There are currently three refinery-based IGCC power plants at various stages of commissioning in Italy. The ISAB Energy plant in Sicily, which is now in commercial operation, is the first IGCC in the world to use asphalt as fuel.

Commercial Operation OF ISAB IGCC PLANT

In recent years, many refineries around the world have been re-equipped with “severe” processes, both thermal (coking) and catalytic (hydrocracking, catalytic cracking, dewaxing), to change their product mix in favor of an increased proportion of light products – in line with market trends. In Italy, however, there has been a reluctance to invest in these technologies, with a tendency to favor less severe thermal processes such as visbreaking and thermal cracking.

These processes take as input the residue from the bottom of the vacuum column and produce as output other distillates plus a residue (tar). The characteristics of tar are high viscosity, making it difficult to move, high sulfur (ranging between 3 and 6% depending on the quality of the crude processed) and the presence of various metals (notably nickel, vanadium, iron).

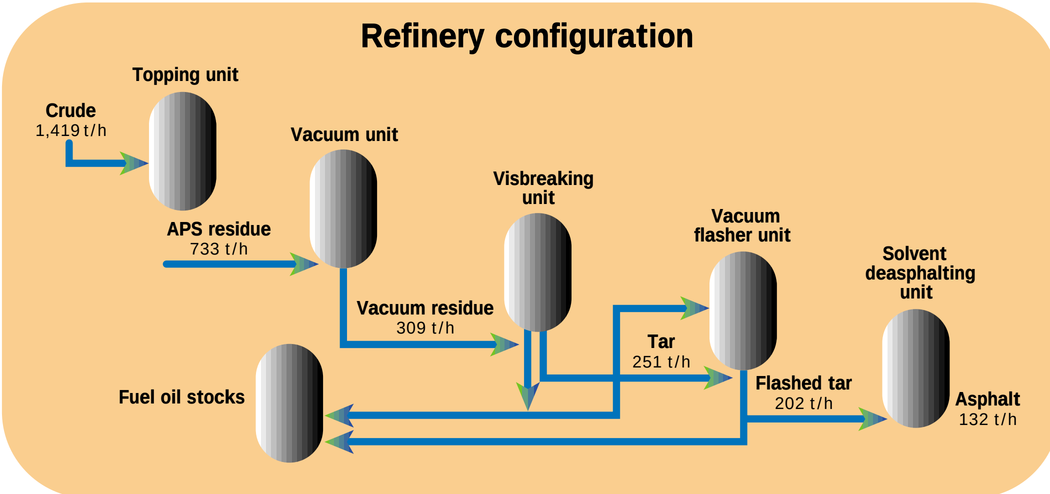
The Italian approach depended on the capacity of the state-owned utility, Enel, to buy and burn high sulfur fuel oil obtained from the tar. The tar was mixed with lighter products having very low sulfur content, to produce a power station fuel with high sulfur content (1–3%) but good calorific value.

When Italian and EU environmental regulations did not allow products with sulfur content over 0.25–0.30 wt % to be burned in power stations without flue gas desulfurization fitted, it resulted in a sharp decline in the high (2.5–3%) and medium (1–2%) sulfur fuel oil market. This has forced refiners to make the substantial investment needed to change their product mix or to find new outlets for their tar.

As well as these environmental pressures and the decline in the demand for residual fuel oils, other factors also came into play in Italy in the early 1990s. These included a referendum putting an end to the national regional nuclear program and a growing need for new generating capacity in several regions of the country.

Back to Contents

FIGURE 1



THE DECISION TO GASIFY

The ISAB refinery predominantly processes heavy crudes. In spite of upgrading its cracking facilities (visbreaker and thermal cracker) about 30% of its output is tar, resulting in large volumes of heavy fuel oil. Three options for addressing the new market conditions were considered:

Against this background, the Italian government passed a law in 1991 and the CIP Resolution in April 1992 providing tariff incentives to power projects to offset these negative effects. The disposal of refinery residues by Integrated Gasification Combined Cycle (IGCC) fell into this category. Three major IGCC projects, sponsored by different refineries, were announced. Two are close to completion, while the 520.8 MWe (net) ISAB Energy project, located in Priolo, Sicily, next to ERG Petroli's ISAB refinery—the second largest in Italy, was the first to enter the commissioning phase (mid 1998) and go into commercial operation.

