Technology Specification

KENTEC ENERGY

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Introduction

KENTEC Energy is a technology company supplying and developing gasification technology. The company supplies gasification solutions for energy conversion of flue gas through heat exchanger systems to effective energy such as hot water and/or steam. After energy utilization the flue gas is cleaned through a filter system where activated carbon and hydraulic lime is added. Other suitable cleaning methods can also be used.

The following is describing the “the core technology” as delivered by KENTEC Energy. The technology is constantly under development and specifications may vary depending upon waste specifications as well as energy utilization.

Core technology

- Gasification module with inlet for fuel and outlet for ash with a manifold system for injection of air mixed with recycled flue gas.
- Gas aspiration in bottom with secondary gasification chamber and gas injection system for feeding air mixed with recycled flue gas.
- Cyclone with combustion chamber for flue gas.
- Control system with PLS for operation of the gasification system, air supply and feeding of flue gas. The control system consists of HMI with displays and PLS for operation of the gasification unit. The control system is prepared for connection of other external control systems to e.g. boiler and filter.
- Installation and operation instructions

After feeding, the fuel drops down into the gasification area in the primary chamber where air is added and the gasification is done. The generated combustible low calorific gas is sucked out of the primary chamber and into the secondary chamber where fresh air is added and the combustion is completed. The temperature on the gas in the primary zone is approximately 700°C while the temperature in the secondary zone is over 850°C. After the secondary chamber, the flue gas is transported into a cyclone where the combustion takes place and where the fly ash is being deposited.

The flue gas is then led to a heat exchanger for production of hot water or steam. The energy recovery plant is adjusted the customers requirements. Accordingly the cooled flue gas is fed into the flue gas cleaning system, through the flue gas fan and chimney and then out in open-air. The exhaust gas is cleaned to meet standards as required in the EU's proposed directive for (large) waste to energy plants.

The process that is recycling the fuel to flue gas with high temperature consists of the following steps: *drying, pyrolysis, gasification and combustion*. The first three steps take places in the primary chamber while the combustion of the gas is located in the secondary chamber. Figure 1 demonstrates a conventional overview of KENTEC Energy gasification technology.

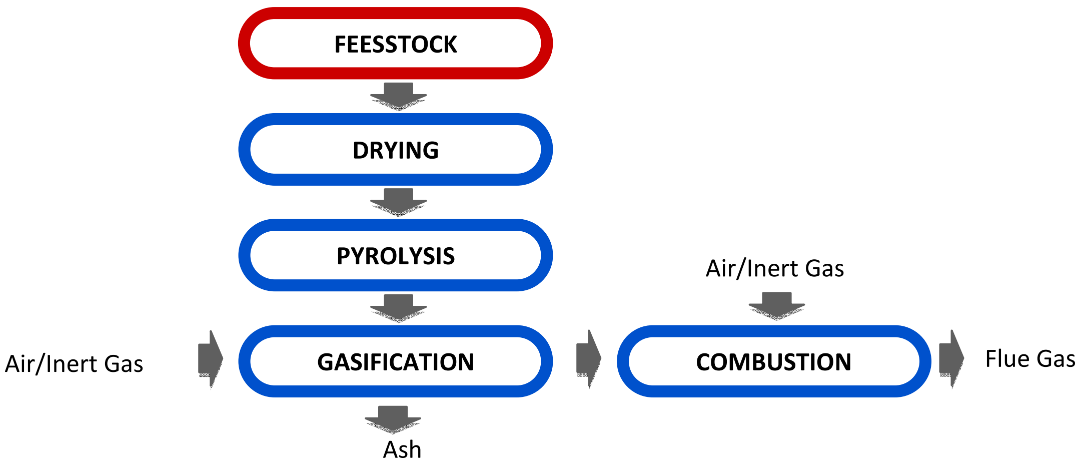

Figure 1 KENTEC Gasification Overview

The biomass in the waste contains volatiles components. While it is heated over 300°C, it is transformed to gas or fluid components and fixed carbon. When Timber is heated, approximately 85% of the solids are transformed into gas (fluid) components at 500°C. Gasification is one of various methods for thermo chemical transforming of biomass. Drying and pyrolysis are always the first step in a gasification process. Pyrolysis is thermal degrading (evaporate) where oxidant is not in place. The process is endothermic. Pyrolysis and gasification is a method for thermo chemical transforming of biomass at respectively 200-800°C and 900-1100°C.

