OFFSHORE NORGE

APPENDIX B
Guideline 044 – ver. 18 - 2020

# Handbook for quantifying direct methane and NMVOC emissions

CONTENTS

# 1 INTRODUCTION

There are new reporting requirements for direct methane and NMVOC emissions with effect from the 2017 emission year.

This handbook summarises proposed models for calculating direct methane and NMVOC emissions from facilities on the Norwegian continental shelf (NCS).

It is intended as an aid to the operator companies in their work of making provision for reporting emissions.

This appendix provides a description of the calculation methods which must/can/should be used for the individual sources of direct methane and NMVOC emissions to be reported in connection with the annual emission report to the NEA.

# 2 EMISSION SOURCES

Pursuant to the new reporting format, 32 emission sources have been defined as potentially present on a facility. In addition there are a number of small sources which are added as a percentage supplement. For practical reasons, these sources are divided into main **sources** and **sub-sources**.

**Table 1 Overview of emission sources.**

| Source ID | Main Source | Sub source |
|---|---|---|
| 1.1 | Measured emissions | Measured common vent |
| 10.1 | Triethyleneglycol (TEG) regeneration | TEG degassing tank |
| 10.2 | Triethyleneglycol (TEG) regeneration | TEG regenerator |
| 10.3 | Triethyleneglycol (TEG) regeneration | Stripping gas |
| 20.1 | Monoethyleneglycol (MEG) regeneration | MEG degassing tank |
| 20.2 | Monoethyleneglycol (MEG) regeneration | MEG regenerator |
| 20.3 | Monoethyleneglycol (MEG) regeneration | Stripping gas |
| 30.1 | Amine regeneration | Amine degassing tank |
| 30.2 | Amine regeneration | Amine regenerator |
| 40.1 | Produced water handling | Produced water degassing tank |
| 40.2 | Produced water handling | Flotation tank / CFU |
| 40.3 | Produced water handling | Flotation gas |
| 40.4 | Produced water handling | Discharge caisson |
| 50.1 | Centrifugal compressor sealant oil | Degassing pots |
| 50.2 | Centrifugal compressor sealant oil | Sealing oil retention tank |
| 50.3 | Centrifugal compressor sealant oil | Sealing oil storage tank |

| Source ID | Main Source | Sub source |
|---|---|---|
| 60.1 | Piston compressor | Separator chamber |
| 60.2 | Piston compressor | Crank shaft housing |
| 70.1 | Dry compressor seals | Primary seal gas |
| 70.2 | Dry compressor seals | Secondary seal gas |
| 70.3 | Dry compressor seals | Leakage of primary seal gas to secondary vent |
| 80.1 | Flare gas that does not burn | Extinguished flare and ignition of flare |
| 80.2 | Flare gas that does not burn | Non-flammable flare gas |
| 80.3 | Flare gas that does not burn | Inert gas flushed open flare |
| 90.1 | Leaks in the process | Larger gas leaks |
| 90.2 | Leaks in the process | Small gas leaks |
| 100.1 | Purge and blanket gas | Purge and blanket gas |
| 110.1 | Gas analysers and test stations | Gas analysers and test stations |
| 120.1 | Drilling | Drilling |
| 130.1 | Storage tanks for crude oil at FPSOs | Gas freeing in connection with tank inspection |
| 130.2 | Storage tanks for crude oil at FPSOs | Abnormal operating situation |
| 140.1 | Gas freeing of process systems | Gas freeing of process systems |
| 150.1 | Ventilation of $CO_2$ from CCS | Ventilation of $CO_2$ from CCS |
| 900.1 | General addition | FPSO |
| 910.1 | General addition | Fixed facilities |

# 3 METHODS FOR CALCULATING EMISSIONS

## 3.1 General

Emissions are calculated for the individual sources and sub-sources. Recommended calculation methods vary from sub-source to sub-source. Where most sources are concerned, waste gas can be emitted to the atmosphere, sent to flaring or recovered. Only waste gases emitted are to be reported. The method used to calculate the emission for each source shall be specified in Footprint. The predefined calculation methods that are possible to select in Footprint are given in Table 2.

**Table 2 Pre-defined calculation methods.**

| Calculation methods |
|---|
| Direct measurements |
| Indirect measurements |
| Mass balance |
| Not on installation |
| GRI-GLYCalc (only for 10 and 20 series) |
| MultiProScale (only for 10 and 20 series) |
| Emission factor |
| 1% general addition (only for 910.1) |
| 3% general addition (only for 900.1) |
| Data from supplier |
| Henrys law (only for 40 serie)* |
| Sent to flare |
| Recycling |
| Included in measured common vent |
| Other ISM |
| Flowrate of stripping gas |
| Calculated from upstream pressure and amount of water |
| Registration of time with unignited flare |
| OGI leak/no leak |
| Calculation of flowrate |
| Annual vented storage tank volume |
| Volume of vented process plant |

*Not relevant method

## 3.2 Measured emissions from common vent - sub-source 1.1

### General quantification method

Where facilities have flow meters on vent headers, these measurements can be used as the basis for reporting instead of quantifying the individual contributory sources/subsources, and providing this yields equally accurate or more accurate emission data (should be documentable). If the gas emitted through the vent header contains large volumes of inert gases, their proportion should be calculated/measured and deducted.

In cases where the contribution from some of the contributory sources can be well-quantified with the methods specified in this handbook, they could be subtracted from the emissions via the vent header and reported under the relevant emission source(s).

Emissions can be calculated in a two-stage operation.

Stage 1. Calculating the quantity of waste gas

$$V_{NG} = V_{Measured} - (V_{N2} + V_{H2O} + V_{CO2}) - (V_{HC\_Source1} + V_{HC\_Source2} + .. V_{HC\_Source\ N})$$

**Table 3 – Explanation of terms in the equation for calculating emissions when metering a vent header.**

| Term | Unit | Explanation |
|---|---|---|
| $V_{NG}$ | $Sm^3$ | Volume of natural gas as basis for calculating methane and NMVOC emissions |
| $V_{Measured}$ | $Sm^3$ | Accumulated measured emissions in the reporting period |
| $V_{N2}$ | $Sm^3$ | Quantified volume of $N_2$ in the waste gas |
| $V_{H2O}$ | $Sm^3$ | Quantified volume of $H_2O$ (water vapour) in the waste gas |
| $V_{CO2}$ | $Sm^3$ | Quantified volume of $CO_2$ in the waste gas |
| $V_{HC\_Source1}$ | $Sm^3$ | Volume waste gas from source quantified by source quantification |
| $V_{HC\_Source2}$ | $Sm^3$ | Volume waste gas from source quantified by source quantification |
| $V_{HC\_Source\ N}$ | $Sm^3$ | Volume waste gas from source quantified by source quantification |

If quantifying the amount of inert gas (such as $N_2$, $H_2O$ and $CO_2$) in the waste gas is difficult, a conservative (low) estimate is better than no deduction. It must be possible to defend the estimate. This deduction can be ignored when inert gas quantities are small.

