Värnamo Demonstration Plant, SWEDEN

Customer	Sydkraft AB
Planning company	Sycon AB / Foster Wheeler Energia OY
Type of plant	CHP Demonstration and test facility
Type of technology	Pressurised Biomass IGCC
Special features	Pressurised CFB gasification, hot gas clean up, air extraction from GT
Fuel power	18 MW
Heat power	9 MW
Electrical power	6 MW
Electricity production	3600 h operation as IGCC, 8500 h of gasification
Fuel	Wood chips, pelletised wood, bark, straw, RDF
Description of the site	Vaernamo (Värnamo), Sweden is located about 230 km north of Malmoe (Malmö). The region is mainly forest and agriculture land. Wood fuel is collected within a radius of 50 km. Power is supplied to the public grid while hot water is supplied to the district heating network at Vaernamo. Since the plant is a test facility, hot water is produced in neighbouring biomass grate fired boilers, when the plant is out of operation. The demonstration programme was concluded in year 2000 and the gasification plant has been mothballed since then.
Period of installation	The plant was constructed September 1991 – March 1993. Commissioning of the combined cycle on liquid fuel was concluded in March 1993 and the integrated plant in March 1996. The test programme was concluded in the end of 1999.
Total costs	Investment 230 million SEK / 25 million Euro
Financing	23 % public funding and 77 % private financing
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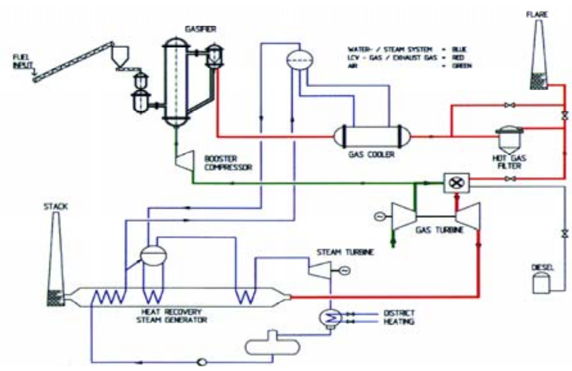
Process Description of the Vaernamo Plant

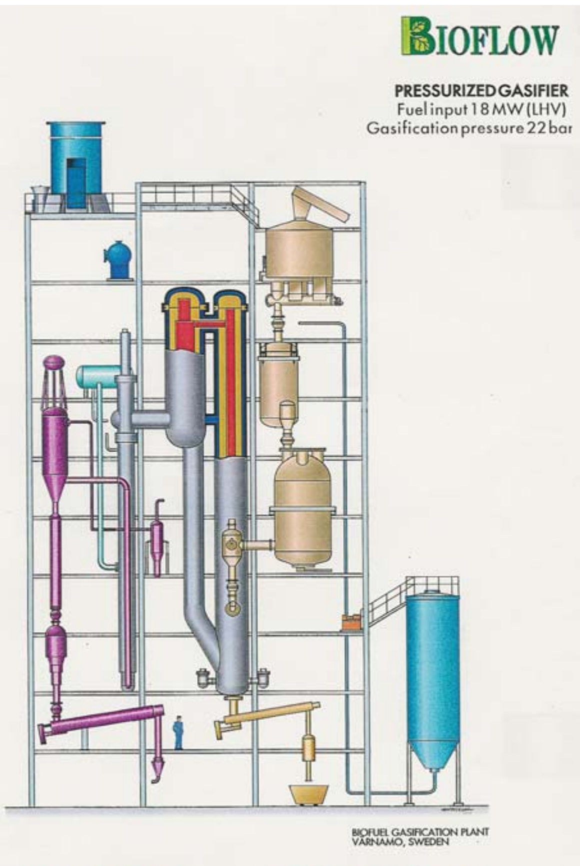
The wood fuel is dried in a separate fuel preparation plant, using a flue gas dryer, to a moisture content of 5-20%. A simplified process diagram and a cross section of the gasification plant are shown below.



The dried and crushed wood fuel is pressurised in a lock-hopper system to a level which basically is determined by the pressure ratio of the gas turbine, and is fed by screw feeders into the gasifier a few meters above the bottom. The operating temperature of the gasifier is 950 - 1000°C and the pressure is approximately 18 bar (g). The gasifier is a circulating fluidized bed and consists of the gasifier itself, cyclone and cyclone return leg. The three parts are totally refractory lined.

The fuel is dried, pyrolised and gasified immediately on entering the gasifier. The gas transports the bed material and the remaining char towards the cyclone. In the cyclone, most of the solids are separated from the gas and are returned to the bottom of the gasifier through the return leg. The recirculated solids contain some char which is burned in the bottom zone where air is introduced into the gasifier. The combustion maintains the required temperature in the gasifier.

After the cyclone, the gas produced flows to a gas cooler and a hot gas filter. The gas cooler is of a fire tube design and cools the gas to a temperature of 350 - 400° C. After cooling the gas enters the candle filter vessel where the particulate clean-up occurs. Ash is discharged from the candle filter, as well as from the bottom of the gasifier, and is in the meantime cooled and depressurised.



The gasifier is air-blown. Thus about 10% of the air is extracted from the gas turbine compressor, further compressed in a booster compressor, and finally injected into the bottom of the gasifier.

