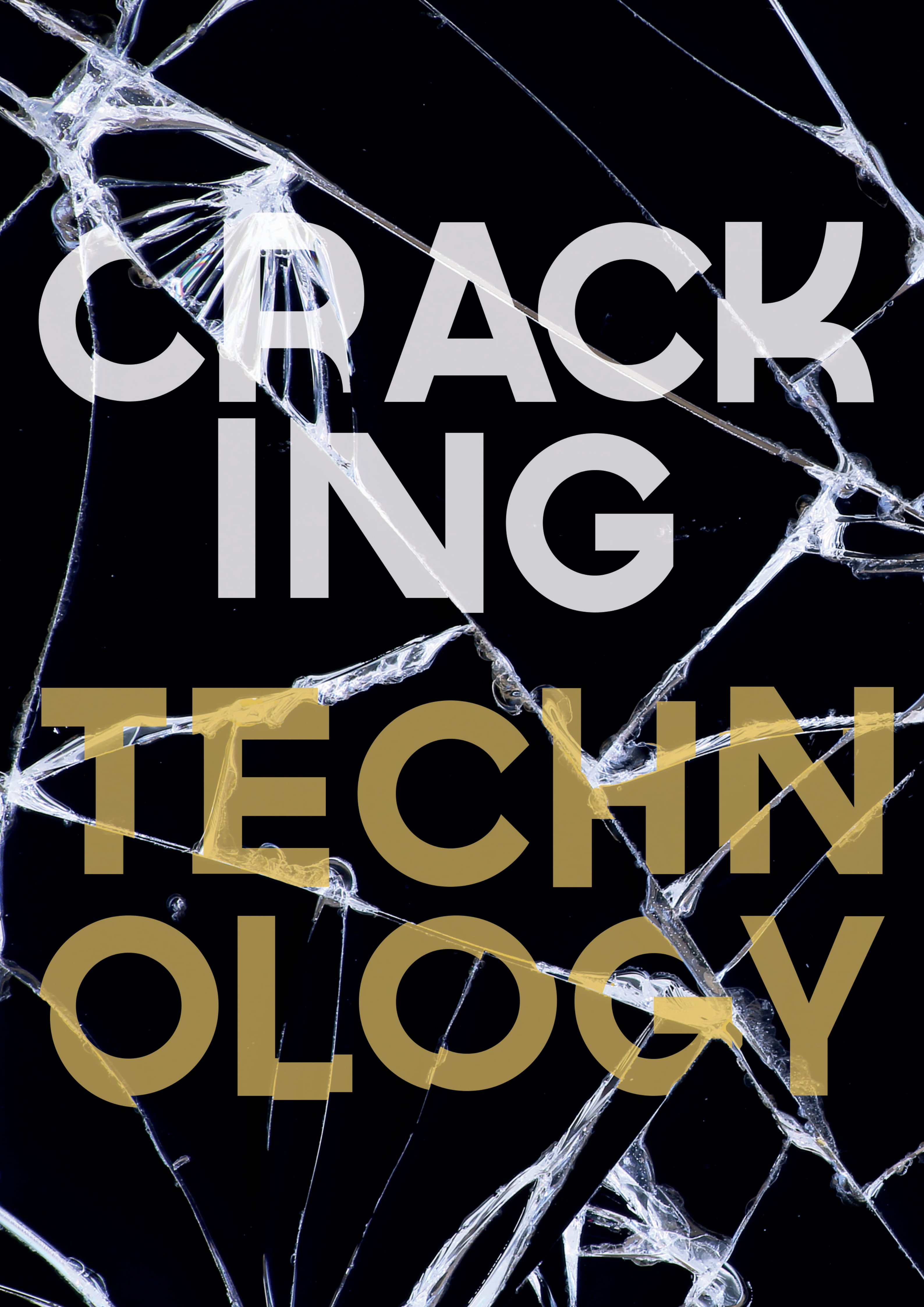

CRACKING TECHNOLOGY

Arsalan Ahmed, **Crane ChemPharma & Energy**, **USA**, discusses process challenges for fluidised catalytic cracking, and how each of these can be mitigated with proper valve selection.

