

RICE MILLING SYSTEM

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RICE MILLING SYSTEM

Milling is a crucial step in post-production of rice. The basic objective of a rice milling system is to remove the husk and the bran layers, and produce an edible, white rice kernel that is sufficiently milled and free of impurities. Depending on the requirements of the customer, the rice should have a minimum of broken kernels.

Most rice varieties are composed of roughly 20% rice hull, 11% bran layers, and 69% starchy endosperm, also referred to as the total milled rice. Total milled rice contains whole grains or head rice, and brokens. The by-products in rice milling are rice hull, rice germ and bran layers, and fine brokens.

Milling is a term that describes the processes of converting paddy into rice. It includes:

- **Cleaning:** Removing foreign material such as particles of sand, stones, straw, seeds, etc. from the paddy.
- **Dehusking and husk separation:** Removing the husk from the paddy with a minimum of damage to the grain, and separating the husk from the paddy.
- **Paddy separation:** Separating dehusked paddy from any remaining paddy grains. Most dehuskers remove about 90% of the husk.
- **Bran removal:** Removing all or part of the bran layer from the grain to produce polished rice.
- **Grading:** Separating (or grading) broken from unbroken rice. The brokens are often separated into different sizes.

A rice milling system can be a simple one or two step process, or a multistage process. In a one step milling process, husk and bran removal are done in one pass and milled or white rice is produced directly out of paddy. In a two step process, removing husk and removing bran are done separately, and brown rice is produced as an intermediate product. In multistage milling, rice will undergo a number of different processing steps.

A commercial rice miller will have following objectives:

- produce edible rice that appeals to the customer- i.e. rice that is sufficiently milled and free of husks, stones, and other non-grain materials
- maximize the total milled rice recovery out of paddy minimize grain breakage

RICE MILLING SYSTEMS AT THE VILLAGE LEVEL

Village-type rice mills can be found in rural communities and are used for service milling paddy of farmers for home consumption. Their capacities range from 45 to 500 kg of paddy/ hour. Single-machine mills are powered by electric motors, diesel engines, or tractors.

HAND MILLING

Hand pounding of paddy in a mortar with a pestle is the traditional milling process in remote villages. Pounding the paddy induces upward and downward forces on grain against grain that removes the husk and bran layers. The pounding also breaks up fissured grain. The final cleaning is by winnowing in a woven bamboo tray. The winnowing process to separate unmilled paddy grain is an art.

THE STEEL HULLER

One of the most popular single pass rice mills is the steel huller which is an adaptation of the "Engleberg" coffee huller from the United States modified for milling

rice (Fig. 1). In earlier days this type of rice mill was very popular in most rice-growing countries. It is still the mainstay technology for milling parboiled paddy in Bangladesh, and in many African countries. The "iron hullers", or "single pass mills" which all refer to the same mill are notorious for breaking the paddy grain. Because of the high breakage, the total milled rice recovery is 53-55%, and head rice recovery is in the order of 30% of the milled rice. The fine brokens are mixed with the bran and the ground rice hull. This by-product is used for animal feed. In many rural areas, Engleberg mills are used for custom milling the rice requirements of households. The bran produced is left to the miller as the milling fee. The poor performance of the Engleberg mill has led governments to discourage its use and has limited further proliferation. In many Asian countries, Engleberg mills can no longer be licensed to operate as service or commercial mills.

It combines the dehusking and polishing process into one operation. A cross section of the steel huller is shown in Figure 2. Paddy is fed into the hopper and, because of the rotational direction of the flutes on the revolving cylinder, is forced to move around the cylinder and toward the outlet. Friction between the grains and the steel parts of the huller (particularly the perforated sheet) causes the husk and bran to be scraped off. In the process, the husk and bran are ground into small pieces and most are pushed through the perforated screen. Some husk and bran are discharged with the polished rice, which requires further sieving.

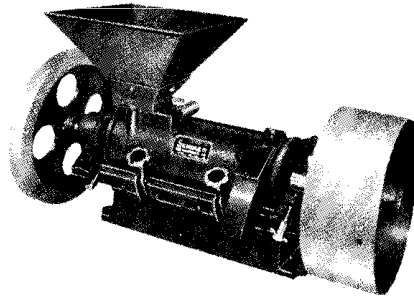


Fig. 1 Steel huller rice mill. (Courtesy of F. H. Schule GMBH)

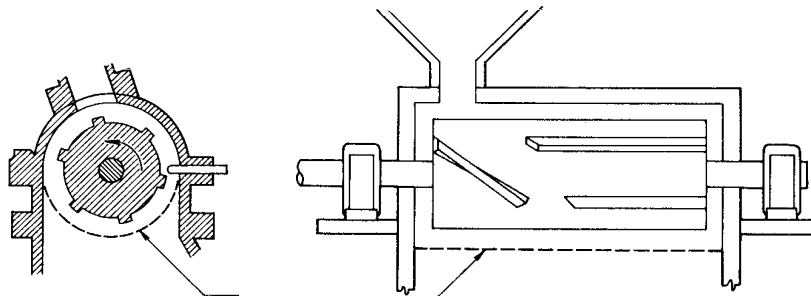


Fig. 2 Cross section of a steel huller.

The steel huller is manufactured in most rice-producing countries and is available in different sizes, capacities, and horsepower requirements.

		<u>Machine size</u>	
Capacity in kg/ h	36-45	113-204	227-295
Horsepower	4-5	7-9	12-14

The steel huller rice mill has larger horsepower requirements per ton of milled paddy than other types of rice mills. It also has the lowest recovery rate in total rice and head rice, primarily because of high rates of breakage and the loss of most small brokens with the bran and husk. Some countries have banned the use of the steel huller because of its high horsepower requirements and low recovery rates. However, the machine is not sophisticated and is relatively simple to manufacture and operate.

THE MODERN SMALL-CAPACITY MILL

Several manufacturers have developed more modern, small-capacity rice mills (Fig. 3 and 4). With this machine, dehusking is done with rubber rollers, husk is separated by aspiration, and bran is removed by friction polishers.

The modern small-capacity mill is available in various sizes and capacities ranging from 150 to 550 kg/ hour. These are small capacity 2-stage rice mills. They are also used for custom milling services in the rural areas. A typical compact rice mill consists of a 6-inch diameter x 6-inch wide rubber roller husker, and a friction whitener. The friction whitener has a very similar design configuration as the Engleberg except that it has no husking knife. The milling performance of the compact rice mill is superior to the single pass Engleberg huller. Milling recoveries are normally above 60%. Efficiency and the modern principle of operation reduce the horsepower requirement to about one-half that of the steel huller.

This machine has a simple design and is fairly easy to manufacture and operate. Like the steel huller, it can be installed in a small space and can be operated by one person. It can be powered by an electric motor, diesel engine or tractor. The modern rice mill is somewhat more sophisticated and has a higher initial cost than the steel huller. However, the increased cost is offset by the lower power requirement and operating cost, and increased rice outturn.



Fig. 3 Modern small-capacity rice mill.

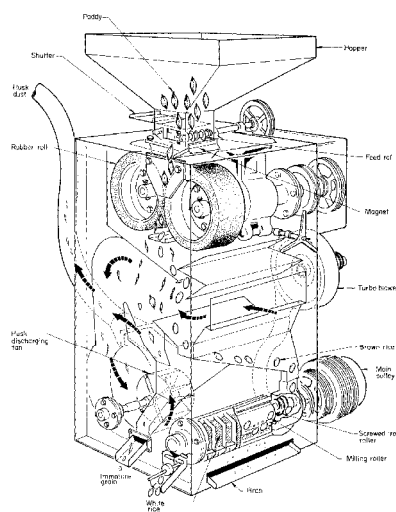


Fig. 4 Cross section of a modern small-capacity rice mill.

The most common types of small capacity rice mills in Thailand use abrasive whitening roll instead of friction whitener. Even though the modern small-capacity mills mentioned earlier are more compact and consume less energy. Since the friction whitener produces higher broken rice especially for long grain variety. There are many types and various sizes. The small rice mills with single and double horizontal abrasive rolls are shown in Figure 5 and 6. Higher capacity mills will contain a rubber husker unit and a single to triple horizontal abrasive whiteners (Fig. 7)



Fig. 5 Village rice mill with single horizontal abrasive roll.



Fig. 6 Village rice mills consisted of 2 horizontal abrasive rolls.

