Manual **015**

Alberta Energy Regulator

Estimating Methane Emissions

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Abbreviations

AUPR	Alberta Upstream Petroleum Research
CAPP	Canadian Association of Petroleum Producers
CBFA	crude bitumen fleet average
CEPEI	Canadian Energy Partnership for Environmental Innovation
CS	compressor station
CT	custom treating
DVG	defined vent gas
EPA	Environmental Protection Agency
ESD	emergency shutdown
GIS	gas in solution
GM	gas migration
LVP	low vapour pressure
OVA	organic vapour analyzer
OVG	overall vent gas
PTAC	Petroleum Technology Alliance of Canada
RCS	reciprocating compressor seal
SCVF	surface casing vent flow
THC	total hydrocarbon
UWI	unique well identifier
VRU	vapour recovery units

1 General Information

This manual is a guide for those tasked with quantifying methane emissions as required by *Directive 060: Upstream Petroleum Industry Flaring, Incinerating, and Venting* and *Directive 039: Revised Program to Reduce Benzene Emissions from Glycol Dehydrators*. This document also references *Directive 017: Measurement Requirements for Oil and Gas Operations*, *Directive 007: Volumetric and Infrastructure Requirements*, and *Manual 011: How to Submit Volumetric Data to the AER*. This manual is organized into sections corresponding to the requirements contained in section 8 of *Directive 060*.

This document explains

- how to report vent gas and fugitive emissions to the AER,
- how to quantify vent gas and fugitive emissions, and
- the relationship between facility IDs and sites.

This manual is not a guide for using the software tools used to report emissions and does not specify methods for estimating methane emissions from incomplete combustion.

The AER and Alberta Environment and Parks collaborated to develop the quantification methodologies in this document and the Government of Alberta document *Quantification Methodologies for the Carbon Competitiveness Incentive Regulation and the Specified Gas Reporting Regulation*. For situations where facilities are regulated both by the AER and under the *Technology Innovation and Emissions Reduction Regulation*, the methodologies for estimating vent gas volumes that are accepted in the *Quantification Methodologies for the Carbon Competitiveness Incentive Regulation* and the *Specified Gas Reporting Regulation* are acceptable as replacement for methodologies described in this manual only for the purposes of estimating methane emissions. Measurement or quantification requirements in other AER regulatory instruments may not be replaced with the alternatives listed above.

1.1 Updates to Definitions

1.1.1 Fuel, Flare, and Vent Definitions

Directive 060 changes the definitions of fuel gas, flare gas, and vent gas, which take effect on January 1, 2020. These changes affect how activities or events are categorized into activity and product codes (given in *Manual 011*) and used for reporting volumes.

Additionally, the changes to *Directive 017* change how flared acid gas is reported at gas plants that are approved to dispose of acid gas by continuous flaring or incineration. ACGAS is an allowable product type for the activity code FLARE after January 1, 2020, and is used to report activities and events that fit the methane reduction requirements.

Duty holders, as defined in *Directive 060*, are encouraged to apply these changes early in the 2019 reporting year.

Table 1 lists examples of activities or events at upstream oil and gas facilities that are affected by these definition changes, including the required activity codes to be reported in Petrinex before and after January 1, 2020.

Table 1. Reference guide for fuel, flare, and vent gas definition changes

Activity	Product code	Activity code before Jan 1, 2020	Activity code after Jan 1, 2020
Pneumatic device gas vented	GAS	FUEL	VENT
Pneumatic device gas flared	GAS	FUEL	FLARE
Sulphur recovery incinerator make up gas	GAS	FUEL	FLARE
Dilution gas	GAS	FUEL	FLARE
Blanket gas, pilot gas, purge gas in flare system	GAS	FUEL	FLARE
Continuous acid gas flaring	ACGAS	SHR	FLARE
Tail gas incineration at sour gas plant	ACGAS	SHR	FLARE
Sulphur recovery reaction furnace and unit gas	GAS	FUEL	FUEL
Intermittent (upset) acid gas flaring	GAS	FLARE	FLARE
Sulphur recovery	ACGAS	SHR	SHR

1.1.2 Controlled Emission Source Characterization

A key distinction between vent gas and fugitive emissions is the intention behind the release of the emission. This is important when emitting equipment is tied to a control device, because the intention behind a control device is to not vent, and emissions are considered fugitive emissions.

Equipment used to control vent gas, including flares and vapour recovery units (VRUs), can experience periods of inactivity due to maintenance, power outages, low flow rates, or facility shut downs. When a control device is inactive, the uncontrolled vent gas volumes are considered to be nonroutine or “upset” vent gas volumes and should be attributed to nonroutine vent gas volumes and reported as part of Petrinex vent gas reporting but not attributed in OneStop to any source category.

For example, if a pneumatic pump is tied into an enclosed combustor, the volumes would normally be reported as FLARE and not reported in OneStop. If the combustor is nonoperational due to maintenance, the volumes should be reported as VENT in Petrinex (with a corresponding reduction in the flare volume at that facility) and still not reported in OneStop. The AER does not expect duty holders to calculate uncombusted emissions associated with gas volumes that are destroyed through a control device. This means that all streams (flare, vent, etc.) are categorized as one product type and not split into methane versus carbon dioxide.

As per section 8.10.2.3 of *Directive 060*, operators must verify control equipment and associated piping integrity as part of fugitive emission survey requirements. Where emissions are detected at control equipment or associated piping, these are considered fugitive emissions. These volumes must be reported as fugitive emissions and determined using the methodology in section 4.7.

Unintended leaks or abnormal process emissions (e.g., leaking pressure safety valve) that occur in or are directed into a vent stream (e.g., open-ended pipes) are considered fugitive emissions, and volumes can be determined using the methodology in section 4.7.

Emissions from tanks with control equipment installed (controlled tanks) are considered fugitive emissions, except where noted in table 2. For example, continuous emissions from a faulty thief hatch seal, improperly seated thief hatch, or open thief hatch outside of the time needed for pressure relief are all considered as fugitive emissions. These volumes are considered fugitive emissions and can be determined using the methodology in section 4.2.2. The AER considers emissions from thief hatches on tanks that do not have control equipment installed to be vent gas and therefore subject to vent gas limits within *Directive 060*. Produced water storage tanks may emit hydrocarbons as a result of leftover entrained hydrocarbons after the separation process. Continuous venting from a water tank may also be an indication of unintended natural gas carry-through from the upstream vessel. Table 2 outlines different scenarios where tanks may have emissions and whether or not they should be classified and reported as vent gas or fugitive emissions.

Table 2. Example of tank emissions characterization summary

Emission source	Uncontrolled tank	Controlled tank
Thief hatch left open*	Vent – routine (DVG)	Fugitive emissions
Thief hatch relieving pressure as designed	Vent – routine (DVG)	Vent – nonroutine (OVG)
VRU / vent control system offline (upset or maintenance)	—	Vent – nonroutine (OVG)
Tank cleaning or de-sanding	Vent – nonroutine (OVG)	Vent – nonroutine (OVG)
Well casing tied into the tank	Vent – routine (DVG)	Vent – nonroutine (OVG)
Produced water tank*	Vent – routine (DVG)	Fugitive emissions
Level gauge seal	Vent – routine (DVG)	Fugitive emissions

* Continuous emissions from either of these sources may be indicative of unintended gas carry-through. These unintentional emissions should be classified as fugitives and the source should be localized as part of a fugitive emission survey and repaired according to *Directive 060*.

2 Reporting Vent Gas and Fugitive Emissions

The AER uses two systems for reporting methane emissions: Petrinex (https://www.petrinex.ca) and OneStop (https://www1.aer.ca/onestop/). The identifier for reporting volumes, masses, and inventories of equipment is the facility ID, which is assigned by Petrinex and used by both systems.

Directive 060 requires that emissions be reported at the location that they occur. This means, where appropriate, vent gas and fugitive emissions are attributed to

- a CS facility ID in the case of gas released from a licensed compressor station,
- a production string UWI in the case of gas released from a well site, or
- the closest upstream facility ID to a gas release that is not already reported to a CS or UWI.

The terminology "reporting facility" is specific to facility IDs that must report production or receipts. CS facility ID refers to a licensed compressor station associated with a gas gathering system or battery. CS facility IDs do not report production volumetrics and are nonreporting facilities as per *Manual 011*. CS facility IDs are required to have vent gas reported to them in Petrinex and vent gas and fugitive emissions reported to them in OneStop. This manual explicitly lists "facility IDs, linked wells (UWIs), and CS facility IDs" each time they are referenced. This is to clarify and reinforce that vent gas and fugitive emissions must be reported to where the emission occurred. Care should be taken to ensure that all vent gas and fugitive emission volumes are reported once, and not double counted.

Within Petrinex reporting, the following guidance applies:

- Administrative battery (paper battery) facility IDs:
  - For crude bitumen administrative grouping batteries (subtype 343), report all venting to the UWI and no venting to the administrative battery facility.
  - For gas multiwell group batteries with no licence (subtype 365), report venting to the UWI and no venting to the administrative battery facility.
- For gas gathering systems, vent gas should be reported at the facility level only when emissions and activities that occurred within that facility ID's delineated boundaries are outside licensed compressor stations, batteries, or gas plant sites. This may exclude all vent sources or be limited to vent sources from unlicensed compressor sites (no CS facility ID code), pig traps sites, valve yards, line heaters, and other equipment at pipeline installations.
- For subtype 371 or 381 facilities with linked wells that have drilling, completing, or testing activity, report vent gas to the UWI.

Table 3 summarizes reporting categories, resolution, frequency, and units required to be reported into OneStop and Petrinex.

Table 3. Summary comparison of OneStop and Petrinex reporting for methane emissions

	OneStop reporting	Petrinex reporting
Reporting categories	Defined vent gas Pneumatic devices Compressor seals Glycol dehydrators Fugitive emissions	VENT
Resolution	Facility ID CS facility ID	Facility ID and at any linked UWIs or CS facility IDs
Frequency	Annually	Monthly
Units	m^3 and kg	$10^3 m^3$

Facility IDs are characterized by their subtype code. The subtypes that are included in the methane emission reporting requirements (and reported to OneStop) are listed in table 4.

Table 4. Facility ID subtype codes that report methane emissions to OneStop

Facility type	Subtype code	Subtype description
Battery (BT)	311	Crude oil single-well battery
	331	Crude bitumen single-well battery
	351	Gas single-well battery
	321	Crude oil multiwell group battery
	322	Crude oil multiwell proration battery
	341	Crude bitumen multiwell group battery
	342	Crude bitumen multiwell proration battery
	361	Gas multiwell group battery
	362	Gas multiwell effluent measurement battery
	363	Gas multiwell proration SE Alberta battery
	364	Gas multiwell proration outside SE Alberta battery
	365	Gas multiwell group battery
	366	Gas multiwell proration SE Alberta battery
	367	Gas multiwell proration outside SE Alberta battery
	343	Crude bitumen administrative grouping
	371	Gas testing battery
	381	Drilling and completing
	344	In situ oil sands
	345	Sulphur reporting at oil sands
Custom treating facility (CT)	611	Custom treating facility
	612	Custom treating facility approved as part of an oilfield waste management facility
Compressor station (CS)	601	Compressor station
Gas gathering system (GS)	621	Gas gathering system
	622	Gas gathering system
Gas plant (GP)	401	Gas plant—sweet
	402	Gas plant—acid gas flaring <1.0 t/d sulphur
	403	Gas plant—acid gas flaring ≥1.0 t/d sulphur
	404	Gas plant—acid gas injection
	405	Gas plant—sulphur recovery
	406	Gas plant—mainline straddle
	407	Gas plant—fractionation
Injection/ disposal facility (IF)	501	Enhanced recovery scheme
	502	Concurrent production/cycling scheme
	503	Disposal
	504	Acid gas disposal
	505	Underground gas storage
	506	In situ oil sands
	507	Disposal (approved as part of a waste plant facility)

Facility type	Subtype code	Subtype description
	508	Enhanced recovery scheme
	509	Disposal
Terminal	671	Tank farm/oil loading and unloading terminal
	673	Third-party tank farm/oil loading and unloading terminal
Waste plant	701	Waste processing facility
	702	Cavern waste plants
Water source	902	Water source battery

2.1 Reporting to Petrinex

As per existing definitions, when reporting vent gas to Petrinex on a monthly basis, the GAS product code with the VENT activity code is used. Based on the updated definition of vent gas (in effect January 1, 2020), all types of vent gas, including routine sources (DVG, pneumatic devices, compressor seals, and glycol dehydrators) and nonroutine sources, are included in the volumes reported as VENT. Fugitive emissions are not considered vent gas and are not included in Petrinex reporting. The amount of vent gas reported to Petrinex is the sum of the volumes of all sources across all sites that report to a facility ID, linked UWI, or CS facility ID (in 10^3 m^3). For a sample calculation showing how each emission source for one month rolls up to determine the VENT volume to report to Petrinex, refer to appendix 3.

The following source categories contribute to the total volume of vent gas for each site:

- DVG
- nonroutine vent gas
- pneumatic devices
- compressor seals
- glycol dehydrators

Fugitive emissions are excluded from Petrinex reporting.

VENT volumes reported to Petrinex are in 10^3 m^3 and rounded to one decimal place, meaning any volume less than 49 m^3 in a month is rounded to zero. The relative uncertainty introduced to reported values as a result of rounding may be significant for low vent volumes.

Before the methane reduction requirements come into effect, many facility IDs may have reported no venting, though small amounts of gas were vented at the facility ID. A common explanation for not reporting this was that it would not have met the 49 m^3 per month threshold. Definitions have changed for what is considered vent gas, and a single typical pneumatic level controller at a site may emit 0.1 m^3 per hour (72 m^3 per month) and exceed the 49 m^3 threshold alone. Operators are advised that sites with 0 m^3 reported will be scrutinized.

2.1.1 Overall Vent Gas Limit and Crude Bitumen Fleet Average

The VENT activity code data is used to assess compliance with the overall vent gas (OVG) limit and crude bitumen fleet average (CBFA) limits.

As per *Directive 060*, the OVG limit applies to a reduced set of emission sources until January 1, 2023. The updated definitions for fuel gas, flare gas, and vent gas take effect January 1, 2020, and all vent gas emission sources are reported as vent gas, regardless of whether they are all subject to the OVG limit or not. The AER will take into account the amount of vent gas from pneumatic devices, compressors seals, and glycol dehydrators when assessing compliance on the OVG limit prior to January 1, 2023. The reporting requirements do not change before or after January 1, 2023.

For duty holders that opt to use the CBFA approach to achieve compliance with vent gas limits, the reported facility total VENT volume for all the eligible facility IDs within their fleet is used to determine the fleet average.

Note that reporting is required by the operator of record in both Petrinex and OneStop, so in the case of facilities where the licensee and operator of record differ, the operator is accountable for reporting. The AER calculates the fleet average automatically from data in Petrinex; there is no separate reporting for OVG or CBFA required of operators in OneStop. A sample calculation of CBFA is included in appendix 3.

2.2 Reporting to OneStop

When reporting methane emissions to OneStop, the mass of methane, volumes of vent gas, and equipment inventories are reported annually, as required by *Directive 060*, through the “Methane Emissions” portal into the following source categories:

- defined vent gas (DVG),
- pneumatic devices,
- compressor seals, and
- fugitive emissions.

Nonroutine venting is excluded from OneStop reporting.

The mass of methane emissions of glycol dehydrators is reported to OneStop through the “Benzene Emissions” portal annually, as required by *Directive 039*.

The first reporting period is 2019 and the annual methane emission report is due by June 1, 2020.

The vent gas volume for each source category reported to OneStop is the sum of the relevant volumes at each site in that facility ID or CS facility ID in the year (in cubic metres). Refer to appendix 3 for an example showing a sample calculation for each emission source and how to roll up vent gas and fugitive emission volumes for reporting to OneStop.

In addition to vent gas volume, the corresponding mass of methane must also be reported to OneStop for DVG, pneumatic devices, compressor seals, and fugitive emissions through the “Methane Emissions” portal in kilograms annually, as per section 8 of *Directive 060*. *Directive 060* also requires that a compressor inventory and fugitive emission survey results be reported annually. Glycol dehydrators’ methane masses are reported to OneStop in an equipment inventory through the “Benzene Emissions” portal and do not require vent gas volumes to be reported separately.

Unlike reporting to Petrinex, volumes and masses reported to OneStop are rolled-up and reported to the facility ID or the associated CS facility ID. They are not reported to linked UWIs at battery facility IDs.

2.2.1 Fugitive Emissions Reporting

Fugitive emission survey or screening frequencies in *Directive 060* are based on facility subtypes or specific equipment (controlled tanks) present at a site, and the survey or screening details are reported to OneStop, as per section 8.10.5 of *Directive 060*. As per *Directive 087: Well Integrity Management*, SCVF/GM must be tested and reported in accordance with *Directive 087*, and fugitive emission volumes associated with SCVF/GM are not included in OneStop reporting.

The following examples have been prepared to help describe how to report fugitive emission surveys or screenings to OneStop.

Figure 1 shows a facility and three wells at different sites. They are all linked and report to the facility ID ABBT12345. According to the fugitive emission requirements of *Directive 060*, a complete fugitive emission survey within the facility site boundary is required annually. Fugitive emission screenings would also be required at each well site annually. See table 5 for an example of how to report the fugitive emission screenings and surveys into OneStop. Note that each leak should only be reported once to one facility ID to avoid double counting.

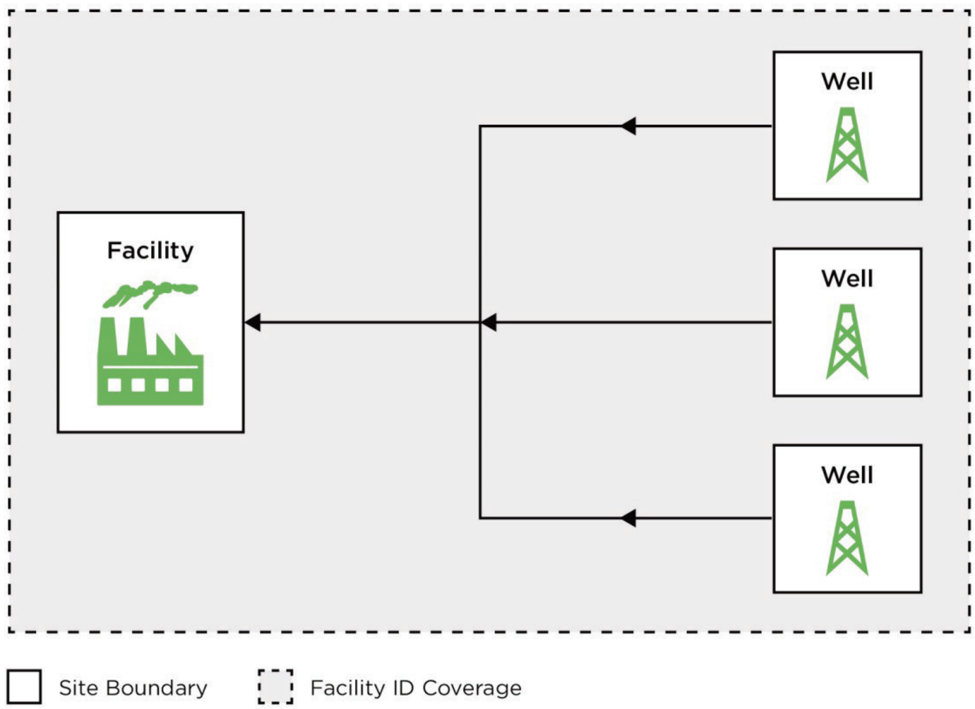

Figure 1. Multiple sites linked to one facility ID

Table 5. Example of how to report fugitive emission survey and screenings to one facility ID

Facility ID	Site description	Survey or screening date	Number of fugitive emission sources identified	Type of survey or screening
ABBT12345	Facility	3/6/2020	6	Site survey
	Well #1	3/6/2020	1	Well screening
	Well #2	3/6/2020	4	Well screening
	Well #3	3/6/2020	2	Well screening

Figure 2 shows multiple facility IDs that are all located at the same site. The fugitive emission survey frequency requirements are different for a sweet gas plant than for a battery. A duty holder may decide to survey the entire site on a triannual basis. If the duty holder is able to clearly delineate the equipment between the sweet gas plant and the battery, they can survey the sweet gas plant triannually and the batteries annually. See table 6 for an example of how to report to each facility ID if the gas plant was surveyed triannually and the other equipment associated to the other facility IDs was surveyed annual.