Crude oil is a naturally occurring mixture of various hydrocarbons, which once extracted cannot be used or applied to multiple applications. To make it more useful, crude needs to be refined or broken in to several different products such as gasoline, diesel, kerosene and other petrochemicals. One way of making crude more valuable is by cracking the heavy product into a lighter set of products through the process of fluidised catalytic cracking (FCC).

FCC, or commonly known as the 'cat unit', is one of the most important conversion processes used in petroleum refineries. It converts high boiling, high molecular weight hydrocarbons to more valuable products such as gasoline, kerosene, olefin gases, and other hydrocarbon based products. Historically, crude cracking was performed using thermal cracking, which has been replaced with the safer, more efficient and more environmentally friendly process of cat cracking. The end result is gasoline with a very high octane rating, among many other valuable products.

FCC is a secondary unit operation primarily used in producing additional gasoline in the refining process. Once crude has passed through primary vacuum and atmospheric distillation, which are physical separation processes, FCC allows for further processing of separated crude through a chemical process using catalysts to create smaller molecules of gasoline and distillate fuels,

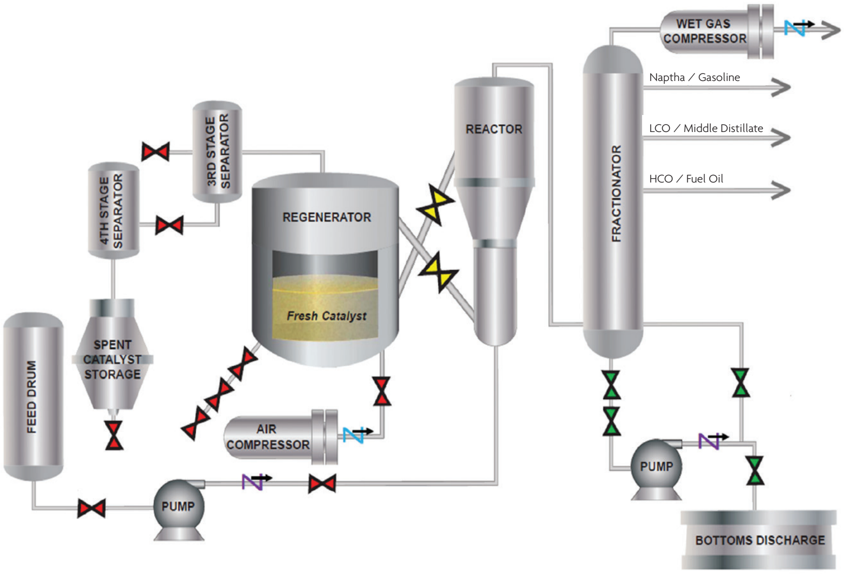

Figure 1. Fluidised catalytic cracking process map. Source: Crane ChemPharma & Energy.

allowing producers to change the product proportions based on market demands.

Throughout this process, it is essential that valves and other fluid handling equipment address the myriad challenges and deliver reliable, safe operation within this volatile environment. The following article will explore the eight subprocesses within the cat unit and examine how the challenges of each can be mitigated with proper valve selection.

The key process steps include:

- Feed system.
- Reactor system.
- Regenerator.
- Regenerator air supply.
- Supply catalyst separation and storage.
- Fractionator.
- Wet gas compressor.
- Fractionator bottoms recirculation and discharge.

Feed system

At the beginning of the FCC process is the unit's feed system. The sole purpose of this system is to preheat the feed to the optimum temperature and pump the feed to the reactor riser where the preheated feedstock will come into contact with the hot, powder like catalyst. The cracking reaction takes place immediately upon this contact. Within the feed system there are several pumps, vessels, and heaters that require isolation valves for maintenance operations as well as check valves for backflow protection.

Due to the modest operating conditions of this system, cast steel gate valves have historically been the valve of choice for these isolation applications. However, end users are often challenged by this selection, as gate valves will periodically 'coke up' due to the viscous properties of the FCCU feedstock.

