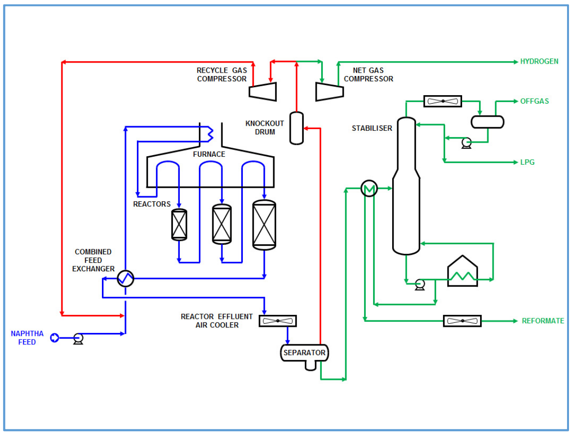
Refining Process Overview
Catalytic Reforming



Process Description

The catalytic reforming process upgrades low-value naphtha streams to high-value "reformate" for use in gasoline blending or aromatics production. "Reforming" refers to a series of chemical reactions which change the shape of hydrocarbon molecules without changing the number of carbon atoms they contain (although the number of hydrogen molecules may reduce). The naphtha feed to the catalytic reforming unit (CRU) is a mixture of molecules containing 6 - 11 carbon atoms (C_6 - C_{11}) with a boiling range of 82 - 204 °C (180 - 404 °F). The main reforming reactions are highly endothermic (require significant heat input) and liberate large volumes of hydrogen as a valuable by-product. C_{5-} molecules are excluded because they cannot form aromatic rings; C_{12+} molecules are excluded because they contain polynuclear aromatics which cause accelerated coking of the catalyst. Sulphur, nitrogen, water, iron, lead, arsenic and oxygen should be removed from the feed by hydrotreating to ensure optimal catalyst performance and unit operation.

The heart of the process is the reaction section which incorporates 3 or more reactors, each containing bi-functional (acid/metal) catalyst. The reactors operate in a hydrogen-rich atmosphere at 480 - 540 °C (896 - 1004 °F) and 5 - 25 barg (72.5 - 363 psig), depending on process technology type. The catalyst is typically activated alumina impregnated with platinum (Pt) and rhenium (Re) or tin (Sn) and is supplied in either extrudate or spherical forms. The acidity of the catalyst is maintained by addition of a chloriding agent. The correct balance between the acid and metal functions of the catalyst is maintained by controlling the water/chloride ratio in the recycle gas.

There are 3 CRU process technology types; semi-regenerative, cyclic and continuous. The main difference between them is the method of catalyst regeneration. In the semi-regenerative CRU, the unit is periodically taken off-line and all catalyst is regenerated in-situ using the main process equipment. In the cyclic CRU, an additional "swing" reactor is provided along with dedicated regeneration equipment including numerous special motorised valves which enables any one reactor to be taken off-line for in-situ catalyst regeneration with the remaining reactors still in service. In the continuous CRU, spherical catalyst flows "continuously" through the reactors by gravity, is pneumatically conveyed to a regenerator, flows through the regenerator by gravity and is pneumatically conveyed back to the first reactor.

Key Variables

The key independent variables affecting CRU performance are temperature, pressure and hydrogen:hydrocarbon ratio. Reactor inlet temperature is the main control variable affecting reformate quality. It should be minimised subject to meeting the required reformate quality specifications in order to minimise reformate yield loss and avoid accelerated catalyst coking. Reactor pressure is the main variable affecting product yield although there is limited scope to vary this once the unit is built. It should be minimised subject to remaining within catalyst coking constraints in order to maximise reformate yield. Hydrogen:hydrocarbon ratio affects coke laydown rate and should be maximised subject to recycle gas compressor capacity and compressor driver utility cost constraints in order to minimise catalyst coking.

Safety Issues

The biggest process safety risks for a CRU are 1) fire/explosion in case of a loss of primary containment (LOPC) due to the wide-ranging explosive concentration limits and low ignition energy for hydrogen and operation above auto-ignition temperatures for hydrocarbons and 2) cross-contamination of oxidising and reducing atmospheres during catalyst regeneration. Benzene and (to a lesser extent) toluene/xylene are toxic and highly carcinogenic so appropriate personal protective equipment (PPE) must be used where exposure to these materials is considered likely.

Availability Issues

The main availability issues are feed/effluent exchanger fouling (gum formation, corrosion deposit accumulation) and tube failure (under-deposit corrosion), charge heater tube failure (coking or polythionic acid stress corrosion cracking), reactor pressure drop rise, catalyst deactivation and reactor effluent air cooler leakage (acid dew point corrosion).