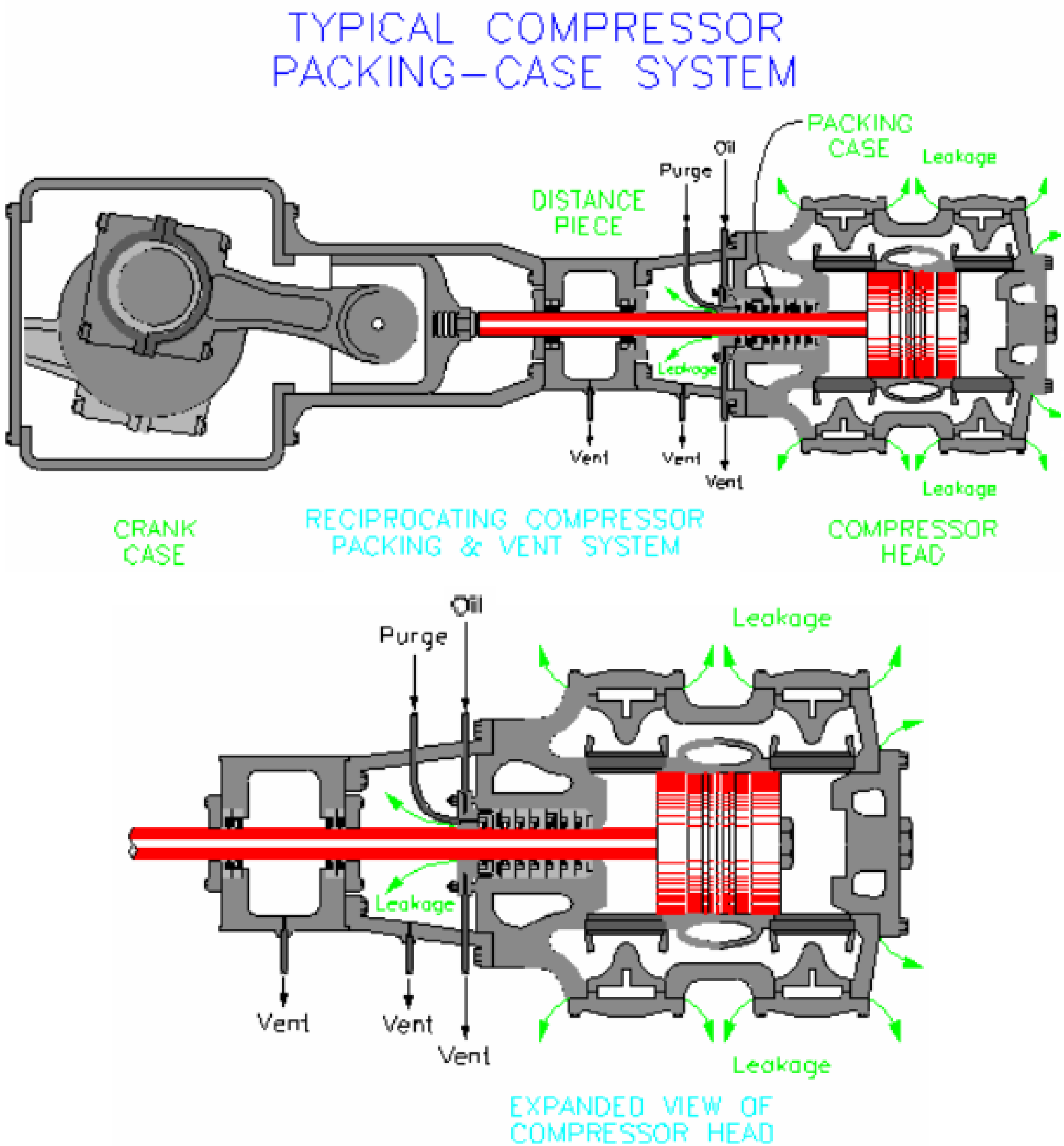
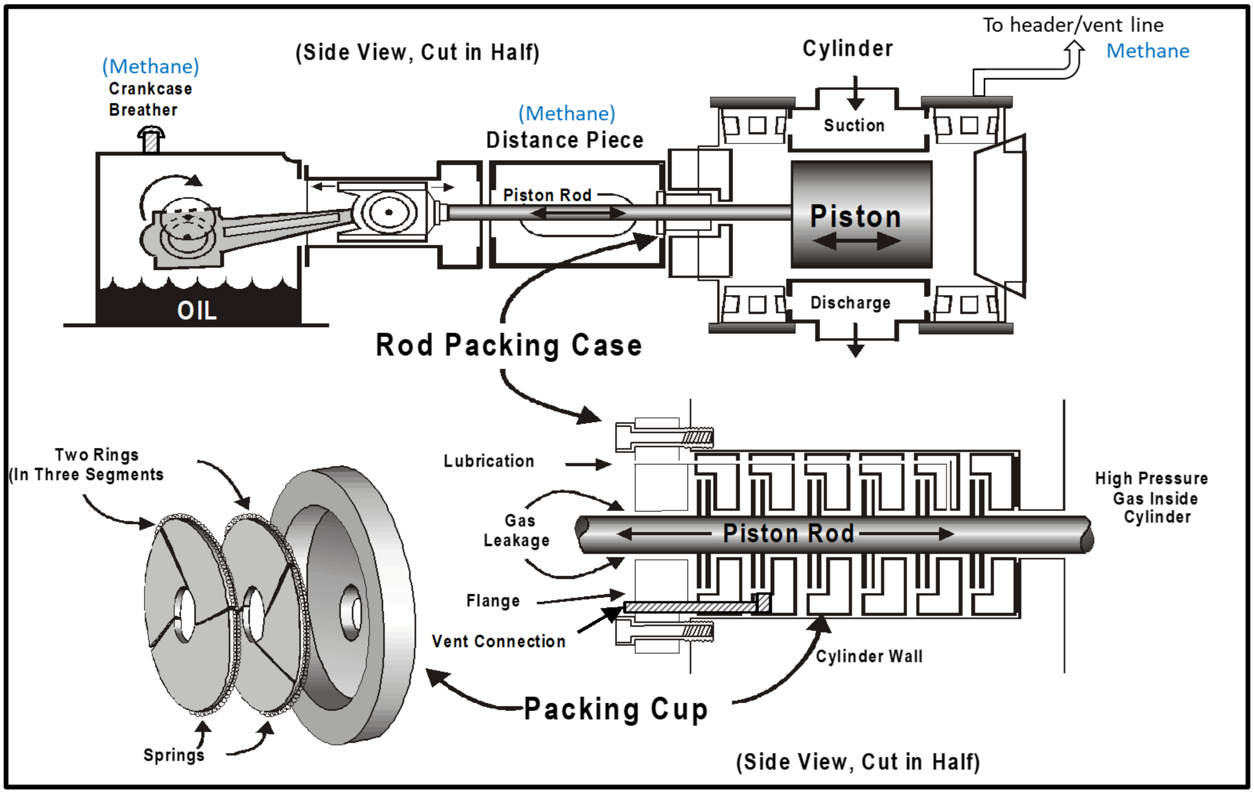
# Brief description of the source