The fuel is fed to gasification through a feeding solution that prevents penetration from “false air”. The feeding solution is depended upon the customer’s total fuel logistic. The fuel level in the primary chamber is measured by a radioactive isotope, installed on upper primary chamber. The feeding system is operated upon signals from level measurement. In the primary chamber, oxygen is added in a mixture of air and inert gas through holes in the bottom of lower primary chamber, named primary air. The primary air is sent through nozzles that together can be opened and closed when required. Altogether 160 nozzles on each side of lower primary chamber give a proper divided air supply. The flow and scale between air and inert gas, which are sent through the nozzles, vary with the fuels humidity, density and fuel-value. The quantity of primary air varies from approximately 2000–4000Nm3/h. Primary air feeding requires a frequency-operated primary air fan.

The “fresh” fuel will lay on the top and be preheated and dried while waiting to sink into the pyrolysis zone and further down to the gasification zone. The primary chamber is operated at under pressure, approximately 5-10mm H2O. A frequency-operated flue gas fan generates the under pressure. In bottom of lower primary chamber, there will be a protecting bed of ash over the ash output that consists of a drum suspended by springs. A temperature sensor analyzes the temperature in the ash and gives a signal for feeding out the ash. There will be continuity between this temperature and the depth on the ash layer. In the bottom of the primary chamber, inert gas is supplied for cooling the ash layer for burnout of carbon and preventing a leakage/outflow of oxygen in the gasifier.

The ash removal is sequence-operated and the time interval is dependent upon the composition of the fuel. Standard temperature on the ash out of the gasifier is approximately 100°C. Together with the ash there may be unknown foreign particles, such as pieces of metal with high temperature. The authorities in Europe require maximum 3% of non combusted material in the ash and the Kentec's BEP (Biomass Energy Plant) comply with this requirement.

The flue gas fan is extracting the combustible syngas from the primary chamber to the secondary chamber where a compound/mixed of air and inert gas, also called secondary air is being added. From the primary chamber the temperature on the combustible gas is normally approximately 400-700°C. The secondary air is fed with a high velocity through 8 nozzles perpendicular to the gas flow. This creates a proper mix and turbulence between combustible gases and secondary air. The amount of secondary air varies from 2000–5000Nm3/h. In a normal operation, the temperature will increase to approx. 850-1100°C.

