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Capacity Building, Technical Services and Supply of Equipment for Biomass Gasification Project in Cambodia

Biomass gasifier fabrication manual-Manual

Prepared for
Project "Access to Clean Energy for Productive Uses" of the United Nations Industrial Development Organization

Prepared by
The Energy and Resources Institute

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1. Introduction

Cambodia currently has one of the lowest electrification rates in Asia with only about 55.7 per cent of its population is connected to power supply while the electricity costs are among the highest in the world. Rural areas are served to some extent by Rural Electricity Enterprises (REE) with diesel generators to provide energy services to households and small businesses connected to their mini-networks. Due to limited grid networks, most rice milling, ice-making businesses and brick factories use their own diesel generators to be energy self-sufficient.

To deal with the energy security problem, biomass gasification was introduced in the country to reduce operating costs. Some SMEs in Cambodia have already accessed this technology option using materials such as wood, corn cob or rice husks. Cambodia produces around 7 million tonne of paddy rice each year. There are about 23,000 large and small rice mills in Cambodia. The milling operation produces a large amount of rice husk. One of the major advantages of rice husk is its ability to be used as fuel to generate electricity through combustion and gasification technologies. Normally, about 2 kilos of rice husk is required to produce 1 kWh of electricity. Rice husk potential is about 22 percent of the paddy milled. With the increase in energy prices, there is a growing interest among rice mill owners to install biomass gasifiers to produce energy.

Biomass gasifier based power generation technology is at development stage. This system is aimed to remove several barriers related to the gasification technology. The conventional gasifier system used wet scrubber technology to cool and clean the gas produced from biomass. The conventional system generates a large quantity of polluted water. These plants need to be introduced with waste water treatment system for safe disposal. These system demands water resource management and waste water treatment system.

The proposed system aims to overcome the issues related to conventional system and to develop an environment friendly rice husk gasifier system. The rice husk gasifier system is designed to work with dry gas cleaning equipment. Hence the advanced rice husk gasifier system completely eliminates generation of polluted water. The system works with a minimum water requirement for cooling the gas using heat exchangers. The components of the gasifier system and its manufacturing/procurement details are presented in this manual.

2. Rice husk based biomass gasifier based system for power generation and its components

The advanced dual fired rice husk based biomass gasifier system is designed to generate power. The proposed system is designed considering clean environment, higher efficiency and ease of operation including minimum human involvement. A block diagram showing the components of rice husk gasifier system is shown in figure 1. The rice husk gasifier based power plant consists of several components. They are listed below. Technical drawings of individual components provided in forth coming chapters.

The Advanced Rice Husk Gasifier system has the following components:

1. Main gasifier unit
2. Rice husk feeder system
3. Fuel agitator
4. Ash removal system
5. Heat Exchanger-I
6. Hot gas filter
7. Heat Exchanger-II & III
8. Cartridge filter
9. Gas Carburetor
10. I C Engine coupled with Alternator
11. Blowers for Air supply to gasifier
12. System
13. Cooling tower
14. Control Panel