Stage 2. Calculating methane and NMVOC emissions

Methane emissions: $U_{CH4} = V_{NG} * Mol\%_{CH4} * \rho_{CH4} * 10^{-5}$

NMVOC emissions: $U_{NMVOC} = V_{NG} * Mol\%_{NMVOC} * \rho_{NMVOC} * 10^{-5}$

**Table 4 – Explanation of terms in the equation for calculating emissions from vent header.**

| Term | Unit | Explanation |
|---|---|---|
| $U_{CH4}$ | tonnes | Methane emissions in the reporting period |
| $U_{NMVOC}$ | tonnes | NMVOC emissions in the reporting period |
| $V_{NG}$ | $Sm^3$ | Volume of natural gas as basis for calculating methane and NMVOC emissions |
| $Mol\%_{CH4}$ | % | Mol% or volume% methane in the seal gas |
| $Mol\%_{NMVOC}$ | % | Mol% or volume% NMVOC in the seal gas |
| $\rho_{CH4}$ | $kg/Sm^3$ | Methane density. This is about 0.68 $kg/Sm^3$ |
| $P_{NMVOC}$ | $Kg/Sm^3$ | NMVOC density. Can be set as equal to two $kg/Sm^3$ |

## 3.3 Calculating emissions from TEG regeneration – sub-source 10.1, 10.2 and 10.3

Three sub-sources from TEG regeneration yield waste gases which could be emitted:

- waste gas from the TEG degassing tank
- waste gas from the TEG regenerator
- HC stripping gas (used gas is blended with waste gas from the TEG regenerator before possible emission).

### 3.3.1 TEG degassing tank - sub-source 10.1

**General quantification method**
In the event of possible emissions from the sub-source, the quantity emitted is calculated as for the TEG regenerator (see chapter 3.3.2).

### 3.3.2 TEG regenerator - sub-source 10.2

**General quantification method**
Two alternatives are available for quantifying waste gas (boil-off) from a TEG regenerator.

*Alternative 1*
Use of the GRI-GLYCalc Windows-based calculation programme, which has been specially developed in the USA for calculating the quantity and composition of waste gases from the various waste-gas sources in glycol systems. This is accepted and used by the US Environmental Protection Agency (US EPA).

The necessary facility-specific input parameters are:

- volume flow of natural gas through the absorption column
- gas composition of the natural gas
- pressure and temperature in the absorption column
- pressure and temperature in the degassing tank
- pressure and temperature in the regenerator (boiler)
- TEG circulation rate.

The software calculates emissions of methane and the individual hydrocarbon components in NMVOC (these are summed to arrive at total NMVOC emissions).

*Alternative 2*
Since GRI-GLYCalc is a commercial programme, alternative methods can also be used. The methane and NMVOC ($C_2$+) content in the TEG solution, measured as mass per unit volume of TEG solution, is determined by sampling and analysis of the TEG downstream from the degassing tank.

Methane emissions: $U_{CH4} = V_{TEG} * k_{CH4} * t$
NMVOC emissions: $U_{NMVOC} = V_{TEG} * k_{NMVOC} * t$

**Table 5 – Explanation of terms in the equation for calculating emissions from the TEG regenerator.**

| Term | Unit | Explanation |
|---|---|---|
| $U_{CH4}$ | tonnes | Methane emissions from the TEG regenerator in the reporting period |
| $U_{NMVOC}$ | tonnes | NMVOC emissions from the TEG regenerator in the reporting period |
| $k_{CH4}$ | tonnes $CH_4$/$m^3$ TEG | Concentration of $CH_4$ in the TEG solution |
| $K_{NMVOC}$ | tonnes NMVOC/$m^3$ TEG | Concentration of NMVOC in the TEG solution |
| $V_{TEG}$ | $m^3$/h | Circulation rate of the TEG solution |
| $t$ | hours | Number of operating hours in the reporting period |

### 3.3.3 Stripping gas - sub-source 10.3

**General quantification method**
Some plants use HG stripping gas to speed up dewatering of the TEG solution. Measurement or other reliable quantification of stripping gas quantity in the regenerator will be needed to quantify emissions. Waste gas composition is the same as the composition of stripping gas in the plant.

Emissions can be calculated in a simplified form as follows.

Methane emissions: $U_{CH4} = V_{NG} * Mol\%_{CH4} * \rho_{CH4} * t * 10^{-5}$
NMVOC emissions: $U_{NMVOC} = V_{NG} * Mol\%_{NMVOC} * \rho_{NMVOC} * t * 10^{-5}$

**Table 6 – Explanation of terms in the equation for calculating emissions from the TEG regenerator.**

| Term | Unit | Explanation |
|---|---|---|
| $U_{CH4}$ | tonnes | Methane emissions from the TEG regenerator in the reporting period |
| $U_{NMVOC}$ | tonnes | NMVOC emissions from the TEG regenerator in the reporting period |
| $V_{NG}$ | $Sm^3$/h | Flow rate of natural gas into the regenerator |
| $Mol\%_{CH4}$ | % | Mol% or volume% methane in the seal gas |
| $Mol\%_{NMVOC}$ | % | Mol% or volume% NMVOC in the seal gas |
| $\rho_{CH4}$ | kg/$Sm^3$ | Methane density (= 0.68 kg/$Sm^3$) |
| $P_{NMVOC}$ | kg/$Sm^3$ | NMVOC density (can be set as 2 kg/$Sm^3$ if the NMVOC composition is unknown, or it can otherwise be calculated on the basis of lab analyses of the fuel gas) |
| $t$ | hours | Number of operating hours in the reporting period |

## 3.4 Calculating emissions from MEG regeneration - sub-source 20.1, 20.2, 20.3

**General quantification method**
Specially developed calculation tools are used to quantify the emissions. The alternatives are:

- **GRI-GLYCalc**: calculation programme described in more detail under the section on TEG regeneration
- **MultiProScale**: process simulation programme specially developed to simulate the chemistry, thermodynamics and equilibrium in oil-gas-water and MEG systems.

