

ADDENDUM TO THE OIL AND GAS PRODUCTION PROTOCOL (Version 1.1)

This addendum expands Task 3 to include oil transportation sector emissions. The oil transportation sector includes oil pipeline emissions from the same types of fugitive and vented sources in E&P, as well as combustion emissions from compressor stations. Vented emissions from this sector will also include pipeline pigging and blowdown activities. This sector also includes emissions from vessels (marine tankers) and trucks used to transport the oil where pipelines are not in place

Addendum to Section 6

6.2 Defining Facility Boundaries

Pipelines are often used to transport crude oil from producing fields to refineries. The latter crude oil transport pipelines sometimes extend over long distances, and may in some cases cross state, provincial, or even national boundaries. As described in Section 6.2 of the GRP, each pipeline or pipeline system should be treated as a single facility, *unless* the pipeline crosses a state/provincial or national boundary. In the latter situation, the pipeline/pipeline system should be subdivided into two separate facilities along the jurisdictional boundary, *if* it is possible to determine emissions separately for the two facilities thus defined. If separate emissions estimates cannot be developed for the two pipeline segments, the pipeline/pipeline system may be treated as a single facility. The following examples illustrate the application of the GRP's rules to pipelines used to transport crude oil from producing fields to refineries.

Example 6-1: Treatment of a Crude Oil Pipeline with Aggregated Energy Use/Emissions Data

A pipeline transports crude oil 50 miles from a producing oil field in Texas to a refinery in Louisiana. The operator of the pipeline plans to report the emissions from the pipeline to The Registry. Although the operator has data on the total energy used to operate the pipeline, it does not have this data broken down for different pipeline segments. Because the operator lacks the data necessary to calculate separate emissions estimates for the Louisiana and Texas segments of the pipeline, the pipeline should be treated as a *single* facility for reporting purposes. Rather than assigning this facility to a specific state, it should be assigned to the U.S. country category (without specifying a state-level assignment).

Example 6-2: Treatment of a Crude Oil Pipeline with Disaggregated Energy Use/Emissions Data

An oil pipeline transports crude oil from a field in Alberta, Canada, through Saskatchewan and Manitoba, to a refinery outside Minneapolis, Minnesota. The pipeline operator has detailed energy/emissions data for each pumping station along the line. In

this case, the data necessary to estimate emissions for each provincial/state pipeline segment is available. Therefore, following the rules established in the GRP, the pipeline should be treated as four separate facilities for reporting purposes: an Alberta facility, a Saskatchewan facility, a Manitoba facility, and a Minnesota (U.S.) facility. Emissions should be calculated and reported separately for each of these four pipeline segments.

If in this example data were available to enable a partial but not a full subdivision of the pipeline along jurisdictional boundaries, the pipeline should be subdivided to the extent enabled by the available data. For example, if separate energy/emissions data were available by country but not by state or province, the pipeline should be subdivided into two separate country segments (a Canadian facility and a U.S. facility) for emissions reporting purposes. Please refer to Section 6.2 of the GRP for more information on the required aggregation, and disaggregation, of pipeline emissions.

Addendum to Section 21

21.7 Transportation Sector - Oil Pump Stations, Gas Compressor Stations, and Pipeline Leaks

Compressor stations are used in gas lines and pump stations are used in crude lines. These stations are located along the line to move the product through the pipeline. Their location is defined by the topography of the terrain, the type of product being transported, or operational conditions of the network.

Fugitive emissions from pipeline leaks originate from: gas leaks that result in CH₄ and CO₂ emissions in proportion to the gas composition, and the partial oxidation of CH₄ as it migrates through the soil. The degree of oxidation depends on factors such as the depth of cover, soil composition, and leak rate, which is a function of the pipeline material.

This section presents emission calculation methods to estimate fugitive emissions from oil pump stations, gas compressor stations, and pipeline leaks.

METHOD 01

COMPONENT LEVEL FUGITIVE EMISSIONS ESTIMATION FROM PUMP STATIONS

Members should refer to Section 21.5, Method 01 of this protocol and use Equation 21-11 and the table of Oil Pump Station Components Average Emission Factors (Table 21.9) shown below to calculate emissions.

