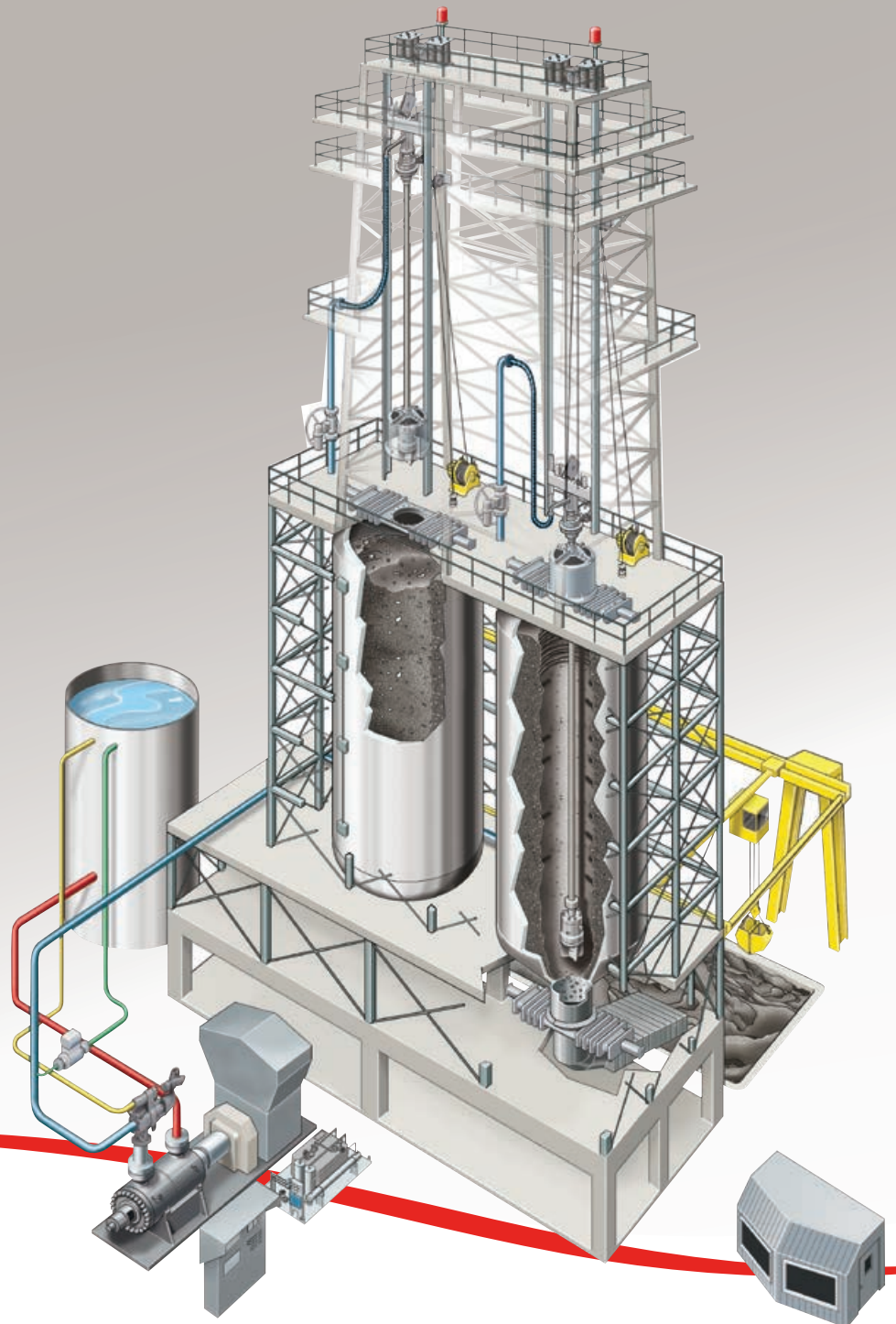


Application Solutions Guide

DELAYED COKER UNIT



Experience In Motion



TABLE OF CONTENTS

THE GLOBAL COKING AND DECKING LANDSCAPE

MARKET OVERVIEW 3

A CLOSER LOOK AT DELAYED COKER AND HYDRAULIC DECKING TECHNOLOGIES

Delayed Coker Units 4
DCU System Overview 5
Process Description 6
Hydraulic Decoking Systems 8
Hydraulic Decoking Explained 9

FLOWSERVE OPPORTUNITIES IN DELAYED COKER UNIT PRODUCTS

Key Pump Products 12
Coker and Heater Charge Pumps 12
Coke Handling and Dewatering 13
General Service Pumps 13
DCU Process Pumps 14
Valves and Actuation Equipment 22
Actuators for Refinery or Process Systems 23
Actuator Products Overview 24
Mechanical Seals and Systems 28
Piping Plans 32

FLOWSERVE OPPORTUNITIES IN HYDRAULIC DECKING SYSTEMS

A Complete Range of Decoking System Equipment 34
Decoking Hoses 36
Rotary Joint 36
Drill Stems 37
Combination Cutting Tools 37

Crosshead With Free-fall Arrestors 38
Latching Mechanism 39
Winch 39
Pulley Blocks, Sheaves and Cable 39
Control Systems, Including Intelligent and Automated Cutting 40
Drum Monitoring Systems 41
Remote Cutting and Automation 42
Tool Enclosures 42

COMMUNICATING OUR VALUE

Value Proposition (Delayed Coker Systems, Pumps, Valves, Seals and Actuation Products) . . . 43
Product Positioning 44
Understanding a Customer's Specific Business Drivers 44
Guidelines on Decoking System Selection Criteria 45

APPENDIX

Sourcing 46
Rotary/Cutting Tool View for DCU 47

GLOSSARY OF KEY TERMS, ABBREVIATIONS AND ACRONYMS

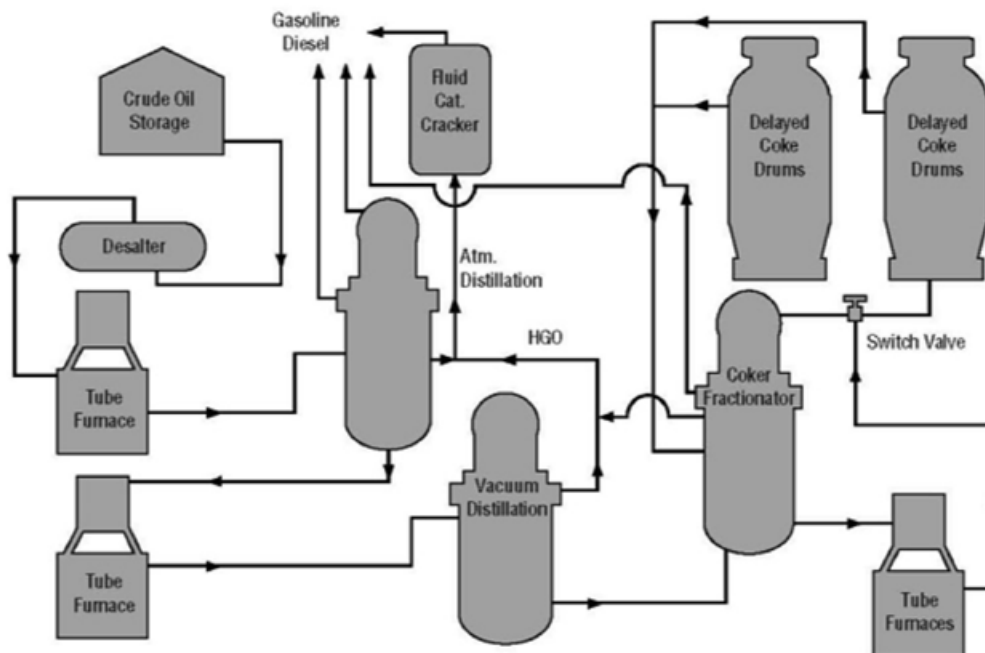
. 48

MARKET OVERVIEW

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

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

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



A CLOSER LOOK AT DELAYED COKER AND HYDRAULIC DECOKING TECHNOLOGIES

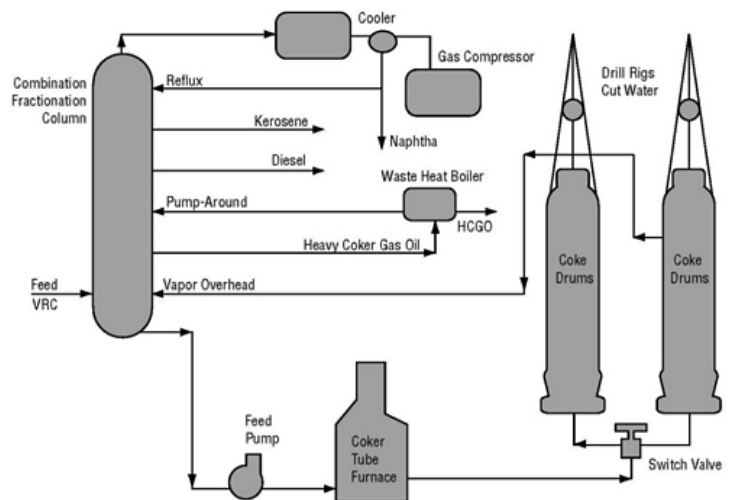
Delayed Coker Units

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

Flowserve can supply many of the [pumps](#) in the delayed coker unit, but we do have a specialty within the unit with the hydraulic decoking system. It is made up of 12–15 different pieces of equipment supplied by Flowserve, depending on the exact end user system. The heart of the system is the decoking jet pump. The remainder of the equipment is a mix of in-house designs and builds as well as buyouts specified by Flowserve engineering teams. Despite the multiple pieces of equipment mounted in the delayed coker unit separately, it should be treated by engineering and sales as a complete system.

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

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



DCU System Overview

Coking Section

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

Fractionation Section

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

Vapor Recovery Unit

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

Coker Blowdown

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

Steam Generation

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

Process Description

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

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

Heavy oil feeds such as VRC or atmospheric-reduced crude are preheated in heat exchanges (1) with coker gas oils and then fed to the bottom section of the coker fractionator (2). Fresh feed combines with recycle, which is net liquid from the fractionator wash section above the feed inlet, and is routed to the coker heaters (3) with the coker charge pumps.

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

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

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

A lower coke drum operating pressure and less recycle will result in more liquid and less coke produced. A modern delayed coker that maximizes liquid yields typically has a coke drum top operating pressure and a recycle to feed ration of 5% or less. Needle coker production, however, usually demands a high pressure and a high recycle-to-feed ratio to achieve the desired needle coke properties.

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

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

Drum Cycle

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

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

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

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

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

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

Application: Upgrade residues to lighter hydrocarbon fractions using the selective yield delayed coking (SYDEC) process.

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

Operating conditions: Typical ranges are:

- Heater outlet temperature
- Coke drum pressure
- Recycle ratio, equiv. fresh feed
- Increased coking temperature decreases coke production; increases liquid yield and gas oil end point
- Increasing pressure and/or recycle ratio increases gas and coke make, decreases liquid yield and gas oil end point

Hydraulic Decoking Systems

About 150 years ago, pioneer oilmen in northwestern Pennsylvania discovered that boiling oil in small iron stills would yield kerosene, a very valuable luminescent. Thus, the whaling industry died and the refining industry was born.