Methane and NMVOC emissions from possible stripping gas is calculated in the same way as for stripping gas in TEG regeneration (see section 3.3.3).

## 3.5 Calculating emissions from amine regeneration - sub-source 30.1, 30.2

**Facility-specific quantification method**
Is established by the operator for the facility. It must be possible to document the accuracy of the method.

## 3.6 Calculating emissions from produced water – sub-source 40.1, 40.2, 40.3 and 40.4

Emissions could normally occur if waste gas from the following sources is emitted:

- produced water degassing tank
- flotation tank/CFU[1] (for facilities which have such equipment)
- added flotation gas (if HC gas is used)
- discharge caisson

### 3.6.1 Degassing tank, flotation tank and discharge caisson - sub-source 40.1, 40.2, 40.4

**General quantification method**
The amount of waste gas is a result of depressurising produced water and can be calculated with the aid of the following general quantification method.

Methane emissions: $U_{CH4} = f_{CH4} * V_{pw} * \Delta p *10^{-6}$
NmVOC emissions: $U_{NMVOC} = f_{NMVOC} * V_{pw} * \Delta p *10^{-6}$

**Table 7 – Explanation of terms in the equation for calculating direct emissions from produced water.**

| Term | Unit | Explanation |
|---|---|---|
| $U_{CH4}$ | tonnes | Methane emissions from produced water in the reporting period |
| $U_{NMVOC}$ | tonnes | NMVOC emissions from produced water in the reporting period |
| $f_{CH4}$ | **14** g/m$^3$/bar | Emission factor for $CH_4$. Grams methane per m$^3$ produced water through the degassing point and per bar pressure drop from nearest upstream degassing point |
| $F_{NMVOC}$ | **3.5** g/m$^3$/bar | Emission factor for NMVOC. Grams NMVOC per m$^3$ produced water through the degassing point and per bar pressure drop from nearest upstream degassing point* |
| $V_{PW}$ | m$^3$ | Accumulated quantity of produced water through the degassification point during the reporting period |
| $\Delta p$ | bar | Operating pressure difference between degassing point and closest upstream degassing point |
| $t$ | hours | Number of operating hours in the reporting period |

*If the pressure and the temperature of the produced water indicate the use of other factors according to [Ref. 1], the operator is free to choose this if relevant documentation is available.

[1] CFU = compact flotation unit.

If the produced water plant has more than one degassing point – from both the CFU and the discharge caisson, for example – the waste gas quantity is calculated for each point and summed.

The produced water quantity $V_{PW}$ is the quantity which passes the degassing point. Where emissions from the discharge caisson are concerned, this will be the quantity discharged to the sea. Emissions from the degassing tank and flotation unit can also include produced water for reinjection.

### 3.6.2 HC gas as flotation gas in flotation tank/CFU - sub-source 40.3

**General quantification method**
Emissions of flotation gas are determined by measuring the quantity of such gas in the plant or quantifying it in another reliable way. The operator should be able to document how the flotation gas quantity is established.

Methane emissions: $U_{CH4} = V_{NG} * Mol\%_{CH4} * \rho_{CH4} * t * 10^{-5}$
NMVOC emissions: $U_{NMVOC} = V_{NG} * Mol\%_{NMVOC} * \rho_{NMVOC} * t * 10^{-5}$

**Table 8 – Explanation of terms in the equation for calculating emissions from the flotation tank/CFU.**

| Term | Unit | Explanation |
|---|---|---|
| $U_{CH4}$ | tonnes | Methane emissions from flotation tank/CFU in the reporting period |
| $U_{NMVOC}$ | tonnes | NMVOC emissions from flotation tank/CFU in the reporting period |
| $V_{NG}$ | $Sm^3/h$ | Flow rate of natural gas (flotation gas) into flotation tank/CFU |
| $Mol\%_{CH4}$ | % | Mol% or volume% methane in the seal gas |
| $Mol\%_{NMVOC}$ | % | Mol% or volume% NMVOC in the seal gas |
| $\rho_{CH4}$ | $kg/Sm^3$ | Methane density (= 0.68 $kg/Sm^3$) |
| $P_{NMVOC}$ | $kg/Sm^3$ | NMVOC density (can be set as two $kg/Sm^3$ if the NMVOC composition is unknown, or it can otherwise be calculated on the basis of lab analyses of the fuel gas) |
| $t$ | hours | Number of operating hours in the reporting period |

## 3.7 Calculating emissions from oil seals on centrifugal compressors - sub-source 50.1, 50.2, 50.3

**Facility-specific method**
Seal oil used in centrifugal compressors absorbs gas from the compressor. This is freed as waste gas from up to three sub-sources:

- degassing pots (also called sour pots) – normally one-two per compressor stage
- seal oil holding tank, which can be common to all the compressors
- seal oil storage tank, common to all the compressors.

Holding and storage tanks are combined as a single tank on some facilities. Emissions are determined using a facility-specific method(s) established by the operator company. It should be possible to document the method's relevance and accuracy.

## 3.8 Calculating emissions from reciprocating compressors - sub-source 60.1, 60.2

**Facility-specific method**
The number of facilities with reciprocating compressors is small, and these use various seal systems. Emissions are determined using facility-specific methods established by the operator company. It should be possible to document their relevance and accuracy.

## 3.9 Calculating emissions from dry compressor seals – sub-source 70.1, 70.2 and 70.3

**Facility-specific method**
Centrifugal compressors with dry seals can give rise to emissions if seal gas containing HC is not recovered or flared. Three potential sub-sources can yield emissions:

- used primary seal gas
- used secondary seal gas (if HC gas is used).
- leakage of primary seal gas to secondary vent.

Emissions are estimated for each compressor stage (two seals per stage) and summed.

### 3.9.1 Primary seal gas - sub-source 70.1

**General quantification method**
Three general quantification methods are recommended, depending on available information.

*Primary method*
Measuring the quantity of seal (barrier) gas <u>out of</u> the primary vent. Certain compressors are fitted with a flow meter for gas out of the primary vent. Emissions from each of the two seals per compressor are calculated using the following formulae.