Table 21.9 Oil Pump Station Components Average Emission Factors

Component – Service	Emission Factor ^a , kg THC/comp/hr	Emission Factor, tonnes THC/component-hr
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Component – Service	Emission Factor ^a , kg THC/comp/hr	Emission Factor, tonnes THC/component-hr
Valves - fuel gas and gas/vapor	1.51E-03	1.51E-06
Valves - heavy liquid	8.40E-06	8.40E-09
Valves - light liquid	1.21E-03	1.21E-06
Connectors - fuel gas and gas/vapor	2.46E-03	2.46E-06
Connectors - heavy liquid	7.50E-06	7.50E-09
Connectors - light liquid	1.90E-04	1.90E-07
Control valves - fuel gas and gas/vapor	1.46E-02	1.46E-05
Control valves - light liquid	1.75E-02	1.75E-05
Pressure relief valves - fuel gas and gas/vapor	1.63E-02	1.63E-05
Pressure relief valves - heavy liquid	3.20E-05	3.20E-08
Pressure relief valves - light liquid	7.50E-02	7.50E-05
Pressure regulators - fuel gas and gas/vapor	6.68E-03	6.68E-06
Open ended lines - fuel gas and gas/vapor	3.08E-01	3.08E-04
Open ended lines - light liquid	3.73E-03	3.73E-06
Controllers - fuel gas and gas/vapor	2.38E-01	2.38E-04
Pump seals - heavy liquid	3.20E-05	3.20E-08
Pump seals - light liquid	2.32E-02	2.32E-05

Footnotes and Sources:

^a Clearstone Engineering Ltd.. A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H₂S) Emissions by the Upstream Oil and Gas Industry, Volume 5, September 2004.

Equation 21-11 relies on the measurement or estimation of the fugitive mass emissions rate of gas. Members can select from three options to determine the mass emission rates for their facility's components- direct measuring methods such as the used of bagging¹ or high volume samplers², source screened rates³, and default rates (when other measuring methods are not available).

¹ “Bagging” is a type of mass emissions sampling, and involves enclosing individual components in an impermeable bag, and measuring the vapors that are leaked into it.

² High volume samplers are another device type that can be used to establish a mass emissions rate for leaking components. High volume samplers pull a large volume of air and leaked gas into a hydrocarbon detector unit, which measures the concentration of hydrocarbons in both the ambient air and in the sampled air.

³ Source screened rates are calculated by measuring the concentration of leaking organic

METHOD 02

COMPONENT LEVEL FUGITIVE EMISSIONS ESTIMATION FROM GAS COMPRESSOR STATIONS

Members should refer to Section 21.5, Method 01 of this protocol and use Equation 21-11 and the table of Gas Compressor Station Components Average Emission Factors (Table 21.10) shown below to calculate emissions.

Table 21.10 Gas Compressor Station Components Average Emission Factors

Component	Emission Factor ^a , kg THC/hr/comp.	Emission Factor, tonne TOC/component-hr
Control valves	0.01969	1.97E-05
Connectors	0.0002732	2.73E-07
Compressor seals – reciprocating	0.6616	6.62E-04
Compressor seals – centrifugal	0.8139	8.14E-04
Pressure relief valves	0.2795	2.80E-04
Open-ended lines (OEL)	0.08355	8.36E-05
OEL - station or pressurized compressor blowdown system ^b	0.9369	9.37E-04
OEL – depressurized reciprocating (comp. blowdown system)	2.347	2.35E-03
OEL – depressurized centrifugal (comp. blowdown system)	0.7334	7.33E-04
OEL – overall pressurized/ depressurized reciprocating ^c (comp. blowdown system)	1.232	1.23E-03
OEL – overall pressurized/ depressurized centrifugal ^c (comp. blowdown system)	0.7945	7.94E-04
Other gas meter	0.000009060	9.06E-09

Footnotes and Sources:

^a D.J.Picard, M. Stribny, and M.R. Harrison. *Handbook for Estimating Methane Emissions from Canadian Natural Gas Systems*. GTC Program #3. Environmental Technologies, May 25, 1998.

^b The compressor type is not specified. The emission factor is assumed to apply to either reciprocating or centrifugal compressor types or stations.

^c Overall OEL average emission factors that account for the time that the compressor unit is pressurized and depressurized during the year have been estimated using the annual fractions of the modes of operation taken from Table 4-20 of Volume 8 of the GRI/EPA methane emissions study (Hummel, et al., 1996). The percentages from the GRI/EPA study are 79.1% pressurized/20.9% depressurized for reciprocating compressors and 30% pressurized/70% depressurized for centrifugal compressors. Therefore, these percentages were applied to the base pressurized and depressurized emission factors provided in the table above to develop overall factors that represent annual average emission factors converted to an hourly basis.

compounds from a component's leak interface using a portable organic compound analyzer (screening device).

METHOD 03

FUGITIVE EMISSIONS ESTIMATION FROM PIPELINES

Members should refer to Section 21.5, Method 02 of this protocol and use Equation 21-19 and the table of CH₄ and CO₂ Emission Factors for Pipelines (Table 21.11) shown below to calculate emissions.