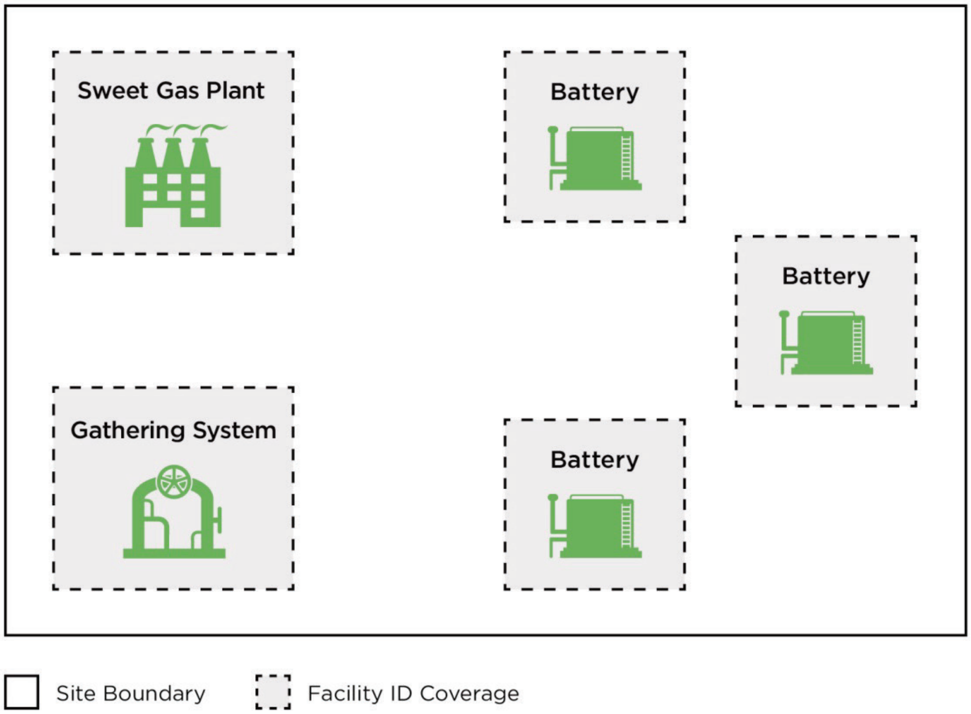

Figure 2. Multiple facility IDs within one site

Table 6. Example of how to report fugitive emission survey and screenings with multiple facility IDs

Facility ID*	Site description	Survey or screening date	Number of fugitive emission sources identified	Type of survey or screening
ABGP12345	Sweet gas plant	15/2/2020	6	Site survey
		3/6/2020	1	Site survey
		22/10/2020	4	Site survey
ABBT11111	Battery #1	3/6/2020	1	Site survey
ABBT22222	Battery #2	3/6/2020	4	Site survey
ABBT33333	Battery #3	3/6/2020	2	Site survey
ABGS12345	Gas gathering	3/6/2020	0	Site survey

* Each Facility ID has its own page in OneStop.

Figure 3 shows a site that requires an annual fugitive emission survey and tank surveys. All process units within the site boundary (including well and controlled tanks) are included in the annual site survey. Two additional tank surveys are required on controlled tanks. There is no additional requirement for a well screening, as it would have been included in the annual site survey. Table 7 shows how to report these surveys within OneStop.

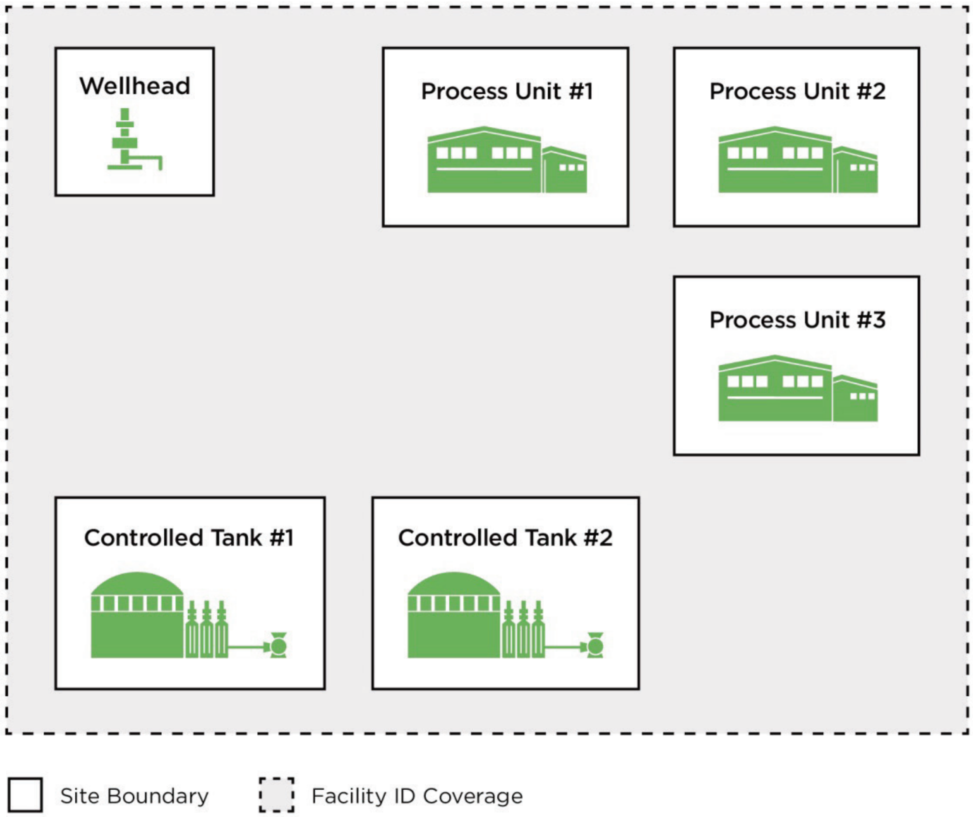

Figure 3. Multiple pieces of equipment on a site with different survey frequency requirements

Table 7. Example of how to report fugitive emission survey and screenings with tanks

Facility ID	Site description	Survey or screening date	Number of fugitive emission sources identified	Type of survey or screening
ABBT11111	Battery 1	15/2/2020	6	Site survey
	Battery 1	3/6/2020	4	Tank survey
	Battery 1	28/9/2020	1	Tank survey

2.3 Relationship Between Petrinex and OneStop Reporting

Table 8 summarizes the reporting categories that pertain to methane emissions and where they are reported.

Table 8. Summary table of relationship between reporting categories

Source requirement	Petrinex: Include in VENT	OneStop: Include the volume and mass	OneStop: Equipment inventory or survey results	Where to find the requirement
DVG	✓	✓		D060 s8.4
Pneumatic devices	✓	✓		D060 s8.6.1
Compressor seals	✓	✓	✓	D060 s8.6.2
Glycol dehydrators	✓	✓	✓	D060 s8.6.3 D039 appendix 2

Source requirement	Petrinex: Include in VENT	OneStop: Include the volume and mass	OneStop: Equipment inventory or survey results	Where to find the requirement
Nonroutine	✓			D060 s10
Fugitive emissions		✓	✓	D060 s8.10

Vent gas volume reported to OneStop are in m^3 and decimal places are not required, although permitted. The AER will compare monthly vent gas volumes reported to Petrinex with the sum of the DVG, pneumatic devices, compressor seals, and glycol dehydrators vent gas annual volumes to assess compliance with the OVG limit. The AER will take into account the differences in reported vent gas volumes that could result from the different rounding rules between the two systems, as well as the differences from nonroutine vent gas. For example, a site could have 35 m^3 of vent gas per month for twelve months of the year (assume all DVG and no vent gas from other sources). In Petrinex, this would appear as zero VENT for each month. In OneStop, the annual DVG vent gas volume would be 420 m^3 for the year.

Table 9 is an example of vent gas and fugitive emission values for the source categories and how those values would aggregate into reportable values. Simulated vent volumes have been listed for each month, for each vent category, and for fugitive emissions. Summary rows and columns show how volumes and masses should be reported to Petrinex and OneStop, respectively. Individual volumes for a single month and vent category are not reported but, as required by *Directive 060*, are to be kept as records.

Report these columns to OneStop

Table 9. Representative sample values for methane emission reporting at a single-well battery

Facility ID ABBT0001234 **UWI** 100020304005W600 **Reporting Year** 2019

		Vent gas volumes (m^3 unless otherwise noted)												Vent gas volumes (m^3)	Mass of methane (kg)
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual total**	**Annual total**
Vent	DVG	2 990	2 690	3 290	3 140	2 990	2 690	3 290	3 140	3 580	3 740	2 840	2 550	**36 930**	**22 154**
	Pneumatic – instruments	1 760	1 580	1 940	1 850	1 760	1 580	1 940	1 850	2 110	2 200	1 670	2 250	**22 490**	**13 305**
	Pneumatic – pumps	10 500	9 500	11 600	11 000	10 500	9 450	11 600	11 000	12 600	13 100	9 980	0	**120 830**	**71 983**
	Compressor seals	73 504	71 205	73 648	0	73 504	78 651	74 648	68 651	73 565	71 205	73 648	73 555	**805 784**	**480 036**
	Glycol dehydrators[1]	*11 900*	*10 700*	*13 100*	*12 500*	*11 900*	*10 700*	*13 100*	*12 500*	*14 300*	*14 900*	*11 300*	*3 300*		**7 629**
	Nonroutine[2]	2 990	2 690	3 290	3 140	2 990	2 690	3 290	3 140	3 580	3 740	2 840	2 550		
	Total (10^3 m^3) (OVG/CBFA)	**103.6**	**98.4**	**106.9**	**31.6**	**103.6**	**105.8**	**107.9**	**100.3**	**109.7**	**108.9**	**102.3**	**84.2**		
Fugitive[3]	Leaks and abnormal processes	—	—	—	—	—	—	—	—	—	—	—	—	**118 249**	**69 956**

Report this row to Petrinex (VENT)

[1] Reported to OneStop as required by *Directive 039*. The volume component of glycol dehydrators is shown monthly, but only the mass of methane is calculated.

[2] Nonroutine venting is not reported to OneStop.

[3] Fugitive emissions are not considered vent volumes and are therefore not reported to Petrinex but are reported to OneStop.

3 Delineating Facility IDs and Sites

The methane requirements set out in *Directive 060* are at the site level, while the reporting of vent gas into Petrinex is at the level of facility ID or linked UWI or CS facility ID. Reporting into OneStop is also at the level of facility ID or associated CS facility ID level (reporting at the linked UWI level is not available in OneStop).

Directive 017 requires that duty holders associate lease sites, equipment, and assets with facility IDs. However, measurement schematics alone may not provide enough detail to definitively place a particular vent source or fugitive emission within a facility ID or CS facility ID boundary.

As defined in appendix 2 of *Directive 060*, surface lease boundaries define a site, but they might not correspond to the boundaries of the facility ID. The following case studies are intended to clarify how emissions are reported and how compliance with site-level requirements will be evaluated.

During a review, an operator may present evidence including measurement schematics, plot plans, and process and instrumentation diagrams to support the delineation method and reported values.

Creating or changing facility ID configurations or linkages for OneStop reporting are done by the licensee or operator of record through the existing AER processes or through Petrinex.

Figure 1 shows a facility and three wells that are at different sites and are all linked and report to the facility ID ABBT12345. Table 10 shows an example of one month of reporting vent gas into Petrinex for this battery. For reporting vent gas to Petrinex, venting is attributed to the location where it occurs. The OVG and DVG limits set forth in *Directive 060* are specific to the site. In this example, the total vent gas that will be reported to the facility ID ABBT12345 is 21 10^3 m^3/month and is compliant with the OVG limit because each site is less than 15 10^3 m^3/month.

Table 10. Example of one month of reporting vent gas to Petrinex for one facility ID

Site description	Facility ID, linked CS or UWI	VENT in 10^3 m^3/month
Facility	Facility level activity	14
Well 1	Linked UWI(1)	3
Well 2	Linked UWI(2)	2
Well 3	Linked UWI(3)	2
Facility ID total	ABBT12345	21

Report underlined red values to Petrinex (10^3 m^3 vent gas).

For reporting vent gas emissions to OneStop in this example, venting from each source category is determined for each site and reported at the facility ID level, see table 11. For this example, assume that ABBT12345 only has methane emissions from defined vent gas, pneumatic instruments, and nonroutine venting. The other source categories are not applicable because there are no pneumatic pumps, glycol dehydrators, or compressors at any of the sites linked to ABBT12345. Values that are reported to OneStop for the facility ID ABBT12345 are 100 000 m^3 in the DVG category and 92 000 m^3 in the pneumatic instrument category. All other source categories would report zero, and nonroutine vent gas is not included in OneStop reporting.

Table 11. Example of one year of reporting vent gas to OneStop for one facility ID

Site	Defined vent gas (m^3/year)	Pneumatic instruments (m^3/year)	Nonroutine (m^3/year)	Total vent gas (m^3/year)
Facility	100 000	8 000	60 000	168 000
Well 1	0	36 000	0	36 000
Well 2	0	24 000	0	24 000
Well 3	0	24 000	0	24 000
ABBT12345	100 000	92 000	60 000	252 000

Report underlined red values to OneStop (m^3 vent gas).

Figure 2 shows multiple facility IDs that are all located at the same site. Table 12 shows an example of one month of reporting vent gas into Petrinex for this site. In this example, it is assumed that all venting from the batteries occurred within the site boundary and are not from associated CS facility IDs or linked UWIs. The OVG and DVG venting limits in *Directive 060* are at the site level, so the total vent gas for the site must be less than 15 10^3 m^3/month.

Table 12. Example of one month of reporting vent gas to Petrinex for one site with multiple facility IDs

Site description	Facility ID, linked CS or UWI	VENT in 10^3 m^3/month
Sweet gas plant	ABGP12345	10
Gathering system	ABGS12345	3
Battery #1	ABBT11111	1
Battery #2	ABBT22222	0
Battery #3	ABBT33333	0
	Total Site	14

Report underlined red values to Petrinex (10^3 m^3 vent gas).

For reporting vent gas emissions to OneStop in this example, venting from each source category is determined for each site and reported for each facility ID, see table 13. For this example, assume that the site only has methane emissions from defined vent gas, compressors, and nonroutine venting. The other source categories are not applicable because there are no pneumatic devices or glycol dehydrators at this site.

Table 13. Example of one year of reporting vent gas to OneStop

Facility ID	Defined vent gas (m^3/year)	Compressors (m^3/year)	Nonroutine (m^3/year)	Total vent gas (m^3/year)
ABGP12345	60 000	0	60 000	120 000
ABGS12345	0	30 000	6 000	36 000
ABBT11111	12 000	0	0	12 000
ABBT22222	0	0	0	0
ABBT33333	0	0	0	0

Report underlined red values to OneStop (m^3 vent gas).

Figure 4 shows a gas gathering system that is not itself a site and is made up two compressor stations and a pig trap. The compressor stations and pig trap are all at different sites and are all linked and report to the facility ID ABGS12345. Table 14 shows an example of one month of reporting vent gas into Petrinex for this gathering system. Venting from the compressor stations are reported to each CS facility ID. The pig trap is at an unlicensed site, and the venting from that site is reported to the gathering system.

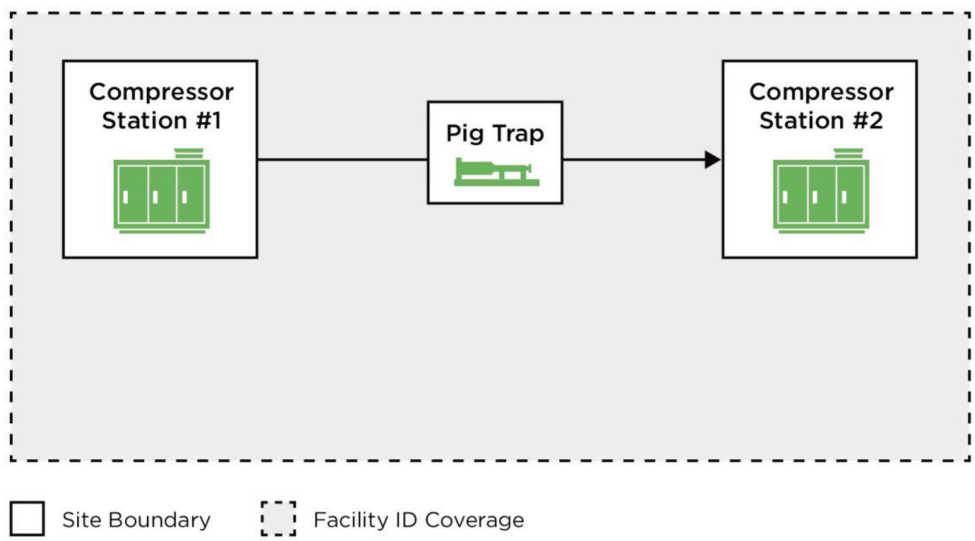

Figure 4. Example for gas gathering systems reporting one month of vent gas to Petrinex

Table 14. Example of one month of reporting vent gas to Petrinex

Site description	Facility ID, associated CS, or UWI	VENT in 10^3 m^3/month
Pig Trap	ABGS12345	5
Compressor station #1	ABCS11111	10
Compressor station #2	ABCS22222	10
Facility ID total	ABGS12345	25

Report underlined red values to Petrinex (10^3 m^3 vent gas)

For reporting vent gas emissions to OneStop in this example, venting from each source category is determined for each site and reported at the facility ID or CS facility ID level, see table 15. For this example, assume that these sites only have venting from compressors and a pig trap (assume there are no other vent sources). The vent gas from compressors is reported at the CS facility ID level and the vent gas from the pig trap is part of DVG.

Table 15. Example of one year of reporting vent gas to OneStop

Facility ID	Compressors (m^3/year)	Defined vent gas (m^3/year)	Total vent gas (m^3/year)
ABGS12345	0	60 000	60 000
ABCS11111	120 000	0	120 000
ABCS22222	120 000	0	120 000

Report underlined red values to OneStop (m^3 vent gas).

4 Estimating Vent Gas and Fugitive Emissions

4.1 General Emission Estimation

Unless otherwise required to measure or test a vent gas stream through *Directive 017* or *Directive 060*, emissions may be estimated using emission factors or rates, the equations included within this document, or engineering estimates as described in Canada (2016).

Site- and equipment-specific data should be used when quantifying and reporting emissions. While not a requirement, continuous direct measurement or periodic testing of individual emission sources is encouraged where possible and where these solutions would result in more accurate reporting of emissions than the methods discussed in this document.

