PetroSA masters materials problems through the power of innovation

By Miel Bingen

South Africa's Southern Cape is more than just friendly people and a beautiful countryside. The Mosselbay region is host to the world's largest gas to liquids plant. Stainless Steel World decided to take the opportunity to visit the plant to hear more about how innovation can contribute to solving materials problems.

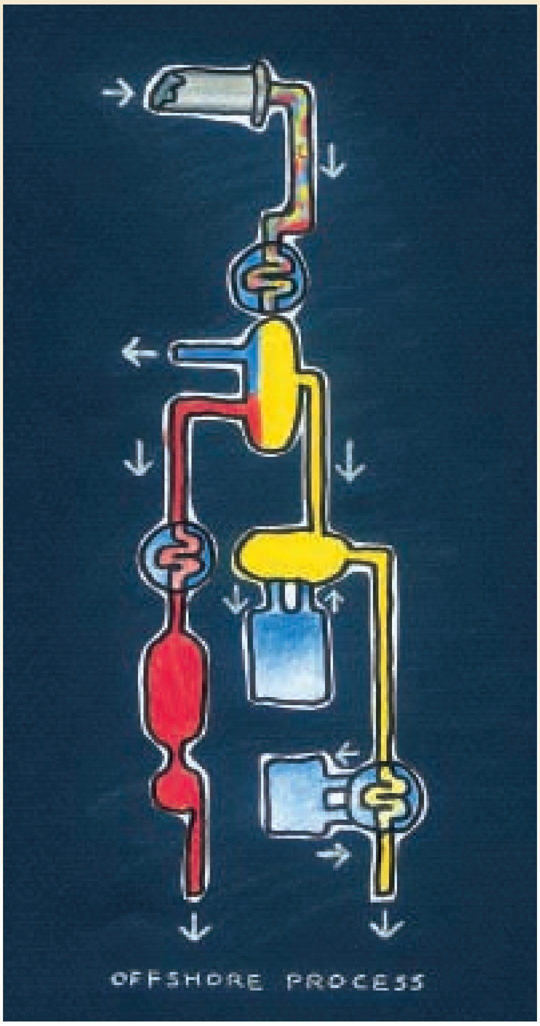
To some extent PetroSA's facilities in Mosselbay where Stainless Steel World was kindly welcomed by Mr Mike Holland (Manager of Metallurgical and Inspection Services) are a remnant of another era of South Africa's history. Following the discoveries of petroleum gas deposits on the continental shelf complex off South Africa's Southern Cape the South African government, suffering under trade restrictions as a consequence of apartheid, announced the Mossgas project in 1987. Through the production of synthetic motor fuels from gas from fields in the Mosselbay area the government hoped to reduce the country's dependence on imported oil.

PetroSA's Mosselbay facilities consist of an offshore gas production platform and an onshore refining facility. The onshore plant is situated approximately 13 kilometres west of the town of Mosselbay on a 410-hectare site on South Africa's scenic Garden Route.

The project turned out to be very successful in many ways. Today, many years after the end of apartheid, its successor PetroSA produces approximately 7% of South Africa's total transportation fuel requirements at a rate of 36 000 barrels of finished products per day. Furthermore a range of special products such as anhydrous alcohols are produced at the plant. PetroSA's Mosselbay facilities also have a significant positive economic effect, particularly in the Southern Cape area. It employs just over 1000 people directly whilst another 7000 people owe their livelihood to the facilities. Also from an environmental point of view

The offshore process

1. The gas, condensate and water mixture flows under natural pressure from the production wells to the platform deck.
2. The hot fluid is initially cooled to a temperature of 32°C before entering a high-pressure separator where the gas, condensate and water are separated.
3. The water is degassed to remove hydrocarbon traces.
4. Water is discarded into the sea.
5. Water vapour remaining in the gas is removed in a glycol contactor.
6. Chilling the gas to –10°C condenses remaining heavier fractions out.
7. Gas is piped ashore.
8. Separated condensate is filtered and remaining water removed in a coalescer. To drive off lighter components, the condensate is heated.
9. Condensate is flashed in a raw condensate drum. The gas that is removed by this process is routed back to the glycol contactor.
10. Remaining condensate, together with the condensate from the chilled gas, is again flashed to produce fuel gas for use on the platform.
11. Condensate is pumped to the onshore plant.



the plant is a success and claims to be the cleanest refinery in the world.

PetroSA's Mosselbay facilities consist of an offshore gas production platform and an onshore refining facility. The offshore platform supplied the first gas to the onshore plant on 31 March 1992. Towering 114 metres above sea level and extending 105 metres below, the production platform is still one of the largest single structures ever constructed in South Africa. The gas and condensate are recovered from between 2 500 metres and 2 800 metres below the seabed. Nine production wells have been drilled from the platform. These include several which are inclined and tap gas and condensate more than four kilometres away from the centreline of the platform. Dedicated pipelines, one of 450 millimetres (18 inches) for gas, and one of 200 millimetres (8 inches) for condensate, link the platform to the onshore plant, 91 kilometres away.

