WHITE PAPER

Safe and Efficient Flare Gas Recovery

How You Can Clarify Specific Process Risks and Requirements Before Implementation

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Steps all flare gas recovery operators should take to avoid unplanned downtime

Safe and efficient operation of liquid ring compressors in flare gas recovery applications depends on careful consideration of process factors in order to ensure trouble-free operation.

Facility operators, including process engineers, specifiers, purchasers and maintenance specialists, along with their equipment suppliers should collaborate to identify and communicate all process requirements and materials during the design and selection of the compressors and related systems. Failure to do so can lead to inefficient flare gas recovery, unplanned downtime due to damaged machines, and costly environmental penalties.

This white paper describes the main process challenges that should be evaluated during the bidding, purchasing and implementation of liquid ring compressors. By applying the recommendations shared here, you can ensure that the operating limits of the compressors are not exceeded and the required flare gas recovery rate is achieved.

Eight risks to identify — and remedies to improve — efficiency and reliability

During the bidding process for liquid ring compressors, it's critical for the facility operator to verify the application and specific process risks. Examples of what should be considered and accommodated in the selection and design of a compressor system include:

Non-condensable gas control	Aftercooler condensate not returned to separator	Suction KO drum near compressor	Gas cooler upstream or isolation valves
Service liquid temperature control	Water quality	Review control narrative/control valve sizing	Correct implementation control narrative in software

Process conditions must be described completely. The majority of the information required to appropriately design the recovery system will be contained in the compressor datasheets prepared by the customer or operator. API 681 datasheets are available and can be used as templates. The API 681 standard addresses the minimum requirements for liquid ring vacuum and compressor systems for service in the petroleum, gas and chemical industries. However, the operator must verify details that fall under each of the risks explained in this white paper. After the compressor purchase order has been received by the supplier, potential issues need to be re-evaluated.

In addition, risks for control narrative and control valve size along with correct implementation of the control narrative in software should be addressed in the following:

- **A hazard and operability (HAZOP) study** to identify and evaluate problems that may represent risks to personnel or equipment
- **Implementation, operation and maintenance (IOM) procedures** to confirm understanding and adherence to the operating sequence and other recommendations from the original equipment manufacturer (OEM)

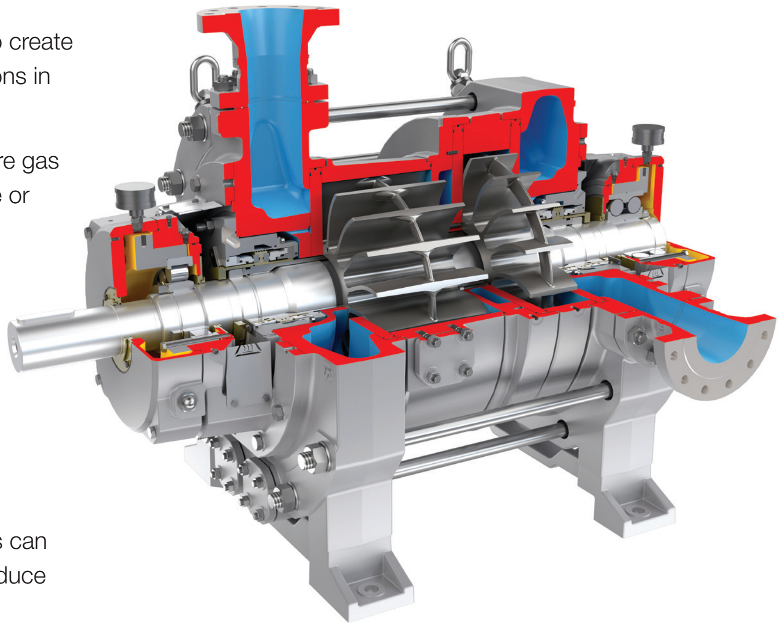
Liquid ring compressors: The optimum solution

Liquid ring compressors can use any kind of service liquid to create a seal, making them ideal for demanding industrial applications in which process contamination is prohibited.

