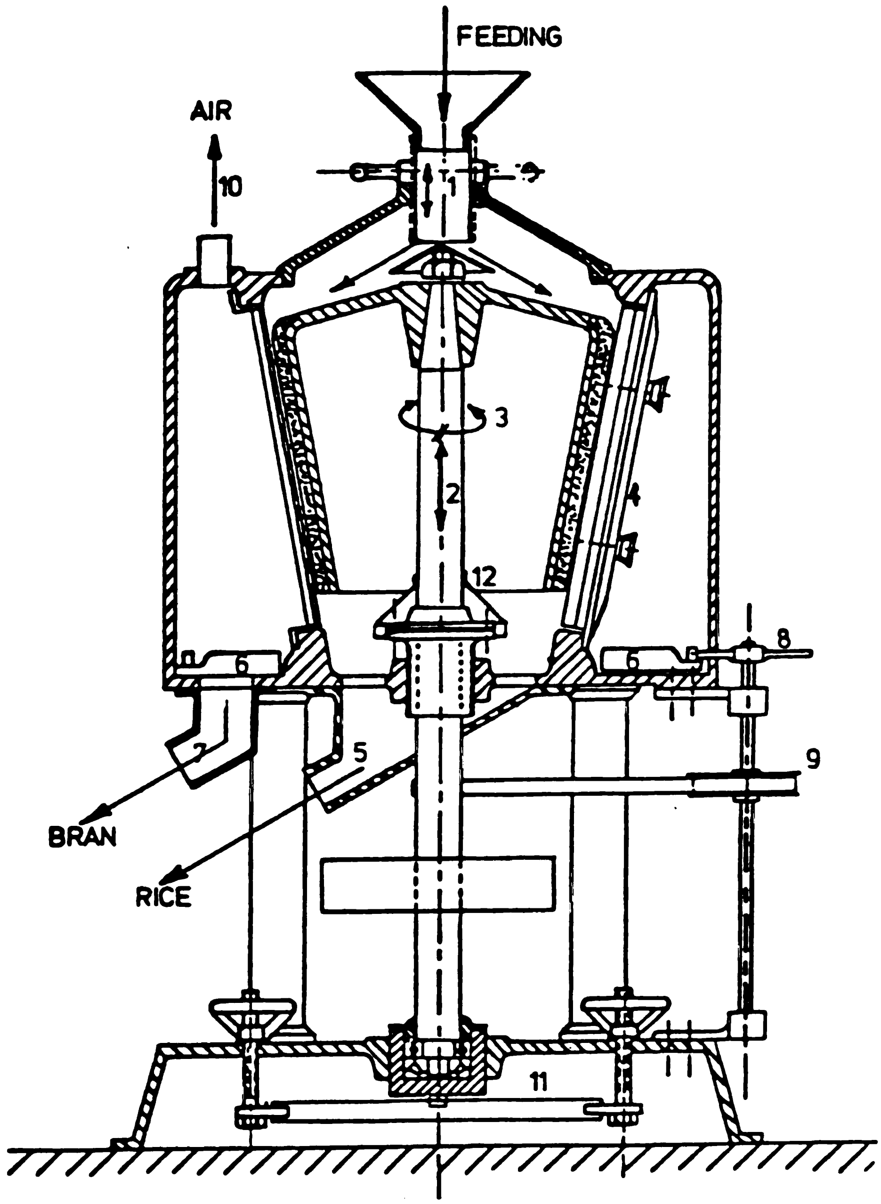
b. the Engleberg friction whitener,

c. the horizontal abrasive whitener, and

d. the horizontal jet friction whitener.

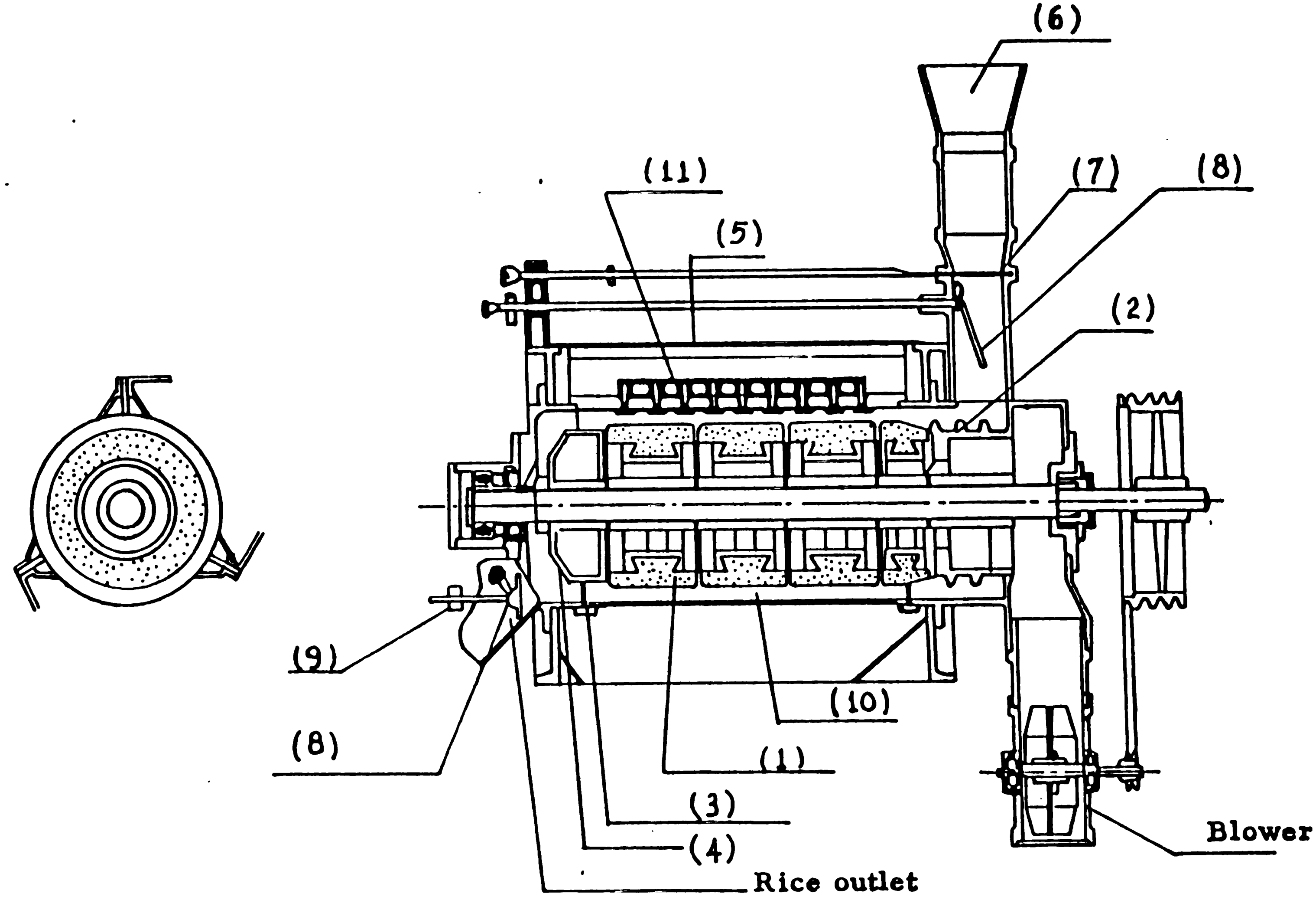
Figure 3.31 shows the whitening cone which consists basically of an inverted frustum of a steel-reinforced cone made of emery and carborundum stone surrounded by a fine mesh sieve and 30 to 50 mm. wide rubber brakes. In operation, brown rice is introduced from the top and is subjected to a grinding action and pressure of about 5 Pa, as the cone rotates and the rubber brakes prevent the rice from moving about freely. The Engleberg whitener is not commonly found in the Philippines as a whitening machine but rather as a one-pass rice mill. However, in some plants in the U.S., it is used in series (10 to 20 units) whitening.

The horizontal abrasive whitener (Figure 3.32) which is also used in conjunction with the horizontal jet friction whitener (Figure 3.33) is the latest technique in rice whitening. The abrasive whitener consists of carborundum rollers and a feed screw mounted on a shaft.



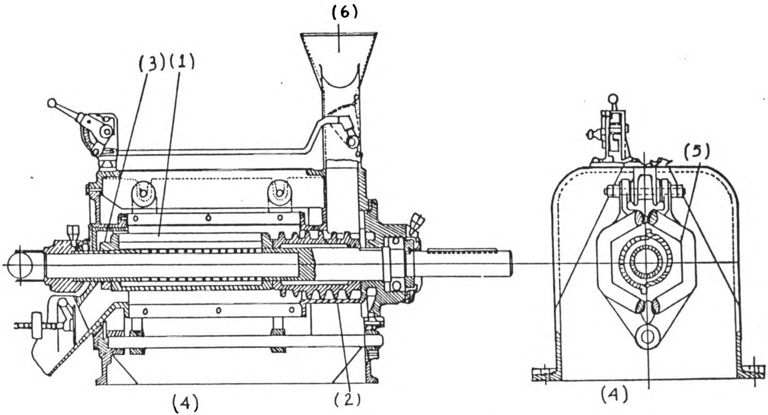
1 - Feeding valve
2 - Drive shaft
3 - Rotation
4 - Rubber brake
5 - Rice outlet
6 - Bran scraper
7 - Bran outlet
8 - Gear drive for bran scraper
9 - Belt drive for bran scraper
10 - Air exhaust
11 - Support bar for clearance adjustment
12 - Upper bearing

Figure 3.31 Whitening cone



1 - Abrasive roller
2 - Iron screw roller
3 - Cap cover
4 - Hollow shaft
5 - Perforated steel cylinder
6 - Inlet hopper
7 - Shutter
8 - Flow regulating valve
9 - Outlet resistance plate
10 - Clearance
11 - Resistance bar

Figure 3.32 Cross-section of abrasive whitener.



1 - Milling roller
2 - Iron screw roller
3 - Lock nut
4 - Hollow shaft
5 - Perforated hexagonal steel screen
6 - Inlet

Figure 3,33 Section of a friction roller type whitening machine.

The assembly is enclosed by a perforated-steel cylinder with three equally spaced bars with resistance pieces (similar in purpose to the rubber brakes of the cone whitener). The horizontal jet friction whitener is a result of several improvements on the Engleberg mill. These improvements include position of the outlet, adjustable weighted outlet and air jet which blows off the bran and cools the milled rice. Figures 3.34 and 3.35, respectively, show the whitening time and power requirement of the different whiteners discussed.

The next operation is the removal of brewer's and small brokens from the milled rice. This is accomplished by the use of an oscillating sieve (Figure 3.36) using the screening principle. The top sieve consists of a single screen which allows the smaller particles to pass through the lower compartment. The oscillating motion of the sieve speeds up the process. The sieve in the middle consists of two screens of different sizes and also works on the "screening" principle allowing the smaller particles to pass through the bottom compartment. This arrangement results in three sizes of grain particles, namely, whole or head grain, large broken and small broken. The bottom system consists of two sieves of single screen each and produces three sizes of product. Any number of grain sizes

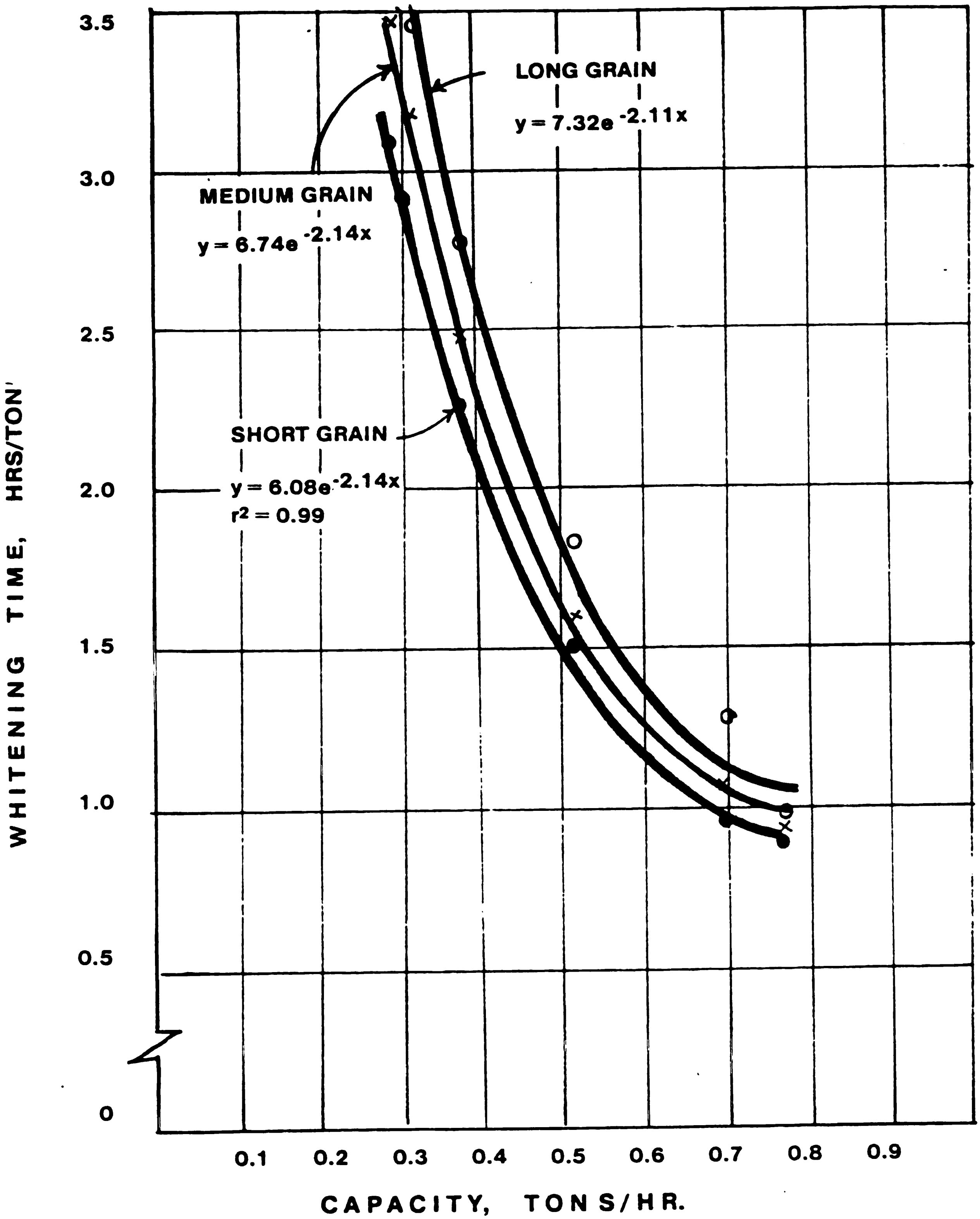


Figure 3.34 Cone Whitener Capacity VS Whitening Time

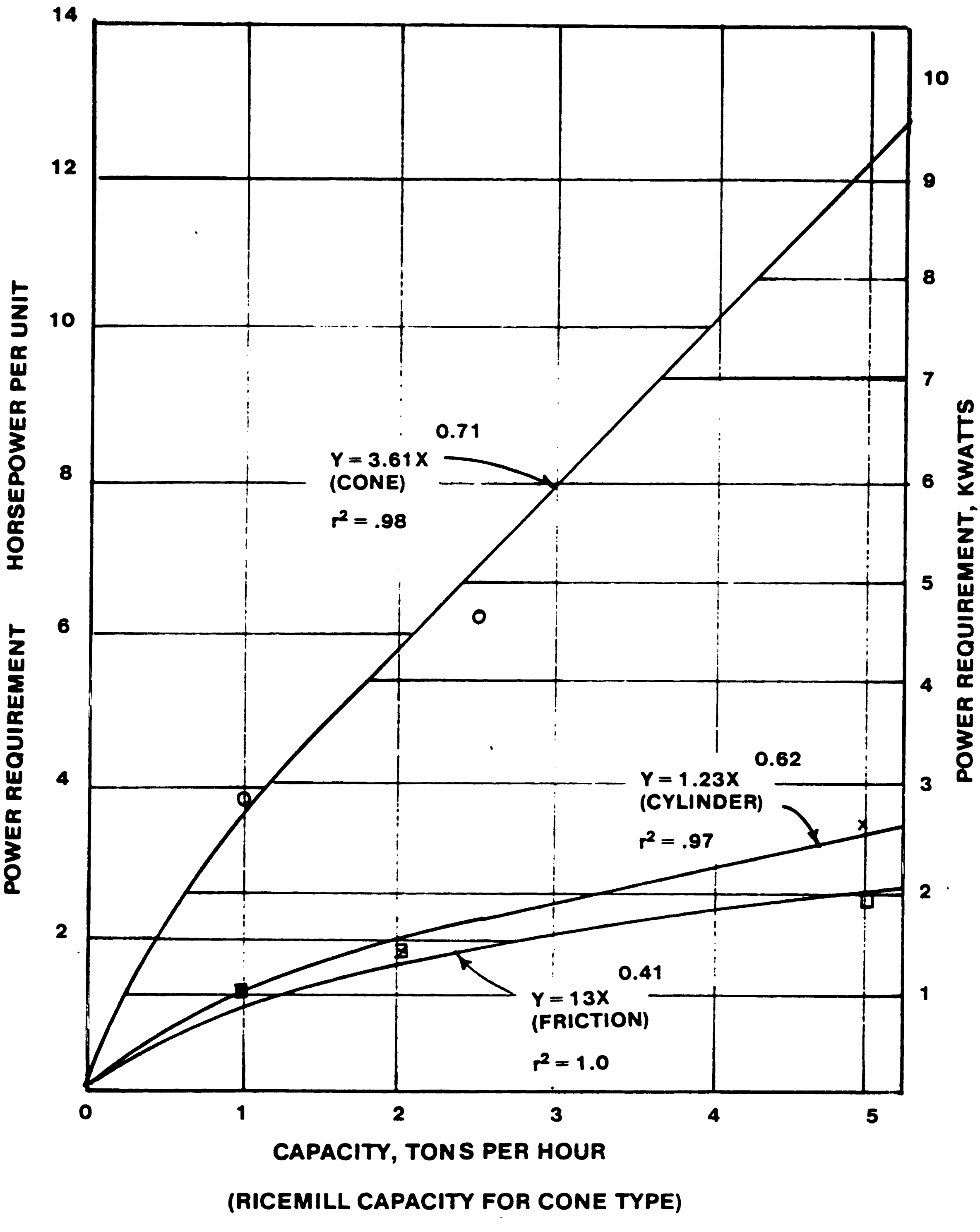


FIGURE 3.35 WHITENER CAPACITY AND POWER REQUIRED

could be separated by the use of different sieve sizes. The power requirement is on Figure 3.37.

3.5 Distribution Functions of Input Paddy Factors

The distribution function of paddy purity and moisture content is determined using the Chi-square goodness-of-fit test (Appendix D). The frequency graphs of these two variables are shown in Figures 3.38 and 3.39. These two variables plus the harvesting data were generated using a table look-up function (Appendix B) in conjunction with the cumulative normal distribution function and a computer built-in random number generator. A table look-up function is one of the computer subroutines specifically designed for simulation work. In some situations, one system variable is to be causally related to another and either an explicit mathematical function is not known or one cannot be reasonably assumed. More details are in Appendix B. Physical damage, i.e., cracking and chemical (fermentation) are affected by drying delay. Drying delay was defined as the number of days from harvesting to drying of paddy at equilibrium moisture content. It was assumed that the delay was the same for sun drying and mechanical drying. Drying delay is caused by three successive delays, cutting, hauling and threshing. It was simulated by a third order gamma distribution function. The actual

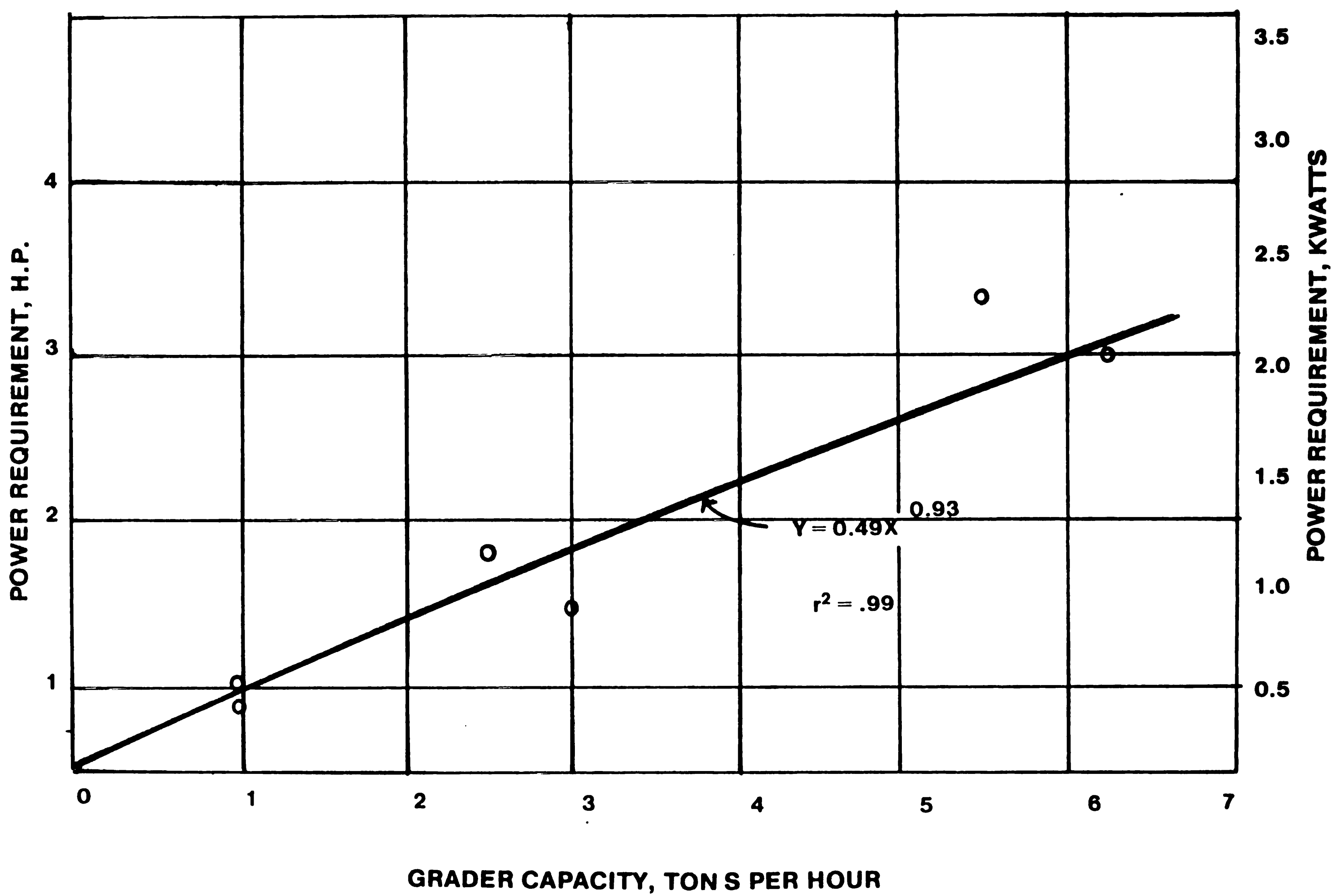


FIGURE 3.37 RICE GRADER CAPACITY AND POWER REQUIRED

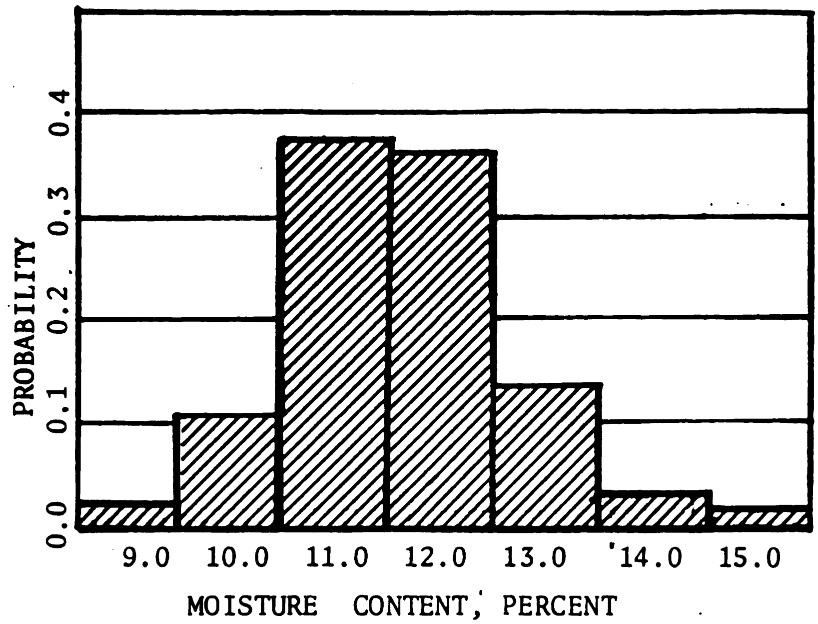


Figure 3.38 Probability distribution for moisture content of paddy delivered for rice milling in the Bicol region.

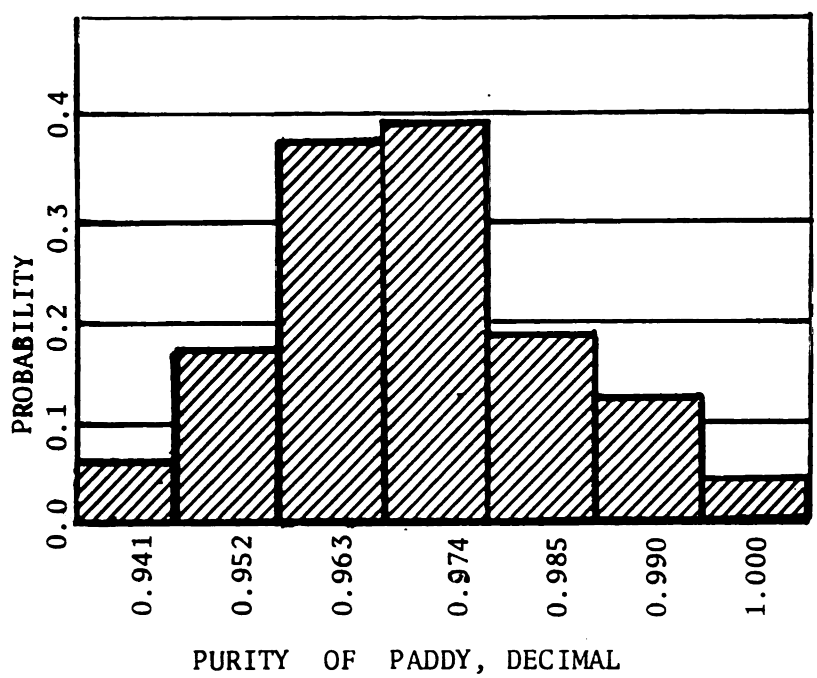


Figure 3.39 Probability distribution for purity of paddy delivered for rice milling in the Bicol region.

cumulative distribution graph is shown in Figure 3.40. For more details on gamma distribution function and the subroutine gamma, see Appendix C.

3.6 Computer Implementation of the Model

The computer used in the modeling was a Radio Shack TRS-80 Model I with 16K RAM and BASIC level II language. The program is depicted by the flow chart in Figure 3.41. After initialization, the rice mill parameters and grain variables were read. These include capacities of the rice mill, precleaner, huller, separator, huller bin, bran sifter bin and whitener bin; huller, whitener and separator types and the number of hullers and whiteners. The grain variables include drying method, grain shape, grain type and the growing season.

The first operation was precleaning, which involves computation of the material reduction variable by using subroutine random. This subroutine is a table look-up function with a normal cumulative distribution function and a random number generator. For more details on the subroutine random, see Appendix B. Other variables computed were run time, time delay to fill huller bin and energy used. The next step was the hulling operation which was by either a disc or rubber-roll huller. The

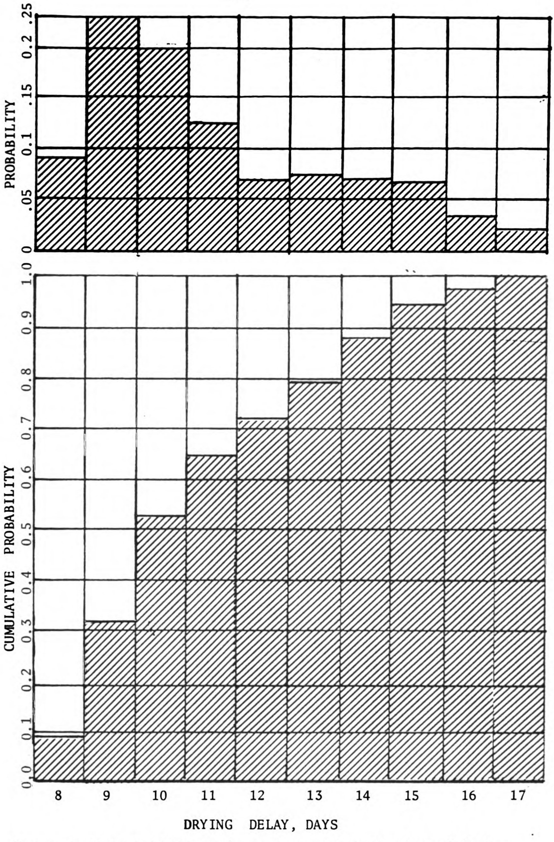


Figure 3.40 Probability and cumulative distribution of drying delay for paddy delivered for rice milling in the Bicol region.

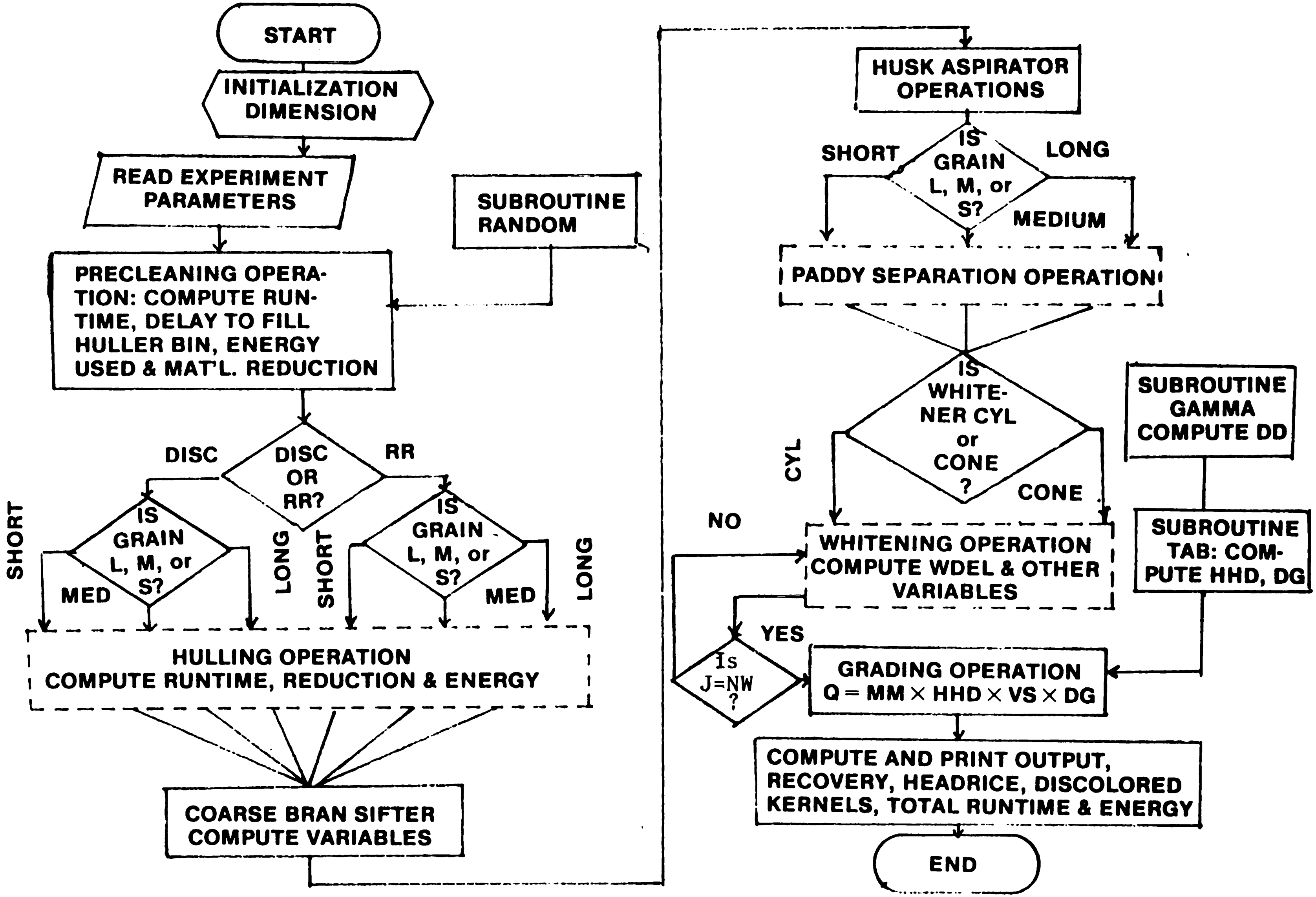


FIGURE 3.41 COMPUTER FLOW CHART OF THE PROGRAM RICEMILL

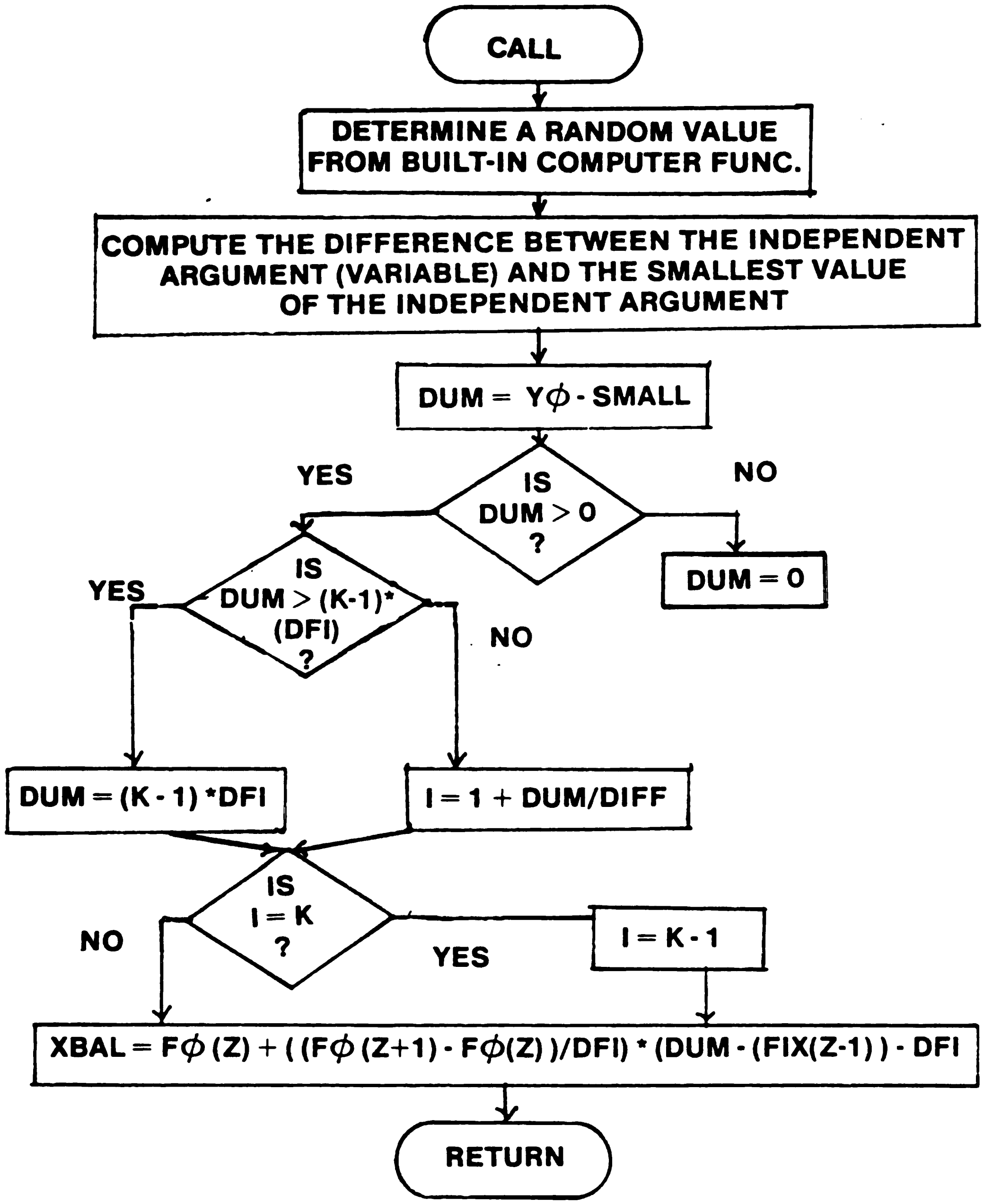


Figure 3.42 Flow chart of subroutine RANDOM. Subroutine TAB is similar to the above chart except for the absence of the first block.

