

*Application Solutions Guide*

# REFINERY PROCESS



*Experience In Motion*



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# GLOBAL REFINERY LANDSCAPE

## Market Overview

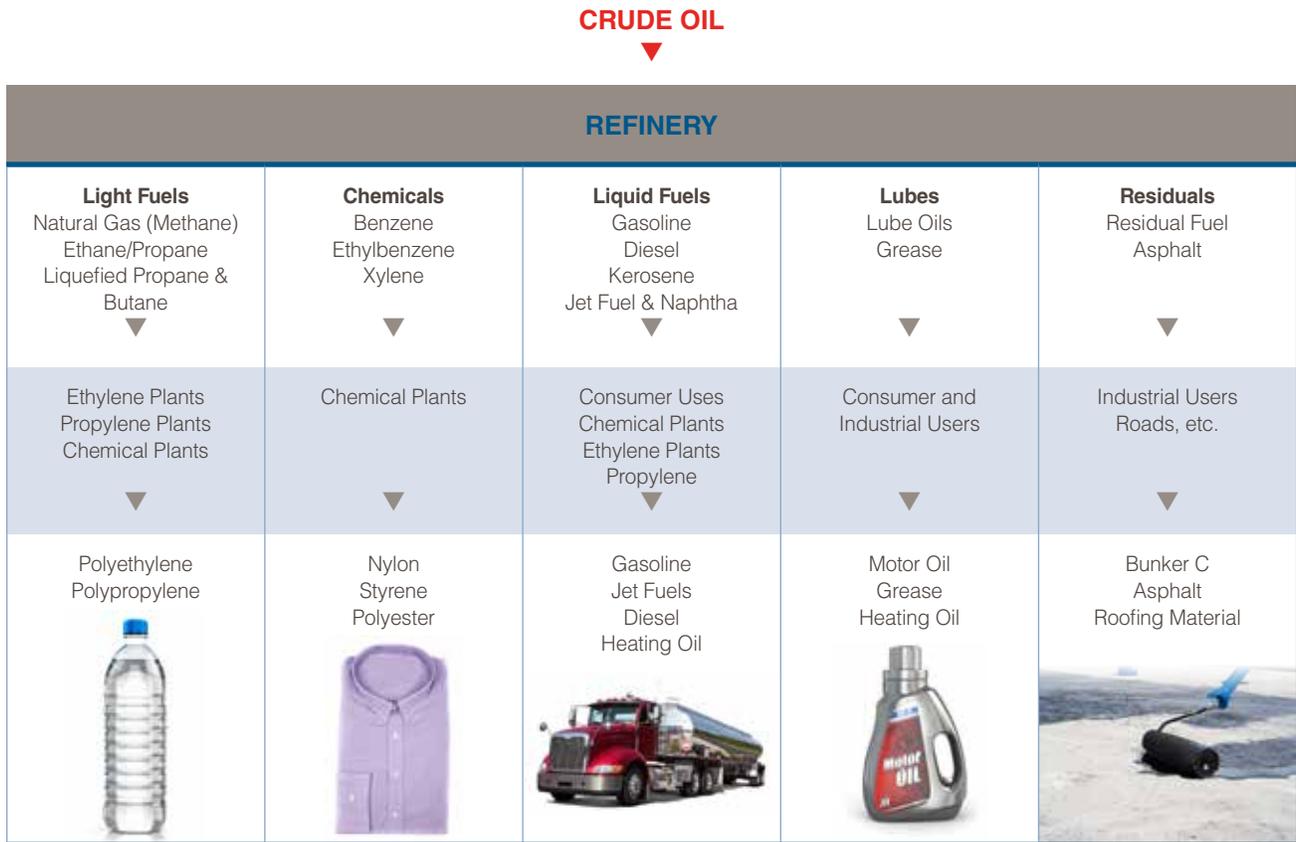
Modern refineries are complex facilities, processing products into a number of various specifications. Refineries are designed or enhanced to make a wide variety of products: gasoline, fuel oil, lube oils, jet/condensates, solvents, diesels, asphalts, coke and gases/LPGs. An average refinery size is between 100 000 to 400 000 BPD. For the purposes of this guide, all our estimates and references are for 200 000 BPD refineries.

The composition of crude oils varies significantly, depending upon their source.

Refineries are complex systems with multiple operations.

- The basics of all refineries are the same, but the specific operations vary and depend on:
  - Properties of the crude oil refined
  - Desired finished product output

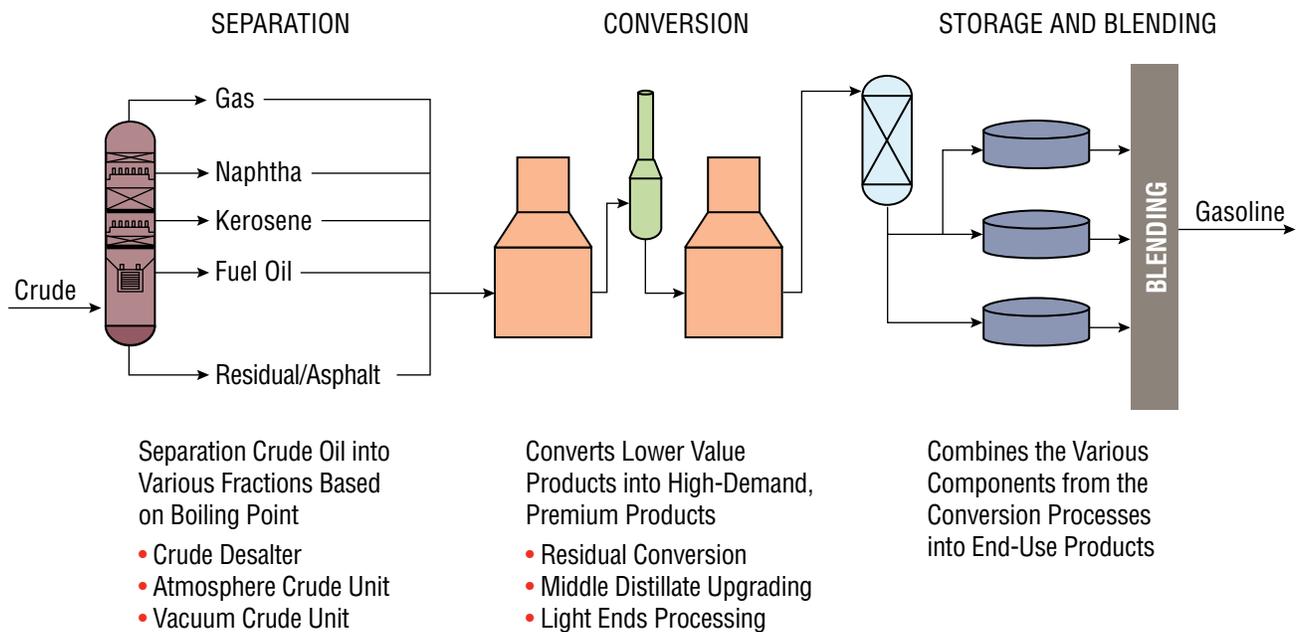
Table 1.1: Refining process



Twenty-first-century technologies have improved to make the processes more efficient, steam and cracking less risky, and MTBF longer for maintenance/shutdown schedules. Shale gas has become an alternative to naphtha as the feed stock to petrochemical sites due to low cost feed stock (specifically in North America) but more important, the electronic monitoring and controls for safety, process improvements and life cycle costs. Today's

refineries are geared toward specific products or are smaller in size. In this regard, refinery operations are predicated on the performance of the mechanical equipment, e.g., pumps, valves, blowers, compressors, drivers and seal systems. The application of these products is key to be properly sized and designed for satisfactory MTBF. Equipment such as pumps and valves usually represent 10% to 15% of the capital investment in the refinery processes; they are the most important type of equipment with respect to plant reliability.

Figure 1.1: Basic refinery process flow



### Nelson Refinery Complexity (NCI)

Allows comparison between different types of refineries.

- Simple “hydroskimming” refineries may only separate and treat
- Complex “hydrocracking” refineries will also have several conversion processes

The Nelson complexity index (NCI) is a measure to compare the secondary conversion capacity of a petroleum refinery with the primary distillation capacity. The index provides an easy metric for quantifying and ranking the complexity of various refineries and units. To calculate the index, it is necessary to use complexity factors, which compare the cost of upgrading units to the cost of crude distillation unit.

### The Equivalent Distillation Capacity (EDC)

- Each unit is assigned a complexity index based on cost relative to the atmospheric crude unit
- The sum of the unit complexities normalized to the atmospheric distillation capacity

Table 1.2: Generalized complexity indices

Refining Process	Generalized complexity index	Refining Process	Generalized complexity index
Atmospheric distillation	1	Catalytic hydrotreating	2
Vacuum distillation	2	Alkylation/polymerization	10
Delayed coking	6	Aromatics/isomerization	15
Visbreaking	2.75	Lubes	10
Catalytic cracking	6	Asphalt	1.5
Catalytic reforming	5	Hydrogen (MCFD)	1
Catalytic hydrocracking	6	Oxygenates MTBE	10
Catalytic hydrorefining	3		

Table 1.3: Circa 2014

	Holland	US	China	Russia
# Refineries	6	125	54	40
Crude M B/D	1197	17 788	6866	5431
Complexity	7.85	9.62	2.26	4.56
EDC ME B/D	9336	171 190	15 551	24 785

### Refinery Crude Terminology

API (American Petroleum Institute) gravity crude oil is classified as light, medium or heavy, according to its measured API gravity.

- Light crude oil is defined as having an API gravity higher than 31.1° API
- Medium oil is defined as having an API gravity between 22.3° API and 31.1° API
- Heavy oil is defined as having an API gravity below 22.3° API

1 barrel equals 42 U.S. gallons

1 BPD = Gallons / (hrs\*min) = 42 / (24\*60) = .0292 gpm

1 gpm = 34.29 BPD

1 barrel equals 158.984 liters

The approximate conversion for BPD to tonnes/year is 49.8, so 100 000 BPD equals around 4 980 000 tonnes per year.

Crude oil has virtually no value in its raw form.

Value is added by refining it into sellable fuels and chemical (Naphtha & Ethane) feed stocks.



### API for valves

The oil and gas industry does not use a universal API specification for valves like they have on pumps and seal systems; however, there are a few specs written, to which are often referred.

1-ANSI: 1610/1634, which are more dimensional guides

2-NACE: specs for metallurgy

Figure 1.4: In-process refinery end products and finished marketable refinery end products diagram

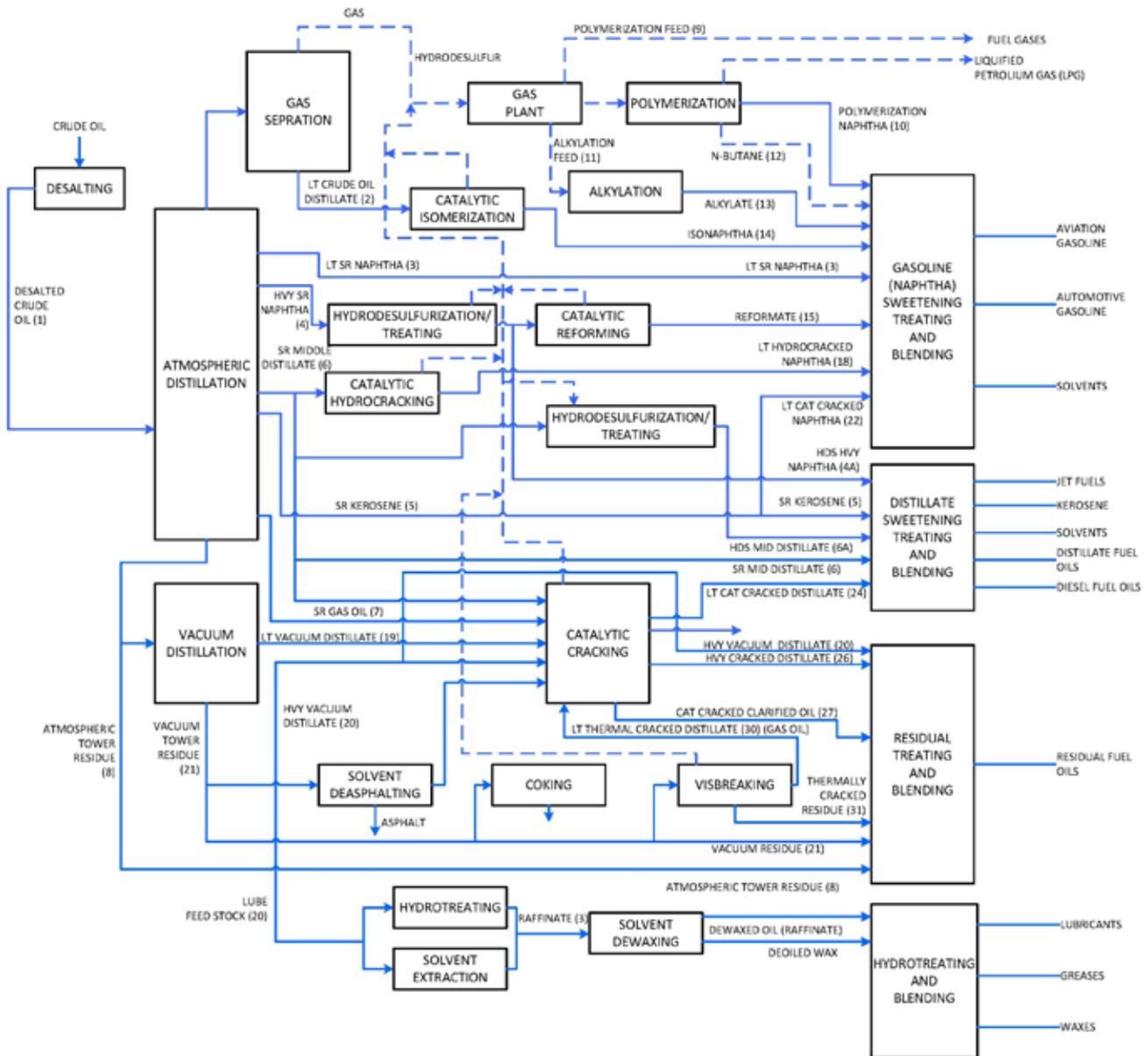
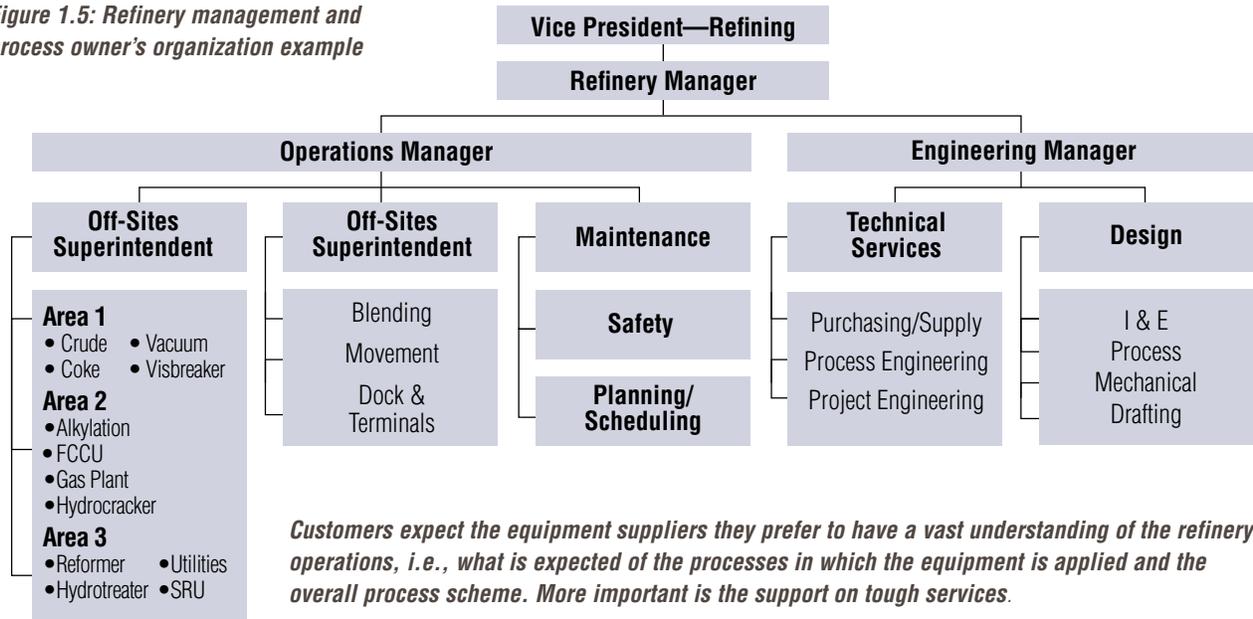


Figure 1.5: Refinery management and process owner's organization example



## Refinery Process Overview

The feedstock of **crude oil** is a gooey mixture of various hydrocarbons which is **de-salted**, heated, separated and broken down big molecules of un-useable heavy product into smaller molecules of useable lighter products. The heavier products are fed into **catalytic cracking** or **hydrocracking** units to obtain gasoline, naphtha and middle distillates. Catalysts are used to improve the yield of the gasoline and lighter products in the cracker. A *catalyst* is a substance which facilitates a chemical reaction without being consumed in the reaction. **Hydrocracking** is similar, but done in an atmosphere of hydrogen (second key feed stock to a refinery). The hydrogenation increases the yield of gasoline and produces saturated hydrocarbons which do not gum up with time.

Hydrogen sites are not always directly located at a refinery, but are key feedstock to several processes within the refinery.

**Hydrotreating** or **reforming** improves the quality of finished products and can require several treaters in a refinery based on the various products broken down after **distillation**. Hydrotreating stabilizes as saturated non-gumming molecules and with reforming, re-arranges the structure to improve to high-octane aromatics.

Naphtha is processed and used in gasoline and solvents, and continues to be key today as the feedstock for petrochemical or polyethylene crackers in chemical plants. However, in the past decade, **shale gas** which is a primary product of **ethane** is also a key, and growing feedstock to the petrochemical industry.

The wet gas from the **fractionated units** in the vapor recovery splits into fuel gas, LPG, butane, isobutane and unsaturated hydrocarbons.

Fuel gas is used in refinery heaters. Butane gets blended into LPG or gasoline, and the unsaturated hydrocarbons along with isobutene are sent to the alkylation unit for conversion into high-octane compounds to be blended into jet fuel and premium gasoline.

An **alky unit** uses sulfuric or hydrofluoric acid as the catalyst to react to unsaturated hydrocarbons with isobutene to form high-octane isoparaffins compounds.



The **maze of equipment** in Figure 1.6 is subdivided into individual process units, each with its own function to perform. The sizes and types of process are dependent on the type of crude charged to the unit and the type of products produced for the specific targeted market.

Each box in Figure 1.6 represents a process unit—**atmospheric distillation, hydrotreater, hydrocracking, reformer, alkylation, isomerization, decoking, FCC**, etc., which all get mixed together to form the final marketable product.

Additionally, the breaking points in a refinery (boiling temperatures) are defined in figure 1.7.

Figure 1.7: The chart below shows the break point for fractions in a refinery

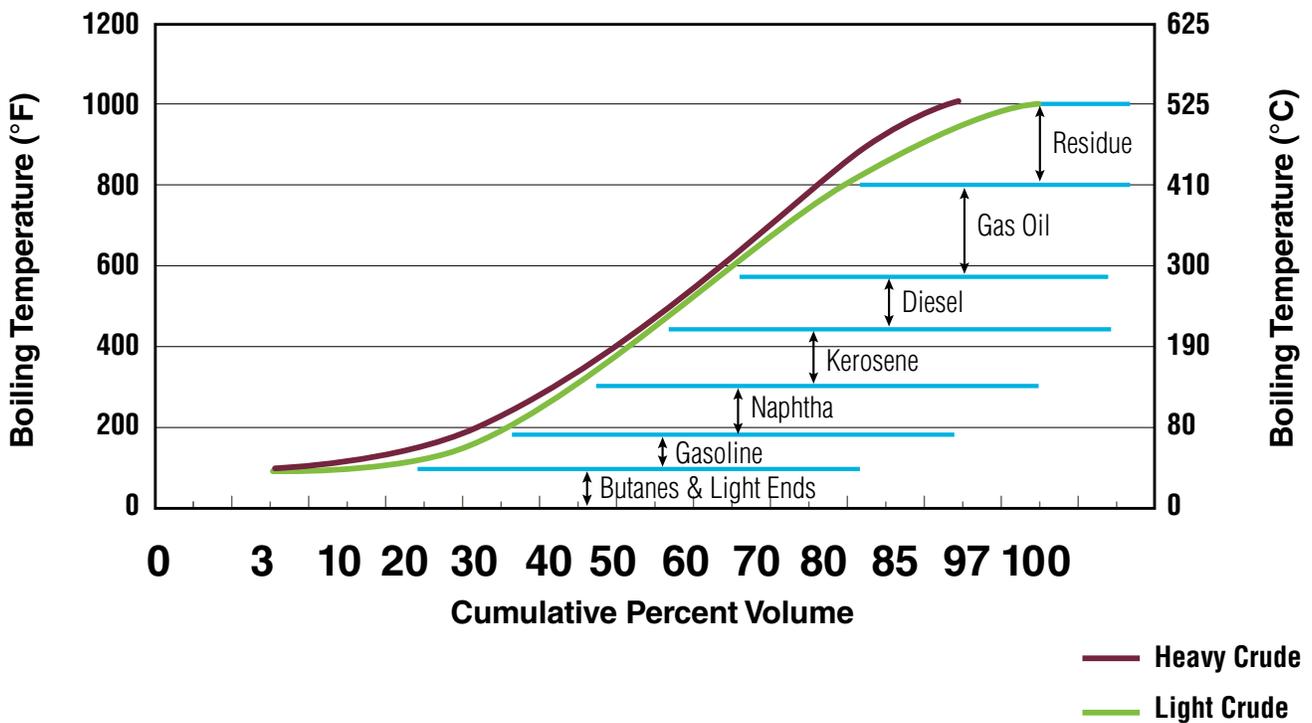
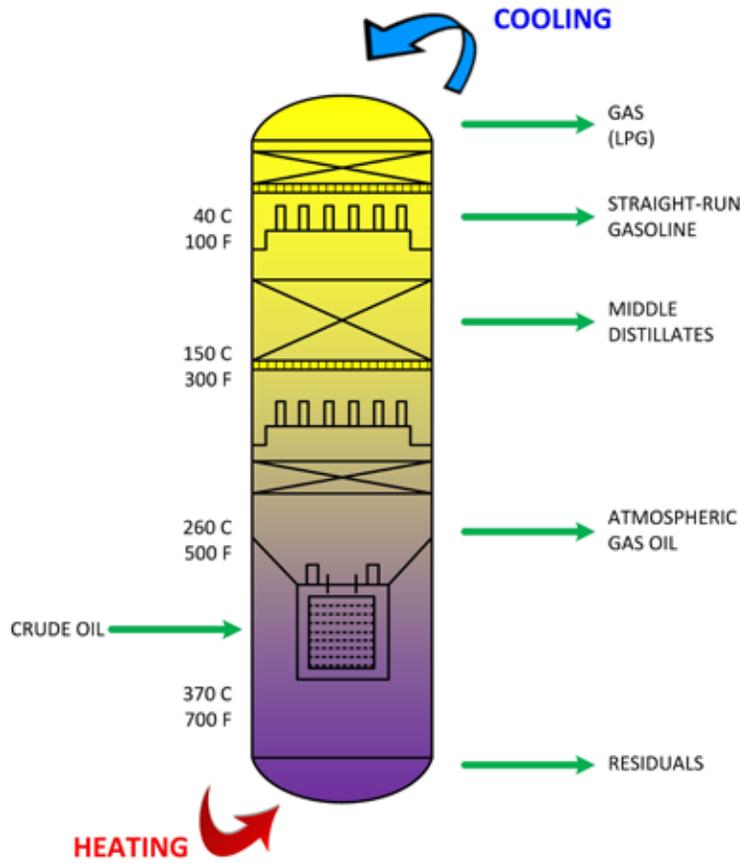


Figure 1.8: The following chart shares the thermal variance in the primary tower



FLOWSERVE CONFIDENTIAL  
 PFD144-00;REFINERY; SEPARATION PROCESS-CRUDE DISTILLATION TOWER;05JUL17;DRAFT;(Confidential-copyright(c) FLS)

Most important, all these processes use Flowserve products in vast applications and dependable service life. Flowserve and its legacy product brands of [valves](#), [pumps](#) and [seal](#) systems are pioneers in many applications and processes such as hydraulic decoking systems.

Also, not shown on the flow diagram are the blending (mixing) tank farms and utility equipment, better known as the powerhouse. Flowserve products also are used in these many applications on which customers depend; we strive to continuously meet their expectations.

# A CLOSER LOOK AT REFINERY PROCESSES

To support the process flow, next we will share the processes used in a refinery to follow the crude fractions in each process and highlight how Flowserve products fit in.

## Cut Points

Initial boiling point (IBP): temperature at which a product (or cut or fraction) begins to boil.

End point: the temperature at which product is 100% vaporized.

The first major process in all refineries is **atmospheric distillation**. Here the crude is heated to its boiling point and separated by means of fractionating columns into various fractions from heavy to light. Each of the downstream processing units will require feedstocks that start with the properties to meet the marketable product requirements.

Most refineries accomplish the distillation process in two steps. First, by fractionating the total crude supply at atmospheric pressure noted above. Second, by feeding the heaviest fraction, atmospheric “bottoms” from the atmospheric distillation unit to a second fractionator operating at a high vacuum called **vacuum distillation**.

These heavy fractions are boiled under a vacuum to make a product suitable for the manufacture of coke in the **delayed coker**, which are also used for heavy fuel oils. The gas oil fractions from the crude unit are feedstocks for gasoline and diesel fuel. These oils are pumped to the **Fluid Catalytic Cracking Unit (FCC)** and the **hydrocracking units** for producing various forms of gasoline, light fuel oils and diesel fuels. The fractionating units separate these products after the cracking reaction takes place so they can be segregated for final treatment prior to market transfer.

Table 2.1

Fraction	Cut Points, °C		Cut Points, °F	
	IBP	End	IBP	End
Butane & Lighter		< 30		< 90
Gasoline	30	100	90	220
Naphtha	100	160	220	315
Kerosene	160	230	315	450
Light Gas Oil	230	340	450	650
Heavy Gas Oil	340	540	650	800
Resid	>540		>800	

## FCC: A Catalytic Cracking Process That Does Not Add Hydrogen

- **Heavy and light gas oils feed** from the crude and other units are pumped through a heater and mixed with a catalyst
- **Catalyst** promotes the cracking process
  - The catalyst has a very high surface area, which accelerates the reaction. The catalyst does not change chemically.
    - The cracked products are sent to a fractionator for separation
    - The target product is gasoline
    - Total product volume is increased
      - Product mass decreases

### Hydrocracker: A Catalytic Cracking Process in the Presence of Hydrogen

- Feeds heavy gas oil from the crude units, FCC and/or delayed coker
- It takes in the worst of the distillate stocks and outturns a better-than-average gasoline blending component
- Relatively large amount of isobutane is produced
  - Useful in balancing feed to the alky plant
- Also reduces impurities like sulfur, metals and nitrogen

The **hydrocracker is a pivot point** in the refinery:

- It can swing refinery yields among gasoline, distillate fuel and jet fuel, and simultaneously improve product quality
- Operation depends on:
  - Feed rates
  - Operating conditions of other resid units (FCC and/or coker) that feed the hydrocracker
- In addition, the hydrocracker:
  - Feeds the alky plant with isobutane
  - Feeds the cat reformer with naphtha

### Ebullated Bed Hydrocracker

A catalytic, hydrogenation cracking process where the catalyst bed is kept in constant motion (ebullated) within the reactor.

- Combines thermal, catalytic cracking and hydrogenation
- Treats resid with hydrogen in presence of an ebullated catalyst bed to produce low sulfur, residuum and distillates, or both
- Two process licensors and fewer than 20 units in the world
- High operating conditions; typically, up to 454°C (850°F) and 238 bar (3452 psi)

### Naphtha Fractions

The light naphtha components from distillers are sent to the **catalytic reformer** for making gasoline with higher octane levels. This product is mixed with gasoline from the catalytic cracking unit and the hydrocracker to obtain the desired octane numbers of the various grades of gasolines.

The **alkylation unit** also produces a high-octane component for blending into gasoline.

### LPG and Gas Fractions

The lightest fractions from the **distillation unit** are used for **LPG** or bottled gases. They are mixed with the lighter components from the refinery processes to produce the marketable final products.

Refineries have a group of processes at various stages of the process flow diagram called **hydrotreaters**, whose primary role is to remove **sulfur** from the product streams prior to them be processed further.

Removing **sulfur** from the final product is necessary, but also benefits from the standpoint of corrosion and process efficiency prior to the high-temperature process reactions.

### Hydrotreating

- The light streams from the crude unit to the **alky** and **isomeric** units
- Gas oil streams before they enter the **FCC**
- Raw diesel oil streams from the **crude unit**
- Naphtha streams from the **FCC** before mixing in the gasoline pool

## Refinery Conversion

Most money, time and effort are spent on the conversion because this is where the money is made in a refinery.

- All conversion processes change the fraction at the molecular level.
- Using heat, catalyst and sometimes pressure, large hydrocarbon molecules are decomposed or “cracked” into lighter, smaller molecules.
- **Conversion** of low-value fractions (resid) to high-value products (gasoline and diesel)

**Table 2.2**

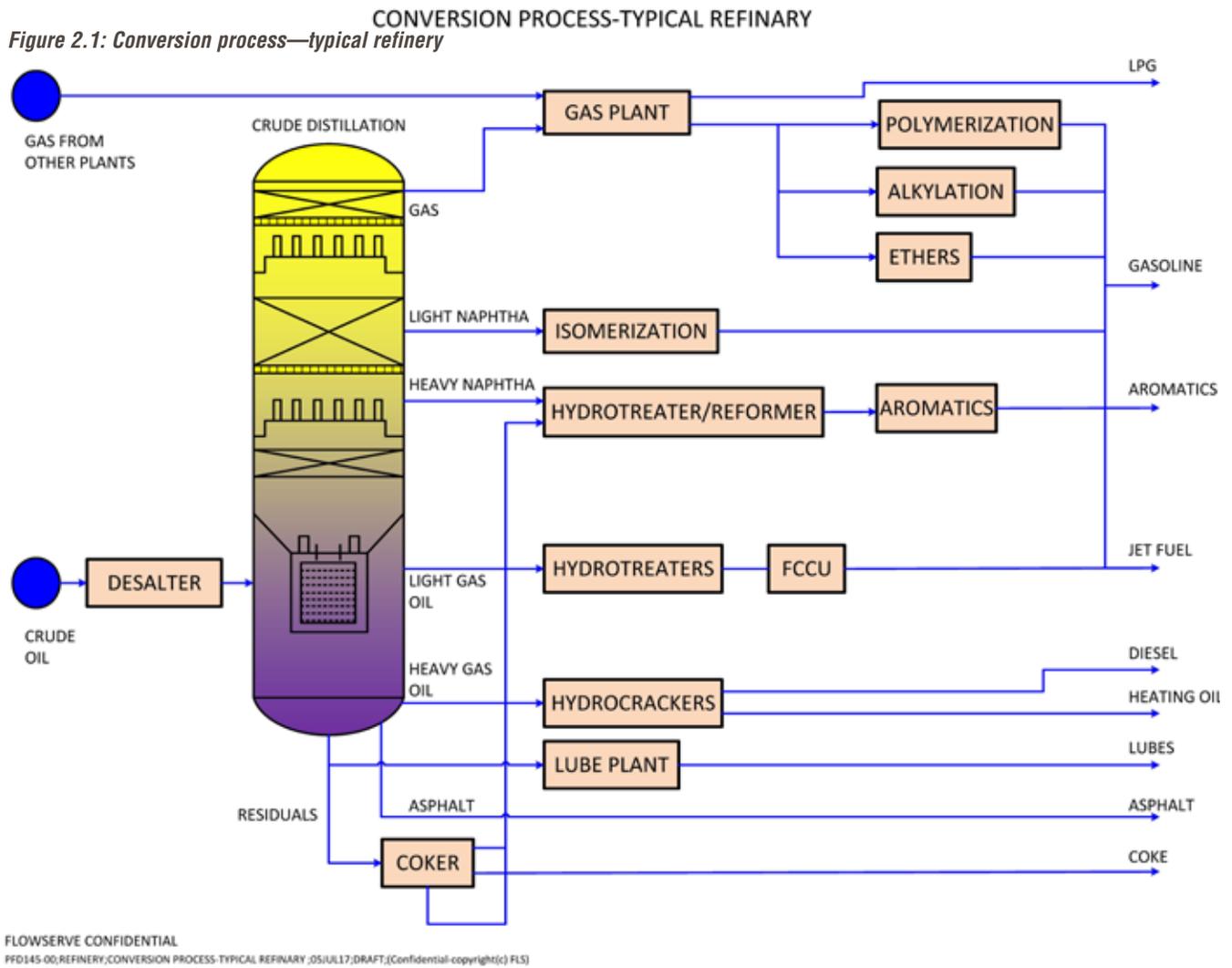
### PROCESS UNITS BY CATEGORY

Processing Category Type	Unit Type
Separation	ATM Crude Distillation VAC Distillation
Reducing Average Molecular Weight	Delayed Coking GO/VR Hydrocracking Visbreaking
Quality Improvement	Hydrotreating (All Streams) Catalytic Reforming Isomerization
Increasing Average Molecular Weight	Alkylation

### Conversion Processes

- Catalytic cracking
- Hydrocracking
- Delayed coking
- Visbreaking
- Catalytic reforming
- Alkylation
- Isomerization

In summary (Figure 2.1), simplified feedstock and commercial end products:



*One of the other feedstocks to a refinery is hydrogen, used in most of the processes (hydrotreater, isomerization, FCC and reformer) and is a complex capital intensive unit.*

## Hydrogen Plant

Refineries are large users of hydrogen. In a typical refinery, the processes described below use hydrogen. The hydrogen is manufactured on-site using a steam reforming process. Propane feed is mixed with super-heated steam and reformed in the presence of catalysts at 1400 to 1600°F. The resultant gas ( $\text{CO}_2/\text{H}_2$ ) is passed through an amine scrubber to remove the  $\text{CO}_2$ . The pump metallurgies for this area are all chrome steel, reflecting the corrosive nature of the  $\text{CO}_2$  mixtures and the boiler feed water. The pumps on this unit are at 100% capacity and normally no standby.

## Desalter

Crude oil often contains water, inorganic salts, suspended solids and water-soluble trace metals. These contaminants must be removed to reduce corrosion, plugging and fouling of equipment, and prevent poisoning catalysts in downstream processing units. Desalting, the first step and one of the most critical processes in refining, removes these contaminants. Desalter efficiency can have a dramatic impact on nearly every downstream unit. Crude oil desalting is the process of “washing” the crude with water to extract salts and solids. The two most typical methods of crude-oil desalting, chemical and electrostatic separation, use hot water as the extraction agent. In chemical desalting, water and chemical surfactants (demulsifiers) are added to the crude, heated so that salts and other impurities dissolve into or attach to the water, and then are held in a tank where they settle out. Electrical desalting is the application of high-voltage electrostatic charges to concentrate suspended water globules in the bottom of the settling tank. Surfactants are added only when the crude has a large amount of suspended solids. Both methods of desalting are continuous.

## Nitrogen Plant

In remote geographic locations, nitrogen for process use may be manufactured on-site. In heavily industrialized areas, nitrogen as well as hydrogen, would be purchased outside. A typical nitrogen plant for a refinery this size would contain four centrifugal pumps operating at ambient temperatures, with flows to 75 gpm and heads to 380 feet. Caustic is used in the process. Some 316SS is used in pump construction. The pumps are at 100% capacity without standby. Sufficient nitrogen can be stored to satisfy requirements during unit maintenance.

## Amine Treating

This process is used for dehydrating and acid **gas removal from refinery gases**. An amine solution is contacted with the sour gases absorbing the impurities. The amine solution is then regenerated.  $\text{H}_2\text{S}$  saturated water is also removed from the stream. Pumping temperatures range from 100 to 250°F and pressures to 500 psig. 316SS and Alloy 20 are used on the more corrosive sour water services. Flowserve SIHI® vacuum units are good applications.

## Sulfur Recovery

Sulfur removal is an integral part of today's refineries, both from the low sulfur fuel point of view and the pretreatment required for processes using a catalyst. The recovery and sale of sulfur are important parts of the refinery. Centrifugal OH2 API pumps are used in this area for handling molten sulfur and sour water. Both of these services require 316SS.

## Asphalt Plant

This area uses positive displacement pumps for handling the high-viscosity product at 300 to 500°F. Flowserve does not have this product in the portfolio.



## Critical Pump Products by Process

In summary, it is important to recognize each refinery globally has its own unique processing scheme which is determined by the equipment available, operating costs and the marketable products demand. The optimum flow pattern for any refinery is dictated by economic considerations, and no two refineries are identical in their operational platform.

### Flowserve Pumps

*Table 2.3: Processing unit in a typical 100 000 barrels/day refinery*

PROCESSING UNIT	API PUMP CODE	QUANTITY OF PUMPS
Atmospheric Tower	OH2	25
	BB2	6
Delayed Coker	OH2	42
	BB2	2
	BB5	3
FCC (Fluidized Bed Catalytic Cracking)	OH2	22
	BB2	8
H.F. (Hydrofluoric) Alkylation	OH2	10
	BB2	4
Naphtha Reforming	OH2	4
	BB5	2
Hydrotreater	OH2	4
	BB5	2
Hydrocracker	BB5	8
Hydro-Desulfurization	OH2	2
	BB2	2
	BB5	3
<b>Total</b>	<b>OH2</b>	<b>114</b>
	<b>BB2</b>	<b>22</b>
	<b>BB5</b>	<b>14</b>

Additional non-API products can include other Flowserve products with Split Case, Verticals and ASME ISO as defined in the next pages.

### Slurry Oil Pump

- Catalyst fines cause severe erosion



- High catalyst content requires either coatings or the **Lawrence® legacy product HPX6000 pump** to prevent erosion as shown here



### Feed Charge Pump

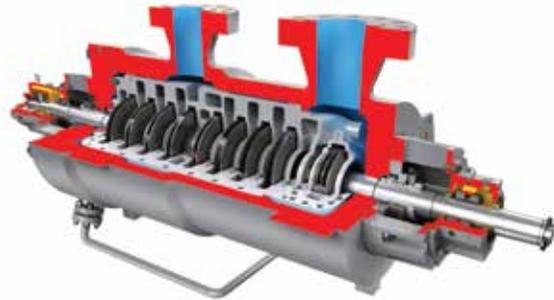
- The high pressure generally requires a barrel pump
  - Usually unspared (**IDP® HDO model**)
  - Some refiners use a (**IDP DMX model**)



Pump: 10x12x15 **DMX** –10-stage

- Capacity: 616 m<sup>3</sup>/hr (2710 gpm)
- TDH: 1990 m (6530 feet)

- An **HPRT** may be used downstream of the reactors to recover energy from the high-pressure stream



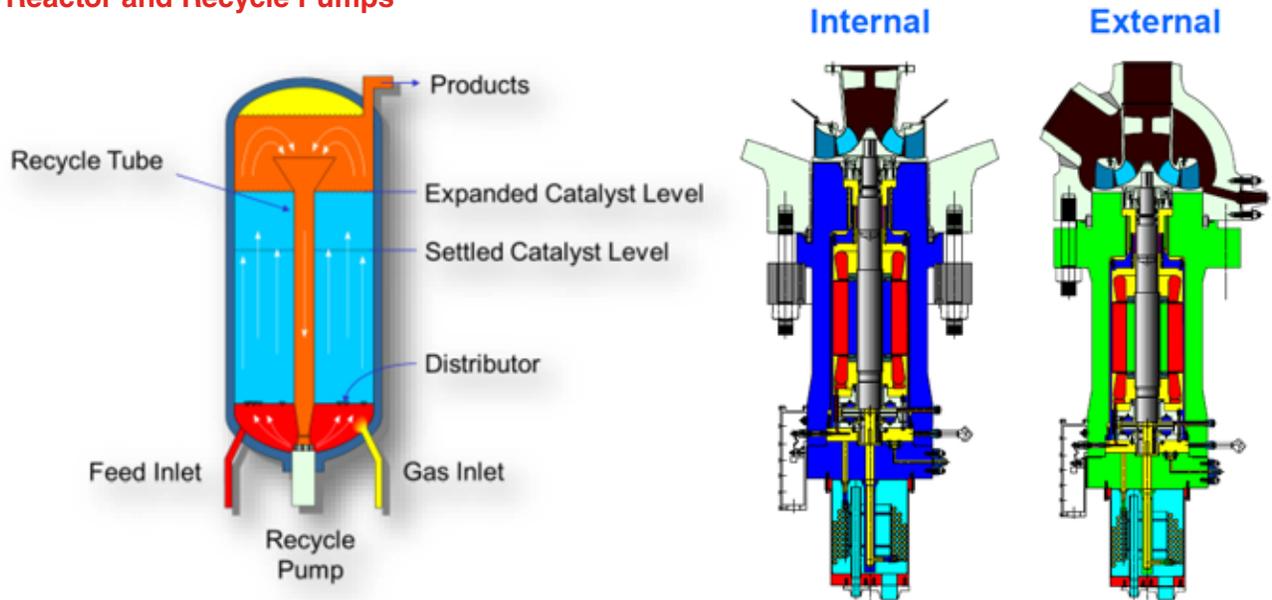
**HPRT**: 6x8x13L **HDO** six-stage

- Cap: 393 m<sup>3</sup>/hr (1730 gpm)
- TDH: 1515 m (4970 feet)



Figure 2.3: Ebullated bed hydrocracking

### Reactor and Recycle Pumps



Flowserve type PR reactor recycle pumps (ebullators) are essential high-temperature, high-pressure (BJ) canned motor pumps.

### Decoking Pumps

Decoking (DCU) has several Flowserve products, but four critical applications:

#### 1. Coker Heater Charge

Several options—model **HED**, **DSTHF**, barrel pump with coke cutter



## 2. Jet Pump

### The largest pump in the refinery

- Pressures to 305 bar (5000 psi)
- Power to 3700 kW (5000 hp)
- Model **WIK** pump is the current standard
  - Other heritage barrels have been used
- Unspared duty with abrasive coke fines

(EMA might use slower-running product “Worthington legacy” WC pump.)



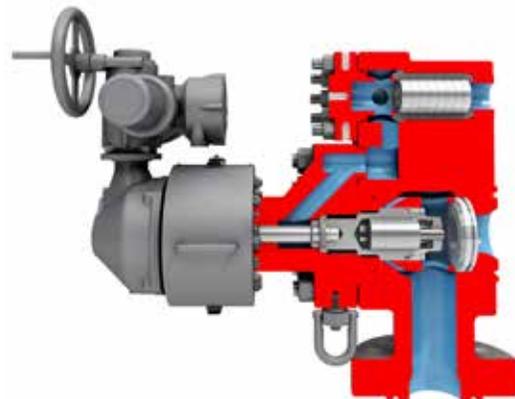
## 3. Bottom Unheading Flowserve Valve



## 4. Decoking Control Valve

### Two-way valve to control flow from the jet pump

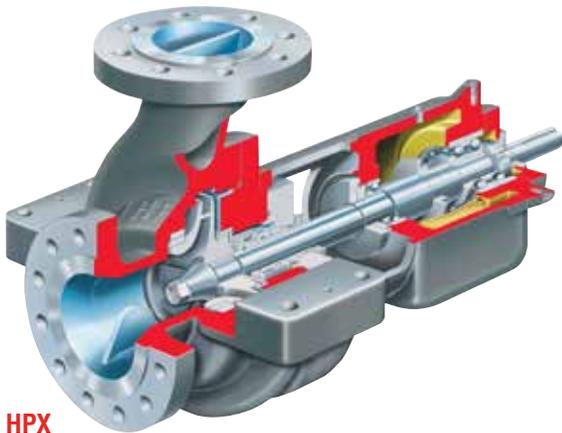
- Function is changed by moving the valve stem
- The Flowserve new advanced DCV **ADCV** simplifies maintenance by allowing field replacement of the orifice stack.
  - Direct replacement of the Flowserve DCV with no piping modifications



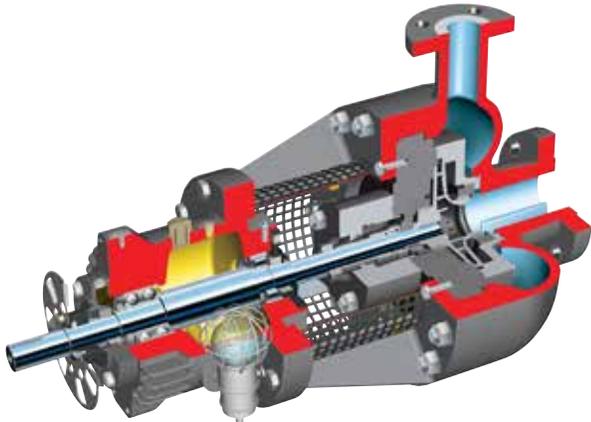
### Alkylation Pumps

The challenge of alkylation is not pressure or temperature, but the hazardous acids.

