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REDUCING METHANE EMISSIONS IN THE TRANSMISSION/STORAGE SECTOR – GAS COMPRESSOR REGULATIONS AND VOLUNTARY ACTIVITIES

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Voluntary actions by natural gas Transmission and Storage (T&S) operators to reduce fugitive and vented methane have been ongoing since the early 1990s in North America and the EU and have in general obviated governmental regulations limiting these emissions. Regulations for this sector, when written, have generally referred to Leak Detection and Repair (LDAR) programs, low-bleed pneumatics, and control of storage vessel emissions. The Paris Climate Accords (2015) have renewed focus on methane as a potent greenhouse gas (GHG), spurning operators and regulators to pursue further avenues to reduce methane in the T&S sector. While many operators have been voluntarily taking actions to minimize vented emissions during pipeline or compressor station maintenance activities, emissions from gas compressors are a relatively recent target considered for methane emissions reductions. Recent regulatory actions associated with gas compressor methane are somewhat novel, particularly for centrifugal compressors equipped with modern dry-gas seal (DGS) systems. This paper covers the background on centrifugal gas compressor methane emissions, summarizes recent regulations in Canada associated with gas compressor emissions, and describes the control strategies available to limit methane from these historically non-regulated types of emissions sources. For international context, notable regulations and voluntary activities in the EU and USA related to gas compressor emissions are also discussed.

Background

Historically, methane reductions in the production sector have been the focus of regulations and various voluntary initiatives for Oil and Gas operations. Since the UN Paris Climate Agreements of 2015, midstream operations, including compressor stations, are increasingly being considered for government regulation as well as in corporate voluntary methane reduction strategies. Many industry groups such as the Oil and Gas Climate Initiative (OGCI), Climate and Clean Air Coalition (CCAC), the Global Methane Initiative (GMI), and others establish emissions GHG reductions goals and recommend management practices for minimizing methane emissions from transmission and storage operations. While historical voluntary activity in the sector has been focused on minimization of blowdown emissions associated with pipeline or station maintenance. Methane emissions from centrifugal gas compressors are with increasing frequency being considered in voluntary or regulatory mitigation strategies.

The federal methane control regulation promulgated in Canada in 2018 is particularly notable for operators of centrifugal gas compressors as the rule establishes explicit emissions limits for these sources, which is the first time anywhere this has occurred on a national basis. The federal rule was quickly followed by similar rules in Alberta and British Columbia. Outside of Canada, similar regulations or policies limiting gas compressor emissions are present in certain areas of France, Germany and central Europe and with a limited basis in the US with state regulations and air pollution permits. Aside from the few regulations in effect, widespread voluntary efforts by T&S companies to reduce methane releases have been ongoing and formalized throughout North America and Europe. Gas compressors are increasingly becoming part of the discussion concerning voluntary methane reduction strategies in the mid-stream sector.

Methane control regulations are universally of the command and control nature; issues with measurement accuracy and accounting for fugitive (unplanned emissions) and vented (operational emissions) methane precludes these types of emissions from inclusion in traditional carbon pricing schemes existing in Canada, the EU, and limited US states where the pricing element requires a strict regimen of emissions monitoring, data quality assurance, and 3rd party verification. Such measures are only practical for application to carbon emissions from highly regulated and monitored combustion processes.

Distinction should be noted between the flaring and venting limits at production sites enforced by national/state governments where significant volumes of natural gas flared or vented represent significant lost revenue for producers and government entities (royalties). In contrast, requirements for midstream operations such as compressor stations may typically include annual site venting limits including blowdown emissions from maintenance activities which are typically associated with lower methane volumes versus production sites. Emissions from centrifugal gas compressors from maintenance blowdowns and/or from the seal system vents may be included in site limits; the generally lower volume of methane from these activities may pose challenges with engineering and economics of mitigation strategies.

