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**Pavel FRIEDEL\*****RECONSTRUCTION OF RESEARCH GASIFICATION TECHNOLOGY AT THE ENERGY RESEARCH CENTER****REKONSTRUKCE VÝZKUMNÉ ZPLYŇOVACÍ TECHNOLOGIE NA VÝZKUMNÉM ENERGETICKÉM CENTRU****Abstract**

Gasification technology was one of the first large projects of the Energy Research Center at the VSB - Technical University of Ostrava. The beginnings of the technology date back to 2006, when construction of the first version of the gasification plant with an autothermal generator was started. During these years of operation, a lot of testing was conducted on the technology to test different types of fuel (pellets from rice husks, pellets from miscanthus, straw pellets, RDF and many other types of fuels) and various modifications to the technology (testing of two cyclones, dolomite reactor testing, scrubber testing). Subsequently reconstructed gasification technology held tests by RDF fuel, wood pellet and mixtures of these fuels. The tests of the fuel was conducted at three temperatures (750, 850, 950 ° C).

**Abstrakt**

Zplyňovací technologie byla jedním z prvních velkých projektů Výzkumného energetického centra na Vysoké škole báňské - Technické univerzitě Ostrava. Počátky technologie se datují k roku 2006, kdy byla zahájena výstavba první verze zplyňovacího zařízení s autotermním generátorem. Během těchto let provozu bylo na technologii prováděno mnoho testů, kdy se zkoušely různé druhy paliv (pelety z rýžových slupek, pelety z miscantusu, pelety ze slámy, RDF a mnoho dalších druhů paliv) a byly prováděny různé úpravy na technologii (zkoušení dvou cyklonů, zkoušení dolomitového reaktoru, zkoušení vymývačky). Následně proběhly na rekonstruované technologii zplyňování testy paliva RDF, dřevěných pelet a směsi těchto paliv. Testy paliv probíhaly ve třech teplotách (750, 850, 950 °C).

**Keywords**

Gasification, RDF, pellets, auto-thermal gasification, gasification medium.

**1 1 GASIFICATION TECHNOLOGY**

The technology is based on a solid bed gasification reactor with a heat output of 100 kW. Fuel in the form of chips or pellets or also RDF is fed to the fuel tank by two screw conveyors into the reactor core. Above the grate in the fuel layer, the syngas is formed at 800-1100 ° C. It passes through a high-temperature solid particle separator (hot filter) and a cooling section into the exhaust fan. Behind it is placed after burner chamber, wherein the gases burnt see. Figure 1.

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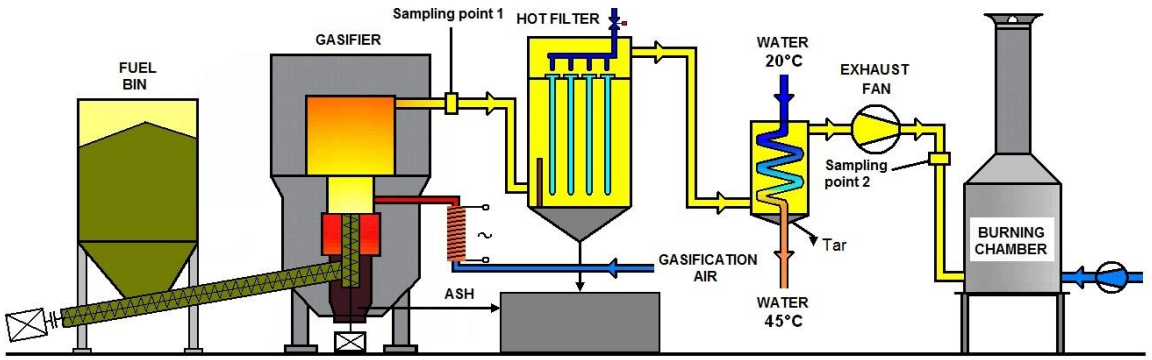


Fig. 1 Gasification scheme[1], [5]

The device operates in the negative pressure mode, which is provided by an exhaust fan, respectively. piston engine cogeneration unit. The medium used in the gasification process is the air which is supplied a system of nozzles disposed circumferentially around the bottom of the gasification reactor. For removing tars from the product gas were tested in various systems - dry processes (dolomitic reactor) and wet processes (cleaning).

