Study on Comparison of Boiler Efficiency Using Husk and Coal as Fuel in Rice Mill

JP Yadav[1*] and Bharat Raj Singh[2]

ABSTRACT

When the large quantity of rice is needed, there is need of installation of the conventional rice mill. From this mill, the rice produced is of good quality and high grade of rice is obtained. In earlier time bran goes together with the husk, now bran is separated from the husk, and the rice is sold at good price. At small scale when coal is used in rice mill plant the operating cost increases thus profit is decreased. More pollution is created due to the use of coal and the husk remains as waste. If husk is utilized in place of coal as fuel, then it is determined that operating cost becomes less and economical profit comes more than the coal for rice production. If the conventional and auto-rice-mill is compared, it is observed that in conventional rice mill operating cost of using husk and coal is less than auto rice mill. But capacity and economical profit comes more in auto rice mill. Through comparative study it is found that the efficiency of using both husk and coal comes out to be the same, but their comparison varies when discussed about economic and expenditure of plant. It is seen that the price / day of using husk is more than that of coal which implies that husk used as fuel is more beneficial than using coal as fuel. When both the fuels are compared i.e. husk and coal then, it is concluded that husk as fuel is used free of cost but coal much maintenance requires which leads it to have more cost in comparison to husk and also pollution created by coal is more than that of husk, which makes husk more reliable than the coal.

1. INTRODUCTION

India is the second largest rice-growing country in the world with an annual production of 93 million tones. For the post-harvest processing of paddy, about 30,000 rice mills exist in the rural areas and most of them are owned by private entrepreneurs. They form one of the major agro-industries in India. Paddy or rice grain consists of husk and brown rice. Brown rice, in turn, contains bran which comprises the outer layer and the edible portion. Rice milling is removal or separation of husk (de-husking) and bran to obtain the edible portion for consumption. The process has to be accomplished with care to prevent excessive breakage of the kernel and improve recovery of paddy or rice. The extent of recovery during milling depends on many factors like variety of paddy, degree of milling required, the quality of equipments used, the operators; etc. Most of the rice mills have high capacity and high-speed processing machines and they are operated using either an electric motor or a diesel engine. These rice mills employ a large number of unskilled labourers for the processing of paddy besides technical man power for repair and maintenance of the machines. As the activities of the rice mills in India are not regulated under any legal provision, they are considered under unorganized sector. Hence, occupational health and safety cover for the workers in rice mills is non-existent [4]. Rice milling is the oldest and the largest agro processing industry of the country. At present it has a turnover of more than Rs 25,500 crore per annum. It processes about 85 million tones of paddy per year and provides staple food grain and other valuable products required by over 60% of the population. Paddy grain is milled either in raw condition or after par-boiling, mostly by single hullers of which over 82,000 are registered in the country. Apart from it there are also a large number of unregistered single hulling units in the country. A good number (60 %) of these are also linked with par-boiling units and sun-drying yards. Most of the tiny hullers of about 250-300 kg/hr capacities are employed for custom

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milling of paddy. Apart from it double hulling units number over 2,600 units, under run disc shellers cum cone polishers numbering 5,000 units and rubber roll shellers cum friction polishers numbering over 10,000 units are also present in the country. Further over the years there has been a steady growth of improved rice mills in the country. Most of these have capacities ranging from 2 tones /hr to 10 tones/ hr [4, 5].

1.1 Description and operation of conventional rice mill

The operation of conventional rice mill using husk as shown in Fig. 1 is as follows; when the husk goes into the furnace, the FD fan (Forced Draft Fan) which is connected to the furnace gets combusted through hot