Reciprocating compressors (also referred to as piston compressors), are found in a variety of oil and gas operations. Reciprocating compressors in the oil and gas industry commonly emit natural gas (methane is the main component) during normal operation and during standby under pressure as the rod packing is a dynamic/moving seal. The aim of this section is to provide the general principles regarding reciprocating compressors, but not all possible configurations are described.

By design, rod packing systems emit small amounts of gas either into an open distance piece to the atmosphere or through an atmospheric vent line connected to the packing case, or both. Individual cylinder packing vents are normally manifolded together to a single vent. The piston rod packing is used to create a seal around the piston rod to prevent large amounts of high-pressure gas leakage from the cylinder. A set of flexible, segmented rings in a packing cup is pressed against the rod to inhibit emissions down the shaft. These rings oscillate back and forth with the rod reciprocal movement, sealing against the cup faces to prevent leakage around the rings. However, some gas slips around the rings with each stroke. This amount increases over time as packings are further worn out.


TYPICAL COMPRESSOR
PACKING-CASE SYSTEM
PACKING
CASE
Leakage
Oil
Purge
DISTANCE
PIECE
Leakage
Vent
Vent
Vent
Leakage
CRANK
CASE
RECIPROCATING COMPRESSOR
PACKING & VENT SYSTEM
COMPRESSOR
HEAD
Oil
Purge
Leakage
Leakage
Vent
Vent
Vent
Leakage
EXPANDED VIEW OF
COMPRESSOR HEAD




The volume of emissions from the compressors depends on cylinder pressure, fitting and alignment of the packing parts during assembly, and amount of wear on the rings and rod shaft. Packings of reciprocating compressors allow some gas escape (leak), including newly installed compressors. This amount increases as the system ages. Replacement of the packings in a timely manner is part of a good maintenance.

Lubricating oil injected into the packing helps seal the rings and cups, reduces wear caused by operation, and lowers heat build-up that accelerates ring wear. But over the thousands of hours of typical compressor operation, rings wear and emissions increase.

Compressors housed in buildings route the emissions from rod packing through the vent pipe connected to the packing case flange, often venting above the roof. However, gas can also be emitted along the rod or around the nose gasket at the end of the packing case (or both). It is also possible to capture and redirect the emitted gas stream to a useful outlet or to a flare. Regular maintenance of rods & rings along with replacement of rods & rings helps in mitigating the leaks from compressors. Schedule for maintenance changes depending on the facility but is often linked to the compressor engine overhaul frequency (typically 3 years or 26,000 hours of operation).