## 2 DESCRIPTION OF THE PRINCIPLE OF SYNGAS

Vertically supplied fuel passes through a drying process during which moisture evaporates. The basic stage of the gasification process is pyrolysis, which produces volatile products and coke. Supported air oxidizes in pyrolysis and fixed carbon products.

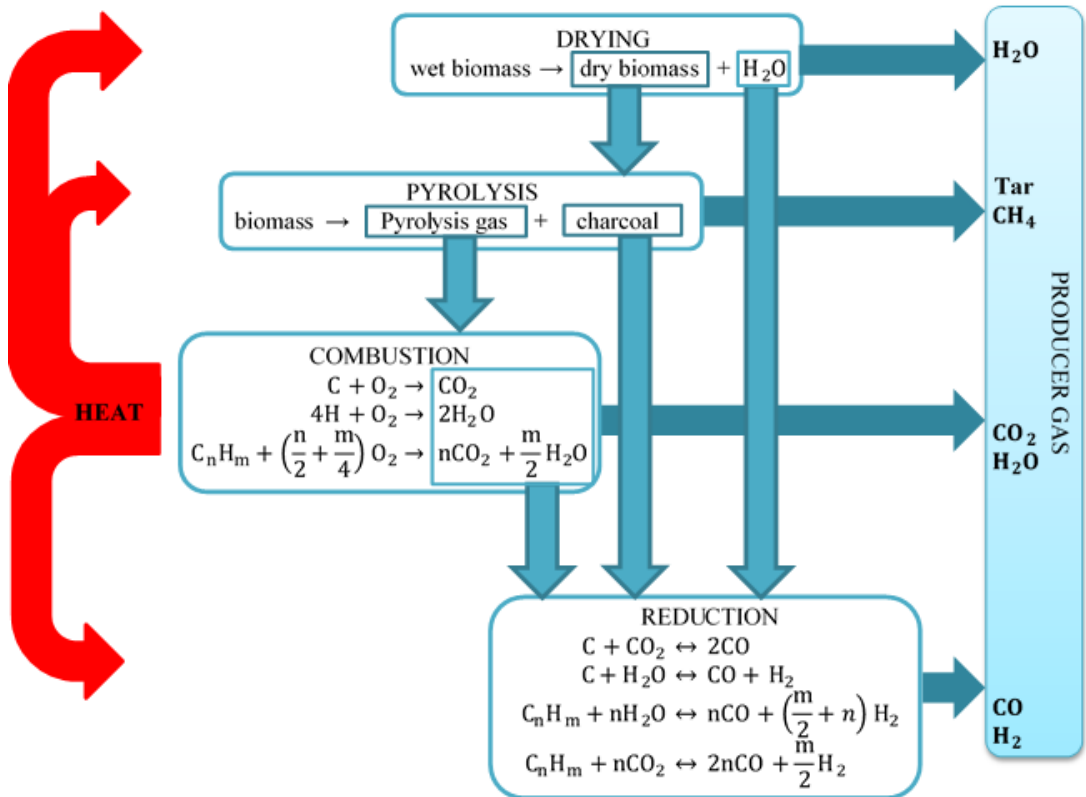


Fig. 1 The ongoing processes of gasification fixed bed [3], [4]

The heat generated is used in the other gasification phases. In the reduction phase, the resulting products react as carbon dioxide and water vapor with the coke formed during pyrolysis. At this stage, a final product of the entire gasification process, the raw gas. The described principles of gasification in the fixed bed reactor are shown in Figure 2. The residence time of the raw gas in the reactor is approximately 1.5 seconds. [3], [4].

### 3 RECONSTRUCTION OF GASIFICATION TECHNOLOGY

Technology was tested with different fuels (straw, rice hulls, etc.) at reactor inner lining, see Fig. 3. Thus causing reduction of the internal space of the reactor and prolonged a period of heating up the reactor. Tests were run at different temperatures. These thermal variations and the speed of cooling and heating cause the rupture of the lining, see Fig. 3.



**Fig. 2** Reactor lining with melted fuel parts and visible crack in lining

For this reason, the reactor was modified in 2016. This included the production of a new interior lining, a new movable grate and the lower part of the reactor.



**Fig. 3** Fixing of the upper part of the reactor on beams

Modification of the reactor consisted in fixing its upper part to three beams that lean against the ground. The lower part of the reactor was supplemented with mechanical jacks, which are stored on the rail. Thus, the modification allows for easier access to the inner lining of the reactor and control over the tests performed and cleaning of possible deposits. See Fig. 4.

