Centrifugal Compressors
The Life Cycle Cost Calculator
&
Economic Considerations
Of Gas Seal Technology

Paul Hosking and Mark Savage
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Executive Summary

The natural gas industry, environment groups and regulators have identified legacy centrifugal compressors equipped with oil seals as one of the leading source of methane emissions in onshore and offshore operations. This challenge represents a significant economic opportunity for operators as there are cost effective technologies available across the gas value chain that can help operators improve economics while preventing releases of methane into the atmosphere. Collaborative initiatives, such as the Global Methane Initiative, US Natural Gas STAR and United Nations Environment Programme, Climate and Clean Air Coalition, and Oil and Gas Methane Partnership, focus on centrifugal compressors and recommend cost-effective technologies and processes.

There are generally three solutions available to reduce methane emissions from existing oil seal equipped centrifugal compressors – (1.) capture and flare the gas, (2.) capture and reuse the gas, or (3.) oil seal to gas seal upgrade. **Gas seal technology** is proven and available and proposed as the **Best Available Technology**. Gas seals are recognized for lower operating cost, improved reliability and improved energy efficiencies while also reducing methane emissions. It is the only option that actually prevents methane emissions, rather than managing escaped natural gas.

Despite the costs associated with retrofitting an oil seal equipped centrifugal compressor with gas seal technology, over the past 15 years, a number of operators have had success in upgrading from
oil seals to gas seal technology to reduce methane emissions, and have realized cost efficiencies as well.

This discussion showcases a decision support tool, a life cycle cost calculator (LCC) that evaluates the three options for operators from an economic and environmental perspective. The LCC provides real time data differentiating itself from previous case studies which were “typical” using “static” data. In many cases it validates a win-win for business and the environment. Indeed gas seal technology is one of a very few technology solutions that has the potential to simultaneously meet the needs of industry, governments and other stakeholders.

**Where are centrifugal compressors applied?**

Centrifugal compressors are an integral part of the natural gas value chain from extraction to the city gate. This equipment is most intuitively understood as providing the motive force behind the intercontinental transmission of natural gas. In addition to transmission, centrifugal compressors are also deployed in a wide range of natural gas applications both onshore and offshore in upstream and midstream natural gas operations including gas processing and storage.

 Shaft sealing technology is an integral sub-system of centrifugal compressors. Prior to the mid-1980s, a variety of contacting oil seal designs were incorporated into centrifugal compressor designs. While representing “state of the art” for many decades, low emissions levels were in most cases not a design objective. Furthermore, in many cases, normal operational wear and tear only further exacerbates emission levels of contacting oil seal designs.

Since the introduction of gas seal technology by John Crane in the mid-1980s, the oil and gas industry has progressively adopted gas seal technology as the preferred design standard for new equipment maximizing economic and environmental benefits. At this time, globally, it is estimated that 90%+ of new centrifugal compressors now incorporate gas seal technology.

Therefore, new installations will likely meet low emission requirements while also being more cost effective and reliable. In many cases, centrifugal compressor operators have an existing fleet of equipment that contains a mix of compressors with oil seal and gas seal technologies with the ratio depending on the age of the equipment. Some legacy oil seal equipped compressors have been upgraded to gas seal technology and this has been motivated by economic factors and/or environmental or both.

It is the remaining fleet of legacy centrifugal compressors with oil seals that is the focus of this discussion paper.

**An introduction to gas seal technology**

It is beyond the scope of this discussion to provide a comprehensive technical review of gas seal technology. The fundamental difference in design is that oil seals utilise a contacting seal concept requiring oil lubrication to reduce friction and heat generation whereas gas seals utilise a non-
contacting grooved design. The result is a favourable step change in operating costs, reliability, emission levels and carbon footprint with additional important benefits relating to safety.

Since its introduction by John Crane in the mid-1980s, gas seals have increasingly become the de facto shaft seal standard in centrifugal compressors throughout the entire oil and gas industry in upstream, midstream and downstream operations in activities beyond natural gas in such markets as extraction, production, reinjection, liquefied natural gas (LNG) refrigeration and refining. It has been adopted by all the major centrifugal compressor manufacturers and by all the oil and gas majors operating the equipment.

