HTW Fluidized-bed Gasification for 400 MW IGCC Power Plant,
Vresova - Czech republic.

Authors : Zdenek Bucko, Sokolovska Uhelna, Czech Republic
Masaki Takahashi, The Worldbank
Helmut Vierrath, Lurgi Envirotetherm, Germany

Background:
Sokolovska uhelna (SU) is a joint-stock company at Sokolov, Czech Republic, around half publicly
owned and another half privately owned. Its main activities are coal (lignite) mining, and electricity
generation. SU built fixed bed pressurized lignite gasifier and gas purification plant in 1960’s to
convert lignite to gas and supply town gas. It was one of the largest town gas generation plant in
Central Europe until 1996. However, the town gas has been replaced by natural gas from Russia
since 1996. SU installed two units of 200 MW gas turbine combined cycle to generate electricity
to be fed by the gas produced by the gasification plant. The existing gasification plant, however,
has problems of high operating and maintenance costs, local environment through tar and phenol
production as by-product of gasification process, low conversion efficiency and lack of fuel
flexibility. SU studied several alternatives to solve the problems including revamping the existing
system, switching fuel to natural gas, and other types of gasifier for the conversion from lignite and
gas, and concluded that installing new units of fluidized bed gasifier with High Temperature Winkler
(HTW) gasification technology is most economical.

Introduction.
In the world, the IGCC technology and equipment have been developed mainly in the USA within
the Clean Coal Technology program, in Japan and European Union. In EU the area of "clean coal
technologies" has been monitored, developed and supported within the "Green coal" program,
which is a part of THERMIE program. Within this program two demonstration and trial plants were
built, namely in Buggenum, Netherlands (for high-quality black coal with ash content up to 15% by
weight), and in Puertollano, Spain.

Sokolovska uhelna, a. s. Sokolov has been operating a new Combined Cycle Power Plant (CCPP),
which was built in the years 1993 - 1996, and is integrated in the Vresova Plant. Syngas is
the basic fuel for the units of total installed capacity 2x 200 MWel. The syngas is produced in
pressure gas-work completed in 1970, which has been equipped with 26 gasifiers for pressure
gasification of coal in fixed bed of Lurgi type.
The pressure gas work is equipped with gas cleaning equipment Rectisol, gas desulphurization
Haldor - Topsoe of 1993, dephenolation and deammoniation of waste gasworks water, which is
subject to secondary biological treatment. Furthermore the house ensures thermic liquidation of
malodorous waste gases (since 1986). Required oxygen has been generated in Air Separation
Unit (ASU).
The construction of the CCPP was initiated by termination of demand for town gas and change-over
of the consumers to imported natural gas. Yearly production of over 1 billion m³ of syngas
represents approx. 90% of the CCPP gas consumption.
Nominal output of the power plant is utilised in accordance with the current consumer only in the
power peak ranges or in the need of a regulating power of the Czech Republic electrical power
system (2000 – 2500 hr/year). Natural gas has been utilised as second fuel to reach the maximal output of the CCPP.

Besides the power gas the current technology has been producing forced by-products, particularly 90 thousand tons of tar, 12 thousand tons of phenol concentrate, 10 thousand tons of crude petrol, 10 thousand tons of ammonia, and 8 thousand tons of sulphuric acid yearly.

The present gasification technology does not enable a principal innovation toward better economic results and further reduction of CO₂ emissions and other negative impacts upon the environment.

High operating costs (repairs, material, wages), limited capability of load regulation, need of high-quality coal charge, and the load of living and working environment by production of cancerous by-products have led SU a.s. to preparation of a project which will eliminate the mentioned minuses of the present coal gasification.

The most suitable solution, which is a result of the studies of leading companies in the field i.e. Lurgi, Rheinbraun and Krupp - Uhde, FRG, seems to be the replacement of 26 existing gasifiers with fixed bed by two pressure gasifiers with modern fluidized bed gasification (HTW - High Temperature Winkler) of total capacity 2 x 120 000 Nm³/h of raw gas before Rectisol unit.