The new internal lining of the reactor was fitted with a new oscillating grate (Figure 5). Movable grate was designed to allow movement in two axes. The horizontal axis oscillates through the control rods and drive. At the same time it moves horizontally. This ensures that any sinter from the fuel will be more easily grasped by the grate, and consequently will be delivered from the generator by the screw extruder. Test fuels exhibit questionable properties in fixed bed gasifiers. Movable grate was granted as utility model No. 29866.



**Fig. 4** Lining of the reactor with a movable grate

After all modifications, the reactor looks like this, see Fig. 6.



**Fig. 5** Reactor after reconstruction



## 4 TESTS

Before the first reactor was switched on, several cold tests of functionality of individual parts of the equipment and control were carried out. Subsequently, a gasification test was carried out where the gasifying fuel was wood pellets, RDF and a mixture of these fuels. The gaseous medium was air. The test was run at 750, 870 and 950 ° C. The parameters studied were the composition of the gas, the amount and the chemical composition of the tar, the amount of dust and the tar contained in it.

### 4.1 Methods for sampling the gas, tar and solid pollutants

#### 4.1.1 Determination of gas composition

The concentration of gaseous components in the gas was measured by the continuous multi-component GAS 3100 Syngas Analyzer. The analyzer is equipped with three types of detectors for individual gaseous components. [2]

The first is a non-dispersive two-beam infrared detector NDIR, operating on the principle of infrared absorption by selected gaseous components. The absorption rate is directly proportional to the amount of gas in the sample. It is suitable for the determination of carbon monoxide CO, carbon dioxide CO<sub>2</sub>, methane CH<sub>4</sub> and higher hydrocarbons C<sub>n</sub>H<sub>m</sub>. [2]

The thermal conductivity detector TCD works by comparing the thermal conductivity of the sample and the reference gas (air). The heated thermistor or platinum fiber is placed in the sample stream. If the sample has a higher thermal conductivity than the reference gas, the temperature of the measuring element decreases, while in the case of lower thermal conductivity it increases. These changes cause changes in electrical resistance, which is measured by a bridge circuit.

The analyzer is used for the determination of H<sub>2</sub>. [2]

For the determination of the O<sub>2</sub> analyzer uses an electrochemical sensor ECD. It consists of a cathode, anode and electrolyte. Through the permeable membrane, maintaining the electrolyte in the measuring cell, oxygen diffuses into the electrolyte. It reacts with the electrolyte to generate an electric current that is directly proportional to the oxygen concentration in the gaseous mixture. [2]

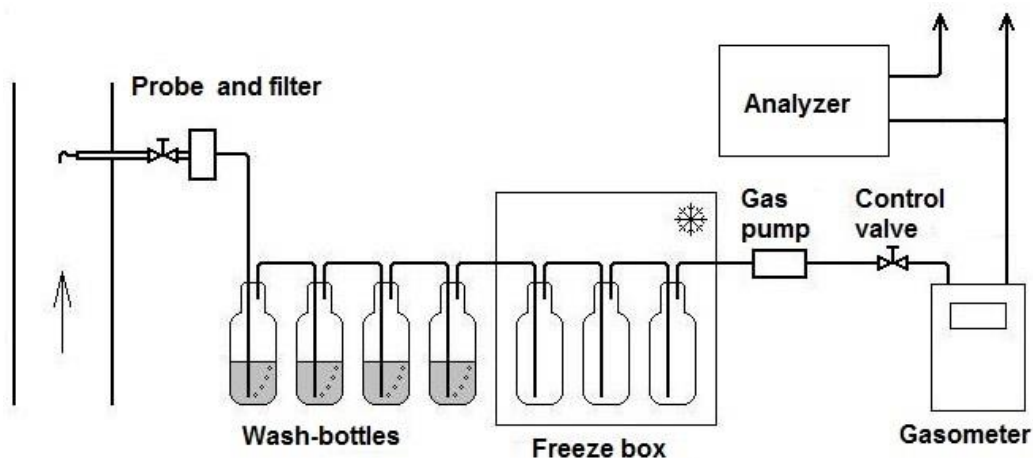


Fig. 6 Diagram of the gas component assembly

The analyzer is capable of measuring the composition of samples of dry gas, free of undesirable substances (especially tar and dust). Therefore, the gas sample is taken with the probe ball valve, which is classified as a heated gripper with a glass fiber filter, on which the entrapped particulates and the portion of tar substances. Further, the gas passes through four wash-bottles filled with celosulf, in which the rest of the tarry substances that pass through the filter are captured.