Gas seal technology is globally available, supported and a proven solution.

**Three options to reduce Methane Emissions from existing Centrifugal Compressors equipped with Oil Seals**

It is generally acknowledged by stakeholders that the technologies available to mitigate uncontrolled vented methane emissions from existing centrifugal compressors equipped with oil seals fall into three categories.

1. Capture of the uncontrolled vented methane emission and route the emission to a flare device
2. Capture of the uncontrolled methane emission and route the emission to use for some other productive purpose
3. Upgrade the oil seal solution to a gas seal solution

Over the years, the methane emissions reduction community has documented examples of all three methods deployed to reduce methane emissions in the natural gas industry. While each approach can address methane emission abatement, there are important variables that should be considered when evaluating each option.

The use of a flare solution is universally applicable but transforms the methane emission into a carbon dioxide emission with no opportunity for economic payback. This also is in direct conflict with parallel efforts in the oil and gas industry to reduce flaring.

The capture of the emission and use for other productive purpose usually takes one of three forms.

A) Reinjection back into the compressor or process
B) Use as a supplementary fuel source for the gas turbine powering (driving) the compressor
C) Use as a supplementary fuel source for other equipment in the vicinity of the compressor (boiler etc.)

In contrast to flaring, all three of these approaches share the common advantage that the methane emission is no longer “wasted” and an economic payback can be achieved. The opportunity to deploy a given solution is situation dependant.
As opposed to both flaring and recycling, the implementation of gas seal technology and resulting transition from contacting to non-contacting seal technology eliminates the source of methane emission. Non contacting gas seal technology eliminates the need for oil lubrication and the resulting need to address methane that becomes entrapped in the oil. The implementation of non-contacting technology also uniquely delivers substantial operational cost benefits over and above the economic value of the methane emissions reduction. With this preventative solution, the emission levels are reduced to near zero. However, the opportunity to deploy a given solution is situation dependant.

The selection process

The selection of an appropriate mitigation option varies from one compressor with oil wet seals versus another, is situation specific, and the evaluation of three factors should be considered:

1. Environmental
2. Technical
3. Economic

This discussion focuses on the economics of the decision.

Assuming a base case of uncontrolled methane emissions from a centrifugal compressor equipped with oil seals, it is relatively straightforward to prepare a qualitative assessment of the economics to implement each of the three solutions.

<table>
<thead>
<tr>
<th></th>
<th>1. Capture and Flare Solution</th>
<th>2. Capture and Reuse Solution</th>
<th>3. Oil Seal to Gas Seal Upgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upfront Investment</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Methane Emission Reduction</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Operational Savings</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

All three solutions deliver broadly comparable reduction in methane emissions. While this analysis is not particularly complex, it is insightful. A fundamental understanding of these basic principles allows all stakeholders a much more informed assessment of the economics behind these solutions. This understanding can take us well beyond the simple measurement of abatement cost. Despite a general view that retrofitting an oil seal with gas seal technology is cost prohibitive, it is clear that in the long term, gas seal technology represents the lowest cost solution.

As the discussion moves from qualitative to quantitative, simple generalities are no longer sufficient. The wide range of centrifugal compressor applications results in a wide range of operating characteristics and resulting economic factors for each mitigation option. Considerations include: whether or not the compressor operator owns the natural gas being compressed and lost
to emissions, whether the compressor is operated in isolation or as part of an installation of multiple compressors, onshore versus offshore installation, percentage of time in operation versus standby, the applicability of carbon tax or credits, the unit value of the gas being emitted, the remaining useful life of the compressor under analysis and others can heavily influence the analysis.

In turn, these factors influence the economic attractiveness of the available solutions relative to each other.

Historically, interested parties have created case studies and guidance based on specific examples, however these examples necessarily relate to typical scenarios and do not allow easy adaption to specific circumstances. There is no substitute for expertise and advanced economic tools that leverage the expertise.

The Lifecycle Cost Calculator - a new decision support tool

Recognizing the opportunity to improve the collective understanding in this critical area, John Crane, utilizing its market leading expertise, has developed a quantitative lifecycle cost calculator which provides an itemized decision tree for all relevant stakeholders.