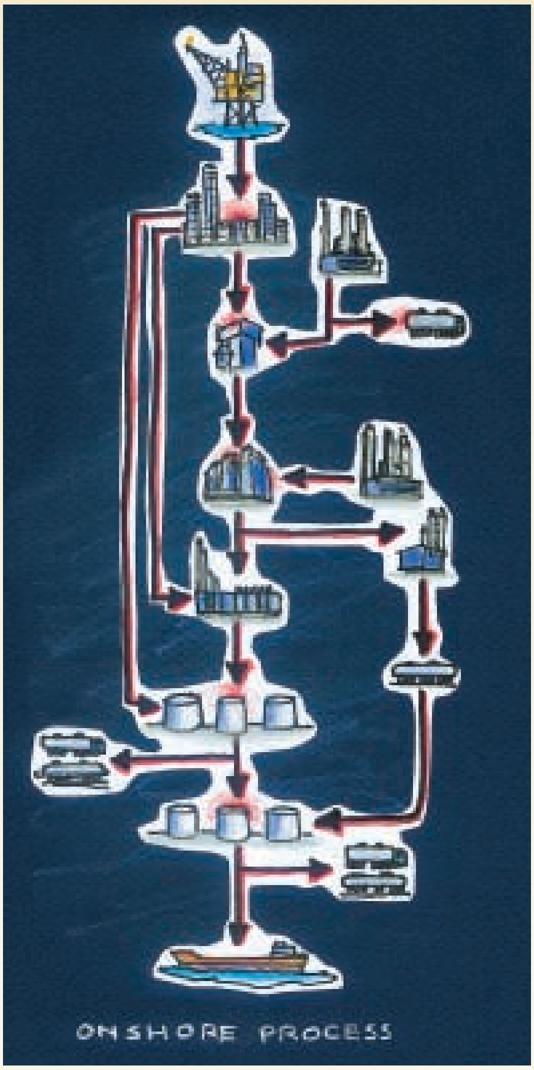
The onshore plant is situated approximately 13 kilometres west of the town of Mosselbay on a 410-hectare site on South Africa's scenic Garden Route. The plant has an original design production capacity of 33 500 barrels of refined products per day. This was increased to 36 000 barrels a day in 2000 to allow the company to process up to 6 000 barrels a day of imported condensate. The plant has 21 process units and 19 utility units such as a power generation station, gas liquefaction/storage facilities and reaction water as well as raw water treatment facilities. Production activities are directed by a sophisticated computer system from a well-protected central control room. A modern laboratory also serves the plant.

Fascinating plant

As Manager of Metallurgical and Inspection Services Mr Holland and his department provide metallurgical advisory services and failure investigation services to both the onshore plant and offshore platform. As such the department is also responsible for both statutory inspection services to the plant for boilers and pressure vessels and is an accredited third party inspection authority in terms of national standards. In order to fulfil these roles the Mosselbay facilities are well equipped. There is a small metallurgical laboratory that enables Mr Holland and his colleagues to do everything that needs doing in-house. Mr Holland: 'The philosophy from the start has been that we have to be self sufficient. We are some 400km distant from Cape Town so this geographical remoteness means we have to be self sufficient. We don't do any research work though, only investigation work.'

Looking at the facilities on- and offshore Mr Holland notes that it is the onshore facility where the true chal-

The onshore process



12. Natural gas and associated condensate are piped ashore from an offshore production platform. On arrival the gas and condensate are routed through the NGL recovery unit. Liquid petroleum gas (LPG) materials such as propane, butane and heavier are recovered from the gas.
13. The gas is routed to the methane reforming unit where it is reformed to synthesis gas using steam and oxygen.
14. An air separation unit produces oxygen for the reforming process.
15. Liquid oxygen and nitrogen are also produced in the air separation unit and sold as by-products of the Mossgas process.
16. The liquid petroleum gas range of materials are piped to the tank farm area for the production of LPG.
17. Stabilised condensate goes to the NGL fractionation unit where it is split into diesel and naphtha fractions. The diesel is refined and the naptha is used in the production of gasoline.
18. Synthesis gas produced in the methane reforming unit is sent to the Synthol reactors for catalytic conversion into synthetic oil.
19. Catalyst is manufactured on site and fed into the Synthol reactors.
20. The synthetic oil is routed to a light oil refinery for treatment and upgrading to high quality motor fuel stocks.
21. A by-product stream of mixed alcohols is produced.
22. The alcohols are railed to the Voorbaai tank farm for shipment to international markets via a conventional buoy mooring.
23. Gasoline (95 octane unleaded and 97 octane leaded), diesel, kerosene and fuel oil produced in the refinery are piped to the tank farm.
24. LPG produced at the tank farm, as well as propane and fuel oil, is transported by road and rail to customers in South Africa as well as to neighbouring countries.
25. Petrol, diesel and kerosene are piped to the Voorbaai tank farm, 12 km away.
26. Twenty per cent of PetroSA's products are supplied to oil company depots in Mossel Bay from where it is distributed to the local market.
27. Eighty per cent of PetroSA's products are shipped via a single point mooring to the coastal cities of Port Elizabeth and East London for distribution by South African oil companies under their own brand names.

