AN APPROPRIATE TECHNOLOGY FOR AN IMPROVED METHOD OF GRAIN DRYING IN RURAL AREAS OF BANGLADESH.

A Thesis
Presented to the Department of Electrical Engineering, Bangladesh University of Engineering and Technology, Dacca in partial fulfilment of the requirements for the Degree of Master of Science in Electrical Engineering.

by
Sheikh Din Mohammad
1979.

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April, 1979.

This is to certify that this work has been done by me and was not submitted any where for the award of any degree or diploma or for publication.

Signature of the Superviser.

Signature of the Candidate.

A C K N O W L E D G E M E N T S

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ABSTRACT

Traditional sun-drying of rice is no more considered suitable in Bangladesh, as change in cropping pattern and other factors demand an artificial grain drying method. A survey on traditional practice of rice drying was made in 1977 in an area of Mymensingh district. The survey reveals that cost in drying rice in traditional method is very high (Only labour cost component is Tk.6.50 per maund) It results in poor grain quality and sometimes drying becomes very difficult.

An artifical rice drier was proposed which will be of size and capacity. Suitable to a group of farmers of Bangladesh. These were determined from the data obtained in the survey on traditional method of rice drying. An improved method of rice drying was selected for the purpose, comparing standard practices of rice drying in other countries.

Choice of suitable type or types of energy sources and required devices for the purpose, were considered important. Dried water hyacinth and other vegetable waste available in rural areas and electricity, were chosen for air heating. As a source of mechanical energy to blow air human-muscle power or electric motor, were chosen. A complete rice-drier in which any combination of the above types of energy may be used was designed frabricated and tested. Detailed cost analysis shows that dried water hyacinth to heat air and electric motor to run the blower result in lowest cost of drying. Performance of the drier developed was studied and a more suitable, Smaller but of same capacity drier is proposed for future study.

Moisture measurement of rice is important for optimised operation of the rice drier. Drying process may be terminated to the desired moisture content if a suitable moisture meter is available, while no moisture meter is used in Bangladesh. An electric moisture meter was proposed for the purpose, which was designed, fabricated and tested.

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CHAPTER - I.

1.1 Introduction.

Traditional method of sun-drying of paddy is no more considered suitable in Bangladesh, as changes in cropping pattern demands an artificial method of paddy drying.

Recent introduction of HYV (High yielding variety) rice has shifted the harvesting period of major food crop from October, November to April-May. Number of sunny days in April-May are much fewer than those in October-November. A more humid environment and an unfavourable atmospheric condition with frequent rains, have made it very inconvenient for sun-drying of paddy in April-May. In the rainy season, dry land for drying paddy becomes rare. Routine use of National High-ways for paddy-drying reveals this fact.

Difficulty in proper drying of paddy not only causes inconvenience but it also causes grain loss and quality detoriation. Thus rice growers in particular and the country in general, is losing in terms of crop, as well as cash every year because, a suitable rice-drying technology is yet to be evolued.

Hence, this project of evolving of an appropriate method of rice-drying for rural areas of Bangladesh had been taken in 1976, in the Bangladesh University of Engineering and Technology, Dacca.

Any artificial system of rice-drying will require certain type of energy or types of energy, to remove moisture from rice. Hence, it becomes a problem of 'Energy Studies' to find out the suitable source or sources of energy in the context of Bangladesh.

Dried water hyacinth and other vegetable waste in dried form, may be a suitable source of heat energy in rice driers in a rural community. Electric heaters may also be used for the purpose, where electricity is available.

Both over-drying and under-drying of rice are undesireable. In an artificial drying method, over-drying may result in greater losses. An instrument for measuring moisture content when in use with a rice drier, may result in an optimum process, terminating each drying cycle at the desired point. The desired end point may very. To obtain best results in milling, generally [1] 17%(W/W) moisture content is desired. And for safe storage of grain, a moisture at or below [2] 14.5%(W/W) in desired.

Considering all these aspects, an aritficial rice drier along with a suitable moisture meter were developed.

CHAPTER -2.

Literature Survey.

In 1913, [3] Charles W.Stanton of U.S.A. invented a vacuum drier for drying corn in united states. Fig 1 shows the drier. Vertical cylinders 1 and 2 are connected by a spout 10. 4 and 3 are vacuum pumps. The corn is introduced into the upper vessel with a vacuum of 25 in. Steam is admitted into heating coil 5 to heat the corn. Drying takes place in vacuum. Moisture is removed to the desired point using a moisture tester. Dried but hot grains are passed to the lower cylinder. In lower cylinder vaccuum is also 25 in. Here cooling takes place. Dried and cooled grains are discharged by spout 13.

In days of cheap coal and steam engines these vacuum driers were in use. Only advantage claimed was that [3] germination of corn will be wholly avoided in this type of drier. Probably, energy consumption was not a very important issue at that time.

In 1935, [4] Karl Dienst of Germany improved this drier. In his drier, the grain is dried under vacuum continuously and in uninterrupted operation within a short time and at comparatively low temperature, the power needed for operating the apparatus being like wise small.

Modern driers use hot air to dry grain. Almost always they comprise of a blower, an air heater and a grain holding bin.

The blower may be a centrifugul type fan with forward - curved, radial or backward curved blades. Orit may be an axial flow fan, while it may be of propeller type, tube axial type or vaneaxial type. Fig 2 shows these different types of fans.

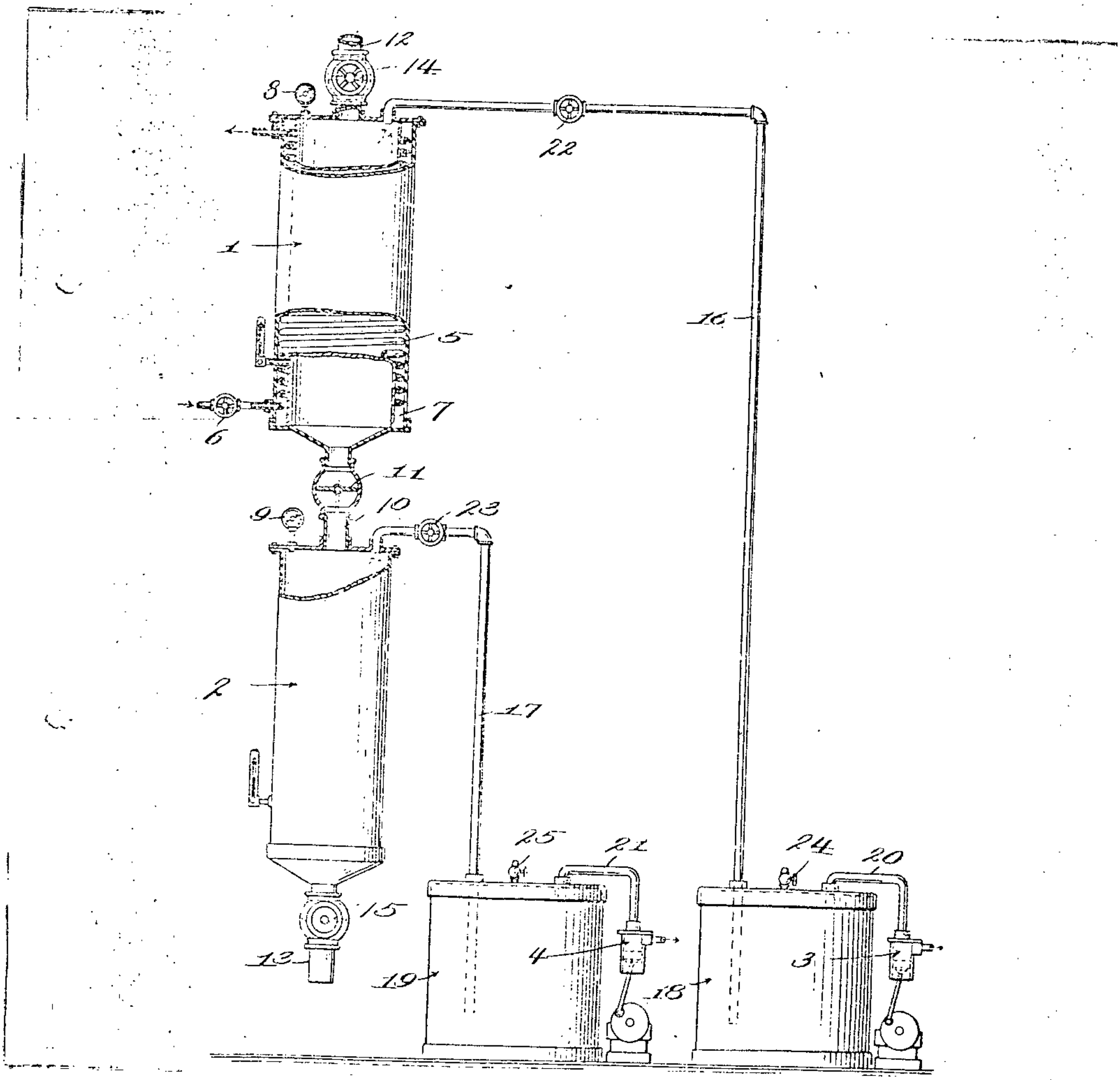


Fig-1 A Vacuum-drier

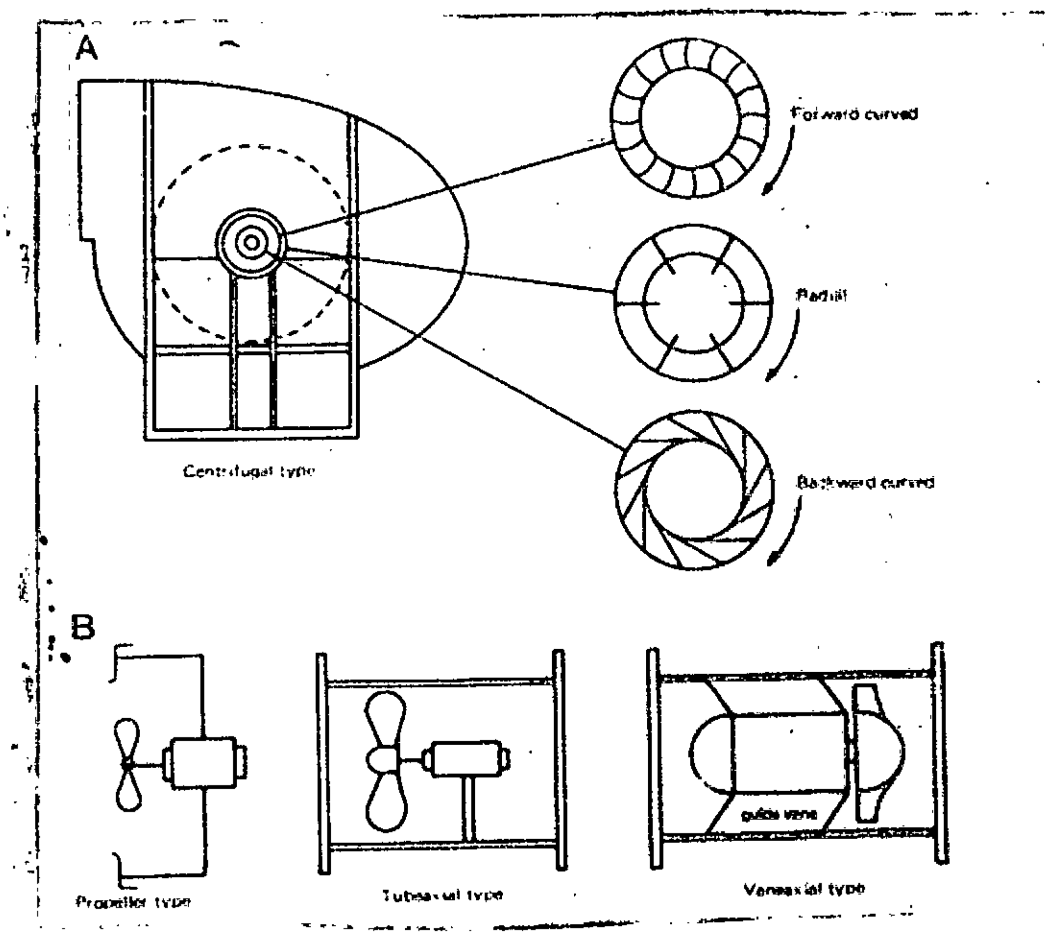


Fig-2 Different types of blower

Air heaters are divided into two types based on the method of heat transfer : (1) driect and (2) indirect. In a direct type heater, products of combustion passes through the grain along with hot air Fig 3 shows two types of heaters. The direct heater is less expensive and utilises heat energy more efficiently; however, smoke may damage the grain. In the indirect type, a heat transfer surface does not permit smoke to mix with the drying air.

Grain holding bins are designed for batch type drying or for continuous flow drying.

Batch type.

Deep-bed drying.

Grain is hold over a false floor covered with a screen mesh. The air-flow rate is a minimum as high power is required for a high rate.

In deep-bed drying bottom layer may be over dried. So a low temporature drying air is used. Such a drier is shown is Fig 4 .

Thin-layer drying.

In this type, the surface-area of the drier is increased and the depth of the drying layer of rice is decreased. In this type, the whole batch dries quickly with less charce of spoilage due to moulding, danger of over drying is less and requires a low air pressure. Fig 5 shows such a drier.

Contirmous-flow type.

Rice flows by gravity from top to bottom through these columnar driers. The disharge rate is controlled. If the rice flows in a straight path, the drier is called a non-Mixing type. In the path is dirertedd, it is a mixing type.