In summarizing the tool, it is useful to maintain the framework described previously. The tool guides the stakeholder to input the baseline costs of methane emissions and annual operating costs related to an oil seal equipped centrifugal compressor with uncontrolled emission, and progresses to input the one-time upgrade costs, cost of resulting methane emissions, and annual operating costs associated with each of the potential solutions. The output consists of comparison of the total lifecycle cost of the baseline sealing solution with each of the three mitigating solutions.

Of interest to those with a technical background, the tool accommodates such factors as offshore and onshore installations, multiple driver types, standby versus operating hours, static and dynamic leakages, seal reliability data, pipeline efficiency factors, parasitic losses and different upgrade costs.

Of interest to other stakeholders, among many outputs, the tool calculates abatement costs and carbon dioxide equivalent emission levels, accommodates different assumptions regarding whether the compressor operator owns the natural gas, wholesale natural gas prices and carbon tax or other incentives. The economic analysis is supplemented by data relating to the energy consumption and carbon footprint of all four scenarios. The LCC also provides default data inputs and assumptions that can be easily overwitten by the user.

The tool has been shared with a number of stakeholders and industry representatives and is insightful, comprehensive, customizable and specific.

The specifics of a quantitative analysis provided by the data from the LCC will result in variations to the economics – and payback - of a given mitigation technology, and go beyond simple upfront capital costs as a determination. This in turn will result in movement in the relative economic attractiveness between the three mitigation technologies (flare, reuse, or prevent). The Lifecycle
Cost Calculator (LCC) calculates these costs and generates graphical output for ease of interpretation. The LCC also accommodates changes to assumptions to examine the sensitivity of certain outcomes to variations in any parameter.

Due to the variety of situations - both technical and economic - it is not possible to examine all the outcomes in this discussion.

**Case studies**

The replacement of oil seal solutions with gas seal technology in centrifugal compressors is well understood in the oil and gas and petrochemical industries in general as well as more specifically in the natural gas industry to mitigate methane emissions. This is undoubtedly supported by the body of industry knowledge emanating from the fact that over 90 percent of new centrifugal compressors are equipped with gas seals.

Industry stakeholders have presented a number of successful case studies in methane emission forums over the years, including installations in the Americas, Europe, Russia and Asia.

**Conclusion:**

Addressing existing oil seal equipped centrifugal compressors is clearly relevant in the context of the global efforts of the natural gas industry and other interested stakeholders to reduce overall methane emissions.

Gas seal technology and the oil seal to gas seal upgrade is a solution that is available now, is well proven, and is available and supported on a global basis. From a long term perspective, gas seal technology provides the maximum environmental benefit, the maximum safety benefit, the maximum reliability and the lowest total lifecycle cost. The LCC can help operators evaluate all the variables in their considerations and provide a guide to maximize the value chain while helping them meet emerging environmental standards.

The application of gas seal technology to existing equipment has been well documented over the years including the economic case.

**About John Crane**

*John Crane* ([www.johncrane.com](http://www.johncrane.com)) is a global leader in rotating equipment solutions, supplying engineered technologies and services to process industries. The company designs and manufactures a variety of products including mechanical seals and systems, couplings, bearings, filtration systems and predictive digital monitoring technologies. John Crane customer service is accessed through a global network of more than 200 sales and service facilities in over 50 countries. Fiscal year 2016 revenue was greater than 1 Billion USD (£830m). John Crane is part of Smiths Group ([www.smiths.com](http://www.smiths.com)), a global leader in applying advanced technologies for markets in threat and contraband detection, energy, medical devices, communications, and engineered components.
John Crane’s comprehensive range of dry gas seals are designed to provide you with the correct seal solution suited for your specific application, to ensure optimal reliability, safety and performance. We are committed to providing the latest technologies and designs in order to provide our turbo machinery customers within global energy industries with the solution they need. As technology and industry standards constantly evolve, so do our gas seals. In 1968 John Crane was first awarded the patent for spiral groove technology. Today, our next generation dry gas seals, Aura™, use the latest technology to reduce your operation and transaction costs. With an unrivalled access to localized technical expertise from the largest global service network in the industry, our experienced team will help you find the solution you need to help you plan for tomorrow.