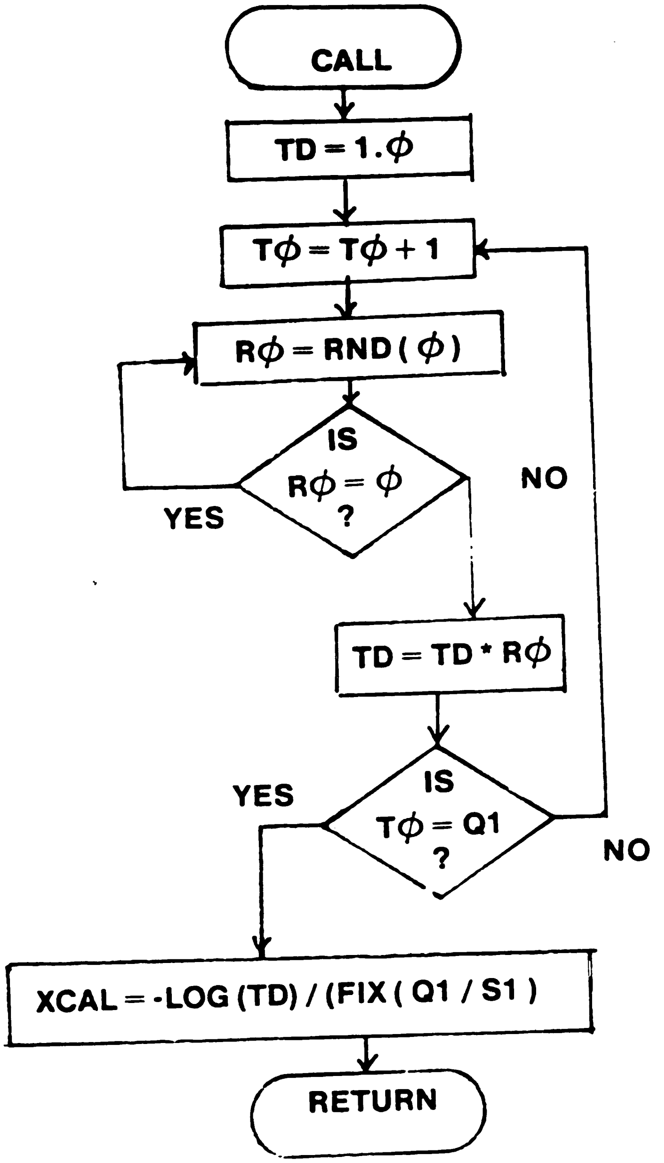


Figure 3.43 Flow chart of subroutine GAMMA.

performance of the huller varied also with grain type, i.e., short, medium or long. The next operation was coarse bran separation. Coarse bran has some monetary value so it was separated before passing the material to the husk aspirator. After the husk aspiration process, the mixture of paddy and brown rice is passed to a separator. The performance of the separator varies again with the grain type. The next step, whitening of the brown rice, was done in series whiteners. The number of whiteners varied from 1 to 6 depending on the size and type of mill. The final step was the grading operation where brewer's rice was separated from the mixture of broken and head rice.

The quality index[1/] was computed in the grading operation. The index is the product of four indices: (1) moisture content at milling, (2) harvesting delay, (3) grain shape and (4) drying delay. The quality of paddy index includes the head rice recovery percentage from the milling operation. Other variables computed were total run time, rice output, recovery, head rice, discolored kernels and total energy used in the operation.

[1/]This is similar to Steele's multiplier used to obtain dry matter loss in corn deterioration. See the work of Steele, et al. (1969).

3.7 An Example of How to Use the Rice Mill Performance Model

The data that the model user must input into the program (lines 175 to 181) in Appendix E are as follows:

a. Number of Replication (R) = 1 to 100

b. Paddy Cleaner Capacity (PCAP) = 0.33 to 1.83 tons per hour

c. Huller Bin Capacity (HBIN) = 0.0069 m^3

d. Whitener Bin Capacity (WBIN) = 0.009 m^3

e. Paddy Separator Bin Capacity (PBIN) = 0.0089 m^3

f. Rice Mill Capacity (RCAP) = 0.33 to 0.83 tons per hour

g. Number of Paddy Cleaner (CPN) = 1.0

h. Separator Capacity (SCAP) = 0.495 to 1.98 tons per hour

i. Number of Whitener (NW) = 1 or 2

j. Whitener Capacity (WCAP) = 0.255 to 0.731 ton per hour

k. Huller Type (HT): Disc or Rubber Roller

l. Whitener Type (WT): Cone or cylindrical

m. Drying Method (DM): Sun or mechanical

n. Paddy Huller Capacity (PHCAP) = 0.294 to 1.83 tons per hour

o. Number of Paddy Huller (HNP) = 1 or 2

p. Grain Shape (GS) = 1.0 to 4.0

q. Input Paddy Mass (I) = any mass, say 10.0 tons

r. Separator Type (ST): Fixed or adjustable

s. Grain Type (GT): Short, medium and long

t. Growing Season (SEAS): Wet or Dry

u. Sifter Bin Capacity (SFBIN) = 0.077 m3

Once all the above information is typed into the statements in lines 175 to 181 of the computer program, the rice mill performance model is ready for a simulation run. In the TRS-80, this is done by typing in "RUN" and pressing the input button. The computer then prints or displays the results as in Table 3.1.

The first column gives the time in hours it took the rice mill to process 10 tons of paddy and the second column is the output in tons of milled rice. Column three is the head rice recovery based on clean paddy. It is obtained by dividing column two by the weight of paddy after the precleaner. The fourth column gives the head rice recovery which is based on the total milled rice recovered. Column five gives the percentage of discolored or fermented grain. The last column gives the energy in kilowatt-hours that was used in the rice milling operation.

Different combinations of equipment such as disc huller-cone whitener-fixed separator or rubber roll huller-cone whitener-adjustable separator, etc. may be used. The bin capacities may also be changed to vary delay times. The number of equipment may also be changed such as from

Table 3.1 Results of simulation runs

Mill Type No. 1

Input (all in tons/hour)

RCAP = 0.33; PCCAP = 0.33; SCAP = 0.495; NW = 1; WCAP = 0.255; PHCAP = 0.294; ST: Fixed; SEAS: Wet;

DM: Sun; HNP: 1; HT: Disc; WT: Cone

Output

	Time	Output	Recov	Head	Disc[1/]	Energy
	Hrs.	Tons	Percent			Kw-hrs.
	31.26	6.65	68.07	61.46	1.20	503.07
	29.50	6.23	66.58	61.43	0.10	485.77
	31.0	6.60	67.89	61.44	3.75	500.85
	30.34	6.43	67.32	62.36	0.05	494.01
	30.47	6.46	67.43	65.44	0.02	495.30
	31.50	6.71	68.27	61.48	0.07	505.54
	27.42	5.74	64.59	59.69	0.76	465.57
	31.65	6.74	68.38	63.22	0.03	506.97
	31.38	6.60	68.16	61.34	1.34	504.25
	31.51	6.71	68.27	61.10	2.74	505.54
AVE_{10}	30.61	6.49	67.50	61.90	1.01	496.68
AVE_{100}	30.76	6.53	67.64	61.94	1.52	498.21

ADV. CAP. = 0.33 ton/hr.

SIM. CAP. = 0.3251 ton/hr.

1/ Discolored grain due to fermentation or water damage.

double parallel to single huller. Growing season, grain type, grain shape and drying method may also be changed.

CHAPTER IV

LINEAR NETWORK ECONOMIC MODEL

The linear network economic model was developed to evaluate the cost of milling rice over a range of capacities. The model takes into account the differences in the amount of by-product produced by each mill. For example, the Engleberg type steel hullers produce large amounts of bran, powdered husks and brewer's rice which have some economic value. To compare such a mill with a rubber-roll mill in terms of rice output alone would be biased as to by-product values.

To evaluate the milling system's cost of operation over a range of capacities, the system was analysed as a set of components described in terms of their mass-energy characteristics. The components of a rice mill are of two types, material transformation and transportation components. A material transformation is conversion of the input material into an output product. The transformations are performed by the application of processing energy which is non-linear. Transportation components incur a movement material transfer energy cost.

4.1 Theory of Linear Network Economic Model

Linear network economic modeling utilizes Electrical Network Theory and the Principle of Energy Conservation. Electrical Network Theory was developed from Kirchoff's Circuit Laws, namely, Kirchoff's Current Law and Kirchoff's Voltage Law. This approach was used by Holtman, et al. in 1972 in the analysis of a poultry farm, and the following year Hughes applied it to the analysis of beef production systems in Michigan. The latter model was also applied to a dairy farm and later to a field crop production system.

4.1.1 Kirchoff's Circuit Laws

These laws could be best explained by an illustration. Consider an electrical circuit consisting of two resistors, 1 and 2, and a battery as shown in Figure 4.1a. Kirchoff's Current Law states that the sum of all currents flowing into a junction is zero. Applying this rule to junction 0 in the figure, the symbols i_1 and i_2 refer to the current passing through resistors R_1 and R_2 and the symbol i_3 refers to the current through battery B_1.

$$i_1 + i_2 - i_3 = 0$$

$$i_3 = i_1 + i_2$$

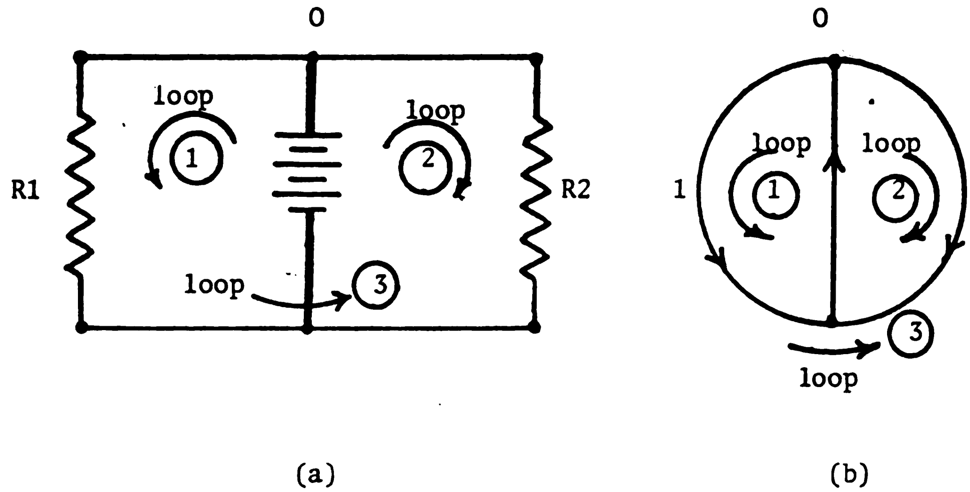


Figure 4.1 Example circuit and its linear network.

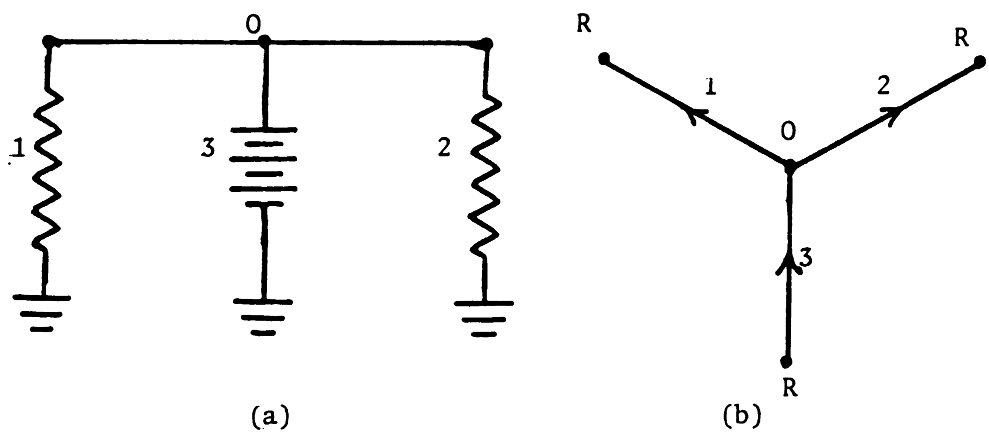


Figure 4.2 Modified circuit and its linear network.

The result is obvious to the reader from the figure by inspection. Kirchoff's Voltage Law on the other hand states that the sum of voltages around a closed loop equals zero. Applying this rule to loops 1, 2 and 3 in Figure 4.1a:

$$\text{loop 3:}\quad V_1 - V_2 = 0$$

$$\text{loop 2:}\quad V_3 + V_2 = 0$$

$$\text{loop 1:}\quad V_3 + V1 = 0$$

Again, the results are seen to be correct by inspection. Figure 4.1a could be transformed into another form called linear network shown in Figure 4.1b. The circuit equations could be written for this network using Kirchoff's Laws. For large and complicated networks, a slight modification of the circuit is necessary. Consider again the circuit in Figure 4.1a. The circuit could be redrawn as shown in Figure 4.2a. This time the bottom leg of the circuit was replaced by a common ground. The linear network could be drawn as shown in Figure 4.2b. All grounded ends of linkages are marked by a letter R which stands for reference. A ground or reference point means that all potentials are at the same level. Kirchoff's Circuit Laws are still applicable to this form of the circuit and the linear network and would give the same results except that when the voltages are added, linkages must be selected that end in a reference point to make sure that a loop is completed. Also, the reader is not supposed to go over a reference point when summing voltages in situations where another linkage is attached to the reference point. Additional discussion of the details of this method is provided in the procedure of the development of this model.

In applying linear network analysis to economic models, electrical currents become flow rates of materials and electric potentials (measured with respect to a reference point) become energy costs. This analogy is applicable to transport and material storage operations. These two operations could be modeled by resistors and capacitors in electrical network theory. It should be observed that the existence of electrical analogs for the transport and storage processes did not imply the existence of every economic and ecological component or system. On the contrary, there are no electrical analogs to material transformation processes. Thus it is necessary to use the Principle of Energy Conservation in the analysis of material transformation processes. This principle states that the sum of all energy input to a process equals the sum of all the energy output.

The production processes in the physical and agricultural industries represent a sequence of transformations of the structural state of materials to achieve a well-defined physical, chemical, biological or technological form. Each such transformation can be abstracted as a material input-output process characterizable by a model as shown in Figure 4.3 for three input materials, one useful product and one by-product. In this model, the Y_i, $i = 1, 2, ..., 5$, represents the flow rates of the five materials. A coefficient K, characterizing the transformation, is introduced here in writing the equations. This coefficient has a variety of specific interpretations, depending on the level of analysis. For example, if the transformation is associated with a firm, industry or geographic region, then it is called the "technological coefficients of production." On the other hand, in other analyses they may be used to characterize the composition of the output material in terms of the inputs and by-products. In the former association, changes in the coefficient K reflect changes in the technology of production. However, in the latter case they are unique to the particular product Y_5.

Applying the conservation of energy principle to the process in Figure 4.3, we have:

Output energy + energy of the inputs + energy lost in the waste + processing energy = 0

or

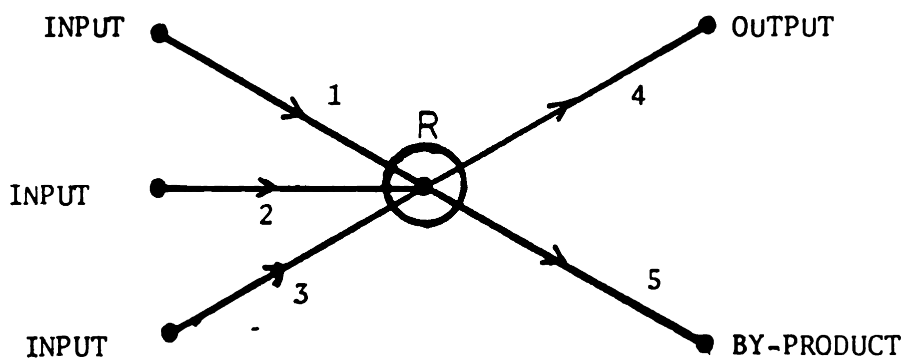


Figure 4.3 A Typical Industrial Process

$$X_5Y_5 + (X_1Y_1 + X_2Y_2 + X_3Y_3 = X_4Y_4) = f(Y_5)Y_5 = 0 \quad (A1)$$

where $f(Y_5)$ is a function of Y_5 and represents the processing energy per unit of output. X_i is the energy per unit of material Y_i.

Also, from the figure, we have the flow model equations:

$$Y_1 = K_1Y_5$$

$$Y_2 = K_2Y_5$$

$$Y_3 = K_3Y_5$$

$$Y_4 = K_4Y_5$$

where K_i = technical coefficient of proportionality for the particular material "i."

Substituting these equations into A(1),

$$X_5 = -K_1X_1 - K_2X_2 - K_3X_3 - K_4X_4 - f(Y_5)$$

or

$$X_5 = \sum_{j=1}^{4} K_jX_j - f(Y_5)$$

or

$$X_5 = [K_1K_2K_3K_4] \begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \end{bmatrix} - f(Y_5)$$

This cost equation constitutes a coordinated linear network and economic model of the transformation process. The matrix product to the right of the equality sign represent the energy costs involved in making the inputs available to the process and in removing the joint products or "waste" from the process. In the context of a system design problem, Y_5 represents the design capacity of the plant and $f(Y_5)$ denotes the variation in the processing costs associated with the scale of operation or design capacity. In the context of existing plant management problems, Y_5 represents the level of output and $f(Y_5)$ denotes the variation of processing costs with the different levels of output. In both cases, this function represents precisely the economies of scale to the various forms of energy and monetary cost associated with volume rates of transformation process. These economies of scale are of central concern in assessing the ecological and sociological impact of modern technology. It is these economies of scale particularly with respect to labor that motivate much of the contemporary trend to high-volume geographically concentrated industrial production and highly specialized large-scale agricultural production with the attendant spatial concentration of people and wastes.

4.2 Procedure

4.2.1 Energy Notations

A notational scheme has been adopted for the formulation of component models (Figure 4.3). Material flow rates of material "i" into or out of component "j" are denoted Y_{ij} (i.e., Y_{ij} has units of quantity of material per unit time). The amount of energy "m" associated with this material is denoted $X^m{}_{ij}$ (i.e., $X^m{}_{ij}$ has units of quantity of energy "m" per unit quantity of material). The product $X^m{}_{ij}Y_{ij}$ then denotes an energy flow rate.

Associated with each material flow rate is a vector value that represents the monetary cost, capital outlay and the energy required to put a unit of the material into its current form and location. In this model, labor is formulated as an energy cost, rather than as a flow of services, and is considered as a nonrenewable resource along with solar and physical forms of energy. Land is a measure of the solar energy needed to produce a crop. Elements of the energy cost vector are denoted by $X^m{}_{ij}$ ("m" indicates the energy type) where:

m = 1: capital ($)

m = 2: human energy or labor (man-hours)

m = 3: fossil energy (horsepower hours)

m = 4: electrical energy (kilowatt-hours)

m = 5: land (acres)

or all the above could be replaced by:

m = 6: dollar cost ($)

Example: $X^m{}_{ij} = X^6{}_{11} =$ ₱ 1.00 per kg. (the cost of paddy)

Instead of using the several energy dimensions discussed above, the analysis could be simplified by an alternate measure, namely, cost per unit of material. The analysis, of course, is valid only for the prices and costs actually used. The unit dollar cost, $X6_{ij}$, of material "i" for component "j" is among other things a scalar function of the energy costs of the other five energy forms. The value of $X6_{ij}$ depends on the relative availability of the five forms of energy and the preference society places on each of the input materials.

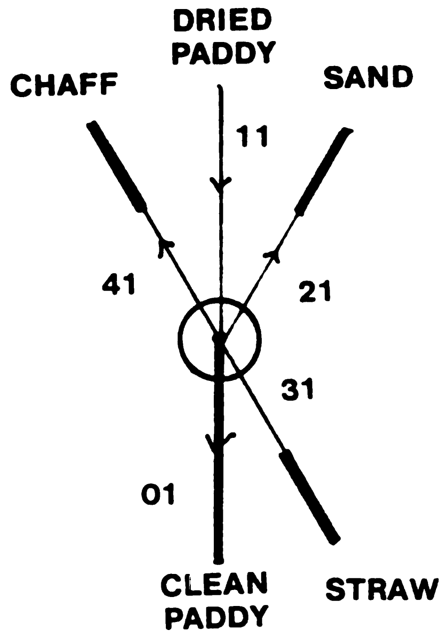
The precleaner subsystem (Figure 4.4) input includes mixed dried paddy rice and impurities which are separated in the process. The flow model equation is:

$$Y_{i1} = K_{i1}Y_{01} \qquad i = 1, 2, \ldots 4$$

where Y_{i1} is the quantity of material "il" required or taken out to produce one unit of clean paddy.

The output Y_{01} determines the quantities of the other flows and is called the stimulus variable. The flows other than the stimulus variable are called response variables. The K_{i1}'s are the technical coefficients for the components.

The conservation of energy principle requires that the net energy flow into the component plus the applied processing energy must equal zero. The expression:



Pre-cleaner component - 1

Material	- ij
Clean paddy	- 01
Dried paddy	- 11
Sand	- 21
Straw	- 31
Chaff	41

$$Y_{ij} = K_{i1} Y_{01} \qquad i = 1, 2, \ldots 4$$

$$X^m_{01} = - \sum_{i=1}^{4} K_{i1} X^m_{i1} - f^m_1(Y_{01}) \qquad m = 1, 2, \ldots 6$$

FIGURE 4.4 DIAGRAM OF PRECLEANER COMPONENT PROCESS

$$\sum_{i=1}^{4} K_{i1}X^{m}_{i1} \qquad m = 1, 2, \ldots 6$$

is an accumulation of various energy forms "m" in the input and output materials required to produce one ton of clean paddy.

Processing costs include the cost of machinery, building, labor, fuel, taxes, depreciation, etc. The processing energy cost function is typically a non-linear function of the production level. The amount of processing energy "m" required for one ton of clean paddy is:

$$f^{m}_{1}(Y_{01}) \qquad m = 1, 2, \ldots 6$$

Cost relation of the components is:

$$X^{m}_{01} = \sum_{i=i}^{4} K_{i1}X^{m}_{i1} - f^{m}_{1}\,(Y_{01}) \quad m = 1, 2, \ldots 6$$

In this particular analysis, the cost per unit of material, which is the economic measure of the energy level spent to place the material in its current form and location was utilized. The analysis is then, of course, valid only for the prices and the costs actually used.

4.2.1.1 Precleaner Component

Applying the representation of a process in Figure 4.3 to the first rice milling component, the diagram of a precleaner component process is obtained as in Figure 4.4.

The input to the process is dried paddy and the output is dried paddy. The by-products are chaff, sand and straw. The flow model equation is:

$$K_{i1} = K_{i1}Y_{01} \qquad i = 1, 2, \ldots 4$$

where Y_{i1} is the quantity of material "i1" required or taken out to produce one unit of clean paddy.

4.2.1.2 Huller Component

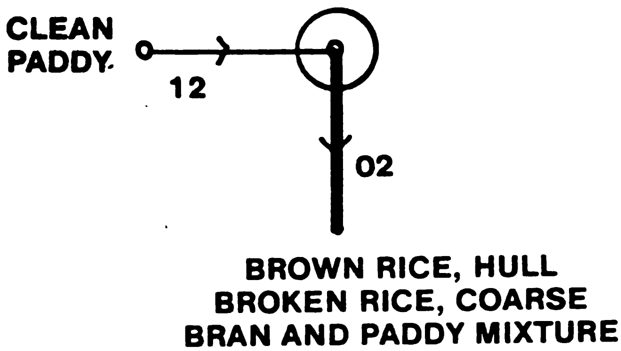
For the huller component, the input is clean paddy and the product is a mixture of brown rice, hull, broken rice, coarse bran and paddy mixture. The flow model equation is:

$$Y_{12} = K_{12}Y_{02} \qquad i = 1, 2$$

where Y_{12} is the quantity of material "12" required or taken out to produce one unit of a mixture of brown rice, hull, broken rice, coarse bran and paddy mixture. Figure 4.5 shows this component and the related equations.

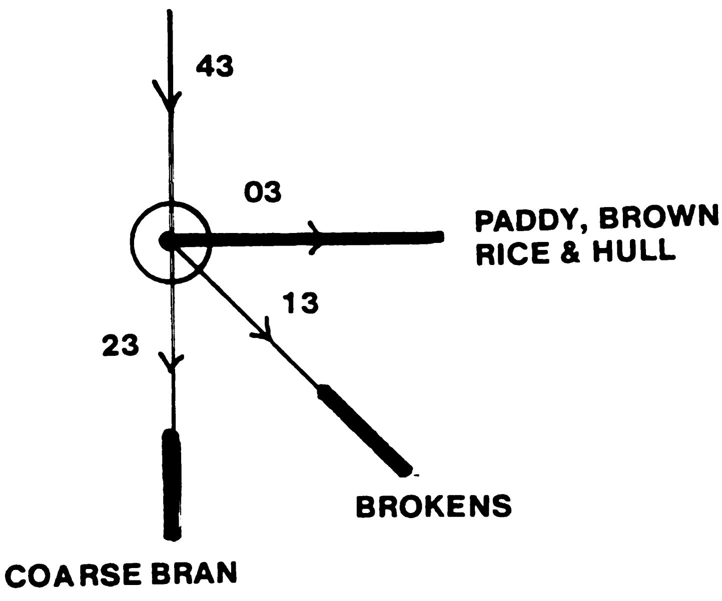
4.2.1.3 Plansifter and Aspirator

The next component after the huller is the plansifter and aspirator component. The input is the mixture of brown rice, hull, broken rice, coarse bran and paddy mixture. The output is a mixture of paddy, brown rice and hull. The by-products are brokens and coarse bran. The flow model equation is:



$$Y_{12} = K_{12}Y_{02}$$
$$X_{02}^{m} = K_{12}X_{12}^{m} - f_{2}^{m}(Y_{02})$$
$$m = 1, 2, \dots 6$$

Figure 4.5 Diagram of Huller Component Process



$$Y_{i3} = K_{i3}Y_{03}$$
$$i = 1, 2, \dots 4$$
$$X_{03}^{m} = -\sum_{i=1}^{4} K_{i3}X_{i3}^{m} - F_{3}^{m}(Y_{03})$$
$$m = 1, 2, \dots 6$$

Figure 4.6 Diagram of Sifter Components Process

$$Y_{i3} = K_{i3}Y_{03} \qquad i = 1, 2, 3$$

where Y_{i3} is the quantity of material "i3" required to produce one unit of mixture. Figure 4.6 shows the component and the related equations.

4.2.1.4 Paddy Separator Component

The next component, the paddy separator, separates the brown rice from the paddy. The flow model equation is:

$$Y_{i5} = K_{i5}Y_{05} \qquad i = 1, 2$$

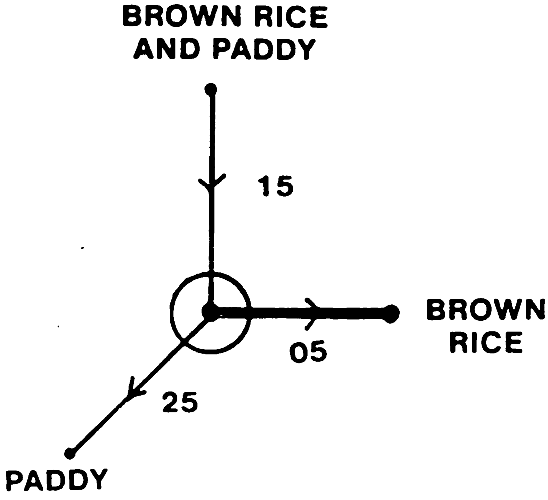
where Y_{i5} is the quantity of material "i5" required or taken out to produce one unit of brown rice. Figure 4.7 shows the component and the related equations.

4.2.1.5 First Stage Whitener Component

The first stage whitening process has brown rice as input. The product consists of first-stage milled rice and the by-product is dark bran. Figures 4.8, 4.9 and 4.10 show the first-, second- and third-stage whitening process components and the related equations which are similar to previously discussed components.

4.2.1.6 Grader Component

The last step in the rice milling process is the grading of milled rice. The input is third-stage milled

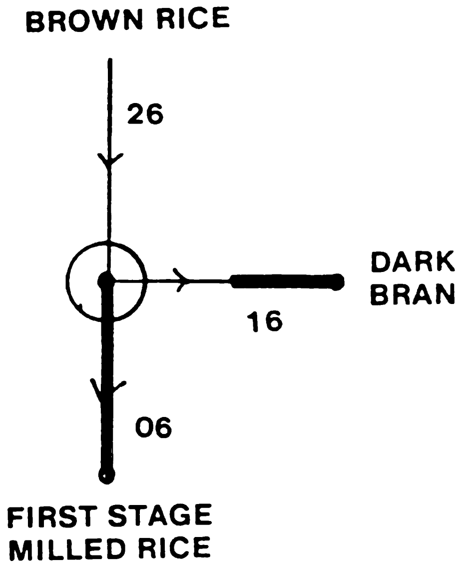


$$Y_{i5} = K_{i5} Y_{05}$$

$$i = 1, 2$$

$$X_{05} = -\sum_{i=1}^{2} K_{i5} X_{i5} - f_4^m \, (Y_{05})$$

FIGURE 4.7. DIAGRAM OF PADDY SEPARATOR COMPONENT PROCESS



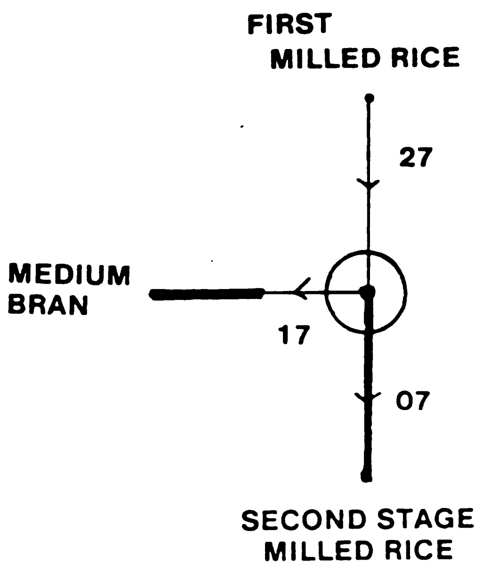
$$Y_{i6} = K_{i6} Y_{06}$$

$$i = 1, 2$$

$$x_{06} = -\sum_{i=1}^{2} K_{i6} \cdot f_6^m \, (Y_{06})$$

$$m = 1, 2 \ldots 6$$

FIGURE 4.8 DIAGRAM OF FIRST STAGE WHITENER COMPONENT PROCESS



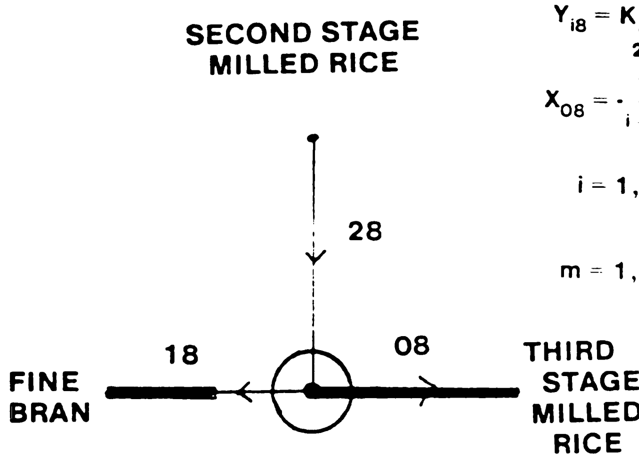
$$Y_{i7} = K_{i7}Y_{07}$$

$$X_{07} = -\sum_{i=1}^{2} K_{i7}X_{i7} \cdot f_7^m \quad (Y_{07})$$

$i = 1, 2$

$m = 1, 2, \ldots 6$

FIGURE 4.9. DIAGRAM OF SECOND STAGE WHITENER COMPONENT PROCESS



$$Y_{i8} = K_{i8}Y_{08}$$

$$X_{08} = -\sum_{i=1}^{2} K_{i8}Y_{i8} \cdot f_8^m \quad (Y_{08})$$

$i = 1, 2$

$m = 1, 2, \ldots 6$

FIGURE 4.10 DIAGRAM OF THIRD STAGE WHITENER COMPONENT PROCESS rice and the output is graded milled rice. The by-products are brewer's rice and polish. The flow model equation is:

$$Y_{i9} = K_{i9}Y_{09} \qquad i = 1, 2, 3$$

where Y_{i9} is the quantity of material "i9" required or taken out to produce one unit of graded milled rice. Figure 4.11 shows the component and the related equations.

4.2.1.7 Transport Component

The transport components are the laborers, elevators, chutes and conveyor in the system. Since the same material flows into and out of a transport component and it is assumed that no losses are incurred, only transport energy costs need be considered. Figure 4.13 shows the location of the transport components. The cost models for the transportation components are:

Elevator 1:

$$X^m{}_{1T} = -f^m{}_{1T}(Y_{1T}) \qquad m = 1, 2, \ldots 6$$

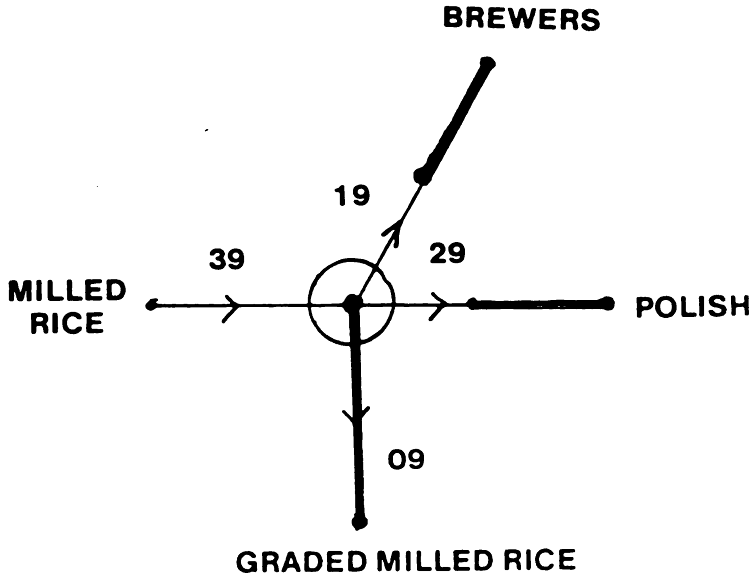
where $f^m{}_{1T}(Y_{1T})$ is read as the function of Y_{1T} and represents the transport energy per unit of material.

Elevator 2:

$$X^m{}_{2T} = -f^m{}_{2T}\ (Y_{2T}) \qquad m = 1, 2, \ldots 6$$

Elevator 3:

$$X^m{}_{3T} = -f^m{}_{3T}\ (Y_{3T}) \qquad m = 1, 2, \ldots 6$$



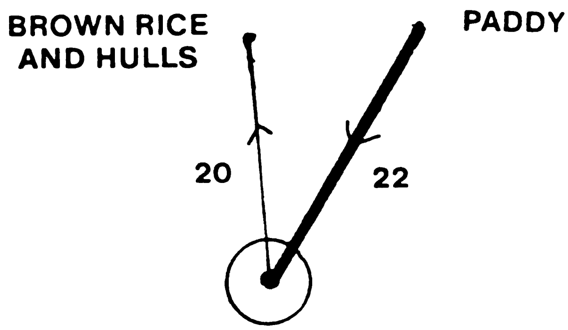
$$Y_{i9} = K_{i9} Y_{09}$$

$$i = 1, 2, 3$$

$$X_{09} = -\sum_{i=1}^{3} K_{i9} Y_{i9} \cdot f_9^m \; (Y_{09})$$

$$m = 1, 2, \ldots 6$$

FIGURE 4.11. DIAGRAM OF GRADER COMPONENT PROCESS



$$Y_{20} = Y_{22} = Y_{25} Y_{05}$$

$$X_{22} = -K_{20} X_{20} + f_{22} \, (Y_{22})$$

FIGURE 4.12 DIAGRAM OF RETURN HULLER COMPONENT PROCESS

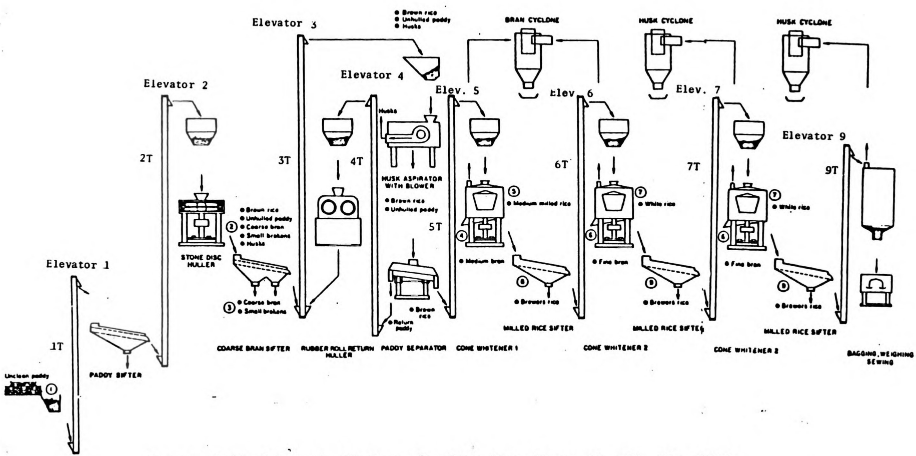


Figure 4.13 Schematic Diagram of a Disc-Cone (Conventional) Rice Mill.

Elevator 4:

$$X^m{}_{4T} = -f^m{}_{4T}\ (Y_{4T}) \qquad m = 1, 2, \ldots .6$$

Elevator 5:

$$X^m{}_{5T} = -f^m{}_{5T}\ (Y_{5T}) \qquad m = 1, 2, \ldots .6$$

Elevator 6:

$$X^m{}_{6T} = -f^m{}_{6T}\ (Y_{6T}) \qquad m = 1, 2, \ldots .6$$

Elevator 7:

$$X^m{}_{7T} = -f^m{}_{7T}\ (Y_{7T}) \qquad m = 1, 2, \ldots .6$$

Elevator 9:

$$X^m{}_{9T} = -f^m{}_{9T}\ (Y_{9T}) \qquad m = 1, 2, \ldots .6$$

4.2.1.8 Return Huller Component

The return huller component performs the hulling of paddy coming from the paddy separators. Figure 4.12 shows the paddy as input and the mixture of brown rice and hulls as output. This component is needed because the efficiency of the primary hullers is only from 60 to 95 percent. The unhulled 5 to 40 percent paddy are dehulled in the return huller. The related equations are also shown in the figure.

