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Research Article

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Case study for a Boiler Heat Recovery System

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Abstract The following is a review paper for a case study of a boiler heat recovery heat system. A boiler is a device which is used to generate steam or hot water by heating water using a fuel source. Boilers are an essential component in many industrial processes, heating systems, and power generation setups. This paper discusses about the theory and application of boilers, and the different types of boilers used in industries. The different boilers used for waste heat recovery are also discussed.

Keywords Boilers, Condensers, Waste heat recovery

Introduction

Boilers of this type generate steam by extracting heat from hot fluid, generally a gas, which is produced as a by-product of a chemical reaction and has no intrinsic value as a chemical, or which is in the form of exhaust from a gas-turbine or internal combustion engine. Heat recovery boilers are also often found in association with high temperature processes such as steel and glass making.

It is not uncommon for these boilers to receive additional heat by supplementary firing of other by- products or by burning gas or light oil to raise the boiler inlet gas temperature to a level commensurate with the desired steam conditions.

The convective elements of boilers fired by municipal industrial or other waste materials are often referred to as heat recovery boilers although, apart from their geometry, they are more akin to the rear end of a furnace-fired boiler. Perhaps the most common heat recovery boiler is now the gas turbine heat recovery boiler.

Most heat recovery applications are characterized by low heat capacity fluids and low pressures, which combine to limit the velocities over the tubes and result in low heat transfer coefficients. For this reason, when the gases are clean, it is almost universal to use finning on the outside of the tubes. Most boilermakers use serrated helical finning but some utilize solid finning despite the reduced thermal efficiency and weight penalty involved. (See Augmentation of Heat Transfer.

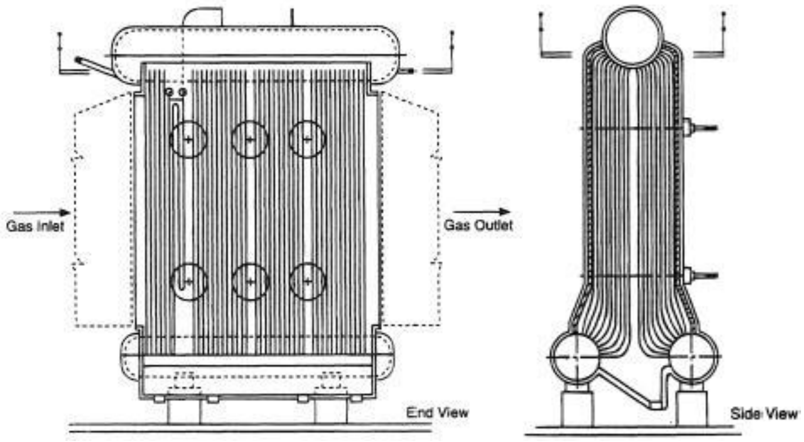


Figure 1: Tri-drum heat recovery boiler for float-glass plant

Boilers designed to recover heat from high temperature gases exhausted from glass making plant have to offer very low pressure drop to the gas stream and the tubes have to be arranged such that deposits, which are unavoidable as a result of the excess of sulphur trioxide in the gas, can be treated and removed regularly by soot-blowing. Such a boiler design is known as the tri-drum, illustrated in Figure 1. Economizer and super heater surfaces may be incorporated before and after the evaporator tubing as required to increase boiler efficiency or optimize steaming rate. A large capacity steam drum is provided to accommodate variations in the steam production rate throughout the soot blowing cycles. Boilers for recovering heat from steel-making plants are similar in concept to those above but, because of the wider swings in heat available from the source, these units are usually provided with auxiliary firing.

