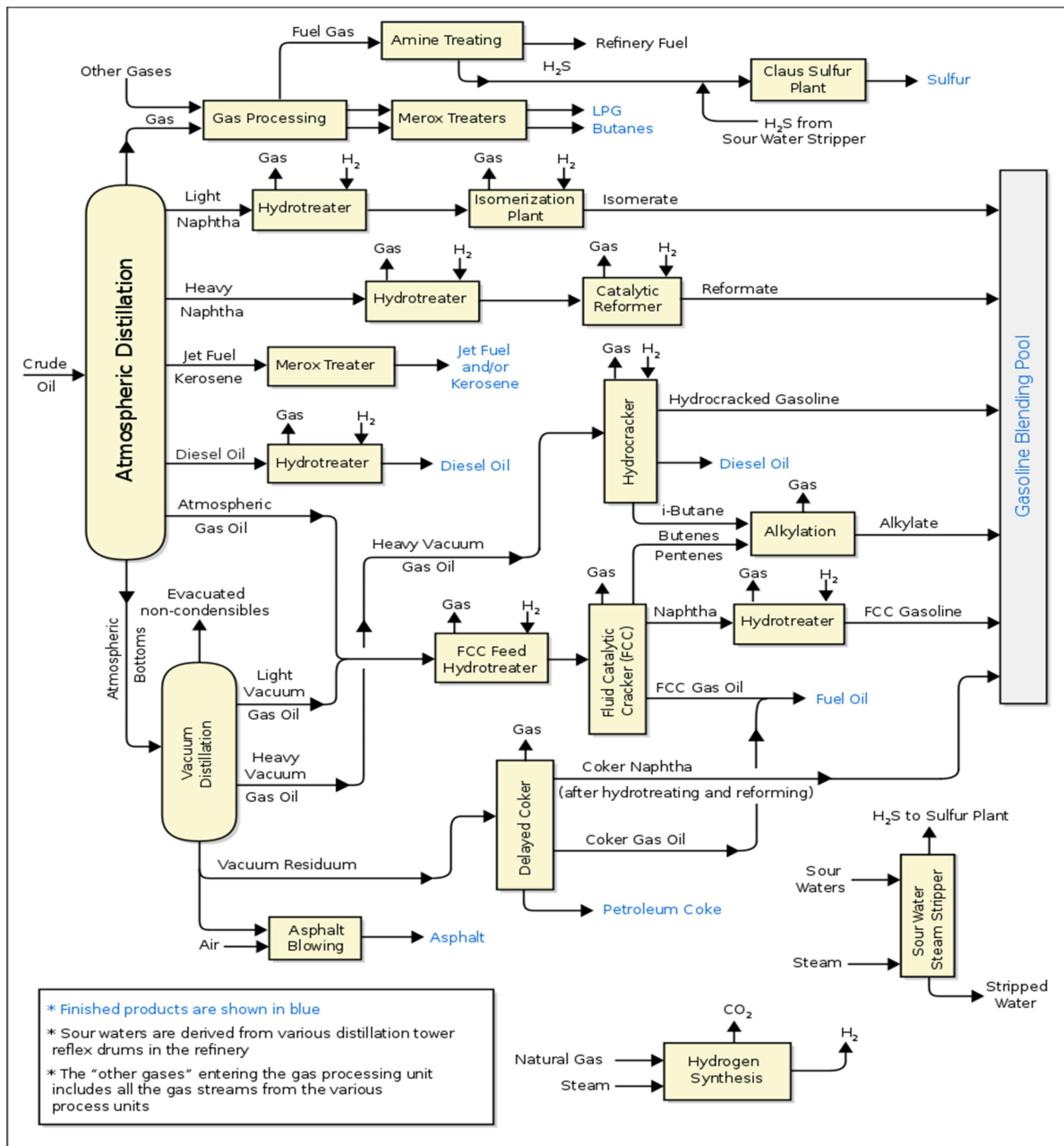




Conventional oil refining

In conventional oil refining catalysts are used to break long hydrocarbon chain lengths into shorter chains required for fuels. These processes are complex, energy intensive and expensive, and require the regeneration of the catalysts as they get poisoned by char formation. After a few cycles, the catalysts which are often nickel supported by zeolites, need to be disposed of, this is expensive and presents an environmental problem. Similarly, aromatic compounds need to be cracked catalytically in a separate operation. Each potential fuel composition requires separate processing and treatment before it can be blended into fuel products. The removal of sulphur from hydrocarbons is a costly operation not practised in all refineries. Smaller refineries usually do not have the complete collection of unit operations as depicted in the flow diagram above, as scale is required to justify the additional capital and operating expense.