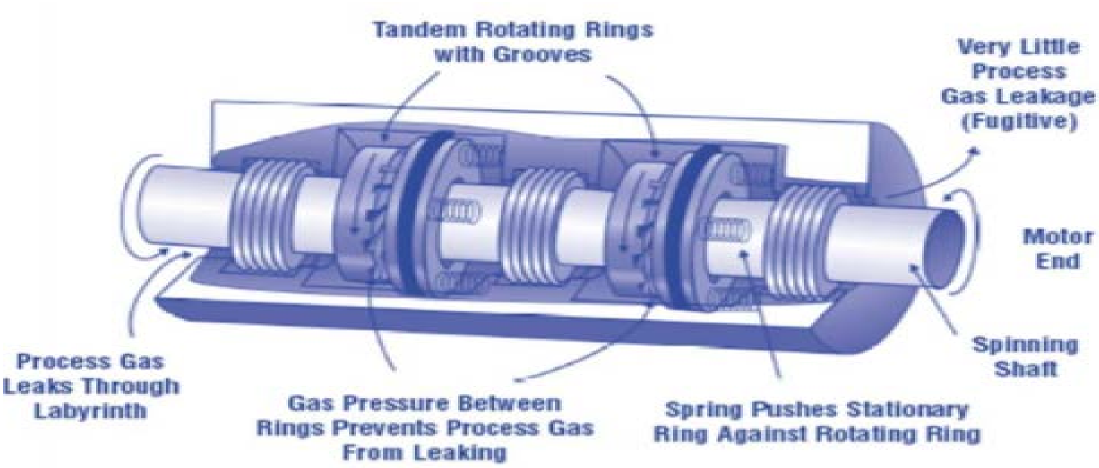
This paper focuses on centrifugal gas compressor emissions as these sources represent a relatively new focus of activity in GHG reduction strategies.

Figure 1: Typical Gas Turbine Compressor Set (L) and Centrifugal Gas Compressor (R)

Centrifugal Gas Compressors with Dry Seals

Figure 1 shows a typical gas turbine compressor set and centrifugal gas compressor. Centrifugal gas compressors contain internal seal mechanisms installed around the rotating shaft which are pressurized to contain the process gas and prevent its escape from where the shaft exits the compressor case. Modern centrifugal gas compressors utilizing dry gas seals (DGS) emit small amounts of methane (process gas) as an inherent function of operation. DGS assemblies contain primary and secondary face seals which are installed in the compressor end caps. The primary seal is exposed to high-pressure seal gas (from an external supply) on one side and atmospheric pressure on the other. This seal provides the primary sealing function for the process gas. A small portion of the primary seal gas leaks across the seal and is routed to a vent to atmosphere. This primary seal vent is the point source of the gas compressor emissions. Figure 2 shows a simplified cutaway of the shaft and sealing mechanism.

Figure 2: Simplified Centrifugal Compressor Shaft and Dry Seal System (US EPA)



A secondary face seal is also typically present and acts as a redundant backup in case of primary seal failure. A more detailed description of a typical DGS system is shown in Figure 3.