## System boundaries

Methane that is vented to atmosphere from rod packing of reciprocating compressors, both operating and shutdown under pressure and including emissions from the distance piece, are considered herein. There are no emissions from rod packing in a compressor shutdown and depressurized, although the compressor blowdown may be through the same vent as rod packing and exhibiting emissions from leaking isolation valves.

Emissions from reciprocating compressor other than emissions vented from rods, rod packing and distance pieces should be reported under fugitive methane emissions (see *Leaks* TDG). Methane emissions from reciprocating compressors that are captured and reintegrated into the process, i.e. not vented, are not to be reported. Methane emissions captured and routed to flare should be reported under Flaring (see *Flaring TGD*).

This TGD has been developed for equipment which is functioning properly. Emissions resulting from malfunctioning equipment (e.g. plugged vent) are to be reported under the corresponding category (see *Incidents, emergency stops and third party damages TGD).*

Guidance on materiality is presented in the *General principles TGD.*

# Quantification methodology – Level 3

## Emission factors

Accepted source-level emission factors, as defined in the *General Principles TGD,* or those prescribed by local regulation are considered as providing Level 3 estimates, provided they are specific for the source type. Practitioners are encouraged to use emission factors that best represent conditions and practices at their facilities and adjust the factors, where warranted, to more accurately estimate emissions given differences between the reference system on which the emission factor is based, and their systems.

The following table presents an example of emission factors which can be used to estimate methane emissions from reciprocating compressors. Partners are encouraged to apply an emission factor that represents emissions of methane volume per year per compressor cylinder for rod packing, adjusted for the actual operating factor (including standby under pressure) of the compressor(s). The recommended methane emission factors may vary by industry segment.

| Industry Segment | Whole Gas Emission Factor[1] | |
|---|---|---|
| | (scm per hr-cylinder) | (scf per hr-cylinder) |
| Production (Well Pads) | 0.0025 | 0.085 |
| Gathering and Boosting | 0.24 | 8.39 |
| Processing | 0.74 | 26.2 |
| Transmission | 0.52 | 18.52 |
| Storage | 0.34 | 12.13 |

NOTE:

- These whole gas emission factors have been back calculated using sector based average number of cylinders and methane volumetric composition as follows (number of cylinders; methane content): Production (4; 78.8%), Gathering and Boosting (3.3; 78.8%), Processing (2.5; 87%), Transmission (3.3; 93.4%), and Storage (4.5; 93.4%). In case of a different methane composition at the facility, Partners can alter emission factors accordingly. Where emission factors for a specific industry segment are not available, those of another segment, with similar characteristics can be used.
- Reciprocating compressors located at production sites are typically smaller than those present in other segments.
- A factor can be applied to default operating emission factors for standby under pressure conditions[2].

These emission factors should be adjusted based on the methane composition, which can be determined as explained in the *General Principles TGD,* of the whole gas for the asset. They can also be adjusted based on

[1] Adapted from EPA/GRI. *Methane Emissions from the Natural Gas Industry: Volume 8 – Equipment Leaks,* 1996., whole gas considers complete gas composition

[2] 150% in Natural Gas STAR Lesson Learned, *Reducing Emissions when taking compressors off-line,* 2016

whether a given compressor is operating or on standby under pressure. Following is a simple example of how to calculate the associated emissions for a single compressor

$$V_r = EF\ x\ methane\ content\ x\ (t_{operating} + t_{standby}\ x\ f_{standby})$$

Where:

$V_r$ = volume of methane released from the compressor over the period
EF = reference emission factor for a given segment
$t_{operating}$ = the number of hours over the period the compressor is in operation
$t_{standby}$ = the number of hours over the period the compressor is in standby
$f_{standby}$ = standby factor

Activity data collection should be conducted based on the data required by the selected emission factor. In the example presented above, data on the number of compressors, number of cylinders per compressors, and hours operating and standby under pressure.

# Level 4 Quantification Methodologies

## Direct measurement and Measurement-based Emission factors

Measurements (including continuous and periodic monitoring) for site-specific emission factors developed based on representative measured emissions are considered Level 4 emissions quantification. Measurements must be taken that represent the total flow of whole gas and associated methane content of each gas stream that is vented to atmosphere. As defined in the *General Principles TGD,* in cases where the methane content can be assumed to meet a regulated specification (e.g. underground gas storage, gas transmission, gas distribution and LNG terminals), the gas specification compositions may be applied[3]

Piping & Instrumentation Drawings and viewing the compressor and the vent with a methane detection instrument (e.g. optical gas imaging camera) can help to identify emission points related to rod packing, that should be measured. It is a good practice to confirm a reciprocating compressor's vents by tracing piping from the source to make sure measured emissions are linked to the corresponding compressor. Moreover, it is important that the measured emissions for each compressor vent stack is expressed per compressor. If rod packing from several compressors are vented through the same stack, total measurements can be reported without requiring individual metering of each compressor, but emissions need to be allocated per compressor (depending on e.g. number of cylinders, size, …) if the aim is to determine a measurement-based emission factor.