The gas generated is burned in the combustion chambers and expands through the gas turbine, generating 4.2 MW of electricity. The gas turbine is a single-shaft industrial unit. The fuel supply system, fuel injectors and the combustors have been redesigned to suit the low calorific value gas (5 MJ/nm^3).

The hot flue gas from the gas turbine is ducted to the heat recovery steam generator (HRSG), where the steam generated, along with steam from the gas cooler, is super-heated and then supplied to a steam turbine (40 bar, 455°C), generating 1.8 MWe.

The plant is equipped with a flare on the roof of the gasification building, which is used during start-up procedure and when testing less well known conditions, in order to protect the gas turbine.

Operation Experience

CONSTRUCTION PHASE OF THE DEMONSTRATION PLANT

The construction period lasted from September 1991 until March 1993.In general the construction went very smoothly, although delays occurred during the gasification plant design stage. This resulted in delays in other parts of the project due to lack of documentation or the fact that the documentation was only provisional and was subsequently modified. However, the construction phase was finally according to time schedule and within the budget.

COMMISSIONING AND DEMONSTRATION PHASE

Commissioning of the combined cycle was completed on liquid fuel in March 1993. The first gasification test on wood at low pressure was performed in June 1993, and combustible gas was produced and burned in the flare. It should be remembered that at the time for commissioning of the gasifier, no experience existed from any biomass gasifiers at this pressure level.

Accordingly, during tests with different bed materials, temperatures and pressure levels, deposits sometimes occurred. Deposits and fouling have verified the importance of carefully controlling the process as well as ensuring a suitable design of components. During the Demonstration Programme, magnesite (MgO) has been used as bed material in the Värnamo gasifier, and this has proved very successful. As magnesite is more expensive than e.g. dolomite, tests were carried out to check feasibility of re-circulation of bottom ash and these proved very successful.

Apart from this, already during the early design stage, in particular two areas were of great concern, namely the gas clean-up and the gas quality.

Originally a hot gas filter of the ceramic type was installed. This filter consisted of ceramic filter candles arranged in six groups with separate back-pulsing. The ceramic filter showed good filtration efficiency, with stable pressure drop. However, after more than 1200 hours of troublefree operation suddenly two ceramic candles broke. The difficulty to detect a relatively small failure in a hot gas filter was then noticed in practice even though no serious damage was caused. To protect the gas turbine in case of a hot gas filter break-down a metallic police filter has been installed down-stream of the main filter. The complete set of candles with a new design was installed, but after about 350 hours one of these candles broke. The reason was established to be caused by mechanical fatigue and chemical attack was excluded. Nevertheless, measurements inside the pipe as well as in pipe work and steel structure have verified the vibrations to be very low.

During the summer 1998 it was decided to install metal filter candles instead of the ceramic candles in the main hot gas filter. The metal filter candles are installed in the original filter vessels but with a new tube sheet and back-pulsing arrangement.

The metal filter has, like the ceramics, shown very good filtration efficiency, with stable pressure drop. This filter has now been in operation for more than 2500 hours without any filter breakage or other damage during operation. Investigations carried out after the end of the last test indicate that there is no degradation of these elements although they have been exposed to gas and ash not only from wood chips but also from RDF and straw.

During the commissioning as well as the demonstration programme the gas quality has been checked regularly. The gas quality has regarding hydrogen content turned out to be slightly lower than predicted, but the heating value has been maintained by an increase in methane.

A typical range of dry gas composition is specified below.

CO	H2	CH4	CO2	N2
16-19%	9.5-12%	5.8-7.5%	14.4-17.5%	48-52%

Percentage in above table is by volume and gas heating values in the range of 5.0 - 6.3 MJ/m3n have been recorded.

Different operating conditions in the gasifier as well as a change of fuel produce different amounts of light tars and benzene as can be seen in the table below. Bark tends to produce less benzene and tars than ordinary wood chips.

Fuel	Benzene mg/m^3n	Light tars, mg/m^3n
Bark 60% and forest res. 40%	5000 - 6300	1500 - 2200
Pine chips	7000 - 9000	2500 - 3700

During almost all tests it has been general practice to measure not only main gas constituents, but also benzene and light tars. An interesting correlation between the amount of light tars and benzene in the product gas has been noticed.

PLANT PERFORMANCE

The accumulated operating experience amounts to about 8500 hours of gasification runs and about 3600 hours of operation as a fully integrated plant as per the end of 1999. The test runs have been very successful and the plant has been operated on different wood fuels as well as straw and RDF. One of the last tests included operation on 100% straw, which was accomplished without disturbances or problems.

Statements of the Customer and Planning Company

The Vaernamo Demonstration project was very successful and many important results were achieved. It is seldom that development projects of this kind are kept within budget and time schedule, but it was done in Vaernamo. The plant has been mothballed since 1999 when the test programme was concluded. Under the present market situation in Sweden is it not possible to operate the plant on commercial basis. However, a restart of the facility looks promising today and there are ongoing discussions to make use of the plant for further R&D work. The focus today is on waste fuels for power production and synthesis gas production in order to demonstrate alternative transportation fuels.

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