Figure 3: Typical DGS Schematic

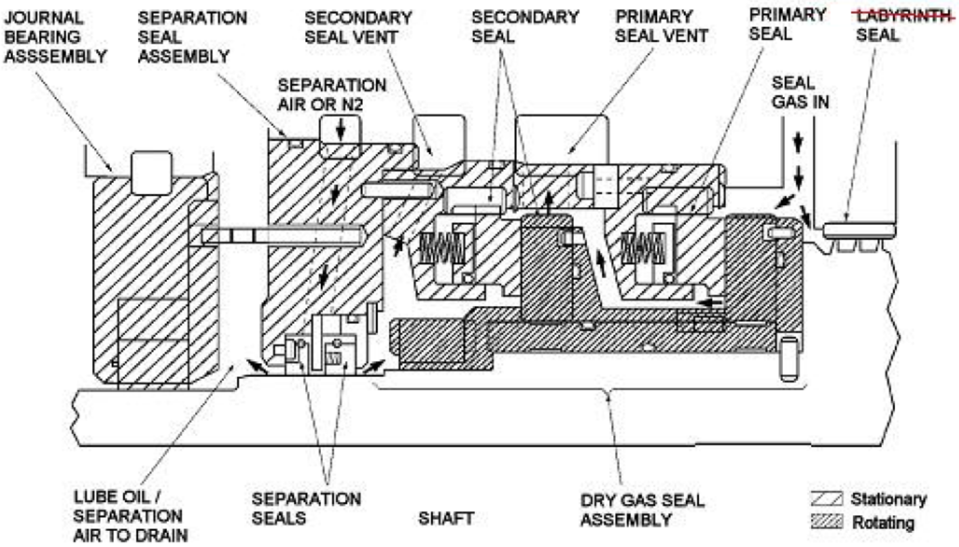
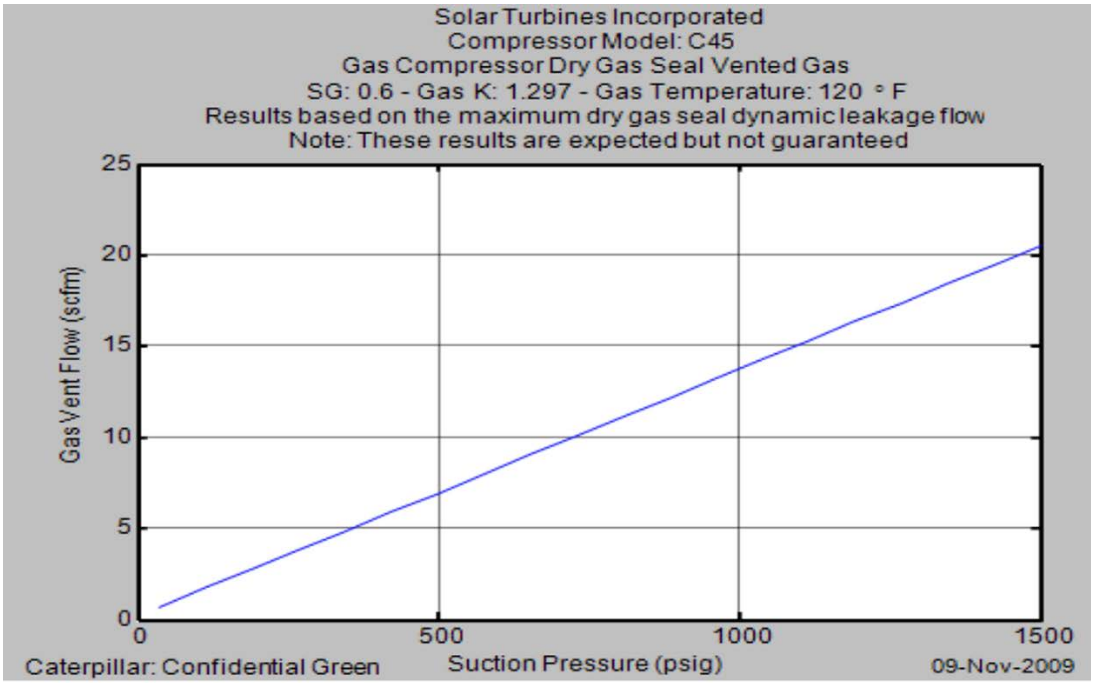


Figure 3. Tandem Seal Assembly Without Intermediate-Labyrinth Seal

Emissions from the gas compressor primary vent are proportional to the operating suction pressure and vary by compressor model. A typical gas compressor emissions profile is shown in Figure 4.

Figure 4: Solar C45 Gas Compressor Dry Seal Emissions



Dry seal emissions control options

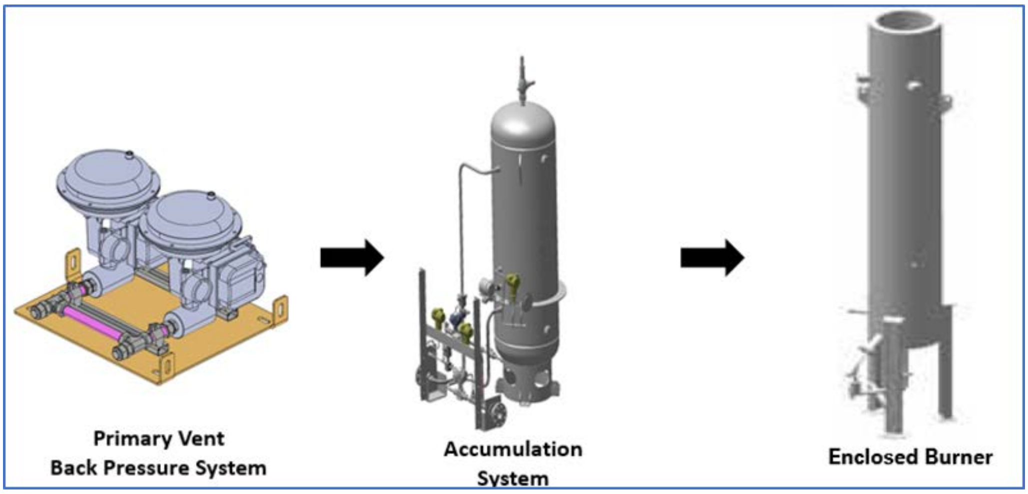
There are two fundamental pathways to mitigate methane emissions from DGS systems. One way is to use pure nitrogen for the seal gas supply instead of process gas (methane). Seal leakage emitted from the primary seal vent will be comprised almost entirely of nitrogen with only trace amounts of methane present. This technique virtually eliminates all methane emissions from the seal system; however, a continuous supply of nitrogen is necessary and nitrogen enters into the process gas which can affect its composition.