- HF is an especially nasty fluid
- Standard OH2 or OH3 pumps can be used
  - Special decontamination is needed when working on alky pumps
  - Seals are of prime importance
  - Sealless (mag drive) pumps have been explored



HPX



PHL

### Hydrotreater Pumps

- Temperatures of 300 to 400°C (570 to 750°F)
- Pressures vary from 30 to 130 bar (430 to 1900 psi)
- Typical API process pumps are used
- Model **DMX** may be used as charge pump

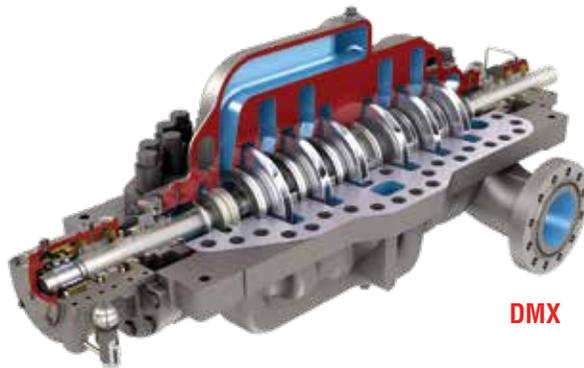


DMX

### Amine Pumps

Pump Types

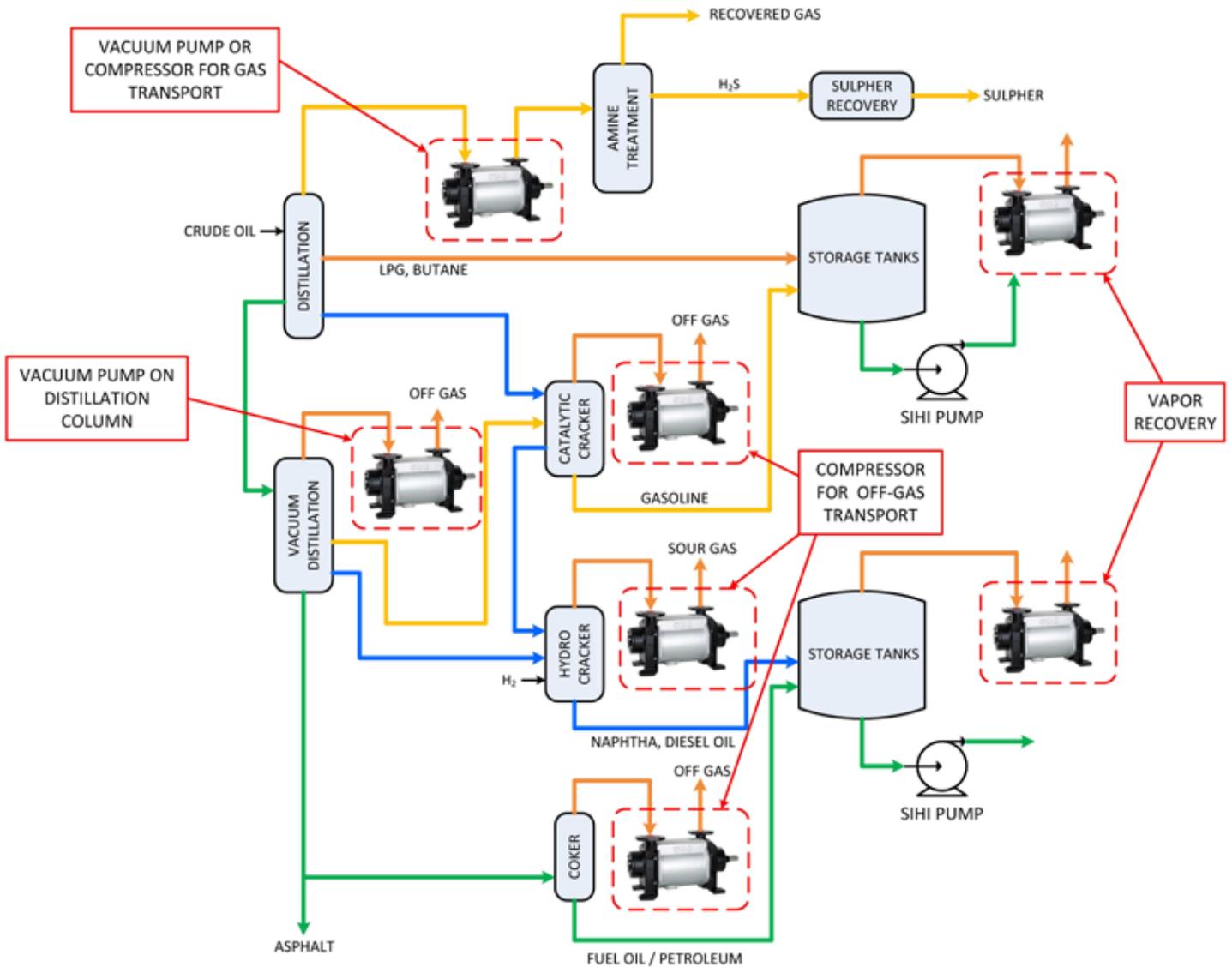
- Amine is corrosive and hazardous; C6 NACE or A8 material; dual seals
- Model **DMX** common for lean amine pump
- OH2/OH3 model **HPX** process pumps for reflux
- Watch for NPSHA and gas breakout in design considerations



DMX

**Specialized Vacuum Pumps  
(SIHI Compressor or Liquid Ring Products)**

Figure 2.4: Refinery simplified



Typical vacuum pump package



# KEY REFINERY PROCESSES WITH EQUIPMENT

## Atmospheric Distillation Detailed Process

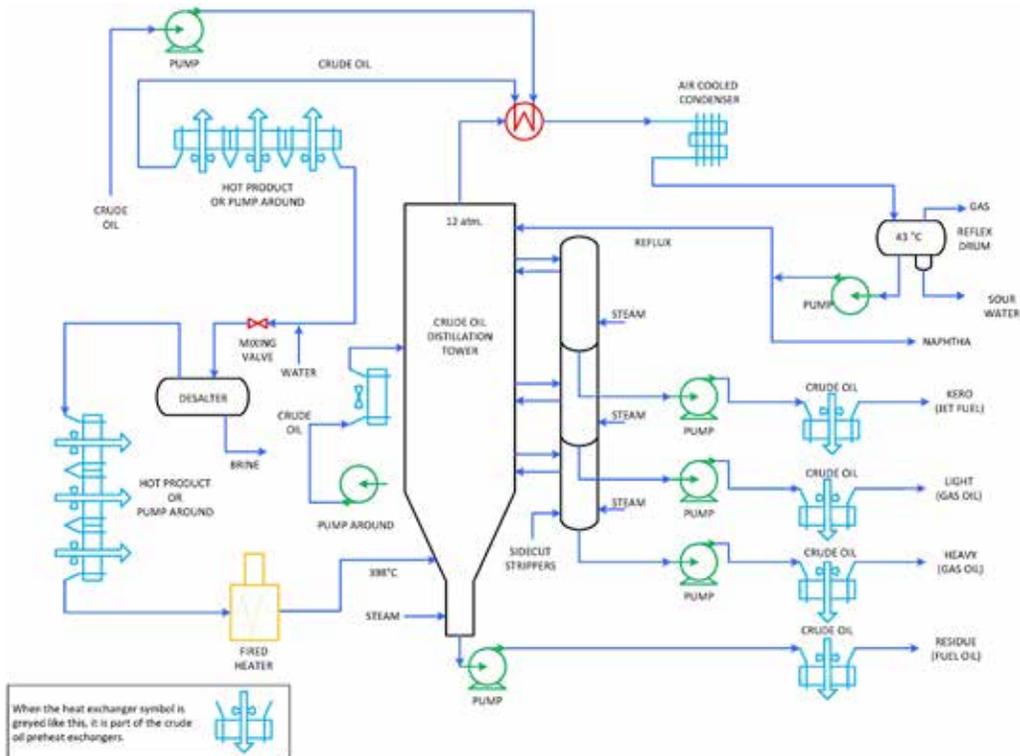
**Atmospheric distillation** or **topping unit** is the starting point in a refinery. As you will recall, it uses **HPX OH2** and **HDX BB2** pumps. The basic objective here is to separate the crude oil into its main fractions. This separation is done in a tall tower, which operates on the same principle as a moonshiner's still, i.e., distillation. The temperature in the tower decreases as you move from bottom to top. Consequently, various fractions condense at different levels in the tower at points where the temperature falls below their boiling point. The lighter fractions condense toward the top of the tower where temperatures are lower and the heaviest fraction remains at the bottom where the temperature is the highest.



The following is a simple schematic of an atmospheric crude distillation unit:

Crude oil is pumped by a charge pump through heat exchangers to a **desalter**. The desalter removes salt from the crude. If the salt is not removed, then it would deposit in heaters and also cause corrosion due to the acid formed by the decomposition of the chloride salt.

**Figure 3.1: Schematic of an atmospheric crude distillation unit**



*Desalter unit:*



After desalting, the crude oil is pumped through a series of heat exchangers to raise its temperature to 550°F by heat exchange with product and reflux streams. These heat exchangers conserve energy by recovering heat from the product and reflux streams. Refineries are sensitive to conserving energy, either in process heat or pump and compressor operating efficiencies. Aftermarket opportunities improve energy conservation and are helpful in selling the energy-saving benefits of Flowserve technology and enhancements. Returning to the flow chart (Figure 3.1), the crude is further heated to 750°F in a heater and charged into the atmospheric tower where it flashes; i.e., a large portion of the liquid crude turns into vapor due to the pressure drop. The vapors on their way upward

bubble through the cooler liquid laying on the bubble-cap tray. During the bubbling, the heavier fraction condenses on the tray and the lighter fraction rises to the next tray. A portion of the vapor condenses at every tray.

**Reflux** — or the cooling medium necessary to maintain lower temperatures in the higher zones — is provided by condensing the tower overhead vapors and pumping a portion of the condensed liquid to the top of the tower. Cooling is also provided by pumping around what is cooling and pumping the liquid from a higher and cooler zone to a lower and hotter part of the tower. Also, note that internal reflux is provided by the cooler liquid from a higher tray overflowing through the spout to the tray below.

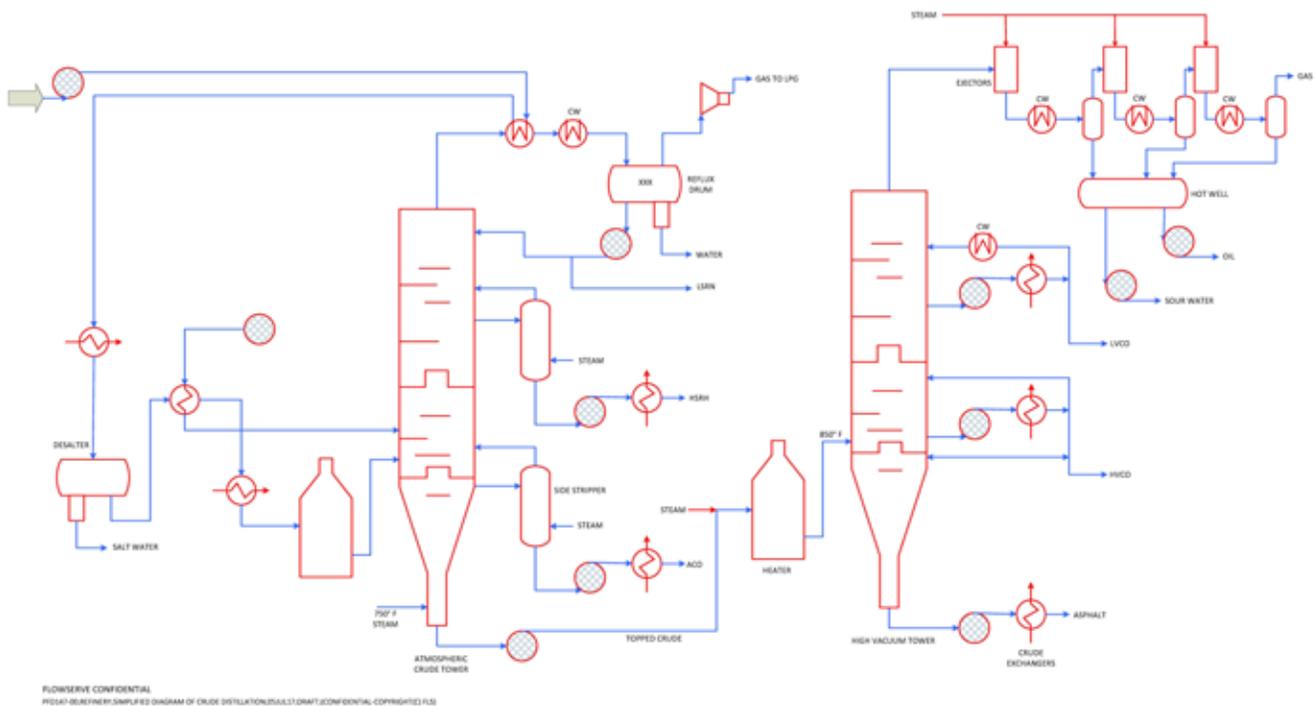
The liquid side streams withdrawn from the tower will contain low boiling components. They are hazardous, as they increase the tendency of the product to flash at lower temperatures. These light ends are stripped from each side stream in a separate small stripping tower by heating the liquid with steam. Each side stream is then pumped through a heat exchanger to downstream treating and blending units. Usually at least four side strippers are used in a plant to produce extra cuts such as kerosene and diesel.

The heavier fractions in the vapors from the top of the tower are condensed in a condenser. This is the light

gasoline portion of the vapors. Some of condensate is returned to the top of the tower as reflux and the remainder is sent to the LSR (low straight run gasoline stabilization unit). The uncondensed vapor is compressed in a reciprocating compressor and sent to the LPG recovery unit.

The major Flowserve interest in **crude distillation** units is the valves and pumping equipment. Usually there are more process control valves and pumps in a crude unit than any other process unit in a refinery. Of course, the sizes of the pumps are dependent on the quantity of crude entering the plant.

Figure 3.2: Simplified diagram—crude distillation



**From the process description, following is a partial list of the critical pumps on a typical crude unit. The pumping service can be associated with the process description.**

**1. Crude Charge Pump**

Usually takes suction off the discharge of the crude tank booster pump. Operates at atmospheric temperatures and fairly high pressure to overcome the system pressure drop due to exchangers, desalter and the furnace. An **HPX** pump will usually handle this service, but for the larger plants, the **HDX** may be better suited.

**2. Reflux and Tops Pump**

Usually a combined service. The pump takes suction on an accumulator at the top of the column and pumps part of the stream back into the column and part to gasoline storage. Type **HPX** pump with low NPSH requirements is the pump for the job. It operates at approximately 150 to 200°F.

**3. Intermediate Reflux Pump**

Takes suction on an intermediate tray and pumps through an exchanger back into the column. Pumping temperature is about 300 to 400°F and is an ideal service for the type **HPX** pump.

**4. Gas Oil Pump**

Takes suction on the bottom of the side cut stripper, **HPX, HDX** or **HED** low NPSH requirement, 500 to 600°F pumping temperature.

**5. Naphtha, Kerosene and Diesel HPX Pumps**

Similar to above gas oil pump, but lower pumping temperature.

**6. Topped Crude Pump**

Takes suction from bottom of fractionator and pumps liquid to vacuum tower for further fractionation. Pump operates at 700°F low NPSH and it is either an **HED, HDX** or possibly **HPX**.

Because of the sulfur in most crude oils, when pump temperature exceeds 550°F, it is necessary to consider the use of alloys, such as 11% to 13% chrome for pump case, impeller and wearing parts.

Flowserve mechanical seals have been developed for all of the above pumping services and should be applied with minimum problems. Please refer to Refinery Mechanical Seal section of the guide.

**Sample of atmospheric distillation pump application for typical smaller BPD refinery, most of which are HPX products.**

**Crude charge**, three required, 4850 gpm each

Design: 600 psig @ 100°F

1050 ft head

Complete with drivers (two motors, one turbine)

**Furnace charge**, three required, 5325 gpm each

Design: 600 psig @ 100°F

1000 ft head

995 hydraulic hp

Complete with drivers (two motors, one turbine)

**First internal reflux**, two required, 1900 gpm each

Design: 375 psig @ 450°F

285 ft head

92 hydraulic hp

Complete with drivers

**Second internal reflux, two required,**

3200 gpm each

Design: 375 psig @ 450°F

250 ft head

135 hydraulic hp

Complete with drivers

**Third internal reflux**, two required, 1500 gpm each

Design: 375 psig @ 600°F

195 ft head

49 hydraulic hp

Complete with drivers

**Topped crude**, three required, 2200 gpm each

Design: 300 psig @ 700°F

390 ft head

157 hydraulic hp

Complete with drivers (two motors, one turbine)

**First sidestream**, two required, 312 gpm each

Design: 250 psig @ 250°F

295 ft head

16 hydraulic hp

Complete with drivers

**Second sidestream**, two required, 680 gpm each

Design: 250 psig @ 350°F

325 ft head

38 hydraulic

Complete with drivers

**Third sidestream**, two required, 700 gpm each

Design: 250 psig @ 425°F

340 ft head

41 hydraulic hp

Complete with drivers

**Flash drum circulating**, two required,

1950 gpm each

Design: 250 psig @ 400°F

146 ft head

60 hydraulic hp

Complete with drivers

**Flash drum accumulator overhead**, two required,

572 gpm each

Design: 250 psig @ 375°F

310 ft head

27 hydraulic hp

Complete with drivers

**Atmospheric tower reflux**, two required,

1760 gpm each

Design: 200 psig @ 350°F

246 ft head

68 hydraulic hp

Complete with drivers

**Overhead product**, two required, 350 gpm each

Design: 600 psig @ 350°F

1000 ft head

57 hydraulic hp

Complete with drivers

**Sour water, two required**, 50 gpm each

Design: 150 psig @ 350°F

184 ft head

3 hydraulic hp

Complete with drivers

**Table 3.1: Atmospheric distillation pump and control valve asset summary**

API/PUMP	APPLICATION	VALVE	APPLICATION
BB2-HDX	Crude Charge	Valtek Multi-Z	Charge Pump Recirc
BB2-HDX	Furnace Charge	Valtek Mark One w/ Pilot Trim	Main Feed Heater Flow
OH2-HPX	Tower Reflux	Valtek MaxFlo 4	Bottoms/Product Streams
OH2-HPX	Wastewater	Valtek Mark One	Sour Water Letdown
OH3-PVML	Sour Water	Valtek MaxFlo 4	Overhead Gas Control
OH2-HPX	Light Gas Oil	Argus HK35/FK76	Feed Isolation
OH2-HPX	Heavy Gas Oil	Argus HK35/FK76	Atmospheric Bottoms Emergency Block
BB2-HDX	Resid Reboiler	Argus HK35/FK77	Atmospheric Bottoms Emergency Block
OH2-HPX	Naphtha	Argus HK35/FK78	Atmospheric Bottoms Emergency Block
OH2-HPX	Kerosene	Argus HK35/FK79	Atmospheric Bottoms Emergency Block
OH2-HPX	Bottoms Pump Recirculation	Argus HK35/FK80	Atmospheric Bottoms Emergency Block
OH2-HPX	LPG Compressor Anti-Surge	Argus HK35/FK81	Atmospheric Bottoms Emergency Block
		Actuators	All Control Valves

*This summary does not include the large quantity of gate, plug, ball, check valves and mechanical seal systems.*

## Vacuum Distillation Detailed Process

Steam is fed into the bottom of the tower to strip any gas oil from the heavy liquid in the flash zone and product a high flash point bottoms. **The bottoms, which cannot be fractionated or separated in the atmospheric tower, are sent to the vacuum distillation tower for fractionation.** The process in the vacuum tower is similar to the atmospheric tower, except that distillation is carried out at less than atmospheric pressure. The lower pressure helps lower the boiling point of hydrocarbons and thus facilitates further fraction.

The PFD (process flow diagram), Figure 3.3 illustrates the vacuum distillation section of the crude unit. The vacuum, still commonly called “vacuum flasher,” is used to separate the heavier portion of the crude into fractions because the high temperature necessary to vaporize the topped crude at atmospheric pressure results in thermal cracking. Thermal cracking causes discoloration of product and formation of coke, which fouls equipment. Under vacuum, the boiling point of the topped crude occurs at a lower temperature where these undesirable reactions, at this stage of the refining process, will not occur.

An absolute pressure of 25 to 40 mm Hg is maintained in the flash zone of the vacuum tower, and the temperature of the topped crude entering the column is 800 to 850°F. The vacuum is maintained by use of steam ejectors pulling the non-condensable gases off the top of the vacuum tower. The **SIHI LPHX** for vapor emissions is also considered.

The pumps on the vacuum unit are similar to the atmospheric unit, except the temperatures are higher and the suctions are under a vacuum.

The bottoms pumps, often called “flasher bottoms,” are the most critical pumps on the unit. They operate at 750°F with minimum NPSH available and vacuum on the suction. The material pumped is very heavy and often laden with coke particles, which form in the bottom of the vacuum tower. In addition, the fluid is near its flash point and thus, leakage from the pump is a risk for the operators; experienced pump suppliers are required.

The **HED** or **HPX6000** pump is usually applied to this service, with special care taken to keep seal pressure above atmospheric. The pump casings and impeller are 11% to 13% chrome, and oftentimes wear ring clearances are made unusually high to prevent pump seizure. Mechanical seals should be arranged with positive pressure on the stuffing box to prevent air leakage into the pump suction, which is under a vacuum.

The **HDX** pump is also a suitable selection. However, two seals and stuffing boxes are a disadvantage because of the high temperature, high vacuum and hazards involved in pump leakage. These disadvantages must be taken into account before finalizing an application.

Figure 3.3: Vacuum distillation primary processes

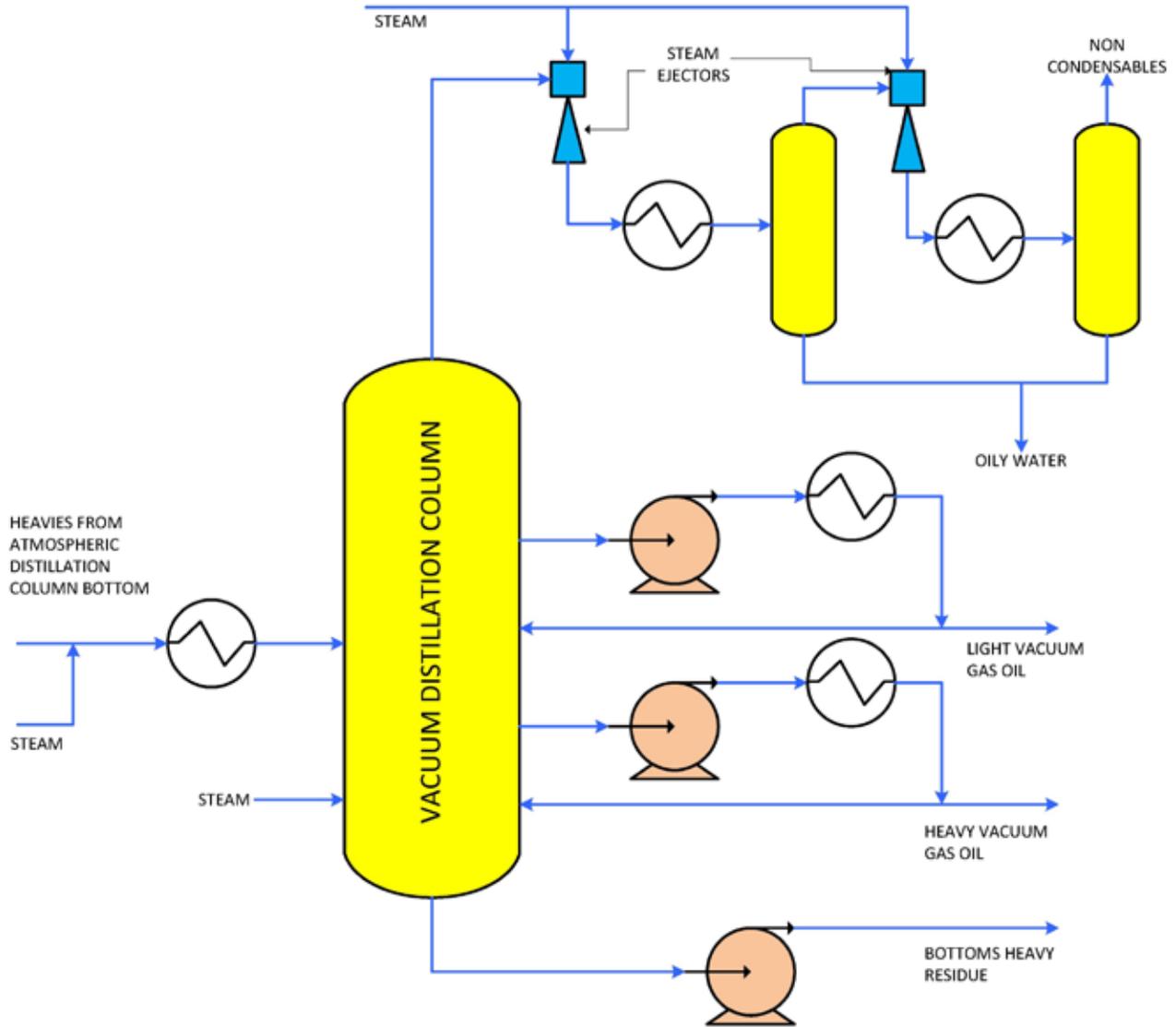
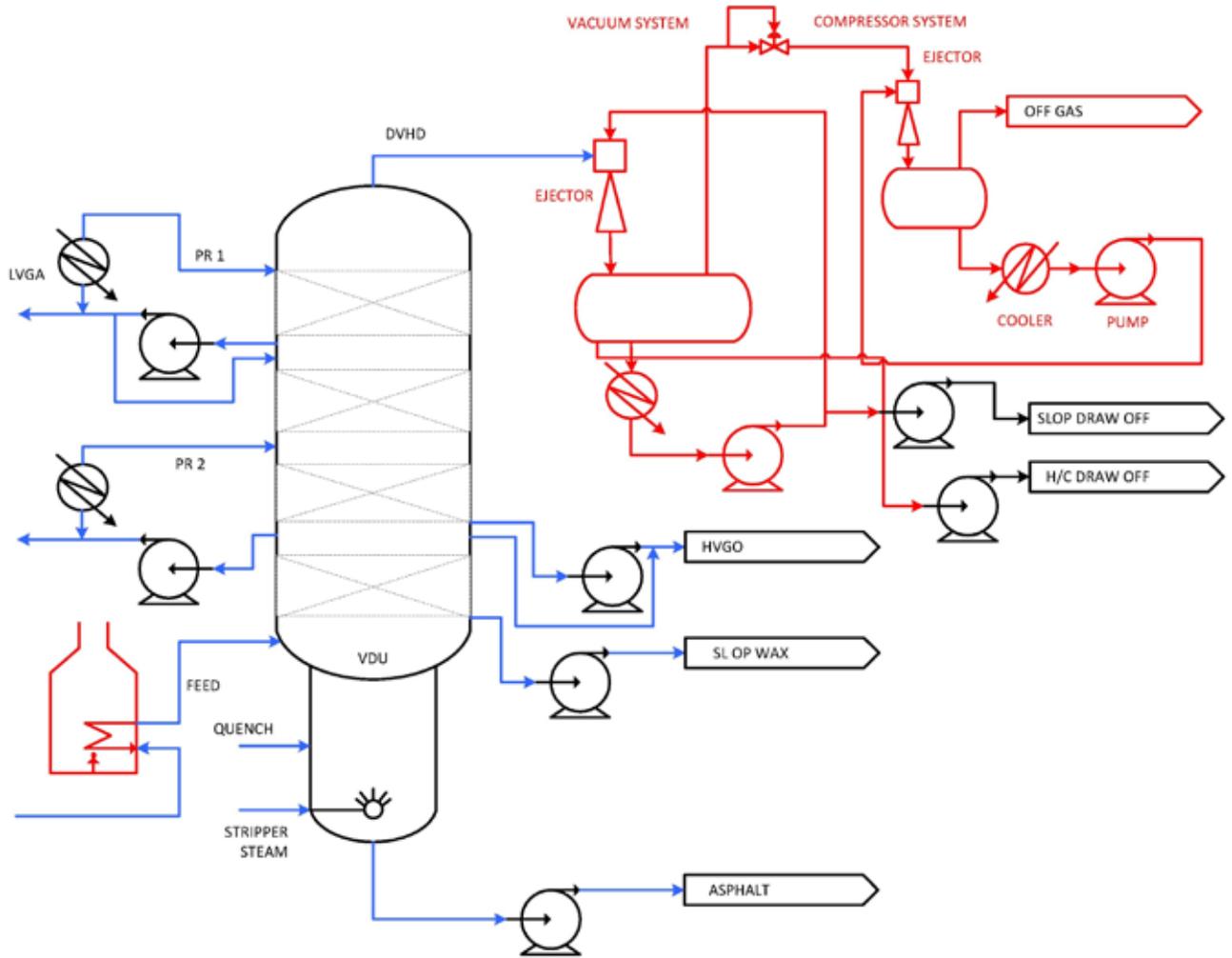


Figure 3.4: Enhanced with SIHI vacuum systems options in **RED**:



### Recommended Control Valve Features for Vacuum Distillation

- Angle Valve Design
- ANSI Class V
- Hardened Trim
- Extension Bonnet
- High-Temp Packing Design
- Possible Expanded Outlet
- Flow to Close/Fail Open Design
- Unbalanced Trim Design
- 400 Series SST, Solid Stellate or TC Trim Package
- Stem Purge

**Table 3.2: Vacuum distillation pump and valve asset summary**

API/PUMP	APPLICATION
OH2-HPX	Light Vacuum Gas Oil
OH2-HPX	Heavy Vacuum Gas Oil
BB2-HDX	Vacuum Residuum
OH2-HPXM6000	Vacuum Tower Bottoms
API Soft - LPHX	Vapor Emissions Systems

VALVE	APPLICATION
Valtek Mark One	Recycle Gas Compressor Surge Control
Valtek MaxFlo 4	Bottoms/Product Streams
Valtek MaxFlo 4	Overhead Gas Control
Argus HK35/FK76	Heavy Vacuum Gas Oil Pump Emergency Block
Argus HK35/FK76	Vacuum Tower Bottoms Emergency Block
Argus HK35/FK76	Vacuum Bottoms Pump Emergency Block
Valtek Survivor	Vacuum Bottoms Pump Recirculation
Argus HK35/FK76	Vacuum Bottoms Exchanger Isolation

*This summary does not include the large quantity of gate, plug, ball, check valves and mechanical seal systems.*

## Delayed Coking Detailed Process



### Delayed Coker Unit Overview

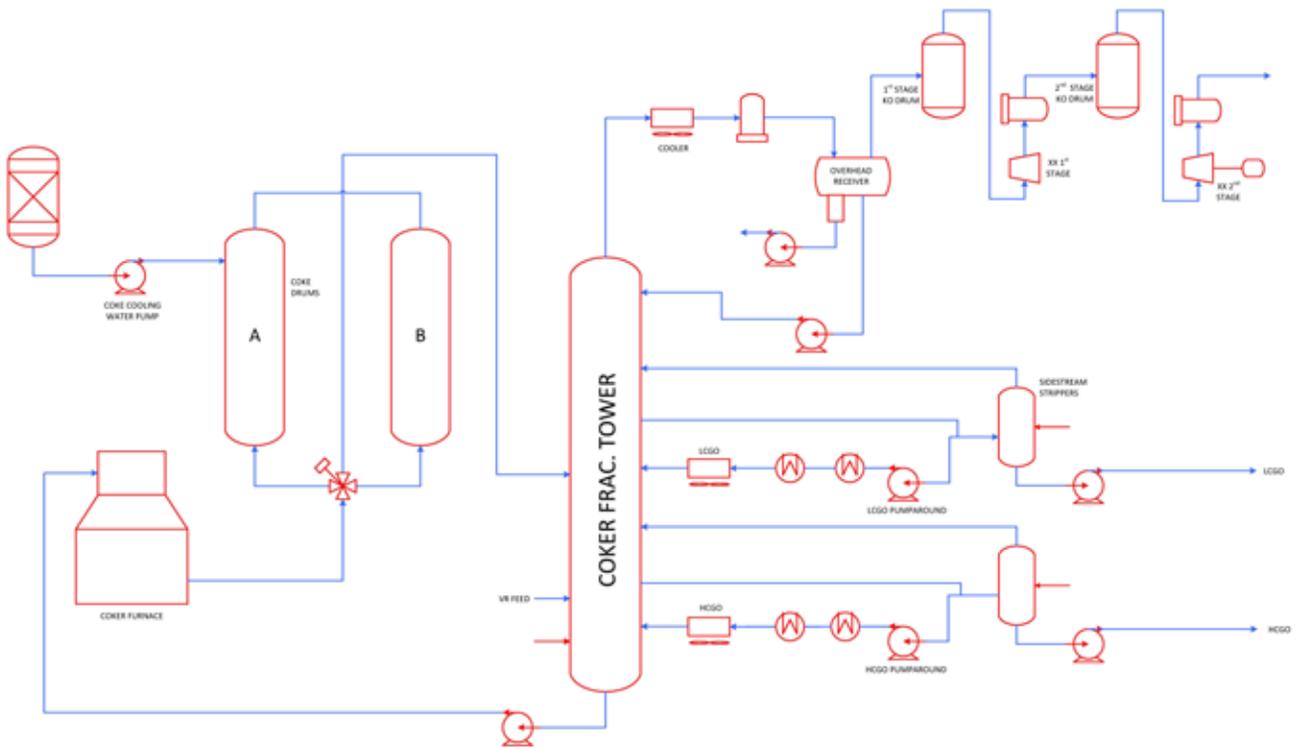
Delayed coker units are the primary selection worldwide for the upgrading of heavy resid into usable liquid products due to their relatively low upfront capital investment. Despite the advent of fracking technologies and the production of lighter crude, the heavy crude is still a large portion of the crude market today and will continue to be in the future. The market is strong for keeping current delayed cokers running. Despite the new lighter crude slates available, new units are still being purchased worldwide due to new environmental regulations and various countries' national interests.

Flowserve can supply all of the pumps in the delayed coker unit, but we do have a specialty within the unit with the hydraulic decoking system (HDS). The HDS is made up of 12–15 different pieces of equipment supplied by Flowserve, depending on the exact end user-system. The heart of the system is the decoking jet pump, typically

a **WIK** selection and the main coker valve. The remainder of the equipment is a mix of in-house designed and built as well as buyouts specified by the Flowserve engineering teams. Despite the multiple pieces of equipment mounted in the delayed coker unit separately, it should be treated by engineering and sales as a complete system.

Flowserve produces the majority of the world's hydraulic decoking equipment, with equipment in more than 215 of the estimated 240 units around the globe, excluding China. In the current market, there is strong price pressure from the primary competition Ruhrpumpen in original equipment. The aftermarket of hydraulic decoking is the primary driver of margin and bookings annually. We do have competition from RP and several other entities on specific pieces of equipment.

Figure 3.5: Basic delayed coking unit operation



**Application Guides**

**For more details on decoking, refer to the Decoking Application Selling Guide on Passport (FLS-1009a ASG-DCU).**

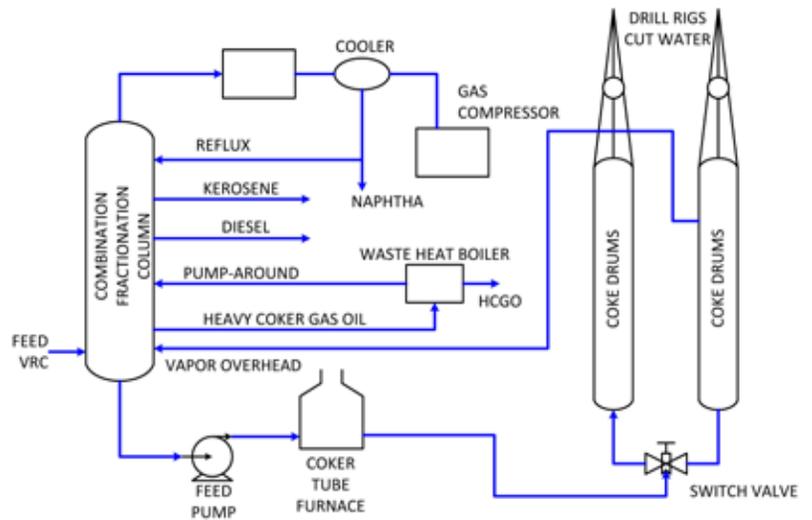
With refinery feed slates becoming more viscous, acidic or sulfur laden, global refiners are preparing for heavier crudes and bitumen from the Middle East, Russia, Canada, Brazil and Venezuela. When selling at sharp discounts to light or sweet intermediates, heavier grades of oil now can account for about a quarter of daily global supplies. Refiners must be able to convert this heavier crude into saleable gallons of gasoline, diesel and jet fuel (see Figure 3.6).

The Energy Information Administration’s (EIA) “International Energy Outlook 2015” shows a slowdown in refiners’ dependence upon heavy oil feed slates, but there is still strong demand in certain markets due to national interests as well as a potential increase in demand with the reduction requirement of bunker fuel sulfur levels, set to be implemented in 2025.

Even with the advent of the natural gas production increase, the world is still awash in heavy crude, and refiners are increasingly utilizing delayed coking processes to produce clean transportation fuels from bottom-of-the-barrel residues. Since the first modern delayed coking unit was installed in 1928, **Flowserve has pioneered virtually every pumping technology advancement in these essential residue conversions processes. Through its Worthington, IDP, Byron Jackson®, Pacific®, Durco® and now SIHI heritage brands, Flowserve has become — and remains — the refining industry’s preferred partner for delayed coking process pumps and hydraulic decoking systems, with more than 200 installations worldwide.**

In its simplest terms, delayed coking is a semi-batch thermal cracking process using alternating drums that are switched offline after filling. Support facilities include closed blowdown, coke cutting and handling, and a water recovery system.

Hot residual oil is fed to the bottom of a fractionator where it mixes with condensed recycle. The combined stream is heated in the furnace to initiate coke formation in the coke drums. Coke drum overhead vapor flows to the fractionator where it is separated into wet gas, un-stabilized naphtha, light gas oils, heavy gas oils and recycle. During the coke drum steam out and coking period, all steam and hydrocarbon vapors are directed to the blowdown system where they are recovered. After the coke drum cooling cycle is complete, the coke is hydraulically cut from the drum and dropped into a pit or pads where water is separated from the coke and recycled.



*Figure 3.6: Basic delayed coking unit operation*

## DCU System Overview

### Coking Section

Pumping heavy oil feeds such as vacuum reduced crude (VRC) combined with heavy coker gas oils (HCGO) from the fractionator to the coker heaters is a difficult service. Low NPSHA and NPSHA drop at startup, due to furnace fouling, can lead to problem-causing first stage cavitation, reduced TDH and high axial thrust. Flowserve heater charge pumps are proven to overcome these conditions and provide reliable service in this critical application.

### Fractionation Section

Coke drum effluent vapors are routed to a fractionator where they are separated into light gases, unstabilized gasoline, distillate, HCGO and a recycle stream. Flowserve pumps are required to handle a wide variety of services, including fractionator bottoms, HCGO circulating reflux and product, light coker gas oils (LCGO), naphtha product, fractionator tower top reflux, lean sponge oil and sour water.

### Vapor Recovery Unit

Vapor and liquid streams from the fractionator are further processed in the vapor recovery unit through absorber-stripper processes. Flowserve pumps perform a wide variety of services, including lean and rich amine transfer, stripper feed, lean oil, debutanizer reflux compressor suction drum, splitter overhead and bottoms, sour water, condensate and others.

### Coker Blowdown

The coke-drum blowdown system recovers hydrocarbons and steam vapors generated during the quenching and steaming of filled coke drums. Pump applications commonly associated with the coker blowdown and settling drums are tower bottoms, sour water, slop oil, and quench and recycle water services.

### Steam Generation

Steam is critical to successful DCU operation. In the coker heater, it helps maintain heater coil efficiency while suppressing coke formation in heater tubes. Steam is used to purge full coke drums and heat empty ones. Flowserve is the acknowledged leader in the design and application of boiler feed water pumps, offering a broad range of cost-effective solutions.

### Process Description

Some derisively refer to the DCU as the “garbage can” of the refinery; in many cases, this is true. Bottoms from atmospheric and vacuum distillation along with heavy cooler gas and recycle oils are the feed slates for delayed coking. Once cracked, however, these residues are converted into valuable products (see Figure 3.7):

- Light gas to LPG and refinery fuel gas
- Naphtha to gasoline pool
- Gas oil to the refinery distillate blend pool for heating oil
- Coke, largely used as fuel for power plants and steel mills and as anodes for the aluminum industry

Heavy oil feeds such as VRC or atmospheric reduced crude are preheated in heat exchanges with coker gas oils and then fed to the bottom section of the coker fractionator. Fresh feed combines with recycle, which is net liquid from the fractionator wash section above the feed inlet, and is routed to the coker heaters with the coker charge pumps.

In the coker heater, the combined feed is heated to 495°C (920°F) or more to allow the coking reaction to occur in the coke drums. High-pressure steam, steam condensate or boiler feed water is injected into heater coils at various locations to increase the velocity through the tubes and CJP, therefore minimizing the amount of coke deposited on the heater tubes.

Effluent from the coker heater accumulates in insulated vessels called coke drums (4). The drums allow sufficient time (delayed) to thermally crack the feed into lighter gases, naphtha, distillates, gas oil and coke.

The coking cycle can be as short as 10 hours in a fuel-grade coker operation, which is built to maximize throughput, or more than 24 hours for higher-value commercial coke products.

A lower coke drum operating pressure and less recycle will result in more liquid and less coke produced. A modern delayed coker that maximizes liquid yields typically has a coke drum top operating pressure of about one bar (15 psi) and a recycle-to-feed ratio of 5% or less. Needle coker production, however, usually demands a high pressure (about seven bar [100 psi]) and a high recycle-to-feed ratio to achieve the desired needle coke properties.

A vapor stream of about 425°C (800°F) from the coke drum is routed to a fractionator (2), where it is separated into light gases, unstabilized gasoline, distillate, heavy coker gas oil and a recycle stream. The coker fractionator off gas is compressed in a wet-gas compressor, which increases the pressure of the gas up to 14 bar (200 psi). This stream then goes to a gas plant (5) along with the unstabilized gasoline, where it is further separated into dry gas, LPG and stabilized gasoline.

The coker gas plant is similar to a fluidized cat cracking (FCC) unit's gas plant and usually consists of an absorber-stripper and debutanizer. Sour coker dry gas from the gas plant is scrubbed with amines to remove hydrogen sulfide before it feeds the refinery's fuel gas system. The sour coker LPG is treated with amine and caustic to remove hydrogen sulfide and mercaptan sulfur to make it suitable as feedstock in other process units such as alkylation. The gasoline, distillate and heavy gas oil from the delayed coker are typically hydrotreated before further processing in other refinery units.

### Drum Cycle

Coke drums are typically installed in pairs, with one coker heater for every two coke drums. The feed stream switches between these two drums. While one drum is filling with heater effluent, the other one is stripped with steam, quenched with water, drained, decoked and warmed up for the next cycle.

The full coke drum is first purged with steam, which initially flows to the fractionator and then to the blowdown drum, to strip hydrocarbons from the coke. After the coke drum is steamed out, water is gradually introduced into the coke drum to cool the drum and coke.

Steam produced due to vaporizing the quench water is sent to the blowdown drum for condensation and to recover water and heavy hydrocarbons. The quench water flow rate then increases until the coke drum is filled with water. This water is subsequently drained from the coke drum, and the top and bottom heads of the drum are opened.

The coke in the drum is cut and removed with high-pressure water. The empty drum is then closed, purged and pressure-tested with steam. Vapors from the coke drum in operation are used to heat the offline, empty coke drum.

Hydrocarbons condensed during the drum-heating step are drained to the blowdown drum or fractionator. When the drum is heated sufficiently, it is ready to receive effluent from the coker heater and start the coking cycle.

### Coking

The dominant decoking process technologies are those licensed by AMEC Foster Wheeler, BHTS and CLG Technologies. The AMEC Foster Wheeler DCU process is summarized here.

**Application:** Upgrade residues to lighter hydrocarbon fractions using the Selective Yield Delayed Coking (SYDEC) process.

