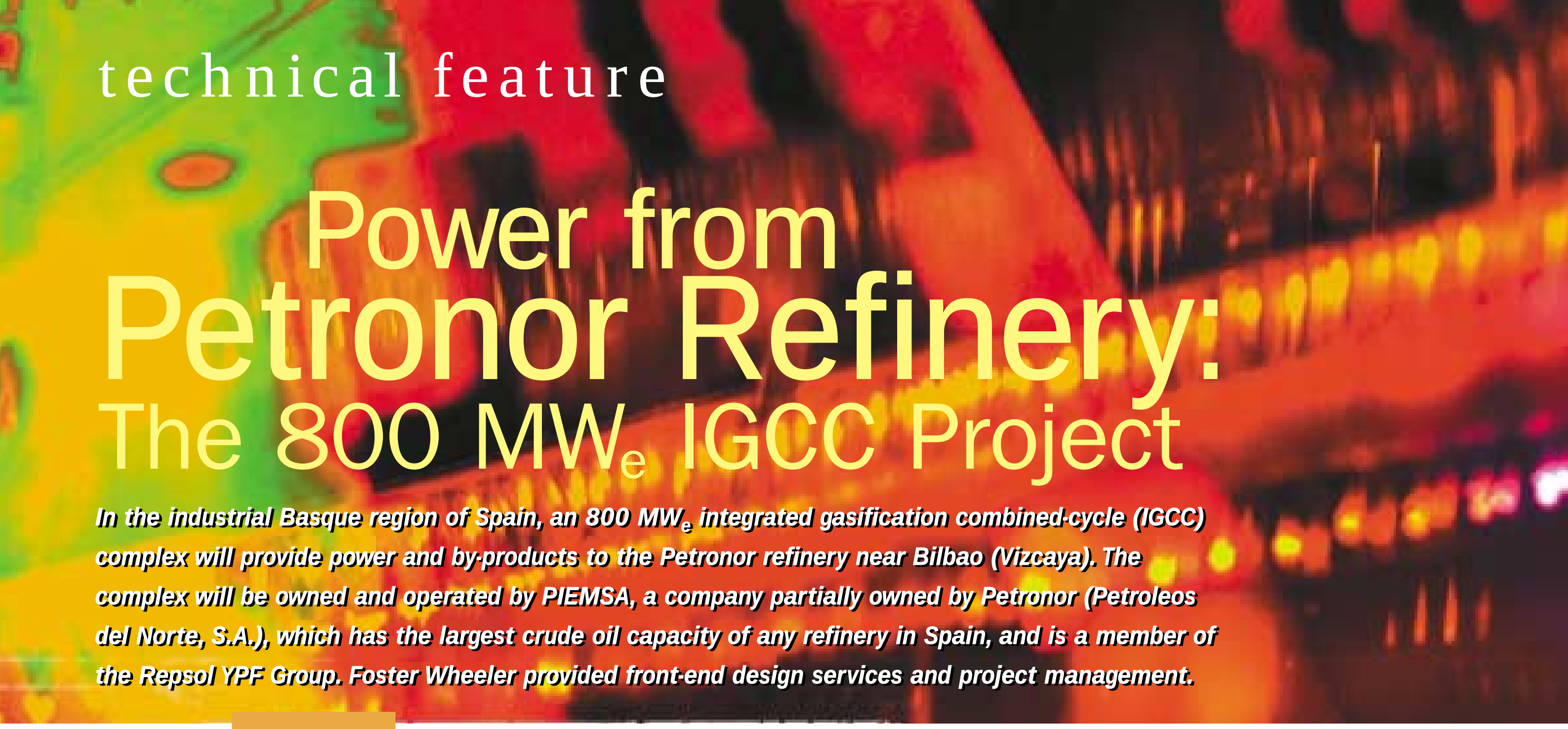

technical feature

Power from Petronor Refinery:

The 800 MW$_e$ IGCC Project

In the industrial Basque region of Spain, an 800 MW$_e$ integrated gasification combined-cycle (IGCC) complex will provide power and by-products to the Petronor refinery near Bilbao (Vizcaya). The complex will be owned and operated by PIEMSA, a company partially owned by Petronor (Petroleos del Norte, S.A.), which has the largest crude oil capacity of any refinery in Spain, and is a member of the Repsol YPF Group. Foster Wheeler provided front-end design services and project management.

