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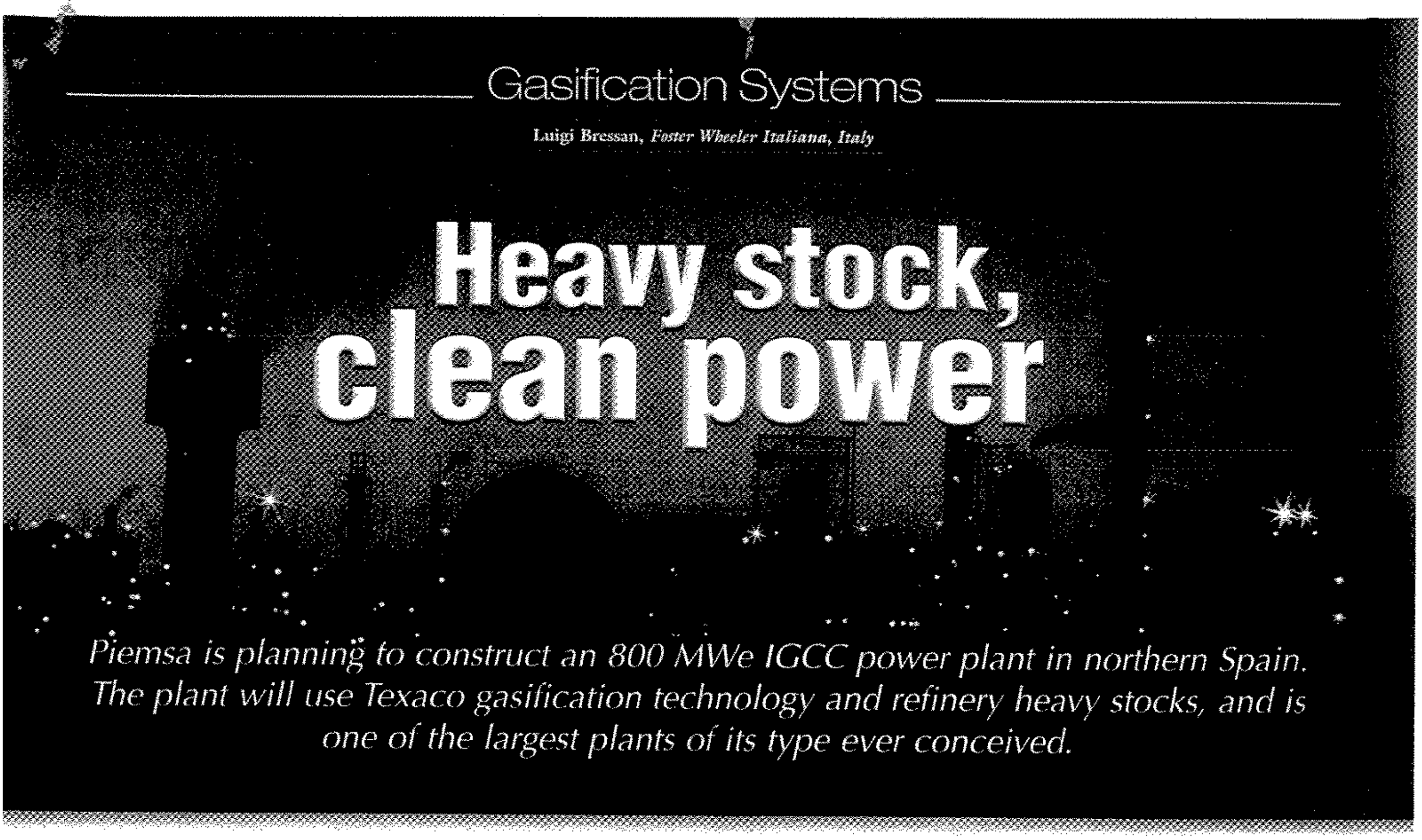
Heavy stock, clean power



Piemsa is planning to construct an 800 MWe IGCC power plant in northern Spain. The plant will use Texaco gasification technology and refinery heavy stocks, and is one of the largest plants of its type ever conceived.

Piemsa, an affiliate of Repsol-YPF-owned Petronor, is to build an integrated gasification combined cycle (IGCC) complex at a refinery near Bilbao in the Basque region of Spain.

The IGCC complex will process refinery heavy stocks to produce electric power as well as hydrogen to be used in the refinery. The expected capacity (800 MWe net) will make this plant the one of the biggest of its kind ever conceived.

Feasibility studies have demonstrated the viability of the project and the basic design has been completed including the technical definition of the IGCC configuration.

