FLOWSERVE

FEBRUARY 2020

Application Solutions Guide

ETHYLENE

Experience In Motion

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GLOBAL ETHYLENE LANDSCAPE

Market Overview

Ethylene is a hydrocarbon with the formula C_2H_4 (or $H_2C = CH_2$). It is a colorless, flammable gas, with a faint “sweet and musky” odor when pure. Ethylene is the simplest alkene (hydrocarbon with carbon-carbon double bonds), and second-simplest unsaturated hydrocarbon after acetylene (C_2H_2). The majority of its commercial production occurs via thermal cracking of feedstocks (ethane or naphtha) around the globe. Structurally, ethylene is one of the simplest starting molecules and is used in the production of plastics, chemicals, solvents and intermediates. Its consumption rate is primarily driven by consumer demand.

Ethylene is widely used in the petrochemical industry; its worldwide production exceeded 161 million tons in 2018. The vast application areas of ethylene and its derivates are ubiquitous and present in almost every aspect of modern life, ranging from engineered polymers to disposable packings.

From 2012 through 2018, worldwide ethylene production rose by 3.9% yearly, from 128 to 161 million tons. In 2018, it was being produced by at least 117 companies operating in 55 countries. To meet rising demand for ethylene, significant increases in production capacity have been made globally, particularly in the United States, the Middle East and China.

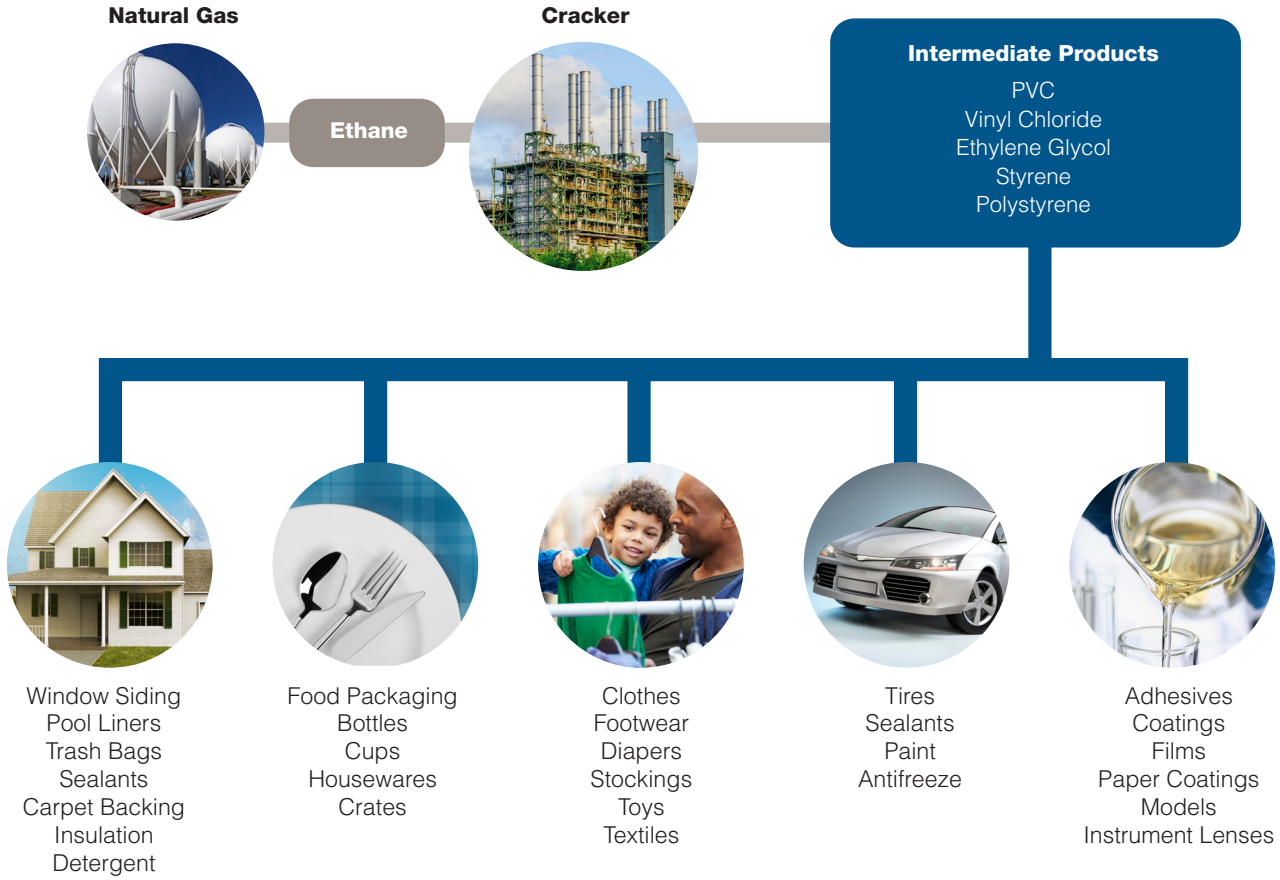


Figure 1.1: End uses of ethylene derivatives

Ethylene Value Chain

Ethylene by itself does not have many end use applications and needs to go through further processing to become valuable products. Major industrial reactions of ethylene (in order of scale) are:

1) Polymerization

2) Oxidation

3) Halogenation and hydrohalogenation

4) Alkylation

5) Hydration

6) Oligomerization

7) Hydroformylation

Polymerization produces polyethylene, which consumes more than half of the world's ethylene supply for films used in packaging, bags and similar products. Linear alpha olefins, produced by oligomerization (the formation of short polymers), are used as precursors, detergents, plasticizers, synthetic lubricants, additives and also as co-monomers in the production of polyethylene.

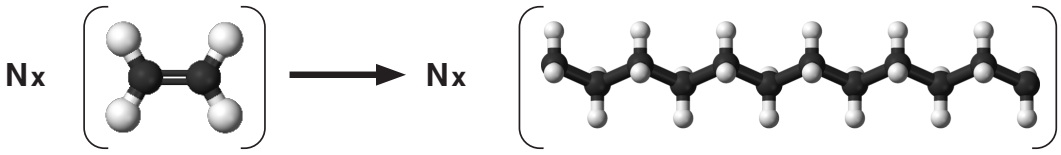


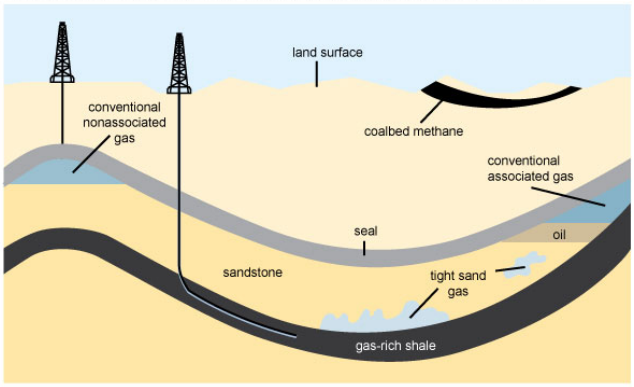
Figure 1.2: Ethylene polymerization

Feedstocks

Crude oil is a mixture of various hydrocarbons. It is de-salted, heated, separated and broken down from big molecules of unusable 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. Naphtha is processed and used in gasoline and solvents, and continues today to be key as feedstock for ethylene crackers in petrochemical plants. However, in the past decade, shale gas (which is a primary source of ethane) is also a key — and growing feedstock — to the petrochemical industry.

The choice of feedstock depends on the resource availability near the location of the ethylene cracker, although trading and transportation of feedstocks at a global level are increasing practices that influence feedstock selection. Traditional regions using naphtha are Europe, India and China; whereas, the United States and Middle East have extensive populations of crackers based on ethane gas and natural gas liquid (NGL). As an alternative, some crackers can use both gas and naphtha, providing additional flexibility to an operator, depending on feedstock prices and availability.

Schematic geology of natural gas resources



Source: Adapted from *United States Geological Survey factsheet 0113-01* (public domain)

Figure 1.3: Schematic geology of shale gas

Ethylene Terminology

The petrochemical industry is very rich in jargon. Technical language is extensively utilized, starting with the different feedstocks through the complex derivatives at the end of the value chain.

Polymer-grade ethylene for the chemical industry, defined as *high-purity grade,* is used primarily for the production of various polymers compared to refinery-grade ethylene. There is no one single chemical grade ethylene specification in existence, but ethylene content normally exceeds 99.70%.

Industry Terminology

Within the petrochemical industry, it's common to find engineering specifications for pumps, seals and valves similar to those used in the petroleum industry, especially in North America. Other regions may be driven by local standards like ISO or GB (China), which in some cases may have a lot of similarities.

Examples of Industry Standards

Pump type[a]			Orientation		Type code
Centrifugal pumps	Overhung	Flexibly coupled	Horizontal	Foot-mounted	OH1
				Centreline-supported	OH2
			Vertical in-line with bearing bracket	—	OH3
		Rigidly coupled	Vertical in-line	—	OH4
		Close-coupled	Vertical in-line	—	OH5
			High-speed integrally geared	—	OH6
	Between-bearings	1- and 2-stage	Axially split	—	BB1
			Radially split	—	BB2
		Multistage	Axially split	—	BB3
			Radially split	Single casing	BB4
				Double casing	BB5
	Vertically suspended	Single casing	Discharge through column	Diffuser	VS1
				Volute	VS2
				Axial flow	VS3
			Separate discharge	Line shaft	VS4
				Cantilever	VS5
		Double casing	Diffuser	—	VS6
			Volute	—	VS7

Figure 1.4: API 610 for pumps

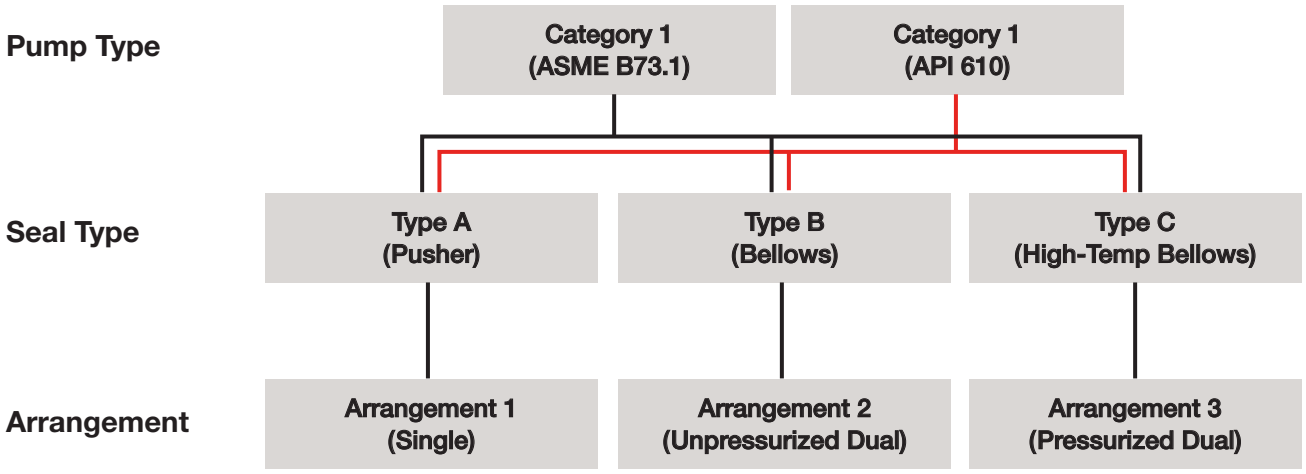


Figure 1.5: API 682 for seals

Industry Standard for Valves

The petrochemical industry does not use a universal API specification for valves like those for pumps and seal systems; however, there are a few specifications written which are often referred.

1) NACE: specs for metallurgy

2) ISA: definitions

- ISA 75.05.01, *angle valve:* a valve design in which one port is colinear with the valve stem or actuator, and the other port is at a right angle to the valve stem.
- ISA 75.05.01, *butterfly valve:* a valve with a circular body and a rotary motion disk closure member, pivotally supported by its shaft.
- ISA 75.05.01, *control valve:* a power-actuated device which modifies the fluid flow rate in a process control system. It consists of a valve connected to an actuator mechanism (including all related accessories) that is capable of changing the position of a flow-controlling member in the valve in response to a signal from the controlling system.
- ISA 75.05.01, *globe body:* a valve body distinguished by a globular-shaped cavity around the port region, wherein the closure member motion is linear and normal to the plane of the port.
- ISA 75.05.01, *positioner:* a position controller, which is mechanically connected to a moving part of a final control element or its actuator, and automatically adjusts its output to the actuator in order to maintain a desired position in proportion to the input signal.
- ISA-TR84.00.03, *final element:* final control elements include the signal connection from the logic solver, the actuation medium supply (typically air), solenoid valves, and the device which affects a process flow change (e.g., valves or pumps).

Across all segments of process control, there are three specific categories of valves:

- There are two types of process valves: automated and manually operated. Typically, automated valves are pneumatically operated as on/off valves and controlled with solenoid valves. This category of valves includes: globe valves (per API Std. 602); butterfly valves (per API Std. 609); gate, plug, ball and check valves (per API Std. 6D), which references ASME B16.10 for valve face-to-face; ASME BPVC, Section VIII, Division 1 or Division 2; ASME B16.34; EN 12516-1 or EN 12516-2; and EN 13445-3 for design principles.
- Control valves are selected for the application based on service conditions, sometimes described as *engineered to order.* The control valve category includes linear motion, globe, angle and rotary motion valves.

For control valves, an industry common practice for face-to-face is in line with ISA 75.08.01, ISA 75.08.02, ISA 75.08.05 and ISA 75.08.06 for globe valves. For angle configuration valves, ASME B16.10 provides guidance for face-to-face. Control valves follow ASME B16.34's design principles.

Final control elements can be configured with pneumatic, electric or hydraulic actuation and are equipped with positioners to provide position throttling.

Ethylene Process Overview

Cracking is a process whereby complex organic molecules (such as long-chain hydrocarbons) are broken down into simpler molecules (such as light hydrocarbons) by the breaking of carbon-carbon bonds in the precursors. The products resulting from the reaction can vary widely, depending on the composition of the feed and the severity (temperature) of the cracking operation.

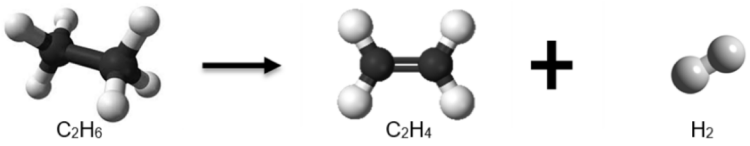


Figure 1.6: Ethane cracking reaction

Most global ethylene production is based on thermal cracking of either naphtha or ethane with steam. Other processes for the production of ethylene are recovery from FCC off-gas, FCC cracking, catalytic pyrolysis, and coal-to-olefins and methanol-to-olefins conversions.

Below is a general production sequence flow sheet for a typical steam cracking process for the production of ethylene from ethane (gas feed) or naphtha (liquid feed).

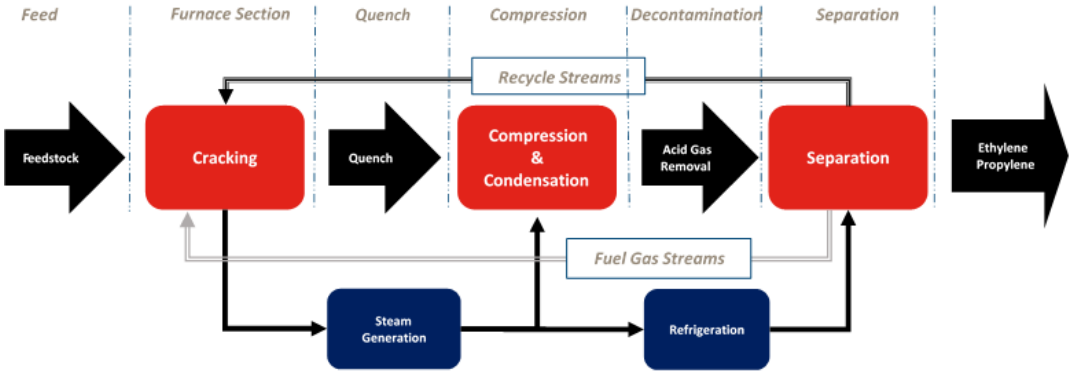


Figure 1.7: Ethylene steam cracker process

This process includes:

1. A feed section where feedstock is pre-treated and conditioned for the process
2. A furnace section where high temperatures are used to crack the hydrocarbon feed into ethylene and other various products
3. A quench tower to rapidly cool the exiting stream from the furnace to preserve the current composition and prevent undesirable side reactions from occurring
4. A compression and condensation section, which is required to control the distribution of light and heavy components in vapor and liquid phases, especially ethylene and propylene
5. A decontamination section to clean up impurities and increase the quality of the end products
6. A fractionation system to separate the remaining products by using distillation at low and cryogenic temperatures

The process outlined above is highly intensive in both capital and energy; thus, it requires long development and construction periods preceded by extensive economic evaluations. An average investment in a new large steam cracker could be well more than $1 billion.