Emission rates are commonly used to estimate a volume of vent gas over a specified unit of time. Emission rates are referenced throughout this document for individual components, equipment, or processes. They are generally expressed as a volumetric emission rate per unit of time, actuation, or event.

In general, emission rates may be determined using the following methods. More specific guidance for estimating each emission source is included in each section.

- Periodic testing of the individual emission source in conditions representative of that component's average emission rate.
- Average emission rate of at least 30 samples of an operator's fleet of equivalent emission sources in conditions representative of that source's average emission rate or with correlations to relevant fluid or operating parameters or representative process simulation software results.
- Average emission rates of at least 30 samples of equivalent emission sources from publicly available studies, with few or no other correlating variables.
- Emission rates published through manufacturer specifications or as specified in this document.

Except as described in section 4.2.1, assigning a vent volume or fugitive emissions to a facility ID, linked UWI, or CS facility ID by reconciling the volumetric imbalance at a facility ID is not an acceptable method of estimating a vent volume or fugitive emission.

Methane emissions tend to arise from numerous small sources in upstream oil and gas facilities. *Directive 060* and this manual present no minimum quantification threshold. *Directive 060* also requires accurate methane emission reports. Compliance assessments and regulatory scrutiny on any reported emission source will be commensurate to the relative contribution to total emissions. Duty holders should make the estimates for the largest emission sources the most accurate.

If, for example, pig trap openings vented 8 m^3 and tanks vented 2500 m^3, the duty holder should focus their efforts on making the estimates of tank emissions as accurate as possible (site-specific parameters or measurements). The pig trap openings could be estimated with less accuracy (generic parameters or average measurements).

4.1.1 Volume and Mass Conversions

To convert a volume of vent gas to a mass of methane, equation 1 or 2 may be used depending on whether the volumetric concentration of methane is known or the mass concentration of methane and density of vent gas is known. All volumes should be corrected to standard conditions of temperature at 15°C and pressure at 101.325 kPa(a). Equation 1 is preferred as the resulting uncertainty is generally lower.

$$M = V \times \phi_{CH4} \times \rho_{CH4} \tag{1}$$

M	the mass of methane [kg CH_4]
V	the volume of gas, corrected to standard conditions [m^3]
ϕ_{CH4}	the volumetric concentration of methane as a fraction, or molar fraction, of vent gas [dimensionless]
ρ_{CH4}	the density of methane at standard conditions is 0.67850 [kg/m^3]

$$M = V \times \omega_{CH4} \times \rho_{gas} \tag{2}$$

M	the mass of methane [kg CH_4]
V	the volume of gas, corrected to standard conditions [m^3]
ω_{CH4}	the mass concentration of methane as a fraction of vent gas [dimensionless]
ρ_{gas}	the density of the vent gas corrected to standard conditions [kg/m^3]

The volume of water vapour or inerts in a gas sample can significantly alter the mass of methane calculated. Both should be considered carefully in the context of the above two equations, especially for tank vents, completion flowback gas, and glycol dehydrator still columns. Both equations 1 and 2 will work for dry or wet basis, but all input parameters should be consistently either dry or wet basis. For emission factors or rates given in this manual that are in units of total hydrocarbon (THC), a representative gas analysis of the stream is needed to convert total hydrocarbon emission rates to volume of vent gas and mass of methane.

4.2 Defined Vent Gas

DVG is vent gas from all routine sources, excluding vent gas from pneumatic devices, compressor seals, and glycol dehydrators, at a facility ID.

As per section 8.11 of *Directive 060*, operators must calculate and record DVG per site per month. As per section 8.4.1 of *Directive 060*, DVG is reported to OneStop by reporting facility ID or CS facility ID annually. When operators report VENT to Petrinex on a monthly basis, DVG is a component of this volume as detailed in section 2.1 of this manual.

The DVG volume at a facility ID or linked UWI or CS facility ID is the sum of all DVG volumes for all sites in that facility ID or linked UWI or CS facility ID. As per section 8.4 of *Directive 060*, defined vent gas (DVG) is vent gas from routine venting, excluding vent gas from pneumatic devices, compressor seals, and glycol dehydrators. Examples of volumes to be included in DVG volumes are as follows:

- Associated gas venting, including production casing vents and other routine production vents of gas not in solution
- Gas-in-solution vents, including tank vents from tanks that are designed to continuously vent (that are not controlled) and vent gas that arises from tank flashing, breathing, and working
- Other tank vents including blanketing and liquid loading/unloading losses
- Online gas analyzer purge vents
- Solid desiccant dehydrator vents
- Pig trap opening and purge vents

Activities listed in the nonroutine vent sources section are explicitly not DVG vent sources, even if they occur regularly at a site. DVG also excludes vent gas from glycol regenerators used for refrigeration, which are reported in the glycol dehydrators source category. When a DVG vent has a control device installed and the control device is not operating, vents are considered nonroutine. Fugitive emissions are not vent gas.

4.2.1 Associated Gas Venting

Routine associated gas venting is the release of produced gas from oil and bitumen reservoirs. It is gas produced at the well head as a gas or gas that evolves from produced liquids through flashing during liquids processing and storage.

Routine associated gas venting from well casings may be determined by equating production to vent for sites that vent all production. It may also be determined by equating production to vent less any fuel consumption for sites that report disposition of all gas production through fuel use and venting. In all other cases, assigning a vent volume or fugitive emissions to a facility ID or linked UWI or CS facility ID by reconciling the volumetric imbalance at a facility ID is not an acceptable method of estimating a vent volume or fugitive emission.

When not equated to production or production less fuel, associated gas may be estimated by point source. For direct vents off gas lines, methods described in section 4.1 may be used. For vents off tanks, the following section provides guidance.

4.2.2 Storage Tank Venting

Liquids stored in uncontrolled tanks (without vapour recovery units or vapour destruction) can be a source of vent gas through flashing, breathing losses, and working losses.

Vent gas from uncontrolled, open atmospheric tanks that arise due to the processes described in the following subsections should be estimated based on best available information and methods described below and reported as DVG.

Vent gas emissions from controlled tanks that arise due to maintenance or periodic, planned, or unplanned shutdowns of vapour recovery or vapour destruction systems should be determined by engineering estimates and reported as nonroutine vent gas.

Gas emissions from controlled tanks that arise due to stuck or malfunctioning thief hatches or failures of equivalent pressure-management devices should be determined by engineering estimates and reported as fugitive emissions.

Gas may be emitted from tank vents when pneumatic level controllers upstream of the tank malfunction. This may entrain undesired gas volumes in liquid flow lines to tanks, which may then be vented through tank vents (i.e., gas carry-through). If detected, these abnormal process emissions should be determined by engineering estimates and reported as fugitive emissions.

Fixed-roof tanks are the primary equipment for storing hydrocarbon liquids (oil and condensate) in the upstream oil and gas industry. If a tank is equipped with a vapour collection system, there is still a potential for some emissions due to potential inefficiencies of the vapour collection system—for example, due to overloading of the system due to inadequate sizing for peak emission rates, down time of the end control device, fouling of the vapour collection piping, etc. These emissions would be considered nonroutine vent gas. Additionally, tanks connected to vapour collection systems can be a source of fugitive equipment leaks (mostly due to leakage around the thief hatch or level gauge seal), see section 1.1.2.

Venting from fixed-roof tanks includes contributions from the following:

- flashing losses
- breathing losses
- working losses
- blanket gas losses

For quantification of produced gas, if a gas-in-solution (GIS) factor is determined that represents the vented gas volumes, it may be used. For sites configured with multiple pressure drops, commingled streams, or other liquids processing, reportable vent volumes may not equate well to GIS factors determined for production measurement requirements. In these cases, other methods for estimating vent volumes are provided below for each of the types of losses, flashing, breathing, and working.

4.2.2.1 Flashing Losses

Flashing may occur when liquids with dissolved gases that have a vapour pressure greater than local barometric pressure are produced into vented storage tanks. When the liquid first enters a tank, a rapid boiling or flashing process occurs as the liquid tends towards a more stable state and the volatile components vapourize. The dissolved gas that flashes out of the liquid is called gas in solution (GIS). A GIS factor is given in equation 3.

$$V_{GIS} = V_{liq} \times GIS \tag{3}$$

V_{GIS} GIS venting in a month [m^3]

GIS GIS factor for the stored hydrocarbon product [m^3 of gas/m^3 of oil] where gas volumes are presented on a dry basis at reference conditions 101.325 kPa and 15° C

V_{liq} Monthly volume of liquid hydrocarbon entering the subject tank [m^3]

All methods of quantifying vent gas emissions that are listed in section 4.1 are acceptable for determining the GIS factor. For estimation methods based on publicly available studies, if the oil can be assumed to be saturated with gas, and conditions are relevant to the dataset used to develop the correlation, a bubble-point pressure correlation may be used. Otherwise use estimation methods based on engineering specifications or where appropriate, use the GIS factor “rule of thumb” from *Directive 017*.

Bubble-Point Pressure Correlation – Vazquez and Beggs

Repeated analyses of various production oils have been compiled into useful references for estimating the GIS that will evolve from saturated oils as they undergo pressure drop. The Vazquez and Beggs correlation is widely cited as the most accurate and comprehensive. Other correlations include Lasater or Standing correlations but are not referenced here further. Duty holders may use the Vazquez and Beggs correlation to estimate vent gas from flashing saturated oils to atmospheric pressure and directed towards tanks (Vazquez and Beggs 1980).

The Vasquez and Beggs correlation is based on a regression of experimentally determined bubble-point pressures for a variety of crude oil systems. The range of parameters for which the correlation is derived is presented in table 16. It is accurate to within 10% more than 85% of the time when input data in the range of values listed in table 16 are used.

If a suitable correlation is not available, the duty holder may apply other methods to determine emission rates described in section 4.1 or the GIS factor “rule of thumb” from *Directive 017*.

Table 16. Range of data used to develop the Vasquez & Beggs correlation (from Vazquez and Beggs 1980)

Parameter	Range
Size of dataset	5008
Bubble pressure, kPa	345 to 36 190
Reservoir temperature, °C	21 to 146
Solution gas-to-oil ratio at bubble-point pressure, m^3/m^3	3.5 to 369
Oil API gravity, °API	16 to 58
Oil Specific gravity, (-)	0.56 to 1.18

4.2.2.2 Breathing and Working Losses

Evaporative losses promoted by daily temperature or barometric pressure changes during the storage of hydrocarbons are known as breathing losses. Evaporative losses during filling and emptying operations are known as working losses and are caused by the displacement of tank vapours during changes in liquid level. Breathing and working losses occur for both stable and unstable products. However, if the product is unstable, the latter type of loss is obscured by the flashing losses. Accordingly, storage losses at oil wells or batteries are taken to be the sum of breathing and flashing losses. Storage losses at gas processing plants and pipeline terminals (i.e., facilities storing stable products) are taken to be the sum of breathing and working losses.

Mass emissions of product vapours from tanks (i.e., breathing and working) containing weathered or stabilized hydrocarbon liquids are estimated using the “Evaporative Loss from Fixed-Roof Tanks” algorithms (US EPA 2006).

Blanket gas may be added to a tank’s dead space to maintain a safe atmosphere above the liquids. For tanks equipped with a blanket gas system, the volume of blanket gas supplied to a tank is a reasonable analogue for estimating working and breathing losses.

4.2.3 Hydrocarbon Liquid Loading Losses

Tank trucks transport low-vapour-pressure (LVP) products such as crude oil, condensate, and pentanes plus. Emissions due to the displacement of tank vapours (i.e., evaporated product) can occur during the loading of these carriers. The volume of emissions depends on the vapour pressure of the liquid product, the recent loading history, and the method of loading. When not measured or when the estimation approaches discussed in section 4.1 are not employed, LVP carrier emissions may be quantified using equation 4.

$$V_{LL} = \frac{SF \times P_v \times T_{std}}{P_{std} \times T_t} \times V_{oil} \tag{4}$$

V_{LL} volume of gas vented from evaporation losses during LVP product loading in a month [m^3]

SF saturation factor in table 17 to account for the method of loading [dimensionless]

V_{oil} monthly volume of the LVP product loaded [m^3]

P_{std} standard reference pressure [101.325 kPa]

P_v true vapour pressure of the LVP product [kPa] determined using equation 5

T_{std} standard reference temperature [288.15 º K]

T_t truck tank operating temperature [º K]

Table 17. Saturation factors for calculating liquid loading losses (from US EPA 2008)

Cargo carrier	Mode of operation	Saturation factor (dimensionless)
Tank trucks and rail tank cars	Submerged loading of a clean cargo tank	0.50
	Submerged loading: dedicated normal service	0.60
	Submerged loading: dedicated vapour balance service	1.00
	Splash loading of a clean cargo tank	1.45
	Splash loading: dedicated normal service	1.45
	Splash loading: dedicated vapour balance service	1.00

The true vapour pressure at bulk liquid temperature may be determined by equation 5.

$$P_V = 6.8929 \exp\left[\left(\frac{1555}{T} - 2.227\right)\left(\log_{10}(RVP) - 0.8384\right) - \frac{4033.89}{T} + 12.82\right] \tag{5}$$

RVP Reid vapour pressure of liquid [kPa] (if site specific liquid properties are not known, typical values presented in table 18 may be applied)

T average liquid temperature [K]

Typical properties that may be used for the above equation is presented in table 18.

Table 18. Typical properties for liquid products

Liquid product	Oil specific gravity	Reid vapour pressure (kPa)	Vapour molecular weight (kg/kmole)
Condensate	0.7150	76.6	28.2
Light/medium crude oil	0.8315	54.8	44.2
Heavy crude oil	0.9153	40.5	19.9
Thermal crude oil	0.9153	40.5	30.6
Cold bitumen	0.9282	39.7	23.3

4.2.4 Online Gas Analyzer Purge Vents

Process analyzers are used to monitor gas quality and ensure that desired process or pipeline quality specifications are achieved. They include analyzers to measure for H_2S, H_2O, O_2/CO_2, hydrocarbon dew point, and natural gas composition. More than 85% of venting emissions from this source are related to the use of bypass or fast-response purge gas loops. When not measured, the estimation approaches discussed in section 4.1 may be used. If using an average emission rate, a value of 68.9 m^3 vent gas/month (Clearstone 2018a) may be used for each analyzer.

4.2.5 Solid Desiccant Dehydrators

Solid desiccant dehydrators consist of at least two vessels that operate in a cyclical manner alternating between drying and regeneration. Gas is vented each time the vessel is depressurized (or "blown down") for desiccant refilling. When not measured or when the estimation approaches discussed in section 4.1 are not employed, the desiccant dehydrator blowdown volume may be estimated using equation 6.

$$V_{DD} = \left(\frac{\mathrm{H} \times D^2 \times \pi \times P_2 \times \mathrm{G}}{4 \times P_1}\right) \times f \tag{6}$$

V_{DD}	volume of desiccant dehydrator vent gas in a month [m^3]
H	height of the dehydrator vessel [m]
D	diameter of the dehydrator vessel [m]
P_2	pressure of the gas [kPa (g)]
P_1	atmospheric pressure [kPa (a)]
G	fraction of the vessel that is filled with gas [dimensionless]
f	frequency of refilling [cycles per month]

4.2.6 Pig Trap Openings and Purges

Pigging operations require a pig trap to be depressurized, opened, loaded, purged, and repressurized. These activities are considered routine for the purposes of estimating and reporting vent gas volumes and are reported as part of the DVG.

Vent volumes from pig traps may be measured or estimated using one of the approaches discussed in section 4.1, or quantified using the following equations. Actual process conditions before each blowdown event should be used when calculating emissions. Equation 7 should be used to estimate vent volumes from pig traps.

$$V_{PT} = \sum_{i=1}^{N} V_v \left[\frac{(273.15+T_s)(P_{a,1}-P_{a,2})}{(273.15+T_a)P_s} + M\right]_i \tag{7}$$

V_{PT}	volume of natural gas vented by the subject vessel or pipe due to blowdowns or depressurization in a month [m^3]
V_v	total physical volume of equipment chambers between isolation valves being depressurized (including pig traps, pipes, compressors, and vessels) [m^3]
T_s	temperature 15°C at standard conditions [°C]
T_a	initial temperature of gas at actual conditions in the equipment system [°C] before depressurization
P_s	absolute pressure 101.325 kPa(a) at standard conditions [kPa(a)]
$P_{a,1}$	gauge pressure at actual conditions in the equipment system [kPa(g)] before depressurization

$P_{a,2}$ gauge pressure at actual conditions in the equipment system after depressurization; 0 if equipment is purged upon depressurization using inert gases [kPa(g)]

N number of blowdown events for the subject month and vessel

M number of purges for the subject blowdown event, use zero if the equipment is depressurized but not purged with gas prior to repressurization

4.2.7 Other Routine Sources

Refer to *Directive 060* for the definition of routine venting. DVG includes routine vent gas sources excluding pneumatic devices, compressor seals, and glycol dehydrators vent gas. Any routine vent gas sources not described in the sections above can be determined using guidance in section 4.1 or engineering estimates. The volume from other routine sources is included in the DVG volume and reported monthly as part of VENT to Petrinex and annually to OneStop as DVG.

4.3 Nonroutine Vent Sources

Nonroutine vent sources are intermittent, infrequent, and may be planned or unplanned vent sources.

As per section 8.11 of *Directive 060*, Operators must calculate and record nonroutine vent gas volumes per site per month as part of existing production accounting reporting. Nonroutine vent gas is reported to Petrinex by facility IDs or linked UWI or CS facility ID monthly as part of VENT. Nonroutine vent gas is not reported to OneStop.

As per section 8 of *Directive 060*, nonroutine venting is intermittent and infrequent venting and can be planned or unplanned. Examples of vent gas sources to be included in nonroutine volumes are as follows:

- Blowdown venting and associated purges
- Vent gas from well testing, completions, and workovers
- Well liquid unloading vent gas
- Engine or turbine start vent gas
- If a vent source is controlled and the control system is not operational due to maintenance or upset, vented gas from those systems
- Other vent sources that do not happen regularly and less than six times in six months

4.3.1 Blowdowns

Blowdown venting for planned or emergency depressurization (e.g., emergency shutdown [ESD] events) or to take equipment out of service for maintenance is estimated using guidance in section 4.1 or equation 7.

Continuous gas loss observed from a blowdown vent stack indicates an equipment leak that should be quantified according to section 4.7, "Fugitive Emissions."

4.3.2 Well Testing, Completions, and Workovers

Vent gas volumes from well testing, completions, or workovers are determined as required by *Directive 040: Pressure and Deliverability Testing Oil and Gas Wells* and *Directive 059: Well Drilling and Completion Data Filing Requirements*. Vent gas volumes from well testing, completions, or workovers contribute to OVG as nonroutine venting and are reported monthly as vent gas into Petrinex.

