Wet Seal Degassing Recovery System for Centrifugal Compressors

Technology/Practice Overview

Description

Centrifugal compressors are used throughout the natural gas industry to compress gas for processing, movement through pipelines, and other needs. These compressors require seals around the rotating shaft to prevent high pressure gases from escaping where the shaft exits the compressor casing. Seals may be either wet seals using oil as a barrier or dry seals that use a mechanical barrier with most new compressors equipped with dry seal. However, there are a large number of centrifugal compressors with wet seals in operation. Wet seals use specialty oil which is circulated under higher pressure than the gas in the adjacent compressor case, between rings around the compressor shaft, forming a barrier against the compressed gas leakage. In the wet seal design shown in Exhibit 1, the center ring is attached to the rotating shaft, while the two rings on each side are stationary in the seal housing, pressed against a thin film of oil flowing between the rings to both lubricate and act as a leak barrier. “O-ring” rubber seals prevent leakage around the stationary rings. Very little gas escapes through the oil barrier; considerably more gas is entrained in the oil that comes in direct contact with the high pressures gas at the “inboard” (compressor side) interface, thus contaminating the seal oil. Prior to recirculation, seal oil must be purged of natural gas (which is primarily methane) in a process called seal oil “degassing.” Methane released during degassing is commonly vented to the atmosphere with vent outlets usually located in elevated areas that are not easily accessible to operators for inspection or maintenance (e.g., roof vent stacks). As a result, the majority of methane emissions from a centrifugal compressor often go undetected by operators.

- ■ Compressors/Engines
- □ Dehydrators
- □ Directed Inspection & Maintenance
- □ Pipelines
- □ Pneumatics/Controls
- □ Tanks
- □ Valves
- □ Wells
- □ Other

Applicable Sector(s)

- ■ Production
- ■ Processing
- ■ Transmission
- ■ Distribution

Economic and Environmental Benefits

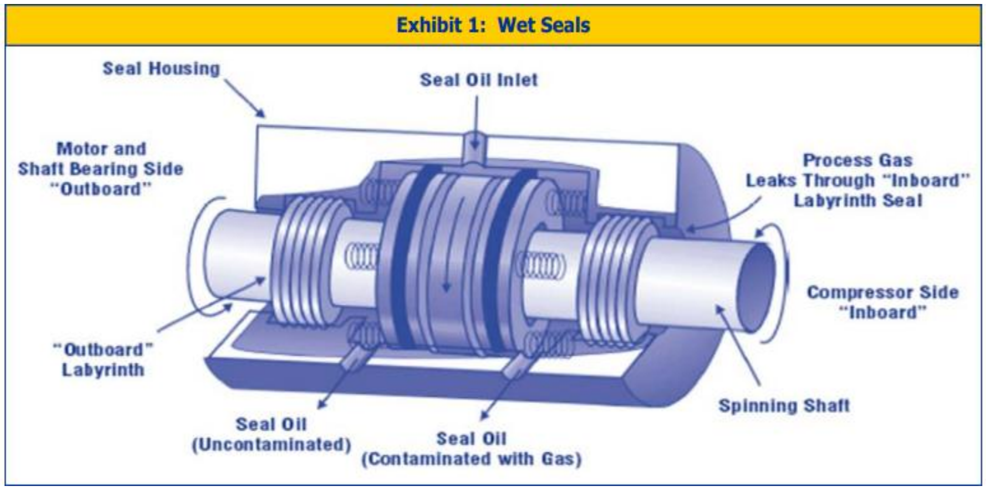
Economics Evaluation

Estimated Gas Price	Annual Methane Savings[1]	Value of Annual Gas Savings	Estimated Implementation Cost	Incremental Operating Cost	Payback
$3.00/Mcf	30,000 Mcf 120,000 Mcf	$90,000 $360,000	$33,000 $90,000	Minimal	5 months 3 months
$5.00/Mcf	30,000 Mcf 120,000 Mcf	$150,000 $600,000	$33,000 $90,000	Minimal	3 months 2 months
$7.00/Mcf	30,000 Mcf 120,000 Mcf	$210,000 $840,000	$33,000 $90,000	Minimal	2 months 1 months

[1] *At each gas price, the costs and savings are for one and four compressors at a station.*

Wet Seal Degassing Recovery System for Centrifugal Compressors

Exhibit 1: A typical wet seal setup, the seal oil enters through the inlet (top) and provides a barrier to gas attempting to escape by forming two thin films under higher pressure between the center rotating ring and the two stationary rings (seen with surrounding o-rings).