Methane emissions: $U_{CH4} = V_{PTut} * Mol\%_{CH4} * \rho_{CH4} * t * 10^{-5}$
NMVOC emissions: $U_{NMVOC} = V_{PTut} * Mol\%_{NMVOC} * \rho_{NMVOC} * t * 10^{-5}$

**Table 9 – Explanation of terms in the equation for calculating emissions of primary seal gas.**

| Term | Unit | Explanation |
|---|---|---|
| $U_{CH4}$ | tonnes | Methane emissions from primary seal gas per seal per compressor in the reporting period |
| $U_{NMVOC}$ | tonnes | NMVOC emissions from primary seal gas per seal per compressor in the reporting period |
| $V_{PTut}$ | $Sm^3/h$ | Flow rate of primary seal gas out of the primary vent |
| $Mol\%_{CH4}$ | % | Mol% or volume% methane in the seal gas |
| $Mol\%_{NMVOC}$ | % | Mol% or volume% NMVOC in the seal gas |
| $\rho_{CH4}$ | $kg/Sm^3$ | Methane density (= 0.68 $kg/Sm^3$) |
| $P_{NMVOC}$ | $kg/Sm^3$ | NMVOC density (can be set as two $kg/Sm^3$ if the NMVOC composition is unknown, or it can otherwise be calculated on the basis of lab analyses of the export/fuel gas) |
| $t$ | hours | Number of operating hours in the reporting period |

Total emissions of primary seal gas will then be as follows.

Methane: $(U^1{}_{CH4} + U^2{}_{CH4})_{kompressor1} + (U^1{}_{CH4} + U^2{}_{CH4})_{kompressor2} + \ldots + (U^1{}_{CH4} + U^2{}_{CH4})_{kompressor\ n}$

NMVOC: $(U^1{}_{NMVOC} + U^2{}_{NMVOC})_{compressor1} + (U^1{}_{NMVOC} + U^2{}_{NMVOC})_{compressor2} + \ldots + (U^1{}_{NMVOC} + U^2{}_{NMVOC})_{compressor\ n}$

Where:
$U^1$ = emissions from seal 1 on the compressor
$U^2$ = emissions from seal 2 on the compressor

*Secondary method*

For compressors where the flow rate of primary seal gas out of the primary vent is not measured. The quantity of seal gas into the primary seal is measured on all compressors with dry seals. The default estimate is that 10 per cent of the seal gas into the seal is emitted as waste gas. The formulae are then as follows.

Methane emissions: $U_{CH4} = k * V_{PTinn} * Mol\%_{CH4} * \rho_{CH4} * t * 10^{-7}$

NMVOC emissions: $U_{NMVOC} = k * V_{PTinn} * Mol\%_{NMVOC} * \rho_{NMVOC} * t * 10^{-7}$

**Table 10 – Explanation of terms in the equation for calculating emissions of primary seal gas.**

| Term | Unit | Explanation |
|---|---|---|
| $k$ | % | Percentage of primary seal gas exiting through the primary vent. The supplier often recommends 10 per cent |
| $V_{PTinn}$ | $Sm^3/h$ | Flow rate of primary seal gas into the seal |
| $Mol\%_{CH4}$ | % | Mol% or volume% methane in the seal gas |
| $Mol\%_{NMVOC}$ | % | Mol% or volume% NMVOC in the seal gas |
| $\rho_{CH4}$ | $kg/Sm^3$ | Methane density (= 0.68 $kg/Sm^3$) |
| $\rho_{NMVOC}$ | $kg/Sm^3$ | NMVOC density (can be set as two $kg/Sm^3$ if the NMVOC composition is unknown, or it can otherwise be calculated on the basis of lab analyses of the export/fuel gas) |
| $t$ | hours | Number of operating hours in the reporting period |

Overall emissions from the compressors are summed as with the primary method.

*Tertiary method*

If no measurement data into the seals are available, they should be obtained from the seal supplier.

## 3.9.2 Secondary seal gas - sub-source 70.2

This sub-source is only relevant in cases where fuel or other HC gas is used as seal gas.

**General quantification method**

Seal gas into the seal is measured (or quantified in another satisfactory way). The quantity in is equal to the quantity out through the secondary vent. Emissions per seal are calculated as follows.

Methane emissions: $U_{CH4} = V_{STinn} * Mol\%_{CH4} * \rho_{CH4} * t * 10^{-5}$

NMVOC emissions: $U_{NMVOC} = V_{STinn} * Mol\%_{NMVOC} * \rho_{NMVOC} * t * 10^{-5}$

**Table 11 – Explanation of terms in the equation for calculating emissions of secondary seal gas.**

| Term | Unit | Explanation |
|---|---|---|
| $U_{CH4}$ | tonnes | Methane emissions from secondary seal gas per seal per compressor in the reporting period |
| $U_{NMVOC}$ | tonnes | NMVOC emissions from secondary seal gas per seal per compressor in the reporting period |
| $V_{STinn}$ | Sm³/h | Flow rate of secondary seal gas into secondary seal |
| $Mol\%_{CH4}$ | % | Mol% or volume% methane in the seal gas |
| $Mol\%_{NMVOC}$ | % | Mol% or volume% NMVOC in the seal gas |
| $\rho_{CH4}$ | kg/Sm³ | Methane density (= 0.68 kg/Sm³) |
| $P_{NMVOC}$ | kg/Sm³ | NmVOC density (can be set as two kg/Sm³ if the NMVOC composition is unknown, or it can otherwise be calculated on the basis of lab analyses of the export/fuel gas) |
| $t$ | hours | Number of operating hours in the reporting period |

Total emissions of secondary seal gas from the compressors are summed as for primary seal gas.

## 3.9.3 Leakage of primary seal gas to secondary seal vent - sub-source 70.3

Quantifying this is only relevant if

- gas from the primary vent is recovered or sent to flaring and
- the seal does not have a mechanical design which prevents such leakage (such as an internal labyrinth).

**General quantification method**

Emissions are calculated as 10 per cent leakage of waste gas from the primary vent into the secondary vent. That corresponds to one per cent of the quantity of primary seal gas into the primary seal. Emissions per relevant compressor stage are calculated as follows (providing the starting point is the measured quantity of primary seal gas out of the primary vent).