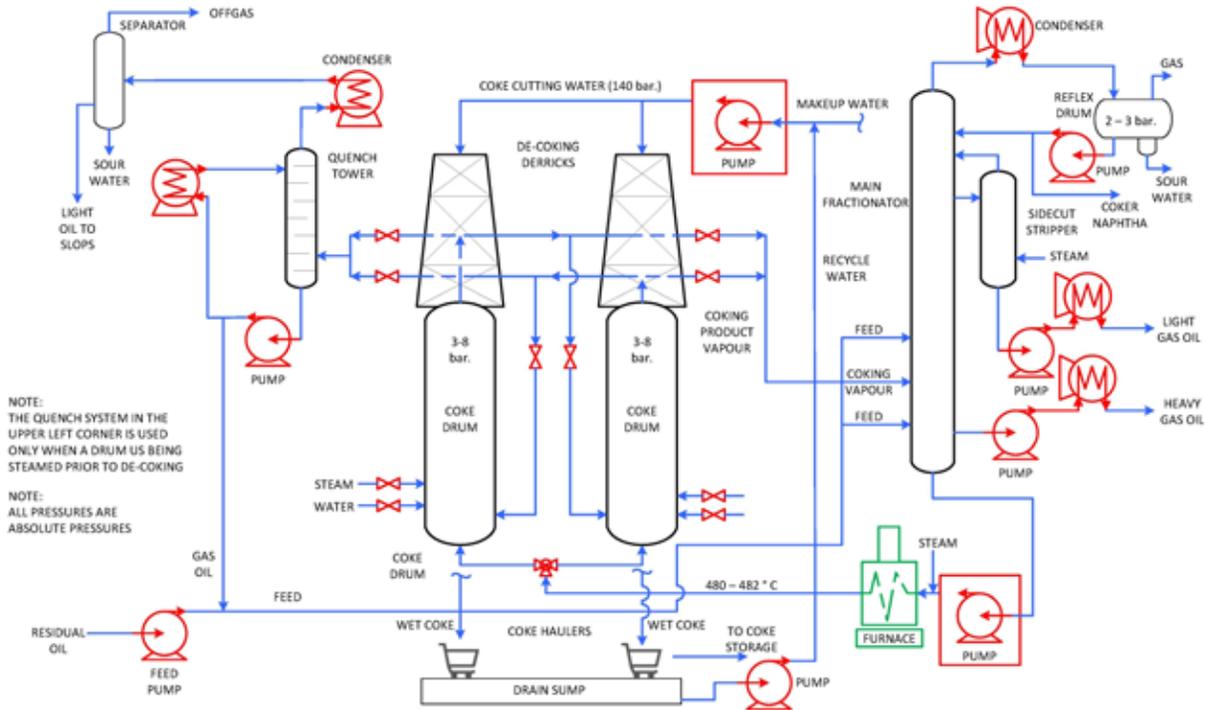
**Description:** Charge is fed directly to the fractionator (1) where it combines with recycle and is pumped to the coke heater. The mixture is heated to coking temperature, causing partial vaporization and mild cracking. The vapor-liquid mix enters a coke drum (2 or 3) for further cracking. Drum overhead enters the fractionator (1) to be separated into gas, naphtha, and light and heavy gas oils. Gas and naphtha enter the vapor recovery unit (VRU) (4). There are at least two coking drums: one coking while the other is decoked using high-pressure water jets. The coking unit also includes a coke

handling, coke cutting, water recover and blowdown system. Vent gas from the blowdown system is recovered in the VRU.

**Operating conditions:** Typical ranges are:

- Heater outlet temperature 480 to 510°C (900 to 950°F)
- Coke drum pressure 1 to 7 bar (15 to 100 psi)
- Recycle ratio, equiv. fresh feed 0 to 10
- Increased coking temperature decreases coke production; increases liquid yield and gas oil end point
- Increasing pressure and/or recycle ratio increases gas and coke make, decreases liquid yield and gas oil end point

Figure 3.7: Example of the decoking thermal and pressure process



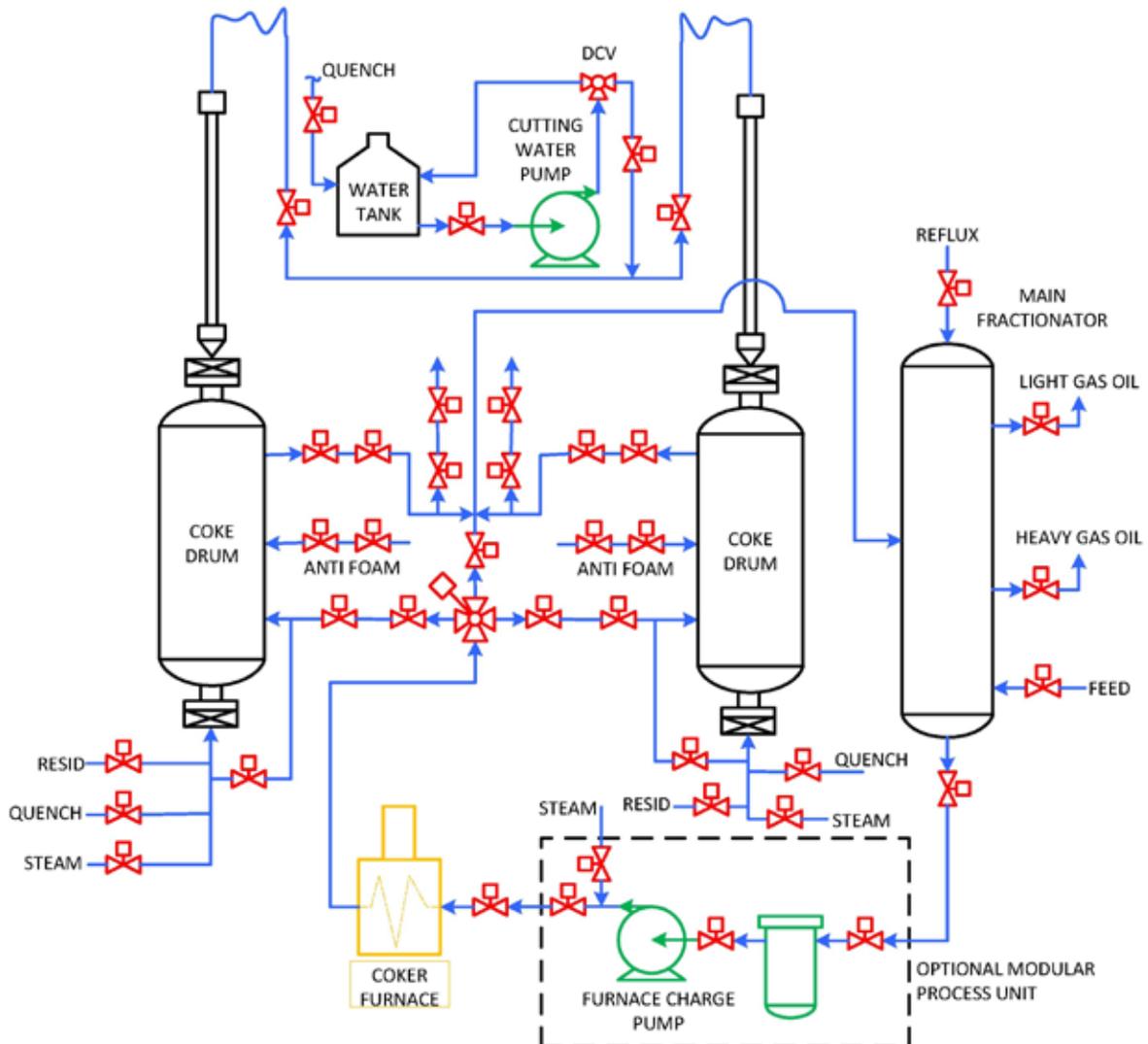
### Pioneers in Decoking Pumps

- Flowserve is the world's leading supplier of delayed coking pumps and decoking systems, with more than 90% of decoking installations deployed worldwide
- Flowserve pioneered the hydraulic decoking system, including the heater charge and decoking jet pump
- Comprehensive offering for all pump applications required for decoking, including: fresh feed, coke drum condensate, heavy gas oil, blowdown,

fractionator reflux, boiler feed, coke pit services and all auxiliary services

- Expert engineers for advanced diagnostics, problem solving and custom designs
- Quick Response Centers worldwide, regionally located for customer service and repairs
- Training to ensure operational support on equipment effectiveness and safety
- Leader in control valve technology for HDS systems

Figure 3.8: HDS (decoking) control valves



**Table 3.3: Delayed coking pump and valve asset summary**

<b>API/PUMP</b>	<b>CRITICAL APPLICATION</b>
BB2-DSTHF	Heater Charge
BB2-HED-DS	Heater Charge
BB2-WIK	Decoking Jet Pump

<b>VALVE</b>	<b>APPLICATION</b>
Valtek Multi-Z	Charge Pump Recirc
Valtek Mark One w/Pilot Trim	Main Feed Heater Flow
Valtek Mark One Tiger Tooth	Hot High Pressure Separator
Valtek Multi-Z	Cold High Pressure Separator
Valtek Mark One w/Stealth Trim	Reactor Loop Depressurization
Valtek Multi-Z	Amine Booster Pump Recirc
Valtek Multi-Z	Recycle Compressor KO Drum Letdown
Valtek Mark One	Recycle Gas Compressor Surge Control
Valtek Valdisk Butterfly	Recycle Gas Compressor Suction Control
Valtek MaxFlo 4	Stripper Reflux Return
Valtek MaxFlo 4	Bottoms/Product Streams
Valtek Mark One	Sour Water Letdown
Valtek Shearstream	Rich/Lean Amine Services
Valtek MaxFlo 4	Overhead Gas Control
Valtek Mark One	BFW Stream Drum
Argus HK35/FK76	HP Pump Inlet Isolation

<b>VALVE</b>	<b>APPLICATION</b>
Argus HK35/FK76	Cutting Water Pump Isolation
Argus HK35/FK76	Quench Extraction
McCANNA	Overhead Vapor Isolation
Argus HK35/FK76	Coke Drum Bypass Isolation
Valbart RSBV	Coke Drum Switching
Argus HK35/FK76	Coke Drum Feed Isolation
Argus HK35/FK76	Vacuum Bottoms Exchanger
Argus HK35/FK76	Quench Extraction Isolation
Argus HK35/FK76	Light Coker Gas Oil Pump EBV
Argus HK35/FK76	Heavy Coker Gas Oil Pump EBV
Valtek Survivor	Frac Bottom EBV
Argus HK35/FK76	Frac Bottom Pump Recirculation
Argus HK35/FK76	Coke Filter Isolation
Argus HK35/FK76	Furnace Charge Pump Discharge Isolation
Argus HK35/FK76	Furnace Feed Isolation
Argus HK35/FK76	Water/Coke Fines
Valtek Mark One	Wet Gas Compressor Anti-Surge

*This summary does not include the large quantity of gate, plug, ball, check valves and mechanical seal systems.*

## Hydrotreater Detailed Process



**Hydrotreating** is the process for removing objectionable elements from products for feedstocks by reacting them with hydrogen in the presence of a catalyst. The objectionable elements include sulfur, nitrogen, oxygen, halides and trace metals. Hydrotreating is also referred to as hydrodesulphurization, or HDS.

**Hydrotreating serves two major purposes in a refinery.**

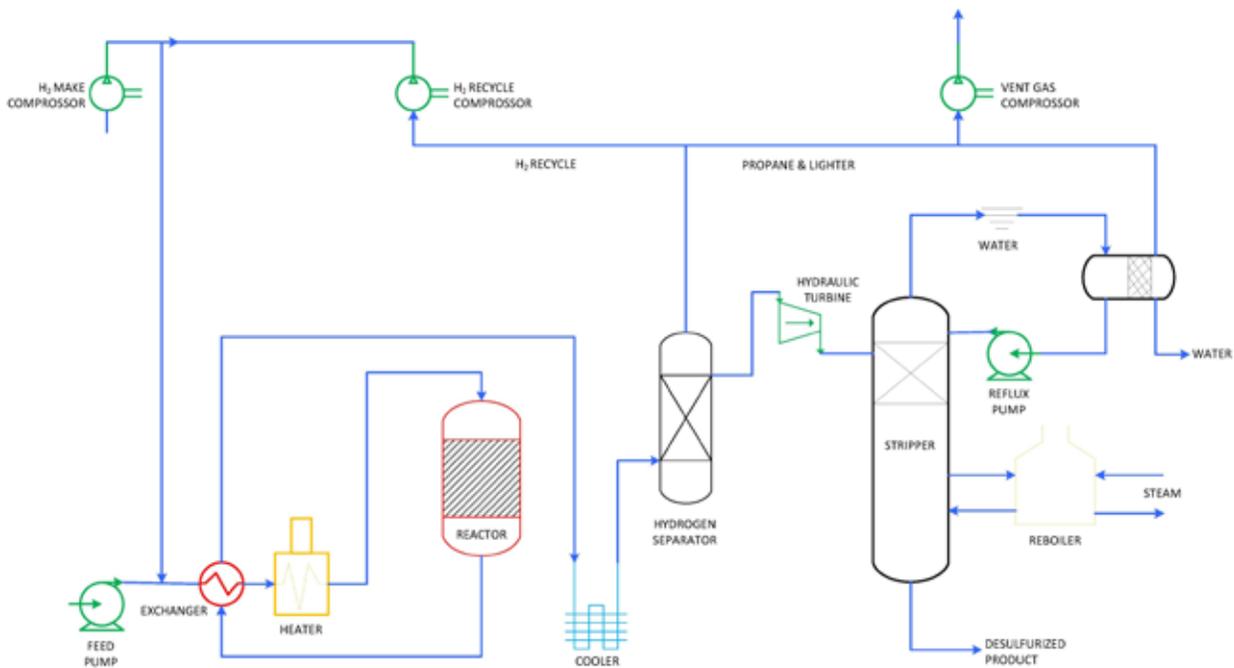
1. It removes impurities such as sulfur, nitrogen, oxygen, halides and trace metals, from marketable products, such as fuel oils, distillates and lube oils.
2. It removes these same impurities from feedstocks to cat crackers, cat reformers and hydrocrackers. Since these impurities are detrimental to the catalysts in these processes, hydrotreating plays a vital role in refining production.

Many refineries have several hydrotreaters to perform the above function. With environmental regulations continuing to dominate industrial processing, hydrotreaters will continue to be in demand.

The Flowserve interest in hydrotreaters includes hydrogen compression equipment and centrifugal pumps. Since the process operates in the 1000 psi range, operating conditions on compression and valve/pumping equipment are somewhat stringent.

Although there are a large number of hydrotreating processes available for licensing, most of them have similar process flow characteristics. The flow diagram below (see Figure 3.9) illustrates a typical process.

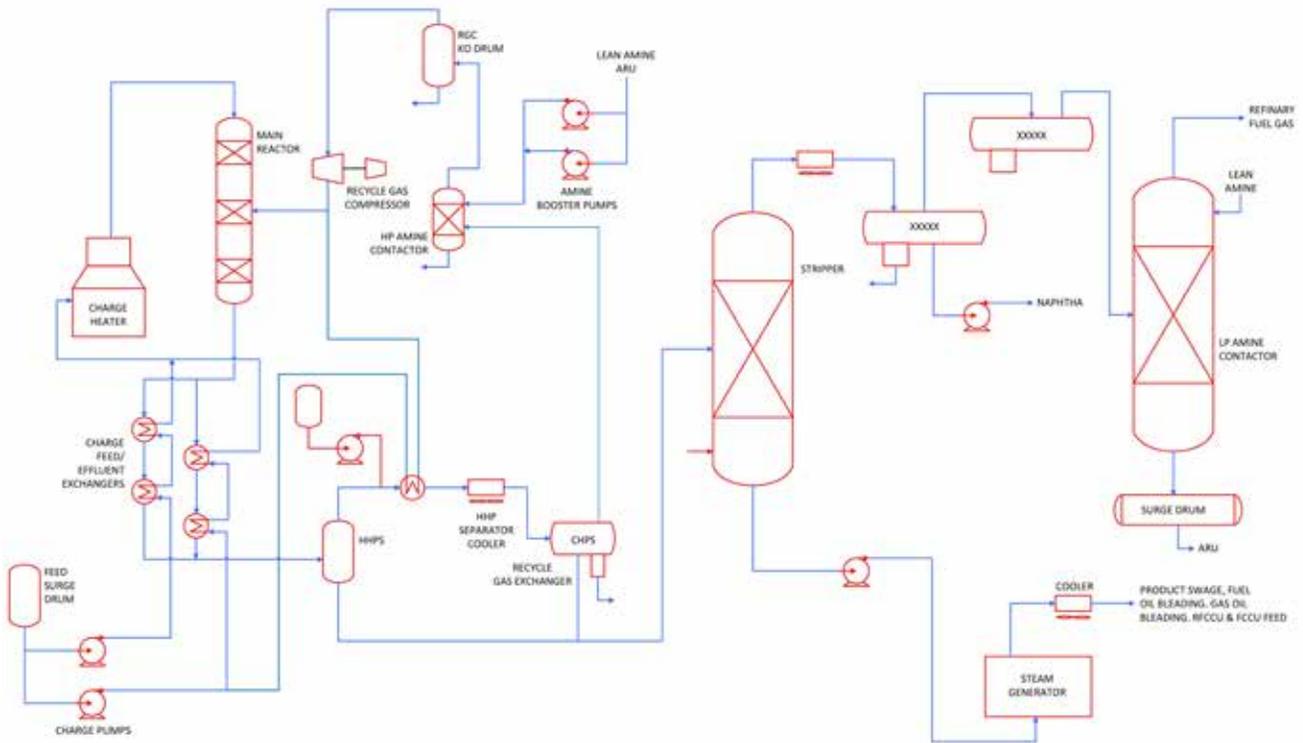
**Figure 3.9: Hydrotreater key components**



**The importance of hydrotreaters has increased for several reasons:**

- Governments are lowering the allowable sulfur content in gasoline and fuel oil (Euro V fuels are limited to 10 ppm.)
- **Pre-treaters** in front of catalytic units protect the catalysts from poisoning by sulfur and some metals
- **Hydrotreating reduces the olefins and aromatics and increases the paraffins and naphthene components in fuels**
- **Benzene** in the gasoline pool is becoming a major environmental issue

Figure 3.10: Simplified diagram for hydrotreater



The charge pump pressures the feedstock up to about 1200 psi. The feedstock joins a stream of hydrogen recycle gas. The mixture of hydrogen and oil is heated by exchangers and a direct-fired heater up to the reaction temperature of 700 to 800°F. The hot mixture enters the reactor, which is a pressure vessel with a fixed bed of catalyst. In the presence of the catalyst, the hydrogen reacts with the oil to produce hydrogen sulfide, ammonia, saturated hydrocarbons and traces of metals. The trace metals remain on the surface of the catalyst, and the other impurities leave the reactor with the hydrogen-oil mixture. This mixture leaving the reactor is known as reactor effluent.

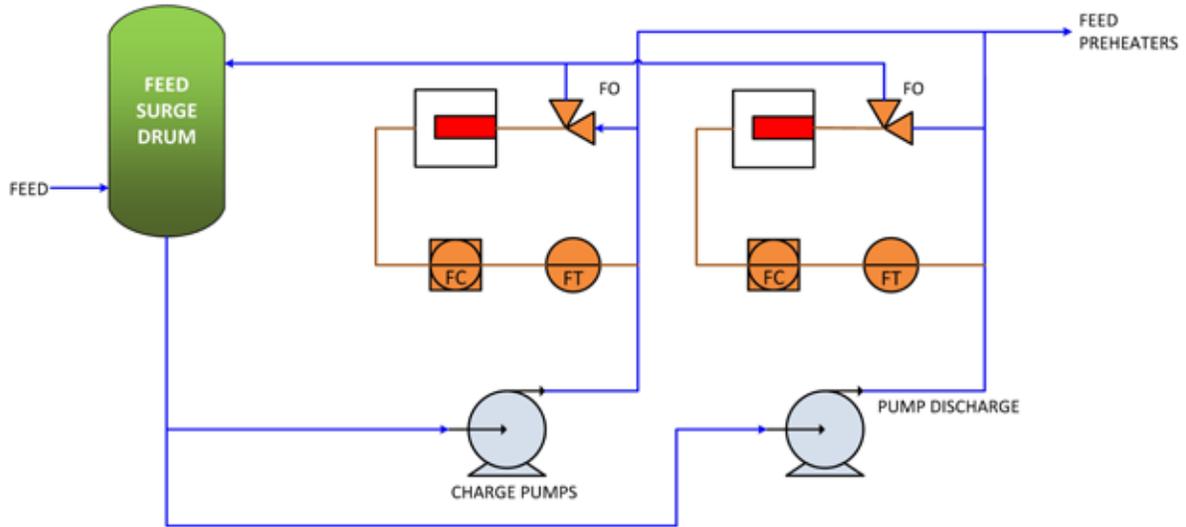
The reactor effluent is cooled before entering the

high-pressure separator where the hydrogen-rich gas comes off the top and the oil off the bottom. The hydrogen-rich gas is treated to remove hydrogen sulfide and is used again in the process. It is recycled back into the front end of the plant by the recycle compressor.

The oil off the bottom of the separator is throttled to a lower pressure and enters the stripper where any remaining impurities are removed. (In some plants, a hydraulic turbine replaces the throttling valve.)

The reaction consumes hydrogen at the rate of about 500 SCF per barrel of feedstock. This figure varies with the process and the amount of impurities that are to be removed. It could be as low as 200 and as high as 800 SCF per barrel.

Figure 3.11: Simplified diagram for charge pump and valve recirculation or spillback



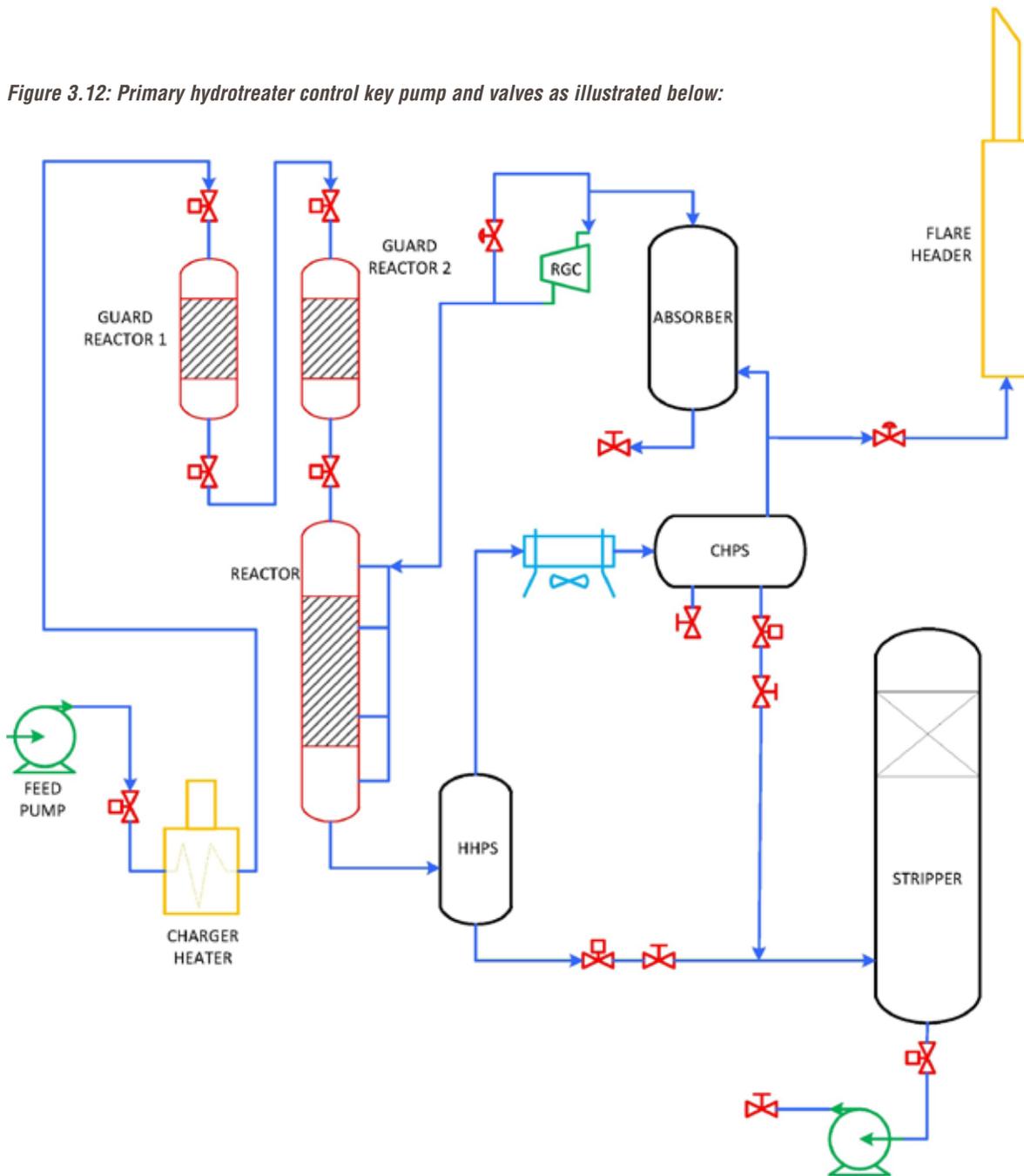
The quantity of hydrogen-rich gas that is recycled is about 2000 SCF per barrel of feedstock.

In addition, there is a small quantity of vent gas, a mixture of propane and lighter, plus hydrogen sulfide, which must be transported from the plant.

The major pump application on a hydrotreater is the charge pump, which is usually a horizontally split, multistage pump or similar. The feed is usually at atmospheric temperature from storage and must be pumped up to about 1200 psig. The feed is normally clean and noncorrosive, so the pumping application is straight forward. Some customers will require a Kingsbury thrust bearing on a one-pump installation to obtain maximum reliability.

On large hydrotreaters, a hydraulic turbine might be applied to assist in driving the feed pump. The power could be generated by substituting a turbine for the throttling valve between the high-pressure separator and the stripper in the liquid line. In the past, the economics for such an addition have been borderline, but with energy prices rising, the application of a power recovery unit might be justified. The multistage pump running as a turbine would be the likely selection, and it would be connected to the charge pump through a mechanical clutch, similar to the hydrocracker hydraulic turbines.

Figure 3.12: Primary hydrotreater control key pump and valves as illustrated below:



Hydrogen plants are installed to support hydrocrackers and hydrotreaters, due to a large demand for hydrogen in refineries, since these processes use large quantities of hydrogen. Cat reformers, on the other hand, produce hydrogen as a by-product, but usually not in sufficient quantities to supply the hydrocracker and hydrotreaters in a refinery. Thus, supplemental hydrogen is often required. There are two processes available for hydrogen production:

1. Partial oxidation of heavy hydrocarbons, such as heavy fuel oil
2. Steam methane reforming (natural gas)

Since steam methane reforming is currently much more widely used than partial oxidation, it will be described in this section.

## Hydrotreater Process Description

The process takes place in three steps, as illustrated in Figure 3.13.

### 1. Reforming

Natural gas (methane,  $\text{CH}_4$ ) is pumped into the plant at approximately 200 psig pressure along with a supply of steam. With the addition of heat, the steam-gas mixture reacts in the presence of a catalyst to produce carbon monoxide and hydrogen:  $\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3\text{H}_2$ .

This is the reforming reaction, and it takes place at 1500°F. The reaction is carried out by passing the gas and steam mixture through a bank of catalyst-filled furnace tubes. The furnace consists of one or two rows of numerous vertical tubes, fired on each side, to obtain even-heat distribution around the tube as well as along the length of the tubes because of the extremely high tube wall temperature: 1700 to 1800°F. Special alloys are used for the furnace tubes.

### 2. Shift Conversion

The product from the reforming reaction is then cooled to about 650°F and enters the shift converter along with additional steam. In the shift converter, a fixed bed catalyst reactor, the

carbon monoxide in the gas reacts with the steam in the presence of shift catalyst to produce more hydrogen to convert the CO into  $\text{CO}_2$ :  $\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2$ .

The  $\text{CO}_2$  is then removed from the gas by absorbing it in a special solution and boiling the  $\text{CO}_2$  off the solution to the atmosphere or to a  $\text{CO}_2$  collector for further use or sale.

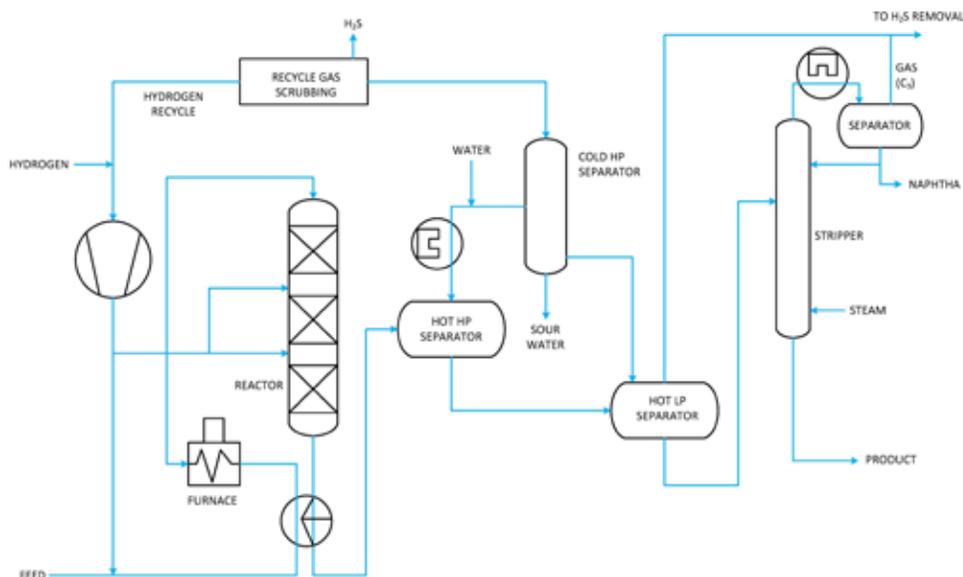
### 3. Methanation

Finally, the remaining small quantities of carbon monoxide and carbon dioxide are converted to methane in another fixed bed catalytic reactor for the final purification step in the process.

The above process steps are required in order to obtain very pure hydrogen as a product, since impurities are detrimental to the expensive catalyst in the hydrocracker. Purities of 95% and higher are obtained in the steam methane reformer.

From the methanator, the gas, with a molecular weight of 2.0+, leaves the plant at about 125 psig and is ready to be compressed to the 2000 psig pressure level for supply to the hydrocracker and hydrotreater.

Figure 3.13: Hydrotreater key process descriptions



### Critical Pumps

**Fractionator reflux**, required, 125 gpm each

Design: 200 psig @ 200°F

220 ft head

3.5 hydraulic hp

**HPX** complete with drivers

**Hydrotreater feed, HPX** required, 325 gpm each

Design: 500 to 1800 psig @ 450°F

595 to 5200 ft head

33 to 290 hydraulic hp

**Fractionator bottoms, HPX** required, 325 gpm each

Design: 200 psig @ 350°F

**Table 3.4: Hydrotreater pump and valve assets summary**

API/PUMP	APPLICATION
BB3-DMX	Hydrotreater Feed
OH2-HPX	Fractionator Bottoms
OH2-HPX	Side Stripper
OH2-HPX	Fractionator Reflux
OH2-HPX	Fractionator Sour Water
BB2-HDO	Lean Amine
BB3-DMX	Charge Pump (Feed) Recirculation

API/PUMP	APPLICATION
OH2-HPX	Hot High Pressure Separator Letdown
OH2-HPX	Cold High Pressure Separator Letdown
OH2-HPX	Sour Water Level Letdown
OH2-HPX	Rich Amine Level Letdown
OH2-HPX	Recycle Gas Compressor Anti-surge
ISO-LPHX	Vacuum Recycle
API Soft - KPH System	Sour Gas Compressor

VALVE	APPLICATION
Valtek Multi-Z	Charge Pump Recirc
Valtek Mark One w/Pilot Trim	Main Feed Heater Flow
Valtek Mark One Tiger Tooth	Hot High Pressure Separator
Valtek Multi-Z	Cold High Pressure Separator
Valtek Mark One w/Stealth Trim	Reactor Loop Depressurization
Valtek Multi-Z	Amine Booster Pump Recirc
Valtek Multi-Z	High Efficiency Separator Level
Valtek Valdisk Butterfly	Recycle Gas Compressor Suction Control
Valtek MaxFlo 4	Stripper Reflux Return
Valtek MaxFlo 4	Steam Temp Control to Stripper
Valtek MaxFlo 4	Bottoms/Product Streams
Valtek Mark One	Sour Water Letdown
Valtek Shearstream	Rich/Lean Amine Services
Valtek MaxFlo 4	Overhead Gas Control

VALVE	APPLICATION
Argus HK35/FK76	Guard Reactor Isolation/ Catalyst Addition
Argus HK35/FK76	Guard Reactor Isolation/ Catalyst Withdrawl
Valtek Mark One	Recycle Gas Compressor Surge
McCANNA	Rich Amine Isolation
McCANNA	Rich Amine Letdown
Argus HK35/FK76	Sour Water Isolation
Valtek Multi-Z	Sour Water Letdown
Argus HK35/FK76	Cold High Pressure Separator Automated LCV Isolation
Argus HK35/FK76	Cold High Pressure Separator Manual LCV Isolation
Argus HK35/FK76	Hot High Pressure Separator Automated LCV Isolation
Argus HK35/FK76	Hot High Pressure Separator Manual LCV Isolation
Argus HK35/FK76	Stripper Bottoms Emergency Block
Argus HK35/FK76	Stripper Bottoms Pump Isolation
Valtek Mark One	Unit Depressurization

*This summary does not include the large quantity of gate, plug, ball, check valves and mechanical seal systems.*

## Fluid Catalytic Cracking (FCC) Detailed Process

The fluid catalytic cracking process, commonly called “**cat cracker**,” is a widely used refining process for manufacturing gasoline and petrochemical feedstocks from the heavier portions of crude oil. Since the process utilizes a wide variety of rotating machinery in large sizes, it is

an extremely important process for Flowserve. The cat cracker (CP) and its associated gas plant have one of the largest and most versatile applications of pumping equipment in a refinery. **A typical cat cracker has 32 Flowserve products and 175 valves.**

*Figure 3.14: Simplified diagram for fluid catalytic cracker*

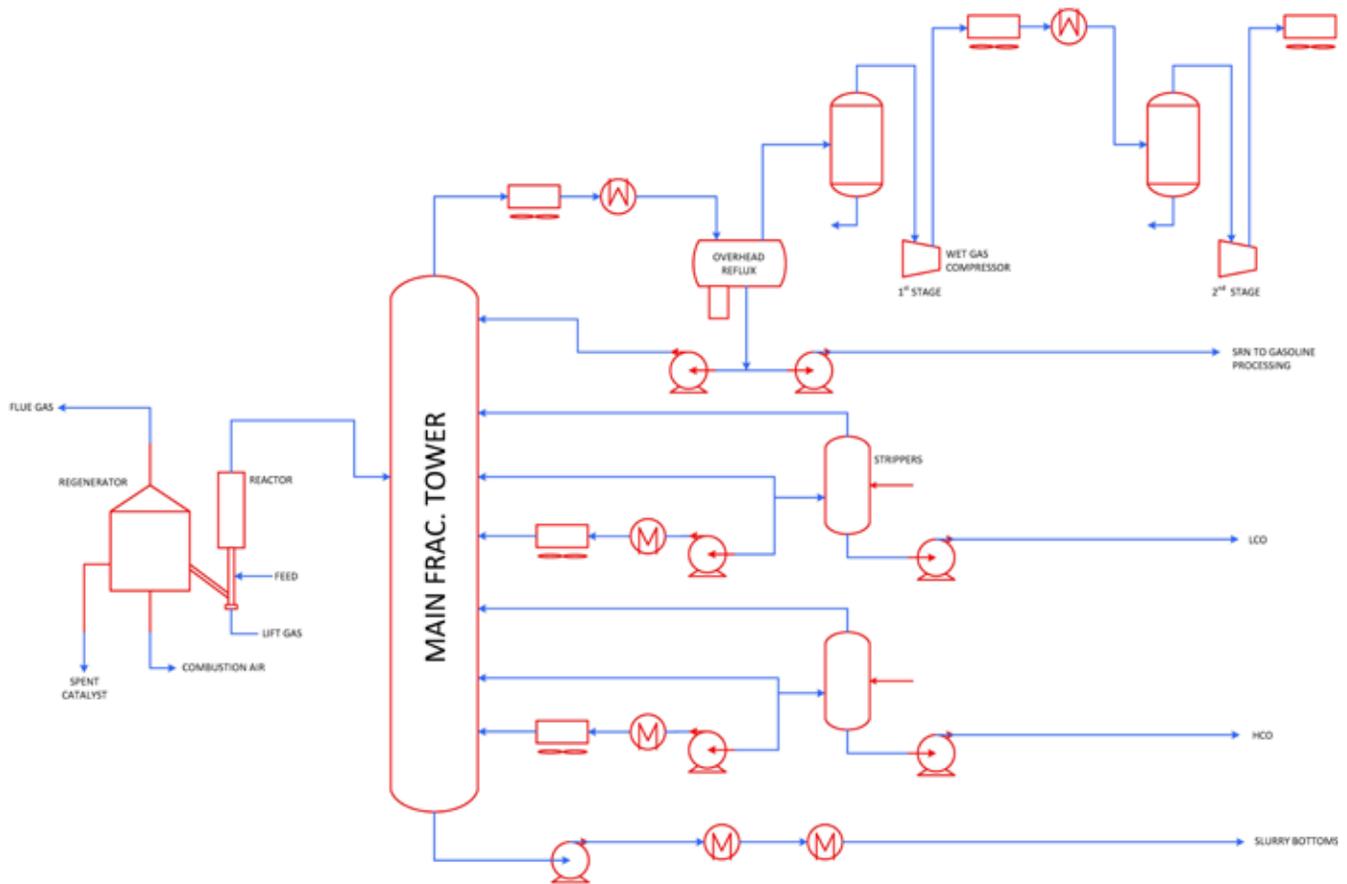
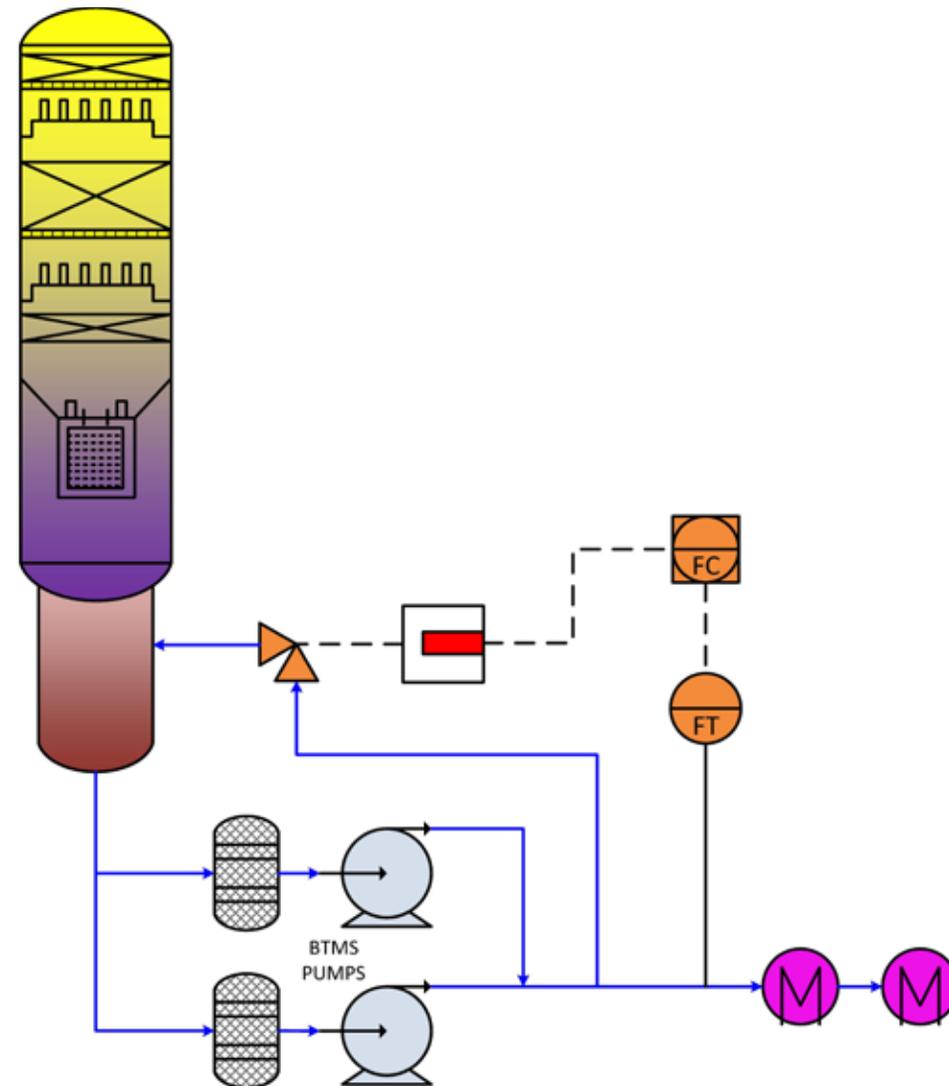


Figure 3.15: Simplified diagram for FCCU main FRAC recirc or spillback



**There are a number of licensed designs: Kellogg, UOP, Orthoflow, Gulf FCC, ExxonMobil Flexicracker and Amoco Ultra Cracker. However, the general principles of operation and applications of equipment are similar to all.**

Since the ratio of production of gasoline to heavier hydrocarbon products is higher in North America than other continents, there are a large number of cat crackers in the U.S. refineries.

In some cases, hydrocracking is considered a competing process. However, the choice between hydrocracking and cat cracking is an economic one and highly dependent on crude and product slate in a given refinery.

Figure 3.16: FCC thermal and pressure balance process

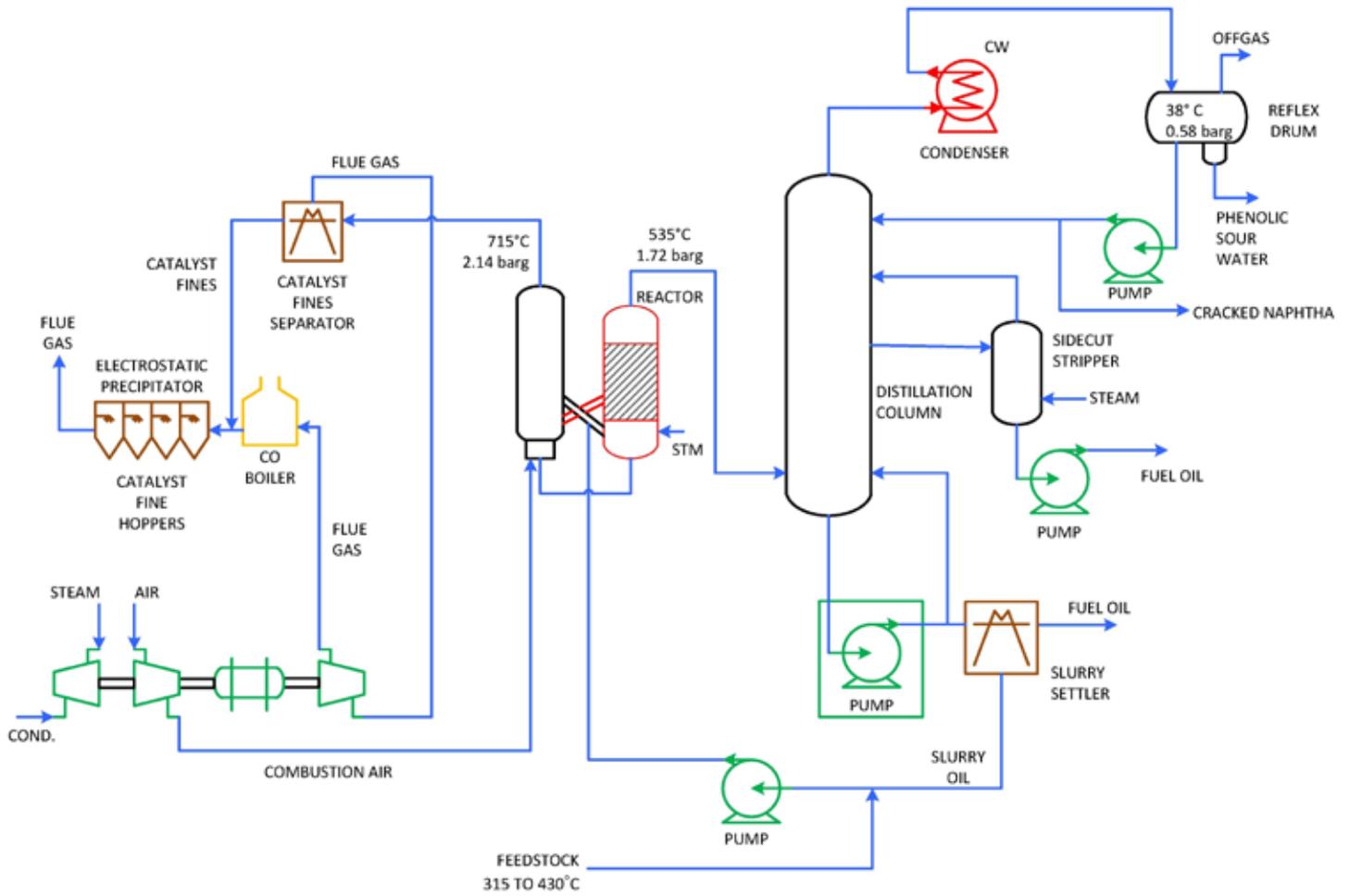
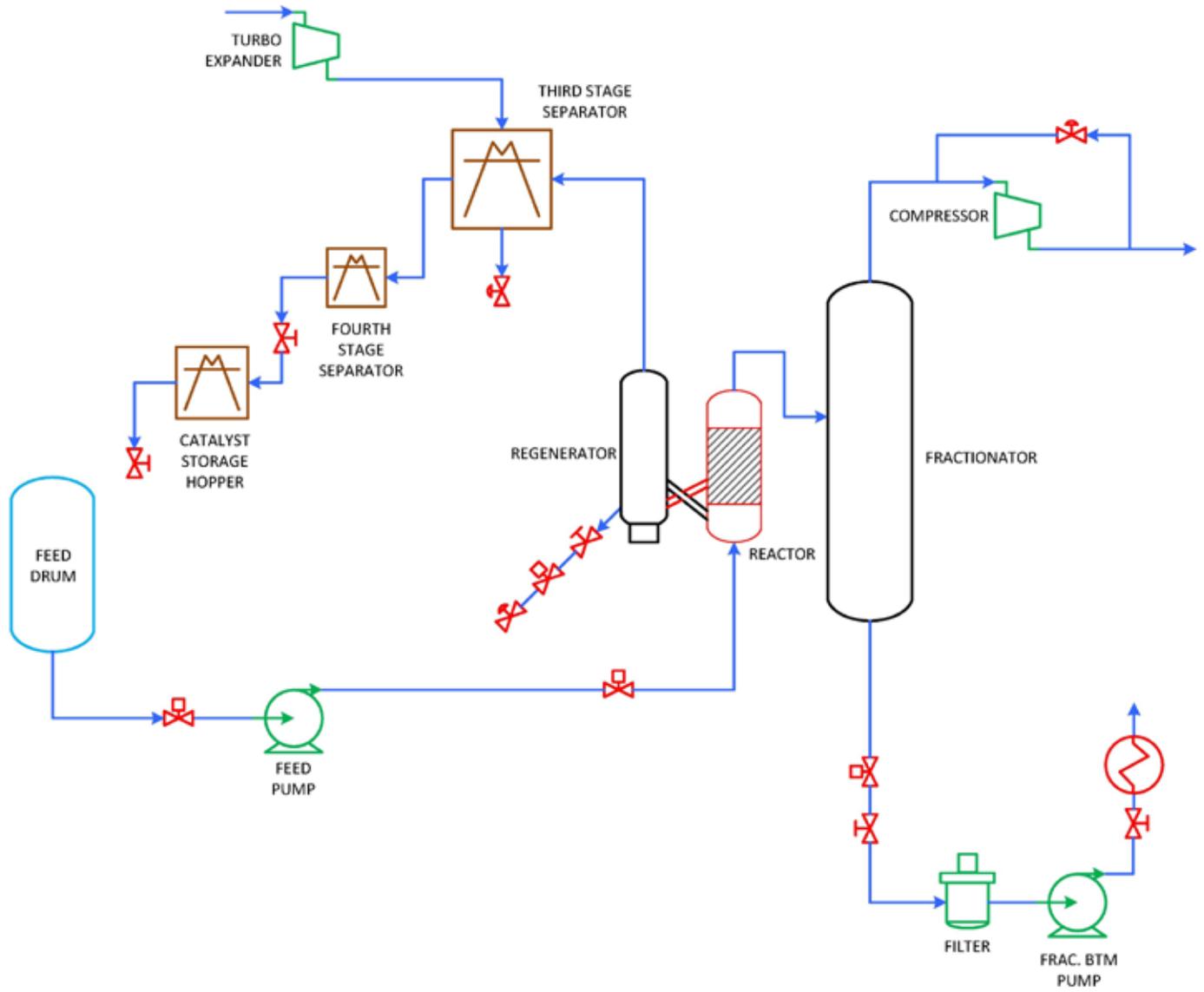


Figure 3.17: Example of FCC unit primary control valves



### FCC Process Description

The feed to the cat cracker can be a variety of heavy products from the crude distillation process. A typical structure of an FCC unit is shown in Figure 3.18.

