Design configurations for lowering quenched coke drum venting pressure

Compare the advantages when installing either an ejector or a water ring compressor for lowering coke drum venting pressure

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Increasingly stringent regulations around the world have caused refiners to review their current refinery operations and search for methods to comply with such regulations. An example of this is the United States Environmental Protection Agency (US EPA) standard[1] for the depressurisation of a coke drum to a closed blowdown system during the decoking cycle. According to this regulation, the pressure of the coke drum is to be lowered to 2 psig or less before venting the drum to the atmosphere at the end of the cooling step. This will result in a lower pressure difference between the coke drum and the atmosphere right before venting, leading to fewer volatile organic compounds (VOC) emissions and quieter openings of the coke drum vent valves.

In a traditional system, a coke drum is typically depressurised to 5-9 psig before it is vented to the atmosphere, depending on the coke drum operating pressure. To achieve a coke drum venting pressure of 2 psig or lower, several design configurations are often considered when designing new grassroots units or integrating into existing units. Two of the most practised and proven design configurations include either the installation of an ejector or the installation of a water ring compressor. The following discussion details the configuration of these two design options and their advantages.

Traditional systems

In a traditional system, the hydrocarbon vapours from the blowdown overhead receiver are sent to the flare or the overhead of the fractionator. In each of these routings, the lowest pressure that the quenched coke drum can depressurise to before venting to the atmosphere is limited by the flare system back pressure or the main fractionator overhead pressure, respectively. The layout of the latter routing is shown in **Figure 1**, in which the hydrocarbon vapours from the blowdown overhead receiver are sent to the overhead of the fractionator. This configuration serves as the baseline system for this article, with the capability to recover hydrocarbons from the blowdown vapour rather than flaring them.

Another routing option using the traditional layout involves sending the blowdown vapour to a flare gas recovery system, if available. Like the fractionator routing shown in Figure 1, sending the blowdown vapours to a flare gas recovery system has the benefit of being able to recover and utilise hydrocarbons from the blowdown vapour rather than flaring them. In this routing, the lowest pressure that the quenched coke drum can depressurise to before venting to the atmosphere is limited by the suction pressure of the flare gas recovery system's compressor.

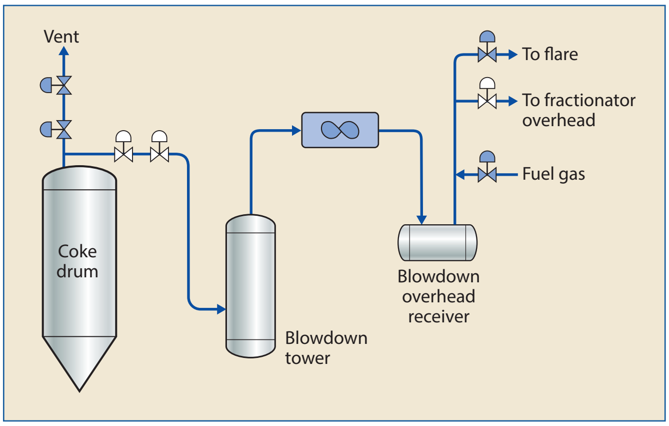

Figure 1 Traditional system with blowdown vapour routed to fractionator overhead

To achieve even lower depressurisation pressures, a different blowdown system configuration can be integrated into the unit design. One such configuration incorporates an ejector, which utilises pressurised steam passing through an expanding nozzle to create a vacuum. Another such configuration incorporates a water ring compressor, which utilises a vaned impeller and a rotating ring of water to compress a gas. The implementation and advantages of both system design options are detailed in the subsequent sections.