The other method, which is currently in use at a number of compressor stations, is to capture the seal emissions at the primary seal vent and route these emissions to a desired process.

Since the primary seal vent releases the seal leakage (methane) at atmospheric pressure, the vent emissions must be recompressed to pressures greater than the working pressure of the intended operational process.

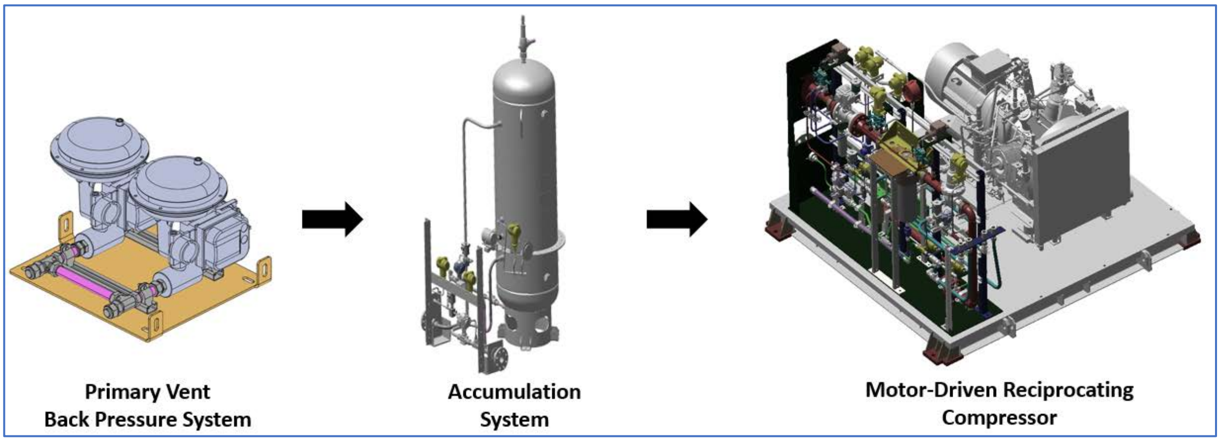
An initial pressurization is accomplished by connecting a backpressure module to the seal vent. An accumulator tank allows the gas volume to be stored until a specified volume is reached as defined by the intended process. If the seal emissions simply need to be eliminated, the gas may be routed to an enclosed burner system and destroyed through thermal oxidation as shown in Figure 5. Methane is captured from the compressor's primary seal vent while the gas compressor is in operation and eliminated in the burner at efficiencies greater than 98%. The enclosed burner in this example has a diameter and height of 2.5 feet and 20 feet, respectively.