The process utilizes a special chemical engineering tool, fluidized solid catalyst, to promote the cracking of the heavy hydrocarbon molecules into light ones. The catalyst, a crystalline alumina silicate, is in the form of a fine powder that circulates through the plant by action of oil vapors and air, much like dust in a windstorm. The heavier catalyst particles are highly erosive to metals when travelling at high velocities, and protective lines in pipes and vessels are required.

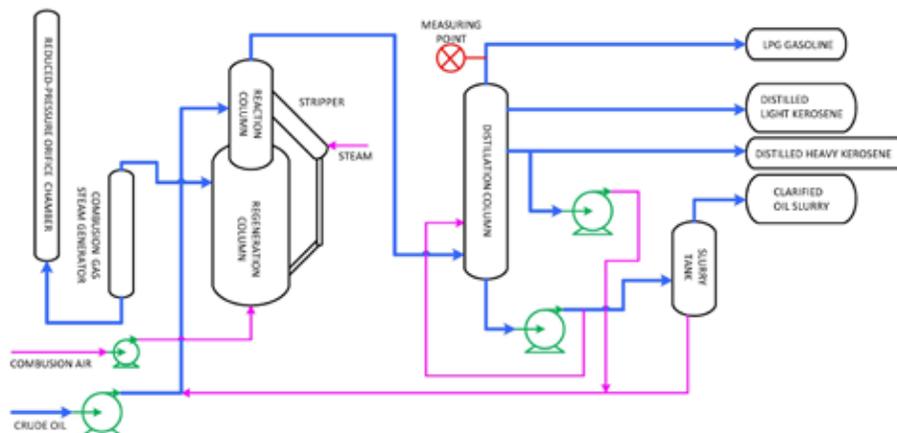
The feedstock is first heated by either heat exchange or a direct-fired furnace and then fed into a large-diameter vertical pipe, which rises into the reactor vessel. The vertical pipe is called a “riser”. As the feed enters the riser, it joins with a stream of hot powdered regenerated catalyst, and the heat from the catalyst completes the vaporization of the oil. The powder is then carried into the reactor by the oil vapors, where it is in intimate contact with the molecules of oil. The reaction, that is, the cracking of the molecules into lighter fractions, begins in the riser, and is completed in the reactor where the temperature is 1000°F.

The powdered spent catalyst is continuously withdrawn from the bottom of the reactor and stripped of hydrocarbon vapor by contact with steam. It is then transferred to the regenerator by an air stream where the carbon deposit is burned off at a temperature of 1200 to 1300°F in a fluidized catalyst bed. The regenerated hot catalyst is then used over again by being carried into the riser by the feedstock as described above.

The regenerator operates at a pressure of 25 to 335 psig and the products of combustion of the burned carbon deposits from the catalyst leave the regenerator after passing through cyclones, which separate out the catalyst. Formerly, this steam escaped to the atmosphere with a large waste of pressure energy. With the advent of power recovery, the escaping gases flow through a special separator where the quantity of catalyst particles is minimized and then through a hot gas expander, which is utilized to drive the air blower.

Returning to the reactor, the cracked oil vapors leave the reactor and enter the fractionator column where the final separation of vapors and liquid is made. Light hydrocarbons are recovered as gases, and gasoline and fuel oil are the liquid products. The fractionator operates at a pressure slightly lower than the reactor and regenerator pressure of 25 to 35 psig.

A residue called slurry oil, containing catalyst particles, is removed from the bottom of the fractionator and recycled with the feed into the reactor.



**Figure 3.18:**  
**Structure of FCC**

### FCC Centrifugal Pumps

There are large quantities of centrifugal pumps associated with the cat cracker, most of them being conventional single-stage and multistage units in cold and hot service. The one special application that merits consideration is the fractionator bottoms pumps, which recycle the slurry oil from the fractionator back to the reactor feed system. The slurry oil consists of a mixture of the heavy oil in the bottom of the fractionator and catalyst particles that carry over from the reactor into the fractionator.

The slurry oil pumps are special units built to withstand the erosive action of the catalyst powder suspended in the air. They usually handle large quantities of 600 to 700°F oil—quantities in the range of 500 to 1000 gpm and are the vertically split overhung or between bearing pumps, Flowserve type.

Since the pressure differential between the fractionator and reactor is low, the heads on the pumps are low. They can operate at reduced speeds in the 1180 to 1750 RPM range to reduce erosion of the catalyst in the slurry. In addition, clean flushing oil is supplied to the wear rings, throat bushings and packing, through specially designed connections, to reduce erosion in wearing parts.

Because of the temperatures and sulfide environment, the pumps are usually furnished with chrome cases and impellers.

The fractionator gas oil pumps, and light, heavy and extra-heavy gas oil, are all heavy-duty refinery type units with low NPSH requirements, high temperature and high head applications.

The gas plant, downstream of the cat cracker, also features a number of heavy-duty process pump applications, mainly for cold, light-end service such as propane, butane and isobutene.

In general, the cat cracker and its associated gas plant have one of the largest and most versatile applications of pumping equipment in a refinery.

### Fluid Catalytic Cracking Power Recovery

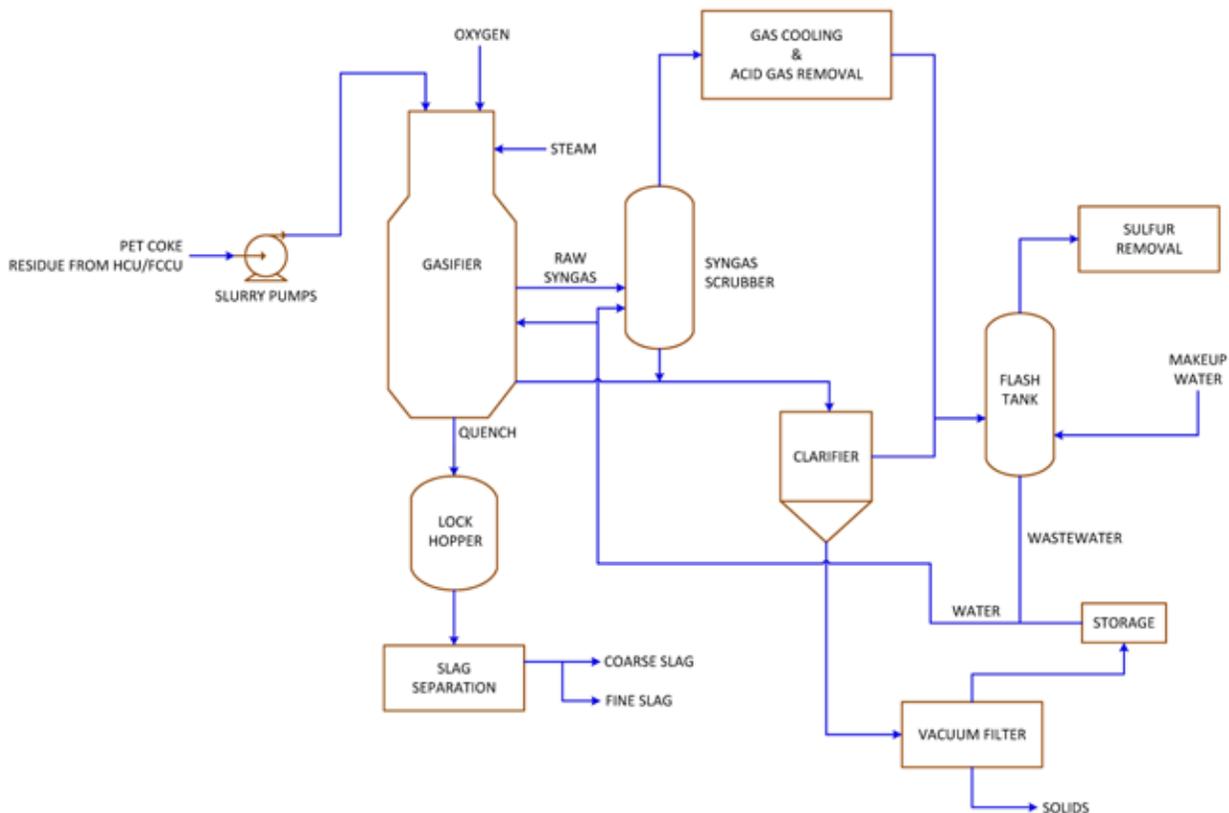
In the mid-1960s, the concept of power recovery was applied to cat crackers. Prior to that time, the 1200°F regenerator flue gas, carrying large quantities of fine catalyst dust, was expanded through a throttling device and then burned in a CO boiler at atmospheric pressure. Since the quantity of gas was so large — in the same order of magnitude as the blower air capacity — the energy wastage, as a result of throttling, was substantial. Unfortunately, the erosive characteristics of the catalyst in the gas stream prevented its expansion through rotating turbine blades.

In the early 1960s, Shell Development Company invented a special separator to remove most of the catalyst particles from the gas stream so that the life of the turbine blades would approach the operating period between turnarounds of the cat cracker: three years or more. Other separator manufacturers followed with their own cyclone-type separator.

The power recovery flow diagram illustrates how the system functions. Flue gas from the regenerator, 1200 to 1300°F and 25 to 35 psig pressure, flows through a refractory-lined duct to the special separator where the dust particles are removed.

A small percentage of the gas is used as blowdown to carry the particles out of the bottom of the separator. The clean gas leaves the top of the separator and enters the expander through throttling butterfly valve, which maintains a constant pressure on the regenerator. In case there is more gas coming from the regenerator than the turbine can handle, the second valve is utilized to bypass the gas to the atmosphere or maximum amount of energy in the gas can be reclaimed. The gas leaves the expander at near-atmosphere pressure to generate steam. (The CO boiler is not considered a part of the power recovery system.) In all cases, the power generated by the expander is used to drive the cat cracker regenerator air blower.

**Figure 3.19: Simplified diagram — gasification**



### Critical FCC Pumps and Valves

**Waste heat boiler feed**, three required, 1400 gpm each  
Design: 250 psig @ 210°F @ disch., 5 psig @ suction  
480 ft head  
170 hydraulic hp  
Main pump with motor driver, the two spares to be turbine driven

**Low-pressure distillate**, two required, 800 gpm each  
Design: 200 psig @ 100°F @ disch., 5 psig @ suction  
400 ft head  
65 hydraulic hp  
Complete with drivers

**Top pump around**, two required, 10 000 gpm each  
Design: 150 psig @ 200°F @ disch., 35 psig @ suction  
170 ft head  
320 hydraulic hp  
Complete with drivers

**Heavy naphtha**, two required, 300 gpm each  
Design: 150 psig @ 275°F @ disch., 25 psig @ suction  
275 ft head  
16 hydraulic hp  
Complete with drivers

**Light heating oil**, two required, 1350 gpm each  
Design: 150 psig @ 365°F @ disch., 20 psig @ suction  
360 ft head  
98 hydraulic hp  
Complete with drivers

**Heavy heating oil**, two required, 325 gpm each  
Design: 200 psig @ 365°F @ disch., 5 psig @ suction  
351 ft head  
25 hydraulic hp  
Complete with drivers

**Mid-pump around**, two required, 5500 gpm each  
Design: 100 psig @ 500°F @ disch., 25 psig @ suction  
190 ft head  
200 hydraulic hp  
Complete with drivers

**Fractionator overhead sour water**, two required, 165 gpm each  
Design: 75 psig @ 350°F  
23 ft head  
1 hydraulic hp  
Complete with drivers

**Light distillate sidestream**, two required, 430 gpm each  
Design: 200 psig @ 500°F  
305 ft head  
39 hydraulic hp  
Complete with drivers (turbine-driven spare)

**Gas oil sidestream**, two required, 600 gpm each  
Design: 200 psig @ 650°F  
270 ft head  
45 hydraulic hp  
Complete with drivers (turbine-driven spare)

**Fractionator overhead product**, two required, 300 gpm each  
Design: 250 psig @ 350°F  
360 ft head  
31 hydraulic hp  
Complete with drivers (turbine-driven spare)

**Recycle and fuel oil pump**, two required, 1200 gpm each  
Design: 125 psig @ 850°F  
115 ft head  
39 hydraulic hp  
Complete with drivers (turbine-driven spare)

**Critical FCC Pumps and Valves** *(continued)*

**Coker Charge Pump**, three required, 1800 gpm each  
Design: 650 psig @ 700°F  
1300 ft head  
630 hydraulic hp  
Complete with drivers (two turbine-driven spares)

**First-stage steam preheat circulation**,  
two required, 2000 gpm each  
Design: 75 psig @ 450°F  
66 ft head  
35 hydraulic hp  
Complete with drivers (turbine-driven spare)

**Second-stage steam preheat circulation**,  
two required, 2000 gpm each  
Design: 100 psig @ 250°F  
63 ft head  
35 hydraulic hp  
Complete with drivers (turbine-driven spare)

**Diluent tower feed, three required**, 1600 gpm each  
Design: 175 psig @ 300°F  
230 ft head  
98 hydraulic hp  
Complete with drivers (turbine-driven spare)

**Heater charge pump, three required**, 1200 gpm each  
Design: 100 psig @ 550°F  
75 ft head  
27 hydraulic hp  
Complete with drivers (two turbine-driven spares)

**Preheat steam condensate removal**, two required,  
230 gpm each  
Design: 100 psig @ 250°F  
68 ft head  
7 hydraulic hp  
Complete with drivers

**Diluent pumps**, two required, 1000 gpm each  
Design: 200 psig @ 225°F  
260 ft head  
76 hydraulic hp  
Complete with drivers (turbine-driven spare)

**Diluent surge drum sour water removal**,  
two required, 120 gpm each  
Design: 100 psig @ 225°F  
70 ft head  
2 hydraulic hp  
Complete with drivers

**Bitumen pumps**, two required, 1150 gpm each  
Design: 75 psig @ 600°F  
70 ft head  
20 hydraulic hp  
Complete with drivers (turbine-driven spare)

**Quench water**, two required, 400 gpm each  
Design: 100 psig @ 200°F  
185 ft head  
20 hydraulic hp  
Complete with drivers (turbine-driven spare)

**Wash oil**, two required, 100 gpm each  
Design: 150 psig @ 400°F  
220 ft head  
6 hydraulic hp  
Complete with drivers

**Coker recovery oil**, two required, 25 gpm each  
Design: 100 psig @ 150°F  
150 ft head  
1 hydraulic hp  
Complete with drivers

**Steam out sour water**, two required, 125 gpm each  
Design: 75 psig @ 150°F  
4 hydraulic hp  
Complete with drivers

Table 3.5: Pump and valve asset summary

API/PUMP	APPLICATION
BB2-HDX	Fractionator Bottom Pump
BB2-HDX	Waste Heat Feed
OH2-HPX	Low Pressure Distillate
OH2-HPX	Fractionator Pump Around
OH2-HPX	Heavy Naphtha
OH2-HPX	Light Heating Oil
OH2-HPX	Heavy Heating Oil

API/PUMP	APPLICATION
OH2-HPX	Overhead Sour Water
OH2-HPX	Distillate Sidestream
OH2-HPX	Fractionator Overhead
OH2-HPX	Bitumen Pump
API Soft - LPHX	Vapor Emission Systems
KPH Liquid Ring Compressor	Sour Gas/Off Gas
Flue Gas Control	Off Gas Vacuum Systems

VALVE	APPLICATION
Valtek Multi-Z	Charge Pump Recirc
Valtek Mark One w/Pilot Trim	Main Feed Heater Flow
Valtek Mark One w/Stealth Trim	Reactor Loop Depressurization
Valtek Mark One	Recycle Gas Compressor Surge Control
Valtek Valdisk Butterfly	Recycle Gas Compressor Suction Control
Valtek MaxFlo 4	Bottoms/Product Streams
Valtek Mark One	Sour Water Letdown
Valtek MaxFlo 4	Overhead Gas Control
Valtek Survivor	Resid Hydrocracking Severe Service
Argus HK35/FK76	Third Stage Separator Isolation
Argus HK35/FK76	Fourth Stage Separator Isolation

VALVE	APPLICATION
Argus HK35/FK76	Spent Catalyst Storage Hopper Isolation
Argus HK35/FK76	Feed Drum Emergency Block
Argus HK35/FK76	Throttling Spent Catalyst Withdrawal
Argus HK35/FK76	Spent Catalyst Withdrawal Emergency Block
Argus HK35/FK76	Spent Catalyst Withdrawal Root Isolation
Argus HK35/FK76	Slurry Feed Isolation
Argus HK35/FK76	Frac Bottoms Emergency Block
Argus HK35/FK76	Frac Tower Bottoms Filter Isolation
Valtek Survivor	Frac Tower Bottoms Recirculation
Argus HK35/FK76	Frac Bottoms Exchanger Isolation
Valtek Mark One	Wet Gas Compressor Surge
TX3 Butterfly	Catalytic Cracker

This summary does not include the large quantity of gate, plug, ball, check valves and mechanical seal systems.

## Hydrocracker Detailed Process



Hydrocracking is another refinery process for making gasoline out of heavier feedstocks from the crude unit. The added interest in hydrocracking in the 1960s was caused by two factors:

1. A heavy demand for more gasoline, which resulted in a need to increase the ratio of barrels of gasoline per barrel of crude oil.
2. There were large quantities of hydrogen by-product available from the many cat reformers that had been built, and hydrocracking requires a large amount of hydrogen.

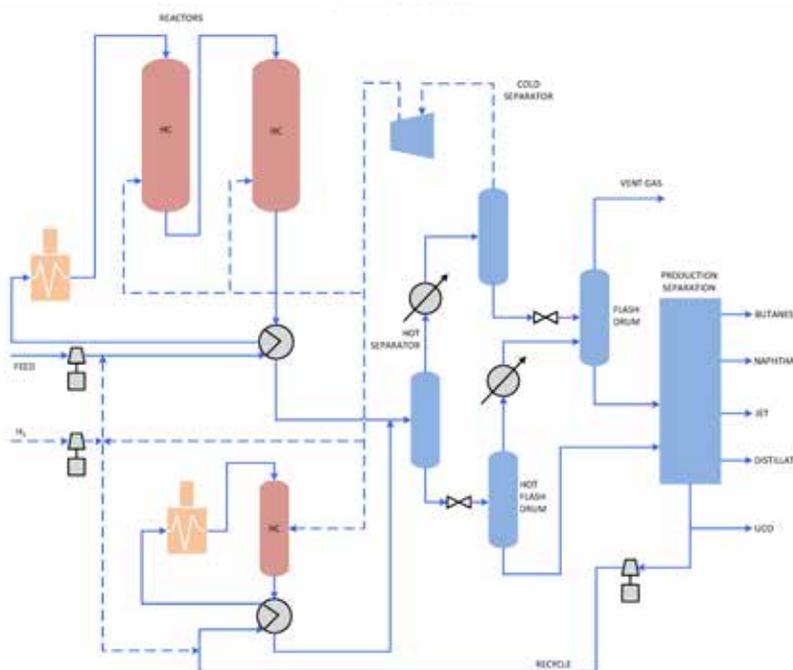
In a number of refineries, cat cracking and reforming work together. The cat cracker takes the more easily cracked oils as feed, while the hydrocracker can crack those oils that are not easily cracked in a cat cracker.

Although they work together, the processes are completely dissimilar. The cat cracker reaction takes place at a low pressure (25 to 35 psig) without hydrogen, and in the presence of a fluidized bed of catalyst. Hydrocracking occurs at a pressure of 1000 to 2000 psig with a high concentration of hydrogen and in a fixed bed of catalyst.

The hydrocracking process is a flexible one. In addition to making gasoline from middle distillate oils, the process is being used to make distillates and light oils from residual oils. Of course, the catalyst and operating conditions are different; however, the same plant can be designed to operate in the alternate modes.



**Figure 3.21: Basic hydrocracker uni-cracker, two-stage structure**



As in cat reforming, the feedstock must be hydrotreated prior to entering the hydrocracker to remove the sulfur, nitrogen and oxygen compounds, which are harmful to the catalyst. Thus, a hydrotreater may be required in conjunction with a hydrocracker, unless there is existing hydrotreating capacity within the refinery. In a two-stage hydrocracker, the first stage may perform the function of a hydrotreater.

There are a number of hydrocracking processes designed in the 1960s/1970s for licensing, as shown below:

Isomax:	Chevron and UOP	Ultracracking:	Standard Oil Company (Indiana)
Unicracking: SHC	Union and Exxon	Hy-C, H-Oil:	Hydrocarbon Research and Cities Service
H-G Hydrocracking:	Gulf and Houdry	Shell:	Shell Development Company

With the exception of H-Oil and Hy-C processes, all hydrocracking processes in use today are fixed bed catalytic processes with liquid down flow through the reactors.

The hydrocracking process is extremely important to the Flowserve marketing efforts because it contains the most sophisticated rotating and reciprocating machinery and process pumps found in refineries or petrochemical plants today.

Flowserve equipment for hydrocrackers can be classified as follows:

1. Barrel type, hot oil pumps for hydrocracker feed service
2. Barrel type, multistage hydraulic turbines driving the feed pumps
3. Numerous process type centrifugal pumps

**Critical centrifugal compressors are not in the Flowserve equipment portfolio.**

Figure 3.22: LC-finishing process

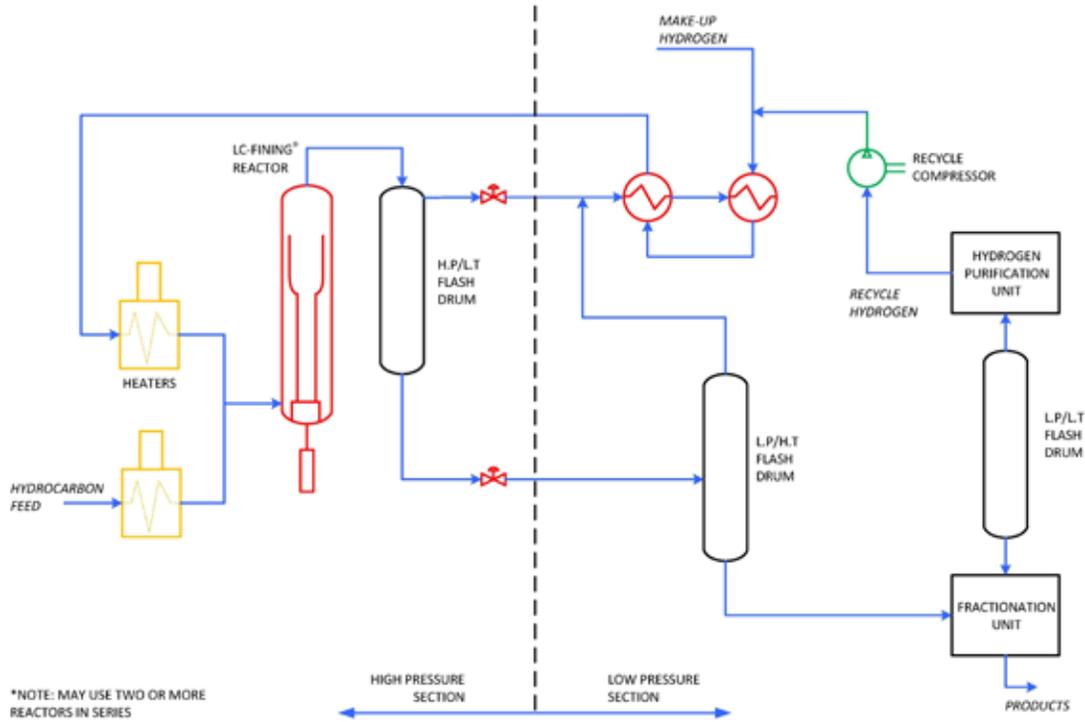
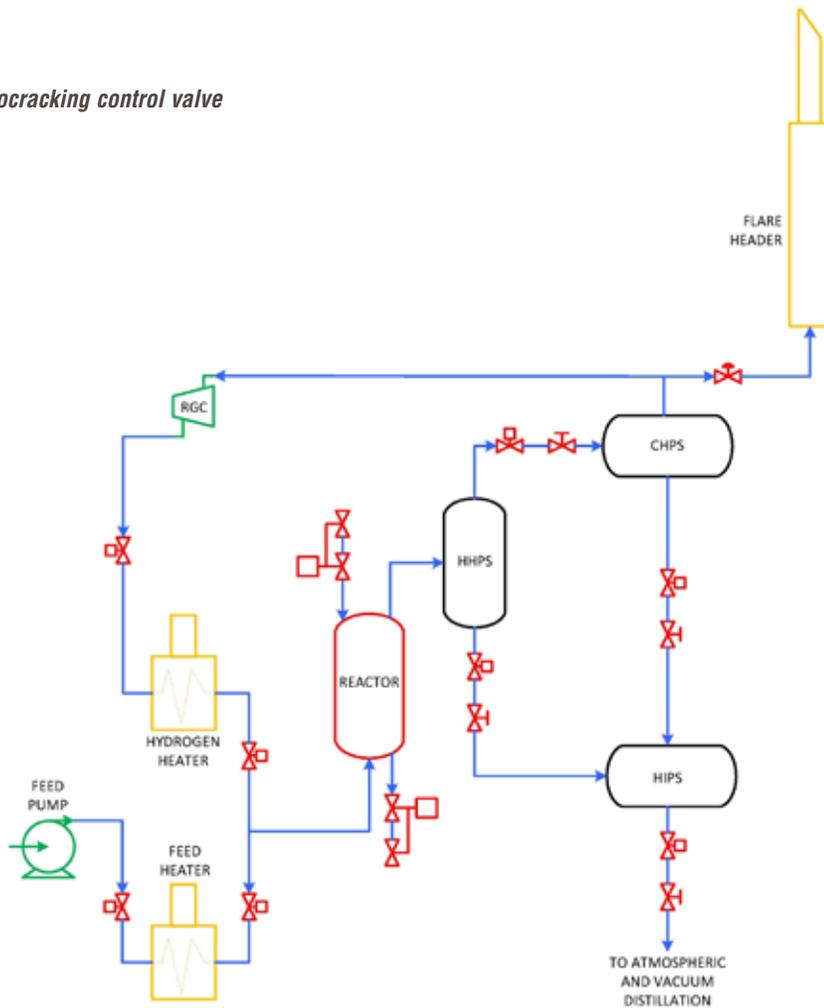


Figure 3.23: Hydrocracking control valve



### Process Description

The PFD (Figure 3.24) shows a typical two-stage hydrocracker. Reaction temperature is approximately 800°F, and pressure in each reactor system is about 2000 psig.

The fresh feed is pumped up to 2000 psi from the crude unit of cat cracker at an elevated temperature of 600°F or higher. The feed mixes with make-up hydrogen, which is compressed into the plant from the hydrogen plant or the cat reformer. Since hydrogen is consumed in the hydrocracking reaction, it must be continuously added to the system. In addition, recycle hydrogen is mixed with the feed to supply the hydrogen atmosphere required by the reaction. The hydrogen recycle stream is circulated through the system by the recycle compressor, a barrel type centrifugal. The mixture of feed, recycle hydrogen and make-up hydrogen is heated in a furnace prior to entering the catalyst beds in the reactor.

From the first-stage reactor, the effluent travels through a bank of exchangers into a high-pressure separator where the hydrogen recycle gas is separated from the liquid product and fed to the recycle compressor for recirculation back through the first-stage reaction system. The liquid product from the high-pressure separator is dropped down through a hydraulic turbine into a low-pressure separator. The hydraulic turbine is utilized to drive the feed pumps.

From the low-pressure separator, the product is pumped to a fractionation column where the gasoline comes off the top and is pumped to storage. The heavier fractions from the bottom of the column are pumped into the second-stage reaction system as feed.

The second stage is similar to the first, except that it operates at higher temperatures in order to crack the unconverted oil from the first stage. The second-stage product is combined with the first-stage product prior to fractionation. Thus, the second stage handles first-stage product plus some recycle of its own product.

### Feed Pumps and Hydraulic Turbines

The feed pumps used on many hydrocrackers are multistage barrel type centrifugal pumps designed to operate at temperatures of 700 to 800°F and pressures greater than 2000 psig. The outer case barrel is usually forged steel overlaid with 316 stainless steel. Internal parts, diffusers, impellers, etc., are 12% or 17% chrome. Due to the high heads involved, 10 to 14 impellers are required in each pump.

Metal bellows mechanical seals have been utilized on these pumps to withstand the high temperatures involved. Some seals operate “dead ended” and some are flushed by cooled pumpage.

Seal failures have been the major problem on the feed pumps. In 1965, when the first hydrocrackers were being streamered, there was little experience at these temperatures and pressures with mechanical seals. However, over time, the seals have been developed to operate satisfactorily for reasonable operating periods in excess of one year of continuous duty.

Horsepower in the 500 to 10 000 range is required on some of the larger hydrocracker feed pumps. (The second-stage pump is usually the larger pump because it handles first-stage product plus some recycle.)

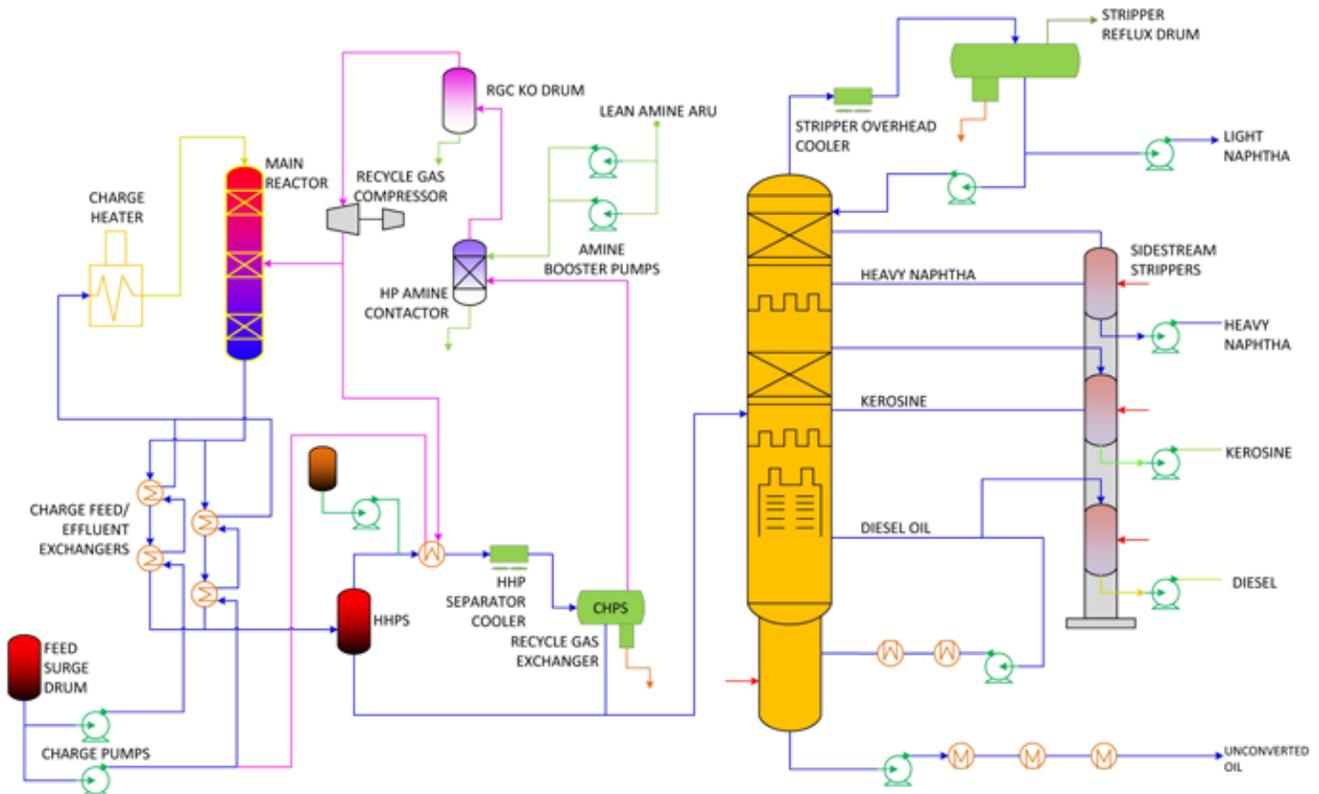
Some of the power is furnished by hydraulic turbines, which develop power from the pressure reduction of the liquid leaving the high-pressure separator in each stage on the way to the low-pressure separator. Instead of taking this pressure drop across a throttling valve, power can be developed in a hydraulic turbine to furnish the feed pump from one-third to one-half of its power requirement.

The turbine is very similar to the feed pump, except that the liquid enters the discharge and exits from the suction. A barrel type multistage unit is used on most plants because of the high entering pressure (2000+ psi). Fortunately, the liquid is relatively cool (150 to 200°F), and the scaling problem is not a critical one.

Some vaporization takes place with the pressure breakdown through the turbine; however, this does not affect the mechanical operation.

The turbine is connected to one end of the feed pump and the motor to the other. A full-size motor is recommended so that plant capacity will be maintained when the turbine is out of service. The turbine is connected to the feed pump through a clutch, which allows the turbine to be energized or de-energized at any time. In other words, if a seal leak occurs, the turbine can be de-energized without affecting pump operation.

Figure 3.24: Simplified diagram hydrocracker



## Critical Pumps

### First-Stage Charge Pumps

Design: 1800 psig @ 150°F @ disch., 100 psi suction  
 1370 gpm of 20° API oil @ 60°F  
 4076 ft head  
 1318 hydraulic hp  
 Complete with drivers (one motor, one turbine)

### Second-Stage Charge Pumps

Design: 1800 psig @ 650°F @ disch., 100 psi suction  
 1370 gpm of 20° API oil @ 550°F  
 5640 ft head  
 1318 hydraulic hp  
 Complete with drivers (one motor, one turbine)

Figure 3.25: Simplified diagram charge pump recirculation or spillback

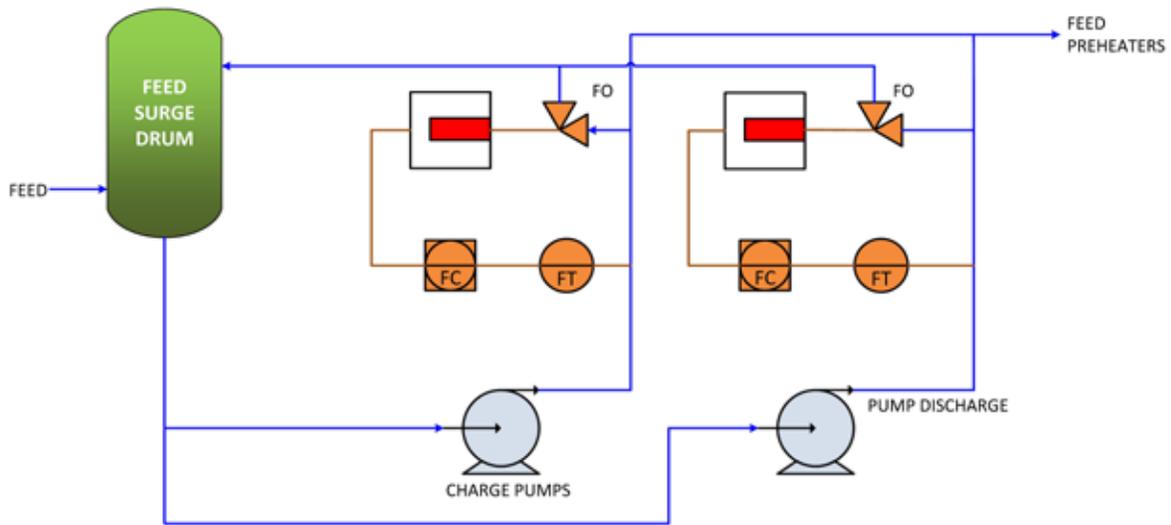


Table 3.6: Pump and valve asset summary

API/PUMP	APPLICATION
BB2-HDO	Hydrotreater Feed
OH2-HPX	Fractionator Bottom Pump
OH2-HPX	Side Stripper
OH2-HPX	Fractionator Reflux
OH2-HPX	Fractionator Sour Water
OH2-HPX	Charge Pump Recirculation
OH2-HPX	Hot High Pressure Separator Letdown
OH2-HPX	Cold High Pressure Separator Depressurization
OH2-HPX	Sour Water Level Letdown
OH2-HPX	Rich Amine Level Letdown
OH2-HPX	Recycle Gas Compressor Anti-surge
OH2-HPX	Fractionator Water
OH2-HPX	Kerosene Pumparound
OH2-HPX	Kerosene Product

API/PUMP	APPLICATION
OH2-HPX	Diesel Pumparound
OH2-HPX	Diesel Product
OH2-HPX	Naphtha Stabilizer
OH2-HPX	Deethanizer Feed
OH2-HPX	Debutanizer Overhead
OH2-HPX	Naphtha Product
OH2-HPX	Caustic Recirculation
OH2-HPX	Caustic Feed
OH2-HPX	Water Wash Recirculation
OH2-HPX	Water Wash
BB2-HDO	Amine Booster
API Soft - LPHX	Vapor Emissions Systems
KPH Liquid Ring Compressor	Sour Gas/Off Gas
KPH Compressor	Off Gas Vacuum Systems

(continued)

**Table 3.6: Pump and valve asset summary (continued)**

VALVE	APPLICATION	VALVE	APPLICATION
Valtek Multi-Z	Charge Pump Recirc	Argus HK35/FK76	Hot High Pressure Separator Automated LCV Isolation
Valtek Mark One w/Pilot Trim	Main Feed Heater Flow	Argus HK35/FK76	Hot High Pressure Separator Manual LCV Isolation
Valtek Mark One Tiger Tooth	Hot High Pressure Separator	Valtek Survivor	Hot High Pressure Separator LCV
Valtek Multi-Z	Cold High Pressure Separator	McCANNA	Hot High Pressure Automated Overhead Vapor Isolation
Valtek Multi-Z	Amine Booster Pump Recirc	McCANNA	Hot High Pressure Manual Overhead Vapor Isolation
Valtek MaxFlo 4	Stripper Reflux Return	Argus HK35/FK76	Cold High Pressure Separator Automated LCV Isolation
Valtek MaxFlo 4	Steam Temp Control to Stripper	Argus HK35/FK76	Cold High Pressure Separator Manual LCV Isolation
Valtek MaxFlo 4	Bottoms/Product Stream	LCV Multi-Z	Cold High Pressure Separator LCV
Valtek Mark One	Sour Water Letdown	Argus HK35/FK75	Hot Intermediate Pressure Separator Automated LCV Isolation
Valtek Shearstream	Rich/Lean Amine	Argus HK35/FK75	Hot Intermediate Pressure Separator Manual LCV Isolation
Valtek MaxFlo 4	Overhead Gas Control	Valtek Survivor	Hot Intermediate Separator LCV
Valtek Survivor	Resid Hydrocracking Severe Services	Valtek Mark One	Unit Depressurization
Valtek Survivor	Chopper Control	McCANNA	Rich Amine Manual Isolation
Argus HK35/FK76	Hydrogen Heater Inlet Emergency Block	Multi-Z	Rich Amine Letdown
Argus HK35/FK76	Feed Heater Outlet Emergency Block	Argus HK35/FK76	Hot Purge
Argus HK35/FK76	Hydrogen Heater Outlet Emergency Block	Argus HK35/FK76	Hydrogen Purge
Argus HK35/FK76	Reactor Catalyst Additions	Argus HK35/FK76	Emergency Reactor Bypass
Argus HK35/FK76	Reactor Catalyst Withdrawal		

*This summary does not include the large quantity of gate, plug, ball, check valves and mechanical seal systems.*

### Special Note

Resid Hydrocracker Reactor Recycle Application (**Ebulating Pump**)

Flowserve invented the type PR recycle pump in the late 1960s and now has more than 100 units installed worldwide. Universally preferred, it consists of a single-stage vertical pump combined with a Flowserve Byron Jackson submersible electric motor and heat exchanger, all enclosed within an ASME-certified forged steel housing. **It is available in two configurations:**

1. Internal “LC-Finer” recycle pump mounted in the reactor
2. External “H-Oil” ebulating pump, which is case mounted

**The type PR recycle pump package consists of:**

- Recycle pump
- Variable Frequency Drive (VFD) to adjust the pump speed/flow to the control of the catalyst bed level
- Clean oil injection systems
- Engineering analysis
- Complete variable speed testing

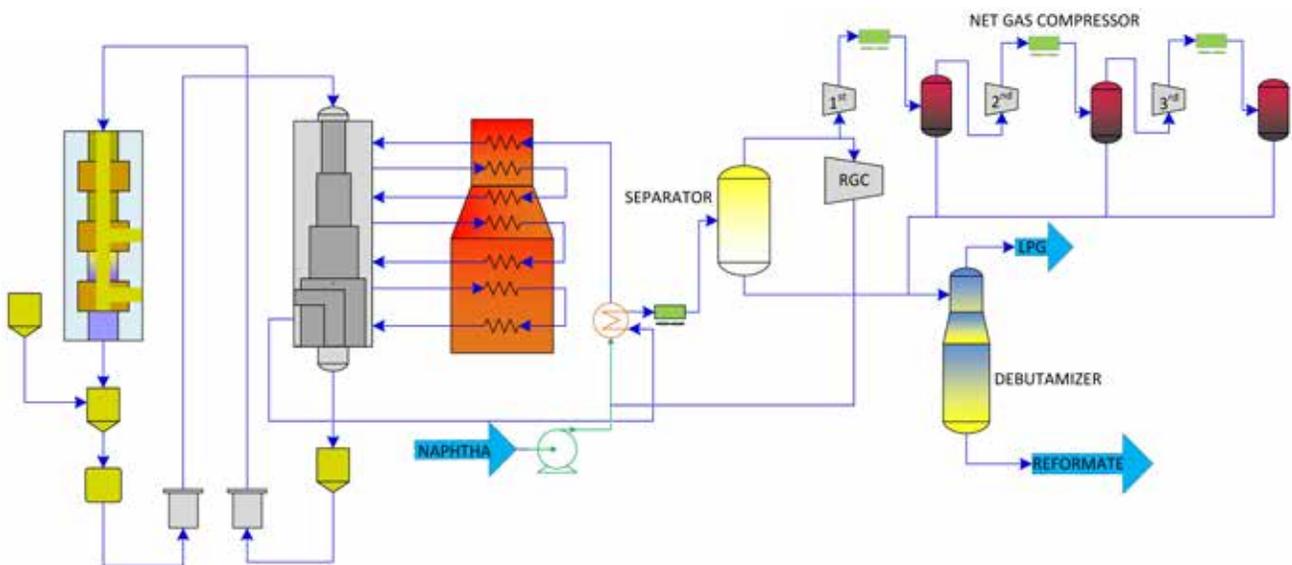
The type PR recycle pump is designed for unspared operation of 26 000 hours mean time between inspections. It can be specified to meet hydroprocessors’ reactor temperature and pressure requirements, typically up to 480°C (900°F) and 220 bar (3200 psi). For higher pressures, consult the Vernon facility.