lenge lies. 'We have a fascinating plant from a metallurgical point of view because our process conditions are so diverse. Temperatures go from cryogenic for oxygen production up to pretty high limits in the reforming unit where we have to deal with temperatures of 1300 to 1400∞C. Pressures go from vacuum up to 110 bar. Fluids range from innocuous substances such as air, moist air and water to fairly aggressive acids such as HF, sulphuric acids and a range of organic acids. This of course means that materials-wise we have to have an extensive range of materials starting right down at the bottom end with cast irons, carbon steel and low alloy steels and running up to stainless steels, super austenitics, high nickel alloys and titanium. Essentially, we have the whole range of materials. Consequently, in terms of failure mechanisms or degradation mechanisms I can say that I have physically seen with my own eyes just about every form of materials degradation that I have ever read about with only one or two exceptions.'

Innovation

One of the approaches that Mr Holland is particularly enthusiastic about is that PetroSA tends to do some quite innovative work in handling problems. For instance his department changed over to a totally risk-based inspection and maintenance philosophy close to three years ago and have been working towards that for the last seven years. In specialised areas this philosophy has been taken quite a bit further Mr Holland explains: 'Risk-based inspection has been a very rewarding experience for us and in some fields we have managed to do some truly pioneering work. The stress corrosion cracking problem of carbon steels in the gas loop is one example of such an area. It was quite a challenge because possibly 1700 pipelines and a few dozen vessels might have been potentially vulnerable. In the gas loop we have moist carbon monoxide and carbon dioxide which is a fairly unusual combination and we had to do quite a bit of work to understand the problem. We used the finer principles of risk-based inspection to understand the mechanism at work and to sort out what was actually happening. In the end we were able to develop an algorithm which we ran on the computer to assess the potential risk for all the process lines. Consequently we put an inspection programme in place to verify the results found with the help of our algorithm. Based on what we found we put a program in place to replace the carbon steel with austenitic stainless in certain areas. Today we feel that we are on top of the problems and are very confident about our risk-based inspection philosophy.'

Another area where PetroSA is at the forefront of technology is metal dusting. "Metal dusting is a particularly interesting subject on which we have quite a lot of experience. There wasn't a great deal of international interest in metal dusting until about ten years ago. There was a big gap in research until the late 80's and then a lot of excellent research was carried out at the Max Planck institute in Dusseldorf, Germany. Even so, metal dusting is probably one of the few areas of technology that is still not fully understood. What makes our experience so particularly interesting therefore is that the theory does not necessarily coincide with our field experience. For one, the theory originally predicted that INCONEL® 600 should resist metal dusting while our first encounter with metal dusting showed something quite different. Back in 1994 a hole was blown in a reformer due to metal dusting. The INCONEL® 600 liner inside the neck of the reformer had actually metal dusted away and a big chunk of it came away and became lodged in a burner/mixer arrangement. This deflected the flame of the burner to the vessel which burned through the side of the reformer. When we looked at it in detail it turned out that quite an interesting error had been made during fabrication. Instead of INCONEL® 600, INCOLOY® 800 had been used for a gusset and what we found was that the INCONEL® 600 was metal dusted away leaving the gusset behind in perfect condition. So we had a lovely example of the comparative resistance of nickel alloys and high chromium alloys against metal dusting. Later we found the same results in quite a number of other cases which gave many people something to think about. Today we use some quite sophisticated materials in those areas where metal dusting occurs such as high nickel alloys INCONEL® 601and 602, INCOLOY® 800 cast 50/50 chrome/nickel and thermal spraying of 50/50 material, mainly for tube sheets. Especially the spraying has been quite a successful technique to counter metal dusting problems. Even so, we are at the stage where only time will tell what the final results will be."

Talking about metal dusting Mr Holland automatically touches upon the most challenging plant at PetroSA, the reforming plant. He notes that around 60% of the department's efforts go into this plant even though it is relatively small. "It keeps coming up with new challenges. What makes the plant so particularly challenging is the fact that it operates under high temperature and high pressure. Furthermore it has these unusual aspects of metal dusting that keep appearing in places where you hadn't expected it and it also has a history of operational problems. We replaced a lot of the original equipment and have enjoyed a long trouble-free run for the past two to three years now. There are some indications that certain areas of the facilities may have come to the end of that curve and we will need to do some replacements but nothing more than might be expected of a plant which is now nearly eleven years old. All in all it is a challenging plant but I think I can say that we have mastered most of the problems very well through the power of innovation."

Manager of Metallurgical and Inspection Services Mr Mike Holland: "We have a fascinating plant from a metallurgical point of view because our process conditions are so diverse."