General overview of the complex taken from the top of the 130m tall stack.

- Deep conversion – this entails complete redesign of the refinery with installation of catalytic processes;
- Tar desulfurization – installation of desulfurization plant to adapt the tar to power plant requirements; and,
- Tar gasification, with integrated power production.

On economic and environmental grounds, the gasification option was chosen.

Ownership of the ISAB Energy IGCC plant is 51% ERG Petroli and 49% Edison Mission Energy.

The project essentially started in 1991 with the assignment to Foster Wheeler of a feasibility study to establish key process features and optimize process design.

In 1992-1993, Foster Wheeler received a contract to develop the basic design of the complex, with the assistance of Texaco, for the gasification unit, and Ansaldo for the power block. In parallel, ISAB initiated the long and complex licensing process.

About 150 permits were required, involving various local and central authorities. In 1995 a consortium formed by Foster Wheeler and Snamprogetti was awarded a lump-sum turnkey contract for engineering, procurement and construction.

The “notice to proceed” was finally given in July 1996, after closure of the nonrecourse, project-financing package.

PLANT DESCRIPTION

Figure 1 represents the refinery scheme for the preparation of the asphalt feed to the IGCC plant. The main units of the plant are

Back to Contents

shown in the block flow diagram of Figure 2.

The feedstock to the gasification unit is asphalt, produced in a solvent deasphalting unit, licensed by Kellogg, where deasphalted oil, sent back to the refinery, is also produced. The asphalt is an extremely heavy stock, with 6% S, about 1,000 ppm metals (Ni-V-Fe) and a softening point close to 120°C. The pumping temperature shall be maintained at 260–280°C.

Two quench-type Texaco gasifiers are used to convert 132 t/h of asphalt to syngas by partial oxidation with pure oxygen and HP steam as asphalt atomizer and reaction moderator.

Oxygen is purchased from a close-by air separation unit operated by Air Liquide.

During gasification some soot is produced, which ends in the quench water blowdown exiting the gasifiers, called soot water.

Soot water is sent to the carbon recovery unit, where soot is released to asphalt through an intermediate closed circuit of naphtha. The soot-asphalt slurry is supplied to the gasifiers, so that all the carbon contained in the feedstock is converted.

The quench water separated from the carbon soot is recycled to the gasifiers, except for a blowdown stream which is chemically treated to precipitate a metal concentrate cake, stripped with steam for ammonia release and finally biologically treated to reduce its oxygen demand. The syngas emerging from the gasification unit at 240°C passes through a heat recovery section, generating MP and LP steam, then a COS catalytic hydrolysis and finally an acid gas removal, using an activated amine solution (MDEA) to remove selectively H_2S with minimum absorption of CO_2.