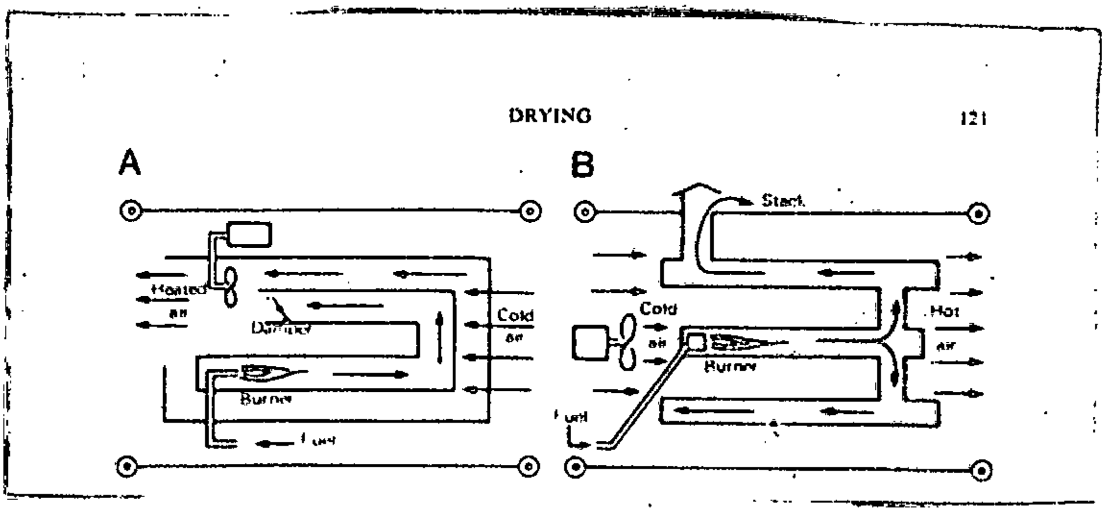
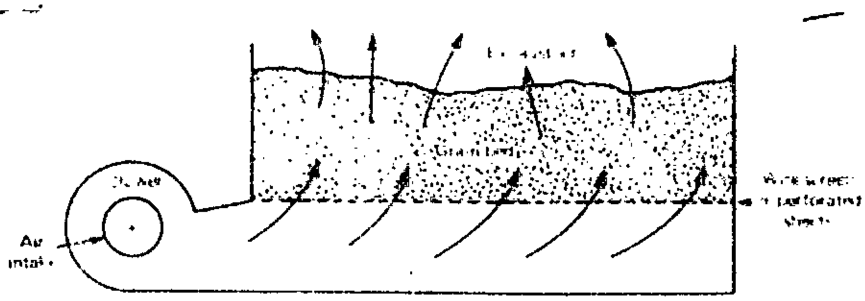
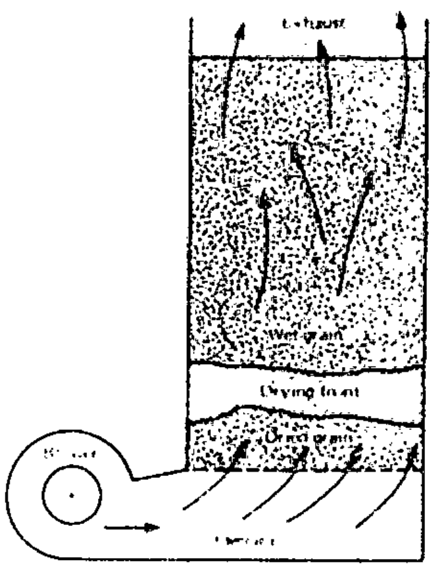


Fig-3 Different types of burner



Flat bed drier



Deep-bed drier

Fig-4 Batch-type driers

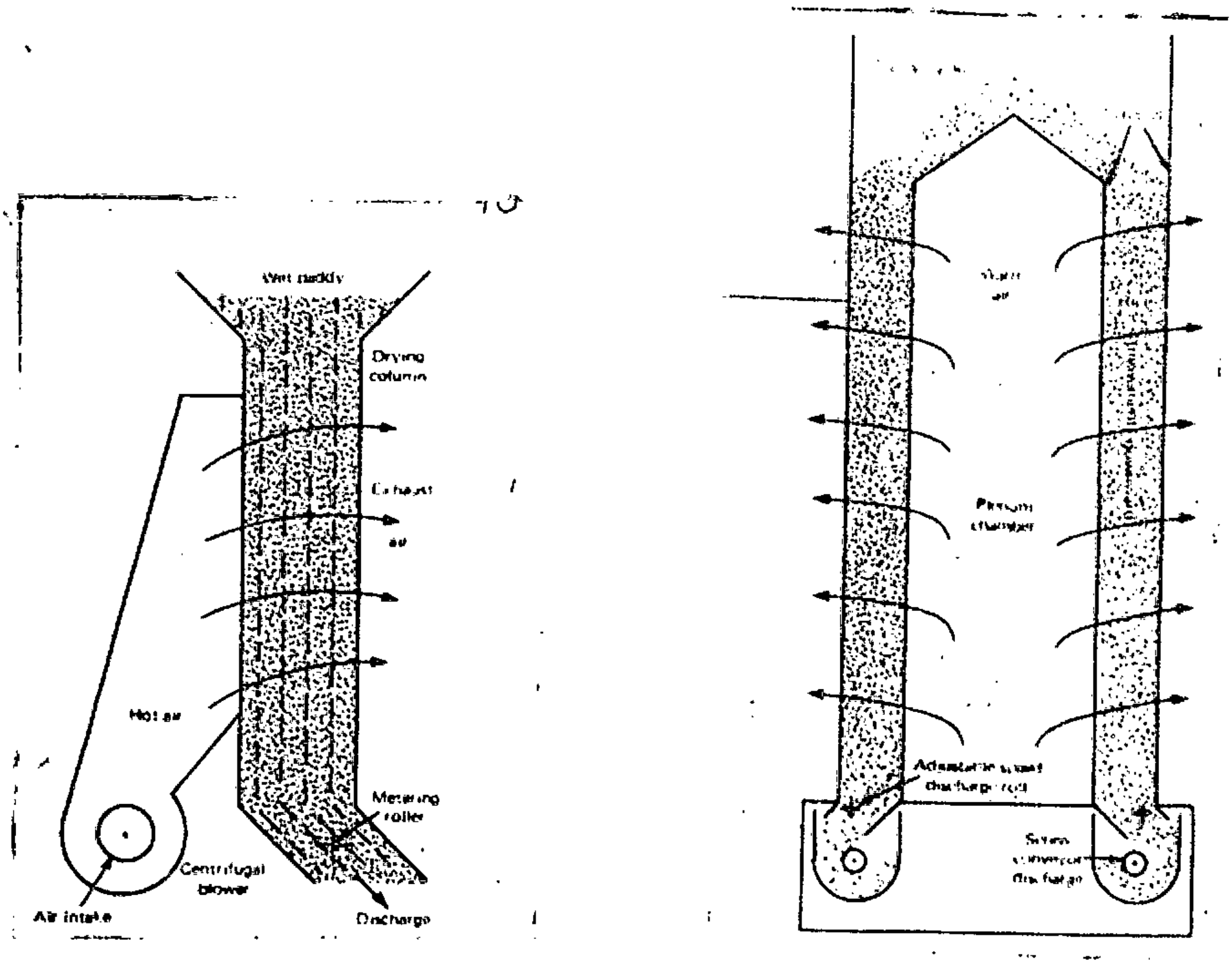


Fig- 5 Non-mixing type columnar drier

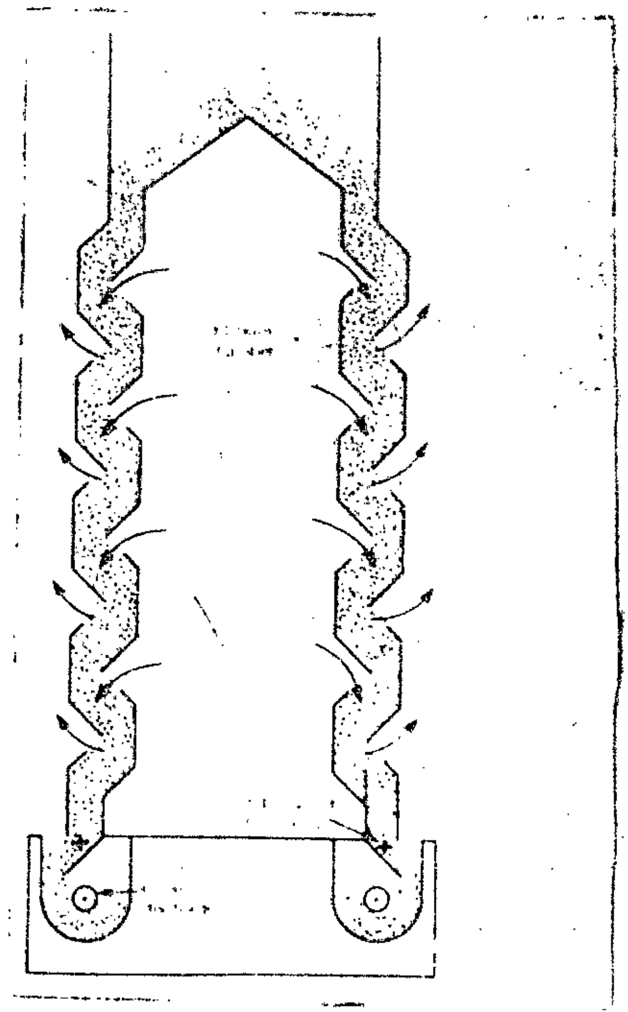


Fig-6 Mixing-type columnar drier

Non-Mixing type.

In Fig 6 , two-types of non-mixing driers are shown Grain flows straight down the column. The layer of rice closest to the imput screen is dried by holter and drier air than the layer next to the exhaust screen. However, mixing takes place during discharging.

Mixing type.

In Fig 7 a baffle type drier is shown. It is equipped with sheet metal buffles, which create turbulence and mixing. In mixing type driers, light particles are blown out with the exhaust air. This improves rice quality.

CHAPTER --3.

3.1 Traditional method of rice drying.

Traditional method of rice drying is practiced almost throughout the country. The grain is usually spread on a concrete floor in the open, where a few hours exposure to the sun is sufficient to ensure dryness. From proper assessment of the necessity of an improved grain-drying system, a survey was conducted on traditional methods of rice drying, in all three harvesting seasons of paddy.

3.2 Survey on traditional practices of rice drying.

In August, 1977, traditional method of rice drying in Avs season was surveyed in Atpara P.S. of Mymensingh District. Later in November, 1977 and in May, 1978, rice drying methods in Aman and Boro seasons were also studied.

Nearly 60 holdings were covered in each survey. A complete case history, beginning from paddy harvesting to paddy husking or storing were recorded.(Refer to Appendix-A.)

3.3 Important informations obtained from the survey.

1. In 85% cases in all the seasons; the farmers prefer to boil his produce just after harvesting, prior to sun-drying. Thus in 85% cases parboiled rice are dried by traditional method.
2. Drying load of a typical farmer's family in the harvesting season is around 300 pounds per day. Maximum load is 400 pounds per day.
3. Time taken to dry each batch completely is 8 hours approximately.
4. In most cases, two days are required for complete drying. Only 3 to 4 hours per day is the effective time for drying.

5. In 48% cases two persons are employed, while in 52% one person is employed for drying.

6. In nearly 64% cases women are employed for drying.

3.4 The question of moisture content.

In traditional method, moisture is determined by cracking a grain with teeth. Based an intuition and experience, farmers determine moisture content. This results in over drying and under drying of paddy with subsequent losses.

It is important to keep the moisture content of rice below a certain limit. This helps to reduce losses in when the reference storage due to fungi. At moisture content above [2] 14%, the fungus spores germinate and grow, although some species of fungi are able to do so at lower humidities. Oxley [2] states that in most Californian mills, paddy with a moisture content about 14 to 15 per cent produces the best result while rice for export cannot obtain a goverment certificate of grade if it contains more than 14.5% moisture.

3.5 Discussion.

The survey on traditional method was conducted in an area (of Mymensingh District). Where agricultural production is at the subsistence level. Major portion of the produce is consumed by the producer himself. It was observed that, in this area in 85% cases; paddy is parboiled before storing, for the producer's own consumption.

Researchers estimate [5] that about 10% of the crop is lost it the grains are left in the field to dry down to 14-16% before they are harvested. Thus farmers in Bangladesh probably lose a considerable protion of their produce. An effecient post-harvest practice may recover this loss.

CHAPTER- 4.

4.1 An improved rice drying system.

An improved method of rice drying is to use any artificial system to remove moisture from grain. Rice grains are hygroscopic in nature. Its moisture content varies depending on the temperature and relative humidity of the surrounding-air. To absorb moisture from the grain, the surrounding air must have a low relative humidity. A simple method of lowening the relative humidity of the air is heating. When in contact with the wet grain, the heated air raises the temperature of the grain and increases the vapour pressure of the moisture within the grain. The heating hastens the transfer of moisture from the grain to the heated air.

The drying rate is influenced by the following factors -

1. the temperature of the drying-air.
2. the relative humidity of the drying air.
3. the availability of moisture at-the surface of the grain where it can be evaporated.
4. the amount of air passing through unit amount of rice.

An improved rice drying system may be composed of the following -

1. a heater for drying air
2. a blower to foree the heated air-through rice
3. a device to hold the riee being dried
4. a system for loading and unloading rice on the holding device
5. a monitoring to control the whole process, as well as checking the moisture content.

4.2 Importance of an improved rice drying system.

i) In artificial method, drying can be done in foul and fair weather.(An all weather continuously running system.)

ii) The drying operation can be controlled accurately. This permits lowering of the moisture content of grain more closely to the levels necessary for milling with maximum head rice recovery(16 to 17% W/W)(1) or to a level suitable for grain storage(below 14.5% W/W)(2)

iii) It permits early harvest of-paddy, subsequently reducing field loss from storm and natural shattering.

iv) The harvest season can be planned to make better use of Labour.

v) It permits long term storage without detoriation.

vi) Viability of seeds may be maintained by an improved artificial system.

vii) It permits use of waste products. This point will be clarified later on.

4.3 An appropriate-rice drying system for Bangladesh.

Bangladesh-needs an improved rice drying system. Traditional sun-drying of rice is no more considered suitable. As any artificial system for drying will utilise energy other than solar, an appropriateness in choosing the right-type of energy or types of energy and the right type of device or devices for utilising that energy, may result in an appropriate rice drying system.

Reported un-employment and under employment in rural areas dictates that more and more human muscle power be used for some fruitful purpose. And a rice drying system may utilise this himan muscle power for blowing air.

For air heating, any locally available vegetable waste like dried water hyacinth may be used. At present water hyacinth - wet or dry - is considered only a nuisance.

In planning and designing for the rice drying system due consideration is given to the present technological state of the country and to the availability of materials in the local market.

A complete rice drying system, with the following salient features was proposed, with due regards to the socio-economic and ecological environment of the country.

1. The size and capacity of the rice drier should be such that it can cater the need of a group of farmers.

2. The whole system should be simple enough and suit the technological state of Bangladesh. Its operation should be simple, so that farmers can well manage it. In any case output quality should be satisfactory.

3. The artificial drier will use hot air to be forced through grains.

a. Mechanical energy to run the blower that forces air through grain may be obtained from two alternate sources. One source is human muscle power. A man may be employed to paddle the blower. Another source is electrical energy. A motor is to run the blower. Provision should be made such that either source can be used for the purpose.

b. To heat drying air, sources of energy may be dried water hyacinth or electrical energy. A furnace and a heat exchanger may heat air, burning dried water hyacinth. Alternatively, an electric heatee may heat air Either of the sources may be used.

4. An accurate moisture measuring equipment is to be used that may help controlling the drying process. It may be an electronic type equipment using locally available cheap and popular electronic spares and may be powered by two pairs of ordinary torch - light cells. Its operation should also be simple enough so that an average farmer can use it.

CHAPTER - 5.

5.1 Planning and design of a rice drying system for rural areas of Bangladesh.

Any technological improvement will be accepted by the users, only when it can serve their purpose in a better way. Hence a close observation of the drying neads of an agricultural community was made. To serve this requirement a community based drying plant is proposed. The plant may be owned by a cooperative and may serve a certain agricultural community. Farmers may utilise the plant for drying their harvest on payment in cash or perhaps commodities.

5.2 Rice drying load of a rural agricultural community.

An average farmers family handles a drying load of 400 lbs per day. This may be taken as an average figure to determine the drying load of a community.

In rural areas, family bond is very strong. Traditionally a few families live in a cluster of houses, where they share a common pond, a common wood lot or a bamboo grove. Most often they are linked by blood. All the families living in the same cluster of houses may well maintain an artificial drying system, while their traditional drying facilities are considered no more suitable.

Usually 4 to 5 in-dependent families form such a duster of houses. Drying load of such a duster of houses is roughly 2000 pounds per day or 24 maunds per day.

5.3 Sources of power for rice drying.

In an artificial drying system mechanical energy is required for blowing air through rice and thermal energy is required to heat the same air.

5.3.1: Sources of mechanical energy for rice drying in rural areas.

a. Human muscle power.

Primitive mechanical energy source is muscle power Down to this age, human muscle power drives the largest transportation system of Bangladesh- the country boat. It is observed that a man can work continuously for 2 hours and than needs a short rest. This enables him to give optimum energy output.