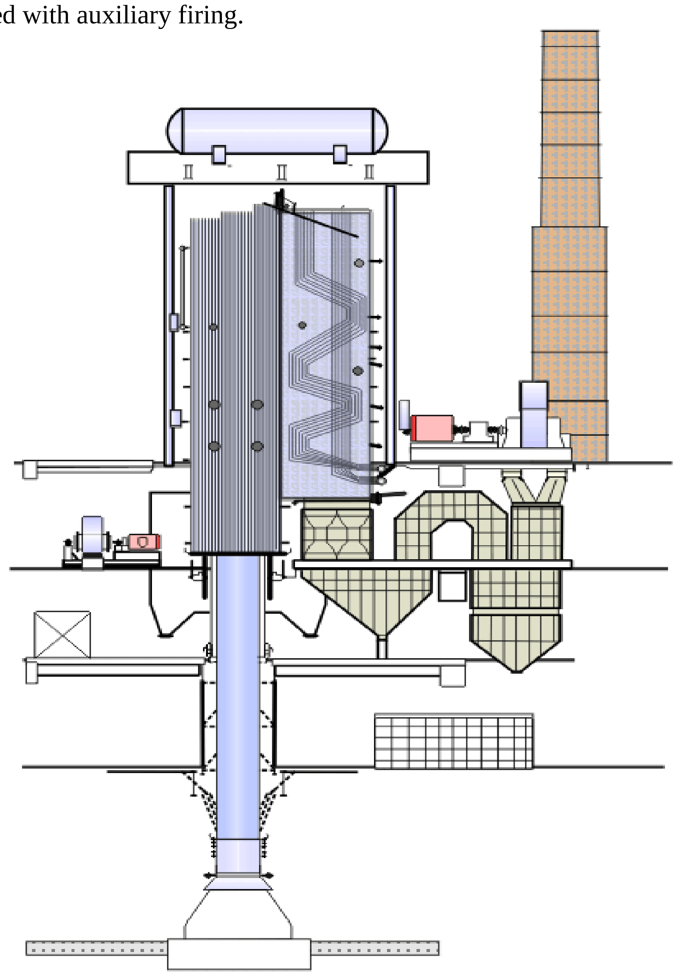


Figure 2: Heat recovery boiler for steel works

A typical design is illustrated in Figure 2 in which the principal features are the elongated duct to draw the hot gases away from the converter, the water-cooled square-section furnace with auxiliary burners forming the up-pass and flue combined evaporator/economizer forming the parallel down-pass. Hoppers are provided to collect particulates carried over from the steel converter and the induced draft fan is used to draw hot gas through the heat recovery system. As in the preceding example, the large- capacity steam drum is noteworthy. Detailed layout of heating surfaces and choice of the balance between longitudinal and crossflow areas is a matter of optimization in conjunction with the auxiliary power of the fan.

Boilers to recover the heat of combustion from waste incinerators may range from simple bi-drums such as shown in Figure 3 to combinations of these with banks of evaporator and super heater tubes mounted in water or steam-cooled ducts, the so called tail-end boiler as shown schematically in Figure 4.

