Division of Air Pollution Control
February 2017

Oil and Gas Fugitive Emissions Worksheet

This fact sheet contains a worksheet that owners/operators of oil and gas facilities can use to calculate emissions from leaking components at their facility. It is designed for the equipment typically found at compressor stations but may be useful for other similar facilities.

Estimating Emissions from Oil and Gas Components

The purpose of this worksheet is to provide an easily used method to calculate emissions of fugitive VOC[1] emissions commonly associated with natural gas production and the gathering network, e. g. from ancillary equipment[2] and associated equipment: compressors, pumps, piping, pneumatic controllers, inlet separators, gas-water/condensate/oil separators, etc. that are in natural gas service, regardless of VOC content. Emissions factors are based on various sources as described in the instructions.

The table found on the next page can be used to compile and calculate the emissions from each component. Instructions for using the table can be found beginning on page 4.

"VOC" is defined in 40 CFR Part 60, Subpart VVa, as "Volatile organic compounds or VOC means, for the purposes of this subpart, any reactive organic compounds as defined in §60.2 Definitions." which is to say, "Volatile Organic Compound means any organic compound which participates in atmospheric photochemical reactions; or which is measured by a reference method, an equivalent method, an alternative method, or which is determined by procedures specified under any subpart."

"Ancillary Equipment" is defined in 40 CFR Part 63, Subpart HH, as ". . . any of the following pieces of equipment: pumps, pressure relief devices, sampling connection systems, open-ended valves, or lines, valves, flanges, or other connectors."

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Releases from equipment containing gas or vapor streams[3]

a	b	c	d	e	f	g	
no. of units	Highest VOC content (mass %)	specific volume (scf/lb)	emission factor lb/hr per unit	short-term HC emission (lb/hr)	Hrs. per year	Annual VOC emission (TPY)	type or subtype
Compressor seals (per seal), for compressors not meeting the definition of "Centrifugal compressor" or "Reciprocating compressor" under 40 CFR 60.5430 or 60.5430a as appropriate. (blowdown events not included) (see instruction C)							
			0.0194				
Centrifugal or reciprocating compressors (by the definition of 40 CFR 60.5430 or 60.5430a) and associated isolation valves and vents (blowdown events not included) (see instruction A)							
			(35.3)MMW$^{1/2}$				wet seals (centrifugal compressor) operating (uncontrolled)
			(??)MMW$^{1/2}$				wet seals (centrifugal compressor) pressurized shutdown (uncontrolled)
			(2.12)MMW$^{1/2}$				dry seals (centrifugal compressor) operating (per seal)
			(0.42)MMW$^{1/2}$				dry seals (centrifugal compressor) pressurized shutdown (per seal)
			(0.59)MMW$^{1/2}$				rod packing seals (reciprocating compressor); operating
			(0.88)MMW$^{1/2}$				rod packing seals (reciprocating compressor); pressurized shutdown
			(16.49)MMW$^{1/2}$				leakage through isolation valves for large compressors during depressurized shutdown
			(1.77)MMW$^{1/2}$				uncontrolled leakage through closed blowdown vents
NG-actuated controllers (including so-called "zero bleed") (see instruction B)							
			(0.60)MMW$^{1/2}$				high-bleed NG controllers (not compliant w/ Subpart OOOO)
			(0.175)MMW$^{1/2}$				low-bleed NG controllers (compliant w/ Subpart OOOO)
			(0.159)MMW$^{1/2}$				zero-bleed NG controllers (as defined by Subpart OOOO; aka "intermittent bleed")

(continued)

[3] Emission factors for equipment in light liquid service have not yet been incorporated into this worksheet. A separate tabulation of those emission sources will need to be supplied by the applicant." "In light liquid service" is defined in NSPS Subpart OOOO, as "In light liquid service means that the piece of equipment contains a liquid that meets the conditions specified in §60.485a(e) or §60.5401(g)(2) of this part."

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a	b	c	d	e	f	g	
no. of units	highest VOC content (mass %)	specific volume (scf/lb)	emission factor lb/hr per unit	short-term HC emission (lb/hr)	hrs per year	annual VOC emission (TPY)	**type** or subtype
Miscellaneous Fittings (see instruction C)							
			0.00044				connectors
			0.0099				valves, other than those listed below
			0.0053				pump seals (per seal)
			0.00086				flanges
			0.0099				valves, other than the isolation valves and blowdown vents associated with compressors meeting the definitions of 40 CFR 60.5430 or 60.5430a, as listed above
			0.0194				relief valves
			0.0044				open-ended lines
			0.0194				others
Equipment not described by any of the above in terms of equipment type or emission factor							
							describe:
							describe:(use additional sheets as necessary)
			n/a				**Totals**

Instructions and Discussion

General Instructions

column (c)	Specific volume (SV) in units of scf/lb is related to mean molecular weight (MMW) by the equation SV = 379.5/MMW.
column (e)	Emission rate is computed as the product of columns (a), (b), and (d) (divided by 100).