4.3.3 Well Venting for Liquids Unloading

Some gas wells have an accumulation of liquids and require liquids unloading in order to maintain production. During this process, vent gas is either tied into a sales line, flared, or vented. Liquids unloading is considered a nonroutine event for the purposes of methane emission quantification when vented. When not measured or when the estimation approaches discussed in section 4.1 are not employed, the monthly volume released for each subject well may be estimated using equation 8 (adapted from WCI 2011).

$$V_{WLU} = \sum_{i=1}^{N} \left[\left(7.854 \times 10^{-5} \times D^2{}_t \times WD \times \left[\frac{P_{shut-in}}{101.325} \right] \right) + \left(Q_{sfr} \times t_{open} \right) \right]_i \tag{8}$$

V_{WLU}	volume of gas vented from liquids unloading at standard reference conditions [m^3]
D_t	casing inside diameter [cm]
WD	well depth [m]
$P_{shut\text{-}in}$	well shut-in pressure [kPa(g)]
Q_{sfr}	maximum monthly production rate as observed over the last 12 months from production records at standard conditions [m^3/hr]
t_{open}	hours that the well was left open with natural gas flowing to the atmosphere; periods when the well was blocked or when inert gas (such as nitrogen) dominated the flowback composition should not be included [hr]
N	number of unloading events for the well each month

4.3.4 Engine or Turbine Starts

Pneumatic starters are widely used to start reciprocating engines or turbines. Specific starting gas requirements will vary according to the pressure of the start gas, the condition of the engine or turbine, the size of the compressor or generator that is being driven, the number of starters installed, the start duration, ambient air temperature, oil viscosity, fuel type, and design cranking speed. These emissions should not be reported as part of the compressor seal category. When not measured, the estimation approaches discussed in section 4.1 may be used. If using a manufacturer-specified emission rate, equation 9 can be used.

$$V = ER \times t \tag{9}$$

V volume of vent gas from engine and turbine start sources released from a site in a month [m^3]

ER emission rate for the device from table 28 or 29 [m^3 vent gas/min or m^3 vent gas/hour]

t amount of time in each month the starter is in use [min or hour]

4.3.5 Other Nonroutine Sources

Refer to *Directive 060* for the definition of nonroutine venting. Any nonroutine vent gas sources not described in the sections above should be determined using guidance in section 4.1 or through engineering estimates and reported as other nonroutine sources. The volume of nonroutine venting must be reported monthly to Petrinex as vent gas at the facility ID level, CS facility ID, or linked UWI.

4.4 Pneumatic Devices

Pneumatic devices include instruments and pumps that are used to provide control or pumping functions and require a supply of pneumatic gas that is commonly vented, including the following:

- Transducers
- Pressure controllers and regulators
- Positioners
- Level controllers
- Corrosion inhibitor or hydrate inhibitor (methanol) injection pumps

Energy exchange pumps that are used to pump glycol in glycol dehydrators are part of the glycol dehydrator vent gas source and not part of pneumatic devices. Pneumatic gas engine or turbine starters are considered nonroutine and not part of pneumatic devices. Pneumatic devices operating on air or propane gas are not estimated or reported as methane. When a pneumatic device vent control system is not operating, vents are considered nonroutine.

The AER considers on/off and throttling relays in level controllers to minimize transient venting to be in compliance with requirement 3 in *Directive 060*, section 8.6.1.

As per section 8.11 of *Directive 060*, operators must calculate and record pneumatics vent gas per site per month. As per section 8.4.1 of *Directive 060*, pneumatic vent gas is reported to OneStop by reporting facility ID or CS facility ID annually. When operators report VENT to Petrinex on a monthly basis, pneumatic vent gas is a component of this volume as detailed in section 2.1 of this manual.

The pneumatic vent gas volume at a facility ID or linked UWI or CS facility ID is the sum of the pneumatic vent gas volumes for all sites.

If not metered, vent gas emitted from pneumatic devices is calculated using equation 9, where the emission rate used is specific to the make, model, and operating conditions of the instrument or pump (m^3 vent gas/hour) and time use is number of hours the device was in operation each month (hours/month).

Emission rates for pneumatic devices may be determined following the guidance outlined in section 4.1. If direct measurement or testing is completed on pneumatic devices, refer to Government of Alberta (2017) for field vent rate sampling guidance. The following sections for pneumatic instruments and pumps include examples of average emission rates and manufacturer-specified vent rates. The AER acknowledges that new publications with updated average emission rates for pneumatic devices will become available over time and we encourage the use of more accurate information as it becomes available.

4.4.1 Pneumatic Instruments

For pneumatic instruments where the supply pressure is known, the average emission rate can be calculated using equation 10.

$$ER_i = m \times SP \tag{10}$$

ER_i the average emission rate specific to the make, model, and operating conditions of the instrument [m^3 vent gas/hour]

m supply pressure coefficient for the specific make and model of pump from table 19 [m^3/hr/kPa gauge]

SP supply pressure to the instrument [kPa gauge]

Table 19. Pneumatic instrument average emission rates (from Prasino 2013)

Type	Manufacturer and model	Supply pressure coefficient
Pressure controllers	Fisher 4150 Fisher 4160 CVS 4150 CVS4160	0.0019
	Fisher C1	0.0003
Level controllers	Fisher 2500	0.0011
	Fisher 2680	0.0014
	Murphy L1200 Murphy L1100	0.0012
Positioners	Fisher FIELDVUE™ DVC 6000 Fisher FIELDVUE™ DVC 6010 Fisher FIELDVUE™ DVC 6020 Fisher FIELDVUE™ DVC 6030	0.0011
Transducers	Fisher 546	0.0017

Type	Manufacturer and model	Supply pressure coefficient
	Fairchild TXI 7800	0.0009
	Fairchild TXI 7850	
	Fisher i2P-100 (1st generation)	0.0009

For pneumatic instruments where average emission rates from publicly available studies are used and the supply pressure is unknown, table 20 has been prepared as a combination of average emission rates from multiple sources.

Table 20. Pneumatic instrument average emission rates*

Type	Manufacturer and model	Published average sampled vent rate (m^3 vent gas/hr)
Pressure controllers	Fisher 4150	0.4209
	Fisher 4160	
	CVS 4150	
	CVS4160	
	Fisher 4660	0.0151
	Fisher C1	0.0649
Level controllers	Fisher 2500	0.3967
	Fisher 2680	0.2679
	Fisher 2900	0.1447
	Murphy L1200	0.2619
	Murphy L1100	
	SOR 1530	0.0531
	Fisher L2 actuating 0-15 mins	0.75
	Fisher L2 actuating >15 mins	0.19
	Fisher L2 (improved low vent relay)	0.10
	Norriseal 1001	0.193
	Norriseal 1001A	
Positioners	Fisher FIELDVUE™ DVC 6000	0.2649
	Fisher FIELDVUE™ DVC 6010	
	Fisher FIELDVUE™ DVC 6020	
	Fisher FIELDVUE™ DVC 6030	
Temperature controllers	Kimray HT	0.0351
Transducers	Fisher 546	0.3547
	Fairchild TXI 7800	0.1543
	Fairchild TXI 7850	
	Fisher i2P-100 (1st generation)	0.2157

* References include Prasino (2013), Spartan Controls (2018), and Greenpath (2018).

If a particular pneumatic instrument is not listed in either of these tables, use manufacturer-specified emission rates. Manufacturer-specified emission rates should be chosen to represent the operating conditions (supply pressure, configuration) of the instrument or else if the operating conditions are unknown then use the highest emission rate available. Some rates from manufactures are included in table 30.

In some situations with very old equipment, the make and model of the pneumatic instrument may not be available. In the case that the make and model cannot be determined by visual examination of the instrument, the generic emission rates in table 21 may be used.

Table 21. Generic emission rates for pneumatic instruments if make and model are unavailable (from Clearstone 2018b)

Type of pneumatic instrument	Emission rate (m^3 vent gas/hr)
Level controller	0.3508
Positioner	0.2627
Pressure controller	0.3217
Transducer	0.2335
Generic pneumatic instrument	0.3206

4.4.2 Pneumatic Pumps

Table 22 has been taken from Prasino 2013 and can be used with equation 11 to determine pneumatic pump average emission rates when the supply pressure, discharge pressure, and strokes per minute are available. The average emission rate for pneumatic pumps can be calculated using equation 11.

$$ER_P = (g \times SP) + (n \times DP) + (p \times SPM) \tag{11}$$

ER_P the average emission rate specific to the make, model, and operating conditions of the pump [m^3 vent gas/hour]

g supply pressure coefficient for the specific make and model of pump, from table 22 [m^3/hr/kPa gauge]

SP supply pressure of the pump [kPa gauge]

n discharge pressure coefficient for the specific make and model of pump, from table 22 [m^3/hr/kPa gauge]

DP discharge pressure of the pump [kPa gauge]

p strokes per minute coefficient for the specific make and model of pump, from table 22 [m^3/hr/stroke per minute]

SPM the strokes per minute of the pump [strokes/minute]

Table 22. Coefficients for determining pneumatic pump emission rates (from Prasino 2013)

Pump type	Supply pressure coefficient (g)	Injection pressure coefficient (n)	Strokes per minute coefficient (p)
Diaphragm	0.00202	0.000059	0.0167
Piston	0.00500	0.000027	0.0091
Morgan HD312	0.00418	0.000034	0.0073
Texsteam 5100	0.00030	0.000034	0.0207

Williams P125	0.00019	0.000024	0.0076
Williams P250	0.00096	0.000042	0.0079
Williams P500	0.00224	−0.000031	0.0046

If the operating conditions are not known, table 23 may be used to determine average emission rates.

Table 23. Emission rates for pneumatic pumps if operating conditions are unavailable (from Prasino 2013)

Type of pump	Emission rate (m^3 vent gas/hr)
Morgan HD312	1.1292
Texsteam 5100	0.9670
Williams P125	0.4098
Williams P250	0.8022
Williams P500	0.6969

Pneumatic pump manufacturers commonly publish charts and graphs in product brochures that can be used to determine the air or gas consumption for each make and model of pump and for a variety of operating conditions. The following method (equations 12 and 13) was derived from multiple manufacturer brochures to simplify the process of determining emission rates from manufacturer brochures. Duty holders may choose to use the following equations or to determine pneumatic pump emission rates directly from manufacturer-specified material.

$$V_{PP} = ER_{PM} \times L \quad (12)$$

VPP volume of vent gas from pneumatic pumps at a site in a month [m^3]

ER_{PM} emission rate of gas-driven pneumatic pumps, shown in equation 14 [m^3 vent gas/litre]

L monthly volume of liquid injected by the pump [litres]

$$ER_{PM} = (P_2 \times CIP^2) + (P_1 \times CIP) + P_0 \quad (13)$$

CIP chemical injection pressure [kPa gauge]

P_2 P_2 coefficient, provided in table 31 [dimensionless]

P_1 P_1 coefficient, provided in table 31 [dimensionless]

P_0 P_0 coefficient, provided in table 31 [dimensionless]

If the preceding options are not available because the make and model of the pneumatic pump is unknown, the emission rates for generic devices shown in table 24 can be used.

Table 24. Emission rates for pneumatic pumps if operating conditions are unavailable (from Prasino 2013)

Type of pump	Emission rate (m^3 vent gas/hr)
Generic piston pump	0.5917
Generic diaphragm pump	1.0542

4.5 Compressor Seals

Reciprocating and centrifugal compressor types have seals that exhaust gas as part of normal operation and, if vented to atmosphere, should be quantified according to this section.

Operators must calculate and record compressor seal vent gas per site per month. As per section 8.4.1 of *Directive 060*, compressor seal vent gas is reported to OneStop by reporting facility ID or CS facility ID annually. When operators report VENT to Petrinex on a monthly basis, compressor seal vent gas is a component of this volume as detailed in section 2.1 of this manual.

Vent gas associated with other compressor types (screw, scroll, etc.) are included under DVG and categorized as other routine venting and not compressor seals. Blowdowns of compressor pistons, volutes, cases, or cavities are nonroutine. Pneumatic gas-driven engine or turbine starters are considered nonroutine and not part of compressor seal venting. For controlled reciprocating compressors, crankcase vents are considered fugitive emissions. When a compressor seal vent control is not operating, compressor seal vents are considered nonroutine vents.

4.5.1 Reciprocating Compressors

Emissions from a reciprocating compressor seal (RCS) occur as part of normal operation when the process gas in the cylinder head migrates through the piston-rod packing and into piston-rod-packing vent and drain, distance piece vent and drain, or the compressor crankcase vent. Emissions from reciprocating compressors whose distance piece vent and drains and piston-rod packing vent and drains are tied to a control device are not required to test their vents, and emissions from the compressor crank case in this circumstance are considered as fugitive emissions.

Vent gas from reciprocating compressors is calculated using equation 9, where the emission rate is from RCS for a given reciprocating compressor [m^3 vent gas/hour] and the time is the pressurized hours in a month for a reciprocating compressor [hours].

Refer to *Directive 060* for compressor seal testing and reporting requirements. To determine the emission rate from an RCS based on periodic testing, the rate is calculated from all the throws of the unit and all potential venting paths. RCS vent and drain systems can be piped in a variety of ways. Figure 5 shows an example of a typical RCS vent and drain system. For this example, it is a four-throw compressor, and figure 5 is a close-up of one of the throws (the other throws are tied into a common drain and vent). The purpose of figure 5 is to help visualize that the RCS emission rate is a combination of all potential venting paths (1, 2, and 3) from the crank end to the head end. For further guidance on procedures for periodic testing of compressor seals, see *CSAZ620.2: Compressor Seal Vent Gas Flow Rate Testing and Recording.*

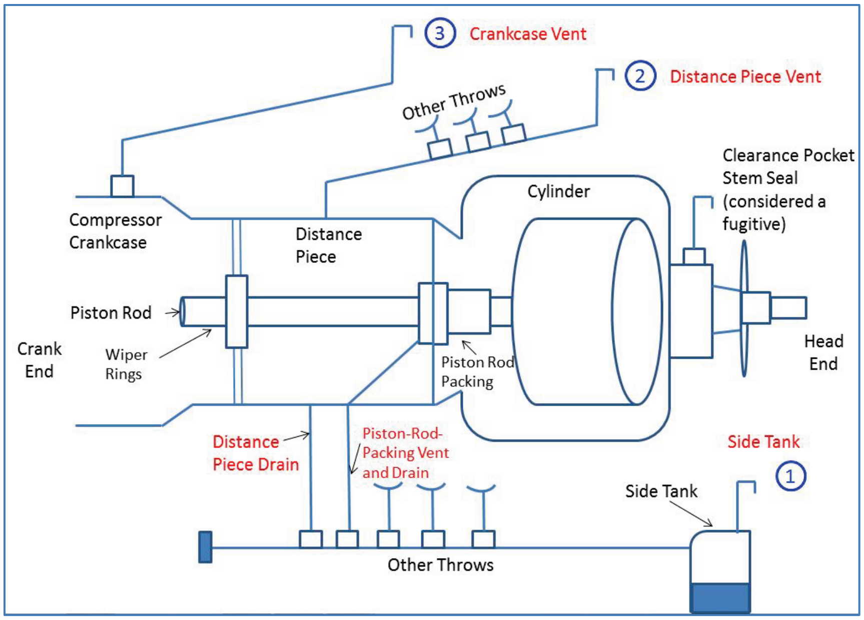

Figure 5. Typical RCS vent and drain system

If a compressor piston-rod packing is replaced on one throw of an RCS *after* a test is completed, venting from that throw can be estimated by following the guidance outlined in section 4.1. If an average emission rate is used, a value of 0.04 m^3 vent gas per hour per throw (from Advisian 2019) can be used until the next test is completed. This value was chosen as it is assumed that a new seal performs similarly to the lowest 25% of measurements analyzed within the Advisian study.

4.5.2 Centrifugal Compressors

Emissions from centrifugal compressor seals occur as part of normal operation when the process gas migrates through the seal at the drive shaft and compressor case interface. Centrifugal compressors have seals that are either wet or dry. Equation 9 may be used to estimate centrifugal compressor seal vents, where the emission rate is from a centrifugal compressor seal [m^3 vent gas/hour] and time is pressurized hours in a month for a centrifugal compressor [hours].

Refer to *Directive 060* for compressor seal testing and reporting requirements. To determine the emission rate from a centrifugal compressor based on periodic testing, the rate is calculated from all potential venting paths from the unit. For further guidance on procedures for periodic testing of compressor seals, see *CSAZ620.2: Compressor Seal Vent Gas Flow Rate Testing and Recording*.

If a centrifugal compressor seal is replaced after a test is completed, venting from that seal can be estimated by following the guidance outlined in section 4.1.

4.6 Glycol Dehydrators

Glycol dehydrators use circulating glycol at varying pressures and temperatures to absorb moisture from process gas and release it, along with other absorbed chemicals, in a reboiler. Glycol dehydrator vent gas emissions include the following:

- Glycol dehydrators flash tank vents, and reboiler still column vents (including glycol regenerators operating as refrigeration units)
- Gas vent resulting from the use of energy exchange pumps that pump glycol in glycol dehydrators

Desiccant dehydrator or membrane type dehydrator emissions are not included in this category and instead be reported as DVG. When a glycol dehydrator vent control is not operating, glycol dehydrator vents are considered nonroutine. Glycol dehydrator vent gas emissions are determined as required by *Directive 039*. Vent gas volumes from glycol dehydrators are included in the monthly reporting of vent gas to Petrinex.

4.7 Fugitive Emissions

Fugitive emissions are unintentional releases of hydrocarbons to the atmosphere. They include

- component-based leaks that result from wear or failure,
- abnormal process fugitive emissions or malfunctioning equipment, and
- surface casing vent flows and gas migration.

Directive 060 defines acceptable detection methods for fugitive emissions for certain sites based on the risk of fugitive emissions from that site type. Quantification methods are linked to the detection methods used. The detection methods, along with the corresponding approach for quantifying the fugitive emission volumes, are shown in the following table.

Emission rates for fugitive emissions may be determined following the guidance outlined in section 4.1 or through the quantification methods listed in this section. The AER acknowledges that new publications with updated average emission rates for fugitive emissions will become available over time, and we encourage the use of more accurate information as it becomes available.

Table 25. Fugitive emission detection and quantification methods

Detection method	Quantification method
Direct measurement of the whole facility	The total quantified volume minus the estimated vent gas volume for the site
Surveys completed using a gas imaging infrared camera or Screenings using audio, visual, or olfactory methods; soap solution; or other methods capable of detecting fugitive emissions	Leaking components: • Directly measured • Estimated using leaker rates as per section 4.7.2 Abnormal process conditions: • Determined using engineering estimates Surface casing vent flow / gas migration (SCVF/GM) tested and reported as per *Directive 087*
Surveys completed using organic vapour analyzers in accordance with EPA's Method 21 (US EPA 2017)	Leaking components: • Directly measured • Estimated using published emission rates – Three-stratum emission rates – Published leak-rate correlation – Unit-specific leak-rate correlation – Leaker rates as per section 4.7.2 Abnormal process conditions: • Determined using engineering estimates SCVF/GM quantified and reported as per *Directive 087*

4.7.1 Sites with Whole-Facility Direct Measurement

Whole-facility direct measurement assess total methane emissions from specific process areas or entire facilities and includes technologies such as sensors mounted on site or mobile tracer release methods. They can be an economical means of determining total methane emissions from large facilities (e.g., multiunit compressor stations). While this method is likely to provide an accurate volume of total methane emissions, it may not be useful for detecting the precise source of an emission. This detection and quantification method should therefore be considered most useful to confirm that a site is emitting below the lower detection limit of the applied technology and provides quantifiable evidence of such. If leaks are detected, *Directive 060* requires the source be repaired, and another detection method would likely be required to localize it.

For sites that use direct measurement options that quantify whole-site emissions (fugitive emissions and vent gas), the vented emissions will have to be subtracted from the whole-site emissions. This will eliminate potential double counting and ensure that the reported emission rate is reflective of the fugitive emission volume only.

4.7.2 Sites with Fugitive Emission Surveys or Screenings

The annual fugitive emission volume at a facility ID or linked UWI or CS is the sum of all monthly fugitive emission volumes from leaking components and abnormal process events. Fugitive emissions from leaking components that are identified through qualitative means (soap test, OGI camera, etc.) are estimated using equation 9, where the emission rate is for a leaking component [m^3 vent gas/ hour] and the time is duration of the leak [hrs].