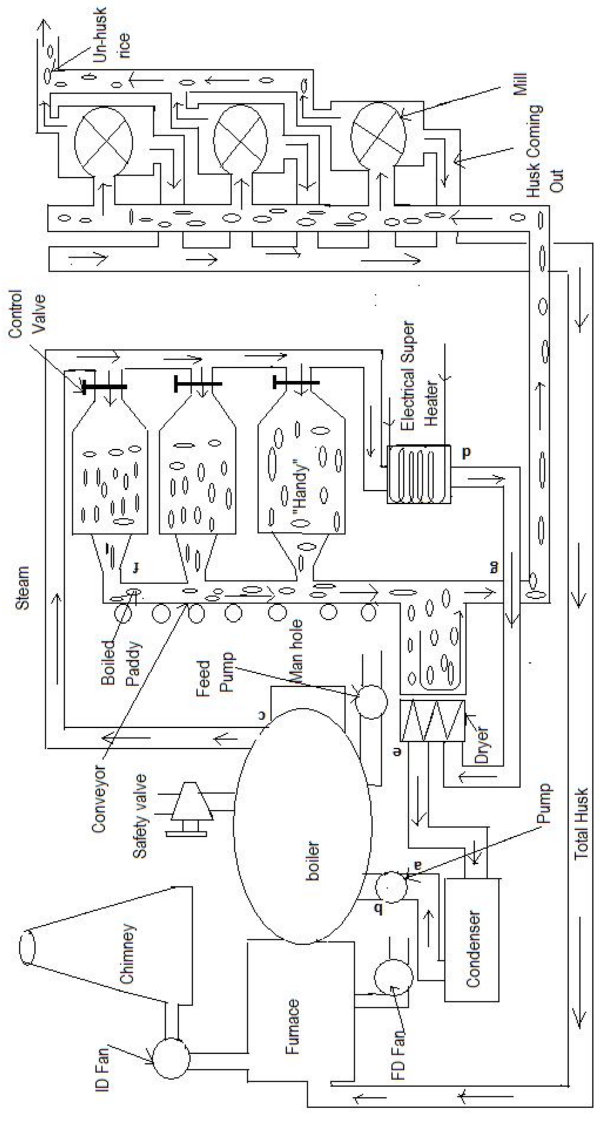

Fig.1: Diagram of conventional Rice-mill using husk

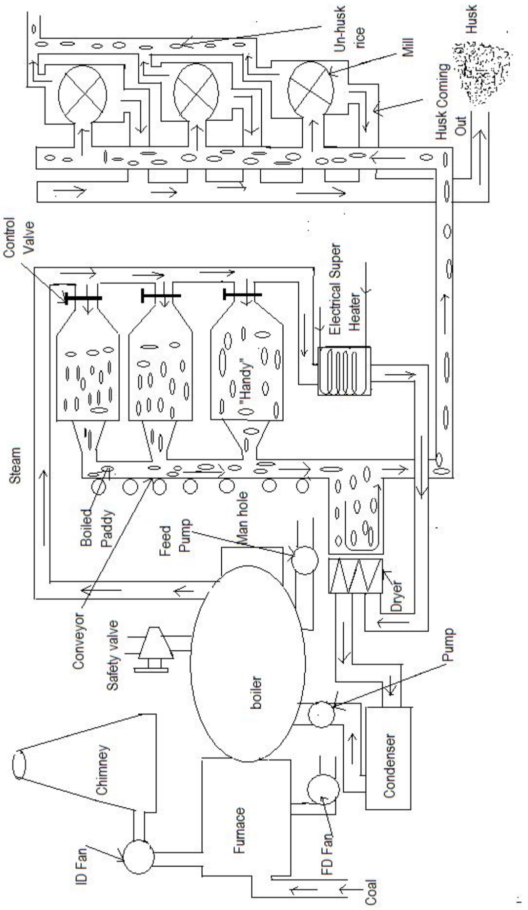

Fig.2: Diagram of conventional Rice-mill using coal

sand thrown up with the help of FD fan, which increases the temperature inside the furnace for the burning of the husk, flue gas is in the furnace goes into the fire tube boiler which in turn generates the steam. The exhaust gas carried out through the ID fan (Induced Draft Fan) to the chimney out to atmosphere. Safety valve which is connected to the boiler, when the pressure is higher than prescribed inside the boiler then the safety valve comes into operation. The Man-hole function is to clean the boiler. To maintain the water level in the boiler a feed pump is installed. Boiler generates steam at 120^0C which goes to the corresponding Handy. Three Handys are used in the plant which is connected through the control valve; it restricts the flow of steam into the handy. When the steam goes into one of the handy, the other two Handy remains closed. At the bottom of Handy, which is on the upper side, the boiled paddy from handy goes along the conveyor belt to the container adjacent to the dryer?

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The remaining steam goes into the electrical super heater, which super heat the steam at temperature of 170^{0}C before going to dryer. In dryer the steam expands intern reduces pressure and temperature (at about 110^{0}C). After that steam flows into the condenser where at constant pressure and temperature, it condenses the steam up to saturated liquid state. The liquid state temperature is 70^{0}C. A pump connected before the boiler to increase the pressure of condensate to the boiler's pressure. The boiled dry paddy with the help of conveyor goes for milling, where husk and rice are separated and husk goes to the furnace for use as fuel and the de-husking rice thus collected. The operation of conventional rice mill using coal as fuel is similar to mill using husk as fuel.

1.2 Part of old rice mill

a. **Conveyor:** In old rice mill bucket and belt type conveyor are used. Paddy are filled in storage and conveyor pick up paddy from storage and reached in handy. With conveyor, plant is more efficient than manual work done.

b. **Handy:** Handy is a local word used which is hopper type container. Steam comes from boiler through piping system in handy and paddy is boiled in handy at 120^{0}C. It is made of alloy steel to avoid corrosion at working temperature. In this plant three handy are used. When steam goes into one of the handy the two remains closed.

c. **Dryer:** It dries boiled paddy by steam. Dryers are fitted with super heater. In rice mill two type of dryer is used viz. LSU dryer and cup-and-cone dryer.

d. **Condenser:** The steam used for boiling is later condensed in condenser and fed into boiler by centrifugal pump at 70^{0}C. The rice mill plants are generally using surface type condenser. In surface condenser, the exhaust steam and water do not come into direct contact. The passes over the outer surface of the tubes through which supply of cooling water is maintained. There may be single or double passes. In single pass condensers, the water flows in one direction only through all the tubes, while in two passes condenser the water flows in one direction through the tubes and returns through the remainder.

e. **Boiler used in conventional rice mill:** There are two ways to convert water into steam. It may be passed through of small diameter tubes the outside of which is exposed to the hot gases produced by combustion as in case of Babcock and Wilcox, Stirling, La and Yyavov boilers. Such boiler are called water tube boiler. The basic principle of a water tube boiler is as shown in the figure. But on the other hand, if the products of combustion or fuel gases are made to circulate through the tubes, the outsides of which are exposed to water as in case of Cornish locomotive, they are called fire tube boilers. Both water and fire tube boilers are used in rice mill plant. Fire tube boilers are not better than the water tube boilers. The steam raised is less rapid, because of lower rate of steam raises; these are unstable for use in large power plant. The operating pressure is limited to 25 bars and moreover more floors are required for the given power. Whereas water tube boiler are mostly used, as the steam raised is more rapid. All large power plants use this type of boiler. Modern high pressure water tube boiler can generate steam at a pressure of 125 bar and even higher. In this less floor area is required for a given power; the construction however is simpler [4].

f. **Furnace:** It is made of concrete brick and cement. It behaves as insulator, and protects more heat loss. Below part of furnace made with concrete fluidized bed. Sand split in furnace and produced more heat with husk.

g. **FD fan:** The forced draft fan is provided to supply air to furnace for burning. This fan protect dust go to furnace.

h. **ID fan:** The induced draft fan removes flue gases from furnace, and to send to chimney. ID fan is important for thermal power plant.

i. **Chimney:** It is made with brick concretes and cement. Its height is 30m to 40m. Its cross section decreases with respect to height. It works on the continuity law ($A1V1=A2V2$).

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j. **Mill:** Boiled and dried paddy is sent in mill and de-husking process starts. Rice mill is a crushing type device and this works by electric motor or diesel engine. By this mill we get rice, bran and husk used in furnace, producing steam in boiler for boiling rice.

1.3 Technology

It is better to use rubber roll shellers for dehusking of paddy in the unit for better performance.

1.3.1 Plant, machinery and electrical:

The details of the nature and type of plant and machinery, their capacity, power consumption, level of automation varies upon the market needs, nature and type of the end products and the investment capacity of the entrepreneur. Whenever paddy is required to be parboiled prior to deshelling, a parboiling unit with steam boilers has to be installed by the milling unit. The same will increase the plant and machinery cost. The details of plant and machinery for the rice milling unit are as paddy cleaner, rubber roll paddy shellers, paddy separators, blowers, husk and bran aspirators, paddy polishers, rice grader/ aspirator, bucket elevators.