The PIEMSA IGCC complex will process refinery heavy stocks to produce electric power for export and internal use, as well as hydrogen to be used in the refinery for hydrogenation. "The expected capacity will make this plant the biggest power plant of this type ever conceived," says Luigi Bressan, technical director, Power division, Foster Wheeler Italiana. "Feasibility studies have demonstrated the project's viability, and the IGCC configuration's basic design has been defined technically."

Petronor's current refinery-operating configuration is oriented toward producing gasolines and diesel oils with a certain amount of residual fuel oil. The average fuel oil production accounts for 25 percent of overall refinery production. The quality and quantity of fuel oil produced, however, depends heavily on the quality of crude processed.

"Nowadays, the fuel-oil production is used partly to sustain combustion in refinery furnaces, and is mostly sold to the market, mainly for ships' bunkering and combustion in power stations," says Bressan. "Environmental constraints and the quest for more efficient power, however, have led to a preference for natural gas combined cycles, instead of the old fuel-oil power stations. As a result, the fuel-oil market available to the refinery is shrinking."

Cheaper crudes are normally the heaviest, with the highest sulfur content. Processing these crudes increases the fuel-oil slate in refinery production. "Internationally, a non-reversible trend for heavier crudes is underway," notes Bressan. "The refinery needed to find alternative routes for disposing of fuel-oil production."

Several options were available, and the one that fit best was IGCC. "The goal is to dispose of almost all fuel oil, despite quality variation among crudes processed, and produce electric power instead of selling fuel oil to thermal power stations." The solution benefits the environment globally. "In fact, control of combustion emissions is more efficient in an IGCC than in a conventional power station," notes Bressan.

The IGCC Complex

The heavy oil IGCC multi-unit complex is designed to process, in an environmentally acceptable manner, the high sulfur by-products of the adjacent Petronor refinery while producing electric energy and hydrogen. The electric energy will be delivered to the distribution grid, while hydrogen will be returned to the Petronor refinery for upgrading its oil products.

Additional IGCC-complex products are sulfur and metal concentrate, which can both be sold. Sulfur will be shipped in solid form for chemical-industry use. Metal concentrate will be sold to the smelting industry for recovering contained vanadium.

The Process Units

The IGCC-complex process units are designed to process 195 metric tons per hour (t/h) of visbroken vacuum residue (VVR) with a sulfur content of 5.5 percent by weight. Gasification can also process an additional small stream of biological and oily-water sludges from the refinery, as well as from IGCC waste-water treatment.

Gasification-Related Units

"The gasification unit is based on two trains operating in parallel, including Texaco quench-

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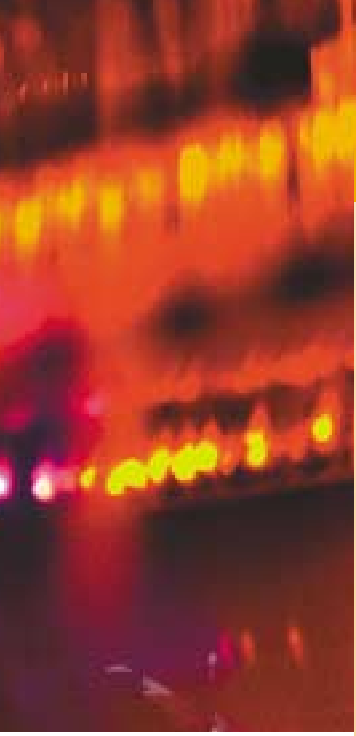