One Partner has reduced methane emissions from centrifugal compressor seal oil degassing by separating gas from seal oil in a small separator/disengagement vessel and routing it back into the compressor suction, to high pressure turbine fuel gas, or to low pressure fuel gas for heaters/burners. A diagram illustrating this partner's approach is shown in Exhibit 2. Seal oil with entrained gas is typically routed directly to an atmospheric pressure degassing tank from which disengaged gas is vented to the atmosphere. In the capture system, the contaminated seal oil is instead separated from entrained gas in a separator operating at seal oil pressure with gas flow control by a critical orifice. The entrained gas captured from the seal oil is

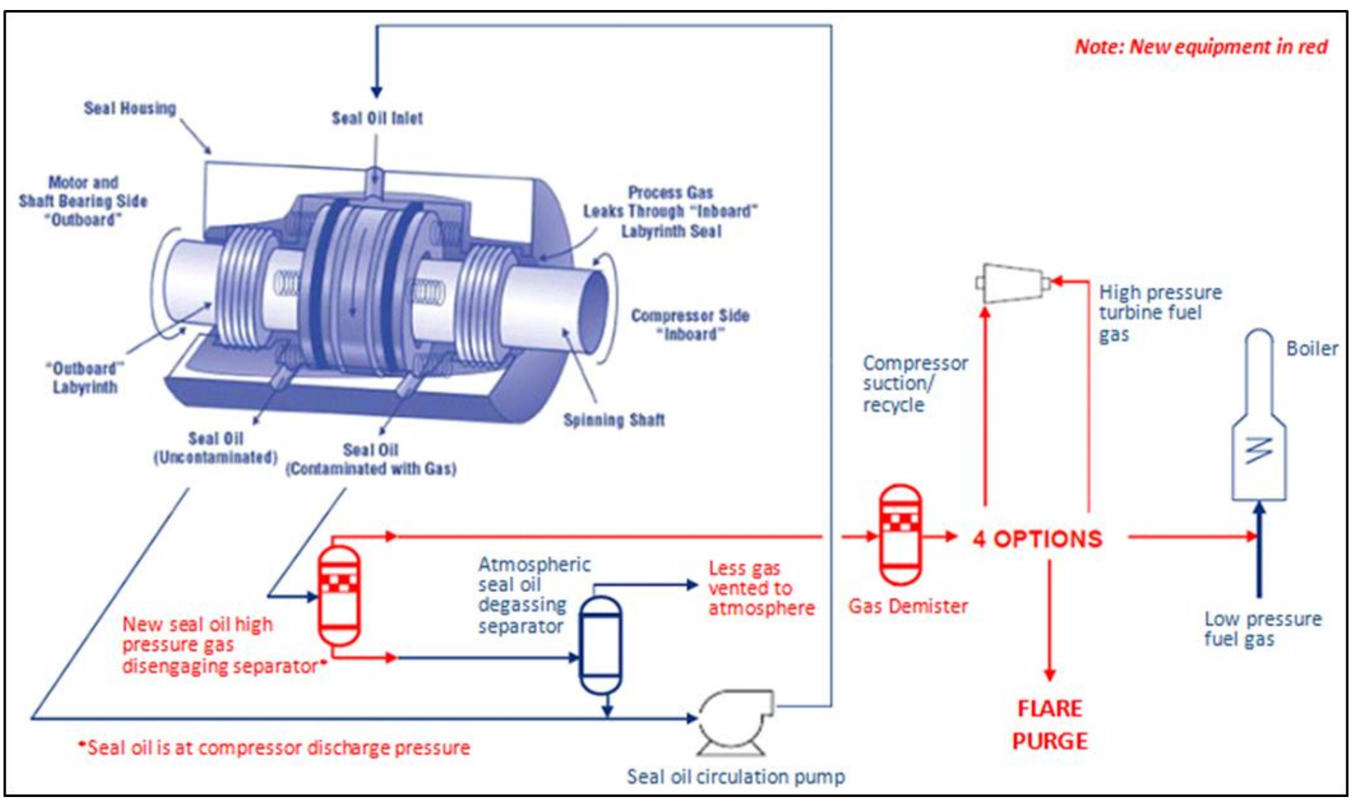


Exhibit 2: General process flow of wet seal degassing recovery system. Existing equipment is shown in blue or black and new equipment for seal oil degassing recovery is shown in red.