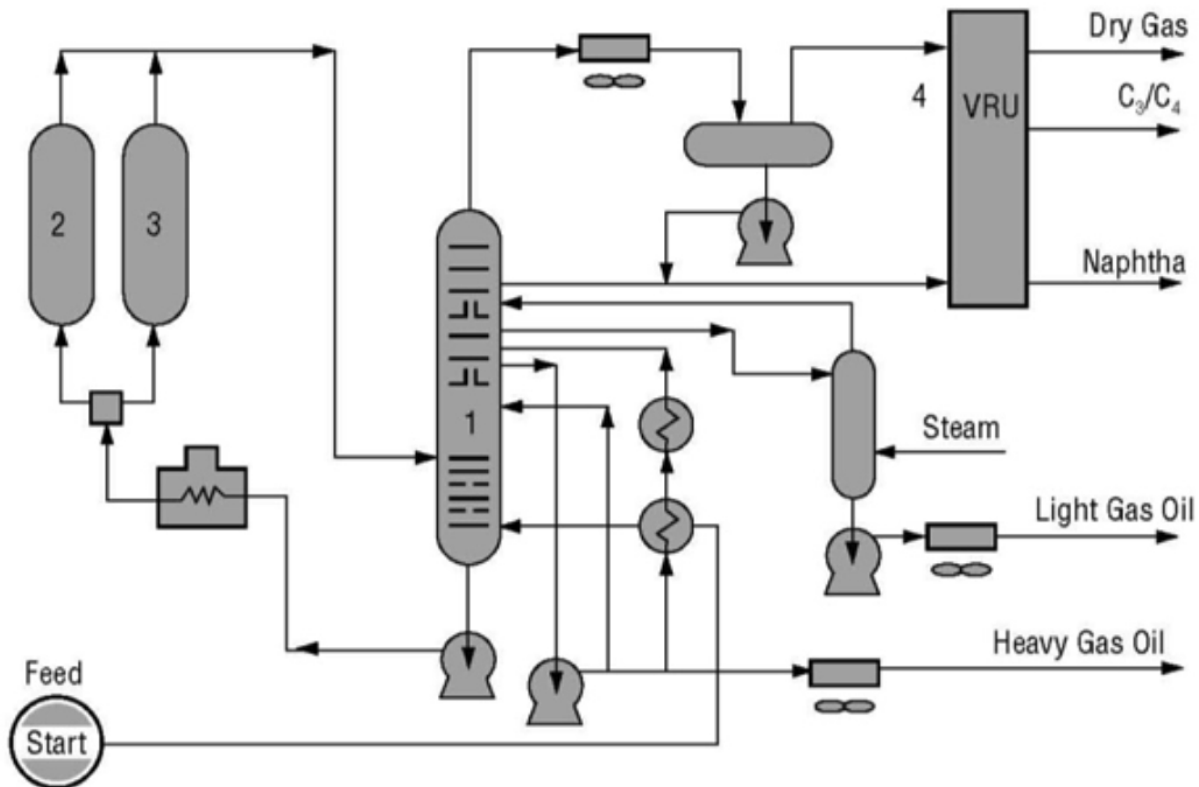
In addition to kerosene, however, one of several by-products was also discovered: coke. And, of course, before the stills could be reused they had to be cleaned, i.e., decoked. Thus, one of the grimmest, nastiest refinery chores — which persist to this day — was born.

From the 1860s through World War I, crude oil was processed in horizontal stills, singly and later in series to increase output. Decoking was accomplished by laborers with picks and shovels. The origin of the vertical coke drum coincided with Standard Oil's development of the Barton Process to convert gas oil to gasoline from 1912

to 1935. Decoking, however, was still a manual job accomplished by using cables, augers, beater balls and hydraulically operated mechanical drills.

In 1938, [Flowserve Worthington](#) designed and manufactured equipment for Shell Oil's Wood River, Illinois, (USA) refinery — the world's first hydraulic decoking installation. Flowserve supplied decoking tools, swivel joints, decoking control valves and high-pressure water jet pumps for that system. In 1940, Flowserve Pacific supplied the jet pumps for a hydraulic decoking system at Standard Oil's refinery in El Dorado, Indiana (USA).

Since then, Flowserve has pioneered many significant advancements in hydraulic decoking. Integrated systems consisting of decoking equipment, jet pump trains and control systems are matched to achieve guaranteed decoking performance. Flowserve has transformed hydraulic decoking into an increasingly safe, efficient and automated process.



Hydraulic Decoking Explained

Delayed coking is one of the most difficult refinery units to operate and control. Page 8 depicts a very simplified diagram of delayed decoking. The unit takes vacuum residual (fresh feed) and heats and injects it into the main fractionator bottom. There it is mixed with an internal reflux recycle of heavy cracked material. The total fresh and recycled feed is then heated in the coker furnace to a high cracking temperature. Hot partially cracked feed flows from the cooler furnace into coke drums, where the reaction continues. Cracked distillate vapor ascends in the coke drum and flows into the fractionator for separation.

Coke remains in the drums and is periodically removed; that is the main reason for the coker being a difficult unit to operate. Twice daily, filled coke drums are switched off for coke removal, and empty drums are connected to the fill lines. The drum that was just filled then goes through a cycle of steaming out, cooling, opening, coke removal, closing, steaming and pressure testing, heating and finally reconnecting to the furnace and fractionator.

Decoking System Components

A decoking system typically consists of:

- Jet pump — ISO 13709/API 610 (BB5)
- Coke cutting equipment
 - Decoking control valve
 - Rotary joint/drill stem/cutting tool assembly
- Decoking water tank
- Main and local control panels and enclosed operator cabin

The Decoking Process, Summarized

High-pressure water cuts the coke out of the drum. The cutting water pump, which is a multistage barrel pump, takes suction from the decoking water tank and delivers the high-pressure water through a hose to the top of the drill stem.

The discharge pressure of the cutting water pump varies according to the size of coke drum and type of coke produced. For large-diameter coke drums, the discharge pressure can be more than 310 bar (4500 psi). An air-, electric- or hydraulic motor-driven rotary joint rotates the drill stem and cutting tool.

The cutting tool, equipped with downward-oriented, pilot hole and side-oriented cutting nozzles, is attached to the bottom of the drill stem. First, a pilot hole is bored through the coke that has built up in the drum with the downward-oriented nozzles. The cutting tool is then pulled up to the top and switched to side-oriented cutting nozzles. The cutting tool then slowly moves through the length of the coke drum to loosen or cut out the coke.

Coke handling. Coke and cutting water from the coke drums fall into an adjacent large concrete pit or pad. Water drained from the pit or pad is collected in a nearby settling basin, which separates small coke particles (i.e., fines) from the water.

Water from the settling basin is pumped back to the decoking water tank for reuse. The decoking water tank also serves as storage for water that is used to quench the hot coke drum. Coke in the pit or pad remains there long enough for the water to drain. A crane or front-end loader moves the dewatered coke to a crusher. Then a conveyor belt typically transfers the coke to storage, railcar, ship or some other transport method. In some units, the coke is cut directly into railcars or to a crusher and then sluiced as a water slurry to dewatering and storage facilities.

Jet Pump Horizontal, Multistage, Double-casing Pumps (API-BB5)

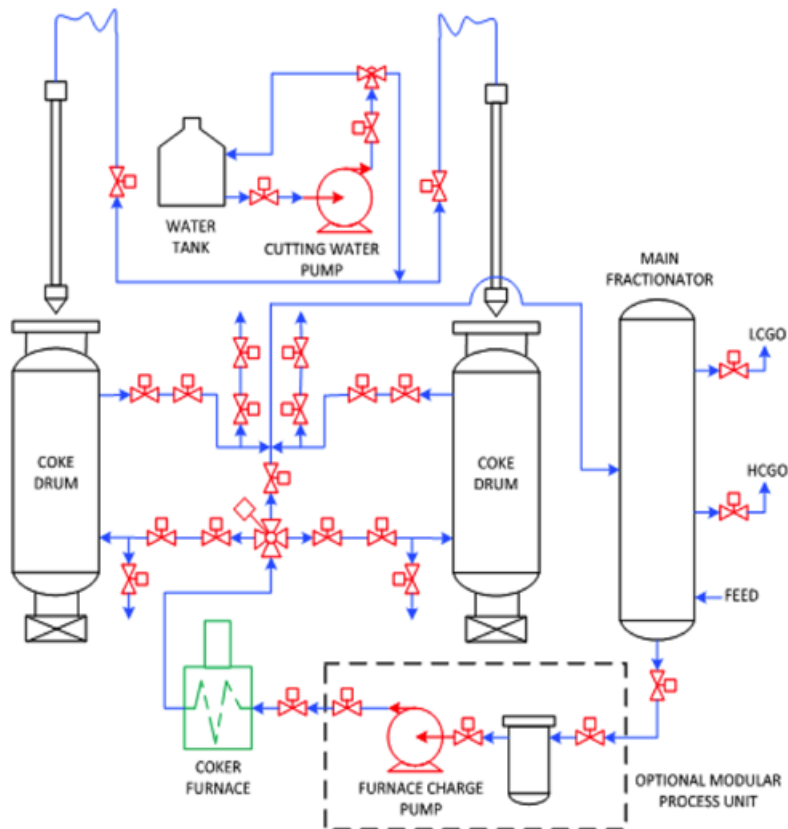
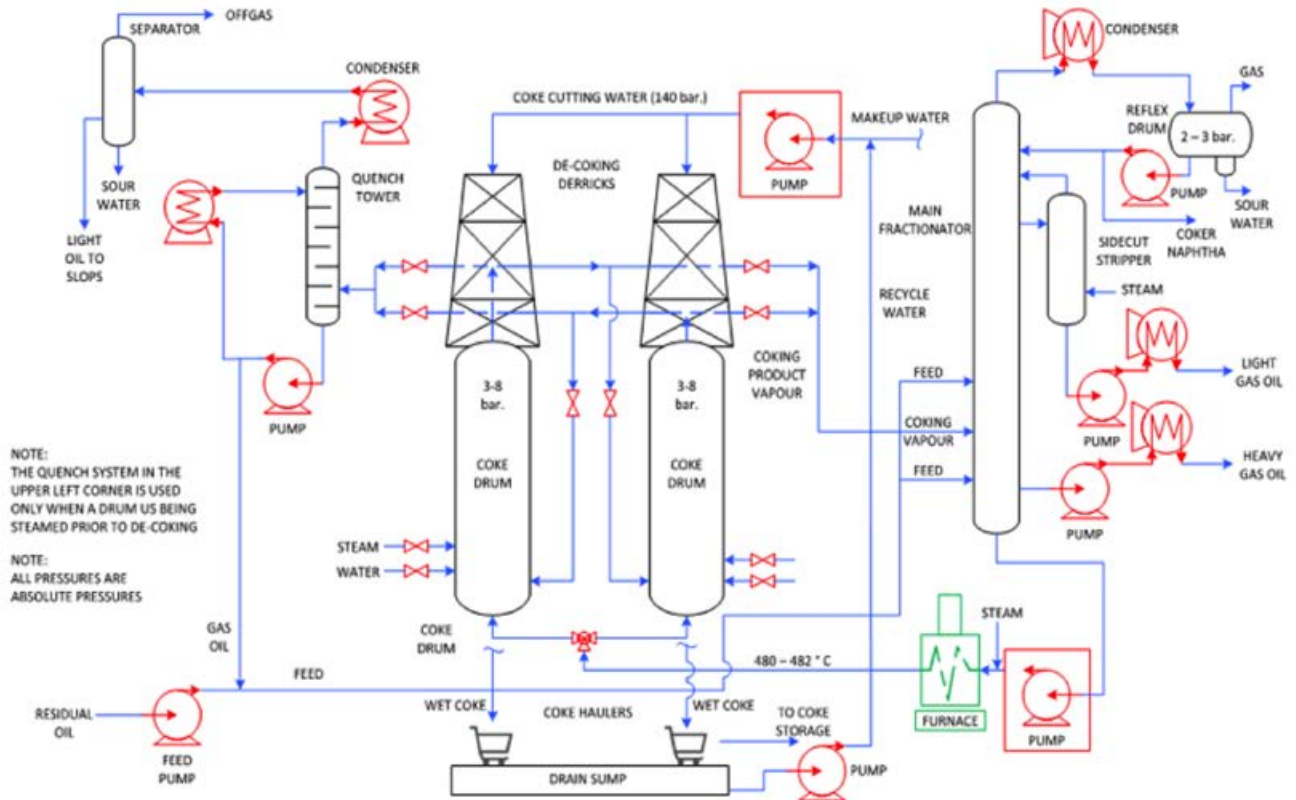
Diffuser barrel pumps for high-pressure service. First-stage, single- or double-suction, depending on available NPSH. Designed for both general purpose (i.e., spared) and special purpose (i.e., unspared) applications such as decoking (i.e., water cutting). The API 610 material code normally specified. The API 610 seal code normally used is QBRW. An auxiliary sealing device comprised of a close clearance floating carbon throttle bushing is also used. API Plan 32.