1.3.2 Civil construction:

The various construction requirement of an improved rice milling Unit are as follows:

a) Raw paddy Godown
b) Cleaning unit
c) Drier and necessary supporting structures such as, boiler /blower system etc.
d) Milling section
e) Finished product stores
f) Machine rooms
g) Auxiliary structures such as office watch and ward etc.

1.4 Auto rice- mill

Rice milling has reached a new levels of automation, sanitation & product quality. It is however not easy to install the auto rice mill which requires 5 tones an hour rice mill in a recently decommissioned flour mill with existing facilities. Auto rice mill plant has been designed for the milling of both parboiled & non parboiled rice [16]

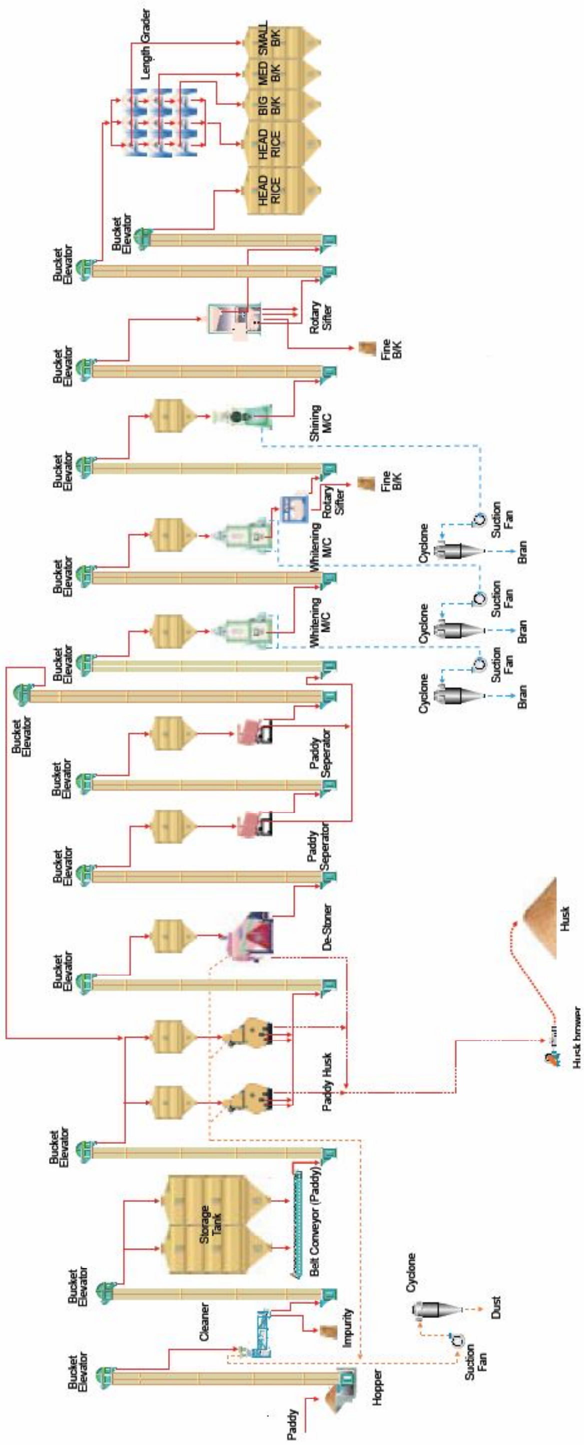

Fig.3: Auto Rice-mill plant 5 to 6 tons/h

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Capacity of plant = 6 tons/h Plant run per day 18 hours Price of one quintal paddy = Rs 850 Labour charge per quintal = Rs 30 Electricity charge = Rs 1500 per day **Total input** = Rs 951900	Paddy contains: 65% rice, 25% husk, 8% bran, 2% dust, Price of rice= Rs 1053000 Price of husk = Rs 13500 Price of bran = Rs 86400 Total price of rice and bran = Rs 1139400 Sale tax @4% = Rs 45576 Total price of rice and bran after sell tax = (1139400 - 45576) = Rs 1093824 **Total output price** = Rs 1107324

Net profit = Total output price -Total input price = Rs 155424 per day

Performance Analysis

In this plant Performance analysis is used to calculate in terms of equivalent evaporation, factor of evaporation, boiler efficiency, capacity of plant, economy and expenditure for both fuels. In this paper equivalent evaporation, factor of evaporation, boiler efficiency, capacity of plant, economy and expenditure is calculated and compared. A suitable data for plant is essential for the working of the plant; if the data varies for the working condition of plant then it may reduce the above factors.

2.1 Performance of boiler using husk

2.1.1 Equivalent evaporation:

The equivalent evaporation of boiler is defined as the mass of water evaporated from water at 1000C to dry and saturated steam at 100^0C by utilizing the same amount of heat as would have been used under the actual working condition, it may be expressed in kJ/kg of fuel [2].

Let

h = Total heat of steam at the pressure

h_{f1} = Sensible heat of feed water

h_{fgo} = Latent heat of steam at atmospheric pressure = 2258kJ/kg

Ma = Mass of water actually evaporated into steam per kg of fuel at the working pressure.

Me = Equivalent evaporation in kJ/Kg of fuel

Then heat absorbed by water

$Me * h_{fgo} = Ma * (h - hf1)$

$Me = Ma * (h - h_{f1})/2258$

$Me = 4.3 * (2706.00 - 293.00)/2258 = 4.59$ kJ/kg

2.1.2 Factor of evaporation:

It is a quantity which when multiplied by the amount of steam generated at given temperature gives the equivalent evaporation from and at 100^0C [2].

F= Factor of evaporation

Then equivalent evaporation from and at 100^0C = Actual evaporation multiplied by

F = Actual evaporation. $((h- h_{f1})/2258)$

$F = (h - h_{f1})/2258$

At temp 120^0C h = 2706.00 kJ/kg

At temperature 70^0C h_{f1} = 293.00 kJ/kg

F = (2706.00 - 293.00)/ 2258 = 1.068

2.1.3 Boiler efficiency:

It is the ratio of the heat actually utilized in generation of steam to the heat supplied by the in the same period [2].