Equation 21-19: CO ₂ and CH ₄ Emissions from Pipeline Leaks	
$E_i = EF_i \times t_{annual} \times AF$	
<i>where:</i>	
E_{CH_4/CO_2} =	the total fugitive emissions of CH ₄ /CO ₂ , in tonnes/yr
EF_i =	CH ₄ /CO ₂ emission factor, in tonnes/hr (Table 21.11)
t_{annual} =	the annual usage, in hr/yr
AF =	Activity factor (i.e. pipelines length)

Table 21.11 CH₄ and CO₂ Emission Factors for Pipelines

Source	Emission Factor ^{a,b} , Original Units		Emission Factor ^c , Converted Units	
Cast iron pipeline	10,096	lb CH ₄ /mile-yr	4.5794	tonne CH ₄ /mile-yr
			2.8455	tonne CH ₄ /km-yr
CO ₂ from oxidation ^d	18,699	lb CO ₂ /mile-yr	8.4817	tonne CO ₂ /mile-yr
			5.2703	tonne CO ₂ /km-yr
CO ₂ from pipeline leaks	993.6	lb CO ₂ /mile-yr	0.4507	tonne CO ₂ /mile-yr
			0.2800	tonne CO ₂ /km-yr
Plastic pipeline	22.55	lb CH ₄ /mile-yr	0.01023	tonne CH ₄ /mile-yr
			0.00636	tonne CH ₄ /km-yr
CO ₂ from oxidation ^d	1.263	lb CO ₂ /mile-yr	0.0005728	tonne CO ₂ /mile-yr
			0.0003559	tonne CO ₂ /km-yr
CO ₂ from pipeline leaks	1.352	lb CO ₂ /mile-yr	0.0006133	tonne CO ₂ /mile-yr
			0.0003811	tonne CO ₂ /km-yr
Protected steel pipeline	15.16	lb CH ₄ /mile-yr	0.006874	tonne CH ₄ /mile-yr
			0.004272	tonne CH ₄ /km-yr
CO ₂ from oxidation ^d	1.286	lb CO ₂ /mile-yr	0.0005833	tonne CO ₂ /mile-yr
			0.0003625	tonne CO ₂ /km-yr
CO ₂ from pipeline leaks	0.9180	lb CO ₂ /mile-yr	0.0004164	tonne CO ₂ /mile-yr
			0.0002587	tonne CO ₂ /km-yr
Unprotected steel	275.9	lb CH ₄ /mile-yr	0.1251	tonne CH ₄ /mile-yr

Source	Emission Factor ^{a,b} , Original Units		Emission Factor ^c , Converted Units	
	pipeline			0.0778
CO ₂ from oxidation ^d	13.87	lb CO ₂ /mile-yr	0.006293	tonne CO ₂ /mile-yr
			0.003910	tonne CO ₂ /km-yr
CO ₂ from pipeline leaks	16.51	lb CO ₂ /mile-yr	0.007487	tonne CO ₂ /mile-yr
			0.004652	tonne CO ₂ /km-yr

Footnotes and Sources:

^a Campbell, L.M., M.V. Campbell, and D.L. Epperson. *Methane Emissions from the Natural Gas Industry, Volume 9: Underground Pipelines*, Final Report, GRI-94/0257.26 and EPA-600/R-96-080i. Gas Research Institute and U.S. Environmental Protection Agency, June 1996.

^b Emission factor derivations are provided in API Compendium (2009)-Appendix C.

^c The average CH₄ concentration associated with these emission factors provided in Table E-4 is 93.4 mole %; the average CO₂ concentration (for buried pipelines) also provided in Table E-4 is 2 mole %. If the actual concentration differs from the default value, the emission factors shown above can be adjusted by the ratio of the site concentration to the default concentration.

^d A portion of CH₄ emitted from underground pipeline leaks is oxidized to form CO₂.

METHOD 04

PUMP STATIONS FUGITIVE EMISSIONS ESTIMATION FROM MAINTENANCE ACTIVITIES

Members should refer use Equation 21-19 and the table of CH₄ Emission Factors for Pump Stations (Table 21.12) presented below to calculate emissions.

Table 21.12 CH₄ Emission Factors for Pump Stations

Source	CH ₄ Emission Factor ^a , Original Units	CH ₄ Emission Factor ^b , Converted to Tonnes Basis	CH ₄ Content Basis of Factor ^c
Oil pump stations (maintenance) ^d	1.56 lb/yr-station	7.076E-04 tonnes/station-yr	Not given

Footnotes and Sources:

^a Shires, T.M. *Methane Emissions from the Natural Gas Industry, Volume 7: Blow and Purge Activities*, Final Report, GRI-94/0257.24 and EPA-600/R-96-080g, Gas Research Institute and U.S. Environmental Protection Agency, June 1996.

^b CH₄ emission factors converted from scf or m³ are based on 60°F and 14.7 psia. The CH₄ emission factors can be adjusted based on the relative concentrations of CH₄ and CO₂ to estimate CO₂ emissions.

