The prasino Group

Project Methodology

For Determining Emissions Factors for Pneumatic Devices in British Columbia

8/6/2013

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1. Introduction

This report outlines the project methodology for developing emission factors for reporting greenhouse gas (GHG) emissions from pneumatic controllers and pumps (collectively referred to as 'devices') in British Columbia. The development of emissions factors that would allow for an alternative method of monitoring and reporting of GHGs from pneumatic devices, as per an agreement between the Canadian Association of Petroleum Producers (CAPP) and the B.C. Ministry of Environment's Climate Action Secretariat (CAS). The Prasino Group (TPG) has been engaged by the Science and Community Environmental Knowledge Fund (SCEK) in order to develop these emission factors based on quantitative sampling of pneumatic devices in BC. This document describes the methodology that will be used in order to achieve the project objectives. Specifically, this document outlines how TPG will:

- Determine which pneumatic controllers and pumps to include in the sample;
- Determine the physical sample size for each unique controllers and pump;
- Determine which oil and gas companies to cover and the required number of devices per company;
- Collect data in the field;
- Conduct the required analysis; and
- Produce and publish a report with the results of analysis.

2. Device Selection Approach

Pneumatic devices used in B.C.'s oil and gas sector fall into two categories:

1. Pneumatic chemical injection pumps (typically injecting methanol into a pipeline); and,
2. Pneumatic controllers, which regulate pressure, temperature, fluid level, or some other process instrument.

Figure 1 below outlines the steps associated with creating the initial list of devices eligible for sampling. The following section describes the process for selecting which pneumatic controllers and pumps to include in the sampling regime.

2.1 Pneumatic Controllers

In order to determine which pneumatic controllers to include in our sample, multiple steps were undertaken as illustrated in Figure 1. Through this process, the most prominent and eligible controllers were identified, with 15 controllers accounting for 97% of field samples in the Cap-Op Distributed Energy Efficiency Project Platform (DEEPP) database.

2.1.1 Compile All Known Controllers

TPG initially developed a complete list of all known (or anticipated) pneumatic low- and high-bleed controllers that are used in the upstream oil and gas industry in BC. Using one or more of the sources listed below, the make, model, and manufacturers' stated bleed rate of each controller was determined:

- *CETAC West: Efficient Use of Fuel Gas in Chemical Injection Pumps. Fuel Gas Best Management Practices.* The BMP lists manufacturer bleed rates of controllers in m^3/hr of natural gas.
- *Pacific Carbon Trust (PCT): High-Bleed to Low-Bleed Conversion for Pneumatic Controllers. Meta-Protocol for Oil and Gas Emission Reductions Projects.* In the protocol, the bleed rates were stated in standard cubic feet per

hour (scfh) of air, based on manufacturer stated specifications. The volume of air bled was converted to natural gas by multiplying by 1.3[1]. When a range of values was listed, the highest value was taken.

- *Environmental Protection Agency: Gas STAR – Options for Reducing Methane Emissions from Pneumatic Devices in the Natural Gas Industry*. This document stated the bleed rates of high- and low-bleed controllers in ft^3/hr of air. These values were converted to m^3/hr of natural gas.
- *Western Climate Initiative (WCI): Final Essential Requirements of Mandatory Reporting.* This report references the BMP, PCT Protocol and EPA Gas STAR for the pneumatic controller list and bleed rates. The manufacturer bleed rates in this document are in m^3/hr.
- *Manufacturer websites* were referenced to determine the steady state air consumption for pneumatic controllers. The highest steady state air consumption was recorded. The bleed rates were stated in m^3/hr and ft^3/hr.
- *Cap-Op Energy samples from the DEEPP database* were used to look at controllers and pumps that are already in the field and have been sampled previously by GreenPath Energy Ltd[2].