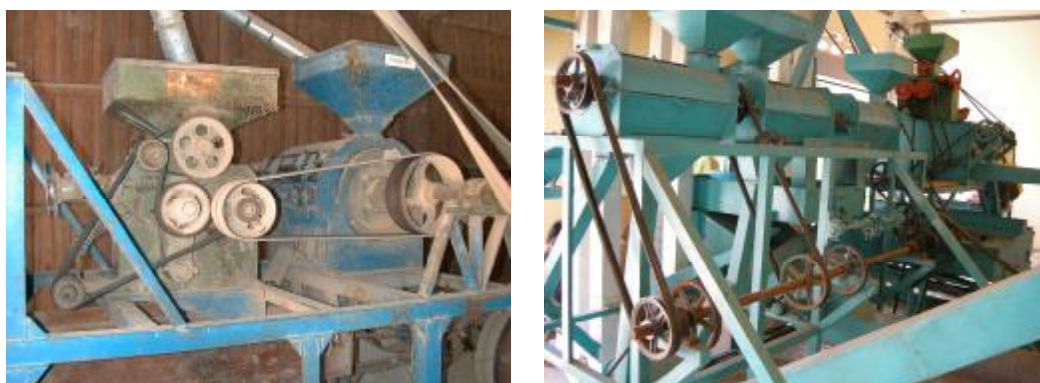


Fig. 7 Village rice mills consisted of a rubber roll huller and single (left) and 3 abrasive rolls (right).

COMMERCIAL RICE MILLING SYSTEMS

Commercial milling systems mill the paddy in stages, and hence are called multi-stage or multi-pass rice mills. The objective of commercial rice milling is to reduce mechanical stresses and heat buildup in the grain, thereby minimizing grain breakage and producing uniformly polished grain. Compared to village-level systems, the commercial milling system is a more sophisticated system configured to maximize the process of producing well-milled, whole grains.

The rice milling facility comes in various configurations, and the milling components vary in design and performance. "Configuration" refers to how the components are sequenced. The flow diagram below shows a modern commercial mill catering to the higher end market (Fig. 8). It has three basic stages, the husking stage, the whitening-polishing stage, and the grading, blending, and packaging stage.

Modern rice milling processes consist of:

- *Pre-cleaning* - removing all impurities and unfilled grains from the paddy
- *Husking* - removing the husk from the paddy
- *Husk aspiration* - separating the husk from the brown rice/unhusked paddy
- *Paddy separation* - separating the unhusked paddy from the brown rice
- *De-stoning* - separating small stones from the brown rice
- *Whitening* - removing all or part of the bran layer and germ from the brown rice
- *Polishing* - improving the appearance of milled rice by removing remaining bran particles
- and by polishing the exterior of the milled kernel
- *Sifting* - separating small impurities or chips from the milled rice
- *Length grading* - separating small and large brokens from the head rice
- *Blending* - mix head rice with predetermined amount of brokens, as required by the
- customer
- *Weighing and bagging* - preparing milled rice for transport to the customer

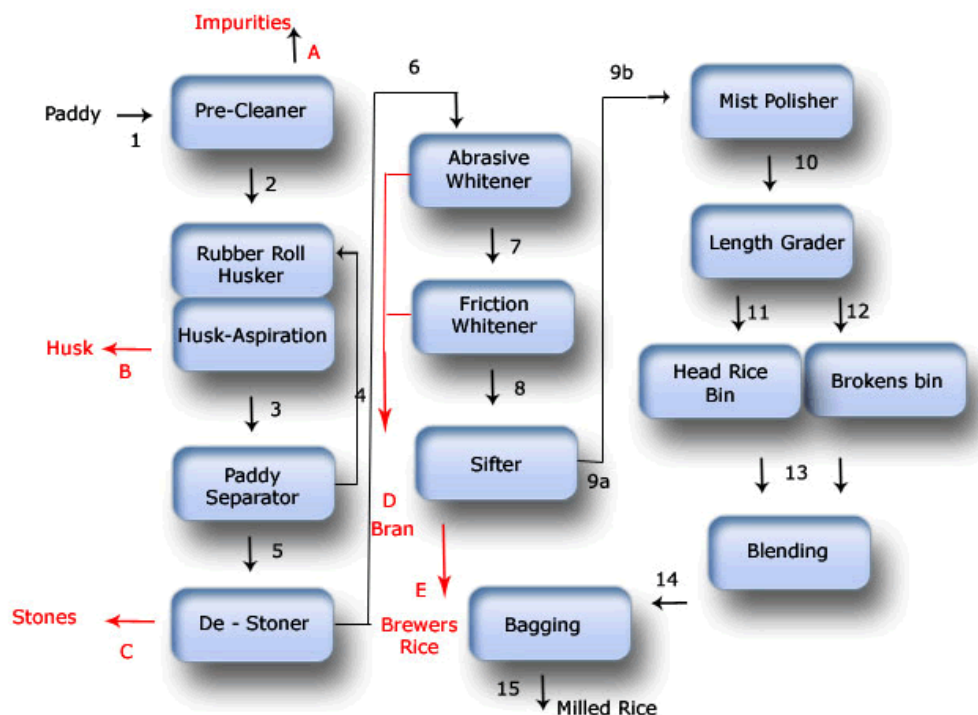


Fig. 8 Flow diagram of a modern commercial mill

- 1 - paddy is dumped in the intake pit feeding the pre-cleaner
- 2 - pre-cleaned paddy moves to the rubber roll husker:
- 3 - mixture of brown rice and unhusked paddy moves to the separator
- 4 - unhusked paddy is separated and returned to the rubber roll husker
- 5 - brown rice moves to the destoner
- 6 - de-stoned, brown rice moves to the 1st stage (abrasive) whitener
- 7 - partially milled rice moves to the 2nd stage (friction) whitener
- 8 - milled rice moves to the sifter
- 9a - (for simple rice mill) ungraded, milled rice moves to bagging station
- 9b - (for more sophisticated mill) milled rice moves to the polisher
- 10 - Polished rice, will move to length grader
- 11 - Head rice moves to head rice bin
- 12 - Brokens moves to brokens bin
- 13 - Pre-selected amount of head rice and brokens move to blending station
- 14 - Custom-made blend of head rice and brokens moves to bagging station
- 15 - Bagged Rice moves to the market
 - A - straw, chaff and empty grains are removed
 - B - husk removed by the aspirator
 - C - small stones, mud balls etc. removed by de-stoner
 - D - Coarse (from 1st whitener) and fine (from 2nd whitener) bran removed from the rice grain during the whitening process
 - E - Small brokens/brewer's rice removed by the sifter

PRECLEANING OF PADDY

Precleaning --removal from the paddy of foreign material such as sand, stones, straw, metal particles, and other seeds - is the first step in modern rice milling. Cleaning not only produces clean rice but also protects the other milling machinery and increases milling capacity.

The paddy received from the farmer is cleaned in precleaning machines. The impurities can be divided into large impurities, small impurities, and impurities of about the same size as the paddy grain. Large impurities normally consist of rice straw, panicles, bag string, soil, stones, and sometimes iron parts. Small impurities consist of dust, sand, soil particles, weed seeds, insects, and small stones. Impurities of about the same size as the paddy grains can be empty grains, stones, and iron particles.

In the precleaning process use is made of differences in the size, weight, and sometimes length of the impurities compared to the paddy grain. Impurities lighter in weight than paddy can be removed by aspiration or by sieving. Large and small impurities heavier than paddy are removed by sieving; whereas, particles the same size but heavier can be removed by gravity separation. Foreign material about the same weight and size as the paddy grain is difficult to remove, and it is presumed to dis-integrate during the actual milling process.

Weed seeds are generally small impurities normally separated through sieves. If they are not separated during the precleaning process, the seeds will not be processed during the milling operation and will finally be mixed with the end product, consequently downgrading the white rice. In those rice mills that produce mainly white rice for high-quality markets, trieurs (rotating grading cylinders) are used to remove the seeds based on differences in their length as compared to paddy grains.

Iron parts or particles are removed by sieving, by gravity separation, or by permanent or electro-magnets.

OPEN DOUBLE-SIEVE PRECLEANER

In most of the rice mills, simple precleaning is performed through open double-layer oscillating sieves (Fig. 9). The paddy is fed into the top of the machine

(A), and passes to the first sieve (1) that has large perforations and retains only large impurities, which are conveyed to the overflow (B). The second sieve (2) with small perforations holds the paddy and allows small impurities to fall to the bottom pan where they are discharged (D). The precleaned paddy, held by the second sieve, is then removed (C).

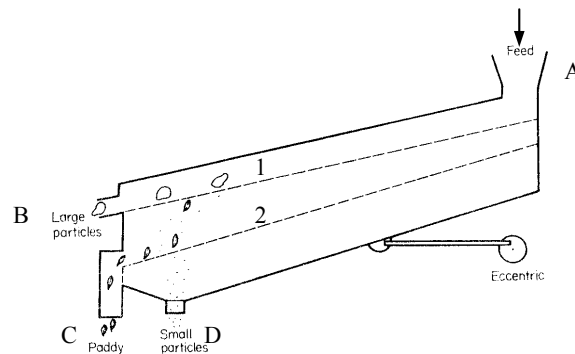


Fig. 9. Open double-sieve precleaner.