^c Shires, T.M., and M.R. Harrison. *Methane Emissions from the Natural Gas Industry, Volume 6: Vented and Combustion Source Summary*, Final Report, GRI-94/0257.23 and EPA-600/R-96-080f, Gas Research Institute and U.S. Environmental Protection Agency, June 1996.

^d Tilkioglu, B.H and D.R. Winters. *Annual Methane Emission Estimate of the Natural Gas and Petroleum Systems in the United States*. Pipeline Systems Incorporated (PSI), December 1989.

The oil pump station emission factor is based on an estimate of annual maintenance activities and an assumed CH₄ content of 100 ppm in the crude (Tilkicioglu and Winters, 1989).

These emission factors can be adjusted based on the CH₄ content of the site-specific gas. When the gas at the facility contains significant quantities of CO₂, the CH₄ emission factor can be adjusted based on the relative concentrations of CH₄ and CO₂ in the gas to estimate the CO₂ emissions.

Example 21-5: Emissions Calculation using the Simplified Emissions Factor Approach

There is an oil transmission system, which has 70 miles of transmission lines and three pump stations. The natural gas in the system has a typical methane content and no CO₂. The CH₄ content is assumed to be consistent with the default emission factor given in Table 21.12 (see above). The Member should calculate the pump stations emissions. Assume maintenance is done once per year.

$$E_{\text{CH}_4} = 3 \text{ stations} \times (7.076 \times 10^{-4} \text{ tonnes CH}_4/\text{station-yr})$$

$$E_{\text{CH}_4} = 2.123 \times 10^{-3} \text{ tonnes CH}_4/\text{yr}$$

22.6 Transportation Sector - Truck, Tanker, Rail Loading

The amount of hydrocarbon emissions from tank, truck and rail loading activities is a relatively small portion of the total for the upstream petroleum industry. Nonetheless, where these activities occur they can be a significant local source of emissions. Emissions from these activities may be attributed to three major effects:

- Physical displacement of residual vapors by the incoming liquid,
- Evaporation effects promoted by agitation of the liquid during the transfer process, and
- Leakage/spillage during the connection of transfer lines and during the transfer process.

This section presents emission calculation approaches from loading activities during oil and gas production operations. The methodologies presented here show methods to estimate TOC emissions that require a vapor phase CH₄ or CO₂ (if present) content to convert to CH₄ or CO₂ emissions. When site-specific data is not available, Members should assume a 15 wt% vapor phase CH₄ content of *live crude*⁴.

METHOD 01

SIMPLIFIED EMISSIONS FACTOR CALCULATION APPROACH FOR LOADING ACTIVITIES

⁴ AP-42 reports that the VOC comprises 55-100 wt% of the TOC, with a typical value of 85%. Thus, a good assumption for the CH₄ content of the TOC is 15 wt% in the absence of site-specific data.

Members should use Equation 22-18 and the table of simplified TOC emissions factor for loading loss emissions (Table 22.6) to calculate CH₄ or CO₂ emissions. In this methodology, TOC emissions should be converted to CH₄ or CO₂ emissions (if present) based on the CH₄ or CO₂ content of the loading vapors.

Equation 22-18: CH₄ and CO₂ Emissions From Loading Operations	
$E_I = L_V \times F_A \times WF_I$	
where,	
E_I = Emission rate of CH ₄ or CO ₂ from all components of a given type in the stream	
L_V = Crude oil loading volume	
F_A = Average emission factor for the component type A	
WF_I = Average weight fraction of TOC, CH ₄ or CO ₂	

Table 22.6 - Simplified TOC Emission Factors for Loading Losses^a

Loading Type	Units		Crude Oil ^{b,c}
Rail / Truck Loading ^d Submerged Loading – Dedicated normal service	Original Units	lb TOC/10 ³ gal loaded mg TOC/L loaded	2 240
	Converted Units ^e	tonne TOC/ 10 ⁶ gal loaded tonne TOC/10 ³ m ³ loaded	0.91 0.240
Rail / Truck Loading ^d Submerged Loading – Vapor balance service	Original Units	lb TOC/10 ³ gal loaded mg TOC/L loaded	3 400
	Converted Units ^e	tonne TOC/ 10 ⁶ gal loaded tonne TOC/10 ³ m ³ loaded	1.51 0.400
Rail / Truck Loading ^d Splash Loading – Dedicated normal service	Original Units	lb TOC/10 ³ gal loaded mg TOC/L loaded	5 580
	Converted Units ^e	tonne TOC/ 10 ⁶ gal loaded tonne TOC/10 ³ m ³ loaded	2.20 0.580
Rail / Truck Loading ^d Splash Loading – Vapor balance service	Original Units	lb TOC/10 ³ gal loaded mg TOC/L loaded	3 400
	Converted Units ^e	tonne TOC/ 10 ⁶ gal loaded tonne TOC/10 ³ m ³ loaded	1.51 0.400
Marine Loading ^f – Ships/ocean barges	Original Units	lb TOC/10 ³ gal loaded mg TOC/L loaded	0.61 73
	Converted Units ^e	tonne TOC/ 10 ⁶ gal loaded tonne TOC/10 ³ m ³ loaded	0.28 0.073
Marine Loading ^f – Barges	Original Units	lb TOC/10 ³ gal loaded mg TOC/L loaded	1.0 120