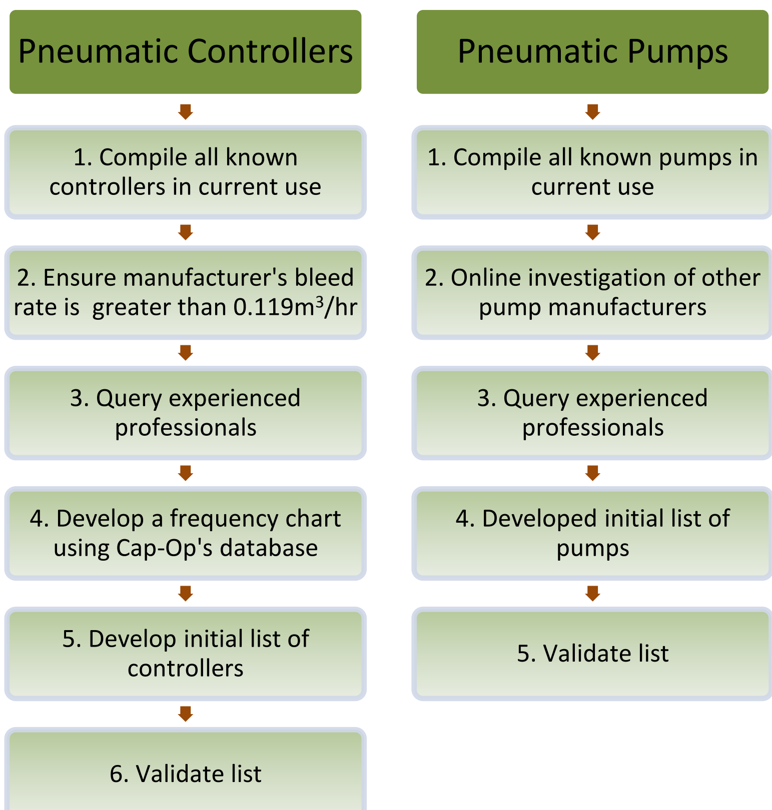

Figure 1: Device Selection Approach[3]

[1] The value 1.3 is based on the density and molar mass of air and natural gas in ideal gas conditions. This is an industry standard.

[2] GreenPath Energy Ltd. is the subcontractor under TPG who is responsible for completing the field sampling protocol.

[3] "Cap-Op's Database" refers to Cap-Op Energy's Distributed Energy Efficiency Project Platform (DEEPP), which can be queried for historical pneumatic controller information. Cap-Op Energy is a sub-contractor under TPG.

2.1.2 Equivalent Devices

Controllers may have different make and models but are effectively the same device. Controllers are considered equivalent devices if they have interchangeable parts (Schedule A, Part 2. Services: 1.1.2). A list of equivalent devices was compiled using information from device vendors and subject matter experts, and is presented in Appendix A (J. Anhalt, personal communication, July 2013; B. Van Vliet, personal communication, July 2013).

2.1.3 Ensure Manufacturer Bleed Rates are less than 0.119 m^3/hr

Manufacturer bleed rates are required to determine which controllers are considered high bleed and therefore eligible for sampling. However, these manufacturer bleed rates are based on manufacturer lab testing and do not reflect accurate field conditions. The steady state bleed rates reported are static bleed rates of controllers that are not actuating. Therefore, the manufacturer bleed rates may not accurately express the actual vented natural gas through these controllers because the steady state does not include dynamic bleeding. The relationship between the bleed rates of controllers that are running on dirty/wet natural gas compared to air is unknown at this time. It is likely that controllers operating in the field bleed more than controllers tested in a laboratory using air.

The current definition whether a controller is a high or low bleed controller is based on the WCI Reporting Regulation definition: "high-bleed devices are defined as all natural gas powered devices which continuously bleed at a rate greater than 0.17 m^3/hr."