Methane emissions: $U_{CH4} = 0{,}1 * V_{PTut} * Mol\%_{CH4} * \rho_{CH4} * t * 10^{-5}$

NMVOC emissions: $U_{NMVOC} = 0{,}1 * V_{PTut} * Mol\%_{NMVOC} * \rho_{NMVOC} * t * 10^{-5}$

**Table 12 – Explanation of terms in the equation for calculating emissions of primary seal gas.**

| Term | Unit | Explanation |
|---|---|---|
| $V_{PTut}$ | Sm³/h | Flow rate of primary seal gas from each primary vent |
| $Mol\%_{CH4}$ | % | Mol% or volume% methane in the seal gas |
| $Mol\%_{NMVOC}$ | % | Mol% or volume% NMVOC in the seal gas |
| $\rho_{CH4}$ | kg/Sm³ | Methane density (= 0.68 kg/Sm³) |
| $P_{NMVOC}$ | kg/Sm³ | NMVOC density (can be set as two kg/Sm³ if the NMVOC composition is unknown, or it can otherwise be calculated on the basis of lab analyses of the export/fuel gas) |
| $t$ | hours | Number of operating hours in the reporting period |

If the compressor is not equipped with a meter which registers the quantity of primary seal gas out of the primary vent, $V_{PTut}$ is replaced with $V_{PTinn}$ and the factor 0.1 is replaced with 0.01.

Total emissions from the sub-source are found by summing emissions from each of the seals on all relevant compressors, in the same way as with emissions of primary seal gas.

## 3.10 Calculation of direct emissions from flare gas not burnt – sub-source 80.1, 80.2 and 80.3

Direct emissions of unburnt flare gas can occur in the following circumstances.

- If the flare is extinguished and in the period between the admission of flare gas (opens for emission of the flare gas) and its ignition. The latter is particularly relevant for facilities with a closed flare.
- Non-combustible flare gas (in other words, the HC content of the flare gas is too small for combustion to occur).
- Open flare purged with inert gas (cold flare).

### 3.10.1 Extinguished flare and flare ignition - sub-source 80.1

**General quantification method**
The emissions are quantified by introducing a log for the time between the flare being extinguished or the flare valve opening and ignition of the flare. Emissions can be calculated in a simplified form as follows.

Methane emissions: $U_{CH4} = V_{FG} * Mol\%_{CH4} * \rho_{CH4} * 10^{-5}$
NMVOC emissions: $U_{NMVOC} = V_{FG} * Mol\%_{NMVOC} * \rho_{NMVOC} * 10^{-5}$

**Table 13 – Explanation of terms in the equation for calculating emissions from extinguished flare/delayed flare ignition.**

| Term | Unit | Explanation |
|---|---|---|
| $U_{CH4}$ | tonnes | Methane emissions from extinguished flare/delayed flare ignition in the reporting period |
| $U_{NMVOC}$ | tonnes | NMVOC emissions from extinguished flare/delayed flare ignition in the reporting period |
| $V_{FG}$ | $Sm^3$ | Volume of directly emitted flare gas not burnt in the reporting period |
| $Mol\%_{CH4}$ | % | Mol% or volume% methane in the seal gas |
| $Mol\%_{NMVOC}$ | % | Mol% or volume% NMVOC in the seal gas |
| $\rho_{CH4}$ | $kg/Sm^3$ | Methane density (= 0.68 $kg/Sm^3$) |
| $\rho_{NMVOC}$ | $kg/Sm^3$ | NMVOC density (can be set as two $kg/Sm^3$ if the NMVOC composition is unknown, or it can otherwise be calculated on the basis of lab analyses of the export/fuel gas) |

### 3.10.2 Non-combustible flare gas - sub-source 80.2

**Facility-specific quantification method**
This applies to a small number of flares, which are characterized by the fact that they contain a HC gas content which is too low to burn. The flare therefore works as a cold vent equipped with a flare gas meter. Since the flare gas meter measures all gas, not just HC gas, the challenge is to estimate the fraction of HC gases.

If the flare gas is never ignited, emissions are quantified according to the total flare gas multiplied by the fraction of HC gases.

If the flare is ignited for periods, for example if it stands close to a neighbouring flare which is ignited under special conditions, this is compensated for by using a flaring log.

The operator establishes a facility-specific quantification method for the relevant facility based on the information given above.

### 3.10.3 Open flare purged with inert gas - sub-source 80.3

**General quantification method**
This applies to a very limited number of flares on the Norwegian continental shelf. These are inert-gas purged flared that do not have emissions under normal operation. These flares are equipped with flare gas meters and are only in operation for short periods in special situations:

a. In the case of pressure relief of smaller equipment or pipe sections in connection with maintenance or emergency blowout. If the emission occurs without the flare being ignited, everything is reported as emissions of methane and NMVOC. If the flare is ignited there no emissions of methane or NMVOC are reported, except during the ignition period registered in the flare log.
b. In the case of pressure relief of large volumes, e.g. pipe systems (very rare), the flare usually ignites. Emissions of methane and NMVOC are calculated only for the short period of time when the flare is not ignited, in connection with the start-up of flaring.

Emissions are calculated based on flare gas measurements. The flare gas quantity is stated in $Sm^3$. The distribution between methane and NMVOC is given by the flare gas composition determined, for example, by the CMR method.

## 3.11 Calculating emissions from HC gas leaks – sub-source 90.1 and 90.2

These emissions are divided into two groups quantified by different general methods:

- big gas leaks
- small gas leaks/fugitive emissions.

### 3.11.1 Large gas leaks - sub-source 90.1

**General quantification method**
Large emission leaks includes:

- Leaks reported in chapter 8 of the emission report. These are leaks quantified and reported in accordance with the HSE regulations and given priority for averting.
- Any other large single leaks from valves/flanges, couplings etc. where the leakage quantity is quantified separately for each leak

The emissions are calculated as follows.

Methane emissions: $U_{CH4} = U_{UGL} * Vekt\%_{CH4} * 10^{-2}$
NMVOC emissions: $U_{NMVOC} = U_{UGL} * Vekt\%_{NMVOC} * 10^{-2}$

The gas composition of such leaks will not normally be known. It can then be assumed that the emitted gas comprises 50-50 weight% methane and NMVOC (corresponds to 75 mol% methane and 25 mol% NMVOC, and an NMVOC density of two kg/Sm³). In such cases, the formulae above can be used.

If the composition is given in mol%, methane and NMVOC can be calculated as follows.

Methane emissions: $U_{CH4} = U_{UGL} * (\boldsymbol{\rho}_{CH4} * mol\%_{CH4})/(\boldsymbol{\rho}_{CH4} * mol\%_{CH4}+\boldsymbol{\rho}_{NMVOC} * mol\%_{NMVOC})$
NmVOC emissions: $U_{NMVOC} = U_{UGL} * (\boldsymbol{\rho}_{nmVOC} * mol\%_{NMVOC})/(\boldsymbol{\rho}_{CH4} * mol\%_{CH4}+\boldsymbol{\rho}_{NMVOC} * mol\%_{NMVOC})$

(If the composition is given in vol%, replace vol% with mol% in the equations. In other words, the gas is assumed to be virtually ideal.)