SINGLE-ACTION ASPIRATOR-PRECLEANER

To avoid the formation of dust by the pre-cleaner, the machines can be combined with an aspirator (Fig. 10) and are known as closed-type aspirator-precleaners. These units consist of a stationary section and an oscillating section. The stationary section is fixed in a wooden or iron frame and houses a suction fan. The oscillating section hangs in this frame and is driven by an eccentric from a transmission shaft. The paddy is fed into this machine through an opening in the top (A). The suction fan draws air through the film of grain and separates all dust and light impurities (1). The flow of the grain and the capacity of the suction air can be controlled (2).

The light impurities drop to the cone-shaped bottom of the aspiration housing for automatic discharge (F) through double air valves. The grain falls to a sieve with large perforations, for discharge of large heavy impurities (B), and is unloaded on the long top sieve of the oscillating section, where more large impurities are removed (C). Quite often magnets are installed under the guide plate of the short top sieve (3). The paddy and remaining impurities fall to the bottom sieve, which allows the small impurities to pass through (D). The overflow of this sieve is the precleaned paddy (E). The fan in the top section of this machine blows air and dust in a cyclone for dust separation, making the entire precleaning operation practically dust-free.

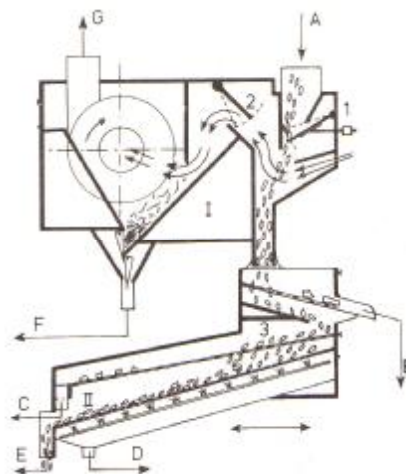


Fig. 10. Closed-type single-action aspirator-precleaner.

SINGLE-DRUM PRECLEANER

The Japanese have developed single-drum type precleaners, sometimes with gravity separation of stones. One of the single-drum type precleaners is made in combination with an oscillating sieve (Fig. 11).

The horizontal rotating cylinder is covered with a wire screen of large mesh for the separation of the large impurities (B). Some of the large impurities, however, are separated by a vibrating inclined sieve prior to the drum cleaning process (1). The paddy and the smaller impurities drop through the wire screen of the drum and reach the oscillating sieve as a film of grain. On the way down, an airstream is sucked through the film of grain, removing light impurities and dust for discharge by the suction fan (C). This fan blows the air and dust into a cyclone for the separation of the impurities.

The oscillating sieve is a double-layer type. The top sieve has large perforations for the separation of the larger impurities (D) and the bottom sieve has small perforations for the removal of small impurities (E). The overflow of the bottom sieve represents the precleaned paddy (F).

Paddy input is controlled by an adjustable valve (2), and equal distribution of the paddy over the full width of the vibrating top sieve and rotating cylinder is secured by a rotating paddle and adjustable flap (3, 4). The wide screen of the cylinder is continuously cleaned by a rotating drum cleaner (5) and a special scraping device on top of the oscillating sieve removes the separated impurities.

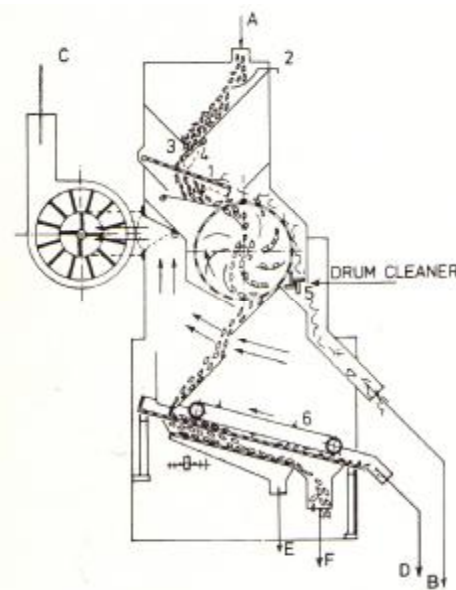


Fig. 11. Single-drum type of precleaner (Japan).

DE-STONER

Stones larger or smaller than the rice grains are separated by the cleaner sieves. However, stones of the same size as the rice grains require a type of separation that is usually accomplished with a specific gravity and forced-air separator known as a de-stoner.

The de-stoner consists of a perforated deck mounted at an angle and operated by a reciprocating motion. A blower is arranged to push air through the deck as shown in Figure 12. Air coming through the deck stratifies the material according to specific gravity differences, while the reciprocating action of the deck separates the heavy stones from the lighter paddy. The heavy products are discharged from the high end of the deck, entirely separate from the light particles which are discharged from the low end (Fig. 13).

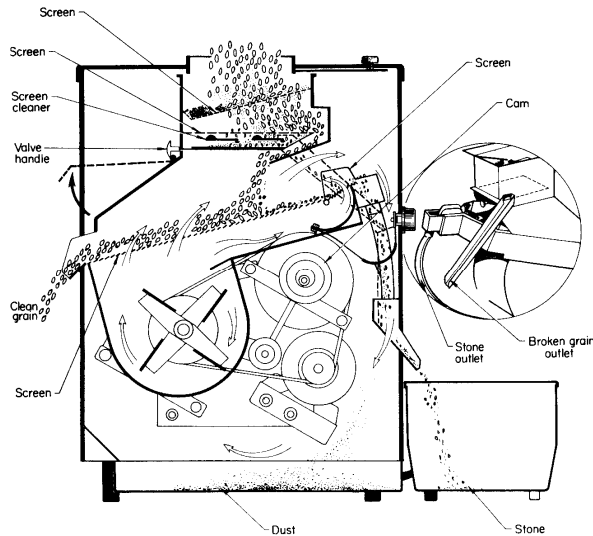


Fig. 12. Cross section of de-stoner deck.

MAGNETIC SEPARATOR

The bulk of the iron particles mixed with the paddy is removed during the normal precleaning operation as large or small impurities. If no special stoner is installed, iron particles of about the same size as the grains can only be removed by magnetic separators. Nevertheless, we have to take into account that bolts and nuts from the paddy processing machines may get loose any time and if not removed can seriously damage the processing equipment. Therefore, magnetic separators are installed not only in precleaning equipment but also in husk separators and the discharge spouts of elevators.

There are simple permanent magnets for machines and/or discharge spouts (Fig. 13, A, B). Another type of permanent magnetic separator is a rotating brass cylinder passing over a half-round permanent magnet (Fig. 13, C). The grain film is transported by the rotating cylinder that unloads the grain in the discharge spout (1), but holds the iron particles attracted on its surface because of the magnet. When the cylinder is not moving over the magnet, the iron is automatically released and is discharged separately (2). In some of the larger rice mills special high-capacity magnetic separators are installed for mechanical and continuous discharge of the iron. Most of the magnetic separators are of the permanent type; however, electromagnets may also be used.

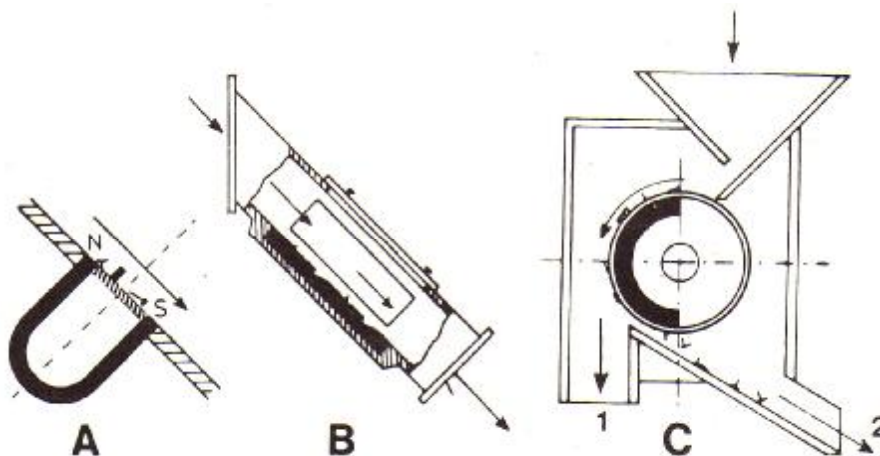


Fig. 13. Different types of magnetic separators: A, B simple permanent magnets; C rotating brass cylinder and permanent magnet.

THE HULLING OF PADDY

The objective of a hulling machine is to remove the husk from the paddy grain with a minimum of damage to the bran layer and, if possible, without breaking the brown rice grain.

The most common machines used in hulling paddy are the under-runner disc huller and the rubber roll huller. A few other types have been tried or are being studied, but they have not proved economical for commercial operations.

Hulling machines are known by different names, such as shellers, hullers, dehuskers, huskers, and hulling mills. Most commonly of these machines are called "hullers".