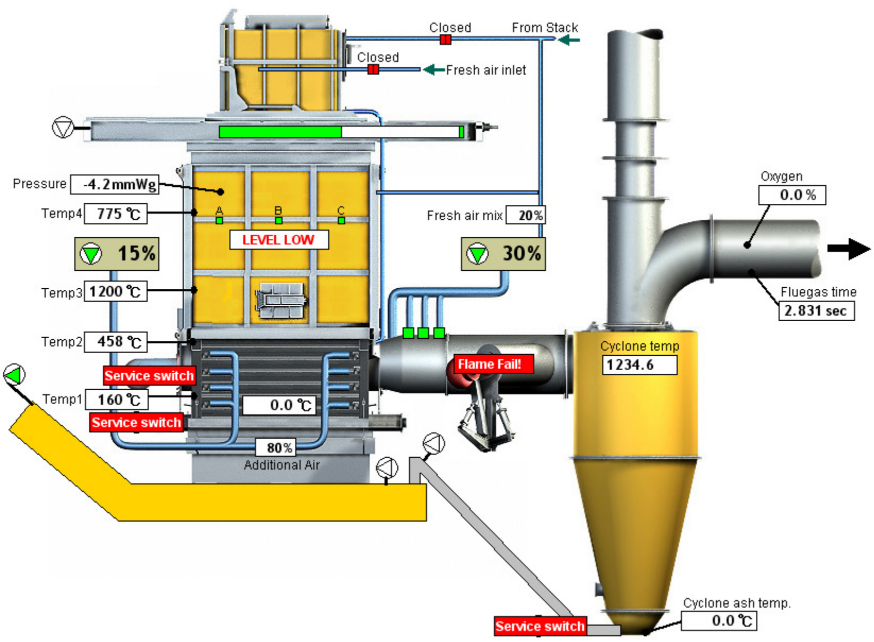

Figure 2 Chambers and Cyclone

After passing the flue gas cleaning system, the inert gas or the recycled flue gas is removed and has now a temperature of approximately 140°C. Inert gas is added to reduce the combustion temperature which gives several advantages. The formation of NOx is increased in high combustion temperature, and too high temperature may melt the ash and form vitreous layer on the internal wall of pipes, cyclone and etc. Recycling of flue gas yields effective cooling without increasing air excess and efficiency decrease.

After ignition of syngas in the secondary chamber, the gas mixture is burnt out in the cyclone for giving sufficient time for oxidation to be completed. The resident time for the gas is minimum 2 seconds. After the gas is burnt out, the thermal energy of the flue gas is utilized for boiler or heat exchanger. The combustion process and heat extraction process is accordingly separate.

The flue gas is cleaned from fly ash through the cyclone. On the cyclone, two redundant temperature sensors are installed to analyze the flue gas. The temperature is one of the operation parameter for the primary and secondary air supply. In plants with several cells, the cells are connected together after the cyclones. On a multi-cell plant, each cyclone must be equipped with a closing damper on the outlet. This makes disconnection of one cell without closing down the whole plant.

One cell must be equipped with two burners. The primary burner is installed on lower primary chamber, and the secondary burner is installed on the lined pipe part of the inlet of the cyclone. Burners are used for preheating of the plant before start-up. In addition, these burners can also be used as supporters if the temperature in the cyclone drops below the specified minimum temperature (850°C). To minimize emissions of dioxins, the cyclone and the lined pipes must be preheated before starting up the gasification; secondary burner is used for this matter. The primary burner is used for ignite the fuel and can be used as heat support if low heat value gets in the gasifier.

Municipal Solid Waste (MSW) with the composition as listed in the table below, have a theoretical Effective Heating Value (EHV) of 14.16MJ/kg or 3.933kWh/kg. The water content will be around 38% to 68%.

	COMPOSITION (%)*	C (%)**	H (%)**	O (%)**	N (%)**	S (%)**	Cl (%)**	ASH (%)**	H_2O (%)**	HHV (MJ/kg)	EHV (MJ/kg)
PLASTIC	20	72.9	10.1	10.6	1.1	0.4	3.9	1	10	36.3	28.2
PAPER/CARDBOARD	29	43.1	5.9	40.3	0.2	0.3	0.3	10	40	17.6	14.3
WOOD/BIOMASS	10	49.1	6.0	44.3	0.5	0.01	0.1	1.3	55	19.2	15.4
CONSTRUCTION	10	48.8	5.3	45.6	0.2	0.03	0.08	0.9	30	15.4	13.9
ORGANIC	20	49.0	6.3	36.4	2.4	0.2	0.6	5.0	70	20.7	3.9
OTHERS	5	52.1	6.6	31.3	2.0	0.7	2.3	5.0	30	22.6	13.3
GLASS	1	-	-	-	-	-	-	100	-	-	-
METAL	3	-	-	-	-	-	-	100	-	-	-
REST FRACTION	2	-	-	-	-	-	-	100	-	-	-
TOTAL	100	49.3	6.4	31.6	0.9	0.23	1.12	10.6	37.6	21.09	14.06

* As Received
** Dry Basis
HHV (High Heating Value)
EHV (Effective Heating Value)

Table 1 Nominal composition of Municipal Solid Waste (MSW)

Flue gas composition

The expected composition of the major components in the flue gas is listed in the table below;

COMPONENT	GRAV (%)	VOL (%)
CO_2	16.1	10.3
H_2O	10.5	16.5
N_2	66.5	67.1
O_2	6.7	5.9
SO_2	0.0410	0.0181
HCl	0.1026	0.0805

Table 2 Expected flue gas composition

Major plant flows

The table 3 indicates the maximum and minimum value for the major mass flow of one cell based on 25T/D plant.