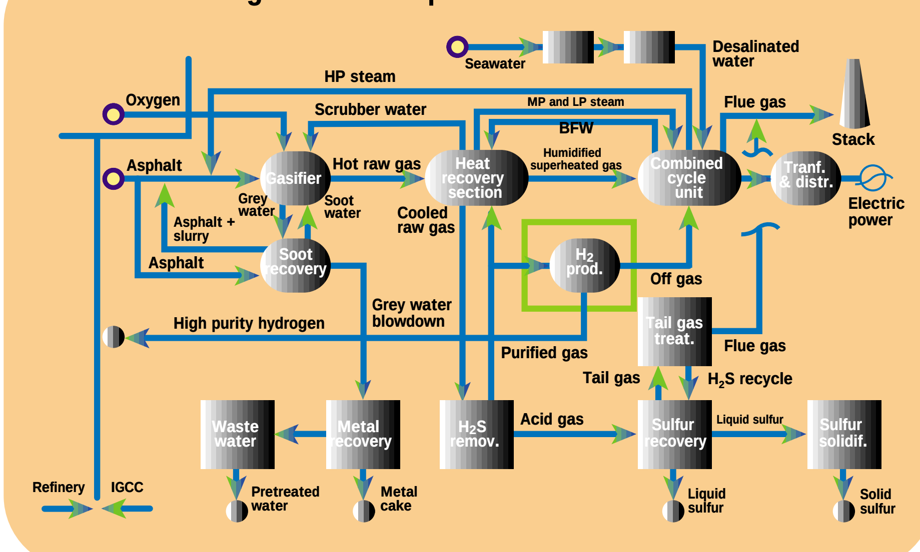
The concentrated acid gas from the MDEA regenerator is converted to elemental sulfur in an oxygen Claus unit followed by a tail gas treatment.

Treated syngas, after pressure reduction in an expander to recover energy, is humidified to a level of 35%, which allows a drastic cut in NO_X produced in the gas turbine combustors.

Treated and humidified syngas is fed to the gas turbines of the power block. The power block consists of two combined cycles, each including one gas turbine, Siemens frame 94/2, one heat recovery steam generator and one condensation steam turbine. HP steam is fed to the gasifiers, while the MP and LP steam produced in the process units is sent to the combined cycles for power recovery.

FIGURE 2

Block flow diagram of IGCC plant



Back to Contents

TABLE 1

EXPECTED PERFORMANCES OF THE IGCC PLANT

Asphalt feed to gasification	132 t/h of asphalt
Gross power output	562.6 MW
MW internal electrical cons. of combined-cycle units	11.8 MW
Net power output	550.8 MW
Process and utility units cons.	30 MW
Net IGCC power	520.8 MW

TABLE 2

OVERALL AIR EMISSION FROM THE IGCC COMPLEX

	IGCC (mg/Nm^3)	European standards for conv. power station (mg/Nm^3)
SO_x	10	130
NO_x	30	150
Particulate	10	16

TABLE 3

SCHEDULE OF THE MAIN COMMISSIONING STEPS

Utility unit commissioned	1998 November
Start of first gas turbine with gasoil	1998 November
Start of second gas turbine with gasoil	1999 March
Start-up of solvent deasphalting unit	1999 March
Start of first gasifier	1999 July
First gas turbine operation with syngas	1999 August
Start of second gasifier	1999 September
First operation with asphalt	1999 October
Two gasifiers lined-up to two gas turbines	1999 November
Functional tests on turbines on syngas	1999 October - November
Lining-up and optimization of the plant	2000 January - March
Plant performance test and reliability test	2000 March 25 - April 5

TABLE 4

PERFORMANCE AND RELIABILITY TEST (MPS) RESULTS

PERFORMANCE	
Net power output	499 MW against 486 MW required for MPS
Asphalt consumption	122 t/h against 132 t/h nominal capacity
HP steam gasifier consumption	50% of maximum design
Oxygen gasifier consumption	10% less than design figure
RELIABILITY	
Service factor	95% against 90% required for MPS

PERFORMANCES AND EMISSIONS

The main performances are shown in Table 1.

The plant is fed with 132 t/h of asphalt, and the expected net power output is 520.8 MW.

The atmospheric emissions are shown in Table 2. The IGCC figures are largely below the current European standards, corrected for the O_2 concentration of the flue gas (15%).

COMMISSIONING AND START-UP OF THE PLANT

Table 3 represents the schedule of the IGCC plant. The most important utility units, such as cooling water and machinery cooling water, seawater desalination and water demineralization, compressed air and fuel gas/fuel oil systems were successfully commissioned in November 1998.

During the same month, the first gas turbine was started with auxiliary fuel, gasoil, and after a few weeks connected to the national grid and brought to the design power value.

Simultaneously, the start-up of the heat recovery steam generator and the steam turbine were completed.