In the event of large gas leaks (> 10 tonnes), efforts should be made to calculate/ estimate the distribution between methane and nmVOC on the basis of the leak site and the gas composition at that location.

**Table 14 – Explanation of terms in the equation for calculating emissions from large gas leaks.**

| Term | Unit | Explanation |
|---|---|---|
| $U_{CH4}$ | tonnes | Methane emissions from large gas leaks in the reporting period |
| $U_{NMVOC}$ | tonnes | NMVOC emissions from large gas leaks in the reporting period |
| $U_{UGL}$ | tonnes | Total quantity emitted from large gas leaks in the reporting period (natural gas) |
| $vekt\%_{CH4}$ | % | Weight% methane in leak emissions |
| $Vekt\%_{NMVOC}$ | % | Weight% NMVOC in leak emissions |
| $Mol\%_{CH4}$ | % | Mol% or volume% methane in the seal gas |
| $Mol\%_{NMVOC}$ | % | Mol% or volume% NMVOC in the seal gas |
| $\rho_{CH4}$ | tonnes/Sm³ | Methane density (= 0.68 kg/Sm³) |
| $P_{NMVOC}$ | tonnes/Sm³ | NMVOC density (can be set as two kg/Sm³ if the NMVOC composition is unknown, or it can otherwise be calculated on the basis of lab analyses of the export/fuel gas) |

Emissions from large gas leaks must also be reported in chapter 8 on unintended discharges. The overall volume of HC gas (methane + NMVOC) emitted is reported.

### 3.11.2 Small gas leaks/fugitive emissions - sub-source 90.2

**General quantification method**
The OGI "leak/no leak" method is used. This is based on the following.

- A database of the facility's components with leak potential. This should be updated in accordance with updating of the quantitative risk assessment (QRA) if that is found appropriate. However, the first measurement campaign should form the basis for determining when the next review should take place.
- Use of infrared camera to detect leakages from components. The camera should have an established lower detection limit.

- Statistically determined (by the API) “standard” leakage rates from components with and without detected leaks.

Quantities of natural gas emitted are determined as follows:

$U = k_{leak} * f_{leak} * 1/A * t_1 /1\,000\,000 + k_{noleak} * f_{noleak} * t_2 /1\,000\,000$ ( tonnes/year)

**Table 15 – Explanation of terms in the equation for calculating emissions from small gas leaks.**

| Term | Unit | Explanation |
|---|---|---|
| $U_{NG}$ | tonnes | Natural gas emissions from small gas leaks in the reporting period |
| $k_{Vleak}$ | number | Number of valves with detected leakage |
| $k_{Vno\text{-}leak}$ | number | Number of valves without detected leakage |
| $k_{Kleak}$ | number | Number of connectors with detected leakage |
| $k_{Kno\text{-}leak}$ | number | Number of connectors without detected leakage |
| $k_{Pleak}$ | number | Number of pumps with detected leakage |
| $k_{Pno\text{-}leak}$ | number | Number of pumps without detected leakage |
| $k_{leak}$ | number | Number of components with detected leakage |
| $k_{no\text{-}leak}$ | number | Number of components without detected leakage |
| $f_{Vleak}$ | g/h/component | Emission factor valves with detected leakage |
| $f_{Vno\text{-}leak}$ | g/h/component | Emission factor valves without detected leakage |
| $f_{Kleak}$ | g/h/component | Emission factor connectors with detected leakage |
| $f_{Kno\text{-}leak}$ | g/h/component | Emission factor connectors without detected leakage |
| $f_{Pleak}$ | g/h/component | Emission factor pumps with detected leakage |
| $f_{Pno\text{-}leak}$ | g/h/component | Emission factor pumps without detected leakage |
| $f_{leak}$ | g/h/component | Emission factor components with detected leakage |
| $f_{no\text{-}leak}$ | g/h/component | Emission factor components without detected leakage |
| $t_1$ | hours | Number of operating hours in the reporting period |
| $t_2$ | hours | Number of hours in the reporting period (8760 hours) |
| $A$ | - | fraction of hydrocarbon-containing systems covered by the IE scan (eg: if 70% was covered, A is equal to 0.7. |

Since the composition of the emitted gas will not be known, assuming 50-50 weight% methane and NMVOC is recommended (this corresponds to 75 mol% methane and 25 mol% NMVOC, which is regarded as satisfactorily representative for this emitted gas).

The emission factors used will depend on the IR camera's detection limit. The factors are presented in Table 16. If the camera's detection limit is not known, emission factors for the highest limit – 60 g/h – can be used. The choice of 60 g/h as the default should also be justified.

**Table 16 – Overview of emission factors used in the OGI leak/no leak method.**

| Component type | Emission factor type | Emission factors *f* (g/h/component) | | | |
|---|---|---|---|---|---|
| | | Detection limit 3 g/h | Detection limit 6 g/h | Detection limit 30 g/h | Detection limit 60 g/h |
| Valves | no-leak | 0.019 | 0.043 | 0.17 | 0.27 |
| | leak | 55 | 73 | 140 | 200 |
| Connectors (flanges, screwed connections) | no-leak | 0.0026 | 0.0041 | 0.01 | 0.014 |
| | leak | 29 | 45 | 88 | 120 |
| Pumps | no-leak | 0.096 | 0.13 | 0.59 | 0.75 |
| | leak | 140 | 160 | 310 | 350 |
| Other/possibly all components | no-leak | 0.007 | 0.0140 | 0.0510 | 0.0810 |
| | leak | 56 | 75 | 150 | 210 |

Measurements must be made with an approved IR camera. FLIR Optical Imaging Camera 320 and OPGAL Eye C Gas are the most commonly used cameras. If these cameras, or a camera with similar resolution is used, the emission factors for detection limit 3 g/hour should be used.

It is recommended to use only the factors for "Other/all components" and that these factors are used for all components. For all components from which leakage has been detected, an emission factor of 56 grams/hour is used, while for all components from which no emission has been detected, an emission factor of 0.007 grams/hour is used.

OGI measurements should be made in accordance to 'Norwegian oil and gas association's industry template 'OGI/IR Leak/No Leak method' which provides further information and details on the methodology for measuring and calculating these emissions.

