Iluka Resources Limited – Synthetic Rutile Plant Waste Heat Recovery Power Generation Plant

Iluka Resources has been actively seeking innovative and profitable Cleaner production solutions to waste problems. Its waste heat recovery power plant is saving it $1.5 million a year while its efforts to find markets for other wastes have resulted in potentially attractive business ventures.

Background

Iluka Resources Limited (formerly Westralian Sands Limited) is an international mining and mineral processing company. The company has operations in Australia, the United States of America and Indonesia and employs over 2500 people.

The company has been mining and processing mineral sands in Western Australia for over 40 years, and is currently ranked second in the world for production levels of titanium minerals and first in the world for zircon production. It is also the most successful producer of synthetic rutile in the world. Other company investments are in tin, coal, copper and quicklime.

Iluka Resources Limited (Iluka) has shown a continued commitment to innovation and the early adoption of new technology. It was one of the first companies to adopt the Becher process for producing synthetic rutile and has also developed methods for turning what were previously waste materials into products for steel manufacture and fertiliser. This level of innovation is a result of the company's continuous focus on process improvement and environmental management.

A major project to more than double the capacity of the company's Synthetic Rutile Plant in North Capel, Western Australia was commenced in 1995. A significant component of this project was to be the handling and treatment of hot waste gas from the plant, which ultimately resulted in the construction of a Waste Heat Recovery Plant. The project was commissioned in the later half of 1997.

The Process

Synthetic rutile is produced by removing iron from ilmenite in order to increase the titanium content. Iluka uses the Becher process which involves feeding the ilmenite ore into a rotary kiln to reduce the iron oxides to metallic iron. The iron is precipitated as hydrated iron oxide, and along with other impurities, is removed from the synthetic rutile.

The reductant used in the process is coal, which also acts as a fuel for the kiln. The process results in a hot, dirty waste gas stream (primarily CO_2) which needs to be treated before it can be released to the atmosphere.

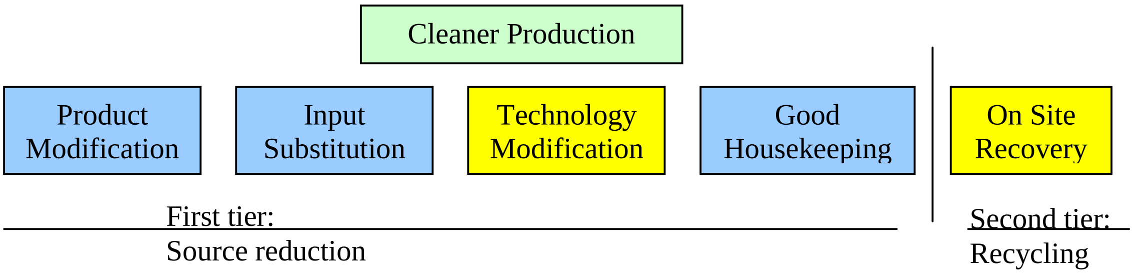
Cleaner Production Initiative

The traditional pollution control method of dealing with a waste gas stream which is high in both temperature and particulates would be to install a wet scrubbing system. While such a system would cool the gas and remove the particulates there are a number of environmental and economic impacts associated with it. These include:

- High water consumption with water converted to steam and released to the atmosphere resulting in loss of heat energy and water
- Generation of high particulate content, acidic liquid waste which requires removal of solids and addition of lime for pH neutralisation
- High energy consumption resulting in consumption of non-renewable fossil fuels and generation of air emissions, including greenhouse gases
- High maintenance and operating costs as a result of pumping of water and liquid waste, neutralisation plant and cleaning and disposal of waste solids.

Iluka investigated alternatives to a wet scrubbing system in order to determine whether there was a more effective way of dealing with the waste gas stream. The company finally decided to adopt a major technology modification in the form of a waste heat power generation facility and an electrostatic precipitator for the removal of particulates. This waste heat power generation facility can also be considered on-site recovery as the company is recovering the heat energy in the waste gas to produce electricity which is used on site, reducing the amount of power purchased.

Cleaner Production: Prevention Practices



A project management team of seven Iluka staff was established and the major construction contract was awarded to Rico Pty Limited of New South Wales. Oracle Engineering provided specialist engineering design services to Rico Pty Limited. Iluka staff maintained a strong involvement with all stages of the project from conceptual design, through to detailed design, construction and commissioning.

The final design consisted of a super-heater, boiler and economiser capable of producing about 30 tonnes/hr of steam. This super-heated steam drives a fully condensing steam turbine capable of producing about 6.5 MW of electricity (after allowing for power to run plant auxiliaries).