If the duration is unknown, half the time between the previous survey at the same facility ID and the repair date may be used. If there was no previous survey, use a duration of 8760 hrs. If the component or leak was not repaired in the reporting period, use the last day of the reporting period as the end date for the volume reported for that year. In the subsequent reporting year, report the leak as a new leak with a duration lasting from the start of the year to the repair date.

Emission rates for leaking components may be determined following the guidance outlined in section 4.1. Direct measurement options may include calibrated bags, high flow sampler, tracer techniques, or other commercially available quantification options. Alternatively, fugitive emission leak factors in table 32 may be used to estimate emissions from leaks detected but not measured.

Emissions from abnormal process fugitive emissions are commonly linked to hydrocarbon storage tanks. Hydrocarbon storage tanks have been identified as significant methane emission contributors in top-down emission surveys. The following lists other examples of abnormal process vents:

- Unlit flares (ignitors and pilots)
- Malfunctioning pneumatic instruments (e.g., level controller venting excessively in its static-state due to controller almost calling for a dump but not enough liquid present in the separator)
- Conservation units out of operation when they are expected to be in operation (such as vapour recovery units that are not running)
- Emissions occurring from equipment components located upstream of equipment that is actively controlling vent gas.

Abnormal process fugitive emissions should be directly measured or determined through engineering estimates.

4.7.3 Fugitive Emission Surveys Using Organic Vapour Analyzers and EPA Method 21

Organic vapour analyzer (OVA) surveys and EPA Method 21 (US EPA 2017) refer to individually inspecting each component at a site that has the potential to emit fugitive emissions.

In this section, fugitive emissions can be calculated using equation 14.

$$V_{FE-S} = V_L + V_{AP} \tag{14}$$

$V_{FE\text{-}S}$	Fugitive emission volume from surveys at a site in a year [m^3]
V_L	Fugitive emission volumes found in fugitive emission surveys for leaks at a site in a year [m^3], can be determined using the following techniques: • Three-stratum emission rates • Published leak-rate correlation • Unit-specific leak-rate correlation • Leaker emission rates, as per section 4.7.2
V_{AP}	Fugitive emission volume from abnormal process fugitive emissions in a year [m^3]

SCVF/GM must be tested and reported in accordance with *Directive 087*, and fugitive emission volumes associated with SCVF/GM are not included in OneStop reporting.

4.7.3.1 Three-Stratum Emission Rates

The three-stratum emission rate method (CAPP 1992) categorizes leaks into three ranges (the strata): between 0 to 1000 ppm, between 1001 to 10 000 ppm, and over 10 000 ppm. A zero screening value means that the true screening value of the source is below the detectable limit of the vapour analyzer used.

$$\mathrm{V}_L = \sum_{j=1}^{J}\sum_{i=1}^{I}\{[(n_{Leak,1} \times ER_{Leak,1,i,j} \times t_{Leak,1}) + (n_{Leak,2} \times ER_{Leak,2,i,j} \times t_{Leak,2}) + (n_{Leak,3} \times ER_{Leak,3,i,j} \times t_{Leak,3})]/(\rho_{gas})\} \tag{15}$$

V_L	fugitive emission volume from leaks from three-stratum emission rates method [m^3]
i	Component type identifier (e.g., valves, open-ended lines, pump seals, connectors)
j	Service identifier (e.g., sweet process gas, sour process gas, light liquid)
I	Number of component types in facility
J	Number of services in facility operation
$n_{leak,1}$	Number of leaks for components of type i in service j for screening concentrations between 0 to 1000 ppm
$n_{leak,2}$	Number of leaks for components of type i in service j for screening concentrations between 1001 to 10 000 ppm
$n_{leak,3}$	Number of leaks for components of type i in service j for screening concentrations over 10 000 ppm
$ER_{Leak,1,i,j}$	Leak emission rate (kg THC/h/source) for components of type i in service j for screening concentrations between 0 to 1000 ppm from table 26

$ER_{Leak,2,i,j}$ Leak emission rate [kg THC/h/source] for components of type i in service j for screening concentrations between 1001 to 10 000 ppm from table 26

$ER_{Leak,3,i,j}$ Leak emission rate [kg THC/h/source] for components of type i in service j for screening concentrations over 10 000 ppm from table 26

$t_{leak,1}$ Time that component of type i in service j for screening concentrations between 0 to 1000 ppm is leaking [hours/year]

$t_{leak,2}$ Time that component of type i in service j for screening concentrations between 1001 to 10 000 ppm is leaking [hours/year]

$t_{leak,3}$ Time that component of type i in service j for screening concentrations over 10 000 ppm is leaking [hours/year]

ρ_{gas} the density of the vent gas at standard temperature and pressure (15°C and 101.325kPa(a)) [kg/m^3]

If the duration is unknown, half the time between the previous survey at the same site and the repair date may be used. If there was no previous survey, use a duration of 8760 hrs. If the component or leak was not repaired in the reporting period, use the last day of the reporting period as the end date for the volume reported for that year. In the subsequent reporting year, report the leak as a new leak with a duration lasting from the start of the year to the repair date.

The table below provides emission rates for common component types at different leak detection strata.

Table 26. Three-stratum emission rates for estimating equipment leaks (from CAPP 1992)

Component	Production type	Service type	0–1000 ppm (kg THC/h/source)	1000–10 000 ppm (kg THC/h/source)	>10 000 ppm (kg THC/h/source)
Valve	Gas	Sweet gas, gas/vapour	0.00012	0.00242	0.26260
		Sour gas, gas/vapour	0.00006	0.00211	0.26260
		Light liquid	0.00074	0.00596	0.08520
	Oil	Gas/vapour	0.00006	0.00158	0.26260
		Light liquid	0.00053	0.00638	0.08520
Connector	Gas	Sweet gas, gas/vapour	0.00031	0.01330	0.03750
		Sour gas, gas/vapour	0.00015	0.01111	0.03750
		Light liquid	0.00031	0.00658	0.03750
	Oil	Gas/vapour	0.00018	0.00877	0.03750
		Light liquid	0.00013	0.00658	0.03750
Pump seals	All	Light liquid	0.00023	0.00406	0.43700
Pressure relief devices	All	Gas/vapour	0.00019	-	1.69100
Open-ended lines	All	All	0.00034	0.00860	0.01195

4.7.3.2 Published Leak-Rate Correlation

Leak-rate correlations is a method to create the component THC leak rate (kg/h) corresponding to the individual screening value of a given component type at a given service. This approach is a considerable refinement over the available emission-factor methods in which constants are applied over discrete ranges of screening values.

$$\mathrm{V}_F = \sum_{j=1}^{J} \sum_{i=1}^{I} \left[\left(n_{i,j} \times ER_{THC,i,j} \times t_{i,j} \right) / (\rho_{gas}) \right] \tag{16}$$

The correlations are given by a two-constant relation of the form given below.

$$ER_{THC,i,j} = e^{[B_0 + B_1 \log(SV)]} \tag{17}$$

V_F	Fugitive emission volume from published leak-rate correlation method [m^3]
$n_{i,j}$	Number of leaks for components of type *i* in service *j*
$t_{i,j}$	Time the component *i* at service *j* is leaking [hrs]
$ER_{THC,i,j}$	THC emission rate for a component type *i* at service *j* [kg THC/h]
B_0, B_1	Constants as shown in table 27
SV	Maximum screening value above background measured using a detector calibrated to methane [ppmv]
ρ_{gas}	The density of the vent gas at standard temperature and pressure (15°C and 101.325 kPa(a)) [kg/m^3]

If the duration is unknown, half the time between the previous survey at the same site and the repair date may be used. If there was no previous survey, use a duration of 8760 hrs. If the component or leak was not repaired in the reporting period, use the last day of the reporting period as the end date for the volume reported for that year. In the subsequent reporting year, report the leak as a new leak with a duration lasting from the start of the year to the repair date.

The constants for upstream oil and gas facilities are presented in table 27.

Table 27. Correlation parameters for estimating leak rates from equipment components at upstream oil and gas facilities (from CAPP 1992)

Source	Service	B_0	B_1
Valves	Gas/vapour	−5.12	0.693
Valves	Light liquid	−3.77	0.47
Flanges	All	−4.77	0.82
Pump seals	All	−5.22	0.898

4.7.3.3 Unit-Specific Leak-Rate Correlation

If using the correlation equations from section 4.7.3.2, some duty holders may wish to develop unit-specific leak-rate correlations to achieve better accuracy for their particular operations.

To develop a leak-rate correlation, it is necessary to compile a reasonable number of data points to cover the desired screening range for each source and service category. Refer to US EPA (1995) when developing unit-specific leak-rate correlations.

Appendix 1 References

Advisian. 2019. *Compressor Seal Vent and Maintenance Study*. Prepared on behalf of the Alberta Energy Regulator.

Canada. 2016. *Guide for Reporting to the National Pollutant Release Inventory (NPRI) – 2016 and 2017*. https://www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory/publications/guide.html.

Clearstone (Clearstone Engineering). 1992. *CH_4 and VOC Emissions from the Canadian Upstream Oil and Gas Industry*. Four volumes. Prepared on behalf of the Canadian Association of Petroleum Producers (CAPP).

Clearstone (Clearstone Engineering). 2018a. *Development of Updated Emission Factors for Process Analyzer Venting*. Prepared on behalf of the Canadian Energy Partnership for Environmental Innovation (CEPEI).

Clearstone (Clearstone Engineering). 2018b. *Update of Equipment, Component and Fugitive Emission Factors for Alberta Upstream Oil and Gas*. Prepared on behalf of the Alberta Energy Regulator (AER). https://static.aer.ca/prd/documents/UpdateofEquipmentComponentandFugitiveEmissionFactorsforAlber-1.pdf.

Government of Alberta. 2017. *Quantification Protocol For Greenhouse Gas Emission Reductions From Pneumatic Devices (Version 2.0)*. https://open.alberta.ca/publications/9781460131633.

Greenpath (Greenpath Energy Ltd). 2018. *Level Controller Emission Study Fisher L2 and Improved Relays, Norriseal 1001A and EVS*. Prepared on behalf of the Alberta Upstream Petroleum Research Fund (AUPRF). http://auprf.ptac.org/wp-content/uploads/2018/10/Final-Report-Level-Controller-V8-20181003.pdf.

Prasino Group. (2013). *Final Report: Determining Bleed Rates for Pneumatic Devices in British Columbia*. Calgary, AB. http://www.bcogris.ca/sites/default/files/ei-2014-01-final-report20140131.pdf.

Spartan Controls. 2018. *Pneumatic Vent Gas Measurement*. Prepared on behalf of Alberta Upstream Petroleum Research (AUPR). http://auprf.ptac.org/wp-content/uploads/2018/05/Pneumatic-Vent-Gas-Measurement.pdf.

US EPA (United States Environmental Protection Agency). 1995. *Protocol for Equipment Leak Emission Estimates*. https://www3.epa.gov/ttnchie1/efdocs/equiplks.pdf.

US EPA. 2006. *Emission Factor Documentation for AP-42: Section 7.1; Organic Liquid Storage Tanks, - Chapter 7 Update Final Report.* Washington, DC. https://www3.epa.gov/ttn/chief/ap42/ch07/final/ch07s01.pdf.

US EPA. 2008. "Transportation and Marketing of Petroleum Liquids." In *AP-42: Compilation of Air Emission Factors*, 5th ed., vol. 1, sec. 5.2. Washington, DC. https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors.

US EPA. 2017. *Method 21 – Determination of Volatile Organic Compound Leaks*. https://www.epa.gov/emc/method-21-volatile-organic-compound-leaks.

Vazquez, M. and H. Beggs. 1980. "Correlations for Fluid Physical Property Prediction." *Journal of Petroleum Technology* 32, no. 6: 968–970.

WCI (Western Climate Initiative). 2011. *Final Essential Requirements for Mandatory Reporting: 2011 Amendments for Harmonization of Reporting Canadian Jurisdictions*. https://www2.gov.bc.ca/assets/gov/environment/climate-change/ind/quantification/wci-2012.pdf.

Appendix 2 Tables

Table 28. Pneumatic starter natural gas consumption rate for turbines

Turbine		Pneumatic starter				
					Natural gas consumption rate*	
Manufacturer	Model	Manufacturer	Model	Supply pressure (kPa_g)	(m^3 vent gas/min)	(m^3 vent gas/hr)
Allison	501-KB 501-KC	Ingersoll Rand	TS799B	1 034	80	4 822
		Tech Development	56K (low pressure)	345	33	1 954
			56K (standard pressure)	621	55	3 288
	570	Ingersoll Rand	TS799G	621	51	3 068
Dresser Clark	DC990	Tech Development	56B (low pressure)	345	36	1 954
			56B (standard pressure)	1 034	86	5 172
Dresser-Rand	DR990 DJ50	Tech Development	56B (low pressure)	345	36	1 954
			56B (standard pressure)	1 034	86	5 172
Garrett	IE831	Ingersoll Rand	TS999G	621	47	2 849
General Electric	LM500 LM1000 LM1600 LM2500 LM5000 LM6000	Tech Development	56G (low pressure)	345	33	1 954
			56G (standard pressure)	1 034	86	5 172
Pratt & Whitney	GG3/F13 GG4/G14	Ingersoll Rand	TS799B	1 034	80	4 822
	GG3 GG4 FT4 FT8	Tech Development	56A (low pressure)	345	33	1 954
			56A (standard pressure)	1 034	86	5 172
Rolls Royce	AVON SPEY	Tech Development	56A (low pressure)	345	33	1 954
			56A (standard pressure)	1 034	86	5 172

Turbine		Pneumatic starter				
					Natural gas consumption rate*	
Manufacturer	Model	Manufacturer	Model	Supply pressure (kPa_g)	(m^3 vent gas/min)	(m^3 vent gas/hr)
Solar Turbines	Saturn 20	Ingersoll Rand	TS725	1 551	27	1 644
			TS750	1 034	44	2 652
		Tech Development	56S	1 034	29	1 725
	Centaur 40 Centaur 50 Taurus 60 Taurus 65 Taurus 70	Ingersoll Rand	TS1401-102	1 551	62	3 726
			TS1435	1 551	69	4 164
			TS1450	1 034	91	5 479
		Tech Development	T100C	1 034	64	3 844
	Mars 90 Mars 100	Recommended by Solar Turbines		2 758	127	7 620

* Consumption rates are from manufacture specifications. Vendors typically assume compressed air is used as the working medium when reporting flow rate requirements. Thus, air consumption rates have been multiplied by 1.29 for equivalent natural gas consumption rates.

Table 29. Pneumatic starter natural gas consumption rate for reciprocating engines

Reciprocating engine		Pneumatic starter				
					Natural gas consumption rate*	
Manufacturer	Model	Manufacturer	Model	Supply pressure (kPa_g)	(m^3 vent gas/min)	(m^3 vent gas/hr)
Caterpillar	G3406	Austart	ATS63	1 034	16	964
	G342 G379 G3412	Austart	ATS73	1 034	22	1 293
	G399	Austart	ATS83	1 034	22	1 293
	G3612 G3616	Austart	ATS93	1 034	48	2 871
	G3616	Austart	ATS103	1 034	56	3 353
	G-342	Ingersoll Rand	150BM	1 034	25	1 490
	G3516	Ingersoll Rand	ST599	1 034	45	2 718
			ST950	1 034	47	2 849
	G3616	Ingersoll Rand	ST950	1 034	47	2 849
	G3612 G3616 G-398 G-399	Ingersoll Rand	SS815	1 034	62	3 726
	G3406 G3408 G3408C	Tech Development	T306-I	827	17	1 048
	G3606		T112-V	1 034	54	3 226

Reciprocating engine		Pneumatic starter				
					Natural gas consumption rate*	
Manufacturer	Model	Manufacturer	Model	Supply pressure (kPa_g)	(m^3 vent gas/min)	(m^3 vent gas/hr)
	G3608 G3612 G3616 C280	Tech Development	T121-V	621	59	3 520
Cooper Ajax	DPC-140 DPC-180	Austart	ATS73	1 034	22	1 293
	DPC-360 DPC-600	Austart	ATS83	1 034	22	1 293
	DP-125 DP-165 DPC-180 DPC-60	Ingersoll Rand	150BM	1 034	25	1 490
	DPC-280 DPC-230 DPC-250 DPC-325 DPC-360 DPC-600 DPC-800	Tech Development	T112-B	621	57	3 419
			T121-B	1 034	5	298
Cooper Bessemer	GMX GMSC	Austart	ATS93	1 034	48	2 871
			ATS103	1 034	56	3 353
	10W330 12V-250 GMVA GMVW MVWC GMXF	Ingersoll Rand	ST950	1 034	47	2 849
	GMXE GMXF GMXH	Ingersoll Rand	SS850	1 034	47	2 794
Cooper Superior	6G-825 8G-825 8GT	Austart	ATS83	1 034	22	1 293
	12SGT 16SGT	Austart	ATS93	1 034	48	2 871
	825 Series 1700 Series 2400 Series	Tech Development	T112-V	1 034	54	3 226
			T121-V	621	59	3 520
Dresser-Rand	512KV PSVG-12	Ingersoll Rand	ST950	1 034	47	2 849
Int Harvester	RD372 RD450	Ingersoll Rand	3BMG	1 034	12	712

Reciprocating engine		Pneumatic starter				
					Natural gas consumption rate*	
Manufacturer	Model	Manufacturer	Model	Supply pressure (kPa_g)	(m^3 vent gas/min)	(m^3 vent gas/hr)
Wartsila	34SG	Ingersoll Rand	ST775	1 034	47	2 849
Waukesha	H24L	Austart	ATS73	1 034	22	1 293
	5790 7042 8LAT27G	Austart	ATS83	1 034	22	1 293
	P9390G 12VAT27G 16VAT25G	Austart	ATS93	1 034	48	2 871
	12VAT27G 16VAT25G 16VAT27G	Austart	ATS103	1 034	56	3 353
	145GZ 6GAK 6WAK F1197G F119G H1077G H1077G H24L H867D	Ingersoll Rand	150T	1 034	26	1 556
	2895G (SI/L) H24GL (D) 12VAT25GL 16VAT25GL 7042 (SI/L) 8LAT27GL F2895 F3521 L36GL (D) L7040G P9390G	Ingersoll Rand	ST950	1 034	47	2 849
	12VAT25GL F2895 F3521 L36GL (D)	Ingersoll Rand	ST999	1 034	62	3 726
	195GL 6BL V1K V1L VRG283 VRG310	Ingersoll Rand	3BMG	1 034	12	712

Reciprocating engine Manufacturer	Reciprocating engine Model	Pneumatic starter Manufacturer	Pneumatic starter Model	Supply pressure (kPa_g)	Natural gas consumption rate* (m^3 vent gas/min)	Natural gas consumption rate* (m^3 vent gas/hr)
	140GZ 140HK 6SRK	Ingersoll Rand	5BMG	1 034	11	679
	6SRB	Ingersoll Rand	SS175G	1 034	18	1 096
	F11G (SI) F18GL (D) H24GL (D)	Ingersoll Rand	SS350G	1 034	33	1 973
	145GZ 6GAK 6WAK F1197G F119G H1077G H24L	Ingersoll Rand	150BM	1 034	25	1 490
	7044 7042G (SI/L) 8LAT25D 8LAT25GLF2895G (SI) F3521G (SI)	Ingersoll Rand	SS815	1 034	62	3 726
	12VAT27GL 16AT27GL 16VAT25GL P9390G	Ingersoll Rand	SS825	1 034	49	2 959
	L5788 L5040 L7042G L7044G	Tech Development	T112-B	621	57	3 419
			T121-B	1 034	5	298
	8LAT27G 12VAT25G 12VAT27G 16VAT27G P9390G	Tech Development	T112-V	1 034	54	3 226
			T121-V	621	59	3 520
White	RXC RXLD RXLX TDXC	Ingersoll Rand	5BMG	1 034	11	679

* Consumption rates are from manufacture specifications. Vendors typically assume compressed air is used as the working medium when reporting flow rate requirements. Thus, air consumption rates have been multiplied by 1.29 for equivalent natural gas consumption rates.