Fuel oil conundrum

Presently Petronor runs a refinery which produces gasolines and diesel oils as well as some residual fuel oil; the average fuel oil production accounts for 25 per cent of the overall refinery production.

Part of the fuel oil is used to sustain combustion in the refinery furnaces while the rest is sold for ships bunkering and to power stations.

The quality and quantity of fuel oil produced is heavily dependent on the quality of crude processed. Cheaper crudes are normally the heaviest and have the highest sulphur content, and on the international market crudes are becoming heavier.

However, environmental constraints and the increased popularity of natural gas as a fuel in power generation has caused the fuel oil market to shrink. It therefore became an urgent strategic problem for the Petronor refinery to find an alternative way of disposing of its fuel oil.

The refinery examined several options but decided that the construction of an IGCC power plant would be the most cost-effective. It will allow the refinery to dispose of almost all of its fuel oil in spite of crude quality variation, and produce electric power.

A complex project

The heavy oil IGCC complex is designed to be a multi unit complex to process, in an environmentally acceptable manner, the high sulphur by-products of the Petronor refinery and produce power and hydrogen. The power will be delivered to the distribution grid while hydrogen will be returned to the Petronor refinery to upgrade refinery oil products.

Additional products of the IGCC complex will be sulphur and metal concentrate, both of which are saleable.

Process units: The process units of the IGCC complex are designed to process the following feedstocks at the nominal design capacity of 195 t/h:

- Design feed: Visbroken Vacuum Residue (VVR) with 5.5 per cent wt sulphur
- Alternative feed: 85 per cent VVR and 15 per cent decanted oil.

Gasification unit: The gasification unit is based on two trains, operating in parallel with two Texaco quench type gasifiers. The gasification reactions are conducted with oxygen, with steam used as a temperature moderator.

High pressure gasification reactors (64 barg) have been selected for the project. The syngas produced is quenched with water inside the gasifiers and then routed to a venturi scrubber followed by a scrubbing tower, adequately sized to remove solid particles originating from unreacted carbon, ashes and metals present in the feedstock.

The syngas temperature at the reactor chambers outlet is approximately 1400°C; the syngas temperature at the scrubber outlet is approximately 240°C and the water content close to 60 per cent (vol.).

The syngas components are H_2, CO, CO_2, H_2O, H_2S, COS, CH_4, and Ar/N_2.

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The black water from the bottom of the gasifiers is sent for treatment to recover any unreacted carbon and eliminate ash and metals.

The first step of black water treatment is soot extraction where unreacted carbon is extracted and recycled back to the gasification reactors. Recycle is achieved by contacting the black water with naphtha and

Table 1. IGCC plant operating performance at design capacity and reference conditions

Feedstock	
Vacuum Visbroken tar, 5.5% S (t/h)	195
Products	
Gross power output (MWe)	935.4
Net power output (MWe)	785
Hydrogen production (Nm³/h)	21500
Sulphur production (t/day)	257.4
Metal cake production (t/h at 50% humidity)	0.97
Overall efficiency (%, LHV)	42

separating the oily phase from the water.

The naphtha stream is then mixed with an adequate portion of the gasification feedstock and then the mixture of carbon-naphtha-heavy oil is sent to a stripper to recover naphtha while the gasification feedstock with the unreacted carbon is routed to the gasification reactors, thus achieving 100 per cent conversion of carbon to syngas.

Table 2. IGCC performance on natural gas fuel

Natural gas consumption (Nm^3/h)	141,500
Net Electric Power production (MW)	784
Overall Net Efficiency (%, LHV)	52.4

After carbon recovery, most of the water (grey water) is recirculated to the syngas scrubber as scrubbing water, while the rest of grey water is sent for metals recovery.

Syngas conditioning units: Raw syngas from the scrubbing section of the gasification unit is processed in the syngas treatment and conditioning unit to purify the syngas to be fed to the combined cycle.

Raw syngas cooling is achieved as follows:

- By generating steam: medium pressure (MP) at 19 barg, low pressure (LP) at 6.5 barg, and very low pressure (VLP) steam (3.2 barg)
- By preheating the condensate coming from the steam turbine condenser
- By water cooling.

Most of the LP steam is delivered to the power island; a portion of LP steam, together with all of the MP and VLP steam, is used as a heating medium in the process units.

The condensate, separated from the raw syngas during the cooling process, is returned back to the gasification unit as scrubbing water.