Behind them are three washing tanks, placed in a freezer box, which serves to precipitate all residual tarry substances and moisture. Sampling track continues silicone hose to pump gas and diaphragm gas meter, among which is included flow regulator. Behind the meter, a T-piece is connected to the analyzer to protect against the overpressure of the incoming gas, and two washing cans are placed in front of the analyzer, the first empty and the second one filled with the whole glass. Analyzer pump ensures a constant sample flow rate of 1 l / min. The entire scheme of the measuring set is in Fig. 7. [2]

#### **4.1.2 Determination of tar content**

A sample of gas was taken by a ball valve probe, which was equipped with a heated glass fiber filter trap, on which solid particles and some tar components were collected. In addition, the gas passed through four wash-bottles filled with medium, in which the tarry substances were passed through the filter. They were followed by three washing container placed in the freeze box that served to precipitate any remaining tar and moisture. All unheated parts of the sampling device up to the last washer were made of glass or Teflon to avoid sorption of tarry substances on the walls of the apparatus. The sampling line continued through the silicone hose into the gas pump and the diaphragm gas meter, which included the flow regulator (Figure 7 - the measuring assembly is the same, as for determining the gas composition, the analyzer is not connected). [2]

After completion of the sampling filter dust particles captured with tar sample is transferred to and formed the first part of the composite sample transported to the laboratory. Glass and Teflon apparatus portion was rinsed several times with pure celosolfem and all liquid aliquots were transferred to the laboratory in a glass-sealed container as the second part of the composite sample. [2]

The exposed filters were dried and weighed (determination of solids with tar) before further laboratory processing.

Tar substance adsorbed on the solid particles (the first portion of the sample) were extracted from the filter in a apparatus. Subsequently, the sample (celosolph with dissolved tarry substances) was filtered, concentrated in a rotary evaporator (RVO) and transferred with acetone to the weighing scale in which the sample was dried (at 50 ° C) and weighed using analytical weights. [2]

The second part of the composite sample (the tar in the liquid fraction) was filtered off, i.e. stripped of any possible salts and insoluble impurities, concentrated in a rotary vacuum evaporator and transferred with acetone to the weighing scale in which the sample was dried (at 50 ° C) and weighed using analytical weights. [2]

The total gravimetric tar concentration was calculated as a proportion of the total amount of tar entrapped on the solids and the tar passing through the filter to the volume of dry gas taken at normal conditions (0 ° C, 101325 Pa). [2]

#### **4.1.3 Measurement of the concentration of solid pollutants**

Measurements were performed modified gravimetric method, the principle of the measuring method is based on aspiration of sample gas from the pipeline. [2]

The determination of the content of solid pollutants (dust) took place simultaneously with the determination of tar. A sample of gas was taken by a ball valve probe, which was equipped with a heated glass fiber filter trap, on which solid particles and some tar components were collected. The gas temperature at the sampling point was measured with the thermocouple before and after the measurement. In the column of cold takes place to capture the water vapor as a condensate. By determining the content of water vapor in the gas. The sampling line continued through the silicone hose into the gas pump and the diaphragm gas meter, between which the flow controller was included. From the measuring line the gas is brought into the air. [2]

At the end of the sampling, the particle filter with tar was transferred to the sampler and formed a sample for determination of the dust content as well as the first part of the tar content. The exposed filters were dried and weighed (determination of solids with tar) before further laboratory processing. [2]

Tar substance adsorbed on the solid particles (the first portion of the sample) were extracted from the filter in a apparatus. Subsequently, the trapped filter particles are dried at a temperature of 105 °C to constant weight and weighed using the analytical weights. [2]

The concentration of solid pollutants concentration is determined as a percentage of the amount of dust captured to the volume of the aspirated wet gas converted to normal conditions (0 °C, 101.325 kPa). [1], [2]

## 4.2 Refuse derived fuel (RDF)

RDF can be all types of combustible waste. Among these wastes we can count on municipal, industrial and commercial waste. RDF fuel is an already sorted waste, which can consist of non-recyclable plastics, cardboard, rubber, various fabrics, wood. RDF is a fuel for which there is no precise classification, specification, and even legislative authorities have not provided any precise guidance on the composition of this alternative fuel.

In this test was used fuel Palozo II from OZO Ostrava Ltd. Palozo consists of municipal and industrial waste and its percentage composition is: 61% plastics, 20% wood, 11% paper, 8% textiles. The basic characteristics of the fuel are evident from the chemical analysis of the fuel Tab. 1.