Many controllers have manufacturer bleed rates just below 0.17 m^3/hr, and thus appear to be a low-bleed controller. Since manufacturers do not consider the dynamic bleed rate in their stated bleed rate, many low-bleed controllers in fact bleed more than 0.17 m^3/hr on a regular basis. To ensure all relevant controllers that bleed more than 0.17 m^3/hr (including static and dynamic bleeding) are included within the sample, the manufacturer bleed rates are compared to a limit of 0.119 m^3/hr (CAS, 2013). In many cases, the manufacturer states a range of bleed rates that are dependent on other operating parameters of the controller (i.e. 1.4 scfh at 20 psi vs. 3 scfh at 30 psi). In this case, the highest bleed rate was recorded to ensure that all controllers with the potential to bleed higher than 0.17 m^3/hr are included. Refer to Appendix A for manufacturer bleed rates. Controllers that have been excluded from sampling as a result of this step are represented at the bottom of the table in Appendix A.

2.1.4 Query Subject Matter Experts

Subject matter experts were queried to determine if the list of pneumatic devices was inclusive and representative. Several low-bleed controllers below the limit of 0.119 m^3/hr have been included based on discussions with subject matter experts, including the Pacific Carbon Trust (PCT), U.S. Environmental Protection Agency (EPA), and pneumatic device equipment vendors. The results of the query are represented in Appendix A.

2.1.5 Determine the Frequency of occurrence of Controllers

The initial list of all pneumatic controllers was filtered down to eligible controllers to focus sampling on devices that are considered common. These eligible controllers were compared with the field samples from the Cap-Op DEEPP database to examine the frequency of eligible controllers previously surveyed in the field. The results are depicted in Figure 2 below.

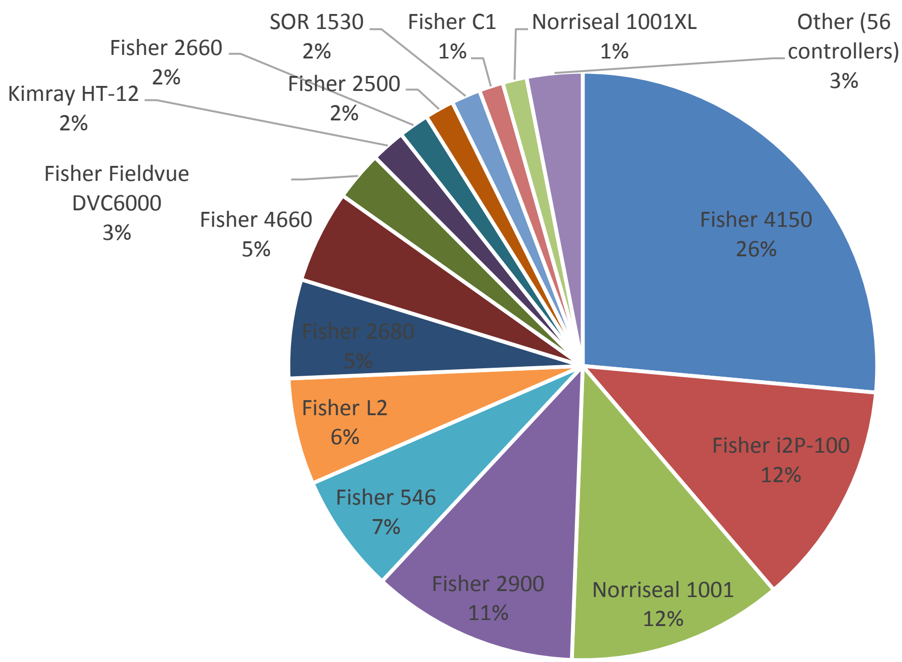

Figure 2: Frequency histogram of pneumatic controllers found in the Cap-Op database

2.1.6 Develop Initial List

The initial list of pneumatic controllers we will be sampling in the field was based on the above Figure 2 and can be found in Appendix B. The results include:

- The top 10 controllers represent 89% of the surveyed controllers in the Cap-Op database.
- The top 15 controllers represent 97% of the surveyed controllers in the Cap-Op database.
- Rare devices are those that comprise the remaining 3% of the surveyed controllers in the Cap-Op database.