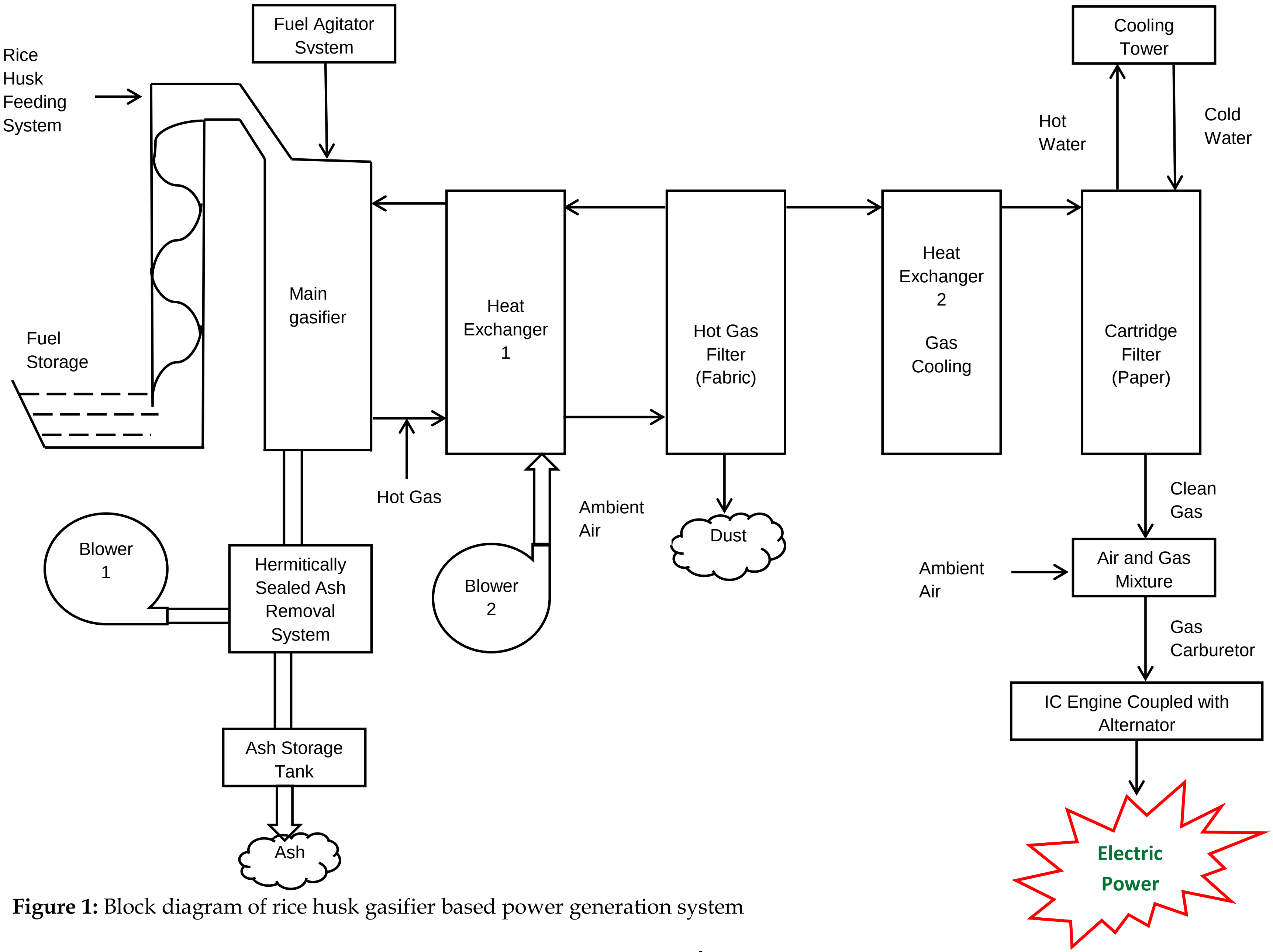

Figure 1: Block diagram of rice husk gasifier based power generation system

2.1 Main gasifier system

The main rice husk gasifier is a down-draft gasifier system with high temperature reactor and hot air supply. The system is designed to produce high quality gas using rice husk as fuel. The main gasifier unit has a fuel hopper to store a certain amount of rice husk for continuous operation, a reactor to produce high quality gas, a fuel agitator to ensure free flow of rice husk, an Ash removal system for continuous removal of ash from the reactor. Rice Husk is converted into a gaseous fuel known as 'producer gas'. The producer gas exits from the main gasifier at 500° C. This is known as raw gas which is further cleaned and cooled before giving to the IC Engine.

Turndown Ratio.

In case of power generation, a gasifier reactor can work at a lower capacity of about one third of its design capacity. When operating a gasifier reactor at a very low capacity may for a long period may reduce the gas quality. It is preferred that the genset is always operated above 30% load. The best efficiency is achieved at above 60 % load

Engine capacity:

Generally the producer gas engines have a de-rating of 20 %in case of diesel engines and 30 % in case of natural gas engine. For example when we need a 100 kWe producer gas based power generator one has to for CNG engine based generator of 130 kWe. For safety it may be better to add another 10% capacity. Hence, a CNG fuelled genset to the order of 140kWe is suitable for 100 kWe power output on producer gas.

2.1.1 Rice Husk feeder system

The main gasifier is coupled with a mechanized Rice Husk feeder system. The Rice Husk Feeder System is designed to operate at a variable fuel feeding rate. The rice husk feeder designed to can handle a feed rate up to 300 kg/h. at 60% load the gasifier system can consume around 150 kg of rice husk per hour. How ever this figure may vary according to the moisture content in fulel. The feeder system is connected through a timer switch which will also enable to vary the fuel feeding rate according to the operating capacity of the system. The mechanized rice husk feeder system reduces manpower requirement. The mechanized rice husk feeder reduces manpower requirement, to be engaged in frequent fuel feeding system. This is also provides a confortable operating condition. Rice husk feeder can be out sourced from professional dealing with conveyer and material handling system

2.1.2 Fuel agitator

Rice husk is a light material and it does not flow in the reactor as it is in the case of fuel wood. Hence, a fuel agitator was introduced using vibrating motors to ensure free flow of material into the reactor. Continuous and free flow of material is important to maintain the temperature and gas quality.

2.1.3 Ash removal system

The rice husk gasifier system is designed to have a rotating scraper based Ash Removal grate. At 60% load 35 to 40 kg of ash will be removed through the grate. Generally the recommended value of ash removal rate is 25-30% of the fuel consumption. The ash removal rate can be adjusted using the timer switch by varying the frequency and duration of the scraper operation. The scrapper is operating using a timer switch at desired intervals according to the operating load of the system. As discussed earlier, rice husk is one of the biomass fuel which has very high ash content; to the order of 17-20%. Hence, it is essential to have an efficient ash removal system. Accumulation of more ash in the reactor can reduce the gas quality. The ash removal system is designed to maintain the gas quality. An additional ash storage tank is incorporated in the design to enable the system for a continuous operation for a long period. Ash from the storage tank can be removed once in 8-10 hrs during the continuous operation.

2.1.4 Heat Exchanger-I

The proposed rice husk gasifier is designed to have three heat exchangers. Heat Exchanger-I is designed to work with high temperature gas. High temperature resistant stainless steel material is used for fabrication of this heat exchanger. Heat Exchanger-I is used to cool the gas and to heat the ambient air. Depending on the operating condition, the air temperature is raised to the order of 300° C. Supply of the hot air to the reactor increases the gas quality by reducing the tar content. Recycling the waste heat from the hot gas to the gasifier increases the gasification efficiency.

Flow rate of the producer gas can be estimated by measured fuel consumption rate. In case of rice husk to producer gas conversion factor is 2 m3/kg of rice husk. The hot air supply is part of the design of nozzle and the reactor. Generally about 0.4 m3 of air supplied to produce one cubic meter of producer gas.

2.1.5 Hot gas filter

A hot gas filter is used to remove the dust particles in the gas. The hot gas filter is made of high temperature resistant fabric which enables to use the filter at high temperature environment. The hot gas filter is insulated to maintain the gas above 110° C to avoid any condensation and clogging in the filter. For a smooth operation of the system, it is essential to have low pressure drop across the filter. Hence, hot gas filtering system was selected. Most of the conventional gas cleaning system employs water scrubbers to clean the gas. In the proposed system, water scrubbers are completely eliminated; due to which this system is environment friendly and does not produce waste water.

2.1.6 Heat Exchanger-II & III

The heat exchanger II and III are designed to cool the gas. Heat Exchanger II and III are designed to cool the gas to 10-15° C above ambient temperature. Both the heat exchangers are shell and tube type exchangers. In heat exchanger II, gas is cooled using ambient air or cool water. In the heat exchanger III, gas cooled using the water from a cooling tower. All the specification including water flow motor capacity is in scope of cooling tower supplier. The cooling tower is standard evaporative cooling equipment used in small power plants.