Ma = Mass of water actually evaporated into steam per Kg fuel at the working pressure,

C = Calorific value of fuel in KJ/Kg

Boiler efficiency = $Ma * (h- h_{f1})/C$

Temperature of steam produced through boiler (t) = 120^0C

Temperature of feed water $t_{f1} = 70^0$C

Respectively enthalpy (at 120^0C); h = 2706.00 kJ/kg

Enthalpy (at 700C); hf1 = 293.00 kJ/kg

Ma = 4.3 kg steam/kg of fuel (husk) [data got from plant]

Calorific value of husk = 15217.20 KJ/Kg

Boiler efficiency (husk) = $Ma * (h- h_{f1})/C$ = 4.30* (2706.00 - 293.00)/ 15217.20 = 0.68 = 68%

2.1.4 Capacity of plant

Plant Capacity = 5 tons/hour

Paddy purchase rate = Rs 850 per quintal

Plant run per day 18 hours then total capacity of plant per day = 90 tons = 900 quintal

Paddy contains,

65% rice, 8% rice bran, 25% husk, 2% dust

Total rice produced by rice mill = 585 quintal

Rice husk produced = 225 quintal

Rice bran = 72 quintal

Dust = 18 quintal

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2.1.5 Economy and Expenditure

Input price	Total output price
Total Paddy purchase price per day = 900x 850 = Rs 765000 Labour charge = Rs 50 per quintal Then total labour charge = 900x50 = Rs 45000 Diesel consumption per hour = 50 liter Total diesel consumption per day (18hours) = 900 liter Then market charge per liter = Rs 35 Then total price per day = 35x 900 = Rs 31500 Staff charge = Rs 4000 Total Expenditure = 765000+45000+31500+4000 = Rs 805000	Selling price per quintal rice = Rs 1500 Total selling price of rice per day = 585x1500 = Rs 877500 Bran selling price per quintal = Rs 1000 Total selling price of bran per day= 1000x72 = Rs 72000 Total price (output) = 877500 + 72000 = Rs949500 Sale tax = {(949500)4}/100 = Rs 37980 Total output price = 949500 – 37980 = Rs 911520

Net profit = 911520 - 805000 = Rs 106520 per day

2.2 Performance of boiler using coal

2.2.1 Equivalent evaporation:

The equivalent evaporation of boiler is defined as the mass of water evaporated from water at 100^0C to dry and saturated steam at 100^0C by utilizing the same amount of heat as would have been used under the actual working condition, it may be expressed in kJ/kg of fuel.

Let

h = Total heat of steam at the pressure

h_{f1} = Sensible heat of feed water

h_{fgo} = Latent heat of steam at atmospheric pressure = 2258kJ/kg

Ma = Mass of water actually evaporated into steam per kg of fuel at the working pressure.

Me = Equivalent evaporation in kJ/kg of fuel

Then heat absorbed by water is

$$Me * h_{fgo} = Ma * (h - h_{f1})$$

$$Me = Ma * (h - h_{f1})/2258$$

$$Me = 9.12 * (2706.00 - 293)/ 2258 = 9.74 \text{ KJ/ Kg}$$

2.2.2 Factor of evaporation:

It is a quantity which when multiplied by the amount of steam generated at given temperature gives the equivalent evaporation from and at 100^0C.

F= Factor of evaporation

Then equivalent evaporation from and at 100^0C= Actual evaporation multiplied by F

= Actual evaporation. $(h- h_{f1})/2258$

$F = (h-h_{f1})/2258$

At temp 120_0C, h = 2706.00 kJ/kg

At temperature 70^0C, h_{f1} = 293.00 kJ/kg

F= (2706.00 - 293.00)/ 2258 = 1.068

2.2.3 Boiler efficiency:

It is the ratio of the heat actually utilized in generation of steam to the heat supplied by the in the same period.

Ma = Mass of water actually evaporated into steam per Kg fuel at the working pressure,

C = Calorific value of fuel in KJ/Kg

Boiler efficiency = Ma. $(h- h_{f1})$/C

Temperature of steam produced through boiler (t) =120^0C

Temperature of feed water t_{f1} = 70^0C

Respectively enthalpy, h = 2706.00 kJ/kg

At temperature 70^0C, h_{f1} = 293.00 kJ/kg

Ma = 9.12 kg steam/kg of fuel (coal)

C V of coal = 32139KJ/Kg

Boiler efficiency (husk) = Ma. (h- hf1)/C

= 9.12x (2706.00 - 293.00)/ 32139 = 0.684 = 68.4%

2.2.4 Capacity of plant :

Plant Capacity = 5 tons/hour

Paddy purchase rate= Rs 850 per quintal

Plant run per day 18 hours then total capacity of plant per day = 90 tons = 900 quintal

Paddy contains,

65% rice, 8% rice bran, 25% husk, 2% dust

Total rice produced by rice mill = 585 quintal

Rice husk produced = 225 quintal

Rice bran = 72 quintal

Dust=18 quintal

Rice Husk Used As Fuel

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2.2.5 Economy and Expenditure of plant :

We known that per day 225 quintal husk or 22500 kg husk (consumed in plant)
One kg husk produced 4.3 kg steam
Therefore 22500 kg husk produced
= 22500x4.3, kg = 96750 kg
One kg coal produced 9.12 kg steam
Therefore 96750 kg steam produced per day 10608.55 kg coal or 106.085 quintal

Input price	**Total output price**
Rate of one quintal coal = 350 Rs Total price of coal = 350 x106.085 = Rs 37129.75 Coal handling + extra labour charge = Rs 2000 Total Paddy purchase price per day = 900x850 = Rs 765000 Labour charge = Rs 50 per quintal Then total labour charge per day = 900x50 = Rs 45000 Diesel consumption per hour = 50 litre Total diesel consumption per day (18 hours) = 900 litre Then market charge per liter = Rs 35 Then total price per day = 35x900 = Rs 31500 Staff charge = Rs 4000 Total expenditure = Rs 884629.75	Selling price per quintal rice = Rs 1500.00 Total selling price per day= Rs 585x1500.00 = Rs 877500.00 Bran selling price per quintal=Rs 1000.00 Total selling price per day= 1000x72 = Rs 72000.00 Total price (output) = 877500 + 72000 = Rs 949500.00 Sale tax@ 4% = {(949500)4}/100 = Rs 37980.00 Output price = 949500 – 37980 = Rs 911520.00 Rate of husk = Rs 50 per quintal Husk produced per day = 225 quintal Profit selling by husk per day = 50x225 = Rs 11250.00 Total output price = 911520 + 11250 = Rs 922770.00 **Net profit =** 922770 - 884629.75 = Rs 38140.25