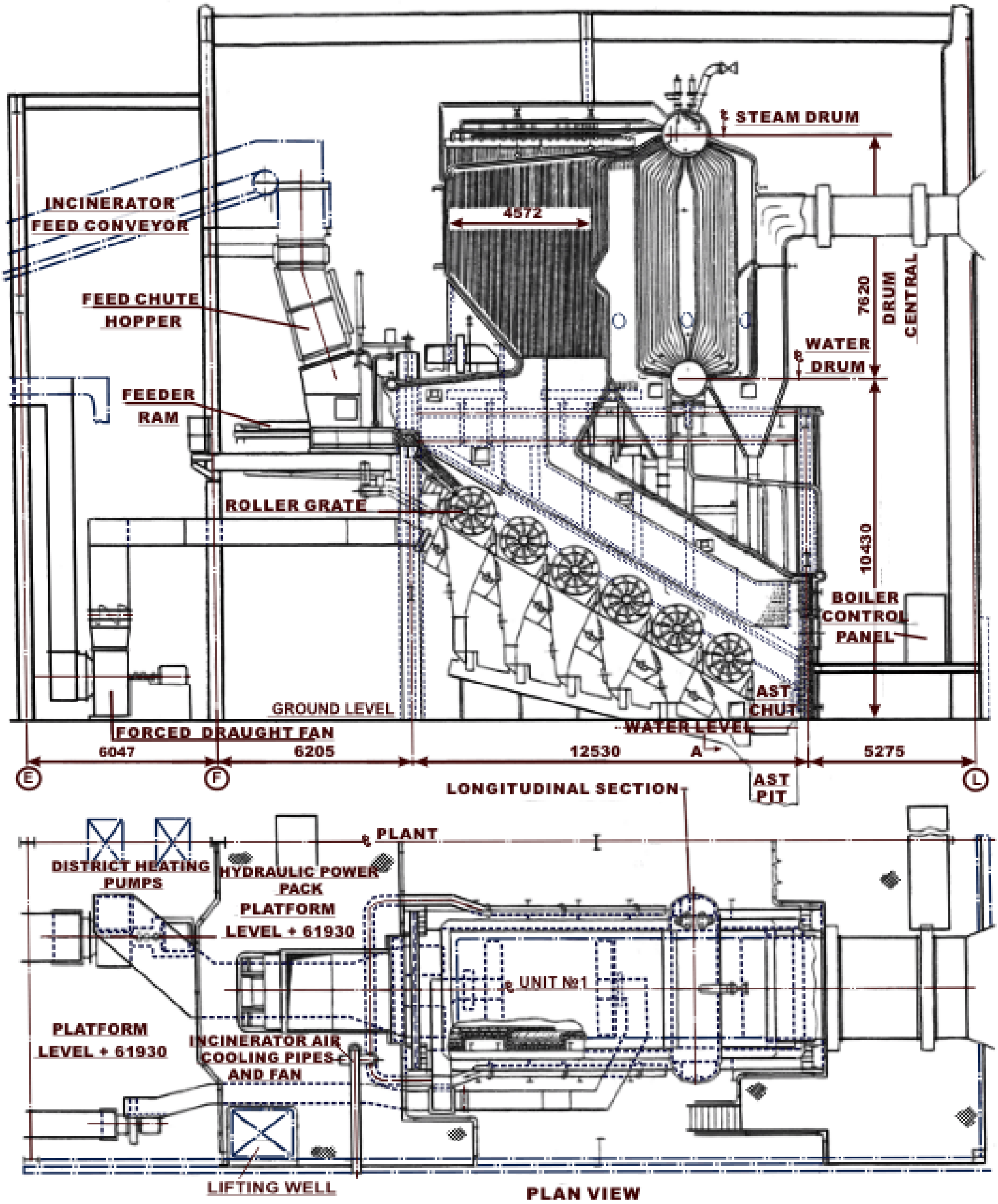


Figure 3: Bi-drum heat recovery boiler for waste heat incinerator

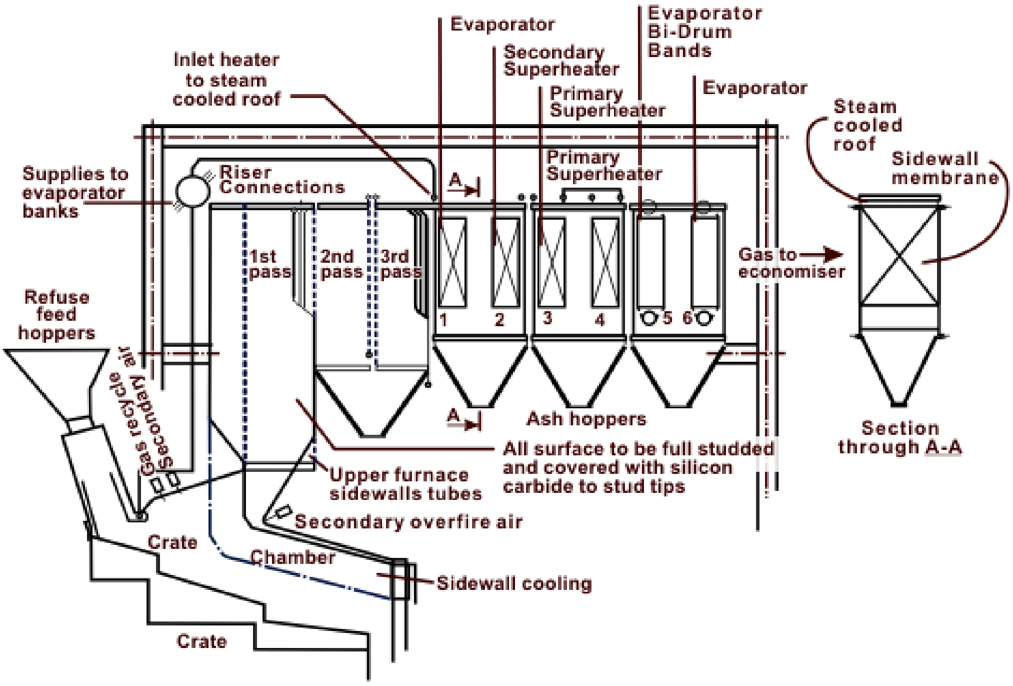


Figure 4: General arrangement of heat recovery boiler for MSW incinerator plant

Waste heat boilers are ordinarily water tube boilers in which the hot exhaust gases from gas turbines, incinerators, etc., pass over a number of parallel tubes containing water. The water is vaporized in the tubes and collected in a steam drum from which it is drawn off for use as heating or processing steam. Because the exhaust gases are usually in the medium temperature range and in order to conserve space, a more compact boiler can be produced if the water tubes are finned in order to increase the effective heat transfer area on the gas side. The Figure shows a mud drum, a set of tubes over which the hot gases make a double pass, and a steam drum which collects the steam generated above the