In this gasification method (with the temperatures 900 - 1100 °C at the gasifier outlet) no by-products arise compared with the existing fixed-bed gasification (e.g. tar and phenol water), and thus the carbon conversion from coal to gas is increased to approx. 92.81 %.

The prepared project, besides the replacement of the gasifiers themselves, has the following basic requirements and goals:

- to reduce substantially the emission of greenhouse gases (particularly CO₂) and other pollutants
- to improve ecological conditions of the future gas plant, mainly through substantial reduction of production, storage and distribution of by-products of gasification (mainly of tar, phenol, petrol and ammonia)
- to improve summary economic results of the company through increase in the productivity of labour, reduction of cost of reproduction of the obsolete fixed assets in terms of repairs and material, and reduction of the charges for impact upon the environment
- to cancel needless technological processes, however use to a maximum possible extent the existing processes needed for the operation of the new fluidized bed gasifiers
- to increase the revenues from the sale of the generated electrical energy and superior coal (low quality coal will be used for gasification)
- to use the fluidized bed technology of pressure gasification of lower quality brown coal as a pilot project of commercial utilisation of possible clean coal technology (CCT), and that in the context of collaboration with other countries.

As it has already been said, the planned new construction is concentrated in the processing part of SU a. s. in Věšová, without the need of new lands.

The objective scope of the project, which is divided into process systems and constructed facilities, has been designed with regard to the solution of basic requirements for process part of the work. These have been mainly the following requirements:

- to solve the gasification concept itself by location of 2 fluidized bed gasifiers of the output 2 x 120 thousand m³/h in an appropriate space to enable parallel operation of the old and new gasification plants in commissioning of the new gasifiers;
- to solve alternatively the utilisation or liquidation of ammonia waste water;
- to solve the issue of site preparation for possible installation of the new gasifiers and other new buildings;
- to solve alternatively the raw gas cooling;
- to solve the utilisation of excess of heat and use of bottom product with relation to the operation of the existing heating plant;
- to consider the consequences of the change of the gas quality and new gasifiers for operation of combustion turbines;
- to resolve the crushing plant innovation program for the needs of coaling of the gas plant and heating plant.

An important of the project is co-operation of Czech engineering companies and the firms from Federal Republic of Germany. The project has been based on the results of previous studies carried out under the leadership of Lurgi Environment, the company based in Frankfurt. On the German side, important partners also include of the joint-stock company Rheinbran (the license holder of the applied method of gasification - HTW) and Krupp - Uhde (GmbH). These companies are co-authors of the Project solution.

**Brief description of pressure fluidized bed gasification of brown coal by HTW method**

Fine grained coal is gasified in the reactor in the fluidized bed. The bed is formed by particles of ash, semi-coke and coal, and is maintained in the fluidized state by properly selected rate of flow of the gasification agent from bottom to up. The coal is led into the reactor continuously directly into the fluidized bed; ash is removed from the bottom continuously as well. Above all it is possible to gasify all grades of more reactive coal (i.e. brown coal, more reactive grades of black coal, both baking and non baking ones) with a higher ash flow point, and also various sorts of biomass (turf etc.). With regard that the outlet temperature reaches approx. 900 to 1100 °C, the generated gas does not practically contain any higher hydrocarbons such as tars, phenols and other heavy and substituted aromatics.

Compared with the current state thus production of tars, which contain polyaromatic hydrocarbons will fully be eliminated. Like the above benzene derivates, as a matter of fact, also all phenols are decomposed at high reaction temperature.

Compared with the current state, also ammonia production will be reduced with the utilisation of the fluidized bed process.

**Physical and chemical comparison of the existing and new technologies.**

The differences between both the technologies are given by the principles of their function.