	MAX	MIN
FEEDSTOCK INPUT (kg/h)	934	267
ASH PRODUCTION (kg/h)	62	31
EXCESS OF AIR	1.5	1.5
COMBUSTION AIR ADDED (kg/h)	4,500	2,250
COMBUSTION AIR TEMP (^{o}C)	20	20
FLUE GAS PRODUCED (kg/h)	6,579	3,290
INERT GAS ADDED (kg/h)	2,000	1,000
FLOW FROM CYCLON (kg/h)	7,996	3,998
FLUE GAS TEMP FROM CYCLON (^{o}C)	950	950
FLOW OUT MAIN STACK (kg/h)	6,579	3,290

Table 3 MAX and MIN flow of one cell based on 25 T/D plant

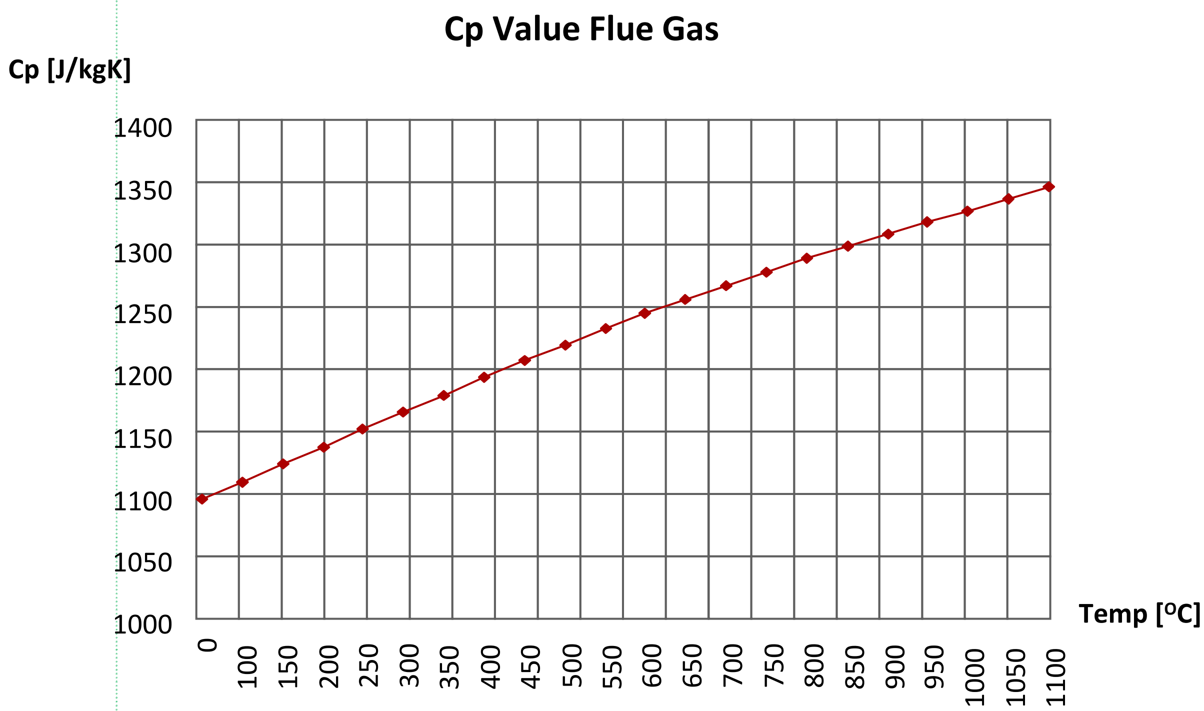

Figure 3 Flue gas heat capacity

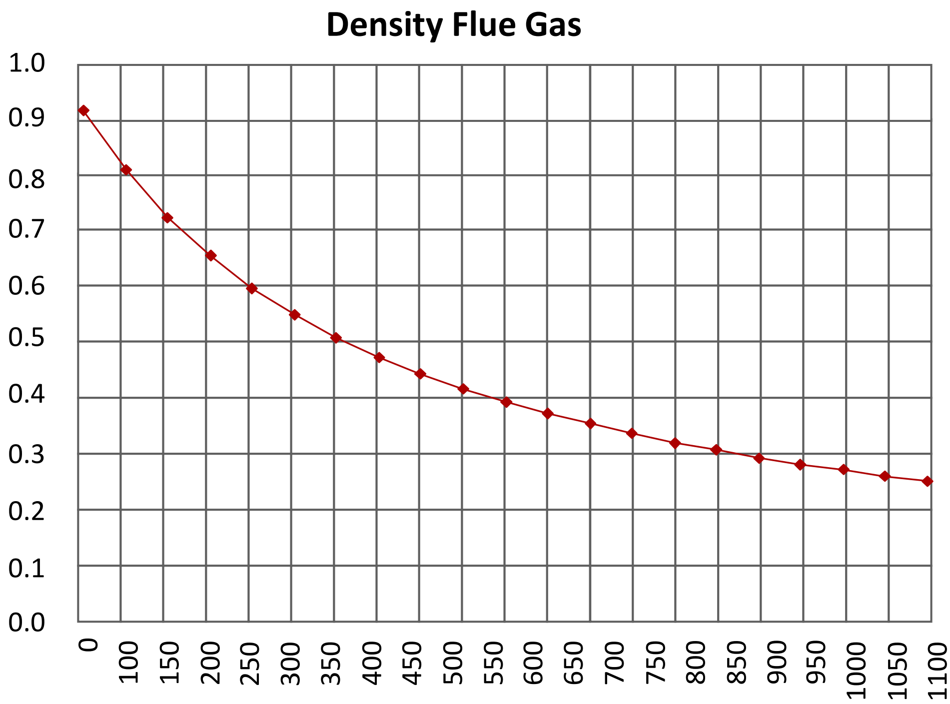

Figure 4 Flue gas densities

BEP gasifier is manufactured in various modules and partly assembled at the factory. The completion of assembly will take place at the site. Following modules are included in KENTEC delivery;

MODULE NO.	DESCRIPTION
Module 0501	Loading chamber
Module 0600	Upper primary chamber
Module 0700	Lower primary chamber
Module 0800	Ash treatment system
Module 0900	Secondary chamber
Module 1100	Cyclone
Module 2300	Gasifier Assembly

Table 4 Core components

Outfits for Gasifier are described as following modules;

MODULE NO.	DESCRIPTION
Module 0730	Primary burner arrangement
Module 0740	Primary air supply
Module 1030	Secondary burner arrangement

Table 5 Gasifier components

The assembly of the entire Gasifier is described as module 2300.