A Complete Range of Decoking System Equipment

Whether for new equipment, system upgrades or replacement parts, Flowserve provides a complete proven decoking system:

- Jet pump train with lube oil skid listed herein
 - There are options in markets in Europe and Russia for historical reasons. Higher-pressure pumps have the option of being run at high speeds.
 - Typical MTBR on the pump with poor maintenance practices and high fines to 10 years or more at sites with exceptional maintenance practices.
 - Application typically has a low NPSHA.
 - For more information, see the high-energy barrel product positioning guide.

Typical process flow diagram with critical pumps and valves



Key Pump Products

The key pumps or “heart” in a DCU are the coker/heater charge pumps and the coke cutter jet pump. A typical DCU uses BB-type pumps plus water and general service pumps. It should also be mentioned that BB3 multistage pumps are found in boiler feedwater and other heavy-duty applications.

Flowserve refinery pumps are fully compliant with ISO 13709/API 610 current edition standards.

- Coking section
 - Pump for heater charge
- Fractionation section
 - Overhung process for general service
- Vapor recovery unit
 - Overhung process
- Coker blowdown
 - Overhung process
- Steam generation
 - Axially split, two-stage between bearings

Coker and Heater Charge Pumps

The Flowserve petroleum process pumps best suited for these services are the between bearings radially split designs. The API 610 material designation for the coker charge pump is normally specified.

[Mechanical seal selection](#) is key to trouble-free operation of these critical pumps. However, new and revamped units are typically supplied with pressurized dual seal and Plan 32/53 or Plan 32/54. These devices improve the efficiencies of these piping plans.

For HCGO, double-suction between bearings radially split (BB2) design is recommended. Low-flow/high head pump is also used in HCGO and LCGO services.

Coke Handling and Dewatering

Solids-handling Submersible Pumps

Choice of API materials in lineshaft (VS4) or cantilever (VS5) configurations. Non-ISO/ API designs

Slurry Sump Pumps

Hard metal type in either lineshaft

Sump Pumps

Choice of API materials in lineshaft (VS4) or cantilever (VS5) configurations

General Service Pumps

Process water sump; anti-foam; storm water sump; dirty oil sump

Vertical Turbine Pumps (API-VS6)

Multistage with above or below grade discharge, enclosed or semi-open impellers, open or enclosed lineshafts, single or double casing

Double-suction, Twin-volute Vertical Pumps

Wet-pit, double-suction impeller, between bearings, double-volute centrifugal pump

DCU Process Pumps

There are many applications within the DCU; these are listed below with comments relative to typical configurations.

RICH AMINE TRANSFER	QUENCH WATER	FRACTIONATOR RECIRC	COMPRESSOR SUCTION DRUM
Splitter Bottoms	LP Condensate	Fractionator Reflux	Stripper Feed
Splitter Overhead	LPG Condenser Recycle	LCGO Product	Lean Oil
Blowdown Lower Bottoms	Vacuum Resid	HCGO Product	Debutanizer Reflux
Blowdown Slop Oil			

API Classification

Pump type			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
	Volute				VS2
	Axial flow				VS3
	Separate discharge			Line shaft	VS4
				Cantilever	VS5
	Double casing		Diffuser	VS6	
Volute			VS7		

Sending new table

OH2

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

- Lower operating costs due to comprehensive hydraulic coverage and numerous specialty configurations that permit precise selection for best operating efficiency
- Longer service life enabled by centerline-supported casing that withstands nozzle loads beyond ISO 13709/API 610 requirements and minimizes shaft misalignment, thereby extending rotor, bearing and seal life
- Stringent emissions containment with ISO 21049/API 682 seal chamber
- Easier maintenance thanks to back pullout design, enabling service without disturbing motor or casing connections

Refer to literature PS-10-5 at flowserve.com/library.



OH2

Fully compliant with ISO 13709/API 610 (OH2)

- Broad application flexibility from innovative multi-channel diffuser technology, which supports more than 170 hydraulic configurations and easily accommodates changing operating parameters
- Improved pump efficiency via diffuser tuning, which widens operational flow window and minimizes radial loads at any flow
- Extremely low total cost of ownership thanks to long MTBF, low seal emission, long mechanical seal life, low energy consumption and low NPSH
- Improved plant and personnel safety enabled by low vibration and noise levels

Refer to literature PSS-10-5.2 at flowserve.com/library.



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.

- Broad application versatility due to extensive hydraulic coverage plus wide variety of configurations, constructions and materials to suit application requirements
- Lower installation costs with low NPSH first-stage impeller that reduces suction can length
- Lower operating costs from available aftermarket rebowl services that revitalize aged VPCs to reduce power consumption, downtime and maintenance costs

Refer to literature PS-40-2 at flowserve.com/library.



VS2

Double-suction vertical turbine pumps. ISO 13709/API 610 (VS2) compliant design available.

- Superior performance from innovative, double-suction impeller that produces more flow and higher head at lower NPSHR
- High uptime with sealed-for-life bottom bearing plus heavy-duty discharge head and integral line shaft bracket, which ensure shaft concentricity and alignment
- High operating efficiency promoted by renewable impeller wear rings that restore original clearances
- Reliable performance in applications containing silt or abrasive solids owing to optional enclosed lineshaft construction

Refer to literature PS-40-4 at flowserve.com/library.



BB3

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

- Increased uptime enabled by opposed mounted impellers operating in a double volute casing, which provide inherent hydraulic balance over the full operating range
- Broad application versatility provided by numerous options that permit the pump to be precisely configured for service requirements
- Superior performance at elevated temperatures with near-centerline mounting
- Ease of maintenance facilitated by cap nuts on top half casing parting flange
- Emissions control with ISO 21049/API 682 seal chambers

Refer to literature PS-30-3 at flowserve.com/library.



OH2

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

- Low lifecycle cost provided by replaceable mechanically fastened liners that protect the pressure casing from erosion and abrasion
- Process flexibility made possible by interchangeable diffuser, casing liner and impeller, which allows operators to adapt performance to changing process conditions
- Extended operating life ensured by a rigid, oversized bearing frame that maintains shaft deflection below ISO/API requirements
- Casing liners are available in multiple abrasion-resistant materials and surface treatments to meet any process or operational requirement

Refer to literature PS-30-3 at flowserve.com/library.

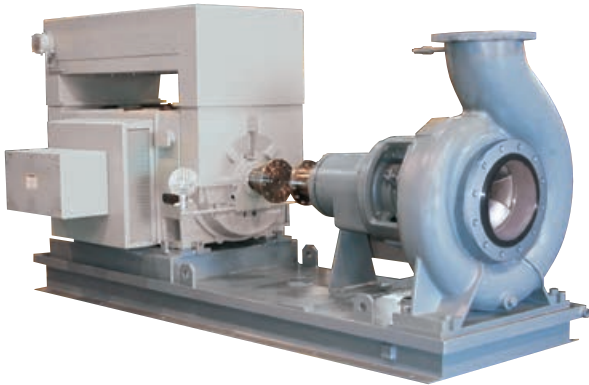


End Suction Horizontal Single Stage

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

- High uptime and efficiency ensured by unobstructed suction, large streamlined flow channel, and semi-open impeller with back pump-out vanes, which prevent air binding and clogging, even in thick, pulpy mixtures
- Reduced maintenance provided by rigid one-piece bearing frame; ensures positive alignment and offers ample access to gland and seal chamber
- Reliable, efficient performance with a steep head-capacity curve, which prevents driver overload and minimizes changes in flow, despite changes in system head
- Low total cost of ownership resulting from high-efficiency, low-maintenance design

Refer to literature PS-10-16 at flowserve.com/library.



BB2

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

- Increased uptime enabled by double-suction impeller that minimizes thrust problems, reduces NPSHR, and allows mechanical seals to operate at equal and low pressure
- Excellent high-temperature performance provided by centerline mounting plus gasketing with metal-to-metal fit to ensure proper sealing and alignment
- Installation ease with top-top, side-top and side-side nozzle configurations available to meet any customer piping layout
- Safety and environmental compliance with ISO 21049/API 682 seal chambers
- Power recovery turbine configuration available

Refer to literature PS-20-4 at flowserve.com/library.



BB5

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

- Outstanding reliability assured by low static deflection, the result of a large diameter shaft and short bearing spans
- Optimized efficiency due to precision-cast, low specific speed impellers, multi-vane diffuser and milled channel collectors to ensure repeatable performance
- Smooth, stable performance with multi-vane, split diffuser and channel ring collectors that eliminate radial imbalance
- Performance tested in accordance with API and Hydraulic Institute standards
- Ease of maintenance with back pullout, cartridge-style construction

Refer to literature PS-30-9 at flowserve.com/library.

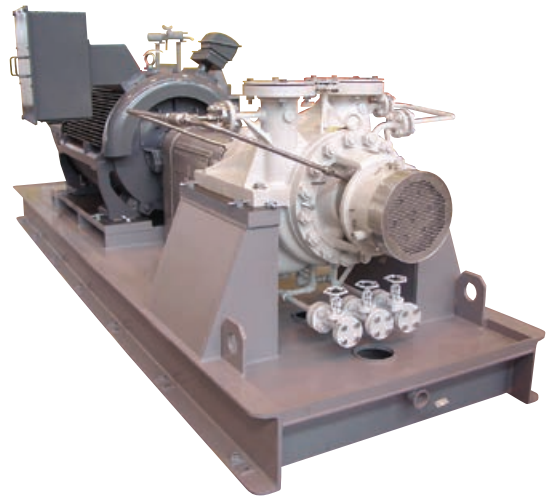


BB2

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).

- Extended reliability and life made possible by heavy-duty, single- or dual-volute casings with a staggered arrangement, which ensures radial balance
- Application versatility provided by numerous options — including 50- or 60-cycle operation and top-top, side-top and side-side nozzle orientations — that permit the pump to be precisely configured for service and site requirements
- Increased reliability provided by stiff shaft design, which ensures trouble-free operation below the first critical speed
- Environmental regulatory compliance with ISO 21049/API 682 seal chambers

Refer to literature PS-30-4 at flowserve.com/library.



Condensate Transfer

- Operating conditions: 150°C (300°F), 7 bar (100 psi)
- API material code — C-6
- Mechanical seal: pusher type
- Auxiliary seal system: Plan 23

Fractionator Overhead Reflux

- Operating conditions: 107°C (225°F), 7 bar (100 psi)
- Recommended pump: API material code — S-5
- Mechanical seal: metal bellows
- Auxiliary seal system: Plan 11/52

Fractionator Overhead Sour Water

- Operating conditions: 107°C (225°F), 5 bar (75 psi)
- Recommended pump: API material code — A-8
- Mechanical seal: metal bellows, Plan 11/53

Light Distillate Sidestream

- Operating conditions: 260°C (500°F), 14 bar (200 psi)
- Recommended pump: API material code — S-5
- Mechanical seal: metal bellows
- Auxiliary seal system: Plan 02/53

Gas Oil Sidestream

- Operating conditions: 345°C (650°F), 14 bar (200 psi)
- Recommended pump: API material code — S-5
- Mechanical seal: metal bellows
- Auxiliary seal system: Plan 02/53

Fractionator Overhead Product

- Operating conditions: 107°C (225°F), 17 bar (250 psi)
- Recommended pump: API material code — S-5
- Mechanical seal: metal bellows
- Auxiliary seal system: Plan 11/52

Dilute Tower Feed

- Operating conditions: 150°C (300°F), 12 bar (175 psi)
- Recommended pump: API material code — S-6
- Mechanical seal: metal bellows
- Auxiliary seal system: Plan 02/53

Preheat Condensate Steam Removal

- Operating conditions: 121°C (250°F), 7 bar (100 psi)
- Recommended pump: API material code — C-6
- Mechanical seal: pusher type
- Auxiliary seal system: Plan 23

Diluent Pump

- Operating conditions: 107°C (225°F), 14 bar (200 psi)
- Recommended pump: API material code — S-6
- Mechanical seal: pusher type
- Auxiliary seal system: Plan 11/52

Diluent Surge Drum Sour Water Removal

- Operating conditions: 107°C (225°F), 7 bar (100 psi)
- Recommended pump: HPX, API material code — A-8
- Mechanical seal: metal bellows
- Auxiliary seal system: Plan 11/52

Quench Water

- Operating conditions: 93°C (200°F), 7 bar (100 psi)
- Recommended pump: API material code — S-6
- Mechanical seal: metal bellows
- Auxiliary seal system: Plan 13

Wash Oil

- Operating conditions: 204°C (400°F), 10 bar (150 psi)
- Recommended pump: API material code — S-5
- Mechanical seal: metal bellows
- Auxiliary seal system: Plan 02/53

Coker Recovery Oil

- Operating conditions: 65°C (150°F), 14 bar (200 psi)
- Recommended pump: API material code — S-6
- Mechanical seal: pusher type
- Auxiliary seal system: Plan 11/52

Steamout Sour Water

- Operating conditions: 65°C (150°F), 5 bar (75 psi)
- Recommended pump: API material code — A-8
- Mechanical seal: pusher type
- Auxiliary seal system: Plan 11/53

Hydraulic Decoking Pump, Cutting Equipment and Water Service Pumps

- These pumps will be discussed in the following section, Hydraulic Decoking.

