“ The 800 MW PIEMSA IGCC Project”

J.Basabe – Repsol YPF
L.Bressan – Foster Wheeler Italiana
L.O’Keefe – Texaco Power and Gasification

ABSTRACT

PIEMSA, an affiliated company of Petronor, one of the companies of the Repsol YPF group, are planning to build an IGCC complex adjacent to the Petronor Refinery in Bilbao area, in the Basque region of Spain.
The IGCC complex will process refinery heavy stocks to produce electric power and hydrogen to be used in the Refinery for hydrogenation purposes. The expected capacity will make this plant the biggest power plant of this type ever conceived. Feasibility studies have demonstrated the viability of the project and the Basic Design has been completed with the complete definition of the IGCC configuration from the technical point of view. In this paper an indication of the reasons why Petronor decided to implement this project, a description of the project with most meaningfull information will be given with some indication on next implementation steps.
The estimated start-up date for this project is the second half of 2005.

1. INTRODUCTION

Presently Petronor runs a refinery with an operating configuration oriented to the production of gasolines and diesel oils with a certain amount of residual fuel oil; the average fuel oil production accounts for 25 % of the overall refinery production. The quality and quantity of fuel oil produced is heavily dependent from the quality of crude processed.
Nowadays the fuel oil production is partially used to sustain the combustion in the refinery furnaces and mostly sold to the market mainly for ships bunkering and combustion in power stations.
The environmental constraints and the request to have more efficient power stations (natural gas combined cycles are preferred versus conventional fuel oil power stations) cause the shrinking of the fuel oil market available to the Refinery.
Additionally cheaper crudes are normally the heaviest with the highest sulphur content. The processing of cheaper crudes increases the fuel oil slate in the Refinery production scheme.
More, it has been recognized on the international market a non reversible trend for crudes to become heavier.
It became an urgent strategical problem for the Refinery to find alternative routes to dispose the fuel oil production.
Several options were available and the one that better fitted the requirements was the IGCC with the aim to dispose almost all fuel oil in spite of quality variation of crudes processed and produce electric power instead of selling fuel oil to thermal power station.

The solution is globally environmentally beneficial, in fact the control of the combustion emissions is more efficient in an IGCC than in a conventional power station.

2. IGCC COMPLEX DESCRIPTION

The heavy oil Integrated Gasification Combined Cycle (IGCC) Complex is a multi unit complex, designed to process, in an environmentally acceptable manner, the high sulfur by-products of the adjacent Petronor Refinery and produce electric energy and hydrogen. The electric energy 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 are sulphur and metal concentrate; both these products are saleable. Sulfur will be shipped in solid form for use by the chemical industry. The metal concentrate will be sold to the smelting industry for the recovery of the contained vanadium.

The IGCC Complex includes the following units (the number of parallel trains is indicated with their relative design capacity):

Process Units	
Oxygen Plant	(2 x 50%)
Gasification	(2 x 50%)
Soot Extraction	(2 x 50%-1 x 100%)
Grey Water Treatment	(1 x 100%)
Syngas Treatment and Conditioning line	(2 x 50%-1 x 100%)
AGR Solvent Regeneration and Acid	
Gas Enrichment	(1 x 100%)
Sulfur Recovery with Tail Gas Recycle	(2 x 80%)
Hydrogen Production	(1 x 100%)
Power Island	
Gas Turbines	(2 x 50%)
Heat Recovery Steam Generators	(2 x 50%)
Steam Turbine	(1 x 100%)
Electrical Power Generation	
Utilities Units	
Offsites Units	

The description reported below should be read in conjunction with the attached block flow diagram of the Complex.

2.1 PROCESS UNITS

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

- Design feed: Visbroken Vacuum Residue (VVR) with 5.5% wt S
- Alternative feed: 85% VVR and 15% Decanted Oil

The Gasification is also suited to process an additional small stream of biological and oily water sludges coming from the Refinery and from the IGCC Waste Water Treatment.

2.1.1 Gasification related Units

The Gasification Unit is based on two trains, operating in parallel including two Texaco quench type gasifiers, which assure superior reliability when compared to the waste heat recovery type.