The existing gasification in sliding bed is carried out in a counterflow reactor, in which the highest temperature is generally at the inlet (in the reactor bottom in combustion of the last residues of the coal mass in ash). In passage through the reactor, the gas temperature is decreased by effect of running gasification reactions. Coal pyrolysis takes place only in the last zone (except for drying zone, which however does not influence the chemical composition of the gas) at relatively low temperature (600 – 300 °C) and, as a matter of fact, just prior to gas exit from the reactor. That is why the pyrolysis products, which contain a large amount of higher hydrocarbons (tars, phenols, aromatic hydrocarbons), are carrier out for the greater part from the reactor. These higher hydrocarbons then must be removed from the gas in course of its cleaning.
Fluidized bed reactor is a mixed reactor, where the reaction mixture is mixed intensively, which results in more even course of temperature. In the fluidized bed itself, into which the fresh coal is supplied, the temperature is about 700 °C. The pyrolysis takes place more quickly thanks to higher temperature, higher hydrocarbons are more pyrolyzed, and intensive mass exchange contributes to their quick reaction with the gasification agent to gaseous products. This is also enhanced by supply of the gasification agent in more levels along the reactor height. The last gasification agent is delivered over the thick fluid bed i.e. into so called after-reaction zone, wherein the gas temperature is increased by supply of oxygen almost to 1000°C. In this zone also the last residues of higher hydrocarbons (tars, phenols) are decomposed.

Current state

The construction of the new fluidized bed gasification (HTW) is presupposed inside the existing area of Vřesova Plant which is located in eastern part of the Sokolov's brown-coal basin, approximately between the cities Karlovy Vary and Sokolov. The area lies 450 to 500 m above sea level.

The production of SU Vřesová, a. s., is for most part integrated in the structure of the national power complex. For briquettes, the company is the biggest producer and supplier in the home market. It belongs to the biggest both producers and exporters of coal in the Czech Republic. It is connected to the gas industry networks. It is interconnected with the nation-wide electrical power system by 4 lines 110 kV and 2 lines 220 kV. The present system of centralized heat supply is built for the Karlovy Vary agglomeration.

In connection with the change-over of consumers to natural gas a variant was adopted of the conversion of production of lighting gas to production of heat and power in the steam-gas cycle (PPC) on the basis of power gas produced by pressure gasification of brown coal, with maximum output flexibility reached thanks to the natural gas.

Current state of environment load

The present operation of the Vřesová Plant (mainly coal preparation plant, pressure gas work and power and heating plant) affects the neighbouring environment mainly by exhalation of pollutants in the ground air, discharging of waste water in the surface water, and also by waste handling and noise emission.

Impact upon the air

The impact upon the air must be understood aggregately as a synergistic impact of the sources in Vřesová and a number of other exhalation sources in both the region and a wider area. According to the results of emission monitoring, as a result of implementation of a number of measures the share of emissions from the air pollutant sources has been showing a continuously decreasing trend in Vřesová (except for 1996, when CCPP was put into operation), namely:

<table>
<thead>
<tr>
<th>Year</th>
<th>Coal consumption (t/y)</th>
<th>Solid matters (t/y)</th>
<th>SO₂ (t/y)</th>
<th>NOₓ (t/y)</th>
<th>NH₃ (t/y)</th>
<th>Org.S compounds (t/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>2 301 179</td>
<td>2 778</td>
<td>21 669</td>
<td>9 809</td>
<td>585.9</td>
<td>0,2</td>
</tr>
<tr>
<td>1991</td>
<td>2 355 160</td>
<td>2 317</td>
<td>21 217</td>
<td>6 941</td>
<td>536.6</td>
<td>0,7</td>
</tr>
<tr>
<td>1992</td>
<td>2 460 047</td>
<td>2 254</td>
<td>20 281</td>
<td>7 723</td>
<td>89.2</td>
<td>0,3</td>
</tr>
</tbody>
</table>
From the viewpoint of the impact upon the air it is possible to state that after the implementation of the new fluidized bed technology of pressure gasification of coal and other related investment or operating measures the emissions of CO2 and other pollutants (dust, SO2 and NOx) in air i.e. the existing imission load of ground air will be reduced substantially in the environs of Vøesová and in adjacent regions. Emission limits will be met by all potential air pollution sources.