After bagasse, rice husks are probably the largest mill-generated source of biomass available for energy use. As large quantities of rice husks are normally available at the rice mills, there are no additional efforts or costs involved in the collection of this biomass for use as an energy source. Due to the availability of large quantities at any given location, rice husks can be put to use for comparatively larger energy applications, like generation of steam for process heating applications. In the northern parts of India, like in the states of Haryana and Punjab, due to the practice of dry milling of paddy rice, there is practically no captive consumption of husks within the rice mills. Thus, large quantities of rice husks are available for use as fuel. Traditionally, part of the rice husk is used as an admixture in poultry feed and the balance is normally a disposal problem, in the absence of any market for the husk. Taking advantage of the lower cost of rice husks, small process industries located near the rice mills started using it as a fuel in their boilers to generate steam [11]. Some of the units started pelletisation of rice husks for use as a substitute for firewood and coal at the household and small industry level, but pelletisation of rice husks, as practiced during those days, had its own set of problems and could not progress further. Such small-sector process industries use fixed, great fire-tube boilers with low capacity, which are manually fired, using coal as the fuel. Such combustion practices and boiler designs are primitive in nature and have built-in problems of partial fuel combustion and low efficiency. As husk was available virtually for free, the boiler efficiency and the degree of combustion were the issues receiving the least attention. Partial and uneven combustion of husks in the furnaces of the boilers also would lead to smoke emissions. The disposal of partially burned husks and ash also created environmental hazards [3]. The development of compact, fluidized bed process steam boilers by the boiler manufacturers led to more efficient and environment-friendly utilization of this widely available bio-fuel resource. As a result, such process steam boilers are now widely used by even the comparatively larger process industries.

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3.1 Composition of Husk

Table 5: Composition of Husk

S.No.	Parameter	Unit	Result	Basic
1	C	%	38.250	dry
2	H2	%	5.800	dry
3	O2	%	40.500	dry
4	N2	%	1.210	dry
5	S	%	0.041	dry
6	Total moisture	%	11.940	As received dry
7	Ash content	%	14.220	dry
8	Low heating value	kJ/Kg	13158.70	As received dry
9	High heating value	kJ/Kg	15217.20	dry
10	Volatile matter	%	59.870	dry
11	Fixed carbon	%	18.560	dry

3.2 Objectives

The driving factor behind the efforts to develop technology and equipment for effective utilization of rice husks as fuel in the process steam boilers was the need to meet energy needs in a more cost-effective way. Development and commercialization of fluidized bed process steam boilers using rice husks and other such biomass as fuel led to widespread use of rice husks as fuel by the process industry in the rice cultivation areas of the country for their process steam requirements [3].

3.3 Technology

The technology of Fluidized Bed Combustion was earlier available only to large steam users. It was realized medium and small process steam users would find it just beneficial to have access to this technology. The result is the Fluidized Bed Combustion Boilers that have developed to cater to the economical and efficient technology needs saving crores of rupees every year. The Fluidized bed combustion technology can be employed as a versatile efficient means of utilizing the vast resource of rice for production of energy. A number of fluidized bed boilers and combustors using rice-husk as fuel have been engineered for manufactured and installed applications like process steam for parboiling. The combustion of rice husk in conventional method leads to very high burnt combustibles. This is mainly because of the nature of the fuel, in which carbon is trapped in carbon free white in colour and rich in silica. The white ash is also having a market value as a by-product [3, 11]. The rice husk fired fluidized bed boilers offer advantages like excellent combustion, quick start-up low pollution and simple operation and maintenance. Compared to a boiler efficiency of 55-60% achievable with stepped grate furnace, the fluidised bed combustion technology offered will give a high efficiency of the order of 75-80%; the other advantages are quick start-up, low pollution, simple operation and maintenance.

3.4 Impacts

The use of rice husks for process steam generation has the following benefits.

a. Rice husk is a carbon-neutral and renewable source of energy, thereby reducing the emission of greenhouse gases.

b. Results in a reduction in emissions of sulfur and other pollutants associated with the use of fossil fuels, thereby improving local environmental conditions.

c. Results in an improvement in the efficiency of the husk-fired boilers, leading to its acceptability by the industry and other stakeholders as an acceptable practice.

d. Develops the local economy by creating a market for rice husks, formerly a waste disposal problem.

e. Meets the thermal energy requirements of the process industry in a more cost-effective manner; and generates employment at the local level for collection and supply of rice husks [11].

3.5 Application

The use of rice husk-fired boilers for the generation of process steam has already been applied at a large number of locations throughout the country. The decision regarding the choice of fuel for process steam is made based on the availability of biomass and other techno-commercial considerations, like space availability and cost benefits. In some instances industry has modified their present oil-fired process steam boilers to husk-fired boilers. In rice mills where the practice of boiling of paddy prior to milling is practiced, a part of rice husks generated is used in-house. Due to the demand for both the process

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steam and electricity at the same location with the added advantage of in-house availability of the fuel, facilities for simultaneous generation of power and steam can be constructed [3]. The development of fluidized bed rice husk boilers has also enabled the establishment of some power plants using rice husks as the fuel. Further development of the technology and equipment designs, such as gasifier systems for co-generation, will enable the use of rice husks or other similar biomass as fuel for process steam and power generation in situations where there are still barriers to its use. The strategy for developing suitable technologies and equipment for effective combustion and utilization of biomass fuels can be applied for other available biomass-based energy sources, like that for rice straw, mustard stalks, etc. Such an effort is likely to increase the sustainability of such biomass resources on a larger scale [3, 11].

3.6 Rice Husk Ash

Globally, approximately 600 million tonnes of rice paddy is produced each year. On average 20% of the rice paddy is husk, giving an annual total production of 120 million tonnes. In the majority of rice producing countries much of the husk produced from the processing of rice is either burnt or dumped as a waste.