For compressors with open distance pieces, emissions should be measured with a suction instrument with the distance piece openings temporarily covered. This measurement will represent one cylinder. If the emissions exceed the capacity of a high-volume sampler, a low pressure drop instrument, such as an ePV flow meter should be used to avoid pushing gas out the crankcase breather cap.

Depending on the configuration of the compressor, measurements should be taken from different points:

- Closed distance piece and rod packing connected to a vent – the vent should be measured. The emissions from the crankcase breather should be observed. If

[3] For example, within the EU, regulated specifications and quality standards may be applied

emissions are present, the vent line may be obstructed. If these emissions are negligeable or not detectable, they should be considered as fugitive emissions.

- Open distance piece and no vent connection – measure through the distance piece opening at the location of the piston rod entering/exiting the rod packing flange, using a suction instrument or temporarily cover the openings in the distance piece and measure through the crankcase breather cap, or have a port in the cover of the distance piece and measure at that port with a suction instrument

| Configuration | Closed distance piece | Open distance piece |
|---|---|---|
| Measurement | Measure the rod packing vent (the measured emissions from the vent include both distance piece emissions and rod packing emissions).<br><br>Observe the emissions from the crankcase breather. If these are significant, the vent line may be obstructed, otherwise it can be considered as a malfunction and can be reported as such<br><br>Measurement of the distance piece is not required. | Measure the rod packing vent (the measured emissions from the vent include rod packing emissions).<br><br>Emissions from the distance piece should also be measured. To do so, there are several options:<br>• Measure through the distance piece opening at the location of the piston rod entering/exiting the rod packing flange using a suction instrument<br>• If the crankcase has a breather, temporarily cover the openings in the distance piece and measure through the crankcase breather<br>• Have a port in the cover of the distance piece and measure at the port with a suction instrument |

Level 4 emission factors should be based on measurements conducted on a representative sample of compressors or cylinders. As emissions from rod packing increase over operating time due to rod packing rings losing tightness, the emission factor should take the time factor into account. To do this, for example, a linear relationship of emission rate to age of packing can be developed by taking measurements over the life of packing and then applying the relationship to compressors with varying durations from packing replacement and applied to “like” compressors. A possibility is to have a first set of measurements taken a certain period (e.g. three months) after the replacement of rod packing rings, to leave sufficient time for the rod packing rings to be broken in and a second set of measurements is taken right before the replacement of rod packing rings. The linear relationship between these two measurements allows the Practitioner to determine the evolution of emissions over time.

As compressors under standby, pressurized conditions can be expected to release more gas than those operating, similar linear relationships can also be developed from measurements taken on standby compressors over this same rod packing lifecycle.

System configurations and operating conditions should be considered in determining ‘like’ systems that carry a common emission factor. Key factors for reciprocating compressors can be size of compressor, number of cylinders, time since last replacement of the rod packing and other factors, where appropriate. Each system that is not ‘like’ will require determination of a separate emission factor for that system based on the appropriate measurement studies. For guidelines on the methodology to develop a statistically representative sample, please refer to the [see *Uncertainty and reconciliation guidance*].

Measurement based emission factors can be expressed in terms of whole gas emission per compressor cylinder per hour of operation and per hour of standby pressurized. Prior to measurement, the Partner should determine where the gas stream resulting from rod packing is routed. Main release points related to compressor venting are the compressor cylinder open distance piece, crankcase breather cap and the packing vent. Recommended measurement tools include the following[4] [5]:

- Vane anemometer (to measure vent flow)
- Hotwire anemometer (to measure vent flow)
- Turbine meter (to measure vent flow)
- ePV meter (especially for open distance piece)
- Calibrated bag (to measure vent flow)
- High-volume sampler (especially for open distance piece)
- Orifice meter (to measure vent flow)
- Coriolis meter (to measure vent flow)

Continuous and predictive emissions monitoring systems (CEMS and PEMS) can also be used to quantify methane emissions, provided they are in line with the measurement guidelines above.

[4] More details on various detection and measurement equipment can be found at CCAC, *Conduction Emissions Surveys, Including Emission Detection and Quantification Equipment – Appendix A of the OGMP Technical Guidance Document,* 2017

[5] More details on various detection and measurement equipment can be found at Marcogaz, *Assessment of methane emissions for gas Transmission and Distribution system operators,* 2019 – Section 7 (p. 34-39)