Figure 5: Dry Seal Thermal Oxidation System



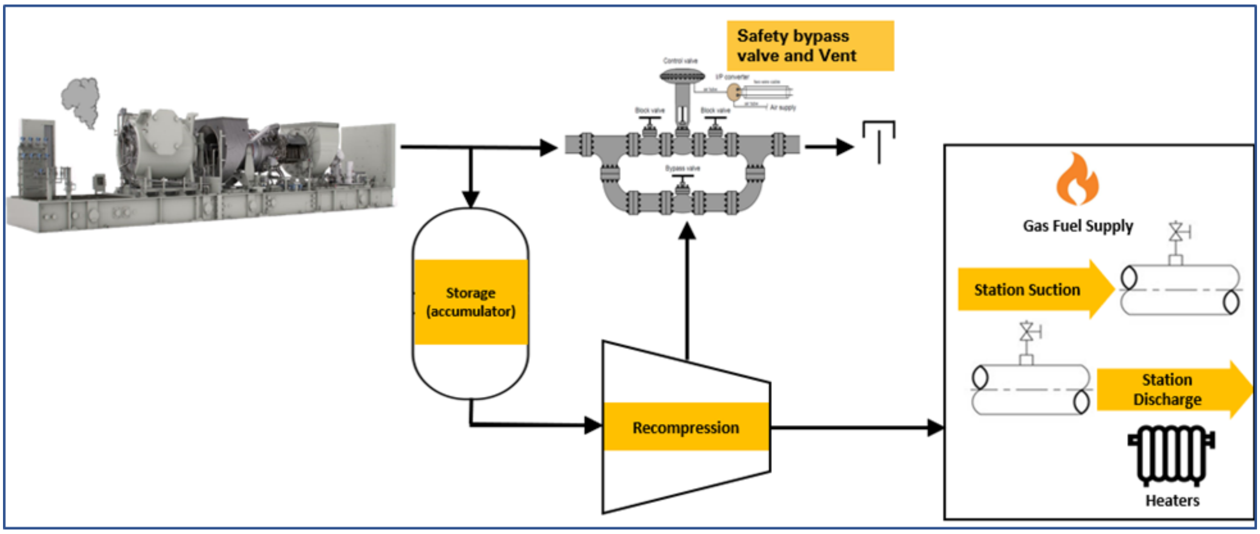
A more desirable technique may be to recover the seal emissions for injection back into an operational process. Available options include reinjection into the process gas or fuel gas for the turbine, fuel heating, or to power an onsite electrical generator for local load demand. For any of these options, the captured gas needs to be recompressed to a pressure level suitable for the application. Recompression to the required process pressures can be accomplished with an electric motor-driven reciprocating compressor as shown in Figure 6.

Figure 6: Dry Seal Emissions Recompression System



The reciprocating compressor in this example is designed to increase the pressure of the gas from 3 psi (0.2 bar) to 2000 psi (138 bar). The recompression system size is based on the volume and flow of the gas compressor's process gas. Once recompressed, the recovered methane can be reinjected to the station suction or discharge header (preferred), or used as a fuel for an onsite beneficial use as outlined in Figure 7. The recompression system has its own safety bypass valving and vent independent of the station equipment.

Figure 7: Dry Seal Emissions Recompression and Reinjection/Re-use Concept



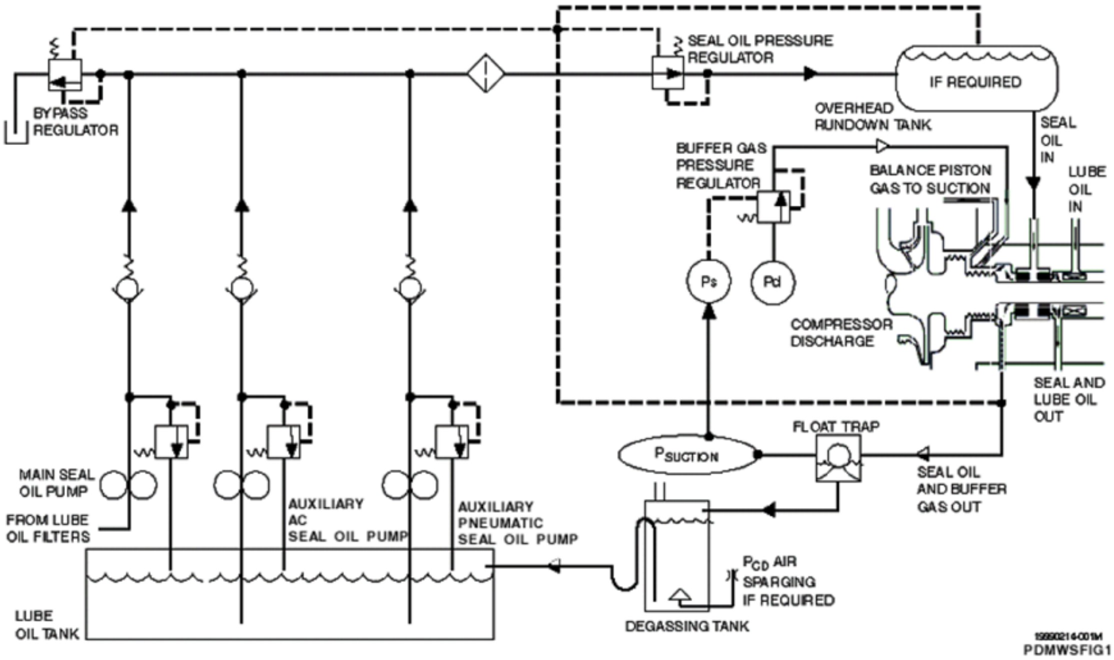
<u>Centrifugal Gas Compressors with Wet Seals</u>

Prior to the invention of DGS systems in the 1990s, centrifugal compressors utilized wet seals based on pressurized lubricating oil as the internal gas sealing mechanism.