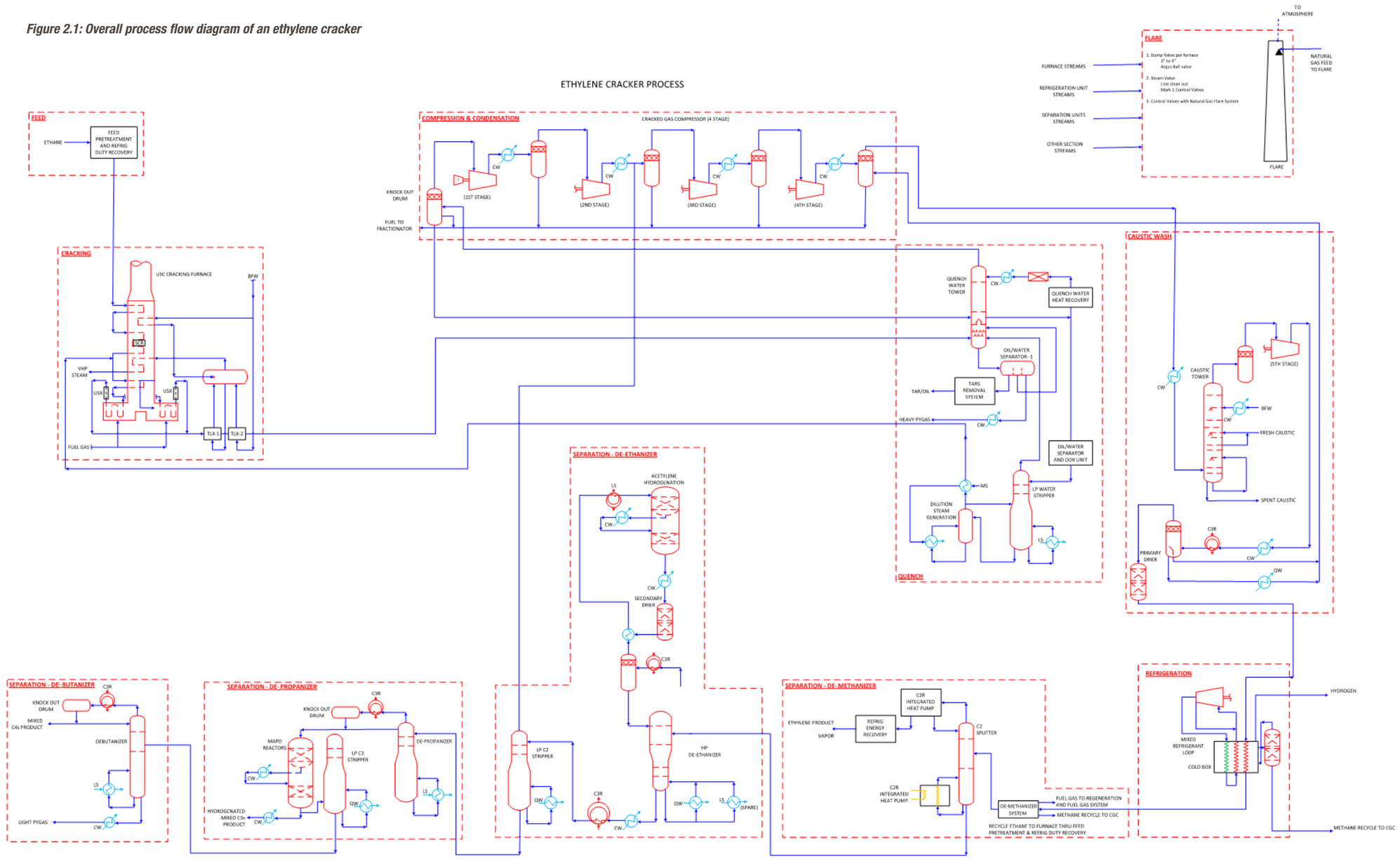
Technology Providers

From a technological perspective, steam cracking is a mature process that has been applied for more than 50 years with steady improvements in yields. Many technology developers currently emphasize making gas and steam crackers increasingly larger to realize economy of scale and reduce investment costs. Currently, the largest steam crackers have an annual ethylene capacity of 1.5 million tons, but some are now approaching 2 million tons. These crackers are designated as *world-scale crackers.* Today, there are four major licensors of ethylene plants: KBR; Technip; Linde; and McDermott. While ethylene production differs slightly by licensor, among them its overall process is fairly similar. Licensors compete and differentiate on the basis of technology capabilities to provide optimum performance characterized by:

- Purity of ethylene produced
- Energy consumption
- Flow and feed rates
- Low cost of operation
- Low investment cost

A CLOSER LOOK AT ETHYLENE PROCESSES

Figure 2.1: Overall process flow diagram of an ethylene cracker



Feed

Crackers are specifically designed to crack ethane gas, naphtha liquid or mixed-gas liquid feeds, and end up being designated as such by the nature of the feed. Crackers in growth locations like the U.S. typically crack ethane gas as the feed, whereas in China, steam cracking of naphtha liquid is the preferred feedstock. In some regions, like in the Middle East, where a gas (ethane) and liquid (naphtha, LPG) mixed feed is used as the starting point, these units are called *mixed feed crackers.* Depending upon the nature of the feed and the associated impurities of the pre-treatment, the processing steps will vary. Pre-treatment is important to eliminate poisons that could impact the performance of the furnace coils, meet regulatory standards, and reduce the frequency of decoking — all of which contribute to a safe, efficient and economical operating process.

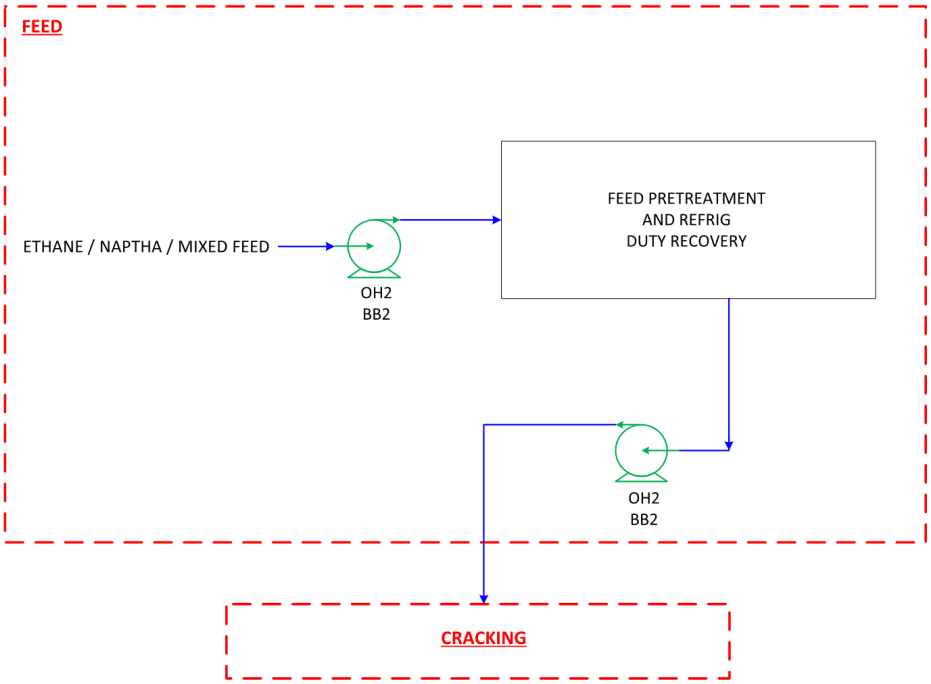


Figure 2.2: Ethylene cracker, feed section

API/PUMP	APPLICATION
OH2: HPX	Heavy naphtha furnace feed
OH2: HPX	Fuel oil recycle to naphtha
BB2: HDX/HED	Feed pumps

VALVE	APPLICATION
Argus™	Hydrocarbon feed shutoff

Cracking

The hydrocarbon feed (naphtha, ethane or mixed feed) is preheated or mixed with steam and then heated to higher temperatures. This heated steam is then fed to a tubular reactor, also known as the *hot section,* where it is further heated up and cracked. Controlling the temperature in this section is critical in order to avoid any side reaction or breakdown of the heated hydrocarbon stream. Adding dilution steam enhances ethylene yield and is also used as an operating step to reduce coking in the furnace coils, especially for naphtha crackers.

The deposition of coke residue on the reactor walls typically results in a reduction of heat transfer coefficient. This also causes the pressure drop to rise across the reactor, which hurts the overall production capability of the unit. The combination of coke deposition and a pressure drop across the reactor necessitates a higher number of periodic shutdowns. Careful and deliberate control of the coking rate permits operators to run the furnace at a higher severity; combined with a reduction in downstream unloading equipment, this increases overall throughput.

If a unit resorts to frequently utilizing decoking, it will reduce coil life and increase utility costs. Historically on average, a run length before decoking usually lasts for ~90 days for ethane feed and slightly lower ~60 days for naphtha feedstocks. Leading cracking furnace designers target furnace capacity, cracking severity, ethylene selectivity, thermal efficiency and reduced decoking as areas of continuous improvement for boosting capacity and reducing total costs. This is where most technology providers continually distinguish themselves — and also should be an area of focus for Flowserve to address our end customers' pains. The cracker is the largest consumer of energy in an ethylene plant and by far the highest operational cost contributor.

API/PUMP	APPLICATION
OH2: HPX	Dilution steam generator feed
BB3: DMX BB5: WCC/HDO	Boiler feedwater
OH3: PVXM, HPXV OH2: HDX OH1: Mark 3™	Boiler feedwater condensate
OH2: HPX	Bottom cracker

VALVE	APPLICATION
Valtek® Mark 100	Dilution steam
Valtek Mark 100	Hydrocarbon feed
Valtek Mark 100	Furnace fuel gas
Valtek Mark 100	Decoking air
Argus FK76 trunnion ball valve	Transfer line valves
Argus FK76 trunnion ball valve	Decoking effluent
Argus FK76, Worcester®	Furnace fuel shutoff
Automax, Supernova	Furnace feed

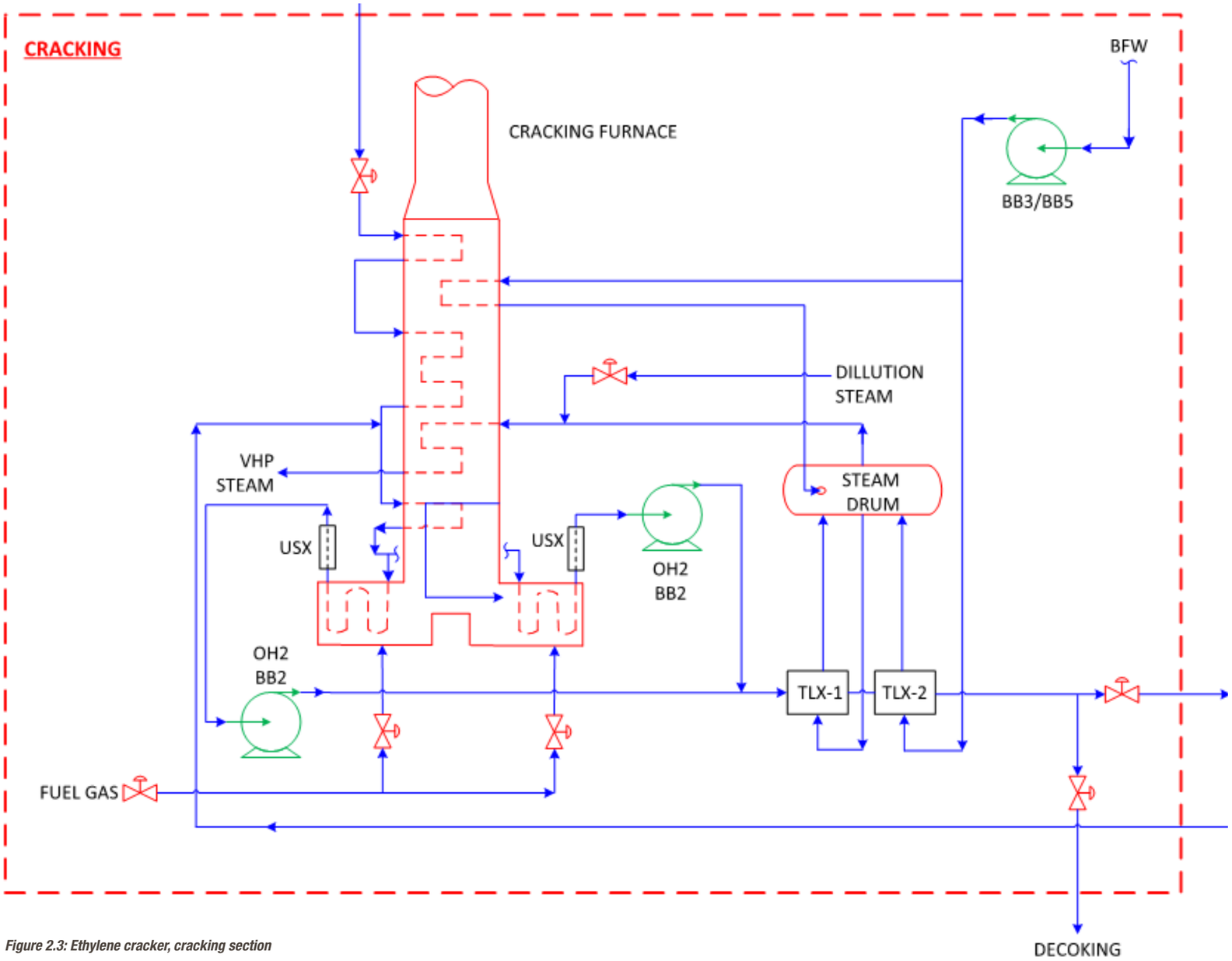


Figure 2.3: Ethylene cracker, cracking section

Quench

To reduce and eliminate undesirable cracking reactions that lead to coking and polymerization, the hot effluent or hydrocarbon steam is cooled down in the quench section. Heat exchangers are used to decrease the temperature of the effluent, usually in an indirect water-cooling mode. The hot water produced during this cooling step is used to generate process steam for use in other parts of the plant. This is also where technology providers differentiate their process designs by combining multiple functionalities into one unit.

API/PUMP	APPLICATION
BB1: LPN BB2: HDX	Quench water
BB1: LPN BB2: HDX	Quench oil
OH2: HPX	Quench stripper bottoms

VALVE	APPLICATION
Valtek ShearStream HP Valbart™ TMCBV (trunnion-mounted control ball valve)	Quench tower-level control

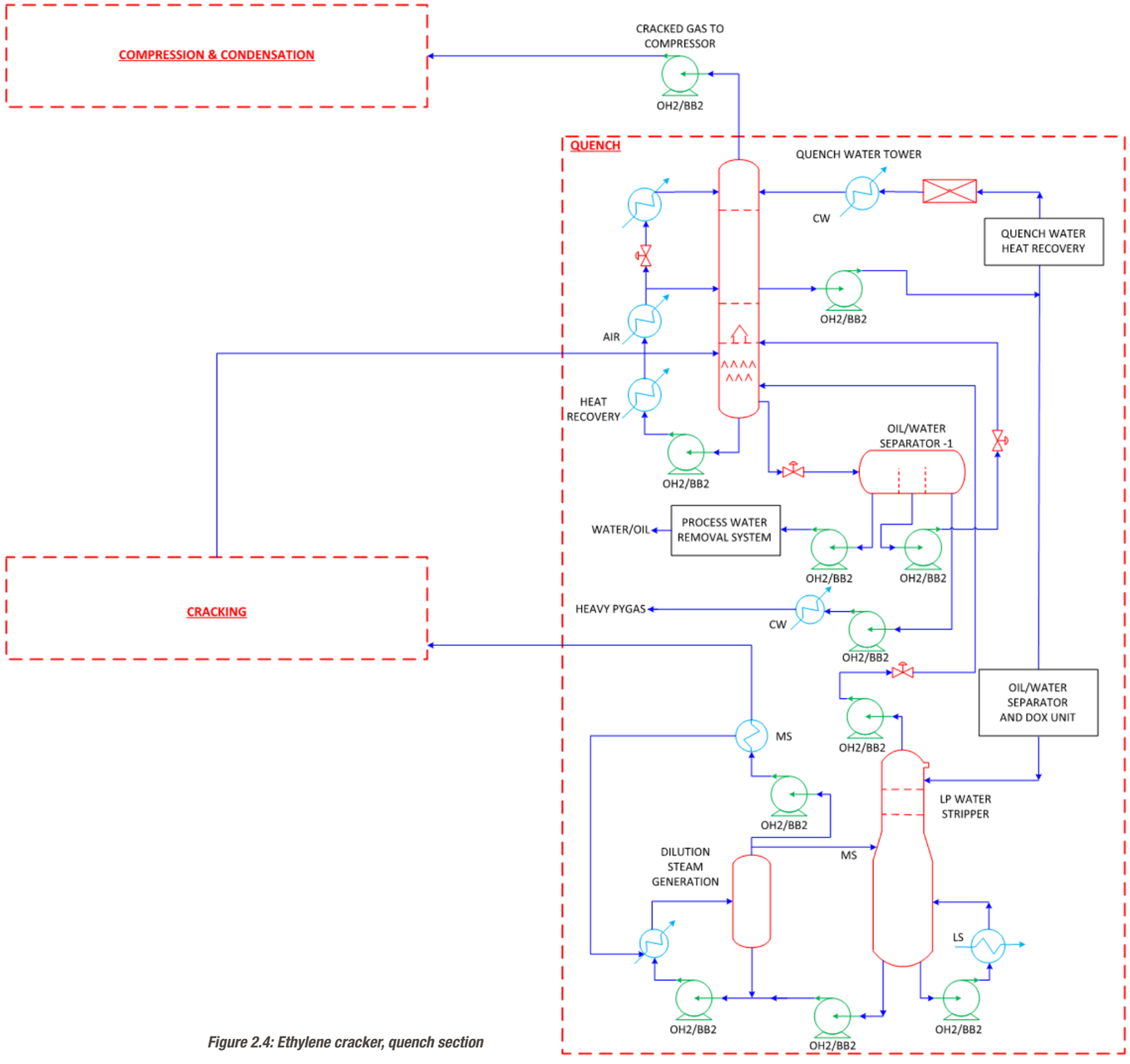


Figure 2.4: Ethylene cracker, quench section

Compression and Condensation

After the cooled gas effluent steam exits the quench section, it is then compressed in a four- or five-stage compressor train for splitting the main steam into various cuts. Water and hydrocarbons are separated (and then recycled) between stages using a knockout drum and heat exchanger configuration. The actual temperature and pressure range varies depending upon the process design and technology capability of the process licensor.