Considering this, wedgeplug valves offer an effective solution within this system. Specifically engineered to handle challenging media such as FCC feedstock, wedgeplug valves can eliminate operational issues caused by coke contamination and buildup. In addition to a simple, rugged, inline repairable design, wedgeplug valves have several boss locations, which provide a variety of purge options. This purging capability prevents process media from entering valve cavities, which eliminates valve coking issues. Moreover, the unique lift and turn operation of wedgeplug valves enables the valve to operate with virtually no rubbing or contact of the seats and plug, a capability that reduces wear and extends valve life. Shut off valve considerations are outlined in Table 1.

Reactor system

The FCC reactor is one of the most critical areas of the FCC process. The FCC reactor is the vessel in which the vapours from the cracked hydrocarbon are separated from the hot, powder like catalyst prior to those vapours being routed to the unit's fractionator system. This separation process takes place by flowing through a set of two stage cyclones within the reactor. Within the reactor section of the FCC, there are approximately 150 - 200 bolted bonnet, cast steel valves in various utility lines such as fuel gas, stripping steam, blast steam and purge steam lines. The steam lines within the FCC unit are low pressure (~130 psi) and do not require a pressure seal design. Along with these utility function valves, there are also a couple of critical slide valves, which are located within the spent catalyst line. These slide valves regulate the flow of spent (coke coated) catalyst to the regenerator. Slide valves within the spent catalyst line are very large in size, ranging from 48 - 60+ in. in diameter, and will most likely be refractory lined to withstand the extreme temperatures within this section of the process. Along with the heat stress, which can cause cracking and distortion to the valve body, the abrasive nature of the catalyst media is also a significant challenge for slide valves within this system.

Regenerator

Equally critical as the FCC reactor is the regenerator. During the process reaction, the catalyst becomes coated with a hydrocarbon residue that is commonly referred to as coke. This coke coating greatly reduces the reactivity of the catalysts and must be removed. The primary purpose of the regenerator is to remove this coating by burning it off. The regenerator accomplishes this by introducing air into the regenerator, which burns off the coke coating, essentially rejuvenating the catalyst. The flow of the regenerated catalyst back to the reactor riser is regulated by slide valves. Typically, there are two regenerated catalyst lines (40 – 60 in.) that flow back to the reactor. Each of these lines will contain a pair of slide valves. Other valve opportunities within the regenerator section of the FCC unit are spent catalyst withdrawal valves and plant air isolation valves.

Spent catalyst withdrawal valves are located directly off the regenerator and are typically used daily for removing old catalyst from the process. While some plants utilise hard coated gate valves in this application, high temperatures and abrasive conditions make metal seated ball valves ideal for this service.

Table 1. Shut off valve considerations

Valve type	Size (in.)	Pressure class	Temperature (°F)	Function
Feed system				
Dual plate check	2 - 88	150 - 2500	300 - 500	Provide back flow protection for feedstock pumps
Wedgeplug	2 - 36	150 - 1500	300 - 500	Pump and system isolation
Gate valves (bolted bonnet)	2 - 36	150 - 1500	300 - 500	Pump and system isolation
Reactor system				
Slide valves	40 - 60	150 - 1500	1300 - 1500	Regulate flow of spent catalyst to regenerator
Gate/globe valves (bolted bonnet)	2 - 36	150 - 1500	1300 - 1500	Isolation for fuel gas, steam lines and other utilities
Regenerator				
Slide valves	40 - 60	150 - 1500	1300 - 1500	Regulate flow of regenerated catalyst back to reactor riser
Metal seated ball	0.5 - 16	150 - 4500	1300 - 1500	Spent catalyst withdrawal
Gate/globe valves (bolted bonnet)	0.5 - 36	150 - 1500	150 - 850	Steam, plant air, process venting
Regenerator air supply				
Nozzle type check valve	30 - 72	150 - 1500	120 - 200	Backflow protection for air blower
Catalyst separation and storage				
Triple offset butterfly	16 - 36	150 - 300	500 - 950	Separator vessel Isolation
Metal seated ball	4 - 16	150 - 300	500 - 950	Separator vessel isolation/catalyst unloading
Gate (bolted bonnet)	4 - 16	150 - 300	200 - 500	Catalyst unloading
Sleeved plug	4 - 16	150 - 300	200 - 500	Catalyst unloading
Fractionator				
Triple offset butterfly	12 - 36	150 - 600	200 - 980	Isolation in fractionator outlet lines
Gate (bolted bonnet)	4 - 16	150 - 300	200 - 650	Isolation in fractionator outlet and utility service lines
Dual plate/nozzle type check	12 - 36	150 - 300	200 - 980	Provide back flow protection for pumps
Wet gas compressor				
Nozzle type check valve	30 - 60	150 - 900	120 - 200	Compressor back flow protection
Fractionator bottoms				
Metal seated ball	8 - 16	150 - 300	600 - 850	Slurry pump isolation
Wedgeplug	8 - 16	150 - 300	600 - 850	Slurry pump isolation (substitute to metal ball valve)
Dual plate check	8 - 16	150 - 300	600 - 850	Provide back flow protection for pumps