OGI measurements on the same facility should preferably be coordinated with the updating schedule for the QRA and carried out with sufficient frequency. It is assumed that the leakage log and actions arising from this in the period between two measurements are updated in accordance with usual practice and entered in the annual reporting (the number of leaks/no leaks is updated annually), and that checks with an IR camera are conducted in smaller areas as and when required.

## 3.12 Calculating emissions from HC purge/blanket gas - sub-source 100.1

**General quantification method**
Two general methods are available for quantifying emissions.

1. **Measurement of or other reliable quantification method for the flow rate in the supply pipe for purge/blanket gas from the fuel gas system.** If measured purge/blanket gas goes to several consumers which deliver waste gas to different recipients as recovery, flaring and emission (venting), the fraction emitted should be quantifiable in an equally reliable way as the supply rate.

Emissions are calculated with the following formulae.

Methane emissions: $U_{CH4} = (V_{STG} – V_{ab}) * Mol\%_{CH4} * \rho_{CH4} * t * 10^{-5}$
NMVOC emissions: $U_{NMVOC} = (V_{STG} – V_{ab}) * Mol\%_{NMVOC} * \rho_{NMVOC} * t * 10^{-5}$

**Table 17 – Explanation of terms in the equation for calculating emissions from purge/blanket gas.**

| Term | Unit | Explanation |
|---|---|---|
| $U_{CH4}$ | tonnes | Methane emissions from purge/blanket gas in the reporting period |
| $U_{NMVOC}$ | tonnes | NMVOC emissions from purge/blanket gas in the reporting period |
| $V_{STG}$ | Sm³/h | Total consumption (flow rate) of purge/blanket gas |
| $V_{ab}$ | Sm³/h | Flow rate to users of purge/blanket gas where waste gas is recirculated or flared |
| $Mol\%_{CH4}$ | % | Mol% or volume% methane in the seal gas |
| $Mol\%_{NMVOC}$ | % | Mol% or volume% NMVOC in the seal gas |
| $\rho_{CH4}$ | kg/Sm³ | Methane density (= 0.68 kg/Sm³) |
| $P_{NMVOC}$ | kg/Sm³ | NMVOC density (can be set as two kg/Sm³ if the NMVOC composition is unknown, or it can otherwise be calculated on the basis of lab analyses of the export/fuel gas) |

| Term | Unit | Explanation |
|---|---|---|
| $t$ | hours | Number of operating hours in the reporting period |

2. **By measuring and categorising the waste gas where purge/blanket gas can be emitted with gas from other sources.** This will require flow meters in the vent pipe and possible analyses of the gas.

In principle, the waste gas is distributed between methane and NMVOC in the same way as in method 1 above.

If alternative 2 is in place, alternative 1 is not relevant. The operator chooses the quantification method on the basis of what is best for the relevant facility.

The distribution between methane and NMVOC is determined by fuel gas composition.

## 3.13 Calculating emissions from gas analysers and test/sample stations - sub-source 110.1

Calculated for facilities where:

a) analysis gas is taken from a slipstream to the main pipe, combined with
b) the slipstream continuously providing emissions to the atmosphere.

Contributions from the other sub-sources to emissions from gas analysers and test/ sample stations are so small that they are included in the general supplement. See chapter (3.17).

**General quantification method**
Two alternative methods can be utilised.

1. By determining the flow rate of the slipstream through measurements or another reliable method. In this case, the emissions are calculated using the following formulae.

Methane emissions: $U_{CH4} = V_G * Mol\%_{CH4} * \rho_{CH4} * t * 10^{-5}$
NMVOC emissions: $U_{NMVOC} = V_G * Mol\%_{NMVOC} * \rho_{NMVOC} * t * 10^{-5}$

**Table 18 – Explanation of terms in the equation for calculating emissions from gas analysers.**

| Term | Unit | Explanation |
|---|---|---|
| $U_{CH4}$ | tonnes | Methane emissions from slipstream feeding gas analyser in the reporting period |
| $U_{NMVOC}$ | tonnes | NMVOC emissions from slipstream feeding gas analyser in the reporting period |
| $V_G$ | $Sm^3/h$ | Measured flow rate through the slipstream |
| $Mol\%_{CH4}$ | % | Mol% or volume% methane in the seal gas |
| $Mol\%_{NMVOC}$ | % | Mol% or volume% NMVOC in the seal gas |
| $\rho_{CH4}$ | $kg/Sm^3$ | Methane density (= 0.68 $kg/Sm^3$) |
| $P_{NMVOC}$ | $kg/Sm^3$ | NMVOC density (can be set as two $kg/Sm^3$ if the NMVOC composition is unknown, or it can otherwise be calculated on the basis of lab analyses of the export/fuel gas) |
| $t$ | hours | Number of operating hours in the reporting period |

The mol% obtained from the analysis is used for analysers which categorise the whole gas stream. Where other analysers are concerned, the operator chooses the composition considered to be most representative (fuel gas, export gas or other). Data averaged over the reporting period should be acceptable.

2. If the slipstream is conducted to a vent header (common vent) to the atmosphere with a meter, the quantity of emission gas will be measured through the vent header's metering station (see section 3.16).

## 3.14 Calculation of emissions from drilling - sub-source 120.1

**General quantification method**

Methane emissions: $U_{CH4} = a * f_{CH4}$
NMVOC emissions: $U_{NMVOC} = a * f_{NMVOC}$

Emission factors cover both quantities emitted from cuttings treatment and screening as well as those released by gas from the mud separator.

**Table 19 – Explanation of terms in the equation for calculating direct emissions from drilling.**

| Term | Unit | Explanation |
|---|---|---|
| $U_{CH4}$ | tonnes | Methane emissions in the reporting period |
| $U_{NMVOC}$ | tonnes | NMVOC emissions in the reporting period |
| $a$ | number | Wellbores completed in the reporting period |
| $f_{CH4}$ | **0.25** tonnes/wellbore | Emission factor for methane |
| $F_{NMVOC}$ | **0.25** tonnes/wellbore | Emission factor for NMVOC |

Note that the activity factor is the number of wellbores (not the number of wells).

There shall not be reported emissions of methane and NMVOC from drilling of dry wells if water-based drilling fluid has been used.

## 3.15 Calculation of emissions from FPSO crude oil storage tanks – sub-source 130.1 and 130.2

This applies to emissions from floating combined production and storage units (FPSO's) where the tank atmosphere is natural gas.