Valves and Actuation Equipment

The key valves in a DCU are the coker and heater charge valves, coke bottoms and frac charge. A typical DCU uses specialty control and ball valves. It should also be noted there are several other general service valves in the power house portion of applications.

When converting heavy hydrocarbon streams to lighter industrial products, the thermal cracking process calls for the frequent operation of the isolation valve system during the coke drum switching operation.

Flowserve designs provide trouble-free operation in heavy coking applications. In addition, our unique engineering requires significantly less maintenance during purging operations, which saves energy costs.

Flowserve's experience includes a broad range of AOV (air) and MOV (motor) actuators and systems.

We draw on years of Flowserve experience and field data from working on DCUs to determine the precise amount of service duty that can be applied to actuator and valve stem sizing, preventing failures caused by increased torque as coke builds up.

Operating Conditions:

- High Temperatures
- Coking Service
- HP Steam Blowdown
- High-pressure Water Service
- High Cycles
- Temperature Cycling
- Erosive Conditions

Valve Types:

- Axial flow for anti-cavitation trim
- Globe control valve, with pilot-operated trim: tight shutoff with anti-cavitation trim
- High-performance butterfly valve
- Eccentric rotary plug valve
- Segmented ball control valve
- Metal-seated trunnion ball valve
- RSBV, rising stem ball valve
- Anti-erosive angle control valve
- Noise abatement trim
- Variety of isolation valves — type gate, plug and ball

DCU Valve Applications Include:

- High-pressure Pump Inlet Isolation
- Cutting Water Pump Isolation
- Quench Extraction
- Overhead Vapor Isolation
- Coke Drum Bypass Isolation
- Coke Drum Switching
- Coke Drum Feed Isolation
- Quench Extraction Isolation
- Light Coker Gas Oil Pump EBV
- Heavy Coker Gas Oil Pump EBV
- Frac Bottoms EBV
- Frac Bottoms Pump Recirculation
- Coke Filter Isolation
- Furnace Charge Pump Inlet Isolation
- Furnace Charge Pump Discharge Isolation
- Furnace Feed Isolation
- Charge Pump Recirc
- Main Feed Heater Flow
- Bottoms/Product Streams
- Sour Water
- Overhead Gas
- BFW Steam
- Water/Coke Fines
- Wet Gas Compressor Anti-surge

Actuators for Refinery or Process Systems

Many refineries will vary their use of actuators from AOV or MOV. Flowserve offers an extensive range of electrical, fluid power and gear box actuators. For example, the Flowserve Limitorque MX non-intrusive, multi-turn actuator. These actuators provide a comprehensive network for users.

The QX quarter-turn actuator would be used for any quarter-turn application (e.g., ball valves).

On new projects, the actuators are normally purchased with the valves and not directly by the EPC or OEM.

Key Certifications and Standards Compliance

- Available according to ATEX 94/9/EC Ex II 2GD c IIC T6
- NEMA4 and NEMA4X per NEMA 250
- IP66/IP66M and IP67/IP67M configurations
- Manufactured and tested in compliance with ISO 9001 and EN 15714 Part 3 for pneumatic actuators and Part 4 for hydraulic actuators
- Actuator spring design in compliance with EN 13906
- Available valve interface in compliance with ISO 5211
- Corrosion protection in compliance with ISO 12944-2 and EN 15714; optionally available up to and including C5-M
- Available in compliance with NACE specification MR0175 for sour gas applications
- Available for use in safety integrated systems up to and including SIL Level 3 in accordance with IEC 61508
- Available in compliance with PED 97/23/EC, ASME BPVC Sec. VIII Div. 1, EN 13445-3 Part 2 for Unfired Pressure Vessels
- Available according to CU TR and GOST-R

Actuator Products Overview

- Limitorque actuator products
- They are defined into three primary categories:
 - Electric Actuators — heavy-duty electric space
 - Fluid Power Actuators — LFPS
 - Gearboxes (manual and motorized)
- Electric actuators are segmented into two categories:
 - Intrusive: the controls cover must be removed, exposing the controls to the environment, in order to configure position and torque limits — types are SMB and L120.
 - Non-intrusive: the control covers are not removed in order to configure position and torque limits — types are MX and QX.
 - Both intrusive and non-intrusive types are available in multi-turn for rising stem valves — SMB, L120 and MX.
 - For quarter-turn valves (BFV, BV and plug), only the non-intrusive QX is available.
 - Limitorque supplies mechanical gearboxes for either manual or automated service. For multi-turn applications, “V” bevel gearboxes and the “SR” spur gearboxes can be supplied.
 - Limitorque supplies WG and HBC worm gearboxes for quarter-turn applications.
- Limitorque also offers optional network protocols which can be fitted to non-intrusive electric actuators.

DCU and Refining (Downstream O&G) Actuators Overview:

Rotork is the leading supplier of electric actuators in the oil & gas industries, especially refining. They developed the first non-intrusive electronic actuator in the early 1990s primarily for the refining industry and continue to enjoy success, although mitigated by the market reset, in global regions.

Flowserve Limitorque followed with the first generation MX in the late 1990s and is believed to be second in the refining market. Limitorque’s strategy is to attempt to isolate specifications to the higher non-intrusive technology against Rotork. We have been successful if the specification can be limited to the Rotork IQ products and Limitorque’s MX and QX. It should be noted that the downstream markets are very competitive.

- When Auma is included, both Rotork and Limitorque non-intrusive technology advantages are mitigated and the projects are won on pricing only. This is particularly true in the current reset in the oil & gas environments.

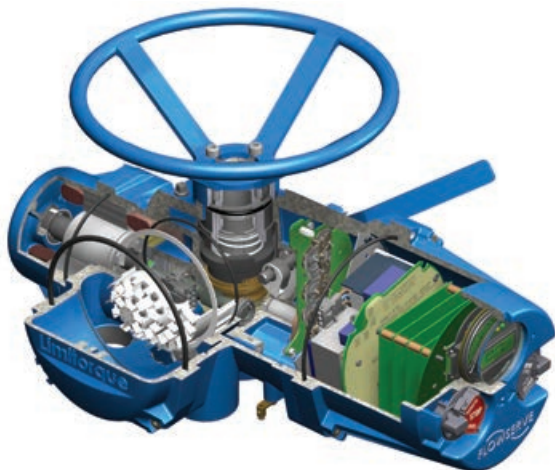
- The upstream and downstream oil & gas markets sometimes require isolation valves that must move to a pre-determined position (open, closed, mid-stroke position) when mains power is removed. This is referred to as a “fail-safe” actuator and typically “just in time” power must be supplied. Rotork offers their CVA actuator with super-cap technology to power an actuator to a pre-determined position. Auma uses a mechanical device similar to a coil spring to move the actuator to a pre-determined position. Limitorque continues to develop technology on our QX actuator.

MX Multi-turn, Non-intrusive Actuator

Flowserve Limitorque introduced the MX electric actuator in 1997 as the first smart actuator providing uncompromised reliability and performance in an easy to use design.

Limitorque MX Single-phase ACV

Flowserve Limitorque introduced the innovative MX electronic actuator with technical features that were market firsts: a patented absolute encoder, patented Limigard technology, and easy-to-use menus in multiple languages. These features and the implementation of a BLDC (brushless DCV) motor were included in the feature-rich QX quarter-turn electronic actuator. All of the innovative features devised for the MX and QX are now combined in the single-phase ACV MX, including a BLDC motor.



QX Quarter-turn Actuator and QXM Limited Multi-turn, Non-intrusive Actuators

QX

The Flowserve Limitorque QX quarter-turn smart electronic valve actuator mimics the state-of-the-art, multi-turn MX actuator by including a unique absolute encoder for tracking position without the use of batteries. The QX design provides enhanced safety and reduced downtime through improved diagnostics, built-in selftest (BIST) features and LimiGard fault protection.

Brushless DC Motors

The QX family of actuators was the first non-intrusive actuator to employ advanced brushless DC motors. BLDC motors eliminate sparks, reduce mechanical and electrical noise, and dissipate heat better than motors with brushes. The brushless actuator design lasts longer than conventional motors and allows for more accurate positioning while permitting a global range of voltages (single-phase and three-phase ACV and DCV) to be connected without modification.



Limitorque Intrusive Electric Actuators

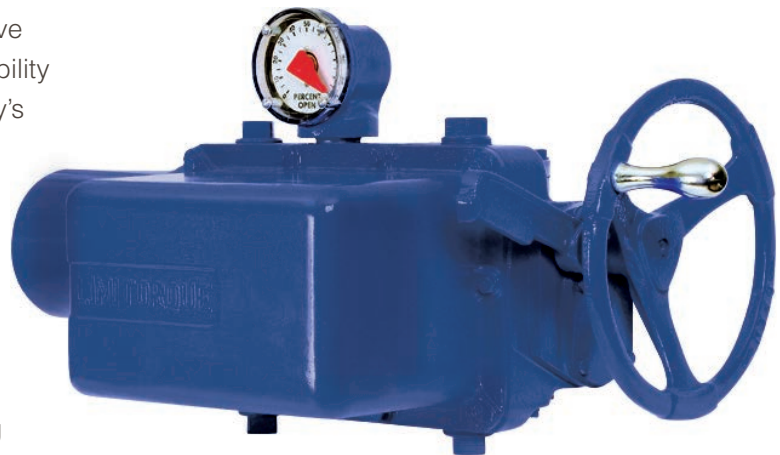
L120 Multi-turn Actuator

The Flowserve Limitorque L120 Series, with more than 25 years of field-proven reliability, is a long-standing product of choice for any valve requiring either rotary or linear actuation. Regardless of the valve design, the L120 performs consistently and predictably in any situation demanding positive, dependable control.



SMB Multi-turn Actuator

With more than 50 years of proven performance and reliability, the eight models in the Flowserve Limitorque SMB Series offer rugged dependability from the smaller SMB-000 through the industry's largest electric valve actuator, the SMB-5XT. An extensive gearing selection for each actuator size delivers unmatched versatility for meeting exacting operating speed requirements. Three-phase, single-phase, pneumatic and DC motors are available to meet wide ranges of power and speed. Optional controls include an integral reversing starter and control voltage transformer package, an actuator-mounted control station, and position indication feedback.



Limitorque Fluid Power Systems

Limitorque is dedicated to providing heavy-duty, fluid-powered valve actuators and control systems for the oil and gas industry. Every product accounts for the most recent and stringent industry standards for safety and service life, providing users with unprecedented operating life and maintenance intervals.

LPS Pneumatic Quarter-turn Scotch Yoke Actuators

Equipment performance and safety standards continue to evolve and increase across the infrastructure industries. To more aggressively meet these demands, Flowserve Limitorque is offering the LPS pneumatic Scotch yoke actuator — specifically designed to meet or exceed the latest and most rigorous of these requirements.

LPC Compact Pneumatic Scotch Yoke Actuator

The Limitorque Pneumatic Compact (LPC) Scotch yoke is a robust yet lightweight, modular, pneumatic, piston-type actuator design, with nodular ductile cast iron or carbon steel housing and carbon steel ENP cylinders. The LPC actuator is available in both spring-return and double-acting configurations, with an easy field conversion feature from Fail Close Clockwise to Fail Open Counter-Clockwise. It is ideally suited for smaller size valves. The LPC is fully complementary to the LPS, employing a similar design philosophy and meeting the same industry specifications, but in a more, lower cost package.

