TCP/CRO/3101 (A) Development of a sustainable charcoal industry

OPTIONS FOR IMPROVED CHARCOAL PRODUCTION IN BELISCE

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This project was launched in July 2006 within FAO Technical Cooperation Programme withthe objective to assess the current status of the charcoal production in Croatia, in order to develop a programme for the revitalisation of this industry.
Apart from recommendations and best solutions for the technological modernisation, the programme will provide guidelines for the production improvement and amplification with a holistic approach.
Ministry of Agriculture, Forestry and Water management is responsible for the project execution on behalf of the Government of the Republic of Croatia.

OPTIONS FOR IMPROVED CHARCOAL PRODUCTION IN BELISCE

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Semi cellulose and paper plant
Packaging plant
Spiral packaging plant
Plastic packaging plant

VALKARTON d.d. - LOGATEC (Slovenia)

KOMUNA AD - SKOPLJE (Macedonia)

UNIJA PAPIR d.d. - ZAGREB

Electric equipment plant - BELIŠĆE

Wood processing plant - BELIŠĆE

Semi cellulose and paper plant

Semi cellulose and paper plant is the biggest Croatian manufacturer of packaging paper with an annual production capacity of 200,000 tons. Produced packaging papers are needed for a complete development of corrugated cardboard packaging.

The packaging plant, a member of "Belišće" d.d. group, has being producing a well known bell- packaging since 1961. After its modernisation in 1998, the plant controls various modern machines, production lines including technological possibilities.

Spiral and plastic packaging plant

Spiral – paper packaging comprises wide range of diameters and thickness of the paper wall tube.

Devised production program based on the process of winding of spiral paper strips enables further processing of packaging products as: paper tubes, rings, barrels. The products can be applied in all industry branches where paper tube serves as a carrier of the final product.

- Wind diameter span : (8-600) mm
- Wall thickness span: (0,5 -15) mm, other dimensions – upon request
- Pressure span: according to demand – on request

Plastic packaging of press injection technology includes:

- o development of plastic packaging with multicolour print
- o services of injection of industrial semi products and products, machines within the range of 32 to 650 tons of closing force

Manufacturing program and devised services are based on the process of injection of polymer material (LDPE, HDPE, PP, PA).

1.2 Historical development

History of the town area starts with the founding of industrial company in 1884 in this part of eastern Croatia then rich with oak forests. That year, Hungarian wholesale merchant and manufacturer Salamon Heinrich Gutmann has bought ten-year exploitation rights of the 2185 hectares Harkanovac - Koska forest complex from Valpovo nobility. Belistje (in the cadastre municipality Bistrinci), a barren meadow on the right bank of Drava was selected as the most suitable site for construction of a sawmill. This area was later renamed Belisce, which was also the name given to the settlement that was built there.

Next to the sawmil, one of the most modern of the time and probably the largest in Europe for processing of oak timber, first residential houses of the Gutman colony sprang out. The firefighting association was founded at the same time, followed by opening of the school classroom and the post office (1886); elementary school building – today's youth center - is built (1890) as well as the cemetery chapel (1891) and the power grid and the water supply and sewage system are built.

In the year S. H. Gutmann Company was founded, the first kilometres of 100 cm wide gauge railroad lines for the wood industry were laid, which soon overgrew into local railroad with public transportation, railroad station, fireroom and technical repair facility in Belisce.

Abundance of Slavonian forests, cheap workforce and great demand for wood-processing products have ensured big profits for the company and allowed it to build factories for production of tannin, barrels, wood distillation products and parquet at the end of the 19th and the start of the 20th century.

The largest building of old Belisce - Palej or the Gutmann Palace, was built in 1905. Due to its monumentality, especially because of its interior furnishings it is ranked among the region's greatest architectural achievements of the early 19th century. Soon afterwards, the railway directorate building was erected (1906), as well as the characteristic residential houses (Five stars, Green houses, Mitrovica, houses with parapet porch), Workers Club, Clerks Club or White House (today a cinema).

Until 1889 the railway was in private ownership of the Gutmann family and Slavonian-Podravska railway dd Belišće afterwards. In the year 1945 all the tracks of this railway entered into a system of state railways. In the second half of the sixties of the last century, the traffic discontinued and these railway tracks were suspended. Industrial track of the normal railway of Belišće Bizovac was built and opened in 1970.