4.2.1.9 Rice Milling System Economic Model

The whole system is shown in Figure 4.14. The flow Y_{10} (milled rice) is the system stimulus variable. The

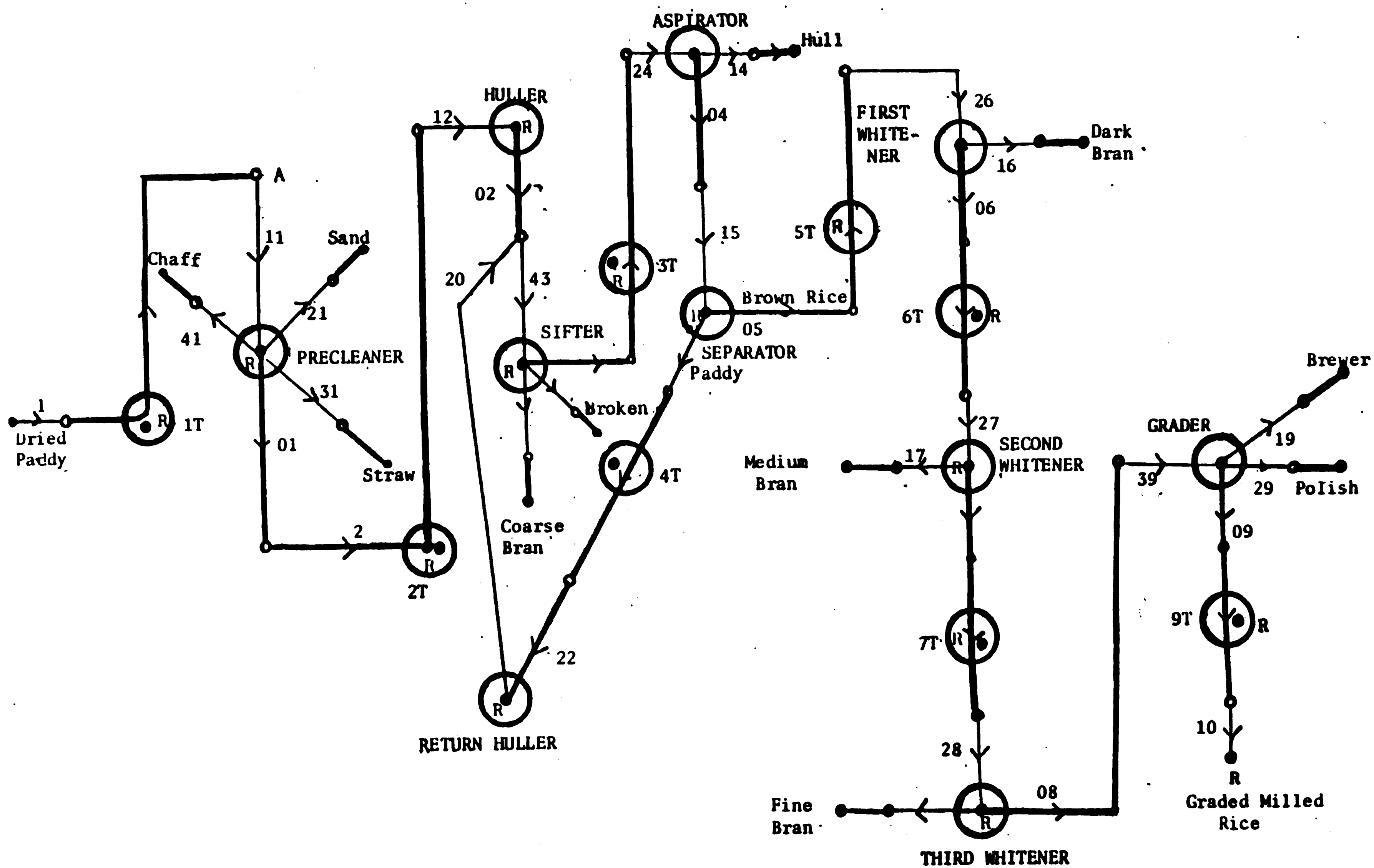


Figure 4.14 Linear Graph of a Rice Milling System.

following material flow relations are from Figures 4.4 through 4.12:

$$Y_{11} = K_{11}Y_{01}$$

$$Y_{21} = K_{21}Y_{01}$$

$$Y_{31} = K_{31}Y_{01}$$

$$Y_{41} = K_{41}Y_{01}$$

$$Y_{13} = K_{13}Y_{03}$$

$$Y_{23} = K_{23}Y_{03}$$

$$Y_{14} = K_{14}Y_{04}$$

$$Y_{15} = K_{15}Y_{05}$$

$$Y_{16} = K_{16}Y_{06}$$

$$Y_{17} = K_{17}Y_{07}$$

$$Y_{18} = K_{18}Y_{08}$$

$$Y_{19} = K_{19}Y_{09}$$

$$Y_{29} = K_{29}Y_{09}$$

In order to complete the rice milling economic model of the system, the energy cost equations must be derived. An energy cost, X_i, per unit of material is defined for each material flow. The energy costs are defined analogously to such intensive physical variables as voltage or velocity (i.e., they are relative measures like elevation, electrical potential and gravity). Energy cost is measured at one point in the system relative to another. A material flow rate is associated with each of the oriented line segments such as 1, 1T and 11 segments (called edges). The vertices such as A in Figure 4.14 (edge endpoints) constitute the set of points at which energy cost evaluations are made for the linear graph in Figure 4.14. The decomposition of variables into stimulus and response subsets are made utilizing the notion of a tree of the linear graph. A tree of the linear graph is a subset of edges of the graph of maximal size such that the edges in the tree form no closed paths or circuits in the system graph. Those edges in heavy lines constitute a tree for the system graph of Figure 4.14.

To facilitate computation, certain conventions have to be adopted.

a. The per unit energy costs of each edge are defined positive at the tail of the arrow of that edge with respect to the narrow tip. Thus X_{11} is the energy cost per unit of paddy at vertex A minus the energy cost per unit of paddy at vertex B.

b. All vertices "R" are reference vertices (analogous to an inertia reference or an electrical ground). Thus, the energy levels of all materials are defined to be zero at "R."

c. Material flows towards a vertex are negative and flows outward are positive. The component interconnection pattern is mathematically described via application of continuity and compatibility laws to the linear system graph of Figure 4.14. The continuity law is analogous to Kirchoff's current law and states that:

The sum of flows into a vertex (not including reference vertices) is zero. Thus we obtain:

$$Y_{11} - Y_{1T} = 0 \qquad A(1)$$

where Y_{11} is the flow rate of dried paddy into the precleaner and Y_{1T} is the flow rate of paddy through the elevator "1T."

$$Y_{12} - Y_{2T} = 0 \qquad A(2)$$

where Y_{12} is the flow rate of brown rice, hull and paddy mixture to the sifter and Y_{2T} is the flow rate of brown rice mixture from the return huller.

$$Y_{43} - Y_{02} - Y_{20} = 0 \qquad A(3)$$

where Y_{43} is the flow rate of brown rice, hull and paddy mixture to the sifter, and Y_{02} is the flow rate of brown rice mixture from the return huller.

$$Y_{22} - Y_{4T} = 0 \qquad A(4)$$

where Y_{22} is the paddy flow rate to the return huller and Y_{4T} the flow rate to elevator 4.

$$Y_{4T} - Y_{25} = 0 \qquad A(5)$$

where Y_{25} is the flow rate of paddy from the separator.

$$Y_{24} - Y_{3T} = 0 \qquad A(6)$$

where Y_{24} is the flow rate of brown rice and hull mixture to the aspirator.

$$Y_{15} - Y_{04} = 0 \qquad A(7)$$

where Y_{15} is the flow rate of brown rice and paddy to the separator and Y_{04} is the flow rate of brown rice and from the aspirator.

$$Y_{26} - Y_{5T} = 0 \qquad A(8)$$

where Y_{26} is the flow rate of brown rice to the first whitener and Y_{5T} is the flow through elevator number 5.

$$Y_{27} - Y_{06} = 0 \qquad A(9)$$

where Y_{27} is the flow rate of milled rice to second whitener and Y_{06} is the flow rate of milled rice from the first whitener.

$$Y_{28} - Y_{7T} = 0 \qquad A(10)$$

where Y_{28} is the flow rate of milled rice to the third whitener and Y_{7T} is the flow rate of milled rice through elevator number 7.

$$Y_{39} - Y_{08} = 0 \qquad A(11)$$

where Y_{39} is the flow rate of milled rice to the grader and Y_{08} is the flow rate of milled rice from the third whitener.

$$Y_{09} - Y_{8T} = 0 \qquad A(12)$$

where Y_{09} is the flow rate of milled rice from the grader and Y_{8T} is the flow rate of milled rice through elevator number 8.

$$Y_{12} - Y_{01} = 0 \qquad A(13)$$

where Y_{12} is the flow rate of paddy and Y_{01} is the flow rate of paddy from the precleaner.

$$Y_{24} - Y_{03} = 0 \qquad A(14)$$

where Y_{24} is the flow rate of brown rice and hull mixture to the aspirator and Y_{03} is the flow rate of brown rice and hull mixture from the sifter.

$$Y_{27} - Y_{6T} = 0 \qquad A(15)$$

where Y_{27} is the flow rate of milled rice to the second whitener and Y_{6T} is the flow rate of milled rice through elevator number 4.

$$Y_{28} - Y_{07} = 0 \qquad A(16)$$

where Y_{28} is the flow rate of milled rice to third whitener and Y_{07} is the flow rate of milled rice from the second whitener.

$$Y_{26} - Y_{05} = 0 \qquad A(17)$$

where Y_{26} is the flow rate of brown rice to the first whitener and Y_{05} is the flow rate of brown rice from the separator.

$$Y_{10} - Y_{9T} = 0 \qquad A(18)$$

where Y_{10} is the flow rate of milled rice to the rice mill outlet and Y_{9T} is the flow rate of milled rice through elevator number 9.

The remaining portion of the graph equation was developed via application of the law of compatibility which is an analogy of Kirchoff's Voltage Law. Compatibility states that:

__The sum of oriented energy costs around a closed path of edges vanishes.__ For the path of edges 1T and 11 of Figure 4.13, the following is obtained:

$$X_1 + X_{1T} = X_{11} = 0$$

where X_1 = unit peso cost of input paddy and

X_{ij} = unit peso cost of material "i" for component "j" in Figure 4.14,

recalling that all references to vertices are defined to be at the same energy level.

X_{1T} and X_{11} have the same sign because they have the same orientation in the path from R to R. The complete set of compatibility relation is:

$$X_1 + X_{1T} + X_{11} = 0 \qquad B(1)$$

$$X_{01} + X_{2T} + X_{12} = 0 \qquad B(2)$$

$$X_{02} + X_{43} = 0 \qquad B(3)$$

$$X_{02} + X_{43} = 0 \qquad B(4)$$

$$X_{03} + X_{3T} + X_{24} = 0 \qquad B(5)$$

$$X_{04} + X_{25} = 0 \qquad B(6)$$

$$X_{25} + X_{4T} = 0 \qquad B(7)$$

$$X_{05} + X_{5T} + X_{26} = 0 \qquad B(8)$$

$$X_{06} + X_{6T} + X_{27} = 0 \qquad B(9)$$

$$X_{07} + X_{7T} + X_{28} = 0 \qquad B(10)$$

$$X_{08} + X_{39} = 0 \qquad B(11)$$

$$X_{09} + X_{9T} = 0 \qquad B(12)$$

It has been proven that the above set of continuity and compatibility equations constitute the largest possible set of independent graph equations (Koenig, et al., 1967). Therefore, all of the available information pertaining to component interconnection pattern is contained in these equations. Any system input-output relationship can be obtained using the appropriate combination of component model and graph equations. For example, consider the relationship between paddy and hull in Figure 3.14. The component models are derived by the method illustrated by Holtman, et al. (1972). The flows are:

$$Y_{11} = Y_{1T} \qquad C(1)$$

where Y_{ij} = the flow rate of material i for component j.

$$Y_{12} = Y_{2T} \qquad C(2)$$

$$Y_{43} = Y_{02} + 20 \qquad C(3)$$

$$Y_{24} = Y_{3T} \qquad C(4)$$

$$Y_{15} = Y_{04} \qquad C(5)$$

$$Y_{25} = Y_{4T} \qquad C(6)$$

$$Y_{4T} = Y_{22} \qquad C(7)$$

$$Y_{12} = Y_{01} \qquad C(8)$$

$$Y_{14} = K_{14}Y_{04} \qquad C(9)$$

$$Y_{11} = K_{11}Y_{01} \qquad C(10)$$

$$Y_{12} = K_{12}Y_{02} \qquad C(11)$$

$$Y_{33} = K_{43}Y_{03} \qquad C(12)$$

$$Y_{20} = K_{25}Y_{05} \qquad C(13)$$

$$Y_{15} = K_{15}Y_{05} \qquad C(14)$$

$$Y_{24} = K_{24}Y_{04} \qquad C(15)$$

$$Y_{14} = K_{14}Y_{04} \qquad C(16)$$

In effect, the set of equations above transforms the entire system model into a component model with sixteen material forms. Since we want a relationship between paddy and hull, we begin with equation C(10) which is an expression of the flow rate of paddy.

$$Y_{11} = X_{11}Y_{01} \qquad C(10)$$

Substitution of Equation A(13),

$$Y_{11} = X_{11}Y_{12}$$

Substitution of Equation C(11),

$$Y_{11} = K_{11}K_{12}Y_{02}$$

Substitution of Equation C(3),

$$Y_{11} = K_{11}K_{12}(Y_{43} - Y_{20})$$

Substitution of C(12) and C(13),

$$Y_{11} = K_{11}K_{12}(K_{43}Y_{03} - K_{25}Y_{05})$$

Substitution of C(14),

$$Y_{11} = K_{11}K_{12}(K_{43}Y_{24} - K_{25}(1/K_{15})Y_{15})$$

Substitution of C(15),

$$Y_{11} = K_{11}K_{12}(K_{43}K_{24}Y_{04} - K_{25}(1/K_{15})Y_{04}$$

Substitution of C(16),

$$Y_{11} = K_{11}K_{12}(K_{43}K_{24}(Y_{14} - K_{25}(1/K_{25})Y_{14}$$

The flow Y_{10} (milled rice output) is the stimulus variable that dictates the remaining flows. The main interest in this model is the output cost X_{10} per kilogram milled rice.

To derive an equation for X_{10}, start with the cost equation for node 18 after the grader component.

$$X_{10} = - X_{09} - X_{9T} \quad E(1)$$

$$X_{09} = K_{39}X_{39} - K_{19}X_{19} - K_{29}X_{29} + f_{09}(X_{09}) \quad E(2)$$

$$X_{39} = - X_{03} \quad E(3)$$

$$X_{08} = - K_{18}X_{18} + K_{28}X_{28} + f_{08}(X_{08}) \quad E(4)$$

$$X_{28} = -X_{7T}X_{07} \quad E(5)$$

$$X_{07} = - K_{17}X_{17} + K_{27}X_{27} + f_{07}(Y_{07}) \quad E(6)$$

$$X_{27} = - X_{06} - X_{6T} \quad E(7)$$

$$X_{06} = - K_{16}X_{16} + K_{26}Y_{26} + f_{06}(Y_{06}) \quad E(8)$$

$$X_{26} = - X_{05} - X_{5T} \quad E(9)$$

$$X_{05} = K_{25}X_{25} + K_{15}X_{15} + f_{05}(Y_{05}) \quad E(10)$$

$$X_{15} = - X_{04} \quad E(11)$$

$$X_{04} = K_{14}X_{14} + K_{24}X_{24} + f_{04}(Y_{04}) \quad E(12)$$

$$X_{24} = - X_{03} - X_{3T} \quad E(13)$$

$$X_{03} = - K_{13}X_{13} - K_{23}Y_{23} + K_{43}X_{43} + f_{03}(Y_{03}) \quad E(14)$$

$$X_{43} = - X_{02} \quad E(15)$$

$$X_{02} = K_{12}X_{12} + f_{02}(Y_{02}) \qquad E(16)$$

$$X_{12} = - X_{01} - X_{2T} \qquad E(17)$$

$$X_{01} = K_{11}X_{11} - K_{21}Y_{21} + K_{31}X_{31} + K_{41}X_{41} + f_{01}(Y_{01}) \qquad E(18)$$

$$X_{11} = - X_{1T} - X_{1} \qquad E(19)$$

Combining the above equations to eliminate all internal X values, we could arrive at an expression for X_{10} in terms of the X values of the input and output, i.e., X_1, X_2, X_{31}, X_{41}, X_{13}, X_{23}, etc. Also all the flows could be expressed in terms of Y_{10}. These procedures (see Appendix F) would give us an expression for output cost X_{10} in terms of all input and output cost.

$$\begin{aligned}X_{10} = {} & K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{12}f_{01}K_{39}K_{28}K_{27} \\ & K_{26}K_{12}(K_{43}K_{24}K_{15} - K_{25})Y_{10} \\ & + K_{43}K_{39}K_{29}K_{27}K_{26}K_{24}K_{15}f_{02}K_{39} \\ & \quad K_{28}K_{27}K_{26}(K_{43}K_{24}K_{15} - K_{25})Y_{10} \\ & + K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}f_{03}(K_{39}K_{28}K_{27}K_{26} \\ & \quad K_{24}K_{15}Y_{10}) \\ & + K_{39}K_{28}K_{27}K_{26}K_{15}f_{04}(K_{39}K_{28}K_{27}K_{26}K_{25}Y_{10}) \\ & + K_{39}K_{28}K_{27}K_{26}f_{05}(K_{39}K_{28}K_{27}K_{26}Y_{10})\end{aligned}$$

$$+ K_{39}K_{28}K_{27}f_{06}(K_{39}K_{28}K_{27}Y_{10})$$

$$+ K_{39}K_{28}f_{07}(K_{39}K_{28}Y_{10})$$

$$+ K_{39}f_{03}(K_{39}Y_{10})$$

$$+ f_{09}(Y_{10})$$

$$+ K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{12}K_{11}f_{1T}K_{43}K_{39}$$
$$K_{28}K_{27}K_{26}K_{24}K_{12}K_{11}(K_{43}K_{24}K_{15} - K_{25})$$
$$Y_{10}$$

$$+ K_{43}K_{34}K_{28}K_{27}K_{26}K_{24}K_{15}f_{2T}K_{39}K_{28}K_{27}K_{26}K_{12}$$
$$(K_{43}K_{24}K_{15} - K_{25})Y_{10}$$

$$+ K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}f_{3T}(K_{39}K_{28}K_{27}K_{26}$$
$$K_{24}K_{15}Y_{10})$$

$$+ K_{39}K_{28}K_{27}K_{26}f_{5T}(K_{39}K_{28}K_{27}Y_{10})$$

$$+ K_{39}K_{28}K_{27}f_{6T}(K_{39}K_{28}K_{27}Y_{10})$$

$$+ K_{39}K_{28}f_{7T}(K_{39}K_{28}Y_{10})$$

$$+ f_{9T}(Y_{10})$$

$$+ K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{11}X$$

$$- K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{21}X_{SA}$$

$$- K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{31}X_{ST}$$

$- K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{12}K_{41}X_{CH}$

$- K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{13}X_{BRO}$

$- K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{23}X_{CB}$

$- K_{39}K_{28}K_{27}K_{26}K_{15}K_{14}X_{HU}$

$- K_{39}K_{27}K_{16}X_{DB}$

$- K_{39}K_{28}K_{17}X_{MB}$

$- K_{39}K_{18}X_{FB}$

$- K_{19}X_{BRE}$

$- K_{29}X_{PO}$

$+ K_{39}K_{28}K_{25}f_{4T}(K_{31}K_{28}K_{27}K_{26}K_{25}Y_{10})$

$+ K_{39}K_{28}K_{25}f_{22}(K_{39}K_{28}K_{27}K_{26}K_{25}Y_{10})$

$+ K_{39}K_{28}K_{25}K_{12}K_{11}f_{1T}K_{43}K_{39}K_{28}K_{27}K_{26}K_{12}$
$K_{11}(K_{43}K_{24}K_{15} - K_{25})Y_{10}$

$+ K_{39}K_{28}K_{25}K_{12}f_{01}(K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}$
$K_{12}Y_{10} - K_{39}K_{28}K_{27}K_{26}K_{25}K_{12}Y_{10})$

$+ K_{39}K_{28}K_{25}K_{20}K_{12}K_{11}X_{1}$

$+ K_{39}K_{28}K_{25}K_{20}K_{12}K_{21}X_{SA}$

$+ K_{39}K_{28}K_{25}K_{20}K_{12}K_{41}X_{CH}$

$$- K_{39}K_{28}K_{25}K_{12}f_{2T}(K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{12} Y_{10})$$

$$- K_{39}K_{25}f_{02}(K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}Y_{10})$$

The first nine terms are the processing cost, the tenth to sixteenth terms are transport cost, the seventeenth term is the cost of the paddy input X_1, the eighteenth to twenty-eighth terms are the by-product costs and the rest are the different costs in the return paddy loop.

Using the available data (Appendix G) and the relationship on Figures 3.18, 3.22, 3.24, 3.26, 3.30, 3.35 and 3.37 under Philippine conditions, the above equations were simplified (Appendix H) into the following equations:

(cone)

$$X_{10} = 0.0000048541\ Y_{10}^{-0.14} + 0.684834\ Y_{10}^{-0.54} + 0.0485612\ Y_{10}^{-0.07} + 0.048863\ Y_{10}^{0.36} + 2.922862\ Y_{10}^{0.29} + 0.27699\ Y_{10}^{-1} + 0.466497\ Y_{10}^{-0.08} + 0.00071381\ Y_{10} + 1.1180$$

(RR)

$$X_{10} = 0.0000048454\ Y_{10}^{-0.14} + 1.8958\ Y_{10}^{0.41} + 0.0485612\ Y_{10}^{-0.07} + 0.048863\ Y_{10}^{0.36} + 2.922862\ Y_{10}^{-0.29} + 0.27699\ Y_{10}^{-1} + 0.466497\ Y_{10}^{-0.08} + 0.00071381\ Y_{10} + 1.1062$$

These equations were used in determining the cost of input and processing energy per kilogram of milled rice.

The system analysis of a rice mill based on linear graph theory has been completed. The methodology begins with a decomposition of the system into components. The mathematical structure of the component models emphasized their mass-energy exchange relationship. The following chapter will cover an application of the two equations developed in this chapter to three sizes of rice mills.

CHAPTER V

ANALYSIS OF THE RESULTS

5.1 Rice Mill Performance Model

The rice mill performance model was used to simulate the operating characteristics of rice mill types currently being manufactured in the Philippines. These locally manufactured rice mills need to be given primary attention in upgrading the quality of rice milling systems in the Philippines. Old or existing mills (mostly imports) that were custom built or do not fall into any type studied may be considered on an individual basis.

There were about twelve "standard" mill types produced by two leading manufacturers. The simulation model also included eight models proposed by the author. A total of twenty mill types were therefore simulated from the base data of three rice mills. A brief description of the "standard" mills is presented in Table 5.1. The mill types designated by individual numbers consist of 1 huller and 1 whitener. Those with an A or F (Felson models) designation are equipped with 2 whiteners and those with a B or A (Felson models) designation are equipped with 2 hullers. The second column from the left side presents the

Table 5.1 Rice mill types manufactured in the Philippines

Type Number		Capacity	Huller	Whitener	No. of	Power Required	
Bernabe[1/]	Felson	Ton/hr.	No. X Dia. (m)	No. X Dia. (m)	Separator Compart.	B.H.P.[3/]	KW[4/]
1	2	0.367	1 X 0.50	1 X 0.35	18	20	17.55
2	2	0.477	1 X 0.60	1 X 0.45	24	22	19.31
2A	2F	0.550	2 X 0.60	2 X 0.40	24	25	21.94
3	3	0.660	1 X 0.65	1 X 0.50	30	28	24.57
3A	3F	0.696	1 X 0.65	2 X 0.40	30	30	26.33
4	4	0.916	1 X 0.75	1 X 0.65	39	35	30.72
4A	4F	0.916	1 X 0.75	2 X 0.45	39	36	31.60
4AB	4FA	0.916	2 X 0.50	2 X 0.45	39	40	35.11
5AB	5FA	1.10	2 X 0.65	2 X 0.50	43	43	37.74
6AB	6FA	1.36	2 X 0.65	2 X 0.65	52	45	39.49
7AB	7FA	1.54	2 X 0.75	2 X 0.65	60	50	43.88
8AB	8FA	1.83	2 X 0.75	2 X 0.75	72	60	52.66

1/ The two biggest manufacturers of rice mills in the Philippines are:

(1) Jose Bernabe & Co., Inc., 2535 J. Luna St., Tondo, Manila
(2) H. F. Feliciano Mach. & Iron Works, 2014 J. Luna St., Tondo, Manila

2/ Chapter 3 covers a description of the compartment type paddy separator.

3/ Brakehorsepower, which is defined as the power available at the shaft of an engine or motor as measured by a dynamometer.

4/ Kilowatts.

input capacity of the mill in tons per hour, while the third column gives the number of hullers and the diameter in meters. In the fourth column is the number of whiteners and the diameter in meters. The fifth column presents the number of compartments in the mill's separator, and in the sixth column is the power requirement of the mill in both brake horsepower and kilowatts.

Each simulation included 100 milling runs for each mill type without any modification, modified with an adjustable separator and modified with a single huller for the mills over 0.916 ton-per-hour capacity. Each milling run is different as determined by three random variable generators built into the program and discussed in Chapter 3. A "milling run" is one complete milling operation of a "batch" of paddy with resulting time data, output, etc. Some typical simulation runs are shown in Tables 5.2, 5.6, 5.7, 5.8, 5.9, 5.10 and 5.11. The fixed input data which were used for all simulations were as follows:

a. Huller Bin Capacity (HBIN) = 0.0069 m^3

b. Sifter Bin Capacity (SFBIN) = 0.077 m^3

c. Paddy Separator Bin Capacity (PBIN) = 0.0089 m^3

d. Input Paddy Mass (I) = 10.0 tons

e. Grain Shape (GS) = 3.0

f. Number of Paddy Cleaners (CPN) = 1

Table 5.2 (Table [illegible]

Table 5.2 (Table I1 in Appendix I) Results of simulation runs

Mill Type No. 1

Input (all in tons/hour)

RCAP = 0.33; PCCAP = 0.33; SCAP = 0.495; NW = 1; WCAP = 0.255; PHCAP = 0.294; ST: Fixed; SEAS: Wet;

DM: Sun; HNP: 1; HT: Disc; WT: Cone

Output

	Time	Output	Recov	Head	Disc[1/]	Energy
	Hrs.	Tons	Percent			Kw-hrs.
	31.26	6.65	68.07	61.46	1.20	503.07
	29.50	6.23	66.58	61.43	0.10	485.77
	31.0	6.60	67.89	61.44	3.75	500.85
	30.34	6.43	67.32	62.36	0.05	494.01
	30.47	6.46	67.43	65.44	0.02	495.30
	31.50	6.71	68.27	61.48	0.07	505.54
	27.42	5.74	64.59	59.69	0.76	465.57
	31.65	6.74	68.38	63.22	0.03	506.97
	31.38	6.60	68.16	61.34	1.34	504.25
	31.51	6.71	68.27	61.10	2.74	505.54
AVE_{10}	30.61	6.49	67.50	61.90	1.01	496.68
AVE_{100}	30.76	6.53	67.64	61.94	1.52	498.21

ADV. CAP. = 0.33 ton/hr.

SIM. CAP. = 0.3251 ton/hr.

[1/] Discolored grain due to fermentation or water damage.

Table 5.3 Rice milling rates of small disc-cone mill by region in the Philippines, 1973[1/]

Region	No. of Milling Reports	No. of Trials	All Paddy Milled Kilogram	Rice Recovered	
				Quantity Kilogram	Percent
Ilocos	7	9	378.70	218.30	57.64
Cagayan Valley	19	24	7890.66	4929.49	62.47
Central Luzon	128	223	99207.78	62695.24	63.20
Southern Tagalog	86	135	57813.16	36850.72	63.74
Bicol Region	37	66	83838.30	54042.30	64.46
Western Visayas	24	31	51078.95	32705.50	64.03
Central Visayas	24	24	1079.53	718.95	66.60
Eastern Visayas	20	30	6720.40	4490.40	66.82
Western Mindanao	4	4	1123.48	748.61	66.63
Northern Mindanao	13	15	12805.20	7470.58	58.34
Southern Mindanao	6	6	7669.80	4613.00	60.15
PHILIPPINES	368	567	329605.96	209483.09	63.55

[1/] From Basilio, E.A. and J.C. Alix, 1975. Rice Milling Recovery Rates, 1973. Ag. Econ., Statistics and Market News Digest, Vol. IX, No. 3

Table 5.4 Engine sizes and capacities of disc-cone rice mills[2/]

Capacity Cavan/12 hrs.	Capacity tons/hr.	Engine Size BHP	Average Price Pesos[4/]	Investment Cost[3/] Pesos/cavan cap.
50- 100	0.183-0.366	15- 24	16799.00	376.37
150- 250	0.550-0.915	25- 30	36417.00	286.08
250- 350	0.915-1.281	32- 45	47481.00	260.65
350- 450	1.281-1.647	45- 55	56936.00	219.13
450- 700	1.647-2.562	60- 80	83601.00	193.14
700-1000	2.562-3.660	90-140	146027.00	204.10

[2/] From Duff, B. and I. Estioko, 1972. Establishing Design Criteria for Improved Rice Milling Technologies, Saturday Seminar (Aug. 26, 1972)

[3/] Taken at midpoint of capacity range. Includes cost of engines.

[4/] One dollar was equivalent to ₱7.47.

Table 5.5 Milling recovery and head grain percentage as affected by harvest date, drying method and rice variety. (Gapan, Nueva Ecija, wet season 1972 and dry season 1973).[1]

			Date of harvest[1]												
			-5		-6		0		+5		+6		-10		
Variety	Watering method	Drying method	Head rice	Total milled rice	Head rice	Total milled rice	Head rice	Total milled rice	Head rice	Total milled rice	Head rice	Total milled rice	Head rice	Total milled rice	Mean head rice
			Wet season												
I R 20	Irrigated	Solar			76.92	67.6	78.71	69.5			75.07	70.2			76.90
		Mech.			75.74	67.6	78.80	69.8			75.07	70.2			76.54
	Rainfed	Solar			71.27	65.1	76.62	68.0			69.79	68.2			72.56
		Mech.			72.70	66.3	77.79	68.0			69:87	68.7			73.45
			Dry season												
I R 20	Irrigated	Solar	62.30	67.0			65.75	69.2	56.12	69.5			47.08	68.4	57.84
		Mech.	67.75	67.6			72.62	67.2	60.29	69.0			48.39	68.6	62.26
I R 24	Irrigated	Solar	61.43	68.7			70.52	69.2	66.76	68.9			53.11	67.6	62.96
		Mech.	71.98	67.8			79.13	69.0	71.18	68.0			58.91	66.0	69.55
C4-63	Irrigated	Solar	71.81	68.1			78.05	69.7	77.03	70.1			73.02	69.3	74.98
		Mech.	77.83	67.2			81.71	68.9	79.59	69.1			73.58	68.9	78.18
I R 253	Irrigated	Solar	33.13	64.9			52.71	68.3	45.24	68.3			28.55	66.9	39.91
		Mech.	56.60	62.9			62.50	68.8	56.22	68.3			40.83	67.1	54.04
														$\bar{X}$ =	62.46

[1] From Khan, A.U., 1969. IRRI-Agricultural Engineering Semi-Annual Substantive Report No. 8.

[2] Date of harvest refers to number of days before or after recommended harvest date.

Table 5.6 (Table 12 in Appendix I) Results of simulation runs.

Table 5.6 (Table I2 in Appendix I) Results of simulation runs.

Mill Type No. 1

Input (all in tons/hour)
RCAP = 0.33; PCCAP = 0.33; SCAP = 0.495; WCAP = 0.255; PHCAP = 0.294;
ST: Fixed; NW = 1; SEAS: Wet; DM: Sun; HNP: 1; HT: Disc; WT: Cone

Output

	Time	Output	Recov.	Head	Disc	Energy
	Hrs.	Tons	P e	r c e	n t	Kw.-hrs.
	30.47	6.46	67.43	63.46	0.030	453.30
	31.82	6.78	68.51	60.86	3.750	465.27
	31.26	6.64	68.07	61.28	3.750	460.27
	31.38	6.67	68.17	64.25	0.186	461.34
	29.81	6.30	66.86	61.30	2.266	447.48
	32.03	6.83	68.67	60.63	2.103	467.16
	32.03	6.83	68.67	60.63	3.329	467.16
	31.26	6.64	68.07	65.47	0.014	460.27
	32.34	6.90	68.91	60.28	2.442	469.94
	30.47	6.463	67.43	62.52	0.049	453.30
AVE_{10}	31.29	6.66	67.08	62.07	1.77	460.55
AVE_{100}	30.72	6.52	67.61	62.02	1.57	455.48

Table 5.7 (Table 11 in Appendix D) Results of simulation runs

Table 5.7 (Table I3 in Appendix I) Results of simulation runs

Mill Type No. 2

Input (all in tons/hour)
RCAP = 0.33; PCCAP = 0.33; HNP = 1; SCAP = 0.495; WCAP = 0.255;
PHCAP = 0.294; ST: Fixed; DM: Mec; SEAS: Wet; NW = 1

Output

	Time	Output	Recov.	Head	Disc	Energy
	Hrs.	Tons	Percent			Kw.-hrs.
	29.50	6.23	66.56	65.80	0.99	485.14
	31.14	6.62	67.98	66.45	3.75	501.93
	30.71	6.51	67.62	69.41	0.02	497.61
	31.14	6.62	67.98	66.45	3.75	468.86
	32.34	6.90	68.9	65.52	1.12	513.83
	27.42	5.74	64.59	60.83	0.66	455.64
	29.82	6.31	66.86	65.96	1.88	488.81
	31.14	6.62	67.98	66.45	2.76	501.93
	30.03	6.36	67.05	66.15	3.75	490.91
	29.82	6.31	66.8640	65.94	2.87	488.81
AVE_{10}	30.31	6.42	67.2422	65.89	2.15	493.70
AVE_{100}	30.68	6.51	67.5731	66.95	1.44	497.35

Table 5.4. (Table 14 in Appendix 1). Results of simulation runs

Table 5.8 (Table I4 in Appendix I) Results of simulation runs

Mill Type No. 1

Input (all in tons/hour)
RCAP = 0.33; PCCAP = 0.33; SCAP = 0.495; WCAP = 0.255; PHCAP = 0.294;
ST: Fixed; HT: RR; NW = 1

Output

	Time Hrs.	Output Tons	Recov. (Percent)	Head (Percent)	Disc (Percent)	Energy Kw.-hrs.
	30.31	6.42	68.64	66.28	0.44	485.03
	31.90	6.79	69.99	66.35	2.46	500.13
	31.44	6.69	69.61	66.59	1.30	495.78
	30.86	6.55	69.12	66.38	2.69	490.23
	28.17	5.91	66.58	67.02	0.01	464.94
	31.32	6.66	69.51	66.42	3.75	494.59
	32.25	6.88	70.27	68.58	0.02	503.53
	32.53	6.94	70.49	71.67	0.00	506.24
	32.71	6.99	70.62	67.45	0.03	507.89
	31.56	6.72	69.71	66.43	3.19	496.90
AVE_{10}	31.31	6.65	69.45	67.32	1.39	494.53
AVE_{100}	31.39	6.68	69.53	66.69	1.74	495.35

Table 5.9 (Table I36 in Appendix I) Results of simulation runs

Mill Type No. 8AB'

Input (all in tons/hour)
RCAP = 1.83; HNP = 2; PHCAP = 1.064; PCCAP = 1.83; WCAP = 2 X 0.731;
SCAP = 1.98; ST: Adjust.; NW = 2

Output

	Time	Output	Recov.	Head	Disc	Energy
	Hrs.	Tons	P e r	c e n t		Kw.-hrs.
	5.79	6.89	70.79	61.36	3.75	268.51
	5.71	6.78	70.42	61.51	3.46	265.87
	5.83	6.95	70.99	61.19	3.34	269.91
	5.62	6.66	69.97	63.23	0.03	262.85
	5.55	6.56	69.63	61.29	3.75	260.58
	5.11	5.98	67.26	63.74	0.01	246.54
	5.73	6.81	70.51	61.72	1.11	266.55
	5.75	6.84	70.61	61.82	0.52	267.20
	5.73	6.81	70.51	61.51	2.14	266.55
	5.65	6.59	70.10	61.61	1.48	263.72
AVE_{10}	5.65	6.70	70.08	61.90	1.96	263.83
AVE_{100}	5.73	6.80	70.45	61.90	1.54	266.33

Table 5.10 (Table I41 in Appendix I) Results of simulation runs

Mill Type No. 8AB''''

Input (all in tons/hour)
HT: RR; WT: CYL; SEAS: Wet; DM: Sun; ST: Adjus.

Output

	Time	Output	Recov.	Head	Disc	Energy
	Hrs.	Tons	P e	r c e	n t	Kw.-hrs.
	6.02	7.20	73.29	66.83	0.05	270.07
	5.70	6.77	71.78	66.20	2.99	260.00
	5.25	6.16	69.34	64.18	3.19	246.01
	5.85	6.96	72.50	66.42	3.75	264.62
	5.89	7.02	72.70	68.62	0.03	265.95
	6.02	7.20	73.29	67.43	0.04	270.07
	5.93	7.08	72.89	66.35	3.28	267.25
	5.91	7.05	72.79	66.43	3.37	266.60
	5.99	7.16	73.18	66.08	3.75	269.30
	5.97	7.13	73.08	70.50	0.01	268.58
AVE_{10}	5.85	6.97	72.48	66.91	2.04	264.85
AVE_{100}	5.85	6.97	72.47	66.77	1.57	264.73

Table 5.11 (Table I42 in Appendix I) Results of simulation runs.