Table 30. Manufacturer-specified emission rates for pneumatic instruments (developed from Government of Alberta 2017)

Description	Manufacturer and model	Supply pressure (psi)	Average sampled vent rate (m^3 vent gas/hr)
Pressure controllers	Ametek Series 40	20	0.22
		35	0.22
	Bristol Babcock Series 5453-Model 10F	20	0.11
		35	0.11
	Bristol Babcock Series 5455-Model 624-III	20	0.07
		35	0.11
	Bristol Babcock Series 502 A / D (recording controller)	20	0.22
		35	0.22
	Dynaflo 4000LB	20	0.06
		35	0.09
	Fisher 4100 Series (Large Orifice)	20	1.83
		35	1.83
	Fisher 4194 Series (Differential Pressure)	20	0.13
		35	0.18
	Fisher 4195	20	0.13
		35	0.18
	Foxboro 43AP	20	0.66
		35	0.66
	ITT Barton 338	20	0.22
		35	0.22
	ITT Barton 335P	20	0.22
		35	0.22
	Natco CT	20	1.28
		35	1.28
Transducers	Bristol Babcock Series 9110-00A	20	0.02
		35	0.02
	Fisher i2P-100LB	20	0.08
		35	0.11
	Fisher 646	20	0.11
	Fisher 846	20	0.44
Level controllers	Dynaflo 5000	20	0
		35	0
	Fisher 2660 Series	20	0.03
		35	0.04
	Fisher 2100 Series	20	0.03
		35	0.04
	Invalco CT Series	20	0.05
		35	1.46
	Wellmark 2001	20	0.01
		35	0.01
Positioners	Fisher 3582	20	0.51
		35	0.66

Description	Manufacturer and model	Supply pressure (psi)	Average sampled vent rate (m^3 vent gas/hr)
	Fisher 3661	20	0.32
		35	0.44
	Fisher 3590 (electro-pneumatic)	20	0.88
		35	1.32
	Fisher 3582i (electro-pneumatic)	20	0.63
		35	0.88
	Fisher 3620J (electro-pneumatic)	20	0.66
		35	1.28
	Fisher 3660	20	0.22
		35	0.29
	Fisher FIELDVUE DVC5000	20	0.37
		35	0.55
	Masoneilan SVI Digital	20	0.04
		35	0.04
	Moore Products – Model 750P	20	0.00
		35	1.53
	Moore Products – 73 – B PtoP	20	1.32
		35	0.00
	PMV D5 Digital	20	0.04
		35	0.04
	Sampson 3780 Digital	20	0.04
		35	0.04
	Siemens PS2	20	0.04
		35	0.04
	VRC Model VP7000 PtoP	20	0.04
		35	0.04

Table 31. Emission rates for pneumatic pumps derived from manufacturer specifications

Manufacturer	Model	Plunger diameter (in.)	Stroke length (in.)	P_2 coeff.	P_1 coeff.	P_0 coeff.
ARO	66610	120 psi supply		0	8.579E−06	7.700E−03
Arrow	12	0.25	0.5	0	3.008E-05	1.262E-01
		0.25	1	0	1.473E-05	6.181E-02
		0.5	0.5	0	3.068E-05	3.090E-02
		0.5	1	0	1.534E-05	1.545E-02
	13	0.25	0.5	0	3.273E-05	9.302E-02
		0.25	1	0	1.603E-05	4.556E-02
Bruin	BR 5001	0.25	0.5	0	2.448E−05	4.603E+00
		0.25	1.25	0	9.530E−06	1.848E+00
	BR 5003	0.375	0.5	0	2.467E−05	2.049E+00
		0.375	1.25	0	9.615E−06	8.266E−01
	BR 5005	0.5	0.5	0	2.474E−05	1.133E+00
		0.5	1.25	0	9.731E−06	4.711E−01
	BR 5006	0.75	0.5	0	2.480E−05	5.102E−01
		0.75	1.25	0	9.899E−06	2.042E−01
	BR 5007	1	0.5	0	2.480E−05	2.868E−01
		1	1.25	0	9.932E−06	1.150E−01
	BR 5008	1.25	0.5	0	2.496E−05	1.821E−01
		1.25	1.25	0	9.923E−06	7.243E−02
	BR 5104	0.1875	1	0	9.905E−06	2.054E+00
		0.1875	0.33	0	2.984E-05	6.030E+00
	BR 5101	0.25	1	0	1.005E−05	1.155E+00
		0.25	0.33	0	2.950E-05	3.390E+00
	BR 5103	0.375	1	0	1.009E−05	5.137E−01
		0.375	0.33	0	2.950E-05	1.512E+00
	BR 5105	0.5	1	0	1.008E−05	2.887E−01
		0.5	0.33	0	3.017E-05	8.467E-01
CheckPoint	1250	0.125	0.94	2.360E−10	2.278E−05	1.184E+00
		0.25	0.94	2.224E−10	1.129E−05	2.773E−01
		0.375	0.94	1.255E−10	1.224E−05	1.025E−01
		0.5	0.94	−1.266E−12	1.190E−05	7.104E−02
	1500	0.5	1	4.069E−11	2.733E−05	5.143E−01
		0.75	1	1.335E−10	1.945E−05	1.729E−01
		1	1	−9.817E−11	2.083E−05	1.123E−01
	LPX-04	0.25		0	0	3.464E−01
	LPX-08	0.125		0	0	1.409E+00
Linc	84T-10-x1	0.1875	1	0	1.513E−05	3.872E−01
	84T-11-x1	0.25	1	0	1.071E−05	1.646E−01
	84T-11-x2	0.25	1	0	1.190E−05	2.925E−01
	84T-12-x2	0.5	1	0	1.190E−05	7.313E−02
	84T-12-x4	0.5	1	0	1.058E−05	1.300E−01
	84T-14-x4	1	1	0	1.134E−05	3.250E−02
	87TA-11-x1	1	1	0	9.921E−06	8.545E−02
	85T-11	0.25	1	0	1.498E−05	1.648E−01
	85T-12	0.5	1	0	1.512E−05	7.393E−02
Morgan	HD187-3K-TR2		0.5	−3.059E−11	5.192E−05	3.526E−01

Manufacturer	Model	Plunger diameter (in.)	Stroke length (in.)	P_2 coeff.	P_1 coeff.	P_0 coeff.
	HD187-TR2		0.5	−1.049E−09	7.424E−05	2.494E−03
	HD312-3K-TR2		1	−4.013E−25	2.558E−05	1.058E−01
	HD312-K5-TR2		1	−2.368E−12	2.545E−05	2.546E−01
	HD312-TR2		1	2.655E−09	2.198E−05	−3.868E−03
SandPiper	G05	0.5		7.635E−09	2.563E−05	6.379E−03
	SB-1 and SB-25	1		3.226E−08	−1.070E−05	7.688E−03

Manufacturer	Model	Plunger diameter (in.)	Stroke length (in.)	P_2 coeff.	P_1 coeff.	P_0 coeff.
Texsteam	5002	0.25	0.5	−1.949E−10	5.935E−05	5.222E+00
		0.25	1.25	−2.601E−11	2.817E−05	2.087E+00
	5003	0.375	0.5	−1.078E−11	1.399E−05	2.652E+00
		0.375	1.25	−1.075E−11	1.398E−05	1.044E+00
	5004	0.75	0.5	−4.756E−10	4.049E−05	6.351E−01
		0.75	1.25	−2.109E−10	2.697E−05	2.495E−01
	5005	0.5	0.5	−1.160E−13	1.303E−05	1.496E+00
		0.5	1.25	3.412E−26	1.302E−05	5.985E−01
	5006	1	0.5	−1.293E−25	1.302E−05	3.741E−01
		1	1.25	1.666E−25	1.302E−05	1.496E−01
	5007	1.25	0.5	−7.148E−25	1.302E−05	2.394E−01
		1.25	1.25	−1.293E−25	1.302E−05	9.726E−02
	5101	0.25	0.33	1.499E−09	6.724E−05	5.467E+00
		0.25	1	4.995E−10	2.241E−05	1.822E+00
	5103	0.375	0.33	1.202E−11	1.471E−04	2.592E+00
		0.375	1	4.007E−12	4.902E−05	8.641E−01
	5104	0.1875	0.33	−1.076E−09	1.240E−04	9.996E+00
		0.1875	1	−3.851E−10	4.208E−05	3.330E+00
	5105	0.5	0.33	5.241E−11	3.741E−05	1.159E+00
		0.5	1	1.747E−11	1.247E−05	3.864E−01
	9001	30 psi supply		1.475E−08	8.510E−07	3.167E−03
		50 psi supply		1.102E−08	8.300E−07	4.553E−03
Timberline	2515		1	0	1.176E−05	5.212E−02
	2522		1	0	1.164E−05	9.879E−02
	2530		1	0	1.114E−05	1.627E−01
	5030		1	0	1.100E−05	5.155E−02
	5040		1	0	1.255E−05	3.346E−02
Western	DFF	0.375	0.875	0	1.636E−05	7.795E−01
	DFF	0.625	0.875	0	1.742E−05	3.097E−01
Wilden	P1 Metal	Rubber/PFTE fitted		3.286E−08	−1.261E−05	6.708E−03
Williams	CP125V125	1.25	1	0	0	7.716E−01
	CP250V225	2.25	1	0	0	6.173E−01
	CP250V300	3	1	0	0	1.138E+00
	CP500V225	2.25	1	0	0	1.531E−01
	CP500V300	3	1	0	0	2.822E−01
	CRP1000V4	4	1	0	0	1.224E−01
	CRP1000V6	6	1	0	0	2.472E−01
	CRP1000V8	8	1	0	0	4.360E−01
	CRP500V40	4	1	0	0	4.832E−01
	CRP750V40	4	1	0	0	2.227E−01

Table 32. Emission rates for estimating equipment leaks at upstream oil and gas (from Clearstone 2018b)*

Sector	Component type	Service	Leaking component emission rate (kg THC/h/source)
All	Connector	Process gas	0.13281
All	Connector	Light liquid	0.05906
All	Control Valve	Process gas	0.16213
All	Meter	Process gas	0.07201
All	Open-Ended line	Process gas	0.98904
All	Pressure relief valve	Process gas	0.69700
All	Pump seal	Process gas	0.23659
All	Regulator	Process gas	0.10275
All	Valve	Process gas	0.31644
All	Valve	Light liquid	0.23098

* If fugitive emissions are detected at equipment in heavy liquid service, apply the light liquid emission rate.

Appendix 3 Sample Calculations

In this appendix, there are sample calculations using hypothetical examples to walk through vent gas and fugitive emission estimates. We have included two sites (site A and B) to show how vent gas and fugitive emission volumes from two sites that report to the same facility ID roll up for reporting. Table 33 shows which emission sources we have assumed applicable for site A and B.

This calculation runs through each emission source category for the month of January, to show how one month of VENT would be reported to Petrinex. Then it shows volumes for the entire year, with conversions to mass, to show how annual volumes and masses are reported to OneStop.

Table 33. Site A and Site B emission sources

	Site A	Site B
Oil well head	✓	×
Facility	×	✓
Uncontrolled tank	✓	✓
Online gas analyzer	✓	×
Solid desiccant dehydrator	✓	×
Pig trap	✓	×
Pneumatic device	✓	✓
Compressor	✓	×
Glycol dehydrator	✓	✓

Defined Vent Gas

The following calculations show how to estimate the DVG volume for one month for the hypothetical facility ID, ABBTX. DVG is calculated as the sum of associated gas venting, storage tank venting, hydrocarbon liquid loading losses, online gas analyzer purge vents, solid desiccant dehydrators, pig trap openings and purges, and other routine vent sources (which does not include vent gas from pneumatic devices, compressor seals, or glycol dehydrators).

Associated Gas Venting

In this example, there is an oil well at site A that is venting all the produced gas, which was measured at 100 m^3 of vent gas for the month. Site B has no associated gas vented.

Storage Tank Venting – Flashing Losses

For the tank on site A, the values in table 34 are used to calculate the flashing losses for the tank.

Table 34. Parameters for storage tank venting – flashing losses example

Parameter	Description	Value	Units
V_{liq}	Monthly volume of produced liquid hydrocarbon product	350	m^3
GIS	Gas-in-solution factor (calculated using Vazquez and Beggs correlation)	6.8	m^3 of gas/m^3 of oil

Flashing losses are calculated for the month using equation 3:

$$V_{GIS} = 350 \times 6.8 = 2\ 380\ \mathrm{m}^3$$

For the purpose of calculating storage tank venting for ABBTX, assume the site B storage tank venting from flashing is 3 400 m^3.

Storage Tank Venting – Breathing and Working Losses

The breathing and working losses were determined for site A and site B to be 50 m^3 and 100 m^3 of vent gas, respectively, for the month using the “Evaporative Loss from Fixed-Roof Tanks” algorithm (US EPA 2006).

Storage Tank Venting – Blanket Gas Venting

Assume for this example that blanket gas venting that was determined through an engineering estimate and is 0 m^3 for site A and 150 m^3 for site B for the month.

Table 35 summarizes the storage tank vent gas volumes for site A and B for January.

Table 35. Summary of storage tank venting for ABBTX

Site	Description	Value (m^3/month)
Site A	Flashing losses	2 380
	Breathing and working losses	50
	Blanket gas venting	0
Site B	Flashing losses	3 400
	Breathing and working losses	100
	Blanket gas venting	150
ABBTX	**Storage tank venting**	**6 080**

Hydrocarbon Liquid Loading Losses

For the tank on site A, the values shown in table 36 are used to calculate the hydrocarbon liquid loading losses for one month.

Table 36. Parameters for hydrocarbon liquid loading losses example

Parameter	Description	Value	Units
RVP	Reid vapour pressure of liquid (from table 18)	40.5	kPa
T	Average liquid temperature	283.15	K
V_{oil}	Monthly volume of the LVP product loaded	100	m^3
P_{std}	Standard reference pressure	101.325	kPa
SF	Saturation factor (from table 17)	0.5	Dimensionless

Step 1: The true vapour pressure, P_V, is calculated using equation 5:

$$P_V = 6.8929 \times exp\left[\left(\frac{1555}{283.15} - 2.227\right) \times (\log_{10} 40.5 - 0.8384) - \frac{4033.89}{283.15} + 12.82\right] = 20.385 \text{ kPa}$$

Step 2: The saturation factor is determined from table 17 to be 0.5. Assume the cargo carriers are tank trucks and rail tank cars, and the mode of operation is submerged loading of a clean cargo tank.

Step 3: The vent gas from hydrocarbon liquid loading losses is calculated using equation 4:

$$V_{LL} = \frac{0.50 \times 20.385 \times 288.15}{101.325 \times 283.15} \times 100 = 10.2\ m^3$$

Assume vent gas from hydrocarbon liquid loading at site B is the same as site A.

Online Gas Analyzer Purge Vents

In this example, site A has two online gas analyzers and site B has zero. The vent volume from online gas analyzer purges for site A for the month is calculated as:

$$V_{OGA} = 68.9 \text{ m}^3 \text{ of vent gas/month} \times\ 2 =\ 137.8 \text{ m}^3$$

Solid Desiccant Dehydrators

In this example, site A has one solid desiccant dehydrator and site B has zero. Table 37 provides the values used to calculate the volume of vent gas from the solid desiccant dehydrator V_{DD}, using equation 6.

Table 37. Parameters for solid desiccant dehydrator example

Parameter	Description	Value	Units
H	Height of the dehydrator vessel	0.8	m
D	Diameter of the dehydrator vessel	0.6	m
P_2	Pressure of the gas	1200	kPa(g)
P_1	Atmospheric pressure	101.325	kPa(a)
G	Fraction of the vessel that is filled with gas	0.7	
f	Frequency of refilling	5	Cycles per month

$$V_{DD} = \left(\frac{0.8 \times 0.6^2 \times 3.14159 \times 1200 \times 0.7}{4 \times 101.325}\right) \times 5 = 9.376 \text{ m}^3$$

The vent volume from solid desiccant dehydrators for the month is 9.376 m^3 for site A and 0 m^3 for site B.

Pig Trap Openings and Purges

In this example, site A has one pig trap, and site B does not have any pig traps. The values shown in table 38 are used to calculate the vent gas volume from one event during the month.

Table 38. Parameters for pig trap opening example

Parameter	Description	Value	Units
V_V	Total physical volume of equipment chambers between isolation valves being depressurized	3.693	m^3
T_S	Temperature at standard conditions	15	°C
T_a	Initial temperature of gas at actual conditions	10	°C
P_S	Absolute pressure at standard conditions	101.325	kPa(a)
$P_{a,1}$	Gauge pressure at actual conditions in the equipment system (kPa(a)) prior to depressurization	260	kPa(g)
$P_{a,2}$	Gauge pressure at actual conditions in the equipment system after depressurization	50	kPa(g)

Step 1: The pig trap's total physical volume is calculated as the volume of a vessel, V_V. Assume the pig trap has a 168.3 mm outer diameter, with 4 mm wall thickness, and is 6 feet (1.83 m) long.

$$V_V = \pi \times \left(\frac{\frac{168.3}{2} - 4}{100}\right)^2 \times 1.83 = 3.693 \text{ m}^3$$

Step 2: Venting from the pig trap opening, V_{PT}, is calculated using equation 7 (assuming the pig trap is not purged):

$$V_{PT} = 3.693 \times \left[\frac{(273.15+15)\times(260-50)}{(273.15+10)\times 101.325}\right] = 7.789 \text{ m}^3$$

Other Defined Vent Gas Volumes

In this example, it is assumed there is no vent gas from other DVG emission sources, and all DVG is captured by the sections above.

Defined Vent Gas Summary

Based on the calculations above, the defined vent gas volume for site A and B for the month of January is shown in table 39.

Table 39. Summary of DVG volumes for ABBTX

Category	Site A Vent gas volume (m^3)	Site B Vent gas volume (m^3)	ABBTX Vent gas volume (m^3)
Associated gas venting (V_{AG})	100	0	100
Storage tank venting (V_T)	2 430	3 650	6 080

Category	Site A Vent gas volume (m^3)	Site B Vent gas volume (m^3)	ABBTX Vent gas volume (m^3)
Flashing losses	2 380	3 400	5 780
Breathing and working losses	50	100	150
Blanket gas losses	0	150	150
Hydrocarbon liquid loading losses (V_{LL})	10.2	10.2	20
Online gas analyzer purge vents (V_{OGA})	137.8	0	137.8
Solid desiccant dehydrators (V_{DD})	9.376	0	9.376
Pig trap openings and purges (V_{PT})	7.789	0	7.789
Other routine sources (V_{O})	0	0	0
DVG (V_{DVG})	2 695	3 660	6 355

Similarly, calculate the defined vent gas volume for all the sites in a facility ID, for each month (see table 41). The vent gas volumes for each category in January are from the example calculation above. Repeat the calculations for February to December and fill in table 41.

Report 80 727 m^3 for defined vent gas volume for facility ID ABBTX to OneStop for the reporting period.