### 3.15.1 Tank inspection - sub-source 130.1

**General quantification method**

Methane emissions: $U_{CH4} = V_{tanker} * Mol\%_{CH4} * \rho_{CH4} * 10^{-5}$
NMVOC emissions: $U_{NMVOC} = V_{tanker} * Mol\%_{NMVOC} * \rho_{NMVOC} * 10^{-5}$

If compositions are only known in volume%, mol% is replaced in the equations with volume% since the difference is small in relation to overall uncertainty.

**Table 20 – Explanation of terms in the equation for calculating direct emissions from gas freeing in FPSO/FSO crude oil storage tanks**

| Term | Unit | Explanation |
|---|---|---|
| $U_{CH4}$ | tonnes | Methane emissions in the reporting period |
| $U_{NMVOC}$ | tonnes | NMVOC emissions in the reporting period |
| $Mol\%_{CH4}$ | % | Mol% or volume% methane in the seal gas |
| $Mol\%_{NMVOC}$ | % | Mol% or volume% NMVOC in the seal gas |
| $\rho_{CH4}$ | $kg/Sm^3$ | Methane density. This is about 0.68 $kg/Sm^3$ |
| $P_{NMVOC}$ | $kg/Sm^3$ | NMVOC density. Can be set as equal to two $kg/Sm^3$ |
| $V_{tanker}$ | $m^3$ | Total volume of all crude oil cargo tanks freed of gas in the reporting period |

NMVOC density will depend on the composition of the VOC components. This is not normally known. A density of two $kg/Sm^3$ should be an acceptable approximation. Mol% is calculated on the basis of waste gas composition.

Waste gas composition can be set as equal to fuel gas composition on the facility if the fuel gas was used as blanket gas the last time the tank was emptied.

If the facility is an FPSO with oil storage and an inert gas (neutral gas) is used as the blanket gas after the last tank loading before tank inspection, the general addition is increased to 3% (sub-source 900.1).

### 3.15.2 Abnormal operating conditions - sub-source 130.2

**Facility-specific quantification methods**
These are emissions from storage tanks on an FPSO which could find itself in abnormal operating conditions. The operator company establishes a facility-specific quantification method which takes account of the emission circumstances. It should be possible to document the method.

## 3.16 Calculating emissions from gas freeing of process plants - sub-source 140.1

**General quantification method**
This source is only applicable if all or part of the process plant is gas freed during the reporting year. A conservative approach is taken to calculating the emissions, which assumes that all HC gas in the depressurised plant is emitted to the air when gas freeing begins.

If there are solid documentation on which systems that are depressurised, the volumes of these systems could be used in the calculations instead of the total process plant volume.

Methane emissions: $U_{CH4} = V_{process\ plant} * a * Mol\%_{CH4} * \rho_{CH4} * 10^{-5}$
NMVOC emissions: $U_{NMVOC} = V_{process\ plant} * a * Mol\%_{NMVOC} * \rho_{NMVOC} * 10^{-5}$

**Table 21 – Explanation of terms in the equation for calculating direct emissions from depressurisation and gas freeing of process plants.**

| Term | Unit | Explanation |
|---|---|---|

| Term | Unit | Explanation |
|---|---|---|
| $U_{CH4}$ | tonnes | Methane emissions in the reporting period |
| $U_{NMVOC}$ | tonnes | NMVOC emissions in the reporting period |
| $volum\%_{CH4}$ | % | Mol% or volume% methane in the seal gas |
| $volum\%_{NMVOC}$ | % | Mol% or volume% NMVOC in the seal gas |
| $\rho_{CH4}$ | kg/Sm³ | Methane density. This is about 0.68 kg/Sm³ |
| $\rho_{NMVOC}$ | kg/Sm³ | NMVOC density. Can be set as equal to two kg/Sm³ |
| $V_{Prosessanlegg}$ | m³ | Total volume of process plant(s) freed of gas in the reporting period |
| $a$ | number | Gas freeing processes in the reporting period |

Emissions are only reported for reporting periods with gas freeing.

Composition of fuel gas can be used as a basis for determining the weighting between methane and NMVOC emissions.

## 3.17 Ventilation of $CO_2$ from CO2-capture and storage (CCS)

This source includes vented $CO_2$ from CO2-capture and storage.

The operator shall establish an installation-specific method for quantification. The method should be documented.

## 3.18 General addition - sub-source 900.1 and 910.1

The operator adds one per cent to the total of the other emissions (mandatory). If the facility is an FPSO/FSO with crude oil storage, and inert gas has been used as blanket gas after the most recent tank discharge prior to tank inspection, this general supplement is increased to three per cent.

Sources with small emission contribution that can be included in the general addition:

- Low pressure liquid separators
- Seals on screw compressors
- Pressure relief/gas freeing of instruments and instrument manifolds
- Bleeding of gas from production riser
- Gas turbines
- Pig launcher
- Corrosion coupons
- Flexible risers
- Storage tanks for diesel and other consumable oils
- Double block and bleed (DBB) valves

# 4 DISTRIBUTION OF EMISSION GAS IN METHANE AND NMVOC

In some cases, the distribution of the emission gas is known as mol% or volume%. Emissions are to be reported in mass units. Converting volume% and mol% to weight% is therefore important. Methane has a density of about 0.68 kg/Sm³. The density of NMVOC will vary according to its composition. If this is not known, 2 kg/Sm³ should provide an acceptable approximation.

# 5 CHANGES DURING THE REPORTING PERIOD

Emission conditions can change during the reporting period – through mitigatory measures with an emission source, for example. Such measures could mean that waste gases sent to direct emission are recovered within the same reporting period. In such cases, this must be commented.

# 6 REFERENCES

Ref. 1: *Kaldventilering og diffuse utslipp fra petroleumsvirksomheten på norsk sokkel - Delrapport 2 Utslippsmengder og kvantifiseringsmetodikk*. Add Novatech AS for the Norwegian Environment Agency, 2016.

Ref. 2: *Kaldventilering og diffuse utslipp fra petroleumsvirksomheten på norsk sokkel - Delrapport 4 Kontrollsjekk av beregningsmetoder for diffuse utslipp og smålekkasjer*. Add Novatech AS for the Norwegian Environment Agency, 2016.

Ref. 3: *"Bransjemal – OGI Leak/NoLeak metoden for kvanitfisering av smålekkasjer og diffuse utslipp¨.* The Norwegian Oil and Gas Association, 2019. (In Norwegian only)