Mill Type No. 8A'

Input (all in tons/hour)
RCAP = 1.83; HNP = 1; PHCAP = 1.83; PCCAP = 1.83; WCAP = 0.731;
SCAP = 1.98; NW = 2; ST: Adjus.

Output

	Time	Output	Recov.	Head	Disc	Energy
	Hrs.	Tons	P e r	c e n	t	Kw.-hrs.
	6.00	7.11	71.51	60.62	3.66	501.51
	5.78	6.81	70.51	62.48	0.05	487.79
	5.63	6.62	69.82	61.46	2.39	478.92
	6.05	7.18	71.76	63.65	0.01	505.04
	5.16	5.98	67.26	59.68	0.79	450.04
	5.76	6.78	70.42	61.83	0.45	486.55
	5.90	6.98	71.09	61.37	0.74	495.58
	5.96	7.06	71.34	66.38	0.00	499.11
	5.54	6.49	69.34	61.32	0.71	472.99
	5.88	6.95	70.99	61.36	1.25	494.12
AVE_{10}	5.75	6.77	70.32	62.03	1.25	486.02
AVE_{100}	5.73	6.75	70.27	61.96	1.61	485.18

g. Grain Type (GT) = Medium

h. Whitener Bin Capacity (WBIN) = 0.009 m^3

The variable input data were:

a. Number of Paddy Hullers (HNP = 1 or 2)

b. Huller Type (HT): Disc or Rubber Roller

c. Whitener Type (WT): Cone or cylindrical

d. Growing Season (SEAS): Wet or Dry

e. Drying Method (DM): Sun or Mechanical

f. Rice Mill Capacity (RCAP) = 0.33 to 1.83 tons per hour

g. Paddy Cleaner Capacity (PCAP) = 0.33 to 1.83 tons per hour

h. Number of Whiteners (NW) = 1 or 2

i. Separator Capacity (SCAP) = 0.495 to 1.98 tons per hour

j. Whitener Capacity (WCAP) = 0.255 to 0.731 tons per hour

k. Paddy Huller Capacity (PHCAP) = 0.294 to 1.83 tons per hour

l. Separator Type (ST): Fixed or Adjustable

Table 5.2 is the simulation for mills type No. 1 with a 0.33 ton-per-hour capacity. It shows the time to mill 10 tons of paddy, the milled rice output, the recovery percentage, head grain percentage, discolored kernels and energy consumed in the milling process. Each row represents one simulation run which in this case involves the milling of a 10-ton batch. The result of each run varies due to the random variables built into the program. These variables, namely, moisture content, purity and drying delay, were discussed previously in Section 3.2.1. The first average (AVE_{10}) refers to the average of the first ten simulations and AVE_{100} refers to the average of 100 simulations. For the 0.33 ton-per-hour mill, it takes an average of 30.76 hours to mill 10 tons of paddy.

For a medium grain and grain shape of 3.0, wet season crop and sun drying, the average yield or recovery was 6.53 tons. The head grain percentage was 61.94 percent and the discolored kernel percentage was 1.52. The total energy used was 498.21 kw-hrs. or 49.82 kw-hrs. per ton. The results of the simulation for a Type 1 mill were validated by comparing results with actual data collected in the field. Table 5.3 shows the milling recovery of small disc-cone mills by region in the Philippines (Basilio, et al., 1973). The probability distribution of moisture content, purity and drying delay variables used in the simulation were typical of the Bicol region. Table 5.3 lists the milling recovery from the Bicol region as 64.46 percent. The simulation milling recovery was 65.3 percent based on 6.53 tons milled rice from a paddy input of 10 tons. There were no extensive surveys on head grain percentage. Table 5.5 from Khan, et al. (1973) shows head grain percentage as affected by harvest date, drying method and variety. The mean head grain percentage was 62.46 percent from the field data. The simulation result showed a head grain percentage of 61.94. For comparison of the discolored kernel percentage of the simulation, 64 samples from the work of Camacho, et al. (1978) were analyzed. Camacho's discolored kernel percentage was 1.92 percent with a standard deviation of 2.6. The simulation showed a mean of 1.52 percent. For energy use comparison, Table 5.4 from Duff, et al. (1972) presents engine sizes and capacities of different mills. Duff's calculated energy used for a 0.366 ton-per-hour mill for an input of 10 tons and 30.3 hrs. of operation was 537.54 kw-hrs. The simulation had a value of 498.21 kw-hrs. The simulation value was lower because it measured a continuous operation while actual data included the additional energy required for starting and clogging conditions.

Table 5.6 presents the results of a simulation for which the fixed paddy separator was replaced with an adjustable type. Simulation energy consumption dropped to 455.48 kw-hrs. for ten tons. This is a reduction of 42.81 kw-hrs. for ten tons which, when projected, amounts to yearly savings of P 1,153.18[1/] or roughly the cost of 1 ton of milled rice. Table 5.7 presents simulation for a dry growing season and a mechanical dryer. The head grain increased by 17.5 percent over that for a wet season shown on Table 5.6. This improvement was expected since there was generally a lower relative humidity and no precipitation during the dry season. Dry season conditions reduced the likelihood of grain moisture reabsorption during the harvesting period. Also the use of a mechanical dryer with controlled drying temperature assured lower grain breakage. Table 5.8 shows the simulation results for a rubber-roll huller instead of a disc huller. The head grain increased by 4.75 percent and the energy consumption decreased by 2.86 kw-hrs. compared to the disc-huller equipped mill. Head grain in rubber-roll milled rice was an average of 7.68 percent higher than for milled rice processed by disc hullers. Lower rubber-roll huller energy consumption may be attributed to the higher hulling efficiency[2/] of 82.7 percent as compared to 56.5 percent for the disc huller.

Appendix Table I5 presents the simulation results of two whiteners in series for the 0.33 ton-per-hour rice mill (type 1). There was an increase of 0.15 percent in head rice reovery and 2.93 percent in total recovery with a corresponding 12.22 kw-hr. increase in energy consumption over the use of one whitener. Appendix Table I6 presents

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[1/]Based on 64 percent utilization of 288 hrs. per month and computed as: 4.27 kw-hrs. X 0.33 tons/hr. X 0.64 (utiliz. rate) X 12 mos/yr X $0.05 kw-hr = $155.84 or P1,153.18.

[2/]This term was defined in Section 2.1.

the results after replacing the fixed-stroke paddy separator with an adjustable-stroke paddy separator. The energy consumption dropped 42.47 kw-hr. Appendix Table I5 presents the simulation results of two whiteners in series for the 0.33 ton-per-hour rice mill (type 1). There was an increase of 0.15 percent in head rice recovery and 2.93 percent in total recovery with a corresponding 12.22 kw-hr. increase in energy consumption over the use of one whitener. Appendix Table I6 presents the results after replacing the fixed-stroke paddy separator with an adjustable-stroke paddy separator. The energy consumption dropped 42.47 kw-hr. Appendix Table I7 presents the simulation results for rice mill type 2 rated at 0.44 tons per hour. Table I8 indicates a reduction of 35.51 kw-hr. for the adjustable paddy separator. Table I10 shows a reduction of 39.2 kw-hr. when the separator was replaced with an adjustable paddy separator for a 0.55 ton-per-hour mill (Type 2A). Table I11 shows an increase in total and head rice recoveries of 2.34 and 4.95 percent respectively for the rubber-roll huller over the disc huller. Table I12 presents the results of the simulation of a type 3 rice mill which has a capacity of 0.66 tons per hour. Table I13 shows the results from the same mill with an adjustable separator and Table I14 gives the results from that same mill equipped with two whiteners in series. Table 5.12

Table 5.12 Summary of results of simulations.

Rice Mill Type Number		Unmodified			Equipped with Adj. Separator			Equipped with Two Series Whiteners			Equipped with Two Series Whiteners and Adj. Separator			Equipped with Two Series Whiteners, Adj. Separator and RR Huller		
Bernabe	Felson	Recov. %	Head Rice %	Energy Kw-hr.	Recov. %	Head Rice %	Energy Kw-hr.	Recov. %	Head Rice %	Energy Kw-hr.	Recov. %	Head Rice %	Energy Kw-hr.	Recov. %	Head Rice %	Energy Kw-hr.
1	1	67.64	61.94	498.21	67.61	62.02	455.48	70.57	62.09	510.43	70.56	62.19	467.96			
2	2	67.49	61.98	410.68	67.62	62.01	375.17	70.61	61.84	426.71	70.35	62.05	387.49	72.68	67.00	389.26
2A	2F	70.61	61.84	426.71	70.35	62.05	387.49	70.61	61.84	426.71	70.35	62.05	387.49	72.68	67.00	389.26
3	3	67.65	62.18	327.30	67.59	61.89	292.60	70.53	62.34	347.90	70.50	62.4	315.38	72.59	66.65	314.26
3A	3F	70.53	62.34	347.90	67.59	61.89	292.60	70.53	62.34	347.90	70.50	62.40	315.38	72.58	66.65	314.26
4	4	67.55	61.88	251.29	67.67	61.86	223.28	70.40	61.78	301.14	70.42	62.0	272.40	72.70	66.95	271.60
4AB	4FA	70.52	62.19	447.73	70.45	61.94	418.09	70.52	62.19	447.73	70.45	61.94	418.04	72.69	66.95	271.60
5AB	5FA	70.54	61.87	328.76	70.49	61.86	306.43				70.49	61.86	306.43	72.94	67.17	267.51
6AB	6FA	70.40	61.93	321.52							70.62	61.64	279.83	72.61	67.17	278.50
7AB	7FA	70.52	62.24	279.84							70.51	61.96	263.20	72.64	66.85	262.50
8AB	8FA	70.62	61.90	280.10							70.44	66.57	266.16			

summarizes the results of simulation from Appendix Tables I5 to I40. Table 5.10 shows the results for the 1.83 ton-per-hour mill after substituting a rubber-roll huller and a cylinder whitener for the disc huller and cone whitener, respectively. The energy consumption was reduced by 1.6 kw-hrs. and the head grain went up by 4.87 percent compared to the disc-cone combination. Table 5.11 presents simulation results when double hullers were replaced by a single huller. The energy consumption was 218.85 kw-hrs. higher than for a 1.83 ton-per-hour mill with double hullers. This result indicates that there was a limit on increasing the size of the huller. This finding was utilized in the determination of the proposed mills presented in Figure 5.1. The simulation runs of mill sizes from 0.367 to 1.1 tons per hour indicated that the energy consumption was lowest with a single huller. For the larger mills from 1.54 to 1.83 tons-per-hour capacity, the energy consumption was lowest with double hullers. Other simulation results are shown in Tables I5 to I42 in Appendix I.

Figure 5.1 shows the simulation of the different mills including eight mills proposed by the author. The solid circles indicate the energy consumption of the different mill types studied (Table 5.1). The most popular mill in the Philippines had a 0.916 ton-per-hour capacity

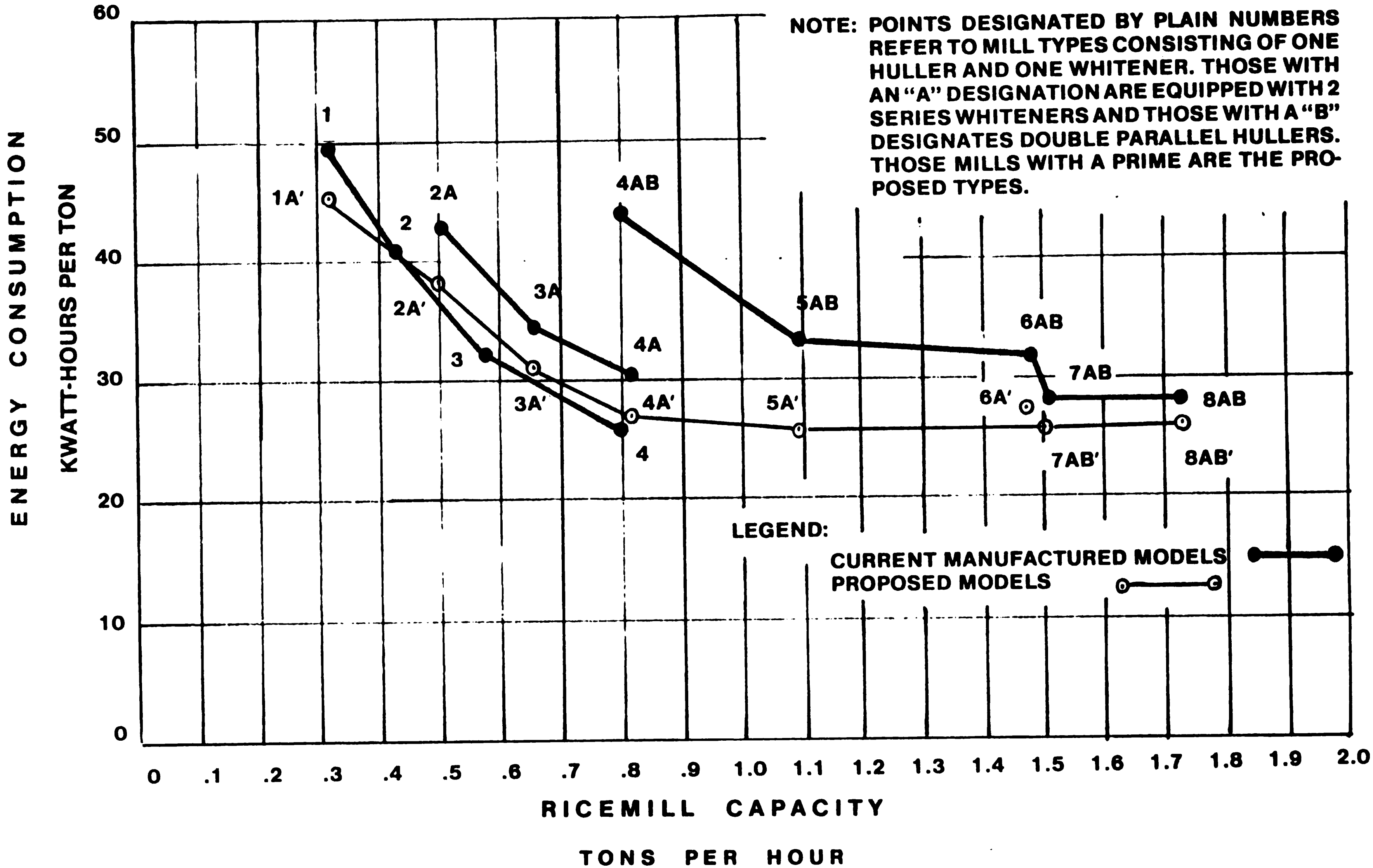

FIGURE 5.1 DIFFERENT SIMULATION OF CAPACITY VS ENERGY CONSUMPTION FOR COMMERCIAL AND PROPOSED MILLS

(Type 4), and was available in three versions with a wide variation of energy consumption, from 25.1 to 44.7 kw-hrs. per ton. The basic type with a single huller and a single whitener (type 4) had the lowest energy consumption. However, the rice quality performance was the poorest, as shown in Table I17 in Appendix I. Both total recovery and head rice percentage suffered. This was confirmed by both the simulation and previous experimental results of Manalabe, et al. (1978). In terms of output rice quality, there was really no difference between the version with double hullers (type 4A) and the version with double hullers and whiteners (type 4AB). But in terms of energy consumption, there was a difference of 14.7 kw-hrs. per ton between the two mill types. The apparent advantage of the double-huller equipped mill (type 4A) was the extra huller which would allow the mill to continue operation in case one huller broke down. With the rising cost of energy in the Philippines, which is dependent on foreign sources for 90 percent of its needs, a trade-off of this magnitude (8% difference) is worth considering. Higher capacity (types 7AB and 8AB) gave the lowest energy consumption among the different types.

To determine which combination and number of components are most desirable, various modifications of existing mill types were considered. One modification that lowered energy consumption was the replacement of the fixed-stroke separator with an adjustable type. Another modification was replacement of double hullers with a single large huller. The single huller reduced energy requirements up to a capacity of 1.1 tons per hour. These two modifications simulated reductions in energy consumption of 6 percent for the 0.367 ton-per-hour mill (type 1); 9 percent for the 0.550 and 0.696 ton-per-hour mills (type 2A and 3A); 10 percent for the 0.916 ton-per-hour mill (type 4A); 19 percent for the 1.1 ton-per-hour mill (type 5AB); and 13 percent for the 1.36 ton-per-hour mill (type 6AB). For larger mills with capacities of from 1.54 to 1.83 tons per hour, the only modification possible was replacement of the fixed-stroke separator with an adjustable stroke. This modification reduced the energy consumption of the larger 1.54 and 1.83 tons-per-hour mills by 6 percent (type 7AB) and 5 percent (type 8AB).

Validation of the model was conducted next. The capacity and energy consumption were compared with currently manufactured mills in Figure 5.2. The energy required to run the power sources for these mills were then computed by:

$$\text{Energy(kw-hr./ton)} = \frac{\text{Required horsepower X 0.746 kw/hp}}{\text{Efficiency}^{1/} \text{ X power factor}^{2/} \text{ X mill capacity (ton/hr)}}$$

The computed values obtained from the above formula were

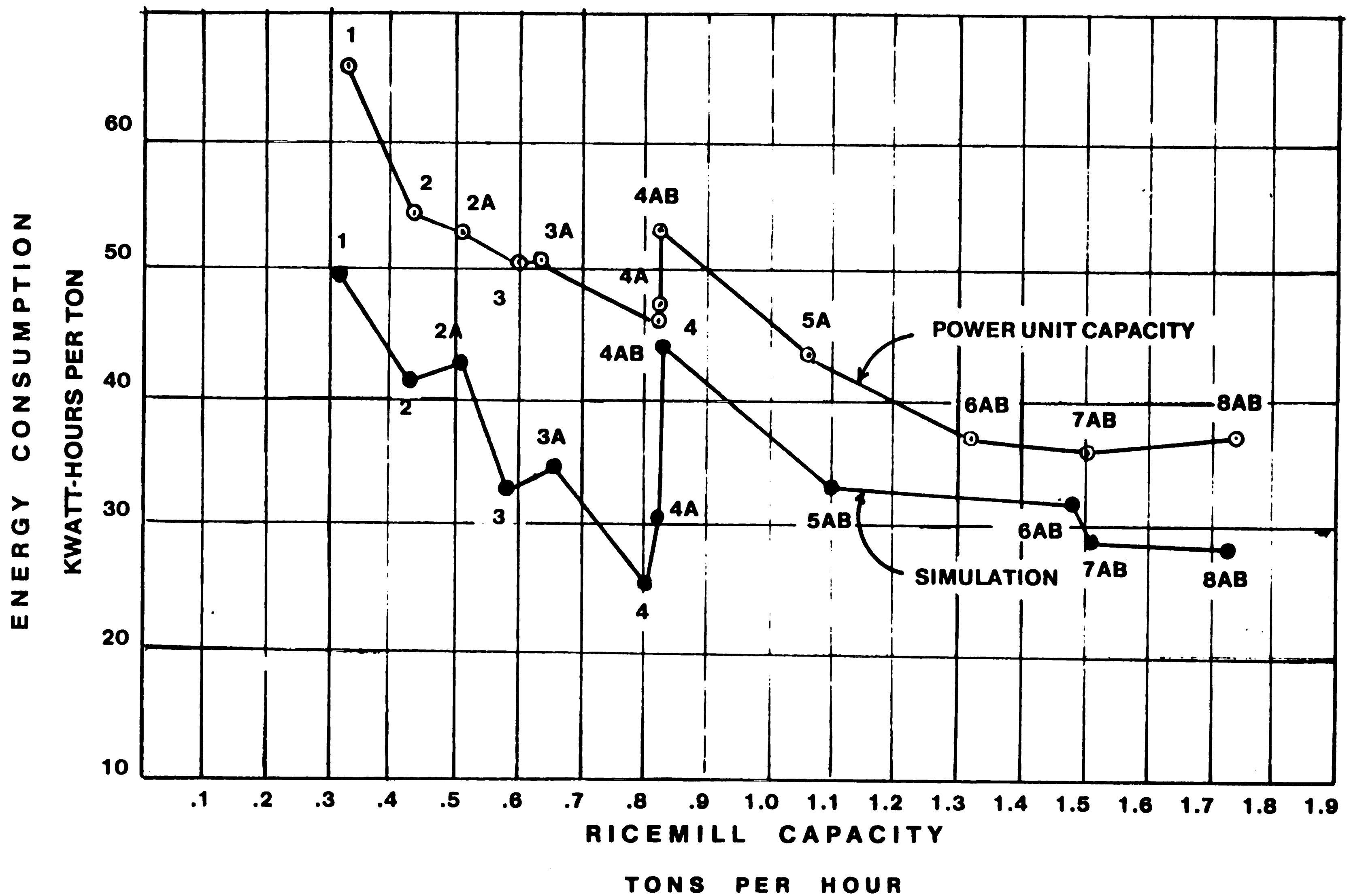

FIGURE 5.2 COMPARISON OF POWER UNIT CAPACITY AND THE SIMULATED VALUES

also plotted in Figure 5.2. There was a varying difference of about 10 kw between the computed and the simulated data. However, the values for the computed and simulated data were in general parallel. The difference may be attributed to the margin of safety provided by the manufacturer for recommended sizes of prime movers. The simulation data were based on continuous operation of the electric motors which would be somewhat lower than the required power unit ratings. Actual power unit ratings should be higher to easily handle the higher starting torque and clogging conditions for interrupted actual operations.

5.2 Linear Network Economic Model

An economic model was applied to six rice milling systems, i.e., three conventional mills with 1/3, 1/2 and 1 ton-per-hour capacity and with three rubber-roll equipped mills with the same capacities. Economic data were available for these mill sizes which represent a common classification of small, medium and large mills in the field. The mills simulated by the rice mill performance model included all mills in production to evaluate undesirable as well as good features. The economic

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1/Efficiency of the electric motor in converting electric energy into mechanical energy.

2/Power factor of the electric motor is the cosine function of the phase angle or the ratio of resistance to impedance.

simulation results are shown in Table 5.13. Tables G1 to G3 in Appendix G present the data used in the analysis. Simulations were made at 50 and 100 percent utilization rate[1/] for comparison purposes.

The simulation results showed the rubber roll milling cost to be higher by 2 to 3 centavos per kilogram (0.025%) based on an asumption that the milling recoveries were equal. Tests[2/] of commercial mills under field conditions showed that the milling recoveries from conventional mills and rubber-roll mills were not significantly different. On the other hand, when mills were carefully serviced, adjusted and operated under the close supervision of well trained technicians, the recovery by rubber-roll mills was observed to be higher by 2 to 3 percent over that of conventional mills.[3/] To determine the effect of this difference on milling costs, a sensitivity test was conducted. The linear network economic model was used to simulate the milling cost with a 2 to 3 percent rubber roll higher recovery at each 100 and 50 percent level of utilization. The simulation results (Table 5.14) under controlled conditions and a 2 to 3%

[1/]Full capacity or 100 percent utilization is 12 hours per day for 24 days a month or 288 hours per month.

[2/]See Andales, et al. (1978).

[3/]See Manalabe, et al. (1978).

Table 5.13 Results of economic modeling of six different mills. (Rubber roll mill recovery is assumed 3 percent greater than conventional mills.)

Type of Mill	Capacity tons/hr.	Fixed Cost	Energy Cost	Rice & Energy	Maint. & Labor	Total Cost[1]	Diff. in Cost
100 percent utilization[2]		Peso per kilogram					
Conventional	0.33	0.031	0.037	1.155	0.0143	1.201	+ 0.003
Rubber roll		0.031	0.039	1.145	0.0212	1.197	
Conventional	0.50	0.028	0.037	1.155	0.0174	1.201	- 0.003
Rubber roll		0.033	0.038	1.145	0.0264	1.205	
Conventional	1.00	0.026	0.037	1.155	0.0133	1.195	+ 0.012
Rubber roll		0.022	0.039	1.145	0.0158	1.183	
50 percent utilization							
Conventional	0.33	0.045	0.037	1.155	0.014	1.214	- 0.014
Rubber roll		0.062	0.039	1.145	0.021	1.228	
Conventional	0.50	0.068	0.037	1.155	0.017	1.239	+ 0.002
Rubber roll		0.066	0.039	1.145	0.026	1.238	
Conventional	1.00	0.047	0.037	1.155	0.013	1.215	+ 0.010
Rubber roll		0.044	0.039	1.145	0.016	1.204	

1/ By-products cost credited.

2/ 288 hours per month is considered as 100 percent utilization.

Table 5.14 Results of economic modeling when milling recovery of rubber roll and conventional mill are equal. (Assuming paddy costs ₱1.00/kg.)

Type of Mill	Capacity tons/hr.	Fixed Cost	Energy Cost	Rice & Energy	Maint. & Labor	Total Cost[1]	Diff. in Cost
100 percent utilization[2]		P e s o	p e r	k i l o	g r a m		
Conventional	0.33	0.031	0.024	1.142	0.014	1.188	- 0.020
Rubber roll		0.031	0.039	1.156	0.021	1.208	
Conventional	0.50	0.028	0.024	1.142	0.017	1.187	- 0.028
Rubber roll		0.033	0.039	1.155	0.026	1.215	
Conventional	1.00	0.026	0.024	1.142	0.013	1.182	- 0.011
Rubber roll		0.022	0.039	1.155	0.016	1.193	
50 percent utilization							
Conventional	0.33	0.045	0.024	1.142	0.014	1.201	- 0.038
Rubber roll		0.062	0.039	1.156	0.021	1.239	
Conventional	0.50	0.067	0.024	1.142	0.017	1.226	- 0.022
Rubber roll		0.066	0.038	1.155	0.027	1.248	
Conventional	1.00	0.047	0.023	1.142	0.013	1.202	- 0.013
Rubber roll		0.044	0.038	1.155	0.016	1.215	

1/ By-products cost credited.

2/ 288 hours per month is considered as 100 percent utilization.

higher recovery showed that rubber-roll mills produced rice at a higher cost of about 0.3 to 1.4 centavos. The differences were greater for the 50 percent utilization level. Since the result in Table 5.13 simulates commercial milling conditions, the higher charge by rubber-roll mill operators seems justifiable.[1/] In actual practice, rubber-roll mill operators charged 2.22 centavos per kilogram (0.02%) higher than other mill types. The differential cost was at the mill level and not at the consumer rice market level. Market prices do not distinguish between rubber-roll and conventional milled rice but may vary due to variety and/or storage duration.

A sensitivity test was made on the effect of rubber-roll costs on the maintenance and total costs of milling (Table 5.15). Prices of locally produced rubber rolls in 1978 and imported rolls in 1976 were used (see Appendix Q). The government stopped the importation of rubber rolls when locally made rolls became available. The 1978 price increase of 10 to 85 percent over 1976 prices increased the total cost of milling per kilogram of milled rice by 1.0 to 2.0 centavos (0.02%).

The change of status of the Philippines from a rice-importing to a rice-exporting nation in 1979 made it

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[1/] See Table P5 in Appendix P, which was adopted from Camacho, et al., 1978.

Table 5.15 Results of economic modeling with increased rubber roll prices. (Rubber roll and conventional mill are equal.)

Type of Mill	Capacity tons/hr.	Fixed Cost	Energy Cost	Rice & Energy	Maint. & Labor	Total Cost[1]	Diff. in Cost
100 percent utilization[2]		Peso per kilogram					
Conventional	0.33	0.031	0.024	1.142	0.014	1.188	- 0.022
Rubber roll		0.031	0.039	1.156	0.023	1.210	
Conventional	0.50	0.028	0.024	1.142	0.017	1.187	- 0.030
Rubber roll		0.033	0.039	1.155	0.029	1.218	
Conventional	1.00	0.027	0.024	1.142	0.013	1.182	- 0.006
Rubber roll		0.022	0.039	1.155	0.011	1.188	
50 percent utilization							
Conventional	0.33	0.045	0.024	1.142	0.014	1.201	- 0.040
Rubber roll		0.062	0.039	1.156	0.023	1.241	
Conventional	0.50	0.067	0.024	1.142	0.017	1.226	- 0.025
Rubber roll		0.066	0.039	1.155	0.029	1.251	
Conventional	1.00	0.047	0.024	1.142	0.013	1.202	- 0.008
Rubber roll		0.044	0.039	1.155	0.011	1.210	

1/ By-products cost credited.

2/ 288 hours per month is considered as 100 percent utilization.

necessary to price rice with respect to its grade classification to cover the extra cost of improved processing and to stimulate quality control.

The paddy and rice grade classifications in the Philippines are shown in Appendix N. There were five grades with ten criteria required for paddy. For milled rice, there were four grades with nine criteria. The higher the grade classification of paddy, the lesser was the undesirable component and impurity content. It therefore follows that the milling yield was higher from the higher grades. A lower milling yield reduces the output and increases the total unit cost of the milled rice with rubber-roll mills (Tables 5.13 and 5.14). The milling cost of the roll was lower than for conventional mills when there was a 3 percent higher milling recovery of the rubber-roll mill. At 100 percent utilization, the rubber-roll-milled rice cost more by 1.1 to 2.8 centavos as compared to the conventional milled rice.

Another undesirable aspect of milling low-grade paddy is the additional sorting processes required to bring it up to a higher grade of milled rice. These processes may involve the use of indented graders (trieurs) and color sorters to eliminate broken and discolored kernels. This means additional cost to the miller in terms of time, energy and equipment.

A prorated price schedule was recommended to encourage improved quality of paddy and milled rice. The prorated price schedule discounted the selling price of rough rice in accordance with its grade. Full price was paid for the highest grade rice while a corresponding gradually increasing discount schedule was applied to the lower grades. This provided an incentive to invest in the extra cost of processing poor-quality paddy and helped ease the problems encountered in marketing surplus rice in other countries.

Chapter Five analyzed the effect of milling recovery on the cost of milling rice by using rubber-roll and conventional mills under simulated and field conditions. The finding was that under ideal conditions the rubber roll has a lower milling cost. However, under actual conditions, the conventional mill has a lower cost. Sensitivity tests on the increased cost of rubber rolls with frequent replacement were also conducted. An increase in the price of rubber rolls from 10 to 85 percent over a 2-year period (1976-78) increased the processing cost by 1 to 2 centavos per kilogram. Another sensitivity test was made on the time utilization rate for mills. A 50% as compared to 100% utilization rate caused the cost of rubber-roll milling to increase from 0.8 to 4 centavos per kilogram over conventional millling.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

The two models developed in this research can be of considerable use to rice mill designers and government policy planners. The models make it possible for the first time to simulate the operation of mills with different capacities and combinations of components without the expensive monitoring of mills in the field. Further, the model will simulate mill sizes not available in the field. The model can simulate various proposed levels of performance and different mill sizes to provide valuable data for policy makers. Mill designers can manipulate the model with different combinations of equipment to predict the most desirable characteristics, without the expense of actually building prototypes.

The specific accomplishments of this research were:

1. The Rice Mill Performance Model was developed to simulate the operation of selected milling technologies. It will predict the milling time, rice output, percent recovery, head grain percentage, discolored kernel percentage and energy consumption. The assumptions used in the model were as follows:

a) Drying delay was defined as the number of days from harvesting to start of drying of paddy.

b) The drying delay was the same for sun-dried and mechanically-dried paddy.

c) Variation of hardness of grains due to varietal differences was not considered.

d) The effect of variation of relative humidity was not included because relative humidity varied only seasonally.

2. The Linear Network Economic Model of rice milling systems was developed for predicting milling costs over a range of capacities for a selected set of rice-milling technologies. Limitations of the final form of this model were as follows:

a) The polisher or refiner by-product which is produced in small amounts with a value of ₱0.65 per kilogram was excluded due to lack of data.

b) The model is applicable to modified mills of from 0.367 to 1.36 tons per hour capacity.

3. Simulation runs were conducted to demonstrate the use of the models in decision- and policy-making processes and also to demonstrate their validity as far as comparisons of technologies and sizes are concerned.

a) Rice Mill Performance Model Simulation Results:

1) The energy consumption of Philippine-manufactured rice mills can be reduced from 4.9 to 8.6 percent by incorporation of adjustable-stroke paddy separators. The initial higher cost of these units would therefore be offset by the energy savings.

2) The energy consumption of medium-size rice mills (1.1 to 1.4 tons per hour) can be reduced by 10.0 to 13.0 percent by replacing the double hullers with a single huller of twice the capacity.

3) The milling recovery and head grain percentage of the smaller size mills (0.367 to 0.916 tons per hour) can be increased by 0.5 and 1.6 percent respectively, by inclusion of two or even three whiteners in series with an increase of about 4.0 percent in energy consumption.

4) The per-ton energy consumption for modified mills (0.7 to 1.8 tons per hour) is not changed appreciably (26.6 to 27.2 kw-hr. per ton).

b) Linear Network Economic Model

1) The rice processed by rubber-roll mills costs more than rice processed by conventional mills under commercial milling conditions by 2 to 3 (1.7 to 2.3 percent) centavos per kilogram.

2) The lowest simulated milling cost was attained at 100 percent level of utilization for the 1.0 ton-per-hour mill.

3) The maintenance cost of the 0.3 and 0.5 ton-per-hour rubber-roll mills was double that for conventional mills.

4) The maintenance cost of 1.0 ton-per-hour rubber-roll mills compares favorably (0.3 centavo difference per kilogram) with conventional mills of the same size.

5) The fixed and energy costs for both conventional and rubber-roll mills were approximately the same (0.4 centavo difference per kilogram).

The recommendations from this research are:

1. Additional field research should be conducted as follows:

a) Duration of drying delays and losses experienced in the field and at what moisture content do these occur.

b) Actual harvesting dates practiced by farmers based on days after initial heading and moisture content.

c) Effect of relative humidity levels on rice head yield of Philippine varieties.

2. Update the Rice Mill Performance Model with current information.

3. The hardness of different varieties grown in the Philippines should be studied.

4. Conduct a study with the National Grains Authority in identifying solutions to current problems in the export of excess rice and their relationship to the improvement of rice-processing facilities. A possible approach is to identify areas where there is an excess of rice for local consumption. Improvement in the rice quality could then be implemented in these areas through the use of rice dryers and improved rice mills.

5. Coordinate with the Rice Mill Manufacturers Association through the NGA on the implementation of the results of this research in the manufacture of future energy-efficient rice mills.

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APPENDICES

APPENDIX A

ENERGY CONSUMPTION MEASUREMENT RESULTS

APPENDIX A

Appendix Table A1 presents the results of energy consumption measurement on three electrically driven rice mills in the Philippines. The second column gives the rated horsepower of the electric motor drive. The next three columns give the efficiency, power factor and amperage as measured. The sixth column gives the output horsepower as measured and computed. The measured voltage was 220 volts througout the test. All the values indicated were averages of three readings.

Table A2 presents the power requirement of adjustable and non-adjustable separators as computed from the formula given by Van Ruiten (1974).

Table A3 gives the power requirement of Japanese rice mill components as published by Satake Engineering Co. Ltd. of Tokyo, Japan.

TABLE XI. ENERGY CONSUMPTION MEASUREMENTS OF THREE PHILIPPINE MILLS

TABLE A1. ENERGY CONSUMPTION MEASUREMENTS OF THREE PHILIPPINE MILLS

	RICE MILL CAPACITIES														
Machine	TOBACCO INDUSTRIES, PHIL. 2.5 tons per hour[1/]					MINPROCOR, Q.C. 6.5 tons per hour					UPLB GRAIN PROC. LAB 1 ton per hour				
	Rated H.P.	Eff.	P.F.	I[2/] Amps.	H.P.	Rated H.P.	Eff.	P.F.	I Amps.	H.P.	Rated H.P.	Eff.	P.F.	I Amps.	H.P.
Precleaner	1.5	0.78	0.82	4.0	1.30	-	0.78	0.82	9.0	2.96	1.5	0.75	0.80	2	0.61
Huller 1	7.5	0.84	0.88	7.3	2.80	-	-	-	-	-	3.5	0.82	0.78	6.2	2.04
Huller 2 Return	7.5	0.84	0.88	7.11	2.72	-	-	-	-	-	-	-	-	-	-
Huller 3	7.5	0.84	0.88	8.4	3.22	3.3	0.81	0.85	6.1	2.14	-	-	-	-	-
Aspirator	5.0	0.83	0.87	7.0	2.60	-	-	-	-	-	2.0	0.79	0.81	2.3	0.75
Dust Blower	4.0	0.84	0.88	5.9	2.25	1.1	0.80	0.76	2.2	0.68	-	-	-	-	-
Separator[3/]	7.5	0.84	0.88	17.0	6.5[4/]	4.0	0.82	0.81	6.5	2.2[5/]	3.0	0.84	0.85	4.0	1.46[4/]
Whitener 1	10.0	0.85	0.89	14.9	5.80	24.2	0.88	0.82	38.0	14.0	6.0	0.84	0.81	11.0	3.82
Whitener 2	10.0	0.85	0.89	18.3	7.12	24.2	0.88	0.82	38.0	14.0	6.0	0.84	0.81	10.8	3.75
Whitener 3	10.0	0.85	0.89	14.5	5.66	24.2	0.88	0.82	38.0	14.0	6.0	0.84	0.81	11.0	3.82
Intake Elevator 1	10.0	0.85	0.89	9.3	3.63	3.4	0.81	0.82	-	-		-	-	-	-
Elevator 2 Rice	10.0	0.85	0.89	9.2	3.60	2.3	0.80	0.81	3.67	1.2	-	-	-	-	-
Elevator 3	10.0	0.85	0.89	12.7	4.90	2.3	0.80	0.81	5.33	1.0	-	-	-	-	-
Rice Sieve	1.5	0.78	0.82	4.0	1.3	4.0	0.82	0.81	7.5	2.5	1.0	0.76	0.70	1.71	0.46
Paddy Sieve	1.5	0.78	0.82	4.0	1.3	-	-	-	-	-	-	-	-	-	-

1/ This mill has a duplex construction with a total capacity of 5 tons per hour.