Converting to mass and considering the concentration of methane in the vent gas from storage tank venting by volume is 95% for site A, convert volume to mass using equation 1:

$$M_T = 33211\ \mathrm{m}^3\ \times 95\%\ \times 0.67850\ \frac{\mathrm{kg}}{\mathrm{m}^3} = 21407\ \mathrm{kg}$$

Table 40 shows volume to mass conversions by DVG category.

Table 40. Summary of annual DVG volume and mass conversion

Category	Site	Volume (m^3)	Concentration of methane	Mass (kg)
Associated gas venting	Site A	1 200	0.85	692
	Site B	0	N/A	0
Storage tank venting	Site A	33 211	0.95	21 407
	Site B	44 508	0.96	28 991
Hydrocarbon liquid loading losses	Site A	107.6	0.95	69
	Site B	107.6	0.96	70
Online gas analyzer purge vents	Site A	1 378	0.9	841
	Site B	0	0.9	0
Solid desiccant dehydrators	Site A	137	0.5	46
	Site B	0	N/A	0
Pig trap openings and purges	Site A	78	0.95	50

Category	Site	Volume (m^3)	Concentration of methane	Mass (kg)
	Site B	0	N/A	0
Other routine sources	Site A	0	N/A	0
	Site B	0	N/A	0
DVG	Site A	36 111	N/A	23 107
	Site B	44 616	N/A	29 061
	ABBTX	**80 727**	N/A	**52 167**

Report 52 167 kg for defined vent gas mass of methane for facility ID ABBTX to OneStop for reporting period 2021. In conclusion, the DVG volume and mass for this hypothetical example are 80 727 m^3 and 52 167 kg.

Table 41. Sample calculation of annual defined vent gas volume

	Associated gas venting (m³)		Storage tank venting (m³)		Hydrocarbon liquid loading losses (m³)		Online gas analyzer purge vents (m³)		Solid desiccant dehydrators (m³)		Pig trap openings and purges (m³)		Other routine sources (m³)		Defined vent gas summary (m³)		
	Site A	**Site B**	**Site A**	**Site B**	**Site A**	**Site B**	**Site A**	**Site B**	**Site A**	**Site B**	**Site A**	**Site B**	**Site A**	**Site B**	**Site A**	**Site B**	**ABBTX**
Jan	100	0	2 430	3 650	10.2	10.2	137.8	0	9.38	0	7.79	0	0	0	2 695	3 660	6 355
Feb	100	0	2 270	3 653	12.33	12.33	137.8	0	11.25	0	7.79	0	0	0	2 539	3 665	6 205
Mar	100	0	2 735	4 330	10.53	10.53	137.8	0	7.50	0	0	0	0	0	2 991	4 341	7 331
Apr	100	0	3 101	3 860	16.50	16.50	137.8	0	13.13	0	7.79	0	0	0	3 376	3 877	7 253
May	100	0	2 931	3 130	11.20	11.20	0	0	15.00	0	7.79	0	0	0	3 065	3 141	6 206
Jun	100	0	2 675	2 890	8.89	8.89	137.8	0	16.88	0	7.79	0	0	0	2 946	2 899	5 845
Jul	100	0	2 615	3 330	10.67	10.67	137.8	0	18.75	0	0	0	0	0	2 882	3 341	6 223
Aug	100	0	3 236	3 770	7.72	7.72	137.8	0	9.38	0	7.79	0	0	0	3 499	3 778	7 276
Sep	100	0	3 070	3 570	0	0	0	0	9.38	0	7.79	0	0	0	3 187	3 570	6 757
Oct	100	0	2 825	4 330	8.85	8.85	137.8	0	11.25	0	7.79	0	0	0	3 091	4 339	7 430
Nov	100	0	2 765	4 145	10.86	10.86	137.8	0	7.50	0	7.79	0	0	0	3 029	4 156	7 185
Dec	100	0	2 558	3 850	0	0	137.8	0	7.50	0	7.79	0	0	0	2 811	3 850	6 661
2021 (Jan–Dec)	1200	0	33 211	44 508	107.8	107.8	1 378	0	137	0	78	0	0	0	36 111	44 616	**80 727**

Nonroutine Vent Sources

The following sample calculations show how to estimate the nonroutine vent volume for one month for the hypothetical facility ID ABBTX. Nonroutine vent volume is calculated as the sum of blowdowns; well testing, completions, and workovers; well venting for liquids unloading; engine or turbine starts; and other nonroutine sources.

Blowdowns

In this example, both site A and B had a blowdown event on January 6, 2021. The values shown in table 42 are used to calculate the vent gas volume from one event during the month.

Table 42. Parameters for blowdowns example

Parameter	Description	Value	Units
V_V	Total physical volume of equipment chambers between isolation valves being depressurized	1 000	m^3
T_S	Temperature at standard conditions	15	°C
T_a	Initial temperature of gas at actual conditions	10	°C
P_S	Absolute pressure at standard conditions	101.325	kPa(a)
$P_{a,1}$	Gauge pressure at actual conditions in the equipment system (kPa(a)) prior to depressurization	260	kPa(g)
$P_{a,2}$	Gauge pressure at actual conditions in the equipment system after depressurization	50	kPa(g)

Similar to pig trap openings and purges calculation, calculate blowdown venting V_{BD} for site A using equation 7:

$$V_{BD} = 1000 \times \left[\frac{(273.15+15)\times(260-50)}{(273.15+10)\times 101.325}\right] = 2109 \text{ m}^3$$

For site B, the total physical volume of equipment chambers between isolation valves being depressurized, V_V, is 1 200 m^3. Blowdown vent volume for site B is 2 531 m^3.

Well Testing, Completions, and Workovers

In this example, there is an oil well at site A that is venting from workover activities, which was measured to vent 100 m^3 of vent gas for the month. Site B has no vent gas from well testing, completions, and workovers because there is no well on site.

Well Venting for Liquids Unloading

Site A had a liquids unloading event on January 28, 2021. The values shown in table 43 are used to calculate the vent gas volume from one event during the month.

Table 43. Parameters for well venting for liquids unloading example

Parameter	Description	Value	Units
D_t	Production string diameter	22	cm
WD	Well depth	2 000	m
$P_{shut\text{-}in}$	Well shut-in pressure	1 200	kPa(g)
Q_{sfr}	Average sales flow rate of gas well at standard conditions	50	m^3/hr
t_{open}	Hours that well was left open	0.5	hours

Well venting for liquids unloading volume is calculated for the month using equation 8:

$$V_{WLU} = \left(7.854 \times 10^{-5} \times 22^2 \times 2000 \times \frac{1200}{101.325}\right) + (50 \times 0.5) = 925.4\ \mathrm{m}^3$$

Well venting for liquids unloading volume for site B is 0 because there is no well on site.

Engine or Turbine Starts

In this example, there are three engine or turbine start events on site A for January. The type, manufacturer, and model are shown in table 44, with the corresponding max natural gas consumption rates from table 28 and table 29.

Table 44. Inventory for engine or turbine starts example for site A

	Engine/turbine			Pneumatic starter			Max natural gas consumption rate	
	Type	Manufacturer	Model	Manufacturer	Model	Supply pressure (kPa_g)	(m^3/min)	(m^3/hr)
1	Turbine*	Garrett	IE831	Ingersoll Rand	TS999G	621	47	2 849
2	Turbine*	Solar Turbines	Saturn 20	Tech Development	56S	1 034	29	1 725
3	Reciprocating engine†	Waukesha	7042G (SI/L)	Ingersoll Rand	SS815	1 034	62	3 726

* Data from table 28.

† Data from table 29.

The operating time of each engine or turbine is shown in table 45.

Table 45. Parameters for engine or turbine starts vent gas volume calculation example

Engine or turbine #	Max natural gas consumption rate (m^3/min)	Operating time (min)	Vent gas volume (m^3)
1	47	6	282
2	29	9	261
3	62	5	310
Total on site A			853

Vent gas volume for each engine or turbine start is calculated by multiplying the max natural gas consumption rate with its operating time for each event and summed over the month, using equation 9.

$$V_{ETS} = 47\,\mathrm{m}^3/\mathrm{min} \times 6\,\mathrm{min} + 29\,\mathrm{m}^3/\mathrm{min} \times 9\,\mathrm{min} + 62\,\mathrm{m}^3/\mathrm{min} \times 5\,\mathrm{min} = 853\,\mathrm{m}^3$$

Engine or turbine starts vent volume for site A is 853 m^3. The engine or turbine starts vent volume for site B is 1012 m^3.

Other Nonroutine Vent Volumes

In this example, it is assumed that site A doesn't have other nonroutine venting activities. Site B had a facility turnaround during January, causing 2000 m^3 of nonroutine vent volume.

Nonroutine Vent Sources Summary

Based on the calculations above, the nonroutine vent volume for site A and B for January is shown in table 46.

Table 46. Summary of nonroutine vent volumes for ABBTX

Category	Site A Vent gas volume (m^3)	Site B Vent gas volume (m^3)	ABBTX Vent gas volume (m^3)
Blowdowns (V_{BD})	2 109	2 531	4 640
Well testing, completions, and workovers (V_{WT})	100	0	100
Well venting for liquids unloading (V_{WLU})	925.4	0	925.4
Engine or turbine starts (V_{ETS})	853	1 012	1 865
Other nonroutine sources (V_O)	0	2 000	2 000
Nonroutine vent gas (V_{NR})	3 987	5 543	9 530

Similarly, calculate the nonroutine vent gas volume for all the sites in a facility ID for each month (see table 47). The vent gas volumes for each category in January are from the example calculation above. Repeat the calculations for February to December if there is nonroutine activity and fill in table 47.

The nonroutine vent volume is 42 117 m^3 for facility ID ABBTX in reporting period 2021.

There is no need to convert nonroutine volumes to mass since the nonroutine category is not reported to OneStop.

Table 47. Example of nonroutine vent volumes

	Blowdowns (m^3)		Well testing, completions, and workovers (m^3)		Well venting for liquid unloading (m^3)		Engine or turbine starts (m^3)		Other nonroutine sources (m^3)		Nonroutine vent gas summary (m^3)		
	Site A	**Site B**	**Site A**	**Site B**	**Site A**	**Site B**	**Site A**	**Site B**	**Site A**	**Site B**	**Site A**	**Site B**	**ABBTX**
Jan	2 109	2 531	100	0	925.4	0	853	1 012	0	2 000	3 987	5 543	9 530
Feb	0	0	100	0	0	0	833	1 258	0	0	933	1 258	2 191
Mar	0	0	100	0	0	0	798	1 137	0	0	898	1 137	2 035
Apr	0	0	100	0	801.1	0	712	1 014	0	0	1 613	1 014	2 627
May	0	0	100	0	0	0	826	1 157	0	0	926	1 157	2 083
Jun	3 216	3 428	100	0	0	0	810	1 069	0	0	4 126	4 497	8 623
Jul	0	0	100	0	0	0	703	1 131	0	1 900	803	3 031	3 834
Aug	0	0	100	0	0	0	850	1 240	0	0	950	1 240	2 190
Sep	0	0	100	0	918.5	0	922	1 170	0	0	1 941	1 170	3 111
Oct	0	0	100	0	0	0	861	1 137	0	0	961	1 137	2 098
Nov	0	0	100	0	0	0	831	1 012	0	0	931	1 012	1 943
Dec	0	0	100	0	0	0	901	851	0	0	1 001	851	1 852
2021 (Jan–Dec)	5 325	5 959	1 200	0	2 645	0	9 900	13 188	0	0	19 070	23 047	**42 117**

Pneumatic Devices

This manual provides a variety of methods to calculate emissions from pneumatic devices. This section will go through an example for each method listed in the manual, for the purpose of showing how each method works. We recommend choosing one approach and not combining various estimation methods wherever possible.

Pneumatic Instruments

For an example of how to determine the vent gas volume from one pressure controller for the month of January, equation 9 and 10 are used with the parameters given in table 48.

Table 48. Parameters for pneumatic instrument with known supply pressure example

Parameter	Description	Value	Units
From inventory	Make	Fisher	
	Model	4150	
	Supply pressure	30	Psi
SP	Supply pressure	206.8	kPa
m	Supple pressure coefficient	0.0019	
t	January operating hours	720	hours

$$ER_i = m \times SP = 0.0019 \times 206.8 = 0.39\ m^3/hr$$

$$V_{PI} = ER \times t = 0.39 \times 720 = 283\ \mathrm{m}^3$$

The next example is for one level controller for the month of January that has been retrofit with a low venting relay during the month. Table 49 lists the parameters used to calculate the vent gas volume for the month using equation 9.

Table 49. Parameters for pneumatic device example using average emission rates

Parameter	Description	Value	Units
From inventory	Make & model (before retrofit)	Fisher L2	
	Make & model (after retrofit)	Fisher L2 (improved low vent relay)	
	Time between actuations	5	mins
ER	Emission rate as L2	0.75	m^3/hr
	Emission rate as L2 (improved low vent relay)	0.1	m^3/hr
t	Operating hours as L2	500	hours
	Operating hours as L2 (improved low vent relay)	220	hours

$$V_{PI} = ER \times t = (0.75 \times 500) + (0.1 \times 220) = 397\ \mathrm{m}^3$$

Pneumatic Pumps

To calculate the vent gas volume from one pneumatic pump on site A in January, where the supply pressure, discharge pressure and strokes per minute is known, the parameters in table 50 are used with equation 11.

Table 50. Parameters for pneumatic pump example with operating conditions known

Parameter	Description	Value	Units
	Make	Texsteam	
	Model	5100	
SP	Supply pressure	206.8	kPa
DP	Discharge pressure	6894.8	kPa
SPM	Strokes per min	10	strokes/min
g	Supply pressure coefficient	0.0003	
n	Discharge pressure coefficient	0.000034	
p	Strokes per min coefficient	0.0207	
t	Operating hours	720	hours

$$ER = (g \times SP) + (n \times DP) + (p \times SPM)$$
$$= (0.0003 \times 206.8) + (0.000034 \times 6894.8) + (0.0207 \times 10) = 0.503 \text{ m}^3/\text{hour}$$

$$V_{PP} = ER_P \times t = 0.503 \times 720 = 362 \text{ m}^3/\text{month}$$

To calculate the vent gas volume from one pneumatic pump on site B for the month of January, where manufacture specifications (equation 12 and 13) are used, the parameters in table 51 are used.

Table 51. Parameters for pneumatic pump example using manufacturer specifications

Parameter	Description	Value	Units
	Make	Bruin	
	Model	BR 5001	
CIP	Chemical injection pressure	10,000	kPa
	Plunger diameter	0.25	In
	Stroke length	0.5	In
P2		0	
P1		0.0000245	
P0		4.60	
L	Monthly volume of chemical pumped	15	L/month

$$ER_{PM} = (P_2 \times CIP^2) + (P_1 \times CIP) + P_0 = (0 \times 10000^2) + (0.0000245 \times 10000) + 4.60$$
$$= 4.85 \text{ m}^3 \text{ vent gas/litre}$$

$$V_{PP} = ER_{PM} \times L = 4.85 \times 15 = 72.7 \text{ m}^3/\text{month}$$

Pneumatic Devices Summary

Based on the calculations above, the pneumatic vent gas volume for site A and B for the month of January is shown in table 52. The total volume of 1115 m^3 contributes to the value that is reported as part of VENT to Petrinex.

Table 52. Summary of pneumatic device vent gas volumes for ABBTX

Category	Site A Vent gas volume (m^3)	Site B Vent gas volume (m^3)	ABBTX Vent gas volume (m^3)
Pneumatic instruments (V_{PI})	283	397	680
Pneumatic pumps (V_{PP})	362	73	435
Total pneumatic devices			1 115

The pneumatic vent gas volume has been calculated for all the sites in the facility ID for each month (see table 53). The vent gas volumes in the January column of table 53 are from the sample calculations above. Similar calculations have been completed for February to December to complete the year.

Table 53. Sample calculation of annual pneumatic instrument and pump volumes

	Pneumatic instruments (m^3)		Pneumatic pumps (m^3)		Pneumatic instruments (m^3)	Pneumatic pumps (m^3)	Pneumatic devices (m^3)		
	Site A	Site B	Site A	Site B	ABBTX		Site A	Site B	ABBTX
Jan	283	397	362	73	680	435	645	470	1 115
Feb	283	100	362	73	383	435	645	173	818
Mar	283	100	362	73	383	435	645	173	818
Apr	283	100	362	73	383	435	645	173	818
May	283	100	362	73	383	435	645	173	818
Jun	283	100	0	0	383	0	283	100	383
Jul	283	100	0	0	383	0	283	100	383
Aug	283	100	0	0	383	0	283	100	383
Sep	283	100	0	0	383	0	283	100	383
Oct	283	100	362	73	383	435	645	173	818
Nov	283	100	362	73	383	435	645	173	818
Dec	283	100	362	73	383	435	645	173	818
2021 (Jan–Dec)	**3 395**	**1 497**	**2 900**	**582**	**4 892**	**3 482**	**6 292**	**2 081**	**8 374**

For reporting to OneStop, 4892 m^3 is reported to ABBTX for pneumatic instruments, and 3482 m^3 is reported for pneumatic pumps.

Converting to mass and considering the concentration of methane in the vent gas used by all pneumatic devices is 90%. The volume is converted to mass using equation 1, and the results are summarized in table 54.

Table 54. Summary of pneumatic instruments and pumps volume and mass conversion

Category	Site	Volume (m^3)	Concentration of methane	Mass (kg)
Pneumatic instruments	Site A	3 395	90%	2 073
	Site B	1 497	90%	915
	ABBTX			**2 987**
Pneumatic pumps	Site A	2 900	90%	1 771
	Site B	582	90%	355
	ABBTX			**2 126**

Report 2987 kg and 2126 kg for pneumatic instrument and pump mass of methane, respectively, for facility ID ABBTX to OneStop for reporting period 2021.

Compressor Seals

In table 55, compressor 1 with a common vent line for all throws was tested in June of 2020. This test measurement was then divided among the number of throws. Until either a rod packing is changed out or a new test is taken in the following year, this measurement will be used for calculating the annual emissions. This factor carries over into 2021 for the months of January and into June until a new test was done on June 8th.

The next event is downtime which occurred on October 14th, when the unit was down for 2 days (48 hours) and a packing was changed on throw 1. During this downtime the unit will receive emissions of zero for the days it was down. When a packing is changed a new measurement is not required at that time, and the operator can use the emission rate for a new packing (in this case we used 0.16 m^3/hr/throw) until the next measurement is required, in this case June 2020. The new estimated emission rate of 0.16 m^3/hr was for only throw 1 and comes into effect after the downtime on October 16th, giving the remaining time in October emission rate of 0.16 m^3/hr on throw one and the previous rate of 0.64 m^3/hr for the other three throws since this was the result of the last test.

When a new test is done in June 2021 the emission rate is now based on the last measurement moving forward.