## Catalytic Reformer

The demand of today's automobiles for high-octane gasoline, especially without the addition of lead, has stimulated the interest in **catalytic reforming** (cat reforming). The major function of the cat reformer is to produce a high-octane product which, when blended with other gasoline, streams from the cat cracker and hydrocracker and results in an overall gasoline octane number within market specifications. As lead is legislated or banned as an additive of gasoline, more cat reforming capacity will be required to make up for the octane improvement obtained with lead.

In catalytic reforming, the hydrocarbon molecules are not cracked, but their structure is rearranged to form higher-octane products. The reaction resulting in the molecular rearrangement takes place in a series of three or four reactors at a temperature of 900 to 1000°F in the presence of a metallic catalyst containing platinum. Thus, a hydrotreating plant is usually built along with a cat reformer.

*Figure 3.26: Simplified diagram continuous catalytic reformer*



There are several proprietary catalytic reforming processes, all with somewhat similar operating conditions and using some type of platinum catalyst.

### These include:

- |                                       |                                  |
|---------------------------------------|----------------------------------|
| a. Platforming—UOP                    | d. Houdriforming—Houdry Division |
| b. Powerforming—ExxonMobil            | e. Catalytic Reforming—Englehard |
| c. Ultraforming—Standard Oil, Indiana | f. Rheniforming—Chevron          |

### Why Is This Process So Important to Flowserve?

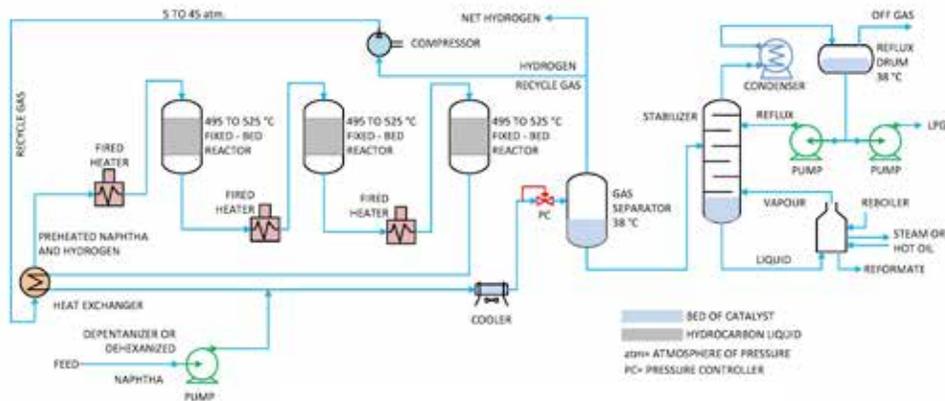
Flowserve has been a major supplier of cat reformer equipment through the years. There are more than 1500 cat reformers in operation throughout the world and many more proposed as the lead phase-out occurs. It's a natural market for Flowserve. Flowserve equipment for cat reforming can be classified as follows:

- Numerous process-type centrifugal pumps, valves and seal systems

- Please note our QRC service centers also are involved with repairs of other non-Flowserve equipment such as compressors

With the large number of units in service, retrofits will continue to be a factor in equipment sales, especially since many of the plants were designed when energy costs were one-fourth that of present-day costs. There are new catalysts on the market which will allow a plant to run at lower power consumption. Rotor revisions or unit replacement could be required in many instances.

Figure 3.27: Example of thermal exchange in reformer



### Process Description

For illustrative purposes, the platformer process by UOP is used for the process description. Although operating conditions are slightly different, the other cat reforming processes are similar in principle.

The reaction takes place in three reactors, which are filled with the platinum-bearing catalyst pellets. The mixture of hot oil and hydrogen is recycled through the beds to affect the molecular rearrangement. The reactors are steel vessels internally lined with refractory to insulate the metal from the 1000°F reaction temperature.

Now the process flow: the pretreated feed and recycle hydrogen are heated to 900 to 1000°F before entering the first reactor. In the first reactor, the major reaction is dehydrogenation of naphthenes to aromatics and, as this is strongly endothermic, a large drop in temperature occurs. To maintain the reaction rate, the gases are reheated before being passed over the catalyst in the second reactor. Usually three reactors are sufficient to provide the desired degree of reaction, and heaters are needed before each reactor to bring the temperature up to the desired reaction temperature.

As the mixture of product and hydrogen leaves the last reactor, it is cooled and the hydrogen is separated from it in the hydrogen separator. The liquid products are condensed and sent on for further processing in the stabilizer column where high-octane reformate (final product from the reformer) is accumulated and pumped to the gasoline pool (CJP).

The hydrogen leaving the hydrogen separator splits into two streams: one is recycled back through the process to mix with feed going to the reactors; the excess hydrogen is pumped away by compressors to be used in other processes. Since hydrogen is manufactured in the cat reformer process, there is always a sizable stream leaving the unit. It is one of the pluses for cat reforming, since hydrogen is an expensive product.

Unfortunately, catalyst deteriorates over a period of time and has to be regenerated. There are three types of regeneration:

#### 1. Semi-regenerative

Here, the plant is shut down after a six-month to two-year run, dependent on the severity of operating conditions, and the catalyst is regenerated by high-temperature oxidation and chlorination. The hydrogen recycle compressor is used in this regeneration to pump air through the reactors to furnish oxygen for the regeneration reaction.

#### 2. Cyclic regenerative

In the cyclic process, there is an extra reactor installed in the train, and it is used as a “swing” reactor. Every 24 to 48 hours, one reactor is valved out of service and the catalyst in it is regenerated. In this type of plant, a separate compressor is installed for circulation of air for regeneration. In many plants, it is a single-stage overhung compressor.

#### 3. Continuous regenerative

A recent development by UOP features continuous regeneration. The reactors are stacked one on top of the other and the catalyst is continuously circulated; regeneration occurs almost continuously in a separate regenerator vessel. Again, a separate compressor is used for regeneration. It is a single-stage unit, but it handles gases at 900°F and requires special metallurgy.

## Centrifugal Pumps

The cat reformer requires a small number of process pumps, mostly single-stage overhung OH2 **HPX** type for medium temperature and pressure service. There are no unusual pumping requirements in most cat reformers.

### Upset Conditions

Operation of the recycle and make-up compressors is, for the most part, trouble free. The recycle gas is fairly clean and noncorrosive; however, on extended runs there might be deposits on the wheels that necessitate rotor cleaning.

**Flowsolve seals and systems** are a major product to minimize MTBF and improve confidence.

There are cases when fouling of reactor catalyst beds occurs and pressure drop through the system increases. Recycle flow is decreased and remains until the problem is solved.

Reactor switching on cyclic units sometimes results in a temporary change in molecular weight of the recycle gas stream. The operator usually becomes accustomed to this change and can handle it with speed adjustment or suction throttle valve position.

## Catalytic Reformer Unit

**Reformer, cat reformer, platformer, CCR (continuous catalytic reformer). Other less common licenses include: rheniforming, powerforming, magnaforming, ultraforming, houdriforming, octanizing.**

The catalytic reformer unit uses heat, catalyst and moderate pressure to convert crude and coker naphtha into a high-octane blendstock called reformate. The process is endothermic, requiring multiple reactors and heaters in between each reactor to reheat the process. This process rearranges paraffinic and cyclic hydrocarbon molecules into products that are higher in aromatic content. This unit is also a net hydrogen producer that is used elsewhere in the refinery.

The catalytic reforming process upgrades low-octane naphtha feedstocks to high-octane reformate for the gasoline-blending pool. Heated naphtha is reacted with hydrogen in the presence of a catalyst to reform the naphtha components into a stream that is rich with high-octane aromatic and branched hydrocarbons, usually using a platinum catalyst. The incoming naphtha is pretreated in a hydrotreater to protect the catalyst used in this process, which can be poisoned by sulfur and nitrogen.

The unit is also a net hydrogen producer, as the reactions strip hydrogen away from saturated hydrocarbons to create the aromatics. Prior to the evolution of catalytic reforming, lead was used as an additive to increase octane in gasoline. After it was discovered that lead created air pollution and became a monitored pollutant, catalytic reformers were developed. Cat reformers change long carbon chains into aromatics, which, like lead, also increase octane. However, a common aromatic produced by cat reformers is benzene. Benzene is a known carcinogen, and now is also highly regulated. This means that today's reformers have to be closely monitored either by controlling the feed into the reformer, or extracting benzenes from the reformate after the process is complete.

There are two general types of cat reformers: **fixed bed** and **continuous**. In a fixed bed reformer, there are reactors in series with fixed catalyst beds. Originally, most units were built with three reactors and separate heaters. However, these three reactors need to run simultaneously to provide the best conversion to reformate. Because the catalyst becomes inactive over time, this three-bed unit required annual maintenance to clean and regenerate the catalyst. Over time, refiners realized that the fixed-bed reformer could be upgraded to a four-bed system. This allowed them to change out catalysts one reactor at a time, eliminating the lengthy annual shutdown.

**A fixed four-bed cat reformer** is depicted in Figure 3.28. However, the valve applications identified will not be discussed in this text. In a fixed four-bed reformer, the incoming naphtha feed is heated in a furnace to reaction temperature. It is combined with a recycle hydrogen stream before flowing through the first of four reactors. This process repeats, and after the fourth reactor the effluent is sent to a separator. Vapor from the separator is recycled through a compressor back to the feed, or it becomes export hydrogen. Liquid from the separator is sent to a stabilizer.

In the stabilizer, the reactor effluent is separated into vent gases, light-end liquids and high-octane reformate product streams. Make-up hydrogen is used only to start up the unit. **The second type of cat reformer is a continuous catalytic reformer (CCR)**. However, you will notice many of the valve applications are similar to the fixed bed version. The continuous catalytic reformer was developed in 1971 to improve efficiency, extend run life and reduce cat reformer maintenance. In this design, catalyst is constantly fed into the first stage of a stacked reactor and flows down through three stages.

Simultaneously, treated naphtha feed is heated and enters the first stage of the reactor, exits the first stage and is reheated before moving on to the next stage. The spent catalyst enters a separate regenerator where coke is removed and catalyst is reconditioned through treatment with oxygen and chlorides. This continuous regeneration of catalyst allows up to six years between maintenance shutdowns. A diagram of the CCR is depicted in Figure 3.29. Downstream of the reactor, the fixed bed and continuous cat reformers are nearly identical; in fact, some refiners have changed their fixed bed reformer to a CCR and left most of the downstream infrastructure intact. A continuous catalytic reformer can be split into two sections: reformer and regenerator. **Due to the tightly licensed nature of the regenerator section in a CCR, this text will only discuss the reformer valve applications. The majority of the valves used in this process unit are general service valve styles, but they are still very critical to the operation of the unit.** Because the feed to this unit is pretreated, NACE (National Association for Corrosion Engineers) should not be required.



**Table 3.7: Catalytic reformer pump and control valve asset summary**

<b>API/PUMP</b>	<b>APPLICATION</b>
OH2-HPX/M	Naphtha Feed
OH2-HPX/M	Reflux
OH2-HPX/M	Charge Heater
OH2-HPX	Net Gas Compressor Anti-Surge

<b>VALVE</b>	<b>APPLICATION</b>
Valtek Mark One	Recycle Gas Compressor Surge Control
Valtek Valdisk Butterfly	Recycle Gas Compressor Suction Control
Valtek MaxFlo 4	Stripper Reflux Return
Valtek MaxFlo 4	Bottoms/Product Stream
Argus HK35/FK76	Automated Reactor Overhead Purge
Argus HK35/FK76	Automated Reactor Overhead Regeneration
Argus HK35/FK76	Manual Standby Reduction Zoom Purge
Argus HK35/FK76	Manual Reactor Bottoms Unloading Valve
Argus HK35/FK76	Automated Reactor Bottoms Unloading Valve
Argus HK35/FK76	Manual Hydrogen Loading to Lockhopper 1
Argus HK35/FK76	Manual Hydrogen Vent for Lockhopper 1 & 2
Argus HK35/FK76	Manual Nitrogen Purge for Lockhopper 1 & 2
Argus HK35/FK76	Manual Catalyst to Lift Engager 1 & 2
Argus HK35/FK76	Automated Catalyst to Lift Engager 1 & 2
McCANNA	Manual Air Valve to Regeneration Cooler
McCANNA	Manual Air Valve to Surge Hopper
McCANNA	Automated Fresh Catalyst Addition
McCANNA	Manual Regen Catalyst Uploading from Surge Hopper
McCANNA	Automated Regen Catalyst Uploading from Surge Hopper
Valtek Mark One	Net Gas Compressor Anti-Surge
McCANNA	Manual Pressure Balancing for Lockhopper/Lift Engage

*This summary does not include the large quantity of gate, plug, ball, check valves and mechanical seal systems.*

## Isomerization

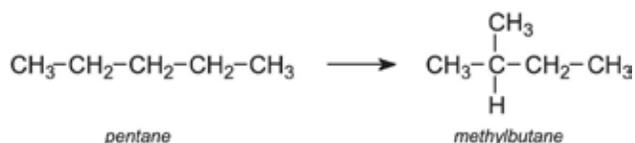
The isomerization process is gaining importance in the present refining context due to limitations on gasoline benzene, aromatics and olefin contents. The isomerization process upgrades the octane number of light naphtha fractions and also simultaneously reduces benzene content by the saturation of the benzene fraction. Isomerization complements catalytic reforming process by upgrading the octane number of refinery naphtha streams. Isomerization is a simple and cost-effective process for octane enhancement compared with other octane-improving processes. Isomerate product contains very low sulfur and benzene, making it an ideal blending component in a refinery gasoline pool. Due to the significance of isomerization to the modern refining industry, it becomes essential to review the process with respect to catalysts, catalyst poisons, reactions, thermodynamics and process developments.

**Isomerization** (also **isomerisation**) is the process by which one **molecule** is transformed into another molecule which has exactly the same atoms, but the atoms have a different arrangement, e.g., A-B-C → B-A-C (these related molecules are known as **isomers**). In some molecules and under some conditions, isomerization occurs spontaneously. Many isomers are equal or roughly equal in **bond energy**, and so exist in roughly equal amounts, provided that they can interconvert somewhat freely, i.e., the energy barrier between the two isomers is not too high. When the isomerization occurs **intramolecularly**, it is considered a **rearrangement reaction**.

Isomerization in **hydrocarbon cracking** is usually employed in **organic chemistry**, where fuels, such as diesel or **pentane**, a straight-chain isomer, are heated in the presence of a platinum catalyst. The straight- and branched-chain isomers in the resulting mixture then have to be separated. Another industrial process is the isomerization of **N-butane** into **isobutane**.

### Isomerization in the Refinery Process

Isomerization in the refinery process when hydrocarbon molecules are rearranged into a more useful isomer. For example:



The process is particularly useful in enhancing the octane rating of gasoline, as branched alkanes burn more efficiently in a car engine than straight-chain alkanes.

An important example is the isomerization of butane (from LPG) to 2-methylpropane (isobutane):

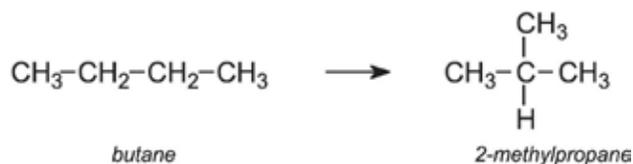


Figure 3.30: Key Isomerization process with pumps

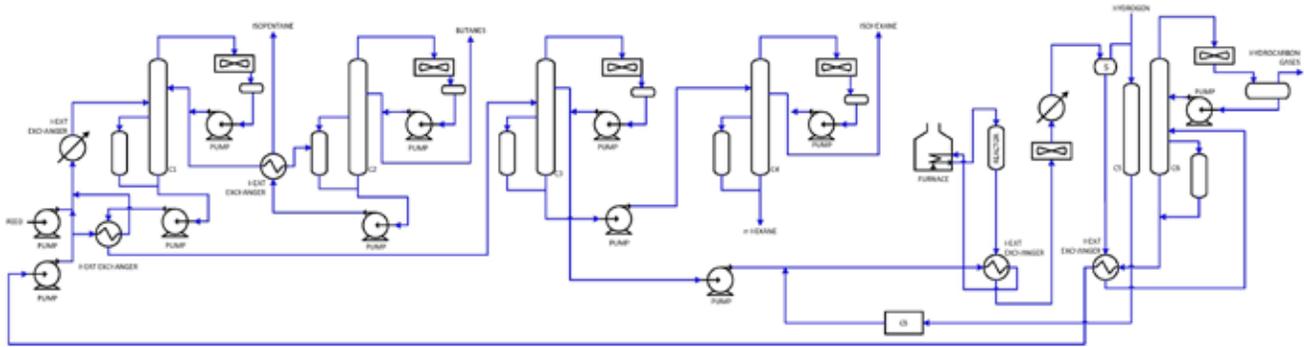


Table 3.8: Pump and valve asset summary

API/PUMP	APPLICATION
BB2-HDO	Reactor Charge
OH2-HPX	Recycle Pump
OH2-HPX	Diesel
OH2-HPX	Kerosene
OH2-HPX/M	Heavy Naphtha
OH2-HPX/M	Stabilizer Reflux
OH2-HPX/M	Stabilizer Feed
OH2-HPX	Splitter Charge

VALVE	APPLICATION
Argus HK35/FK76	Diesel Isolation
Valtek Multi-Z	Charge Pump Recirc
Valtek Mark One w/Stealth Trim	Reactor Loop Depressurization
Valtek MaxFlo 4	Overhead Gas Control

This summary does not include the large quantity of gate, plug, ball, check valves and mechanical seal systems.

## Alkylation (Hydrofluoric)

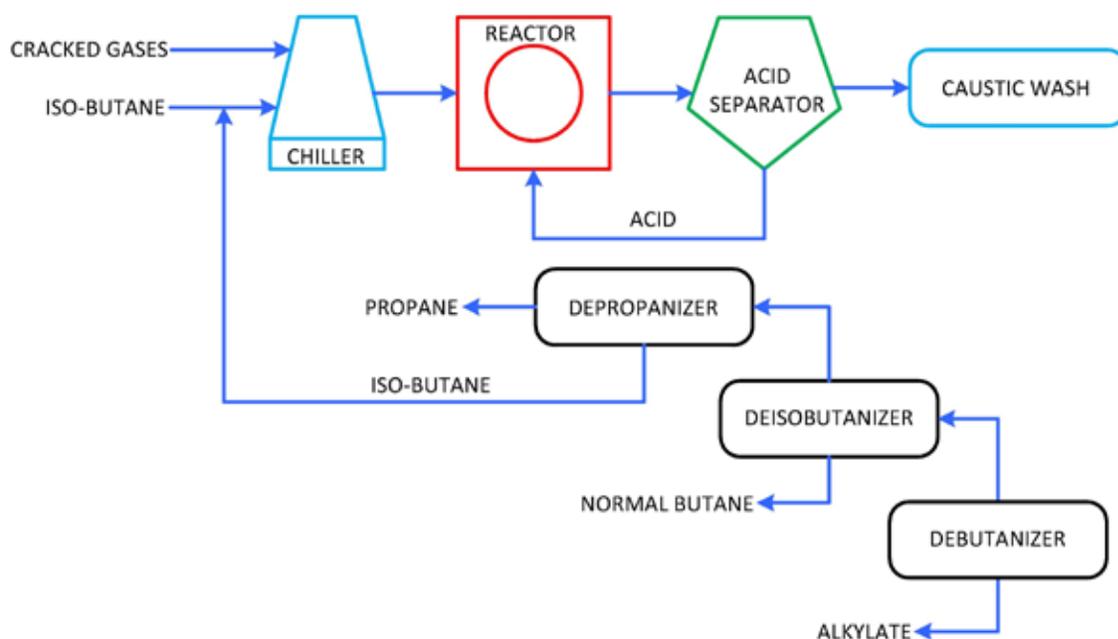
### Alkylation (alky, HF, sulfuric acid unit, SAAU, HFAU, alky unit)

The alkylation unit is used to convert light olefins, usually propylene or butylene, produced by an FCC or delayed coker unit into a gasoline-blending component called alkylate. Alkylate is one of the more valuable blending components for gasoline because it has a high octane rating coupled with a low Reid vapor pressure. It consists of branched chain paraffinic hydrocarbons (isooctane and isoheptane). **There are two types of alkylation units: hydrofluoric acid (HF) alkylation and sulfuric acid alkylation.** Alkylation is a catalyzed reaction that uses acid as the catalyst; this is not a solid catalyst that we see in most other refining applications. This liquid catalyst is efficient, but hazardous. There have been many attempts made over the years to use a solid acid catalyst, but this has resulted in reduced conversion and deactivated catalyst.

The overall process is similar between an HF and a sulfuric acid alky unit. The major differences are the reactor style and the reaction temperature.

Either type of alkylation plant consists of seven sections: chiller, reactor, acid separator, caustic wash and three distillation columns. In an HF alky unit, isobutane feed, olefin feed and recycled isobutane are chilled (using refinery cooling water), then fed into an acid reactor. Acid is fed into this reactor in a separate stream. The alkylation reaction takes place in this unit, and the resulting product is then sent to a series of separators and acid strippers to split out the resulting product streams, including propane, N-butane and alkylate. Simultaneously, the acid is separated in the reactor and recycled through the unit. After separating the propane, N-butane and alkylate product, any unreacted isobutane is recycled back to the acid reactor. In a sulfuric acid alky unit, the isobutane-olefin mixture, along with sulfuric acid and refrigerant, is sent to a cascade reactor.

**Figure 3.31: Alkylation plant consists of 7 main parts**



In the presence of the acid, the olefins and isobutane react, forming the alkylate compounds and generating heat. There are several systems for removing the heat. The process illustrated uses an auto-refrigeration system where some of the isobutane is vaporized to provide cooling. The vapors are routed through a compression section and are condensed before being returned to the reactor. Any propane that is produced in the reactor is concentrated in the refrigeration system and, after caustic and water washes, is sent to a depropanizer.

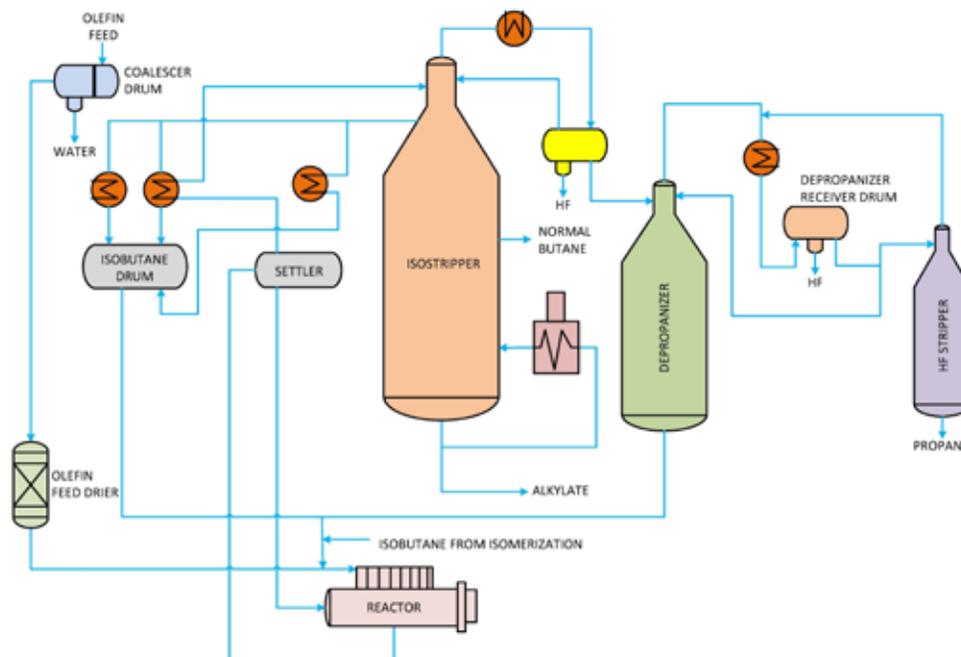
The depropanizer overhead is a propane product, and the bottom stream is returned to the process. The reactor effluent is sent to a settler, where acid is removed from the hydrocarbon. The acid is recycled to the reactor. The hydrocarbon continues through caustic and water washes before entering the deisobutanizer (DIB) tower. Any make-up isobutane is generally added as feed to the DIB tower. The DIB overhead stream is mostly isobutane and is returned to the reactor. The DIB bottom stream becomes the feed to the debutanizer. The debutanizer overhead is a butane product stream. The debutanizer bottom stream is the alkylate product for gasoline blending.

### Alkylation Application

In an alkylation unit, tight process control is required to maintain temperature, acid strength and isobutane concentration. If temperature drops too low, sulfuric acid will become viscous and inhibit complete mixing of acid and olefins. If the temperature is too high, compounds other than isoheptane and isoctane will be formed, decreasing the overall alkylate quality. Acid strength is also important to maintain. If the acid is diluted with water, the acid can pick up tar and become less reactive.

It is known that as the process unit operates over time, acid concentration decreases. When the concentration drops below 89%, it loses efficiency. In addition, weaker acids can lead to additional undesired side reactions, decreasing alkylate quality. The preservation of isobutane concentration is essential to the proper operation of the unit. Both propylene and butylene are reactive in the presence of the acid catalyst — even with each other. If the isobutane concentration is not maintained at a high concentration, they will react with each other, rather than with the isobutane. Typically, about 10 times the amount of isobutane is used to prevent this from happening.

**Figure 3.32: Alkylation-unit flow diagram**



**Table 3.9: Pump and valve asset summary**

API/PUMP	APPLICATION	VALVE	APPLICATION
OH2-HPX	KOH Feed	Valtek Multi-Z	Recycle Compressor KO Drum Letdown
BB2-HDX	Depropanizer	Valtek MaxFlo 4	Bottoms/Product Streams
OH2-HPX	Acid Rerun	Valtek Mark One	Sour Water Letdown
OH2-HPX	Depropanizer Reboiler	Valtek MaxFlo 4	Overhead Gas Control
OH2-HPX	Depropanizer Reflux	Argus HK35/FK76	Diesel
OH2-HPX	Caustic Circulation	Argus HK35/FK76	Gasoline
OH2-HPX	Water Wash	Argus HK35/FK76	Oil Purge
OH2-HPX	Lead Acid Circulation	Argus HK35/FK76	ISO Pentane
OH2-HPX	Tail Acid Circulation	McCANNA	Asphalt
OH2-HPXM	Flare Accumulation		
OH2-HPXM	Flare		
OH2-HPX	Olefin Feed		
OH2-HPX	Isobutane Feed		
KPH Liquid Ring Compressor	Sour Gas/Off Gas		

*This summary does not include the large quantity of gate, plug, ball, check valves and mechanical seal systems.*

## Vapor Recovery Unit

**Please also refer to the Flowserve SIHI vacuum products section of the guide for applications.**

The vapor recovery unit is used to reject fuel gas, recover C3 and C4 liquid products and produce debutanized gasoline within the required vapor pressure levels. The main fractionator overhead vapors are compressed in the wet gas compressor, which is typically a two-stage device.

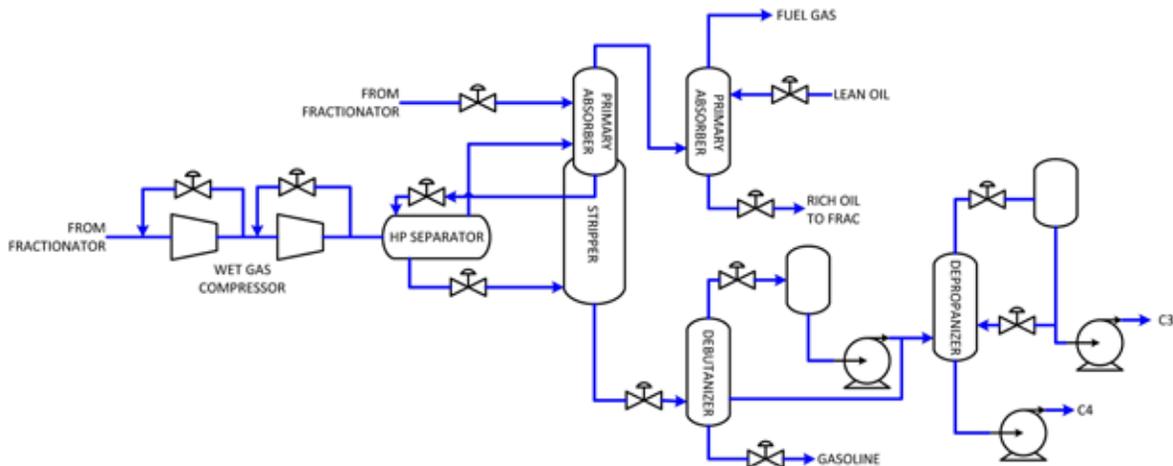
The high-pressure gas and liquids from the low-pressure knock out drum are cooled and combined with liquid from the primary absorber and flow to the high-pressure separator. Liquid from the high-pressure separator is pumped to the top of the stripper. The stripper removes C2s and lighter products that go to the primary absorber. The C3 and heavier products are removed in the stripper bottoms. In the primary absorber, vapor from the high-pressure separator flows to the bottom of the absorber, while raw gasoline and lean oil from the debutanizer flow to the top of the absorber. The liquids absorb C3 and heavier components from

the vapor. The gases leaving the top of the primary absorber are sent to the secondary absorber. In the secondary absorber, heavy naphtha from the main fractionator is used to recover any liquids left in the vapor stream.

Fuel gas leaves the top of the absorber and is typically subjected to further treatment in an amine treatment unit. The bottoms return to the main fractionator. Liquid from the bottom of the stripper flows to the debutanizer. The overhead liquids can be treated and sent to storage, or further separation of C3 and C4 products can occur. Further separation of the bottoms products is possible, but will vary from plant to plant.

Figure 3.33 shows the layout of the vapor recovery system and the commonly associated control valves, typically **Flowserve Valtek MaxFlo 4** or **McCanna**. This depiction includes a depropanizer, which may or may not be present. Other units may be present, i.e., a depentanizer. However, this depends upon the overall desired final products.

**Figure 3.33: Vapor recovery system process**



## Vacuum or Flue and Flare Gas Applications

### Flare System with **Flowserve SIHI Vacuum Products**

Throughout the refinery there are flare systems designed to burn off excess and waste gas. The system normally employs a knock-out drum to separate liquid from gas. The liquid is then pumped away for treatment. Our typical refinery has six flares, each requiring a 25 HP **SIHI** pump for liquid removal.

Flare gas is waste gas, vented from oil and gas processes or petrochemical plants.

Waste gas is collected in a flare header and burned to protect employees, facilities and the environment from hazardous emissions

Flare gas can be dirty, flammable, explosive, toxic, corrosive, lethal and wet!

### *Vapor recovery system process*



Figure 3.34: Typical vacuum systems

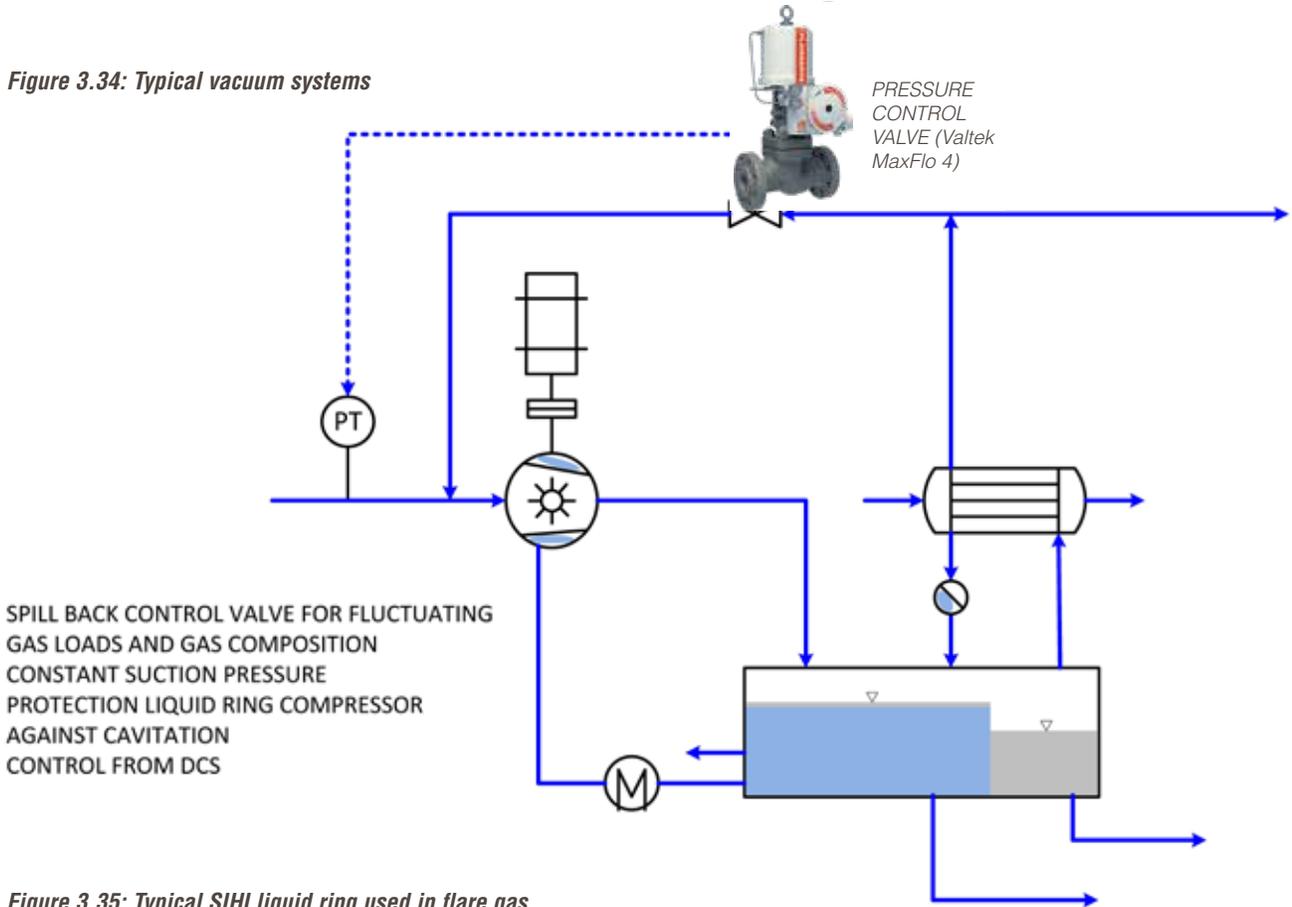


Figure 3.35: Typical SIHI liquid ring used in flare gas

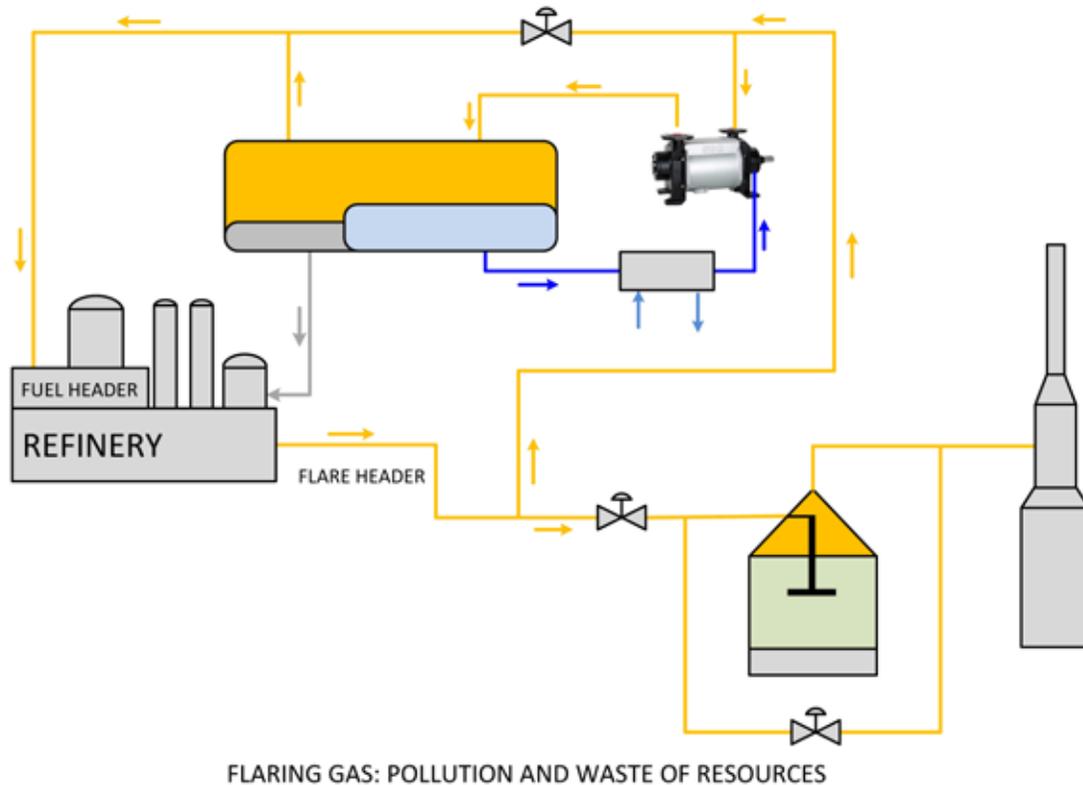
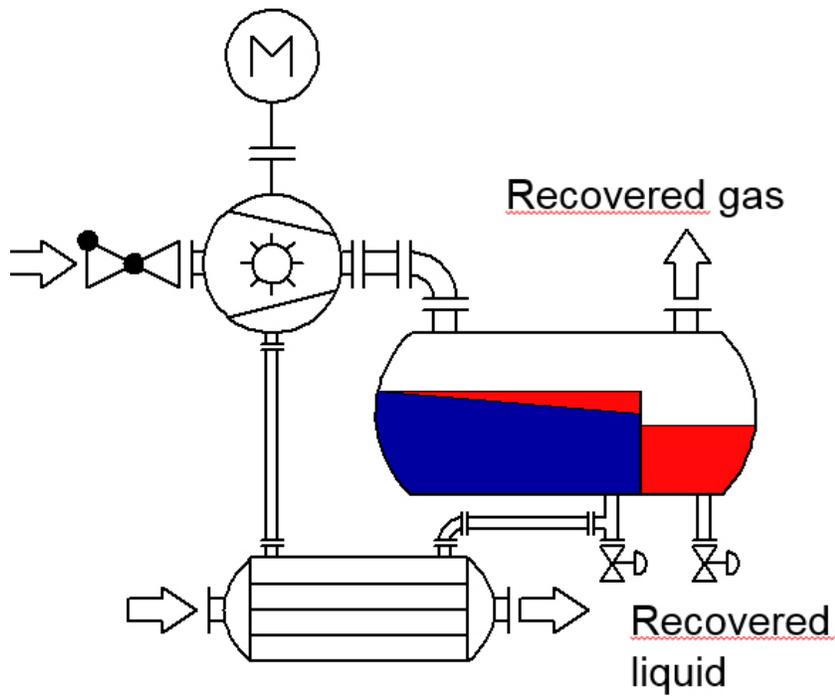


Figure 3.36: Horizontal separator with decanter:  
Three-phase separation for recovery of hydrocarbons



Vacuum Dryer Shell Refinery

## Auxiliary (Power House)

### Steam and Power

Many refineries operations, including atmospheric and vacuum distillation, catalytic cracking and visbreaking, use steam. Many pumps are steam turbine-driven. To supply this steam, a refinery requires steam-generating facilities. Some refineries may also generate their own power. Boiler feed and associated pumps such as condensate and service water are required. This area is similar to many industrial powerhouses. Our typical refinery power house contains 31 Flowserve centrifugal pumps ranging from an 850 psig boiler feeder through condensate circulators.

**Please refer to one of Flowserve Application Selling Guides for Conventional Steam (FLS-1011) or Combined Cycle (FLS-1010) for the Power Industry for the detailed processes and how our products support these applications. These guides can be found on Passport.**

## Tank Farms, Blending (Mixing) and Off-Sites

### Tankage and Blending

Refinery end products are refined in steps. Crude is stored for feed. Intermediate products are stored between processes. Final end products, in this case fuels, are stored prior to shipment. This movement of liquids requires transfer pumps. Since this storage occurs outdoors, generally using vented tanks, the pumping conditions are low in temperature, usually 100°F max. and low in suction pressure. The refinery may also have a loading facility for barges or rail tank

car or tank truck loading. Typical gasoline, kerosene, jet fuel and fuel oil transfer pumps will be horizontally split, double suction, rated for 2000 gpm at 200 ft. They will generally have carbon steel cases, although some refineries will use cast iron. A central pump station will serve a number of tanks. Two or three OH2 **HPX** pumps are needed for each service.

Blending of various hydrocarbon streams is used to obtain the desired anti-knock qualities of motor fuel. Additional additives for today's fuel are required. Among the most important is TEL (tetraethyl lead). Even in today's "no-lead fuels," small amounts of TEL are added. All the blending operations require pumps to move liquids to and from blending tanks. As in transfer, the pump temperatures and pressures are relatively low. Carbon steel is the prevalent material. In most cases, the blending pumps are not spared. The tankage and blending area of this typical refinery contains 50+ OH2 API **HPX** centrifugal pumps.

### Off-Sites and Wastewater

The processes not directly connected with making product, such as utilities, storage and wastewater treatment, are referred to as off-sites. Users are not as strict on the requirements for these services as they are for the main process work. **Durco ASME/ISO** pumps may come into wide usage in the off-site services. Horizontal double suction pumps and vertical turbines may not require conformance to API 610.

The refinery has its own wastewater treatment plant designed to handle their particular waste. Refineries use 40+ centrifugal pumps for services ranging from storm water to sludge to acid loading pumps. This area is similar to other industrial wastewater treatment plants. Flowserve has a vast range of dry-pit and wet-pit sewage products.

Product types include: **MF/MN, MSX/MQX** and **AFV**.