As this was the first time a plant such as this had been installed on a synthetic rutile plant in Australia a number of challenges were encountered. These were addressed through the innovation, originality and dedication of the team. The challenges included:

- ***Dirty waste gas:*** the gas leaving the kiln has a very high particulate load that can create erosion and fouling problems on the gas side of the boiler tubes. Deltec (USA), which has extensive experience in the design and manufacture of boilers for waste heat recovery plants, were engaged to design the boiler.

  Design features adopted to reduce erosion potential were increased tube wall thickness (by 1.2mm to 4.19mm) and reduced gas velocity through the boiler. To minimise fouling problems a three drum (one steam and two water drums) boiler design was adopted. The two water drums are at the bottom allowing the boiler tubes to be installed vertically, hence reducing dust build up. In addition, a gap between the two drums allows dust to fall into dust collection hoppers during cleaning operations. There are no finned tubes in the super-heater, boiler or economiser, again to reduce the build up of dust.

- ***Input heat variations:*** The gas generated by the kiln varies widely in both flow and heat over short periods of time. By incorporating an over-sized steam drum the effects of such wide variations are effectively balanced out.

- ***Maximising electricity production:*** The waste gas contains high levels of SO_2 and SO_3 as a result of the sulfur required in the kiln. The waste gas must therefore be kept at a temperature of greater than 150^{o}C to prevent these compounds condensing out of the gas as sulfuric acid. Sulfuric acid is highly corrosive and would severely damage downstream equipment such as the electrostatic precipitator, fans, dampers and the exhaust stack.

  A split economiser design was adopted to prevent corrosion while maximising electrical output. The economiser ensures that the gas temperature remains above the acid dew point until it reaches a condensate heater directly before the exhaust stack. The heat extracted from the gas in the condensate heater is used to preheat the condensate entering the deaerator of the boiler, eliminating the use of steam for preheating and thus providing the capacity to generate an additional 1 MW.

  Aside from the energy benefits achieved through this design were cost savings. By reducing the temperature of the gas immediately before discharge through the exhaust, only the stack and the condensate heater had to be made of expensive duplex stainless steel suitable for highly corrosive environments.

  Another innovative aspect of the design that promotes maximum electricity output is the boiler cleaning system. Traditional steam soot blowers were installed to clean the superheater, while an infrasonic blower was installed to clean the boiler and economiser tubes. This was the first application of infrasonic blowers for boiler cleaning in Australia. It works by generating a low frequency, high power noise to acoustically shake the dust from the tubes.

- ***Low resistivity dust:*** The dust contained in the waste gas has a very low resistivity that is not ideal for removal by an electrostatic precipitator. However, by incorporating extra wide plate widths and higher than normal plate voltages the manufacturer was able to guarantee dust removal.

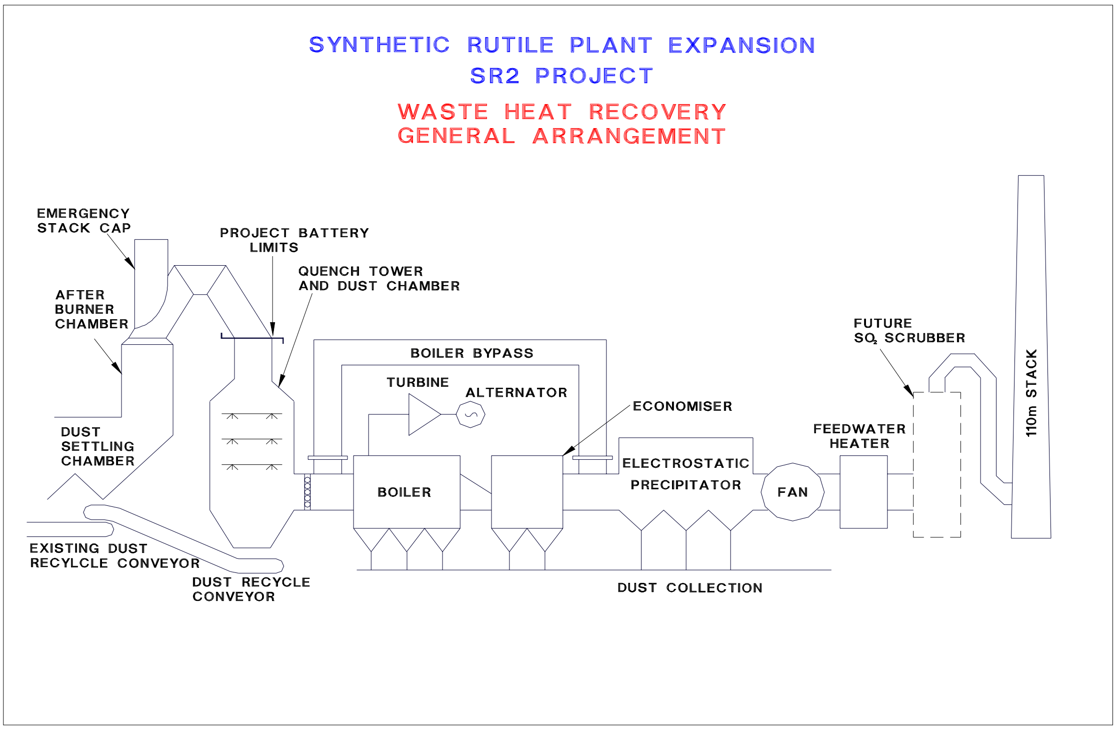
- ***Priority of kiln output:*** As the core business of the Synthetic Rutile Plant is to produce product, it was important that the Waste Heat Recovery Plant not dictate kiln operations. A waste gas bypass system was installed to allow kiln operation during maintenance shutdowns of the boiler.