40 % of the total gas fraction is the hot air entry through the heat exchanger. For example about 120 m3 of air will flow through the heat exchanger, at 60% load.

2.1.7 Cartridge filter

Cartridge filter is a standard paper filter used for supply of clean air to IC Engines. The size of the cartridge filter is selected to work at a lower pressure drop across the equipment. Cartridge filter acts as a safety filter. This filter removes all fine particles from the gas and provides clean gas to the IC Engine. It is ensured that the gas is sufficiently dry when entering the cartridge filter, to avoid any increase in pressure drop.

2.1.8 Gas Carburettor

The gas component and the stoichiometric air requirement of the producer gas generated from rice husk are entirely different from that of natural gas. The fuel mixture intake manifold was designed to supply the appropriate fuel mixture of air and gas required to the engine according to the variation in the operating load conditions. The intake manifold is provided with a mixing chamber to produce a homogeneous mixture of producer gas and air.

2.1.9 IC Engine and Alternator

Natural gas engines are equipped with spark ignition system and suitable for operation in producer gas without carrying many modifications. Natural gas engines with a compression ratio of 10:1 found to be more suitable for operation with producer gas. The natural gas available in market will be used with above gas carburettor for operation with the producer gas generated from rice husk. To run on producer gas, the ignition timing of the engine will be kept at 28 ° before TDC. The IC engine is coupled with a 3 phase alternator, which is capable of delivering power at 415 V with 50 Hz frequency. Natural gas engine for a suitable capacity can be outsourced as per the capacity of requirement

2.1.10 Blowers used in the system

The rice husk gasifier system will be equipped with four blowers, which performs deferent functions.

The first blower is known as flare blower. At the initial stage the gasifier produces a poor quality gas for about an hour. During this period, the reactor temperature is raised to the required level to produces a good quality gas. During this period the raw gas is flared with a separate gas line using the flare gas blower.

The second blower is known as pressure blower which is connected to the heat exchanger I. This blower is used to provide the hot air required for gasification of rice husk. The third blower is known as booster blower which takes care of the pressure drop created across the system, through various components. The fourth blower is known as cooler blower. This blower is used to cool the gas from 120 °C to 60 °C. The forth blower is connected to heat exchanger II. By using air cooling method the system reduces the load on cooling tower used to cool the water used in heat exchanger III. These systems are used to cool the gas, by replacing the conventional wet scrubber systems. Hence, the proposed rice husk gasifier system is designed to eliminate the generation of polluted water.

2.1.11 Control Panel

The rice husk based power plant is provided with two control panels. One of the panels is equipped with operating switches and indicators related to the electrical equipment in the gasifier system. Another panel is equipped with the operating switches and indicators related to the electric generator.

1. The control panel to be provided with the genset will have the following components:
2. MCCB of suitable rating with overload and short circuit protection
3. On/off Indicators
4. Frequency meter
5. Power (KW) meters

6. Indicating lamps for "Load On" and "Set Running"
7. Aluminum bus-bars of suitable capacity with incoming and outgoing termination

3. Fabrication of the gasifier system

3.1 Fabrication of the fuel hopper

Fuel Hopper is the large component of the gasifier system. It is made in the shape of conical-frustum. Due to its geometrical shape, the Hopper has three key dimensions:

- Radius at the base of the hopper (r)
- Radius at the top of the hopper (R)
- Height of the hopper
- Area of the reactor : $(R+r)\sqrt{(R-r)^2+h^2}$
- Volume of the reactor : $1/(3\pi \times h\ (r^2+R^2+r.R))$

The direct dimensions which can be derived from these three parameters are:

- Diameter at the base and the top of the hopper
- Angle of inclination
- Area of the sheet required
- Weight of the sheet for fabrication of the hopper

For fabrication of the Fuel Hoper, a formula can be used to estimate the area and weight of the sheet, which is actually required. However, it is necessary to estimate the area of the sheet required as per its available dimensions, including wastage. The sheet requirement for fuel hopper lid needs to be calculated separately. The sheet cutting profiles need to be followed as per the specifications given in Figure 2.

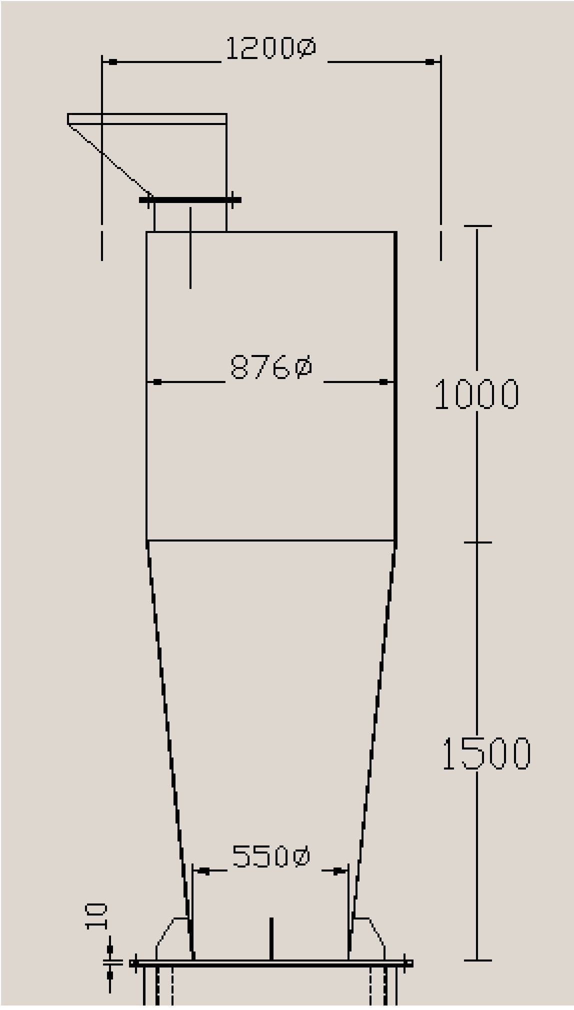

Figure 2: Sheet cutting specifications

Caution:

The dimensions are arrived based on the following factors. The general arithmetic formula related to volume of cone, frustum, cylinder and cubical are adopted. These formulas are available in high school level mathematics book. According to this project a fabricator should be well versed to follow the drawing and dimensions given in the manual. Once he gain experience about the information in the manual then he may extend in to calculation of new dimensions using any mathematics book has the information about Area and volume of different geometrical structures. We recommend this manual is meant for fabricator who has basic knowledge about the formula for volume and area. Otherwise they may end up with fabrication of different product which may not be the purpose of this project. However, if the manufacturer wants to become designer, then they can use the following references.