The main applications for liquid ring compressors include flare gas recovery and processing of especially aggressive, flammable or corrosive gases and vapors found in:

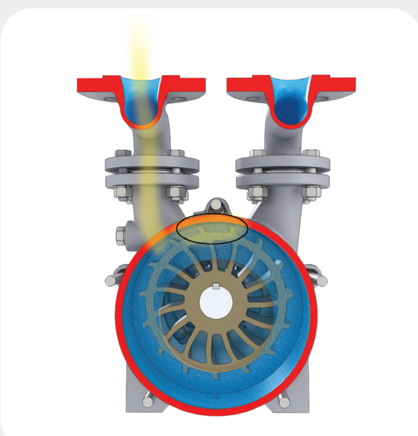
- Chemical processing
- Chlorine compression
- CO_2 treatment
- Ozone bleaching
- Vinyl chloride monomer (VCM) or aromatics recovery
- Water treatment

Flammable waste gases recovered from industrial processes can be used for fuel or other purposes in order to significantly reduce emissions and energy costs.

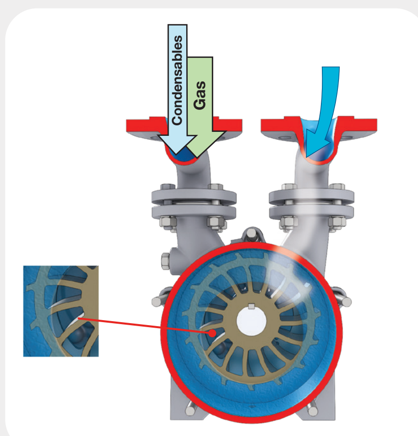


Flare gas recovery

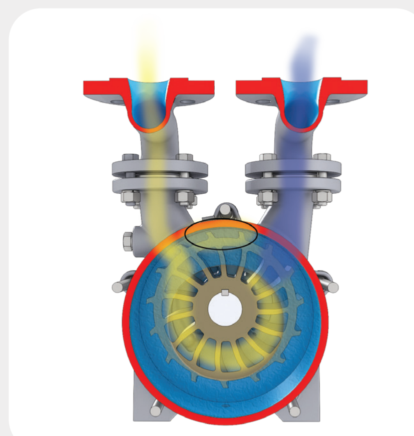
Liquid ring compressors can withstand wet process streams and fouling that can damage reciprocating or screw compressors. A service liquid (typically water) creates a seal as a result of the impeller's rotation.



Process gases, liquids and vapors enter the compressor inlet.



A rotating impeller separates waste gas from the process material as a result of isothermal compression.



The process material leaves the compressor while the separated waste gas is recovered for additional processing or utilized as fuel.

With only a few moving parts, liquid ring compressors are highly reliable, enabling facility operators to avoid downtime and flaring waste gas — as well as potential fines or penalties for not complying with state and federal environmental regulations.

Process risks and remedies

Consider these eight process risks during the bidding process when implementing flare gas recovery systems.

1. Non-condensable gas control

A liquid ring compressor requires a minimum amount of non-condensable gas to be present at the suction side in order to operate properly. The flow can come from the process liquid as well as through the spill-back control valve (recycled gas from the discharge separator back to the compressor suction). Spill-back is controlled via a pressure transmitter in the compressor suction line to maintain a specific suction pressure.

The minimum non-condensable gas flow must be identified by the customer and listed on the datasheet. The compressor supplier must confirm the baseline non-condensable load.

Risk

- If the non-condensable gas amount is not sufficient, the compressor will operate inefficiently or could be damaged.