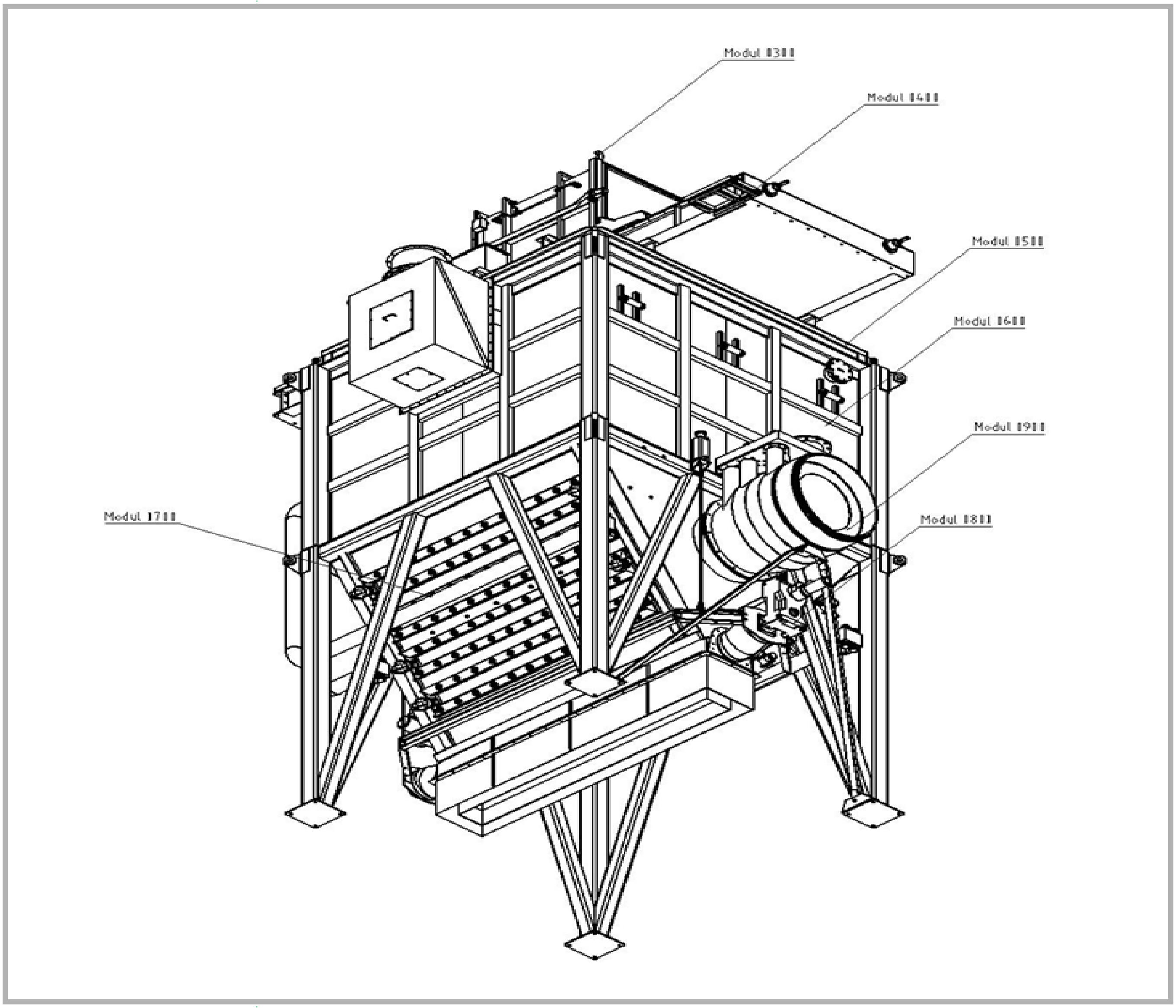

Figure 5 Gasifier modules

Module 0501 Loading chamber

The loading chamber is on the top of the gasifier and is designed for shredded waste feeding. The feeding mechanism depends on the fuel type and consistence. Pre-sorted and shredded waste could be fed by e.g. a screw compactor connected to the inlet flange, which is not included in the KENTEC's core technology package and could be purchase form various manufactures. Other alternatives such as conveyers, cranes etc. could also be applied. In this case, an adaption of the loading chamber is necessary.

Feeding mechanism such as screw compactor prevents any air leakage in to the system during the feeding operation and helps to maintain a stabile negative pressure in the system. In addition, the loading chamber is equipped with a pressure relief hatch with a counterbalance weight. A box is bolted enclosing this hatch and a check valve is mounted on the top of the box. A steel pipe is routed through the roof to free air. The loading chamber is inside insulated and refractory lined.

Figure 5 Loading chamber

Module 0600 and 0700 Upper and lower primary chamber

The primary chamber is the gasification unit of the BEP. Primary air is added through nozzles in the inclined walls of the lower primary chamber during the gasification of the fuel. The air is partly added with high velocity through nozzles as primary nozzle air and partly around the nozzles as primary additional air. On the outer side of each of the inclined walls there are four duplex canals (nozzle air and additional air) for air supply.

At the bottom of the primary chamber an ash layer will be gathered. Above the ash layer and in the lower primary chamber there will be an oxidizing - and gasification zone, and on top of that a new batch of fuel to be loaded. The upper primary chamber is equipped with a manhole hatch for access to the interior of the primary chamber. A skirt immersed in a water seals the ash conveyor from the primary chamber and prevents false air to enter the system. The framework of the gasifier is a part of module 0700. The primary chamber is insulated and refractory lined.

Figure 6 Primary chamber

Module 0800 Ash treatment system

The ash treatment system handles the ash discharge from the primary chamber. A continuous shaft with drums welded on is aligned with the ash outlet at the bottom of module 0700.