THE UNDER-RUNNER DISC HULLER

The under-runner disc huller consists mainly of two horizontal cast-iron discs, partly coated with an abrasive layer (Fig. 14). The top disc is fixed in the frame housing; the bottom disc rotates. The rotating disc is vertically adjustable (2) so the clearance between the abrasive coating of the disc can be adjusted (3). This adjustment depends on the variety of paddy, the condition of the grain, and the wear of the coating.

The paddy is fed into the centre of the machine through a small hopper. A vertically adjustable cylindrical sleeve (1) regulates the capacity and equal distribution of the paddy over the entire surface of the rotating disc. By centrifugal force the paddy is forced between the two discs and under pressure and friction most of the grain is dehusked.

The adjustment of the clearance between the discs is rather critical and requires continuous rechecking to avoid excessive breakage or insufficient huller efficiency. Quite often, the effective width of the abrasive coating is made too large, causing unnecessary breakage of the grain. Empirically, it has been proven that this width should not be more than $1/6$ to $1/7$ of the stone diameter. The peripheral speed of the disc should be about 14 m/s. Making the speed a function of the diameter of the stone, the larger the diameter, the revolutions of the shaft will be lower.

The main advantages of the disc huller are its operational simplicity and its low running cost; moreover, the abrasive coverings can be remade at the site with inexpensive materials. The main disadvantages are grain breakage and the abrasions to outer bran layers. Capacities and power requirements of the common disc huller are given in Table 1.

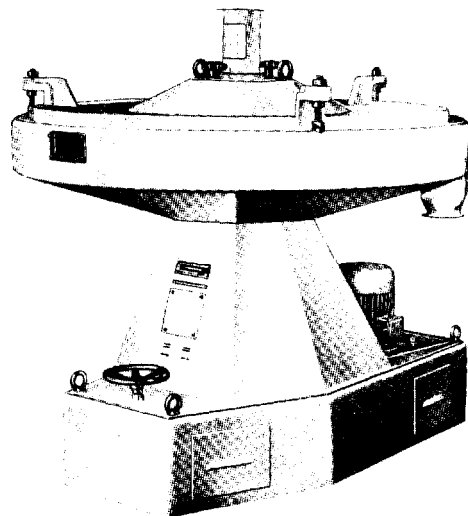


Fig. 14. The Under-runner disc huller.

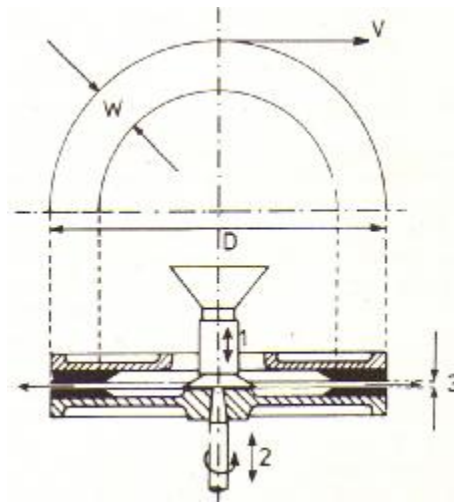


Fig. 15. Particulars of the under-runner disc huller: V = peripheral speed (recommended 14 m/s); W = width of coating; D = stone diameter; and $W/D = 1/6$ or $1/7$.

Table 1. Capacities and power requirements of disc huller s.

Disc diam (mm)	Capacity (kg paddy/h)	Horsepower requirements
750	450-600	3.0
1000	700-1000	3.5
1250	1000-1400	4.0
1400	1600-2100	5.5

RUBBER ROLL HULLER

The rubber roll huller is by far the most important technology used today for hulling rough rice. The rubber roll paddy husker, often referred to as a huller or sheller (Fig. 16), consists of two rubber rolls rotating in opposite directions at different speeds (Fig. 17). One roll moves about 25% faster than the other. The difference in peripheral speeds subjects the paddy grains falling between the rolls to a shearing action that strips off the husk. The clearance between the rolls is adjustable and is kept at less than the thickness of the grain.



Fig. 16. Rubber roll husker. (Courtesy of Satake Engineering, Ltd.)

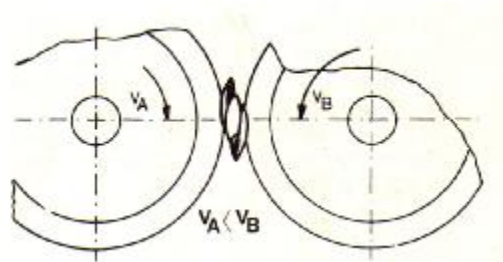


Fig. 17. Dehusking principle of rubber roll huller.

Compared with the disc sheller, the rubber roll offers many advantages. It reduces grain breakage and the loss of small broken; it does not remove the germ; sieving the husked products is unnecessary; it reduces the risk of damage to the grain and machine by unskilled operators; it increases hulling efficiency; and it does not require a beard-cutting machine. The main disadvantage is the cost of replacing the rubber rollers as they wear. That is offset, however, by the reduction of breakage and increased total rice outturn.

The machine is complex and consists of many moving parts to have rollers operating at different speeds. Manufacturers use chains, belts, and gear drives. Horsepower requirements are slightly less than those for the disc sheller.

The durability or capacity of the rubber rolls varies with cleanliness of paddy, moisture content, and pressure applied to the rolls. It also depends on the paddy variety and age and quality of the rolls. A pair of good-quality rolls has an average capacity of 100 to 200 t paddy/pair. The capacity is higher with short grains (Table 2). The optimum age for rubber rolls begins 2-3 months after manufacture and decreases rapidly when the rubber is 6 to 9 months old. Therefore, rubber rolls should be stored only for a limited time.

Most rubber roll huskers are manufactured in standard sizes. Capacities and power requirements are given in Table 2.

In general, the faster operating, unadjusted rubber roll wears out faster than the adjusted roll. The rolls are interchangeable, and should be switched from time to time to ensure even wear. Uneven wear on a roll changes the peripheral speed and reduces hulling capacity.

Table 2. Capacities and power requirements for different rubber-roll huskers.

Size	Dimensions of rolls (mm)		Capacity (t/h)		Horsepower requirements
	Length	Diam	Long grains	Short grains	
4	100	220	0.9	1.25	2.5
6	150	220	1.2	1.9	4
10	254	254	2.2	3.8	6

For optimum performance, the grain should be evenly distributed over the full width of the rolls. Otherwise, the roll surface wears out unevenly, reducing efficiency and capacity. Unevenly worn rolls can be corrected by turning them on a lathe.

Heating adversely affects the durability of the rubber rolls. To prolong their life, the rollers are switched when they are too hot and allowed to cool. Most rubber roll huskers incorporate an air cooling system whereby air is drawn through the housing to reduce roll temperatures.

HUSK SEPARATION

The disc huller produces a mixture of dehusked paddy grains (called brown rice), unhusked paddy, husks, and some broken rice and germs along with stone bran. The dehusked and unhusked paddy are separated later in a paddy separator, but first the husks, brokens, germs, and stone bran must be separated.

The brokens, germs, and stone bran can be separated through an oscillating sieve with fine perforations and discharged separately. Husks, being lighter than any of the other particles, are easily separated with aspiration. The two separations can be done in one machine by the provision of an oscillating sieve and an air aspirator.

HUSK ASPIRATOR WITH PLANSIFTER

In Figure 18, the plansifter is equipped with two self-cleaning sieves. Sieve 1 has fine perforations for separating bran and dust at A. Sieve 2 has larger perforations for separating brokens at B. The sieve overflow is a mixture of husk, paddy, and brown rice.

The lower part of this machine, the husk aspirator, pulls air through the mixture and lifts the husks to be discharged through the blower at D. The immature grains are lifted by the airstream and dropped into the V-shaped compartment for automatic discharge through the double air valves at E. The brown rice and the paddy are discharged at F.

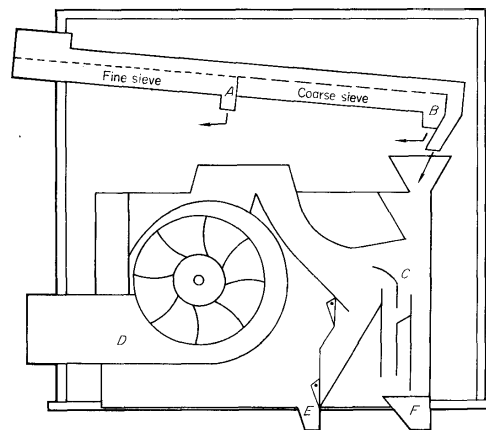


Fig. 18. Husk aspirator with plansifter: A, bran and dust; B, brokens; C, air mixing chamber; D, husk; E, paddy; F, brown rice.