With wet seal-based systems very little process gas escapes the oil seal face. However, as the pressurized oil contacts the process gas, hydrocarbons in the process gas are absorbed and entrained in the seal oil. This entrained gas must be purged from the seal oil for safety and system reliability, typically through a de-gassing mechanism. These 'de-gas' emissions can be recycled back into the process gas at the compressor suction, captured for beneficial use, or flared.

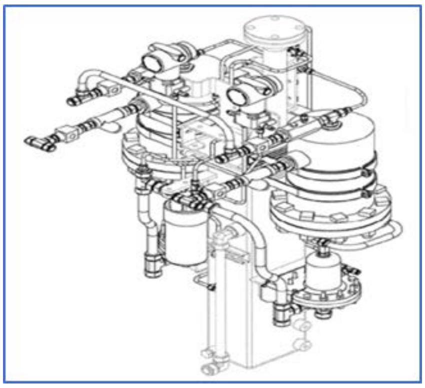
A basic wet-seal system overview is shown below in Figure 8. Gas compressors are lubricated from the main lube oil system. Seal oil pumps using lube oil raise the oil pressure to a level of about 15 psi above the compressor suction pressure. Oil ring seals and gas labyrinth seals separate the medium. This allows only small amounts of gas and oil to leak into the mix chamber where some gas is absorbed and entrained in the oil. The amount of gas absorbed is a function of the pressure, temperature, and gas composition. This mix is then separated in a seal oil trap where the lighter gas can be ported back to the compressor suction, and the heavier oil is discharged through a liquid level operated valve, back to the atmospheric degassing tank. Most of the gas, dissolved in the oil, is released and vented at this point. The rest of the gas, still dissolved in the oil, will be released into the main lube oil tank and mixed with the engine seal air where the lower explosive limit (LEL) must be maintained at less than 25%.

Figure 8: Typical Wet Seal System Diagram



Many variations of the wet seal system can be implemented to capture the de-gas emissions more effectively. For example, a separate de-gassing module with multiple seal oil traps and/or air sparging systems can be installed to recover the de-gas emissions more efficiently. Rather than venting through the lube oil tank, the de-gas emissions can be routed back to suction directly from the traps and any small amount of residual methane can be routed to a designated flue installed with the module. A typical de-gassing module is shown below in Figure 9. This design ensures optimum degassing while minimizing oil carry-over to the process. Dual traps ensure proper drainage from both bearing capsules and prevent oil carry-over to the process gas reducing the cost of turbine oil replenishment and the need for liquid scrubbing equipment down-stream.

Figure 9: Wet Seal De-Gassing Module



Wet seals have been in use since the 1960s and many are still operating today, either in their original configuration or with alterations, though compressors with dry seals far outnumber those using wet systems presently. Internal estimates show that around 30 wet-seal compressors supplied by Solar Turbines still operate in Canada.

Unlike dry gas seal systems which have a consistent, and low emissions profile universally, wet-seal de-gas emissions volumes can widely vary based on system configuration. US EPA has estimated that wet seal systems can typically emit 40 to 200 scfm [1]. A wet seal system configured to recycle the de-gas emissions back into the process gas and utilizing an efficient de-gas module can have much lower emissions.

Unlike dry seal compressors, wet seal systems typically are not capable of maintaining a pressurized hold condition.

Centrifugal Gas Compressor Emissions Regulations - Canada

The federal rule titled 'Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector)' was finalized in 2018 with the goal of reducing methane emissions from large sources in the oil and gas sector by 40-45% below 2012 levels by 2025. The rule is unique in the world as it is the first to place specific emissions limits on gas compressors (including DGS systems) on a nationwide basis. The compressor methane limits will take effect 1/1/2023 and are based on date of installation and compressor size as summarized in Table 1 below. Emissions limits are also applied to reciprocating gas compressors starting 1/1/203.