The formation of char during catalytic reactions in conventional refining is one of the main technical challenges. This is the same problem encountered in most processes aimed at the conversion of organic waste and plastics into oil or fuels. The reason is that during the breaking of a hydrocarbon chain, the free carbon will preferably bind to another free carbon and also onto the walls of the processing vessels. If hydrogen can be made available rapidly enough this carbon- carbon bonding will be prevented, but this is difficult to achieve in practice. Hydrogen can be generated by the water-gas shift reaction combining natural gas or crude oil and steam. The flow diagram above shows that hydrogen is required in all the reforming reactors where heavier hydrocarbons are converted to shorter chains.

Sulphur is removed from the crude oil by treating the various fractions by hydrogen, which displaces the sulphur and moves it into the gaseous phase, which is then scrubbed in a complex system from which elemental sulphur is removed in a Claus plant.

As scale is required in conventional oil refining, it is costly to build a flexible system that allows for wide fluctuations in market demand. That is why few smaller refineries have survived, unless they cater for only one market segment. Moreover, smaller refineries do not have the capability to deal with substantial changes in the quality of crude oil.

The Carbofusion process

In contrast with conventional refining, the Carbofusion process combines all the different reactions into one reactor, with only separation processes executed in separate vessels. This capability is achieved by combining the following unique features resulting from many decades of research and development:

1. Supercritical processing (high pressure of 15 to 20 bar) is used, which allows rapid reaction rates as there is no gas-liquid interface. Numerous academic papers have discussed the application of supercritical processing to petrochemicals and the conversion of one hydrocarbon form into another, so the idea is not new. However, academic research usually refers to batch processing and therefore does not deal with the engineering challenges of feeding material, especially solids, at high pressure into a pressure vessel, and also the removal of reaction products at high pressure. These engineering challenges have not been addressed by competitors that usually feed slurry into a supercritical reactor, thereby distorting the reaction conditions resulting in low efficiencies. Therefore, the Carbofusion process is unique in allowing continuous feeding to and removal from a supercritical reactor.
2. Only a few academic articles have combined catalysis with supercritical processing. Although catalysis can be contemplated in a batch supercritical reactor, it becomes complex in a continuous system if the catalyst needs to be removed for regeneration. The Carbofusion reactor uses a proprietary conductive ceramic element that is gradually fed into the reactor without loss of productivity.
3. The principle of Non-Faradaic Electrochemical Modification of Catalytic Activity (NEMCA) has been known in the academic literature, with several papers showing that catalytic activity can be accelerated hundred to a thousand-fold when electric current is applied. Prof Costas Vayenas of the University of Patras in Greece has been the pioneer in the field of NEMCA. The combination of NEMCA with supercritical processing allows cook off temperatures of 200 to 300 °C lower than normal, so gasification proceeds at 550 to 600 °C instead of 840 °C minimum.
4. An operating principle of the Carbofusion process is that the catalyst makes hydrogen available so rapidly that char formation is eliminated. This rapid catalysis also allows for

close control over the hydrocarbon chain length, hence the bell curve of chain length is narrower than usual. Higher pressure gives longer chain length, while a higher temperature reduces chain length. The electric current and frequency during NEMCA are also used to control product quality