The gasification reactions are conducted with oxygen, in presence of steam as temperature moderator.

High pressure gasification reactors have been selected (64 barg). 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 originated by 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 scrubbers outlet is approx. 240°C and the water content close to 60% (vol.).

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

The black water from the bottom of gasifiers is sent to the treatment for the recovery of unreacted carbon and elimination of ashes and metals.

The first step of black water treatment is the 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 separating the oily phase from the water. Carbon soot having more affinity with the oily phase, migrates to the naphtha stream.

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

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 delivered to the chemical treatment for metals recovery.

The chemical treatment of the grey water blowdown is based on precipitation, settling and filtration of the solid particles (ashes and metals) and stripping of ammonia before releasing the water to the biological waste water treatment of the Complex.

2.1.2 Syngas Conditioning Units

The raw syngas from the scrubbing section of the gasification unit is processed in the syngas treatment and conditioning, to purify the syngas to be fed to the combined cycle.

The raw syngas cooling is achieved as follows:

- by generating steam: MP (19 barg), LP (6.5 barg) and VLP steam (3.2 barg);
- by preheating the condensate coming from the steam turbine condenser;
- by water trim cooling.

Most of the LP steam is delivered to the Power Island; a portion of LP steam, together with the entire amount of MP and VLP steam, is used as heating medium in the process units.

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

The purification consists of the selective sulfur removal by means of a 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.
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% is sent to the Refinery.
The clean syngas, after partial H_2 separation, at high pressure is ready to be fed 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 up to 135°C using available waste heat.

2.1.3 <u>Sulphur Recovery Units</u>

The MDEA rich solution coming from the absorption tower is expanded in a hydraulic turbine to recover power to pump the lean MDEA stream to the absorption tower. The rich MDEA solution is, then, flashed, raised in temperature and stripped in a regeneration tower to free the contained H_2S and CO_2. The lean MDEA before starting again the absorption step is cooled down to ambient temperature and partially treated to remove the heat stable salts that are not regenerated in the stripping tower. The accumulation of heat stable salts (namely oxalates, tyocianites, formiates, etc...) must be avoided because they reduce the MDEA solution activity. The control is achieved by treating a slipstream of amine solution in a special ion-exchange unit which captures and eliminates the anions of the heat stable salts.
The H_2S rich stream from the MDEA Regenerator flows to the Acid Gas Enrichment Section. This section utilizes a special amine solvent, suitable to capture, at low pressure, the H_2S selectively, with minimum absorption of CO_2.
The H_2S rich stream coming from the MDEA Regenerator is scrubbed, with this solvent, in the enrichment absorber; the emerging CO_2 rich gas stream goes to postcombustion in the Heat Recovery Steam Generators, while the amine rich solution is regenerated in a stripping tower delivering acid gas, with high H_2S concentration (approx. 70% conc.), to the Claus Unit , and lean solvent solution recycled back to the enrichment absorber.
The enrichment absorber also treats the Claus tail gas, after hydrogeneration and recompression.
In the sulfur recovery unit the H_2S rich stream is burned in the presence of oxygen in a muffle furnace followed by two reactors in series where the Claus reaction takes place to produce liquid sulfur.
The muffle furnace is also used to treat sour gas and ammonia from the water flash separators, naphtha stripper, ammonia stripper and sour water stripper. Due to the level of maintenance required by the sulfur units it has been decided to install two units, each sized for 80% of sulfur contained in the gasification feedstock, operating in parallel, both able to pick up a maximum load when the other one goes out of service.
The tail gas from Claus unit is processed in a tail gas treatment unit where the SO_2 present is completely converted to H_2S by catalytic hydrogenation. The treated tail gas is compressed and sent to the Acid Gas Enrichment, as described before.