API/PUMP	APPLICATION
OH2: HPX BB1: LPN BB2: HDX	Cracked gas condensate

VALVE	APPLICATION
Valtek Mark 100	Anti-surge valve
Valbart TMBV (trunnion-mounted ball valve)	Fast-stop valve
McCANNA™	Compressor isolation

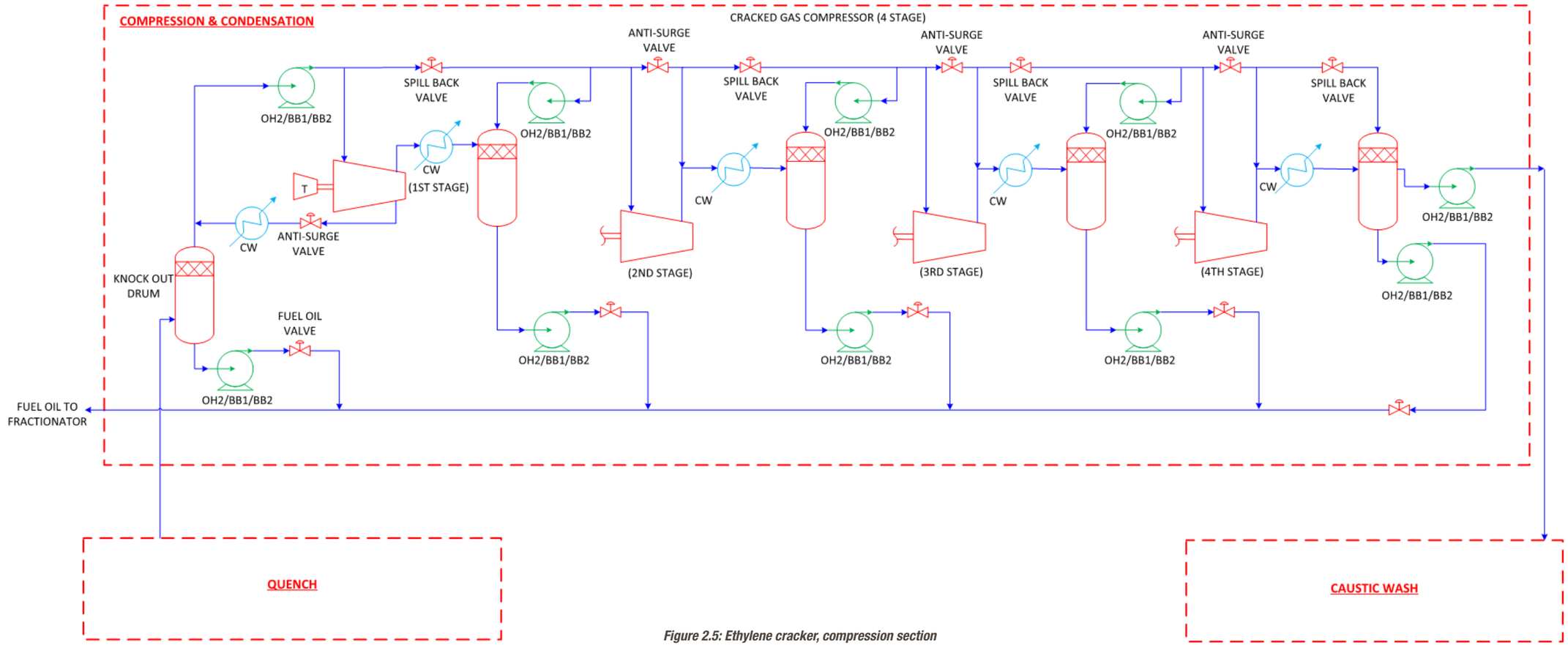


Figure 2.5: Ethylene cracker, compression section

Caustic Wash

Acid gases, particularly carbon dioxide (CO_2) and hydrogen sulfide (H_2S), are removed in the latter compression stages. Depending upon the quality of the feedstocks (especially sulphur content), fewer or more separating processes may be required in the decontamination section. This process is also known as the *acid-gas removal step.* It comprises the following:

- Carbon dioxide is removed because it can freeze at low temperatures in heat exchanger and fractionation equipment. It can also be absorbed into ethylene, affecting product quality and further processing.
- Hydrogen sulfide is corrosive, a catalyst poison and a potential product contaminant.

CO_2 and H_2S concentrations in the overhead steam of the caustic wash are typically below 0.2 ppm.

Spent caustic is the most contaminated liquid effluent in an ethylene plant because it is the outlet for various trace components accumulating in the process. In addition to the sulfur and carbonate load, the steam further carries traces of dissolved hydrocarbons, organic acids, ketones, alcohols and aldehydes. In a final step, moisture must be removed before separation to prevent the formation of hydrates and ice. Typically, this is accomplished by chilling and adsorption on molecular sieves. Due to sodium hydroxide's concentration and temperature, some valve applications deemed to be in a highly corrosive process demand high-nickel materials such as Monel® 400.

API/PUMP	APPLICATION
OH2: HPX	Caustic circulation
OH2: HPX	Wash oil circulation
OH2: HPX	Spent caustic discharge

VALVE	APPLICATION
Mark One™ standard	Several caustic wash systems
Valtek MaxFlo®	General caustic applications

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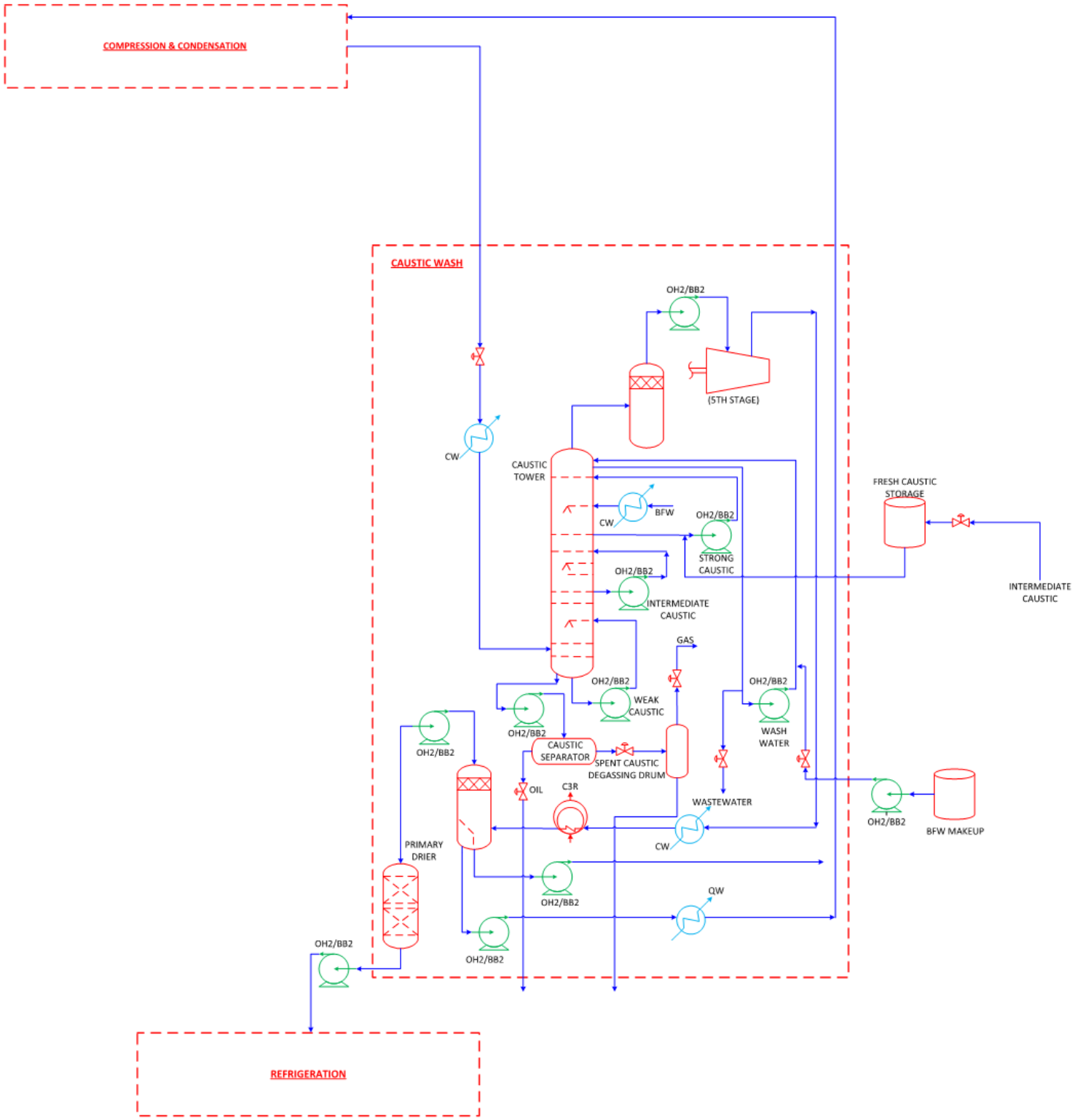


Figure 2.6: Ethylene cracker, caustic wash section

Refrigeration

One of the critical functions of the refrigeration section is to condense the pyrolysis gases over multiple steps. The incoming effluent temperature is reduced to cooler exiting temperatures using a cryogenic refrigeration system. In some processes, a dual refrigeration system comprising of ethylene and propylene refrigeration units is used instead of a mixed refrigerant loop. These refrigeration systems (either open or closed loop) are closely heat-integrated into the fractionation section.

Some also employ a small methane refrigeration loop around the De-methanizer section. The refrigeration section also generates a significant amount of hydrogen gas that is sent to the pressure swing adsorption (PSA) unit. A typical PSA unit generates high-purity gases like hydrogen and oxygen, which are used in specialized applications such as the semiconductor and medical industries. The majority of flow control in this unit is done using a large quantity of valves in addition to various compressors.

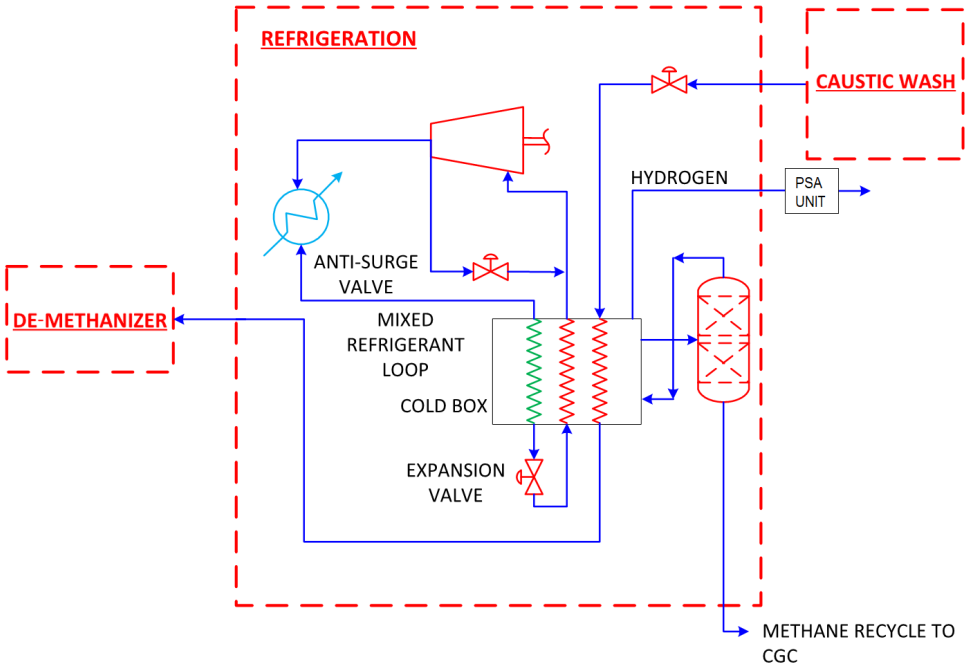


Figure 2.7: Ethylene cracker, refrigeration section

VALVE	APPLICATION
Valtek Mark 200	Expansion valve
Valtek Mark 100	Anti-surge
Valtek Mark 100 Valtek MaxFlo Valtek Valdisk™	PSA unit

Separation

After exiting the refrigeration section, the effluent enters the final separation section, wherein high-value products like ethylene, propylene, butylene and mixed hydrocarbons (higher than C_4) are separated. This is implemented using a series of tower fractionation systems for each of the valuable steams in addition to high-pressure steam.

From a process flow perspective, each of the subsequent columns receives the bottom feed of the previous column, starting with the De-methanizer or De-ethanizer column and ending with the De-butanizer column. The effluent (compressed cracked gas) enters the separation section for separation into various hydrocarbon fractions at specified qualities and concentrations. Most of these separations are undertaken through a series of distillation columns and hydrogenation reactors using acetylene. Today, cryogenic separation is a predominant but challenging process that is utilized for separating the components from the cracked gas.

Some processing routes have gained commercial importance using a combination of a separation (fractionation) step in conjunction with the position of the hydrogenation of the acetylene step contained in the cracked gas.

These basic processes differ in the configuration of steps for any given feedstock, but provide similar overall capabilities for fractionation and hydrogenation. The differences are primarily in the sequence of fractionation and hydrotreating steps downstream of the cracked gas compression.

Methane gas removal primarily occurs in the De-methanizer column as the overhead component, while ethylene and other heavier contents form the bottom components. Methane is usually used as fuel gas to heat a plant, and ethylene is separated from the heavier steams using the ethylene splitter. This is also a critical processing stage, which leads to a significant generation of hydrogen coming out of the De-methanizer column and recycled back into other areas of the plant that need it, such as the PSA unit.

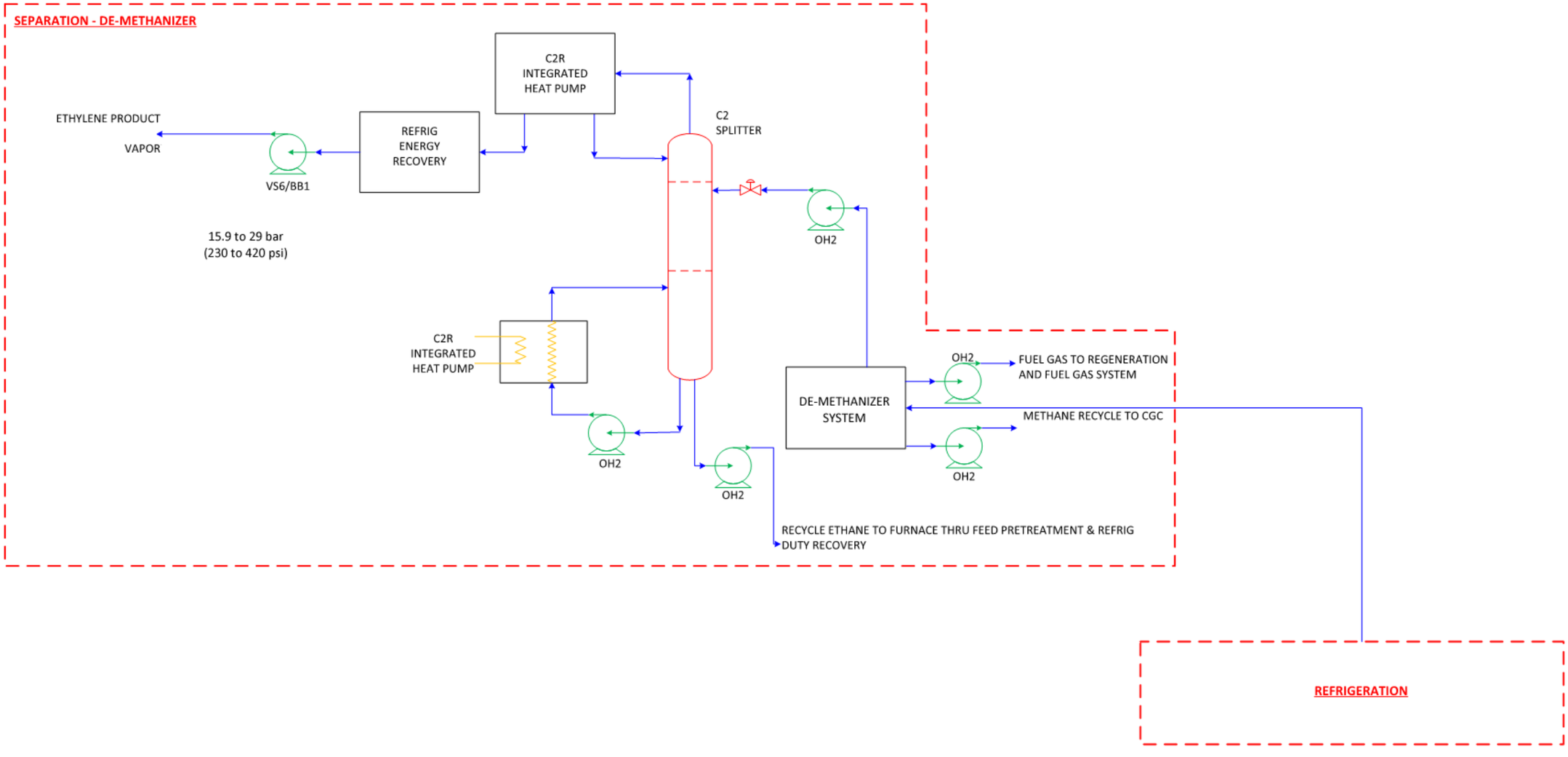


Figure 2.8: Ethylene cracker De-methanizer

Next in the De-ethanizer section: ethylene, unconverted ethane and acetylene are separated from C_3 and higher fractions which comprise the bottom components. The prime ethylene component then forms the top stream coming out of the ethylene stripper and is routed to the ethylene collection pool. The unconverted acetylene is recycled back to the process area, where it is reused for hydrogenation.

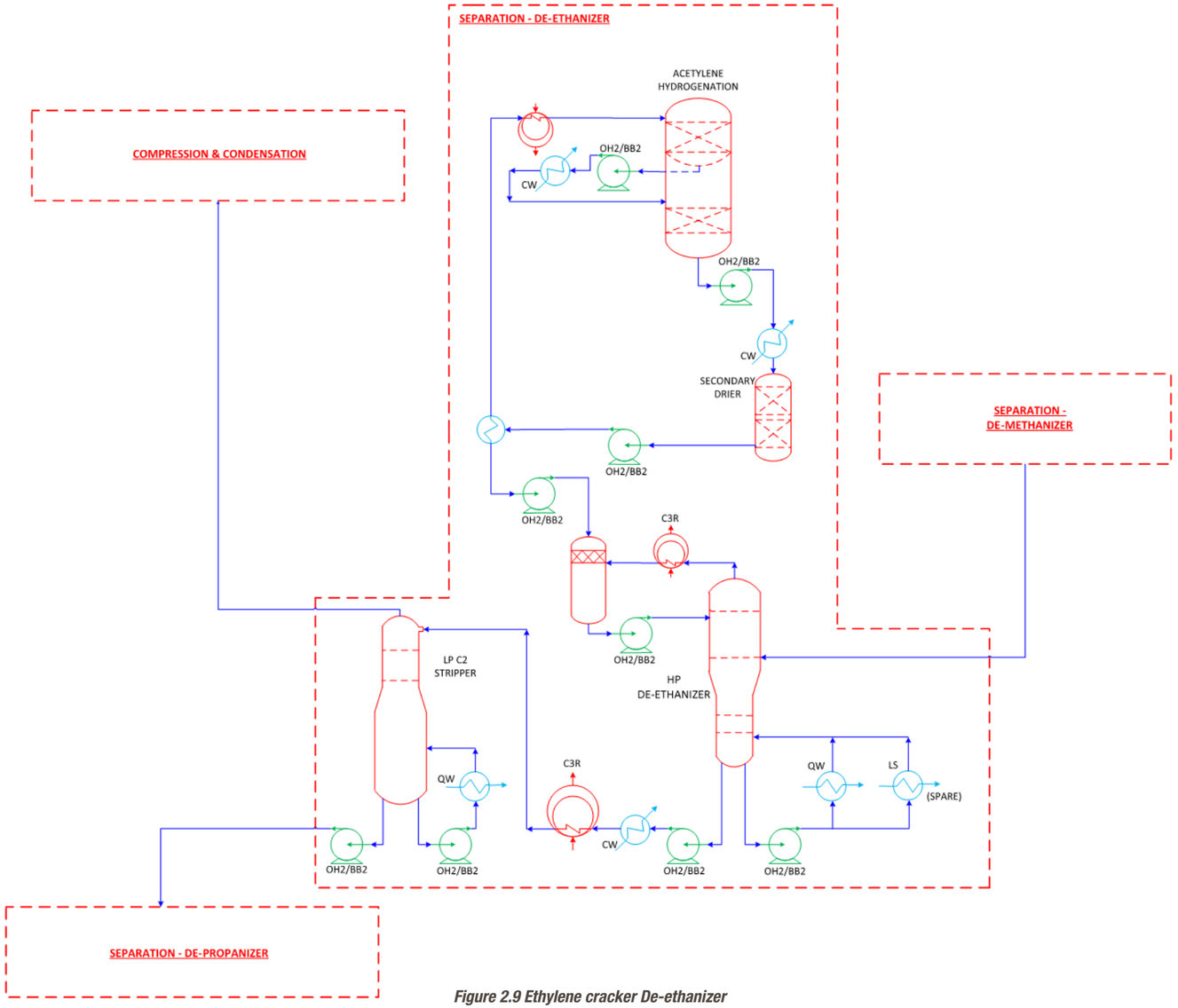


Figure 2.9 Ethylene cracker De-ethanizer

The De-propanizer section separates propane and propylene (especially when naphtha feed is used as the liquid feed) as the top or light end component, while C_4 and higher components form the bottom components. Once again, any leftover ethylene is fractionated using the ethylene splitter and routed back to the ethylene pool. Available propylene, especially when naphtha feed is used, is then separated using a propylene splitter column and routed back to the propylene pool.