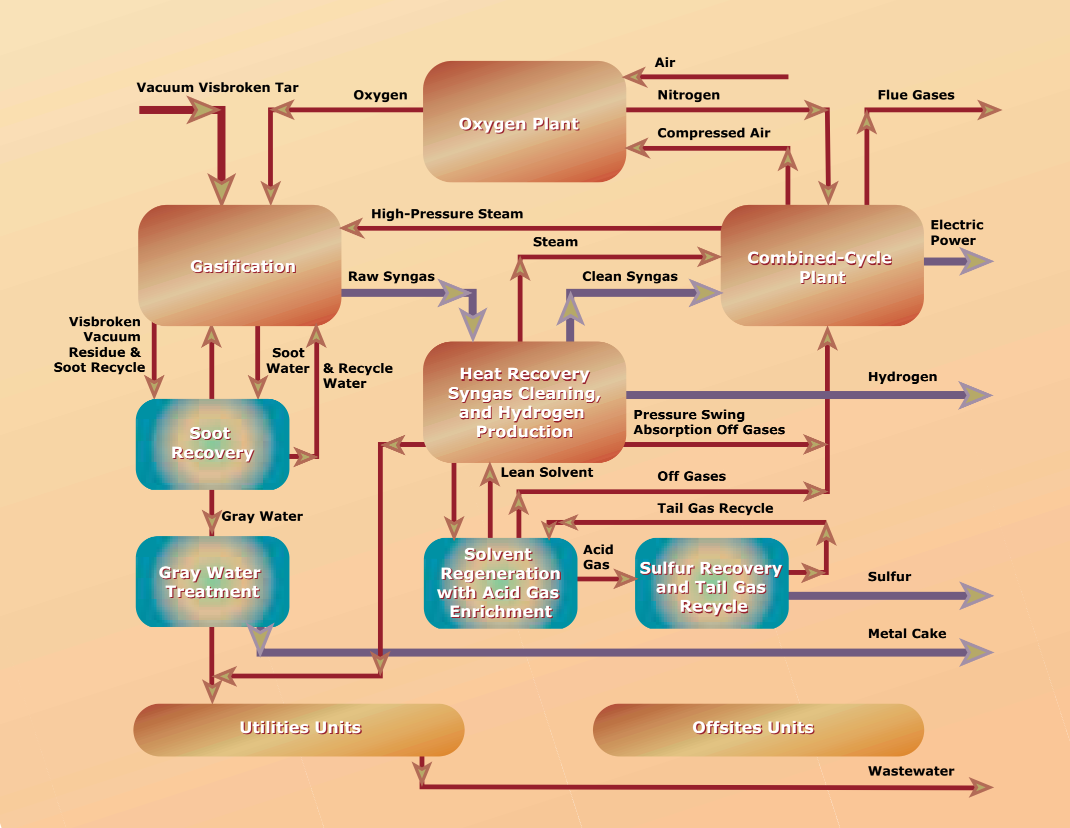

Figure 1. **The 800 MW PIEMSA IGCC Project**

type gasifiers, which assure superior reliability when compared to the waste-heat-recovery type," says Bressan. Gasification reactions are conducted with oxygen, with steam serving to moderate temperature.

High-pressure, 64 barg (i.e., 928 pounds per square inch gauge, or psig) gasification reactors have been selected for the unit. 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 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 the scrubbers outlet, around 240°C, and the water content, close to 60 percent by volume." The syngas components are H_2, CO, CO_2, H_2O, H_2S, COS, CH_4, and Ar/N_2.

The black water from gasifier bottoms is treated to recover unreacted carbon and eliminate ashes and metals. "The first step of black-water treatment is extracting soot, where unreacted carbon is extracted and recycled back to the gasification reactors." This recycling is achieved by contacting the black water with naphtha and separating the oily phase from the water. Carbon soot with more affinity to the oily phase migrates to the naphtha stream.

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

After carbon recovery, most of the water (now gray) is recirculated to the syngas scrubber as scrubbing water. The remaining gray water is delivered to chemical treatment for metals recovery. The water is then released to a biological wastewater treatment complex.