References:

i. Handbook of Biomass Downdraft Gasifier Engine Systems. http://www.nrel.gov/docs/legosti/old/3022.pdf

ii. A dual fired downdraft gasifier system to produce cleaner gas for power generation: Design, development and performance analysis. http://www.sciencedirect.com/science/article/pii/S0360544213002077

3.2 Fabrication of gasifier reactor

The Reactors are the key components of the gasifier system. The Reactor consists of a metallic shell and two layers of high temperature castable (refractory cement). The metallic cylinder is provided with two sets of flare gas to conveniently fit the adjoining equipment. Generally the flanges are made of 8 to 10 in thick M S Flats.

The gasifier reactor works at above 1000°C. Hence it is essential to insulate them suitably withstand the temperature. The gasifier is lined with two layers of high temperature castable. Castable lining need to be done carefully as per the instruction given in this manual. The gasification reactor has three key dimensions:

- Outer diameter of the reactor
- Inner diameter of the reactor
- Height of the reactor

Additional information derived from the reactor dimensions are:

- The sheet requirement,
- Flange details,
- Insulation thickness
- Insulation material required.

The system supplied as part of this project has two reactors, apart from the height of the reactor; diameter remains the same for the reactors. The details of the reactor can be seen in Figure 3.

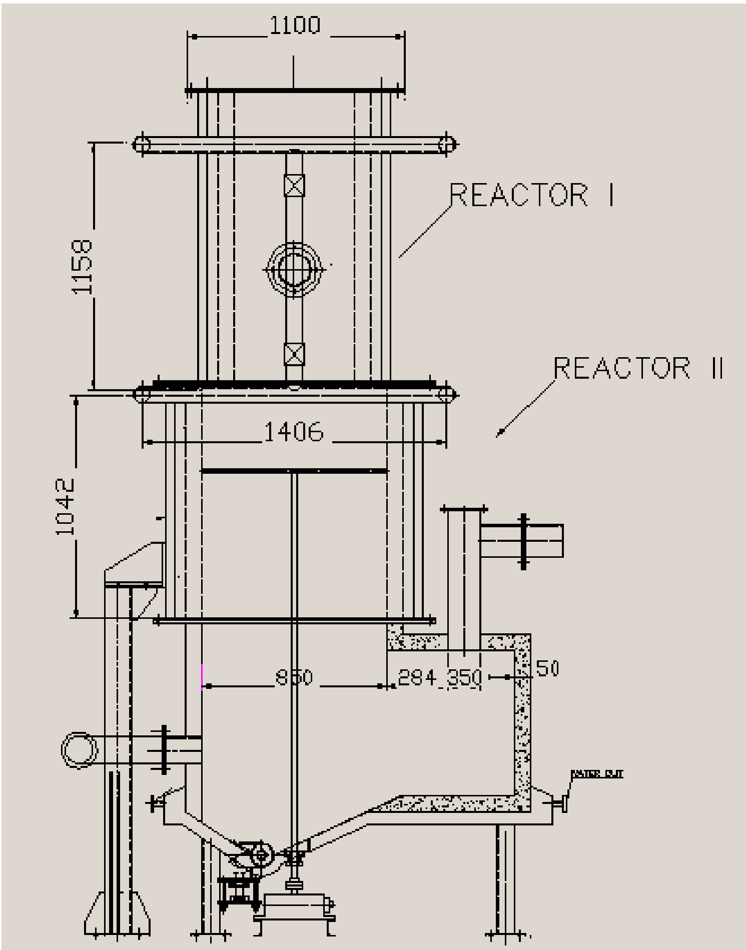

Figure 3: Details of the reactors and the air supply nozzle header

Air for gasification is supplied using multiple nozzles in (both) the reactors. The air control valves need to be provided in between the nozzle headers.

3.2.1 Refractory lining

Refractory lining of the reactor is the heart of the gasifier. These are the linings which are exposed to high temperature like 100-1200°C. Hence, adequate core need to be taken for casting the lining. Generally, the castable material supplier provides instruction for casting and curing. The key steps to be followed are:

a) The mixture of the castable + water need to be made with minimum quantity of water, about 15%.

b) Mixing of mortar + water need to be done carefully to appoint homogenous mixture.

c) Casting need to be done with adequate metal chassis fixed to the drum (which is important to hold the material when it is wet)

d) Appropriate scaffolding/ mould need to be made to pour the castable mixture.

e) It should be packed without air bubble (may need needle vibrators used for RCC concrete)

f) After 12 hrs of casting, the castable need to be covered by sack-cloths and cured at every two hours with water sprinkling for two days

g) Allow it for shade drying for three days

h) Allow it for sun drying for four days

i) After sun drying, the castable need to be preheated at an open space for two days by having small fire at the centre of the reactor

j) Flame should not touch the castable lining while it is preheated

k) Allow reactor to cool for two days under shade. The reactor needs to be cooled slowly (blower/ water spray should not be used to cool the reactor).

The reactor is a delicate part of the gasifier. It needs to be made carefully as per the instructions given step-by-step.