The company stagnated during the First World War due to neglected production subjected to wartime conditions. By moving its headquarters from Budapest to Belišće in 1918, the

Belišće became a joint stock company with the Gutmann family as its largest shareholder.

After the years of development and occasional business difficulties there was considerable standstill in production and sales of products between the two World Wars. The plants were forced to reorganize (new production of charcoal briquetting, production chestnut tannin extract etc.) and to modernize their production lines (retorts, distillates processing, many new secondary chemical products etc.). These procedures enabled the company to become the second largest manufacturer in Croatian wood processing industry. The 1927 would be remembered as the year of Belišće becoming an autonomous county, the title it held until the 1955.

After the confiscation (in 1945), during the post-war recovery period, the company successfully resisted the commanded dismantling and moving of plants to Bosnia and Gorski Kotar. Building of wool plant, restructuring of existing repairing shop into a market producer of machines and setting of final wood processing plant were initiated in 1951. However, most of the production plants are technically as well as technologically out of date, competitiveness of their products continues to decline and their raw material base is considerable reduced. Possible solutions for continuation of the successful manufacturing could be found in new production lines, technologies as well as products.

Crucial year in further development of Belišće is 1960. It was then when the plant production of semi-cellulose, paper and corrugated cardboard packaging started. Through the four phases of plant development afterwards, Belišće became the leading market player in this part of Osječko Baranjska county as well as in East European paper - cellulose industry. During the sixties, the plants stopped with the production of wood wool, parquet, barrels and tannin

1.3 Current production and future trends

According to present condition of charcoal production, the compound-kiln is in drive 270 days per year with an average daily capacity of 12 tons

Table 1.1: Annual charcoal production within the last 6 years

Year	**2001.**	**2002.**	**2003.**	**2004.**	**2005.**	**2006.**
Production (t)	**2.950**	**3.229**	**2.815**	**2.920**	**3.150**	**3.217**

The daily production could easily be increased up to 15 tons, but the number of annual workdays unfortunately not.

The existence of internal reserves of 20 % may mean the increase of production, however, this increase is influenced by various limiting factors: storage space, sale etc.

2 TECHNOLOGICAL PROCESS DESCRIPTION

2.1 Introduction

Facility for dry distillation of wood - wood processing factory
Dry wood distillation facility, a part of wood processing plant Belišće d.d. (joint stock company) was built couple of decades ago with its primary function of raw wood acid production, also a necessary raw material for production of many different chemical products. The products that could be obtained by dry wood distillation as well, are charcoal and methyl alcohol.

The production of raw acetic acid has become uneconomical due to development of chemical industry and production of synthetic chemical compounds that result in purer synthetic acid. At the same time, the production of the charcoal has become gradually more profitable, however, the by-products thereof (acetic acid and methyl alcohol) have started to cause ecological difficulties to their manufacturers. On the one hand, the placement of such products to end-users discontinued, but on the other hand, ecologically acceptable disposal of by-products has become a serious problem demanding significant financial engagement. It should be noted, that the natural gas was used in the process of distillation.

Considerable costs of charcoal production initiated need for process rationalisation. In terms of rationalisation there was also an idea to use retort gasses as a necessary fuel for the whole process in order to have advantage on both occasions. On the one hand, the received ethanol vapours and acid were properly disposed, and on the other hand, the consumption of process energy sources reduced. The mentioned, initial idea developed the project solution following hereto.

2.2 Detailed description

Detailed plant description can be observed in the scheme presented in the drawing P-04054/0700-01-1.

Retort gasses from dry wood distillation process are received in 6 retorts, accumulated in the main pipeline (ref. No. 006) and by natural ventilation fed to the combustion chamber (ref. No 01-01-01). Additional secondary air enables combustion of gasses in the amount sufficient to cool the exhausting gasses up to the temperature of 900 - 950 °C, which is monitored, at the same time, by separated sensor mounted at the end.

Secondary air, supplied by separated air fan (ref. No. 02.05-01), is pressed to the combustion chamber through the secondary air pipe (ref. No. 009) and separately mounted air nozzle/jet.