2/ All voltages are 220 volts. Measurements are average of three readings

3/ Additional data was obtained using Reference No. 19 formulas for computation (see Table A2).

4/ Non-adjustable separator.

5/ Two adjustable separators are used in this mill.

TABLE A2. COMPUTED[1/] ENERGY REQUIREMENT OF SEPARATORS

CAPACITY	POWER REQUIREMENT, H.P.	
Tons per hour	Adjustable	Non-adjustable
1	1.0	1.5
2	2.0	3.0
3	3.0	4.5
4	4.0	6.0

[1/] Formulas in Reference No. 23 were used and results checked by actual measurement in Table A1.

TABLE A3. ENERGY CONSUMPTION OF JAPANESE RICE MILLS[2/]

CAPACITY	M A C H I N E			
Tons per hour	Precleaner	Huller	Abrasive Whitener	Friction Whitener
	Horsepower			
0.9	0.54	2.0	-	-
1.0	-	-	1.3	1.3
1.2	2.01	-	-	-
1.75	-	5.0	-	-
2.0	-	-	1.73	1.73
2.75	-	10.0	-	-
3.5	-	14.75	-	-
4.0	4.02	-	-	-
5.0	-	-	3.5	2.5
7.5	3.02	-	-	-
15.0	7.51	-	-	-

[2/] Satake Rice Processing Machinery, Satake Engineering Co. Ltd., Tokyo, Japan

TABLE A4. DATA ON MACHINE CAPACITIES[1/]

MACHINE	CAPACITY	PROCESSING TIME		
	Tons per hour	Long	Medium	Short
Precleaner	0.257	3.89	3.40	3.03
	0.293	3.41	3.03	2.72
	0.403	2.48	2.27	2.10
	0.623	1.61	1.52	1.43
	1.027	0.97	0.94	0.91
Disc Huller	0.330	3.89	3.40	3.03
	0.367	3.41	3.03	2.72
	0.477	2.48	2.27	2.10
	0.697	1.61	1.52	1.43
	1.100	0.97	0.94	0.91
Rubber Roll Huller	0.850	1.00	1.18	1.43
	1.75	0.80	0.67	0.50
	2.75	0.40	0.36	0.33
	3.50	0.33	0.29	0.25
Paddy Separator	0.352	3.25	3.03	2.84
	0.528	2.16	2.02	1.89
	0.704	1.62	1.52	1.42
	0.880	1.30	1.21	1.14
	1.056	1.08	1.01	0.95
	1.408	0.81	0.76	0.71
	1.525	0.75	0.70	0.66
	1.760	0.65	0.61	0.57
	2.112	0.54	0.51	0.47
	2.346	0.49	0.45	0.43
Whitener	0.278	4.31	3.92	3.60
	0.292	3.98	3.68	3.42
	0.362	3.27	2.99	2.76
	0.501	2.39	2.17	2.00
	0.697	1.80	1.59	1.43
	0.766	1.43	1.37	1.31

[1/] Jose Bernabe & Co., Inc., 1535 J. Luna St., Manila, Philippines

TABLE A5. MATERIAL REDUCTION FOR DIFFERENT MACHINES [1/]

MACHINE	MATERIAL REDUCTION VARIABLE BY GRAIN TYPE		
	Long	Medium	Short
Rubber Roll Huller	0.74	0.78	0.82
Disc Huller	0.72	0.76	0.80
Whitener			
1-pass	0.922	0.922	0.922
2-pass	0.961	0.961	0.961
3-pass	0.974	0.974	0.974
Separator			
Disc Huller	0.61	0.61	0.61
RR Huller	0.88	0.88	0.88

1/ See Reference No. 1

APPENDIX B

RICE MILL PERFORMANCE
SIMULATION MODEL PROGRAM

APPENDIX B

RICE MILL PERFORMANCE SIMULATION MODEL PROGRAM

This program simulates the performance of a conventional disc-cone type rice mill. The program user could select the mass of input paddy, type (within a prescribe type group), sizes and number of component machinery to be used in the simulation. He could also select the crop season, drying method, grain type and shape. Other variables like drying delay, purity and moisture content of paddy are based on probability distribution functions. The output of the program includes milling time, mass of rice output, milling recovery, head rice percentage, discolored grain percentage and energy used.

APPENDIX B

RICEMILL PERFORMANCE SIMULATION MODEL PROGRAM

```
  Ø RANDOM
  5 REM * PROGRAM RICE MILL *
 1Ø REM * EP = ELEVATOR ENERGY REQUIREMENT, KWATT-HRS *
 15 REM * PCCAP = PADDY CLEANER CAPACITY, TONS/HR *
 2Ø REM * HBIN = HULLER BIN STORAGE CAPACITY, TONS *
 25 REM * WBIN = WHITENER BIN STORAGE CAPACITY, TONS *
 3Ø REM * PHCAP = PADDY HULLER CAPACITY, TONS/HR *
 35 REM * RCAP = RICEMILL CAPACITY, TONS/HR *
 4Ø REM * CPN = NO. OF PADDY CLEANER IN PARALLEL *
 45 REM * HNP = NO. OF PADDY HULLER IN PARALLEL *
 5Ø REM * SCAP = CAPACITY OF PADDY SEPARATOR *
 55 REM * ST = SEPARATOR TYPE: FIXED, VARIABLE STROKE *
 6Ø REM * HT = HULLER TYPE: DISC, RUBBER ROLL *
 65 REM * WT = WHITENER TYPE: CONE, CYLINDER *
 7Ø REM * WCAP = WHITENER CAPACITY, TONS/HR *
 75 REM * MC = MOISTURE CONTENT AT MILLING, PERCENT WET BASIS *
 8Ø REM * DD = DRYING DELAY, DAYS *
 85 REM * DM = DRYING METHOD: SOLAR, MECHANICAL *
 9Ø REM * DAH = DAYS AFTER HEADING *
 95 REM * SR = SHAPE RATIO, LENGTH/WIDTH *
1ØØ REM * GT = GRAIN TYPE: SHORT, MEDIUM, LONG *
1Ø5 REM * SEAS = PLANTING SEASON: WET, DRY *
11Ø REM * TRLGTH = TOTAL RUNLENGTH , HR. *
115 REM * TENRGY = TOTAL ENERGY, KWATT-HR. *
12Ø REM * CRLGTH = PRECLEANER RUN TIME, HR. *
125 REM * HDELAY = HULLER TANK FILLING TIME DELAY *
13Ø REM * COT = PRECLEANER OUTPUT, TONS/HR. *
135 REM * HP = POWER REQUIREMENT, HORSEPOWER *
14Ø REM * CENRGY = PRECLEANER ENERGY CONSUMPTION, KWATT-HR. *
145 REM * HTIME = HULLER RUNTIME, HRS *
```

```
150 REM * VNW = REDUCTION VARIABLE FOR WHITENER *
155 REM * THD = TOTAL MILLED RICE RECOVERY DUE TO HARVEST DELAY *
160 REM * HHD = HEADRICE RECOVERY DUE TO HARVEST DELAY, PERCENT OF MAX *
165 REM * DG = HEADRICE RECOVERY DUE TO DRYING DELAY, PERCENT OF MAX *
170 REM * DCK = DISCOLORED KERNELS, PERCENT
174 DIM  RATE (6), FØ(21), GØ(21)
175 INPUT R
176 FOR Z = 1 to R
177 PCCAP = Ø.33: HBIN = Ø.244: WBIN = .35 : PBIN = .313
178 RCAP = Ø.33: CPN = 1: SCAP = Ø.495: NW = 2: WCAP = .255
179 HT$ = "DISC": WT$ = "CONE": DM$ = "SUN": PHCAP = .294
180 HNP = 1: GS = 3.Ø: IN = 1Ø: ST$ = "FIXED"
181 GT$ = "MEDIUM": SEAS$ = "WET": SFBIN = Ø.27
190 RG = Ø
191 DAH = Ø: WØ = Ø: COT = Ø: WOT = Ø
195 TRLGTH = Ø
200 TENRGY = Ø
205             REM * PRECLEANING OPERATION *
206 WØ = Ø
207 IF CPN = Ø: GOTO 212
212 IF PCCAP = Ø: GOTO 217
215 CRLGTH = IN/PCCAP : GOTO 22Ø
217 CRLGTH = Ø
220 HDELAY = (HBIN/2)/PCCAP
227             REM * REDUCTION VARIABLE AT PRECLEANER *
229 FØ(1) = -4. : FØ(2) = -1.645 : FO(3) = -1.282 : FØ(4) = -1.036 :
    FØ(5) = -.842 : FØ(6) = -.674 : FØ(7) = -.524 : FØ(8) = -.385 :
    FØ(9) = -.253 : FØ(10) = -.126 : FØ(11) = Ø : FØ(12) = .126 :
    FØ(13) = .253 : FØ(14) = .385 : FØ(15) = .524 : FØ(16) = .674 :
    FØ(17) = .842 : FØ(18) = 1.Ø36 : FØ(19) = 1.282 : FØ(2Ø) = 1.645 :
    FØ(21) = 4
236 SMALL = Ø : DFI = Ø.Ø5
237 DFI = D1FI
240 K = 21
242 GOSUB 3ØØØØ
```

```
243 PDEV = XBAL : WØ = Ø.969 + Ø.Ø2 * PDEV
244 COT = WØ * IN
245                 REM * PRECLEANER ENERGY REQ *
246 EP = 3.63 * CRLGTH * Ø.746
247 TENRGY = Ø : RLGTH = Ø : WOT = Ø : DCK = Ø : TYLD = Ø :
    HEAD = Ø : TRLGTH = Ø
25Ø HP = Ø.Ø8 + Ø.47 * RCAP
255 W1 = HP * Ø.746
26Ø CENRGY = W1 * CRLGTH
261 TRLGTH = HDELAY + TRLGTH
265 TENRGY = TENRGY + CENRGY + EP
27Ø RATE(1) = IN/CRLGTH
271 IF GT$ = "SHORT" GOTO 331
272 IF GT$ = "MEDIUM" GOTO 315
275                 REM * HULLING OPERATION *
28Ø                 REM * DET HULLING TIME FOR LONG GRAIN BY CAPACITY *
29Ø HTIME = 5.89 * (2.72↑(-1.76 * PHCAP)
295 HRLGTH = HTIME * COT
3ØØ GOTO 345
3Ø5                 REM * DET  HULLING TIME FOR MEDIUM GRAIN *
315 HTIME = 5.Ø4 * (2.72↑(-1.64 * PHCAP)
32Ø HRLGTH = HTIME * COT
325 GOTO 345
33Ø                 REM * DET HULLING TIME FOR SHORT GRAIN *
331 PHCAP = RCAP/HNP
335 HTIME = 4.65 * (2.72↑(1.54 * PHCAP)
34Ø HRLGTH = HTIME * COT
345 HDT = Ø.77 * COT
35Ø                 REM * DET HULLING ENERGY REQUIREMENT *
355 IF HT$ = "RR" GOTO 365
36Ø HP = 2.7 * RCAP↑(0.46) : GOTO 37Ø
37Ø W7 = HP * Ø.746
375 HENRGY = W7 * HRLGTH
380 EP = 3.63 * HRLGTH * Ø.746
385 TENRGY = TENRGY + HENRGY + EP
```

```
39Ø RATE(2) = COT/HRLGTH
395                  REM * COARSE BRAN SIFTER *
4ØØ                  REM * DET PROCESSING TIME AND ENERGY *
4Ø5 BSDEL = (SFBIN/2)/PHCAP * HMP)
41Ø TRLGTH = TRLGTH + BSDEL
415 B2SLGTH = HRLGTH
419 HP = Ø.49 * PHCAP ↑ (Ø.93)
42Ø FSENRGY = B2SLGTH * HP * Ø.746
425 EP = 3.63 * B2SRLGTH * Ø.746
43Ø TENRGY + FSENRGY + EP + TENRGY
435                  REM * HUSK ASPIRATOR *
440                  REM * DETERMINE PROCESSING TIME AND ENERGY *
445 HADEL = (WBIN/2)/Ø.95 * PHCAP * HMP)
45Ø TRLGTH = TRLGTH + HADEL
455 HURLGTH = HRLGTH
459 HP = Ø.75 * RCAP ↑ (1.36)
46Ø HNUNRGY = HURLGTH * HP * Ø.746
465 EP = 3.63 * HURLGTH * Ø.746
47Ø TENRGY = HNUNRGY + EP + TENRGY
475                  REM * PADDY SEPARATION *
48Ø                  REM * PROCESSING TIME *
485 PSDEL = (PBIN/2)/(Ø.73 * PHCAP * HMP)
49Ø TRLGTH = TRLGTH + PSDEL
495 IF GT$ = "LONG" GOTO 51Ø
5ØØ IF GT$ = "MEDIUM" GOTO 515
5Ø5 SRLGTH = 2.84 * (2.72 ↑(-Ø.89 * SCAP))* HOT : GOTO 525
5Ø6 GOTO 525
51Ø SRLGTH = 3.24 * (2.72 ↑ (-Ø.89 * SCAP))* HOT : GOTO 525
511 GOTO 525
515 SRLGTH = 3.Ø4 * (2.72 ↑ (-Ø.89 * SCAP))* HOT
52Ø                  REM * DET SEPARATOR REDUCTION VARIABLE *
525 IF HT$ = "RR" GOTO 535
53Ø SOT = HOT * Ø.61 : GOTO 545
535 SOT = HOT * 0.82
54Ø                  REM * DET SEPARATOR ENERGY REQUIREMENT *
```

```
545 IF ST$ = "FIXED" GOTO 555
55Ø C1 = Ø.746 * (0.76 * RCAP  ( 1.19) : GOTO 56Ø
555 C1 = Ø.746 * (1.5 * RCAP  (1.07)
56Ø SENRGY = C1 * SRLGTH
565 EP = 4.9 * SRLGTH * Ø.746
57Ø TENRGY = TENRGY + SENRGY + EP
575 RATE(3) = HOT/SRLGTH
58Ø                  REM * WHITENING OPERATION *
585 WDEL = (WBIN/2)/SCAP
59Ø TRLGTH = TRLGTH + WDEL
595                  REM * WHITENING TIME *
6ØØ FOR A = 1 TO (NW-1)
6Ø5 WDEL = (WBIN/2)/WCAP * (Ø.Ø78) * (A/NW)
61Ø TRLGTH = TRLGTH + WDEL
615 NEXT A
62Ø FOR B = 1 TO NW
625 IF GT$ = "LONG" GOTO 64Ø
63Ø IF GT$ = "MEDIUM" GOTO 64Ø
635 C2 = 6.08 * (2.72↑(-2.Ø7 * Ø.77 * PHCAP)) : GOTO 645
64Ø C2 = 7.32 * (2.72↑(-2.11 * Ø.77 * PHCAP)) : GOTO 645
645 WRLGTH = HOT/C2
65Ø                  REM * DET REDUCTION VARIABLE FOR WHITENER *
655 VNW = (Ø.922)↑(1/NW)
67Ø IF WT$ = "CYL" GOTO 69Ø
675                  REM * DET, CONE WHITENER ENERGY REQ *
68Ø C5 = 3.61 * RCAP↑(Ø.71)
685 WENRGY = C5 * WRLGTH
69Ø EP = 4.9 * WRLGTH
695 TENRGY = TENRGY + WENRGY + EP
7ØØ NEXT B
7Ø5 GOTO 775
71Ø                  REM * DETERMINE ABRASIVE/FRICTION ENERGY REQ *
715 C6 = 1.21  * WCAP↑(Ø.62)
72Ø C7 = 1.3 * WCAP↑(Ø.41)
725 WENRGY = (C6 + C7) * WRLGTH
```

```
73Ø EP = 4.9 * WRLGTH
735 TENRGY = TENRGY + WENRGY + EP
74Ø FOR C = 1 TO NP
745 PDELAY = (PBIN/2)/PCAP)
75Ø TRLGTH = TRLGTH + PDELAY
755 NEXT C
76Ø                REM * GRADING OPERATION *
765                REM * DETERMINE REDUCTION VARIABLE DUE TO QUALITY *
77Ø                REM * MOISTURE CONTENT
775 GDELAY = 14.Ø/6Ø.Ø
78Ø TRLGTH = TRLGTH + GDELAY
781 MDEV = XBAL
782 MC = Ø.1157 + Ø.ØØ11 * MDEV
785 MM = (257.996) * (MC↑3)-(123.97) * (MC↑2) + (18.715072) * Ø.Ø9121
787                REM * MATURITY (DAYS AFTER HEADING) *
788 IF SEAS$ = "DRY" GOTO 9Ø4
79Ø DAH = 34 + 2 * PDEV
792 IF DAH > 44 GOTO 79Ø
794 IF DAH < 24 GOTO 79Ø
825                REM * MATURITY (DAYS AFTER HEADING) *
83Ø IF SEAS$ = "DRY" GOTO 9Ø6
835 IF DM $ = "SUN" GOTO 846
84Ø HHD = -Ø.68 + Ø.1012 * DAH -Ø.ØØ15 * (DAH↑2)
845 GOTO 87Ø
846 ZØ = DAH
847 GØ(1) = Ø.92 : GØ(2) = Ø.94 : GØ(3) = Ø.95 : GØ (4) = Ø.95
848 GØ(5) = Ø.94 : GØ(6) = Ø.925 : GØ (7) = Ø.89 : GØ(8) = Ø.85
851 SMALL = 28 : K = 8.Ø : DFI = 2.Ø
855 GOSUB 25ØØØ
86Ø HHD = XAL
865                REM * HEAD RICE DUE TO DRYING DELAY *
87Ø Q1 = 3 : S1 = 1Ø.49
872 GOSUB 4ØØØØ : DD = XCAL
873 IF DD  18 GOTO 872
876 ZØ = DD
```

```
378 GØ(1) = Ø.925 : GØ(2) = Ø865 : GØ(3) = Ø.83 : GØ(4) = Ø.8Ø
879 GØ(5) = Ø.798 : GØ(6) = Ø.795 : GØ(7) = Ø.795 : GØ(8) = Ø.795
881 SMALL = Ø : K = 8 : DFI = 2
882 TØ = ZØ
883 GOSUB 25ØØØ
884 DG = XAL
885                 REM * DISCOLORED KERNELS DUE TO DRYING DELAY *
892 GØ(1) = Ø.Ø : GØ(2) = Ø.Ø1 : GØ(3) = Ø.Ø 2 : GØ(4) = Ø.Ø6
893 GØ(5) = 1.Ø1 : GØ(6) = 1.94 : GØ(7) = 2.88 : GØ(8) = 3.75
895 SMALL = Ø : K = 8 : DFI = 2.Ø
896 ZØ = DD
897 GOSUB 25ØØØ
898 DCK = XAL
899 GOTO 98Ø
9Ø1                 REM * DRY SEASON *
9Ø2 DAH = 28 + 2 * XBAL
9Ø4 IF DAH> 38 GOTO 9Ø2 : IF DAH<18 GOTO 9Ø2
9Ø6 Q1 = 3 : S1 = 1Ø.49
9Ø8 GOSUB 4ØØØØ : DD = XCAL
9Ø9 IF DD  18 GOTO 9Ø8
91Ø IF DM $ = "SUN" GOTO 921
915 HHD = -1.1372 + 0.1412 * DAH - Ø.ØØ23  * DAH↑2)
92Ø GOTO 938
921 ZØ = DAH
923 GØ(1) = Ø.94 : GØ(2) = Ø.94 : GØ(3) = Ø.93 : GØ(4) = 0.92
924 GØ(5) = Ø.88 : GØ(6) = Ø.84 : GØ(7) = Ø.79 : GØ(8) = 0.72
925 SMALL = 28 : K = 5 : DFI = 3
93Ø GOSUB 25ØØØ
935 HHD = XAL
938 GØ(1) = 1.Ø : GØ(2) = Ø.97 : GØ(3) = Ø.96 : GØ(4) = Ø.955
939 GØ(5) = Ø95 : GØ(6) = Ø.95 : GØ(7) = Ø.95 : GØ(8) = Ø.95
941 SMALL = Ø : K = 8.Ø : DFI = 4.Ø
942 ZØ = DD
945 GOSUB 25ØØØ
95Ø D6 = XAL
```

```
954 GØ(1) = Ø.Ø : GØ(2) = Ø.3 : GØ(3) = Ø.79 : GØ(4) = 1.35
955 GØ(5) = 1.72 : GØ(6) = 1.74 : GØ(7) = 1.99 : GØ(8) = 1.99
956 SMALL = Ø : K = 8.Ø : DFI = 6.Ø
957 ZØ = DD
96Ø GOSUB 25ØØØ
97Ø DCK = XAL
975                REM * SHAPE-RATIO FACTOR *
98Ø VS = (1ØØ.73 - 9 * GS)/1ØØ
983 QP = MM * HHD * VS * DG
984 THD = 37.17 + 17.38 * LOG(DAH)
985 IF HT$ = " RR " GOTO 988
986 WOT = VNW * HOT * Ø.97 * THD/1ØØ : GOTO 99Ø
988 WOT = VNW * HOT * THD/1ØØ
989 GOTO 992
99Ø GOT = QP * WOT : GOTO 1ØØ2
992 GOT = QP * WOT * 1.Ø8 : GOTO 1Ø2Ø
995                REM * DETERMINE ENERGY REQ BY CAPACITY *
1ØØØ IF HT $ = "RR" GOTO 1Ø2Ø
1ØØ5 GRLGTH = (WOT/.922)/WCAP
1Ø1Ø GENRGY = (Ø.49 * RCAP↑(Ø.93)) * Ø.746 * GRLGTH
1Ø15 GOTO 1Ø3Ø
1Ø2Ø GRLGTH = (WOT/Ø.922)/WCAP
1Ø25 GENRGY = 1Ø.48 *WCAP↑(Ø.92)) * 0.746 * GRLGTH
1Ø3Ø TENRGY = TENRGY + GENRGY
1Ø35 RATE (6) = POT/GRLGTH
1Ø4Ø TRLGTH = TRLGTH + GRLGTH
1Ø45               REM * DETERMINE PERFORMANCE CRITERIA *
1Ø55 HEAD = 1ØØ * (GOT/WOT)
1Ø6Ø BROK = 1ØØ * 1ØØ (WOT-GOT)/WOT
1Ø65 TYLD = 1ØØ * (WOT/COT)
1Ø7Ø PRINT    64 "TIME OUTPUT RECOV HEAD DISC ENERGY"
1Ø75 PRINT    128, "HRS TONS PERCENT PERCENT PERCENT KWATT-HRS"
1Ø8Ø PRINT TAB (Ø) TRLGTH ; TAB  (8) WOT ; TAB (14) TYLD ; TAB (24) HEAD ;
         TAB (35) DCK ; TAB (46) TENRGY
1Ø89 RTNRGY = RTNRGY + TENRGY
```

```
1090 RRLGTH = RRLGTH + TRLGTH
1100 RDCK = RDCK + DCK
1115 RHEAD = RHEAD + HEAD
1118 RYLD = RYLD + TYLD
1125 PRINT TAB(0) RRLGTH ; TAB(6) RWOT ; TAB(13) RYLD ; TAB(21) RHEAD ;
        TAB(32) RDCK ; TAB(46) RTNRGY
1138 STOP
1140 NEXT Z
24899 END
25000             REM * SUBROUTINE TAB *
25065 DUM = Z0 - SMALL
25070 IF DUM< 0 THEN DUM = 0
25075 IF DUM>((K-1) * DFI) THEN DUM = (K-1) * DFI
25080 R = 1 + DUM/DFI
25085 IF R = K THEN R = K - 1
25090 XAL = G0(R) + ((G0(R+1) - G0 (R))/DFI) * (DUM -(FIX(R-1) * DFI))
28995 END
30000             REM * SUBROUTINE RANDOM *
30035 Y0 = RND(0)
30040 DUM = Y0 - SMALL
30045 IF DUM< 0 THEN DUM = 0
30050 IF DUM>((K-1) * DFI)  THEN DUM = (K-1) * DFI
30055 I = 1 + DUM/DFI
30060 IF I = K  THEN I = K - 1
30065 XBAL = F0(Z) + ((F0(Z+1) - F0(Z))/DFI) * (DUM -(FIX(Z-1)) * DFI
30070 RETURN
38995 END
39000             REM * SUBROUTINE GAMMA *
40000 TD = 1.0
40005 FOR T0 = 1 TO Q1
40010 R0 = RND (0)
40015 IF R0 = 0 GOTO 40010
40020 TD = TD * R0
40025 NEXT T0
40030 XCAL  = - LOG (TD)/(FIX(Q1)/S1)
40035 RETURN
```

APPENDIX C

GAMMA DISTRIBUTION FUNCTION

APPENDIX C

GAMMA DISTRIBUTION FUNCTION

In any activity or project there is a time lag or delay between initiation and completion. This type of delay is frequently encountered in aggregative processes where streams or flows made up of many entities are subject to delays which vary from entity to entity. Examples are the rate of adoption of an attitude or innovation, the aggregate growth of capital in an economy and the rate at which plants reach maturity. This type of delays can be modeled by a differential equation such as shown in this appendix. Delays come in different orders depending on the distribution function of the delay. The order of the delay is defined as the order of the differential equation.

APPENDIX C

GAMMA DISTRIBUTION FUNCTION

$$E(t) = k\left[\frac{D}{k}\right]^{k} \frac{dB(t)}{dt} + k\left[\frac{D}{k}\right]^{k-1} \frac{d^{k-1} B(t)}{dt^{k-1}} + \ldots + k\left[\frac{D}{k}\right] \frac{dB(t)}{dt} + B(t)$$

D = expected average delay (no. of years to complete a project)

k = order of the delay

E = rate of completion scheduled per year

when K = 0, B(t) = E(t) which implies instantaneous completion

k = 1, $E(t) = D^* \frac{dB(t)}{dt} + B(t)$ (exponential distribution)

$K = \infty$, B(t) = E(t-D)

$k \to \infty$, the time profile of the completion approaches the normal distribution.

APPENDIX D

CHI-SQUARE ANALYSIS OF RANDOM VARIABLES

APPENDIX D

Among the parameters used in the rice mill performance model were three random variables. These were moisture content, purity of paddy and drying delay. Base data from the work of Camacho, et al., (1978) was analyze to determine the kind of distribution function for these variables. The hypotheses that the distribution function for these variables was a normal curve was tested by the Chi-square test. Table D1 shows the Chi-square value computed for moisture content of samples taken from rice mills used in the study. The Chi-square value was 12.55 which is less than the tabular value of 13.3. This indicates that the distribution function is normal. The same is true for Table D2 which shows the analysis for purity of paddy and the cumulative probability table for drying delay.

APPENDIX D

TABLE D1

CHI-SQUARE ANALYSIS OF MOISTURE CONTENT OF PADDY SAMPLES FROM RICE MILLS

MOISTURE CONTENT, % X = 11.57(11%) Sx = 1.25 N = 77

Range of M.C.	8.1-9.0	9.1-10.0	10.1-11.0	11.1-12.0	12.1-13.0	13.1-14.0	14.1-15.0
Mid-point	8.5	9.5	10.5	11.5	12.5	13.5	14.5
Observed Freq.	2	6	22	23	17	6	1
End-point	9.0	10.0	11.0	12.0	13.0	14.0	15.0
Deviation from X	-2.57	-1.57	-0.57	0.43	1.43	2.43	3.43
Standard Deviation	-2.06	-1.26	-0.42	0.34	1.14	1.94	2.74
Probability	0.0197	0.1038	0.3372	0.3669	0.1271	0.0268	0.0031
Expected Freq.	1.58	8.3	26.98	29.35	10.17	2.14	0.025
Contri. to X^2	0.10	0.64	0.44	1.37	0.79	6.96	2.25

$\chi^2 = 12.55$ TABULAR $\chi^2 = 13.3$ 0.01 SIGNIFICANCE LEVEL

APPENDIX D

TABLE D2

CHI-SQUARE ANALYSIS OF PURITY OF PADDY SAMPLES AND THE CUMULATIVE PROBABILITY TABLE OF DRYING DELAY

PURITY OF PADDY, X = 0.969 Sx = 0.018(2%) N = 87

Range of Purity	-0.941	.942-.952	.953-.963	.964-.974	.975-.985	.986-.996	.997-1.00
Mid-point	0.936	0.947	0.958	0.969	0.980	0.991	0.999
Observed Freq.	4	9	14	26	15	14	5
End-point	0.941	0.952	0.963	0.974	0.985	0.990	1.00
Deviation from X	-0.0280	-0.017	-0.006	0.005	0.016	0.021	0.031
Standard Deviation	-1.56	-0.944	-0.333	0.278	0.889	1.167	1.722
Probability	0.0594	0.1736	0.3707	0.3936	0.1867	0.1230	0.0427
Expected Freq.	4.752	13.89	29.65	31.49	14.94	9.84	3.42
Contribution to X^2	0.12	1.71	8.26	0.96	0.000241	1.76	0.73

$\chi^2 = 13.54$ TABULAR $\chi^2 = 14.9$ 0.005 SIGNIFICANCE LEVEL

DRYING DELAY, DAYS X = 10.49 Sx = 3.4 N = 88

Mid-point	8	9	10	11	12	13	14	15	16	17
Observed Freq.	8	20	18	11	6	7	7	6	3	2
End-point	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5
Probability	0.0909	0.2273	0.2045	0.1250	0.0682	0.0795	0.0795	0.0682	0.0341	0.0227
Cum. Problem	0.0909	0.3182	0.5227	0.6477	0.7159	0.7954	0.8749	0.9431	0.9772	1.0000

APPENDIX E

VALIDATION OF THE LINEAR NETWORK ANALYSIS

APPENDIX E

This appendix provides a validation on the result of the linear network economic analysis. The cost of milled rice with the corresponding credit to by-product was computed by an accounting method. The result which gave the total cost of milled rice as ₱ 1.25 per kilogram was closed to the values given by the linear network equations.

APPENDIX E

ESTIMATE OF COST OF MILLED RICE[1/]

Cost of Paddy = ₱ 1.00 per kg.[2/]		
Cost of paddy needed to produce 1 kg. rice		₱ 1.43
Less cost of broken 1.43 X 0.075 X 0.80	= 0.090	
Less cost of dark bran 1.43 X 0.025 X 0.4	= 0.014	
Less cost of medium bran 1.43 X 0.06 X 0.5	= 0.430	
Less cost of fine bran 1.43 X 0.0803 X .65	= 0.075	
Less cost of brewers 1.43 X 0.005 X 1.0	= 0.070	
Total	= 0.229	
Cost of paddy less by-product		₱ 1.201
Cost of processing		0.05
Total Cost of Milled Rice		₱ 1.251

[1/]Includes material and processing energy cost
[2/]14 percent moisture content

APPENDIX F

DERIVATION OF LINEAR NETWORK ANALYSIS

APPENDIX F

DERIVATION OF THE LINEAR NETWORK ECONOMIC MODEL

This Appendix gives the detail of the combination of equations E(1) to E(19) and C(1) to C(16) in Section 4.2.1.8 to obtain the equation for the rice milling economic model. For example, equation F(1) gives the equation for X_{43} which was obtained by combining equations E(15), E(16), E(17) and E(18).

APPENDIX F

LINEAR NETWORK ECONOMIC MODEL

$$X_{43} = K_{12}K_{11}X_{11} - K_{12}K_{21}X_{21} - K_{12}K_{31}X_{31} - K_{12}K_{41}X_{41} + K_{12}f_{01}(Y_{01}) + K_{12}X_{2T} - f_{02}(Y_{02}) \qquad F(1)$$

$$X_{24} = K_{13}X_{13} + K_{23}X_{23} + K_{43}K_{11}K_{12}X_{11} + K_{43}K_{12}K_{21}X_{21} + K_{43}K_{12}K_{31}X_{31} + K_{43}K_{12}K_{41}X_{41} + K_{43}K_{12}f_{01}(Y_{01}) - K_{43}K_{12}X_{2T} + K_{43}f_{02}(Y_{02}) - f_{03}(Y_{03}) - X_{3T} \qquad F(2)$$

$$X_{04} = -K_{14}X_{14} - K_{24}K_{13}X_{13} + K_{24}K_{23}X_{23} + K_{43}K_{24}K_{12}K_{11}X_{11} + K_{43}K_{24}K_{12}K_{21}X_{21} + K_{43}K_{24}K_{12}X_{2T} + K_{43}K_{24}f_{02}(Y_{02}) - K_{24}f_{03}(Y_{03}) - K_{24}X_{3T} - f_{04}(Y_{04}) \qquad F(3)$$

$$X_{05} = -K_{25}X_{25} + K_{15}K_{14}X_{14} + K_{15}K_{24}K_{13}X_{13} - K_{15}K_{24}K_{23}X_{23} - K_{43}K_{24}K_{15}K_{12}K_{11}X_{11} - K_{43}K_{24}K_{15}K_{12}K_{21}X_{21} - K_{43}K_{24}K_{15}K_{12}K_{31}X_{31} - K_{43}K_{24}K_{15}K_{12}K_{41}X_{41} - K_{43}K_{24}K_{15}K_{12}f_{01}(Y_{01}) + K_{43}K_{24}K_{15}K_{12}X_{2T} - K_{43}K_{24}K_{15}f_{02}(Y_{02}) + K_{24}K_{15}f_{03}(Y_{03}) + K_{24}K_{15}X_{3T} + K_{15}f_{04}(Y_{04}) \qquad F(4)$$

$$X_{06} = -K_{16}X_{16} + K_{26}X_{5T} - K_{26}K_{25}X_{25} - K_{26}K_{15}K_{14}X_{14} - K_{26}K_{24}K_{15}K_{13}X_{13} - K_{26}K_{24}K_{15}K_{23}X_{23} - K_{43}K_{26}K_{24}K_{15}K_{12}K_{11}X_{11} - K_{43}K_{26}K_{24}K_{15}K_{12}K_{21}X_{21} - K_{43}K_{26}K_{24}K_{15}K_{12}K_{31}X_{31} - K_{43}K_{26}K_{24}K_{15}K_{12}X_{2T} - K_{43}K_{26}K_{24}K_{15}f_{02}(Y_{02}) - K_{26}K_{24}K_{15}f_{03}(Y_{03}) + K_{26}K_{24}K_{15}X_{3T} + K_{26}K_{15}f_{04}(Y_{04}) \qquad F(5)$$

$$Y_{09} = - K_{39}K_{18}X_{18} + K_{39}K_{28}X_{7T} - K_{39}K_{28}K_{17}X_{17} + K_{39}K_{28}K_{27}X_{6T}$$

$$- K_{39}K_{28}K_{27}K_{16}X_{16} + K_{39}K_{28}K_{26}X_{5T} - K_{39}K_{28}K_{25}X_{25} - K_{39}K_{28}K_{26}$$

$$K_{15}K_{14}X_{14} - K_{39}K_{28}K_{26}K_{24}K_{15}K_{13}K_{13} - K_{39}K_{28}K_{26}K_{24}K_{15}K_{23}X_{23}$$

$$- K_{43}K_{39}K_{28}K_{26}K_{24}K_{15}K_{12}K_{11}X_{11} - K_{43}K_{39}K_{28}K_{26}K_{24}K_{15}K_{21}X_{21}$$

$$- K_{43}K_{39}K_{28}K_{26}K_{24}K_{15}K_{12}K_{31}X_{31} - K_{43}K_{39}K_{28}K_{26}K_{24}K_{15}K_{12}K_{41}X_{41}$$

$$- K_{43}K_{39}K_{28}K_{26}K_{24}K_{15}K_{12}f_{01}(Y_{01}) - K_{39}K_{28}K_{27}K_{26}f_{05}(Y_{05}) -$$

$$- K_{39}K_{28}K_{27}f_{06}(Y_{06}) - K_{39}K_{28}f_{07}(Y_{07}) - K_{39}f_{08}(Y_{08}) - K_{19}X_{19}$$

$$- K_{29}X_{29} - f_{09}(Y_{09}) + K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{12}X_{2T} - K_{43}K_{39}K_{28}$$

$$K_{27}K_{26}K_{24}K_{15}f_{02}(Y_{02}) - K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}f_{03}(Y_{03}) + K_{39}K_{28}K_{27}$$

$$K_{26}K_{24}K_{15}X_{3T} - K_{39}K_{28}K_{27}K_{26}K_{15}f_{04}(Y_{04}) + K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}$$

$$K_{12}K_{11}X_{1T} - K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{11}X_{1} \qquad F(6)$$

$$X_{25} = f_{4T}(Y_{4T}) + K_{12}K_{11}f_{1T}(Y_{1T}) - K_{12}K_{11}X_{1} - K_{12}K_{21}X_{21} - K_{12}K_{31}X_{31}$$

$$- K_{12}K_{41}X_{41} + K_{12}f_{01}(Y_{01}) - K_{12}f_{2T}(Y_{2T}) - f_{02}(Y_{02}) + f_{22}(Y_{22}) \qquad F(7)$$

To have a cost equation in terms of the output Y_{10}, we have the following relations:

$$Y_{08} = Y_{39} = K_{39}Y_{09} = K_{39}Y_{10} \qquad F(8)$$

$$Y_{07} = Y_{28} = K_{28}Y_{08} = K_{28}K_{39}(Y_{10}) \qquad F(9)$$

$$Y_{06} = Y_{27} = K_{27}Y_{07} = K_{27}K_{28}K_{39}(Y_{10}) \qquad F(10)$$

$$Y_{05} = Y_{26} = K_{26}Y_{06} = K_{26}K_{27}K_{28}K_{39}(Y_{10}) \qquad F(11)$$

$$Y_{04} = Y_{15} = K_{15}Y_{05} = K_{15}K_{26}K_{27}K_{28}K_{39}(Y_{10}) \qquad F(12)$$

$$Y_{03} = Y_{24} = K_{24}Y_{04} = K_{15}K_{24}K_{26}K_{28}K_{39}(Y_{10}) \qquad F(13)$$

$$Y_{02} = Y_{43} - Y_{20} = K_{43}Y_{03} - Y_{25} = K_{43}Y_{03} - K_{25}Y_{05} \qquad F(14)$$

$$= K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}(Y_{10}) - K_{39}K_{28}K_{27}K_{26}K_{25}(Y_{10})$$

$$Y_{01} = Y_{12} = K_{12}Y_{02} = K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{12}Y_{10}$$

$$- K_{39}K_{28}K_{27}K_{26}K_{25}K_{12}Y_{10} \qquad F(15)$$

Also, the component models by the principle of conservation of energy for the transport processes are:

$$X_{1T} = - f_{1T}(Y_{1T}) \qquad Y_{1T} = Y_{1} \qquad F(16)$$

$$X_{2T} = - f_{2T}(Y_{2T}) \qquad Y_{2T} = Y_{01} \qquad F(17)$$

$$X_{3T} = - f_{3T}(Y_{3T}) \qquad Y_{3T} = Y_{03} \qquad F(18)$$

$$X_{4T} = - f_{4T}(Y_{4T}) \qquad Y_{4T} = Y_{04} \qquad F(19)$$

$$X_{5T} = - f_{5T}(Y_{5T}) \qquad Y_{5T} = Y_{05} \qquad F(20)$$

$$X_{6T} = - f_{6T}(Y_{6T}) \qquad Y_{6T} = Y_{06} \qquad F(21)$$

$$X_{7T} = - f_{7T}(Y_{7T}) \qquad Y_{7T} = Y_{07} \qquad F(22)$$

$$X_{9T} = - f_{9T}(Y_{9T}) \qquad Y_{9T} = Y_{09} = Y_{10} \qquad F(23)$$

Also,

$$X_{41} = - X_{CHAFF} = - X_{CH} \qquad F(24)$$

$$X_{21} = -X_{SAND} = -X_{SA} \qquad F(25)$$

$$X_{31} = -X_{STRAW} = -X_{ST} \qquad F(26)$$

$$X_{23} = -X_{CBRAN} = -X_{CB} \qquad F(27)$$

$$X_{13} = -X_{BROKEN} = -X_{BRO} \qquad F(28)$$

$$X_{14} = -X_{HULL} = -X_{HU} \qquad F(29)$$

$$X_{16} = -X_{DBRAN} = -X_{DB} \qquad F(30)$$

$$X_{17} = -X_{MBRAN} = -X_{MB} \qquad F(31)$$

$$X_{18} = -X_{FBRAN} = -X_{FB} \qquad F(32)$$

$$X_{19} = -X_{BREW} = -X_{BRE} \qquad F(33)$$

$$X_{29} = -X_{POLISH} = -X_{PO} \qquad F(34)$$

APPENDIX G

VALUES OF LINEAR NETWORK COEFFICIENTS

APPENDIX G

TECHNICAL COEFFICIENTS (K), MATERIAL COST (X) AND PROCESSING COST (f(Y)

Values of K, X and f(Y) for a one-ton per hour conventional mill and IR-26 rice variety are listed in the appendix. The values for the technical coefficients were obtained from the work of Manalabe, et al., (1978). The values of material cost were obtained from the price list of the National Grains Authority (1978) and the processing cost was from measurements taken from three rice mills described in Section 3.4 and Appendix A. These values were used in the linear network equations that gave the cost of milled rice (See Appendix H). The results are valid for IR-26 or any medium length and bold shape grain (See Appendix J). The model is also applicable to rice mills ranging in size from one-fourth to one and one-half tons per hour capacity equipped with at least two whiteners.