  During bypass operation, water sprays are used to cool the waste gas from 900^{o}C (exit temperature form the kiln) to about 200^{o}C in order to protect the electrostatic precipitator, ducts and fans. Such cooling and the resulting thermal shock, if performed in a traditional ducting lined refractory, would result in cracking and dislodging of the lining. The alternative adopted for the quench tower was an internally insulated structure consisting of an internal shingle plate construction made from high temperature steel plates.

- ***Quick turbine response:*** As already noted, the fuel source for the Waste Heat Recovery Plant cannot be controlled, so two operational modes had to be adopted. In “connect” mode, the turbine is controlled by the inlet pressure and electricity generation is maximised by matching the heat output of the boiler. In “island” mode, control is based on speed and steam bypass, dumping excess steam to match electricity generation with the plant load.

  Rather than installing the traditional stand alone electronic turbine speed controllers, the turbine controls have been incorporated into the overall digital control system (DCS) for the Waste Heat Recovery Plant. Having the two systems fully integrated allows fast response to operational changes, and automatic changeover from one control mode to the other.

- ***Safe and reliable connection to the electricity grid:*** Digital High Voltage protection relays were required for the connection of the system to the Western Power electricity grid. This included distance protection, generator protection, transformer protection and protection against pole slipping on the generator. The relays are linked back to the main DCS for the plant, providing extensive monitoring and status information, and allowing disconnection and reconnection with grid as required.



Advantages of the Process

The financial and environmental benefits of the project are summarised in Table 1. The total cost of the Waste Heat Recovery Plant was just over $20 million and the expected rate of return on the investment was 16%. This compared favourably with the traditional wet scrubbing system that was expected to cost around $9 million but had no financial return on investment.

The plant now generates up to 6.5 MW of electricity, with an average of 5.5 MW. Of this 4 MW is used in the new synthetic rutile plant, 0.7 is used to run the Waste Heat Recovery Plant auxiliaries and any excess is used in other parts of the North Capel operations. By avoiding the need to purchase electricity and taking into account operational costs, the company is saving over $1.5 million per annum. With a payback time of 8 years and an expected operating lifetime of over 25 years, savings will continue to accumulate well after the plant has paid back.

Table 1. Financial and Environmental Benefits

Total Investment	$20 million
Energy Generated on Site	Up to 6.5MW pa
Annual Energy Cost Savings	$1.5 million
Expected Return on Investment	16%
Expected Payback Period	8 years
Expected Operating Life	25 years
Annual Greenhouse Gas Emission Reductions	52,000 tonnes $CO_{2equivalent}$
Annual Water Savings (compared to alternative technology)	1.2 million litres

As electricity generation is primarily based on the burning of fossil fuels, this project significantly reduces the associated environmental impacts. The project reduces the volume of coal required to provide electricity to the site by about 25,000 tonnes per annum and reduces the greenhouse gas emissions that would result from burning the coal by about 52,000 tonnes of CO_2 per annum.

Other environmental benefits include a decrease in water consumption of about 1.2 million litres per annum as opposed to if the wet scrubbing system had been installed. In addition, the electrostatic precipitator reduces particulate emissions from the plant to well below current regulations. The levels are also expected to be below any regulations that may be imposed in the forseeable future.

Cleaner Production Incentive

As part of a major upgrade at the North Capel Synthetic Rutile Plant in 1995, the treatment of hot waste gas was an important consideration. Making use of the energy contained in the waste stream became a significant area of focus, with several options being investigated.

Barriers

The main barrier to the implementation of this project was the perceived risk of adopting a new and somewhat unknown (at least to Iluka Resources) technology. Most businesses would agree that it is far easier to adopt the traditional, well established processes. However, this means that the benefits of newer technologies are frequently overlooked. Iluka had to look closely at what financial and environmental benefits the project offered, and at how they could minimise their exposure to risk. In the end, by weighing the risks against the benefits of the project the decision was made to go ahead.

In addition, Iluka Resources had to address an issue faced by many organisations investigating distributed power generation. The company’s core business is not power generation, but the mining and processing of minerals. Consequently, they have to ensure that production takes precedence over energy generation, and that at no time does energy generation dictate production conditions.

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