Hot chamber gasses are diverted by separately isolated duct (ref. No. 001) further to the retort system of heating pipes, six pcs. of which are mounted in the bottom of the each retort.

The heat of retort pipes, conveyed by radiating and convection, rises the temperature up to the process level required. Automatically monitored chamber temperature is in accordance to assigned diagram and regulated by the amount of incoming gasses in heating pipes. The amount is also regulated by separated outlet flaps (ref. No. 12.01-01.1,2,3 - 12.01.-06. 1,2,3).

Fuel gasses are cooled by one fan per 3 retorts to app. 500 °C (ref. No. 12.01-01.1,2,3 - 12.01.-06. 1,2,3) and pressed to the wood kiln (ref No. 05.13-01 and 02) driving off wood moisture prior the wood comes into retorts.

A bypass channel/duct placed around the chambers enables optional drying in chambers while emitting flue gasses through the flue exhaust (ref. No. 05.03-01 and 02) with the temperature of 350 - 500 °C depending on the variability of heat conveyance in kiln.

An automatic burner (ref. No. 02.01-01), installed in the chamber bottom, enables initial heating of the facility as well as adding of optional, necessary hot gasses. The temperature of gasses at the top of the combustion chamber regulates starting of the burner. The maximum output of the burner of 204 Nm^3/h of natural gas with 33.300 kJ/Nm^3 of heating power enables operating of 2 retorts not utilizing the retort gasses. As retort operations run in 4 h intervals and drying processes last 3-7 h, the emission of retort gasses starts precisely from the first retort enabling heating of the 3 retorts. The estimation of the mentioned time intervals was based upon conditions experienced at direct loading of raw wood into retorts. The period of drying could be essentially shortened, proving the sufficiency of the selected burner.

The facility process starts with loading of retort chamber with previously chamber dried wood or fresh wood. During the initial phase the wood is heated, driving off water vapour which is emitted through the opening at the door. As the process advances the wood moisture reduces until various carbon gasses start to gasify. At this vary moment the opening at the door is closed and the bolt (ref. No. 12. 01-7 - 12.01.-12) on gas pipes opened, conveying retort gasses to the combustion chamber (ref. No. 01.01.01).

Photocells of the burner (ref. No. 02.01-01) as well as of the chamber (07.16-01) monitor the flame existence in the chamber. In case of flame disappearance, the flow of the retort gas to the chamber is interrupted by instantaneous closing of the flap 12.01-19 and simultaneous opening of the flap 12.01-17 emitting the gasses into the atmosphere through the emergency flue.

Rise of the combustion chamber temperature above the allowed values, stops the chamber process and causes emitting of the gasses through the emergency flue.

The burner built in the chamber bottom includes all necessary safety equipment in accordance to European regulations and enables automatic maintaining of prescribed temperatures of the combustion products at the chamber outlet. Additional safety equipment is installed on the gas pipe as well as on the air duct with pressure safety switches, which stop the heating process if needed.

Secondary air fan is also monitored and in case of insufficient combustion air amount, the previously noted safety switches activate, but the burner remains in operation.

The alarm will sound in case of the temperature rise above the prescribed levels and the operating of the facility will be manually adjusted by the operator, due to the possible temperature rise even in case of normal (correct) operating of the facility. The mentioned could happen while pulling out the coal wagon, after opening of retorts, due to unavoidable excessive air penetration into the same retort. In such cases the operator has to close manually the gas retort outlet into the main duct of retort gasses.

An alarm will also signal insufficient pre-pressure of retort gasses (< 2 mm SV) and the operator will react if needed, because the alarm does not necessarily mean the incorrect facility operating.

2.3 Technical solutions of environmental protection

Dry wood distillation process is a technological process comprising a line of physical and chemical processes basically including: 1st Phase – airless heating and drying of woods and 2nd Phase – heating and gasification of various gases. Charcoal and various compounds including vapour, carbon monoxide, various acids, methanol and tars are final products of this process.

Dry wood distillation processes were developed 100 years ago as processes of manufacturing various acids, solutions, methanol. As synthetic production of these chemicals became commercialized, the dry wood distillation products could no longer be competitive.