HUSK ASPIRATOR COMBINED WITH RUBBER ROLL HULLER

The compact, lightweight construction of the rubber roll husker makes it possible to combine the husker and the husk aspirator. Because the rubber roll husker does not damage the bran layer of the brown rice, the husker discharge does not contain any bran. Neither does the rubber roll husker discharge any stone bran and only a very small amount of brokens. Therefore, following the rubber roll husker a plansifter is not required and only a husk aspirator is used.

A typical husk aspirator with rubber roll husker is shown in Figure 19. About 90% of the paddy from the rubber rolls is dehusked in the first pass and the combination is fed immediately into the husk aspirator. An airstream is pulled through the grain to separate the husks and immature grains. The immature grains drop into a separate hopper for discharge. The paddy and brown rice are discharged separately. Efficiency is generally high with this type of husk aspirator.

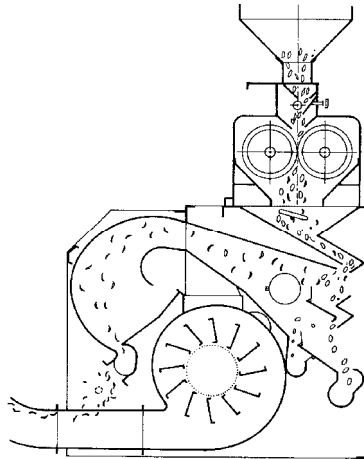


Fig. 19. Rubber roll husker with built-in husk aspirator.

CLOSED CIRCUIT HUSK SEPARATOR

The closed circuit husk separator separates the husks and immature grains from the paddy and brown rice. The machine is called a "closed circuit" separator because it does not blow the husks out with the air; the air used for the separation of the husks is continuously recirculated (Fig. 20).

The mixture of paddy, brown rice, immature grains, and husks is loaded into a hopper on top of the machine. This mixture passes through inclined plates and falls as a grain film. A strong airstream built up by the pressure or discharge side of a built-in suction blower passes this film of grain and separates the husks from the mixture. Because of the special shape of the separator housing, the husks follow the housing pattern as in a cyclone. As a result of the speed of the air and the impact of the separating centrifugal force, the husks are freed from the recirculating airstream and drop into the bottom of the V-shaped housing (1) for side discharge through a screw conveyor (B).

The air, now free from husks, is recirculated by the blower and is used to lift the immature grains from the grain film. The immature grains and a mixture of brown rice and paddy fall into separate compartments and are discharged by screw conveyors (2, 3).

The quantity of air recirculated is controlled by a bypass valve (4) and the separation performance by an adjustable throttle valve (5). This machine does not separate bran, dust, and brokens from the huller discharge, so that prior to husk separation a plansifter or oscillating sieve must be installed.

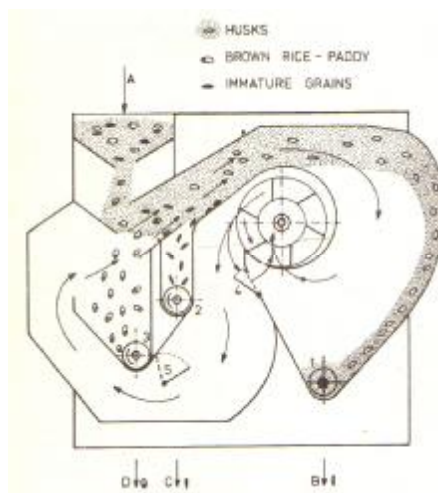


Fig. 20. Closed circuit husk separator.

PADDY SEPARATION

A mixture of 85-90% brown rice and 10-15% paddy is fed into the paddy separation stage. The paddy must be separated before the brown rice goes to the bran removal stage. The separated paddy is returned to the husker for dehushing.

Paddy and brown rice have different characteristics that make separation easy:

1. The average weight of paddy by volume is less than that of brown rice (specific gravity of paddy is lower than that of brown rice).

2. The paddy grains are longer, wider, and thicker than those of brown rice.

3. The coefficient of friction is different.

Two types of paddy separators commonly used are the compartment type and the tray type.

COMPARTMENT-TYPE SEPARATOR

The compartment-type separator (Fig. 21) is older and has been used for about 80 years. The main part is the oscillating compartment assembly in which the separation takes place. The steel or wood construction consists of a number of compartments in one or more decks (Fig. 22). The number of compartments determines the capacity. One deck may have up to 10 compartments; 2 decks, up to 20 compartments; 3 decks, up to 50 compartments; and 4 decks, up to 80 compartments. The capacity of each compartment is about 40 kg brown rice/ hour for long grains and 60 kg/ hour for short grains.



Fig. 21. Compartment-type paddy separator. (BUHLER: DNTB)

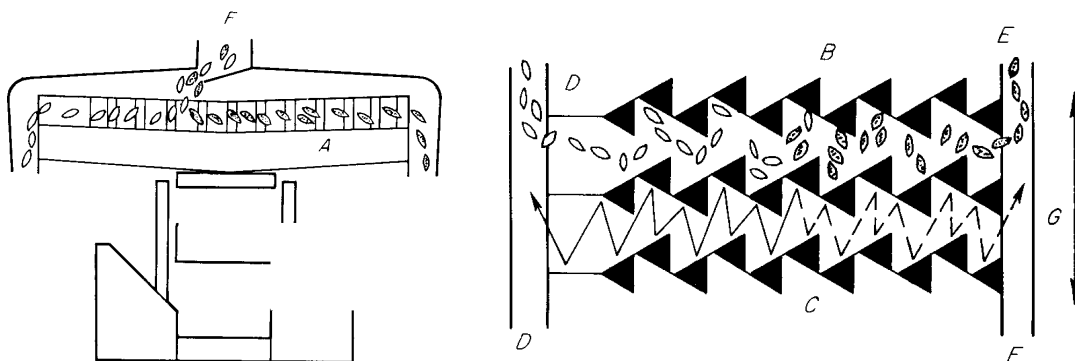


Fig. 22. Cross section of compartment separator with tray details: A, oscillating table; B and C, zigzag compartments; D, high side of table; E, low side of table; F, input hopper; G, oscillating directions.

Thus, a 2-t/ hour rice mill, producing 1,600 kg of long grain brown rice per hour, would need 40 compartments. In this case, a standard-size unit with 48 compartments (3 decks of 16 each) would be used.

The operation is best illustrated in Figure 22. Only one deck is shown. The table (A), oscillating as shown by (G), is divided crosswise into zigzag compartments (B) and is inclined with the high side at (D). Paddy and brown rice are fed into the hopper (F). The bottom of the table on which the grains move back and forth (C) is smooth steel. The impact of the grains on the sides of each compartment causes the unhusked paddy grains to move up the inclined slope toward (D). The dehusked brown rice moves down the slope to (E). The slope of the table is adjustable to meet the needs of paddy of different size or condition and to ensure complete separation. The oscillation frequency is generally set between 95 to 105 double strokes per minute.

New models incorporate a stroke adjustment. This offers the advantage of changing the stroke to meet various paddy requirements, e.g. changes in varieties and conditions, and increases the separation capacity. This means smaller separators can be used. The capacity with stroke adjustment is about 65 kg/ hour per compartment for long-grain rice and 100 kg/ hour for short-grain. The 24-compartment separator would have a capacity of 1,560 kg/ hour for long grains and 2,400 kg/ hour for short grains. The new separator is available with either 24, 36, or 45 compartments.

This type of separator has low power consumption, operating cost, and maintenance cost. The tray bottoms and compartment zigzags can be replaced locally as they wear out. The machine, however, is bulky, requires a strong foundation, and takes considerable space in the mill.

TRAY SEPARATOR

The tray separator has become widely used over the past 25 years. It consists of several indented trays mounted one above the other about 5 cm apart, all attached to an oscillating frame (Fig. 23). The tray section moves up and forward, making a slight jumping movement (Fig. 24).

Paddy moves onto each tray from the inlet hopper. As it moves across the tray, the brown rice separates from the paddy. The brown rice has a smoother surface and a greater bulk density and moves to the top of the tray where it is conveyed to the polishers. The paddy moves to the lower part of the tray where it is conveyed back to the husker. Some of the unseparated paddy moves to the center of the tray where it is returned to the inlet of the separator. The table inclination is adjustable to meet different paddy varieties and conditions and to achieve maximum separation capacity.



Fig. 23. Tray-type paddy separator.

Capacities vary with long and short grains. One model has 2,270 kg/ hour for long grain and 3,180 kg/hour for short grain, and uses a 1-hp electric motor. Power requirements are small - about one-half the horsepower required for the compartment-type separator. Models are available with capacities of 1.2, 1.9, 3.2, 4.5, and 9.5 t/ hour.

The all-steel construction, low horsepower requirements, and simple operation assure low operating and maintenance costs. The indented steel plates require replacement after long years of use. One advantage of the tray separator is the small space required. This makes the mill more compact and saves floor space.