As to the output of an average Bangladeshi man, no previous data can be gethered. Physiologists (6) have determined that strenuous activities, suchas, swimming, running, by-cycling etc. result in 360 kilogram calories per hour, or more energy consumption in a human body. This figure is for peoples in temparate climate. Assuming that the same figure is applicable in Bangladesh and that effeciency of human body in 30%, output of a man becomes.

$$360 \times 0.30 = (108 \text{ Kcal/hour})(.00156 \text{ HP-hour/kcal})$$
$$= 0.168 \text{ HP. } (125 \text{ Watts})$$

When situation permits, a man prefers to use his leg muscles for doing strenous jobs. Hence, in designing any system utilising human muscle power, the man may be allowed to use his legs.

This may be the most suitable source of mechanical energy for drying rice. A bi-cycle may be placed on steel stands, keeping at least its rear wheel free to turn(see photo-1). Now if a man seats comfortably on the cycle's seat and paddles at a speed that results in optimum energy output, power may be taken from the rear wheel, using one method-a frictional coupling. The bi-cycle may be used for riding when drying is not required.

b. Animal muscle power.

Most of the prosent agricultural operations like tilling and threshing, are done in Bangladesh by animal muscle power. Already these sectors are demanding more and more power. While the animal muscle power in rural areas is dwindling. Hence, it may be wise not to use this source for drying.

c. Electric motors/Diesel engines.

Rural Electrification Board in their effort for area coverage, may make available electrical energy to every nook and corner of Bangladesh in the near future. Hence electric motor may be the only competitor of human-musele power, for rice-drying. Only a proper evaluation of capital expenditure and running cost of both electrically driven machines and human muscle power driven machines, can show which one is the most suitable for a certain purpose. This is considered important.

Our experience suggests that, diesel engines are far too complicated than electrical machines. Its intricate components discourage its wide use in rural areas. Introduction of these engines in mid-sixties for irrigation or tillage, are yet to be popular among masses. Moreover, recent high oil price diminishes further its utility in rural areas. Hence diesel engines were not considered as a mechanical energy source for rice drying.

In view of the above facts, only an electric motor is considered to be an alternative drive for the blower. Hence an electric motor is incorporated in the air blower. As an alternative to the human muscle power drive, this motor can also drive the blower (see photo-1)

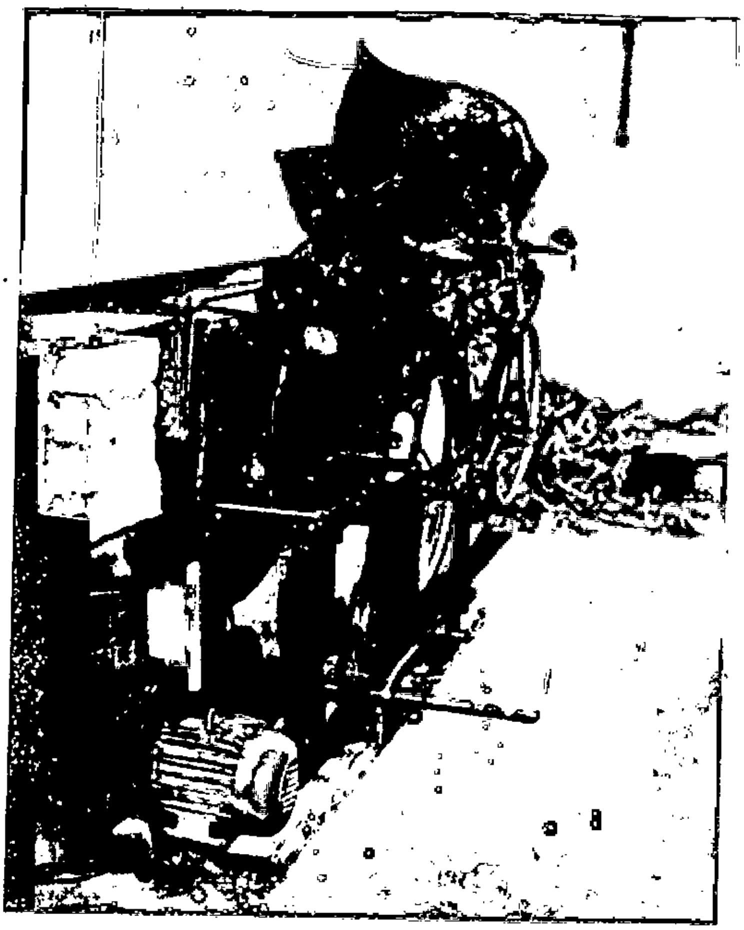


Photo-1 Air-blower, bi-cycle & electric motor

5.3.2: Source of heat for a rice drying system in rural areas.

a. Dried water hyacinth.

Water hyacinth a well-known aquatic weed is considered as a nuisance in rural Bangladesh. In every year this enters into rice field and causes considerable loss to crop production. Moreover, it causes difficulties in navigation during antumn season and destroys the fisheries.

Only to a very little extent, this water hyacinth in dried form is used as fuel. It was observed in Munshiganj-Manikganj areas of Dacca district, that poor people collect water hyacinth in dried form from road-side ditches to burn for domestic purpose.

For domestic purpose, this dried water hyacinth may be considered as the worst type of fuel. A study on domestic energy sources of Bangladesh (7) reveals that when used for the same purpose, dried water hyacinth takes 48% more time than fire wood. (see table -1).

In an certificial drying system; a blower is to be used for blowing air. If a small portion of this air is used for burning of dried water hyacinth, on effecient burning can be assured. Hence dried water hyacinth is chosen as perhaps the best source of heat for the rice drying system.

Water hyacinth does not have any production cost at the moment. But its high moisture content results in a very high handling cost. Table shows the observations on collection of water hyacinth.

Table No 1

Results of experiments on utilisation of domestic energy sorces of Bangladesh in cooking 2 seers of rice

Type of fuel used	Fuel required (in lbs)	Time of cooking (in min)
Fire wood	3·0	56
Cow dung	3·0	78
Dried water hyacinth	3·5	83
Twigs & leaves	2·5	58
Jute stick	1·5	38

Refer to project report on "Study of Domestic Energy sources of Bangladesh", submitted to the E.E. Deptt. of Bangladesh University of Engineering & Technolgy, Dacca in 1976.

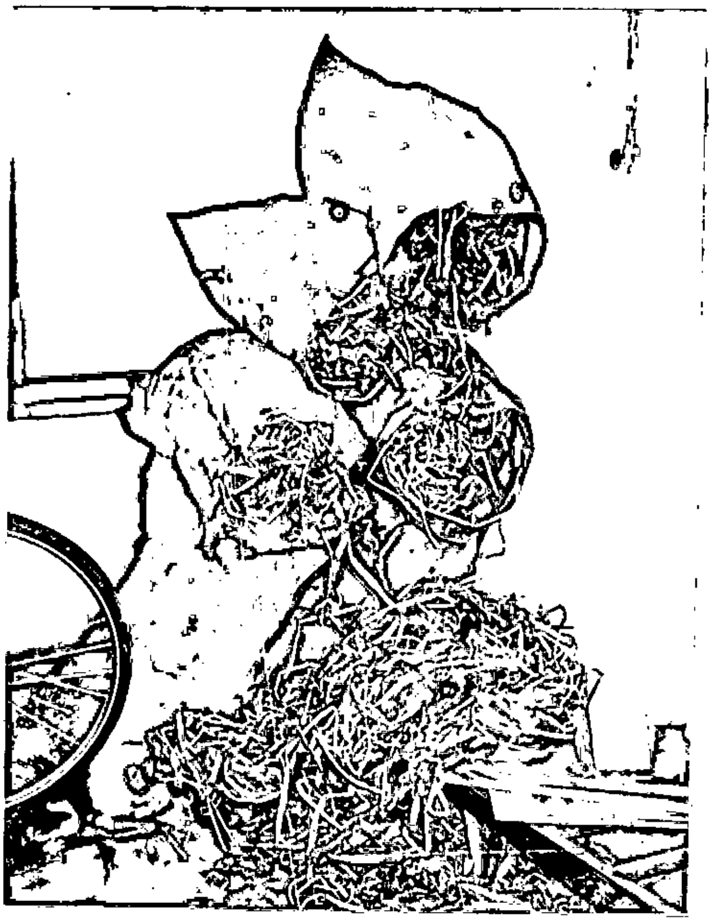


Photo-2 Dried water hyacinth

About 300 pounds of fresh water hyacinth can be collected in one man-hour. Since daily wage of a Bangladeshi labour is Tk.10/- per day(maximum, working period, 8 hours per day); collection cost of dried water hyacinth (as moisture content is about 95.5%) is approxinately Tk.0.10 per pound.

b. Electrical Energy.

When electrical energy will be available in most of rural areas of Bangladesh and other cheap sources of energy will be more scarce than the present time, electric heater may be used in place of burners using vegetable waste. Hence in the ultimate design of the rice drying system, an electric heater was provided as an alternative to the oven. It will also serve the purpose of comparison between water hyacinth and electric heating.

c. Other vegetable wastes.

Dry vegetable waste like leaves, twigs etc. obtainable fro home-stead forest or from crop field, may well be used in dried form, instead of dried water hyacinth.

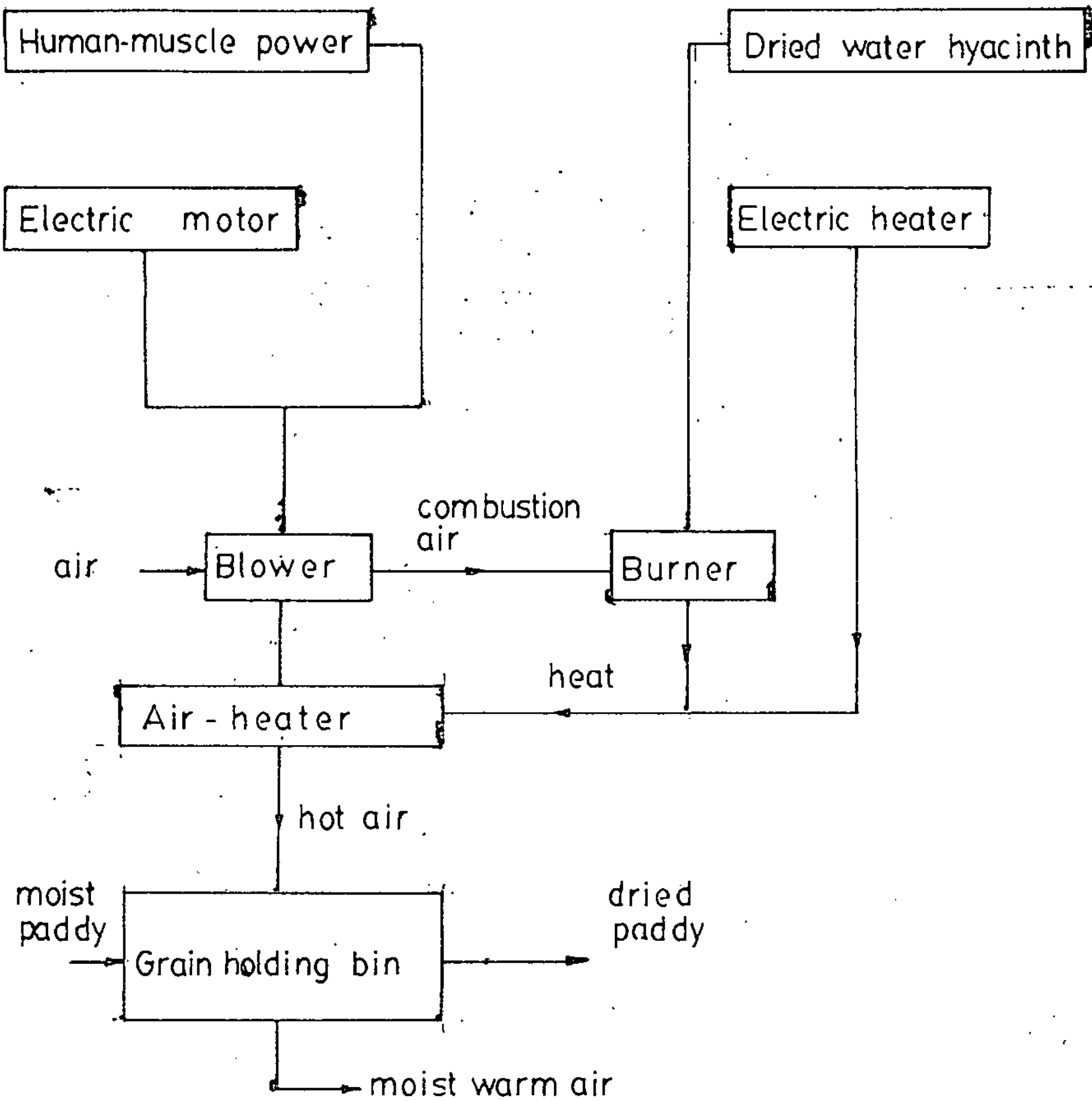


Fig - 7 Proposed rice drying system

5.4 Moisture measurement in the rice-drying system.

Accurate measurement of moisture content is a pre-requisite for the quality control and optimum operation of the rice-drying system.

An electronic moisture meter with the following features is considered to be the most suitable for the purpose.

1. It should be a small, portable meter using ordinary torch cells as power source.
2. Its operation should be simple enough, so that an average farmer can master its operation.
3. Readily available electronic spares,familiar to rural electronic technicians(radio makers) be used in its design.
4. Electronic circuits be simple enough that permits rural electronic technicians to repair it.
5. Accuracy and reproducibility should be such that it serves the intended purpose.
6. Its range should be such that it covers the usual moisture variation in paddy(and other common cereals)

5.5 Design of an appropriate rice-drying system.

Most often in a design problem there is a limiting factor. Entire design procedure then depends on this "Limiting factor". In designing the rice drying system, the "limiting factor" is the human-muscle power. Output from such a drive when only one man is paddling is very low. No dependable information about the power output and other characteristic of such drive is available. As the blower is driven by human-muscle power, its output becomes low in both volume of air, as well as, velocity head of output air.

Aim in the design is to dry maximum amount of rice in a minimum amount of time, while there remains two constraints. One is to use a man for paddling the blower, another is to use dried water hyacinth as fuel to heat the air. Designer can optimise the design in two ways.

i) Available air from the blower may be forced through the maximum amount of rice, through which this air can pass. It requires a higher velocity head at the discharge point of the blower. In a commercial drier 50-100 cfm of air passes through each bushel of rough rice.

ii) Temperature of drying air, when it enters into grain may be kept as high as possible. According to C.W. Hall (8) temperature of drying air can be as high as 130°F(55°C) as long as the grain temperature does not exceed 110°F. Air temperature upto 150°F (66°C) might be used to reduce the drying time, but there is a noticeable effect on the milling qualities and germination at these higher temperatures.

As stated earlier, desired capacity of the drying system is at least 24 maunds per day. Taking the above stated limiting factor in consideration it was decided that ;

1. nearly 100 cfm of air per bushel will be passed through rice, (1 bushel 45 pounds of rough rice) and

2. drying air temperature will be 55°C.

The actual capacity will then depend on the output of the blower. If the capacity of the drying system becomes around 24 maunds per day, the design may be considered satisfactory. Otherwise, only an increouse in the human-muscle power drive can result in a larger drying capacity.

5.5.1: Design of a blower.

The blower can both be driven by human-muscle power drive or by an electric motor.

Using a bi-cycle fitted on steel frames with its rear-wheel free to rotate and taking power by friction coupling from this wheel, a blower was tried to be driven. At first the blower was an axial one. The output was very low and was considered inadequate. Two cycles in tendem were then used. The result was still unsatisfactory. Speed difference between the cycles result in high frictional loss, vibration and noise. The axial-type blower was then changed by a radial type blower.