water surface. The pressure at which the steam is generated and the rate of steam production depends on the temperature of waste heat. The pressure of a pure vapour in the presence of its liquid is a function of the temperature of the liquid from which it is evaporated. The steam tables tabulate this relationship between saturation pressure and temperature. If the waste heat in the exhaust gases is insufficient for generating the required amount of process steam, auxiliary burners which burn fuel in the waste heat boiler or an after-burner in the exhaust gases flue are added. Waste heat boilers are built in capacities from 25 m^3 almost 30,000 m^3 / min. of exhaust gas.

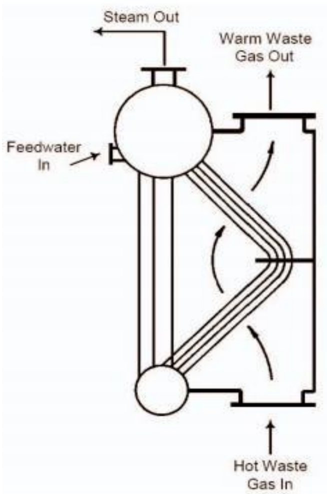


Figure 5: Two-Pass Water Tube Waste Heat Recovery Boiler

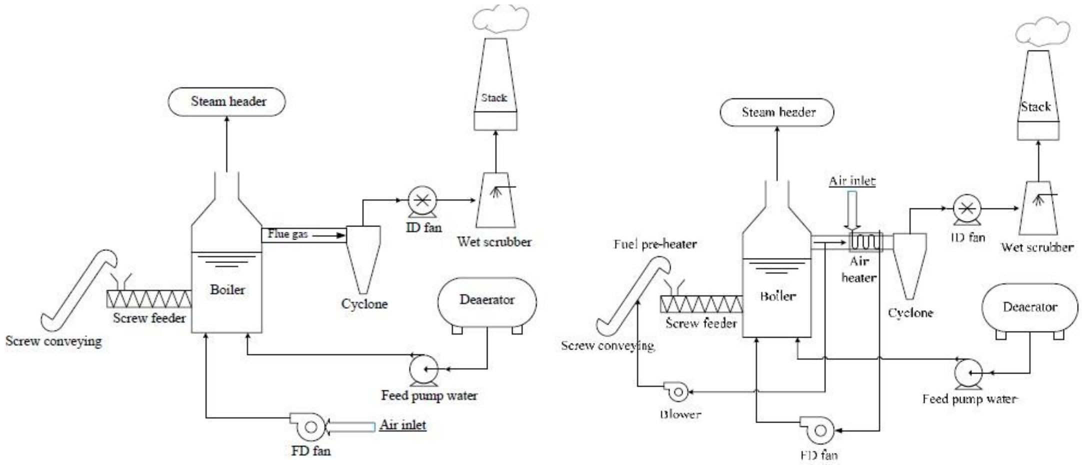


Figure 6: (a) Steam production before improvement; (b) Steam production after installing the heat recovery system