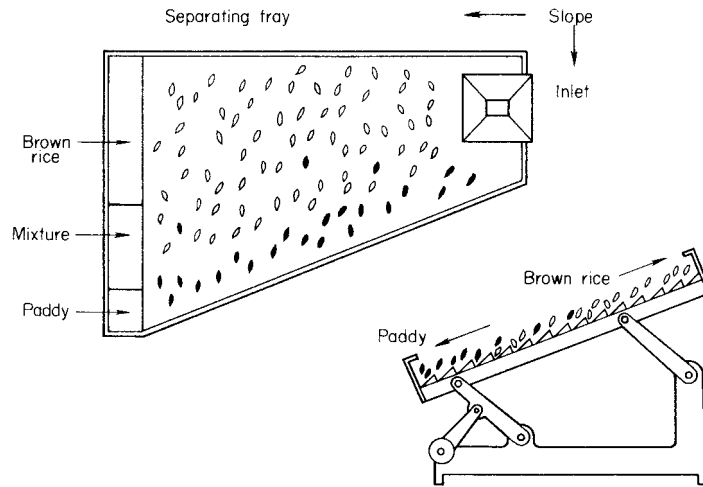


Fig. 24. Details of tray-type paddy separator.

WHITENING AND POLISHING

In the process of whitening, the silver skin and the bran layer of the brown rice are removed. In the process of polishing the whitened rice, the bran particles still sticking to the surface of the rice are removed, and the surface of the rice is slightly polished to give it a shinier appearance. Polishing, therefore, always takes place after completion of the whitening process.

Some confusion exists about the words used for these processes. Whitening is sometimes called "polishing" or "milling". Polishing is sometimes called "refining" or "grinding".

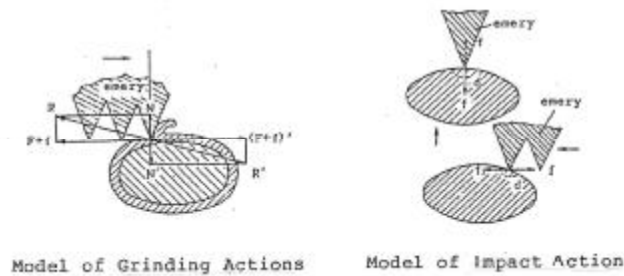


Fig. 25 Abrasive process of bran removal.

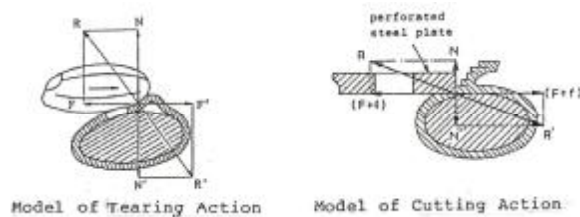


Fig. 26 Friction process of bran removal.

The two processes used to remove the bran layer from the grain are abrasion and friction. Note that the abrasion process uses a rough surface, which is an abrasive stone, to break and peel the bran off the grain (Fig. 25). The friction process uses the friction between the grains themselves to break and peel off the bran (Fig. 26).

Three kinds of whitening machines are widely used in the rice processing industry: (1) the vertical abrasive whitening cone; (2) the horizontal abrasive whitening machine; and (3) the horizontal friction whitener (the horizontal jet pearler).

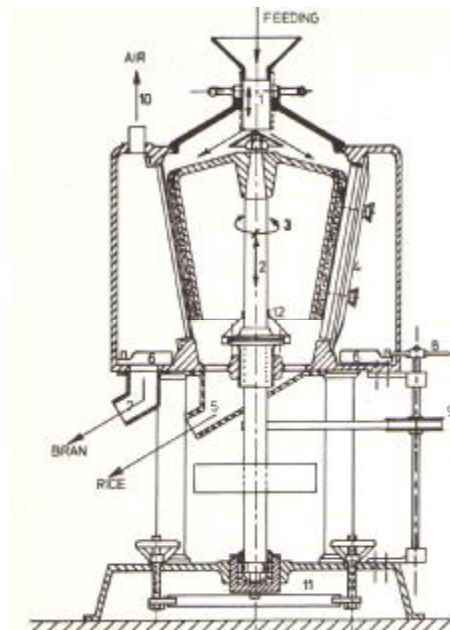
VERTICAL ABRASIVE WHITENING CONE

A typical vertical abrasive whitener is shown in Figure 27A. This machine has been used in the paddy industry for many years and is manufactured in many countries. It is available with the cone directed either up or down, but with no difference in performance or capacity. Its operation is illustrated in Figure 27B.

The dehusked paddy (brown rice) enters at the top center and moves outward by centrifugal force to the edge of the metal cone. The cone has an abrasive surface and turns inside a cylinder covered with a wire screen. The clearance between the cone and screen is adjusted about 10 mm by raising or lowering the cone. The peripheral speed of the cone should be about 13 m/s. Making the speed of rotation of the shaft a function of the diameter of the cone, the larger the diameter of the cone, the speed of the shaft must be lower. The abrasive surface of the cone can be replaced locally. The screens and rubber brakes are also easily replaced. The screens wear out the quickest and require frequent replacement.



(A)



(B)

Fig. 27. The vertical abrasive whitening cone.

Removing all the bran in one whitening operation causes much breakage and reduces total rice recovery. Therefore, most modern rice mills use multipass whiteners. For example, a capacity of 1,200 kg/ hour can be obtained by 1) a single pass with one 1,000-mm cone, 2) a double pass with two 800-mm cones, or 3) a multipass with three 600-mm cones. The last produces the least amount

of broken rice and the largest total rice recovery, and is usually more economical. Sizes, horsepower requirements, and capacities are shown in Table 3.

Multipass whitening produces higher rice mill recovery because there is: (1) an increased head rice yield; (2) a reduced percentage of large broken rice, and (3) a reduced percentage of small broken rice (Fig. 28).

Table 3 Vertical cone whitener size, power requirements, and capacities.

Cone Diam (mm)	hp ^a	Capacity (kg brown rice/h)					
		Single pass		Double pass		Triple pass	
		Long grain	Short grain	Long grain	Short grain	Long grain	Short grain
500	4	350	420	570	680	680	800
600	7.5	550	650	890	1100	1050	1250
800	10	750	900	1230	1450	1460	1725
1000	15	1000	1200	1700	2000	1900	2300
1250	20	1350	1600	2200	2600	2600	3000
1500	25	1700	2000	2700	3200	3200	3800

^aAdd 30% for whitening parboiled paddy.

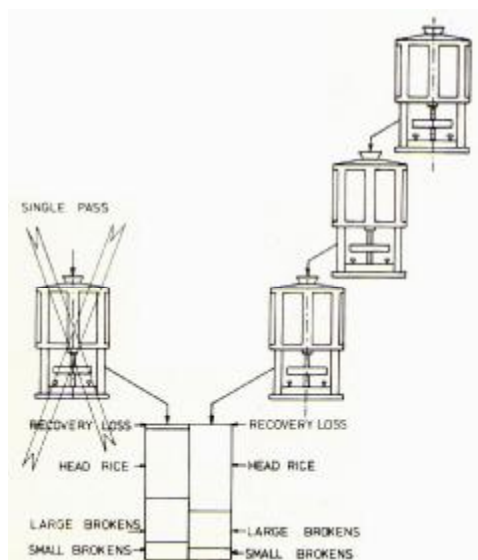


Fig. 28. Multipass whitening increases rice mill recovery by reducing the amount of rice breakage.

HORIZONTAL ABRASIVE WHITENER

A typical horizontal abrasive whitener is shown in Figure 29. It is more compact than the vertical abrasive whitener. The machine consists of an abrasive roll (emery stone attached to a steel shaft) operating in a cylindrical metal perforated screen mounted horizontally (Fig. 30). Brown rice enters one end, and moves around and around the abrasive roll to the opposite end before discharge. The abrasive action is the same as that in the vertical abrasive whitener where the abrasive roll and perforated screen cut and peel the bran layers from the grain.

The intake hopper (Fig. 30) has a control that regulates the flow of brown rice into the machine and keeps the machine full during the entire operation. Running the machine partially full causes excessive breakage and uneven whitening. The pressure on the grain is controlled by an adjustable weighted discharge gate.

The newer models of horizontal abrasive whiteners use an airstream blown through the hollow shaft and then through the many small openings in the abrasive roller. The air passes through the rice and out the perforated screen. This keeps the rice temperature lower, thus reducing breakage and helping to remove the bran sticking to the grains or to the machine. The bran is collected after it leaves the machine. Special abrasive rollers with high durability and sharpness are used to obtain faster peeling of the bran without excessive pressure. One disadvantage of this type of machine is that the clearance between the roll and screen cannot be adjusted. When the roll wears down, it cannot be resurfaced and must be replaced with a new one.