Figure 3.37: Typical tank farm diagram

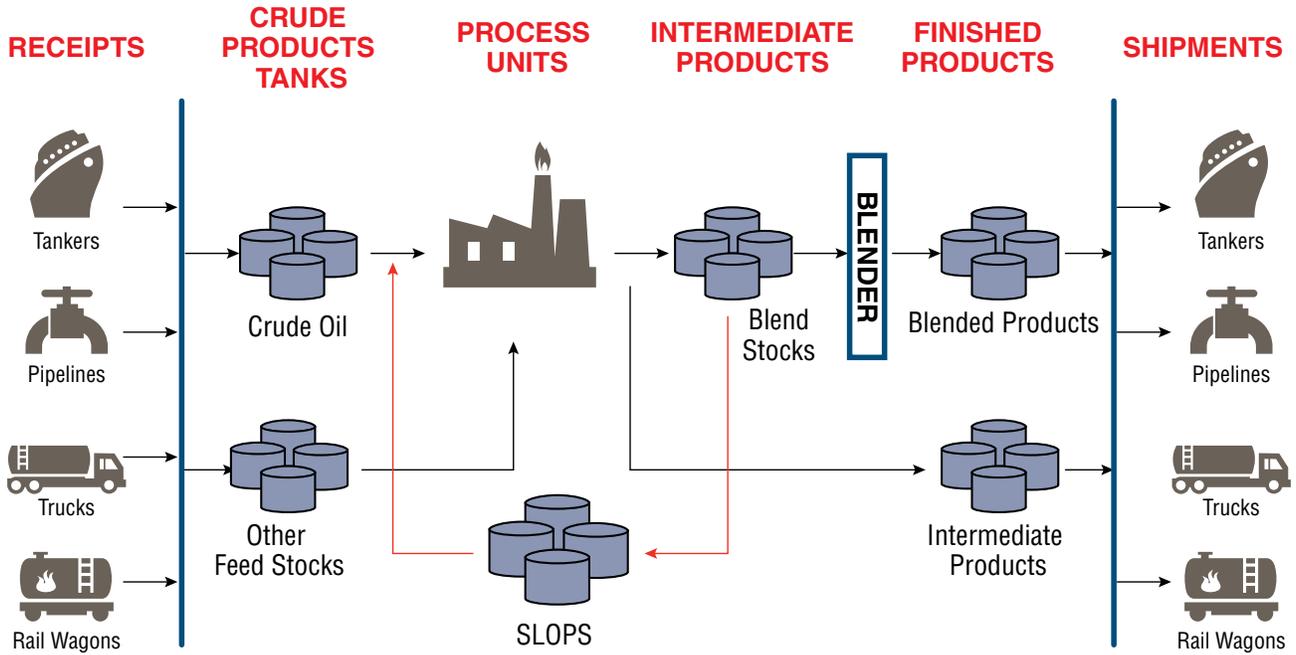
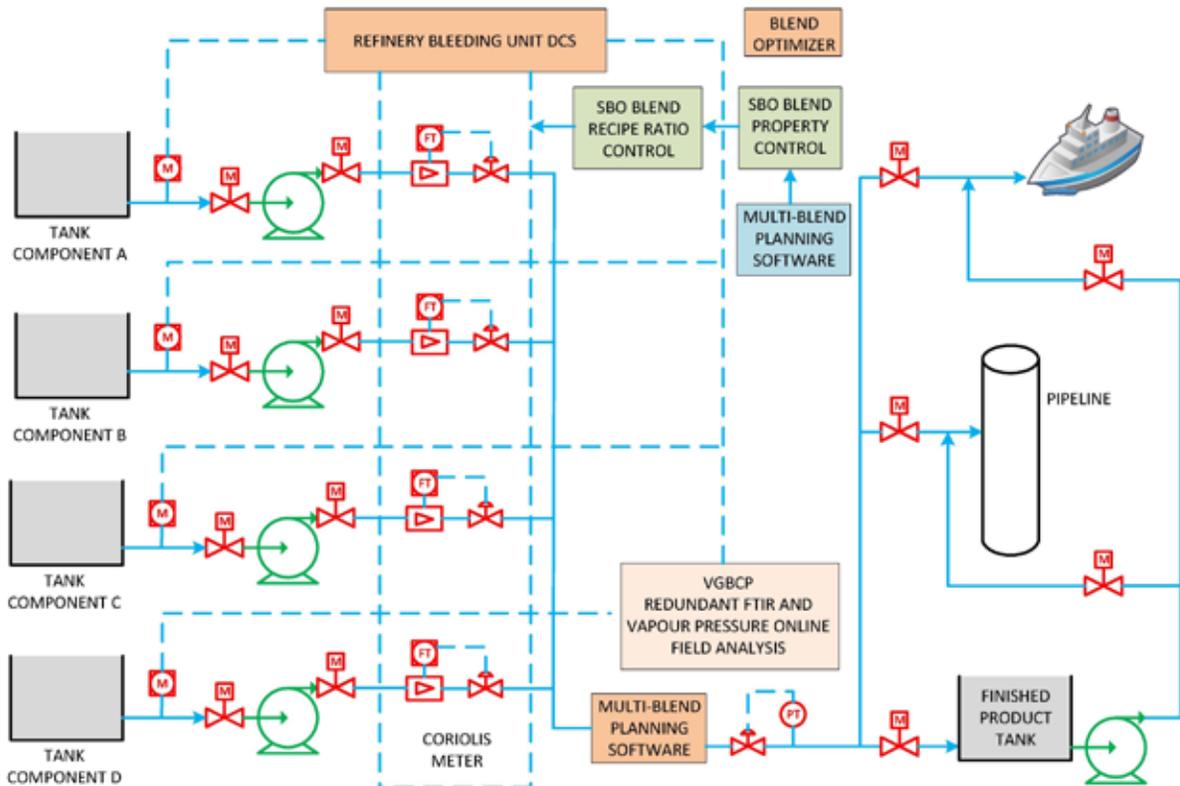
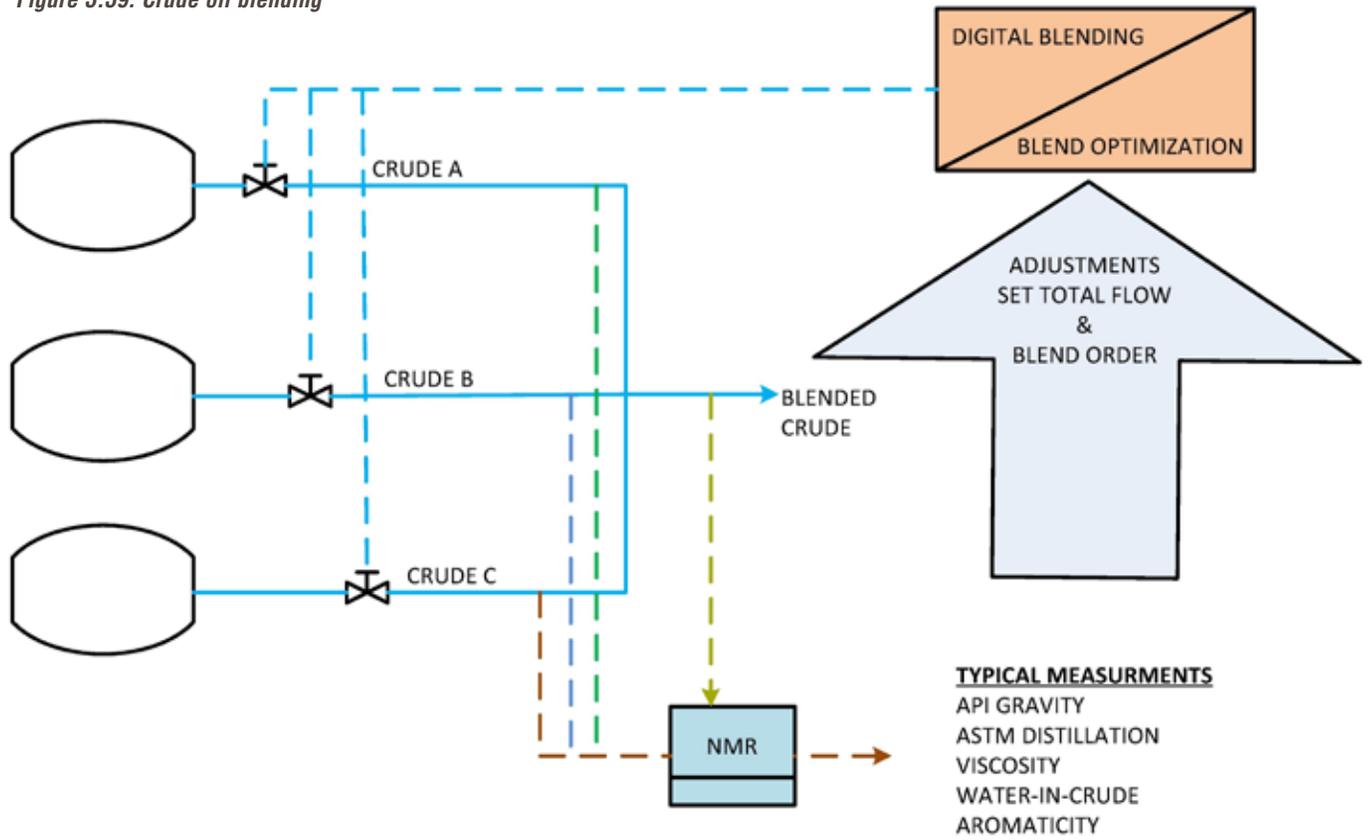


Figure 3.38: Blending (mixing) flow diagram



Multiple Flowserve pumps and control/block valves are included in blending processes.

Figure 3.39: Crude oil blending



## Hydrodesulphurization

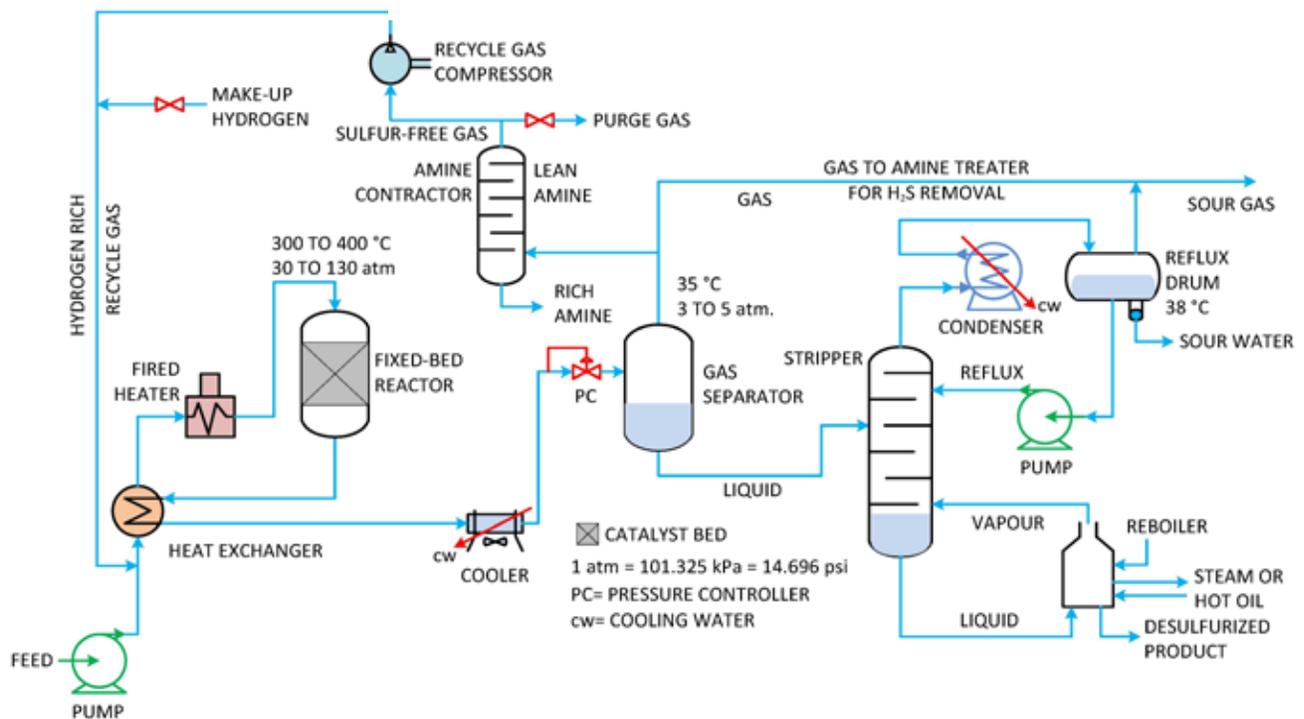
Not to be confused with flue-gas desulfurization.

Hydrodesulphurization (HDS) is a catalytic chemical process widely used to remove sulfur (S) from natural gas and from refined petroleum products, such as gasoline or petrol, jet fuel, kerosene, diesel fuel and fuel oils. The purpose of removing the sulfur, and creating products such as ultra-low-sulfur diesel is to reduce the sulfur dioxide (SO<sub>2</sub>) emissions that result from using those fuels in automotive vehicles, aircraft, railroad locomotives, ships, gas- or oil-burning power plants, residential and industrial furnaces, and other forms of fuel combustion.

Another important reason for removing sulfur from the naphtha streams within a petroleum refinery is that sulfur, even in extremely low concentrations, poisons the noble metal catalysts (platinum and rhenium) in the catalytic reforming units that are subsequently used to upgrade the octane rating of the naphtha streams.

Application selections are usually six **HPX** OH2 API process pumps and eight Valtek control valves.

Figure 3.40: Typical process flow diagram



## Amine Treating Unit

Amine treater units are used to clean up the various sour light-gas streams created by the refinery's cracking and treating units. The objective of an amine unit is to strip hydrogen sulfide (H<sub>2</sub>S), sulfur dioxide (SO<sub>2</sub>), and other environmental poisons from sour light-gas streams.

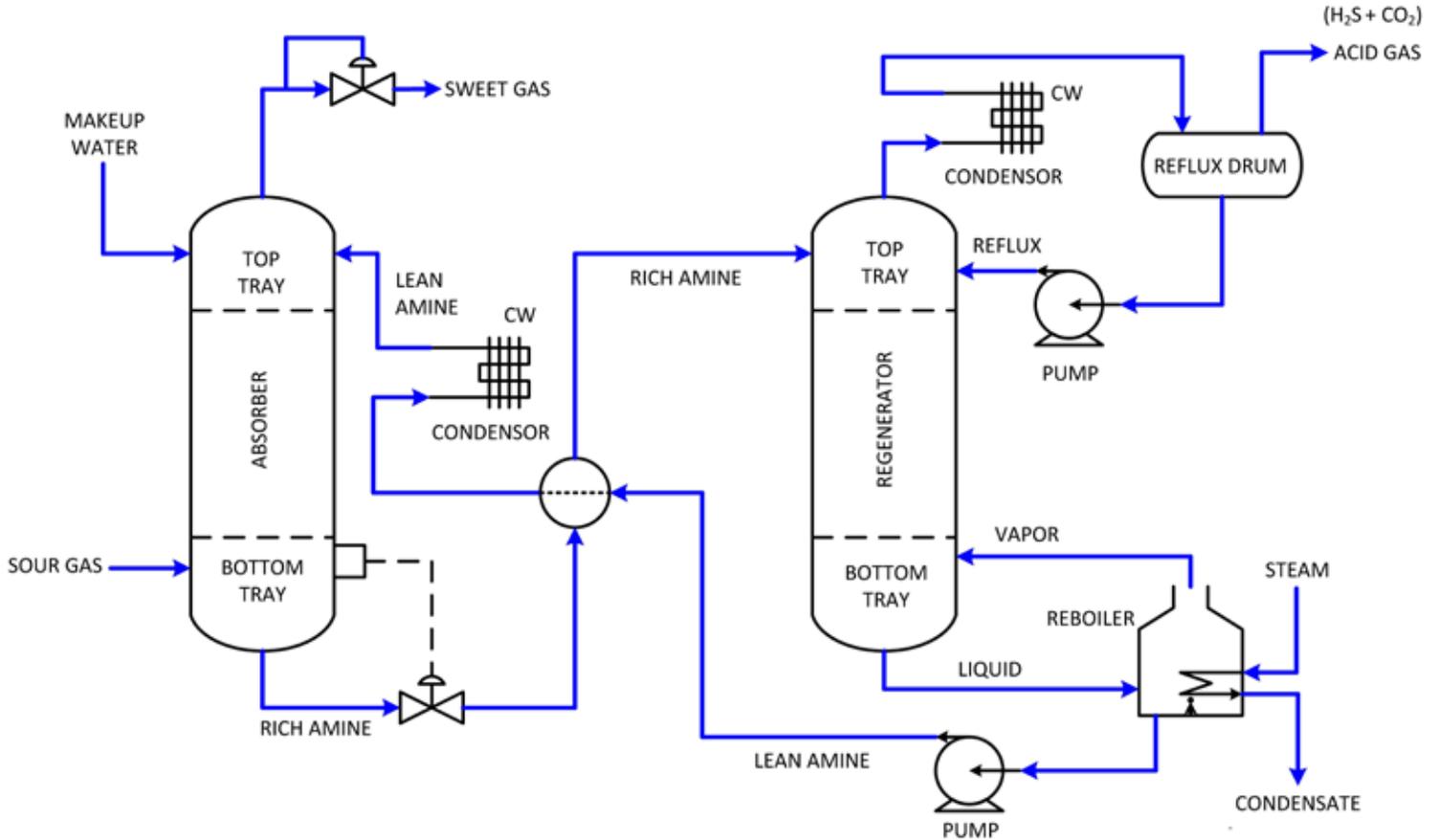
This prepares the light-gas streams to be used in other processing units, to be sold as products or to be burned as fuel gas. The term **amine unit** can be misleading. Rarely is amine treating considered to be a standalone unit in a refinery. In many cases, each processing unit will have a small amine scrubber located within its unit boundaries or will share a scrubber with a few other units. Several of these scrubbers will receive and return amine to a central regenerator located within one of the units. The most widely used process to remove acid gases from natural gas is the alkanolamine process. The term **alkanolamine** encompasses the family of specific organic compounds or monoethanolamine (MEA), diethanolamine (DEA) and triethanolamine (TEA).

Newer amine units use methyl diethanolamine (MDEA). This is a continuous operation liquid process. Using absorption, acid-gas components are removed via amine and the addition of heat. After any free liquids are removed from the gas in an inlet scrubber, the gas passes to the absorber section. There it rises counter-currently in close

contact with the descending amine solution. Purified gas flows from the top of the absorber. Lean amine enters the tower at the top where it flows across trays downward, against the flow of the gas. At the bottom, the acid-gas-rich amine (aka **rich amine**) leaves the absorber through a dump valve (rich amine letdown valve) that is actuated by a liquid-level controller. The Flowserve valve recommended is **Valtek MaxFlo 4**. The rich amine then goes to the flash tank, operating at a reduced pressure, where a great portion of the physically absorbed gases are flashed off. From there, the rich amine goes through various processes to be regenerated by removing the H<sub>2</sub>S and CO<sub>2</sub> from the amine solution and starts the cycle over again as lean amine.

This process is used for dehydrating and acid gas removal from refinery gases. An amine solution is contacted with the sour gases absorbing the impurities. The amine solution is then regenerated. H<sub>2</sub>S saturated water is also removed from the stream. Pumping temperatures range from 100 to 250°F and pressures to 500 psig. The **Durco Mark 3** family of products would be the best suited pumps for this application; however, for higher pressure and temperature applications, the **HPX** family of products would be best suited. 316SS and Alloy 20 are used on the more corrosive sour water services. Only the more critical pumps are spared.

Figure 3.41: Process Flow diagram of a typical amine treating process used in petroleum refineries and natural gas processing plants



Application selections are usually four **HPX** API OH2 process pumps and three **Valtek** control valves.

## Sulfur Recovery Unit

The crude oil processed by refineries contains varying amounts of sulfur. The sulfur recovery unit (SRU) **usually follows the AMINE process**. Sulfur is removed during processing, mostly as hydrogen sulfide.

Environmental regulations restrict the amount of H<sub>2</sub>S and other sulfur compounds that can be released to the environment. The SRU is used to convert H<sub>2</sub>S to elemental sulfur through a series of reactors. The Claus process is most commonly used to recover sulfur from various refinery gases that contain a high concentration (more than 25%) of H<sub>2</sub>S. The feed sources for an SRU are acid gases from the amine unit(s) and sour gas from the sour water strippers. The acid and sour gases are burned in a reaction furnace in the presence of enough air and/or oxygen to combust approximately one-third of the incoming H<sub>2</sub>S plus any remaining hydrocarbons and ammonia.

The combustion products are cooled in the waste heater boiler/thermal sulfur condenser. After the thermal reaction and condensation, there are three catalytic reactor stages. Each reactor stage consists of a reheater, catalytic converter and condenser. The elemental sulfur recovered from each condenser is run down into a sulfur pit.

The final tail gas stream can be sent to an incinerator or, depending on local environmental regulations, a tail gas treating unit. **The SRU is usually viewed by refinery operations personnel as an “overhead” or utility unit.** However, because of environmental regulations, this unit is extremely important to total refinery production. Most refineries have multiple SRUs so that a shutdown does not halt the entire refinery. If an SRU does shut down, the refinery typically has to reduce production to keep from producing more acid gas than can be processed by the remaining SRUs.

Also, the SRU capacity in many refineries dictates what types and how much high-sulfur crudes can be processed. A small incremental gain in capacity for these refiners can yield significant profit. The need for recovering sulfur is increasing globally. In the U.S., sulfur content in crude oil input to refineries has increased from approximately 0.9 to 1.4 wt%. However, in that same time frame, sulfur content allowed in transportation fuels has reduced from 450 to 15 ppm and will continue to decrease to 10 ppm by 2020. Other countries are seeing the same trends as sweet (low sulfur) crude becomes less available.

Sulfur removal is an integral part of today's refinery, both from the low sulfur fuel point of view and the pretreatment required for processes using catalyst. The recovery and sale of sulfur are important parts of the refinery.

### Centrifugal Pumps

OH2 **HPX** pumps are used in this area for handling molten sulfur and sour water. Both of these services require 316SS.

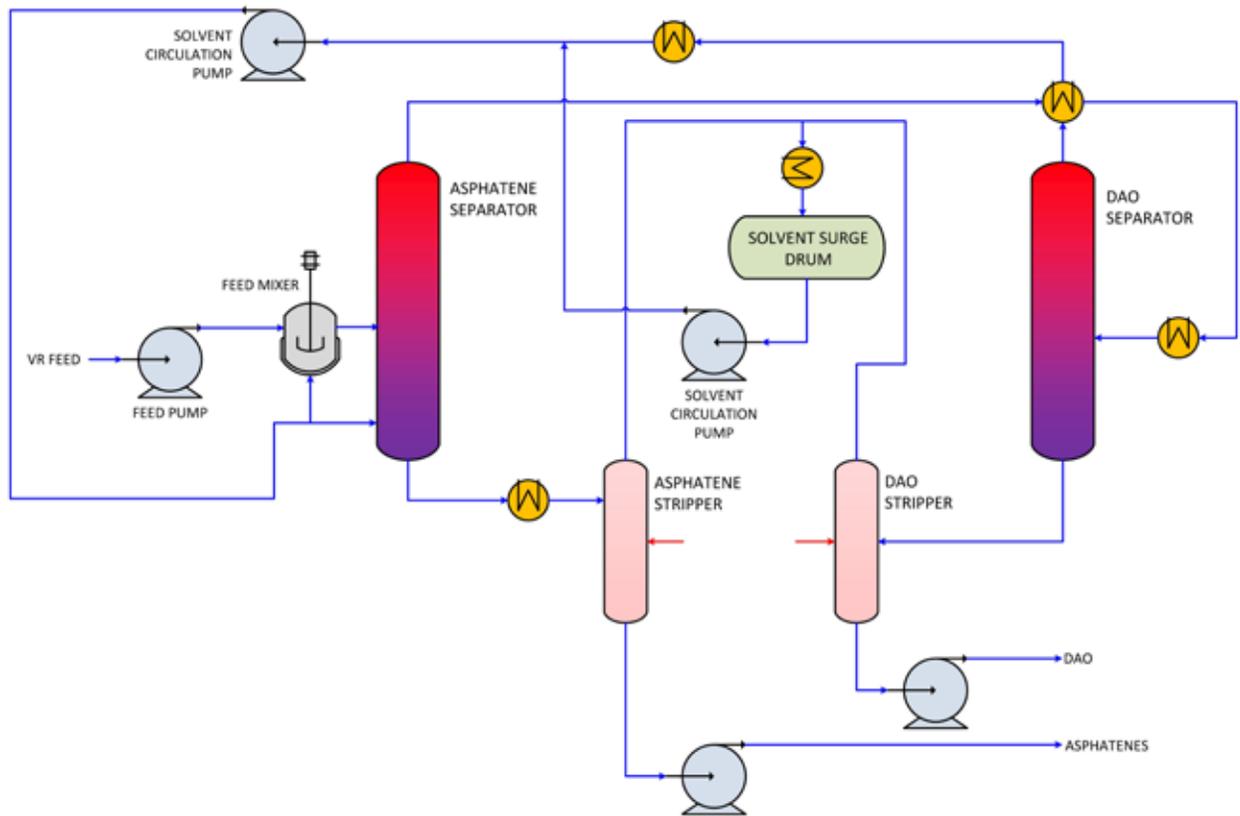
### Application Review

Control for valves, typically **Valtek**, in the sulfur recovery unit will be prone to corrosion from sulfur. Fluids with high concentrations of sulfur also require very stable temperature control due to the potential for solidification. Many refiners have added steam jackets to both their control valves and process equipment to prevent sulfur solidification.

## Asphalt Plant

This process primarily uses positive displacement pumps for handling the high-viscosity product at 300 to 500°F. The Flowserve portfolio has limited positive displacement products for this process.

Figure 3.42: Simplified diagram – de-asphalter



# GLOBAL REFINERY LANDSCAPE



## Business Impact and Focus Areas

Table 4.1: Pump and valve asset summary

### THE INDUSTRY'S MOST COMPLETE FLOW CONTROL PORTFOLIO

				
<b>PUMPS</b>	<b>VALVES</b>	<b>SEALS &amp; SUPPORT SYSTEMS</b>	<b>SERVICE &amp; SOLUTIONS</b>	<b>SPECIALIZED OFFERINGS</b>
<ul style="list-style-type: none"> <li>• Overhung</li> <li>• Between Bearings</li> <li>• Vertical</li> <li>• Positive Displacement</li> <li>• Specialty Products</li> <li>• Decoking Systems</li> <li>• Vacuum Systems</li> </ul>	<ul style="list-style-type: none"> <li>• Control</li> <li>• Quarter-Turn</li> <li>• Multi-Turn</li> <li>• Check</li> <li>• Positioners</li> <li>• Gate</li> <li>• Globe</li> </ul>	<ul style="list-style-type: none"> <li>• Standard Cartridge</li> <li>• Pusher and Bellows</li> <li>• Slurry</li> <li>• Lift Off and Dry Running</li> <li>• Mixer and Compressor</li> <li>• OEM and Special Duty</li> </ul>	<ul style="list-style-type: none"> <li>• Aftermarket Parts and Services</li> <li>• Engineering and Technical Services</li> <li>• Education and Training</li> <li>• Asset Management and Optimization</li> </ul>	<ul style="list-style-type: none"> <li>• Actuation and Instrumentation</li> <li>• Steam Taps and Systems</li> <li>• Hydraulic Decoking Systems</li> <li>• Energy Recovery Devices</li> <li>• Monitoring and Controls</li> <li>• Castings and Foundry Services</li> </ul>

Single Source Provider

Table 4.2: Oil and gas industry pumping application guide (refineries' focus would be downstream products)

APPLICATIONS		Oil and Gas															
		Upstream				Mid		Downstream									
PUMP CATEGORY	Sub-Category	Heavy Oil, Oil Sands and Shale	Drilling and Production	Water and CO <sub>2</sub> Injection	Water Supply and Treatment	FPSO	Crude, Product and CO <sub>2</sub> Pipeline	Distillation	Hydrotreating	Hydrocracking	Catalytic Cracking	Residuum and Heavy Oil Upgrading	Gas Treating and Sulfur Recovery	LNG	NGL and LPG	Gas to Liquids	Off-Sites and Waste Treatment
OVERHUNG	Chemical Process — ANSI, ISO	X	X		X	X	X						X	X	X		X
	Industrial Process	X	X		X	X											X
	Slurry and Solids Handling	X									X	X	X				X
	API Process	X	X	X	X	X		X	X	X	X	X	X	X	X	X	
BETWEEN BEARINGS	Single Case — Axially Split	X	X	X	X	X	X	X					X	X	X	X	X
	Single Case — Radially Split	X		X		X	X	X	X	X	X	X	X	X	X	X	X
	Horizontal — Multistage Single Case				X												
	Horizontal — Multistage Double Case	X		X		X	X		X	X	X	X		X	X	X	
VERTICAL	Wet-Pit		X		X	X								X	X		X
	Double Case			X			X						X	X	X		X
	Deep Well Submersible Motor		X		X	X											
	Slurry and Solids Handling																X
	Sump	X	X		X	X		X	X	X	X	X	X	X	X	X	X
POSITIVE DISPLACEMENT	Diaphragm																
	Gear	X															
	Screw	X	X			X	X					X					X
	Multiphase	X	X														
SIDE CHANNEL	Side Channel														X	X	
VACUUM PUMPS & COMPRESSORS	Dry Vacuum Pumps							X									
	Liquid Ring Vacuum Pumps				X			X					X				
	Liquid Ring Compressors				X								X			X	
	Systems				X			X					X			X	
SPECIALTY PRODUCTS	Nuclear Pumps and Seals																
	Thruster		X			X											
	Hydraulic Decoking Systems											X					
	Energy Recovery Devices																
	CVP Concrete Volute Pumps																
	High-Temperature Process Slurry	X									X	X				X	X
	Axial Flow																
Polyolefin Reactor																	

## Products for Refinery – At a Glance

Flowserve is the driving force in the global flow control marketplace. No other pump, valve, mechanical seal products company in the world has the depth or breadth of expertise in the successful application of pre-engineered, engineered and special purpose products and systems.

Flowserve can trace its expertise in the pumps, valves and seals industry back to the 18th century and the earliest application of steam-pumping engines. Today, the Flowserve [pump portfolio](#) boasts some of the world's most renowned pump brands.

### Industry-Leading Brands

Accord™	Logix™
Aldrich™	McCANNA™
Anchor/Darling®	NAF™
Argus™	Niigata Worthington™
Atomac™	Norbro™
Automax™	Nordstrom Audco™
BW Seals®	Pacific®
Byron Jackson®	Pac-Seal™
Calder™ Energy Recovery Devices	Pleuger®
Durametallic®	PMV™
Durco® Valves and Pumps	Scienco™
Edward®	Serck Audco™
Flowserve®	Sier-Bath®
IDP®	SIHI®
INNOMAG®	TKL™
Interseal™	Worthington®
Kammer®	Valbart™
Lawrence Pumps®	Valtek®
Limitorque™	Worcester Controls™

*Flowserve addresses challenges the end users face every day.*

## Pump Types

### Overhung

Chemical Process—ISO

#### Durco Mark 3 ISO

ISO 2858/5199-compliant pump for corrosive applications in chemical, hydrocarbon and pharmaceutical processing that require unmatched reliability, outstanding hydraulic performance and increased pump availability.

#### SPECIFICATIONS

Flows to: 1400 m<sup>3</sup>/h (6160 gpm)

Heads to: 220 m (720 ft)

Press. to: 25 bar (362 psi)

Temp: -80 to 400°C (-110 to 750°F)

For more information, refer to PS-10-31.

Chemical Process—ANSI

#### Durco Mark 3 ANSI

ASME B73.1 chemical process pump for corrosive applications in chemical, petrochemical hydrocarbon and pharmaceuticals processing requiring unequaled efficiency, extended life and repeatable pump performance.

#### SPECIFICATIONS

Flows to: 4540 m<sup>3</sup>/h (20 000 gpm)

Heads to: 215 m (700 ft)

Press. to: 27 bar (400 psi)

Temp: -73 to 370°C (-100 to 700°F)

For more information, refer to PS-10-13.



**INNOMAG®**

Chemical Process—ANSI, ISO

**TB-MAG**

ASME B73.3 and ISO 2858-compliant, thrust-balanced, fluoropolymer-lined, magnetic drive pump for chemical processing, metals and other industries seeking outstanding leak protection and reliability.

SPECIFICATIONS

Flows to: 360 m<sup>3</sup>/h (1585 gpm)

Heads to: 153 m (500 ft)

Press. to: 25 bar (362 psi)

Temp: -29 to 121°C (-20 to 250°F)

For more information, refer to PS-10-36.



**SIHI®**

CHEMICAL PROCESS—ISO

**CBE and CBM**

Modular process pumps with hydraulics, closed impellers and magnetic couplings for bare shaft (CBM) or close coupled (CBE) configurations. Meets all ISO 5199, 15783 and 2858 requirements.

SPECIFICATIONS

Flows to: 650 m<sup>3</sup>/h (2862 gpm)

Heads to: 150 m (492 ft)

Press. to: 25 bar (362 psi)

Temp: -40 to 300°C (-40 to 572°F)

For more information, refer to PS-10-42.



**SIHI**

Chemical Process—ISO

**CBT**

Single-stage pump with ISO 2858/5199 design features and nominal rating. Engineered for applications in chemical, petrochemical and pharmaceuticals processing with flows beyond the range defined by ISO 2858.

SPECIFICATIONS

Flows to 2200 m<sup>3</sup>/h (9686 gpm)

Heads to: 160 m (524 ft)

Press. to: 25 bar (362 psi)

Temp: -20 to 350°C (-4 to 662°F)



**SIHI**

Industrial Process—EN

**ZTN, ZTK and ZTI**

Volute pumps developed specifically for handling mineral and synthetic heat transfer oils, compliant with dimensions and nominal rating according to EN 733. Choose from bare shaft (ZTN), compact (ZTK) or inline (ZTI) units.

SPECIFICATIONS

Flows to: 1000 m<sup>3</sup>/h (4403 gpm)

Heads to: 95 m (311 ft)

Press. to: 16 bar (232 psi)

Temp: to 350°C (662°F)

For more information, refer to PS-10-41.



**SIHI**

Industrial Process

**FRBH**

Heavy-duty paper stock pump designed primarily for pulp and paper applications, but also has considerable use in the chemical processing and oil and gas industries.

SPECIFICATIONS

Flows to: 9085 m<sup>3</sup>/h (40 000 gpm)

Heads to: 100 m (330 ft)

Press. to: 14 bar (200 psi)

Temp: to 150°C (300°F)

For more information, refer to PS-10-16.



**Worthington**

Slurry

**M**

Hard-metal slurry pump designed to handle high concentrations of coarse, abrasive solids in suspension. Well-suited for the harshest applications in shale gas but also certain slurry applications.

SPECIFICATIONS

Flows to: 10 000 m<sup>3</sup>/h (44 000 gpm)

Heads to: 90 m (300 ft)

Press. to: 10 bar (150 psi)

Temp: to 120°C (250°F)

For more information, refer to PS-10-19.



**Worthington**

API Process

**HPX (OH2)**

Fully compliant with ISO 13709/API 610 (OH2) design criteria, the HPX pump is the workhorse of the oil and gas and hydrocarbon processing industries, boasting unequalled versatility, reliability and safety.

SPECIFICATIONS

Flows to: 3000 m<sup>3</sup>/h (13 200 gpm)

Heads to: 350 m (1100 ft)

Press. to: 80 bar (1160 psi)

Temp: -160 to 450°C (-250 to 842°F)

For more information, refer to PS-10-5.



**IDP**

API Process

**PHL (OH2)**

Fully compliant with ISO 13709/API 610 (OH2), the PHL's innovative multi-channel diffuser technology allows the hydraulics to be custom-tuned to ensure best efficiency hydraulic fits while maximizing parts' interchangeability.

SPECIFICATIONS

Flows to: 900 m<sup>3</sup>/h (3963 gpm)

Heads to: 400 m (1312 ft)

Press. to: 40 bar (600 psi)

Temp: to 450°C (842°F)

For more information, refer to PSS-10-5.2.



**Flowserve**

API Process

**PVXM (OH3)**

Compliant with ISO 13709/API 610 (OH3), the PVXM vertical in-line pump is a space-saving alternative to horizontal overhung process pumps in upstream and downstream services.

SPECIFICATIONS

Flows to: 500 m<sup>3</sup>/h (2200 gpm)

Heads to: 275 m (900 ft)

Press. to: 40 bar (600 psi)

Temp: -100 to 250°C (-148 to 480°F)

For more information, refer to PS-10-29.



**Flowserve**

API Process

**HWMA (OH3)**

With its small footprint, this low-flow, high-head process pump is a space-saving alternative to many overhung process pumps. Compliant with ISO 13709/API 610 (OH3), latest edition. The two-stage configuration (HWMA2) is also available.

SPECIFICATIONS

Flows to: 36 m<sup>3</sup>/h (160 gpm)

Heads to: 370 m (1215 ft)

Press. to: 64 bar (930 psi)

Temp: -46 to 260°C (-51 to 500°F)

For more information, refer to PS-10-23.



**IDP**

API Process

**PVML (OH5)**

Compliant with ISO 13709/API 610 (OH5) and BS 4082R, the PVML vertical in-line pump is ideal for upstream and downstream applications where precision hydraulics are required but floor space is limited.

SPECIFICATIONS

Flows to: 500 m<sup>3</sup>/h (2220 gpm)

Heads to: 275 m (900 ft)

Press. to: 40 bar (580 psi)

Temp: -100 to 250°C (-148 to 480°F)

For more information, refer to PS-10-28.



**Flowserve**

API Process

**MSP (OH4)**

Closely following ISO 13709/API 610 (OH4) and featuring a medium-speed induction motor, the MSP delivers peak efficiency, excellent economy, simplified installation and reduced maintenance in low-flow, high-head applications.

SPECIFICATIONS

Flows to: 34 m<sup>3</sup>/h (150 gpm)

Heads to: 900 m (2955 ft)

Press. to: 64 bar (930 psi)

Temp: -46 to 250°C (-51 to 482°F)

For more information, refer to PS-10-1.



## Between Bearings

### Flowserve

SINGLE-CASE-AXIALLY SPLIT-API

#### DVSH (BB1)

Fully compliant with ISO 13709/API 610 (BB1), this heavy-duty, single-stage pump with side-side nozzles is well-suited for process charge, transfer and pipeline services where uncompromising reliability over a wide flow range is paramount.

#### SPECIFICATIONS

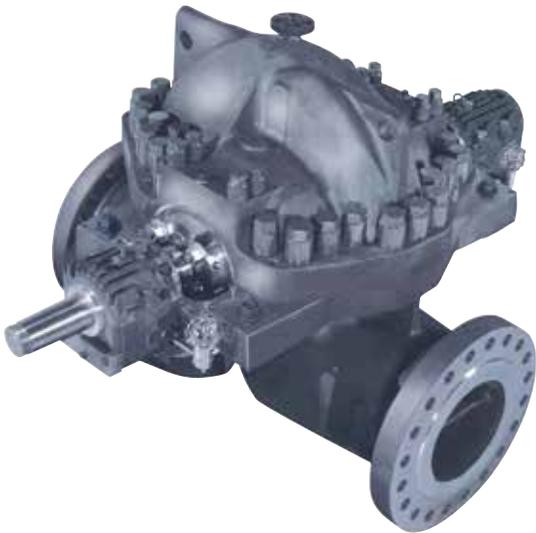
Flows to: 12 000 m<sup>3</sup>/h (52 835 gpm)

Heads to: 565 m (1854 ft)

Press. to: 150 bar (2175 psi)

Temp: to 200°C (400°F)

For more information, refer to PS-20-2.



### Flowserve

SINGLE-CASE-AXIALLY SPLIT-API

#### LPN (BB1)

With a double-suction impeller and side-side nozzles, this medium-pressure pump is a natural solution for low-NPSH applications, such as water and hydrocarbon transfer service. Designed to ISO 13709/API 610 (BB1) criteria.

#### SPECIFICATIONS

Flows to: 15 000 m<sup>3</sup>/h (65 000 gpm)

Heads to: 250 m (820 ft)

Press. to: 50 bar (725 psi)

Temp: -80 to 204°C (-110 to 400°F)

For more information, refer to PS-20-5.



**Worthington**

SINGLE-CASE – AXIALLY SPLIT – API  
**LPN (BB1)**

A two-stage pump with a double-suction, first-stage impeller, the UZDL is designed for water pipelines, transfer services, firefighting and high-pressure duties. ISO 13709/API 610 (BB1)-compliant models available.

SPECIFICATIONS

Flows to: 2950 m<sup>3</sup>/h (13 000 gpm)

Heads to: 685 m (2250 ft)

Press. to: 64 bar (910 psi)

Temp: to 200°C (400°F)

For more information, refer to PS-30-2.



**IDP**

SINGLE-CASE – AXIALLY SPLIT – API  
**DMX (BB3)**

With more than 10 000 units supplied, this highly reliable pump is ideal for high-flow, high-pressure applications across the gamut of industries, including oil and gas, chemical and desalination. Designed to ISO 13709/API 610 (BB3) criteria.

SPECIFICATIONS

Flows to: 5621 m<sup>3</sup>/h (24 750 gpm)

Heads to: 2620 m (8600 ft)

Press. to: 275 bar (4000 psi)

Temp: to 204°C (400°F)

For more information, refer to PS-30-3.



**Flowserve**

SINGLE-CASE – RADIALLY SPLIT

**HDX (BB2)**

In full compliance with ISO 13709/API 610 (BB2) standards, the HDX centerline-mounted pump with single-stage, double-suction impeller and double volute casing with top nozzles is engineered for heavy process services.

SPECIFICATIONS

Flows to: 5000 m<sup>3</sup>/h (22 000 gpm)

Heads to: 450 m (1500 ft)

Press. to: 100 bar (1450 psi)

Temp: to 450°C (842°F)

For more information, refer to PS-20-4.



**IDP**

SINGLE-CASE – RADIALLY SPLIT

**DVSR (BB2)**

Compliant with ISO 13709/API 610 (BB2), the radially split design of the DVSR makes it ideal for applications at very high pressures or low specific gravity, such as liquefied gases, including CO<sub>2</sub>.

SPECIFICATIONS

Flows to: 6585 m<sup>3</sup>/h (29 000 gpm)

Heads to: 330 m (1080 ft)

Press. to: 260 bar (3750 psi)

Temp: to 204°C (400°F)

For more information, refer to PS-30-17.



**Byron Jackson**

**SINGLE-CASE – RADIALLY SPLIT  
HED and HED-DS (BB2)**

Two-stage, centerline-mounted pump engineered for safe, reliable operation in heavy-duty process services and elevated temperatures. Fully compliant with ISO 13709/API 610 (BB2).

**SPECIFICATIONS**

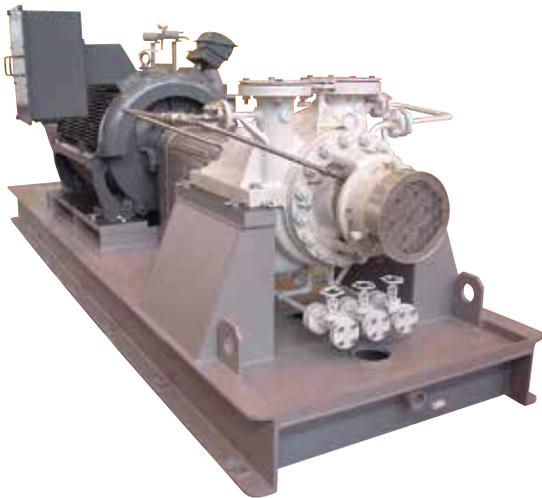
Flows to: 2000 m<sup>3</sup>/h (8800 gpm)

Heads to: 650 m (2100 ft)

Press. to: 120 bar (1750 psi)

Temp: to 450°C (842°F)

For more information, refer to PS-30-4.



**Pacific**

**HORIZONTAL – MULTISTAGE – DOUBLE-CASE  
WXB**

Based on ISO 13709/API 610 design requirements, this diffuser-casing barrel pump is the first choice for demanding applications in refineries, chemical and petrochemical plants, liquefied gas stations and boiler feed service. WXB-B with Barske-style impeller design option.

**SPECIFICATIONS**

Flows to: 300 m<sup>3</sup>/h (1320 gpm)

Heads to: 1560 m (5116 ft)

Press. to: 200 bar (2900 psi)

Temp: to 425°C (800°F)

For more information, refer to PS-30-6 and PSS-30-6.1.



**Worthington**

**HORIZONTAL – MULTISTAGE – DOUBLE-CASE  
WCC (BB5)**

Medium-duty, diffuser-type barrel pump built to ISO 13709/API 610 (BB5) and customer specifications. Typically used in refinery services, pipeline, amine and ethylene feed, water and CO<sub>2</sub> injection, plus hydraulic power recovery.

**SPECIFICATIONS**

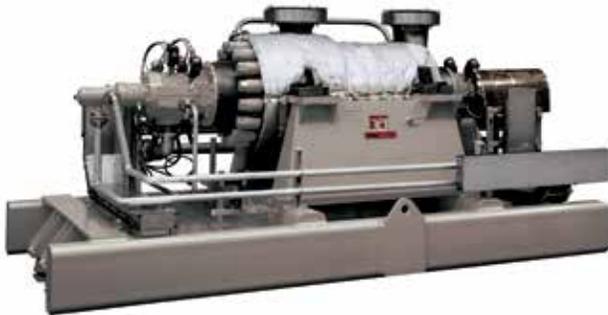
Flows to: 1000 m<sup>3</sup>/h (4400 gpm)

Heads to: 2800 m (9200 ft)

Press. to: 275 bar (4000 psi)

Temp: to 425°C (800°F)

For more information, refer to PS-30-7.



**IDP**

**HORIZONTAL – MULTISTAGE – DOUBLE-CASE  
HDO and HSO (BB5)**

Offered in both general and special purpose configurations, these volute-style barrel pumps are manufactured to customer specifications, often exceeding ISO 13709/API 610 (BB5).

**SPECIFICATIONS**

Flows to: 4000 m<sup>3</sup>/h (17 610 gpm)

Heads to: 5365 m (16 000 ft)

Press. to: 450 bar (6525 psi)

Temp: to 425°C (800°F)

For more information, refer to PS-30-8.



**Byron Jackson**

HORIZONTAL – MULTISTAGE – DOUBLE-CASE

**WIK and WIKO (BB5)**

Extra heavy-duty barrel pump intended for special purpose, unspared, high-power density applications. Pumps are custom engineered to customer requirements, often exceeding ISO 13709/API 610 (BB5).

SPECIFICATIONS

Flows to: 1600 m<sup>3</sup>/h (7000 gpm)

Heads to: 7000 m (23 000 ft)

Press. to: 1000 bar (14 500 psi)

Temp: to 425°C (800°F)

For more information, refer to PS-30-9.



**Verticals**

**Flowserve**

DOUBLE-CASE

**VPC (VS6)**

Diffuser-type, vertical turbine pump, well-suited for closed system and low-NPSH applications. Available in single or multistage units, as well as standard and ISO 13709/API 610 (VS6)-compliant designs.

SPECIFICATIONS

Flows to: 13 600 m<sup>3</sup>/h (60 000 gpm)

Heads to: 1070 m (3500 ft)

Press. to: 100 bar (1450 psi)

Temp: -73 to 230°C (-100 to 450°F)

For more information, refer to PS-40-2.



**Worthington**

DOUBLE-CASE

**QLC and QLQC (VS2)**

Double-suction vertical turbine pumps in single (QLC) or multistage (QLQC) units featuring true twin volutes. ISO 13709/API 610 (VS2)-compliant design available.