LHS and LHH Limitorque Hydraulic Scotch Yoke Actuators

The Limitorque Fluid Power family of heavy-duty actuators includes the Limitorque Hydraulic Scotch yoke actuators (LHS and LHH).

Often lighter and more compact than its LPS counterpart, the LHS/LHH offers a choice for those preferring hydraulic motive power. For some, such as those working in an offshore environment, it may be the only practical option in terms of fluid-power availability and performance requirements. The LHS/LHH Limitorque hydraulic actuators have a robust, modular Scotch yoke design, and are available in both spring-return and double-acting configurations. They are suitable for actuating ball, butterfly and plug valves or any other quarter-turn applications. LHS hydraulic actuators deliver precisely controlled torque (contact factory for larger sizes).

Mechanical Seals and Systems

Safe and reliable handling of fluid is vital in today's hydrocarbon processing plants. Complex refining techniques generate a broad range of shaft sealing challenges.

A growing focus on environmental stewardship demands continuous innovation in process containment.

The Flowserve commitment to technology development has produced sealing solutions for:

- Zero emissions on services containing volatile hazardous air pollutants
- Specialized applications, including viscous refinery bottoms, polymerizing fluids and flammable gases
- Corrosive, caustic, acidic, sour and abrasive products
- A wide range of temperatures
- High speeds and pressures
- Tolerance to process upsets

API 682

Flowserve seals and support systems for the refinery industry satisfy all requirements of the latest edition of API 682.

Delayed Coker Unit Applications

Typical Services

- Acids
 - Engineered Bellows
- Amine
 - Engineered Pusher
 - Engineered Bellows
- Caustic
 - Standard Cartridge Bellows
 - Engineered Bellows
- Flashing Hydrocarbons
 - Engineered Pusher
- Non-flashing Hydrocarbons
 - Engineered Pusher
- Hot Hydrocarbons
 - Engineered Bellows
- High-pressure; High-viscosity Hydrocarbons
 - Engineered Pusher
- Water
 - Standard Cartridge Pusher
 - Engineered Pusher
- Water — Sour
- Standard Cartridge Pusher
 - Engineered Pusher
- Water — Hot
 - Engineered Pusher

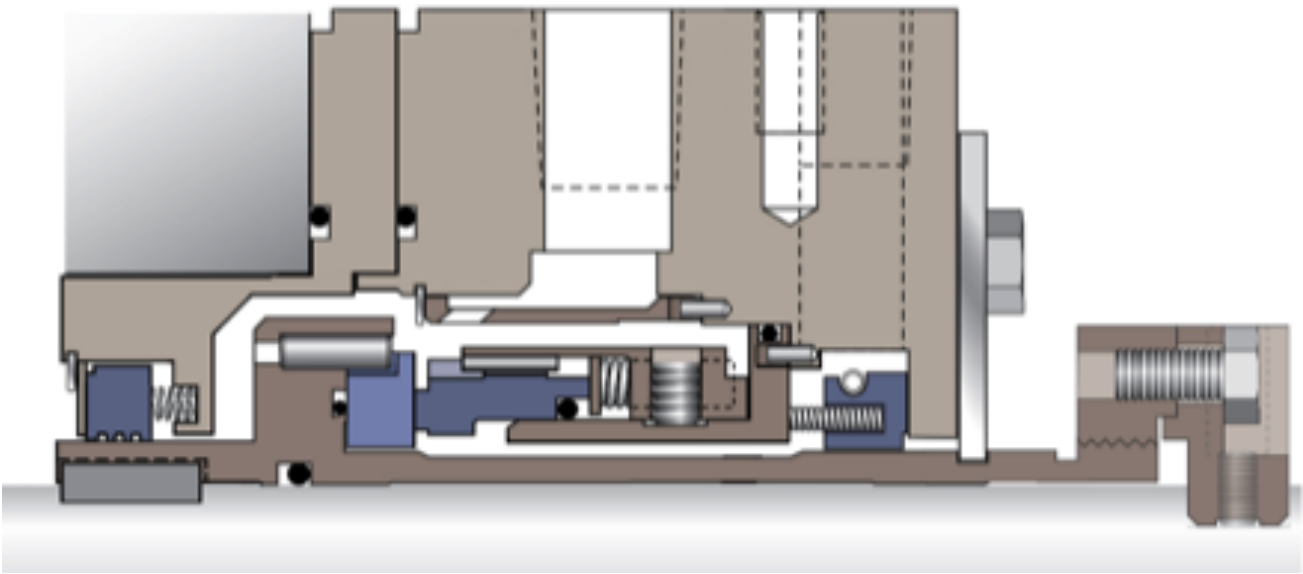
Specialty Applications

- Low-temperature Containment Seal
- High-temperature Containment Seal
- Pressurized Pump Gas Seal
- Integrally Geared Equipment
- Turbomachinery; Compressors

Decoking Jet Water Pump Seals

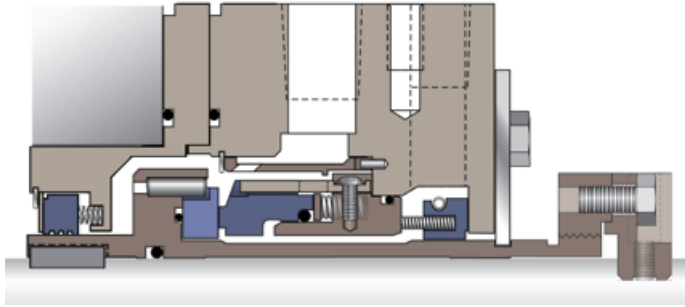
Flowserve has established a very successful formula for designing and applying decoking jet water seals. In 2016, Flowserve released a new seal design with additional pressure-handling capability. Both seal types are available for use in decoking jet water applications, depending on conditions of service and customer preferences.

Seals up to 750 psi (51.7 bar)



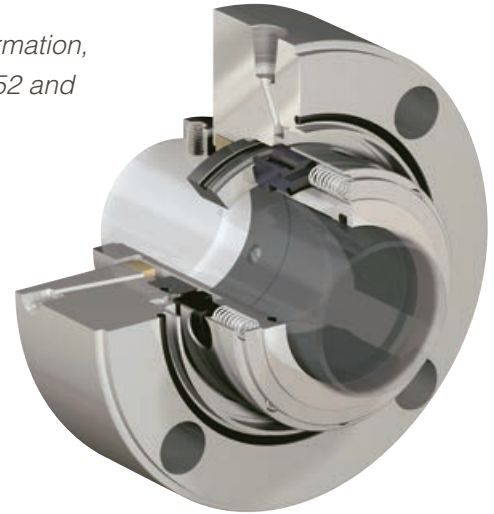
Seals up to 1500 psi (103.4 bar)

Flexible stator cartridge seals are built for extended reliability in high-pressure and high-speed pumps. Fully compliant with API 682 Type A requirements.



This compact, medium- to high-pressure seal features a high balance face that meets the lowest hydrocarbon emissions level — less than 500 ppm. Designed to suppress flashing and minimize heat generation.

For more information, refer to FSD152 and FSD216.



Descriptions of Engineered Seals Applied in Delayed Coker Units

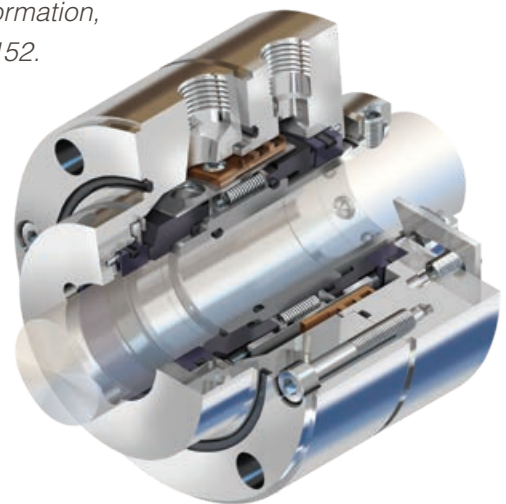
The family of balanced pusher and metal bellows seals designed to fully comply with the design and qualification requirements of API 682.



Pusher Seals

Dual pressurized pusher seals are capable of zero emissions. Provide reverse pressure capability for API 682 Arrangement 3 requirements.

For more information, refer to FSD152.



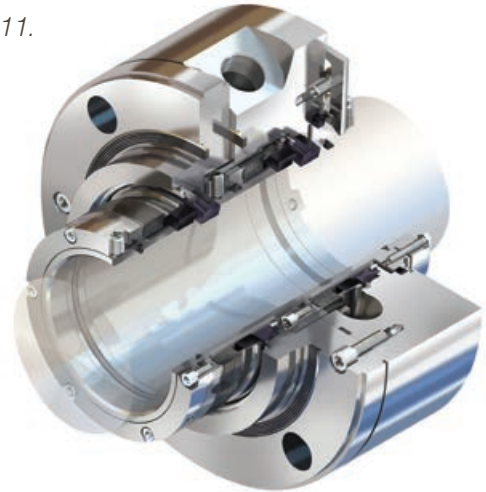
Balanced rotating metal bellows seals provide exceptional reliability in corrosive and non-corrosive fluids, especially those that crystallize. Fully compliant with API 682 Type B design requirements.

For more information, refer to FSD109.



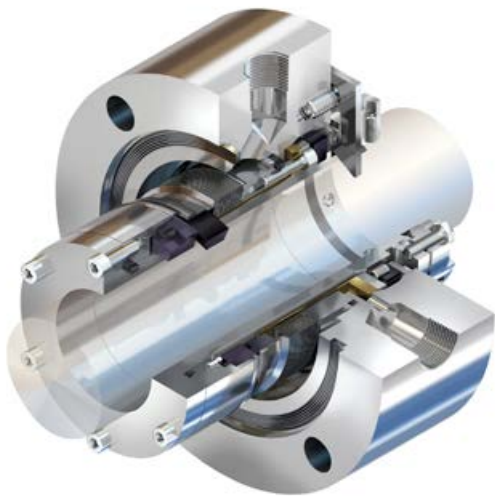
Balanced rotating metal bellows seals are designed for refinery and petrochemical services at high and low temperature extremes, beyond the reliable usefulness of elastomers. Meet API 682 Type C requirements.

For more information, refer to FSD111.



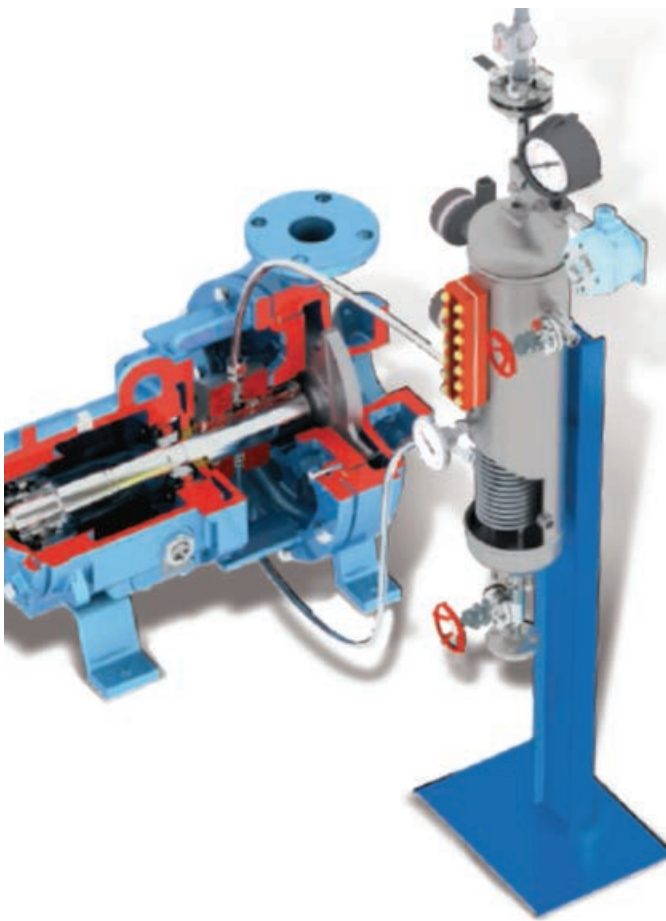
When extreme temperatures push the limits of elastomers, stationary metal bellows seal offers reliable sealing at high speeds. Meets all API 682 Type C requirements.

For more information, refer to FSD111.