By gradual decline of the economic profitability of dry wood distillation, the economic growth of charcoal production became more justified. Since charcoal manufacturing could not be possible without production of retort gases (i.e. by-products of dry distillation), in certain market conditions problems of product placing appear. The problems could partly be solved by burning of tars and methanol in certain burners useful in wood processing and manufacturing of briquette.

Project solution of retort gases combustion in separated combustion chamber, while utilizing the heat during the same process of wood heating, presents the best ecological solution which reduces considerably the need for primary energy.

Combustion of retort gases in combustion chamber enables complete combustion of: carbon hydrogen compounds, carbon monoxide, carbon and various tars. In this way, vapour and carbon dioxide are emitted from the burner surface, and emissions of CO, NO_x

and dust are within the levels prescribed by GVP. Thus, a double environmental benefit is realised through reduction of dangerous substances because of strictly controlled combustion, as well as complete reduction of primary energy source up to 75%, thanks to utilisation of the heat energy produced in combustion processes of retort gases.

2.4 Mass and energetic balance

Dry distillation of wood in retorts presents a thermal as well as chemical procedure:
Wood is heated in retorts with no presence of air up to the temperature of 400 ^{o}C, at which process water is driven off and a line of chemical compounds derived in gasiform, while dry residue remains as charcoal.

According to literature, dry wood distillation could be presented by the following chemical equity:

$$2C_{42}H_{60}O_{28} \rightarrow 3C_{16}H_{10}O_2 + 28H_2O + 5CO_2 + 3CO + 2CH_3COOH + CH_3OH + C_{23}H_{22}O_4$$

Wood → charcoal + water + carbon dioxid + carbon monoxid + acetic acid + alcohol + tar

In order to continue the mass balance survey, the values of mol masses of all products (substances) involved in the process of dry distillation of wood are needed (table 2.1).

Table 2.1: Dry wood mass balance

Substance	mol mass (g/mol)	mol	Mass share (%)
$C_{42}H_{60}O_{28}$	*1012*	*98,814*	*100,00*
$C_{16}H_{10}O_2$	234	148,22	34,68
H_2O	18	1383,40	24,90
CO_2	44	247,04	10,87
CO	28	148,22	4,15
CH_3COOH	60	98,814	5,93
CH_3OH	32	49,41	1,58
$C_{23}H_{22}O_4$	362	49,41	17,89

If only gasiform products of the dry distillation of wood are observed (excluding charcoal), a different picture of compounds arises (table 2.2).

Table 2.2: Compounds of gasiform products of dry distillation

Substance	mol	mass (kg)	Mass share (%)	Volume share (%)
H_2O	18	24,90	38,12	70,00
CO_2	44	10,87	16,64	12,50
CO	28	4,15	6,35	7,50
CH_3COOH	60	5,93	9,08	5,00
CH_3OH	32	1,58	2,42	2,50
$C_{23}H_{22}O_4$	362	17,89	27,39	2,50
Total:	**1976,29**	**65,32**	**100**	**100**

Reduced to the entry of the dry distillation of dry wood i.e. 100 kg of raw wood (dry), the result of the process of dry distillation of wood follows:

$$1976{,}29 \text{ mol x } 22{,}4\cdot10^{-3} \text{ Nm}^3/\text{mol} = 44{,}27 \text{ Nm}^3$$

gasiform products consisting of combustible (CO, CH_3COOH, CH_3OH and $C_{23}H_{22}O_4$ – a total of 45,24 % mass shares) and non-combustible gases (H_2O and CO_2 – a total of 54,76 % mass shares).

The process of retort gases combustion could be presented in equations as follow:

$$CO + 1/2O_2 \rightarrow CO_2$$

$$CH_3COOH + 2O_2 \rightarrow 2CO_2 + 2H_2O$$

$$CH_3OH + 3/2O_2 \rightarrow CO_2 + 2H_2O$$

$$C_{23}H_{22}O_4 + 3/2O_2 \rightarrow 23CO_2 + 11H_2O$$

The oxygen needed for combustion (air) can easily be surveyed in the table 2.3.