Analysis

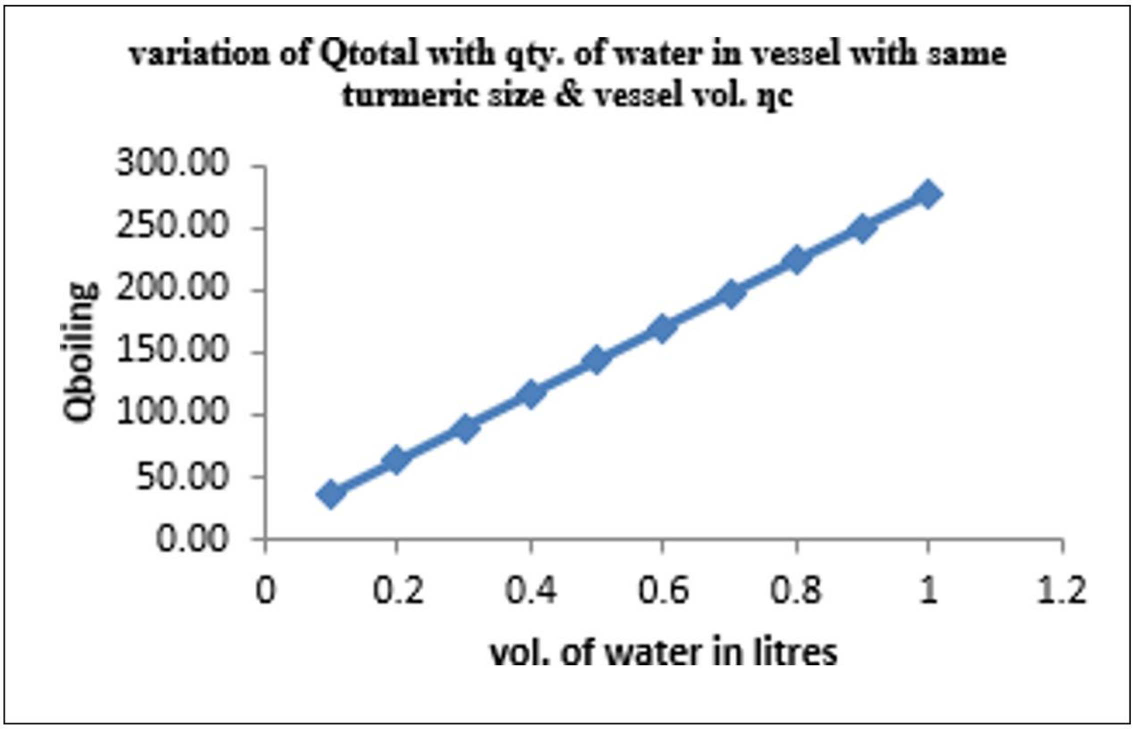
No. of samples of turmeric	1		
Diameter of vessel used for boiling (d)	0.135		m
Height of vessel used for boiling (h)	0.06		m
volume of vessel (v)	0.000858398	0.858	m^3
material of vessel	aluminium		
specific heat of Al vessel (Cp)	0.9		kJ/kg-K
specific heat of water (Cp)	4.187		kJ/kg-K
specific heat of turmeric (Cp)	10.36		kJ/kg-K
weight of vessel(W_V)	0.126		kg
qty. of water used for boiling in litres	0.3		lit
qty. of water remain after boiling in litres	0.05		lit
total time require for boiling	0.5		hrs
weight of samples before boiling	0.005		kg
weight of samples after boiling	0.0053		kg
weight of sample which is directly dried w/o boiling	0.00065		kg
weight of sample which is boiled first then openly dried	0.000506		kg
weight of sample which is boiled first then closely dried	0.7		
initial moisture content in turmeric	0.87	87	%
increase in moisture content during boiling	0.06	6	%
total moisture to be removed in drying	0.93	93	%
initial liquid content of turmeric	0.00435		kg
initial solid content mass of turmeric	0.00065		kg
weight of moisture in turmeric after boiling	0.004929		kg
weight of solid content in turmeric after boiling	0.000371		kg

energy require for boiling	kJ
energy require for solid content of turmeric	0.43
energy require for moisture content of turmeric	1.17
energy require for heating Al pot	7.26
energy require for water in the vessel	80.39
total energy require for boiling (Qboiling)	**89.24**
energy require for drying	**11.12**
total energy require (boiling + drying) (Qtotal)	**100.37**
total energy require (boiling + drying) per gram	**20.07**
total energy require (boiling + drying) per kg	**20073.88**

