CHEMICAL ECONOMICS - REFINERIES

It now seems likely that Australia will be one of the first (if not the first) major industrialised country to close all of its oil refinery operations. An old and outdated refinery in Adelaide (Port Stanvac) closed in the 1990s. The two refineries in New South Wales (Shell at Clyde and Caltex's refinery at Kurnell) have closed in the past years, BP's Bulwer Island near Brisbane is slated to close and there are persistent rumours that the BP refinery at Kwinana in WA will follow suit. This leave the two refineries in Victoria (Viva Energy, formerly Shell near Geelong and ExxonMobil's refinery at Footscray in Melbourne) and Caltex's refinery at Lytton near Brisbane. If these refineries will survive their scheduled major shut-down and maintenance times over the next few years, when new capital is usually required for upgrades or replacing major equipment, is a moot point.

The duty of a refinery is to convert crude oil which has a hydrogen to carbon stoichiometric ratio of 1.5 or less, into refined fluids for motor transport, which have hydrogen to carbon ratios of over 1.8 for gasoline (petrol) and the best quality diesel. This role is performed in refineries by either rejecting carbon in the crude oil or by adding hydrogen.

In Australia, carbon rejection is the favoured method via fluid catalytic-cracking (FCC). In this process hot solid-acid catalysts react with heavy oils (H/C <1.5) to form gasoline, olefins and a low quality diesel with H/C ratios of 1.8 or more. The reaction is very rapid and the catalyst becomes coated in carbon (coke). The catalyst is regenerated by separating it from the hydrocarbons and burning the coke off the catalyst to form carbon dioxide and reheating the catalyst to the required reaction temperature.

An alternative to FCC is hydro-cracking which is used at the Bulwer Island refinery (and at New Zealand's refinery at Marsden Point). For this operation, hydrogen is required which usually comes from natural gas by the steam reforming reaction:

$$CH_4 + H_2O = CO + 3H_2$$

or, as is used for the Bulwer Island operation, by partial oxidation:

$$CH_4 + 1/2O_2 = CO + 2H_2$$

more hydrogen is made by water-gas-shift:

$$CO + H_2O = CO_2 + H_2$$

The carbon dioxide is removed and emitted to atmosphere.

For completeness, another method for rejecting carbon, which is not used in Australia, is to form coke by liquid phase pyrolysis of heavy components. This makes a low quality gasoline and diesel which require further hydro-treatment and petroleum coke which can be used to make anodes for smelting aluminium.

One of the main effects of increasing the ratio of hydrogen to carbon in the products is that the density of the products is significantly lower than the crude oil feedstock. This results in an increase in the total volume and because oil products are universally sold on a volume basis this results in increased product volumes and sales (the so called refinery gain).

In modern refineries producing fuels to the latest quality standards, more hydrogen is required to hydro-treat diesel fuels to virtually eliminate sulphur (less than 10ppm). This is required to minimise the tail pipe emissions of particulates from diesel as required by the latest vehicle engine technology.

A significant issue is the economy of scale. Refineries have a good response to economy of scale (unit production costs fall with increasing size of the refinery). Recently in our region several refineries have been built with outputs near to or exceeding Australia's total refinery capacity. Some of the major export refineries in the region are given in Table 1.

Table 1: Major export refineries in the Middle and Far East with output similar to Australia's total refinery capacity

Company	Location	Country	Capacity (bbl/d)
Formosa Petrochem.	Maliao	China Taiwan	540,000
Essar Refinery	Vadinar	India	405,000
Reliance Industries	Jamnagar	India	580,000
Reliance Industries	Jamnagar	India	660,000
Kuwait National Petroleum	Min Al-Ahmadi	Kuwait	466,000
Saudi Aramco	Rabigh	Saudi Arabia	400,000
Saudi Aramco	Ras Turana	Saudi Arabia	550,000
Saudi Aramco/Total	Jubail	Saudi Arabia	400,000
Saudi Aramco/Mobil	Yanbu	Saudi Arabia	400,000
ExxonMobil	Jurong/Pulau Ayer	Singapore	592,000
Shell Eastern	Pulau Bukom	Singapore	462,000
GS caltex Corp	Yeosu	South Korea	785,000
S-Oil Corp	Onsan	South Korea	669,000
SK Innovation	Ulsan	South Korea	840,000
Australian Refineries			
BP PLC	Bulwer Island, QLD	Australia	96,850
BP PLC	Kwinana, WA	Australia	136,698
Caltex Australia	Lytton, QLD	Australia	108,600
ExxonMobil	Footscray, VIC	Australia	77,000
Viva Energy Australia	Geelong, VIC	Australia	120,000
Total Australian refinery capacity			539,148