Blowdown system design option: ejector

An ejector is a device using steam as a motive force to compress a gas. The simple ejector design has no moving parts. Instead, pressurised steam is passed through an expanding nozzle to create suction in the ejector's inlet. In the blowdown system, an ejector can be installed in the vapour line downstream of the blowdown overhead receiver shown in **Figure 2.**

The main purpose of the ejector is to lower blowdown system pressure, allowing coke drum depressurisation to a lower pressure before venting. The ejector also has the added benefit of being able to send the blowdown vapour to the fractionator overhead for recovery of hydrocarbons near the end of the coke drum cooling step.

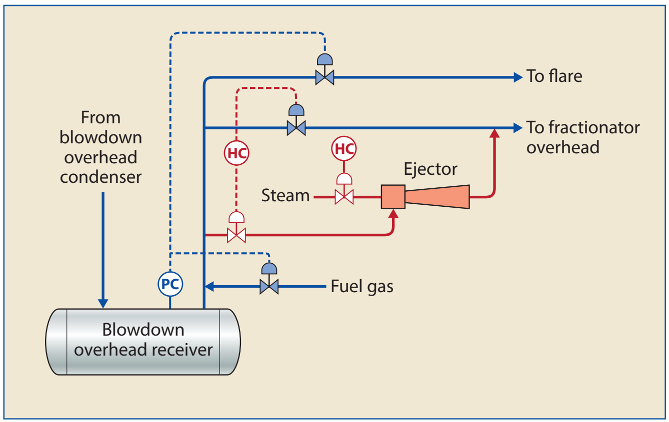

Figure 2 Ejector implementation

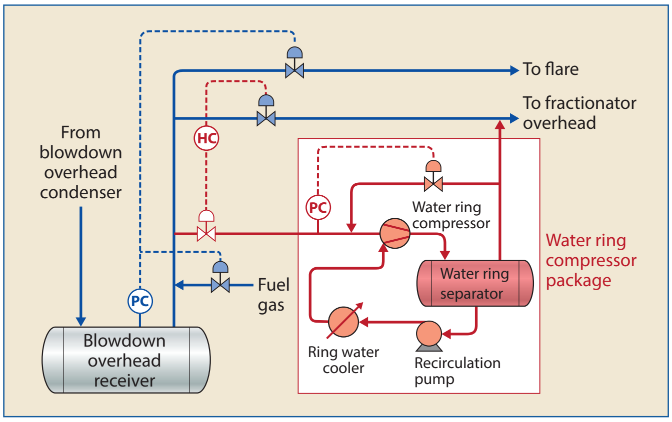

Figure 3 Water ring compressor implementation

The operation of the ejector is as follows: during the beginning of the coke drum cooling step, the ejector is offline and bypassed, as there is a high enough pressure from the vaporisation of the coke drum cooling water to send the blowdown vapours directly to the fractionator overhead. As the coke drum cooling progresses, the ejector is manually taken online, wherein the ejector inlet valve is opened, while the valve to the fractionator is closed. This typically occurs about 3-4 hours into the coke drum cooling step. By the end of the cooling step, the coke drum can achieve pressures as low as 2 psig or less, depending on the blowdown system layout and the system hydraulics. The ejector is then taken offline at the end of the cooling step, right after the closing of the coke drum-to-blowdown isolation valves.

As for its incorporation into the design of the blowdown system, the ejector is a static piece of equipment with no moving parts and is, therefore, easy to maintain. An ejector is also relatively small, which is advantageous when considering plot space availability, and has a lower capital cost when compared to other design options. However, the ejector does require pressurised steam to operate, and because this steam enters the process directly, the amount of sour water from the coker unit will increase during the ejector's operation. The above points must be taken into consideration when determining the design of the blowdown system.

Blowdown system design option: water ring compressor

Another option for the blowdown system design is the water ring compressor. A water ring compressor utilises a rotating, vaned impeller to accelerate water such that an outer ring of water is formed inside a cylindrical casing. Because the impeller is eccentrically placed within the casing, the impeller vanes and the outer water ring create spaces of varying volume. Gas drawn into the inlet of the compressor enters a space of larger volume and experiences compression as the impeller turns, causing the volume of the space to be reduced. The compressed gas then exits at the discharge of the compressor.