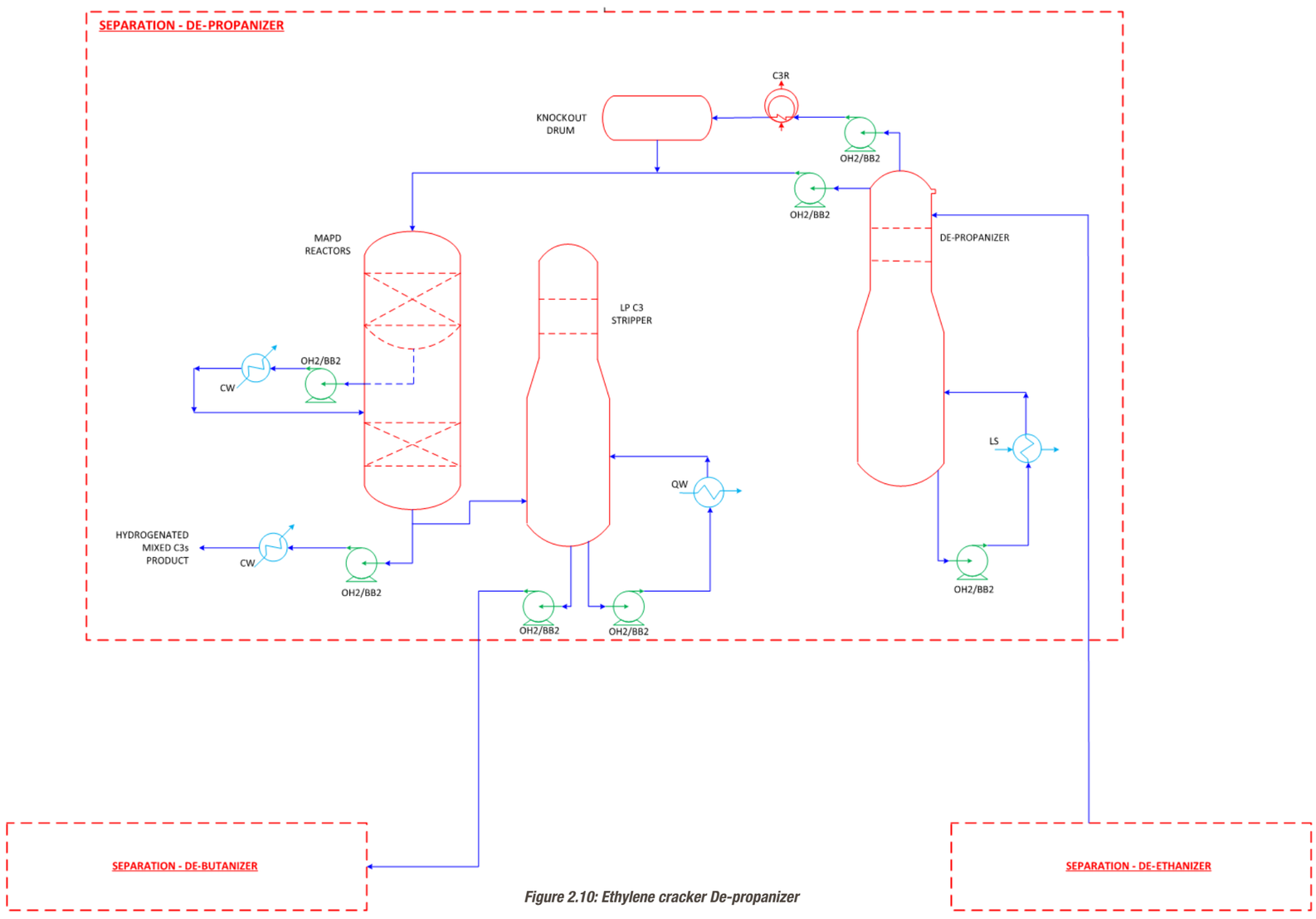


Figure 2.10: Ethylene cracker De-propanizer

In the final De-butanizer section, butane and butylene are separated as the lighter end coming out of the De-butanizer column with pyrolysis gasoline (pygas) forming the bottoms. If there is a sufficient quantity of butylene available in the top stream, then it is further separated and collected for a wide variety of specialty chemical production activities.

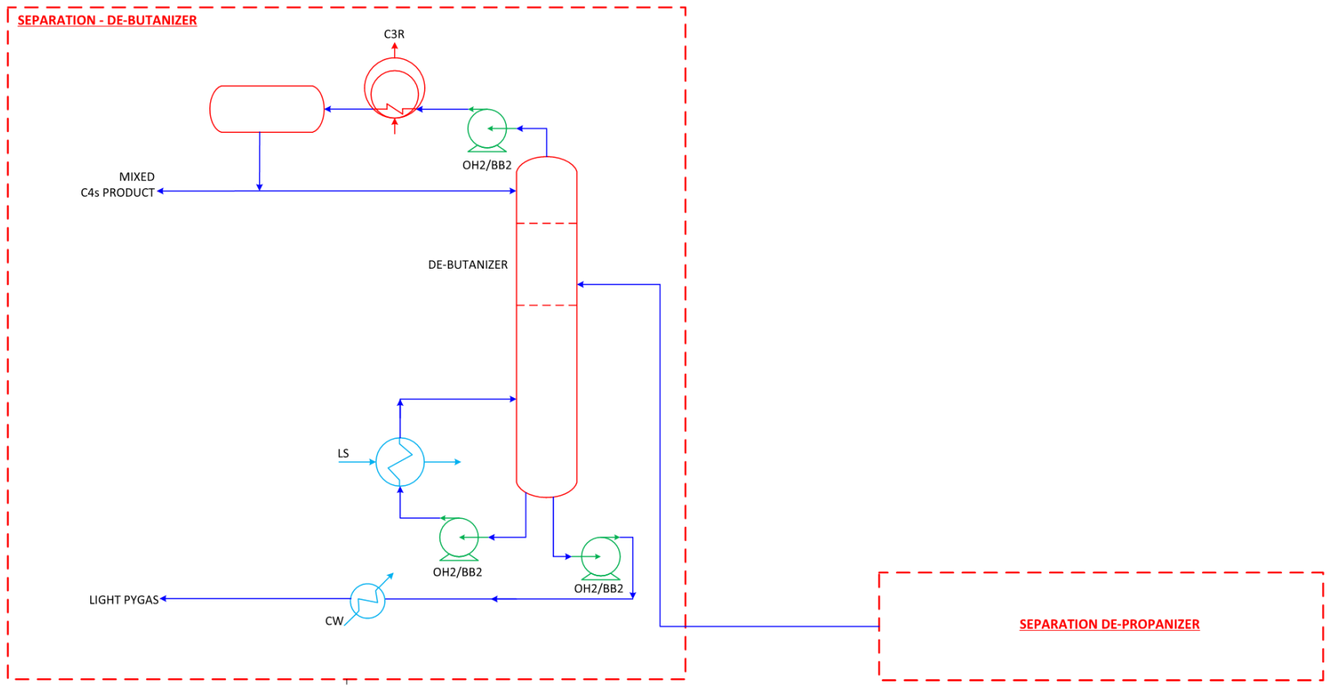


Figure 2.11: Ethylene cracker De-butanizer

API/PUMP	APPLICATION
BB5: HDO/WIK VS6: WUC	Ethylene product
VS6: WUC	De-methanizer reflux

VALVE	APPLICATION
Argus FK76 trunnion ball valve	Acetylene reactor
Valtek Mark One	Ethylene depressurizing
Valtek Mark One	Reflux valves
Valtek Mark One ChannelStream™	Bottom product
Valtek Mark One MegaStream™	Overhead product

Fundamental Principles Behind Selection and Use of Pump, Valve and Actuation Products

In all of the various processing sections of a cracker, high-temperature cracking, compression, refrigeration and distillation are the most common processes utilized. Refrigeration in ethylene plants is a highly critical and expensive operation. Typically, refrigeration compression trains are used for ethylene and propylene compression in addition to cracked gas. High-pressure, anti-surge valves are used often in these applications; this is a critical area of focus for Flowserve. The use of anti-surge control valves is typically preferred in these compression systems for controlling the operation instead of adjusting the speed of the turbine in the event of a surge.

Distillation columns are used to separate the input stream into light-component and heavy-component streams. The whole process relies on the differences in boiling points of each of the components and using heat (temperature differences) as the driving element to separate these components. The operation of the distillation column is highly complex and uses a combination of temperature differential, pressure drop and flow control elements in addition to reflux and recycled streams and residence time.

Feed pumps are used for charging the feed stream into any of these sections at designed flow rates, whereas feed valves are used as flow- or level-control loops. Any deviation from the desired feed properties in terms of pressure, temperature, flow and recycle rate has an adverse effect on operational costs (utilities), purity targets and overall energy consumption.

Reflux pumps and valves are usually used for flow or temperature control (or both). Typically, the performance of an overhead reflux loop varies with the changing purity requirement necessary to meet the final product's quality target. However, severe swings in operation of the reflux loop can significantly impact the operation of the unit, leading to higher operational costs and occasional process upsets. A poorly designed or operating pump and valve can have operational implications for the producer, which typically result in higher costs, efficiency of the column (lower production rate) and oscillations in product purity.

The bottom and top product pumps and valves set the levels within the column and the overhead receiver. If the pumps and valves do not function as designed, they negatively affect the level in the column or reactor, causing flooding or an overall reduction in efficiency.

Pressure control valves provide the designed back pressure for stable operation of the column or reactor and impact on operational stability. In most cases, when a reactor or column experiences pressure swings and difficulty in control, it is usually the result of a valve's under or overdesign (and in some cases, pumps).

The reboiler pump (which is used in heat exchangers) and valve control the feed rate and amount of heat that goes in and out of the column from the reboiler. Although not all processes utilize reboilers, it is a very critical piece of equipment used to provide the designed amount of heat or temperature control to the top, middle and bottom sections of a column.

Many processes described herein are performed at low or even cryogenic temperatures in an ethylene cracker. This threshold represents a technical challenge that can be overcome only with sound engineering practices. These include:

- Adequate selection of materials to avoid embrittlement at low temperatures
- Fatigue-proof designs
- Outstanding hydraulic designs for low viscosity and low suction pressure fluids
- Specific seals and sealing systems minimizing the formation of ice and eliminating the use of expensive barrier fluids

Auxiliary Services

Like in many other large-scale industrial facilities, numerous auxiliary services are required for the proper performance of the main systems. These applications are usually covered by standard pumps, seals and valves, which are also designed to meet strict quality and reliability standards. Most typical processes are related to cooling or recirculation applications, with different grades of complexity, depending upon the pumped fluid and customer-specific requirements.

API/PUMP	APPLICATION
OH1: Mark 3	Closed cooling circuit
BB2: HDX	Water recirculation
VS1/VS6: VTP	Cooling water intake

VALVE	APPLICATION
Argus/Worcester ball valves	Drain, steam tracing, isolation, bypass

FLOWSERVE-ETHYLENE LANDSCAPE

Business Impact and Focus Areas

THE INDUSTRY'S MOST COMPLETE FLOW CONTROL PORTFOLIO

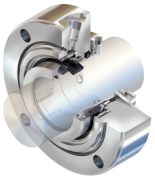
				
PUMPS	**VALVES**	**SEALS & SUPPORT SYSTEMS**	**SERVICES & SOLUTIONS**	**SPECIALIZED OFFERINGS**
• Overhung • Between Bearings • Vertical • Positive Displacement • Specialty Products • Decoking Systems • Vacuum Systems	• Control • Quarter-Turn • Multi-Turn • Check • Positioners • Gate • Globe	• Standard Cartridge • Pusher and Bellows • Slurry • Lift-Off and Dry Running • Mixer and Compressor • OEM and Special Duty	• Aftermarket Parts and Services • Engineering and Technical Services • Education and Training • Asset Management and Optimization	• Actuation and Instrumentation • Steam Traps and Systems • Hydraulic Decoking Systems • Energy Recovery Devices • Monitoring and Controls • Castings and Foundry Services

Table 3.1: Pump and valve asset summary

Products for Ethylene – At a Glance

As the global demand for petrochemicals continues to grow, Flowserve is the driving force in the flow control marketplace. No other pump, valve, actuation and mechanical seal product 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, our pump portfolio boasts some of the world's most renowned pump, seal, valve and actuator brands.

Industry-Leading Brands

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

Flowserve addresses the challenges end users face every day.

PUMP TYPES USED IN ETHYLENE CRACKERS

Overhung

Chemical Process—ISO

Durco Mark 3 ISO (OH1)

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

SPECIFICATIONS
Flows to 1400 m^3/h (6160 gpm)
Heads to 220 m (720 ft)
Pressures to 25 bar (362 psi)
Temperatures -80°C to 400°C (-110°F to 750°F)
For more information, refer to PS-10-31.

Chemical Process—ANSI

Durco Mark 3 ANSI (OH1)

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

SPECIFICATIONS
Flows to 4540 m^3/h (20 000 gpm)
Heads to 215 m (700 ft)
Pressures to 27 bar (400 psi)
Temperatures -73°C to 370°C (-100°F to 700°F)
For more information, refer to PS-10-13.

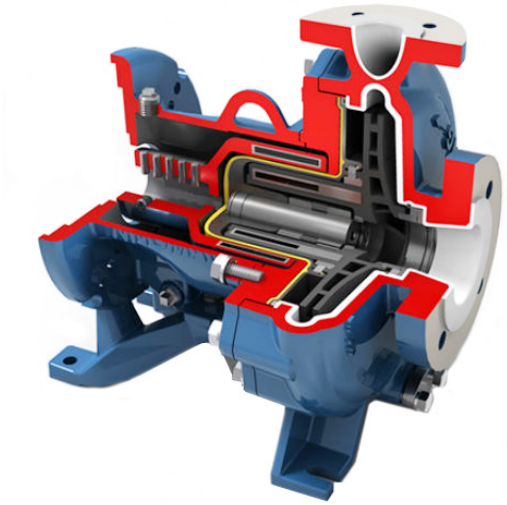
Overhung

Chemical Process—ANSI, ISO

INNOMAG® TB-MAG (OH1)

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^3/h (1585 gpm)
Heads to 153 m (500 ft)
Pressures to 25 bar (362 psi)
Temperatures -29°C to 121°C (-20°F to 250°F)
For more information, refer to PS-10-36.

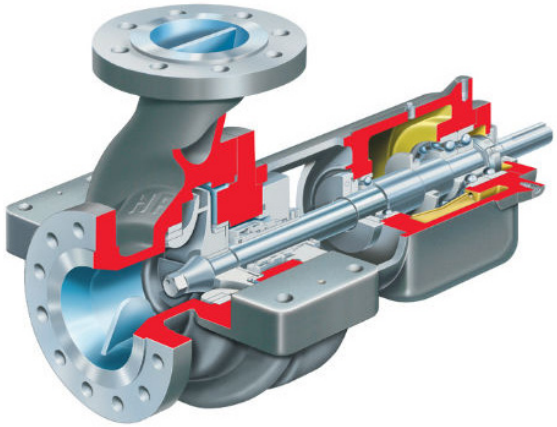


API Process

Worthington, 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 unequaled versatility, reliability and safety.

SPECIFICATIONS
Flows to 3000 m^3/h (13 200 gpm)
Heads to 350 m (1100 ft)
Pressures to 80 bar (1160 psi)
Temperatures -160°C to 450°C (-250°F to 842°F)
For more information, refer to PS-10-5.



Overhung

API Process

Flowserve HPX-V (OH3)

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

SPECIFICATIONS
Flows to 1200 m^3/h (5200 gpm)
Heads to 325 m (1070 ft)
Pressures to 42 barg (600 psig)
Temperatures -40°C to 400°C (-40°F to 750°F)
For more information, refer to PS-10-43.

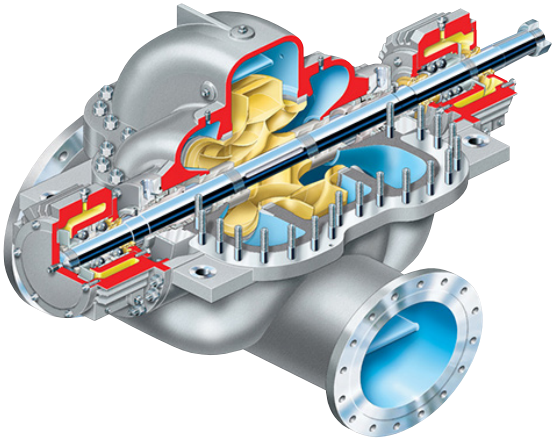
Between Bearings

Single-Case—Axially Split—API

Worthington 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^3/h (65 000 gpm)
Heads to 250 m (820 ft)
Pressures to 50 bar (725 psi)
Temperatures -80°C to 204°C (-110°F to 400°F)
For more information, refer to PS-20-5.



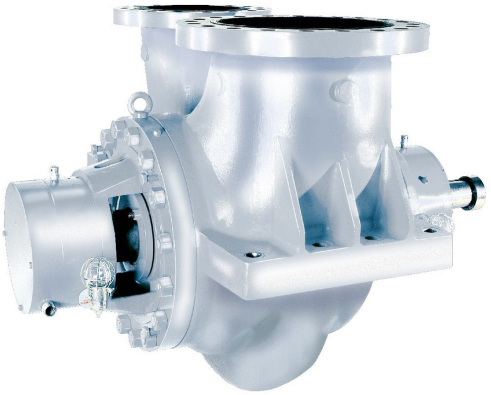
Between Bearings

Single-Case—Radially Split

Flowserve 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^3/h (22 000 gpm)
Heads to 450 m (1500 ft)
Pressures to 100 bar (1450 psi)
Temperatures to 450°C (842°F)
For more information, refer to PS-20-4.