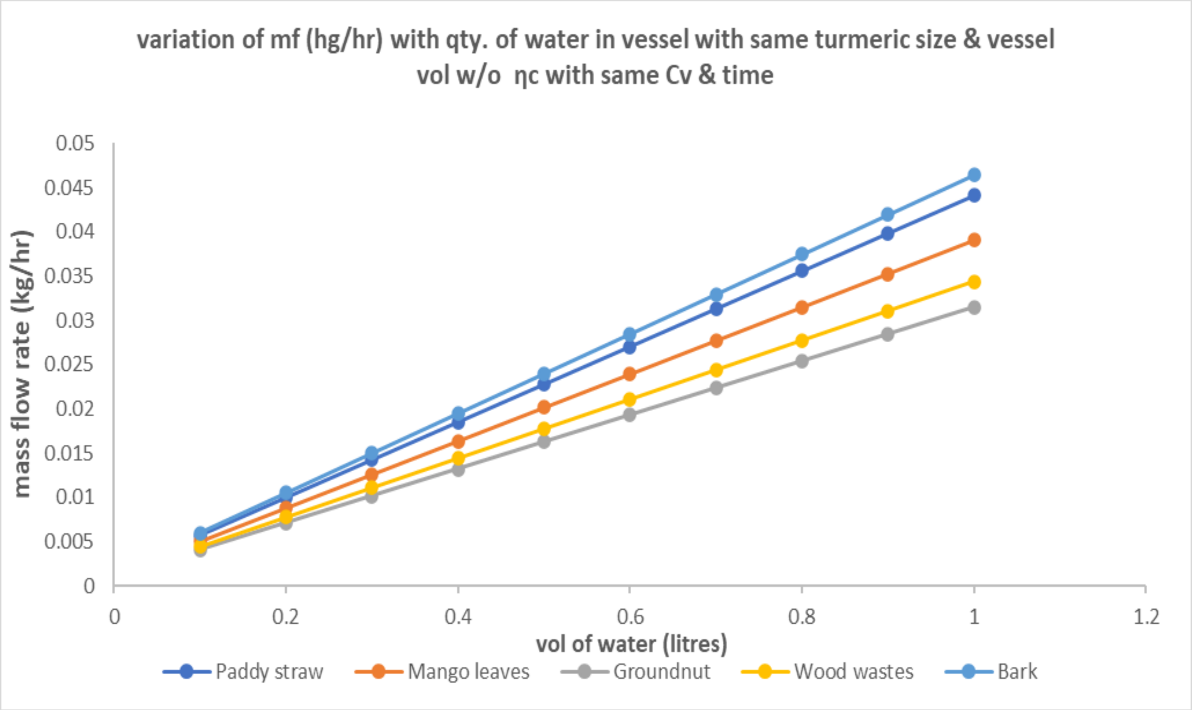
mass flow rate of fuel require for 5 g in (kg/hr)	**0.0158**
mass flow rate of fuel require for 5 g in (kg/hr) with(ηc)	**0.0166**

Observations:

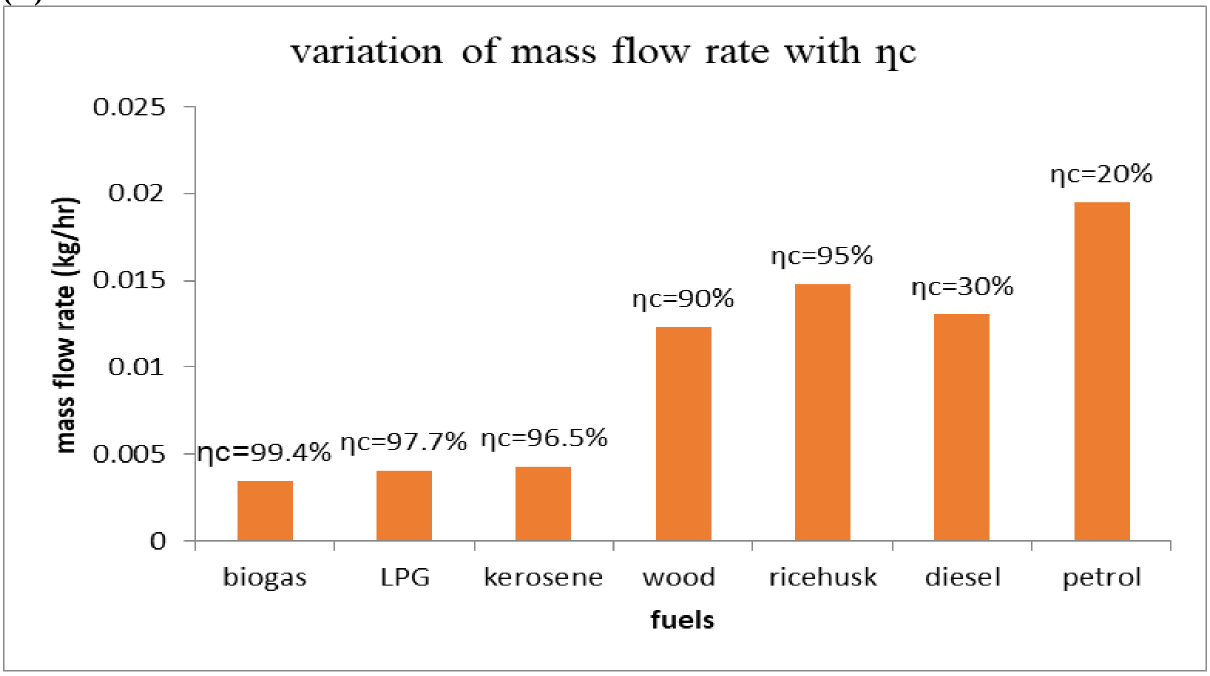
(i)