Table 1: Canada - Centrifugal Compressor Emissions Limits

Install Date	Size	*Limit, m3/min (scfm)
>= 1/1/2023	All	0.14 (4.94)
< 1/1/2023	>= 5 MW	0.68 (24.0)
< 1/1/2023	< 5 MW	0.34 (12.0)

*Limit per compressor, standard m3/min

The Rule also requires measurement of the vented seal emissions by a flow meter or a continuous monitoring device with 10% maximum error margin. Calibrated bags are not allowed for measurement. Initial measurements are required by 1/1/2021 for compressors installed prior to 1/1/2020 and within 365 days after installation for new compressors installed after 1/1/2020.

The Rule limits methane venting on a facility basis to 15,000 standard cubic meters per year for all sites which process or deliver more than 60,000 cubic meters of hydrocarbons annually. Note that several exemptions apply including blowdowns of equipment or pipelines, start-up and shutdown of equipment, and safety/emergency situations.

Leak Detection and Repair (LDAR) requirements in the Rule are effective 1/1/2020 and include extensive inspection, repair, and recordkeeping activities.

ALBERTA AND BRITISH COLUMBIA – METHANE RULES

Both provinces have their own rules similar to the federal regulation although with stricter compressor emissions limits and quicker timelines. Directive 60 in Alberta and BC's Drilling and Production Regulation (BC Reg 282/2010) were both amended in 2018 to include limits on emissions from gas compressors and other methane sources. Notably, the limits apply in BC 1/1/2022 for all units (new and existing), one year earlier than the federal limits. For new units in Alberta the limits also apply beginning 1/1//2022 but units installed prior to this date have until 1/1/2023 to comply, as with the federal rule. Emissions limits in the two provincial rules are lower than the federal limits and compressor size is not a factor as shown in Tables 2 and 3 below.

Table 2: BC - Centrifugal Compressor Seal Emissions Limits - Effective 1/1/2022

Install Date	Size	*Limit, m3/min (scfm)
>= 1/1/2021	All	0.057 (2.0)
< 1/1/2021	All	0.17 (6.0)

*Limit per compressor, standard m3/min

Table 3: ALBERTA - Centrifugal Compressor Seal Emissions Limits

Install Date	Size	*Limit, m3/min (scfm)	Effective Date
>= 1/1/2022	All	0.057 (2.0)	Upon Installation
< 1/1/2022	All	0.17 (6.0)	1/1/2023

*Limit per compressor, standard m3/min

As with the federal rule, both provincial regulations require periodic fugitive emissions surveys and impose restrictions on flaring and venting.

International Activity – EU

Outside of Canada, gas compressor emissions, particularly for DGS systems, are mostly unregulated presently except in select areas of France and Germany. DGS emissions represent an area of potential focus for midstream operators for voluntary mitigation efforts as well as a target for new regulations.

Some areas of Germany require compressor stations to recover all methane emissions from gas compressors as a condition of operation. Romania requires methane controls above a threshold of 100,000 Nm3 of methane emissions per site. Other areas in central EU are also known to be developing methane regulations that may affect gas compressors.

The European Commission's Madrid Forum references many Best Available Techniques (BATs) for methane mitigation across the natural gas supply chain which are being voluntarily implemented by industry. Example BATs for centrifugal compressor methane include: use of dry-gas seals; vent recovery systems; and thermal oxidation. These BATs are recommended for voluntary implementation; federal EU-wide regulation of gas compressor emissions (particularly for dry seal systems) is not foreseen in the near future. Regulations affecting gas compressor methane will continue to be on the regional/local levels.

International Activity – USA Regulations

US EPA New Source Performance Standards (NSPS) Subparts OOOO/OOOOa

Centrifugal compressor methane leakage from dry seal systems is not federally regulated in the US. US federal and some state regulations address wet seal de-gas emissions with limits or controls. The federal regulation issued by the US EPA in 2012 known as Subpart OOOO ('Quad O') placed limitations on fugitive and vented volatile organic carbon (VOC) emissions in certain segments of the natural gas supply chain. For example, OOOO placed requirements on new/modified/reconstructed gas compressors equipped with wet seals at gas gathering or processing plants. This rule had limited impact on existing wet seal compressors.

In 2015 EPA expanded upon OOOO to enact Subpart OOOOa. The rule applies to both VOC and methane and brought into scope gas compressors used in the transmission and storage segments in addition to gathering and processing. DGS systems are considered 'state of the art' for both OOOO/OOOOa and no activity (e.g. measurements or reporting) are required for the seal emissions. Many US operators are now considering DGS emissions in voluntary mitigation strategies.