An electric motor is incorporated in the design, as an alternative to the bi-cycle drive. Both the friction pulley which is coupled with the bi-cycle wheel and the electric motor, are connected by rubber belts to a common shaft. This common shaft may be driven at will be either of the drives. The fan shaft is connected with the common shaft by a rubber belt. (see photo-4).

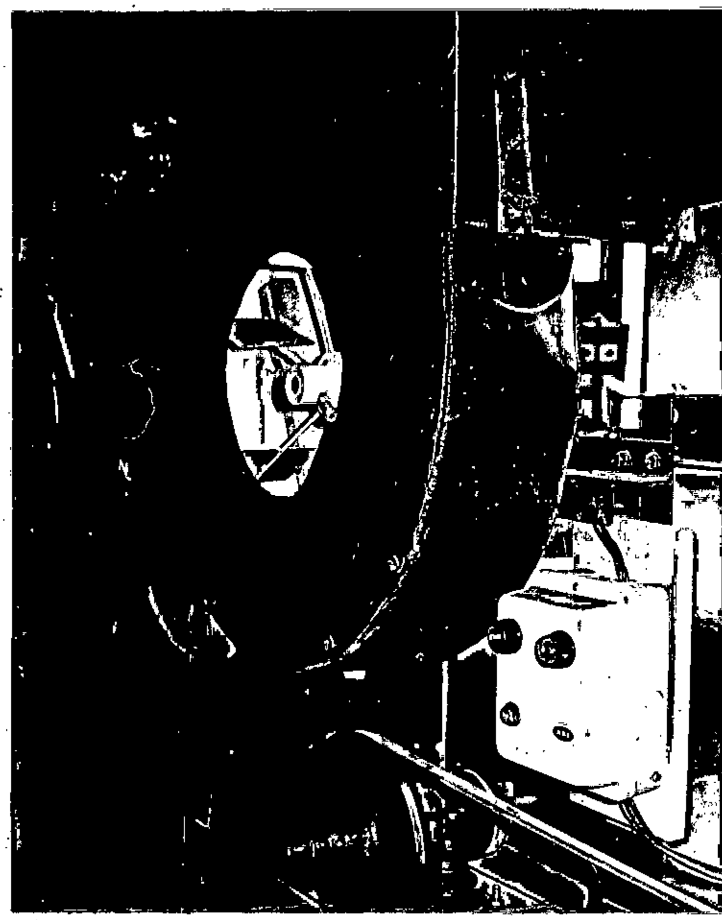


Photo-3 Air-blower

To determine the speed, at which an average Bangladeshi can drive continuously, an optimum amount of load, number of experiments (trial and error) were performed on the bi-cycle drive, with the axial-type fan as the load. Table no-2 shows the ultimate results obtained. Thus fan speed was set at 465 rpm when both motor and bi-cycle drive result in same speed, that is, 465 rpm.

A rotor diameter of 25 inch is chosen for the radial-type blower. For a rotor speed of 465 rpm, tip speed of the blower becomes.

II.D.N. = 3042 fpm

Here D = diameter of rotor, 25 in.

N = rotor speed, rpm.

An example (9) of a radial-type straight-blade blower shows that for a tip speed of 3042 fpm, total static pressure at the blower outlet is 1.3 in of water.

For a tip speed of 3042 fpm, static pressure will be

$$1.3 \times \left(\frac{3042}{4000}\right)^2 = 0.75 \text{ in of water.}$$

Assuming that only 50% of the total developed presure will be available for forcing air through grains and the rest 50% will be lost in the air heater and other ducts, them only 0.4 in of water pressure will be available.

The blower was tested for its air output. Total measured output was recorded as 700 cfm.

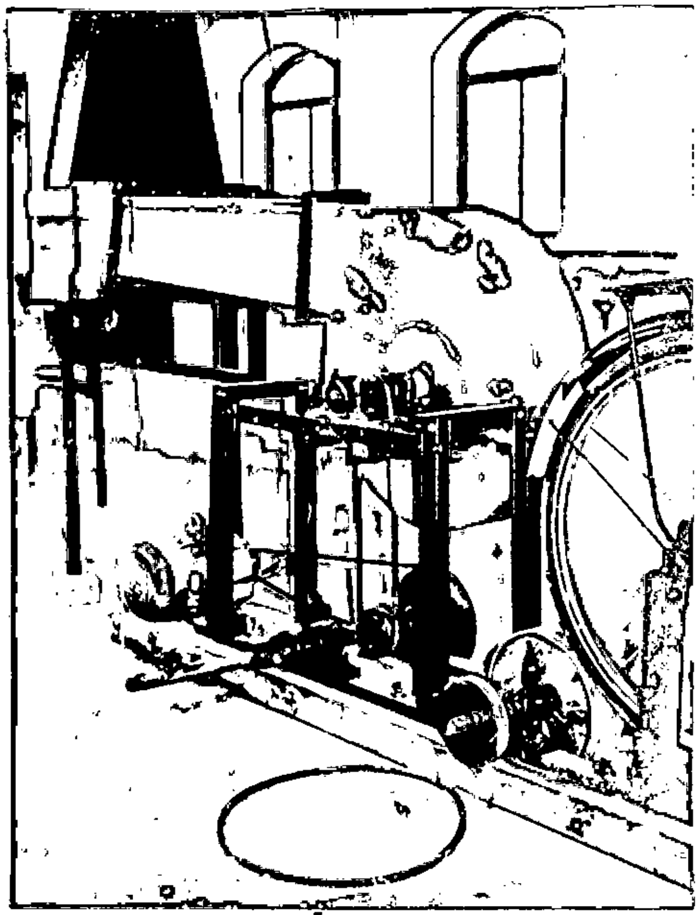


Photo- 4 Common shaft, pulleys with belts

Table No 2

Measured speed in rpm at various points

Fan shaft	Common shaft	Friction pully shaft	Bi-cycle rear wheel	Paddle
465	350	180	60	25

5.3 Design of the rice-holding bin.

A vertical continuous type drier was chosen for the purpose. To be more exact, the drier is a combination of a batch-type and a continuous-type. Grain flows through it intermittently. It is a counter-flow drier. Theoratically (9) this type of drier gives the best fasted method. A schematic diagram is shown is Fig-8, while the detailed drawings are shown in Drg-1 and 3.

According to 'Norton (10) the most economical depth for D(see Fig-8) will depend largely upon the lowest combination of corresponding costs of fan power and drier construction for the various grains and initial and final moisture conditions. For example if air flow rate of 80 CFM per bushel through rice were desired, the depth of section D would be limited to around 9 to 10 inches.

In designing, it was assumed that out of 700 cfm output of the blower only 300 cfm will be available for blowing through rice. Increase in back pressure, decreases the output of the blower. Pressure available is assumed to be 0.4 in of water. Available 300 cfm can be blown through 3 bushels of rough rice, as 100 cfm/bushel is the desired maximum flow rate.

Let us choose, grain depth = 6 in.

Density of wet rough rice = 27 lbs/ft.^{3}

(Determined experimentally)

∴ Required floor area for (3 x 45) = 135 lbs of rough rice

$$= \frac{3 \times 45}{27 \times 0.5} = 10 \text{ ft.}^2$$

Air flow through the floor area is 30 cfm/sq.ft.

From the graph shown in Fig-9, for air flow rate of 30 cfm/ft.^{2} through rough rice(13% moisture content) pressure drop/ft is 0.8 in of water. Hence for a grain depth of 6 inch, pressure drop becomes 0.4 in of water.

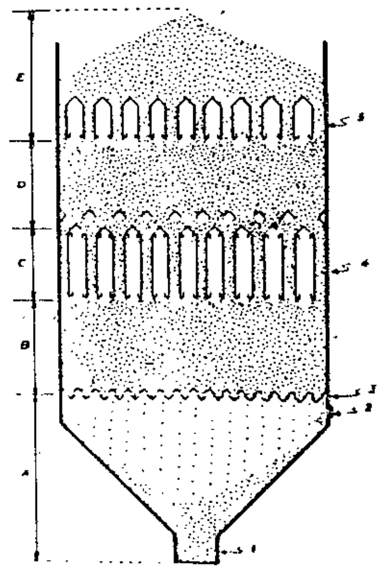


Fig-8 Schemetic diagram of a counter flow drier

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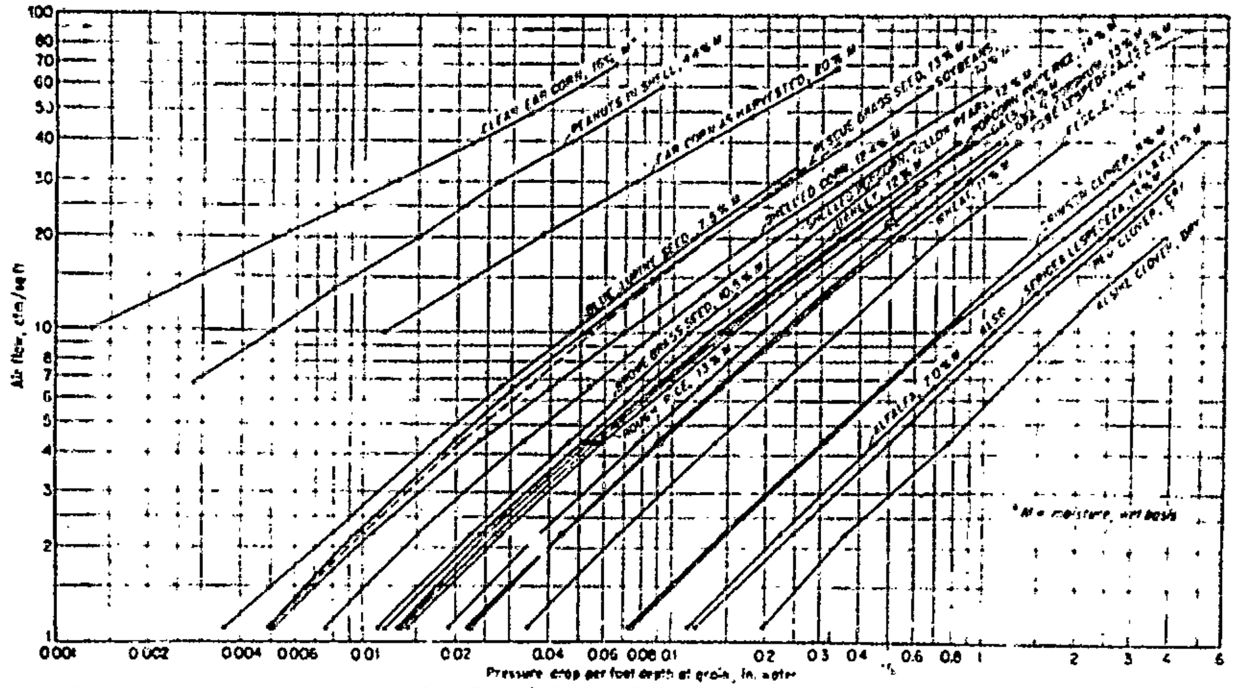


Fig. 49-1. Resistance of grains and seeds to air flow. (*Shedd, Resistance of Grains and Seeds to Air Flow, Agr. Eng., 34 616-619, September, 1953.*)

Fig- 9 Air-flow Vs. pressure drop curve

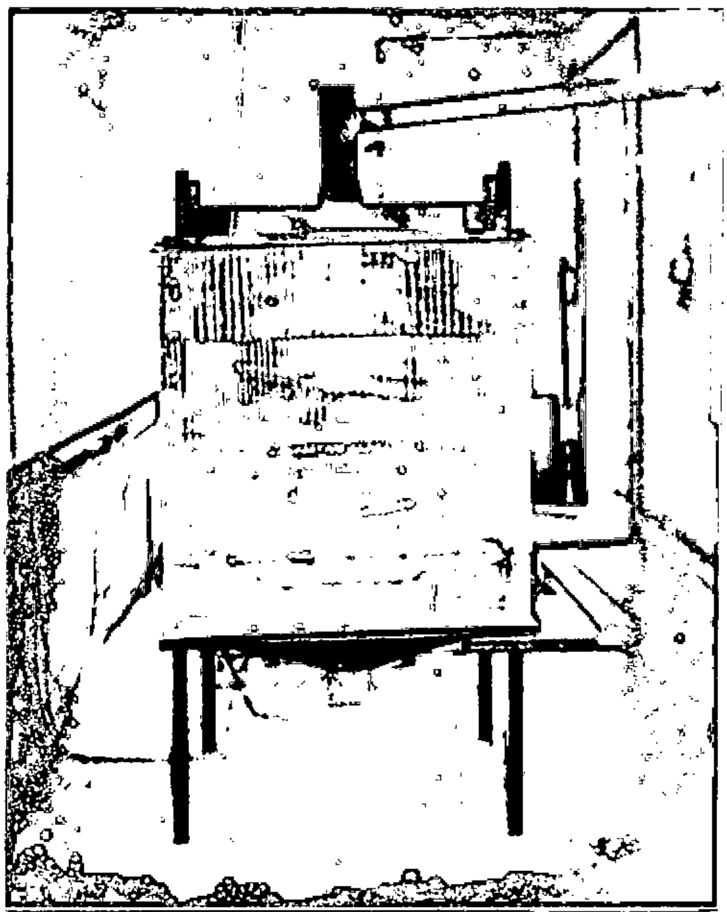


Photo-5 Grain holding bin

5.5.3: Design of the air-heater.

An indirect type of heater is chosen to heat drying air. Dried water hyacinth burns inside a furnace that gets its combustion air from the same blower. Combustion process is controlled by controlling the air for combustion. Resulting ash and other unburnt portion of the fuel grate. Air for combustion passes through the ash chamber and the grate, to the furnace.

In determining the heat requirement to heat air, practical design practice is to avoid complicated conversions from weight to volume at various state points by assuming all air supply to be at standard specific volume of 13.34 cu-ft per pound and, standard specific heat of 0.24 Btu per (pound)(deg)(11)

In this way, the sensible heat delivered to the air stream may be expressed as

$$H_3 = 0.24 \left(\frac{60}{13.34} Q\right) \Delta T = 1.1\ Q\ \Delta T.$$

Where H_3 = sensible heat absorbed, in Btu per hour
Q = Cu-ft of air delivered per minute(cfm)
T = Change in dry-bulls temperature of the air.

In this case, final air temperature = 140°F(60°C)
Let, ambient temperature = 77°F (25°C)

$\therefore \Delta T = 63°F$

Required air-flow = 300 cfm.

Estimating total requirement of combustion air and other losses as 50 cfm, total air to be heated becomes 350 cfm.

Thus, required heat flow is
$H_3 = 1.1(350)(63) = 24{,}255$ Btu per hour.

Effeciency of indirect heater is assumed 45% only. And heating value of dried water hyacinth is assumed as 5,400 Btu per pound.