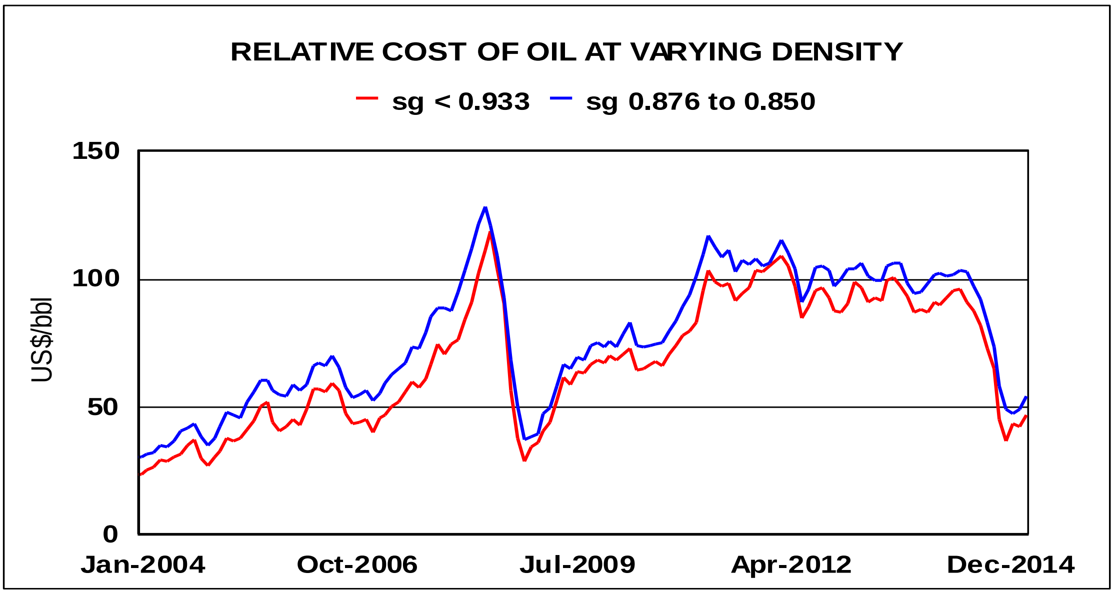
These refineries are export oriented refineries in that they take crude oil from the Middle East, including Iran, and convert it into products which are exported to the region. These refineries use the latest technology to produce high quality fuels now being adopted throughout Asia. Also they use heavy oil hydro-cracking so that high density, high sulphur crude oil (i.e. cheap) can be used rather than the more expensive light crudes that Australian refineries require; the figure shows the persistent price differential between heavy oil (sg < 0.933; API gravity <20) and the lighter crude oils (sg > 0.876; API > 35.1. This benefit is increased by a larger refinery gain because of the relatively higher density of the feedstock oil.

Closure of Australian refineries has resulted in the facilities being refurbished as import terminals importing high quality specification fuels from these export refineries.

As well as the smaller scale, one of the major issues for Australian refineries competing with these facilities is that coastal shipping in Australia (cabotage) is very expensive compared to shipping from foreign ports using foreign flagged vessels. It is cheaper to service an Australian port from Singapore (say) than from an expanded refinery somewhere else in Australia. Also, from the above equations, it is evident that refinery operations are major emitters of carbon dioxide. The enthusiasm for taxing or proscribing such emissions in Australia increases the investment risk versus investments in countries with little enthusiasm or even hostility to carbon emission taxes and the like.

One of the major issues for the chemistry profession is that as refineries close there is less opportunity for chemists and chemical engineers both working for and servicing refinery operations. But it is worse than this because refineries also supply many downstream chemical manufacturers with feedstock. This ranges from propylene for making high valued polymers to sulphur for the fertilizer and the agricultural industries.

Compared to the furore over the demise of vehicle manufacturing, there has been little concern expressed with the demise of hydrocarbon processing in Australia. This is a very worrying situation as it leaves the country exposed to the vagaries of international supply of high added value products and further reduces exports to basic minerals and LNG which have minimal added value.



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July 6, 2015