The high temperature demands and volatile environment of refineries make metal seated ball valves a preferred alternative to soft seated valves in severe service conditions. Designed to withstand temperatures in excess of 1000˚F, metal seated ball valves provide uninterrupted service in these challenging applications and are less susceptible to the degradation common with soft seated ball valves in similar applications.

Some advantages of metal seated ball valves include low repair cost, bidirectional sealing, fire safe and anti static (API and BS) features, a long life span and lower total cost of ownership. They likewise deliver optimal torque transmission and are able to withstand temperatures up to 1500˚F or 800˚C.

With metal seated ball valves, a variety of coatings can be chosen for the ball and seat rings, whose metal to metal contact provides tight shutoff and a longer service life when compared to alternative valves types. As air is necessary for catalyst regeneration, numerous plant air lines provide air to this system. These lines are not oxygen rich and therefore do not require any exotic alloy materials such as Inconel or Monel. Rather, these lines are grounded to prevent potential hazards caused by sparks or other ignition sources.

Regenerator air supply

The air supply within an FCCU is provided by the system's main air compressor, which is often referred to as the air blower. Air is a key component of the catalyst regeneration process and without this vital air supply, the regenerator would not be able to accomplish its primary task of burning the coke coating from the catalyst so that it could be reused in the catalytic cracking process. In a recent survey, major rotating equipment failure accounted for nearly 40% of FCCU shutdowns, approximately 50% of which contributed to air blower failure.

In the event of an air blower failure, a critical check valve is located in the air blower discharge line to protect the blower from harmful, catalyst containing backflow, which could severely damage the blower when an outage occurs. Many refineries utilise a swing check valve in this application and have experienced issues with severe valve pulsation to the point that the valve plate has broken, causing an unexpected unit outage.

To reduce the instance of pulsation, highly engineered nozzle type check valves consider the design velocity required to stabilise the disc open against its stop, even with moderate flow oscillation. When a noticeable reduction in flow occurs,

Figure 2. Highly engineered Noz-Chek® valve.

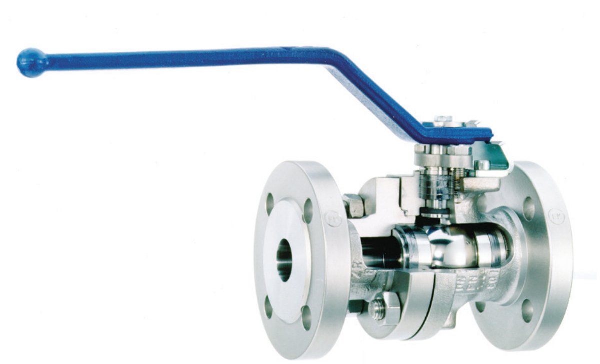

Figure 3. Krombach® metal seated ball valve.