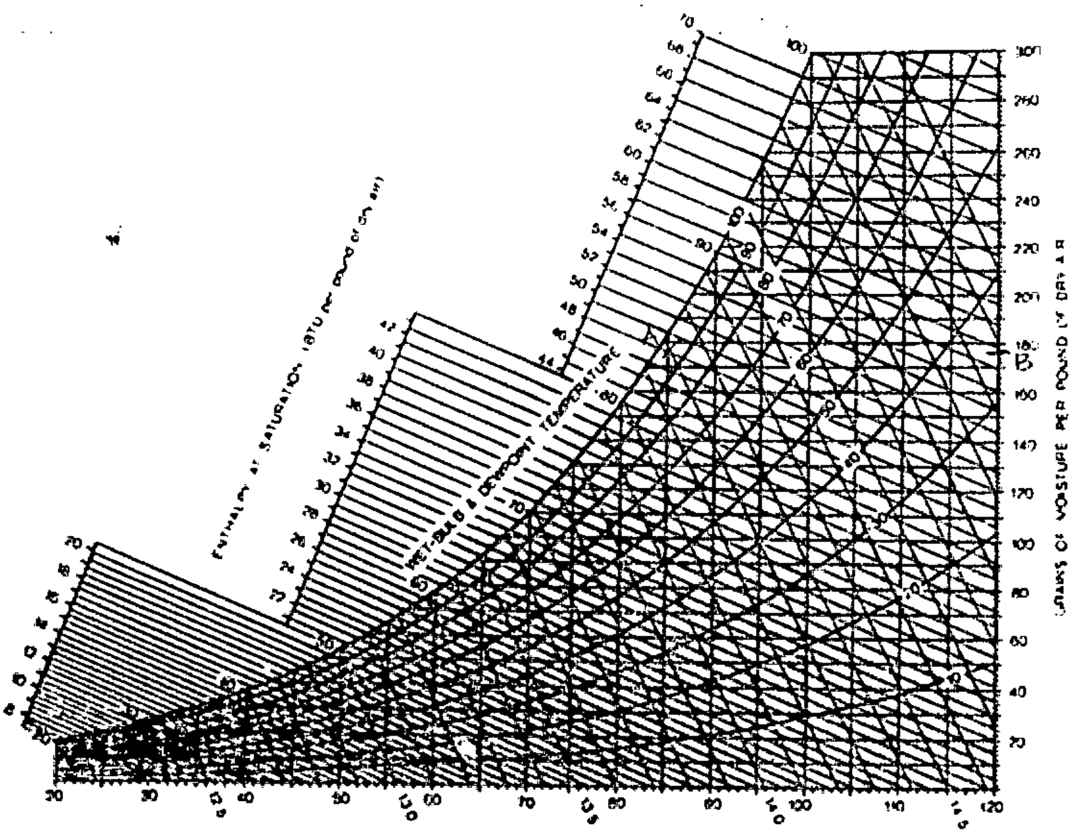


Fig. 61. A typical psychrometric chart (barometric pressure 14.696 lb/in ²).

Fig 10 Psychrometric chart

Hence, fuel requirement $= \frac{24.255}{0.45 \times 5,400}$

$= 10$ lb/hour.

Composition of dried water hyacinth is shown in table -

Air required for combustion (12) is given by

$$P = 11.48C + 34.19(H_2 - \frac{O_2}{8}) + 4.305$$

$$= 11.48(.335)+34.19(0-.056)+4.30(.0035)$$

$$= 5.78 \text{ lbs of air / lb. of fuel}$$

Required air-flow for combustion for a fuel rate of 10 lbs of dried water hyacinth per hour is

= 5.78 x 10

= 57.8 lbs. of air per hour.

At 80°F ambient temperature and 80% relative humidity, density of air is 14.0 cu-ft/lb(From the psychrometric table, Fig 10)

Thus, combustion air requirement

= 57.8 lbs of air/hour x 14.0 cu.ft/lb.

= 14 cfm.

Above the furnace is the heat exchanger(see Drg 4) Hot gases and product of combustion passes through this heat exchanger. The 20 in. x 8 in. cross section of the heat exchanger is divided into 20,1in. x 8 in. sections which are separated by thin sheet metals. Hot gases pass through alternate sections, while cold air passes through remaining sections. Flow of hot gases and cold air are opposite to each other. Heat from hot gases pass to the cold air and then the hot gasses escapes to the atmosphere through the chimney.

To minimise conduction loss of heat from the heat exchanger, it is thermally insulated at both ends by insulating bricks of conventional dimensions.

5.5.4: Electric heater design.

The electric heater is placed between the heat exchanger and the inlet to the drying section. Heating elements are placed inside the space enclosed by insulating bricks.

Assuming 100% effeciency for electric heaters, and knowing the requirement of air heating as 24.255 Btu/hour (art 5.5.3) heater capacity becomes.

24,255 x 0.293 = 7107 watts(1 Btu=0.293 watt-hour)

Line-to-line voltage at the laboratory is 425 volts. No.22 size of 'Nichrome' wire available in the local market and sold as '2000 watt heating coils, were procured for the purpose. Experiment shows that when 6V A.C. is impressed on 14 turns of the heating coil, a current of 5.6 amp flows through the turns.

A total of 9 pieces of 2 in. x 8 in. mica-sheets of $\frac{1}{8}$ in. thickness were arranged vertically in equal spacing inside a 20 in. x 8 in. frame of 0.25 in thick asbestos sheet(see Fig-11). In total 24 segments of heating coils with 14 turns/coil were arranged in each of the 2 in. x 8 in. mica-sheets. Then, segments, in 3 adjacent sheets were all placed in series. This was termed as a coil. Then all the 3 coils were connected in delta. Full line voltage was impressed on these coils that are connected in delta.

Total number of segments.

= (24 segments/sheet)(3 sheets/coil)(3 coils in delta)

= 216

Voltage impressed on each segment = 5.9 Volts

Current in each segment is 5.6 amp.

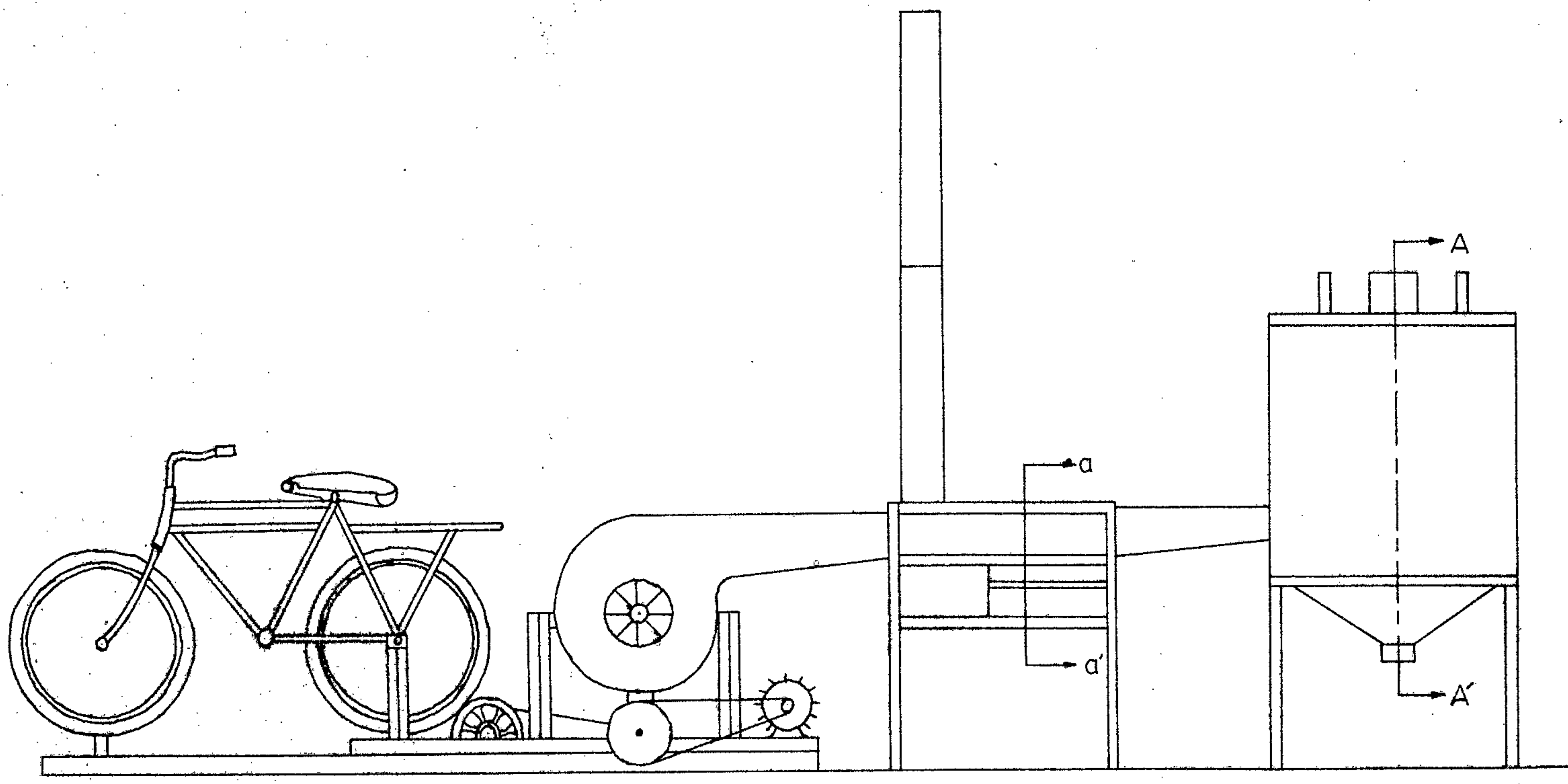
Total power dissipation =(Power dissipation/segment)

X (Total number of segments)

=(5.9 x 5.6) x (216)

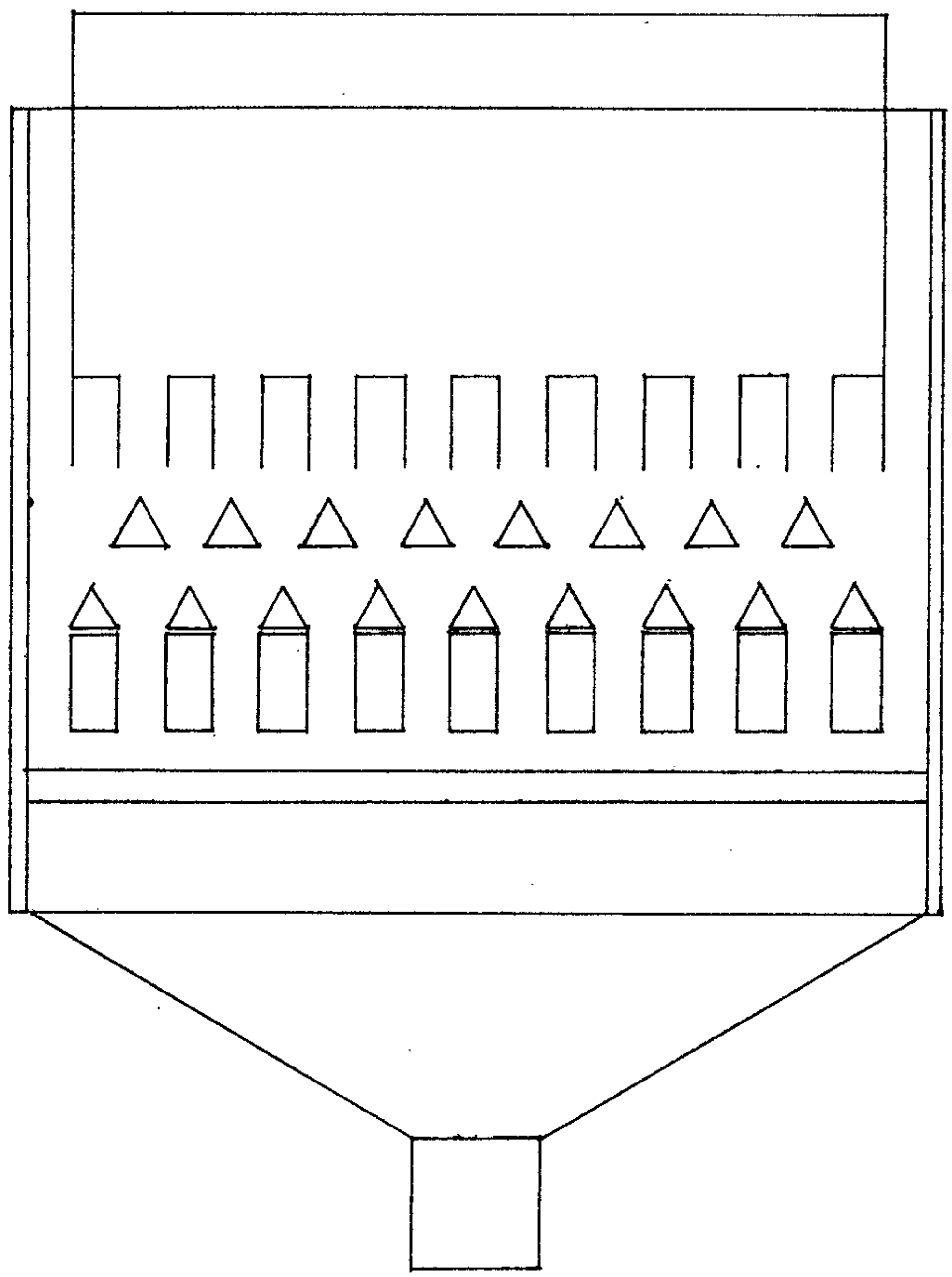
= 7,137 watts.

Actual test on the electric heater shows that only 14 turns per segment result in nearly 68°C air temperature (with 25°C ambient). The heat seems to be detrimental to the heater it self. Hence, number of turns were changed to 17 **turns** per segment. This gives required 60°C at 25°C ambient.