The treatment of rice husk as a 'resource' for energy production is a departure from the perception that husks present disposal problems. The concept of generating energy from rice husk has great potential, particularly in those countries that are primarily dependant on imported oil for their energy needs. Rice husks are one of the largest readily available but most under- utilized biomass resources, being an ideal fuel for electricity generation.

Rice husk is unusually high in ash compared to other biomass fuels - close to 20%. The ash is 92 to 95% silica, highly porous and lightweight, with a very high external surface area. Its absorbent and insulating properties are useful to many industrial applications. RHA is a general term describing all types of ash produced from burning rice husks. In practice, the type of ash varies considerably according to the burning technique. The silica in the ash undergoes structural transformations depending on the conditions (time, temperature, etc) of combustion [12]. At 550°C - 800°C amorphous ash is formed and at temperatures greater than this, crystalline ash is formed. These types of silica have different properties and it is important to produce ash of the correct specification for the particular end use.

If a long term sustainable market and price for rice husk ash (RHA) can be established, then the viability of rice husk power or co-generation plants are substantially improved. Many more plants in the 2 - 5 MW range can become commercially viable around the world and this biomass resource can be utilized to a much greater extent than at present [14].

3.6.1 Objectives

a. To determine the current markets for rice husk ash (RHA) through a publication review

b. To evaluate the current and potential value of each market.

c. To determine the type and quality of RHA produced from different boilers and relate this to market specification.

d. To analyses the economics of producing and selling the different types of RHA in conjunction with bio-energy projects [14].

3.6.2 Potential and current uses of RHA

3.6.2.1 Steel industry

a. RHA is used by the steel industry in the production of high quality flat steel. Flat steel is a plate product or a hot rolled strip product, typically used for automotive body panels and domestic 'white goods' products.

b. RHA is an excellent insulator, having low thermal conductivity, high melting point, low bulk density and high porosity. It is this insulating property that makes it an excellent 'tundish powder'. These are powders that are used to insulate the tundish, prevent rapid

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cooling of the steel and ensure uniform solidification in the continuous casting process [12].

3.6.2.2 Cement industry

a. Substantial research has been carried out on the use of amorphous silica in the manufacture of concrete. There are two areas for which RHA is used, in the manufacture of low cost building blocks and in the production of high quality cement.

b. Ordinary Portland Cement (OPC) is expensive and unaffordable to a large portion of the world's population. Since OPC is typically the most expensive constituent of concrete, the replacement of a proportion of it with RHA offers improved concrete affordability, particularly for low-cost housing in developing countries.

c. The addition of RHA to cement has been found to enhance cement properties:

d. The addition of RHA speeds up setting time, although the water requirement is greater than for OPC.

e. At 35% replacement, RHA cement has improved compressive strength due to its higher percentage of silica.

f. RHA cement has improved resistance to acid attack compared to OPC, thought to be due to the silica present in the RHA which combines with the calcium hydroxide and reduces the amount susceptible to acid attack.

g. More recent studies have shown RHA has uses in the manufacture of concrete for the marine environment. Replacing 10% Portland cement with RHA can improve resistance to chloride penetration [13].

3.6.3 Technical overview

a. There is a wide range in the physical and chemical properties of RHA. The chemical and physical properties of the ash may be influenced by the soil chemistry, paddy variety and fertilizer use.

b. The change from amorphous to crystalline ash occurs at approximately 800ºC, although the process is often 'incomplete' until 900ºC is achieved. All the combustion processes devised to burn rice husks remain below 1440ºC, which is the RHA melting temperature.

c. The most commonly used boilers are based on fixed grate technologies, which tend to produce ash with high carbon content and high proportions of crystalline to amorphous ash. This type of ash is more suited to the steel industry.

d. Suspension fired boilers generally produce more amorphous ash than stoker fired boilers despite the fact that they may operate at higher temperatures. This is because the operating time at high temperatures for suspension fired boilers is comparatively short.

e. Commonly, in the production of highly amorphous ash, low temperatures and fairly long "burn-times" are used.

f. Fly ash is a fine material and is of higher marketable value since it requires less grinding than the generally coarser bottom ash [12, 14].

3.6.4 Advantages

a. Small markets exist for RHA in the manufacture of refractory bricks and as oil absorbent.

b. Potential markets in the future include silicon chip manufacture, in the manufacture of activated carbon, and in the production of lightweight construction materials and insulation.

c. Currently the largest and most commercially viable markets appear to be in the concrete and steel industry.

d. Limited Distribution - UK Companies only Limited Distribution - UK Companies only

e. The market within the steel industry is well established, but there are constraints to the expansion of this market due to health issues associated with using crystalline ash.

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f. The cement markets are not as well developed as steel, but there is great potential for the use of amorphous RHA. Two main issues appear to be limiting its use: lack of awareness of the potential for RHA and the quality of the product itself. Boiler modifications may be required to produce ash of the quality required [13].

3.6.5 Recommendation for the future

a. The best choice would seem to be to produce RHA for the steel industry as this requires no boiler modifications and attracts a high price.
b. However, our market study suggests that, whereas growth in the market for RHA to the steel market is limited, growth in the market for RHA in the cement industry is growing and is potentially very large.
c. A new entrant to the market place may prefer to target the somewhat less high returns but better longer term prospects of the amorphous silica market [13, 14].

Coal used as fuel

Coal is our most abundant fossil fuel resource. Coal is a complex mixture of organic chemical substances containing carbon, hydrogen and oxygen in chemical combination, together with smaller amounts of nitrogen and sulfur. This organic part of coal has associated with it various amounts of moisture and minerals. Coalification is the name given to the development of the series of substances known as peat, lignite or brown coal, sub-bituminous coal, bituminous coal, and anthracite. The degree of coalification, also called the rank of the coal, increases progressively from lignite to low rank coal, to high rank coal, to anthracite. The carbon content increases, while the oxygen and hydrogen contents decrease throughout the series. The hardness increases, while the reactivity decreases. Different amounts of heat and pressure during the geochemical stage of coal development cause these differences in rank. It is not due to the kind of plants the coal is formed from. Coals in the US range from lignite with approximate as-mined carbon content of 30%, volatile matter 27%, and heating value of 7,000 Btu per pound, to anthracite with an average of 85% carbon, 5% volatile matter, and heating value of 12,750 Btu per pound. Sub-bituminous and bituminous coals are intermediate between these values [9, 10].