**Tab. 1** Chemical analysis Palozo II

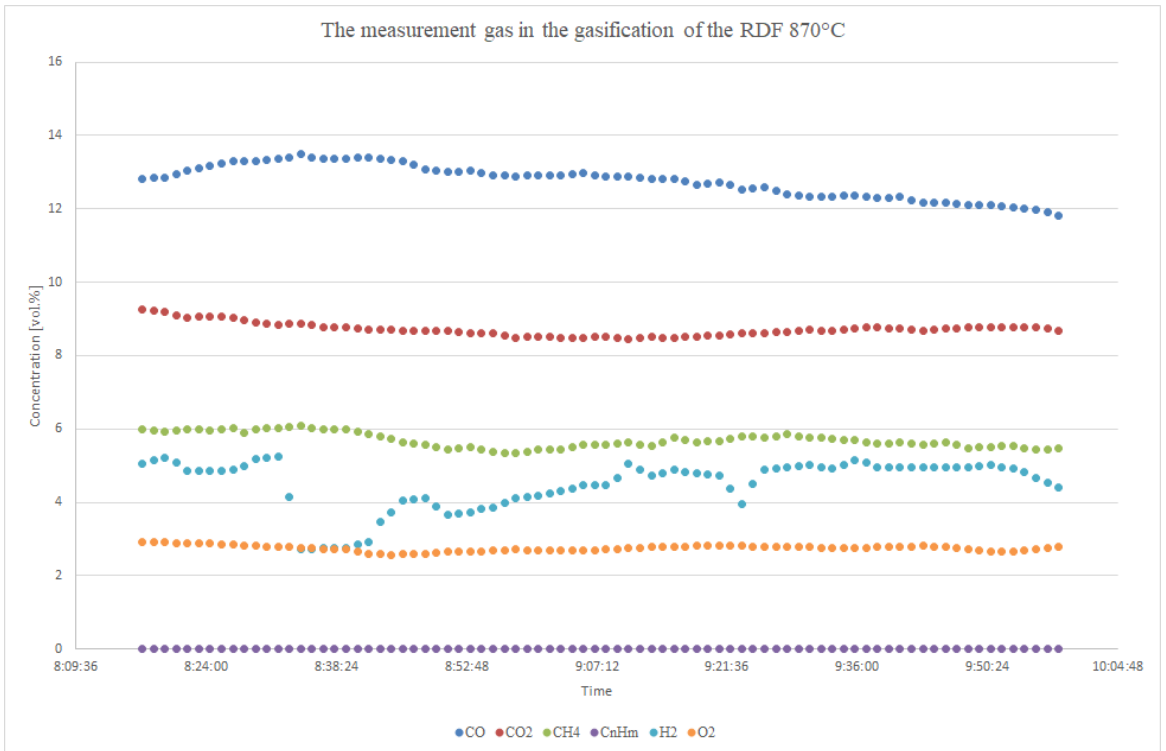
	Chemical composition Palozo II (%)						HHV	LHV
	A <sup>d</sup>	S <sup>d</sup>	H <sup>d</sup>	C <sup>d</sup>	Cl	U	(MJ/kg)	(MJ/kg)
Palozo II	12,63	0,03	7,95	59,51	0,18	±0,07	25,49	23,7