In March 1999, the second combined cycle was started. In this period, several official functional tests were completed, such as load rejection, trip and overspeed on gas turbines and steam turbines.

At the end of March, the SDA unit was commissioned and left in recycle condition, i.e. deasphalted oil and asphalt were recombined and sent back to the refinery, while awaiting the gasifier start-up.

The SDA passed all the functional, hydraulic and performance tests successfully in the middle of June.

On July 17, gasifier number one started producing syngas, processing low sulfur oil and visbroken vacuum residue at a capacity variable between 70 and 100%. The gasifier was kept in operation for six weeks. Starting from early August, one gas turbine was operated on syngas for short periods, followed by cooling and inspection, to control mainly the combustion system. Each time, the switch from gasoil to asphalt was smooth and full capacity of the gas turbine was reached successfully, without any problem of hummering or burner overheating.

In September 1999, gasifier number two was started. In October, asphalt was

Back to Contents

used for the first time as feed to one gasifier. In November 1999, the complete lining-up of the plant was finally reached, i.e. two gasifiers operated with asphalt, feeding syngas to two gas turbines.

During this period, several contractual functional tests on gas turbines and steam turbines were completed successfully: load rejection, trip, overspeed, change-over from gasoil to syngas and vice versa.

At the end of November, a refractory failure of one gasifier forced a shutdown for repair. The plant was restarted in January. In the following two months, the units were completely lined-up; the process parameters optimized and the plant was prepared for the performance and reliability tests, which took place from March 25 to April 5, 2000.

SUCCESSFULLY MEETING CHALLENGES DURING COMMISSIONING PHASE

The adopted solutions to problems faced during the commissioning period are described below.

H_2/CO ratio of syngas

The H_2/CO ratio was higher than expected, especially using oils lighter than asphalt as feedstock. This deviation of syngas composition from expected values restricted for some time its use in the gas turbines and was temporarily resolved by operating the gasifier at lower temperature and lower steam flow, thus moving in the direction of higher soot production.

The problem was overcome after some tests made by Ansaldo/Siemens on a gas turbine burner of a pilot plant. The test demonstrated the capability of the burners to handle a syngas having a H_2/CO ratio much higher than those considered in the design phase.

Corrosion in water circuits of gasification unit

Severe corrosion developed in several components of the soot water and grey water circuits.

The corrosion was caused mainly by higher than expected concentration of formic acid and was more severe in the presence of high fluid velocity, such as valves and pump impellers.

As remedial actions, the metallurgy of some pump components was modified from carbon steel to 12% Cr steel or duplex; the type of many flanges was changed and, since then, the Ph of the circuits has been controlled by ammonia injection.

Hot spots on gasifiers

As previously mentioned, a refractory failure at the top of one gasifier occurred, which required a long shutdown for repair. In the months before, some hot spots on the correspondent external surface were observed on both gasifiers. Minor modifications to the refractory and to the burners, proposed by Texaco, resolved the situation. Since then, monitoring the gasifier's skin temperature has been even closer than before. The hot spots elimination is an example of the continuous cooperation between the consortium team and the Texaco team on problem solving and plant operation optimization.

Expander failure

In the middle of October, the syngas expander had a failure during an overspeed test and was shipped back to the manufacturer for extensive repair. The plant was restarted without the expander, using a bypass control valve.

PERFORMANCE TEST AND RELIABILITY TEST (MPS)