4.2 Calorific value of coal

At the time there was a penalty for being outside a certain net c v value, both high and low. We applied this system at a colliery called Cotgrave in Nottinghamshire, where the moisture content was very variable. It worked well. The ash content and the moisture content have a linear reduction relationship with the net cv (final cv) in percentage terms as follows: net c v=100((total ash + totalh20)/100)* dry, ash free c v is determined by lab analysis c.v. = calorific value [9].

4.3 Efficiency of boiler (using coal):

It is the ratio of the heat actually utilized in generation of steam to the heat supplied by the in the same period [2].

Ma = Mass of water actually evaporated into steam per Kg fuel at the working pressure,

C = Calorific value of fuel (Coal) in KJ/Kg Boiler efficiency= Ma * (h- hf1)/C

h = Total heat of steam at the pressure h_{f1} = Sensible heat of feed water

Ma = 9.12 kg steam/kg of fuel (coal), C V of coal = 32139KJ/Kg

Boiler efficiency (husk) = Ma * (h- h_{f1})/C = 9.12(2706.00 - 293.00)/ 32139 = 0.684 = 68.4%

Result and Discussion

In result, the comparative study of husk and coal has been shown in terms of curtained parameter like efficiency and graphical representation, in which fuel consumption rate v/s efficiency is plotted and in another graph which is plotted between temperature and entropy using husk

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and coal, it is found efficiency of using coal little more than the husk, where as temperature- entropy graph was the states such as condensation, super heating, vaporization, expansion has been shown. Also, the adverse effect on human being by rice mill terms noise and air pollution has been mention below.

5.1 Comparative study of efficiency of boiler Efficiency of boiler (using husk and coal)

If we used coal and husk as a fuel then we that get different efficiency of conventional boiler.

C V of husk=15217.20 KJ/Kg

C V of coal=32139KJ/Kg

It is the ratio of the heat actually utilized in generation of steam to the heat supplied in the same period.

Ma = Mass of water actually evaporated into steam per Kg fuel at the working pressure,

C= Calorific value of fuel (Coal or Husk) in KJ/Kg

Boiler efficiency= Ma * (h- hf1)/C

h = Total heat of steam at the pressure

h_{f1} = Sensible heat of feed water

(a) Husk

Ma=4.3 kg steam/kg of fuel (husk)

C V of husk=15217.20 KJ/Kg

Boiler efficiency (husk) = Ma* (h- h_{f1})/

C = 4.30(2706.00 - 293.00)/ 15217.20 = 0.68 = 68%

(b) Coal

Ma=9.12 kg steam/kg of fuel (coal)

C V of coal=32139KJ/Kg

Boiler efficiency (husk) = Ma * (h- h_{f1})/

C = 9.12(2706.00 - 293.00)/ 32139 = 0.684= 68.4%

5.2 Graphical relation between fuel consumption rate and efficiency of boiler

Table 6.1: Data of fuel consumption rate and efficiency of boiler

Fuel consumption (Kg)		Produced steam (Kg)		Formula Efficiency= Ma. (h-hf1)/C(calorific value of husk or coal)		Efficiency	
Husk	**Coal**	**Husk**	**Coal**	**Husk**	**Coal**	**Husk**	**Coal**
0.2	0.2	0.86	1.824	0.13	0.1369	13%	13.69%
0.4	0.4	1.72	3.648	0.27	0.2739	27%	27.39%
0.6	0.6	2.85	5.472	0.408	0.4108	40.8%	41.08%
0.8	0.8	3.44	7.296	0.5450	0.5479	54.50%	54.79%

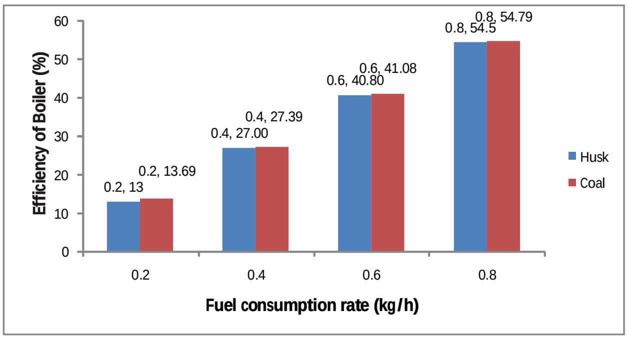

Fig.4: Fuel consumption rate v/s Efficiency of boiler

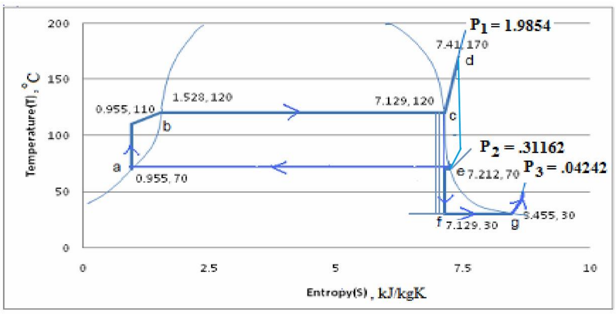

Fig.5: Temp. Vs. Entropy Diagram

Process a-b = Adiabatic compression in pump

Process b-c = Saturated liquid changes into saturated vapour

Process c-d = Saturated vapour is superheated in electrical super heater

Process d-e = partly assumed adiabatic expansion in dryer

Process e-a = Condenser works

Process c-f = Assumed adiabatic expansion of part steam in three handys

Process f-g = Wet vapour changes into dry vapour due to heat transfer in drier and steam evaporates totally before entering the mill

5.3 Discussion

It is observed that the efficiency of boiler comes approximately same, it is seen from the graph that efficiency of using husk and coal overlaps, but economical aspect is more better when using husk as that of coal, which however requires material handling and transportation cost, therefore using husk as fuel is much more cheaper than coal.

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It is observed that if using husk then profit comes out to be 106520 Rs per day but when we use coal then profit comes out to be 38140.25 Rs per day. Husk produces less pollution than coal. If the old and auto rice mill plant is compared then it is seen that auto rice mill provides more profit than the old rice mill.