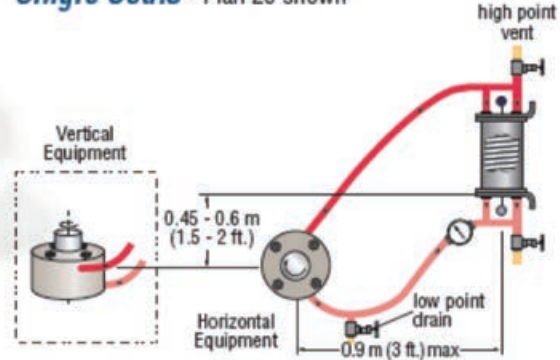


Piping Plans

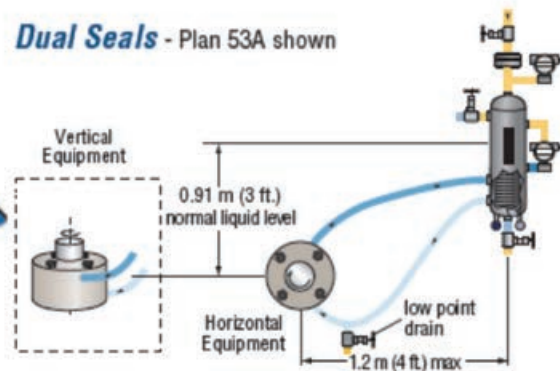
Flowserve recognizes that one of the most effective ways to achieve long, uninterrupted mechanical seal life is to create a healthy environment around the seal faces. Piping plans help keep mechanical seals run cool and clean, promote safe handling of dangerous fluids, and extend the operational availability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



Single Seals - Plan 23 shown

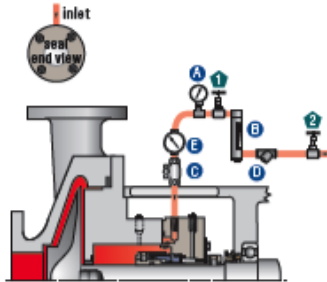


Dual Seals - Plan 53A shown



Plan 32

Seal flush from an external clean source.

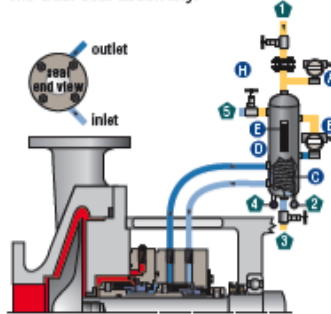


- A - pressure indicator
- B - flow indicator (optional)
- C - check valve
- D - strainer
- E - temperature indicator (optional)
- 1 - flow control valve
- 2 - from clean source, normally open

Plan 53A

Pressurized barrier fluid circulation through reservoir.

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

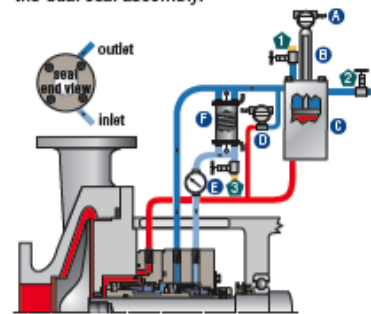


- A - pressure transmitter
- B - level transmitter
- C - cooling coils
- D - reservoir
- E - level indicator
- F - reservoir
- G - level indicator
- 1 - pressure source, normally open
- 2 - cooling in
- 3 - drain, normally closed
- 4 - cooling out
- 5 - liquid fill, normally closed

Plan 53C

Pressurized barrier fluid circulation with piston accumulator.

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

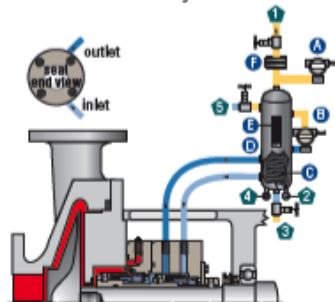


- A - level transmitter
- B - level indicator
- C - piston accumulator
- D - differential pressure transmitter
- E - temperature indicator (optional)
- F - cooler
- 1 - vent, normally closed
- 2 - liquid fill, normally closed
- 3 - drain, normally closed

Plan 52

Unpressurized buffer fluid circulation through reservoir.

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

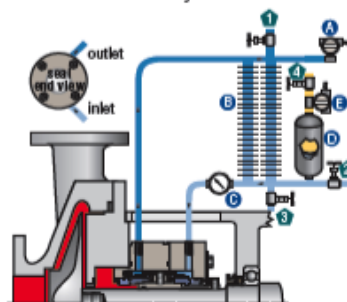


- A - pressure transmitter
- B - level transmitter
- C - cooling coils
- D - reservoir
- E - level indicator
- F - orifice
- 1 - vent, normally open
- 2 - cooling in
- 3 - drain, normally closed
- 4 - cooling out
- 5 - liquid fill, normally closed

Plan 53B

Pressurized barrier fluid circulation with bladder accumulator.

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

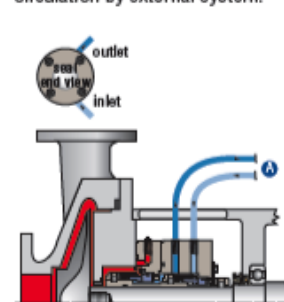


- A - pressure transmitter
- B - finned pipe (alternative reservoir)
- C - temperature indicator
- D - bladder accumulator
- E - temperature transmitter
- 1 - vent, normally closed
- 2 - liquid fill, normally closed
- 3 - drain, normally closed
- 4 - pressure source, normally closed

Plan 54 & 55

Plan 54 - Pressurized barrier fluid circulation by external system.

Plan 55 - Unpressurized barrier fluid circulation by external system.



- A - from / to external circulating system

FLOWSERVE OPPORTUNITIES IN HYDRAULIC DECOKING SYSTEMS

A Complete Range of Decoking System Equipment

Whether for new equipment, system upgrades or replacement parts, Flowserve provides a complete proven decoking system:

Jet Pump Train

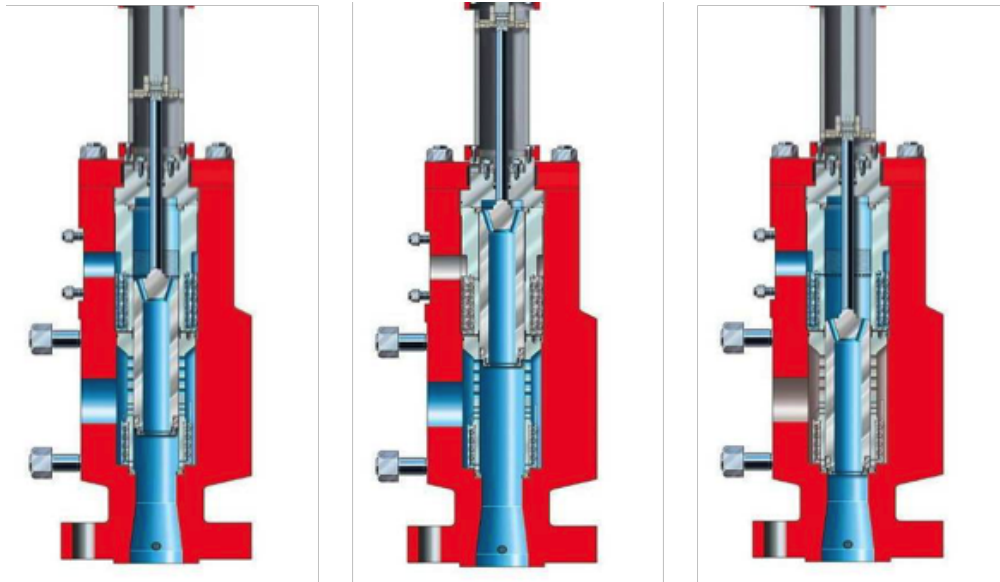
- Current standard is a 6WIK15.
- Typical MTBR on the pump can be anywhere from one to two years at sites with poor maintenance practices and high fines to 10 years or more at sites with exceptional maintenance practices.
- S6 modified material is most common.
- Application typically has a low NPSHA.

Decoking Control Valve

The decoking control valve is placed just downstream of the pump and is often mounted on the pump. It serves to isolate the drums from the pump and allows it to continue running during normal cutting operations.

Three-position valve with no true shutoff

- Bypass
 - Provides minimum flow bypass for the jet pump
 - Always open to prevent deadheading pump
- Pre-fill
 - Provides low-pressure, pre-fill sequence until system filled, then provides full flow to the combination tool for cutting
- Full flow
 - Provides full cutting pressure to cutting assembly
 - Low-pressure drop C_v of more than 200



*Bypass (left), prefill (center) and cut (right) modes.
The actuator (not shown) would be mounted on top of the valve.*

The current main offering is the advanced decoking valve

- Primary actuation is MOV with option for AOV
- Hard seats
- Pressure breakdown via internal orifice plates
 - Bypass orifice plates can be accessed with the valve body installed in the field
- Field-maintainable cartridge construction

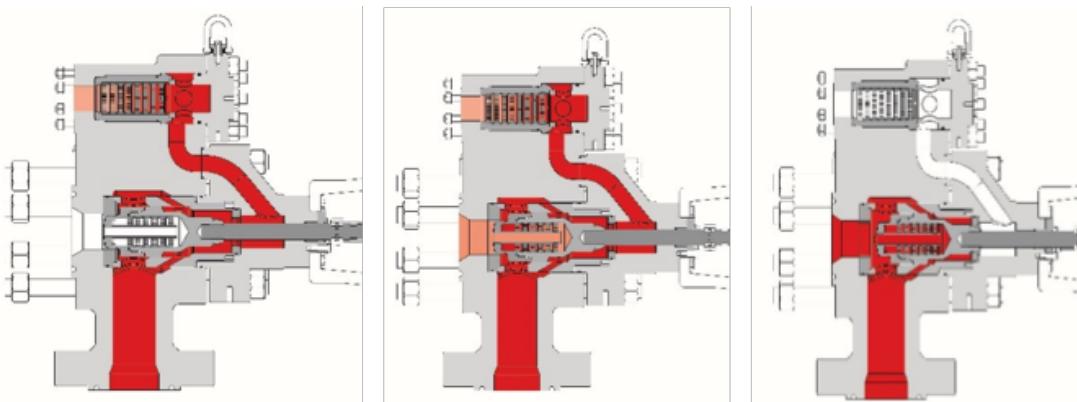
Isolation and Bleed Valve

The isolation valves are typically ball valves. They function to isolate the drums or pumps from each

other during normal operation. Bleed valves function to bleed the pressure between the DCV and the drum isolation valves at all sites where they are installed. At cold weather sites, they are used to drain the system of water when a drum is not being cut during the winter to prevent freezing.

Most of the installed base has air actuators on the bleed and isolation valve, but most new installations use MOVs.

These are buyout items available from the Flowserve Valve division.



Bypass (left), prefill (center) and cut (right) modes. The actuator (not shown) would be mounted on right side of valve as shown.

Decoking Hoses

The hose's purpose is to allow the high-pressure water to be transported from a fixed point to the moving rotary joint.

- Design follows oil field practice and is a buyout item

- Manufactured per API-7K unless metal jacketed
- Swivel flange to avoid twisting
- Arranged to be non-draining to reduce tower dimensions or self-draining to aid maintenance
- Metal jacketing available

Rotary Joint

The rotary joint provides rotational motion to the cutting tool and has a sealing system to allow the high-pressure water from the jet pump to pass into the rotating drill stem without leakage.

There are two legacy designs in service:

- Worthington-style RJ
- Pacific-style RJ
- The current main offering is dependent on location and previous customer installations
- Many installations worldwide are air powered, but this legacy item has air-powered winches; new installations are using electric or hydraulic power.



Pacific pneumatic



Worthington electric

Drill Stems

There are two types of drill stems: the FLS standard threaded drill stems, and an optional welded stem. The welded stems are only provided upon specific request, typically in the aftermarket.

- Drill stems serve to connect the rotary joint to the cutting tool and transfer the water and torque from the rotary joint to the cutting tool.
- High flexural strength, heat-treated material
- Sections joined with NC lathe cut API extreme line threads

- Certified API thread gauge and hydrostatic tests
- Supplied in standard 20-foot segments, stocked in Vernon



Combination Cutting Tools

The cutting tool is the equipment in the drum actually removing the coke. It has a bore mode, which has four nozzles pointing down that creates ~6' (2 m) hole. After the hole is drilled, it can be automatically switched using the water pressure to cut mode, which has two nozzles pointed horizontally to remove the remainder of the coke.