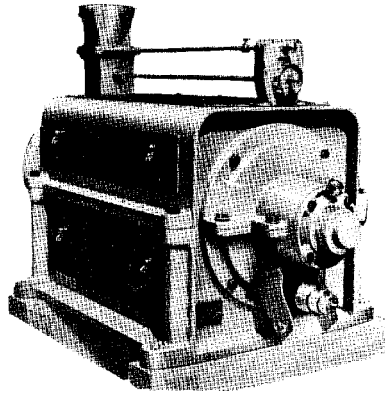


Fig. 29. Horizontal abrasive whitener. (Courtesy of Satake Engineering, Ltd.)

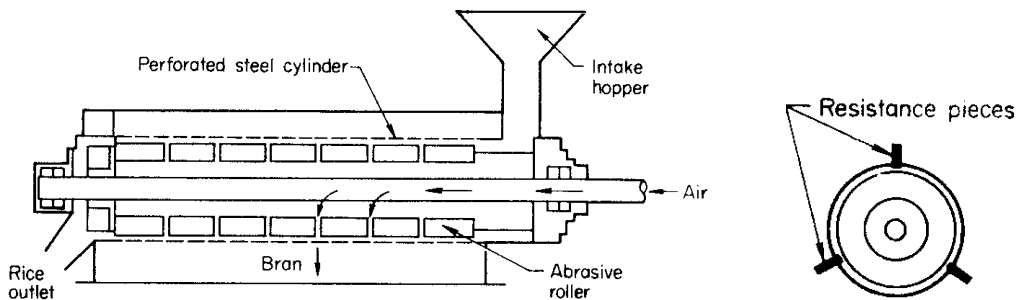


Fig. 30. Cross section of horizontal abrasive whitener.

Resistance pieces (Fig. 30) installed along the length of the perforated cylinder assist in slowing the tumbling speed of the grain and keeping the grain closer to the abrasive roll.

The airstream through the abrasive roll is particularly useful in the milling of parboiled rice. Bran on parboiled rice tends to stick to and cake up the perforations in the screen. The airstream assists in keeping the perforations clear.

Just as with the vertical whitener, multipass whitening is recommended with the horizontal machines. Often several horizontal whiteners are mounted in a stacking arrangement as shown in Figure 33. This arrangement permits continuous flow from one machine to another without extra conveying equipment and conserves space in the mill.

Power requirements per capacity of machine are about the same as for vertical abrasive whiteners. Keep in mind that for whitening parboiled paddy, power requirements are increased by 25-30%.

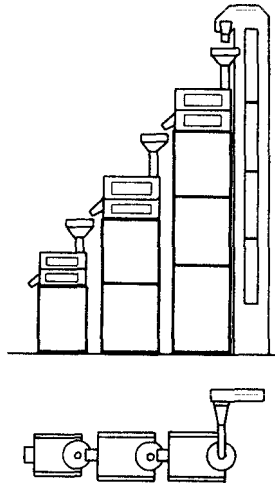


Fig. 31. Stacking arrangement for horizontal whiteners.

HORIZONTAL FRICTION WHITENER

Examples of horizontal friction-type whiteners are shown in Figures 32. These are often called jet or pneumatic pearlers. Each of these machines uses the friction process in which the bran is peeled off by friction of the rice grains. Steel hullers are also used as friction-type whiteners, particularly for parboiled paddy.

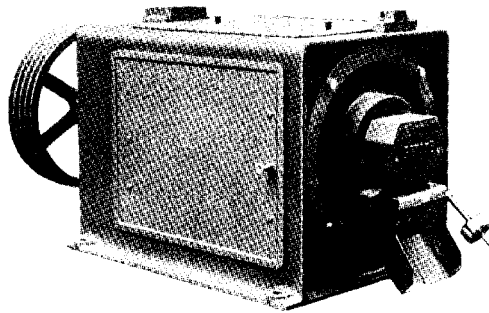


Fig. 32. Friction-type whitener. (Courtesy of Satake Engineering, Ltd.)

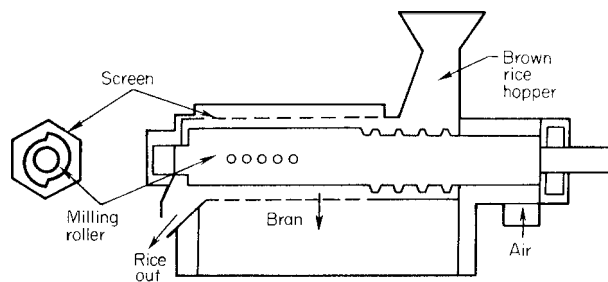


Fig. 33. Cross section of friction-type whitener.

Air is used to remove the bran as shown in the cross section in Figure 33. An airstream is blown into the hollow shaft, through the steel milling roller, through the rice, and out through the perforated screen. The airstream also cools the grain and reduces breakage.

The major components of the friction whitener are the metal roller and the metal perforated screen. A feeding worm is used to force the grain into the milling cylinder. The clearance between the screen and the steel cylinder is adjustable. The pressure on the rice is controlled by a weight adjustment on the valve in the outlet spout.

When the friction-type whitener is used as a single pass whitener, the capacity is low and excess breakage occurs (similar in operation to the steel huller). However, it is more often used in a multipass operation.

Like the horizontal abrasive whitener, the horizontal friction whitener may also be used in a stacking arrangement with one unit above the other (Fig. 31). This arrangement conserves space and reduces the cost of conveying equipment. Horsepower requirements are about the same as those required for both the vertical and horizontal abrasive whiteners of the same throughput capacity.

RICE POLISHERS

Some rice markets require a glossy, highly polished rice. In this case, rice polishers (sometimes called pearlers or refiners) are used after the whiteners. Vertical and horizontal polishers are available (Fig. 34 and 35). In these machines, the cones or drums (vertical or horizontal) are covered with leather strips; the screens are perforated and operate at a lower rpm.

The leather strips roll the whitened rice over and over against the screen. Under slight pressure, the remaining bran is removed and the rice becomes shinier and glossier. This machine produces few broken grains. Its power consumption is 30 to 40% less than that of whiteners.

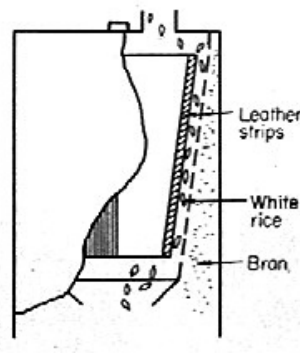


Fig. 34 Vertical polisher.

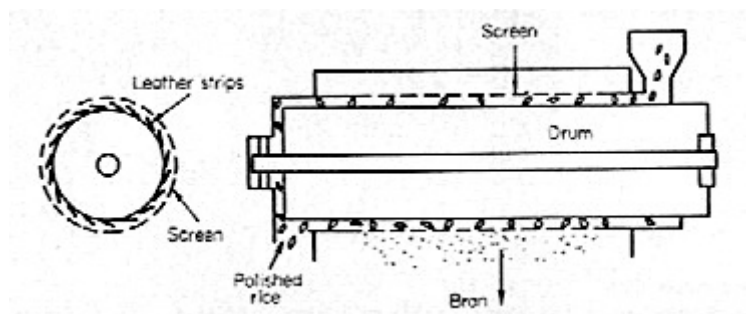


Fig. 35 Horizontal polisher.

MIST POLISHERS

For mills that produce premium or export quality rice, a mist polisher or humidifying rice milling machine (Fig 36) is employed to brush off remaining bran dust and to create a characteristic gloss on the milled rice. In mist polishers, a controlled amount of water mist is injected, resulting in highly polished grain. Mist polishing improves the storability of milled rice because of the complete removal of the bran.

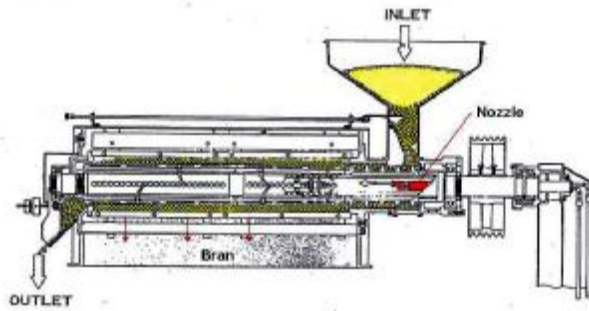
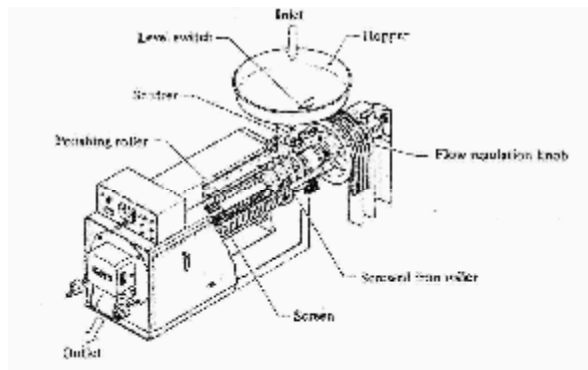


Fig. 36 Horizontal mist polisher.

