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Deliverable 4.2

Initial design of gasification system

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LIFE+ PROJECT NAME or Acronym

ENERGY WASTE

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Summary:

Basic process and equipment design has been done based on the characteristics of the produced RDF (as those are known from the sampling and analysis actions), on the preliminary results of the gasification laboratory testing (TGA analysis) and on the analysis of the gasification properties (as those are reported in the deliverable 4.1). Operating experience of the involved personnel was important and critical information was used especially in the mechanical design of the equipment. Main outcome of this report is the basic design of the main process equipment that will be constructed and operate to fulfil the testing camping of the project. It is important to stress that the designed equipment is prototype and the operating conditions may vary according to the operating results.

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Contents

1 Introduction ... 4
2 RDF characteristics and properties ... 4
3 Process design ... 5
3.1 Gasification reactor (gasifier) ... 5
3.2 Heat exchanger ... 6
3.3 Cyclone ... 6
3.4 Combustion chamber ... 6
4 Gasification unit ... 7
4.1 Fuel and bed material feeding section ... 8
4.2 Gasification reactor ... 9
4.3 Gas conditioning section ... 9
4.4 Auxiliary equipment and instrumentation ... 10

1 Introduction

Basic process and equipment design has been done based on the characteristics of the produced RDF (as those are known from the sampling and analysis actions), on the preliminary results of the gasification laboratory testing (TGA analysis) and on the analysis of the gasification properties (as those are reported in the deliverable 4.1). Operating experience of the involved personnel was important and critical information was used especially in the mechanical design of the equipment. Main outcome of this report is the basic design of the main process equipment that will be constructed and operate to fulfil the testing camping of the project. It is important to stress that the designed equipment is prototype and the operating conditions may vary according to the operating results.

The aim of the project is the development of a gasification unit able of utilizing a certain type of Refuse Derived Fuel-RDF. Gasification unit embodies circulating fluidized bed technology with air as fluidization medium and olivine sand as bed material. Fuel consumption is planned to reach 30 kg/h leading to a thermal power up to 125 kW (based on fuel input terms).

2 RDF characteristics and properties

Critical RDF properties regarding the core process of gasification and the handling / feeding are the size, the density, the moisture content, the ash content and the higher heating value.

RDF is produced at the end of the production line of EPANA in the form of discrete parts sized between 65-280mm consisted of easily definable species such as small size packaging (i.e. plastic bottles, paper boxes, tetra pack), organics, textiles, rubbers and leather (i.e. clothes, towels, shoes), tins and cans, pieces of wood and inert materials (i.e. broken glasses, stones) which is shredded down to a mean side of 20 mm (more details in Deliverable 3.1).

RDF bulk density is in the range of 150 – 250 kg/m3 depending on the moisture content which varies considerably on a daily basis. Moisture, ash and heating content are presented in the Figure 2.1.