Table 2.3: Oxygen needed for combustion

RETORT GAS			NEEDED COMBUSTION		FLUE GASES (mol)		
Substance	**mol**	**vol.%**	**O_2 (mol)**	**air (mol)**	**CO_2**	**H_2O**	**N_2**
H_2O	1383,40	0,700	-	-	-	1383,4	-
CO_2	247,04	0,125	-	-	247,04	-	-
CO	148,22	0,075	74,11	352,90	148,22	-	278,79

CH_3COOH	98,81	0,050	197,62	941,05	197,62	197,62	743,43
CH_3OH	49,41	0,025	74,11	352,90	49,41	98,82	278,79
$C_{23}H_{22}O_4$	49,41	0,025	1309,37	6235,07	1136,43	543,51	4925,71
Total	**1976,29**	**1,000**	**1655,21**	**7881,92**	**1778,72**	**2223,35**	**6226,72**

The results of the above survey theoretically present that flue gasses originate from combustion of the retort gases, which are produced by dry distillation of 100 kg of raw (dry) wood (table 2.4).

Table 2.4: Flue gasses produced by dry distillation of 100 kg of raw (dry) wood

Substance	**Mol**	**mol. % of vol. %**
CO_2	1778,72	17,39
H_2O	2223,35	21,74
N_2	6226,72	60,87
Total	**10.228,79**	**100**

It must be underlined that the real combustion air, as real wood too, comprises moisture, which changes depending on atmospheric conditions. A surplus of air is also essential for complete combustion of certain fuel (in this case retort gas). It is necessary to correct real air amounts essential for the combustion of retort gases.

For the combustion of the specified fuel a surplus of 15% (λ = 1,15) of air will be sufficient. The amount of the flue gases can be recapitulated as in table 2.5.

Table 2.5: Recapitultion of the flue gases amount (without wood moisture content)

Substance	**Mol**	**mol. % or vol. %**
CO_2	1778,72	15,59
H_2O	2223,35	19,48
N_2	7.160,65	62,75
O_2	248,21	2,18
Total	**11.410,93**	**100**

The outcoming result of the total amount of flue gases thereof makes: V_{dp} = 255,60 m^3, i.e. the total amount of flue gases m_{dp} = 330,50 kg at dry distillation of 100 kg raw (dry) wood.

Energetic balance:

The formula necessary to calculate the lower thermal (heating) value of fuel (comprising mostly carbon and hydrogen) follows here to:

$$\mathbf{H_d = 33.900 \cdot C + 11.700\ (H - O/8) + 10.500 \cdot S - 2.500 \cdot w \quad (kJ/kg)}$$

C – presenting mass content of carbon , H – content of hydrogen, O – content of oxygen , S – content of sulphur and w – content of moisture.

According to previous calculations the retort gases have lower thermal value:

$$\mathbf{H_d = 10.600\ kJ/kg}$$

Daily mass balance

Theoretic balance

In normal operating mode (full drive) the plant for dry distillation of wood has a daily capacity of 93,60 m^3 of wood per day, i.e. specific mass (wood density) of 700 kg/m^3 and mass capacity of **65.520 kg wood per day**.

The above data are competent presuming that all 6 retorts and two drying wood chambers are in drive, as well as the wood enters the chambers dried in air conditions with approximately 25 % of moisture. These are the common parameters for the production of charcoal.

Table 2.6: Daily products of the dry distillation of wood

Substance	**Mass (kg / day)**
$C_{16}H_{10}O_2$	22.722,34
H_2O	16,314,48
CO_2	7.122,02
CO	2.719,08
CH_3COOH	3.885,34

CH_3OH	1.035,22
$C_{23}H_{22}O_4$	11.721,53
Total	**65.520**

Certain utilization grade in charcoal production, described in current state, presents relation between the produced amount of charcoal and the amount of raw wood entering the process of dry distillation of wood:

$$\eta_{sd} = 22.722{,}34 / 65.520 = 34{,}7\ \%$$

Practical balance:

The plant has daily output of approximately 20 t of ready product (wood charcoal) on the basis of annual production of 3.230 t and approximately 270 business days p.a.

Energy balance:

Daily flue gases production resulting from combustion of gasiform products and products of dry distillation of wood, amounts approximately 517.301 kg at an average temperature of app. 910 ^{o}C.