Remedy

- Change the process or method of operation to compensate for a low non-condensable flow (e.g., hydrogen, methane, nitrogen, propane). This can be accomplished by:
  - Using an existing valve or process in the compressor operator's scope of supply upstream
  - Installation of an additional valve upstream of the compressor that will be controlled by a flow transmitter located on the outlet of the compressor skid

2. Condensate not returned to separator

In some processes, an aftercooler is required before condensate can be returned to a separator tank. In this application, close attention must be paid to the amount and composition of condensate returning to the tank. The condensate leaving the aftercooler is a much lower temperature than the liquid in the separator. If there is no aftercooler required or installed, no further action is required.

Risks

- Temperature differences could be enough to vaporize the condensate (depending on its composition). Vaporized condensate will keep circulating and may also go through the spill-back control valve into the suction of the compressor, potentially increasing the condensable load.
- C5+ or Pentanes Plus (hydrocarbon mixture of pentane, isopentane, hexanes-plus and condensate) along with butanes can cycle from liquified vapor back into a gas, if available in high concentrations and subject to the discharge pressure.

Remedies

- Install a knock-out tank to trap liquid in front of the compressor. This avoids overfilling the machine with liquid, which wears out components prematurely.
- Redirect the aftercooler condensate to a knock-out tank or drum, from which it can be pumped off to be treated.
- If the condensate amount and composition are acceptable, drain into the water side of a separator or, if allowed by the facility operator, drain into the slop oil side of a three-phase separator.

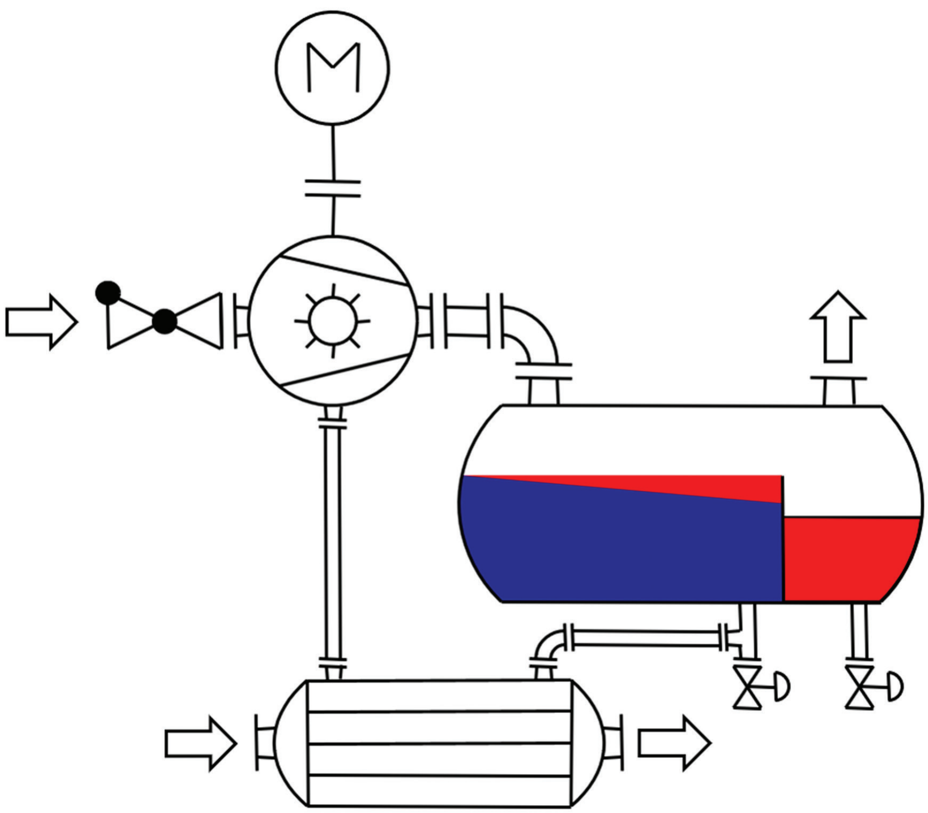
Process risks and remedies

3. Suction knock-out drum near compressor

Knock-out drums are used to avoid overfilling liquid ring compressors. The suction line from a knock-out drum is a source of additional condensate or liquid slugs into the compressor.