APPENDIX G

Values of K,X and f(Y) for a one-ton/hour conventional rice mill and IR-26 rice variety.

$K_{11} = 1.015$

$K_{12} = 1.0$

$K_{13} = 0.075$

$K_{14} = 0.249$

$K_{15} = 1.0$

$K_{16} = 0.025$

$K_{17} = 0.06$

$K_{18} = 0.0808$

$K_{19} = 0.005$

$K_{21} =$ no data

$K_{25} = 0.67$

$K_{26} = 1.03$

$K_{27} = 1.03$

$K_{28} = 1.03$

$K_{29} = 0.0$

$K_{31} =$ no data

$K_{41} =$ no data

$K_{43} = 1.04$

$K_{37} = 1.05$

$K_{24} = 1.20$

$X_{1} =$ ₱ 1.00/kg. paddy

$X_{21} = 0$

$X_{31} = 0$

$X_{41} = 0$

$X_{13} =$ ₱ 0.80/kg. broken

$X_{23} =$ ₱ 0.30/kg. coarse bran

$X_{14} =$ ₱ 0.05/kg. hull

$X_{16} =$ ₱ 0.40/kg. dark bran

$X_{17} =$ ₱ 0.50/kg. medium bran

$X_{18} =$ ₱ 0.65/kg. fine bran

$X_{19} =$ ₱ 1.00/kg. brewers

$X_{29} =$ ₱ 0.65/kg. polish

$f^{6}_{01} =$ ₱ 0.00012/kg.

$f^{6}_{02} ==$ ₱ 0.00025/kg.

$f^{6}_{03} =$ ₱ 0.00018/kg.

$f^{6}_{04} =$ ₱ 0.00057/kg.

$f^{6}_{05} =$ ₱ 0.00051/kg.

$f^{6}_{06} =$ ₱ 0.00063/kg.

$f^{6}_{07} =$ ₱ 0.0005/kg.

$f^{6}_{08} =$ ₱ 0.00011/kg.

$f^{6}_{09} =$ ₱ 0.00012/kg.

$f^{6}_{10} =$ ₱ 0.000283/kg.

$f^{6}_{1T} = f^{6}_{2T} = f^{6}_{3T} = f^{6}_{4T} = f^{6}_{5T} =$ ₱ 0.00032/kg.

$f^{6}_{6T} = f^{6}_{7T} = f^{6}_{9T} =$ ₱ 0.00043/kg.

APPENDIX H

EVALUATION OF THE LINEAR NETWORK EQUATIONS

APPENDIX H

EVALUATION OF THE LINEAR NETWORK EQUATION

This appendix shows the evaluation of the different terms in the Linear Network Equations. Values of K, X and f(Y) from Appendix G were substituted into the corresponding variables in the equations. The terms were then added and similar terms combined.

APPENDIX H

EVALUATION OF LINEAR NETWORK EQUATION

CONE TYPE:

1st term = $0.0000835\ f_{01}(Y_{10}) = 0.0000835\ (0.61)(Y_{10}/0.70)^{-0.14} = 0.00000484541\ Y_{10}^{-0.14}$

2nd term = $0.3025\ f_{02}(Y_{10}) = 0.3025\ (2.7)\ Y_{10}(.97)/0.70^{0.41} = 0.840268\ Y_{10}^{0.41}$

3rd term = $0.10161\ f_{03}(Y_{10}) = 0.10161\ (0.49)(Y_{10}/0.70)^{-0.07} = 0.0485612\ Y_{10}^{-0.07}$

4th term = $0.0573\ f_{04}(Y_{10}) = 0.0573\ (0.75)(Y_{10}/0.70)^{0.36} = 0.0488631\ Y_{10}^{0.36}$

5th term = $0.03925\ f_{05}(Y_{10}) = 0.03925\ (4.94/Y_{10} + 0.62)(1/0.70) = 0.0347643 + 0.27699/Y_{10}$

6th term = $0.017023\ f_{06}(Y_{10}) = 0.017023\ (3.61)(Y_{10}/0.70)^{-0.29} = 0.0554143\ Y_{10}^{-0.29}$

7th term = $0.146\ f_{07}(Y_{10}) = 0.146\ (3.61)(Y_{10}/0.70)^{-0.29} = 0.473268\ Y_{10}^{-0.29}$

8th term = $0.35545\ f_{08}(Y_{10}) = 0.35545\ (3.61)(Y_{10}/0.70)^{-0.29} = 1.15708\ Y_{10}^{-0.29}$

9th term = $f_{09}(Y_{10}) = 0.48\ (Y_{10}/0.70)^{-0.08} = 0.466497\ Y_{10}^{-0.08}$

10th term = $0.00007496\ Y_{10}$

11th term = $0.00007496\ Y_{10}$

12th term = $0.0000293\ Y_{10}$

13th term = $0.00001257\ Y_{10}$

14th term = $0.00002907\ Y_{10}$

15th term = $0.00006295\ Y_{10}$

16th term = $0.00043\ Y_{10}$

17th term = $K_{43}K_{39}K_{28}K_{27}K_{24}K_{15}K_{11}X_1 = 1.1535$

18th term = 0

19th term = 0 no commercial value

20th term = 0

21st term = $- K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{13}X_{BRO} = - 0.0309$

22nd term = $- K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{23}X_{CB} = - 0.06$

23rd term = $- K_{39}K_{28}K_{27}K_{26}K_{15}K_{14}X_{HU} = - 0.002985$

24th term = $- K_{39}K_{27}K_{16}X_{DB} = - 0.0260$

25th term = $- K_{39}K_{28}K_{17}X_{MB} = - 0.0115$

26th term = $- K_{39}K_{18}X_{FB} = - 0.0337$

27th term = $- K_{19}X_{BRE} = - 0.0054403$

28th term = $- K_{29}X_{PO} = 0$ (no data)

29th term = $K_{39}K_{28}K_{25}f_{4T}(K_{31}K_{28}K_{27}K_{26}K_{25}Y_{10}) = .000003621\ Y_{10}$

30th term = $K_{39}K_{28}K_{25}f_{22}(K_{39}K_{28}K_{27}K_{26}K_{25}Y_{10}) = 1.237\ Y_{10}^{-0.29}$

31st term = $K_{39}K_{28}K_{25}K_{12}K_{11}f_{1T}K_{43}K_{39}K_{28}K_{27}K_{26}K_{12}K_{11}(K_{43}K_{24}K_{15} - K_{25})Y_{10} = 0.0000564\ Y_{10}$

32nd term = $K_{39}K_{28}K_{25}K_{12}f_{01}(K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{12}Y_{10} - K_{39}K_{28}K_{27}K_{26}K_{25}K_{12}Y_{10}) = 1.21032\ Y_{10}^{-0.14}$

33rd term = $- K_{39}K_{28}K_{25}K_{20}K_{12}K_{11}X_{1}$ (combined with 17th term)

34th term = $K_{39}K_{28}K_{25}K_{20}K_{12}K_{21}X_{SA} = 0$

35th term = $K_{39}K_{28}K_{25}K_{20}K_{12}K_{41}X_{CH} = 0$

36th term = $- K_{39}K_{28}K_{25}K_{12}f_{2T}(K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{12}Y_{10})$ (combined with 11th term)

37th term = $- K_{39}K_{25}f_{02}(K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}Y_{10})$ (combined with 2nd term)

SIMPLIFYING AND COMBINING SOME TERMS:

$$X_{10} = 0.0000048454\ Y^{-0.14} + 1.8958\ Y_{10}^{0.41} + 0.0485612\ Y^{-0.07} + 0.048863\ Y_{10}^{0.36} + 2.922862\ Y_{10}^{-0.29}$$

$$0.27699\ Y_{10}^{-1.0} + 0.466497\ Y_{10}^{-0.08} + 0.0007138\ Y_{10} + 1.118$$

RUBBER ROLL TYPE:

17th term = $K_{43}K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{11}X_{1} = 1.1048$ (3% higher recovery)

21st term = $- K_{39}K_{28}K_{27}K_{26}K_{24}K_{15}K_{13}X_{BRO} = - 0.0206$

27th term = $- K_{19}X_{BRE} = - 0.0022056\ X_{BRE} = -0.0022056$

SIMPLIFYING AND COMBINING SOME TERMS:

WITH 3% MORE RECOVERY

$$X_{10} = 0.000004854\ Y_{10}^{-0.14} + 1.8958\ Y_{10}^{0.41} + 0.0485612\ Y_{10}^{-0.07} + 0.048863\ Y_{10}^{0.36}$$
$$+ 2.922862\ Y_{10}^{-0.29} + 0.27699\ Y_{10}^{-1} + 0.466497\ Y_{10}^{-0.08} + 0.0007138\ Y_{10} + 1.1062$$

WITH EQUAL RECOVERY

$$X_{10} = 0.0000048454\ Y_{10}^{-0.14} + 1.8958\ Y_{10}^{0.41} + 0.0485612\ Y_{10}^{-0.07} + 0.048863\ Y_{10}^{0.36}$$
$$+ 2.922862\ Y_{10}^{-0.29} + 0.27699\ Y_{10}^{-1} + 0.466497\ Y_{10}^{-0.08} + 0.0007138\ Y_{10} + 1.1166$$

APPENDIX I

RESULTS OF THE RICE MILL PERFORMANCE MODEL SIMULATIONS

APPENDIX I

This appendix includes the results of the mill performance modeling. Tables I1 to I42 are the results of the simulation run of 12 rice mills in their regular and modified configuration. An input of 10 tonnes paddy was used for each run. The values obtained for each run varies because of the use of three random input data (moisture content, purity and drying delay). Drying delay affects the head rice and discolored grain percentages. This simulation process is discussed in more detail in Section 5.1.

The output data includes the following variables:

(1) Time - milling time in hours.

(2) Output - milled rice output in ton.

(3) Recovery - total milled rice recovery or milling yield in percent of clean input paddy.

(4) Head - head rice recovery in percent of milled rice output.

(5) Discolored - discolored (yellow) grain in percent of milled rice output.

(6) Energy - energy usage per run in kwatt-hrs.

The data used in the simulation are as follows unless specified on the table of a particular run.

(1) Bin Capacities $(ft^3)/m^3$

Huller Bin (HBIN) = 0.244/0.0069

Sifter Bin (SFBIN) = 0.270/0.0077

Paddy Separator Bin (PBIN) = 0.313/0.0089

Whitener Bin (WBIN) = 0.350/0.010

(2) Number of Paddy Cleaner (CPN) = 1

(3) Huller Type (HT): Disc

(4) Grain Shape (GS) = 3.0

(5) Grain Type (GT): Medium

(6) Drying Method (DM): Sun

(7) Growing Season (Seas): Wet

(8) Input (I) = 10 ton

(9) Whitener Type (WT): Cone

(10) Number of Paddy Huller (HNP) = 1

Model Numbers are those used by the manufacturer as in Table 5.1 of the text body. Those model numbers with apostrophe are modified models. The following abbreviations in addition to those given above were used in the tables.

(1) Rice Mill Capacity (RCAP)

(2) Paddy Cleaner Capacity (PCCAP)

(3) Number of Paddy Cleaner (CPN)

(4) Separator Capacity (SCAP)

(5) Number of Whiteners (NW)

(6) Whitener Capacity (WCAP)

(7) Paddy Huller Capacity (PHCAP)

(8) Separator Type (ST): Fixed or Adjus.

All machine capacities are in ton per hour.

TABLE I5

RESULTS OF SIMULATION RUNS

TYPE NO. 1A
RCAP = 0.33; PCCAP = 0.33; SCAP = 0.495; WCAP = 2 X 0.255; PHCAP = 0.294; ST: FIXED;
NW = 2

OUTPUT

	TIME Hrs.	OUTPUT Ton	RECOV. Percent	HEAD Percent	DISC Percent	ENERGY Kw.-hrs.
	33.52	7.18	71.76	60.27	2.84	525.11
	33.52	7.18	71.76	61.12	0.05	525.11
	31.44	6.69	70.10	61.49	1.97	504.76
	31.29	6.63	69.97	61.83	0.32	503.29
	31.58	6.73	70.22	61.79	0.65	506.08
	32.65	6.98	71.09	61.82	0.05	516.59
	30.89	6.56	69.63	65.40	0.014	499.42
	31.82	6.78	70.42	61.51	2.56	508.46
	31.44	6.69	70.10	61.66	1.27	504.76
	32.05	6.84	70.61	64.04	0.02	510.68
AVE_{10}	32.02	6.83	70.57	62.09	0.97	510.43

TABLE I6

RESULTS OF SIMULATION RUNS

TYPE NO. 1A'
INPUT (all in ton per hour)
RCAP = 0.33; PCCAP = 0.33; SCAP = 0.495; WCAP = 2 X 0.255; PHCAP = 0.294; ST: ADJUS;
NW = 2

OUTPUT

	TIME Hrs.	OUTPUT Ton	RECOV. Percent	HEAD Percent	DISC Percent	ENERGY Kw.-hrs.
	32.98	7.06	71.34	60.95	1.56	476.40
	31.58	6.73	70.22	61.60	1.52	464.08
	30.89	6.56	69.63	67.13	0.009	458.09
	33.52	7.18	71.76	60.35	1.64	481.22
	28.40	5.98	67.26	59.58	1.31	436.61
	33.20	7.11	71.51	63.80	0.018	478.35
	32.80	7.02	71.21	63.93	0.019	474.87
	32.80	7.02	71.21	68.43	0.005	474.87
	31.94	6.81	70.51	61.89	0.084	467.23
	32.52	6.95	70.99	61.19	2.974	472.36
AVE_{10}	32.06	6.84	70.56	62.88	0.91	468.41
AVE_{100}	32.02	6.83	70.56	62.19	1.40	467.96

TABLE I7

RESULTS OF SIMULATION RUNS

TYPE NO 2
INPUT (all in ton per hour)
RCAP = 0.44; PCCAP = 0.44; SCAP = 0.66; WCAP = 0.334; PHCAP = 0.44; ST: FIXED;
NW = 1

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton	Percent			Kw.-hrs.
	24.59	6.90	68.90	60.27	3.75	425.23
	24.19	6.78	68.51	60.85	2.00	420.84
	24.07	6.74	68.38	61.06	1.64	419.45
	22.83	6.35	67.04	61.80	0.33	405.92
	23.86	6.67	68.16	62.06	0.05	417.16
	22.42	6.23	66.58	61.23	1.18	401.54
	20.83	5.74	64.59	59.43	3.75	384.58
	24.35	6.83	68.67	60.62	2.05	422.61
	23.86	6.67	68.16	61.19	2.01	417.16
	23.77	6.64	68.07	61.27	3.37	416.16
AVE_{10}	23.48	6.55	67.71	60.98	2.01	413.06
AVE_{100}	23.26	6.49	67.48	61.98	1.47	410.68

ADV. CAP. = 0.440 ton /hr.
SIM. CAP. = 0.4299 ton /hr.

TABLE I8

RESULTS OF SIMULATION RUNS

TYPE NO. 2'
INPUT (all in ton per hour)
RCAP = 0.44; PCCAP = 0.44; SCAP = 0.66; WCAP = 0.334; PHCAP = 0.44; ST: ADJUS;
NW = 1

OUTPUT

	TIME Hrs.	OUTPUT Ton	RECOV. Percent	HEAD Percent	DISC Percent	ENERGY Kw.-hrs.
	23.96	6.70	68.26	61.29	1.15	380.76
	23.17	6.46	67.42	62.23	0.05	373.05
	22.95	6.39	67.19	61.49	2.71	371.00
	22.95	6.39	67.19	61.49	3.75	371.00
	24.19	6.78	68.51	61.14	0.65	383.09
	23.17	6.46	67.42	61.50	2.20	373.05
	23.07	6.43	67.31	64.59	0.01	372.08
	23.43	6.54	67.71	61.58	1.65	375.61
	23.68	6.62	67.97	61.36	3.75	378.05
	24.19	6.78	68.51	61.02	1.26	383.09
AVE_{10}	23.48	6.55	67.75	61.77	1.72	376.08
AVE_{100}	23.38	6.52	67.62	62.01	1.43	375.17

TABLE I9

RESULTS OF SIMULATION RUNS

TYPE NO. 2A
INPUT (all in ton. per hour)
PCCAP = 0.33; SCAP = 0.495; WCAP = 2 X 0.272; PHCAP = 0.44; ST: FIXED; NW = 2

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton.	Percent			Kw.-hrs.
	15.69	6.89	70.79	61.36	3.46	428.37
	15.81	6.95	70.99	61.19	3.75	430.39
	15.30	6.69	70.10	61.49	3.73	421.46
	15.59	6.84	70.61	61.51	3.75	426.49
	15.69	6.89	70.79	61.37	1.89	428.37
	16.02	7.06	71.34	62.18	0.04	434.21
	16.02	7.06	71.34	61.02	1.24	434.21
	13.88	5.98	67.26	64.11	0.01	396.66
	13.88	5.98	67.26	59.47	1.75	396.66
	13.88	5.98	67.26	60.74	0.04	396.66
AVE_{10}	15.17	6.63	69.78	61.44	1.96	419.35
AVE_{100}	15.60	6.84	70.61	61.83	1.67	426.71

TABLE I10

RESULTS OF SIMULATION RUNS

TYPE NO. 2A'
INPUT (all in ton per hour)
PCCAP = 0.33; SCAP = 0.495; WCAP = 2 X 0.272; PHCAP = 0.44; ST: ADJUS; NW = 2

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton	Percent			Kw.-hrs.
	15.23	6.66	69.97	61.49	3.75	383.89
	15.42	6.76	70.32	62.77	0.04	386.95
	15.48	6.78	70.42	65.86	0.01	387.83
	15.81	6.95	70.99	61.23	1.77	393.03
	15.23	6.66	69.97	61.83	0.32	383.89
	15.75	6.92	70.89	61.27	2.87	392.10
	15.75	6.92	70.89	61.76	0.05	392.10
	13.88	5.98	67.26	59.43	3.75	362.75
	15.59	6.84	70.61	61.51	3.75	389.52
	15.87	6.98	71.09	61.35	0.87	394.03
AVE_{10}	15.40	6.74	70.24	61.85	1.72	386.61
AVE_{100}	15.45	6.77	70.34	62.05	1.49	387.49

TABLE I11

RESULTS OF SIMULATION RUNS

TYPE NO. 2A"
INPUT (all in ton per hour)
PCCAP = 0.33; SCAP = 0.495; WCAP = 2 X 0.272; PHCAP = 0.44; HT: RR; ST: ADJUS;
NW = 2

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton	Percent			Kw.-hrs.
	15.71	6.90	72.27	69.58	0.01	385.55
	16.72	7.41	73.98	65.10	3.75	401.11
	16.56	7.33	73.73	65.47	3.13	398.68
	15.71	6.90	72.27	72.80	0.00	385.55
	16.01	7.05	72.79	66.79	0.38	390.08
	15.95	7.02	72.70	66.63	1.18	389.23
	15.90	6.99	72.60	66.43	3.75	388.38
	16.46	7.28	73.55	69.75	0.01	397.03
	16.17	7.13	73.08	66.56	0.26	392.66
	16.72	7.41	73.98	65.16	1.71	401.11
AVE_{10}	16.19	7.14	73.09	67.43	1.42	392.94
AVE_{100}	15.95	7.02	72.68	67.00	1.64	389.25

TABLE I12

RESULTS OF SIMULATION RUNS

TYPE NO. 3
INPUT (all in tons per hour)
RCAP = 0.66; PCCAP = 0.66; HNP = 1; SCAP = 0.825; PHCAP = 0.66; ST: FIXED; WCAP = 0.46;
NW = 1

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton	Percent			Kw.-hrs.
	17.13	6.59	67.89	62.27	0.05	327.01
	17.48	6.74	68.38	64.00	0.01	331.19
	17.57	6.78	68.51	68.51	0.04	332.32
	16.95	6.51	67.62	67.62	0.02	324.80
	16.53	6.35	67.04	61.46	3.34	320.23
	17.86	6.90	68.90	60.49	1.06	335.88
	17.20	6.62	67.97	61.57	1.06	327.75
	17.69	6.83	68.67	60.80	1.22	333.76
	17.86	6.90	68.90	61.12	0.05	335.88
	16.28	6.23	66.58	61.34	0.61	316.67
AVE_{10}	17.26	6.64	68.05	61.89	0.75	328.55
AVE_{100}	16.99	6.53	67.65	62.17	1.57	325.29

TABLE I13

RESULTS OF SIMULATION RUNS

TYPE NO. 3'
INPUT (all in ton per hour)
PCCAP = 0.66; HNP = 1; SCAP = 0.825; PHCAP = 0.66; WCAP = 0.46
ST: ADJUS.; NW = 1

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton.	Percent			Kw.-hrs.
	16.95	6.51	67.62	61.62	1.49	292.52
	16.28	6.23	66.58	65.15	0.01	285.33
	17.86	6.90	68.90	60.32	1.74	302.33
	16.95	6.51	67.62	61.66	1.31	292.52
	17.13	6.59	67.89	61.54	1.53	294.48
	16.89	6.49	67.52	61.50	2.74	291.84
	17.40	6.70	68.26	61.42	0.40	297.31
	16.89	6.49	67.52	61.50	3.75	291.84
	17.33	6.67	68.16	61.19	3.75	296.53
	17.01	6.54	67.71	61.69	1.19	293.18
AVE_{10}	17.07	6.56	67.78	61.76	1.79	293.79
AVE_{100}	16.96	6.52	67.59	61.88	1.78	292.60

TABLE I14

RESULTS OF SIMULATION RUNS

TYPE NO. 3A
INPUT (all in ton per hour)
PCCAP = 0.66; HNP = 1; SCAP = 0.825; PHCAP = 0.66; WCAP = 2 X 0.272;
ST: FIXED; NW = 2

OUTPUT

	TIME Hrs.	OUTPUT Ton	RECOV. Percent	HEAD Percent	DISC Percent	ENERGY Kw.-hrs.
	14.45	6.49	69.34	61.04	3.75	338.09
	14.86	6.69	70.10	63.14	0.03	344.19
	15.20	6.86	70.70	61.76	0.40	349.22
	15.15	6.84	70.61	65.61	0.01	348.43
	15.84	7.18	71.76	63.74	0.01	358.78
	15.31	6.92	70.89	61.63	0.20	350.85
	15.58	7.06	71.34	61.23	0.08	354.95
	15.15	6.84	70.61	61.51	3.75	348.43
	14.86	6.69	70.10	61.49	3.75	344.19
	14.60	6.56	69.63	61.56	0.77	340.37
AVE_{10}	15.17	6.85	70.62	62.25	1.57	348.72
AVE_{100}	15.11	6.82	70.52	62.33	1.35	347.90

ADV. CAP. = 0.642 ton /hr.

SIM. CAP. = 0.6616 ton /hr.

TABLE I15

RESULTS OF SIMULATION RUNS

TYPE NO. 3A'
INPUT (all in ton per hour)
PCCAP = 0.66; HNP = 1; SCAP = 0.825; PHCAP = 0.66; WCAP = 2 X 0.272;
NW = 2; ST: ADJUS.

OUTPUT

	TIME Hrs.	OUTPUT Ton.	RECOV. Percent	HEAD Percent	DISC Percent	ENERGY Kw.-hrs.
	15.31	6.92	70.89	63.88	0.02	318.15
	15.15	6.84	70.61	61.51	3.75	315.98
	14.79	6.66	69.97	61.62	1.42	311.25
	15.58	7.06	71.34	63.60	0.01	321.80
	14.86	6.69	70.10	61.49	3.75	312.20
	15.04	6.78	70.42	61.71	1.10	314.56
	15.37	6.95	70.99	61.19	3.34	318.93
	14.45	6.49	69.34	64.60	0.01	306.74
	13.43	5.98	67.26	59.48	1.73	292.50
	14.93	6.73	70.22	61.50	2.80	313.04
AVE_{10}	14.89	6.71	70.11	62.06	1.79	312.62
AVE_{100}	15.10	6.81	70.49	62.40	1.34	315.38

TABLE I16

RESULTS OF SIMULATION RUNS

TYPE NO. 3A"
INPUT (all in ton per hour)
WCAP = 2 X 0.272; PCCAP = 0.66; SCAP = 0.825; PHCAP = 0.66;
HT: RR; NW = 2; ST: ADJUS.; HNP = 1

OUTPUT

	TIME Hrs.	OUTPUT Ton	RECOV. Percent	HEAD Percent	DISC Percent	ENERGY Kw.-hrs.
	15.46	6.99	72.60	66.83	0.13	314.05
	15.28	6.90	72.27	66.66	1.01	311.69
	15.57	7.05	72.79	66.43	2.49	315.47
	15.93	7.23	73.41	65.87	3.01	320.19
	15.74	7.13	73.08	66.48	0.69	314.63
	15.51	7.02	72.70	67.08	0.05	314.77
	15.34	6.93	72.39	66.48	1.71	312.54
	15.74	7.13	73.08	66.26	1.60	317.63
	15.68	7.10	72.98	66.26	3.73	316.89
	15.80	7.16	73.18	66.08	2.72	318.41
AVE_{10}	15.60	7.07	72.85	66.44	1.718	315.93
AVE_{100}	15.47	7.00	72.58	66.65	1.706	314.25

TABLE I17

RESULTS OF SIMULATION RUNS

TYPE NO. 4
INPUT (all in ton per hour)
RCAP = 1.064; PHCAP = 1.064; WCAP = 0.627; ST: FIXED; SCAP = 0.990; PCCAP = 1.064
NW = 1

OUTPUT

	TIME Hrs.	OUTPUT Ton.	RECOV. Percent	HEAD Percent	DISC Percent	ENERGY Kw.-hrs.
	12.29	6.43	67.31	61.64	1.36	249.56
	13.10	6.90	68.90	60.27	2.06	260.35
	11.10	5.74	64.59	59.66	0.93	234.08
	12.82	6.74	68.38	60.99	3.75	256.62
	12.34	6.46	67.42	62.65	0.04	250.26
	12.48	6.54	67.71	61.51	3.09	252.11
	12.57	6.59	67.89	62.61	0.04	253.29
	12.76	6.70	68.26	62.84	0.03	255.83
	12.57	6.59	67.89	61.43	3.11	253.29
	12.62	6.62	67.97	61.40	1.75	253.88
AVE_{10}	12.47	6.53	67.63	61.50	1.62	251.93
AVE_{100}	12.42	6.50	67.55	61.88	1.47	251.28

TABLE I18

RESULTS OF SIMULATION RUNS

TYPE NO. 4'
INPUT (all in ton per hour)
WCAP = 0.627; ST: ADJUS.; SCAP = 0.990; PCCAP = 1.064; PHCAP = 1.064
NW = 1

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton.	Percent			Kw.-hrs.
	12.66	6.64	68.07	61.27	3.75	225.40
	12.89	6.78	68.51	63.39	0.02	228.04
	12.66	6.64	68.07	64.73	0.01	225.40
	12.76	6.70	68.26	61.09	2.08	226.57
	12.76	6.70	68.26	61.29	1.15	226.57
	12.98	6.83	68.67	60.62	3.75	229.04
	11.10	5.74	64.59	59.43	2.93	207.60
	12.62	6.62	67.97	61.40	1.77	224.86
	12.44	6.51	67.62	61.53	1.84	222.81
AVE_{10}	12.56	6.58	67.82	61.60	1.88	224.22
AVE_{100}	12.48	6.54	67.67	61.86	1.46	223.28

TABLE I19

RESULTS OF SIMULATION RUNS

TYPE NO. 4A
INPUT (all in ton per hour)
WCAP = 2 x 0.334; SCAP = 0.990; PCCAP = 1.064; PHCAP = 1.064;
NW = 2; ST; FIXED

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton.	Percent			Kw.-hrs.
	12.24	6.842	70.61	61.51	3.21	302.45
	12.60	7.061	71.34	60.85	2.64	308.33
	12.28	6.869	70.70	61.51	1.63	303.17
	10.84	5.980	67.26	59.73	0.51	279.73
	12.06	6.730	70.22	61.72	1.04	299.48
	12.15	6.788	70.42	61.51	3.58	301.02
	11.67	6.491	69.34	62.23	0.04	293.11
	12.06	6.730	70.22	64.51	0.01	299.48
	12.68	7.113	71.51	60.62	3.50	309.73
	12.15	6.788	70.42	61.51	2.36	301.02
AVE_{10}	12.07	6.73	70.20	61.57	1.85	299.75
AVE_{100}	12.16	6.79	70.40	61.78	1.94	301.13

ADV. CAP. = 0.825 ton /hr.
SIM. CAP. = 0.8221 ton /hr.

TABLE I20

RESULTS OF SIMULATION RUNS

TYPE NO. 4A'
INPUT (all in ton per hour)
WCAP + 2 X 0.334; SCAP = 0.99; PCCAP = 1.064;
NW = 2; ST: ADJUS

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton	P e r	c e	n t	Kw.-hrs.
	12.53	7.02	71.21	60.99	2.93	277.87
	12.53	7.02	71.21	60.99	2.35	277.87
	11.95	6.66	69.97	61.49	3.75	269.31
	12.06	6.73	70.22	62.45	0.05	270.93
	12.47	6.98	71.09	65.74	0.01	277.01
	11.95	6.66	69.97	61.49	3.21	269.31
	12.06	6.73	70.22	63.38	0.03	270.93
	12.24	6.84	70.61	61.51	3.75	273.59
	11.88	6.62	69.82	61.81	0.26	268.32
	12.68	7.11	71.51	60.97	0.25	280.10
AVE_{10}	12.24	6.83	70.58	62.08	1.66	273.52
AVE_{100}	12.16	6.79	70.41	62.00	1.43	272.40

TABLE I21

RESULTS OF SIMULATION RUNS

TYPE NO. 4A"

INPUT (all in ton per hour)

WCAP = 2 X 0.334; SCAP = 0.99; PCCAP = 1.064;

HT; RR; NW = 2; ST: ADJUS.

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton	Percent			Kw.-hrs.
	13.04	7.33	73.73	65.47	3.75	278.57
	13.04	7.33	73.73	65.47	2.00	278.57
	12.63	7.08	72.89	67.96	0.04	272.75
	12.40	6.93	72.39	70.93	0.01	269.48
	12.47	6.96	72.50	66.53	1.53	270.18
	12.54	7.02	72.70	67.17	0.05	271.48
	12.72	7.13	73.08	66.54	0.36	274.06
	12.77	7.16	73.18	66.91	0.05	274.76
	12.00	6.69	71.48	65.93	3.75	263.83
	12.49	6.99	72.60	66.53	1.56	270.84
AVE_{10}	12.61	7.06	72.83	66.94	1.31	272.45
AVE_{100}	12.55	7.03	72.69	66.95	1.51	271.60

TABLE I22

RESULTS OF SIMULATION RUNS

TYPE NO. 4AB

INPUT (all in ton per hour)

RCAP = 1.064; PHCAP = 0.33;PCCAP = 1.064; WCAP = 2 X 0.334;

NW = 2; HNP = 2; ST: FIXED

OUTPUT

TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
Hrs.	Ton	Percent			Kw.-hrs.
12.38	6.815	70.51	63.92	0.025	477.27
12.78	7.061	71.34	62.16	0.043	457.37
12.24	6.730	70.22	61.50	2.411	443.81
12.38	6.815	70.51	61.51	3.082	447.27
12.34	6.788	70.42	66.15	0.012	446.17
11.85	6.491	69.34	63.06	0.031	434.07
12.86	7.113	71.51	60.62	2.404	459.51
11.98	6.569	69.63	61.29	3.350	437.22
12.34	6.788	70.42	61.51	2.028	446.17
11.85	6.491	69.34	67.07	0.008	434.07
AVE_{10} 12.30	6.766	70.33	62.88	1.339	445.29
AVE_{100} 12.40	6.825	70.52	62.18	1.364	447.73

TABLE I23

RESULTS OF SIMULATION RUNS

TYPE NO. 4AB'
INPUT (all in ton per hour)
RCAP = 1.064; PHCAP = 0.33; WCAP = 2 X 0.334; HNP = 2; ST: ADJUS.;
NW = 2

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton	Percent			Kw.-hrs.
	11.85	6.49	69.34	61.13	1.607	406.19
	12.19	6.69	70.10	61.49	3.750	414.05
	12.07	6.62	69.82	61.69	1.014	411.12
	11.85	6.49	69.34	65.99	0.116	406.19
	12.78	7.06	71.34	61.84	0.049	427.74
	12.60	6.95	70.99	64.74	0.016	423.74
	12.78	7.06	71.34	60.85	3.750	427.89
	12.38	6.81	70.51	61.84	0.433	418.48
	12.19	6.69	70.10	61.49	3.750	414.05
	12.42	6.84	70.61	61.51	3.018	419.50
AVE_{10}	12.31	6.77	70.35	62.26	1.740	416.91
AVE_{100}	12.36	6.80	70.45	61.94	1.644	418.04

TABLE I24

RESULTS OF SIMULATION RUNS

TYPE NO. 5AB
INPUT (all in ton per hour)
RCAP = 1.32; HNP =2; PHCAP = 0.66; WCAP = 2 X 0.46; SCAP = 1.32; ST: FIXED;
NW = 2

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Tonnes	Percent			Kw.-hrs.
	8.95	6.81	70.51	61.51	1.93	328.33
	7.97	5.98	67.26	59.43	3.35	303.81
	8.95	6.81	70.51	61.87	0.20	328.33
	9.05	6.89	70.79	61.36	3.75	330.73
	8.57	6.49	69.34	61.04	3.75	318.72
	8.72	6.62	69.82	61.46	2.77	322.57
	9.30	7.11	71.51	60.93	0.52	307.24
	9.02	6.86	70.70	63.22	0.03	329.93
	9.30	7.11	71.51	63.28	0.02	337.24
	9.05	6.89	70.79	67.02	0.00	330.73
AVE_{10}	8.89	6.76	70.28	62.11	1.63	326.76
AVE_{100}	8.97	6.82	70.54	61.87	1.62	328.76

ADV. CAP. = 1.063 ton /hr.
SIM. CAP. = 1.1144 ton /hr.

TABLE I25

RESULTS OF SIMULATION RUNS

TYPE NO. 5AB'
INPUT (all in ton per hour)
RCAP = 1.32; HNP = 2; PHCAP = 0.66; WCAP = 2 X 0.46; SCAP = 1.32; PCCAP = 1.32;
NW = 2; ST: ADJUS.