2.1.4 Air Separation Units (Oxygen Plants)

The oxygen required both for the gasification reaction and the Claus reaction 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%) required by the Oxygen Plant is delivered directly from the gas turbine compressors.
Two units operating in parallel have been foreseen each having a capacity equal to 50% of the required oxygen amount. A 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 both a gaseous and liquid form; gaseous nitrogen is compressed to feed the gas turbine to reduce NOx emissions and increase power output. Liquid nitrogen is produced to constitute a holdup to be used for emergency purging of the gasifiers and for back up of LP nitrogen distribution.

2.2 POWER ISLAND

The clean syngas produced in the gasification section and syngas treatment is fed to the Power Island.
Two gas turbines followed by two heat recovery steam generators and one steam turbine have been provided to convert syngas thermal power to electric energy.
The gas turbines burn almost all the syngas produced; a postcombustion system, foreseen in the heat recovery steam generators, burns the PSA off-gas coming from the Hydrogen Production and the treated gas produced by the Acid Gas Enrichment and excess (if any).
Nitrogen is used to dilute the syngas to obtain reduced NOx emission and to improve the gas turbines power output up to their maximum limit.
The Power Island is accurately integrated with the process units in order to increase the Complex overall efficiency; high pressure steam is exported mainly to the gasification reactor while the recovered low pressure steam is processed in the combined cycle and cold condensate is preheated within the syngas cooling train and in other process units.
The gas turbines can also 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.

2.3 UTILITIES AND OFFSITES UNITS

Several service units are foreseen to operate the Complex.
Cooling water for use in the steam turbine condenser and for Oxygen Plant users is once through sea water pumped from a sea water intake installed in the Refinery harbour. The return to the sea is located out of the Refinery harbour paying attention to avoid interference between the discharge and the sea water intake.
Circulating conditioned sweet water, cooled by sea water, is used as cooling stream for machinery cooling and process users.

Demineralized water system, condensate recovery system, plant and instruments air system, auxiliary fuels systems and firefighting are the other utilities units.
The IGCC Complex includes also a flare system to dispose hazardous gases during emergencies and misoperations.
Other major auxiliary systems of the Complex are:

- liquid sulphur solidification and storage;
- metal cake handling and storage;
- electrical distribution;
- step-up transformers and connections to the grid.

3. TEXACO QUENCH GASIFICATION TECHNOLOGY

Detailed studies for this project were performed in 1998 by Texaco, comparing the use of a syngas cooler boiler design (higher efficiency, higher capital and operating costs) vs. a water quench design (lower efficiency, offset by lower capital costs and higher expected hours of operation). Studies confirmed that along with these benefits using a quench design, only two quench gasification trains would be required, vs. the possible need for four syngas cooler gasification trains, at the higher capital cost. Texaco have commercial experience using heavy oil feedstocks in both quench and syngas cooler designs. The fundamental premise for this project is that it must compete on a delivered electricity cost basis with both competing fuels and technologies in Spain. The Texaco quench gasification technology was selected by PIEMSA for this project in March 1999, with the engineering design basis completed and basic engineering work beginning in September 1999.

4. IGCC COMPLEX PERFORMANCES

The IGCC Complex performances can be summarized as follows when the Complex is operating at design capacity and at reference conditions:

Feedstock		
Vacuum Visbroken tar (5.5% S)	195	t/h
Products		
Gross power output	**935.4**	**MWe**
Net power output	783.9	MWe
Hydrogen production	21500	Nm^3/h
Sulphur production	257.4	t/day
Metal cake production (@ 50% humidity)	0.97	t/h
Overall IGCC gross efficiency (LHV)	46.3	%
Internal power consumption	150	MW
Overall IGCC net efficiency (LHV)	42	%
Combined cycle overall gross efficiency	60.1	%
Gas turbine efficiency	39.2	%
Combined cycle overall net efficiency	58.8	%

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.