5. The Carbofusion reactor also incorporates the principles of cavitation that causes localised shockwaves in the reaction zone that have been shown to increase the effective temperature and pressure through an increase in entropy, hence a reduction in the free energy for reactions. The CarboSync team has extensive expertise and a proven track record in this field.
6. Water is injected directly into the Carbofusion reactor, so hydrogen is generated in-situ, so no separate hydrogen plant is required. Importantly, the process is not sensitive to the quality of water, as organic impurities are converted to fuel, while inorganic impurities are removed.
7. Sulphur in the crude oil or any other feed material is removed as solid sulphates and sulphides, together with other particulate and dissolved inorganic material, in the cyclone underflow after the Carbofusion reactor.
8. Waste heat generated elsewhere in the refinery is recovered and used to pre-heat the crude oil
9. No flaring takes place as all unused gaseous hydrocarbons or synthesis gas is recycled to the Carbofusion reactor for conversion to fuel products.
10. Depending on process optimisation and the composition of the crude oil, about 70% of the crude is converted to fuel products in the Carbofusion reactor, then separated by subsequent distillation, while the remaining 30% of hydrocarbons are returned to the reactor for further conversion.
11. Without doing testing on the crude oil and knowing the market demands, it is not known whether some mixtures may be azeotropic, hence cannot be separated by evaporative distillation. In that case, standard pervaporation membranes will be used. The innovation here is that recovered heating will be used to heat the pervaporation membranes, hence accelerating separation. This is expected to be the case if aviation fuel is produced where a low level of wax content is required, so then pervaporation will be used.
12. By using higher temperature and increased current, waxy aromatic compounds can be decomposed completely to form alkanes, however, the same conditions will also produce more light gas in the Carbofusion reactor. Consequently, it may be more optimal to not

convert all aromatics and rather separating them from alkane fuels using pervaporation.

13. During process optimisation it may be decided to separate hydrogen from carbon monoxide in synthesis gas formed in the Carbofusion reactor and coming off the top of the distillation column. Standard polymer membranes will be used for this purpose. It is possible that the carbon monoxide is used for energy generation, while the hydrogen is returned to the reactor.
14. The Carbofusion reactor decomposes effectively long chain hydrocarbons, which results in a deficiency of bitumen compared with a conventional refinery. If the market demands bitumen and it is economical to sell bitumen instead of fuel, then a separate Carbofusion reactor can be installed that is controlled to form bitumen, hence by increasing pressure and decreasing temperature.
15. Like in any refinery, the process control and optimisation of production conditions to meet market demand are complex functions that are largely computerised, using commercial software integrated with specific software controlling the Carbofusion reactors. The project team has extensive experience in the automation of plants.
16. During the 6 years of operation of a Carbofusion supercritical plant, no catalyst poisoning or wear was observed. The equipment required very low maintenance. There were no emissions from the reactor itself, with emissions below background level from the boilers and generators running on the clean fuels produced. The diesel produced was used to run a fleet of Mercedes Benz vehicles over 3 years without deleterious effects. The diesel quality will be determined by techno-economic optimisation of conditions.

Advantages of a Carbofusion oil refinery

1. Lower capital cost, because one reactor replaces numerous complex units
2. Lower operating cost, because maintenance is low
3. Flexibility in production and product range
4. Smaller parallel units can be used instead of one large unit, with lower cost, enhanced flexibility and less downtime
5. No flaring as gas is re-used