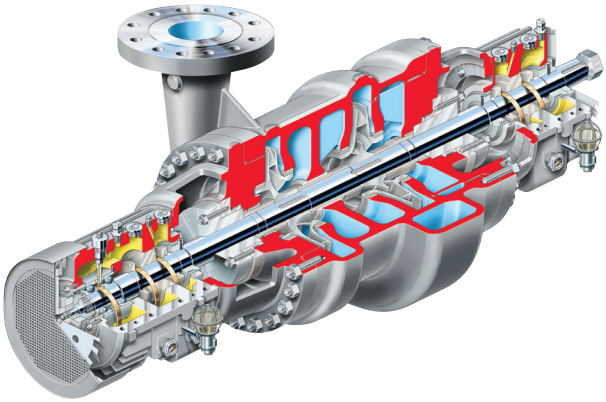


Single-Case—Radially Split

Byron Jackson 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^3/h (8800 gpm)
Heads to 650 m (2100 ft)
Pressures to 120 bar (1750 psi)
Temperatures to 450°C (842°F)
For more information, refer to PS-30-4.



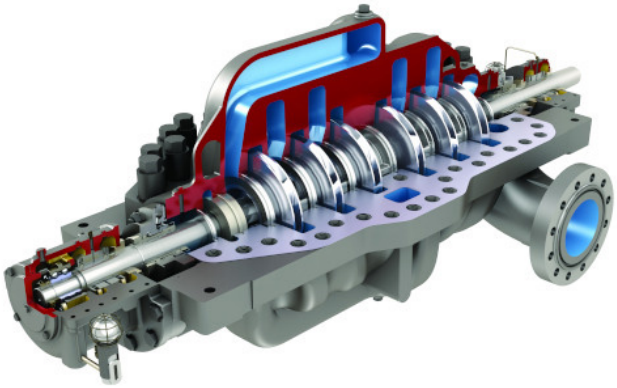
Between Bearings

Single-Case—Axially Split—API

IDP DMX (BB3)

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

SPECIFICATIONS
Flows to 5621 m^3/h (24 750 gpm)
Heads to 2620 m (8600 ft)
Pressures to 275 bar (4000 psi)
Temperatures to 204°C (400°F)
For more information, refer to PS-30-3.

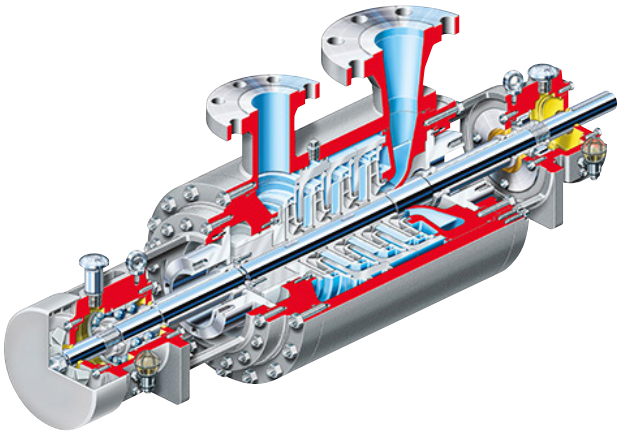


Horizontal—Multistage—Double-Case

Pacific WXB (BB5)

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. A WXB-B with Barske-style impeller design option is available.

SPECIFICATIONS
Flows to 300 m^3/h (1320 gpm)
Heads to 1560 m (5116 ft)
Pressures to 200 bar (2900 psi)
Temperatures to 425°C (800°F)
For more information, refer to PS-30-6 and PSS-30-6.1.

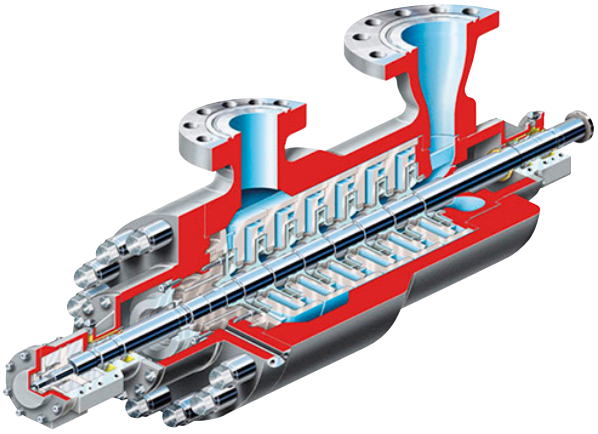


Between Bearings

Horizontal—Multistage—Double-Case
IDP 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_2 injection, plus hydraulic power recovery.

SPECIFICATIONS
Flows to 1000 m^3/h (4400 gpm)
Heads to 2800 m (9200 ft)
Pressures to 275 bar (4000 psi)
Temperatures to 425°C (800°F)
For more information, refer to PS-30-7.



Horizontal—Multistage—Double-Case
Byron Jackson 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^3/h (17 610 gpm)
Heads to 5365 m (16 000 ft)
Pressures to 450 bar (6525 psi)
Temperatures to 425°C (800°F)
For more information, refer to PS-30-8.

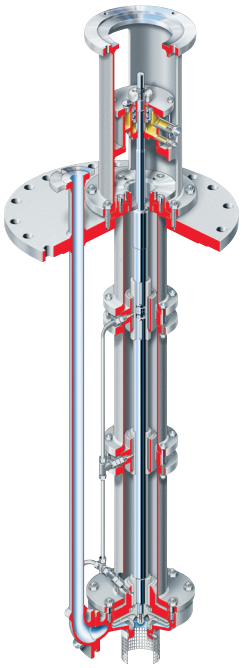
Verticals

Sump

Worthington 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^3/h (4400 gpm)
Heads to 150 m (500 ft)
Pressures to 20 bar (285 psi)
Temperatures to 350°C (660°F)
For more information, refer to PS-10-10.

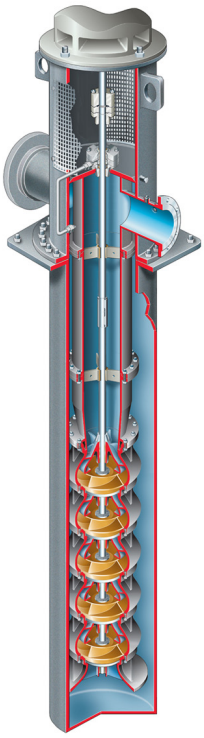


Double-Case

Flowserve 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^3/h (60 000 gpm)
Heads to 1070 m (3500 ft)
Pressures to 100 bar (1450 psi)
Temperatures -73°C to 230°C (-100°F to 450°F)
For more information, refer to PS-40-2.



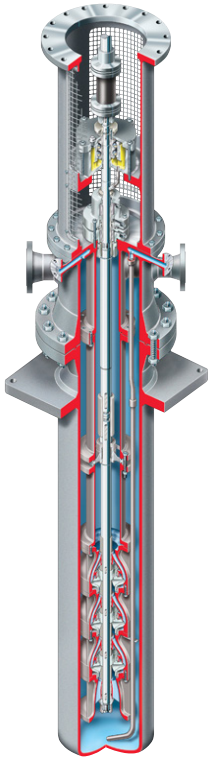
Verticals

Double-Case

Worthington 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^3/h (13 200 gpm)
Heads to 2000 m (6560 ft)
Pressures to 200 bar (2900 psi)
Temperatures -200°C to 350°C (-328°F to 660°F)
For more information, refer to PS-40-9.



Specialty Products

Hydraulic Decoking Systems (HDS)

Flowserve

Installed in more than 95% of the world's DCUs, Flowserve's hydraulic decoking systems are the most advanced in the world. They provide ethylene producers with maximized unit output, increased unit reliability and unparalleled personnel safety. Please refer to the DCU Application Solutions Guide for further information.

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.

VALVE TYPES USED IN ETHYLENE CRACKERS

Block Valves

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 cryogens 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 shutoff 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 user 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.

McCANNA Floating Ball Valve

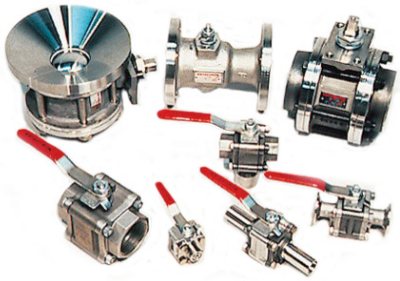
The McCANNA floating ball valve is a top-entry ball valve.

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

Worcester Floating Ball Valves

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 designs provide long service life and low cost of ownership
- Top-mounting platform and low operating torque for ease of actuation



Argus Floating Ball Valves

Argus FK75M and FK79 valves 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

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 valve delivers durability and low operating torques with a clear separation of sealing and bearing functions. It is fire-safe to both 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 valve 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 Valves (RSBV)

Valbart 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 TX3 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 valve 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

ACTUATOR TYPES USED IN ETHYLENE CRACKERS

VL

The VL Series is the standard set of actuators for Valtek control valves, providing precise control and reliable performance for more than 30 years.

- Up to 59 000 lb-ft (262 000 Nm)
- Operating pressure to 150 psi (10.3 barg)
- Increased efficiency provided by substantially higher thrust capabilities compared to diaphragm actuators, allowing tighter valve shutoff
- Installation and maintenance ease made possible by exceptionally compact and lightweight aluminum cylinder
- Ease of maintenance further enabled by durable construction and cylinder design, which provides easy access to all internal components
- Lower installation and replacement costs with standard O-rings for static and dynamic seals

VL-ES

Using many of the same design concepts as the VL-C actuator, the VL-ES actuator offers external spring cans for applications where longer strokes or unusually high spring thrust are required.

- Up to 37 400 lb-ft (166 000 Nm)
- Operating pressure to 150 psi (10.3 barg)
- Longer service life — up to 2 million cycles — from dynamic quad seal design, stronger springs, plug stem jam nut, and thrust bearings that prevent windup
- Installation and maintenance ease made possible by exceptionally compact and lightweight aluminum cylinder
- Ease of maintenance via spring cylinder actuator design requiring the removal of just two parts to access all internal components
- Lower installation and replacement costs, thanks to standard O-rings for static and dynamic seals

Automax Supernova

Flowserve Automax Supernova series rack and pinion actuators are designed for butterfly, plug or ball valves, and offer a compact design for double-acting and spring-return functionalities:

- Up to 3690 lb-ft output torque (5005 Nm)
- Operating pressures to 120 psi (8 barg)
- Increased efficiency and cycle life from precision die-cast pistons with large cylinder bearings
- Greater precision and reliability assured by integral travel stops in both directions, plus 10 degrees of overtravel for precise adjustment
- Longer, trouble-free service life enabled by precision-extruded hard anodized aluminum body and a one-piece, factory-lubricated, nitride-protected pinion gear
- Ease and flexibility of installation via dual ISO 5211 mounting pattern

Limitorque SB

These spring-compensated extensions of the SMB product line are available for applications where thermal expansion may pose the risk of a jammed valve, or where valve discs are subject to extremely high-speed closure:

- Up to 8300 lb-ft torque (11 250 Nm)
- High-temperature capability enabled by design that allows for thermal expansion and contraction of the valve stem and actuator stem nut
- High-speed performance made possible by spring-loaded stem nut, which absorbs the seating shock caused by rapid closing
- Longer service life via impact-dampening capability, which enables actuators to function at speeds as high as three times normal rates
- Optimized performance for stem contraction and torque back-seating applications available with double-compensating SBD configuration

CONTROL VALVE TYPES USED IN ETHYLENE CRACKERS

Different control valve requirements demand a broad spectrum of constructive designs, applicable for various operating conditions, flow media and environments. The needs of a specific ethylene cracker will determine its possible applications and characteristic designs.

Control valves with high-flow capacity based on the nominal diameter (rotary, plug, ball and check valves) are used primarily for simple operating conditions or on/off functions, and 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 models: Schmidt Armaturen, Valtek Flowserve
- Three-Way Control Valves: Mixing and spreading process medium
  - Typical models: Schmidt Armaturen, Flowserve
- Double-Seated Control Valves: Relatively low operating force
  - Double-seated, lined and diaphragm
  - Typical model: 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 and isolation purposes
  - Typical 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

Rising stem ball valves are used in several installation services within ethylene crackers.

Characteristics

1. Outside screw and yoke with emissions-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 buttweld ends (no welded pipe pups) is possible.

Ethylene Cracker Severe Service Valve Solutions

Typical Flowserve Control Valves

VALTEK MARK ONE	VALTEK MARK TWO	VALTEK MARK 100	VALTEK MARK 200
			
½ to 36 in Class 150 to 4500	½ to 6 in Class 150 to 2500	6 to 36 in Class 150 to 600	2 to 30 in Class 900 to 2500

Valtek GSV (Globe)

- 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 fluids
- 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 stem 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

Actuator Products Used in Ethylene Crackers

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 Limitorque, 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 Limitorque Fluid Power Systems 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.

There are three primary categories of actuators:

- **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). NOTE: It is not the intent of this document to describe LFPS products.

There are two categories of electric actuators:

- **Intrusive:** The controls cover must be removed, exposing the controls to the environment, in order to configure position and torque limits. Flowserve's intrusive electric actuator 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. Flowserve's non-intrusive electric actuator types are MX and QX, with output torque ranges from ~30 lb/41 Nm to 1700 lb/2036 Nm.

Flowserve's intrusive and non-intrusive actuators are available in multi-turn for rising stem valves, e.g., SMB, L120 and MX, with valve thrust ranges from ~8000 lb/35 kN to 500 000 lb/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.

Limitorque supplies mechanical gearboxes for either manual or automated service. For multi-turn applications, "V" bevel gearboxes and "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 lb/7650 kN.

Limitorque 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.

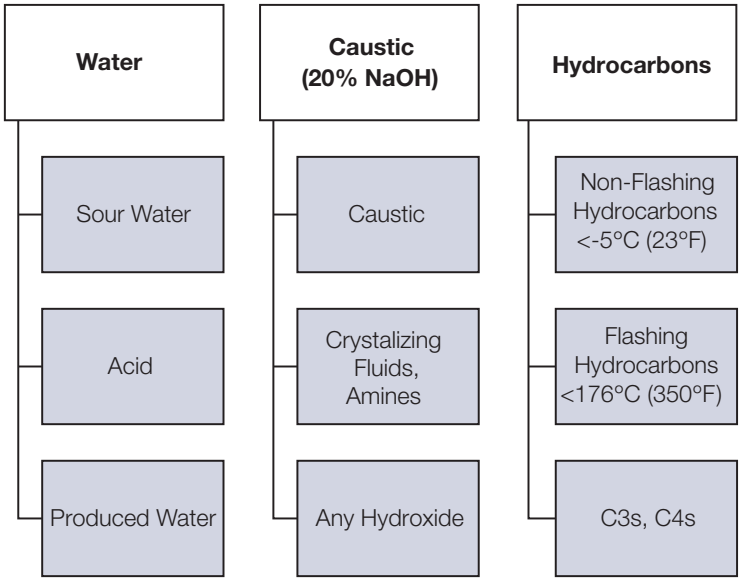
Limitorque also offers optional network protocols, which can be fitted to non-intrusive electric actuators, and include:

- Modbus-DDC, Foundation Fieldbus H1, Profibus DP_ V1 with Redundancy and PA, DeviceNet and HART
- Refer to Limitorque's APB (All Product Bulletin), LMENBR0001-05

Seals and System Types Used in Ethylene Crackers

Mechanical Seals

Table 3.2: Best practices



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 3.3: Best practices — water

Temperature	17.6 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)
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

Pressure

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

Table 3.4: Best practices — hydrocarbons

Specific Gravity	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)
< 0.4	QBQ/QBQ QBB/QB2B	QBQ/QBQ	QBQ/QBQ	QBQ/QBQ HSH/DHTW UHTW/GSLW	UHTW/GSLW HSH/DHTW
0.59 – 0.4	QBB/QBQ/QB2B QBB/QB2B/ GSL/QBQLZ QBB/QBQ	QBB/QBQ/QB2B QBB/QB2B QBQLZ/GSL QBB/QBQ	QBQLZ/GSL QBQLZ/QBQ	QBQLZ/QBQ	UHTW/GSLW/HSH UHTW/HSH 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/HSH GSLW DHTW/DHTW
1.1 – 0.8	QBQ QBQ/QBQ QBB/QBQ/QB2B	QBQ QBB/QB2B	QBQ QBQ/QBQ	QBQ QBQ/QBQ	UHTW/HSH DHTW

Pressure

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

Table 3.5: 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_2S or hydrocarbons may require a dual seal

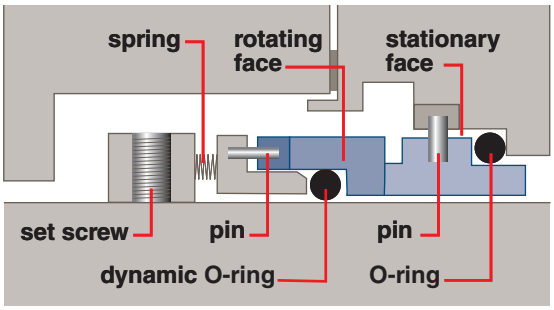
Guidance shown here is for presentation purposes, not for seal selection.