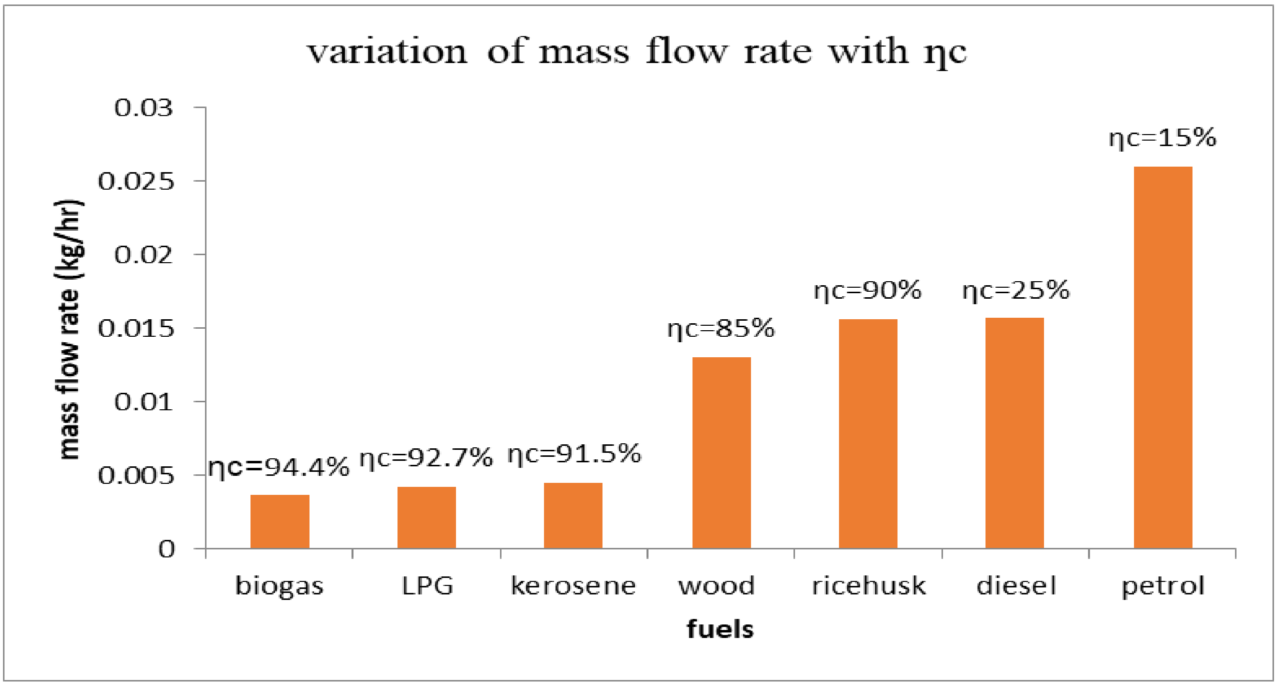
(ii) Variation of mass flow rate with quantity of water for different biomasses