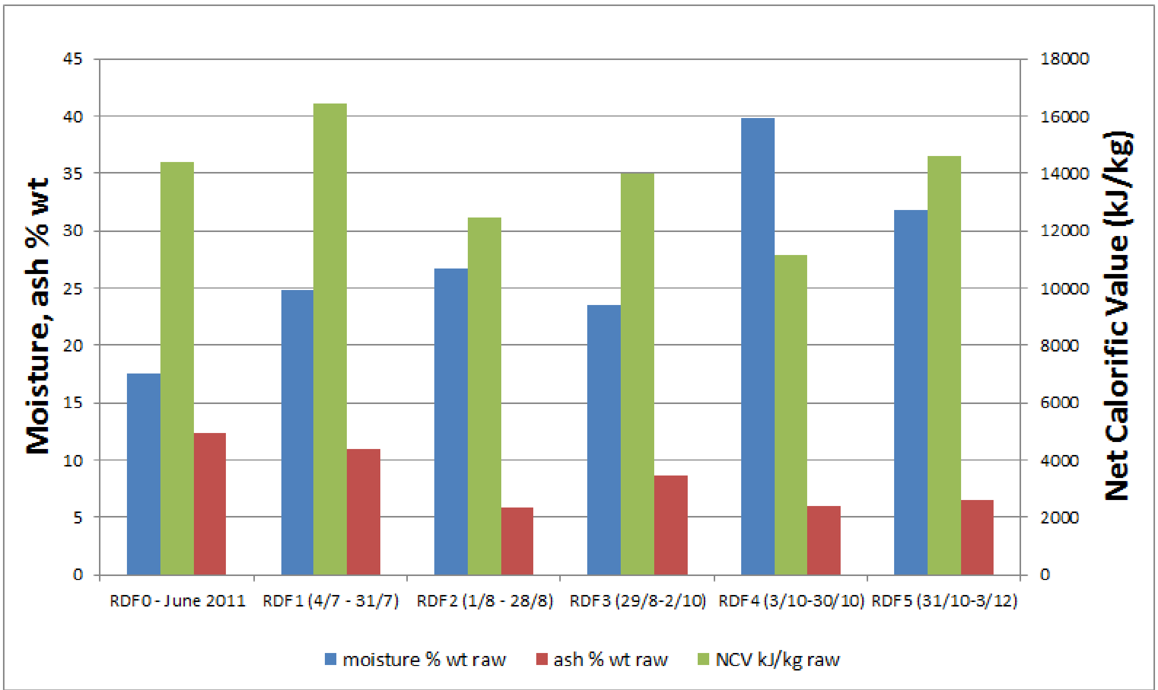
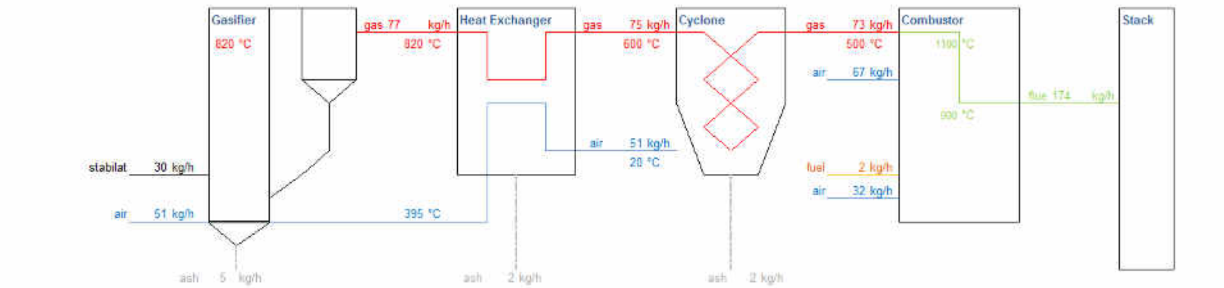


Figure 2.1: Monthly average values of RDF moisture, ash and net calorific value (NCV)

3 Process design

Basic design concerns the mass balances of the main process equipment namely gasification reactor, the gas – air heat exchanger, the cyclone and the combustion chamber. The process flow chart is shown below.



Mass flow, kg/h	in	out	in	out	in	out	in	out	in	out
Stabilat	30	0	0	0	0	0	0	0	0	0
Air	51	0	51	51	0	0	99	0	0	0
Bottom ash	0	5	0	0	0	0	0	0	0	0
Producer gas	0	77	77	75	75	73	73	0	0	0
Fly ash	0	0	0	2	0	2	0	0	0	0
Flue gas	0	0	0	0	0	0	0	174	174	174
Fuel, oil	0	0	0	0	0	0	2	0	0	0

Figure 3.1: Basic equipment process flow chart

Special process figures for some of the equipment such as process conditions, thermal capacity, operating efficiency are presented for main process equipment.

3.1 *Gasification reactor (gasifier)*

The gasifier is a circulating fluidised bed reactor. Critical process parameters apart from the input and output for the design of the gasification reactor are the operating conditions and the thermal performance. Critical process figures are presented in table 3.1.

Table 3.1: Gasifier operating conditions and thermal performance

Operating conditions	
Temperature	820°C
Equivalent factor	0,3
Pressure	200 mbarg
Surficial gas velocity	6 m/s
Terminal velocity	11,2 m/s
Thermal performance	
Thermal input	125 kW
Thermal output	87 kW
Efficiency	70%

The above calculations are based on RDF energy content 15.000 kJ/kg and using olivine sand as bed material with mean size of 500 μm, bulk density 1.900 kg/m3 and particle density of 3.300 kg/m3.

3.2 Heat exchanger

The heat exchanger is double con-centrical tube with inner fins attached in the internal tube. Critical process parameters apart from the input and output for the design of the heat exchanger are the operating conditions. Critical process figures are presented in table 3.2.

Table 3.2: Heat exchanger operating conditions

Operating conditions	
Working media	Gas inner tube, air oute tube
Gas inlet / outlet temperature	800 / 550°C
Air inlet / outlet temperature	20°C / 395°C
Pressure	50 mbarg

The abovementioned process conditions may vary according to the mass flows of the gas and air.

3.3 Cyclone

The centrifugal cyclone is designed to capture the fly ash and small bed material particles. The discharged material will be conducted to physical and chemical analysis. Critical process parameters apart from the input and output for the design of the cyclone are the operating conditions. Critical process figures are presented in table 3.3.