The shaft frame is suspended in threaded bars with springs to the frame of module 0700. The drums are arranged with pockets in which ash will collected. As the shaft rotates, the ash in the pockets will be discharged into the ash conveyor. The ash layer above the shaft, provide protection from high temperatures. The flexible suspension of the shaft enables the system to remove larger objects that might be brought together with the ash. The ends of the shaft are protected with flexible hoses. These provide an air seal around the ends of the shaft. The shaft is driven by a electric motor. Motor and gear are mounted on the end of the shaft and suspended on a bracket on the shaft frame.

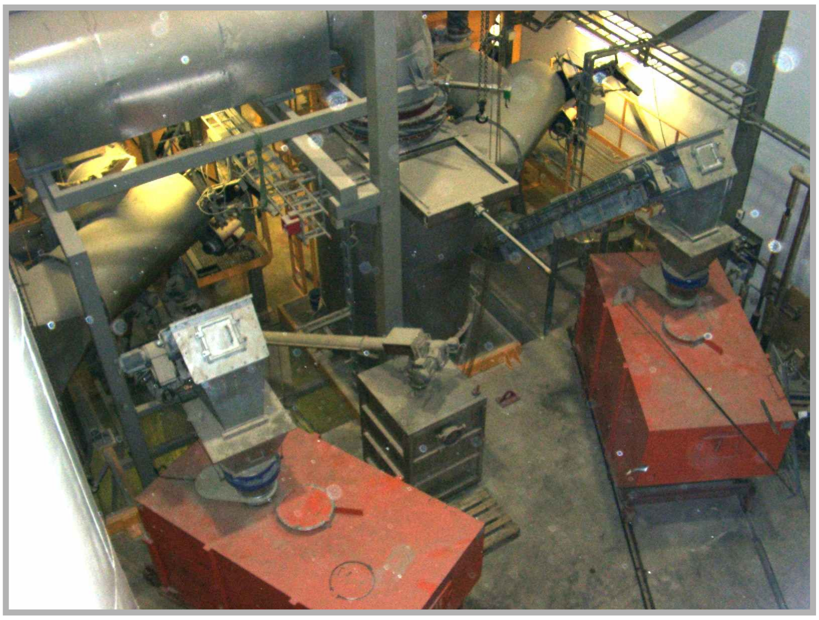

Figure 7 Ash treatment system

Module 0900 Secondary chamber

The secondary chamber is the oxidation section of the cell. Combustible gasses from the gasification in the primary chamber are sucked into the secondary chamber due to negative pressure in the system and oxidized by adding secondary air, an "oxygen mixture" of fresh air and recirculated flue gas.

The chamber is divided into two sections, in longitudinal direction, the tapered end and the cylindrical end. Each section has four inlet nozzles each, rotated 45° related to each other. Secondary air enters combustion chamber through these eight nozzles and reacts with combustible gases. The secondary chamber is bolted to the outlet flange of the primary chamber. The secondary chamber is inside insulated and refractory lined.

Figure 8 Secondary chamber

Module 1100 Cyclone

From the secondary chamber the flue gas flows through a pipe with inside insulation and refractory lining to the cyclone. In this pipe and in the cyclone the oxidation of the combustible gases is completed. The cyclone with its huge volume is consequently an important “final oxidation section.” The cyclone functions as a particle separator too. It is cylindrical with a conic lower part and has an inner pipe, an immersion tube at the center. The cyclone is installed vertically. At the bottom of the cyclone an ash conveyer is mounted. The flue gas enters tangential to the cyclone on the top and is exposed to heavy rotation. Due to centrifugal force major part of the particles are forced to the cyclone wall. During this process the particles lose most of the rotation speed due to friction, and fall therefore down in the conic part of the cyclone and are fed to the ash conveyor.

The “purified” flue gas will concentrate in the center part of the cyclone and will flow upwards and out through the immersion tube. The lower part of the cyclone is equipped with an inspection hatch. The cyclone is inside insulated and refractory lined. In a multi-cell plant (when two or more cells of BEPs are connected together) a cut-off damper is recommended at the cyclone outlet to make isolation of each cell possible. The outlet of the cyclone has a flange connection.