Loading Type	Units		Crude Oil ^{b,c}
		Converted Units ^e	tonne TOC/ 10 ⁶ gal loaded tonne TOC/10 ³ m ³ loaded

Footnotes and Sources:

^a The factors shown are for total organic compounds. AP-42 reports that the VOC comprises approximately 85% of the TOC for crude oil. Thus, a simplifying assumption for the CH₄ content of the TOC is 15% in the absence of site-specific data, recognizing that this will likely overestimate emissions.

^b EPA, AP-42, Section 5, Tables 5.2-5 and 5.2-6, 2008.

^c The example crude oil has an RVP of 5 psia.

^d The rail/truck loading emission factors were derived using Equation B-5 assuming a liquid temperature of 60°F.

^e Converted from original emission factors provided in units of mg/L in AP-42. Thus, round-off errors may result in some small differences when converting from the emission factors provided in units of lb/10³ gallons.

^f Marine loading factors based on a loaded liquid temperature of 60°F.

The following example illustrates the use of loading emission factors for crude oil loading operations.

Example 22-1: Crude Oil Loading Loss Emissions Calculation using the Simplified Emissions Factor Approach

A Member is loading 45,000 bbl/yr of crude oil into a tank truck via submerged loading and dedicated normal service. The crude vapors con 10 wt% CH₄, the crude oil loading loss emission factor from tank truck submerged loading, dedicated normal service is 0.91 tonnes TOC per million gallons loaded. Calculate CH₄ emissions.

$$E_{\text{CH}_4} = (0.91 \text{ tonnes TOC}/10^6 \text{ gal}) \times (42 \text{ gal/bbl}) \times (45,000 \text{ bbl/yr}) \times (10 \text{ tonnes CH}_4/100 \text{ tonnes TOC})$$

$$E_{\text{CH}_4} = 0.179 \text{ tonnes CH}_4/\text{yr}$$

METHOD 02

EMISSIONS CALCULATION APPROACH FOR CRUDE OIL LOADED INTO MARINE VESSELS

This calculation method requires Members to input the true vapor pressure of the crude oil (P), the Reid Vapor Pressure (RVP), and the molecular weight of the vapors (M)⁵. Table 22.7 presents the physical properties of crude oil based on the average temperature of a facility. This table is limited to crude oil with a RVP of 5 and TVP between 40°F and 100°F. Members should use site-specific data, if available.

⁵ Physical properties sources can be found in the following publications: Perry's Chemical Engineering Handbook (Perry, 1984); CRC (CRC Press, 1984).

Table 22.7 - Crude Oil Physical Properties

Petroleum Liquid	Vapor Molecular Weight 60°F, (lb/lbmole)	Condensed Vapor Density 60°F, (lb/gal)	Liquid Density 60°F, (lb/gal)	True Vapor Pressure (psi)						
				40°F	50°F	60°F	70°F	80°F	90°F	100°F
Crude Oil RVP 5	50	4.5	7.1	1.8	2.3	2.8	3.4	4.0	4.8	5.7

Source: EPA, AP-42, Table 7.1-2, February 1996.

Members should use Equation 22-19 to calculate emissions from loading crude oil into ships and ocean barges.

Equation 22-19: Total Loading Loss TOC Emission Factor

$$C_L = C_A \times C_G$$

where,

C_L = Total loading loss TOC emission factor, in lb/10³ gallon of crude oil loaded

C_A = Arrival arrival emission factor, from vapors in the empty tank vessel before loading, in lb/10³ gallon loaded (Table 22.8)

C_G = Emission factor for emissions generated during loading, in lb/10³ gallon (calculated using Equation 22-20, presented below)

Equation 22-20: Emission Factor for Losses Generated during Loading Activities

$$C_G = 1.84 \times (0.44P - 0.42) \times (MG/T)$$

where,

P = True vapor pressure of crude oil loaded, in psia

M = Molecular weight of the vapors, in lb/lb-mole

G = Vapor growth factor = 1.02, dimensionless

T = Temperature of the vapors, °R (°R = °F + 459.7)

Table 22.8 - Average Arrival TOC Emission Factor (C_A)