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

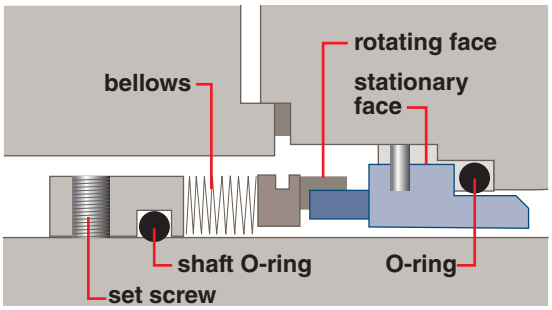
Pressure

Figure 3.1: 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 204°C (400°F)
  - – Lowest pressure capability
  - – Highest cost

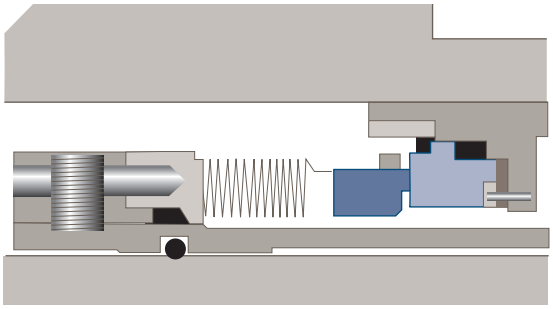
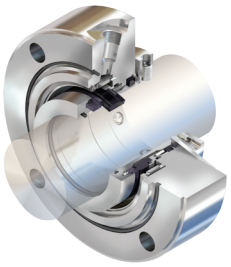


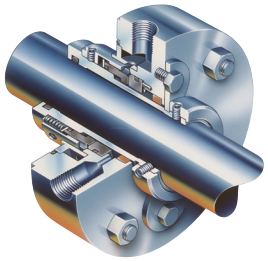
Figure 3.2: Pusher seals

Type A:
Pusher

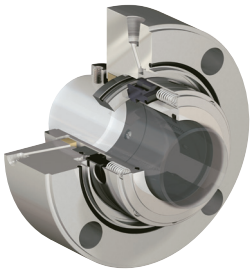
- Categories 1 and 2
  - ISC2-682PX
  - QBQ
- Categories 2 and 3
  - QBQ
  - QBQLZ
  - DQ
- Arrangement 2 Containment Seal
  - GSL
- Arrangement 3 Gas Barrier Seals
  - GF-200
- Engineered Seals
  - HSH
  - UHTW/DHTW



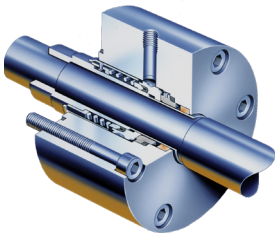
ISC2-682PX



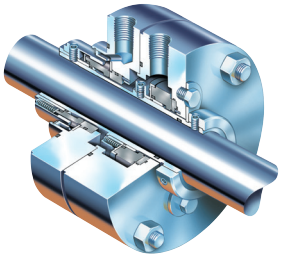
QBQ



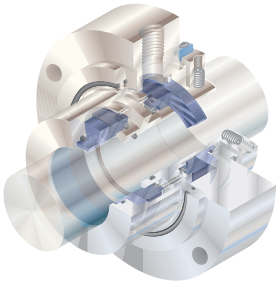
QBQLZ



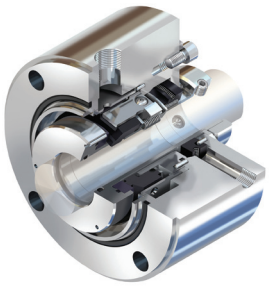
DQ



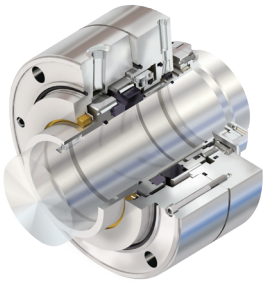
GSL



GF-200



HSH

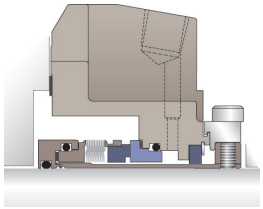


UHTW/DHTW

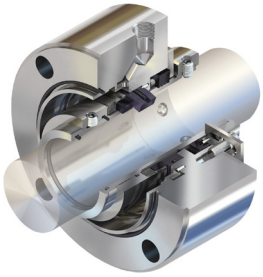
Figure 3.3: Bellows seals

Type B: Bellows

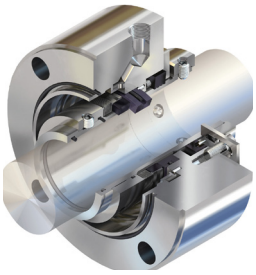
- Categories 1 and 2
  - ISC2-682BX
- Categories 1, 2 and 3
  - BX
  - BXQ



ISC2-682BX



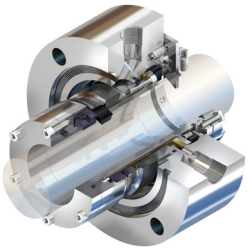
BX



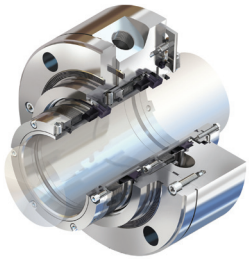
BXQ

Type C: High-Temperature Bellows

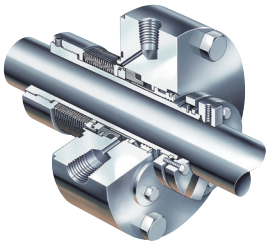
- Category 2
  - BXRH
  - BXHHS
  - BRCSH
- Categories 2 and 3
  - BXRH
  - BXHH
  - BRC
- Arrangement 2 Containment Seal
  - GSDH
- Arrangement 3 Steam Barrier Seal
  - GTSP



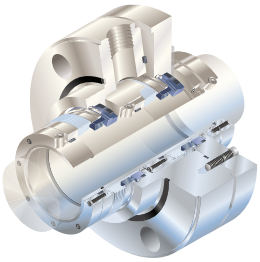
BXRH



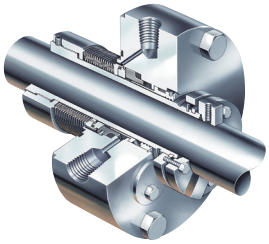
BXHHS



BRCSH

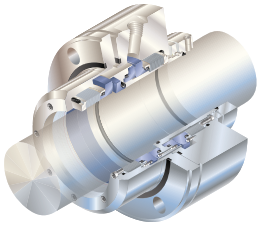


BXHH



BRC

GSDH

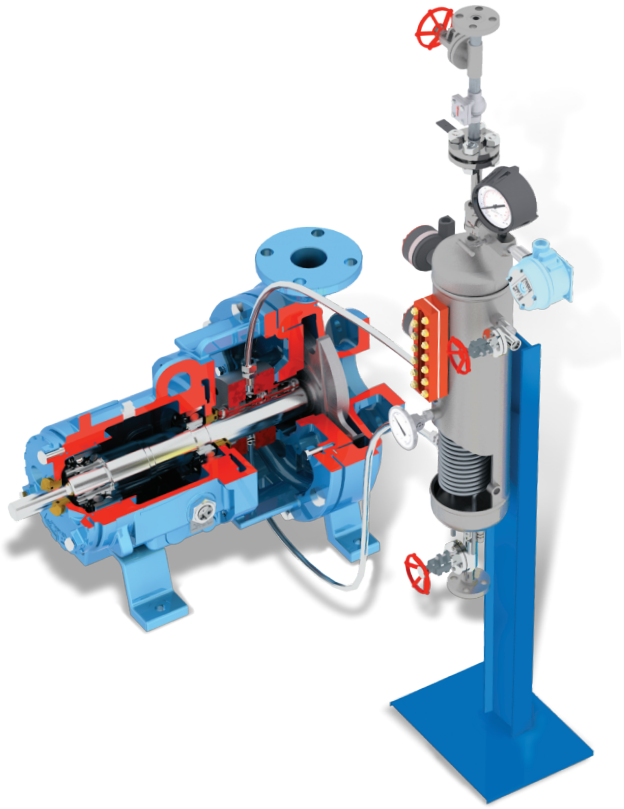


GTSP

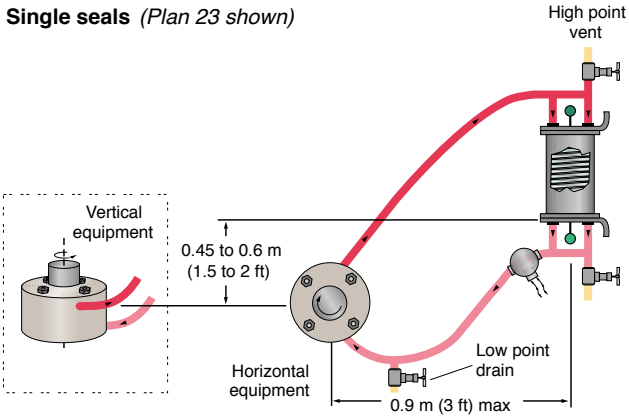
Seal System Piping Plans

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 ethylene 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 meets your application requirements.

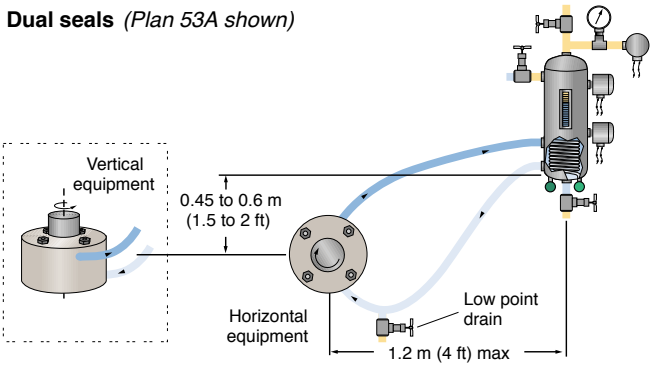
Figure 3.4: Seal system piping plans



Single seals *(Plan 23 shown)*

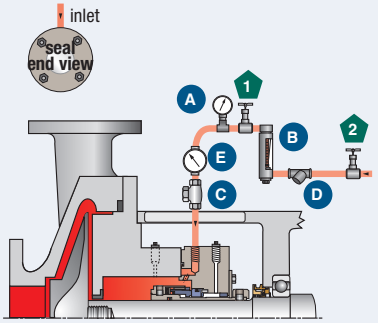


Dual seals *(Plan 53A shown)*



Plan 32 — *Single Seals*

Seal flush from an external clean source.

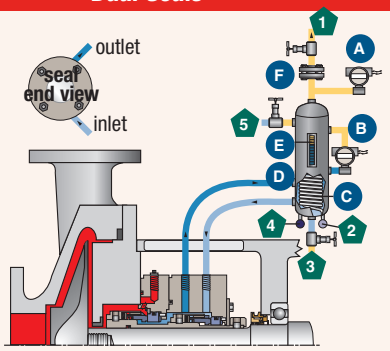


A - pressure indicator
B - flow indicator (optional)
C - check valve
D - strainer
E - temperature indicator (optional)
1 - flow control valve
2 - from clean source, normally open

Plan 52 — *Dual Seals*

Unpressurized buffer fluid circulation through reservoir.

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

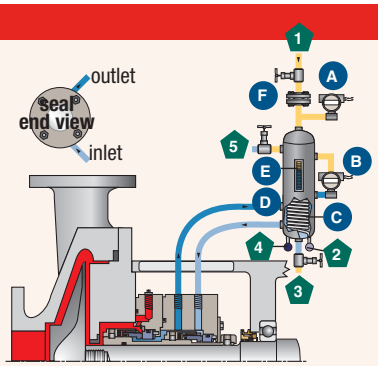


A - pressure transmitter
B - level transmitter
C - cooling coils
D - reservoir
E - level indicator
F - orifice
1 - vent, normally open
2 - cooling in
3 - drain, normally closed
4 - cooling out
5 - liquid fill, normally closed

Plan 53A

Pressurized barrier fluid circulation through reservoir.

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

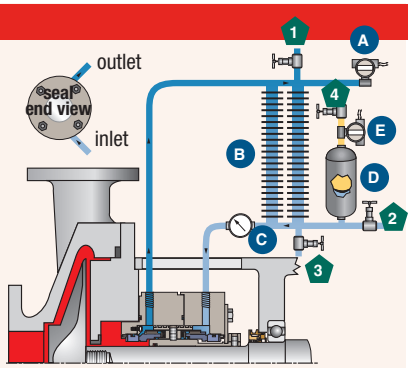


A - pressure transmitter
B - level transmitter
C - cooling coils
D - reservoir
E - level indicator
F - orifice
1 - vent, normally open
2 - cooling in
3 - drain, normally closed
4 - cooling out
5 - liquid fill, normally closed

Plan 53B

Pressurized barrier fluid circulation with a bladder accumulator.

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

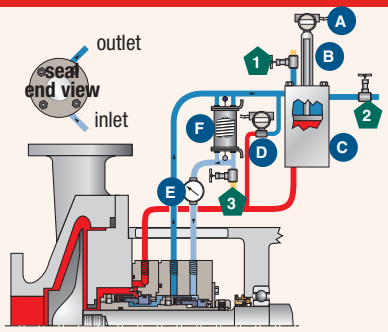


A - pressure transmitter
B - finned pipe (alternative reservoir)
C - temperature indicator
D - bladder accumulator
E - temperature transmitter
1 - vent, normally closed
2 - liquid fill, normally closed
3 - drain, normally closed
4 - pressure source, normally closed

Plan 53C

Pressurized barrier fluid circulation with piston accumulator.

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

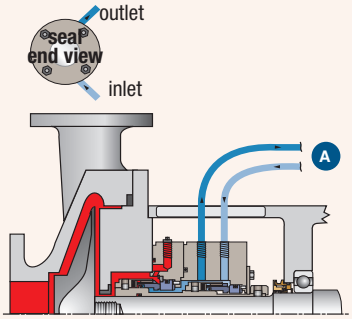


A - level transmitter
B - level indicator
C - piston accumulator
D - differential pressure transmitter
E - temperature indicator (optional)
F - cooler
1 - vent, normally closed
2 - liquid fill, normally closed
3 - drain, normally closed

Plans 54 and 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 & SERVICES IN ETHYLENE CRACKERS

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.

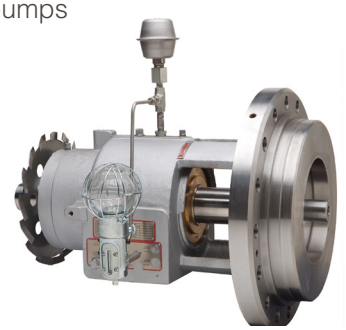
We have two centuries of pump and mechanical seal innovation under our belt, an installed base exceeding one million units and a global footprint. It's no wonder Flowserve is the industry leader when it comes to knowledge, experience and resources.

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

Flowserve has multiple programs where it can supply parts for customers. These include:

Quick Response Pump Impellers
(Impeller in a Week)

Quick Response Turned Parts (Rings)

Quick Response Pump Shaft Products

Quick Response FastCast Impellers

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 the same day** or next day; special parts can be delivered in days instead of weeks.

Available quick response programs include:

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

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 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 agreement is carefully customized to meet each customer's unique operating goals and requirements.

Your 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 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

Flowserve 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 programs
- 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:

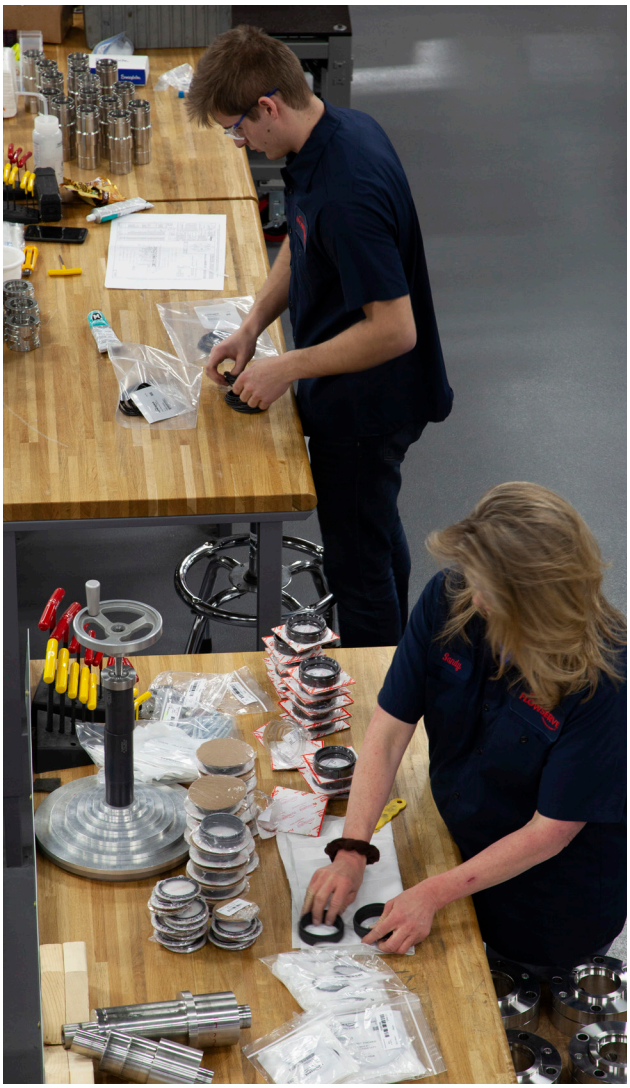
- View ongoing performance metrics through easily interpreted visuals
- Monitor real-time equipment performance
- Conduct predictive analysis
- Recommend corrective action based on facts and verifiable data
- Review historical equipment information
- Manage timing and costs for equipment change-outs, 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**, 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
- Bills 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

Upgrade Programs

RVX Pump Upgrade; ISO 13709/API 610 Back Pull-out Retrofit (detailed example of the program shared below)

RHWX and RHWX-S Vertical Inline Power Frame Upgrade

VTP: Vertical Turbine Pump Dished Bottom (suction can upgrade)

ANSI/ASME **Mark 3/Prima3 Power End Programs**

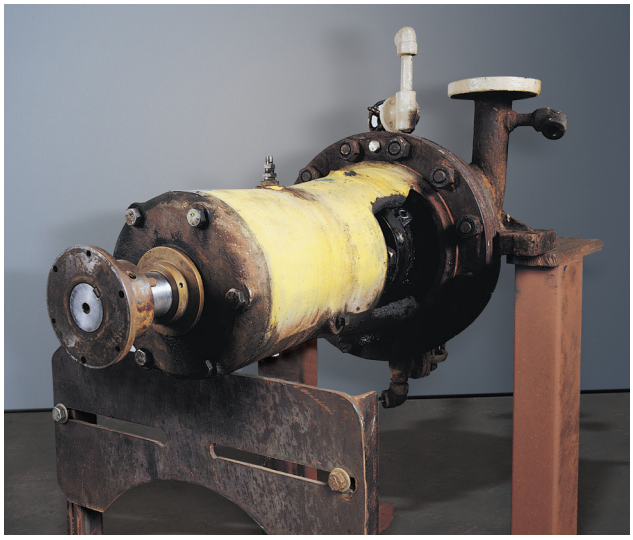
RVX-MAG

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

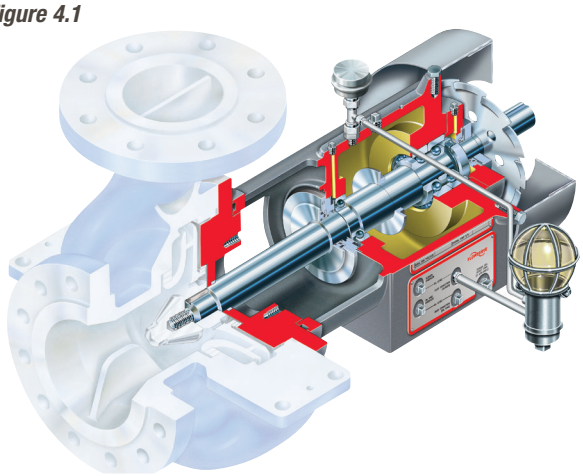
The RVX program applies to any existing ISO/API OH1 and OH2 pump installation, regardless of OEM.

- 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 to 525 mm (8.5 to 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 4.1



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® 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. ***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.

® Inpro is a trademark of Inpro/Seal Company.

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 pump** 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 pump. 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 pump.** 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 pump** 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 pump is just five weeks — a savings of 33 weeks (see Figure 4.2).

Quick Payback and Reduced Lifecycle Costs
Reliability Payback
The reliability payback of the **RVX pump** in a recent 50-pump program was 1.84 years, as calculated by the user.