routed to a seal oil demister to remove entrained seal oil before routing to beneficial use. The seal oil then flows from the bottom of the seal oil degassing separator to the atmospheric degassing separator where the remaining minimal volume of entrained/dissolved gas is removed and vented to the atmosphere. The regenerated seal oil is then recirculated back to the compressor seal oil system.

Operating Requirements

In order to implement this recovery and use of gas separated from seal oil there must be a use for the recovered gas. Operators may configure the wet seal degassing recovery system to route the recovered gas as low pressure heater/boiler fuel (approximately 50 pounds per square inch gauge [psig]), high pressure turbine fuel (approximately 250 psig), to compressor suction, flare sweep gas, or any combination of the four options. One Partner has configured their wet seal degassing recovery systems to route recovered gas from multiple centrifugal compressors to all four of these choices. If routed to fuel gas use, the small amount of entrained seal oil mist in the gas stream from the new seal oil high pressure gas disengagement separator (shown in red in Exhibit 2 above) requires a demister/filter knock-out vessel (s) be installed to remove residual oil.

Applicability

Wet seal degassing recovery systems could be installed at most locations with wet seal centrifugal compressors, particularly in lieu of retrofitting compressors with dry seals. Retrofitting wet seal centrifugal compressors with dry seals is not always feasible due to operating conditions/requirements, substantial costs, and compressor downtime. Wet seal degassing recovery systems offer an economic alternative to installing dry seals to mitigate methane emissions from wet seal degassing with very little downtime.

Methane Emissions

According to previous measurements of seal oil degassing reported in Bylin, et al. (2009), emissions from degassing centrifugal compressor seal oil can be as high as 185 standard cubic feet per minute (scfm) (5.2 cubic meters (m3) per minute) of gas per compressor, with an average value of 63 scfm (1.8 m3 per minute) of gas per compressor. Gas volume from degassing centrifugal compressor seal oil varies primarily due to: the number of seals per centrifugal compressor, the rate of seal oil circulation, the size of the compressor, and the compressor discharge pressure. One Partner currently operates wet seal degassing recovery systems that recover 99 percent of the degassing emissions from fifteen centrifugal compressors – four low pressure compressors, nine high pressure compressors, and two tandem compressors at one facility. Based on a study conducted at this particular facility, the wet seal gas recovery system captures 3,300 scfm of gas; that equates to 1.6 billion cubic feet (Bcf) of gas per year (8,500 hours of operation per year as indicated by the Partner). This Partner reports another approximately 85 wet seal centrifugal compressors with the same or similar seal oil gas recovery systems in this particular operation.

Economic Analysis

The analysis for installing a wet seal degassing recovery system should consider the capital and operational costs along with the revenue generated by recovered gas. As shown in the overview table (Economic and Environmental Benefits) above, the economics for recovering wet seal degassing losses are compelling at even low gas prices. The detailed economic analysis in Exhibit 3 below presents two scenarios. The first scenario depicts the wet seal degassing recovery system installed for one centrifugal compressor, and the second scenario illustrates a wet seal degassing recovery system installed at a centrifugal compressor station with four centrifugal compressors. These examples are based on one Partner's emissions measurements, savings, and installed equipment costs which have high pressure gas disengagement separators on each seal of 15 compressors, with one recovered gas two stage filter/demister system.