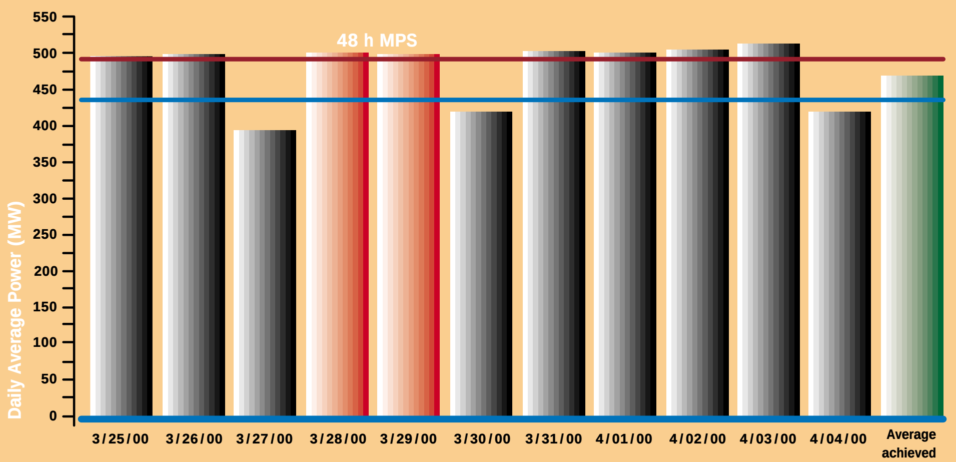
The test, contractually called MPS (minimum performance standard), was carried out

Back to Contents

FIGURE 3

Daily electrical power during 10-day (240 hrs) reliability test

Day	3/25/00	3/26/00	3/27/00	3/28/00	3/29/00	3/30/00	3/31/00	4/01/00	4/02/00	4/03/00	4/04/00	Average achieved
Average MW	493.9	498.5	391.5	499.2	497.4	419.2	500.7	499.5	501.6	509.7	416.6	
Average for MPS	486.4	486.4	391.5	486.4	486.4	419.2	486.4	486.4	486.4	486.4	416.6	465.3



Net electric power to be guaranteed during performance test (average over 48 h) = 486.4 MW

Net electric power to be guaranteed during reliability test (average over ten days - 240 h) = 437.76 MW

successfully from March 25 to April 5, 2000. The results are summarized in Figure 3, which shows the average daily net electric power outputs, as well as the average daily production during the 10 days (see the green bar of the diagram).

Making reference to the red bars of the diagram, the performance test demonstrated the capability of the IGCC plant to produce continuously for 48 hours more than 486.4 MW at ISO conditions as net electric power output.

Making reference to the green bar of the diagram, the reliability test demonstrated the capability of the plant to get a service factor of 90% during the 10-day operation, i.e., to produce an average net power output higher than 437.7 MW.

Table 4 provides some details of the tests. During the performance test, for example, an average net power output of 499 MW was obtained, against 486 MW required for the test, with a plant efficiency higher than expected.

In fact, the consumption of asphalt was 122 t/h against 132 t/h nominal capacity. HP steam consumption was half of the maximum expected value, and oxygen consumption was 10% less than the expected value.

During the 10-day reliability test, the service factor was 95% against 90% required. The peak net power output during the test was 513 MW.

NET FUTURE OBJECTIVES

Following the completion of the performance and reliability tests, the plant was officially handed over to ISAB Energy for commercial operation. Further tests on the gas turbines at extreme conditions of H_2/CO ratio will verify the flexibility of the IGCC plant to operate with feedstocks much lighter than asphalt.

The last and most important target is the guaranteed performance and 30-day reliability tests (contractually called GPS or guaranteed performance standard), which will take place in the next months.

The target for a GPS test is to produce 512 MW net power output for 48 hours and to achieve a 93% service factor.

By interpolation from operating data, this result should be achieved by using about 126 t/h of asphalt, largely below the maximum allowable feedstock consumption for the test.

CONCLUSION

On the basis of the results of the MPS test and the experience acquired during the commissioning and start-up of the plant, it is expected that the next performances and reliability tests will be successfully executed. The experience of the design and commissioning of the IGCC plant of ISAB Energy, today the most powerful in the world, will allow Foster Wheeler and Snamprogetti to optimize the design of similar future projects. ❑

This article by Silvio Arienti, Luigi Bressan, Giovanni Lorenzo Farina, and Pierfranco Lionetto of Foster Wheeler Italiana was first published in Power Technology.

Back to Contents