There is a long legacy of prior cutting tools that Flowserve supplies, but many of the tools currently installed are listed below:

- Rotary Shift Cutting Tool
 - Original nozzle design
 - Slim nozzle design
- AutoShift Cutting Tool
 - Original nozzle design
 - Slim nozzle design

The primary offering currently is the AutoShift with slim nozzle design.

- Shifts modes automatically and remotely by water pressurization and depressurization WITHOUT lifting the tool out of the drum. This is an important selling feature. Switching of the tool is achieved when the decoking control valve changes from full flow to bypass.
- Override manual shifting feature is inherently designed into the tool and used to either set the tool position at startup or manually shift as the need arises.
- The slim nozzle setup allows the cutting tool to be more streamlined, which requires less force to remove it if the coke collapses during cutting.



Crosshead With Free-fall Arrestors

The crosshead with freefall arrestor has two functions. The primary function during normal operation is to counteract the torque created by the rotary joint and ensure all of the rotational motion is driven into the cutting tool instead of the suspension system. The secondary function is to prevent a catastrophic collapse of the cutting assembly if the wire rope breaks. This is the free-fall arrestor system. It is not used on a normal basis, but is necessary to be maintained regularly to ensure it is in working order.

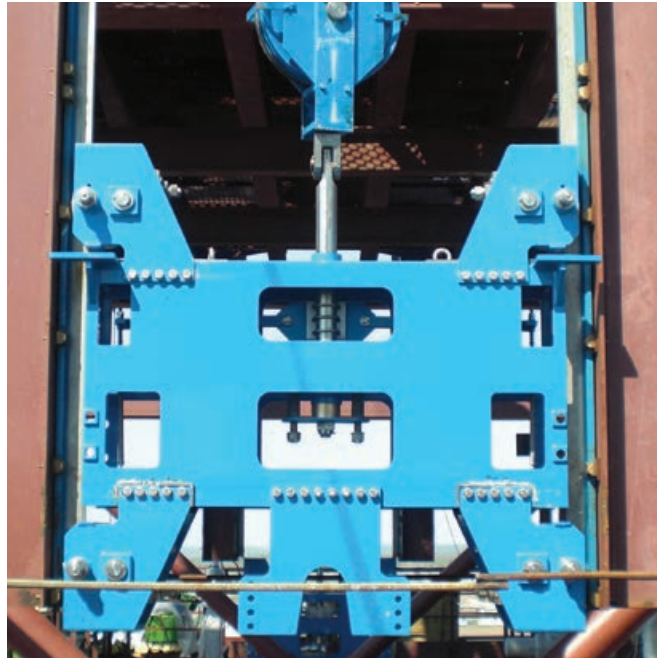
Flowserve has sold two types of crossheads and free fall arrestors:

Shoe Type

- The Flowserve current standard offering is the shoe type with cable gripping fall arrestor
 - Not available with rail gripping fall arrestor

Wheeled Type

- Typically seen with rail gripping fall arrestor
- Available with cable gripping fall arrestor



Wheeled type crosshead with rail gripping freefall arrestor



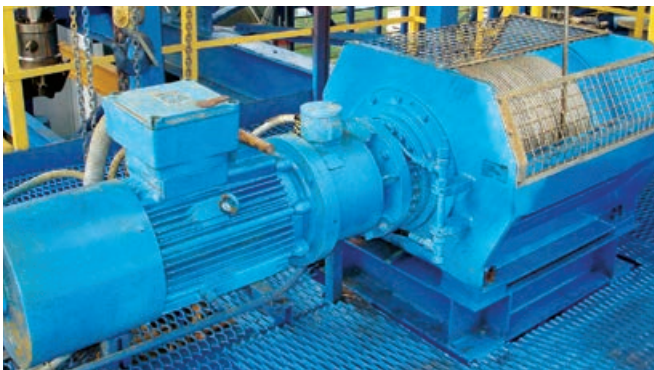
Shoe type crosshead with cable gripping free fall arrestor

Latching Mechanism

The latch is located at the top of the tower and can lock the crosshead in the parked position. It should be used to take the load off of the winch and wire rope system during normal operation.

Winch

- The winch lifts and controls the cutting assembly.
- The majority of installations worldwide has air-powered winches, but this is a legacy item and new installations are using electric or hydraulic power.
- The typical winch in North and South America is purchased from Ingersoll Rand.
- There are several legacy vendors for the Hamburg systems, but most recently the vendor is Zollern.



Pulley Blocks, Sheaves and Cable

The pulley blocks guide the wire rope from the winch to the cutting assembly, where there is a traveling block mounted to the crosshead.

Control Systems, Including Intelligent and Automated Cutting

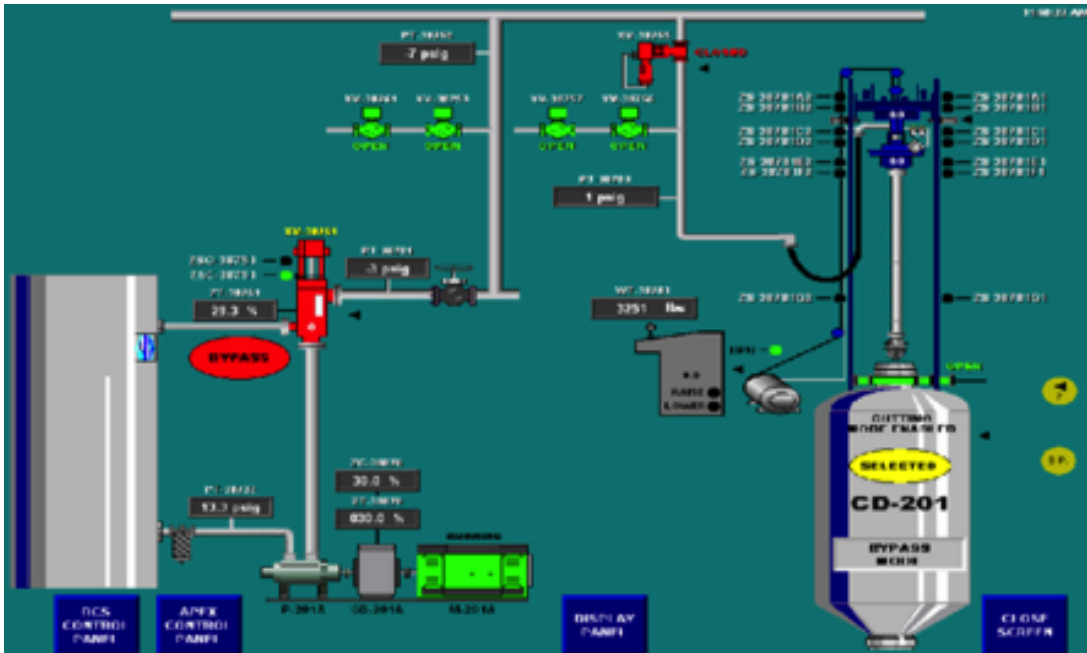
The control system is a PLC-based system that allows the operator to control the cutting equipment safely by being removed from the proximity of the cutting tools, winches, etc. Each control system is different for every end user and depends on the equipment supplied, refinery standards and licensor requirements. They are typically made up of the following sections:

Field Instruments

- Pressure Transmitters
- Flow Transmitters
- Proximity Switches
- Tensiometer

Operator Panels

- These can be located at the pump, on the cutting deck and/or remotely, depending on the system.
- New units have HMI screens that provide the operator all the information in the entire system to help with both operation and troubleshooting.



Safety and Operational Interlocks

The interlocks surround the pump, high-pressure water and cutting assembly location to ensure that the proper process is followed so that no high-pressure water is released outside the drum.

High-pressure water has caused fatalities in delayed coker units in the past, but not with an operational Flowserve control system.

Drum Monitoring Systems

Drum monitoring systems are the key to both remote and automated cutting. These technologies are driving the new units and upgrades.

Video Drum Monitoring

This offering is a buyout of cameras and a camera server. Flowserve puts in the camera requirements and location specifications to make the system work. It is not typically tied into the control system.

Audio Drum Monitoring

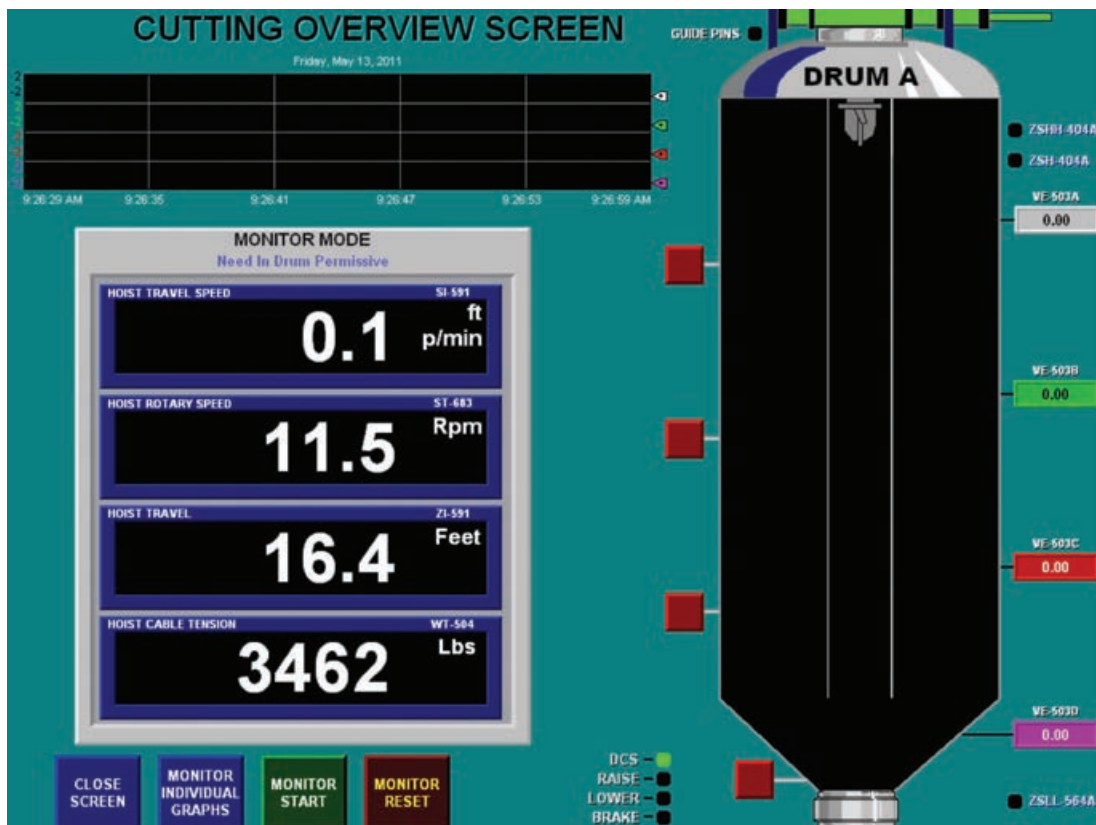
- This allows the operator (who normally is on top of the cutting deck listening to the water jets in the drum) to hear the same information in a remote location.
- The system consists of two to three microphones per drum located along the length of the drum.

- There is a proprietary filtering program that eliminates some background noise and can also determine drum cleanliness.
- This system requires a site survey to confirm feasibility and microphone placement.

Vibration Drum Monitoring

This system provides information that was not previously available to the operators on local cutting systems. It directly measures the vibration on the drum wall and provides a strip chart of the vibration to the operator to show the cleanliness of any given section of drum.

- The system uses the frequency and amplitude of the vibration signal from the cutting tool water jet to determine drum cleanliness prior to refilling the drum.
- This is the system that is the heart of the automation algorithm.
- All the information is displayed on the HMI screen for the operator to cut the drum.