The mollier diagram showing the variation of temperature and entropy when operating the old rice mill plant we get, at 70^0C temperature the pressure is 0.31162 bar and entropy comes out to be $s_1 = 0.955$ kJ/kg and also, at 120^0C pressure is 1.9854 bar, entropy $s_2 = 7.129$ kJ/kg.

From the moiller diagram, it is observed that from point a to b pump works, which increases pressure of feed water up to the boiler's pressure. From b to c saturated liquid changes into saturated vapour at 120^0C in the boiler. From c to d saturated vapour is super heated in the electrical super heater at temperature of 170^0C. From d to e the dryer works, in which pressure and temperature decreases. From e to f super heated vapour changes into saturated vapour. From e to a, the condenser works in which the super heated vapour changes into saturated liquid at constant pressure. From c to f the vapour expands in handy. From f to g wet vapour changes into dry vapour with the help of dryer and the temperature of paddy reaches to 50^0C.

5.4 Adverse Effect

5.4.1 Factor affecting human assessment

A major occupational hazard for the workers in rice mills is the noise during the operation of various machines. A noise survey was conducted in the workrooms of eight renowned rice mills of the north-eastern region of India established during the period between 1980 and 1985. The rice mills were selected on the basis of the outcome of a walk-through noise survey involving several rice mills of the region. A noise survey map of each rice mill was drawn to identify the predominant noise sources and the causes of high noise in the workrooms of the rice mill. The sound-pressure level (SPL) in the workrooms of the rice mill varied from 78 to 92 dab [7]. The paddy cleaner, rubber roll sheller, compartment separator, rice cleaner, auxiliary sieve shaker and an electric motor without enclosure were found to be the predominant noise sources in the workrooms of the mill. The causes of high noise in the rice mills may be attributed to the use of a long flat belt drive, crank-and-pitman mechanism, absence of an electric motor enclosure, poor machine maintenance and inadequate acoustic design of the workroom of the rice mill. About 26% of the total labourers were found to be exposed to higher levels of noise than 85 dBA. Subjective response indicated that about 26% of the total labourers felt noise interferes in their work and about 49% labourers were of opinion that noise interferes with their conversation. Context: Noise from machines in the rice mills was found to be the major occupational hazard for the rice mill workers. The predominant noise sources need to be identified and the causes of high noise need to be studied to undertake the appropriate measures to reduce the noise level [7, 8].

5.4.2 Control of Noise Pollution

The workers in the rice mills are exposed to high noise, which will have detrimental effect on their health. Apart from undertaking appropriate noise control measures, preventive maintenance of machines needs to be given due importance in all the rice mills. The noise survey in the eight select rice mills of the major paddy-growing region of India revealed that the workrooms of the five rice mills had SPLs more than 85 dBA in locations where workers were engaged for most of the time[8]. The predominant noise sources in the rice mills were the paddy cleaner, rubber roll sheller, compartment separator, rice cleaner, sieve shaker and an electric motor without enclosure. The causes of high noise in the rice mills may be due to the use of a long flat belt drive, crank-and-pitman mechanism, absence of an electric motor enclosure, poor machine maintenance and inadequate acoustic design of the workroom of the rice mill. In general, a well-maintained rice mill with each machine being run individually using an electric motor produced less noise than that being run using a single electric motor along with flat belt drives. The normal working period in the rice mills was 48 h/week and it was 56 h/week during

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the peak season of rice milling. About 26% of the total workers were exposed to noise of more than 85 dBA. Subjective response indicated that about 26% of the total workers felt noise interferes in their work and about 49% workers were of opinion that noise interferes with their conversation. Apart from undertaking appropriate noise control measures, preventive maintenance of machines needs to be given due importance in all rice mills [7, 8, 15].

5.4.3 Results

The noise survey in eight select rice mills of the major paddy-growing regions of India revealed that the workrooms of five rice mills had SPL more than 85 dBA in the locations where workers were engaged for most of the time[15]. The predominant noise sources in the rice mills were paddy cleaner, rubber roll sheller, compartment separator, rice cleaner, sieve shaker and an electric motor without enclosure. The causes of high noise in the rice mills may be due to the use of a long flat belt drive, crank-and-pitman mechanism, absence of an electric motor enclosure, poor machine maintenance and inadequate acoustic design of the workroom in the rice mill. In general, a well-maintained rice mill with each machine being run individually using an electric motor produced less noise than that being run using a single electric motor along with flat belt drives. The normal working period in the rice mill was 48 h/week and it was 56 h/week during the peak season of rice milling. About 26% of the total workers were exposed to noise of more than 85 dBA. Subjective response indicated that about 26% of the total workers felt noise interferes in their work and about 49% workers were of opinion that noise interferes with their conversation [7, 8].

6. CONCLUSIONS

The study and comparisons of boiler efficiency using husk and coal as a fuel is carried out and following points are concluded;

- In rice- mill husk as fuel is more reliable than coal because of coal demands the material handling and transportation which is more difficult than using husk.
- In rice mill, husk as fuel is used free of cost but coal requires more maintenance in comparison to husk.
- Rice husk produces much less pollution a coal, as coal produces CO_2, CO, NO_2, & SO_2 gases. In rice mill husk fuel used in fluidized bed combustion directly, but coal needs to be pulverized first, before going into the fluidized bed.
- Rice husk ash used in steel, cement, concrete, steel industry in the production of high quality flat steel. Since Ordinary Port Cement is typically the most expensive constituent of concrete, the replacement of a proportion of it with RHA offers improved concrete affordability where as coal ash is not of any use and is treated as waste.
- In rice mill less skilled labours are required, but when talking about coal it requires high skilled labour because of material handling and storage problems.
- Production of steam becomes costiler than the labour and whole cost of plant increased in using coal as fuel.
- The capacity of conventional rice mill is generally 5 tones /h where as the capacity of auto rice mill is 6 tones /h. It is more than old conventional rice mill and fewer workers are required.
- The result and discussion, it is depicts that efficiency comes out to be approximately same when using husk and coal, but their comparison much varies when economic analysis is discussed, which implies that using husk is more profitable than using coal as fuel.

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