In the blowdown system, a water ring compressor package can be installed in the vapour line downstream of the blowdown overhead receiver shown in **Figure 3**. Aside from the compressor itself, the water ring compressor package consists of multiple equipment, including the water ring separator, the recirculation pump, and the ring water cooler. The water ring separator removes any working water from the compressed gas. This water is then pumped by the recirculation pump to the ring water cooler to remove the heat of compression from the water. The working water is then reused in the water ring compressor. A spillback valve at the outlet of the water ring separator controls the suction pressure of the water ring compressor.

Like the ejector, the main purpose of the water ring compressor is to allow the coke drum pressure to be lowered even further before venting the coke drum to the atmosphere after the quenching step. The blowdown vapours from this process can be sent via the water ring compressor to the fractionator for recovery.

The operation of the water ring compressor is similar to that of the ejector. At the start of the coke drum cooling step, the water ring compressor is bypassed, and blowdown vapours are sent directly to the fractionator overhead. As the coke drum cooling progresses and the blowdown system pressure lowers, the water ring compressor is taken online. This typically occurs about 2-3 hours into the fast water cooling step. By the end of the cooling step, the coke drum can achieve pressures as low as 2 psig or less, depending on the blowdown system layout and the system hydraulics. The water ring compressor is then taken offline at the end of the cooling step, right after the closing of the coke drum-to-blowdown isolation valves.

The benefits of selecting a water ring compressor over other blowdown system design options such as an ejector are its cost-effective operation and robustness. In terms of utility consumption, the water ring compressor package uses electric power rather than the pressurised steam of an ejector. Furthermore, because most of the water is separated from the compressed gas in the water ring separator, there is minimal impact on the sour water generation of the unit when compared to the operation of an ejector.

The compressor package also recycles this water via the recirculation pump and ring water cooler shown in Figure 3 and requires only a small amount of make-up water. In terms of robustness, if a refinery does not already have a flare gas recovery system, the water ring compressor can also be used as a flare gas recovery compressor by sending flare gases to the coker fractionator overhead. However, utilising the water ring compressor in this service will require extensive study to ensure proper operation and handling of the refinery's flare gases.

The water ring compressor does have its tradeoffs, however. When compared to an ejector, the water ring compressor package has multiple pieces of equipment, leading to higher capital costs and a larger plot area footprint. In addition, the rotating equipment of the water ring compressor package may require more maintenance than the ejector, which is just a single static piece of equipment.

The water ring compressor and the ejector also share some added benefits. For example, both can be used to speed up coke drum warm-up times, if needed. This can be accomplished by drawing in more vapours from the operating coke drum towards the warm-up coke drum, although fewer operational upsets can be achieved in units with more than one coke drum pair. Similarly, both the ejector and water ring compressor can also be used to speed up coke drum cooling times by allowing a higher flow rate of water to be used during the coke drum quenching step. Using a higher flow rate of quench water creates a higher rate of steam in the coke drum, which would normally cause an increase in coke drum pressure. However, by using the ejector or the water ring compressor, the increase in vaporisation can be appropriately handled. With the capability of shortening both coke drum warm-up and cooling times, the ejector and the water ring compressor can offer flexibility to the decoking schedule.

Conclusion

The ejector and the water ring compressor are the most commonly practised and proven design configurations that can lower the coke drum pressure to 2 psig before venting the coke drum to the atmosphere, leading to lower VOC emissions. The ejector and water ring compressor configurations have already been implemented into a few of CLG's licensed operating units in both revamps and grassroots designs, and these units have all reported satisfactory results. While the ejector and water ring compressor both serve a similar role, the choice will ultimately depend on the tradeoffs between steam versus electricity costs, the plot area availability, and the refiner's Capex versus Opex strategies.

References

1 US EPA 40 CFR § 63.657 - Delayed coking unit decoking operation standards.

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