Table 3.3: Cyclone operating conditions

Operating conditions	
Operating temperature	530°C
Pressure	30 mbarg
Collection efficiency	98%

3.4 Combustion chamber

The combustion chamber will be used to burn the gas by means of an auxiliary burner. Critical process parameters apart from the input and output for the design of the combustion chamber are the operating conditions. Critical process figures are presented in table 3.4.

Table 3.4: Combustion chamber conditions

Operating conditions	
Operating temperature	1100°C
Pressure	30 mbarg
Residence time	2,2 s

4 Gasification unit

The gasification unit consists of several sections, each one having a clearly defined scope, that have to be designed and implemented considering operational and security issues ensuring project targets. Those sections are:

- Fuel and bed material feeding section (shown below)
- Gasification reactor (shown below)
- Gas conditioning section (shown below)
- Auxiliary equipment and instrumentation (not shown below)

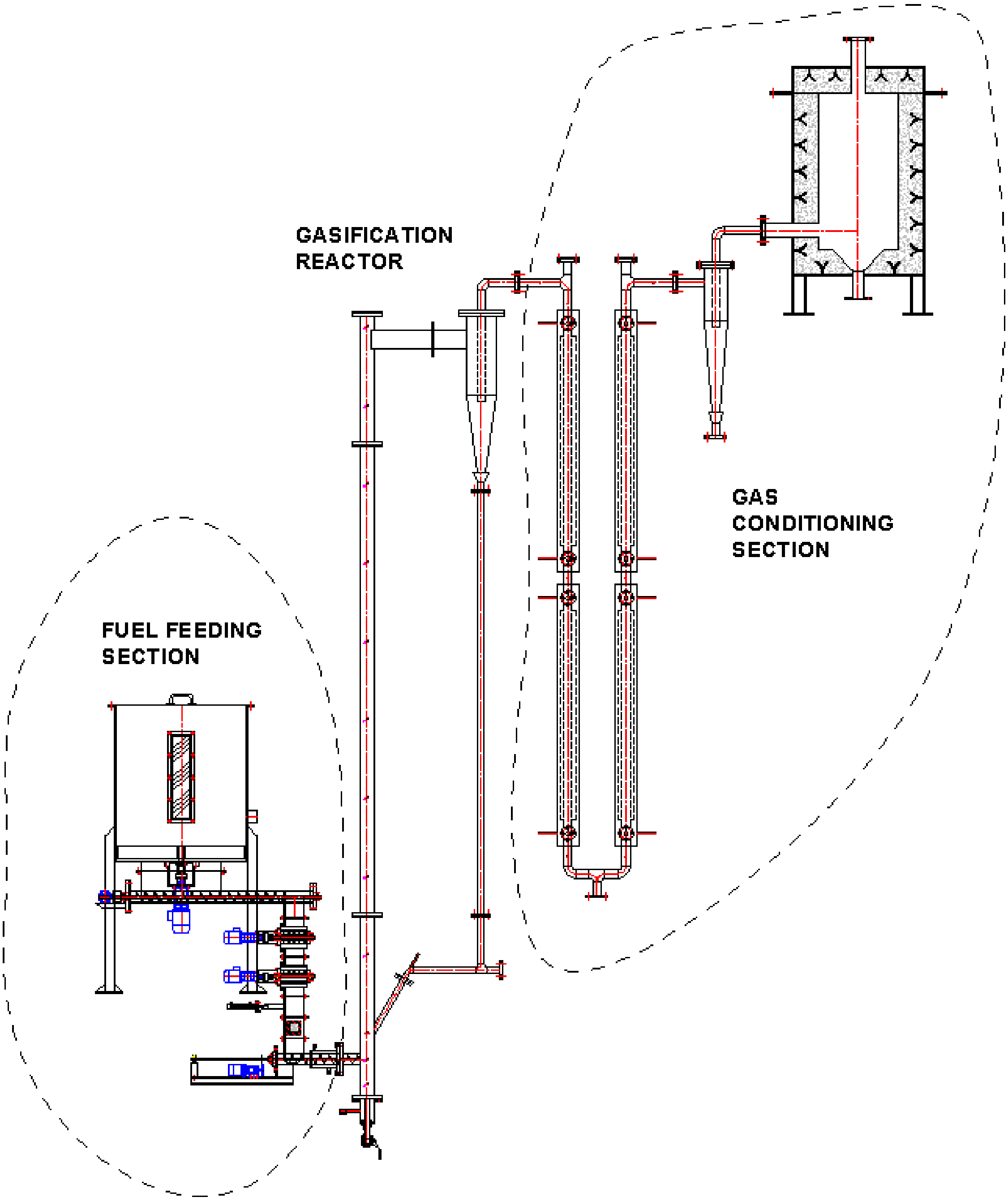


Figure 3.1: Basic parts of the gasification unit

4.1 Fuel and bed material feeding section

Fuel and bed material feeding section is designed to ensure stable feeding rate of RDF and bed sand material. It is equipped with an inverter motored screw feeder which gives the option of varying the mass feeding rate of RDF so as to control the equivalent rate ER (in relation to air flow). The feeding section consists of the following parts that are listed in table 4.1.