Capital Costs

The investment per compressor to recover seal oil degassing emissions using this technology includes the cost of a high pressure seal oil gas disengagement separator for each compressor seal or pair of seals operating at the same seal oil pressure, new piping, the appropriate pressure and flow controls, and the labor to design and install the equipment. Operating and maintenance (O&M) costs are expected to be minimal. The investment per station to condition the recovered degassing emissions for injection into a low pressure fuel system would include the cost of a gas demister to remove residual seal oil from the recovered gas. If the recovered gas is routed to a higher pressure turbine fuel system, a second seal oil high efficiency filter/separator is likely required to ensure all remaining seal oil mist is removed.

The capital cost (estimated) for each separator includes the purchase cost of the process vessel, piping, instrumentation, structural support, electrical, painting, shipping, insurance, and installation. Exhibit 3 summarizes the estimated capital costs for each piece of equipment installed in a wet seal degassing recovery system.

design pressure of 720 psig. The cost for a seal oil single-stage demister/filter system designed for a single centrifugal compressor or a compressor station with four centrifugal compressors is $9,000.

If any of the recovered gas is being used as high pressure turbine fuel, the recovery system may include a second seal oil gas high-efficiency filter to ensure trace amounts of seal oil do not foul the turbine fuel injectors. This economic analysis assumes the seal oil gas filter for turbine fuel quality gas will be vertical and have a 1-foot diameter and 3-foot height with a design pressure of 300 psig and be made of carbon steel. The cost for the second seal oil high-efficiency filter for a single centrifugal compressor or a compressor station is $5,000.

Exhibit 3: Wet Seal Degassing Recovery System Installation and Equipment Costs

Equipment	One Centrifugal Compressor Capital Cost ($2011)	Centrifugal Compressor Station Capital Cost ($2011)
Seal-Oil/Gas Separator [1]	$19,000	$76,000
Seal Oil Gas Demister – Low Quality Gas	$9,000	$9,000
Seal Oil Gas Demister – High Quality Gas	$5,000	$5,000
Total	**$33,000**	**$90,000**

[1] *Assuming two seals per centrifugal compressor and four centrifugal compressors at the station. An individual high pressure seal oil gas separator costs $9,500 per seal.*

High Pressure Seal Oil Gas Disengagement Separators

For each centrifugal compressor connected to the wet seal degassing recovery system, a seal oil gas separator will be installed for each seal or pair of seals if operating at the same seal oil pressure. The seal oil gas separators can be designed to operate at the same pressure as the seal oil exiting the seal housing. Based on a Partner's installation, the size of these separators assumes 1-foot diameter, 3-foot height seal oil gas separators with a 1,125 psig design pressure and made of carbon steel. The total cost of each seal oil gas separator is $9,500; assuming two seal-oil/gas separators per compressor, the total cost per compressor is $19,000.

Seal Oil Recovered Gas Demister/Filter

Before the recovered gas can be sent to a fuel line it must pass through at least one high-efficiency demister to remove entrained seal oil that may foul burners and potentially clog fuel injectors. The seal oil gas demister can be designed to receive recovered gas from multiple centrifugal compressors with wet seals. Therefore, the design characteristics of this vessel will vary depending on the number of centrifugal compressors connected to the vessel. Based on a Partner's installation, this economic analysis assumes, for a single centrifugal compressor, the seal oil gas demister will be vertical and have a 1-foot diameter and 4-foot height with a

Piping and Instrumentation

Operators will need to route seal oil exiting the compressor seal to the new seal-oil/gas separator and then to the degassing tank which will require piping modifications. Additionally, pipes and valves to transport the recovered gas from the seal oil gas disengagement separators to the seal oil gas demister/filters and further to the fuel gas, compressor suction or flare line(s) will be required. Pressure and flow controls will also need to be installed to regulate the pressure and flow of the recovered gas from each high pressure seal oil degassing separator. In this Partner's installations this is accomplished with a critical orifice (1/16 inch/1.59 mm) on the gas outlet from each seal-oil/gas separator which restricts gas flow using choke flow effects. For example, this Partner has set up the wet seal degassing recovery system to route captured gas to a high pressure turbine fuel line, low pressure process heater fuel line, and flare purge which requires additional instrumentation and flow control. The majority of the gas is routed to the high pressure turbine fuel line with excess gas routed to the low pressure process heater fuel line or flare, depending on fuel requirements. The piping and instrumentation costs are included in the installation and capital costs for each individual piece of equipment listed in Exhibit 3.