Syngas Conditioning

Raw syngas from the gasification-unit scrubbing section is processed in the syngas treatment and conditioning unit. The purified syngas is then fed to the combined cycle.

The raw syngas is cooled by generating steam, and by preheating the condensate coming from the steam-turbine condenser. Most steam is delivered to the power island. A portion

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

Purification takes place when selective sulfur is removed by means of a mono-diethanolamine (MDEA) solution. “The absorption reaction takes place at ambient temperature, and is limited to H_2S, with a minor quantity of CO_2,” says Bressan. 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. This permeated, hydrogen-rich gas is sent to a pressure swing absorption (PSA) unit for hydrogen purification. The hydrogen produced – at a pressure of 21 barg (304 psig) and with a purity of 99.8 percent – is sent to the refinery.

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

Sulfur Recovery

The MDEA-rich solution coming from the absorption tower is flashed, raised in temperature, and stripped in a regeneration tower to free the contained H_2S and CO_2. Before again starting the absorption step, the lean MDEA is cooled to ambient temperature, and is partially treated to remove the heat-stable salts that are not regenerated in the stripping tower.

“Accumulation of heat-stable salts, such as oxalates, tyocianites, and formiates, must be avoided since they reduce MDEA-solution activity,” says Bressan. Control is achieved by treating a slipstream of amine solution in a special ion-exchange unit. This 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, which uses an activated amine solvent suitable for capturing, at low pressure, the H_2S selectively, with minimal CO_2 absorption.”

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 post-combustion in the heat recovery steam generators. The amine-rich solution is regenerated in a stripping tower. There, acid gas – with high H_2S concentration of approximately 70 percent – is delivered to the Claus unit. A lean solvent solution is recycled back to the enrichment absorber, which also treats the Claus tail gas, after hydrogeneration and recompression.

“Due to the level of maintenance required by the sulfur units, two units were installed. Each is sized for 80 percent of the sulfur contained in the gasification feedstock. Operating in parallel, both are able to pick up a maximum load when the other one goes out of service,” said Bressan.

The tail gas from the Claus unit is processed in a tail-gas treatment unit. There, 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 section.

Air Separation (Oxygen Plants)

Oxygen required for both the gasification and Claus reactions is produced in the oxygen plant, where air is fractionated by cryogenic distillation. The plant is partially integrated with the power island. In fact, 30 percent of the compressed air required by the plant is delivered directly from the gas-turbine compressors.

Two units, operating in parallel, have been planned, says Bressan, each having a capacity equal to 50 percent of the required oxygen amount. “A liquid oxygen storage tank equipped with the required facilities allows IGCC operation at its design capacity for a limited time, even if one oxygen plant unit is out of service.”

Nitrogen is also co-produced in the oxygen plant in both gaseous and liquid forms. “Gaseous nitrogen is compressed to feed the gas turbine, which reduces NO_x emissions and increases power output. Liquid nitrogen is produced and put in reserve, for emergency gasifier purging, as well as for low-pressure (LP) nitrogen-distribution backup.”

Power Island

The clean syngas produced in the gasification section and syngas treatment is fed to the power island. There, two gas turbines, followed by two heat recovery steam generators and one steam turbine, convert syngas thermal power to electric energy.

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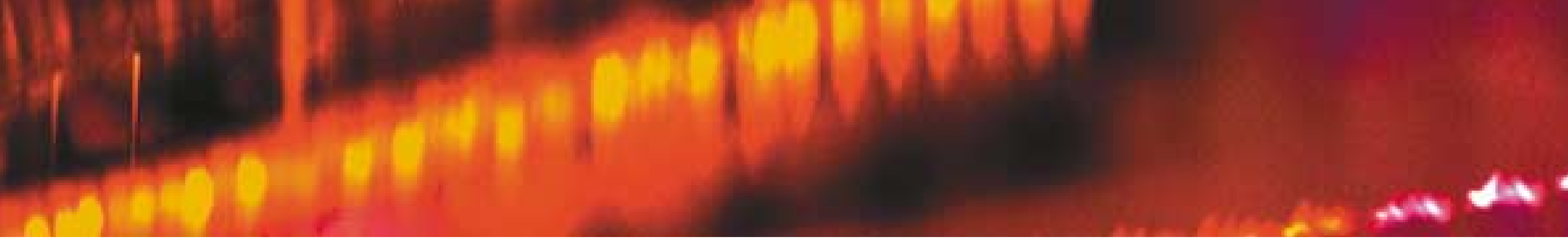