## 5 RESULTS

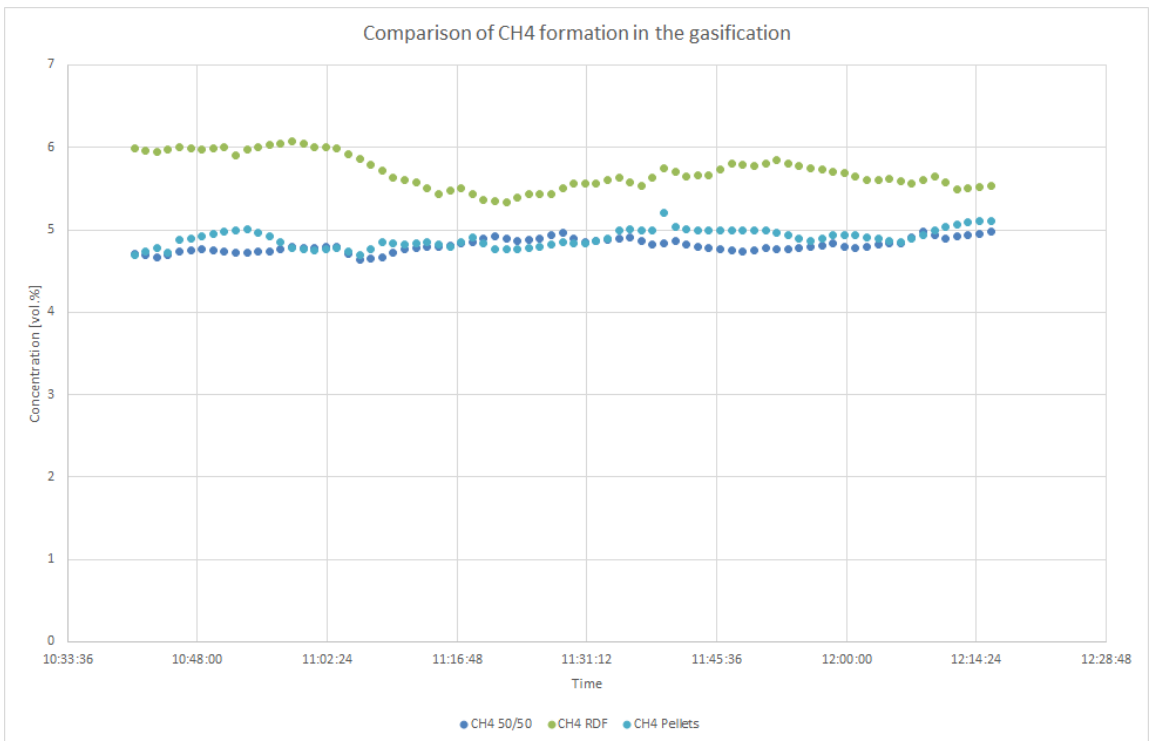
Tests were conducted at 750, 870 and 950 ° C on the gasification technology described in Chapter 2. Air was used as the gasifying medium. The fuel used was, see chapter 5.2, pellets and mix these fuels 50/50. Measurement of all necessary parameters was carried out as described in Chapter 5.1.

The measurement RDF at 870 ° C, see Figure 1. The graph shows that the hydrogen formed fluctuates, the reason for this variation is the fuel composition. Other chemical constituents of the gas produced has a uniform waveform.

Another second graph compares the evolution of methane at 870 ° C. It can be seen on the graph that using pure pellets or a fuel mixture (RDF and pellets), the development of the methane is very similar. But the gasification of RDF was higher methane development, the reason for this phenomenon is the diversity of fuel and thus there was a higher form of methane.



**Chart 1** The measurement gas evolution RDF and 870 ° C.



**Chart 2** The formation of methane during fuel gasification, at 870 ° C



Table 2 shows the average composition of the gas produced and the calorific value of the gas produced. It can be seen from the table that the highest calorific value of the produced gas has clean pellets.

**Tab. 2** The average composition of the product gas at 870 ° C.

	Compounds						LHV (MJ/m <sup>3</sup> <sub>N</sub> )
	CO	CO <sub>2</sub>	CH <sub>4</sub>	C <sub>n</sub> H <sub>m</sub>	H <sub>2</sub>	O <sub>2</sub>	
Pellets	17,0	10,8	4,9	0	5,3	2,5	4,5
Pellets/RDF	11,8	10,8	4,8	0	4,9	2,9	3,7
RDF	12,8	8,7	5,7	0	4,5	2,7	4,1

Table 3 lists the amount of tar, the chemical composition of tar and the amount of dust per sample. As a sample is meant one measurement of one type of fuel at one temperature. It can be seen in the table that the largest amount of tar was produced by gasification of pellets, and most of the dust was when the mixture of pellets and RDF was gasified.

**Tab. 3** Quantity and chemical composition of tar

	Pellets	Pellets/RDF	RDF	Units
Tar	970	400	330	mg/sample
Dust	0,6771	1,2219	1,10486	g/sample
<b>Chemical composition of tar</b>				
Naphthalene	221000	297600	260100	ug/sample
Benzene	121720	299200	443700	ug/sample
Toluene	73610	103200	154530	ug/sample
Xylene	22270	14176	23103	ug/sample
Styrene	123590	187200	348840	ug/sample

## 6 CONCLUSION

All modifications made to the technology have been validated by this test, they are functional. The technology will be used to conduct further fuel tests and use in different technologies.

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