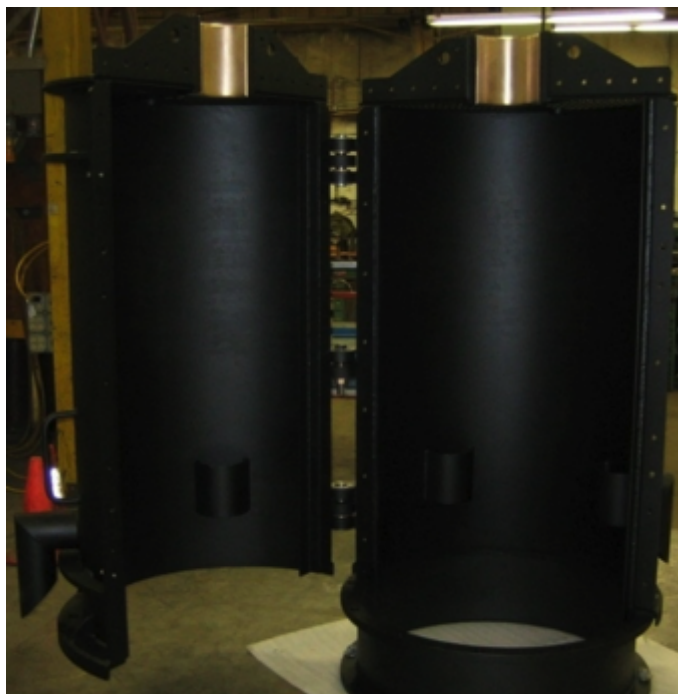


Remote Cutting and Automation

- These systems are the heart of the new control system upgrades for aftermarket as well as most new original equipment units.
- The driver for remote cutting is safety. This is the strongest trend currently in North America and Europe, but is being pushed elsewhere including China, the Middle East and Latin America.
- The driver for automation can also be safety, but refinery management concern about inexperienced operators can also drive them toward automation. This is a risky conversation with operations, as some are dead set against it.
- Automation is not a panacea for the refinery that will remove operators. There are still cases due to the nature of coke cutting and the coker in general being unpredictable, that operators may still need to be involved at times.

Tool Enclosures

Tool enclosures sit on top of the drum unheading device and enclose the cutting tool, preventing it from spraying high-pressure water on the cutting deck in case of control system malfunction. They are a passive safety device. Often, they also incorporate a drill stem guide. Flowserve also has a sealed version that can divert any off gasses from the drum to a safe location. This is a buyout item in North America due to patent issues.



COMMUNICATING OUR VALUE

Value Proposition (Delayed Decoking Systems, Pumps, Valves, Seals and Actuation Products)

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
Safety	The Flowserve number one goal is to remove the operator from the deck.	Increased safety engineered into the system to take the operator out of harm's way
Reliability	To provide operator safety from harm's way requires that Flowserve engineer the operation of the unit and the equipment for reliability.	Reduced downtime due to mechanical failure increases throughput and reduces the need for operators to be placed in harm's way.
Engineering excellence	The Flowserve depth of engineering experience is unparalleled in hydraulic decoking.	Optimized product and material selection for each application ensures reliable operation.
Experience	Flowserve has been the leader through its various heritages since the process was commercialized in 1938.	Lessons learned have been built into today's products with constant development to improve, increasing reliability, maintainability and product life.
Aftermarket support	Dedicated decoking specialist in the region	Implanted within the aftermarket group with the sole objective to resolve operational issues quickly and provide expert recommendations on upgrades and safety outlook
Local Quick Response Centers	Fully equipped Quick Response Centers are located in many regions around the globe.	Skilled team to handle upgrades and repairs. Localized to reduce downtime, full access to Flowserve component drawings, procedures and standards.
Aftermarket solutions	Long-term maintenance	Specialist group capable of maintaining, servicing and upgrading equipment to meet operating goals throughput
Industry partnerships	Constant discussions with all process licensors and a triennial decoking symposium dedicated to the communications of concerns and developments	End users and licensors have direct access to engineers to influence design needs and ensure concerns are properly communicated.

Product Positioning

Flowserve has more than 90% of the market. We are often perceived as the technology leader, but this perception is challenged by Ruhrpumpen and at the end user level is driven primarily by relationship.

The products listed herein are sold as a system in the OE market and must be supported as a system for aftermarket. The aftermarket for the decoking system is split into parts, repairs, replacement units and major upgrades. Flowserve must maintain a strong sales and technical relationship over the life of the delayed coker unit to ensure we keep the large aftermarket potential in our hands.

The coker operators are often very hard on the decoking equipment regardless of affiliation, but at sites cut by third parties the equipment can have lower mean time between repair (MTBR), depending on the company and training level. Technical and timely parts support for the site is important in maintaining the relationship.

Understanding a Customer's Specific Business Drivers

Each individual refinery site requires deep understanding of the customers and external organizations that support a decoking system. This often will be different from the rotating equipment maintenance and reliability specialists with whom we interact for pumps and seals. Each can have a significant role as influencer or decision maker.

Operations management is heavily involved with equipment decisions:

- I&E group is involved with control systems, valve actuation and sometimes valve maintenance.
- Fixed equipment reliability and maintenance groups often support equipment above grade at the cutting deck and in the structure.
- Third party coke handling companies are expanding their roles.
- Enterprise SME influence customers with multiple refineries.

Process licensor or engineering contractors develop the specifications that apply to the specific process license. They are often involved in major upgrades or drum replacement. Drum replacements are significant opportunities for decoking system upgrades such as remote/automated cutting, drum monitoring, etc.

Flowserve must understand the customer's specific business drivers and risk profile. This will impact spares and maintenance strategies. Flowserve must also understand the customer's planned maintenance cycles and restrictions.

- Maintenance between coke cuts
- Do they allow access to structure during the cutting process?
- Do they require cranes to position equipment or spares?
- Maintenance performed during short planned outages such as furnace decoking (different from drum decoking). This is an offline process to clean furnace tubing and nozzles with a duration of one to three days several times per year.
- Unit outages are typically every four to five years.
 - This is the preferred window for major structure equipment and jet pumps.

Flowserve must identify opportunities for use of support resources to facilitate meeting account support requirements.

- Decoking Specialist
- Sales/Product Management Decoking
- Technical Services and CommOPS
- Repair Services — QRC and FS
- Regional Parts Specialist and RPSO

Guidelines on Decoking System Selection Criteria

There are several areas of the hydraulic decoking system that have to be selected in order to specify an entire system.

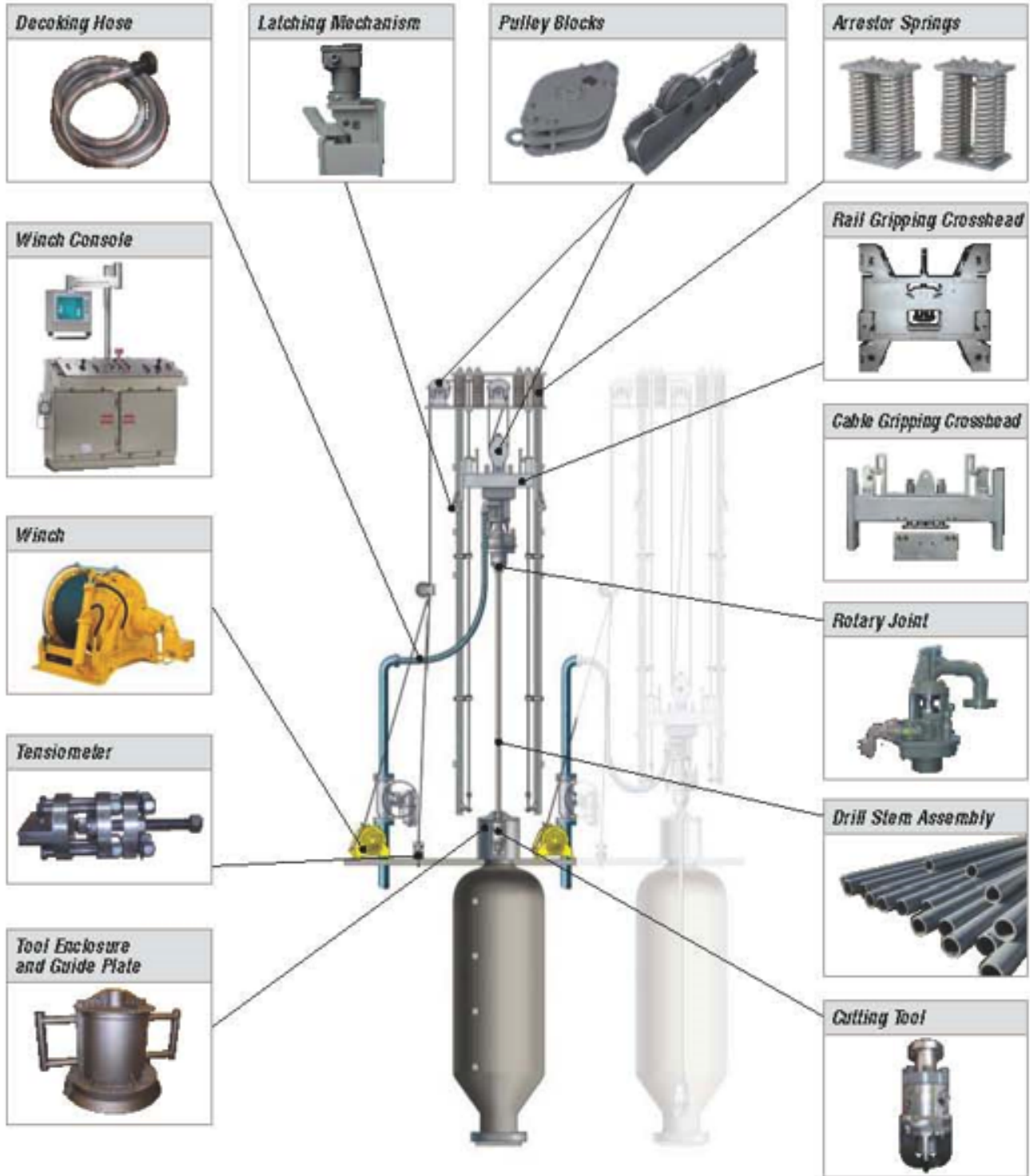
- *Pump Hydraulics*: The pump hydraulics are selected based on the customer drum size. For sizing of the system, contact the product team. The primary pump product is the WIK and is usually in a high-pressure classification.
- Winch and Rotary Joint Drive: electric, air or hydraulic
- Cutting Equipment Scope
- Control System
- *Ancillary Options*: There may be other options that are requested by the customer, including but not limited to: operator shelters, soft starters, pump VFDs and tool enclosures. For the common requests, a Flowserve specification is available, but all special requests will be reviewed by the CommOPS team.

APPENDIX

Sourcing

Currently Flowserve has two business unit locations building and servicing hydraulic decoking systems: Vernon (LPO) Design, Build and Service and Hamburg Service. Both factories have historical ties to hydraulic decoking and have been manufacturing these systems for well more than 50 years. The selection of the BU is decided by the product director based on the EPO sourcing guide in Vernon, and considers project location, plant loading, plant commercial competitiveness and project preference.

Rotary/Cutting Tool View for DCU



GLOSSARY OF KEY TERMS, ABBREVIATIONS AND ACRONYMS

API: American Petroleum Institute

BIC: best in class

CommOps/CSOA: Commercial OPS has replaced customer service and order acquisition

DCU: delayed coking unit

EBV: emergency block valve

EIA: Energy Information Administration

EPO: Engineered Products operation

FCC: fluidized cat cracking

HCGO: heavy coker gas oils

HMI: human machine interface

I&E: instrument and electrical

ISO: International Standards Organization

LCGO: light coker gas oils

LPO: lead product operation

MOV: motor-operated valve

MRO: maintenance, repair & operations

MTBR: mean time between repair

NC: pneumatic control

NPSHA: net positive suction head available

OE: original equipment

PLC: process logic control

QRC: Quick Response Centers

RP: Ruhrpumpen

RPSO: regional procurement service officer

RSBV: rising stem ball valve

SME: subject matter experts

SPO: secondary product operation

SYDEC: selective yield delayed coking

VRC: vacuum-reduced crude

VRU: vapor recovery unit

VTP: vertical turbine pumps

WC, WCC or WIK: multistage process barrel pump



North America

Latin America

Europe

Middle East

Africa

Asia-Pacific

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

Experience In Motion