The OOOO and OOOOa regulations impose extensive leak detection and repair (LDAR) activities on operators.

US State Methane Regulations and Permitting – Midstream Sector

Some activity concerning fugitive/vented methane for the midstream sector is occurring on the US state level with regulations and also during the air permitting process for new installations. States particularly active include California, Colorado, Maryland, Pennsylvania, New York, and Virginia. Example requirements include limitations on methane venting from equipment blowdowns and pressurized hold capability for gas compressors. Specific limits on operational DGS emissions similar to the rules in Canada do not exist in the US presently.

Industry Voluntary Activities and Partnerships for Methane Reductions

Throughout North America and the EU, minimization of methane emissions from midstream operations has taken on new importance since the 2015 Paris Climate Agreements. Voluntary initiatives and industry partnerships such as the OGCI, GMI, US EPA Natural Gas STAR and Methane Challenge programs, among others, strive for methane reductions throughout the natural gas supply chain. Many mid-stream participants in these programs focus on reducing methane from blowdowns associated with maintenance activities. Converting wet seal to dry seal systems is a common recommendation as well. Emissions from gas compressors with dry gas seals are a relatively new focus for voluntary reductions.

Through participation in such voluntary activities, oil and gas companies have made significant historical reductions in methane lost from the supply chain since official statistics began tracking this activity in the 1990s. For example, the US-based Interstate Natural Gas Association of America (INGAA) estimates US methane emissions from transmission and storage facilities decreased by 44 percent from 1990 to 2016 due to reduced compressor station and fugitive emissions, despite a 43 percent increase in U.S. natural gas consumption during the same time frame [2]. Similarly, Gas Naturally [3] estimates that between 1990 and 2015, methane emissions from gas operations decreased by 46% in the EU.

SUMMARY AND FUTURE CONSIDERATIONS

Canada has taken the lead with regulatory measures to reduce methane from the natural gas supply chain. The gas compressor emissions limits established nationwide and in Alberta and British Columbia are precedents and may be used as models in other jurisdictions considering similar regulations. While some centrifugal compressors in Canada may already meet the limits in their present configurations, others may need mitigation through the various options described above such as recovery and recompression of the seal emissions for recycling back into the process gas or for another beneficial use.

Ongoing voluntary actions undertaken by midstream operators throughout North America and the EU to reduce methane emissions should alleviate pressure on national governments to enact new legislation similar to the Canadian rules for the midstream sector; future regulations are more likely to be enacted on a state/regional/local basis such as is occurring in select areas of the EU and USA at present.

Pressure to achieve even further methane reductions continues unabated. Corporate sustainability goals and industry partnerships to minimize methane emissions demonstrate proactive measures taken by industry. Environmental organizations are also keeping watch: for example, the Environmental Defense Fund (EDF) cites as achievable overall methane reductions by 2025 of 75% or a 0.20% methane emissions intensity target [4]. The OGCI has adopted this long term 0.20% intensity target with the concept of moving 'Towards Zero Methane Emissions' from the supply chain with an interim goal of 0.25% methane intensity by 2025 [5]. In 2018 EDF published a report tracking individual company methane-related activities for both upstream and midstream sectors in the US in a methane 'scorecard' [6]. The issue of minimizing methane emissions from the midstream sector certainly has high visibility and for many operators, reducing methane emissions from centrifugal gas compressors may represent a potential opportunity to achieve further GHG reduction goals.

References

[1] U.S. EPA, 'Replacing Wet Seals with Dry Seals in Centrifugal Compressors.' 2006. https://www.epa.gov/sites/production/files/2016-06/documents/ll_wetseals.pdf.

[2] Interstate Natural Gas Association of America, ' Improving Methane Emissions from Natural Gas Transmission and Storage.' 2018.

[3] Gas Naturally, 'Fact Sheet - Exploring Methane Emissions in Europe.' 2018.

[4] Environmental Defense Fund, 'Taking Aim: Hitting the mark on oil and gas methane targets.' 2018.

[5] Oil and Gas Climate Initiative, 'AT WORK Committed to climate action - A report from the Oil and Gas Climate Initiative.' 2018.

[6] Environmental Defense Fund, 'THE DISCLOSURE DIVIDE - Revisiting Rising Risk and Methane Reporting in the U.S. Oil & Gas Industry.' Sean Wright and Kate Gaumond. 2018.

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