For heating and drying of raw wood in kilns as well as for the initial phase (endothermic) of dry distillation in retorts, approximately 227.820 kJ/day of available thermal energy are to be used (approximately 63,3 kWh). For some other purpose, there are as much as 5.757.000 kJ/day (approximately 15.900 kWh) of thermal energy available, that can be used for the planned drying of wood mass necessary for manufacturing of „white" briquettes and drying of „black" briquettes respectively.

Table 2.7: Energy balance

Substance	**Mass (kg / day)**	**Heat value (MJ / kg)**	**(MJ / day)**
$C_{16}H_{10}O_2$	22.722,34	(28,114)	(638.816)
H_2O	16.314,48	- 2,5	- 40.786
CO_2	7.122,02	0	0
CO	2.719,08	10,11	27.490
CH_3COOH	3.885,34	13,56	52.685
CH_3OH	1.035,22	19,51	20.197

$C_{23}H_{22}O_4$	11.721,53	26,30	308.276
Total	**65.520**	**-**	**367.862**

2.5 Technological schemes

- P&I plant diagram of retort gases utilisation PR.224.FD-01 (see Apendix 1)

3 RECOMMENDATIONS FOR TECHNOLOGICAL PROCESS OPTIMISATION

3.1 Charcoal production

It is not possible to improve the quality of the technological process in itself. The charging with six chambers encircles the process, as six loadings / unloadings are completed within the period of 24 h comprising 4 h per chamber cycle.

It is possible to optimise the technological process by alternation or application of a different technology as well as suitable equipment.

3.2 Energetic process efficiency

Daily consumption of additional energy source (natural gas) during the period of full production amounts app. 500 Nm^3. The energetic value of natural gas amounts 33.340 kJ/Nm^3. Daily consumption of additional energy amounts consequently approx. 16.670.000 kJ.

The existing facility enables approx. 5.757.000 kJ/day (or 15.900 kWh) of thermal energy which can be used for the planned/expected drying of wood mass, necessary for manufacturing of „white” briquettes and drying of „black” briquettes respectively.

In case 3.500.000 kJ/h (or 84.000.000 kJ/day) of the available thermal energy are used for drying of „white” as well as „black” briquettes, there will practically remain no thermal waste influencing (temperaturely) environmental pollution.

3.3 Description of possible savings and cost estimation

«Wood processing plant - Tvornica za preradu drva» (TPD), a part of Belišće complex, has enabled utilisation of retort gases, resulting from dry distillation of wood, in its facility established for the purpose of rationalisation and energy saving in 2005. The dry distillation of wood is nowadays primarily used for manufacturing of charcoal. The gaseous products of the same process do not have the economic value as they previously have had in the form of raw material, essential for production of: acetic acid, methyl alcohol, a line of different technical and chemical products.

As retort gases have perceptible heat as well as certain thermal value, their combustion follows within the new facility. The originated gases at temperature of approx. 950 ^{0}C are used afterwards for heating of retorts, and for continuing the process of dry distillation. The used gases are emitted through two flues into the atmosphere at the temperature of 350 ^{0}C, but the temperatures could be higher even up to approx. 450 ^{0}C.

The amount of gases emitted through each of the flues varies in relatively wide limits depending on the particular retort phase of the distillation process. The maximum amount of approx. 7500 Nm^3/h per each flue presents a standard value determined by the project.

The stated amounts of hot gases emitted into the air take along substantial energy amount and should be additionally analysed in order to find acceptable technical solutions for thermal waste utilisation, that could also influence the consumption of primary energy sources as well as cost side reduction.

Considering the existing technological processes in TPD, the thermal waste could also be utilised within manufacturing of coal (so-called „black“) as well as wood (so-called „white“) briquettes.

Coal briquettes that are made of coal dust of charcoal production, are dried after their manufacturing by the same hot gases resulting from the combustion of heavy fuel oil (HFO).

The fuel oil is combusted in the separated combustion chamber, the so-called generator of hot gases, and the flue gases compound enriched by cool air, after finishing of combustion process in order to achieve necessary kiln temperature.

As opposed to coal briquettes, the manufacturing of so-called „white“ briquettes needs dry raw material, primarily wood saw dust with determined moisture contents essential for press briquetting procedures. The hot gases, which generate through combustion of natural gas during the mentioned process in the separated chamber, are flowed into the rotary kiln.