ARIAN GROUP

Industries

Tel: +61(03)94677563

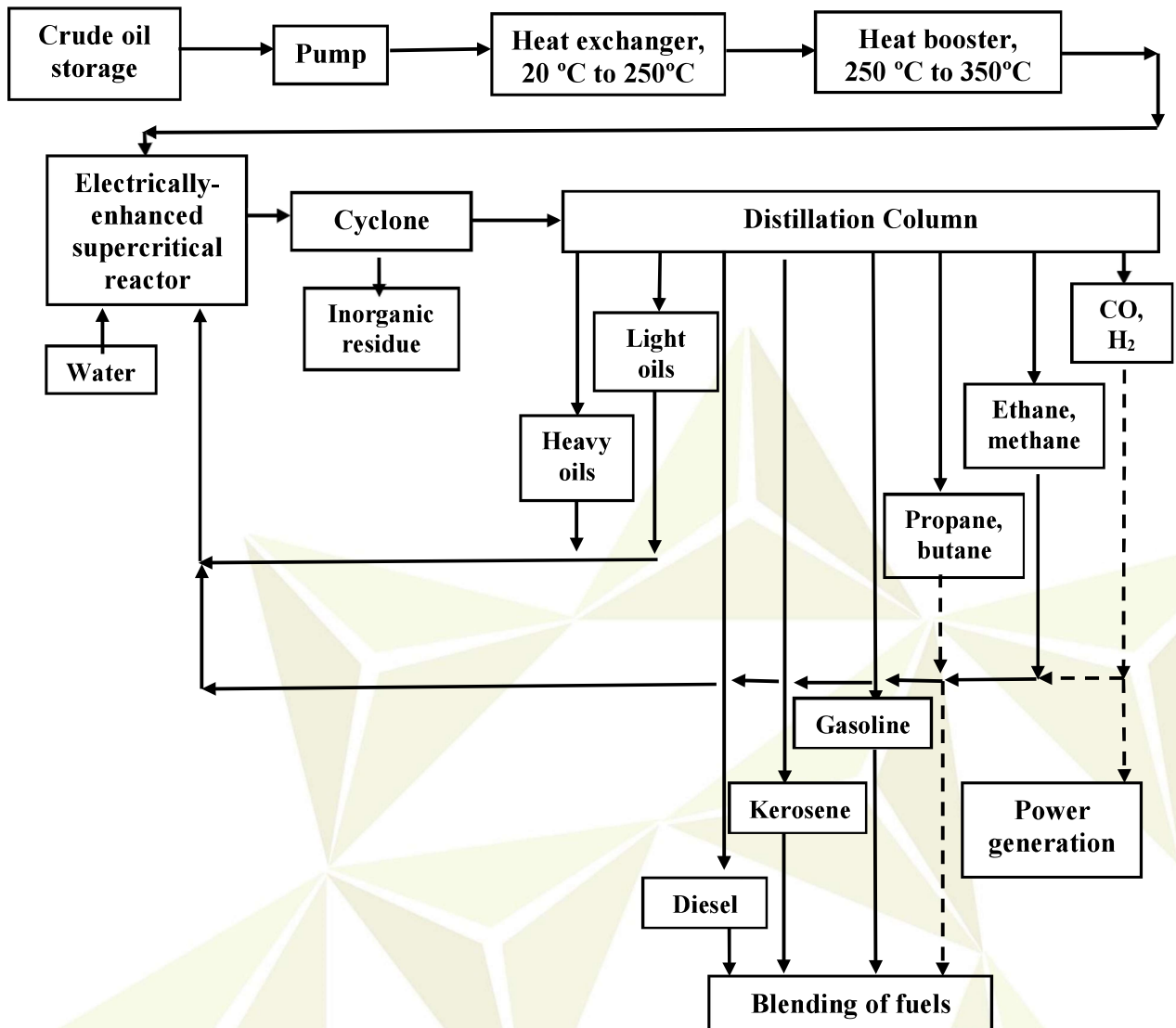
Fax: +61(03)94677563

Mob: +61(0)400747385

6. Emissions lower and more environmentally compliant
7. Char formation is eliminated, which reduces operating cost and maintenance
8. No nickel-zeolite catalyst consumption or disposal, hence lower cost and environmental impact
9. Can tolerate any sulphur level in crude oil or feedstock
10. The power consumption of a conventional oil refinery is between 3 and 6% of the calorific value of the crude oil processed. At 3% for a 75,000 bbl/day refinery it is 150MW. In contrast, it is estimated that the Carbofusion refinery will require maximum 60 MW power.
11. A conventional refinery consumes between 0.3 and 0.5 L water per L crude, depending on the processing and fuel product distribution. Most of this water is not consumed chemically in the production of hydrogen, but instead it is used in treatment of fuel products post distillation. In the Carbofusion this post-treatment is largely eliminated, so that the water consumption is estimated as 0.16 L per litre crude, which is a saving of 60% of water consumption. So the water consumption is 1.9 million L per day, with some of it being recycled.

Flow diagram for Carbofusion oil refinery

Typical Carbofusion refinery line



Total refinery