SPECIFICATIONS

Flows to: 25 000 m<sup>3</sup>/h (110 000 gpm)

Heads to: 500 m (1640 ft)

Press. to: 70 bar (1015 psi)

Temp: -45 to 204°C (-50 to 400°F)

For more information, refer to PS-40-4.



**Worthington**

DOUBLE-CASE

**WUC (VS6)**

Compliant with ISO 13709/API 610 (VS6), the WUC is a highly engineered heavy-duty, multistage process vertical pump designed for continuous duty in critical applications at high pressures and temperatures.

SPECIFICATIONS

Flows to: 3000 m<sup>3</sup>/h (13 200 gpm)

Heads to: 2000 m (6560 ft)

Press. to: 200 bar (2900 psi)

Temp: -200 to 350°C (-328 to 660°F)

For more information, refer to PS-40-9.



**Byron Jackson**

Deep Well Submersible Pump/Motor

Oil-filled submersible motor pump built for the world's most demanding deep-well services. Rugged, reliable and long-lasting, the Byron Jackson SUBM offers significant total lifecycle cost savings.

SPECIFICATIONS

Flows: to 6000 m<sup>3</sup>/h (26 415 gpm)

Heads: to 800 m (2625 ft)

Motor Sizes to: 1650 kW (2200 hp)

For more information, refer to PS-50-3.



**Byron Jackson**

SUMP

**ECPJ (VS4)**

This rugged, single-stage, vertical-lineshaft sump pump is a proven performer in tough chemical and hydrocarbon processing applications. Fully compliant with ISO 13709/API 610 (VS4).

SPECIFICATIONS

Flows to: 1000 m<sup>3</sup>/h (4400 gpm)

Heads to: 150 m (500 ft)

Press. to: 20 bar (285 psi)

Temp: to 350°C (660°F)

For more information, refer to PS-10-10.



## Vacuum Pumps and Compressors

### SIHI

Dry Vacuum Pump

### KPHX

Liquid ring compressors of the series KPH are one-to-three-stage displacement compressors of simple and robust construction.

#### SPECIFICATIONS

Flows to 3400 m<sup>3</sup>/h (2000 CFM)

Pressures to 12 barg (174 psig)

Temperatures to 100°C (212 °F)

Hydraulic overpressure test 22,5 barg (326 psig)

Service liquid max. admissible temperature 80°C (183 °F)



### SIHI<sup>boost</sup>

Dry Vacuum Pump

Dual-stage vacuum systems that deliver deep vacuum with less power. Provides completely dry compression of gases from vacuum up to atmospheric conditions.

#### SPECIFICATIONS

Suct. Cap. to: 8000 m<sup>3</sup>/h (4800 cfm)

Ult. Press. to: <0.001 mbar (<0.0007 torr)



**SIHI**

LIQUID RING VACUUM PUMPS

**LEM and LEL**

Compact, single-stage liquid ring vacuum pumps featuring simple and robust construction. Typically used for handling and exhausting dry and humid gases as well as vapors and quantities of water carryover.

SPECIFICATIONS

Suct. Cap. to: 470 m<sup>3</sup>/h (276 cfm)

Suct. Press: 33 to 1013 mbar

(24.7 to 760 torr)



**SIHI**

LIQUID RING VACUUM PUMP

**LEH/LPH**

Single-stage liquid ring vacuum pumps with a bare shaft design. Often applied in distilling and degassing operations in the refinery, chemical, pharmaceutical and plastics industries.

SPECIFICATIONS

Suct. Cap. to: 5150 m<sup>3</sup>/h (3030 cfm) or 12 000 m<sup>3</sup>/h (7063 cfm)

Suct. Press: 33 to 1013 mbar

(24.7 to 760 torr)



**SIHI**

VACUUM SYSTEM

**PL**

These tailor-made vacuum systems are individually designed for trouble-free operation in almost any application, including heavy-duty and critical applications.



**SIHI**

MEMBRANE SYSTEM

**PM**

SIHI membrane technology efficiently separates process media from inert gas for recycling or recovery. The result is a very simple and highly effective means of pure substance recovery and emission control.



**SIHI**

COMPRESSOR SYSTEM

**PK**

Dependable compression makes this liquid-ring technology invaluable, even for the fiercest or thermally unstable processes.



## Specialty Products

### Flowserve

Hydraulic Decoking Systems (HDS)

Installed in more than 95% of the world's DCUs, Flowserve hydraulic decoking systems are the world's most advanced. They provide refiners with maximized unit output, increased unit reliability and unparalleled personnel safety. Please refer to the DCU Application Selling Guide which shares in detail all aspects and products.

#### MAJOR SYSTEMS

- ISO 13709/API 610 (BB5) jet pump train
- Coke cutting system
- Automation, controls and instrumentation

For more information, refer to PS-90-6 and PS-90-22.



### Flowserve

HIGH-TEMPERATURE PROCESS SLURRY  
**HPX6000 (OH2)**

Fully lined slurry pump built to ISO 13709/API 610 (OH2) and used in heavy oil processing. It reliably and safely handles abrasive solids at elevated temperatures without the danger of pump casing erosion.

#### SPECIFICATIONS

Flows to: 3409 m<sup>3</sup>/h (15 000 gpm)

Heads to: 244 m (800 ft)

Press. to: 83 bar (1200 psi)

Temp: -20 to 400°C (-30 to 826°F)

For more information, refer to PS-10-33.



### Block Valve Types

Whether it's critical, lethal, toxic or aggressive, you'll find Flowserve valves doing the job around the world. That's because extended service life, safe operation and environmental protection are at the core of every valve we manufacture. Global customers can easily find the configurations they require, engineered to meet requisite performance and safety standards, whether it's a standard or custom-engineered solution. It's a portfolio of brands for quarter-turn, rotary, linear, control and specialty configurations that covers today's toughest demands for valve performance. But we're looking ahead to the new challenges that will test the current state of valve manufacturing. This mindset pushes us to continually pursue advancements in materials and severe-duty enhancements and the next levels of precision control, optimized flow and fail-safe shutoff.

### Ball Valves

Long life and safe operation in tough services, from cryogenics to highly corrosive fluids — these are the hallmarks of our comprehensive and respected ball valve portfolio. Maximum safety and environmental protection are the driving factors in every design, achieved through corrosion-resistant materials, fire-safe testing, blowout-proof stems and tight shut-off features. Global customers can fulfill requirements from dozens of configurations built to a full range of international design and performance standards.

### Plug Valves

The range of plug valve applications is broad, and the Flowserve portfolio reliably addresses the vast majority of requirements. High temperatures and pressures. Corrosive media. Lethal, toxic and sub-zero fluids. Our family of plug valves delivers low energy consumption through low-torque designs and safe operation with tight shutoff performance. High levels of uptime are achieved through pressure-balanced designs. Absolute shutoff requirements can be addressed by double-isolation models.

### Butterfly Valves

Ideal for precision throttling and on-off applications, especially in lighter-weight piping systems, the Flowserve family of butterfly valves is often specified for its versatility. Outstanding throttling accuracy for process control is achieved through low-friction, erosion-resistant sealing surfaces with very low operating torques. A broad range of applications can be met via metal- and soft-seated designs as well as lined versions for corrosive and hygienic applications.

### NAF™ Duball Ball Valve

The Duball DL is a high-performance, metal-seated, full-bore ball valve, equally suitable for isolation, on-off and modulating control applications.



- Blowout-proof stem and high-torque transmission with minimum mechanical backlash
- Broad application versatility enabled by extensive size range and options, including fire-safe tested versions
- Direct actuator mounting capabilities of the Turnex actuator
- Excellent control, noise reduction and cavitation abatement
- Easy installation and replacement

### McCANNA™ Floating Ball Valve

The McCANNA floating ball valve is a top-entry ball valve.

- Wedge seat design
- Low torque
- Wide range of materials
- Severe applications
- In-line repair



### Argus™ Floating Ball Valves

Argus FK75M and FK79 are split-body ball valves for the chemical and petrochemical industries with highly standardized designs.



- Increased uptime and durability from robust designs with chemical coating and high-performance cladding
- Reliable performance to highest zero-tightness demands enabled by FCI 70-2 Class VI seat design
- Reduced replacement cost via easy upgrades and chemical coating options for diverse applications
- Improved plant and personnel safety assured by valve compliance with fugitive emissions standard ISO 15848

### Worcester® Floating Ball Valve

Worcester floating ball valves are reduced, full-bore flanged and three-piece ball valves with a large variety of special application builds to suit customer requirements.



- Wedge seat design
- Variety of designs and seats to meet customer applications
- Proven design provides long service life and low cost of ownership
- Top mounting platform and low operating torque for ease of actuation

### Atomac™ Lined Ball Valve

Designed to reduce energy and pumping costs, the AKH Series two-piece, full-port design minimizes pressure losses and increases flow capacity.



- Minimized downtime and maintenance from long-life seats and large stem sealing area, plus substantial middle flanges and molded liner
- Reduced energy costs enabled by low frictional coefficients and operating torques
- Reduced fugitive emissions made possible by reduction of stem side loads, eliminating potential valve gland leaks
- Increased plant and personnel safety assured by anti-blowout stem and anti-static design

### NAF Segmented Ball Valve

Setball segmented ball valves are cost-competitive general service valves that offer excellent rangeability and high-flow capacity.



- V-shaped sector provides high control accuracy over a wide range under severe conditions
- Low lifecycle and maintenance costs due to the ability to use low operating torque actuators
- Versatile design that combines the best control characteristics of ball and butterfly valves, allowing it to function as a control and shutoff valve
- Application versatility made possible by specialized options for solutions and stem seals

### McCANNA Top-Entry Ball Valve

The McCANNA top-entry ball valve has the following:



- Floating or trunnion design for inline maintainability
- Wedge seat design for less wear and longer life
- Stem seal design complying to ISO 15848 fugitive emissions requirements
- Special low-torque cryogenic seat profile

### Argus Trunnion-Mounted Ball Valve

Designed to meet API-6D, ANSI B16.34 and BS 5351

requirements, the FK76M delivers durability and low operating torques with a clear separation of sealing and bearing functions. It is fire-safe to BS 6755 and API 607.



- Long service life in severe applications owing to chemical coating and high-performance cladding
- Reliability ensured by seat design to FCI 70-2 Class VI, enabling it to meet the highest demands with zero tightness
- Reduced replacement cost, as performance capabilities of valves can be easily upgraded and coatings can be applied to suit different applications
- Improved plant and personnel safety from valve design, which meets fugitive emissions standard ISO 15848

### Argus Trunnion-Mounted Ball Valve

The HK35 has all the benefits of the FK76M in a high-pressure design. It is designed to perform in severe conditions where compliance to the highest demands in tightness for leak rate and fugitive emissions is mandatory. It is designed to meet API-6D, ANSI B16.34 and BS 5351.



- Increases durability, as robust design with chemical coating and high-performance cladding ensures continuous functioning, even during severe service conditions and extreme environments
- Seat design to FCI 70-2 Class VI to perform to highest demands and zero tightness
- Reduces replacement cost, as the performance capabilities of the valves can be easily upgraded and various chemical coatings can be applied to stem/seat arrangements to suit different applications
- Improves plant safety, as the valves are designed to meet fugitive emissions standard ISO 15848

### Valbart™ Rising Stem Ball Valve

Valbart RSBV rising stem ball valves are the oil and gas industry's choice for applications requiring a mechanically energized metal or soft seat to prevent losses from process contamination or material leakage. They are ideal for frequent cycling.



- Combination of a quarter-turn ball valve with a linear movement of non-rotating stem
- Trunnion-mounted design
- Reduced or full bore
- Single seat (no-valve body cavity)
- Unidirectional or bidirectional
- Metal-to-metal seat with Stellite welding overlay (soft seat insert on request)
- Outside screw and yoke for adjusting of stem packing
- Blowout-proof stem
- Suitable for very high frequent cycling operations (switching valves)
- Tight shutoff by means of application of external mechanical force and not dependent on differential pressure
- Proper selection of materials to avoid galling and high friction
- Protected lower trunnion against solid particles intrusion
- Clearance control to consider high/low temperature shrinkages
- Self-cleaning closure member

### Durco® BX Butterfly Valve

The TX3 is a triple-offset butterfly control valve with an elliptical sealing surface that is completely in contact at the final position only. Upon opening, all contact points are released immediately from the seat ring.

- Provides reliable, long-lasting, zero leakage (API 598) shutoff
- Combined with the high-thrust actuator, the TX3 achieves high performance throttling control in a wide range of industry applications
- The smart positioner makes sure the valve is always exactly in the right position to optimize process parameters and provide operators with the information they need



### NAF Butterfly Valve

High-performance, triple-offset, metal- or soft-seated butterfly valve frequently used for isolation or on-off applications, but equally suitable for control, especially on high-flow, low-pressure applications.

- Longer service life provided by triple-offset design, which minimizes seat wear during opening and closing
- Minimized pressure loss and low energy costs due to tight shutoff
- Low installation costs enabled by compact wafer design and low weight
- Improved safety assured by Safety Integrity Level (SIL) 3 and IEC 61508 certifications
- Increased uptime — even in difficult media and demanding pressures — through excellent design, materials and performance characteristics



### Durco BX Butterfly Valve

The Big Max BX2001 is a high-performance, all-purpose valve designed for precise throttling control or on-off service with lighter-weight piping systems and less expensive, energy-efficient actuators.



- Broad application versatility via numerous design options: wafer and lug bodies; standard PFA, optional UHMWPE, fire-sealed, Apex® and TriFlex™ seated versions; and multiple packing options
- Reduced fugitive emissions through triple-leak protection of primary stem seal plus two optional secondary seals
- Increased capacity and improved flow control with low-profile, double-offset disc
- Improved personnel and plant safety per adherence to API 609 criteria for safe, reliable anti-blowout protection

### Durco Lined Butterfly Valve

The BTV lined butterfly valve is a reliable, leak-free service valve designed for a wide range of demanding requirements in corrosive chemical applications and process industries.



- Reduced downtime through the standard lined body and disc that defends against the most corrosive chemicals
- Lower maintenance costs from the triple-seal design and live-loaded shaft seal that never needs adjustment
- Increased application flexibility provided by a large selection of metal discs for use when greater protection is required
- Increased abrasion resistance in applications up to 93°C (200°F) with optional UHMWPE disc and body

### Durco Non-Lubricated Plug Valve

Non-lubricated plug valves — HF alkylation service is a sleeved plug valve.

- Specifically designed and refinery proven for use on HF alkylation, with bonnet and flanges painted in HF detection paint



### Durco Non-Lubricated Plug Valve

The Mach 1 is a non-lubricated (sleeved), quarter-turn plug valve capable of in-line service and repair.

- Replaceable seat
- Lower operating torques
- Higher temperature capability
- In-line maintenance



### Durco Lined Plug Valve

Durco T4E valves provide maximum corrosion resistance while eliminating product contamination at a reasonable cost. They are available with pneumatic or electric actuators for on-off or modulating control applications.

- Cost-effective alternative to high-alloy body materials
- Reliable performance in extreme service conditions such as severe cycling, vacuum applications and elevated temperatures ensured by T-slots and anchor holes that provide strong attachment of lining to body and plug
- Efficient, high-flow capacity due to large ports, which reduce friction losses and pressure drop
- High availability and easy maintenance with in-line adjustment; no disassembly is required to restore seating



## Actuators

### Worcester Series 75 Actuator

The Worcester 75 Series electric actuator is specifically designed for rotary valve applications, on/off and modulating.



- Torque: 30–3000 in-lbs
- General purpose, water-tight and hazardous locations
- 120 VAC, 240 VAC, 12 VDC, 24 VDC
- -40 to 150°F temperature range
- Many options available

### Worcester Series 72 Actuator

The Flowserve Worcester 72 Series electric actuator is a powerful, compact and economical means of actuating valves with spring return/fail-safe capability to meet system safety requirements.



- Simple two-wire 120 VAC control
- Water-tight, corrosion-resistant enclosure
- ISO 5211 mounting
- 0 to 150°F temperature range
- Fail-safe on loss of power

### Norbro 33R Actuator

Based on the robust 40R design, the 33R provides 180-degree operation in both double-acting and spring-return formats for use on diverter valves and other applications.



- Torque: 30–3000 in-lbs
- Limit stops in both directions of stroke
- ISO mounting with star drive output for standard valve attachment
- Unique moving guide rod design minimizes wear and provides long service life

### Norbro 40R Actuator

Designed for high performance and reliability using the unique guide rod design, the 40R can be used on a variety of quarter-turn valves in a wide range of applications.



- Limit stops in both directions of stroke
- ISO mounting with star drive output for standard valve attachment
- Unique moving guide rod design minimizes wear and provides long service life

### Norbro P61 Actuator

The P61 brings new levels of control to batch filling operations.



Based on the 40R, it is designed specifically to provide rapid, repeatable and highly accurate filling control for weigh/measuring processes.

- High repeatability for fast control on batch filling operations
- ISO mounting platform with star drive output for standard valve attachment
- Based on the Norbro 40R actuator

### Worcester F39 Actuator

Designed for high performance and reliability using the unique guide rod design, the F39 can be used on a variety of quarter-turn valves in a wide range of applications.



- Limit stops in both directions of stroke
- ISO mounting with star drive output for standard valve attachment
- Unique moving guide rod design minimizes wear and provides long service life

### WG Worm Gearbox

The Flowserve Limitorque WG Series of worm gearboxes is designed for quarter-turn, butterfly, ball and plug valve applications as well as quarter-turn and multi-turn dampers and offers unsurpassed quality and longevity in a wide variety of weatherproof, submersible and buried-service applications.

- Torque output to 326 000 ft-lb (442 000 Nm)
- Weatherproof, temporary submersion and buried services
- Features self-locking gearing
- Quarter-turn or multi-turn, manual or motorized operation available
- -300°C to 900°C ambient temperature range



### SP Spur Gearbox

The Flowserve Limitorque SR Series of spur gearboxes is designed for manual and motorized operation of gate and globe valves, and slide gates in tight space or high-vibration applications.

- Torque output to 16 984 ft-lb (23 000 Nm); Thrust output to 787 000 lb (3500 kN)
- Well suited for high vibration or tight space requirements
- Available in weatherproof and submersible constructions as well as a wide range of output speeds and torques
- Ductile iron housing and roller bearing-supported shafts and drive sleeve
- -300°C to 900°C ambient temperature range



### V Series Gearbox

The Flowserve Limatorque V Series of bevel gearboxes is designed for manual and motorized operation of gate and globe valves as well as slide gates.

- Torque output to 38 350 ft-lb (52 000 Nm)
- Thrust output to 1.7 million lb (7650 kN)
- Weatherproof or temporary submersion applications
- High-strength bevel gearing for extremely high thrust and torque requirements
- Ductile iron housing and roller bearing-supported shafts and drive sleeve
- -300°C to 900°C ambient temperature range



### SMB

The Flowserve Limatorque SMB electric actuator is designed for critical and severe service applications in nuclear and thermal power, water, and oil & gas industries.

- Output torque to 60 000 ft-lbs (81 349 Nm)
- Output thrust to 500 000 lbs (2224 kN)
- Cast iron housing and precision-machined gearing
- Extreme environment performance enabled by nuclear, weatherproof, submersible or explosion-proof construction
- Lower maintenance and downtime owing to torque-limiting feature, which de-energizes the motor to prevent valve damage in the event of an obstruction
- Fully qualified for nuclear applications to IEEE 384, 323 and 344



### L120 Actuator

The Flowserve Limitorque L120 electric actuator is designed for a wide range of environmental applications in power, oil & gas, and water industries.

- Output torque to 60 000 ft-lbs (81 349 Nm); Output thrust to 500 000 lbs (2224 kN)
- Explosion-proof certification, torque overload protection, plus resistance to lightning, EMI, fire, vibration and high-pressure steam
- Aluminum and ductile iron housings, plus anti-friction bearing-supported alloy steel worm shafts with bronze worm gears
- Integration with most network protocols through UEX electronic controls package
- Available in weatherproof, submersible and explosion-proof construction options
- 100% repeatable, geared limit switch with 300V rated contacts
- 300V rated torque switch
- Three-phase, one-phase and DC motors



### QX Actuator

The Flowserve Limitorque QX, non-intrusive electric actuator is designed for a wide range of environmental applications in power, oil & gas, and water industries. The QX design builds on more than 20 years of proven MX technology to provide all the user-preferred features in a quarter-turn smart actuator package.

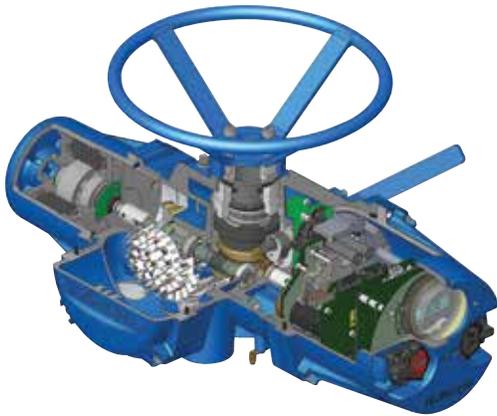
- From 40 to 1500 ft-lbs output torque
- Non-contacting absolute encoders provide accurate position sensing
- B.I.S.T. (built-in self-test) never needs batteries to retain position data, even in the event of main power loss
- Extreme environment performance made possible by non-intrusive design, 100% solid-state controls, and reliable digital communication control system
- Versatility provided by flexible control configurations, setup and diagnostics in 11 languages, and advanced brush-less DC motor that supports most global voltages, AC or DC
- 100% repeatable and redundant absolute encoder for position sensing
- Electronic torque switch
- Three-phase, one-phase and DC motors



### MX Actuator

The Flowserve Limitorque MX, non-intrusive electric actuator is designed for a wide range of environmental applications in power, oil & gas, and water industries.

- From 20 to 1700 ft-lbs output torque; with addition of gearboxes, additional torque can be supported
- Non-intrusive electronic design
- Wide variety of configurations, including torque-only, thrust-based, linear thrust base and rising stem applications
- Weatherproof, explosion-proof and submersible applications
- 100% repeatable and redundant absolute encoder for position sensing
- Electronic torque switch
- Three-phase, one-phase and DC motors
- Instant actuator status and valve position in 11 languages
- Low-temperature capability to -60°C (-76°F) with arctic temperature and solid-state starter options for modulation to 1200 starts per hour



### QXM Actuator

The Flowserve Limitorque QXM, limited multi-turn, non-intrusive electronic valve actuator is designed for limited, short stroke, light torque rising stem valve applications such as choke or control valves in the power, oil & gas, and water industries.

- From 18 to 250 ft-lb output torque
- Non-intrusive electronic design
- Weatherproof, explosion-proof and submersible applications
- 100% repeatable and redundant absolute encoder for position sensing
- Three-phase, one-phase and DC motors
- Lower operating costs compared to pneumatic actuators, with the added advantages of electrical operation
- Greater process control from accuracy that meets and exceeds EN 15714 (Class D) and IEC 60034 standards for modulating service
- Increased reliability via electro-magnetic noise protection of analog process control signals and electronic torque switch



## HBC Worm Gearbox

The Flowserve Limatorque HBC Series of worm gearboxes is designed for quarter-turn, butterfly, ball and plug valve applications as well as quarter-turn and multi-turn dampers.

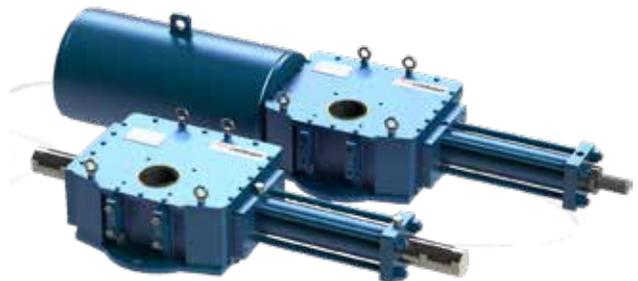
- Torque output to 93 000 ft-lb (126 204 Nm)
- Broad application versatility, both manually or motorized, at a considerable range of output speeds and torque
- Ductile iron housing and roller bearing supported shafts and drive sleeve
- Weatherproof, temporary submersion and buried services available
- Splined valve shaft adapter
- Nuclear qualified
- Self-locking gearing
- Lower maintenance costs due to heavy-duty construction
- Ease of operation by a valve position pointer, which makes at-a-glance position checking easier than ever



## LHS/LHH Actuator

The Limatorque LHS and LHH hydraulic scotch yoke actuator series is designed to meet or exceed the most current and stringent safety and reliability standards for applications in the oil & gas industry. The LHS and LHH models are ideal where hydraulic motive power is preferred for the operation of quarter-turn valves and applications requiring a robust heavy-duty design, long service life, and high-torque and high-speed operation.

- Up to 221 000 ft-lbs (300 000 Nm)
- LHS Series: 3000 psig (207 barg) MAWP
- LHH Series: 5000 psig (345 barg) MAWP
- Efficient design based on computational modeling
- High performance with reduced size, weight and consumption
- Symmetrical and canted Scotch yoke types perfectly fit individual valve torque requirements
- Quick stroking time: less than 0.5 seconds
- Rugged heavy-duty fabricated carbon steel build, epoxy painted and electroless nickel plated (ENP) cylinders
- Dust/water proofing to IP66/IP66M and IP67/IP67M
- 25-year design life and maintenance intervals up to six years
- Modular construction allows easy on-site maintenance



### Master Station III

The Flowserve Limitorque Master Station III is a Modbus master station designed to interface between the field unit (actuator) and the user DCS or PLC. It can be used in all global industrial markets.

- Single and hot-standby configurations
- Hot-swappable PLCs and redundant system control



### LPS Actuator

Limitorque's LPS heavy-duty pneumatic Scotch yoke actuator is the innovative, reliable choice for on/off, inching and modulating automation applications on quarter-turn, medium-to-large-sized valves in general and protective services for the oil & gas market.

- Up to 221 270 ft-lb (300 000 Nm)
- Operating pressure: 36.3 to 174 psig (2.5 to 12 barg)
- MAWP: 174 psig (12 barg)
- Efficient design based on computational modeling
- High performance with reduced size, weight and consumption
- Symmetrical and canted Scotch yoke types perfectly fit individual valve torque requirements
- Rugged heavy-duty fabricated carbon steel build, epoxy painted and electroless nickel plated (ENP) cylinders provide maximum protection against corrosion
- Dust/water proofing to IP66/IP66M and IP67/IP67M
- 25-year design life and maintenance intervals up to six years
- Easy on-site maintenance without special tools or removal from the valve



### LPC Actuator

The Limitorque LPC Series is a compact pneumatic Scotch yoke actuator for on/off, inching and light modulating applications on quarter-turn, small-to-medium sized valves in general and protective services for the oil & gas market.

- Torque rating range: up to 4057 ft-lb (5500 Nm)  
Operating pressure: 36.3 to 174 psig (2.5 to 12 barg)
- MAWP: 174 psig (12 barg)
- Improved safety and service life (25 years) due to heavy-duty design and excellent corrosion resistance on all sizes
- Low total cost of ownership due to simplified installation, operation and on-site maintenance
- Easy retrofitting through a specially designed coupling interface



### LDG Actuator

The Limitorque LDG direct gas-powered scotch yoke actuator series is specifically designed to be operated by high-pressure natural gas, or any other high-pressure pneumatic fluid up to a maximum of 1500 psig (105 barg). LDG actuators are ideal for pipeline applications where no external sources of motive power are present and provide a robust heavy-duty design and long service life with industry-leading maintenance intervals. This makes them the actuator of choice for installation in remote or unmanned facilities.

- Torque rating range: up to 221 000 ft-lbs (300 000 nm)
- Operating pressure: from 145 to 1500 psig (10 to 105 barg)
- MAWP: 1500 psig (105 barg)
- Efficient design based on computational modeling
- High performance with reduced size, weight and consumption
- Symmetrical and canted Scotch yoke types perfectly fit individual valve torque requirements
- Rugged heavy-duty fabricated carbon steel build, epoxy painted and electroless nickel plated (ENP) cylinders provide maximum protection against corrosion
- Dust/water proofing to IP66/IP66M and IP67/IP67M
- 25-year design life and maintenance intervals up to six years
- Modular construction allows easy on-site maintenance without special tools and removal from the valve



## Control Valve Types

Different control valve requirements demand a broad spectrum of constructive designs, which result from operating conditions, flow media and environment. Based on a refinery need, special possible applications and characteristic designs may result.

Typically, control valves with high flow capacity based on the nominal diameter (rotary, plug, ball and check valves) are used mainly on simple operating conditions or On/Off functions, and control valves for higher pressure loss (regarding pressure difference), flow and performance.

## Single-Seat Control Valves

**Single-Seat control valves regulate and control neutral and aggressive gases, vapor and liquids.**

- Straight Through, Angle and Pressure Balance Styles
  - Typical model is Schmidt Armaturen or Valtek Flowserve
- Three-Way Control Valves: Mixing and spreading process medium
  - Typical model is Schmidt Armaturen Flowserve
- Double-Seated Control Valves: Relatively low operating force
  - Double-seated, lined and diaphragm; typical model is Kammer series
- Rotary Valves: Good for contamination, ease of service or negative effect on temperature
  - Rotary, plug, butterfly and ball)
  - Typical models: MaxFlo 4™, NAF™ Duball, NAF Torex
- Self-Acting Regulators: Used upstream or downstream; pressure to be kept constant
  - Typical models: Armaturen 5610 and 5801
- Special Application Valves: specific applications
  - Low flow: Kammer
  - Steam conditioning: Kammer
  - Injection cooler: Schmidt Armaturen
  - Cryogenic: Kammer
  - Slurry
- Standard Valves: shut-off, check, plug, gate, ball isolation purposes
  - Models: Schimdt Armaturen, Argus™, Durco
- Safety Valves: Used for protection under ISO 4126 and DIN 3320
  - STD safety, full lift, proportional, diaphragm, bellows, foil-type valves

### Tough Application with a Proven Record

The rising stem ball valve (RSBV) has several installation services in a refinery.

- A. Hydrogen processes
- B. Isomerization
- C. Hot oil (thermal)

### Valve Characteristics

1. Outside screw and yoke with emission-free graphite stem packing consisting of three die-formed rings and top and bottom anti-extrusion rings, which prevent any leakage to the atmosphere, the stem packing is easily accessible and can be adjusted with normal tools.
2. Mechanical force is generated externally for seat-ball sealing and not by spring-energized seat design.
3. Usually castings in this service are required with radiographic examination. However, our rising stem ball valves can also be manufactured with forged body and bonnet materials.
4. No contact during open-close operation and non-rubbing between ball and seat, assuring very low maintenance, reliability and long life.
5. One-piece body with butt weld ends (no welded pipe pups) is possible.

### Refinery Severe Service Valve Solutions

#### Typical Flowserve Control Valves



**Valtek GSV (Globe)**

Value Add

- High-capacity
- High-performance
- Ease of maintenance



**Valtek Mark One (Globe)**

- Heavy top guiding
- High-performance
- Severe service trim available
  - Noise reduction trim
  - Anti-cavitation trim
- VL Series actuator
  - Field-reversible
  - Double-acting spring return



**Valtek MaxFlo 4 (Eccentric Plug)**

- Highest rated  $C_v$
- Precise control
- Reliable shutoff



**Valtek ShearStream (Segmented Ball)**

- Highest capability and rangeability
- Abrasive, erosive and corrosive fluid
- Slurry, two-phase flow



**Valtek Valdisk (Butterfly)**

- Jam-lever toggle soft seat
- Single pivot point for actuator to disc connection
- Self-centering seal
- Non-selective disc and shaft for cost reduction



**Flowserve Butterfly Valve (Butterfly)**

- Seat design options
- Stuffing box packing options
- Primary steam seal plus two optional secondary seals provide triple-leak protection
- Wide range of optional materials includes: 020, DMM, DC2, DC3, DNI and DNIC
- Exceeds shutoff requirements of ASME/FCI 70-2 for all classes



**Worcester® and Audco (Ball Valves)**

- Wide applications in the oil process lines such as in a biodiesel plant or a dry fractionation plant
- Total ball seat interchangeability
- Fire-safe design
- Low torque
- Bi-directional sealing



## Actuator Products Overview Changing the Valve Control Industry

In the 1920s, Payne Dean, an emigré inventor from England, was issued a U.S. patent for a machine with the unique ability to sense and subsequently limit output torque in a controlled manner. This “limit the torque device,” or Limatorque, fundamentally changed the valve control industry. Today, all heavy-duty electric actuators employ some method that limits torque in order to safely operate automated valves while protecting people and property.

In 2012, Flowserve established the Limatorque Fluid Power Systems team with the expressed mission to develop a comprehensive line of fluid power valve actuators that meet the oil and gas industry’s most current and stringent standards for safety, performance and reliability. Unlike the modified or re-purposed actuators offered by competitive manufacturers, the engineers specifically designed and built heavy-duty, fluid-power, piston-type Scotch yoke actuation for rotary and linear valve operation.

Limatorque actuator products are manufactured in Lynchburg, Va. (LPO); Suzhou, China (SPO); and QRCs in Houston, Texas and Mezzago, Italy.

Actuators are positioned into three primary categories:

- **Electric Actuators** — heavy-duty electric space
- **Fluid Power Actuators** — LFPS
- **Gearboxes** (manual and motorized)

LFPS designations are for fluid power (pneumatic, hydraulic and electro-hydraulic). It is not the intent of this document to describe LFPS products.

Electric actuators are segmented into two categories:

- **Intrusive:** The controls cover must be removed, exposing the controls to the environment, in order to configure position and torque limits. Types are SMB and L120 with output torque ranges from ~30 lb/41 Nm to 60 000 lb/81 350 Nm.
- **Non-intrusive:** The control covers are not removed in order to configure position and torque limits. Types are MX and QX with output torque ranges from ~30 lb/41 Nm to 1700 lb/2036 Nm.

**Both intrusive and non-intrusive** types are available in multi-turn for rising stem valves — SMB, L120 and MX with valve thrust ranges from ~8000 lb/35 kN to 500 000 lbs/2250 kN

For **quarter-turn** valves (BFV, BV and plug), only the non-intrusive QX is available with output torque ranges from ~22 lb/41 Nm to 1500 lb/2033 kN

**Limatorque** supplies mechanical **gearboxes** for either manual or automated service. For multi-turn applications, “V” bevel gearboxes and the “SR” spur gearboxes can be supplied with output torque ranges from 723 lb/980 Nm to 38 353 lb/52 000 Nm and valve thrust ranges from ~31 698 lb/141 kN to 1 719 800 lbs/7650 kN.

Limatorque supplies WG and HBC worm gearboxes for quarter-turn applications with output torque ranges from 885 lb/1200 Nm to 449 900 lb/610 000 Nm.

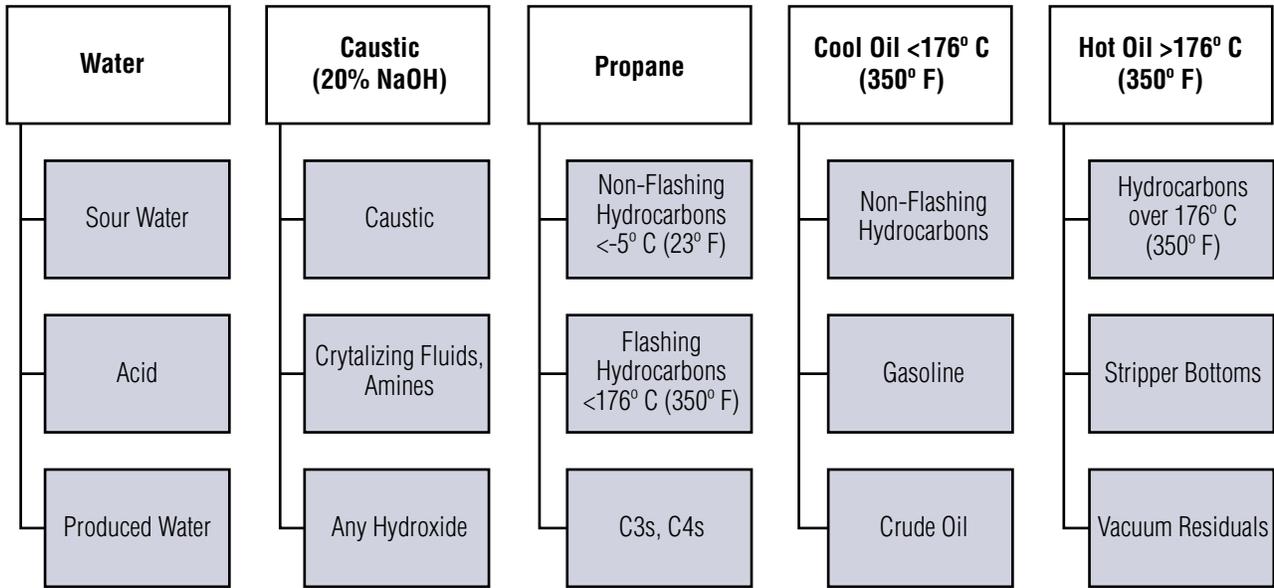
Limatorque also offers optional network protocols which can be fitted to non-intrusive electric actuators and include:

- Modbus-DDC, Foundation Fieldbus H1, Profibus DP\_V1 w/ Redundancy and PA, DeviceNet and HART
- Refer to Limatorque’s APB (All Product Bulletin), LMENBR0001-05

## Seals and System Types

### Mechanical Seals

Figure 4.1: Best practices – identify the fluid group relevant for the application



API 682 fluid groups are used to make seal and piping plan selections as well as to define where seals are qualified to be used

Table 4.3: Best practices – water

<b>Temperature</b> 	350° C (662° F)	DHTW	DHTW	DHTW	DHTW	DHTW	DHTW	DHTW
	300° C (572° F)	DQ	DQ	DQ	DQ	DQ	DHTW	DHTW
	200° C (392° F)	QBQ	QBQ	QBQ	QBQ DQ	DQ	DP DHTW	DHTW
	150° C (302° F)	ISC2-682PX QBQ	QBQ	QBQ	QBQ DQ	DQ	DP DHTW	DHTW
	75° C (167° F)	ISC2-682PX QBQ	ISC2-682PX QBQ	QBQ	QBQ	HSH		UHTW
		176 bar (255 psig)	20.7 bar (300 psig)	34.4 bar (500 psig)	51.7 bar (750 psig)	68.9 bar (1000 psig)	103.4 bar (1500 psig)	137.9 bar (2000 psig)
		 <b>Pressure</b>						

Guidance shown here is for presentation purposes; not for seal selection.

**Table 4.4: Best practices – propane**

<b>Specific Gravity</b> ↑	< 0.4	QBQ/QBQ QBB/QBQ	QBQ/QBQ	QBQ/ QBQ	QBQ/ QBQ DHTW/DHTW UHTW/GSLW	UHTW/GSLW DHTW/DHTW
	0.59 – 0.4	QBB/QBQ QBB/GSL QBQLZ/GSL QBB/QBQ	QBB/QBQ QBB/GSL QBQLZ/GSL QBB/QBQ	QBQLZ/ GSL QBQLZ/ QBQ	QBQLZ/QBQ	UHTW/GSLW UHTW/DHTW DHTW/DHTW
	0.79 – 0.6	QBQ QBQ/QBQ QBQ/GSL QBB/QBQ	QBQ/QBQ QBQ/GSL	QBQ/ QBQ QBQ/ GSL	QBQ/QBQ	UHTW/DHTW UHTW/ GSLW DHTW/DHTW
	1.1 – 0.8	QBQ QBQ/QBQ QBB/QBQ	QBQ QBB/QBQ	QBQ QBQ/QBQ	QBQ QBQ/QBQ	UHTW DHTW
		13.8 bar (200 psig)	27.6 bar (300 psig)	41.4 bar (600 psig)	51.7 bar (750 psig)	68.9 bar (1000 psig)

**Pressure** →

Guidance shown here is for presentation purposes; not for seal selection.

**Table 4.5: Best practices – cool oil**

<b>Viscosity</b> ↑	5000 cP	HSH	HSH	HSH	HSH	HSH	UHTW	UHTW
	200 cP	QBRW HSH	QBRW HSH	QBRW HSH	QBRW HSH	HSH	HSH UHTW	UHTW
	5.0 cP (Hard faces this level and up)	QBQ BXQ, BX	QBQ BXQ, BX	QBQ BX	QBQ	HSH	HSH UHTW	UHTW
	1.0 cP	ISC2-682PX ISC2-682BX QBQ BXQ, BX	ISC2-682PX QBQ BXQ, BX	QBQ BX	QBQ	HSH	HSH UHTW	UHTW
		13.8 bar (200 psig)	20.7 bar (300 psig)	34.4 bar (500 psig)	51.7 bar (750 psig)	68.9 bar (1000 psig)	103.4 bar (1500 psig)	137.9 bar (2000 psig)

**Pressure** →

**Dual seals may be offered when customer specifies or when advantageous.**

Guidance shown here is for presentation purposes; not for seal selection.

**Table 4.6: Best practices – caustic**

- Usually supported with Plan 62
- Usually requires DSSiC vs DSSiC seal faces
- Usually requires perfluoroelastomers
- Usually three 16ss metal parts with C-276 bellows core
- Contamination by H<sub>2</sub>S or hydrocarbons may require a dual seal

*Guidance shown here is for presentation purposes; not for seal selection.*

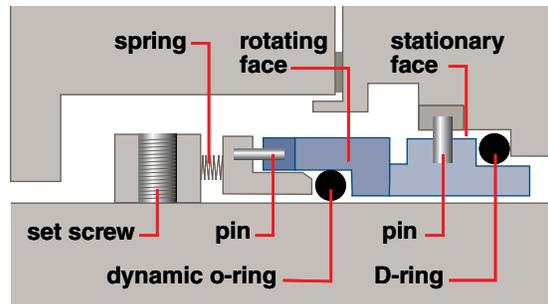
<b>Concentration</b> ↑	50%	ISC2-682BB BxB/BX BXQ, BX	BXB/BX BXQ	QBQ/QBQ
	20%	ISC2-682BB BXQ, BX	BXQ	QBQ
		13.8 bar (200 psig)	27.6 bar (400 psig)	51.7 bar (750 psig)

→ **Pressure**

**Figure 4.2: Seal basics**

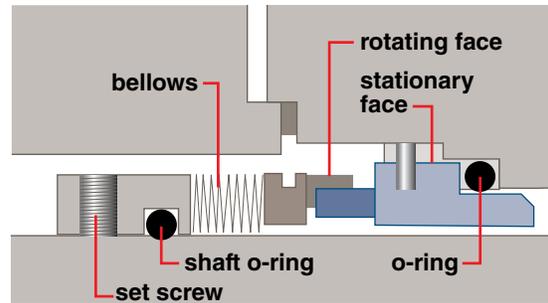
• **Type A — Pusher**

- Uses springs to hold faces in contact
- Most cost-effective
- Highest pressure capability
- Widest available size range



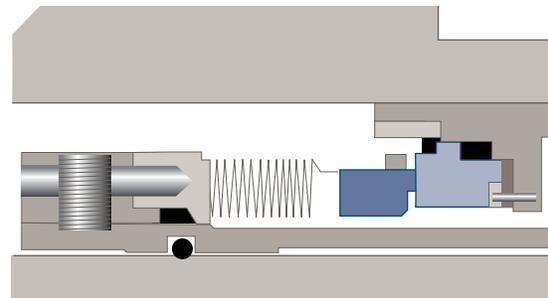
• **Type B — Bellows**

- Applied in caustic or applications with some solids



• **Type C — High Temperature Bellows**

- Typically applied when temperatures exceed 400°F
- Lowest pressure capability
- Highest cost

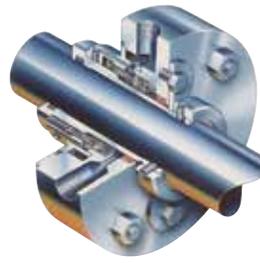


**Type A —  
pusher seals**

- Category 1 and 2
  - ISC2-682PX
  - QBQ
- Category 2 and 3
  - QBQ
  - QBQLZ
  - DQ
- Arrangement 2  
Containment Seal
  - GSL
- Arrangement 3  
Gas Barrier Seals
  - GF-200
- Engineered Seals
  - HSH
  - UHTW/DHTW



**ISC2-682PX**



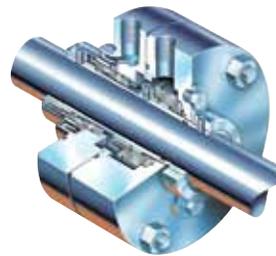
**QBQ**



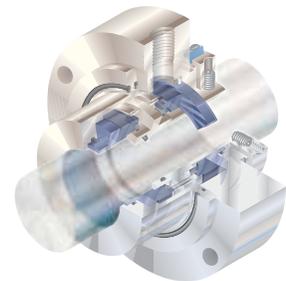
**QBQLZ**



**DQ**



**GSL**



**GF-200**



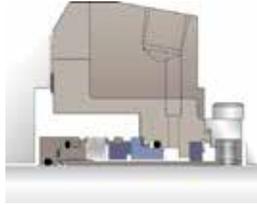
**HSH**



**UHTW/DHTW**

**Type B — bellows seals**

- Category 1 and 2
  - ISC2-682BX
- Category 1, 2 and 3
  - BX
  - BXQ



**ISC2-682BX**



**BX**



**BXQ**

**Type C — high-temperature bellows seals**

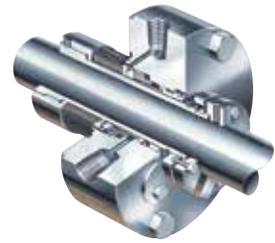
- Category 2
  - BXRH
  - BXHHS
  - BRCSH
- Category 2 and 3
  - BXRH
  - BXHH
  - BRC
- Arrangement 2  
Containment Seal
  - GSDH
- Arrangement 3  
Steam Barrier Seal
  - GTSP



**BXRH**



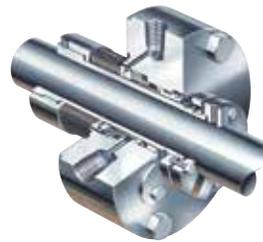
**BXHHS**



**BRCSH**



**BXHH**



**BRC**



**GSDH**

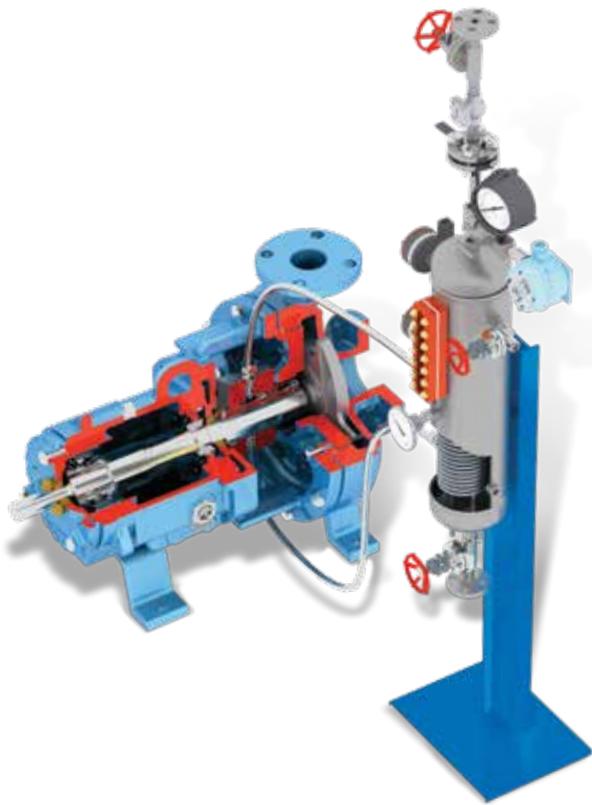


**GTSP**

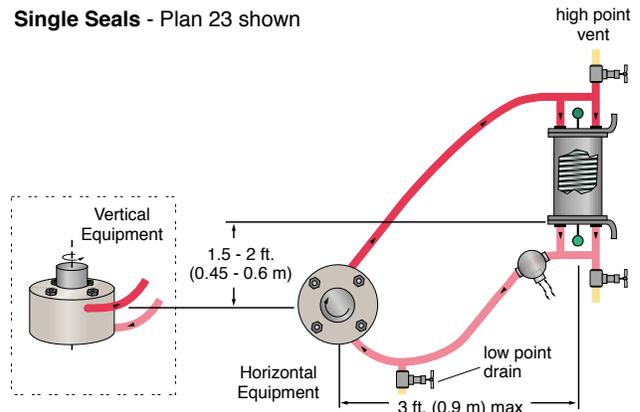
## Seal System Piping Plans

Flowserve recognizes that one of the most effective ways to achieve long, uninterrupted mechanical seal life is to create a healthy environment around the seal faces. Piping plans help keep mechanical seals running cool and clean, promote safe handling of dangerous fluids and extend the operational availability of rotating equipment. The following pages provide a concise summary of the most essential piping plans used successfully in today's process plants. Each plan shows all the standard and optional components referenced in API 682 and recommended by Flowserve. Consult your local Flowserve sales engineer to identify the right solution that satisfies your application requirements.