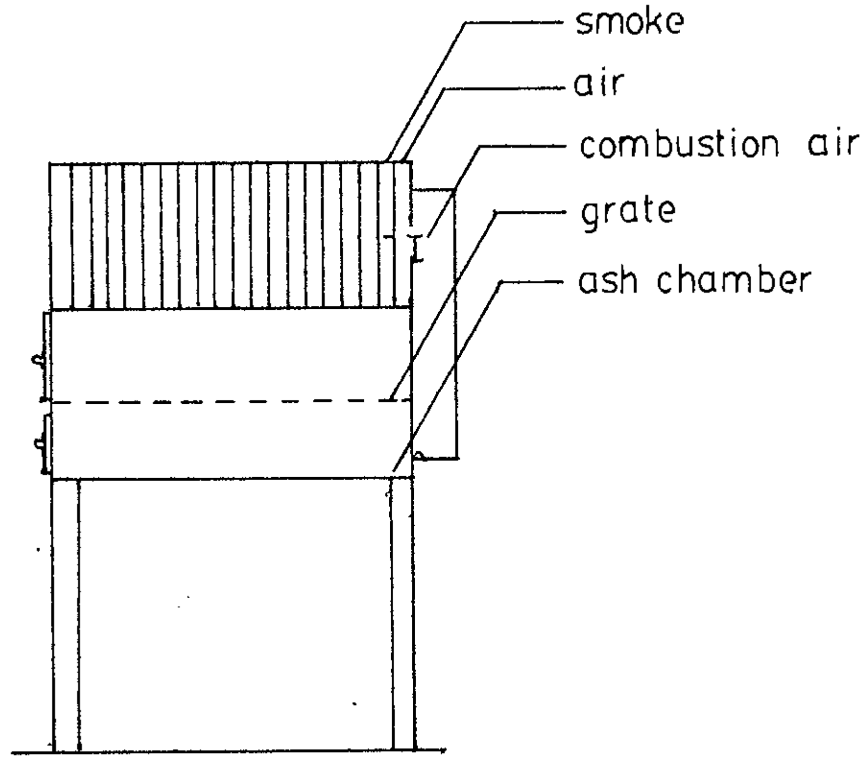
DRG-1 THE RICE DRIER

SCALE 1"=

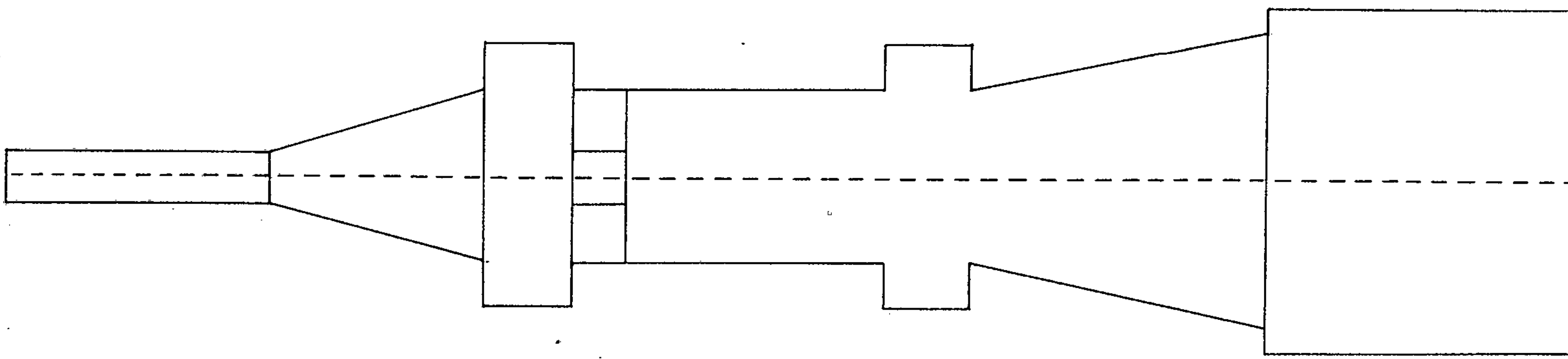


DRG-2 CROSS-SECTION AT AA' GRAIN HOLDING BIN

SCALE 1"=10"

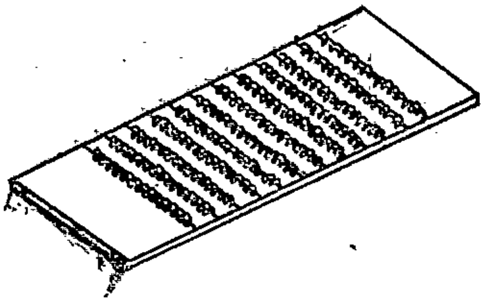


DRG - 3 Cross-section of air heater at a - a′

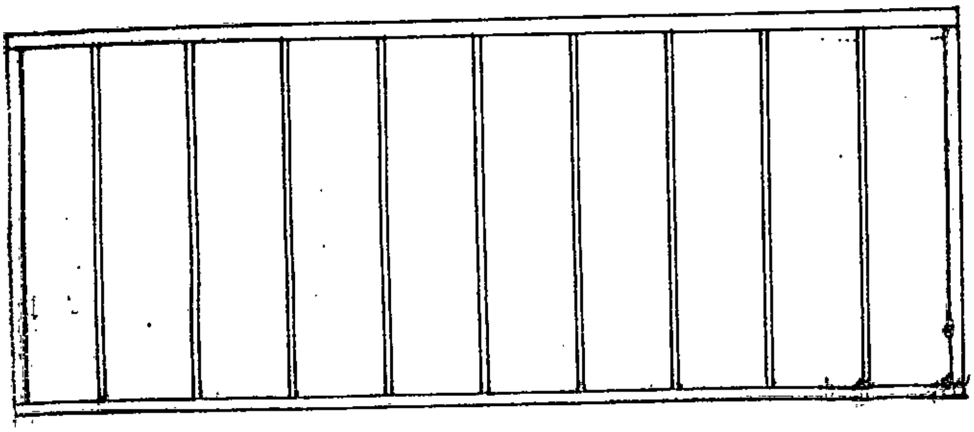


DRG-4 PLAN OF THE RICE DRIER

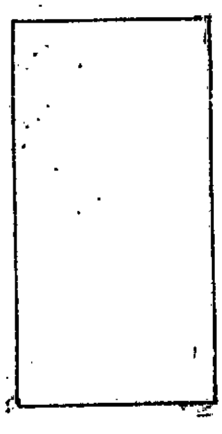
SCALE



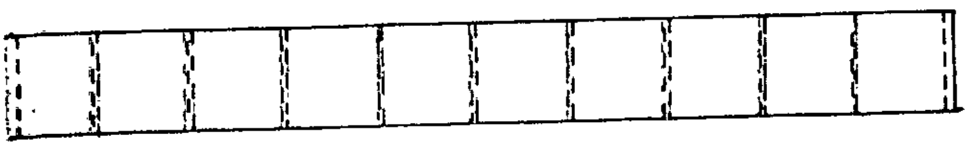
HEATING COILS



FRO FRONT VIEW



SIDE VIEW



TOP VIEW

Fig-11 THE ELECTRIC HEATER

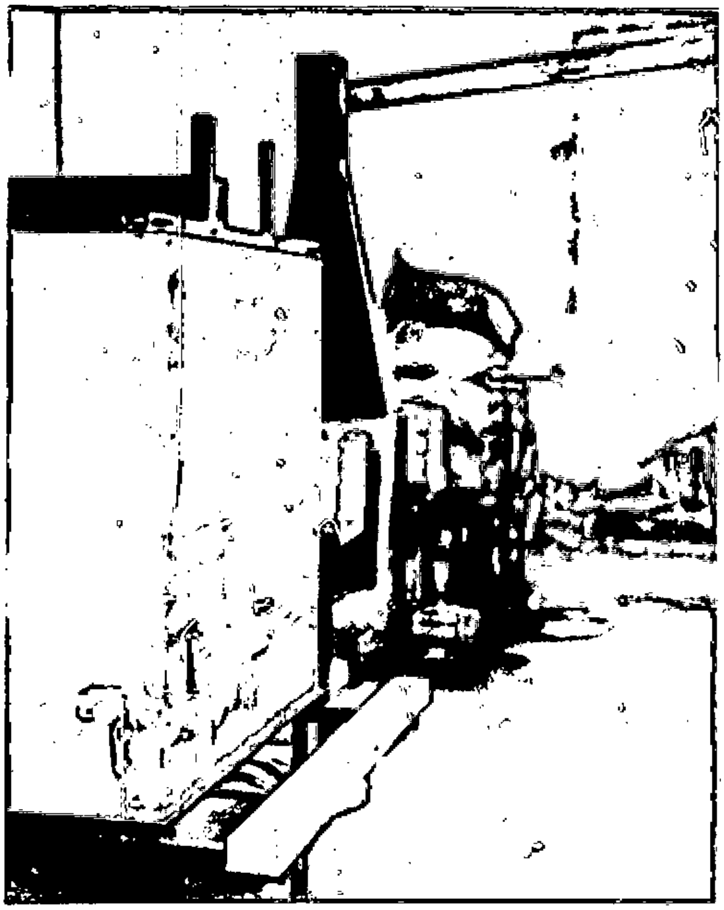


Photo-6 The rice drier

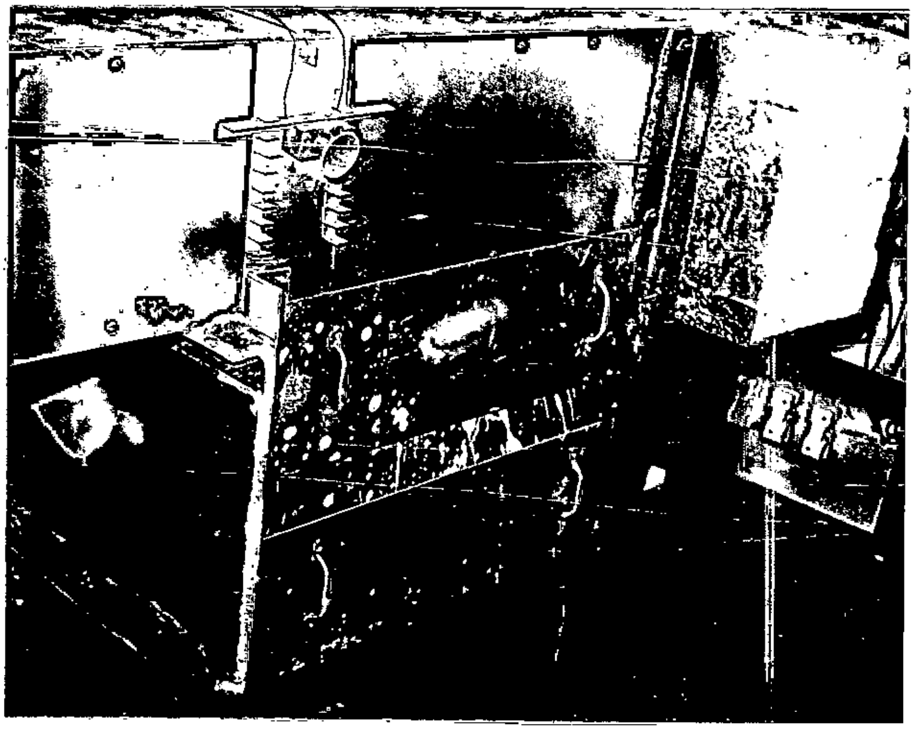


Photo-7 Air-heater & burner

Photo-8 Chimney of burner

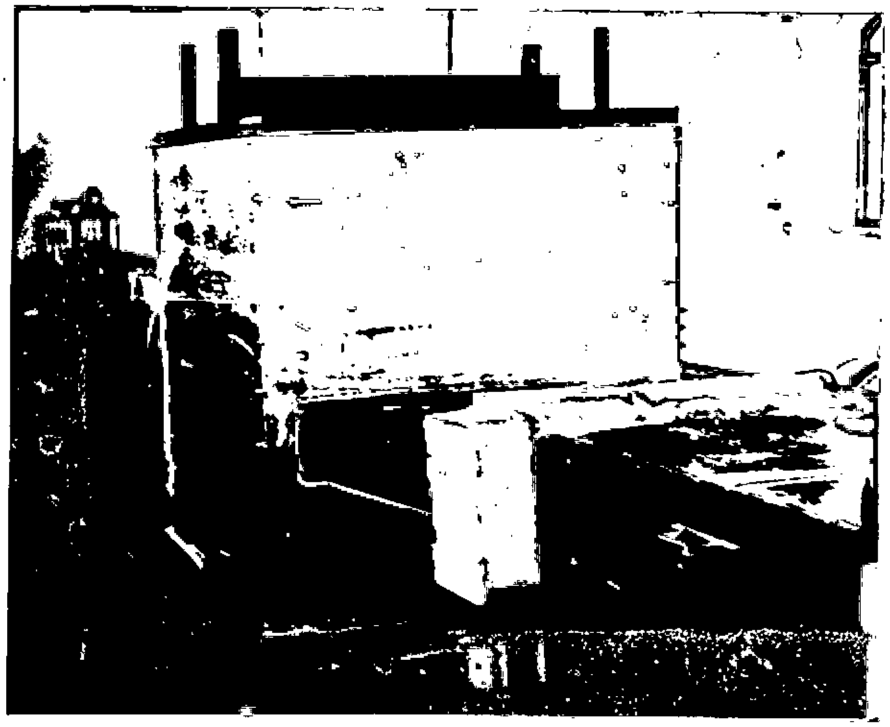


Photo - 9 Burner & rice holding bin

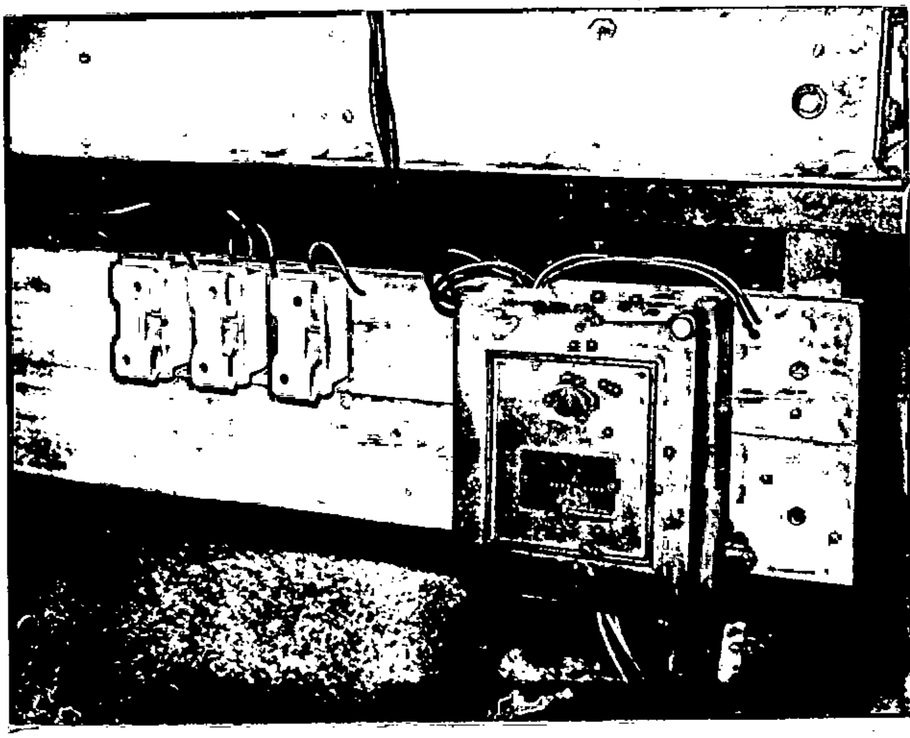


Photo - 10 Electric panel for heater & motor supply

CHAPTER - 6.

6.1 The moisture-meter-its design and calibration.

An accurate method of moisture measurement helps in optimum utilisation of the rice drier. The drying process can be controlled effectively to the desired end point. This has led to the development of a portable moisture-meter for rapid determination of moisture content.

6.2 Theory.

Moisture present in grains changes the dielectric constant of grains. Dielectric constant of dry grains is 5, while that of water is 80 (13) Thus percentage of water present in grains changes the overall dielectric constant of grains.

If grains at various moisture content are used as dielectric between two plates of a capacitor, the change in moisture content changes the capacitance of the capacitor. If a capacitance bridge is used to measure this change in capacitance the result of measurement may be used in moisture determination. Usually the scale is directly graduated in percentage of moisture..

6.3 Description on the design, fabrication and operation.

The Schematic diagram shown in Fig -12 shows in block diagram, the major elements of the moisture-meter. The oscillator shown, generates a sine-wave of 350 KC with a voltage level of 50V peak-to-peak. This sinusoidal voltage is impressed on the bridge network shown. Its a simple a.c. bridge. Two of the four arms are containing resistance of equal values(24.53 KΩ). These resistance levels were adjusted accurately using kelvin bridge for measuring resistance. One arm of the A.C-bridge contains a specimen holder with two parallel plates(4 in. x 5 in.) spaced 0.5 in apart, between which the grain specimen is placed.