With regard to the mentioned reduction of total emission production it is really possible to expect also a reduction of the overall imission load of the ground air in the environs. This assumption will be verified by a dispersion study in assessment of the project impact upon the environment in the frame of elaboration of the EIA documentation.

This follows from the comparison of the current yearly production of pollutant emissions in the air (i.e. the emissions from the heating plant, PPC, liquidation of weak expansion gases and desulphurization of rich expansion gases), with the following prospective state after the desulphurization of the heating plant and implementation of the new fluidized bed technology of gasification and other related measures:

<table>
<thead>
<tr>
<th>Current State</th>
<th>State after HTW implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction to approx.:</td>
<td></td>
</tr>
<tr>
<td>- solid matters</td>
<td>532.8 t/year</td>
</tr>
<tr>
<td>54.4 %</td>
<td></td>
</tr>
<tr>
<td>- sulphur dioxide SO2</td>
<td>11 246.3 t/year</td>
</tr>
<tr>
<td>13.1 %</td>
<td></td>
</tr>
<tr>
<td>- nitrogen oxides NOx</td>
<td>4 703.0 t/year</td>
</tr>
<tr>
<td>60.0 %</td>
<td></td>
</tr>
</tbody>
</table>

In routine operation the fluidized bed gasification technology does not produce any emissions. Gaseous wastes arise only in the equipment startup or shutdown, both emergency and operating ones.

The desulphurization unit represents a modern ecological wasteless technology of processing of off-gases containing poisonous hydrogen sulphide and malodorous organic compounds of sulphur, to sulphuric acid.

The unit is designed for liquidation of waste gas of the existing Rectisol unit. The waste gas contains, besides hydrocarbons, also hydrogen sulphide causing gas toxicity even with low
concentration, and organic compounds of sulphur, which would burden the environment with their penetrating malodour.

The principle of this technology is oxidation of all sulphur compounds to sulphur dioxide, denitrification of process gas by NOx reaction with ammonia on catalytic bed of the reactor and subsequent catalytic oxidation of the sulphur dioxide to sulphur trioxide. By cooling of the reaction mix concentrated sulphuric acid condensates and off-gas is released (after its pass through the filter to arrest the drops of sulphuric acid) through the existing stack in the atmosphere.

**Basic conception of the technological process.**

A. Basic criteria for replacement of gasification technology

a) to minimize the impacts upon the environment;

b) to use to a maximum possible extent the existing equipment; to maximize the waste product recycling;

c) to minimize the financial costs of the project;

d) to use the existing Plant area;

e) to ensure maximal reliability;

f) to size the equipment for fuel horizon of the years 2015-2020;

g) to preserve or improve the dynamic characteristics of the facility as a whole;

h) to ensure conditions for potential automated control of the new technology operation;

i) to minimize the operating costs (maintenance and operation)

Main attention is paid to assurance of minimal environmental impacts, minimization of investment costs while observing all current advantages and benefits

**Syngas combustion**

Combustion of syngas in the gas turbine is preserved including all characteristics of the existing CCPP. By virtue of improved dynamics of the new gasification process it is possible to expect a reduced natural gas consumption for coverage of quick changes of the demand for electrical energy.
Main technical parameters of gasifiers:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of coal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- dried (13 % H₂O)</td>
<td>81.6</td>
<td>t/h</td>
</tr>
<tr>
<td>Quantity of bottom product</td>
<td>15.5</td>
<td>t/h</td>
</tr>
<tr>
<td>Quantity of cyclone dust</td>
<td>3.2</td>
<td>t/h</td>
</tr>
<tr>
<td>Raw gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- normal volume flow rate</td>
<td>159600</td>
<td>m³/h</td>
</tr>
<tr>
<td>- mass flow rate</td>
<td>140600</td>
<td>kg/h</td>
</tr>
<tr>
<td>- operating volume flow rate</td>
<td>25700</td>
<td>m³/h</td>
</tr>
<tr>
<td>Outputs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>gross</td>
<td>376</td>
<td>MW</td>
</tr>
<tr>
<td>net</td>
<td>358</td>
<td>MW</td>
</tr>
<tr>
<td>Gasification pressure</td>
<td>27.5</td>
<td>bar (abs)</td>
</tr>
</tbody>
</table>

The above data applies for 100% load. With gasification pressure 27.5 bar the gasifiers can be operated within the range from 60% to 100%.