(A)

These emission factors are derived from the following factors extracted from the GASSTAR reports issued by the U.S. EPA:

coeff. (see below)	emiss. fac. (scf/hr)	unit
0.59	50	each rod packing under normal operation (reciprocating compressor)
0.88	75	each rod packing during pressurized shutdown (reciprocating compressor)
35.3	3,000	each wet seal during normal operation (centrifugal compressor) (uncontrolled)
?	?	each wet seal during pressurized shutdown (centrifugal compressor) (uncontrolled)
2.12	180	each dry seal during normal operation (centrifugal compressor)
0.42	36	each dry seal during pressurized shutdown (centrifugal compressor) (estimated from Exhibit 3 in ref.(b))
16.49	1,400	through a closed isolation valve
1.77	150	through a closed blowdown valve

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<table>
<tr><td></td><td>The GASSTAR emission factors are based on a lean gas stream with mean molecular weight of perhaps 20. To convert to mass rate of emission for rich gas streams, a free-orifice assumption has been made for the purpose of this worksheet, i.e., it has been assumed that volumetric release rate is proportional to the square root of mean molecular weight. In that case, the Gasstar emission factor "G" in units of scf/hr is converted to lb/hr as follows:
volumetric rate adjusted by MMW: G' = G(20/MMW)$^{1/2}$ scf/hr
converting to mass rate with the ideal gas constant 379.5 scf/lb-mol:
mass rate = G'(MMW)/379.5 (scf/hr)(lb/lb-mol)(lb-mol/scf) = G(20$^{1/2}$)(MMW)$^{1/2}$/379.5 = G(MMW)$^{1/2}$/84.9

The coefficients in the left-hand column above are the Gasstar factors divided by 84.9, which are then multiplied by MMW$^{1/2}$.</td></tr>
<tr><td>(B)</td><td>"Zero bleed" in this context means "zero <u>continuous</u> bleed" consistent with the definition of "bleed rate" in 60.5430 under Subpart OOOO. If the continuous bleed is zero, there still remain the per-actuation releases, the aggregate quantity of which depends on the details of usage of that device. In other contexts, for instance "Oil and Natural Gas Sector Pneumatic Devices (April 2014)" prepared by U.S. EPA OAQPS, the term may describe a true zero release of hydrocarbons. And, for the so-called "low-bleed" and "high-bleed" categories, there may be ambiguity as to whether the stated worst-case and "typical" release rates cited in the literature represent the continuous-bleed component only, or if they include a "per-actuation" component reflective of details of daily usage. For the purpose of this worksheet the former is being assumed, i.e. nominal emission rates of continuous-bleed controllers should have an assumed intermittent rate added, to produce a realistic emission factor. The three factors listed here are derived from Table W-1A to Subpart W of Part 98, which the Background Technical Support Document for the proposed Part 60 Subpart OOOOa refers to as "the best emissions rate estimates for pneumatic controllers:"
<table>
<tr><td>Low Continuous Bleed Pneumatic Device Vents</td><td>1.39</td><td>scf/hr/component</td></tr>
<tr><td>High Continuous Bleed Pneumatic Device Vents</td><td>37.3</td><td>"</td></tr>
<tr><td>Intermittent Bleed Pneumatic Device Vents</td><td>13.5</td><td>"</td></tr>
</table>
A pneumatic device schematic (see, for instance, Exhibit 1 in reference (d)) makes it clear that an operational unit consists of a control circuit ("weak signal") and an actuator circuit ("strong signal"), with the former being continuous-bleed and the latter intermittent-bleed. Thus the total emission is the sum of the two, i.e. for high-bleed control systems, 13.5 scfh + 37.3 scfh = 50.8 scfh; low-bleed 13.5 + 1.39 = 14.89 scfh; no-bleed = 13.5 scfh. These volumetric rates are converted to mass rates by the same mean molecular weight adjustment used elsewhere on this worksheet.</td></tr>
<tr><td>(C)</td><td>The origin of the emission factors is table 2-4 in the 1995 EPA document identified as reference (a). Note that, for the purpose of this worksheet, some of the factors in 2-4 are superseded by the newer factors provided above, and the "others" category is modified to exclude large compressors and natural-gas actuated controllers.</td></tr>
</table>

References

(a)	"***Protocol for Equipment Leak Emission Estimates***," Table 2-4, for Oil and Gas Production Operations (EPA-453/R-95-017, November 1995
(b)	"Replacing Wet Seals with Dry Seals in Centrifugal Compressors," from the U.S. EPA "Lessons Learned from Natural Gas STAR Partners" series, at ***http://www3.epa.gov/gasstar/documents/ll_wetseals.pdf***
(c)	"Reducing Emissions When Taking Compressors Off-line," from the U.S. EPA "Lessons Learned from Natural Gas STAR Partners" series, at ***http://www3.epa.gov/gasstar/documents/ll_compressorsoffline.pdf***
(d)	"Options for Reducing Methane Emissions From Pneumatic Devices In The Natural Gas Industry," from the U.S. EPA "Lessons Learned from Natural Gas STAR Partners" series, at ***https://www3.epa.gov/gasstar/documents/ll_pneumatics.pdf***