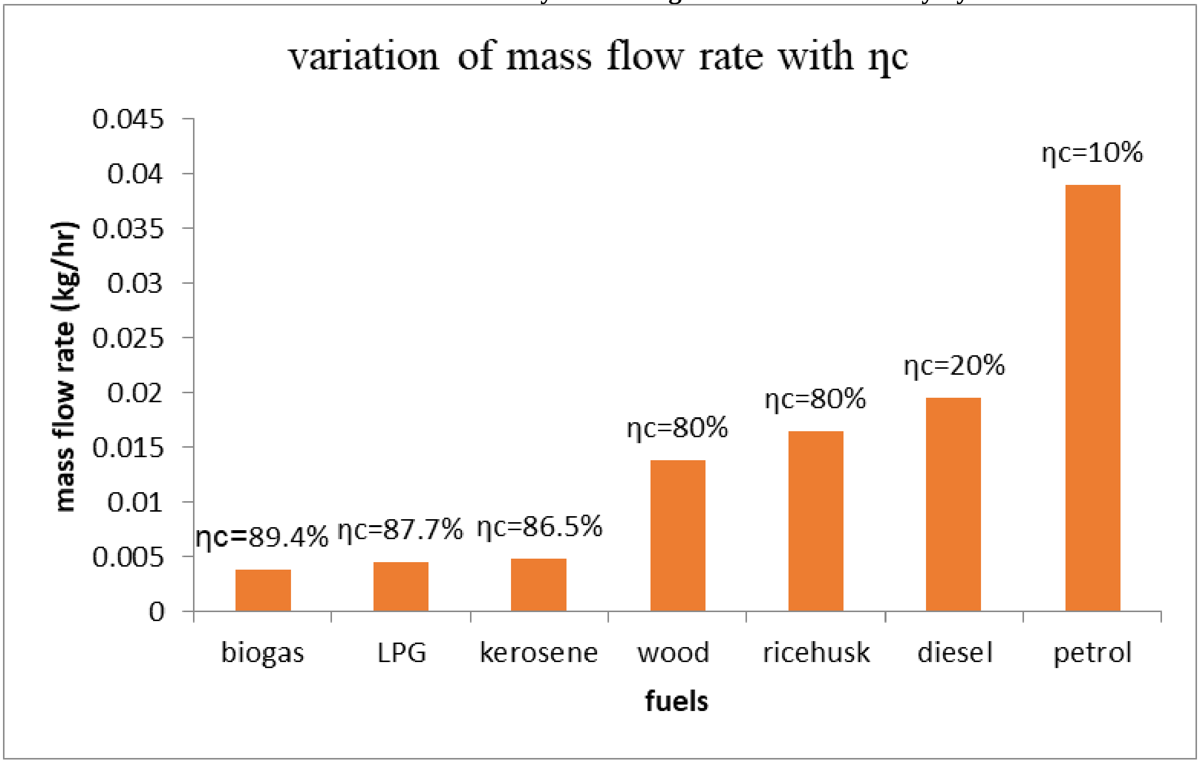
(iii)



Variation of mass flow rate for different fuels by decreasing combustion efficiency by 5%



Variation of mass flow rate for different fuels by decreasing combustion efficiency by 10%



Based on the analysis done we can observe the following points through the graph:

- The heat required for boiling is directly proportional to the volume of water. The graph is linear in nature.
- The second graph shows the variation of the mass flow rate with volume of water for different fuels. We can observe that irrespective of the fuel the nature of the graph is linear.
- The third graph indicates the variation of mass flow rate of the fuel with the combustion efficiency. On decreasing the combustion efficiency, the mass flow rate for the required fuel increases.

Conclusions

Based on the graphs we can draw the following conclusions.

- The heat required for boiling is directly proportional to the volume of water and irrespective of the fuel the nature remains same because the expression does not contain any terms of the calorific value.
- The variation of the mass flow rate with volume of water for different fuels indicates to us that irrespective of the fuel taken, the nature would remain the same. Only the value of slope of the line would change as it is inversely proportional to the calorific value. Higher the calorific value, lower will be the mass flow rate required.

From the third graph it is obvious that as the combustion efficiency decreases, the amount of fuel required will be more as it would require more energy for the complete combustion of the fuel.

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