Table 55. Compressor events example

Year	Month	Event	Test result (m^3/hr)	Pressurized time (hours)	Emission rate by throw (m^3/hr) 1	2	3	4	Vent volume (m^3)
2020	Jan	Estimate	0.68	744	0.160	0.160	0.160	0.160	506
2020	Feb			672	0.160	0.160	0.160	0.160	457
2020	Mar			744	0.160	0.160	0.160	0.160	506
2020	Apr			720	0.160	0.160	0.160	0.160	490
2020	May			744	0.160	0.160	0.160	0.160	506
2020	Jun			192	0.160	0.160	0.160	0.160	131
		Test	2.56	528	0.640	0.640	0.640	0.640	1 352
2020	Jul			744	0.640	0.640	0.640	0.640	1 905
2019	Aug			744	0.640	0.640	0.640	0.640	1 905
2020	Sep			720	0.640	0.640	0.640	0.640	1 843
2020	Oct			312	0.640	0.640	0.640	0.640	799
		Downtime		48	0.000	0.000	0.000	0.000	0
		Packing change only on throw 1		384	0.160	0.640	0.640	0.640	799
2020	Nov			720	0.160	0.640	0.640	0.640	1 498
2020	Dec			744	0.160	0.640	0.640	0.640	1 548
								Annual volume 2020	**14 242**
2021	Jan			744	0.160	0.640	0.640	0.640	1 548
2021	Feb			672	0.160	0.640	0.640	0.640	1 398
2021	Mar			744	0.160	0.640	0.640	0.640	1 548
2021	Apr			696	0.160	0.640	0.640	0.640	1 448
		Downtime		24	0.000	0.000	0.000	0.000	0
2021	May			744	0.160	0.640	0.640	0.640	1 548
2021	Jun			720	0.160	0.640	0.640	0.640	1 498
2021	Jul	Test	3.02	744	0.755	0.755	0.755	0.755	2 247
2021	Aug			744	0.755	0.755	0.755	0.755	2 247
2021	Sep			720	0.755	0.755	0.755	0.755	2 174
2021	Oct			744	0.755	0.755	0.755	0.755	2 247
2021	Nov			720	0.755	0.755	0.755	0.755	2 174
2021	Dec			744	0.755	0.755	0.755	0.755	2 247
								Annual volume 2021	**22 322**

In this example, the vent volume for compressor 1 in 2021 is 22 322 m^3.

For reporting facility ID ABBTX, there are two compressors on site A and no compressor on site B. Compressor 1 has a power rate of 150 kW and compressor 2 has a power rate is 50 kW. The vent volume of each compressor for each month is shown in table 56.

Table 56. Summary of compressor seals vent volumes (m^3) for ABBTX (site B has no compressors)

	Site A		
	Compressor 1	Compressor 2	ABBTX
Jan	1 548	690	2 237
Feb	1 398	623	2 021
Mar	1 548	690	2 237
Apr	1 448	645	2 093
May	1 548	690	2 237
Jun	1 498	668	2 165
Jul	2 247	1 002	3 248
Aug	2 247	1 002	3 248
Sep	2 174	969	3 143
Oct	2 247	1 002	3 248
Nov	2 174	969	3 143
Dec	2 247	1 002	3 248
2021 (Jan–Dec)	**22 322**	**9 948**	**32 270**

The compressor seals vent volume for ABBTX is the sum of all the compressors on a site, then sum all the sites within a facility ID.

$$V_C = V_{Unit\ 1} + V_{Unit\ 2} = 22322\ \mathrm{m}^3 + 9948\ \mathrm{m}^3 = 32270\ \mathrm{m}^3$$

Convert to mass, considering the concentration of methane in the vent gas by volume is 93% from compressor 1 and 94% from compressor 2, using equation 1:

$$\begin{aligned} M_C &= M_{Unit\ 1} + M_{Unit\ 2} \\ &= 22322\ \mathrm{m}^3 \times 93\% \times 0.67850\ \frac{\mathrm{kg}}{\mathrm{m}^3} + 9948\ \mathrm{m}^3 \times 94\% \times 0.67850\ \frac{\mathrm{kg}}{\mathrm{m}^3} \\ &= 20430\ \mathrm{kg} \end{aligned}$$

Report compressor seals vent volume 32 270 m^3 and mass of methane 20 430 kg for facility ID ABBTX to OneStop for reporting period 2021. Also report compressor inventory: serial number, location, installation year, compressor type, throw count (if reciprocating), seal type, seal control indication, pressurized time, and vent gas volume for compressor 1 into OneStop because it is rated over 75 kW and operated over 450 hours in calendar year 2021. Report 22 322 m^3 as the vent gas volume for compressor 1.

Glycol Dehydrators

Glycol dehydration emissions estimates should be produced from GRI-GlyCALC or equivalent software. Tables 57 and 58 are sample input for a glycol dehydrator.

Table 57. Glycol dehydrator summary of input values

Input	Unit	Value
Temperature and pressure in the absorber column	F / psig	82.40 deg. F/870.23 psig
Type of glycol pump	Electric/Energy Exchange	Electric
Type of glycol	TEG or DEG	TEG
Stripping gas (if used)	scfm	0.283
Wet gas composition	Percent volume	See table 58

Table 58. Glycol dehydrator wet gas composition

Component	Composition (vol %)	Component	Composition (vol %)
Carbon dioxide	1.3900	Isobutane	0.4700
Nitrogen	0.2300	n-Butane	0.5700
Methane	84.8600	Isopentane	0.2500
Ethane	8.4000	n-Pentane	0.1900
Propane	2.7800	n-Hexane	0.2300
Cyclohexane	0.0460	Toluene	0.0820
Other Hexanes	0.1050	Ethylbenzene	0.0020
Methylcyclohexane	0.1160	Xylenes	0.0220
2,2,4-Trimethylpentane	0.0090		
Benzene	0.0460		

The resulting output methane mass for this glycol dehydrator is 2.4237 tonnes/year for 8760 hours of operation in a year. Use equation 1 to convert mass to volume:

$$V_{D,site\ A,Dehy\ 1} = \frac{2.4237\,\frac{\text{tonnes}}{\text{year}} \times 1000\frac{\text{kg}}{\text{tonne}} \times \frac{1\ \ \text{year}}{12\ \text{month}}}{(84.86\%\ \times 0.67850\ \frac{\text{kg}}{\text{m}^3})} = 350.8\ \text{m}^3/\text{month}$$

The calculated vent volume for all glycol dehydrators at a facility ID is then given in table 59.

Table 59. Summary of glycol dehydrator vent volumes for ABBTX

Site	Dehydrator ID	Mass of methane (kg/year)	Vent volume V_D (m³/month)	Vent volume (m³/month)	Vent volume (m³/year)
	1	2 423.7	350.8		
A	4	2 400.5	347.4	698.2	8 379
B	3	1 500.0	217.1	217.1	2 605
Reporting facility ID Total		6 324	915	915	**10 984**

The methane mass from glycol dehydrators for ABBTX is the sum of all the glycol dehydrators on a site, then all the sites in a facility ID:

$$M_D = (2423.7 + 2400.5) + 1500.0\ \text{kg/year} = 6324\ \text{kg/year}$$

In conclusion, the glycol dehydrator vent volume and mass for this hypothetical example are 10 984 m^3 and 6324 kg.

Overall Vent Gas

The OVG is the sum of all the vent sources—DVG, nonroutine, pneumatic devices, compressor seals, and glycol dehydrators—for all the sites in ABBTX for each month (table 60). For the month of January, 10.2 10^3 m^3 is reported to Petrinex as VENT for ABBTX at the well activity (UWI) level for site A, and 9.9 10^3 m^3 is reported as VENT at the facility activity level for site B. Petrinex will roll up all the well activity and facility activity entries and display 20.1 10^3 m^3 as VENT on the summary view for ABBTX.

Sample Fugitive Survey Results

The following example demonstrates how fugitive emission survey results at a facility would be calculated using the data in table 61. There was one site survey required at each site based on the type of facility. A well screening was not required since the site survey counted as the well screening. Sixteen leaks were found across the two sites associated with this facility ID and are listed below based on the component type and site where they were found. The emission rate was determined by converting a total hydrocarbon mass emission rate (kg THC) from the three stratum estimation method to volumetric values (m^3/hr) using a relevant gas sample from site.

$$V_{FE\ 2020} = 6285\ \mathrm{m}^3$$

Convert to mass, considering the concentration of methane in the fugitive emissions by volume is 95%:

$$M_{FE\ 2020} = 6285\ \mathrm{m}^3\ \times 95\%\ \times 0.67850\ \frac{\mathrm{kg}}{\mathrm{m}^3} = 4051\ \mathrm{kg}$$

Report 6285 m^3 and 4051 kg as fugitive emissions volume and mass into OneStop for this reporting facility ID. Report fourteen leaks at site A, two leaks at site B along with the survey type (“site survey” for both) and date of survey (November 7, 2020, for both). Report the serious SCVF as per *Directive 087*. Fugitive emissions are not VENT and are not reported to Petrinex.

Fleet Averages Sample Calculation

There are three fleet averages in the methane reduction requirements in section 8 of *Directive 060*: the crude bitumen fleet average, the existing reciprocating compressor fleet average, and the existing glycol dehydrator fleet average. Duty holders do not report the fleet averages.

Crude Bitumen Batteries

Table 62 demonstrates how the crude bitumen fleet average would be calculated based on a hypothetical set of facility IDs.

Table 60. Summary of vent volumes for ABBTX

	DVG		Nonroutine vent sources		Pneumatic devices		Compressor seals		Glycol dehydrators		OVG		
	Site A	**Site B**	**Site A**	**Site B**	**Site A**	**Site B**	**Site A**	**Site B**	**Site A**	**Site B**	**Site A**	**Site B**	**ABBTX**
Jan	2 695	3 660	3 962	5 543	645	470	2 237	0	698	217	10 238	9 890	20 128
Feb	2 539	3 665	933	1 258	645	173	2 021	0	698	217	6 836	5 313	12 150
Mar	2 991	4 341	898	1 137	645	173	2 237	0	698	217	7 469	5 868	13 337
Apr	3 376	3 877	1 638	1 014	645	173	2 093	0	698	217	8 450	5 281	13 731
May	3 065	3 141	926	1 157	645	173	2 237	0	698	217	7 571	4 688	12 260
Jun	2 946	2 899	4 126	4 497	283	100	2 165	0	698	217	10 219	7 713	17 932
Jul	2 882	3 341	803	3 031	283	100	3 248	0	698	217	7 915	6 689	14 604
Aug	3 499	3 778	950	1 240	283	100	3 248	0	698	217	8 678	5 335	14 013
Sep	3 187	3 570	1 941	1 170	283	100	3 143	0	698	217	9 252	5 057	14 309
Oct	3 091	4 339	961	1 137	645	173	3 248	0	698	217	8 643	5 866	14 509
Nov	3 029	4 156	931	1 012	645	173	3 143	0	698	217	8 447	5 558	14 005
Dec	2 811	3 850	1 001	851	645	173	3 248	0	698	217	8 404	5 091	13 495
2021 (Jan–Dec)	**36 111**	**44 616**	**19 070**	**23 047**	**6 292**	**2 081**	**32 270**	**0**	**8 379**	**2 605**	**102 122**	**72 349**	**174 471**

Table 61. Summary of fugitive emission volumes for ABBTX

Fugitive emission ID	Component or equipment type	Emissions rate (m^3/hr)	Repair date	Repair integrity confirmed w/in 7 days	Site	Previous survey	Duration of emission (days)	Fugitive emission (m^3)
000001	Valve	0.138752565	7-Nov-20	Yes	Site A	21-Oct-19	192	638
000002	Flange	0.116099085	7-Nov-20	Yes	Site A	21-Oct-19	192	534
000003	Connector (other)	0.036811905		No	Site A	21-Oct-19	365	322
000004	Open-ended line 2	0.07928718	7-Nov-20	Yes	Site A	21-Oct-19	192	364
000005	Pressure relief valve	0.127425825	7-Nov-20	Yes	Site A	21-Oct-19	192	586
000006	Pump seal	0.104772345	7-Nov-20	Yes	Site A	21-Oct-19	192	482
000007	Other 3	0.127425825	7-Nov-20	Yes	Site A	21-Oct-19	192	586
000008	Valve	0.09061392	7-Nov-20	Yes	Site A	21-Oct-19	192	416
000009	Flange	0.076455495	7-Nov-20	Yes	Site A	21-Oct-19	192	351
000010	Connector (other)	0.02831685	7-Nov-20	Yes	Site A	21-Oct-19	192	130
000011	Open-ended line	0.04530696	7-Nov-20	Yes	Site A	21-Oct-19	209	227
000012	Pump	0.104772345	7-Nov-20	Yes	Site A	21-Oct-19	192	482
000013	Agitator seal	0.104772345	7-Nov-20	Yes	Site A	21-Oct-19	192	482
000014	SCVF serious	12.70833333		No	Site A	21-Oct-19	Do not report SCVF or GM volumes in methane emission report. Include them as a leak in the count.	
000015	Valve	0.09061392	7-Nov-20	Yes	Site B	1-Dec-19	171	372
000016	Flange	0.076455495	7-Nov-20	Yes	Site B	1-Dec-19	171	314
							Total	**6 285**

Table 62. Crude bitumen batteries fleet average sample

Facility ID/UWI	Subtype	Licence #	Peace River	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ABBT001	322	FXX	N	0.1	1.4	0.5	1.0	0.8	0.9	1.6	1.3	1.8	1.4	1.0	0.6
ABBT002	311	WXX	N	1.5	0.1	0.8	1.1	0.9	0.7	1.0	0.7	1.4	1.2	1.0	1.0
ABBT003	311	WXX	N	2.2	1.5	1.7	1.8	1.5	1.6	2.0	1.9	2.1	1.8	1.4	1.3
ABBT004	322	FXX	N	5.5	3.6	2.8	3.1	3.8	4.5	3.0	3.9	3.6	4.2	3.9	3.2
UWI	100020304005W600			Linked UWI level volumes contribute to CBFA through facility totals only, not individually											
UWI	100020304006W600			Linked UWI level volumes contribute to CBFA through facility totals only, not individually											
UWI	100020304007W600			Linked UWI level volumes contribute to CBFA through facility totals only, not individually											
ABBT005	311	WXX	N	0.1	0.1	0.1	0.2	0.5	0.4	0.1	0.1	0.9	0.8	0.5	0.5
ABBT006	311	WXX	N	1.4	0.1	0.1	1.0	1.0	0.8	0.8	1.0	0.7	0.7	0.7	0.4
ABBT007	321	FXX	N	2.7	1.4	1.2	1.5	1.3	1.7	1.0	1.3	1.2	1.4	1.8	1.0
ABBT008	331	WXX	N	0.1	2.7	1.7	1.5	1.8	1.5	1.3	1.2	1.0	0.5	0.8	0.8
ABBT009	341	WXX	N	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
ABBT010	342	FXX	N	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
ABBT011	342	WXX	N	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
ABBT012	341	WXX	N	2.7	1.0	1.5	1.3	2.0	1.8	1.5	1.8	1.7	1.9	1.5	1.5
ABBT013	331	FXX	N	1.5	2.7	2.0	1.8	1.7	1.6	1.5	1.6	2.0	2.2	2.5	1.8
ABBT014	331	WXX	N	2.2	1.5	2.0	1.8	1.6	2.2	2.0	1.8	2.0	1.9	2.0	1.1
ABBT015	331	WXX	N	1.8	2.2	2.0	1.7	1.6	1.5	1.7	1.8	1.5	1.4	1.8	1.7
ABBT016	331	FXX	N	0.1	0.1	0.5	0.8	0.4	0.3	0.1	0.1	0.5	0.4	0.2	0.4
ABBT017	341	WXX	N	0.1	0.1	0.4	0.6	0.5	0.7	0.6	0.5	0.4	0.3	0.1	0.1
ABBT018	342	FXX	N	2.6	2.3	2.5	2.6	1.9	2.2	1.6	1.7	1.9	1.8	2.1	1.9
UWI	100020304008W600			Linked UWI level volumes contribute to CBFA through facility totals only, not individually											
UWI	100020304009W600			Linked UWI level volumes contribute to CBFA through facility totals only, not individually											
ABBT019	331	FXX	N	1.9	1.7	2.3	3.2	2.2	2.1	1.5	1.4	2.6	2.6	1.6	1.9
ABBT020	331	WXX	N	0.1	0.1	0.3	0.6	0.3	0.7	0.9	0.8	1.0	0.7	0.9	0.7
ABBT021	343	FXX	N	Not included in crude bitumen fleet average (not the targeting facility subtype)											
ABBT022	311	FXX	Y	Not included in crude bitumen fleet average (in *D084* Peace River area)											
Crude bitumen batteries fleet average				**1.35**	**1.15**	**1.14**	**1.30**	**1.21**	**1.28**	**1.13**	**1.16**	**1.34**	**1.28**	**1.21**	**1.01**

Reciprocating Compressors

The following is a sample calculation that demonstrates how the existing reciprocating compressor fleet average would be calculated based on a hypothetical set of reciprocating compressors in a duty holder's fleet.

Table 63. Existing reciprocating compressor fleet average sample calculation

No.	Operating days	Hours	Rated power (kW)	Installation date	Vent gas rate (m^3/hour)	# throws	Control	Vent volume	Throw-hours
1	360	8640	150	3/6/2018	1.90	2	N	16 416.0	17 280
2	364	8736	200	6/16/2018	2.00	4	N	17 472.0	34 944
3	200	4800	300	1/1/2019	2.50	4	N	12 000.0	19 200
4	120	2880	250	1/1/2019	0.10	4	N	288.0	11 520
5	353	8472	150	5/27/2019	1.86	2	N	15 774.9	16 944
6	357	8568	200	8/18/2019	1.96	3	N	16 793.3	25 704
7	259	6216	300	1/1/2020	2.45	4	N	15 229.2	24 864
8	118	2832	250	3/6/2020	0.10	4	N	277.5	11 328
9	365	8760	150	1/1/2021	1.82	2	N	15 984.9	17 520
10	350	8400	200	3/6/2021	1.92	4	N	16 134.7	33 600
11	192	4608	300	2/2/2022	0.00	4	Y	Excluded from fleet average because installed after Jan 1, 2022, with four or more throws	
12	115	2760	250	3/6/2022	0.00	6	Y		
13	339	8136	150	3/6/2022	1.79	2	N	14 549.3	16 272
14	343	8232	200	1/1/2023	1.88	2	N	15 495.8	16 464
17	365	8760	50	3/6/2018	Excluded from RCS fleet average because of rated power <75 kW or operates for less than 450 hrs per calendar year				
18	15	360	150	5/15/2018					
Sum of the column								156 415.61	245 640
Reciprocating compressors fleet average									**0.64**

$$\text{Reciprocating compressors fleet average} = \frac{156\ 415.61\ \mathrm{m}^3}{245\ 640\ \text{throw}-\text{hour}} = 0.64\ \ \mathrm{m}^3/\text{throw}\ /\text{hour}$$

Existing Glycol Dehydrators

The following is a sample calculation that demonstrates how the existing glycol dehydrator fleet average would be calculated based on a hypothetical set of glycol dehydrators in a duty holder's fleet.

Table 64. Existing glycol dehydrator fleet average sample calculation

No.	First operating date	Mass of methane (kg)	Days operated	Note
1	1-Jan-18	10 000	365	
2	15-Jan-18	8 000	330	
3	15-Mar-18	15 000	360	
4	1-Jan-19	1 000	300	
5	15-Dec-19	79 000	275	
6	1-Jun-20	6 800	300	
7	15-Oct-20	90 000	365	
8	15-Nov-20	80 000	330	
9	15-Dec-20	5 000	182	
10	1-Jan-21	10 000	300	
11	1-Apr-21	8 000	275	
12	1-Jul-21	15 000	300	
13	15-Oct-21	1 000	85	
14	15-Nov-21	79 000	330	
15	15-Dec-21	6 800	360	
16	15-Jan-22	90 000	300	Exclude from glycol dehydrator fleet average because first operating date after Jan 1, 2022
17	15-Aug-22	80 000	275	
18	18-Sep-22	5 000	300	
19	9-Aug-23	10 000	182	
20	11-Nov-23	30 000	300	
Sum of column		414 600	4 457	
Glycol dehydrator fleet average		**93.02**		**kg of methane/day/glycol dehydrator**