3.3 Ash pit

Ash pit is coupled at the bottom of the reactor II. Ash pit is a hermetically sealed container in which ash is collected and at the same time it is used as a passage to draw the gas from the reactor. Generally the gasifier has a single ash pit, but in rice husk gasifier system, it is preferable to have an additional equipment to have additional ash storage space with ease of removal during operation of the system. Ash removal system is a combination of conical and cylindrical vessels. Ash handling equipment operates at high temperature. Hence, ash pit and its accessories need to be fabricated with high temperature resistant stainless steel material, ash handling screws, conveyors and reduction gear box; VFD, etc. need to be outsourced. The details required for fabrication of ash pit is shown in Figure 4.

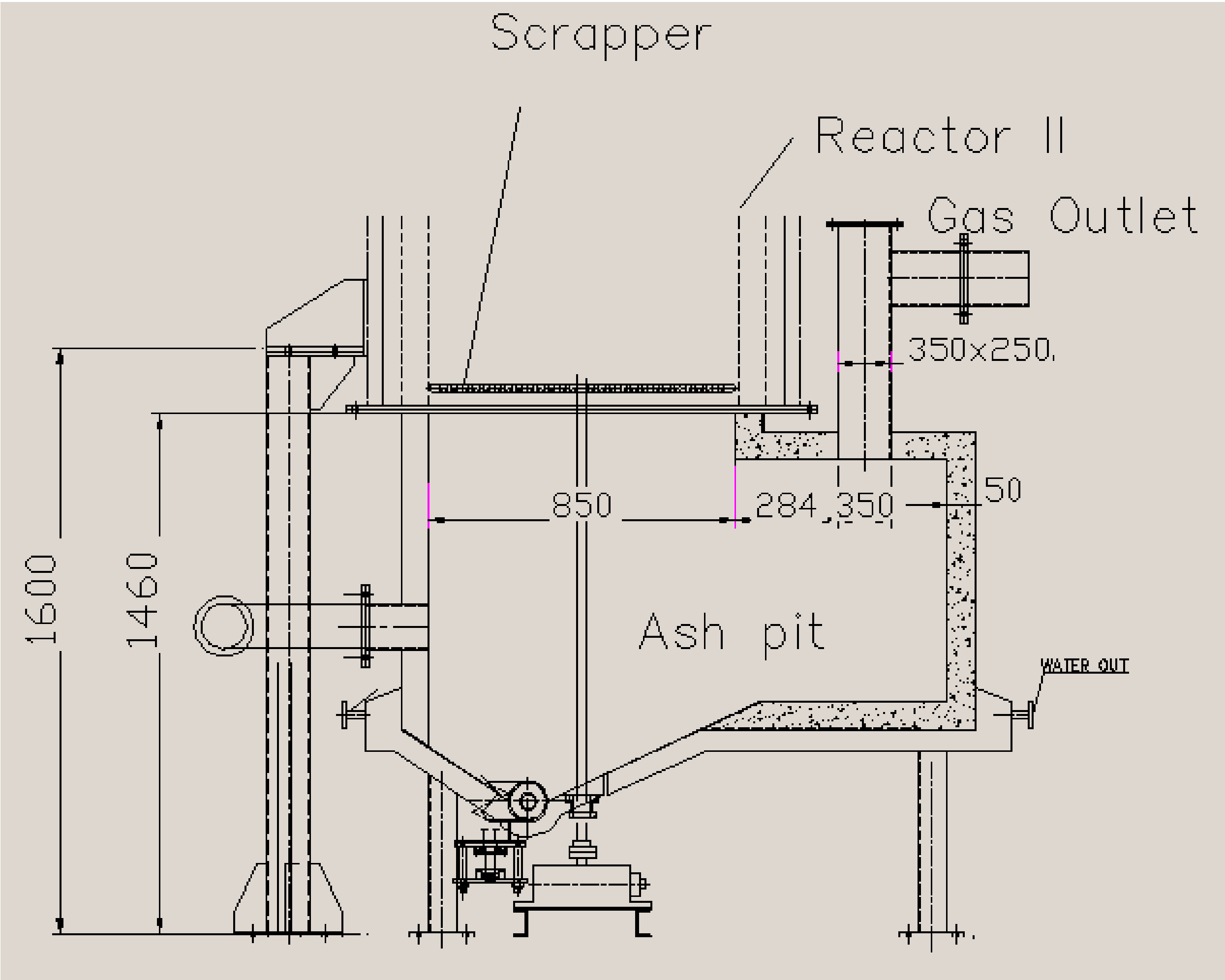

Figure 4: Details of ash pit

3.4 Hot air line

In this gasifier air is preheated and hot air is supplied to the reactor. A pressure blower is connected to the Heat Exchanger-I. The air exit of Heat Exchanger is connected to the gasifier reactors. The hot air line is provided with SS ball valves to control the air supply to the reactors. Hot air need to be insulated with mineral wool of a thickness of 30mm. The insulation need to be covered with metal cladding is very essential to protect the insulation layer and to decrease the heat loss from the hot air line.

3.5 Heat exchangers

The advanced gasification system has three heat exchangers.

3.5.1 Heat Exchanger-I

This is placed next to the main gasifier unit. The hot gas (at a temperature of 500-600°C) exits from the Ash Pit of the gasifier. Using the Heat Exchanger-I, ambient air of the temperature of about 30-40°C temperature, is heated to 200-300°C is heated to 200-300°C. The dust particles are collected and removed from the base of Heat Exchanger-I. The hot air outlet from this heat exchanger is connected to the gasification reactor. Cold gas outlet at 200-250°C of the heat exchanger is connected to hot gas filter through a cyclone filter. A diagram of the Heat Exchanger-I is shown in figure 5.