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton	Percent			Kw.-hrs.
	9.198	7.020	71.21	61.26	0.76	312.16
	8.857	6.730	70.22	61.85	0.25	304.14
	8.988	6.842	70.61	61.51	3.00	307.22
	9.156	6.985	71.09	61.12	1.81	311.18
	9.397	7.189	71.76	60.47	1.14	316.88
	8.892	6.760	70.32	61.50	2.02	304.95
	8.819	6.698	70.10	63.81	0.02	303.26
	8.575	6.491	69.34	65.36	0.01	297.55
	9.198	7.020	71.21	65.05	0.01	312.16
	9.119	6.953	70.99	61.55	0.17	310.23
AVE_{10}	9.020	6.86	70.68	62.35	0.92	307.98
AVE_{100}	8.95	6.81	70.48	61.86	1.53	306.43

TABLE I26

RESULTS OF SIMULATION RUNS

TYPE NO. 5A'
INPUT (all in ton per hour)
HNP = 1; PHCAP = 1.1; ST: ADJUS.: RCAP = 1.32; WCAP = 2 X 0.46; SCAP = 1.32; PCCAP = 1.32
NW = 2

OUTPUT

	TIME	OUTPUT	RECOV	HEAD	DISC	ENERGY
	Hrs.	Ton	Percent			Kw.-hrs.
	9.25	7.02	71.21	60.99	3.75	273.03
	8.83	6.66	69.97	61.49	3.75	264.47
	8.97	6.78	70.42	61.67	1.28	267.46
	8.78	6.62	69.82	61.46	3.75	263.48
	9.25	7.02	71.21	62.11	0.04	273.03
	8.72	6.56	69.63	61.29	3.75	262.23
	9.10	6.89	70.79	61.36	2.98	270.03
	8.02	5.98	67.26	59.43	2.53	248.41
	9.45	7.18	71.76	60.27	2.57	277.11
	8.94	6.76	70.32	61.74	0.98	266.79
AVE_{10}	8.93	6.75	70.24	61.18	2.53	266.60
AVE_{100}	8.98	6.78	70.38	61.83	1.56	267.52

TABLE I27

RESULTS OF SIMULATION RUNS

TYPE NO. 5A"
INPUT (all in ton per hour)
HT: RR; HNP = 1; PHCAP = 1.1; ST: ADJUS.; RCAP = 1.32; WCAP = 2 X 0.46; SCAP = 1.32; PCCAP = 1.32; NW = 2

OUTPUT

	TIME Hrs.	OUTPUT Ton	RECOV. Percent	HEAD Percent	DISC Percent	ENERGY Kw.-hrs.
	9.19	6.96	72.50	66.71	0.81	265.74
	8.24	6.16	69.34	64.57	0.17	247.49
	9.02	6.82	71.98	69.42	0.01	262.46
	8.86	6.69	71.48	65.93	3.75	259.38
	9.02	6.82	71.98	67.75	0.01	262.46
	9.07	6.86	72.14	66.41	2.21	263.44
	9.29	7.05	72.79	66.79	0.42	267.69
	8.86	6.69	71.48	71.78	0.00	259.38
	9.15	6.93	72.39	66.66	1.05	265.04
	9.19	6.96	72.50	66.42	3.25	265.74
AVE_{10}	8.99	6.80	71.86	67.24	1.17	261.88
AVE_{100}	9.28	7.04	72.73	67.16	1.53	267.51

TABLE I28

RESULTS OF SIMULATION RUNS

TYPE NO. 6AB
INPUT (all in ton per hour)
RCAP = 1.32; HNP = 2; PHCAP = 0.66; WCAP = 2 X 0.627; SCAP = 1.4295; PCCAP = 1.32;
NW = 2; ST: FIXED

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton	Percent			Kw.-hrs.
	7.07	7.18	71.76	60.27	2.78	333.15
	6.75	6.81	70.51	63.11	0.03	322.18
	6.73	6.78	70.42	61.53	1.84	321.40
	6.80	6.86	70.70	61.43	2.91	323.74
	6.54	6.56	69.63	61.29	3.75	315.03
	6.77	6.84	70.61	61.71	1.13	322.96
	7.01	7.11	71.51	60.85	1.00	330.90
	6.47	6.49	69.34	62.65	0.03	312.78
	6.62	6.66	69.97	62.50	0.04	317.75
	6.93	7.02	71.21	64.13	0.01	328.18
AVE_{10}	6.77	6.83	70.57	61.95	1.35	322.81
AVE_{100}	6.73	6.79	70.40	61.92	1.42	321.52

ADV. CAP. = 1.32 ton /hr.
SIM. CAP. = 1.4851 ton /hr.

TABLE I29

RESULTS OF SIMULATION RUNS

TYPE NO. 6A"
INPUT (all in ton. per hour)
RCAP = 1.32; HNP = 1; PHCAP = 1.28 ; WCAP = 2 X 0.627; SCAP = 1.4295; PCCAP = 1.32;
NW = 2; ST: ADJUS.

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton.	Percent			Kw.-hrs.
	6.69	6.73	70.22	61.50	1.98	276.83
	6.89	6.95	70.99	61.55	0.17	282.38
	6.86	6.92	70.89	61.54	0.80	281.65
	6.94	7.02	71.21	61.00	1.87	284.07
	6.89	6.95	70.99	61.21	1.83	282.38
	7.02	7.11	71.51	60.62	2.43	286.40
	6.77	6.81	70.51	65.31	0.01	278.94
	7.02	7.11	71.51	60.62	1.93	286.40
	6.84	6.89	70.79	61.67	0.51	280.95
	7.09	7.18	71.76	60.27	3.75	288.32
AVE_{10}	6.90	6.97	71.04	61.53	1.53	282.83
AVE_{100}	6.80	6.85	70.61	61.63	1.56	279.82

TABLE I30

RESULTS OF SIMULATION RUNS

TYPE NO. 6A"
INPUT (all in tons per hour)
RCAP = 1.32; HNP = 1; PHCAP = 1.28; WCAP = 2 X 0.627; SCAP = 1.4295; ST:ADJUS; HT: RR;
NW = 2

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Tons	Percent			Kw.-hrs.
	6.73	6.77	71.78	66.20	3.75	272.71
	7.02	7.10	72.98	66.60	0.51	280.84
	7.10	7.20	73.29	65.98	3.29	283.06
	7.21	7.33	73.73	67.46	0.03	286.28
	6.85	6.90	72.27	66.41	3.75	275.93
	7.05	7.13	73.08	66.48	0.70	281.53
	7.13	7.23	73.41	66.11	1.01	283.95
	6.90	6.96	72.50	66.42	2.86	277.46
	6.66	6.69	71.48	65.93	3.65	270.79
	6.73	6.77	71.78	66.26	1.71	272.71
AVE_{10}	6.94	7.01	72.63	66.39	2.12	278.53
AVE_{100}	6.94	7.01	72.60	67.17	1.55	278.50

TABLE I31

RESULTS OF SIMULATION RUNS

TYPE NO. 7AB
INPUT (all in ton per hour)
RCAP = 1.503; HNP = 2; PHCAP = 1.064; PCCAP = 1.503; SCAP = 1.650; WCAP = 2 X 0.627;
ST: FIXED

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton	Percent			Kw.-hrs.
	6.65	6.84	70.61	61.51	3.75	280.28
	6.89	7.11	71.51	62.00	0.04	287.16
	6.95	7.18	71.76	60.36	1.57	289.11
	6.42	6.56	69.63	61.62	0.40	273.40
	6.50	6.66	69.97	61.83	0.32	275.76
	6.50	6.66	69.97	62.76	0.04	275.76
	6.89	7.11	71.51	60.93	0.53	287.16
	6.65	6.84	70.61	61.51	2.52	280.28
	6.81	7.02	71.21	60.99	3.75	284.80
	6.63	6.81	70.51	61.51	2.34	279.60
AVE_{10}	6.69	6.88	70.73	61.50	1.52	281.33
AVE_{100}	6.64	6.82	70.51	62.23	1.35	279.83

ADV. CAP. = 1.503 ton /hr.
SIM. CAP. = 1.5056 ton /hr.

TABLE I32

RESULTS OF SIMULATION RUNS

TYPE NO. 7AB'
INPUT (all in ton per hour)
HNP = 2; ST: ADJUS. RCAP = 1.503; HNP = 2; PHCAP = 1.064; PCCAP = 1.503; SCAP = 1.65;
WCAP = 2 X 0.627

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton	Percent			Kw.-hrs.
	6.95	7.18	71.76	60.27	3.75	272.00
	6.72	6.92	70.89	61.27	2.30	265.67
	6.61	6.78	70.42	64.65	0.01	262.46
	6.72	6.92	70.89	61.27	3.29	265.67
	6.42	6.56	69.63	61.29	3.75	257.29
	6.75	6.95	70.99	61.19	3.05	266.36
	6.72	6.92	70.89	61.32	1.74	265.67
	6.81	7.02	71.21	60.99	2.14	267.96
	6.53	6.59	70.10	61.49	3.75	260.35
	6.61	6.78	70.42	61.85	0.33	262.46
AVE_{10}	6.68	6.87	70.72	61.56	2.41	264.59
AVE_{100}	6.63	6.81	70.50	61.96	1.51	263.20

TABLE I 33

RESULTS OF SIMULATION RUNS

TYPE NO. 7AB''
INPUT (all in ton per hour)
HNP = 2; ST: ADJUS.; RCAP = 1.503; PHCAP = 1.064; PCCAP = 1.503; SCAP = 1.65;
WCAP = 2 X 0.627; HT: RR

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton	Percent			Kw.-hrs.
	6.81	7.02	72.70	66.72	0.78	262.63
	6.88	7.10	72.98	66.26	3.75	264.53
	6.91	7.13	73.08	66.18	3.21	265.19
	6.84	7.05	72.79	66.43	3.72	263.26
	6.59	6.77	71.78	69.51	0.01	256.84
	6.93	7.16	73.18	66.50	0.06	265.89
	6.88	7.10	72.98	66.28	1.86	264.53
	6.07	6.16	69.34	64.34	1.30	243.22
	6.07	6.16	69.34	64.34	1.30	243.22
	6.84	7.05	72.79	66.55	1.52	263.26
	6.93	7.16	73.18	66.08	3.71	265.89
AVE_{10}	6.77	6.97	72.48	66.49	1.99	261.52
AVE_{100}	6.81	7.01	72.64	66.85	1.47	262.49

TABLE I34

RESULTS OF SIMULATION RUNS

TYPE NO. 7A'
INPUT (all in ton per hour)
RCAP = 1.47; HNP = 1; PHCAP = 1.47; PCCAP = 1.503; SCAP = 1.650; WCAP = 2 X 0.627;
ST: ADJUS.

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton	Percent			Kw.-hrs.
	6.68	6.78	70.42	61.61	1.52	317.87
	6.96	7.11	71.51	60.75	1.42	327.35
	6.83	6.95	70.99	61.27	1.61	322.67
	6.75	6.86	70.70	61.72	0.65	320.21
	6.58	6.66	69.97	61.49	2.05	314.24
	6.88	7.02	71.21	61.09	1.52	324.63
	6.71	6.81	70.51	61.52	1.90	318.66
	6.85	6.98	71.09	61.17	1.63	323.59
	6.63	6.73	70.22	61.50	2.35	316.20
	6.78	6.89	70.79	62.59	0.04	321.00
AVE_{10}	6.77	6.88	70.74	61.47	1.47	320.64
AVE_{100}	6.70	6.80	70.45	62.01	1.38	318.44

TABLE I35

RESULTS OF SIMULATION RUNS

TYPE NO. 8AB
INPUT (all in ton per hour)
RCAP = 1.83; HNP = 2; PHCAP = 1.064; PCCAP = 1.83; WCAP = 2 X 0.731; SCAP = 1.98;
NW = 2; ST: FIXED

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton	P e r	c e n	t	Kw.-hrs.
	5.49	6.49	69.34	61.04	3.75	270.89
	5.49	6.49	69.34	61.31	0.79	270.89
	5.71	6.78	70.42	66.30	0.01	278.45
	5.62	6.66	69.97	62.26	0.05	275.25
	5.86	6.98	71.09	61.09	2.84	283.47
	5.77	6.86	70.70	63.02	0.03	280.50
	5.62	6.66	69.97	61.49	3.34	275.25
	5.73	6.81	70.51	65.02	0.01	279.13
	6.01	7.18	71.76	60.62	0.26	288.74
	5.95	7.11	71.51	64.30	0.01	286.77
AVE_{10}	5.73	6.80	70.46	62.64	1.11	278.94
AVE_{100}	5.76	6.85	70.62	61.90	1.63	280.10

ADV. CAP. = 1.742 ton /hr.
SIM. CAP. = 1.7346 ton /hr.

TABLE I37

RESULTS OF SIMULATION RUNS

TYPE NO. 8AB'
INPUT (all in ton per hour)
RCAP = 1.83; DM: Mec.; HNP = 2; PHCAP = 1.064; PCCAP = 1.83; WCAP = 2 X 0.731;
SCAP = 1.98; ST: ADJUS.

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton.	Percent			Kw.-hrs.
	5.77	6.86	70.70	69.02	0.02	267.85
	5.73	6.81	70.51	66.49	2.45	266.55
	5.86	6.98	71.09	66.26	2.72	270.68
	5.55	6.56	69.63	68.05	0.03	260.58
	5.59	6.62	66.14	66.14	3.18	261.85
	5.59	6.62	69.82	67.05	0.05	261.85
	5.77	6.86	70.70	66.83	0.38	267.85
	5.73	6.81	70.51	66.89	0.15	266.55
	5.69	6.76	70.32	66.46	3.75	265.21
	5.59	6.62	69.82	66.14	2.23	261.85
AVE_{10}	5.69	6.75	70.29	66.93	1.49	265.08
AVE_{100}	5.72	6.79	70.43	66.57	1.70	266.15

TABLE I38

RESULTS OF SIMULATION RUNS

TYPE NO. 8AB'
Input (all in ton per hour)
DM: MEC; SEAS: DRY; RCAP = 1.83; HNP = 2; PHCAP = 1.064; PCCAP = 1.064; WCAP = 2 X 0.731;
SCAP = 1.98; ST: ADJUS.

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton.	Percent			Kw.-hrs.
	5.49	6.49	67.71	77.83	0.59	264.38
	4.90	5.68	63.99	59.19	1.20	246.40
	5.75	6.83	69.08	80.62	0.41	272.44
	5.64	6.69	68.53	80.37	0.28	269.08
	5.75	6.83	69.08	80.01	0.84	272.44
	5.79	6.89	69.28	79.86	1.04	273.71
	5.47	6.45	67.57	77.28	0.69	263.60
	5.79	6.89	69.28	80.45	0.55	273.71
	5.37	6.32	66.99	74.97	0.92	260.46
	5.58	6.60	68.19	81.22	0.10	267.09
AVE_{10}	5.56	6.57	67.97	77.18	0.66	266.33
AVE_{100}	5.56	6.58	68.06	78.50	0.55	266.56

TABLE I39

RESULTS OF SIMULATION RUNS

TYPE NO. 8AB'
INPUT (all in ton . per hour)
DM: SUM; SEAS: DRY; RCAP = 1.83; HNP = 2; PHCAP = 1.064; PCCAP = 1.83; SCAP = 1.98;
WCAP = 2 X 0.731; ST: ADJUS.

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton	Percent			Kw.-hrs.
	5.58	6.60	68.19	73.72	0.36	267.09
	5.72	6.79	68.92	73.16	0.77	271.44
	5.62	6.66	68.41	73.79	0.34	268.40
	5.44	6.41	67.41	72.88	0.98	262.73
	5.69	6.75	68.77	75.57	0.08	270.57
	5.56	6.57	68.07	73.31	0.61	266.44
	5.37	6.32	66.99	72.69	1.30	260.46
	5.65	6.69	68.53	73.06	0.85	269.08
	5.37	6.32	66.99	73.31	0.58	260.46
	5.66	6.72	68.65	73.33	0.62	269.80
AVE_{10}	5.56	6.58	68.09	73.48	0.65	266.65
AVE_{100}	5.55	6.56	67.98	73.59	0.55	266.19

TABLE I40

RESULTS OF SIMULATION RUNS

TYPE NO. 8AB'''

INPUT (all in ton per hour)
HT: DISC; WT: CYL; SEAS: WET; DM: SUN

OUTPUT

	TIME	OUTPUT	RECOV.	HEAD	DISC	ENERGY
	Hrs.	Ton.	Percent			Kw.-hrs.
	5.91	7.06	71.34	63.94	0.01	272.55
	5.75	6.84	70.61	61.72	1.09	267.20
	5.73	6.81	70.51	61.86	0.28	266.55
	5.91	7.06	71.34	60.85	3.75	272.55
	6.01	7.18	71.76	63.29	0.01	275.69
	5.62	6.66	69.97	63.25	0.03	262.85
	5.75	6.86	70.61	65.59	0.01	267.20
	5.91	7.06	71.34	60.85	3.53	272.55
	5.86	6.98	71.09	61.44	0.30	270.68
	5.77	6.86	70.70	61.43	3.75	267.85
AVE_{10}	5.82	6.93	70.93	62.42	1.28	269.57
AVE_{100}	5.72	6.80	70.44	62.16	1.70	266.27

APPENDIX J

SOME PHYSICAL PROPERTIES OF RICE

APPENDIX J

SOME PHYSICAL PROPERTIES OF RICE GROWN IN THE PHILIPPINES

This appendix presents the type, shape, total and head rice recovery of some rice varieties grown in the Philippines. Grain length and width was measured by the FAO recommended method of measuring the length and width of brown rice laid end to end and side by side, respectively, and dividing by the number of grain used. Milling recoveries were obtained under ideal conditions in the laboratory using rubber roll huller and three-stage stone whitening. The rice samples were grown under the same ideal field conditions.

APPENDIX J

SOME PHYSICAL PROPERTIES OF RICE GROWN IN THE PHILIPPINES

Variety	Type[1/]	Shape[2/]	Length/Width	Recovery	Head Rice
				p e r c e	n t
IR-12[3/]	II	bold	2.59	68.06	92.98
IR-20	II	bold	2.53	63.08	78.95
IR-26	II	bold	2.69	66.82	81.47
IR-28	I	slender	3.80	66.69	76.91
IR-30	II	bold	2.90	66.57	85.34
IR-32	I	slender	-	62.89	87.15
IR-34	I	slender	-	66.75	74.88
IR-36	I	slender	3.25	68.39	79.66
IR-38	I	slender	3.50	67.60	73.50
IR-42	II	bold	-	66.80	90.93
C-1[4/]	I	slender	3.27	66.99	83.38
BPI 76[5/]	II	bold	2.62	66.04	84.07
Wagwag	III	bold	2.36	65.90	87.30
Peta	I	bold	2.49	67.70	81.10
Milagrosa	III	bold	2.02	65.80	89.95

1/ Based on grain length: longer than 5.9 mm. (Type I); 5.0 to 5.9 mm. (Type II); shorter than 5.0 mm. (Type III)

2/ Based on length/width ratio (see Figure 3.15).

3/ IR stands for International Rice Research Institute .

4/ C stands for College of Agriculture.

5/ BPI stands for Bureau of Plant Industry.

APPENDIX K

RELATIONSHIP OF MILLING RECOVERY AND MOISTURE CONTENT AT MILLING

APPENDIX K

RELATIONSHIP OF MILLING RECOVERY AND MOISTURE CONTENT AT MILLING

This appendix presents the result of milling tests (milling recovery, rice and by-product composition) at different moisture contents and periods of storage after drying. There was a strong correlation between moisture content at milling and milling recovery. In general, the milling recovery dropped down as the moisture content went up beyond equilibrium moisture content (14 % wet basis). There was no control on the relative humidity during storage in this experiment.

APPENDIX K

Table K1. Milling recovery and percentages of different sizes[1] of grain and by-products of rough rice dried and stored with 13.0 per cent moisture

P E R C E N T

DATE OF MILLING	MILLING RECOVERY	POLISHED RICE [2]				BY-PRODUCTS			MOISTURE CONTENT AT MILLING
		Whole	3/4	1/2	1/4	M-B[3]	Bran	Hull	
One day after drying	69.90	58.85	2.06	4.11	4.06	1.08	7.11	21.78	13.07
58 days later	63.56	38.22	4.00	13.50	7.84	2.24	6.55	25.79	14.16
119 days later	62.86	35.91	3.38	13.52	10.47	2.09	10.47	23.06	13.72
173 days later	64.23	43.48	4.00	9.85	6.90	1.44	9.40	23.41	13.70
Average	65.14	44.13	3.36	10.24	7.20	1.71	8.38	23.51	13.66

Correlation coefficient (r) between milling recovery and moisture content = -0.62

1/ See reference no. 22

2/ Fraction of whole grain

3/ Germ and bran mixture

TABLE K2. Milling recovery and percentages of different sizes of grain and by-products of rough rice dried and stored with 13.5 per cent moisture

DATE OF MILLING	MILLING RECOVERY	POLISHED RICE				BY-PRODUCTS			MOISTURE CONTENT AT MILLING
		Whole	3/4	1/2	1/4	M-B	Bran	Hull	
One day after drying	68.24	58.40	1.85	4.53	3.46	1.28	7.95	21.73	13.52
58 days later	65.66	38.18	5.44	13.98	8.06	2.07	8.84	24.90	14.37
119 days later	63.37	32.95	4.20	14.67	11.55	1.94	10.56	23.31	14.10
173 days later	65.88	44.80	4.13	10.80	6.13	1.28	8.28	23.56	13.90
Average	65.54	43.58	3.90	11.00	7.05	1.64	8.91	23.38	13.97

Correlation coefficient (r) between milling recovery and moisture content = -0.56

TABLE K3. Milling recovery and percentages of different sizes of grain and by-products of rough rice dried and stored with 14.0 per cent moisture

DATE OF MILLING	MILLING RECOVERY	POLISHED RICE				BY-PRODUCTS			MOISTURE CONTENT AT MILLING
		Whole	3/4	1/2	1/4	M-B	Bran	Hull	
One day after drying	69.00	58.30	2.50	4.65	3.55	1.18	1.17	21.79	14.07
58 days later	64.94	38.03	4.86	14.14	7.92	2.27	8.13	25.65	14.65
119 days later	63.06	33.76	3.28	15.02	11.00	2.04	10.94	23.12	14.40
173 days later	65.50	42.55	5.60	11.00	6.35	1.20	8.66	23.37	14.16
Average	65.62	43.16	4.06	11.20	7.20	1.67	8.72	23.48	14.32

Correlation coefficient (r) between milling recovery and moisture content = -0.66

TABLE K4. Milling recovery and percentages of different sizes of grain and by-products of rough rice dried and stored with 14.5 per cent moisture

DATE OF MILLING	MILLING RECOVERY	POLISHED RICE				BY-PRODUCTS			MOISTURE CONTENT AT MILLING
		Whole	3/4	1/2	1/4	M-B	Bran	Hull	
One day after drying	68.82	58.50	2.47	4.88	2.97	0.95	7.16	22.08	14.52
58 days later	63.20	34.56	4.40	15.18	9.06	2.37	8.81	24.92	14.72
119 days later	63.13	32.74	4.06	16.21	10.12	2.06	10.64	23.19	14.68
173 days later	65.08	41.46	4.40	12.60	6.60	1.10	7.66	23.23	14.40
Average	65.06	41.83	3.84	12.22	7.19	1.65	8.57	23.23	14.56

Correlation coefficient (r) between milling recovery and moisture content = −0.58

TABLE K5. Milling recovery and percentages of different sizes of grain and by-products of rough rice dried and stored with 15.0 per cent moisture

DATE OF MILLING	MILLING RECOVERY	POLISHED RICE				BY-PRODUCTS			MOISTURE CONTENT AT MILLING
		Whole	3/4	1/2	1/4	M-B	Bran	Hull	
One day after drying	60.93	12.80	17.49	10.03	20.61	3.33	14.59	19.79	15.10
31 days later	61.86	18.56	15.53	14.61	13.17	3.68	8.27	25.17	14.96
79 days later	59.03	14.29	15.63	9.17	19.94	4.37	9.12	25.01	15.20
142 days later	58.02	15.62	16.53	9.76	16.11	4.58	11.04	24.05	13.86
Average	59.98	15.32	16.29	10.89	17.46	3.99	10.76	23.50	14.78

Correlation coefficient (r) between milling recovery and moisture content = +0.63

TABLE K6. Milling recovery and percentages of different sizes of grain and by-products of rough rice dried and stored with 15.5 per cent moisture

DATE OF MILLING	MILLING RECOVERY	POLISHED RICE				BY-PRODUCTS			MOISTURE CONTENT AT MILLING
		Whole	3/4	1/2	1/4	H-B	Bran	Hull	
One day after drying	61.33	233.87	14.29	11.44	11.73	2.45	12.77	21.41	15.55
31 days later	61.60	20.80	16.80	13.92	10.08	3.57	8.32	26.03	15.30
79 days later	59.00	13.48	14.92	12.56	18.04	4.20	8.80	25.36	15.42
142 days later	58.04	15.52	16.72	10.16	15.64	4.72	11.04	25.34	14.40
Average	59.99	18.42	15.68	12.02	13.87	3.74	10.23	24.52	15.17

Correlation coefficient (r) between milling recovery and moisture content = +0.73

TABLE K7. Milling recovery and percentages of different sizes of grain and by-products of rough rice dried and stored with 16.0 per cent moisture

DATE OF MILLING	MILLING RECOVERY	POLISHED RICE				BY-PRODUCTS			MOISTURE CONTENT AT MILLING
		Whole	3/4	1/2	1/4	M-B	Bran	Hull	
One day after drying	53.64	16.96	14.82	11.63	15.24	2.98	13.80	22.00	15.98
31 days later	58.98	13.97	19.04	13.49	12.48	4.48	8.32	26.40	15.25
79 days later	58.54	13.44	16.20	10.04	18.88	4.40	9.04	25.40	15.32
142 days later	58.39	19.94	15.89	8.64	13.92	4.80	10.88	24.64	13.55
Average	57.39	16.08	16.49	10.95	15.13	4.16	10.57	24.61	15.02

Correlation coefficient (r) between milling recovery and moisture content = -0.55

TABLE K8. Milling recovery and percentages of different sizes of grain and by-products of rough rice dried and stored with 16.5 per cent moisture

DATE OF MILLING	MILLING RECOVERY	POLISHED RICE				BY-PRODUCTS			MOISTURE CONTENT AT MILLING
		Whole	3/4	1/2	1/4	M-B	Bran	Hull	
One day after drying	56.48	13.49	18.19	13.47	13.33	3.04	11.39	25.52	16.73
31 days later	58.51	15.31	14.24	12.32	16.64	4.00	7.84	28.00	15.36
79 days later	59.40	18.56	11.52	11.94	17.38	3.84	8.85	25.54	15.40
142 days later	59.95	20.64	14.82	13.94	10.51	3.41	12.11	24.48	14.20
Average	58.58	17.00	14.69	12.92	14.46	3.57	10.05	25.88	15.42

Correlation coefficient (r) between milling recovery and moisture content = -0.94

APPENDIX L

TIME STUDIES ON RICE MILLS

APPENDIX L

TIME STUDIES ON RICE MILLING

Time studies were conducted on two commercial mills, namely, the Tobacco Industries of the Philippines Mill and the Mindanao Progress Corporation Mill. The purpose of the study was to validate the results of the simulation of milling time which were computed based on machine capacities and time delays due to filling up of the bins. The procedure consists of noting the time the paddy enters and leaves each particular machine. These times were indicated on each machine in the accompanying diagram starting with time equals zero at the intake of the mill. Note the big difference in processing time lag between the Philippine-built mill and the imported German mill. It took the rice to travel from intake to output 53 minutes or almost an hour in the Philippine mill while it took only 7 minutes for the imported mill.

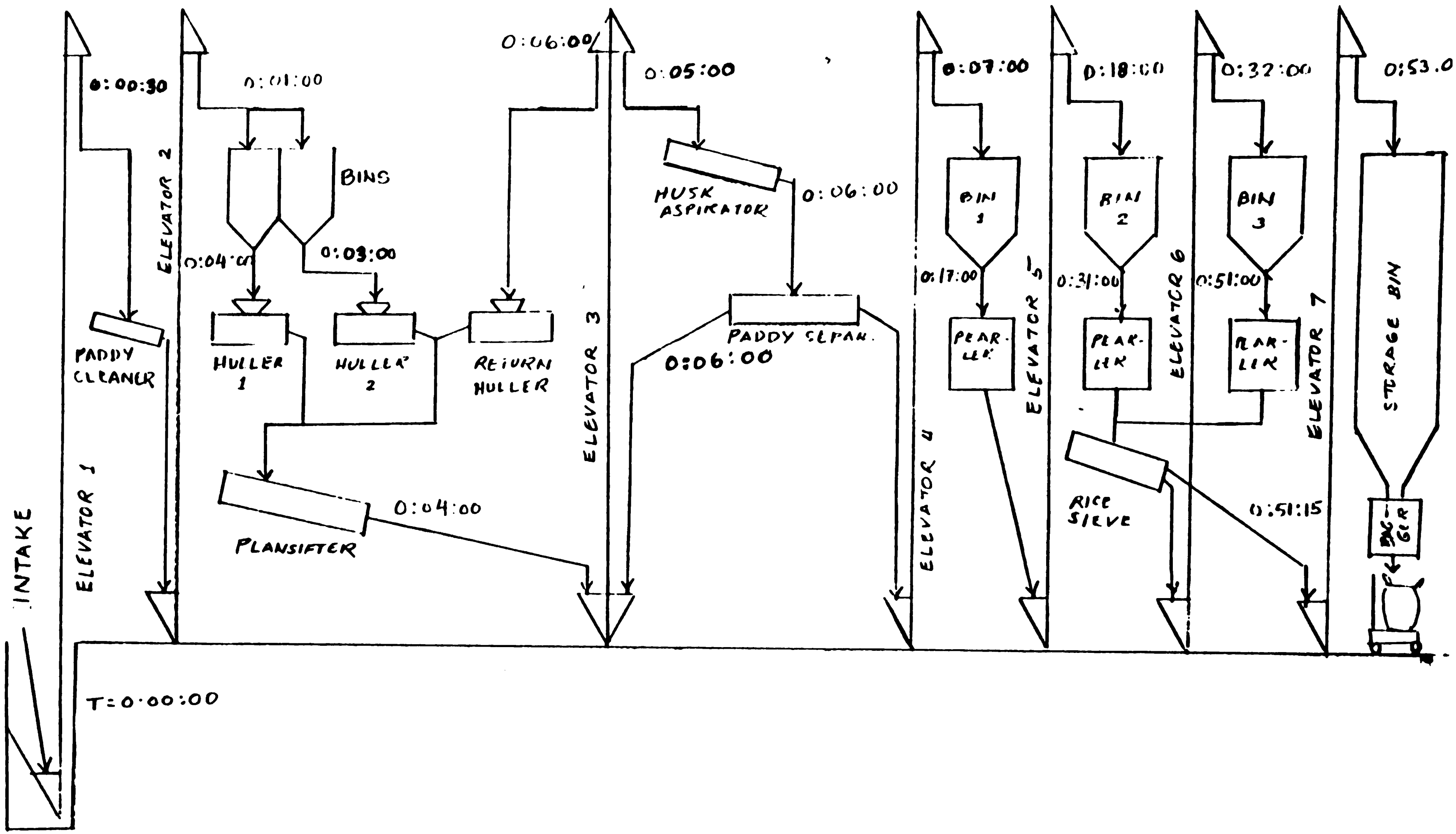

Figure L1 Time Study of a 2.5-ton per hour Rice Mill in the Philippines

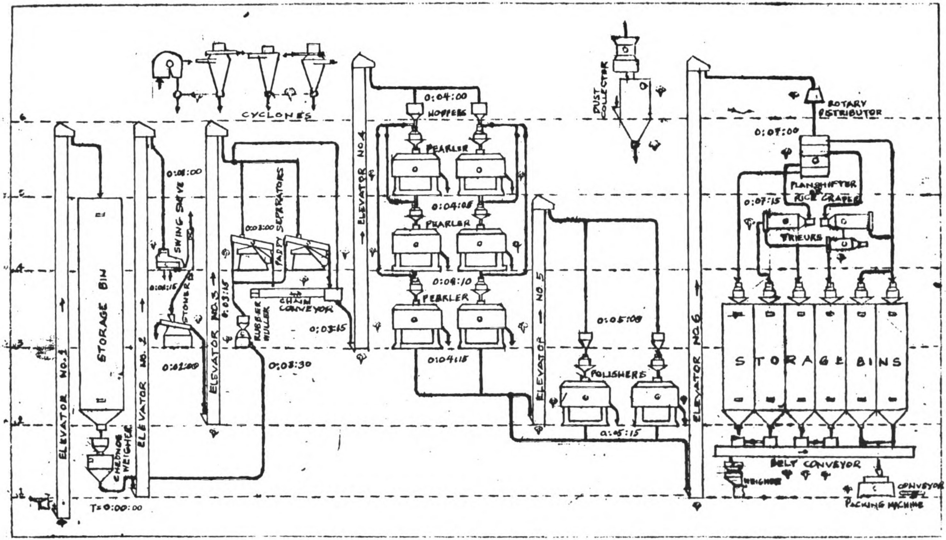

Figure L2. Time Study of a 6.25-ton per hour Rice Mill

APPENDIX M

LINEAR NETWORK ECONOMIC MODEL

COMPUTER PROGRAM

APPENDIX M

LINEAR NETWORK ECONOMIC MODEL COMPUTER PROGRAM

The following computer program is the computer implementation of the linear network equations. Statement no. 50 is for conventional disc-cone mills and statement no. 100 is for rubber roll equipped mills.

APPENDIX M

```
Ø REM* PROGRAM MILLING COST*
5 INPUT HT$ : INPUT Y1Ø
1Ø IF HT$ = "DISC" GOTO 65
15 YA = Ø.ØØØØØ48454* Y1Ø  (-.14)
2Ø YB = 1.8958* Y1Ø  Ø.41
25 YC = Ø.Ø485612* Y1Ø  (-.Ø7)
3Ø YD = Ø.Ø48863* Y1Ø  (.36)
35 YE = 2.922862* Y1Ø  (-.29)
4Ø YF = Ø.27699* Y1Ø  (-1)
45 YG = Ø.466497 * Y1Ø  (-.Ø8)
47 YH = ØØØØ7138* Y1Ø
5Ø X1Ø = (YA + YB + YC + YD + YE + YF + YG +YH)* Ø.ØØØ276 +  1.1180
55 PRINT "X1Ø ="; X1Ø
6Ø STOP
65 YA = Ø.ØØØØØ48454* Y1Ø  (-.14)
70 YB = 1.89580* Y1Ø  (Ø.41)
75 YC = Ø.Ø485612* Y1Ø  (-.Ø7)
80 YD = Ø.Ø48863* Y1Ø  (.36)
85 YE = 2.922862* Y1Ø  (-.29)
9Ø YF = Ø 27699* Y1Ø  (-1)
95 YG = Ø.466497* Y1Ø  (-Ø.08)
1ØØ X1Ø = (YA + YB + YC + YD + YE + YF + YG + YH +)* .ØØØ276  +  1.1062
1Ø5 PRINT "X1Ø = "; X1Ø
11Ø STOP
```

APPENDIX N

PHILIPPINE TRADE STANDARDS FOR RICE

APPENDIX N

PHILIPPINE TRADE STANDARD
SPECIFICATION FOR MILLED RICE
(Second Revision)
PTS 042-02; 1973

FOREWORD

This standard specification for Milled Rice is hereby promulgated under a fixed designation PTS (Philippine Trade Standard) No. 042-02; 1973.

This standard was revised due to the request of the National Grains Authority and upon the suggestion of the Technical Committee to up-date the standard specification and the definition of terms to suit the present trend in the rice industry. It also includes the weight per sack of rice to be 50 kilos in accordance with NGA Act.

Suggestions for revision should be addressed to the Bureau of Standards, P.O. Box 3719, Manila.

1. SCOPE

1.1 This standard specification covers milled rice produced in the Philippines, both for foreign and domestic trade.

2. DEFINITION OF TERMS

2.1 For the purpose of this standard, the following terms related to milled rice are hereby defined as follows:

2.1.1 Milled Rice - whole or broken kernels where the hulls and at least the outer bran layers and a part of the germ were removed.

2.1.2 Non-Glutinous Rice - generally translucent with greater amylose content than amylopectin and turns bluish when treated with potassium iodide-iodine solution.

2.1.3 Glutinous Rice - generally opaque, sticky when cooked, with high amylopectin than amylose con tent and turns reddish-brown when treated with potassium iodide-iodine solution.

2.1.4 Brewer or Binlid - portions of a kernel which will pass through a 4/64 sieve (1.587 mm.)

2.1.5 Broken kernels - milled rice smaller than head rice but larger than brewer or binlid.

2.1.6 Chalky kernels - kernels with 50% or more white portion.

2.1.7 Flinty kernel - kernel with less than 50% white portion.

2.1.8 Foreign Matter - impurities such as weed seeds, stones sand, dirt, etc. foreign to milled rice.

2.1.9 Head rice - whole kernels and those not less than 3/4 in size.

2.1.10 Kernel - edible portion of a paddy grain.

2.1.11 Milling degree - the extent or degree of polishing the rice kernel.

2.1.12 Other varieties - rice kernels of different variety/ies other than the variety under consideration.

2.1.13 Paddy or Palay - unhulled grain.

2.1.14 Red rice - rice with any degree of redness.

2.1.15 Yellow Kernel - yellowish milled rice due to fermentation or heat.

2.1.16 Damaged kernel - kernels attacked by micro-organisms, insects and/or other means.

3. CLASSIFICATION AND GRADING

3.1 Philippine milled rice shall be of the following type based on the length of the kernel.

3.1.1 Type I, Long grain - longer than 5.9 mm.

3.1.2 Type II, Medium grain - length ranges from 5.0 to 5.9 mm

3.1.3 Type III, Short grain - shorter than 5.0 mm

3.2 Each type shall be graded into sub-types according to the shape based on the length-width ratio.

3.2.1 Slender, Length-width ratio 3.0 or more
3.2.2 Bold, Length-width ratio ranges from 2.0 to 2.9
3.2.3 Round, Length-width ratio is less than 2.0

3.3 The description of the milled rice according to types and sub-types shall be taken collectively under the terms Grain type.