The Combined Cycle of the IGCC can be operated with natural gas when the gasification section is down; in this case the performances are:

Natural gas consumption	141,500	Nm^3/h
Net Electric Power production	788	MW
Combined Cycle Efficiency	52.4	%

On a yearly basis the following performances can be anticipated:

Vacuum Visbroken tar (5.5%S) consumption	1,536,000	t
Natural gas consumption	28,000,000	Nm^3
Hydrogen production	169,420,000	Nm^3
Electric power production	6,294,000	MWh
Sulphur production	84,500	t
Metal cake production (@ 50% humidity)	7,600	t

The above yearly performance has been calculated taking into account the expected equivalent availability of the IGCC.
Calculations developed on the basis of R.A.M. (Reliability, Availability, Maintainability) methodology have indicated that expected operation with the syngas production line in service can be accounted for 7880 hours, while the natural gas operation of the Combined Cycle can be expected for 148 hours.

5. ENVIRONMENTAL IMPACT

IGCC technology is by far the cleanest technology for power production, no matter how much sulphur is contained in the feed.

5.1 GASEOUS EMISSIONS

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 the following table:

Expected		Design	
Flow	Nm^3/h	6,203,200	6,203,200
NOx	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 sulphur removal efficiency of the IGCC, intended as the ratio between recovered liquid sulphur and sulphur in the feedstock is 98.7% at design conditions while the expected figure is 99.5%.
The NOx concentration in the flue gas from the Combined Cycle is achieved by nitrogen injection into the gas turbine, without the need of catalytic DeNOx.

5.2 LIQUID EFFLUENTS

The major continuous process liquid effluent is the water blowdown from the quench gasification. The water is subject to the following sequence of treatment.

- extraction: for soot removal
- chemical: precipitation of ash/metal
- stripping: dissolved gas removal
- biological: BOD reduction

In addition boiler water blowdown, the discharges from demiwater resins regeneration, discontinous stripped waters, possibly contaminated oily water and sanitary waters are treated in the Waste Water Treatment plant.
The characteristics of the final effluent are:

- Flow	270 m^3/h max
- COD	< 70 mg/l
- TSS	< 30 mg/l
- Total Hydrocarbons	< 10 mg/l
- Total Nitrogen	< 30 mg/l
- Total Toxic Metals	< 1 mg/l

5.3 SOLID WASTES

No solid wastes are produced in the IGCC Complex.

6. THE SITE

The IGCC Complex will be erected nearby Petronor Refinery in Bilbao area, in the Basque region of Spain. The site is located southeast side of the Petronor Refinery and is at an average elevation of 50 mt. above sea level.
The total area foreseen for the IGCC Complex is 277.000 m^2; process units areas, slope access roads, internal roads, area for construction temporary facilities and spare area have been considered.
The plant is located in a hilly area and the soil preparation requires extensive earth movement; the expected earth movement is calculated in about 1,500,000 m^3.
While the site is optimal for interconnection with Petronor Refinery, the cooling water supply has required an extensive optimization study. A specialized Consultant has been selected with the aim to define the most adequate way to bring sea water to the site. Final solution is to provide a tunnel, excavated with an optimized routing inside the hills between the sea shore and IGCC site, in order to take the sea water up to the site; after cooling service a calm collection basin is foreseen and then under gravity flow a second excavated tunnel will drive back the water to the sea in a suitable discharge

point. The tunnels are approx. 5 km long while their diameter is around 3.6 m. In the sea water return system, close to the sea, a hydraulic turbine is foreseen to recover the static head available between the calm basin and the sea water level. The proposed solution will permit an environmentally friendly use of sea water.

7. INVESTMENT COST

An investment cost estimate (accuracy ± 10%) has been prepared for the IGCC Complex project.
The total investment cost calls for:

1,100,000,000 Euros

The total investment cost figure is made up as follows:

Process Units including Oxygen plants	35	%
Combined Cycle Unit, incl. HV swtgr.	33	%
Utilities and Offsites	20	%
Escalation and Owner Cost	12	%
Overall Total	100	%

The following numbers that were used in making up the estimate are reported with the aim to brief about the job size.

-	Earth movement:	1,500,000	m^3
-	Detailed Engineering Manhours:	1,350,000	h
-	Construction Supervision Manhours:	450,000	h
-	Total Construction Manhours:	6,500,000	h

8. REFERENCES

This paper makes reference to a similar presentation made during S.Francisco Gasification Conference in year 2000 and to a paper issued in Hydrocarbon Engineering in April 2001.
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