Risk
• Non-continuous slugs have the potential to damage the compressor.

Remedies
• The installation of a knock-out drum in front of the compressor is recommended. This will remove any condensate or liquid slugs from the gas or liquid to be processed. The distance of piping from the knock-out drum to the compressor has to be kept as short as possible.
• Heat tracing can also assist with minimizing condensation in the suction line during winter months.



A liquid ring pump compressor discharges vapor and service liquid into a separator tank. Because condensed hydrocarbons are lighter than water, they build a liquid phase layer on top of the water. Using gravity, the vapor and liquid can then be separated, with the vapor exiting the top and the recovered liquid discharging into the recovered liquid chamber.

Process risks and remedies

4. Gas cooler upstream or isolation valves

A liquid ring compressor has to be protected from rising gas inlet temperature and increasing condensable loads during steam-out scenarios conducted in preparation for maintenance or other processes. Steaming out a process creates a large load of vapors and an increase in temperatures that can damage a liquid ring compressor.

Risks

- In periods with excessive condensable flow like steam-out conditions, the inlet gas will condense during compression in a liquid ring compressor.
- This has to be avoided to reduce non-condensable flow, which can deflect or damage impeller blades and the impeller shaft.

Remedies

- Install an inlet gas cooler. The gas cooler will remove the excess heat and condense water vapor. Gas inlet coolers provide protection against excessive condensable loads.
- Install a compressor-actuated isolation valve to bypass the gas stream to the flare.

5. Service liquid temperature control

Temperature of the service liquid is a key factor that determines the amount of condensation within a liquid ring compressor. The colder the service liquid is, the more condensation that occurs. In periods of low temperatures, the amount of condensation can more than double under excessive condensable load.

Special attention is required with air coolers, as the ambient temperature may have a direct effect on cooler outlet temperature. If the minimum temperature is sufficient to avoid large portions of condensation, there is no need for further action. If the minimum temperature is not sufficient, the service liquid temperature needs to be controlled.

Risk

- A liquid ring compressor can only handle a recovery application if there is sufficient non-condensable gas available. When temperatures fall below the minimum of the process range, flare gas recovery becomes inefficient.

Remedies

- The cooling medium and minimum temperature should be defined in the facility operator’s datasheet.
- The liquid ring compressor supplier must confirm temperature requirements with the customer before equipment installation.
- Install a heat exchanger.
  - Shell and tube coolers control the cooling water flow based on service liquid supply temperature to the compressor. An additional control valve may be required.
  - Variable-speed fans under the coolers and/or automatic louver control can reduce the water outlet temperature.

Process risks and remedies

6. Water quality

Water used for the service liquid or to offset water lost during liquid ring compressor processes has to be free of particles and compatible with the piping material. Boiler feed water in carbon steel piping can transport particles that cause piping wear in front of or inside a liquid ring compressor.

Risks

- Particles and water composition that reacts with the piping material will eventually create a safety issue with wear in piping and inside a liquid ring compressor, faulty instrument readings and seal failure.
- Liquid added to make up for what's lost in processing can modify temperatures inside the compressor and impact flare gas recovery efficiency.
- Supplying more service liquid or make-up water can lower temperatures inside the compressor by 1 to 2°C (34 to 36°F). This can cause more vapor to condense.

Remedies

- Install strainers in the recirculated liquid lines.
- Avoid using untreated boiler feed water when carbon steel piping/equipment is specified to avoid excessive particulate from corrosion in the recirculated liquid.
- Precisely control the temperature of make-up water in order to influence the service liquid temperature inside the compressor.

7. Review control narrative/control valve sizing

A spill-back control valve prevents the backflow of gases at start-up or shutdown of the flare gas recovery system. The valve is typically controlled by the compressor's suction pressure. The compressor's suction flow rate is constant, so the valve opens during periods of low incoming gas and closes during periods of higher flow.