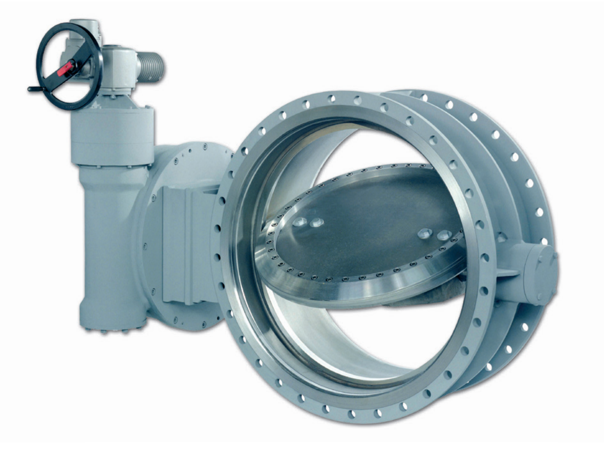

Figure 4. Krombach® triple offset butterfly valve.

the disc reacts immediately to limit backflow and slamming. This design can minimise the damaging effects of water hammer, eliminate chatter, protect rotating equipment, reduce pressure loss in piping systems and provide a quick dynamic response for immediate shutoff. The typical line size for this valve will be 30 - 48 in. but can go larger to 72 in.

Catalyst separation and storage

During the regeneration process, during which the coke coating is burned off in the presence of air, flue gas is created and exits at the top of the regenerator unit. Prior to being released to the atmosphere, this gas must undergo an air purification process that removes any catalyst fines entrained in this gas stream by routing the flue gas through a series of separators. Isolation valves are typically utilised between each separator.

Depending on the line size, different types of isolation valves may be used including metal seated ball valves and triple offset valves. For smaller lines (4 – 12 in.), MSBVs will be used, whereas lines of 16 in. and larger are more conducive to TOVs.

The most effective butterfly valves in high pressure and high temperature applications, triple offset butterfly valves offer the best sealing and longest life of all butterfly valve designs while delivering bidirectional gas tightness. With innovative self centering, flexible disc sealing and optimal torque transmission, these valves offer fire safe designs and the flexibility to create customised solutions, making them ideal for catalyst separation applications.

After completing the separation process, the catalyst fines are routed to the spent catalyst lock hopper where they are stored until being hauled off for disposal. The spent catalyst lock hopper is equipped with several isolation valves for incoming catalyst as well as catalyst unloading. These isolation valves are typically in the range of 4 - 8 in. and can be gate, sleeved plug or metal seated ball valves.

Fractionator

Following the cracking reaction that takes place in the unit's reactor, the hydrocarbon vapours are immediately routed to the unit's fractionator, also referred to as the distillation tower.

The distillation tower is arranged with a stack of chambers at different temperatures, each chamber cooler than the one below. The tower is designed so that vapours can rise and condensate can drain. As the hydrocarbon vapours are fed into the bottom chamber, they will rise until they reach the chamber where they condense and collect on trays. If they drain down, they revapourise and rise again. This distillation process essentially separates the hydrocarbons into the different yield streams such as naptha, gasoline, distillate, light cycle oil and heavier hydrocarbon products.

Due to several pumps and numerous product lines running from the fractionator, this section of the FCCU presents several opportunities for engineered check, triple offset (TOV) and cast steel gate valves. Check valves are used for pump protection and the TOV and gate are used in isolation applications. TOVs are commonly used for isolation in the lighter product lines such as naptha and gasoline while cast steel gate valves are used in the heavier product lines.

Among the various designs of gate valves, parallel disc and flexible wedge are desirable in refining applications, as the flexibility of the parallel disc requires little torque, as it is position seated and uses system pressure for tight seal. The wedge type is fully guided and resists sticking or binding due to thermal expansion. Likewise, the straight through design of the valve body and wedge maximise flow while minimising turbulence, pressure drop and the erosion of moving parts. The advantages of gate valves include superior shutoff service for high pressure and