"The gas turbines burn almost all the syngas produced. A post-combustion system, foreseen in the heat recovery steam generators, burns the PSA off-gas coming from hydrogen production, the treated gas produced by acid gas enrichment, and any excess." Nitrogen is used to dilute the syngas, with the aim to lower NO_x emission and improve the gas turbines' power output up to their maximum limit.

The power island is accurately integrated with the process units, to increase the complex's overall efficiency, says Bressan. High-pressure steam is exported mainly to the gasification reactor. The recovered LP steam is processed in the combined cycle. Cold condensate is preheated within the syngas cooling train, as well as in other process units.

"The gas turbines can also operate with natural gas when syngas production is down, for startup, and even while co-firing (syngas plus natural gas), in case of syngas shortage."

Utilities and Offsites Units

Several service units are planned for operating the complex.

Cooling water, used in the steam turbine condenser and oxygen plant, is once-through seawater pumped from an intake installed in the refinery harbor. The return to sea is carefully located out of the refinery harbor, to avoid interference between the discharge and the seawater intake.

Circulating conditioned sweet water, cooled by seawater, is used as a cooling stream for machinery, as well as for process users. Other utilities units include systems for demineralized water, condensate recovery, plant and instruments air, auxiliary fuels, and fire-fighting.

The IGCC complex also contains a flare system for disposing of hazardous gases during emergencies and mis-operations. Other major auxiliary systems include liquid sulfur solidification and storage, metal cake handling and storage, and electrical distribution, as well as step-up transformers and grid connections.

Environmental Impact

"IGCC technology is, by far, the cleanest technology for power production," says Bressan, "no matter how much sulfur is contained in the feed."

Gaseous Emissions

Continuous gaseous effluents from the complex consist of flue gases from the combined-cycle plant (see Figure 1, on page 17).

IGCC sulfur-removal efficiency, intended as the ratio between recovered liquid sulfur and sulfur in the feedstock, is 98.7 percent at design conditions, while the expected figure is 99.5 percent. NO_x concentration in flue gas from the combined cycle is achieved by injecting nitrogen into the gas turbine, without requiring catalytic deNO_x.

Liquid Effluents

The major continuous-process liquid effluent is water blowdown from the quench gasification. The water is subjected to a treatment sequence that includes extraction for soot removal, chemical precipitation of ash/metal, stripping for dissolved gas removal, and biological content (i.e., biological oxygen demand, or BOD) reduction.

In addition, boiler-water blowdown, discharges from regenerating demi-water resins, discontinuous stripped waters, possibly contaminated oily water, and sanitary waters are treated in the wastewater treatment plant.

Table 2.
Characteristics of the final effluent

Flow	**270 m^3/h max**
Chemical Oxygen Demand (COD)	**< 70 mg/l**
Total Suspended Solids (TSS)	**< 30 mg/l**
Total Hydrocarbons	**< 10 mg/l**
Total Nitrogen	**< 30 mg/l**
Total Toxic Metals	**< 1 mg/l**

No solid wastes are produced in the IGCC complex.

The Site

The IGCC complex will be erected near the Petronor refinery, west of Bilbao, in the Basque region of Spain. The site is located southeast of the refinery, at an average elevation of 50 meters above sea level.

Total area designated for the complex is 277,000 square meters. This allows for process-unit areas, slope access roads, internal roads, an area for temporary construction facilities, and more. The plant is located in a hilly countryside, and the soil preparation requires extensive earth movement: around 1.5 million cubic meters.