The above mentioned leads undoubtedly to conclusion that the dry wood distillation facility releases considerable amounts of thermal energy into the air and uses, at the same time, substantial amounts of fuel (HFO and natural gas) during the drying processes of briquette manufacturing („white“- wood and „black“-coal briquettes). However, a logical conclusion follows in the question:

Is it possible to reduce the fuel consumption by utilising the thermal energy waste of flue gases from the dry wood distillation facility?

While trying to find a suitable answer, the following should be taken into consideration:

- there is a distance of approx. 100 m between two particular locations of facilities („white“ and „black“ briquettes);
- complete operating cycle of charcoal manufacturing lasts approx. 24 h, including the wood drying phase as well as generating of retort gases. The alterations of the content and temperature of retort gases during the phase of generation should also be taken into consideration.

On the basis of measurements conducted, the estimated utilisation of hot exhaust gasses can realise savings of up to $3{,}5 \times 10^6$ kJ/h.

The flue gases from the drying wood facility could technically be used for direct briquette drying during the manufacturing procedure. However, the distance between facilities makes evident that flue gases should not be run on such distances.

Thus, the drying of coal briquettes initiates hot gases which are generated in a separated generator of hot gases. The fuel consumption within GVP amounts max 170 kg/h. Hot gases have temperature of approx. 315 ^{0}C, and they are cooled at the kiln inlet to approx. 290 ^{0}C. The mentioned values are project ones, and are higher in reality at the outlet of

GVP due to the lack of flue conduit isolation, which is placed in the open causing substantial thermal losses.

At the production of wood briquette the GVP has thermal effect of 8,37 MJ/h, and the temperature of hot gases amounts max. 400 ^{0}C.

Transfer of heat by using medias of lower volume and higher specific thermal values could be acceptable solution. With reference to flue gases temperature as well as necessary temperature levels in the drying processes, usage of water as a medium could not be possible due to extremely high pressure demand. Only usage of thermic oils could be technically justified due to the reachable operating temperature of up to 350 ^{0}C, which is in the mentioned case sufficient.

3.4 Technical description of the solution selected

The technical solution could be conceptually best viewed in P&I scheme in the drawing no. PR.297.IR.FD.0.001.

The distribution of heat of the exhaust gases to the transport medium i.e. thermo-oil, proceeds in two identical alternators- thermo oil heater (pos.1), whereas the flue gases from 3 retorts are used by each of the alternators. Each group of three retorts generates, according to the phases of the technological process of dry distillation, a sort of summary position indicating quantity and temperature of the product of combustion. As a rule, all six retorts are placed in the facility with an annual engagement of approx. 8000 h.

Resulting form the above mentioned are the both heaters of thermo-oil being in drive most of the time. If, due to any reason, a situation occurs in which a group of retorts is disconnected, the respective heater is to be disconnected from thermo oil circulation by manual bolt fixtures, as well. In conditions when retort chambers are in operating mode, the respective heater should be out of operation (there will be no need for heat, remount or reparation of heater or other system parts), and the flue gases will be directly emitted through the flue duct using the system of hatches.

The heated thermo oil is transported by circulating pump to the heat consumer, that are heat alternators – air heaters mounted at drying facilities for manufacturing of „black“ and „white“ briquettes. In both cases the air is heated, but for drying of „black“ briquettes the air will be heated up to approx. 290 ^{0}C and it will substitute hot gases from GVP. During the drying process of „white“ briquettes the temperature as well as the heat available, will not be sufficient to achieve necessary parameters for drying of the wood saw dust, which is why the heated air has to be blown into the fire box of GVP reducing the natural gas consumption.

As drying facilities are in drive for a lesser number of hours annually (“black” briquette facility approx. 2500 h; “white” briquette facility approx. 4000 h), various drive mode situations are to be expected, as well as smooth functioning of the entire system in accordance with the project.

In order to insure an adequate high temperature of thermo-oil, it is necessary to regulate the amount circulating through heaters, which is done by frequent regulation of circulating pump revolutions. The regulated volume presents the initial temperature of thermo-oil, which is measured on the common initial duct.

4 APPENDICES (TECHNICAL DRAWINGS)

- P&I facility diagram for utilisation of retort gases PR.224.FD-01
- Waste heat utilisation facility PR.297.IR.FD.0.001