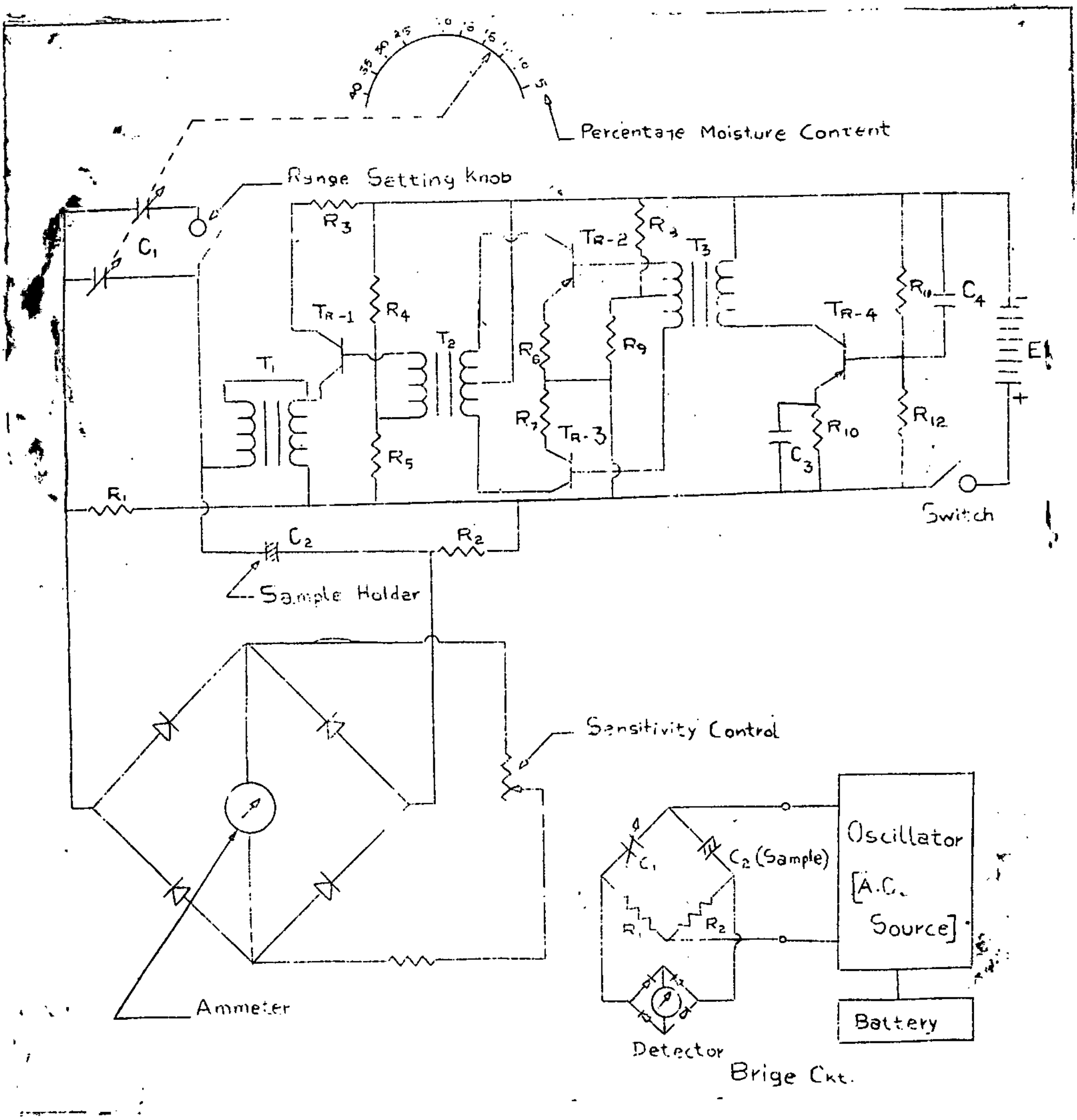


Fig - 12 Circuit diagram of the moisture meter

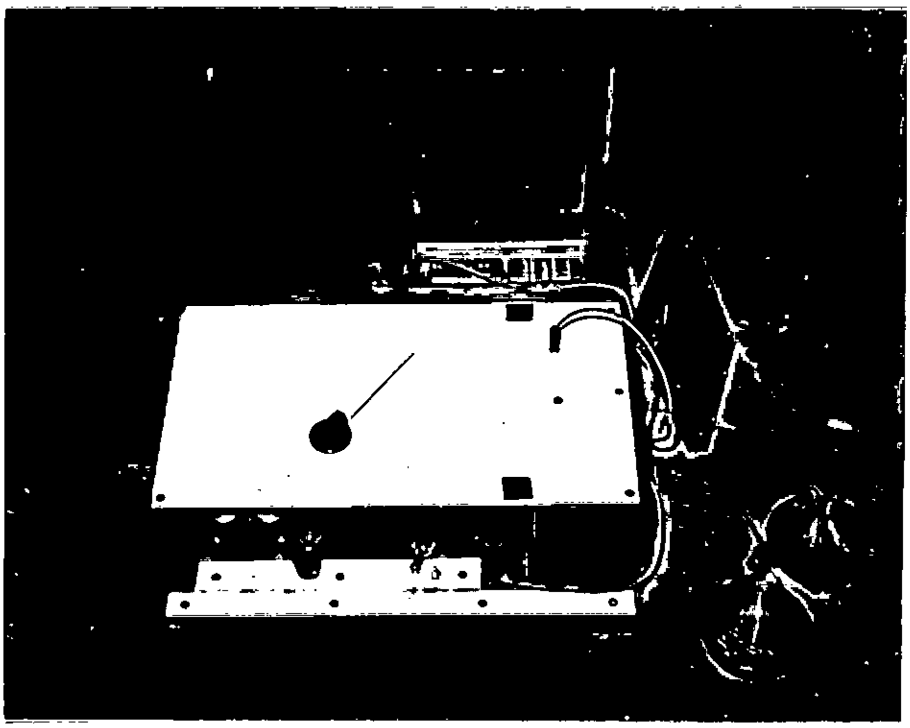


Photo -11 The moisture meter

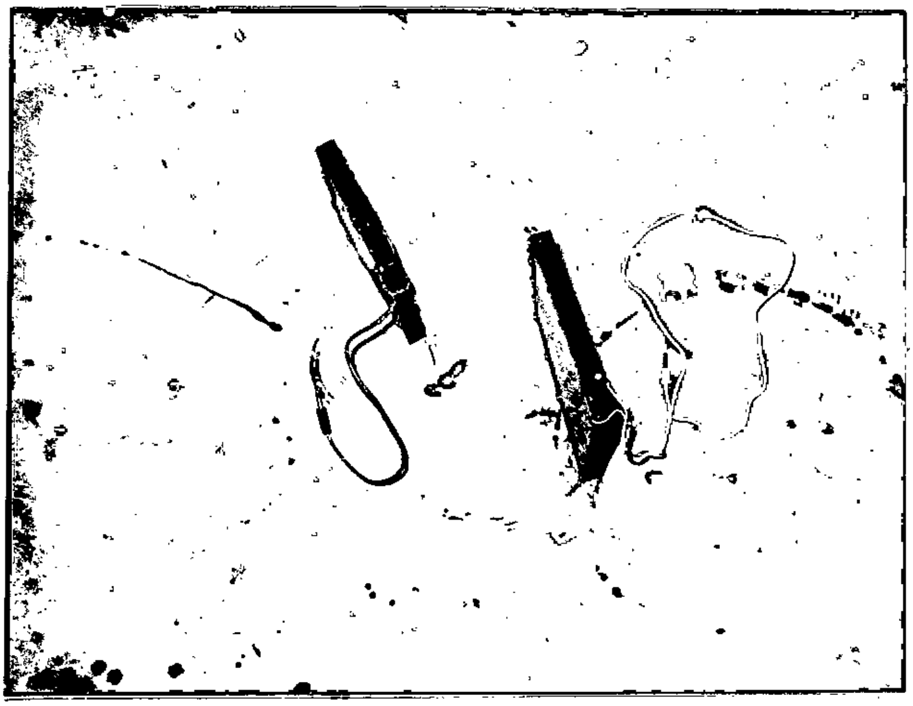


Photo - 12 Sample holding devices of the moisture meter

The fourth arm contains a variable capacitor (1450 f.) The bridge can be balanced by adjusting the variable capacitor. Different specimen in the specimen holder results in a differnet final position of the variable capacitor in order to achieve a null point. The variable capacitor carries a needle which travels on a scale directly graduated in moisture content. To determine the null-point, a null indicating circuit is used. It comprises of a milli-ammeter(0-50 mA) with a adjustable shunt resistance(0-10k).

Detailed circuit diagram is also shown in Fig- 12. Description of major equipments and elements are shown in the diagram.

6.4 Calibration of the moisture-meter.

The moisture-meter is calibrated against a resistance-type moisture meter(SATAKE, Made in Japan) The scale of the moisture meter is first graduated in an arbitary scale. This scale was subsequently converted to a graduated scale that gives values of moisture content of paddy(in weight basis).

The specimen holder of moisture meter is designed for 80 gms of paddy. For calibration purpose, Parboiled rice with very high moisture content was collected. At first, 80 gms of moist paddy was measured in a scale and was placed in the specimen holder. The moisture meter is then used to measure the moisture content in the arbitary scale. Moisture content is also measured in the standard meter. Both readings were recorded. Moist paddy samples were than dried in a drying oven, as well as, in sun-light. Various readings were taken at different moisture level.

Photo -13 Chemical balance & ohaus moisture meter

Simultaneously, in both meters. Table 3 shows the results of experiment. Based on these results, a calibration curve shown in Fig 13 was drawn. From this curve, points on the arbitary scale corresponding to the different percentage of moisture were determined. These values are shown in table 4. These points are established on the arbitary scale and are marked directly in percentage of moisture content (weight basis). The calibration curve is shwon in Fig 13 .

Table No 3

Experiment on moisture meter for calibration

Observation Number	Moisture content in percent	Arbitary scale reading
1	11·0	57
2	12·5	58
3	16·5	61
4	18·6	63
5	24·5	67

Table No 4

Comparison between two scales

Percentage Scale	Arbitary Scale
11	56·3
12	56·7
13	57·2
14	57·6
15	58·0
16	58·5
17	58·9
18	59·3
19	60·2
20	60·7
21	61·1
22	61·5
23	62·0
24	62·4
25	62·8
26	63·3
27	63·7
28	64·1
29	64·6
30	65·0

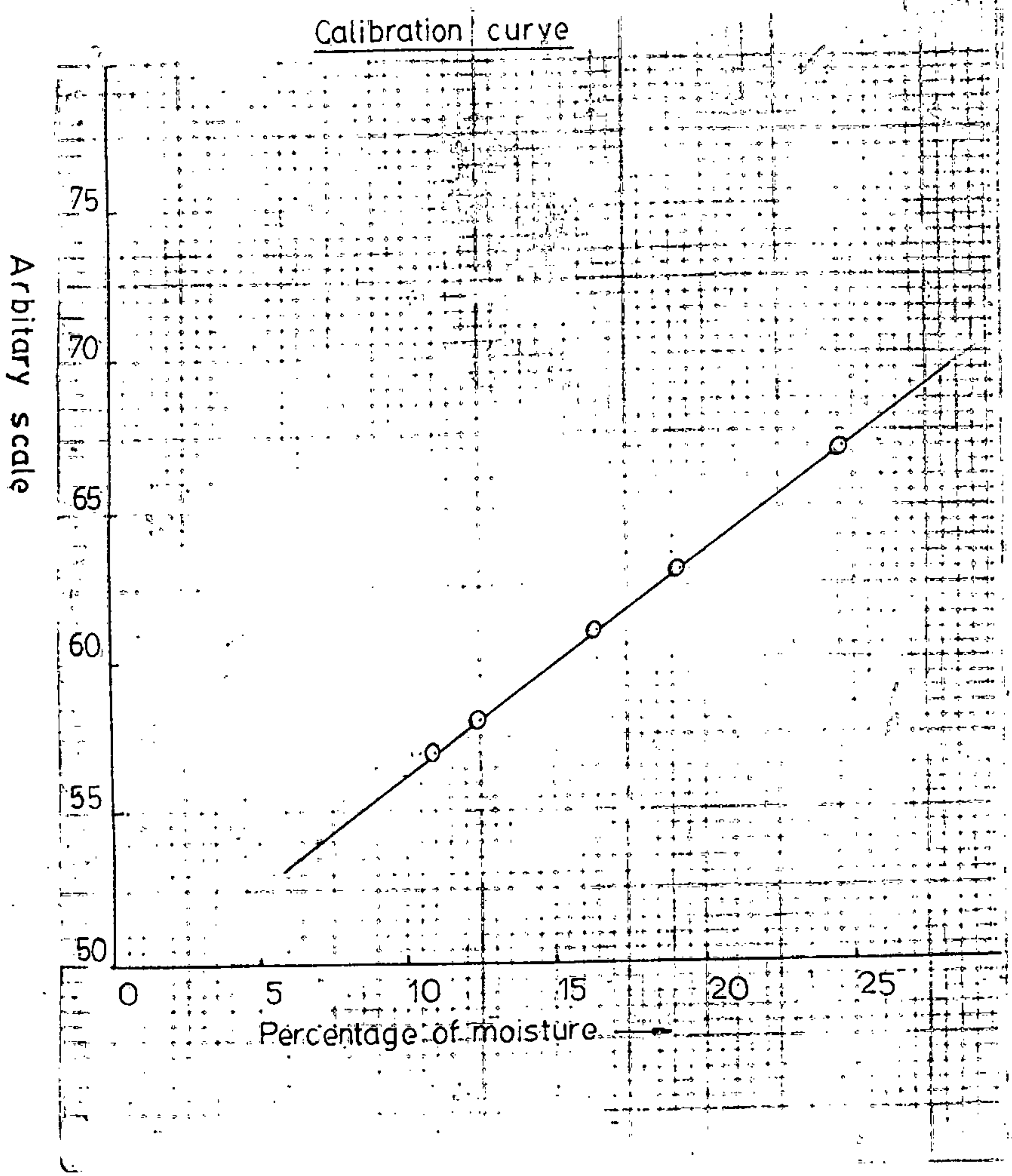

Calibration curve
Arbitary scale
75
70
65
60
55
50
0
5
10
15
20
25
Percentage of moisture

Fig - 13

CHAPTER - 7.

7.1 Discussion.

The drier was tested with parboiled rice. A total of eight maunds of very moist paddy, collected just after parboiling, were dried in the drier in nearly eight hours.

The whole charge of eight maunds was placed on the drying section. Both the blower and heater were started. The temperature of hot air was adjusted at 60°C.(It was checked that, the furnace or the electric heater, both can be adjusted to raise the hot air temperature to 60°C). Blower output was measured to be 352 cfm. at the outlet of the drying section. Thus the two goals of the design, namely :- an air flow rate of 100 cfm/bushel of rice and 140°F(60°C) air temperature, were achieved. These two conditions result in a fast but satisfactory drying of rice. The blower was operated by the electric motor at a blower speed of 465 rpm. If a man of average health paddles the bi-cycle, he can maintain continuously 465 rpm speed at the blower. Thus the electric motor or human muscle power drive are interchangeable, because both result in a 465 rpm blower speed. And for a blower speed of 465 rpm, air flow through grains is 352 cfm. Similarly, both the furnace and the electric heater are interchangeable, because they result in a equal air temperature of 60°C. This fulfills one of the major requirements of the design.

7.2 Evaluation of dried water hyacinth as a fuel.

Dried water hyacinth burns at the rate of 10.5 pounds per hour to raise air temperature to 60°C from an ambient of 25°C. Since average rate of drying is 1 maunds of paddy per hour (8 maunds in 8 hours); fuel requirement is, 10.5 pounds per maund of paddy.