Waste handling

Compared with the present production of gasifier slug from coal gasification in the fixed bed gasifiers, the fluidized bed coal gasification process and subsequent cleaning of raw gas will produce solid products, namely the bed ash (so called bottom product) and dust from the hot filter. The yearly production of the bottom product reaches approx. 167 370 tons a year (max. 2 x 15.5 – 31.0 t/hr), and that of the hot filter dust approx. 34 670 tons a year (max. 2 x 3.2 – 6.4 t/hr).

It follows from the hitherto carried out preliminary (informative) tests of elutriation of these products (test gasification of Sokolov coal in Aachen) that the water digestion of the bottom product from the proposed HTW plant would show favourable values for their storage on the present coal-ash settling basin, without the need of implementation of other technical measures. Therefore the bottom product will preferably be transported hydraulically and stored in the present coal-ash settling basin.

The results of the above elutriation tests of the HTW bottom product in comparison with the existing state (slug from fixed bed gasifiers and ash from the heating plant) were handed over as one of the inputs for elaboration of the EIA documentation.

The hot filter dust from the raw gas cleaning process is not a waste, shows higher heating value, and will be utilised above all in power generation (in heating plant boilers).

B. Basic technical requirements for HTW and linked technologies

- to solve the gasification by two-gasifier configuration – two independent units of the capacity of 120000 Nm³/h of raw gas at the Rectisol inlet
- control range of one unit 60 to 100% Nj (nominal output)
- rate of change of the output 8% Nj/min
to solve a possibility of temporary parallel operation of the old and new technology
automated control of the whole technological process from the PPC operator’s workplace
to solve the liquidation of ammonia waste water
to resolve the location of new technologies and site preparation
to solve the raw gas cooling
to solve the use of excess of heat
to consider the consequences of change of gas quality for combustion turbines
to solve a possibility of gas plant and heating plant coaling with a uniform charge

Already with the implementation of the complete CCPP with integrated coal gasification (IGCC) in the present form, Vøesová has been ranged among few plants in the world, which managed similar technologies. By replacement of the old coal gasification process, Vøesová will get to the absolute top in the world, for it will be the first CCPP with modern brown coal gasification technology in the world.

Furthermore, the experience and knowledge of IPPZ Vøesová would substantially help in solving the home issues of improvement of the ecology of power production from coal. After approx. 10 years, some of the existing power plants will have to be replaced by new sources. It is possible to presuppose that undoubtedly not all coal-burning plants will be replaced by nuclear or gas ones, but that a part of the coal-burning plants will remain. In this case the experience from IGCC Vøesová will be invaluable for implementation of new coal-burning plants from the viewpoint of both good knowledge of operation economy and setting substantially higher environmental targets.

Fully integrated coal gasification combined cycle (IGCC) is still in early stage of commercialization. Several commercial demonstration projects are on going in Netherlands, Spain and the US. There are associated technical risks and higher cost with the IGCC technology, however, it is one of the advanced coal utilization technology with high efficiency and low environmental emissions including CO2. It has a large potential to reduce GHG in the long term when the technology is wide spread in the world. Fluidized bed gasifier technology can use low quality (high ash content) coal or lignite which can be found in many developing countries such as India, Turkey and China.

The construction of the new fluidized bed gasification at the 21st century state of art and its integration into the already existing processes of the processing part of Sokolovská uhelná including the new CCPP will make it possible to build a large commercial unit of integrated combined cycle cycle, the most ecological power generation on the brown coal basis with relatively low investment costs.