GRADING AND BLENDING

After the whitening operation the unbroken rice is still mixed with different sized broken rice, bran, and dust. Separation of these particles after whitening is termed "grading". The degree of grading is determined by the rice market or consumer preference. Many rice markets do not require any grading; others require a sophisticated grading system that will produce a clean, bran-free rice with no brokens. Most rice markets will accept a small percentage of brokens but demand a clean and bran-free rice.

Bran and dust particles are separated by air aspiration. This may be in the form of a blower pulling an airstream through a column of rice, similar to that used in a cleaner, or a special aspirator installed just for this purpose.

Small brokens and germs are separated by a vibrating or rotary sieve. The vibrating sieve oscillates and is similar to that used in cleaners. A rotary sieve, termed a rotary sifter or plansifter, is the same perforated sheet moving in a circular motion.

Simple plansifters can be made with one, two or more trays, each tray having a different perforation: the largest perforations for the top tray; the smallest perforations for the bottom tray (Fig. 37).

In large capacity rice mills so-called high capacity plansifters are used. These very compact machines consist of two, four, six, or eight rectangular steel boxes or sections that hold a large number of trays that have different mesh wire screen sieves (Fig. 38). These are often used to produce rice for the most sophisticated markets.

Oscillating or rotating sieves are not used to separate large brokens because their perforations are the same diameter as unbroken rice. Because the length of the brokens differs from the length of the unbroken rice, length separators may be used. These are called Trieurs, rotating cylinders, length graders or drum graders. A cross section of a rotating grader is shown in Figure 39. An indented cylinder is installed at a slight incline. The inside of the cylinder has a catch trough and screw conveyor to catch and remove the

broken. The unbrokens remain in the lower part of the cylinder and are discharged at the low end of the machine.

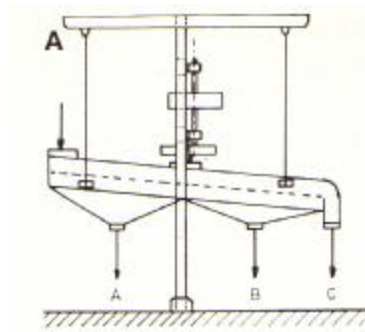


Fig. 37 Plansifters. (A) Sieve divided into two sheets with different sized perforations for the separation of two grades of broken.

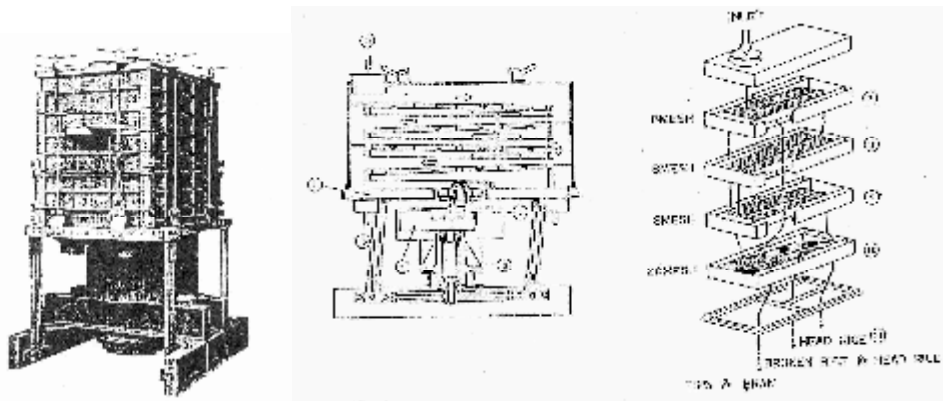


Fig. 38. High capacity plansifters consist of rectangular steel boxes that hold a variety of sieves.

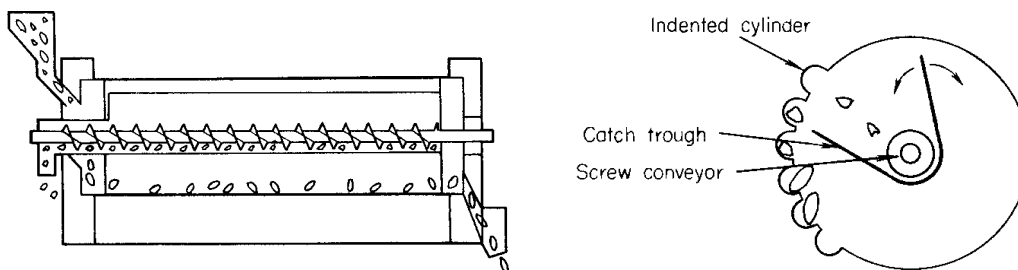


Fig. 39. Cross section of a rotating cylinder grader.

Rice grading plants can be very simple or they can be very complicated and offer a large program of alternative grain flows. Some examples of white rice grading units using plansifters (or oscillating sieves) and trieurs are given below.

(1) Using one single layer sifter and two trieurs in series (Fig. 40A) the paddy can be graded into points and very small broken (P), small broken (SB), large broken (LB), and head rice (HR).

(2) Using one double layer sifter and two trieurs- in parallel (Fig. 40B) the paddy can be graded into points (P), small broken 1/8-2/8 (SB), large small broken 3/8 (LSB), large broken (LB), and head rice (HR).

(3) Using one double layer sifter and three trieurs in series (Fig. 40C) the paddy can be graded into points (P), small brokens 1/8-2/8 (SB), small large brokens 3/8-4/8 (SLB), large brokens 5/8-6/8 (LB), and head rice (HR):

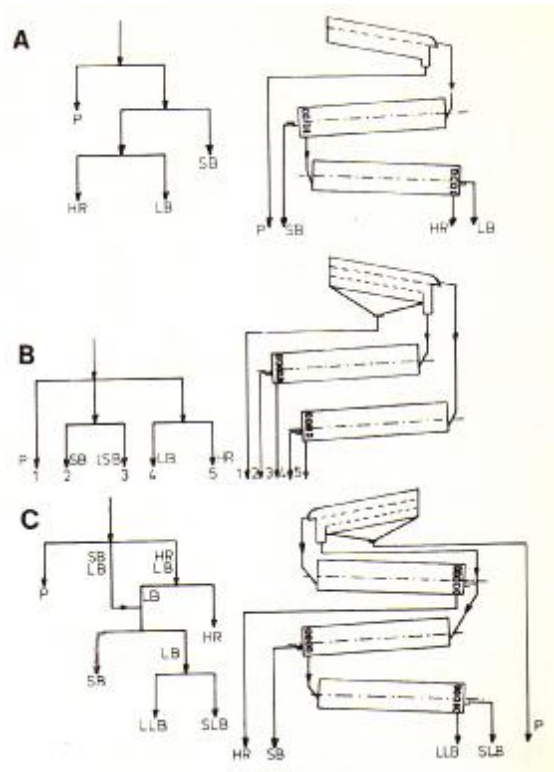


Fig. 40. Examples of white rice grading. (A) One single layer sifter and two trieurs in series. (B) One double layer sieve and two trieurs in parallel. (C) One double layer sifter and three trieurs in series.

A simple installation for the grading of milled rice (Fig. 41) into points, small brokens, large brokens, and head rice followed by mixing consists of: (1) a bin holding the ungraded rice; (2) a single layer plansifter for the separation of points; (3) an elevator to lift the rice; (4) a trieur for the separation of the small brokens; (5) a bin for small brokens; (6) a second trieur for the separation of the large brokens and head rice; (7) a bin for large brokens; (8) a bin for head rice; (9) volumetric mixers; (10) a belt conveyor; (11) an elevator; and (12) a bin for bagging.

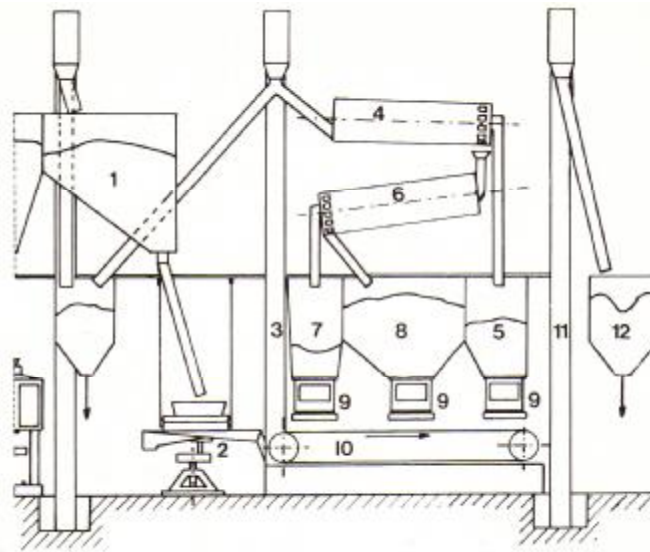


Fig. 41. Simple installation for the grading of milled rice.

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