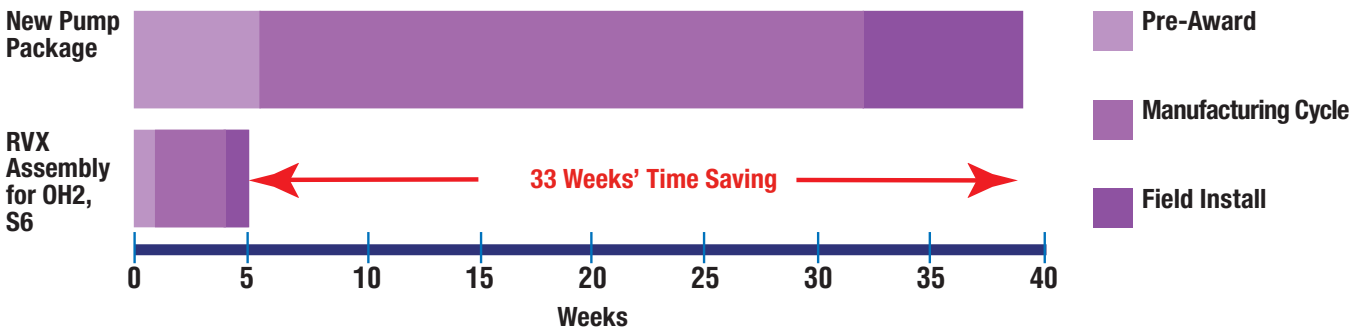
This was based on the significant reduction in cost and time to upgrade the pull-out assemblies instead of completely replacing pumps. Improved reliability to ISO 13709/API 610, latest edition, is also assured.

Energy Payback
Energy payback on the **RVX pump** 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 pump** assemblies.

Figure 4.2: Lead time comparison



INSTALLATIONS AND EXPERIENCE

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.

Partial Listing Where Considerable Applications of Flowserve Products Are Installed

Flowserve majority of all applications of either pumps, valves or mechanical seal systems:

Typical 400 000 bpd capacity unit with HDS system would include >1000 pumps, >1000 seals and systems and >2000 valves for Flowserve. Flowserve would not provide 100% of the equipment, but a considerable installed population.

Sadara — DOW/Aramco — KSA

Garyville — Marathon — U.S.

YASREF — Saudi Aramco/Sinopec JV — KSA

Hengli — China

RIL Jamnagar — India

Trusted Experience Across the Oil and Gas Industry

Global Users:

Global Accounts:

COMMUNICATING OUR VALUE

Flowserve Value Proposition for Ethylene Crackers

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 ethylene 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 learned 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, with full access to Flowserve component drawings and procedures.
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, low-risk design factors and maintainability.	Maximize MTBF, ease of monitoring equipment.

Table 6.1

Innovative Ways Flowserve Addresses Customer Challenges

Expertise and Experience	• Flowserve has more than 80 years of experience in the ethylene industry and has been a key supplier of pumps, valves and seals for ethylene production for decades. • Flowserve has one of the largest installed bases of pumps and valves in ethylene applications around the world. • Specialist “Virtual Centers of Excellence” ensure that expertise acquired over multiple products and manufacturing sites is shared across the global Flowserve organization.
Single-Source Provider	• Flowserve offers a full range of pumps, valves and seals for the ethylene market, simplifying the procurement process for our customers. • Flowserve is also a provider of SOLUTIONS. Thanks to the large installed base of products and its wide portfolio, Flowserve can provide a unique combination of products and features, delivering the best match for the toughest applications. • Global commercial operations organization ensures knowledgeable and professional reviews and responses to customer RFQs, including those with the most complicated technical requirements.
Streamlined Execution	• Each Flowserve factory has efficient and professional project management teams to ensure on-time completion of projects to customer requirements. • 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.
Local Support Worldwide	• A large field service organization ensures technicians are available for installation, commissioning and troubleshooting without delay. • Service and maintenance contracts for the highest availability and continuous efficiency optimization can be tailored to customer needs. • A global network of Flowserve Quick Response Centers means that local service and repair are always available. • Product upgrades are continuously being introduced to improve the performance and reliability of Flowserve products in the field. • Full operation and maintenance training are available to end users. • Equipment monitoring programs are also available.
Optimized Efficiency	• Flowserve’s close involvement within the ethylene market has provided the industry feedback needed to develop the range of hydraulics optimally suited to customer requirements, ensuring the best and most efficient selections are always available. • As one of the largest engineered pump manufacturers in the world, Flowserve’s hydraulic engineering capabilities and resources are second to none. Flowserve is able to provide pumping equipment that consumes the least amount of power.

Table 6.2

Business Pain Points and Opportunities

Flowserve Meets the Customers' Challenges

The overall impact of equipment on the total cost structure of an ethylene plant is quite significant — especially when you consider the various processes involved within its production. 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 ethylene production industry, especially hydraulic decoking systems, ethylene processes and enhancements
- Ethylene cracker plants 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

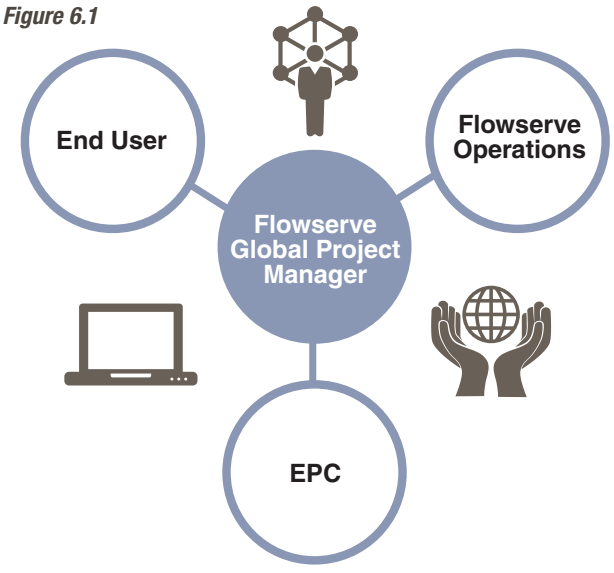
This section provides a high-level guide to how we can communicate our value to influencers and decision makers.

Business Pains and Challenges

Table 6.3

– Knowledgeable and reliable technical support in preparing specifications – Access to selection tools to optimize energy cost and plant performance
– Competitive prices – Specification performance – Quick response on information and documentation – Effective project management – Reliable on-time delivery – Startup services – Minimize number of suppliers
– All of the above, plus ... – Sustainable high-efficiency; reduced power consumption – Project completion on time and at budget
– Equipment reliability – Local services – Contract maintenance for unmanned or understaffed plants – Upgrades for energy and maintenance savings

Figure 6.1



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:

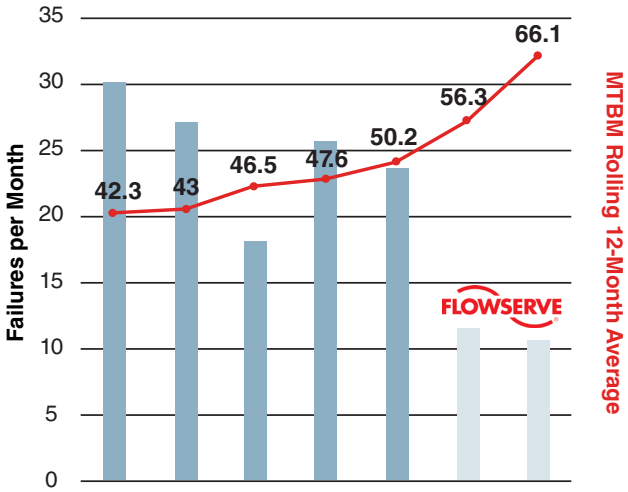
1. Pump, valve and seal application and design **engineering expertise**
2. Class-leading products with **proven** local installations
3. **Local** content
4. **Packaging** capabilities
5. Industry-leading testing capabilities
6. Project management services
7. Installation and **startup services** and support
8. Training facilities
9. **After-sales** 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

Figure 6.2: Our involvement helps improve mean time between maintenance within the first two years by 50%.



Source: Flowserve Corporation internal data

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

Value Proposition Summary: Why Flowserve?

Industry-Leading Products and Services in Ethylene Processes

- Flowserve is the world's leading supplier of pumps, seals and valves for use in ethylene applications worldwide.
- Flowserve handles challenging applications found in ethylene plants. 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

Addressing Customer Challenges

Table 6.4: Pumps

	MAINTENANCE MANAGER	RELIABILITY/ROTATING EQUIPMENT ENGINEER	OPERATIONS PERSONNEL	EPC ENGINEER/ MANAGER
Challenges	Improving MTBF	Identifying and eliminating bad actors	Safety	Keeping projects on schedule
	Component maintenance team that can effectively and quickly repair any equipment across the refinery	Improving MTBF and lifecycle performance	Automation and monitoring	Product design, features, testing and performance
	Safety through automation	Safety	Inventory	Compliance with specs
Our Capabilities	Extensive decoking experience and complete product line for decoking	Extensive decoking experience and complete product line for decoking	Automation opportunities for safety	Broad line of products
	Strong MTBF	Strong MTBF	Training on how to safely operate equipment	Global project management
	Global service and aftermarket capability; ease of doing business; safety through automation	Reliability services/ technical assessments	Single source for ease of inventory	Applications engineering

Table 6.5: Seals

	MAINTENANCE MANAGER	RELIABILITY/ROTATING EQUIPMENT ENGINEER	OPERATIONS PERSONNEL
Challenges	Average MTBF—Need a team that can do an analysis and proven experience to improve it	Average MTBF—Need a team that can do an analysis and proven experience to improve it	Aging workforce lacking in experience
	Managing inventory—stocking the right parts in the right quantities	Reducing costs through service outsourcing	
	Reducing costs through service outsourcing	Insufficient experience to make decisions	
Our Capabilities	Aging skilled labor workforce	Lack of documentation/ information on existing equipment	Many types of seal flush plans, auxiliaries, seal types and configurations to know
	Technical analyses to improve MTBF	Technical analyses to improve MTBF	Quickest repair cycle times in the industry due to QRC network
	Inventory consignment and standardization programs	Turnkey service programs (parts, inventory, service)	Alliance programs with on-site personnel who help operations
	Turnkey service programs (parts, inventory, service)	Reliability program audits	Developing seal standardization plans that are site-specific
	Reliability program audits	Training programs and classes for engineers	Training for operators, both in-person and online, available
	Mechanic/Milwright assessments and training	IPOP program for pump BOMs and documentation	Technical analyses to improve MTBF
	Quickest repair cycle times in the industry due to QRC network		

Table 6.6: Valves

	MAINTENANCE MANAGER	RELIABILITY/ROTATING EQUIPMENT ENGINEER	OPERATIONS PERSONNEL	EPC ENGINEER/ MANAGER
Challenges	Ease of maintenance	Improving MTBF	Having the right valves in inventory	Keeping projects on schedule
	Improving MTBF		Improving MTBF	Product design, features, testing and performance
	Having the right valves in inventory			Compliance with specs
Our Capabilities	Extensive decoking experience and complete valve product line for decoking	Extensive decoking experience and complete valve product line for decoking	Extensive decoking experience and complete valve product line for decoking	Writing our specs into their RFP
	Designed for easy maintenance	Broad line/single source for inventory management ease	Designed for easy maintenance	Global project management
	Strong MTBF	Strong MTBF	Strong MTBF	Broad line/single source

CONCLUSION

Ethylene plants use hundreds of pumps and even more valves in the production process, and the configuration of these products varies with each technology licensor's design. A thorough understanding of the applications where these pump, valve and actuation products are used is very critical. This understanding should drive the selection and design of engineered flow solutions that meet the needs of both technology licensors and customers. Safety, performance, quality, technical knowledge, high reliability and economics are critical areas of customer needs in any ethylene cracker.

APPENDIX

Control Valve Terms

Accessory: A device that is mounted on the actuator to complement the actuator's function and make it a complete operating unit. Examples include positioners, supply pressure regulators, solenoids and limit switches.

Actuator: A pneumatic, hydraulic or electrically powered device that supplies force and motion to open or close a valve.

Actuator Assembly: An actuator, including all the pertinent accessories that make it a complete operating unit.

Backlash: The general name given to a form of dead band that results from a temporary discontinuity between the input and output of a device when the input of the device changes direction. Slack, or looseness of a mechanical connection, is a typical example.

Capacity (Valve): The rate of flow through a valve under stated conditions.

Closed Loop: The interconnection of process control components such that information regarding the process variable is continuously fed back to the controller set point to provide continuous, automatic corrections to the process variable.

Control Loop: (See Closed Loop.)

Control Range: The range of valve travel over which a control valve can maintain the installed valve gain between the normalized values of 0.5 and 2.0.

Control Valve: (See Control Valve Assembly.)

Control Valve Assembly: Includes all components normally mounted on the valve: the valve body assembly, actuator, positioner, air sets and transducers, limit switches, etc.

Controller: A device that operates automatically by use of some established algorithm to regulate a controlled variable. The controller input receives information about the status of the process variable and then provides an appropriate output signal to the final control element.

Dead Band: The range through which an input signal can be varied, upon reversal of direction, without initiating an observable change in the output signal. Dead band is the name given to a general phenomenon that can apply to any device. For the valve assembly, the controller output (CO) is the input to the valve assembly and the process variable (PV) is the output. When the term *Dead Band* is used, it is essential that both the input and output variables are identified, and that any tests to measure dead band be under fully loaded conditions. Dead band is typically expressed as a percent of the input span.

Dead Time: The time interval (Td) in which no response of the system is detected following a small (usually 0.25 to 5%) step input. It is measured from the time the step input is initiated to the first detectable response of the system being tested. Dead Time can apply to a valve assembly or to the entire process.

Disk: A valve trim element used to modulate the flow rate with either linear or rotary motion. Can also be referred to as a *valve plug* or *closure member.*

Equal Percentage Characteristic: An inherent flow characteristic that, for equal increments of rated travel, will ideally give equal percentage changes of the flow coefficient (C_v).

Final Control Element: The device that implements the control strategy determined by the output of the controller. While the final control element can be a damper, a variable-speed drive pump, or an on-off switching device, the most common final control element in the process control industries is the control valve assembly. The control valve manipulates a flowing fluid, such as gases, steam, water or chemical compounds, to compensate for the load disturbance and keep the regulated process variable as close as possible to the desired set point.

First-Order: A term that refers to the dynamic relationship between the input and output of a device. A first-order system or device is one that has only one energy storage device and whose dynamic transient relationship between the input and output is characterized by an exponential behavior.

Friction: A force that tends to oppose the relative motion between two surfaces that are in contact with each other. The friction force is a function of the normal force holding these two surfaces together and the characteristic nature of the two surfaces. Friction has two components: static friction and dynamic friction.

> **Static Friction** is the force that must be overcome before there is any relative motion between the two surfaces. Once relative movement has begun, dynamic friction is the force that must be overcome to maintain the relative motion.
>
> **Running and Sliding Friction** are colloquial terms that are sometimes used to describe dynamic friction. Stick/slip or "stiction" are colloquial terms that are sometimes used to describe static friction. Static friction is one of the major causes of dead band in a valve assembly.

Gain: An all-purpose term that can be used in many situations. In its most general sense, gain is the ratio of the magnitude of the output change of a given system or device to the magnitude of the input change that caused the output change. Gain has two components: static gain and dynamic gain. Static gain is the gain relationship between the input and output and is an indicator of the ease with which the input can initiate a change in the output when the system or device is in a steady-state condition. *Sensitivity* is sometimes used to mean static gain. Dynamic gain is the gain relationship between the input and output when the system is in a state of movement or flux. Dynamic gain is a function of frequency or rate of change of the input.

Hysteresis: The maximum difference in output value for any single input value during a calibration cycle, excluding errors due to dead band.

Inherent Characteristic: The relationship between the flow coefficient and the closure member travel as it is moved from the closed position to rated travel with constant pressure drop across the valve. Typically, these characteristics are plotted on a curve where the horizontal axis is labeled in percent travel and the vertical axis is labeled as percent flow (or C_v). Because valve flow is a function of both the valve travel and the pressure drop across the valve, conducting flow characteristic tests at a constant pressure drop provides a systematic way of comparing one valve characteristic design to another. Typical valve characteristics conducted in this manner are named Linear, Equal-Percentage and Quick Opening.

Inherent Valve Gain: The magnitude ratio of the change in flow through the valve to the change in valve travel under conditions of constant pressure drop. Inherent valve gain is an inherent function of the valve design. It is equal to the slope of the inherent characteristic curve at any travel point and is a function of valve travel.

Installed Characteristic: The relationship between the flow rate and the closure member travel as it is moved from the closed position to rated travel as the pressure drop across the valve is influenced by the varying process conditions.

Installed Valve Gain: The magnitude ratio of the change in flow through the valve to the change in valve travel under actual process conditions. Installed valve gain is the valve gain relationship that occurs when the valve is installed in a specific system and the pressure drop is allowed to change naturally according to the dictates of the overall system. The installed valve gain is equal to the slope of the installed characteristic curve, and is a function of valve travel.

I/P: Shorthand for current-to-pressure (I-to-P). Typically applied to input transducer modules.

Linear Characteristic: An inherent flow characteristic that can be represented by a straight line on a rectangular plot of flow coefficient (C_v) versus rated travel. Therefore, equal increments of travel provide equal increments of flow coefficient, C_v.

Linearity: The closeness to which a curve relating to two variables approximates a straight line. (It also means that the same straight line will apply for both upscale and downscale directions. Thus, dead band as previously defined would typically be considered a non-linearity.)

Loop: (See Closed Loop.)

Loop Gain: The combined gain of all the components in the loop when viewed in a series around the loop. Sometimes referred to as *open-loop gain.* It must be clearly specified whether referring to the static loop gain or the dynamic loop gain at some frequency.

Manual Control: (See Open Loop.)

Open Loop: The condition where the interconnection of process control components is interrupted such that information from the process variable is no longer fed back to the controller set point so that corrections to the process variable are no longer provided. This is typically accomplished by placing the controller in the manual operating position.

Packing: A part of the valve assembly used to seal against leakage around the valve disk or stem.

Positioner: A position controller (servomechanism) that is mechanically connected to a moving part of a final control element or its actuator and automatically adjusts its output to the actuator to maintain a desired position in proportion to the input signal.

Process: All the combined elements in the control loop, except the controller. The process typically includes the control valve assembly, the pressure vessel or heat exchanger that is being controlled, as well as sensors, pumps and transmitters.

Process Gain: The ratio of the change in the controlled process variable to a corresponding change in the output of the controller.

Process Variability: A precise statistical measure of how tightly the process is being controlled about the set point. Process variability is defined in percent as typically (2s/m), where "m" is the set point or mean value of the measured process variable and "s" is the standard deviation of the process variable.

Quick Opening Characteristic: An inherent flow characteristic in which a maximum flow coefficient is achieved with minimal closure member travel.