Arrival Emission Factor, C_A	
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Ship/Ocean Barge Tank Condition	Previous Cargo ^b	Original Units	Converted Units	
		lb TOC/10 ³ gallon ^a	tonnes TOC/gal	tonnes TOC/m ³
Uncleaned	Volatile	0.86	0.39	103
Ballasted	Volatile	0.46	0.21	5.9
Cleaned or gas-freed	Volatile	0.33	0.15	1.1
Any condition	Non-volatile	0.33	0.15	0.57

^aThe factors shown are for total organic compounds. AP-42 reports that the VOC comprises 55-100% of the TOC, with a typical value of 85%. Thus, a good, conservative assumption for the CH₄ content of the TOC is 15% in the absence of site-specific data.

^b"Volatile" cargo refers to those cargoes with a vapor pressure greater than 1.5 psia.

Example 22-2: Crude Oil Loading Loss Emissions Calculation from Loading into Marine Vessels

A Member is loading 45,000 bbl/day of crude oil (RVP 5) into ships. The ships are clean prior to loading. The average ambient temperature of the facility is 60°F based on annual meteorological data. The molecular weight of the crude oil is 50lb/lbmole and the true vapor pressure is 2.8 psi. Calculate CH₄ emissions.

$$C_G = 1.84 \times [(0.44 \times 2.8) - 0.42] \times [(50 \times 1.02)/519.7]$$

$$C_G = 0.15 \text{ lbTOC}/10^3 \text{ gal}$$

The average arrival TOC emission factor for clean marine vessels is 0.33 lbTOC/10³ gal
The total loading loss factor is:

$$C_L = 0.33 + 0.15 = 0.48 \text{ lbTOC}/10^3 \text{ gal}$$

$$E_{CH_4} = (0.48 \text{ lbTOC}/10^3 \text{ gal}) \times (42 \text{ gal}/\text{bbl}) \times (45,000 \text{ bbl}/\text{yr}) \times (15 \text{ lbCH}_4/100 \text{ lbTOC}) \times (\text{tonne}/2204.62 \text{ lb})$$

$$E_{CH_4} = 0.062 \text{ tonnesCH}_4/\text{yr}$$

METHOD 03

EMISSIONS CALCULATION APPROACH FOR CRUDE OIL LOADED INTO TANK TRUCKS AND RAIL CARS (GENERAL EQUATION APPROACH)

Members should apply Equation 22-21 to calculate emissions from loading crude oil into tank trucks and rail cars.

Equation 22-21: Emission Factor for Losses Generated during Tank Truck and Rail Car Loading Activities

Equation 22-21: Emission Factor for Losses Generated during Tank Truck and Rail Car Loading Activities

$$L_L = 12.46 \times [(S \times P \times M) / T] \times [1 - (C_E / 100)]$$

where,

L_L = loading loss emission factor, in lb/10³ gallon of liquid loaded. This factor is for total organic compounds (TOC)

S = Saturation factor (see Table 22.9 below)

P = Liquid true vapor pressure, in psia

M = Molecular weight of the vapors, in lb/lb-mole

T = Temperature of bulk liquid loaded, °R (°R = °F + 459.7)

C_E = Control efficiency⁶ (%)

Table 22.9 - Saturation, S, Factors for Estimating Loading Losses

Cargo Carrier Type	Mode of Operation	S Factor
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 vapor balance service	1.00
	Splash loading of a clean cargo tank	1.45
	Splash loading, dedicated normal service	1.45
	Splash loading, dedicated vapor balance service	1.00

Source: EPA AP-42, Section 5.2, January 1995.

Example 22-3: Crude Oil Loading Loss Emissions Calculation using General Equation Approach

A Member is loading 500 bbl/day of crude oil (RVP 5) into a tank truck via submerged loading and dedicated normal service. The saturation factor of the tank truck is 0.60. No control devices are used to minimize emissions. The average ambient temperature of the facility is 50°F. The molecular weight of the crude oil is 50lb/lbmole and the true vapor pressure is 2.3 psi. Calculate CH₄ emissions.

$$L_L = 12.46 \times [(0.6) \times (2.3) \times (50)] / 509.7 \times (1 - 0\% / 100)$$

⁶ The control efficiency term is included in the loading loss emission factor equation because some loading operations are controlled using various collection systems, such as Vapor Recovery Units (VRU). If applicable, the overall estimated control efficiency for the particular control system should be used.

$$L_L = 1.69 \text{ lbTOC}/10^3 \text{ gal}$$

$$E_{\text{CH}_4} = (1.69 \text{ tonnesTOC}/10^3 \text{ gal}) \times (42 \text{ gal}/\text{bbl}) \times (182,500 \text{ bbl}/\text{yr}) \times (15 \text{ lbCH}_4/100 \text{ lbTOC}) \times (\text{tonne}/2204.62 \text{ lb})$$

$$E_{\text{CH}_4} = 0.881 \text{ tonnesCH}_4/\text{yr}$$

Addendum to Section 22

22.7 Transportation Sector - Pipeline Blowdowns and Pigging

Pipeline pigging operations occur at oil pipelines during product transfer, product separation, and maintenance. Pigging following product transfer is used to remove residual product from the pipeline after loading occurs. Pigs can also be used for product separation when switching products in the line as well as for maintenance activities such as pipeline cleaning, gauging, or dewatering. Pipeline blowdowns can occur during repair work or when lines are put out of service.