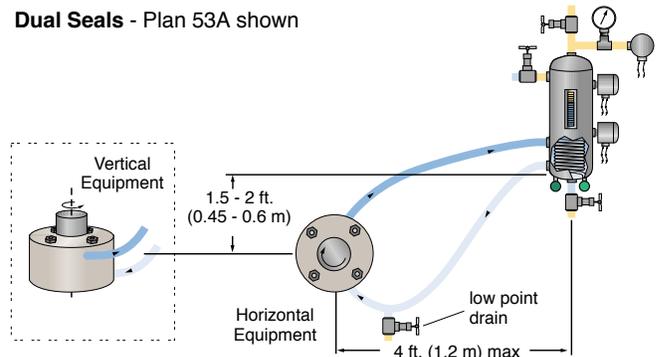
**Figure 4.3**



**Single Seals - Plan 23 shown**



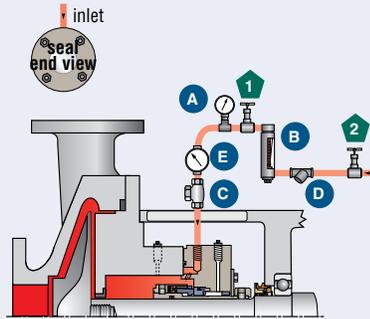
**Dual Seals - Plan 53A shown**



Plan 32

Single Seals

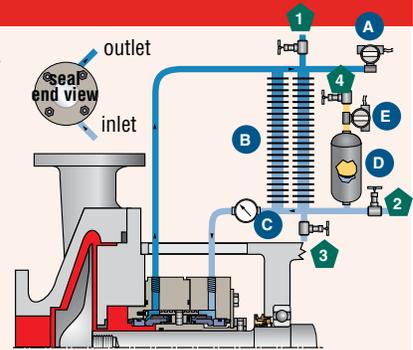
Seal flush from an external clean source.



- A - pressure indicator
- B - flow indicator (optional)
- C - check valve
- D - strainer
- E - temperature indicator (optional)
- 1 - flow control valve
- 2 - from clean source, normally open

Plan 53B

Pressurized barrier fluid circulation with a bladder accumulator.



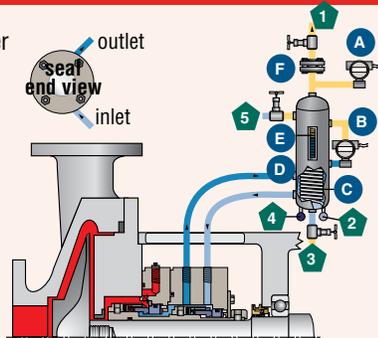
- A - pressure transmitter
- B - finned pipe (alternative reservoir)
- C - temperature indicator
- D - bladder accumulator
- E - temperature transmitter
- 1 - vent, normally closed
- 2 - liquid fill, normally closed
- 3 - drain, normally closed
- 4 - pressure source, normally closed

Plan 52

Dual Seals

Unpressurized buffer fluid circulation through reservoir.

Fluid is circulated by a pumping ring in the dual seal assembly.

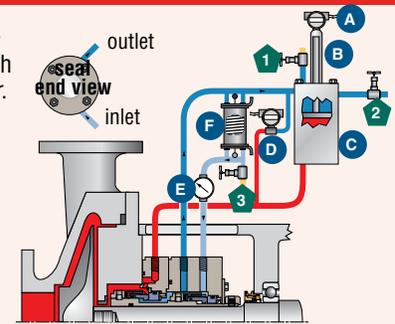


- A - pressure transmitter
- B - level transmitter
- C - cooling coils
- D - reservoir
- E - level indicator
- F - orifice
- 1 - vent, normally open
- 2 - cooling in
- 3 - drain, normally closed
- 4 - cooling out
- 5 - liquid fill, normally closed

Plan 53C

Pressurized barrier fluid circulation with piston accumulator.

Fluid is circulated by a pumping ring in the dual seal assembly.

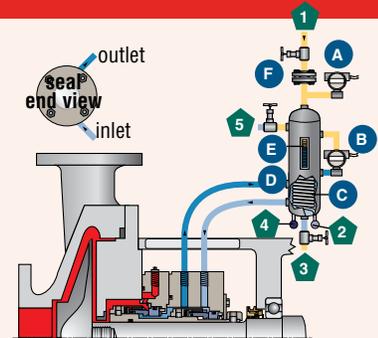


- A - level transmitter
- B - level indicator
- C - piston accumulator
- D - differential pressure transmitter
- E - temperature indicator (optional)
- F - cooler
- 1 - vent, normally closed
- 2 - liquid fill, normally closed
- 3 - drain, normally closed

Plan 53A

Pressurized barrier fluid circulation through reservoir.

Fluid is circulated by a pumping ring in the dual seal assembly.

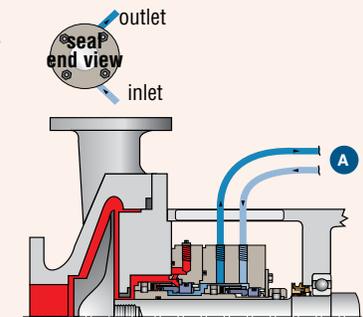


- A - pressure transmitter
- B - level transmitter
- C - cooling coils
- D - reservoir
- E - level indicator
- F - orifice
- 1 - vent, normally open
- 2 - cooling in
- 3 - drain, normally closed
- 4 - cooling out
- 5 - liquid fill, normally closed

Plan 54 & 55

Plan 54 - Pressurized barrier fluid circulation by external system.

Plan 55 - Unpressurized barrier fluid circulation by external system.



- A - from/to external circulating system

# AFTERMARKET PARTS AND SERVICES IN REFINERIES

## Flowserve exceeds the customer challenges

Investments in well-equipped [Quick Response Centers](#), mobile service fleets and advanced manufacturing technologies along with the unrivaled expertise of its engineers, technicians and craftsmen enable Flowserve to address virtually every service requirement for process equipment, on- or off-site, regardless of OEM.

- **Repair and upgrades** — From machining to mechanical upgrades to on-site management, Flowserve repair and upgrades services improve equipment performance while reducing downtime and costs
- **Replacement parts and components** — Through quick response programs, rapid prototyping and other innovative approaches, Flowserve supplies

customers with the quality parts needed to keep operations running smoothly and profitably

Flowserve provides a wide variety of pump system upgrades and enhancements that improve overall performance, increase reliability and extend the life of critical assets. From simple equipment upgrades or seal replacements to complete system overhauls, Flowserve is here to tackle the toughest challenges.

We have two centuries of pump and mechanical seal innovation under our belt, an installed base exceeding one million units and a global footprint. It's no wonder Flowserve is the industry leader when it comes to knowledge, experience and resources.

## Mechanical Upgrades and Retrofits

Flowserve upgrade and retrofit options **improve the reliability** and availability of your pumps. Leaking pumps can be refurbished to “as new” condition, to meet or exceed current industry standards.

Options include:

- ISO 13709/API 610 latest edition upgrades: Convert old overhung process pumps to current API standards. Includes new power end, API 682 seal chamber and cartridge mechanical seals.
- ASME and ISO power end exchange programs: quick, cost-effective upgrades of chemical process pumps

Other available mechanical upgrades and retrofits include:

- Increased rotor stiffness
- Bearing housing and bearings/bearing pads
- API 682 seal chambers
- Mechanical seal upgrades (single, tandem, double)
- Dry gas seal retrofits
- Couplings
- Wear rings
- Motor heat exchanger upgrades
- Impeller upgrades



## LifeCycle Management Programs

Minimize customer downtime, improve efficiency, streamline customer inventory, reduce costs and extend the life of their equipment (**MTBF**).

Making sure you make the right investment every time is almost impossible. And it can be daunting knowing your business is vulnerable to risk. Our methodology is simple: you're not in this alone!

**LifeCycle Advantage** enables us to partner with you to deliver immediate improvements in equipment reliability, operational efficiency and measurable cost savings.

LifeCycle Advantage is our formal methodology for evaluating an operation and implementing

programs created with the complete lifecycle of your equipment and systems in mind. Through this methodology, we form a **strategic partnership with mutually compatible goals and key performance indicators** to ensure that everyone wins. Basically, when you thrive, we thrive.

We welcome the challenge that comes with optimizing your unique operating goals and equipment. Together we'll minimize downtime, streamline your inventory, reduce costs and extend equipment life. The results are an immediate impact in operating performance and a quick delivery of results to the bottom line.

## Educational and Consultative Services

Flowserve looks at learning from a customer's perspective, which is why students come away from our education and consultative programs with the skills they need to strengthen their company's competitive position.

The Flowserve Educational Services group provides educationally sound hands-on technical training in equipment design, operation and maintenance in our **global state-of-the-art Learning Resource Centers**. We can also provide customized on-site training.

The LifeCycle Advantage program also provides access to additional consultative services such as system analysis, diagnostics and energy management. These services develop expertise in equipment performance and reliability to pinpoint problem areas, diagnose complete system impacts and deliver solutions to improve the operation of your plant.

## Replacement Parts and Component Offerings

### Standard OEM Replacement Parts and Components

Quality OEM parts and components for the entire range of Flowserve products are readily available from a worldwide network of manufacturing centers, service centers, Quick Response Centers and stocking centers.

All Flowserve parts and components are manufactured to meet or exceed the latest design standards and material specifications. With Flowserve, customers are ensured the highest quality parts and components for reliable operation and lowest equipment ownership costs.

### Parts Programs

- A. Quick Response Pump Impellers (Impeller in a Week). **FPD 1158a**
- B. Quick Response Turned Parts (Rings). **FPD 1156e**
- C. Quick Response Pump Shaft Products. **FPD 1157e**
- D. Quick Response FastCast Impellers. **FPD 1378a**



### Quick Response Programs

Flowserve quick response programs provide customers with rapid delivery of parts and components to minimize equipment or plant downtime. **Standard parts and components can be supplied same day** or next day; special parts can be delivered in days instead of weeks.

Available quick response programs include:

- Shafts
- Mechanical seals
- Impellers
- Auxiliary systems
- Wear rings



### Rapid Prototyping

Flowserve can **re-engineer and produce non-Flowserve parts and components** for equipment that is now obsolete or where the original equipment manufacturer cannot be located. By integrating powerful laser scanning technology with advanced modeling software, the **Flowserve Components Technology Group (CTG)** can develop a highly accurate part that could then be quickly produced with rapid prototyping techniques. State-of-the-art mechanical, hydraulic and materials upgrades may be incorporated as well. CTG's combination of technical expertise and global facilities makes it the ideal technical resource for users of critical pumping equipment and other rotating machinery.

### Equipment Performance

Flowserve has decades of experience serving the needs of process-driven companies. **LifeCycle Advantage** combines our expertise in equipment management with your team's process knowledge to increase reliability and performance of industrial process systems.

We begin with a complete survey of your equipment and document its maintenance history to identify critical and under-performing equipment, the root causes of failures and corrective courses of action.

Key performance indicators are established to measure program success, and implementation teams meet routinely to review performance indicators and assure program goals are met.

**The results:** fewer equipment failures, less downtime, lowered total cost of ownership and increased overall profitability.

### Strategic Procurement

In addition to the costs of materials and services, the Flowserve **LifeCycle Advantage** program focuses on reducing the man-hours associated with procurement. Our program promotes a collaborative relationship that drives efficiency and cost reduction.

As part of your **LifeCycle Advantage** agreement, we'll review procurement processes and help you reduce the number of your transactions, minimize procurement paperwork and increase your administrative productivity. By consolidating business with Flowserve, you can process fewer purchase orders and invoices.

The key to driving efficiency is having the proper personnel, processes and tools available. LifeCycle Advantage enhances all three elements at your plant. By leveraging our equipment expertise and enhancing your existing processes, we can make immediate impacts — reducing costs and increasing productivity.

**LifeCycle Advantage** can help you optimize procurement by:

- Automating and streamlining the entire procurement process
- Updating parts codes and product nomenclature in business systems
- Providing clear documentation of reduced inventories, improved reliability and cost savings
- Performing periodic reviews to evaluate performance and maintain focus on procurement efficiency

### Streamlined Inventory

While the **LifeCycle Advantage** program is based on a highly structured implementation process, every LifeCycle Advantage agreement is carefully customized to meet each customer's unique operating goals and requirements.

Your LifeCycle Advantage agreement will include plans of action for streamlining inventory activities through:

- A comprehensive analysis of your current inventory and its requirements
- Recommendations for the consolidation and reduction of inventory
- Assignment of criticality and availability ratings for pump, seal, valve and automation assets

After evaluating inventory options, an inventory management program is established with just-in-time equipment procurement. A targeted program is created to reduce both transaction and carrying costs.

Flowserve manages this important aspect of the LifeCycle Advantage solution to reduce the number of inventory items that need to be controlled, and helps plants reduce inventory costs and related expenses. This allows your personnel to focus on more profitable, mission-critical activities.

### Technical Support

LifeCycle Advantage brings together a global team of mechanical sealing experts, rotating equipment specialists, reliability engineers and specialists in valves and automation. This may be on-site at your facility or through our global network of service experts and Quick Response Centers.

On-site technical support for your rotating equipment or valve and automation equipment is augmented by our technical development facilities. There, equipment can be modeled and tested under actual running conditions through computer-aided and finite element analysis programs.

Your LifeCycle Advantage team **includes technical and resource support from a global network** of engineers and specialists whose responsibilities include:

- Troubleshooting and recommendations in the field regarding installation, design and operations
- Oversight and coordination of standardization and inventory program
- Providing application engineering and technical support

### Tools and Technology

A consistent, comprehensive view of asset data is vital to improving operational performance. That is where our proprietary web-based software applications come in — **IPS Insight and Flowstar.net**. These help customers collect, store, manage and interpret asset data to achieve meaningful business results.

With these applications, you can:

- View ongoing performance metrics through easily interpreted visuals
- Monitor real-time equipment performance
- Conduct predictive analysis
- Recommend corrective action based on facts and verifiable data
- Review historical equipment information
- Manage timing and costs for equipment change-outs, repairs, maintenance and commissioning
- Receive alarms and notifications via email, SMS text and smartphone applications

### Flowstar.net

Flowstar.net is a secure, web-based application used to help customers implement comprehensive reliability improvement programs. It tracks performance data such as **mean time between failure (MTBF)**, and offers real-time access to equipment databases with powerful filtering and sorting capabilities.

Key features include:

- Lifecycle cost and energy savings calculations
- Equipment drawing repositories
- Inventory management features
- Failure mode reporting

### IPS Insight

IPS Insight is a **data aggregation system** that offers a unique view of key performance indicators for pumps, other rotating equipment and critical plant assets. Easy-to-interpret visuals show real-time operational data obtained from customer control systems and onboard sensors, comparing actual data to expected performance levels.

The centralized view can also include:

- Installation and operation information
- Bill of material data, including drawings
- Historical data, including parts usage, upgrades and maintenance records
- Parts and service availability from Flowserve Quick Response Centers

### Key Engineering Technologies

- Computational fluid dynamics (CFD)
- Flow visualization
- Erosion modeling
- Rotor dynamics analysis
- Pipe flow analysis
- Thermodynamic modeling
- Computer-aided mechanical design
- State-of-the-art test loops
- Process and system simulations
- State-of-the-art data acquisition systems
- Special field performance tools



## Large Capital Project Support



In today's challenging economy, many of our customers find that they lack the resources and the specific equipment, or the complete system or application expertise they need to keep complex equipment and systems operating at their maximum efficiency.

That's where **Flowserve project managers** and **engineers** come in. For challenges large and small, they help customers like you every day to ensure projects exceed expectations.

### Typical engagements include:

- Equipment removal and handling
- Equipment transportation
- Maintenance activities
- Equipment installation
- Start-up and commissioning

## Quick-Ship Products

A. Quick-Ship **HPX** and **HPXM**

B. Quick-Ship **DA-DMX** Internal Element Program

C. IPO Products: **SIHI Vacuum**, **ASME/ISO Mark 3** and **VTP Bowl Assemblies**

## Upgrade Programs

- A. **RVX Upgrade**; ISO 13709/API 610  
Back Pull-out Retrofit (Detailed example of the program shared below)
- B. **RHWX & RHWX-S** Vertical Inline Power Frame Upgrade
- C. **VTP**: Vertical Turbine Pump Dished Bottom (suction can upgrade)
- D. ANSI/ASME **Mark 3/Prima3 Power End Programs**
- E. **RVX-MAG**
- F. **Ebulator** Rebuild program

### RVX Upgrade

#### ISO 13709/API 610 Back Pull-Out Retrofit

Flowserve developed the RVX back pull-out assembly upgrade program to address users' needs for improved pump reliability with reduced maintenance costs. The **RVX program** assists users in reducing fugitive volatile organic compound (VOC) emissions while gaining the advantages of a bearing frame in full compliance with ISO 13709/API 610, latest edition. It also addresses users' needs for improving pump hydraulic efficiency or operating stability by replacing existing impellers with ones specifically selected for current operating modes. This dedicated aftermarket support program makes Flowserve unbeatable as a problem solver for improving field equipment reliability and reducing total lifecycle costs.

*Before*



*After*



## RVX Upgrade Benefits

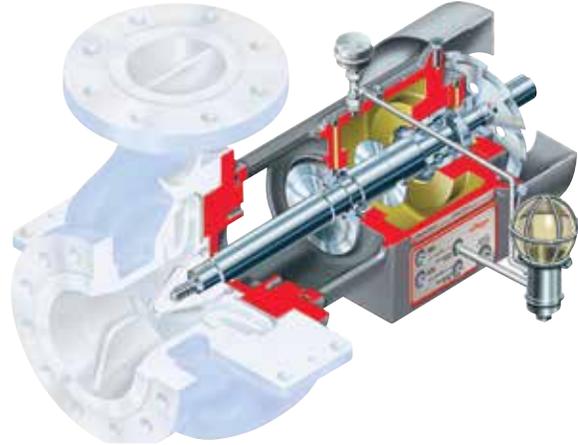
The RVX program applies to any existing ISO/API OH1 and OH2 pump installation, regardless of OEM.

- Increased reliability based upon a robust design with larger radial and thrust bearings and low  $L^3/D^4$  ratio
- Full compliance with API 610 L10h bearing life requirements
- Increased seal life attributed to large-diameter shaft with low  $L^3/D^4$  ratio for reduced shaft deflection with increased MTBR and reliability
- Elimination of cooling water by an outboard fan for heat convection
- No disturbance to existing suction and discharge piping
- High parts interchangeability based upon same parts used from new Flowserve **HPX** pump product
  - Three standard frame sizes accommodate impeller diameters from 215 mm (8.5 in) to 525 mm (21 in)
  - Utilizes standard OEM cartridge seals
- Pristine, closed lubrication system with bearing isolators for increased MTBR
- Oil slinger design to mitigate “dirty oil” appearance
- Quick Ship Program for significantly reduced turnaround time to upgrade existing pumps instead of replacing with new equipment. Upgrade in two to five weeks instead of new pumps, which can take up to 38 weeks.

### Features and Benefits

Heavy-duty construction to ISO 13709/API 610, latest edition, including carbon steel bearing housing assures maximum reliability and safety.

Figure 5.1



### Metal-to-Metal Casing/Cover

Fit with fully confined, controlled compression gasket ensures proper sealing and alignment.

### Outboard Cooling Fan

Reduces shaft temperature migration on high-temperature services.

### Large Radial and Thrust Bearings

Combined with very low shaft stiffness ratios ( $L^3/D^4$ ) and low shaft deflection, promote long life for bearings and mechanical seals.

### Pristine Closed Lubrication System

With expansion chamber, oiler and Inpro<sup>®</sup> bearing isolators, ensures optimal bearing lubrication and prevents ingress of contaminants and moisture for increased MTBR. Oil slinger design mitigates “dirty oil” appearance. Oil mist optional. (® Inpro is a trademark of Inpro/Seal Company.) **Important to know Flowserve also has a series of bearing isolator models.**

### Fixed Throat Bushing Design

Accommodates metallic and non-metallic bushings, permitting greater control of seal chamber pressure to suit application needs.

### ISO 21049/API 682 Seal Chamber

Accommodates all popular dual-seal arrangements without special engineering.

**Air Gap**

Between drip pocket and cover; helps insulate the bearing housing in high-temperature applications.

**Standard Outboard Fan**

Standard outboard fan eliminates the need for bearing cooling water and extends the operating temperature of the pump to 450°C (840°F) with no auxiliary support required.

**Maximized Parts Interchangeability**

The **RVX** enables users to maximize parts' interchangeability. All **ISO/API OH1** and **OH2** single-stage, two-stage and double-suction overhung pump wet ends, regardless of OEM, may be retrofitted with the **RVX**. Bearing housing parts are interchangeable with **HPX** and **HPXM** components.

**Dimensional Consistency**

With very few exceptions, the pump's discharge centerline to driver coupling face dimension remains unchanged on pumps retrofitted with the **RVX**. This is accomplished by selecting a longer coupling spacer, if necessary, to permit a drop-in-place assembly. Additionally, shafts are machined to fit the original pump dimensions.

**Significantly Reduced Lead Time**

The **RVX** retrofit improves pump performance and reliability significantly faster than purchasing a new pump. Typical lead time for a new pump is 38 weeks; the typical lead time for an **RVX** is just five weeks — a savings of 33 weeks. (Figure 5.1)

**Quick Payback and Reduced Lifecycle Costs**

**Reliability Payback**

The reliability payback of the **RVX** in a recent 50-pump program was 1.84 years, as calculated by the user.

This was based on the significant reduction in cost and time to upgrade the pull-out assemblies instead of completely replacing pumps. Improved reliability to **ISO 13709/API 610**, latest edition, is also assured.

**Energy Payback**

Energy payback on the **RVX** can be realized by application of an optimized impeller. Consider the following facts from an actual case history:

- Reduction of 100 kW/h (135 hp/h)
- Power cost reduction of US \$35 415 annually using US \$0.04 per kW/h and around-the-clock operation
- 0.62 years payback on energy savings

**New Product Warranty**

Flowserve offers a new product warranty on all **RVX** assemblies.

Figure 5.1: Lead time comparison



## INSTALLATIONS AND EXPERIENCE

Flowserve continues to be a pioneer and preferred supplier in the [oil and gas industry](#), specifically in the downstream refinery sector, which this ASG guide covers.

Our valves, seals and systems, pumps and HDS products are installed in more than 90% of all refineries in some or all customer sites globally.

Our customers include some of the world's broadest refinery EPCs, contractors, developers and end users.

### Preferred Supplier Agreements



Flowserve also has **frame agreements** (alliances) with several key EPC contractors and end users globally. They prefer Flowserve for specific applications as their premier supplier of pumps, valves and mechanical seals and systems. Due to various agreements, validity and regional implications, please contact your local Commercial OPS manager or sales leadership for details.

Trusted Experience Across the Oil and Gas Industry

Global Users:



Global Accounts



# COMMUNICATING OUR VALUE

## Flowserve Value Proposition for Refineries

Table 8.2

FLOWSERVE	PROPOSITION	CUSTOMER BENEFIT
Ethical Business Practices	Flowserve sets the highest standards in business integrity in its dealings with suppliers and customers.	A trustworthy partner to work toward their project success
Quality	Flowserve manufactures to the most rigorous quality standards to provide reliable products.	Satisfaction in supplier choice, on-time commissioning and project startup.
Engineering Excellence	The Flowserve depth of engineering experience is unparalleled in refining plants.	Optimized product and material selection for each application ensures reliable operation.
Experience	Flowserve has been a leader since the process was commercialized on a large scale.	Lessons learnt have been built into today's products, increasing reliability, maintainability and product life.
Broad Product Range	Flowserve comprises a list of world-renowned heritage brands and a wide portfolio of products and services.	A product for every service designed by specialists in their respective fields ensures low-cost, high-efficiency solutions.
Project Management	Dedicated project managers certified by IPMA.	Professional team to handle documentation and ensure on-time delivery.
After-Sales Support	Dedicated after-sales support engineers.	Implanted within project management, with the sole objective to resolve warranty issues quickly and painlessly.
Local Quick Response Centers	Fully equipped Quick Response Centers in the region.	Skilled team to handle upgrades and repairs; localized to reduce downtime, full access to Flowserve component drawings, procedures and standards.
Aftermarket Solutions	Long-term maintenance.	Specialist group capable of maintaining, servicing and upgrading equipment to meet operating goals throughput.
Safety	Considerable experience and pioneer in power industry; with product designs considering industry standards and low-risk design factors and maintainability.	Maximize MTBF, ease of monitoring equipment.

## Innovative Ways Flowserve Addresses Customer Challenges

Table 8.3

<p>Expertise and Experience</p>	<ul style="list-style-type: none"> <li>• Flowserve has more than 80 years of experience in the oil and gas industry and has been a key supplier of pumps, valves and seals for refineries since the beginning of the conventional steam era</li> <li>• Flowserve has one of the largest installed bases of pumps and valves in refinery applications around the world</li> <li>• Specialist "Virtual Centers of Excellence" ensures that expertise acquired over multiple products and manufacturing sites is shared across the global Flowserve organization</li> </ul>
<p>Single-Source Provider</p>	<ul style="list-style-type: none"> <li>• Flowserve offers a full range of pumps, valves and seals for the oil and gas market, simplifying the procurement process for our customers</li> <li>• Global commercial operations organization ensures knowledgeable and professional review and response to customer RFQs, including those with the most complicated technical requirements</li> </ul>
<p>Streamlined Execution</p>	<ul style="list-style-type: none"> <li>• Each Flowserve factory has efficient and professional project management organizations to ensure on-time completion of projects to customer requirements</li> <li>• Where projects involve multiple Flowserve manufacturing locations, global project managers can be provided to coordinate order fulfillment. This ensures less errors and delays, and simplifies communications between Flowserve and the customer.</li> </ul>
<p>Local Support Worldwide</p>	<ul style="list-style-type: none"> <li>• A large field service organization ensures technicians are available for installation, commissioning and troubleshooting without delay</li> <li>• Service and maintenance contracts for highest availability and continuous efficiency optimization can be tailored to customer needs</li> <li>• A global network of Flowserve Quick Response Centers (QRCs) means that local service and repair are always available</li> <li>• Product upgrades are continuously being introduced to improve the performance and reliability of Flowserve products in the field</li> <li>• Full operation and maintenance training is available to end users</li> <li>• Equipment monitoring programs are also available</li> </ul>
<p>Optimized Efficiency</p>	<ul style="list-style-type: none"> <li>• The Flowserve close involvement with the refinery market has provided the industry feedback needed to develop the range of hydraulics best suited to customer requirements, ensuring the best and most efficient selections are always available</li> <li>• As one of the largest engineered pump manufacturers in the world, the Flowserve hydraulic engineering capabilities and resources are second to none. Flowserve is able to provide pumping equipment that consumes the least amount of power.</li> </ul>

## Business Pain Points and Opportunities

### Flowserve Meets the Customers' Challenges

The overall impact of equipment on the total cost structure of a refinery is quite significant — especially when you consider the various processes from distillation to storage. Safety factors are critical due to the sensitive interactions of the fluids and processes.

Consider the following:

- It is common for pumps (including seals and systems), valves and specialty equipment such as those used in decoking, installation and commissioning to comprise up to 10% of the total capital expenditures
- Flowserve has been a pioneer in the oil and gas industry, especially hydraulic decoking systems, refinery processes and enhancements
- Refineries typically operate 24/7; therefore, reliability and service are critically important
- Aftermarket services is a global requirement; Flowserve has continued to support all end-user needs and behaviors
- Considerable experience and alliances with multi-national oil and gas end users globally

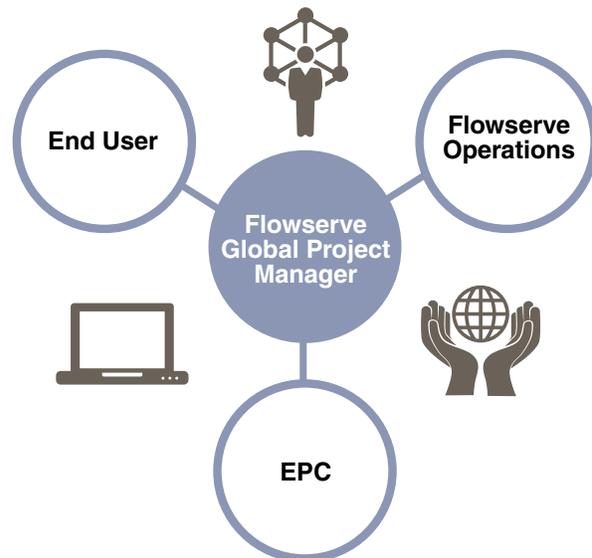
This section provides a high-level guide to how we can communicate our value to influencers and decision makers.

### Business Pains and Challenges

Table 8.4

<ul style="list-style-type: none"> <li>– Knowledgeable and reliable technical support in preparing specifications</li> <li>– Access to selection tools to optimize energy cost and plant performance</li> </ul>
<ul style="list-style-type: none"> <li>– Competitive prices</li> <li>– Specification performance</li> <li>– Quick response on information and documentation</li> <li>– Effective project management</li> <li>– Reliable on-time delivery</li> <li>– Startup services</li> <li>– Minimize number of suppliers</li> </ul>
<ul style="list-style-type: none"> <li>– All of the above, plus ...</li> <li>– Sustainable high-efficiency; reduced power consumption</li> <li>– Project completion on time and at budget</li> </ul>
<ul style="list-style-type: none"> <li>– Equipment reliability</li> <li>– Local services</li> <li>– Contract maintenance for unmanned or understaffed plants</li> <li>– Upgrades for energy and maintenance savings</li> </ul>

Figure 8.1



### Flowserve Response

1. Global **project management** team
2. Affinity pump selection tools
3. Vast experience — present at 98% of global refineries
4. **Low total cost** due to high-efficiency products
5. Conservative approach to published equipment performance
6. Complete **field installation and commission** support through service and solutions
7. Pumps, seals, systems and valves from **one supplier**
8. Broad range of hydraulics to meet applications
9. Legacy means high-reliability equipment
10. Global footprint includes —  
175 **Quick Response Centers**
11. Turnkey maintenance and equipment through services and solutions
12. Technical services for **re-rates and upgrades**
13. Contract agreements for equipment performance and maintenance

### The Flowserve value proposition is a combination of the following components:

1. Pump, valve and seal application and design **engineering expertise**
2. Class-leading products with **proven** local installations
3. **Local** content
4. **Packaging** capabilities
5. Industry-leading testing capabilities
6. Project management services
7. Installation and **startup services** and support
8. Training facilities
9. **Aftersales** service
10. Upgrades
11. Local regional spare parts manufacturing
12. Local **regional repair facilities**
13. Routine maintenance services
14. Dedicated project execution teams
15. Flowserve commitment to **quality**
16. Flowserve commitment to **safety**

### Examples of These Components

- **Leverage our purchasing power and save time by using one supplier**

- Less time shopping
- Less time evaluating
- Less time managing the project

- **CAPEX: Economies of Scale**

- Project management: single point of contact, flawless execution
- Receipt of materials, installation and startup
- Procurement activities: global sourcing, product bundling, capital spares
- Engineering design for safety, operational reliability, efficiency and standardization

- **Installation and Startup Services**

- Reduced time to operation
- Improved startup performance
- Optimal installation costs
- Fast issue resolution
- Condition monitoring — A flexible, scalable way to avoid failures and improve maintenance
- Safe, secure, reliable access to equipment and system data
- Real-time information for vibration, pressure, temperature, gas leak detection and any other sensor
- Fraction of the cost of a wired system

- **Dedicated applications engineers are located adjacent to design engineers and hydraulics specialists**

- Rapid modification of hydraulic performance
- Detailed specification reviews and comments
- Specialty scope consideration
- From order acquisition to execution, the handoff is seamless
- Applications engineer initiates order review with all factory-functional leads
- Handoff of scope occurs between applications engineer and project manager
- Order review
- Order validation
- Kick-off meeting readiness

- **Installation**

- Inspect the equipment when it arrives at the job site to make sure it was not damaged in shipment
- Work with the site installation team to help ensure that the equipment is installed properly, following the instructions in the Flowserve Instruction Manuals and API 686 (Recommended Practices for Machinery Installation and Installation Design)
- Check the baseplate leveling
- Check the baseplate grouting
- Check the driver and pump for soft feet
- Check the piping alignment
- Check the driver-to-pump alignment

• **Startup**

- Work with the site startup team to help ensure that the equipment is operating properly
- Check that the seals set screws' are locked before startup
- Check that the startup strainers are installed correctly
- Check that the pump is lubricated correctly
- Check that the pump and seals are properly vented
- Check that the system valves are set for the pump operation
- Monitor the pump after startup
- Coordinate the communication among the Flowserve factories and the site commissioning and startup personnel on the job site
- Technicians available for quick response to resolve any pump- and seal-related issues during the facility's break-in period

**Typical User Challenges With Valves in the Processes**

- High-pressure drop, potential for flashing, erosion, corrosion
- Leakage across seat will cause wire draw and damage
- Coke particulates in flow stream
- High-temperature sticky service
- Plugging of downstream piping
- Temperature shock of downstream piping

## Hydrocracking Process Challenges on Pumps and Valves

In a global scenario of oil supplies shifting toward heavy and sour crudes that are more difficult to process, refiners must meet increasingly tighter environmental regulations, difficult technical challenges and complex safety requirements.

The supply of heavy crude oil has increased significantly over the years, and projections indicate a continuation of these increases in the trend of reduced light crude production. Transportation fuel regulations have significantly decreased the allowable level of pollutants over the past decade and even lower targets are set for the near future. Levels of sulfur and aromatics are key targets for more stringent regulation, meaning that the majority of the worldwide distillate and gasoline will need to become an ultra-low sulfur product by the end of this decade.

The need to increase the capacity of petroleum refineries capable of handling very low API gravities including “unconventional crudes,” while maintaining or even increasing the percentage of light transportation fuel produced, requires the upgrading of refinery processes with the introduction of new cracking facilities. The refining of heavy oil is a complex process that requires experience and sophisticated technology.

A **hydrocracking unit, or hydrocracker**, normally takes the feed or heavy gas oil from atmospheric or vacuum distillation and cracks the heavy molecules into distillate and gasoline in the presence of

hydrogen atmosphere in the presence of a catalyst. The hydrocracker upgrades low-quality heavy gas oils into high-quality, clean-burning jet fuel, diesel and gasoline. There are two main chemical reactions occurring in the hydrocracker:

- catalytic cracking of heavy hydrocarbons into lighter hydrocarbons
- saturation of these newly formed hydrocarbons with hydrogen

The catalytic cracking of the heavier hydrocarbons uses heat and causes the feed to be cooled as it progresses through the reactor. The saturation of the lighter hydrocarbons releases heat and causes the feed and products to heat up as they proceed through the reactor. Hydrogen is also used to control the temperature of the reactor. It is fed into the reactor at different points. This keeps the reactor temperature from cooling to the point that cracking will not occur and from rising too high as to jeopardize the safety of the operation. In the growing low-sulfur world, the hydrocracker often converts high-sulfur materials, which used to end up in marine or boiler fuel and other industries, into low-sulfur fuels for vehicles and airplanes. The ability to upgrade low-value products into high-value products and convert high-sulfur material to low-sulfur material with a secondary unit like a hydrocracker plays a key role in determining its economic fate.

## Solutions for Challenges in Hydrocracker Installations

Our product line spans feedstock pumps, hydraulic power recovery turbines (HPRTs) for power recovery and reduced emissions and valves.

### Pumps

Feed pumps are supported by the Flowserve BB5 flagship portfolio, **WCC**, **HDO/HSO** and **WIK** in accordance with API 610 latest edition. These pumps feature a cylindrical barrel designed to handle a wide range of conditions at high pressure and temperatures, with a broad experience supported by thousands of references in refinery applications.

#### WCC

Medium-duty, cost-effective, general purpose, diffuser-type barrel pump conforming to ISO 13709/API 610 (BB5) requirements and manufactured to customer specifications. Typically used in refinery services, pipeline, amine feed, ethylene feed, water and CO<sub>2</sub> injection plus hydraulic power recovery applications.

- Optimized hydraulic efficiency and repeatable performance due to precision-cast tandem impellers and optimized balance drum design
- Single-diameter balance drum and multi-vane diffusers balance the hydraulic loads over the operating range while maximizing efficiencies at duty conditions
- Incredible reliability in severe services with advanced close clearance technologies, state-of-the-art erosion- and abrasion-resistant materials in the running fits and robust bearing system
- Reduced downtime and maintenance from the standard cartridge-type construction that allows major assembly and disassembly in the workshop, rather than the field
- Performance testing in accordance with API and Hydraulic Institute testing standards

#### Specifications:

Flows to 1000 m<sup>3</sup>/h (4400 gpm)  
 Heads to 2800 m (9200 ft)  
 Pressures to 275 bar (4000 psi)  
 Temperatures to 425°C (800°F)

#### HDO/HSO

Offered in both general and special purpose configurations, these volute-style barrel pumps are manufactured to customer specifications, often exceeding ISO 13709/API 610 (BB5). Typically used for refinery services, pipeline, amine feed, ethylene feed, water and CO<sub>2</sub> injection plus hydraulic power recovery applications.

- With enhanced features for service in critical processes, the **HDO/HSO** supports the highest reliability supported by all of the advantages of a volute design.
- Improved hydraulic efficiency and performance repeatability provided by the precision-cast opposed impellers
- Nearly balanced axial thrust over the full operating range of the pump is supported by the volute-type opposed impeller design. This limits the pressure breakdown over running clearances to a maximum of 50% of the differential pressure. Increased reliability and excellent rotor dynamics due to the dynamically balanced rotor ensure inherently balanced axial thrust over the full operating range.
- Performance tested in accordance with API and Hydraulic Institute testing standards

#### Specifications

- Flows to 4000 m<sup>3</sup>/h (17 610 gpm)
- Heads to 5365 m (16 000 ft)
- Pressures to 450 bar (6525 psi)
- Temperatures to 425°C (800°F)

**WIK**

Heavy-duty barrel pump intended for special purpose, un-spared, high-power density applications. Pumps are custom engineered to customer requirements, often exceeding ISO 13709/API 610 (BB5).

- Outstanding reliability assured by a high stiffness rotor design with low static deflection, the result of a large diameter shaft and short bearing spans
- Optimized efficiency due to precision-cast, low specific speed impellers, multi-vane diffuser and milled channel collectors to ensure repeatable performance. Smooth, stable performance with multi-vane, split diffuser and channel ring collectors that eliminate radial imbalance across the entire operating range.

- Performance tested in accordance with API and Hydraulic Institute testing standards
- Ease of maintenance with back pullout, cartridge-style construction, allowing quick replacement of the entire sub assembly

**Specifications:**

- Flows to 1600 m<sup>3</sup>/h (7000 gpm)
- Heads to 7000 m (23 000 ft)
- Pressures to 1000 bar (14500 psi)
- Temperatures to 425°C (800°F)

**Power Recovery Turbines**

There are many instances in the hydrocarbon industry where the process of a fluid stream requires its pressure to be reduced (Figure 8.4). This pressure reduction is usually accomplished through the use of a throttling valve where the energy of the fluid stream is lost. In processes where, core hydrocracking and amine regeneration is required, the feedstock must be at high pressure to allow certain reactions to take place. Because downstream units are operated at lower pressure, instead of dissipating power through a valve, energy can be captured by using a power recovery turbine in the liquid flow. Typically, reverse running pumps are being used as power recovery turbines. The internal feedstock flow direction is reversed but the proven design features

taken from the traditional pump product are the same with only minor modifications to the flow paths. The high-pressure flow enters the turbine and activates the rotor, creating a helper effect for the electric motor. The power transmitted is resulting in a saving of electric energy. This energy may then be used for pumping other process liquids. Flowserve produces reliable, highly efficient rotating equipment for hydraulic power recovery with improved internal design to raise efficiency and performance. Flowserve has a proven installed base in heavy-duty refining applications.

Energy savings and reducing CO<sub>2</sub> emissions are the key drivers for the use of this equipment.

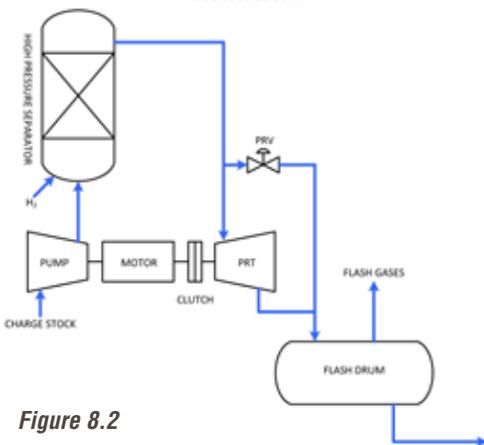


Figure 8.2



Typical power recovery train unit

## Value Proposition Summary: Why Flowserve?

### Industry-Leading Products and Services in Refinery Processes

- Flowserve is the world's leading supplier of pumps, seals and valves for use in refinery applications worldwide.
- Flowserve handles challenging applications found in refineries. From the heavier feeds through the light-end outputs, Flowserve products can effectively pump, seal and control the flow of all phases of the processes.
- Flowserve product designs, materials and auxiliary systems can handle clean products, aromatic compounds and catalyst streams to provide complete solutions to unit operations. Solutions are available to meet all environmental and regulatory requirements.
- Expert engineers for advanced diagnostics, problem solving and custom designs
- Quick Response Centers worldwide, regionally located for customer service and repairs
- Training to ensure operational support on equipment effectiveness and safety



North America

Latin America

Europe

Middle East

Africa

Asia-Pacific

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***Experience In Motion***