Estimated Savings

The savings for capturing seal oil degassing emissions are realized by generating additional gas sales and revenue through using recovered gas for site fuel gas or recycling directly to suction and sales or processing. Based on the measurement studies discussed in Bylin, et al. (2009), the average methane emissions from centrifugal compressor wet seal degassing is 63 scfm (1.8 m3 per minute) of gas per compressor. Assuming 8,000 hours of operation per year, the total gas emissions per year is 30 million cubic feet (MMcf) per compressor. Based on one Partner's experience, over 99 percent of the entrained gas in the seal oil was captured and used as fuel – proving this technology performs as well as dry seal systems from an emission perspective. This analysis assumes 99 percent of the potential degassing emissions are captured and 1 percent is vented. Therefore, 30 MMcf of gas is recovered per centrifugal compressor and displaces the same volume in fuel gas or is routed to compressor suction and sales. At $3.00 per thousand cubic feet (Mcf), savings from reduced fuel gas consumption is estimated to be $90,000 per year per centrifugal compressor connected to a wet seal degassing recovery system. A station with four centrifugal compressors connected to a wet seal degassing recovery system could potentially generate $360,000 per year of additional revenue.

Comparing Costs to Savings

The economics of implementing a wet seal degassing recovery system is shown below using a five-year cash flow table. This analysis presented in Exhibit 4 and Exhibit 5 considers capital costs and methane emissions savings. The capital and installation costs in this economic analysis assume the operator installs both the seal oil gas demister/filter separator for low pressure fuel gas and seal oil gas high efficiency filter for high pressure turbine fuel gas, which will allow the operator to route to a flare, low pressure burner, or turbine fuel line. Exhibit 3 shows the detailed breakdown of the equipment and capital cost used in this economic analysis. It is important to note that all analyses will be highly site-specific, but the economics of installing a wet

Exhibit 4: Wet Seal Degassing Recovery System Costs and Savings for One Compressor

Costs and Savings ($)	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Wet seal recovery system capital & installation costs	($33,000)					
Annual natural gas savings ($3.00/Mcf of Methane)		$90,000	$90,000	$90,000	$90,000	$90,000
NPV (Net Present Value) = $280,000 **IRR (Internal Rate of Return) = 270%** **Payback Period = 5 months**						

Exhibit 5: Wet Seal Degassing Recovery System Costs and Savings for Four Compressors at a Station

Costs and Savings ($)	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Wet seal recovery system capital & installation costs	($90,000)					
Annual natural gas savings ($3.00/Mcf of Methane)		$360,000	$360,000	$360,000	$360,000	$360,000
NPV (Net Present Value) = $1,200,000 **IRR (Internal Rate of Return) = 400%** **Payback Period = 3 months**						

seal gas recovery system are so attractive that companies should consider implementing this technology at any and all facilities with at least one centrifugal compressor with wet seals.

Exhibit 4 presents the economics of installing a wet seal degassing recovery system for a single centrifugal compressor. Exhibit 5 presents the economics of installing a wet seal degassing recovery system at a station with four centrifugal compressors. The net present value and payback period are calculated using a 10 percent discount rate.

Operational Reliability

The Partner reporting the seal oil degassing systems reports them being in place with constant use since 1977 and no failures due to the degassing systems. With about 100 such systems installed and operating from very low pressures to very high pressures across a range of gas compositions, the operational reliability of seal oil degassing systems has been clearly demonstrated.

Discussion

A wet seal oil degassing recovery system is likely to provide the lowest cost for retrofit with the quickest payback for compressor stations, offshore production platforms or gas processing plants with single or multiple wet seal centrifugal compressors. All options pay back in less than a year. The economics are compelling, but the installation may require a brief shut-down of each compressor to tie the seal oil circulation piping into the new gas disengagement vessels. New facilities requiring the installation of wet seal centrifugal compressors can also integrate wet seal degassing recovery systems into their process design at the same costs. As demonstrated by a Partner facility, wet seal degassing recovery systems are highly effective at capturing degassing emissions from wet seal centrifugal compressors and subsequently reducing fuel gas purchases and/or increasing gas sales with a high rate of return.

References

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