This section presents emission calculation methods to estimate vented emissions from pipeline blowdowns and pigging operations.

METHOD 01

PIPELINE BLOWDOWNS AND PIGGING EMISSIONS ESTIMATION METHODOLOGY

This methodology relies on an estimated volume of gas vented during pipeline blowdowns and pigging operations. This volume is determined using engineering estimates based factors such as the dimensions of the pipeline and operating pressure and temperature. This protocol recommends Members to keep proper records of their pipeline blowdowns and pigging activities.

Equation 22-22: Pipeline Blowdowns and Pigging Activities Emissions Estimation

$$E_i = Q \times (\text{lbmole}/379.3\text{scf}) \times MW_i \times f_i / 2200$$

where,

E_i = emissions of the GHG (either CO₂ or CH₄), in tonne/yr

Q = total volume of gas vented, in scf/yr

MW_i = molecular weight of GHG, in lb/lbmole

f_i = molar fraction of the GHG

2200 = conversion factor from lbs to tonnes

In order to determine the volume of gas associated with pipeline operations, Members should estimate the volume of gas vented at the process temperature and pressure and convert the calculated volume to standard conditions (15°C and 101.325 kPa). Equation 22-23 presents a method to calculate volume.

Equation 22-23: Volume of Gas Released

$$Q_T = Q_A \times (T_s / P_s) \times [(P_i / z_i T_i) - (P_f / z_f T_f)]$$

where,

Q_T = total volume of gas released at standard conditions at 15°C and 101.325 kPa, in m³

z = compressibility factor for the gas

P = process pressure, in kPa

T = process temperature, in K

P_s = standard pressure, in kPa

T_s = initial process temperature, in K

i = initial pressure and temperature

f = final pressure and temperature

Equation 22.24: Actual Volume (Q_A)

$$Q_A = L_P \times F$$

where,

Q_A = actual volume at process conditions

L_P = pipeline length, in m

F = volume factor (Table 22-10)

Table 22.10 - Volume Occupied by a One-Meter Length of Various Standard Pipe Sizes^a

NPS Size	Sch 40 m ³ /m	Sch 60 m ³ /m	Sch 80 m ³ /m	Sch 100 m ³ /m	Sch 120 m ³ /m	Sch 140 m ³ /m	Sch 160 m ³ /m
1	5.574E-4		4.639E-4				3.366E-4
2	2.165E-3		1.905E-3				1.446E-3
3	4.770E-3		4.261E-3				3.489E-3
4	8.213E-3		7.419E-3		6.652E-3		5.987E-3
6	1.864E-2		1.682E-2		1.534E-2		1.365E-2
8	3.228E-2	3.093E-2	2.946E-2	2.804E-2	2.619E-2	2.484E-2	2.352E-2
10	5.088E-2	4.817E-2	4.635E-2	4.395E-2	4.163E-2	3.879E-2	3.661E-2
12	7.221E-2	6.849E-2	6.557E-2	6.203E-2	5.855E-2	5.586E-2	5.195E-2
14	8.728E-2	8.320E-2	7.917E-2	7.451E-2	7.072E-2	6.701E-2	6.343E-2
16	1.140E-1	1.093E-1	1.038E-1	9.844E-2	9.323E-2	8.728E-2	8.320E-2
18	1.443E-1	1.380E-1	1.318E-1	1.247E-1	1.178E-1	1.121E-1	1.056E-1
20	1.794E-1	1.711E-1	1.630E-1	1.541E-1	1.464E-1	1.379E-1	1.308E-1

Footnotes and Sources:

^a Canadian Association of Petroleum Producers (CAPP). *Estimation of Flaring and Venting Volumes from Upstream Oil and Gas Facilities*, Guide. May 2002.

If the compressibility factor is unknown, Members should estimate it using the equation below.