Table 4.1: 4.1 Fuel and bed material feeding section

Equipment	**Characteristics**
Fuel hopper	Volume: 1000 l
	Rotation speed: 10 rpm
	Special features: Rotating floor
Screw feeder	Feeding rate (nominal): 30 kg/h
	Rotation speed: 16 rpm
	Special features: Inverter controlled
Rotary valves (two identical)	Feeding capacity: 80 kg/h
	Rotation speed: 20 rpm
	Special features: Airtight
Gate valve	Manually controlled
	Special features: Airtight
Injection screw feeder	Feeding rate: 50 kg/h
	Rotation speed: 50 rpm
	Special features: High temperature design
Sand hopper	Volume:20 l
	Special features: Conical bottom design
Discharge valve	Manual handling
	Special features: Airtight

All the equipment is specially designed for this specific application, taking into account the high temperature and the overpressure that exists in the reactor during the process. The high temperature design of the injection screw feeder and the air tight design of the rotary valves have been chosen to overcome operational problems such as elevated temperature in the feeding section and backflow of the produced gas.

The control of the feeding section is obtained through the central automation and control system of the gasification unit. There is a series of sensors and measuring points for the monitoring of temperature, pressure and material level in critical process areas. The recording of those parameters is also executed by the central automation and control system.

4.2 Gasification reactor

The gasifier is a circulating fluidised bed reactor which has been designed to operate at gasification conditions of overpressure 200 mbar, temperature 820°C and ER 0,3. The main parts of the reactor are listed in Table 4.2.

Table 4.2: Gasification reactor equipment design

Equipment	Characteristics
Gasification reactor	Diameter: 170 mm
	Height: 6000 mm
Recirculation cyclone	Diameter: 220 mm
	Total height: 1200 mm
Loop section	L design
Air distributor	Perforated plate
Ash and sand discharging	Intermittent

All the equipment is specially designed for this specific application, taking into account the high temperature, the overpressure that exists in the reactor during the process and the necessary recirculation. The height to diameter ratio is chosen to provide a high superficial velocity which is expected to lead to a smooth temperature profile long the main reactor.

There is a series of sensors and measuring points for the monitoring of temperature, pressure and material level in critical process areas. The recording of those parameters is also executed by the central automation and control system.

4.3 Gas conditioning section

The gas conditioning section receives the gas which is produced though the process at a high temperature (~820°C) with high tar and particle content, and aims to recover a certain amount of heat content and reduce the level of particle content without causing a condensation of the entrained tars. Tars are oxidized at the later stage in a controlled combustion chamber. The main parts of the gas conditioning system are listed in Table 4.3.

Table 4.3: gas conditioning section equipment design

Equipment	Characteristics
Gas – air heat exchanger	Inner tube Diameter: 90mm
	Inner tube Total length: 8000 mm
	Inner tube num. of fins: 8 (longitudinal array)
	Outer tube Diameter: 170 mm
	Outer tube Total length: 8000 mm
Cyclone	Diameter: 170 mm
	Total length: 1100 mm
Combustion chamber	Diameter: 1280 mm
	Height: 1400 mm

4.4 Auxiliary equipment and instrumentation

As auxiliary equipment are the:

- air feeding section which is a compressed air unit able of maintaining a constant 50 kg/h mass rate as minimum requirement,
- ball valves, butterfly valves, extension joints, discharge hoppers and process armature that will be used to collect sand, bed ash and fly ash,
- electrical resistances that will be used to warm up the reactor during each start up and maintain the proves temperature in cases that the process heat will not be enough,
- high temperature isolation blanket and outer aluminum protection cover,
- auxiliary burner which will be attached to the combustion chamber in order to fire up the produced gas and maintain the flame when the gas quality will be poor,
- electrical switch board which will power the whole unit and will be equipped with all the necessary automation and control systems,
- instrumentation and measuring sensors and devices that will be used to measure, monitor and control critical process variables,
- central programmable control system with SCADA which will receive the signals and execute the control of the unit,
- metal structure and supportive equipment structures, as well as a control room arrangement for the housing of PCL station, and sensitive instrumentation,
- piping and cabling.

The design of the auxiliaries will be finalized during the construction and operation of the unit.