3.4 Rice shall be classified according to varietal names. See Appendix B.

3.5 Each group of milled rice shall conform to any of the following classes according to the degree of milling.

3.5.1 First Class - milled rice from which the husk, the germ, the outer and inner bran layers have been removed.

3.5.2 Second Class - milled rice from which the husk, germ, the outer and major part of the inner bran layers have been removed.

3.5.3 Third Class - milled rice from which the husk, a part of the germ and outer bran layer but not the inner bran layer has been removed.

3.5.4 Pinawa (brown rice) - milled rice from which only the husk and part of the germ has been removed.

3.6 Each class of milled rice shall be graded according to the following description.

3.6.1 Premium Grade - Head rice not less than 95%, not more than 5% of which are 3/4 kernels, broken 4%; Binlid 1%, yellow and damaged, 0.5% chalky and immature kernels - 2%, Paddy-none, other varieties - 2.0%, Red rice - none, and Foreign matter - none.

3.6.2 Grade I - Head rice not less than 85%, not more than 5% of which are 3/4 kernels, broken - 12%, binlid - 3%, yellow and damage - 1.0%, chalky and immature kernels - 4%, Paddy - 1 grain/100 grams, other varieties - 4%, Red Rice - 0.50% and foreign matter - 0.25%.

3.6.3 Grade II - Head rice not less than 75%, not more than 5% of which are 3/4 kernels, broken 20%, binlid 5%, yellow and damaged - 2%, chalky and immature - 6% Paddy - 2 grains/100 grams, other varieties - 6%, Red Rice 1.0% and Foreign matter 0.5%.

3.6.4 Grade III - Head rice not less than 65%, not more than 5% of which are 3/4 kernels, broken 28%, Binlid - 7%, yellow damaged - 4%, chalky and immature kernels - 8%, paddy 3 grains/100 grams, other varieties 8%, Red Rice 1.5% and Foreign matter 1.0%.

4. GENERAL REQUIREMENTS

4.1 Moisture content shall not exceed 14%.
4.2 It shall be free from unpleasant and/or repulsive odor.
4.3 It shall be free from insect infestation.
4.4 The unit of trading shall be by weight expressed in kilograms or metric tons.

5. PACKING

5.1 Milled rice shall be packed in new or good used Hessian cloth bag, jute gunny or plastic sacks without patches and weighing 50 kilograms not to afford maximum protection from normal hazard of transportation and handling. Smaller packages may be allowed provided the net weight shall be in full kilograms of 1, or multiple or 5 kilograms subject to buyer/seller agreement.

6. MARKING

6.1 Each bag shall be properly labelled with the following information:

a) Type & Subtype; variety, class and grade
b) Name and address of miller
c) Net weight in kilograms
d) Crop year and date of milling

7. SAMPLING

7.1 Ten percent (10%) of the total number of bags should be sampled but in no case should the number of bags sampled be less than five (5) bags.

7.2 Each probe or handfull of sample drawn is called the primary sample. The combined primary samples is called composite sample. When a composite sample has been properly reduced, it is called the submitted sample. A sample obtained from the submitted sample is called working sample.

7.3 The submitted sample shouldcarry the following information:

7.3.1 Name and Address of owner
7.3.2 Variety
7.3.3 Lot number
7.3.4 Number of bags in the lot
7.3.5 Crop year & Date of milling
7.3.6 Date of sampling
7.3.7 Name of inspector

7.4 Preparation of the working sample - samples received in the laboratory are reduced to a working sample. The sample submitted shall be repeatedly divided so that the working sample will be the representative of the original. An efficient divider must to used on in the absence of a mechanical divider.

8. TEST METHOD

8.1 Grading Test - Weigh about 100 grams of milled rice from the representative sample. The head rice shall be separated from other extraneous matters and weighed to determine the percentage.

8.2 Moisture content determination - the moisture content of milled rice shall be determined by using a properly calibrated moisture tester or by oven drying. In case of air-oven method the temperature should be maintained at $105^{\circ} \pm 0.1^{\circ}C$.

8.3 Potassium iodide-iodine test - In case of doubt whether a variety is glutinous or not, a KI-I test shall be made on the kernels.

9.

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9. EFFECTIVITY

9.1 This Standards Administrative Order shall take effect 20 days after completion of its publication in the Official Gazette.

(SGD.) VIDALITO F. RANOA
Officer-in-Charge

RECOMMENDED BY:

(SGD.) MARIO R. REYES
(Administrator, NACIDA)
Officer-in-Charge
Office of the Undersecretary of Trade
Chairman, Philippine Standards Council

A P P R O V E D : January 21, 1973
(Date)

(SGD.) TROADIO T. QUIAZON, JR.
Secretary of Trade

STANDARD GRADE REQUIREMENTS FOR
*** PHILIPPINE MILLED RICE ***

		Premium Grade %	Grade I %	II %	III %
1.	Head Rice	95 Min.	85.0 Min.	75.0 Min.	65.0 Min.
2.	Brokens	4 Max	12.0 Max.	20.0 Max.	28.0 Max.
3.	Binlid (Passes through Sieve 4/64)	1	3.0 "	5.0 "	7.0 "
4.	Yellow & damaged	0.5	1.0 "	2.0 "	4.0 "
5.	Chalky & Immature kernels	2.0	4.0 "	6.0 "	8.0 "
6.	Paddy (No./100 grams)	None	1 "	2 "	3 "
7.	Other varieties	2	4 "	6 "	8.0 "
8.	Red Rice	None	0.50 "	1.0 "	1.5 "
9.	Foreign Matter	None	0.25 "	0.5 "	1.0 "

PHILIPPINE TRADE STANDARD SPECIFICATION FOR PALAY (ROUGH RICE)
PTS 042-01.02; 1968

FOREWORD

This standard specification for Philippine Palay or Rough Rice is hereby promulgated under a fixed designation PTS (Philippine Trade Standard) No. 042-01.02: 1968. This standard was formulated by the Philippine Standards Council, in order to fix a uniform basis of determining quality. The cooperation of the Rice and Corn Administration, Rice and Corn Board, U. P. College of Agriculture, Bureau of Plant Industry, International Rice Research Institute, Rice and Corn Production Coordinating Council, Agricultural Productivity Commission, Araneta University Foundation, and Greater Manila Rice and Corn Association, were in a large measure responsible for the formulation of this Standard.

Suggestion for revision should be addressed to the Bureau of Standards, P. O. Box 3719, Manila, Philippines.

1. SCOPE

1.1 This standard covers the system of classifying and grading palay of Philippine origin.

2. DEFINITION OF TERMS

2.1 For the purpose of this specification, the following terms are hereby defined:

2.1.1 Rough rice - Those which contains 50% or more of unhulled kernels.

2.1.2 Foreign matters - These are impurities such as stones and sand but excluding weed seeds.

2.1.3 Immature kernels - Those which are mostly green and/or chalky.

2.1.4 **Damaged kernels — Those which are** distinctly discolored or damaged by water, insects, heat or any other means.

2.1.5 Other varieties - Those kernel which differ distinctly from the characteristics of the palay under consideration.

2.1.6 Fermented kernels - Those which are yellowish or otherwise discolored.

2.1.7 Cracked kernels - Those which are either cracked or broken.

2.1.8 Red rice - Those palay, the kernels of which are red.

2.1.9 Weed seeds and other crop seeds - All seeds which are other than palay.

2.1.10 Moisture content - This is the water content of the grain computed on wet basis, as received.

2.1.11 Percentages - These are quantities expressed in weight.

3. GENERAL REQUIREMENTS

3.1 It shall be free from such foreign odors as mouldy ground, insect, rancid, sharp acrid and chemical, which are common to unsound rice.

3.2 It shall be free from live insect infestation.

3.3 The unit of trading shall be by weight expressed in kilograms or in metric tons.

4. CLASSIFICATION AND GRADING

4.1 Palay varieties shall be classified in accordance with the length of the kernel.

4.1.1 The types of palay based on the length of the brown kernel shall be the following:

Type I - Long grain - the length of the kernel is above 6.5 mm.

Type II - Medium grain - the length of the kernel ranges from 5.5 mm. to 6.5 mm.

Type III - Short grain - the length of the kernel is below 5.5. mm.

4.2 Each type of palay shall be grouped as follows:

4.2.1 Fancy - the kernels have a flinty uniform appearance, shiny, translucent or creamy white.

4.2.2 Special - the kernels exhibit a desirable uniform white, creamy white or gray color.

4.2.3 Ordinary - the kernels exhibit a white to dull white or light gray color.

4.2.4 Inferior - 1. Milled rice with colored pericarps regardless of cooking characteristics and translucency.

2. Milled rice which are discolored due to handling and storage.

4.3 Each group of palay shall be graded according to the result of analysis as follows:

4.3.1 Grade I - Palay having at least 98% purity, foreign matter not more than 2%, weed seeds none, immature kernels none, damaged grains 2%, cracked kernels 3%, other varieties 3%, fermented kernels none, red rice trace, moisture content not exceeding 14%.

4.3.2 Grade 2 - Palay having at least 96% purity, foreign matter not more than 4%, weed seeds none, immature kernels 2%, damaged kernels 3%, other varieties 5%, cracked kernels 4%, fermented kernels 0.5%, red rice 1%, moisture content not exceeding 14%.

4.3.3 Grade 3 - Palay having at least 94% purity, foreign matter not more than 6%, weed seeds trace, immature kernels 4%, other varieties 8%, damaged kernels 4%, cracked kernels 5%, fermented kernels 1%, red rice 2%, moisture content not exceeding 14%.

4.3.4 Grade 4 - Palay having at least 92% purity, foreign matter not more than 7.75%, weed seeds 0.25%, immature kernels 7%, damaged kernels 6%, other varieties 12%, fermented kernels 2%, red rice 3%, cracked kernels 6%, moisture content not exceeding 15%.

4.3.5 Grade 5 - Palay having at least 90% purity, foreign matter not more than 9.5%, weed seeds 0.5%, immature kernels 10%, damaged kernels 8%, other varieties 17%, fermented kernels 3%, red rice 4%, cracked kernels 7%, moisture content not exceeding 15%.

4.3.6 Sub-standard grade - Palay that would not meet any of the above requirements but the moisture content shall not exceed 16%.

5. PACKING AND MARKING

5.1 Packing

5.1.1 Palay shall be packed in jute, gunny sacks or in similar protective containers, weighing 50 kilograms net on the basis of 14% moisture content.

5.2 Marking

5.2.1 Each bag shall be properly labelled in big letters with a suitable tag measuring approximately 18 x 12 cm., containing the following information:

5.2.1.1 Province where grown and crop year
5.2.1.2 Type, group, variety and grade
5.2.1.3 Name and address of warehouse
5.2.1.4 Net weight in kilograms

6. SAMPLING

6.1 Samples are drawn from the lot with the use of sampling instruments like the Stick Trier or Sleeve-type Trier or Hobbe Trier. When there are 10 bags or less, each bag shall be sampled. If there are more than 10 bags but not exceeding 100 bags at least every tenth bag but not less than 10 bags shall be sampled. If a lot contains more than 100 bags, at least 10% of the number of bags shall be sampled at random.

6.2 When a lot is sampled, several individual samples are drawn from different places in the bulk. Each probe or each handful of sample is called the primary sample. All primary samples drawn are combined in a suitable container. This combined primary sample is called the composite sample.

When the composite sample has been properly reduced, it is called the submitted sample. This sample is submitted to the laboratory for quality tests. The reduced sample, obtained from the submitted sample, is termed as working sample.

6.3 The sampling shall be done at random from top middle and bottom of each container. The inspector shall be responsible for sampling the entire lot and the submitted samples should carry the following information:

6.3.1 Name and address of owner

6.3.2 Variety name

6.3.3 Lot number

6.3.4 Number of bags in the lot

6.3.5 Date harvested

6.3.6 Name of inspector

6.4 Preparation of the working sample - Samples received in the laboratory are reduced to a working sample. The sample submitted shall be repeatedly divided so that the working sample will be as representative as the original. An efficient divider must be used.

6.4.1 Use of Mechanical Divider - The equipment usually used is the Boerner Sample Divider. The sample is emptied into a hopper at the top of the divider and released by a hand lever to let it flow over an inverted cone. It passes through a series of slots around the circumference of the cone and falls into two chutes. At the mouth of each chute is a bucket into which half of the sample runs. The sample is divided into approximately equal halves again and again until it is about 1 kilogram.

6.4.2 Halving Method - In the absence of a mechanical sample divider, the halving method will be used. The submitted sample is repeatedly divided until about 100 grams of the quantity remains.

7. INSPECTION

7.1 Destination Inspection - When the palay is passed through points other than destination, the contract may require that

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the palay be inspected at destination for quantity and quality.

7.2 At the time of loading palay for foreign trade, shipping weights shall be taken and certified before the inspectors of the Bureau of Standards or a government weigher in the locality.

8. TEST METHODS

8.1 Grading Test - Weigh about 100 grams of palay from the representative sample. The palay shall be separated from other extraneous matters and weighed to determine the percentages.

8.2 Moisture content determination - The moisture content of palay shall be determined by using a properly calibrated moisture tester.

8.2.1 Brown-Duvel Moisture Tester - Duplicate samples of 100 grams each are taken from thoroughly mixed palay sample. Each weighed sample is transferred into the flask of the tester which is then filled with 450 c.c. of the Brown-Duvel testing oil (Spica oil has similar properties.) A thermometer is inserted through the stopper of this flask. Four-fifths of the mercury bulb of the thermometer should be submerged in the sample and the oil. After tightly fitting the stopper, the flask is connected to the condensing tube of the tester. Heat is applied until the cut-off temperature or 210°C, is reached. The moisture distilled off is collected in a clean, dry graduated cylinder. The amount of moisture collected will determine directly the percentage of moisture content of the sample. It is read after the temperature has gone down to 160°C (as prescribed in the direction for using the Brown Duvel Moisture Tester).

8.2.2 Air-Oven Method - Two to five grams of the sample are ground and weighed in a weighing bottle with a constant weight. The powdered sample is placed in an electric oven 5 hours at a temperature of 130°C. Then it is allowed to cool inside a dessicator and weighed afterwards. The percentage moisture content is computed on the wet basis.

9. EFFECTIVITY

9.1 This Standards Administrative Order shall take effect upon its approval.

(SGD.) R. E. RACELA
Director

JA/TQB/lpl

RECOMMENDED BY:

(SGD.) CESAR A. VIRATA
(Undersecretary of Industry)
Chairman, Philippine Standards Council

APPROVED: July 19, 1968

(SGD.) MARCELO S. BALATBAT
Secretary of Commerce and Industry

STANDARD GRADE REQUIREMENTS FOR ROUGH RICE

Grade	Purity (Max. %)	Foreign Matter (Max. %)	Weed & Other Crop Seed (Max. %)	Cracked Kernels (Max. %)	Immature Kernels (Max. %)	Damaged Kernels (Max. %)	Other Variety (Max. %)	Fermented Kernels (Max. %)	Red Rice (Max. %)	Moisture Content (Max. %)
1	98	2	None	3	None	2	3	None	Trace	14
2	96	4	None	4	2	3	5	0.5%	1	14
3	94	6	Trace	5	4	4	8	1	2	14
4	92	7.75	0.25	6	7	6	12	2	3	15
5	90	9.5	0.5	7	10	8	17	3	4	15

Palay + F. M. + Seeds = 100%

VARIETY
CLASSIFICATION OF GRAIN AS TO GROUP AND SIZES

Type I – Long Size Grain

Fancy	Special	Ordinary
1. None	1. Tjeremas	1. Ramadia
	2. Intan	2. Peta
	3. Bengawan	
	4. Ac 440 Dr. 260	
	5. Azucena	
	6. BPI – 121	
	7. Raminad Str. 3	

Type II – Medium Size Grain

Fancy	Special	Ordinary
1. Milflor	1. B E – 3	1. Peta
	2. BPI – 76	2. I R – 8
	3. Macapagal	3. Macan
	4. Raminad	4. Kinandang Puti
	5. 12 – 36	5. Kinandang Pula
	6. Bencer	6. Ramai
	7. Sinampablo	7. Palawan
	8. Seraup Ketchil	
	9. Kinanda	
	10. Elon-Elon	
	11. C – 18	
	12. Milbuen	
	13. Dinalaga	

Type III – Short Size Grain

Fancy	Special	Ordinary
1. Milagrosa	1. Hinumay	1. Binato
2. Wagwag		2. Palagad Imus
3. Minantika		3. Ninoro
		4. Mangarez
		5. Macan – 700

FUNCTIONS OF THE BUREAU OF STANDARDS PURSUANT TO REPUBLIC ACT 4109

1. To formulate and promulgate rules and regulations for the establishment of standard specification for Philippine products, codes, and methods of tests, subject to the approval of the Secretary of Commerce and Industry.

2. To inspect and sample in order to determine if, and to certify that, the products satisfy the requirements as to kind, class, grade or standard of any of the products, before the government, including government owned or controlled corporations, make a purchase and/or producer manufacturer and/or dealer offers for sale any commodity which affects the life, health and property of the people.

3. To inspect and sample in order to determine the standard commodities for which a standard has been promulgated and approved and to certify the inspection and standard thereof as conforming to the standard set, before it is sold and/or disposed of in any manner, either for local distribution and/or for export abroad.

4. To inspect and sample commodities projected for shipment abroad for which no standard has or shall have as yet been established in order to determine if, and to certify that, the whole shipment satisfies the buyer's or importer's requirement as to kind, class, grade, quality or standard.

5. To inspect, sample and certify to the quality of commodities imported into the Philippines to determine the country of origin and to determine if they satisfy the buyer's or importer's requirements or specifications for domestic consumption.

6. To confiscate any article which are the growth, raw materials, manufacture, process or produce of countries without trade relation with the Republic of the Philippines.

7. To fix and collect fees for the services of inspection and/or testing or analysis of commodities, and for other services.

ADVANTAGES AND PURPOSE OF STANDARDIZATION

Standardization:

a. Helps in increasing the productivity of industry of which economic progress ultimately depends.

b. Improves quality of products continuously, for in standardization, technical knowledge applied is recorded from which to base the desired improvement.

c. Promotes scientific research and improves basic knowledge in physical constants and properties of materials.

d. Effects economy on the use of labor, materials and time; thus reduces costs of goods and services.

e. Conserve efforts that would otherwise have to be used in rediscovering and reinventing elements involved in quality and production of goods.

f. Eliminates needless variation of types, sizes, designs, or excessive quality, which lead in turn to production and distribution economics, and brings dividends through such simplification.

g. Makes possible the use of cheaper materials, eliminates painstaking production steps, reduces inspection requirement, and makes possible employment of simpler equipment and operation.

h. Prevents waste of efforts among competing establishments in their duplicating or even in their conflicting system of standards.

i. Make possible interchangeability of component parts, assemblies and complete products; thus facilitating repair and replacement, amking possible long-run highly repetitive manufacturing.

j. Gives buyers adequate reliance on the consistent quality of standardized products, thus simplifying purchase or sale thereof or facilitating the consummation of business transaction.

k. Promotes truthful branding and advertising of goods and services by providing suitable safeguards against the use of confusing or spurious elements just for purposes of huge, though shortrange, profit motive.

APPENDIX O

NORMAL VALUES OF LOS BANOS
WEATHER DATA

APPENDIX O

NORMAL VALUES OF LOS BANOS WEATHER DATA

Appendix Table 01 gives the normal (mean) values of weather elements in Los Banos which is included in the Southern Luzon type of weather. This table was used in determining the variation of relative humidity on a month to month basis.

APPENDIX O

TABLE 01. Normal Values of Los Banos Weather Data

ELEMENTS	TEMPERATURE[1] °C						RAINFALL[1]				R.H.[2]	WIND			DAY LENGTH	SOLAR RADIATION[6]
MONTH	Max.	Min.	Mean	Highest	Lowest	Day/Yr. Highest / Lowest	Amount (mm)	No. of Rainy Days	Greatest 24-hour (mm)	Date Day/Year	Per cent (%)	Prevailing Direction[3]	Speed[4] (kph)	Fastest[5] Speed D'tion	Hours	Langley/Month
January	28.4	21.6	25.0	33.4	15.6	20/56 / 11/71	53.8	12	98.0	1/57	84	NE	5.6	43-NE	353.30	345
February	29.6	21.6	25.6	36.3	16.6	4/72 / 13/68	24.1	7	33.8	25/60	80	NE	6.0	39-E	338.67	420
March	30.7	22.4	26.5	36.2	16.7	25/61 / 7/72	30.2	6	67.1	12/71	78	NE	6.1	43-S	373.74	487
April	33.2	23.4	28.3	37.2	18.2	28/59 / 4/63	37.6	6	56.4	24/75	78	NE	5.8	56-W	373.39	549
May	33.5	24.1	28.8	37.8	20.6	22/58 / 23/48	153.4	12	276.1	27/60	80	NE	5.5	64-SW	395.98	497
June	32.2	24.0	28.1	37.2	20.4	1/70 / 24/52	217.4	17	321.6	29/64	84	SE	4.3	105-W	388.18	437
July	31.1	23.8	27.4	35.0	20.0	23/55 / 8/61	279.6	21	209.8	20/72	85	VRBL	4.8	69-W	398.63	394
August	30.3	23.7	27.0	34.8	20.6	15/71 / 31/74	264.4	20	249.4	10/47	85	SW	4.5	48-SW	390.03	365
September	30.8	23.6	27.2	35.0	20.4	1/57 / 8/59	243.6	20	180.3	15/62	86	VRBL	4.2	64-W	365.29	379
October	30.5	23.4	27.0	34.5	18.8	9/51 / 10/59	247.4	18	178.6	16/60	86	NE	4.7	88-SE	366.46	369
November	29.4	23.0	26.2	34.0	18.6	3/56 / 25/74	276.6	18	257.8	4/67	86	NE	5.6	121-NW	344.71	320
December	28.5	22.5	25.5	32.8	17.7	8/72 / 29/58	167.1	17	166.9	25/71	86	NE	5.2	46-S	350.88	289
ANNUAL	30.7	23.1	26.9	37.8	15.6	5/22/58 / 1/11/71	1995.2	174	321.6	6/29/64	83	NE	5.2	121-NW	370.02	40[illegible]

[1] Normal for 51 years.
[2] Normal for 22 years.
[3] Normal for 39 years.
[4] Normal for 44 years.
[5] Normal for 21 years.
[6] Normal for 17 years.

APPENDIX P

ECONOMIC VARIABLES USED IN THE NETWORK EQUATIONS

APPENDIX P

TABLE P1. Capital Investment for Rubber Roll Mills, 1976-77[1/]

CAPACITY	CAPITAL INVESTMENT LAND	BLDG.	MACHINE & EQUIPMENT	TOTAL	FIXED COST INTEREST[2/]	DEPRECIATION[3/]	OTHERS[4/]	TOTAL ANNUAL FIXED COST
kg./hr.	Dollars				Dollars			
350-500	807.97	5,040	13,160	19,007.97	3,421.43	1,568.00	72.03	5,061.46
500-650	1,737.03	12,800	15,512	330,049.03	5,408.83	2,191.00	150.00	7,749.43
1000-1200	2,424.05	20,000	17,999	40,423.05	7,276.15	2,800.00	184.05	10,260.15

1/ Prices quoted by Mechanical Factors, Manila, Philippines (authorized distributor of Satake Engineering Co., Ltd. Tokyo, Japan). Cost of land = \$2.03 per sq. m. and Bldg. cost = \$ 40.54 per sq. m.

2/ Interest = 18 percent per annum.

3/ Depreciation: straight line method with no salvage value (10 years life for mill machinery and equipment; 20 years life for building).

4/ Others include taxes, fees, licenses, insurance, etc.

TABLE P3. Capital Investment for Conventional Mills, 1976-77[5/]

CAPACITY	CAPITAL INVESTMENT LAND	BLDG.	MACHINE & EQUIPMENT	TOTAL	FIXED COST INTEREST	DEPRECIATION	OTHERS	TOTAL ANNUAL FIXED COST
kg./hr.	Dollars				Dollars			
250-350	807.97	5,040.00	7,553.92	13,300.95	2,394.05	1,007.03	72.03	3,472.97
500-600	1,737.03	12,800.00	15,675.95	30,212.97	5,457.97	2,207.97	150.00	7,795.95
850-1000	2,424.05	20,000.00	20,275.95	42,700.00	7,685.95	3,027.97	184.05	10,897.97

5/ See Reference No. 5

TABLE P2. Variable Costs per month for Rubber Roll Mills, 1976-77.[1/]

CAPACITY	FUEL & LUBE	REPAIR & MAINTENANCE		LABOR	TOTAL MONTHLY VARIABLE COST	VARIABLE COST/TON[2/]
kg./hr.	D O	L Import	L Local	A	R	S
350 - 500	189.90	163.63	189.39	127.87	439.17	6.35
500 - 650	300.67	240.87	250.60	312.78	725.12	5.04
1,000 - 1,200	555.05	167.34	254.90	459.79	1,111.72	4.39

1/ See Reference No. 5
2/ Repair and Maintenance plus Labor Cost.

TABLE P4. Variable Cost for Conventional Mills, 1976-77[3/]

CAPACITY	FUEL & LUBE	REPAIR & MAINTENANCE	LABOR	TOTAL MONTHLY VARIABLE COST	VARIABLE COST/TON
kg./hr.	D O	L L	A	R S	
250 - 350	45.91	39.41	48.59	133.91	5.09
500 - 600	47.80	25.84	56.30	130.00	4.20
850 - 1,000	249.00	58.50	446.00	753.70	3.09

3/ See Reference No. 5

APPENDIX P

Table P5. Revenue and profit per ton for alternative milling systems,[a] Bicol River Basin area, 1976-77.

Milling system	No. of obser-vation	Milled rice output[b] (t/mo.)	Milling fee ($/t)[c]	Revenue from milling ($/mo.)	Revenue per ton ($/t)	Actual	Utilization rate 25%	50%	75%	100%
						Profit/t ($/t)[d]				
Steel huller	4	8.5	13.51	114.86	8.36	(2.43)	1.46	3.36	3.96	4.27
Rubber roll single pass	1	11.9	13.51	160.81	9.12	(4.18)	(4.18)	.22	1.82	2.53
Rubber roll-steel huller combination	1	47.8	13.51	645.95	9.24	2.74	2.55	1.34	2.74	3.34
Multiple steel huller	1	5.9	13.51	79.73	8.57	(9.53)	(2.34)	.97	2.16	2.66
Stone disc-steel huller combination	1	4.4	13.51	59.46	8.50	(17.41)	(1.0)	1.50	2.50	2.91
Centrifugal huller	1	6.6	13.51	89.19	8.59	(13.11)	(1.0)	.89	1.50	1.84
Cone type (av.)	(3)	56.3	13.51	760.81	9.03	(2.27)	(9.84)	(2.47)	.03	1.32
large	1	162.6	13.51	2197.30	8.92	2.12	(8.47)	(1.27)	1.03	2.23
medium	1	21.0	13.51	283.78	9.12	(15.99)	(10.08)	(2.58)	(.08)	1.12
small	1	17.6	13.51	237.84	9.05	(6.99)	(12.74)	(4.45)	(1.64)	.24

a/ Revenue is derived from milling fee only.

b/ Paddy input x milling recovery from monitoring data.

c/ In actual practice rubber roll mills are charging $0.003/kg higher than other mills.

d/ profit/t = revenue/t - total costs/t; values in parentheses indicate that the mill incurred losses.

APPENDIX Q

COST OF RUBBER ROLLS

APPENDIX Q

TABLE Q1

VACU-LUG PHILIPPINES, INC.
Industrial Products Department
Dealer's Price List

RICE HULLER RUBBER ROLLS
As of May 1, 1978

DRUM TYPE

WIDTH (INCHES)	OUTER DIAMETER INCHES	OUTER DIAMETER MM.	INNER DIAMETER INCHES	INNER DIAMETER MM.	RUBBER THICKNESS INCHES	RUBBER THICKNESS MM.	NUMBER OF BOLT HOLES	INSERT TRADE-IN VALUE	COMPLETE RUBBER ROLL PRICE/PIECE
2.5	6-1/8	155.5	4-5/8	117.5	3/4	19.1	3	₱ 2.00	₱ 50.00
3.0	6.0	152.4	4-1/2	114.3	3/4	19.1	3	3.00	55.00
4.0	8-3/4	222.3	7-1/4	184.2	3/4	19.1	3	4.00	100.00
6.0	8-3/4	222.3	7-3/16	182.6	3/4	19.1	3	6.00	120.00
8.0	10.0	254.0	8-1/4	209.6	7/8	22.2	4	8.00	220.00
10.0	10.0	254.0	8.0	203.2	1.0	25.4	4	10.00	290.00
STEEL TYPE									
10.0	10-1/8	257.2	8-1/8	206.4	1.0	25.4	*	6.00	₱ 290.00
	*Width of key--------		7/8	22.3	2-1/8	54.0-Distance of Screw Holes from Rim Edge			
	Height of key-------		3/8	9.5	5-3/4	146.1-Center to Center Distance of Screw Holes			
SPECIAL (CHINA RICE MILL) STEEL TYPE									
8.0	8-1/2	215.9	6-1/2	165.1	1.0	25.4	*	8.00	₱ 245.00
	*Length of keyway---		1-1/4	31.8	1.8	3.2-Depth of keyway			
	Width of keyway----		1/4	6.4	1-1/4	31.8-Distance Bore from Rim Edge			

TRADE-IN ACCEPTANCE OF INSERTS is subject to the set standards particularly that they are not extensively corroded, distorted, dented or broken; and, That the bolt holes are not destroyed, chipped or oversized.

ALL PRICES ARE SUBJECT TO CHANGE WITHOUT PRIOR NOTICE. PRICES FOR OTHER SIZES AND TYPE OF ROLLERS NOT SHOWN ABOVE MAYBE MADE AVAILABLE UPON REQUEST. PRICES ARE F.O.B.-METRO MANILA. FREIGHT CHARGES EQUIVALENT TO THE INSERT TRADE-IN VALUE WILL BE APPLIED TO DELIVERIES OUTSIDE METRO MANILA.

Executive Offices : 2nd Floor, Vinnell-Belvoir Bldg.
2322 Pasong Tamo Ext., Makati,
Metro Manila, Tel. 85-40-56
Cable : Vacu-Lug Makati
Cebu Dist. Offices : Km. 12 National Road,
Barrio Linao, Talisay, Cebu
Tel. 7-96-38 / 7-80-20
Cable : Vacu-Lug Cebu

WAREHOUSES SERVICE OFFICES	TELEPHONE
San Fernando, Pampanga	38-11
Santiago, Isabela	
Magsaysay Street, Naga City	
Singcang, Bacolod City	2-95-50
Lapasan, Cagayan de Oro City	48-50
Butuan City	21-29
Bajada, Davao City	7-91-69

APPENDIX Q

TABLE Q2

Specifications and Prices of Rubber Rolls (1976)[1/]

Type	Width in	Width mm	Dia. mm	RPM Fixed Roll / Movable Roll	Power P.S.	Capacity tons/hr	Durability (tons paddy per pair) Satake Rubber Rolls (Japan): Japan clean, short	Satake Rubber Rolls (Japan): Asia unclean, long	Satake Rubber Rolls (Japan): U.S.A. clean, long	Organo (India) Asia long grain clean	Local Price Marvex Commercial FOB, Manila Unit Price
25	2.5	63	165		1-2	0.4-0.6	30	15	-	-	₱ 35.00
30	3.0	76	165	1200/900	-	[illegible]	35	20	-	-	50.00
40	4.0	100	222		-	1.3-1.7	75	40	-	-	55.00
60	6.0	150	222	1320/900	3-4	1.8-2.8	110	60	-	35	65.00
80	8.0	200	250	1000/740	-	2.3-2.6	240	140	-	50	-
100	10.0	250	250		8-10	3.1-4.4	300	170	260	80	1 60.00

[1/] See reference no. 23

APPENDIX R

PADDY PLANTING AREA
IN THE PHILIPPINES

APPENDIX R1

Palay (Rough Rice) Planting Area in 1977 Compared with that in 1976 By Region, Philippines

Region	Cropyear 1977	Cropyear 1976	Increase/ (decrease) (percent)
	(hectare)		
Philippines	3,547,500	3,579,320	(0.9)
Ilocos	310,860	342,590	(9.3)
Cagayan Valley	432,600	418,700	3.3
Central Luzon	412,210	464,720	(11.3)
Southern Tagalog	456,120	461,080	(1.1)
Bicol	334,410	338,590	(1.2)
Western Visayas	474,170	448,730	5.7
Central Visayas	88,000	89,600	(1.8)
Eastern Visayas	180,530	181,200	(0.4)
Northern Mindanao	157,810	163,840	(3.7)
Southern Mindanao	164,700	162,840	1.1
Central Mindanao	392,480	367,140	6.9
Western Mindanao	143,610	140,290	2.4

Source: Bureau of Agricultural Economics

APPENDIX S

RICE MILL STATISTICS

IN THE PHILIPPINES

APPENDIX S1

STATISTICS ON THE RICE INDUSTRY IN THE PHILIPPINES

Statistical Data Based on an Early 1973 Survey

E – Engleberg Rice Milling Unit
C – Commercial Rice Mill (Cono Type)

Name of the Province	Total Riceland in Hectare	Number of Farmer Families	Cooperatives		Rice Mills		Warehouses	
			No.	Members	E	C	No.	Capacity
Ilocos Norte	30,023	35,613	23	3,351	332	-	8	155,200
Ilocos Sur	27,344	26,157	58	5,764	128	1	14	225,00
Abra	22,436	15,606	11	865	79	1	5	37,600
La Union	23,941	23,744	35	2,335	202	2	12	322,000
Pangasinan	124,902	81,359	35	10,449	449	85	107	2,484,761
Zambales	19,826	12,082	5	130	117	19	5	63,000
Batanes	79	611						
Cagayan	87,145	41,776	25	1,591	523	70	256	1,985,250
Kalinga-Apayao	-?	-?	1	521			1	?
Mountain Province	56,034	46,593			99	3	16	479,400
Benguet								
Ifugao								
Isabela	112,879	45,445	22	5,750	227	33	128	2,516,600
Nueva Vizcaya	30,970	14,767	9	935	86	13	82	1,409,000
Tarlac	97,114	34,448	17	5,279	152	55	66	1,136,000
Pampanga	73,593	22,023	24	2,763	81	93	141	4,217.100
Bataan	20,111	6,405	6	318	25	47	64	1,390,750
Bulacan	67,730	29,778	19	2,512	63	198	239	3,048,200
Nueva Ecija	167,261	55,465	31	15,875	125	170	477	9,379,080
Rizal	15,046	7,954	39	3,656	49	46	56	522,100
Cavite	34,557	17,995	12	386	73	93	153	943,000
Batangas	69,798	47,356	16	3,293	221	11	96	201,780
Laguna	39,325	16,259	18	1,182	93	89	127	1,192,320
Quezon	60,633	39,931	10	2,171	312	34	62	148,240
Marinduque	16,474	10,453	5	1,103	45	1	28	3,693,880
Mindoro Or.	45,957	21,232	6	384	107	18	25	1,012,000
Mindoro Occ.	21,581	7,576	3	182	84	2	40	1,194,300
Camarines Norte	14,970	7,824	3	330	45	15	17	142,500
Camarines Sur	112,277	57,320	15	2,914	462	64	142	1,501,600
Albay	80,475	28,363	8	423	77	25	44	1,099,500
Sorsogon	27,298	15,617	5	83	62	12	60	241,800
Catanduanes	10,275	7,968					8	176,800
Masbate	28,602	12,261	2	529	66	5	50	125,000
N.W. & E. Samar	102,133	60,396	10	738	117	22	65	127,807
Northern Leyte	74,689	45,195	12	907	151	53	112	987,170
Southern Leyte	8,509	8,334	2	543	23	11	4	4,310

Statistics on the Rice (cont'd)

Name of the Province	Total Ricoland in Hactare	Number of Farmer Families	Cooperatives		Rice Mills		Warehouses	
			No.	Members	E	C	No.	Capacity
Bohol	44,883	40,535	10	9,600	49	46	30	67,342
Cebu	3,818	3,800	7	70	61	26	98	3,693,880
Negros Or.	17,911	12,101	4	505	72	33	25	59,770
Negros Occ.	83,477	36,748	35	25,246	97	41	99	921,200
Iloilo	157,699	69,634	30	2,152	444	70	45	1,167,090
Capiz	54,214	27,634	10	915	160	29	49	527,680
Antique	39,977	25,640	2	626	148	5	11	52,700
Aklan	24,149	19,129	2	138	66	1	6	13,000
Romblon	10,114	8,367	1	240	45		9	17,800
Palawan	19,853	17,207			73	5	3	14,000
Sulu	14,916	10,504			14		2	25,000
Surigao del Norte	14,092	8,728	2	427	30	5	11	104,700
Surigao del Sur	25,939	14,910	4	250	39	3	10	101,500
Agusan N. & S.	18,449	10,822	5	2,332	30	18	47	284,000
Bukidnon	23,555	13,788	4	474	128	29	12	406,000
Davao N. & S.	43,911	30,384	11	2,423	239	110	53	635,050
Misamis Or.	8,202	5,843	4	216	20	23	25	1,012,000
Misamis Occ.	13,784	12,117	2	60	54	25	31	473,410
Lanao del Norte	24,852	12,221	3	182	83	33	38	672,450
Lanao del Sur	54,416	24,285	4	240	35	2	31	75,608
Cotabato N. & S.	251,278	105,389	19	1,744	505	89	178	8,720,117
Zamboanga del Norte	18,547	15,941	6	604	48	9	13	44,700
Zamboanga del Sur	68,349	40,124	9	274	249	36	127	1,524,000
TOTAL	2,760,402	1,469,757	661	117,296	7,383	1,929	3,662	63,876,045