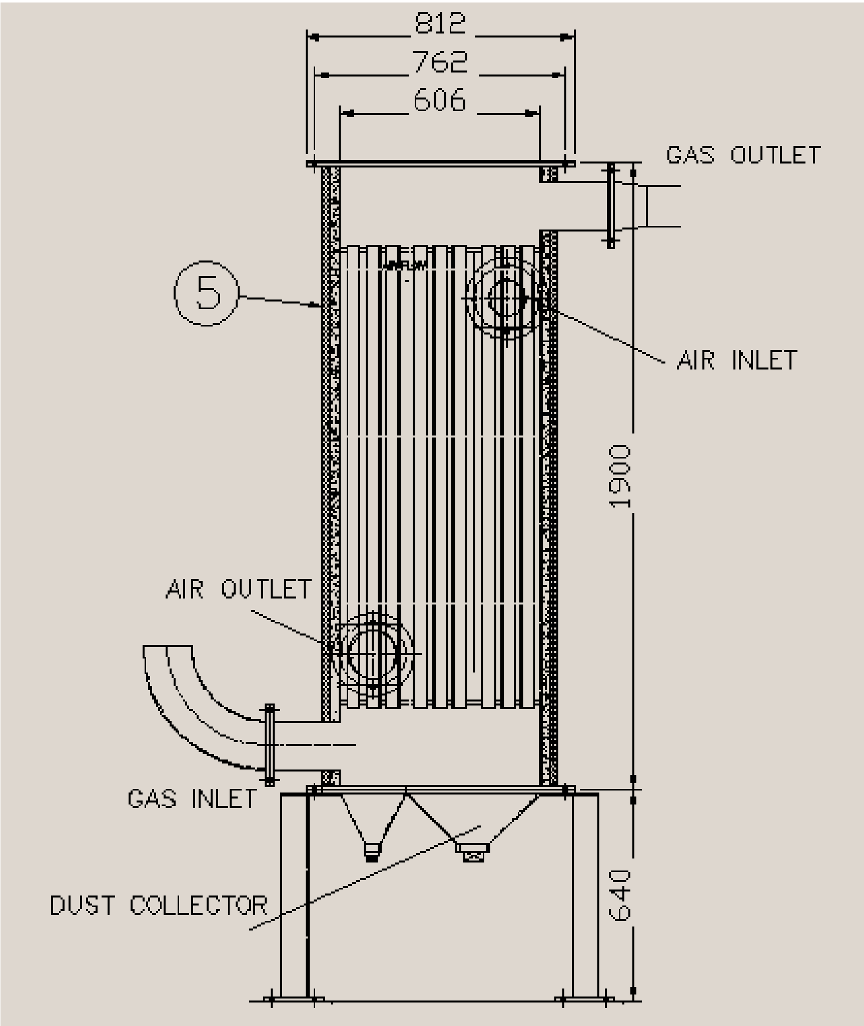

Figure 5: Details of Heat Exchanger- I

3.5.2 Heat Exchanger-II and III

Heat exchanger-II and III are identical and all are shell and tube. Heat exchanger II & III are used to bring down the temperature of the producer gas closer to ambient (10-15°C above ambient). The gas is passed through the tubes and cooling fluid (water) is passed through the shell. Condensates are removed from the bottom chamber. Details of heat exchanger-II & III are shown in Figure 6.

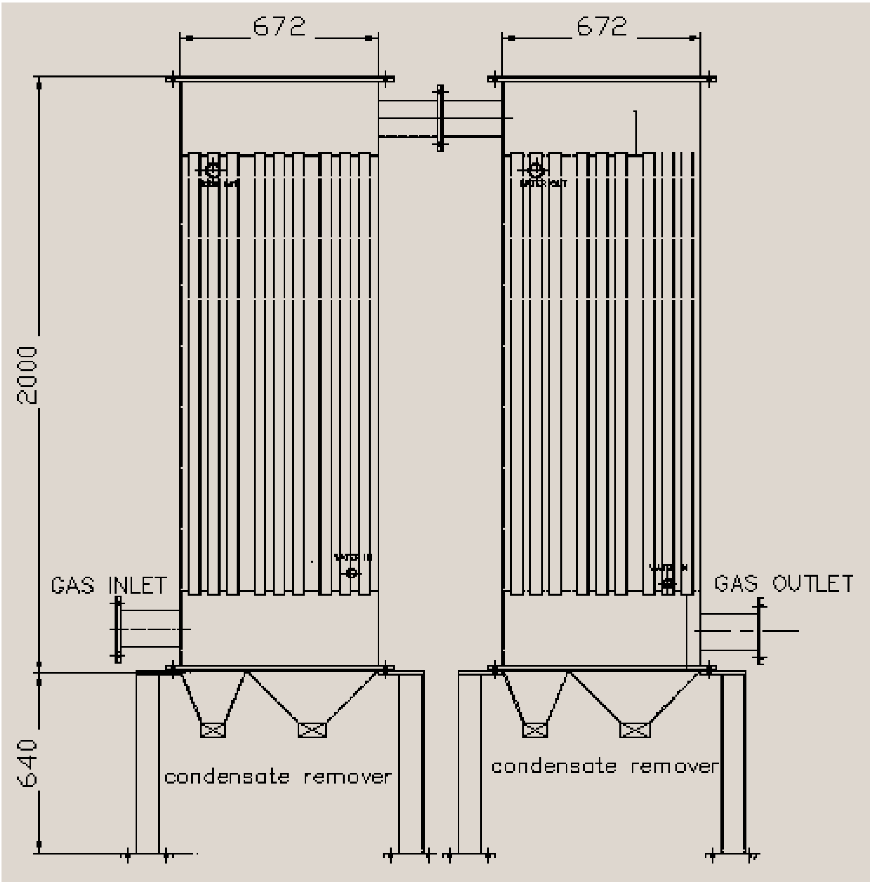

Figure 6: Details of Heat exchangers II and III

3.6 Hot gas filter

Hot gas filter consists of a set of bag filters. The bag filters are capable to withstand 200-250°C. the gas filter need to be outsourced from the suppliers who deal with dust filters. The metallic enclosure for the bag filter needs to be fabricated as per the details given in Figure 7. The hot gas filter is provided with frames to fix the filters. The lid of the hot gas filter is made as a removable door using nuts and bolts. The top door of the hot gas filter is made removable to clean/ replace the bag filters. Hot gas filter is placed between Heat Exchanger-I and Heat Exchanger-II. The hot gas filter needs to be insulated using a 50 mm thick mineral wood blanket. All the insulations in the system need to be got done by professionals and provided with metal claddings. A flare line also has to be provided between the Ash Pit and the Fabric Filter to avoid condensation in Fabric Filter during the initial start-up period.