Valves often are installed to operate with two or more compressors. This can result in a fairly large valve. With one compressor in operation, the valve can operate in a non-favorable position under 15% open; in certain circumstances, it becomes erratic and closes. One valve may not be sufficient to handle varying flow rates when two or more compressors are being used.

Risks

- A liquid ring compressor can only handle a recovery application if there is sufficient non-condensable gas available. The amount varies based on the process material, its flow and other operating conditions.
- If gas flow increases to a point at which the spill-back control valve closes, the compressor can be damaged.

Remedies

- Size the spill-back valve appropriate to the process conditions. Low molecular weights of gas compositions can affect the control valve drastically. Controllability of the valve must be verified with the valve manufacturer.
- The spill-back valve should never be fully closed. Utilize software to monitor and control the valve's position.

Process risks and remedies

8. Correct implementation of control narrative in software

Start-up procedures, cooling water temperature control, timed delays on valves, and the proper sequencing of valves during start-up all influence the longevity of liquid ring compressors. Therefore, close attention should be paid to ensure that the facility operator is adequately informed and equipped to properly operate flare gas recovery processes.

Risk

- Unplanned downtime due to prematurely worn or damaged equipment is costly, disrupts operations, and can result in fines and penalties when flaring occurs.

Remedies

- The liquid ring compressor supplier must participate in the HAZOP with the facility operator on each project. This can ensure correct implementation of all indicated remedies in the flare recovery system software and operating procedures.
- Implement start-up and shut-down procedures along with procedures for proper equipment operation.
- Protect the compressor by establishing a minimum control valve opening based on a baseline for non-condensable flow.

Conclusion

Purchasers of flare gas recovery systems frequently order standard equipment without confirming whether the materials and capacities of the compressors, valves, tanks and piping configured on a skid can reliably handle the process conditions — gas volume flows, weights of gases, gas composition and range of temperatures — unique to the location and operation. In addition, purchasers might not be aware of how processes, conditions and materials upstream of the compressor can negatively impact the efficiency and durability of liquid ring compressors.

Instead of specifying only that a flare gas recovery compressor must meet the API 681 standards, purchasers should collaborate with process engineers and maintenance specialists to identify specific process requirements and share as much information as possible with equipment suppliers during bidding and before implementation. Examples include:

- Gas composition and percentage of each component
- Service liquid and its temperature
- Required capacity:
  - Mass flow rate (pounds/hr), or
  - Volumetric flow rate (ACFM or SCFM) or
  - Existing installed hp
  - Peak and average or typical flow rates
- Suction pressure and temperature

While it's understandable that some companies might be reluctant to reveal proprietary information about their materials and processes, equipment suppliers cannot precisely match equipment to an operator's requirements without it. This can lead to corroded or damaged parts inside liquid ring compressors, piping, tanks and valves. What too often follows are unplanned downtime, additional maintenance costs, and the risks of fines and penalties for waste gas flaring in violation of environmental standards.

These business disruptions and additional expenses can be minimized when flare gas recovery operators collaborate with their equipment suppliers early and fully in the equipment acquisition and implementation processes.

Flowserve can help

Please contact Stefan Lähn at SLaehn@flowserve.com to learn more about our next-generation liquid ring compressors.

[1] Persistence Market Research, "Global Market Study on Liquid Ring Vacuum Pump: High-capacity Pumps Penetrating Oil & Gas Industry," October 2019, https://www.persistencemarketresearch.com/market-research/liquid-ring-vacuum-pumps-market.asp (accessed June 24, 2020).

[2] Future Market Insights, "Global Flare Gas Recovery Systems Market Analysis & Opportunity Assessment, 2014 – 2020," 2015.

[3] Flowserve internal research, 2020.

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Stefan Lähn is the global product portfolio leader, liquid ring vacuum pumps, compressors and systems at Flowserve. He earned his engineering degree from Fachhochschule Westküste. He also has worked as an application engineer and product specialist for liquid ring technology at Flowserve.

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