Equation 22.25: Compressibility Factor^a Estimation

$$z = a + bP + cT + dP^2 + eT^2 + fPT$$

where,

P = initial process pressure, in kPa

T = initial process temperature, in °C

Table 22.11 - Correlation Coefficients for Estimating Compressibility Factors^a

Correlation Coefficient	Value
a	9.9187E-01
b	-3.3501E-05
c	6.9652E-04
d	6.3134E-10
e	-8.6023E-06
f	2.3290E-07

Footnotes and Sources:

^a Canadian Association of Petroleum Producers (CAPP). *Estimation of Flaring and Venting Volumes from Upstream Oil and Gas Facilities*, Guide. May 2002.

METHOD 02

SIMPLIFIED EMISSIONS FACTOR CALCULATION APPROACH

Members should use Equation 22-26 and the table of CH₄ Emission Factors for Pigging Activities (Table 21.12) to calculate emissions.

Equation 22-26: CH₄ and CO₂ Emissions From Pipeline Blowdowns and Pigging

$$E_l = AF \times EF$$

where,

E_l = Total CH₄ or CO₂ emissions

AF = Activity factor (i.e. pipeline length)

EF = Emission factor

Table 21.12 - CH₄ Emission Factors for Pipeline Blowdowns and Pigging Activities

Source	CH ₄ Emission Factor ^a , Original Units	CH ₄ Emission Factor ^b , Converted to Tonnes Basis	CH ₄ Content Basis of Factor ^c
Miscellaneous (includes M&R, odorizer, drips, sampling, pigging, dehydrators) ^d	1,134 × 10 ³ scfy/station	21.75 tonnes/station-yr	93.4 mole%
Gas transmission pipelines venting/blowdowns ^{e,f}	40,950 scfy/mile	0.7855 tonnes/mile-yr	93.4 mole %
		0.4881 tonnes/km-yr	

Footnotes and Sources:

^a Shires, T.M. *Methane Emissions from the Natural Gas Industry, Volume 7: Blow and Purge Activities*, Final Report, GRI-94/0257.24 and EPA-600/R-96-080g, Gas Research Institute and U.S. Environmental Protection Agency, June 1996.

^b CH₄ emission factors converted from scf or m³ are based on 60°F and 14.7 psia. The CH₄ emission factors can be adjusted based on the relative concentrations of CH₄ and CO₂ to estimate CO₂ emissions.

^c Shires, T.M., and M.R. Harrison. *Methane Emissions from the Natural Gas Industry, Volume 6: Vented and Combustion Source Summary*, Final Report, GRI-94/0257.23 and EPA-600/R-96-080f, Gas Research Institute and U.S. Environmental Protection Agency, June 1996.

^d Developed from data used for the June 1996 GRI/EPA methane emissions study. Emission factors are based on averaging data by site. The average CH₄ concentration associated with these emission factors is provided in Table E-4.

^e See derivation in API Compendium (2009), Appendix B.

^f Radian International. *1995 Air Emissions Inventory of the Canadian Natural Gas Industry*, Final Report, Canadian Gas Association Standing Committee on Environment, September 1997.

The miscellaneous factor includes meter and pressure regulatory (M&R) stations, odorizer, drips⁸, sampling, pigging, and dehydrators. These activities are variable and a material balance equation approach would provide a better estimate of the emissions generated during these operations. For example, emissions of CH₄ released from drips could be estimated based on the volume of gas entrained in the liquid and the liquid quantity captured.

Pipeline blowdowns are non-routine activities that result in intentional releases of gas to the atmosphere. The emission factors presented in the table above can be adjusted based on the CH₄ content (and CO₂ content when applicable) of the site-specific gas.

Example 22-4: Emissions Calculation using the Simplified Emissions Factor Approach

A gas transmission system has 45 miles of pipelines. The gas contains 75 mole % CH₄ and 10 mole % CO₂. The Member should calculate the transmission pipeline blowdowns emissions.

⁸ Pipeline drips involve removing liquids in gas pipelines using in-line separators.

$$E_{\text{CH}_4} = 45 \text{ miles} \times (0.7855 \text{ tonnes CH}_4/\text{mile-yr}) \times (75 \text{ mole \%CH}_4/ 93.4 \text{ mole \%CH}_4)$$

$$E_{\text{CH}_4} = 28.383 \text{ tonnes CH}_4/\text{yr}$$

$$E_{\text{CO}_2} = 45 \text{ miles} \times (0.7855 \text{ tonnes CH}_4/\text{mile-yr}) \times (75 \text{ mole \%CH}_4/ 93.4 \text{ mole \%CH}_4) \times$$
$$(\text{tonne mole \%CH}_4/ 16 \text{ tonnes CH}_4) \times (\text{tonne mole gas}/0.75 \text{ tonne mole CH}_4) \times (0.10$$
$$\text{ tonne mole CO}_2/\text{tonne mole gas}) \times (44 \text{ tonnes CO}_2/ \text{tonne mole CO}_2)$$

$$E_{\text{CO}_2} = 10.407 \text{ tonnes CO}_2/\text{yr}$$