Figure 8 Cyclone

Module 0730 Primary burner arrangement

A burner is mounted on module 0700. This is a diesel oil burner or gas burner after mentioned as "primary burner." The primary burner is mounted on a plate that is bolted to the "burner flange" on module 0700. The device is arranged with a plug (same size as the burner mouth), which is positioned 90° compared to the burner. The primary burner is only used during start-up of the plant, and when the primary burner is not in function the plug should replace the burner. It can be done manually, simply by dismounting the burner flange, rotating the device 90° and attach the plug to burner flange on module 0700. Mounting arrangement is thus included.

Figure 10 Primary burner

Module 0740 Primary air supply

A primary fan supplies primary air, a mixture of fresh air and recirculation of the flue gas to the primary chamber. At module 0600 a manifold, “inlet manifold,” with one inlet and four outlets is mounted to regulate primary air supply. A steel pipe connects each outlet to a new manifold,” a sub-manifold.” On each side of module 700 there are two sub-manifolds for distribution of primary air. Each inclined wall is provided with fore duplex canals. Sub-manifolds have four outlets, one for each duplex canal.

The manifolds and the canals are connected with flexible tubes. At the inlets of the canals there are special on/off valves that enables one and one canal to be opened/closed.

Figure 11 Primary air supply

Module 0940 Secondary chamber manifold

The secondary chamber manifold is mounted on the top of the secondary chamber. The manifold has one inlet and two outlets. One of the outlets can be opened/closed by a remote-operated valve while the other is always open. The manifold divides and controls the secondary air supply to the two sections of the secondary chamber

Figure 12 Secondary chamber manifold

Module 1030 Secondary burner arrangement

On the lined pipe-spool between the secondary chamber and the cyclone inlet, a device is mounted with an auxiliary burner of 1100 kW thermal power. This is a diesel oil /gas burner called the “secondary burner”. The secondary burner and a plug are mounted on a beam together with two pneumatically operated cylinders. The whole device is kept in place by a plate, which is flanged to the lined pipe-spool by bolts. By operating the cylinders one could pull out the burner and insert the plug, and vice versa. This is done automatically via the control system. The secondary burner is used during start-up of the plant and can beyond that be connected when needed. The mounting system is included.

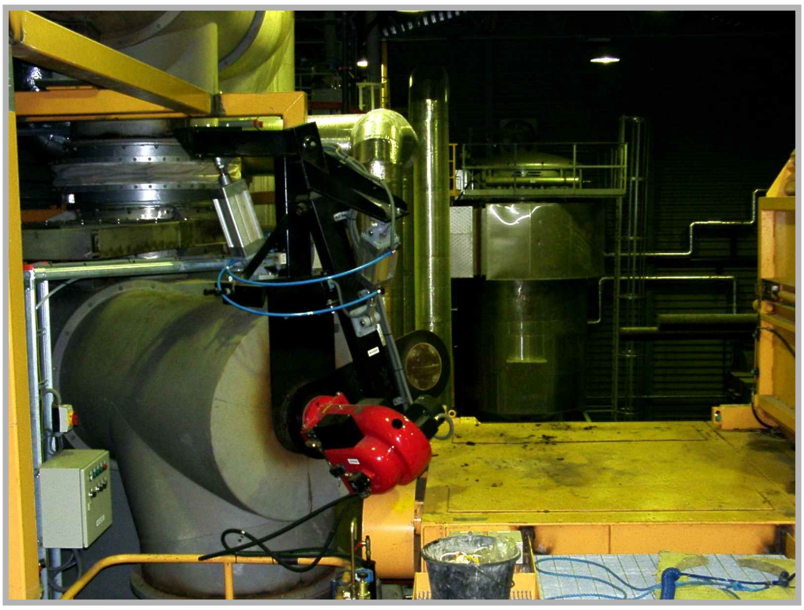

Figure 13 Secondary burner

Module 2300 Gasifier assembly

All modules of the gasifier are to be all-welded together at site. Packing cord is placed between each module. The packing cord material is Superwool 607. Material of equivalent or better quality could to be used.

Figure 14 Gasifier