Table 2. Summary of FCCU process challenges and solutions

FCCU location	Pain points	Valve solution	Valve attributes
Feed system	Inoperable gate valves due to coke buildup	Wedgeplug	**Simple purge options:** Wedgeplug offers several boss locations for purging, which keeps process media from entering valve cavities which leads to valve coking issues. **Rugged design:** The unique lift and turn operation of wedgeplug valves enable the valve to operate with virtually no rubbing or contact of the seats and plug. **Maintenance cost:** Inline repairable, a significant operating cost saving benefit.
Fractionator bottoms	Solids and abrasive media	Metal seated ball or wedgeplug	**Ball hard coating design:** Hard coating on the ball and seat mitigates valve damage caused by abrasive media, enabling the valve to provide a repeatable, bubble tight seal even in the most abrasive conditions. **Wedgeplug:** Compared with alternative valves, wedgeplug valves provide superior protection from erosion damage, solid buildup on sealing surfaces and in cavities, and residual freeze up, which can prevent operation and cause leakage due to packing wear.
Regenerator overhead lines	Leakage of flue gas to atmosphere	Triple offset valves	**Zero leakage valves:** Provides reliable, zero leakage, bidirectional shut off closure from -320˚F to 1000˚F. **Triple offset design:** Eliminates wear associated with sealing surface contact and maintaining sealing integrity and high cycle life. **Bubble tight closure:** Eliminates process media leaks, which can lead to fires and fugitive emission issues.
Catalyst withdrawal lines (regenerator)	Valve erosion due to abrasive catalyst media	Metal seated ball valves	**Hard coating design:** Hard coating on the ball and seat mitigates valve damage caused by abrasive media enabling the valve to provide a repeatable, bubble tight seal even in the most abrasive conditions.
Regenerator air supply and wet gas compressor	Failure of critical check valve	Nozzle type check valves	**Non-slamming high performance:** Protects rotating equipment from damage due to flow reversal. Minimises pressure drop across valve. Provides quick dynamic response reducing reverse velocity.

temperature applications, in which they can eliminate excessive leakage and thermal binding while facilitating inline repair and fitting.

Wet gas compressor

As mentioned in the fractionator overview, light hydrocarbon vapours rise to the top section of the tower and flow through a series of condensers where the vapours are cooled and converted to liquids. The vapours that are not converted to liquids are routed to the wet gas compressor where they are compressed and routed to a high pressure condenser for further processing. The wet gas compressor is typically a multistage centrifugal compressor that can be severely damaged if backflow were to occur. To protect the compressor from damaging backflow, a critical check valve is located on the compressor's discharge line. A non-slamming, axial flow check valve is therefore invaluable in this application. In this unit, the cause of valve failure is generally attributed to severe pulsation, which causes the swing valve to violently open and slam shut until the valve would simply break.

A nozzle type check valve as described above has the lowest pressure drop across the valve, which is a significant benefit when it comes to minimising the pressure loss in piping systems. Although wet gas compressor failure is the least problematic issue in regard to FCC rotating equipment failure, damage to these units can lead to several hundred thousand dollars in repair costs, not to mention the lost production costs that result from downtime.

Fractionator bottoms

Despite the FCCU's ability to convert low value feedstock to high value products, there is a significant volume of heavy, long chain hydrocarbons that cannot be processed by the unit. Along with this heavy tar like oil, solids such as petroleum coke are also present in the FCCU's fractionator bottoms system. These heavy oils and petroleum solids are mixed with lighter cycle oil and pumped to the unit's bottoms discharge system. Strainers and coke pots are designed to collect the petroleum solids from the process stream so that they can be removed. Depending on the crude quality, strainers and coke pots may need to be cleaned or emptied at least once per day.

In order for the cleaning process to occur, operators rely on isolation valves to shut off and/or redirect the flow from a particular section of the bottom discharge unit. Metal seated ball valves are commonly used in this application, although wedgeplug valves also deliver reliable performance in this application.

Conclusion

As the refining industry continues to grow and evolve in the face of increasing energy demands and the need for higher efficiencies, it is essential that valves and other process equipment are engineered to address the specific conditions of each application within the refining process.

The extreme temperatures and pressures and abrasive media characteristic of the fluidised catalytic cracking process require valve solutions that are cost efficient, reliable and specially designed to deliver consistent safety and performance. In valve selection, it is important to consider the benefits of each, and work directly with a proven manufacturer to ensure that valve equipment is equipped to address the needs of next generation refineries. HE