Digging for Seawater

While the site is optimal for interconnection with the Petronor refinery, the cooling-water supply presented a problem, and required an extensive optimization study. The solution: Bring seawater to the site via tunnel, through the hills between

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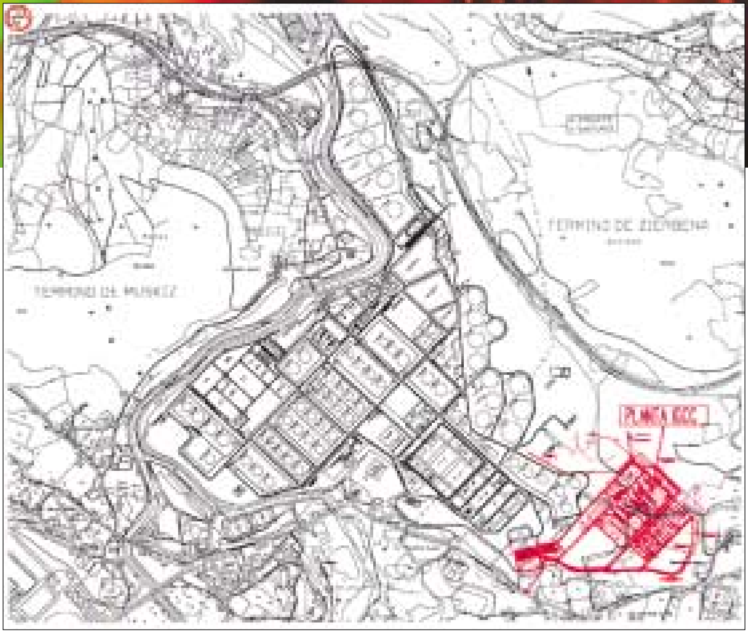

the seashore and IGCC site. After cooling service, the water will be channeled to a calm collection basin. Then, under gravity flow, a second excavated tunnel will drive the water back to the sea at a suitable discharge point. No puny pipeline, each tunnel is approximately five kilometers long, and around 3.6 meters in diameter. In the seawater-return system, located close to the sea, a hydraulic turbine is planned to recover the static head available between the calm basin and the seawater level. The proposed solution will permit environmentally friendly use of seawater, says Bressan.

IGCC Complex Performance

The IGCC design accounts for operation at different ambient temperatures. Although combined-cycle gas turbines are sensitive to air temperature, the operating configuration selected allows an almost constant power output through the area's ambient temperature range.

IGCC Complex Performance

(when complex is operating at design capacity, and at reference conditions)

FEEDSTOCK		
Vacuum visbroken tar (5.5 percent S)	**195**	**t/h**
PRODUCTS		
Gross power output	**935.4**	**MW_e**
Net power output	**783.9**	**MW_e**
Hydrogen production	**21,500**	**Nm^3/h***
Sulfur production	**257.4**	**t/day**
Metal cake production (@ 50% humidity)	**0.97**	**t/h**
Overall efficiency (LHV)	**42%**	

*normal cubic meters per hour

Gaseous Emissions

(Expected flow rates and contaminant concentrations of continuous gaseous effluents, at design capacity)

Flow	**Nm^3/h**	**6,203,200**
NO_x	**mg/Nm^3**	**60**
SO_2	**mg/Nm^3**	**15**
CO	**mg/Nm^3**	**30**
Particulates	**mg/Nm^3**	**5**

Note: Flow rate and concentrations refer to flue gas (dry) and 15 percent vol. O_2.

Investment Cost

For the IGCC complex project, +/- 10 percent, total investment cost calls for € 1.1 billion (Euros).

Investment cost per areas as percentage of the total investment (%):

Process units, including oxygen plants	**35**
Combined-cycle unit, including high-voltage substation	**33**
Utilities and offsites	**20**
Escalation and owner cost	**12**

This article is based on a paper by Luigi Bressan, Foster Wheeler Italiana; Tarcisio Ubis, Repsol YPF; and Luke O'Keefe, Texaco Power and Gasification. It was presented during the Gasification Conference in San Francisco, California, USA, in October 2000.

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