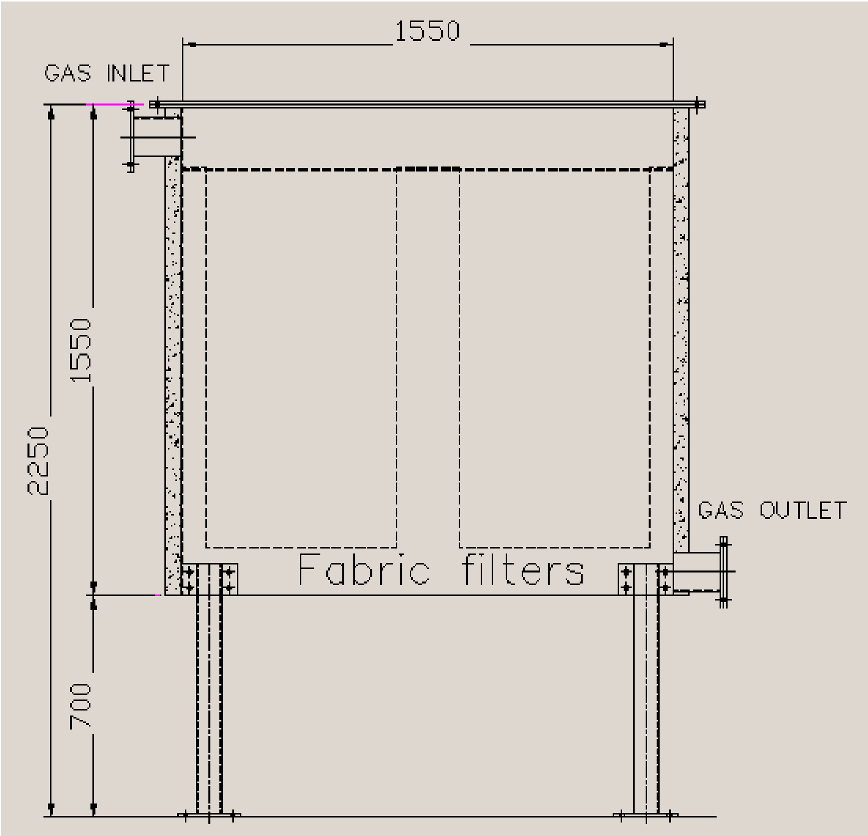

Figure 7: Details of Hot Gas Filter

3.7 Mist Separators

It is the process of cooling the gas at different stages. It loses the moisture holding capacity. Part of the moisture condensed and collected at the base of the cooling equipment. A portion of the moisture condensed is carried away with the gas in the form of 'mist'. The mist in the gas may affect the gas filters' efficiency and engine performance. Hence it is important to separate the mist from the gas. A Mist Separator is included in the system to obtain clean gas. The Mist Separator is placed after the Heat Exchanger-III. The details of the Mist Separator is shown in Figure 8.