The purification consists of selective sulphur removal by means of a monodiethanolammine (MDEA) solution. The absorption reaction takes place at ambient temperature and is limited to H_2S with a minor quantity of CO_2. The syngas, before MDEA absorption, is passed through a hydrolysis reactor to convert the COS into H_2S.

turbine and then preheated to 135°C using waste heat.

Air separation units (oxygen plants): The oxygen required both for the gasification reaction and the sulphur recovery process is produced in the oxygen plant where air is fractionated by cryogenic distillation.

The oxygen plant is partially integrated with the power island. In fact a portion of the compressed air (30 per cent) required by the oxygen plant is delivered directly from the gas turbine compressors.

Two units operating in parallel will each have a capacity equal to 50 per cent of the required oxygen amount. Liquid oxygen storage equipped with the required facilities allows the operation of the IGCC for a limited time at its design capacity even if one oxygen plant unit is out of service.

Nitrogen is also coproduced in the oxygen plant in gaseous and liquid form: gaseous nitrogen is compressed to feed the gas turbine to reduce NO_x emissions and increase power output: liquid nitrogen is used for emergency purging of the gasifiers and for back up of LP nitrogen distribution.

Power island

Clean syngas will be fed to the power island. It will be fired in two gas turbines which are connected to two heat recovery steam generators (HRSGs) and one steam turbine.

The gas turbines will burn almost all of the syngas; a post-combustion system in the HRSGs will burn the pressure swing absorption (PSA) off-gas coming from the hydrogen production and the treated gas produced by the acid gas enrichment and any excess.

Nitrogen is used to dilute the syngas to reduce NO_x emissions and to improve the gas turbines' power output.

The power island will be integrated with the process units to increase the overall efficiency of the complex; HP steam will be exported to the gasification reactor while the recovered LP steam will be processed in the combined cycle. Cold condensate will be preheated within the syngas cooling train and in other process units.

The gas turbines will also be able to operate with natural gas when syngas production is down and for startup purposes, and even in cofiring mode (syngas plus natural gas) in case of syngas shortage.

Piemsa has decided to opt for two GE Frame 9FA gas turbines for the project.

The IGCC design takes into account the operation at different ambient temperatures. In spite of the fact that the gas turbines of the combined cycle are sensible to the air temperature, the operating configuration selected allows an almost constant power output through ambient temperature range in the area.

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A small part of clean syngas is then processed through membranes to recover hydrogen, and the permeated hydrogen rich gas is sent to a pressure swing absorption unit for hydrogen purification. The hydrogen produced at a pressure of 21 barg and with a purity of 99.8 per cent is sent to the refinery.

The clean syngas, after partial H_2 separation, is ready to be fed at high pressure to the power island, but to improve the energy recovery it is expanded down to the minimum pressure required by the gas turbine and then preheated to 135°C using waste heat.

Environmental impact

IGCC technology is considered to be a clean technology for power production, no matter how much sulphur is contained in the feed.

The continuous gaseous effluents from the complex are the flue gases from the power block. The expected flowrates and contaminant concentrations of these continuous gaseous effluents, at design capacity, are given in Table 3.

The sulphur removal efficiency of the IGCC – the ratio between recovered liquid sulphur and sulphur in the feedstock – is 98.7 per cent at design conditions while the expected figure is 99.5 per cent.

The NO_x concentration in the flue gas from the combined cycle is achieved by nitrogen injection into the gas turbine, without the need of catalytic $DeNO_x$.

Table 3. Expected gaseous emissions from the IGCC plant at design capacity

	Design	Expected
Flow (Nm^3/h)	6 203 200	6 203 200
NO_x (mg/Nm^3)	<75	60
SO_2 (mg/Nm^3)	<45	15
CO (mg/Nm^3)	<100	30
Particulates (mg/Nm^3)	<10	5

Note: Flowrate and concentrations are referred to flue gas dry and 15% O_2.

The site

The IGCC complex will be erected near the Petronor refinery in Bilbao area, in the Basque region of Spain. The site is located southeast side of the refinery.

The total area foreseen for the IGCC complex is 277 000 m^2; the process units area, slope access roads, internal roads, area for the construction of temporary facilities and the spare area have been considered.

The plant is located in a hilly area and the soil preparation requires extensive earth movement estimated to be about 1.5 million m^3.

An investment cost estimate (accuracy ±10 per cent) has been prepared for the Piemsa IGCC complex project. The total investment cost calls for €1.1 billion ($967 million).

This figure is made up as follows: process units including oxygen plants – 35 per cent; combined cycle unit, including high voltage switchgear – 33 per cent; utilities and offsites – 20 per cent; escalation and owner cost – 12 per cent.