Relay: A device that acts as a power amplifier. It takes an electrical, pneumatic or mechanical input signal and produces an output of a large volume flow of air or hydraulic fluid to the actuator. The relay can be an internal component of the positioner or a separate valve accessory.

Resolution: The minimum possible change in input required to produce a detectable change in the output when no reversal of the input takes place. Resolution is typically expressed as a percent of the input span.

Response Time: Usually measured by a parameter that includes both dead time and time constant. (Dead Time and Time Constant.) When applied to the valve, it includes the entire valve assembly.

Second-Order: A term that refers to the dynamic relationship between the input and output of a device. A second-order system or device is one that has two energy storage devices that can transfer kinetic and potential energy back and forth between themselves, thus introducing the possibility of oscillatory behavior and overshoot.

Sensor: A device that senses the value of the process variable and provides a corresponding output signal to a transmitter. The sensor can be an integral part of the transmitter, or it may be a separate component.

Set Point: A reference value representing the desired value of the process variable being controlled.

Shaft Wind-Up: A phenomenon where one end of a valve shaft turns and the other does not. This typically occurs in rotary-style valves where the actuator is connected to the valve closure member by a relatively long shaft. While seal friction in the valve holds one end of the shaft in place, rotation of the shaft at the actuator end is absorbed by twisting the shaft until the actuator input transmits enough force to overcome the friction.

Sizing (Valve): A systematic procedure designed to ensure the correct valve capacity for a set of specified process conditions.

Stiction: (See Friction.)

Time Constant: A time parameter that normally applies to a first-order element. It is the time interval measured from the first detectable response of the system to a small (usually 0.25 to 5%) step input until the system output reaches 63% of its final steady-state value. When applied to an open-loop process, the time constant is usually designated as τ (Tau). When applied to a closed-loop system, the time constant is usually designated as λ (Lambda).

Transmitter: A device that senses the value of the process variable and transmits a corresponding output signal to the controller for comparison with the set point.

Travel: The movement of the closure member from the closed position to an intermediate or rated fully open position.

Travel Indicator: A pointer and scale used to externally show the position of the closure member typically with units of opening percent of travel or degrees of rotation.

Trim: The internal components of a valve that modulate the flow of the controlled fluid.

Valve: (See Control Valve Assembly.)

Volume Booster: A stand-alone relay is often referred to as a *volume booster* or simply *booster* because it boosts, or amplifies, the volume of air supplied to the actuator. (See Relay.)

Rising-Stem Control Valve Terminology

Actuator Spring: A spring, or group of springs, enclosed in the yoke or actuator casing that moves the actuator stem in a direction opposite to that created by diaphragm pressure.

Actuator Stem: The part that connects the actuator to the valve stem and transmits motion (force) from the actuator to the valve.

Actuator Stem Extension: An extension of the piston actuator stem to provide a means of transmitting piston motion to the valve positioner.

Actuator Stem Force: The net force from an actuator that is available for actual positioning of the valve plug.

Angle Valve: A valve design in which one port is co-linear with the valve stem or actuator, and the other port is at a right angle to the valve stem. (See Globe Valve.)

Bellows Seal Bonnet: A bonnet that uses a bellows for sealing against leakage around the closure member stem.

Bonnet: The portion of the valve that contains the packing box and stem seal and can guide the stem. It provides the principal opening to the body cavity for assembly of internal parts or it can be an integral part of the valve body. It can also provide for the attachment of the actuator to the valve body. Typical bonnets are bolted, threaded, welded, pressure-seals or integral with the body. (This term is often used in referring to the bonnet and its included packing parts. More properly, this group of component parts should be called the *bonnet assembly.*)

Bonnet Assembly (commonly *Bonnet,* more properly *Bonnet Assembly*): An assembly including the part through which a valve stem moves and a means for sealing against leakage along the stem. It usually provides a means for mounting the actuator and loading the packing assembly.

Bottom Flange: A part that closes a valve body opening opposite the bonnet opening. It can include a guide bushing and/or serve to allow reversal of the valve action.

Bushing: A device that supports and/ or guides moving parts such as valve stems.

Cage: A part of a valve trim that surrounds the closure member and can provide flow characterization and/ or a seating surface. It also provides stability, guiding, balance and alignment, and facilitates assembly of other parts of the valve trim. The walls of the cage contain openings that usually determine the flow characteristic of the control valve.

Closure Member: The movable part of the valve that is positioned in the flow path to modify the rate of flow through the valve.

Closure Member Guide: That portion of a closure member that aligns its movement in a cage, seat ring, bonnet, bottom flange or any two of these.

Cylinder: The chamber of a piston actuator in which the piston moves.

Cylinder Closure Seal: The sealing element at the connection of the piston actuator cylinder to the yoke.

Diaphragm: A flexible, pressure-responsive element that transmits force to the diaphragm plate and actuator stem.

Diaphragm Actuator: A fluid-powered device in which the fluid acts upon a flexible component, the diaphragm.

Diaphragm Case: A housing, consisting of top and bottom section, used for supporting a diaphragm and establishing one or two pressure chambers.

Diaphragm Plate: A plate concentric with the diaphragm for transmitting force to the actuator stem.

Direct Actuator: A diaphragm actuator in which the actuator stem extends with increasing diaphragm pressure.

Extension Bonnet: A bonnet with greater dimension between the packing box and bonnet flange for hot or cold service.

Globe Valve: A valve with a linear motion closure member, one or more ports and a body distinguished by a globular-shaped cavity around the port region. Globe valves can be further classified as: two-way single-ported; two-way double- ported; angle-style, three-way; unbalanced cage-guided; and balance cage-guided.

Lower Valve Body: A half housing for internal valve parts having one flow connection. The seat ring is normally clamped between the upper valve body and the lower valve body in split valve constructions.

Offset Valve: A valve construction having inlet and outlet line connections on different planes but 180° opposite each other.

Packing Box (Assembly): The part of the bonnet assembly used to seal against leakage around the closure member stem. Included in the complete packing box assembly are various combinations of some or all of the following component parts: packing, packing follower, packing nut, lantern ring, packing spring, packing flange, packing flange studs or bolts, packing flange nuts, packing ring, packing wiper ring, felt wiper ring, Belleville springs, anti-extrusion ring.

Piston: A movable pressure-responsive element that transmits force to the piston actuator stem.

Piston Type Actuator: A fluid-powered device in which the fluid acts upon a movable piston to provide motion to the actuator stem. Piston type actuators are classified as either double-acting, so that full power can be developed in either direction, or as spring-fail so that upon loss of supply power, the actuator moves the valve in the required direction of travel.

Plug: A term frequently used to refer to the closure member.

Port: The flow control orifice of a control valve.

Retaining Ring: A split ring that is used to retain a separable flange on a valve body.

Reverse Actuator: A diaphragm actuator in which the actuator stem retracts with increasing diaphragm pressure. Reverse actuators have a seal bushing installed in the upper end of the yoke to prevent leakage of the diaphragm pressure along the actuator stem.

Rubber Boot: A protective device to prevent entrance of damaging foreign material into the piston actuator seal bushing.

Seal Bushing: Top and bottom bushings that provide a means of sealing the piston actuator cylinder against leakage. Synthetic rubber O-rings are used in the bushings to seal the cylinder, the actuator stem and the actuator stem extension.

Seat: The area of contact between the closure member and its mating surface that establishes valve shut-off.

Seat Load: The net contact force between the closure member and seat with stated static conditions. In practice, the selection of an actuator for a given control valve will be based on how much force is required to overcome static, stem and dynamic unbalance with an allowance made for seat load.

Seat Ring: A part of the valve body assembly that provides a seating surface for the closure member and can provide part of the flow control orifice.

Separable Flange: A flange that fits over a valve body flow connection. It is generally held in place by means of a retaining ring.

Spring Adjustor: A fitting, usually threaded on the actuator stem or into the yoke, to adjust the spring compression.

Spring Seat: A plate to hold the spring in position and provide a flat surface for the spring adjustor to contact.

Static Unbalance: The net force produced on the valve stem by the fluid pressure acting on the closure member and stem with the fluid at rest and with stated pressure conditions.

Stem Connector: The device that connects the actuator stem to the valve stem.

Trim: The internal components of a valve that modulate the flow of the controlled fluid. In a globe valve body, trim would typically include closure member, seat ring, cage, stem and stem pin.

Trim, Soft-Seated: Valve trim with an elastomeric, plastic or other readily deformable material used either in the closure component or seat ring to provide tight shutoff with minimal actuator forces.

Upper Valve Body: A half housing for internal valve parts and having one flow connection. It usually includes a means for sealing against leakage along the stem and provides a means for mounting the actuator on the split valve body.

Valve Body: The main pressure boundary of the valve that also provides the pipe connecting ends, the fluid flow passageway, and supports the seating surfaces and the valve closure member. Among the most common valve body constructions are: a) single-ported valve bodies having one port and one valve plug; b) double-ported valve bodies having two ports and one valve plug; c) two-way valve bodies having two flow connections, one inlet and one outlet; d) three-way valve bodies having three flow connections, two of which can be inlets with one outlet (for converging or mixing flows), or one inlet and two outlets (for diverging or diverting flow). The term *valve body,* or even just *body,* frequently is used in referring to the valve body together with its bonnet assembly and included trim parts. More properly, this group of components should be called the *valve body assembly.*

Valve Body Assembly (commonly *Valve Body* or *Valve,* more properly *Valve Body Assembly*): An assembly of a valve, bonnet assembly, bottom flange (if used) and trim elements. The trim includes the closure member, which opens, closes or partially obstructs one or more ports.

Valve Plug: A term frequently interchanged with *plug* in reference to the closure member.

Valve Stem: In a linear motion valve, the part that connects the actuator stem with the closure member.

Yoke: The structure that rigidly connects the actuator power unit to the valve.

Quarter-Turn Control Valve Terminology

Actuator Lever: Arm attached to rotary valve shaft to convert linear actuator stem motion to rotary force to position disk or ball of rotary-shaft valve. The lever normally is positively connected to the rotary shaft by close tolerance splines or other means to minimize play and lost motion.

Ball, Full: The flow-controlling member of rotary-shaft control valves using a complete sphere with a flow passage through it. The flow passage equals or matches the pipe diameter.

Ball, Segmented: The flow-controlling member of rotary shaft control valves using a partial sphere with a flow passage through it.

Ball, V-notch: The most common type of segmented ball control valve. The V-notch ball includes a polished or plated partial-sphere surface that rotates against the seal ring throughout the travel range. The V-shaped notch in the ball permits wide rangeability and produces an equal percentage flow characteristic.

Disk, Conventional: The symmetrical flow-controlling member used in the most common varieties of butterfly rotary valves. High dynamic torques normally limit conventional disks to 60° maximum rotation in throttling service.

Disk, Dynamically Designed: A butterfly valve disk contoured to reduce dynamic torque at large increments of rotation, thereby making it suitable for throttling service with up to 90° of disk rotation.

Disk, Eccentric: Common name for valve design in which the positioning of the valve shaft/disk connections causes the disk to take a slightly eccentric path on opening. This allows the disk to be swung out of contact with the seal as soon as it is opened, thereby reducing friction and wear.

Flangeless Valve: Valve style common to rotary-shaft control valves. Flangeless valves are held between ANSI-class flanges by long through-bolts (sometimes also called *wafer-style valve bodies*).

Plug, Eccentric: Style of rotary control valve with an eccentrically rotating plug which cams into and out of the seat, which reduces friction and wear. This style of valve has been well-suited for erosive applications.

Reverse Flow: Flow from the shaft side over the back of the disk, ball or plug. Some rotary-shaft control valves are capable of handling flow equally well in either direction. Other rotary designs might require modification of actuator linkage to handle reverse flow.

Rod End Bearing: The connection often used between actuator stem and lever to facilitate conversion of linear actuator thrust to rotary force with minimum of lost motion. Use of a standard reciprocating actuator on a rotary-shaft valve body commonly requires linkage with two rod end bearings. However, selection of an actuator specifically designed for rotary-shaft valve service requires only one such bearing and thereby reduces lost motion.

Rotary Control Valve: A valve style in which the flow closure member (full ball, partial ball, disk or plug) is rotated in the flowstream to control the capacity of the valve.

Seal Ring: The portion of a rotary-shaft control valve assembly corresponding to the seat ring of a globe valve. Positioning of the disk or ball relative to the seal ring determines the flow area and capacity of the unit at that particular increment of rotational travel.

Shaft: The portion of a rotary-shaft control valve assembly corresponding to the valve stem of a globe valve. Rotation of the shaft positions the disk or ball in the flowstream and thereby controls capacity of the valve.

Sliding Seal: The lower cylinder seal in a pneumatic piston-style actuator designed for rotary valve service. This seal permits the actuator stem to move both vertically and laterally without leakage of lower cylinder pressure.

Standard Flow: For those rotary-shaft control valves having a separate seal ring or flow ring, the flow direction in which fluid enters the valve body through the pipeline adjacent to the seal ring and exits from the side opposite the seal ring. Sometimes called *forward flow.* (See also Reverse Flow.)

Trunnion Mounting: A style of mounting the disk or ball on the valve shaft or stub shaft with two bearings diametrically opposed.

Control Valve Functions and Characteristics Terminology

Bench Set: The calibration of the actuator spring range of a control valve to account for the in-service process forces.

Capacity: Rate of flow through a valve under stated conditions.

Clearance Flow: That flow below the minimum controllable flow with the closure member not seated.

Diaphragm Pressure Span: Difference between the high and low values of the diaphragm pressure range. This can be stated as an inherent or installed characteristic.

Double-Acting Actuator: An actuator in which power is supplied in either direction.

Dynamic Unbalance: The net force produced on the valve plug in any stated open position by the fluid pressure acting upon it.

Effective Area: In a diaphragm actuator, the effective area is that part of the diaphragm area that is effective in producing a stem force. The effective area of a diaphragm might change as it is stroked, usually being a maximum at the start and a minimum at the end of the travel range. Molded diaphragms have less change in effective area than flat sheet diaphragms; thus, molded diaphragms are recommended.

Equal Percentage Flow Characteristic: (See Control Valve Terms: Equal Percentage Characteristic.)

Fail-Closed: A condition wherein the valve closure member moves to a closed position when the actuating energy source fails.

Fail-Open: A condition wherein the valve closure member moves to an open position when the actuating energy source fails.

Fail-Safe: A characteristic of a valve and its actuator, which upon loss of actuating energy supply, will cause a valve closure member to be fully closed, fully open or remain in the last position, whichever position is defined as necessary to protect the process. Fail-safe action can involve the use of auxiliary controls connected to the actuator.

Flow Characteristic: Relationship between flow through the valve and percent rated travel as the latter is varied from 0 to 100%. This term should always be designated as either *inherent flow characteristic* or *installed flow characteristic.*

Flow Coefficient (C_v): A constant (C_v) related to the geometry of a valve, for a given travel, that can be used to establish flow capacity. It is the number of U.S. gallons per minute of 15°C (60°F) water that will flow through a valve with a one pound per square inch pressure drop.

High-Recovery Valve: A valve design that dissipates relatively little flow stream energy due to streamlined internal contours and minimal flow turbulence. Therefore, pressure downstream of the valve vena contracta recovers to a high percentage of its inlet value. Straight-through flow valves, such as rotary-shaft ball valves, are typically high-recovery valves.

Inherent Diaphragm Pressure Range: The high and low values of pressure applied to the diaphragm to produce rated valve plug travel with atmospheric pressure in the valve body. This range is often referred to as a *bench set range* because it will be the range over which the valve will stroke when it is set on the work bench.

Inherent Flow Characteristic: The relationship between the flow rate and the closure member travel as it is moved from the closed position to rated travel with constant pressure drop across the valve.

Installed Diaphragm Pressure Range: The high and low values of pressure applied to the diaphragm to produce rated travel with stated conditions in the valve body. It is because of the forces acting on the closure member that the inherent diaphragm pressure range can differ from the installed diaphragm pressure range.

Installed Flow Characteristic: The relationship between the flow rate and the closure member travel as it is moved from the closed position to rated travel as the pressure drop across the valve is influenced by the varying process conditions.

Leakage: (See Seat Leakage.)

Linear Flow Characteristic: (See Control Valve Terms: Linear Characteristic.)

Low-Recovery Valve: A valve design that dissipates a considerable amount of flowstream energy due to turbulence created by the contours of the flow path. Consequently, pressure downstream of the valve vena contracta recovers to a lesser percentage of its inlet value than is the case with a valve having a more streamlined flow path. Although individual designs vary, conventional globe-style valves generally have low pressure recovery capability.

Modified Parabolic Flow Characteristic: An inherent flow characteristic that provides equal percent characteristic at low closure member travel and approximately a linear characteristic for upper portions of closure member travel.

Normally Closed Valve: (See Fail-Closed.)

Normally Open Valve: (See Fail-Open.)

Push-Down-to-Close Construction: A globe-style valve construction in which the closure member is located between the actuator and the seat ring, such that extension of the actuator stem moves the closure member toward the seat ring, finally closing the valve. The term can also be applied to rotary-shaft valve constructions where linear extension of the actuator stem moves the ball or disk toward the closed position. (Also called *direct acting*.)

Push-Down-to-Open Construction: A globe-style valve construction in which the seat ring is located between the actuator and the closure member, so that extension of the actuator stem moves the closure member from the seat ring, opening the valve. The term can also be applied to rotary-shaft valve constructions where linear extension of the actuator stem moves the ball or disk toward the open position. (Also called *reverse acting*.)

Quick Opening Flow Characteristic: (See Control Valve Terms: Quick Opening Characteristic.)

Rangeability: The ratio of the largest flow coefficient (C_v) to the smallest flow coefficient (C_v) within which the deviation from the specified flow characteristic does not exceed the stated limits. A control valve that still does a good job of controlling when flow increases to 100 times the minimum controllable flow has a rangeability of 100 to 1. Rangeability can also be expressed as the ratio of the maximum to minimum controllable flow rates.

Rated Flow Coefficient (C_v): The flow coefficient (C_v) of the valve at rated travel.

Rated Travel: The distance of movement of the closure member from the closed position to the rated full-open position. The rated full-open position is the maximum opening recommended by the manufacturers.

Relative Flow Coefficient: The ratio of the flow coefficient (C_v) at a stated travel to the flow coefficient (C_v) at rated travel.

Seat Leakage: The quantity of fluid passing through a valve when the valve is in the fully closed position with pressure differential and temperature as specified.

Spring Rate: The force change per unit change in length of a spring. In diaphragm control valves, the spring rate is usually stated in pounds force per inch compression.

Stem Unbalance: The net force produced on the valve stem in any position by the fluid pressure acting upon it.

Vena Contracta: The portion of a flowstream where fluid velocity is at its maximum and fluid static pressure and the cross-sectional area are at their minimum. In a control valve, the vena contracta normally occurs just downstream of the actual physical restriction.

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Flowserve Corporation
5215 North O'Connor Boulevard
Suite 2300
Irving, Texas 75039
flowserve.com

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