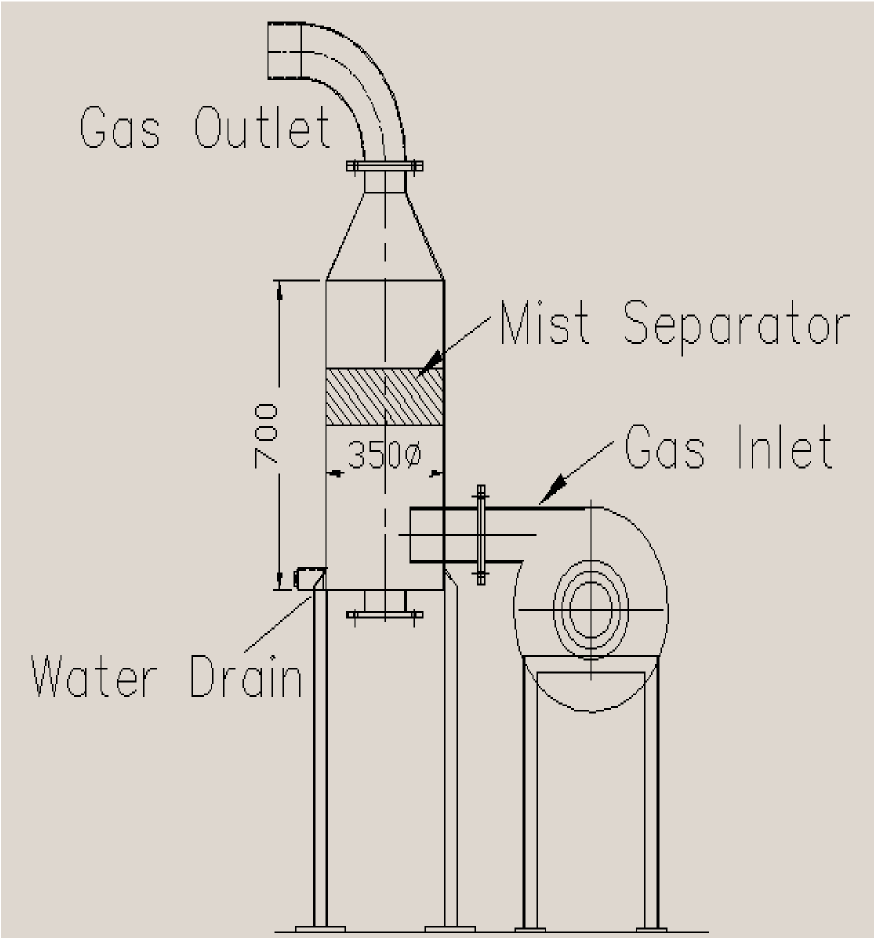

Figure 8: Details of Mist Separator

4. Gas and air intake manifold

The producer gas composition and stoichiometric air requirement of the producer gas is entirely different from that of diesel and natural gas. Gas to air ratio of producer gas is 1:1.2 whereas gas to air ratio for natural gas is 1:13.5. According to the heating value of the gas and its stoichiometric air requirement, a fuel intake manifold was designed to operate the engine on 100% producer gas. The fuel mixture intake manifold is provided to supply the appropriate fuel mixture of air and gas required to the engine according to the variation in the operating load conditions. A diagram of the fuel intake manifold designed to operate the engine on producer gas is shown in Figure 9. From this figure it may be noted that the manifold comprises of two separate chambers for entry of gas and air into the engine. The intake manifold is provided with a mixing chamber to produce a homogeneous mixture of producer gas and air. Individual valves were installed at the inlet of the manifold to maintain the required gas to air ratio. The outlet of the fuel intake manifold has a venturi shaped arrangement for obtaining a homogeneous fuel mixture of air and gas. The outlet of the manifold is connected to the engine inlet through a throttle valve. The inbuilt governor connected to the throttle valve, controls the flow of fuel mixture into the engine according to the electric load.

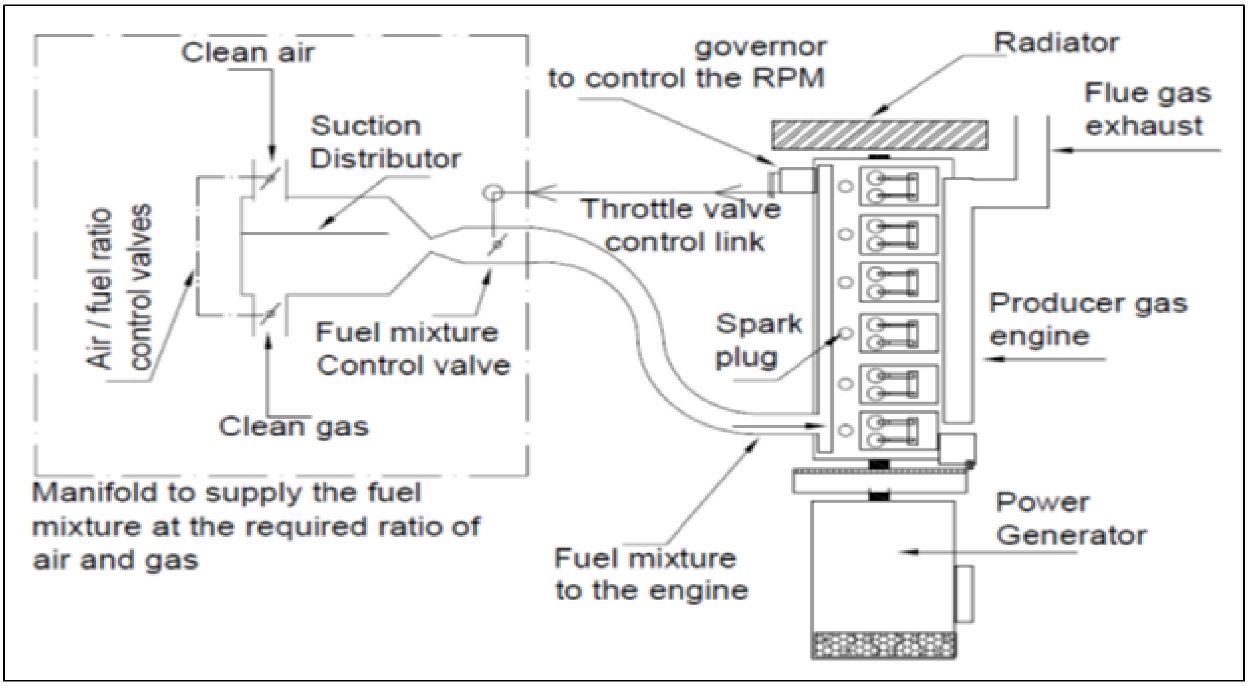

Figure 9: Diagram of the fuel intake manifold designed to operate the engine on producer gas

5. Dos and Donts

Components	Dos	Don'ts	Remark
Materials	Selct apropriate materials. Follw the specifications required to meet the standard	Don't use equallent are substitute of materials for fabrication	Inappropriate use of materials can lead to accidents and also will afect the durablity of the system
Manufacturing process	Stricly adopt the manufacturing process for each component, as prescribed in the manual	Do not deviate from the sugested process	May lower the quality of the system and also quality of the produces gas. Quality and standard is an imprtent aspect of the system
Dimensions	Stricktly follow the dimensions of each component to avoid any manufacturing error.	Do not deviate from the dimensions and do not use any random dimensions	Dimensions are key factors for the best performance of the system
Saftey	Use saftey quipment, like Helmet, saftey specs, Hand gloves, boots etc. to avoid any accident while manufacturing. Use crane or chain Pulley to handle heavy equipment	Don't work with out saftey accessaries and don't lift the heavy materials in an improper manner	Saftey is the basic requirement to abvoid any accidents.
Out sourcing	There are sevral equipment like (Blowers, Genset, control pannal, cooling towers etc.) need to be out sourced. It is important to ensure their quality	Don't out source any under quality/ sub standered components as part of the system	Over all performance , will be affected a lot. The saftey issues may arrise

6. ANNEXURE

Different views of the individual components, during the manufacturering prcess are shown to have an idea about actual shape and structure of the equipments. More clarity may be obtainned during the practical instructionms at site.

Figure 10: A view of the gasification reactors during the manufacturing process

Figure 11: A view of the fuel hopper with the gasification reactors during the manufacturing process

Figure 12: A view of the heat exchanger during manufacturing process

Figure 13: A view of the Hotgas filter

Figure 14: A view of the ash handling system during manufacturing process