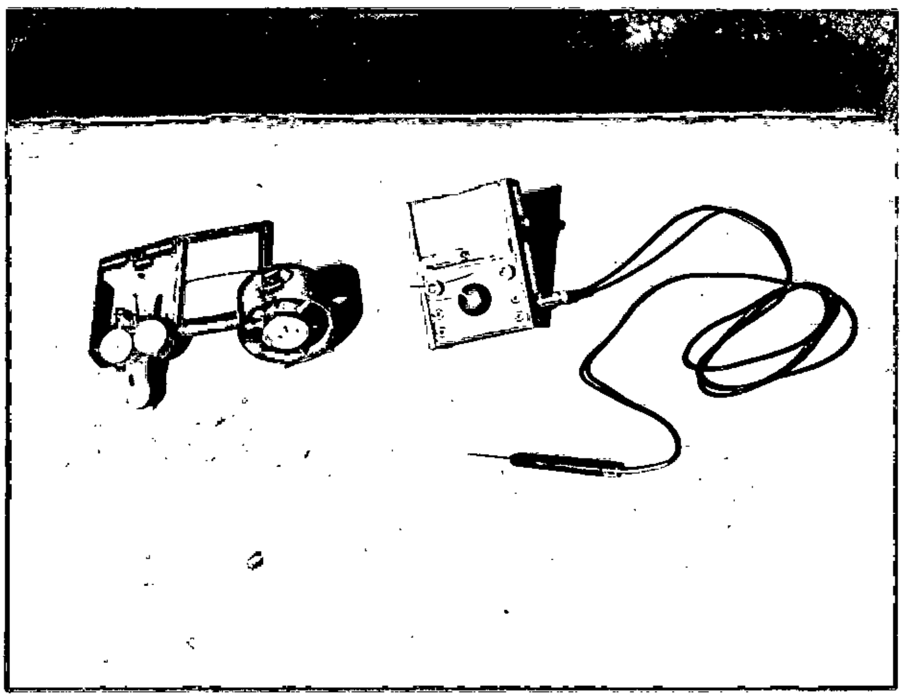


Photo - 14 Equipments used in testing the rice drier - an electronic thermometer, an airflow meter & a tacho-meter [from right]

The capacity of the electric heater is 6.4 KW. Thus electricity requirement for heating air to 60°C from an ambient of 25°C, is 6.4 KW-hour. Hence requirement of electricity for heating is 6.4 kw-hour per maund of paddy.

Fresh water hyacinth were collected from kaoranbazar situated within Dacca Metropolitan area. A place with luxariant growth of water hyacinth was selected. Observation shows that nearly 1000 lbs of dried water hyacinth is available in each acre of pond area, if the whole plant is removed from water for subsequent drying. Nearly 2353 lbs of fresh water hyacinth were collected in five batches. Each batch was collected from an equal area of 88 sq.ft. The whole charge was dried in 4 days to only 10 lbs. About 300 lbs of fresh water hyacinth can be collected per man-hour. From article 4.3.2, cost of dried water hyacinth is Tk.0.10 per pound.

Table 5 shows a comparison between cost of heating air for drying each maund of paddy.

7.3 Evaluation of human-muscle power drive.

Daily wage of a labour is Tk.10.00 per day. Two workers are to be hired for running the drying plant. They may paddle the bi-cycle in turn. Each may padde for 2 hours continuously. If motor is used to run the plant, one man suffices. Thus, cost of paddling the blower for 8 hours is Tk.10.00, or the cost is Tk.1.25 per hour.

The motor load is 200 W, while it consumes 120 watt at no load. Thus energy consumption of the motor is 200 watt hour or 0.2 kw-hour. Running cost of the motor is Tk.0.10 per hour.(If cost of electricity is Tk.0.50 per kw-hour.

Table No 5

Cost of heating air for drying rice

Source of heat	Amount required	Unit cost (in Tk.)	Heating cost (inTk./md.)
Dried water hyacinth	10·5 lbs.	0·10 per lb	1·05
Electric heater	6·4 kw-hour	0·05 per kw-hr	3·20

A comparison of cost of blowing air to dry one maund of paddy per hour, using any of the two sources of mechanical energy, is shown in Table 6.

7.4 Cost of rice-drying.

Where agriculture is still at subsistence level, costing of an agricultural operation becomes difficult. Observations on traditional rice-drying proctice were made in an area, where agriculture is at subsistence level.

Observation shows two persons (in 64% cases women) can dry a charge of 400 lbs of rice in 2 days(effective drying time per day is about 4 hours). Wage of a women Labour is most often in commodities than in cash. However a Tk.8.00 per day is a reasonable figure. Thus, labour cost in rice-drying in traditional method is nearly Tk.6.50 per maund.

(Tk.8.00/person-day x 2 persons x 2 days x 82 lbs/maund)/400 lbs.
= Tk.6.50 per maund.

Over all drying cost /maund, should include the cost of equipments and drying space.

In an artificial method, major cost may be cost of energy. Others may be labour cost and capital cost. Various combinations of energy sources for rice-drying may be possible. These are, human-muscle power and dried water hyacinth, electric motor and dried water hyacinth or electric motor and electric heater. Human-muscle power and electric heater may also be a possible combination, but it has no practical significance. Energy cost with various possible combinations are shown in table 7.

Table No 6

Cost of blowing air for drying rice

Source of mechanical energy	Amount required	Unit cost (in Tk.)	Cost of blowing air (in Tk./Md.)
Human-muscle q power	1 man-hour	1·25 per man-hr	1·25
Electric motor	200 watt-hr	0·50 per kw-hr	0·10

One man can run the artificial drier developed. Two persons are required only when human-muscle power is used instead of electric motor. Thus extra man required may be regarded as an energy source and his wage may be shown as energy cost. Thus labour cost per maund is Tk.1.25 per maund.(One man dries 8 maunds of paddy in 8 hours.)

Estimated cost of major components of the rice drier is shown in table 8. From this table,over call capital investment for the rice-drier,for various combinations of energy resources were prepeared and are shown in Table 9 .

Since utilisation factor of an artifical rice drier is not yet known, capital costs for rice-drying were not determined.

Table 10 shows a comparison of rice drying in various method.

7.5 Scope for future work and suggestions for improvement.

As a source of heat energy, to be used in rice-drying dried water hyacinth may be considered promising Other vegetable waste like dried rice straw,dry leaves and twigs may be tried as fuel. To some extent farmers use rice-straw for parboiling of rice,however major use of rice straw is in feeding cattle. Another important fuel that may also be tried in rice drying is rice hulls (husks). The hulls are valueless as food. Their nutritive value is very low and their high silicon content renders them harmful to the digestive and respiratory organs of animals. Fuel value of rice hulls is [14] 5000 to 6000 Btu/lbs. They are difficult to burn because of high ash content. In a forced drought burner this relatively unpopular fuel may be used in rice drying. A minor modification in the grate of the burner suffices for the purpose.

Table No 7

Cost of energy in rice drying

Source of mechanical energy	Source of heat energy	Cost of blowing air (in Taka)	Cost of heating air (in Taka)	Total energy cost per Md. (in Taka)
Human-muscle power	Dried water hyacinth	1·25	1·05	2·30
Electric motor	Do	0·10	1·05	1·15
Do	Electric heater	0·10	3·20	3·30

Table No 8

Cost of major components of the rice drier

Name of the component	Estimated total cost of material & labour (in Taka)
Blower with human muscle power drive only	2,000/-
Blower with electric motor drive only	3,000/-
Air-heater with burner (To burn water hyacinth)	2,000/-
Electric heater	700/-
Rice holding bin	2,000/-

Table No 9

Approximate amount of capital investment in rice-drier only required for various combinations of energy sources

Source of mechanical energy	Source of heat energy	Major components required	Total investment (in Taka)
Human muscle power	Dried water hyacinth	Blower with human drive, air-heater with burner, grain holding bin.	6,000/-
Electric motor	DO	Blower with electric motor, air-heater with burner, grain holding bin	7,000/-
DO	Electric heater	Electric motor, electric heater, grain holding bin.	5,700/-

Table no - 10

Comprison of rice drying in various method

Method of rice drying	Source of Energy used	Energy cost per maund (in Taka)	Direct labour cost per mound (in Taka)	Total approx capital investment (in Taka)	Total cost of drying
Traditional	Direct sun light	0	6·50		6·50
Artificial	Human muscle power and dried water hyacinth	2·30	1·25	6,000/-	1·5
DO	Electric motor and dried water hyacinth	1·15	1·25	7,000/-	0·42
DO	Electric motor & electric heater	3·30	1·25	5,700/-	2·47

Refer to appendix-B

Table No 10

Comparison of rice drying in various methods

Method of rice-drying	Sources of energy used	Energy cost per maund (in Taka)	Direct labour cost per maund (in Taka)	Total approx capital investment (in Taka)	Sum of energy & labour cost per maund (in Taka)
Traditional	Direct sun-light	0	6·50		6·50
Artificial	Human-muscle power and dried water hyacinth	2·30	1·25	6,000/-	3·55
DO	Electric motor and dried water hyacinth	1·15	1·25	7,000/-	2·40
DO	Electric motor & electric heater	3 30	1·25	5,700/-	4·55

Human muscle power drive of the blower is completed using a bi-cycle and frictional coupling. This may be replaced by direct transmission of power from the paddle to the blower, using a bi-cycle chain sprockets of suitable sizes and if necessary, two or more gears.

The electrical motor used with the blower appears to be over sized. This 1 HP, 440V, 50 H. motor was chosen because this is the smallest size among the products of GEC (General Electric Company) of Bangladesh, local motors manufacturer. Recently, Rural Electrification Board is recommending single phase motors upto 15 HP. Hence, a single phase, 220V, $\frac{1}{4}$ HP, 50 HZ motor may be used replacing the existing 1 HP motor.

The particular rice-holding bin which has been fabricated and tested may be considered effecient in using the available heat as well as mechanical energy of drying air entering into grains. Though it contains nearly 700 lbs of rough rice at a time, air passes only through 150 lbs of rice placed in a layer of about 6 in thickness. Possibilities of forming turbulence in any portion of the air path, is kept to a minimum; Keeping in mind that turbulence in air results in loss of mechanical energy. A modification in this design may be a small rice holding-bin, with a total capacity of only 150 lbs. Fig 14 shows the new type. This type may be suitable for small batches of paddy. Tempering of hot dried grain to be carried in small bin.

Extensive use of bamboo in making grate and side walls, the cost of the grain holding bin may be decreased considerably.

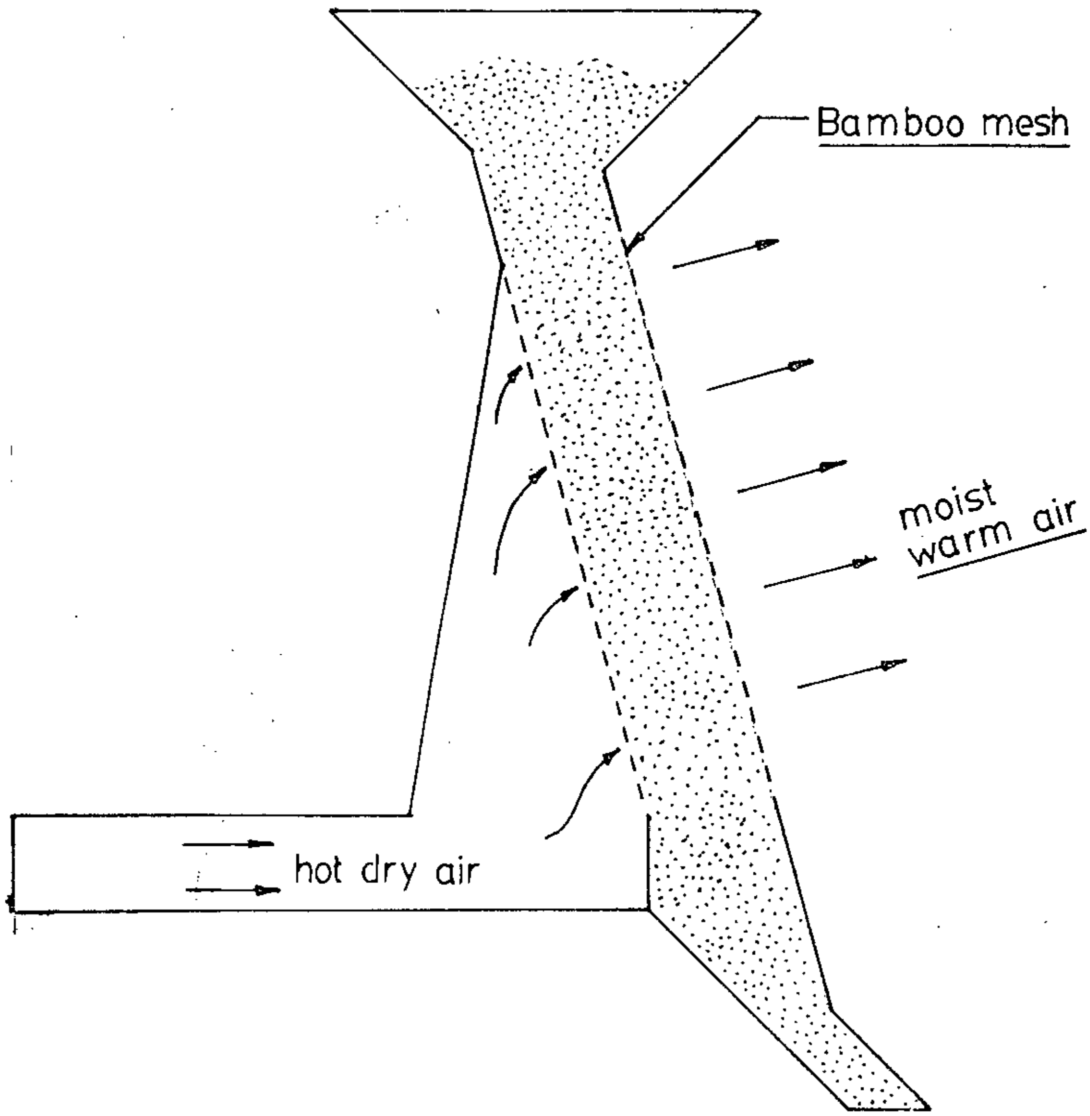


Fig-14 Schematic diagram of the proposed drier

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APPENDIX - A.

SURVEY ON TRADITIONAL METHOD OF DRYING PADDY.

Farmer's Name -
Village -
Block -

Season -
Date -

Case history

1. Paddy type - and Land area -
2. Harvesting was started at- on - of 197 -
3. Total - man completed harvesting in - hours.
4. Harvested crop was heaped in the farmsted for - days.
5. Thresting was started at - on - of 197 - .
6. Total - man with - bullocks completed threshing in - hours.
7. In total - maunds of paddy and - bundles of hay were obtained.
8. At - on - of 197 - about - maunds were parboiled.
9. At - on of 197 - about - maunds parboiled and - maunds of white rice were spread on - nos. and - nos. of bamboo mats, respectively. for sun - drying.
10. Each baches was dried for - hours.
11. Next day, they were dried for - hours and were completely dried/not dried and were dried for - hours in the following day.
12. Total - man/Women was/were engaged in drying - mands of paddy.

APPENDIX - B

Total cost of drying/md = labour cost (in Tk/md + Energy cost (in Tk/md) + Capital cost (in Tk/per md) - Savings (in Tk/md)

Capital cost/md = $\dfrac{\text{Interest on borrowed money (13\%)}}{\text{Total amount of paddy that can be dried per year}}$

Total amoun of paddy that can be dried per year = (Utilisation factor) ×(capcity in md/year

= 0·20 (assumed) × (24mds/day) × (365 days)

= 1752 mds/year

Savings (in Tk-/md)

= Savings due to improved rice drying method

If price of paddy is Tk- 50/-md and as because savings due to improved method of rice drying is reported as 5%; hence savings (in Tk/md)

= Tk - 50/- × 0·05

= Tk - 2·50 per md