This initial device frequency analysis will be used to guide the first round of sampling because those devices should be frequent enough to produce statistical valid emissions factors. The above recommendation is based on an initial analysis and might be subject to change as the project progresses if the assumptions do not hold true in the field.

2.1.7 Validate list

During the first round of sampling, field staff will be creating an inventory of all devices identified. Upon completion of the first round of sampling the original list will be compared with the new field inventory to determine if the anticipated top 15 devices represent what have sufficient samples and if there were controllers not in the initial focus group of devices to include. If a device occurs more than 30 times and was originally considered rare, it will be added to the sample.

In sum, this process was used to determine the initial list of 15 devices. This process has mechanisms to adapt and change if, during the first round of sampling, a particular controller should be included on the list or if a different controller should be removed from the list. The mechanism to add or remove devices from the list results from examining the controller frequency counts conducted during the first round of sampling.

The field data will be monitored as it comes into TPG and a data analyst will provide feedback to the field sampling staff from GreenPath. The data analyst will communicate with field samplers to limit the sampling of certain controllers as the frequency counts of these controllers approach the statistically required number of samples. The sampling approach below will dictate how samples are taken.

2.2 Pneumatic Pumps

The methodology used for determining the list of pneumatic pumps does not mirror the methodology used for pneumatic controllers because the Cap-Op database does not contain sufficient pump field samples to draw similar conclusions. The list of pneumatic pumps was compiled from the CAPP (2008), PCT (2011) and the Cap-Op DEEPP database. These sources were cross-referenced with manufacturer websites to make the initial list more inclusive but all pumps in the field will be sampled. If field sampling staff comes across a pump not on the initial list, they can manually enter the make and model into the Cap-Op application. There are no statistical tests being performed to determine if a specific pump should be sampled. Statistical tests will be done on pumps with interchangeable parts to determine if they have the statically similar bleed-rates. There has been no feedback from EPA that more pump types should be included on the initial list; however, PCT and subject matter experts have provided their input to and approval of the initial list. The initial list is presented in Appendix B.

2.3 Sample Size

The sampling program aims to collect 30 samples of each device type in “more-than-rare” use in B.C. Thirty was chosen as a minimum sample size in order to allow for certain statistical inferences. When the sample size is sufficiently large (conventionally, 30 or larger), the sample variance is approximately equal to the population variance, and can therefore be used instead of the population variance in the calculation of a confidence interval. In the calculation of the confidence interval, the larger the sample size (until approximately 30 samples), the narrower and more accurate the confidence interval. Thirty samples allows for the delivery of a more reliable estimate of the confidence interval (McClave and Sincich, 2003).

2.4 Rare Devices

Some devices are expected to be rarely used within B.C., and therefore it will not be possible to obtain a statistically valid number of samples. Therefore, it will be impossible to generate an accurate mean and confidence interval for that controller or pump type. In order to put forward some sort of confidence interval estimate, two approaches will be considered:

1. *Comparison of field bleed rates with manufacturer-specified bleed rates:* The mean, standard deviations and confidence intervals for each device type in “more-than-rare” use will be compared with manufacturers’ bleed rates. If a trend is present (i.e. the field bleed rate is consistently higher or lower by some amount), then that trend could be extrapolated to the rare devices. In the in the absence of any trend, it is our intention to recommend that the manufacturers’ bleed rates be applied.
2. *Weighted average*: The rare devices could be considered as one group for the purposes of bleed rate reporting. A weighted average technique could be used to generate a “rare device” bleed rate, and confidence interval. This technique may not be appropriate, and may unfairly penalize users of rare devices and thus is not the approach recommended by TPG

3. Sampling Approach

The following section provides detail on how the field samples will be collected as well as justification to which companies and geographic areas have been selected for sampling.

3.1 Hawk 9000 Vent Gas Meter

TPG has elected to use the Hawk 9000 vent gas meter (designed by Calscan Energy) to measure and digitally log flow vent gas over time (which will vary based on the device sampled). This allows both the static and dynamic bleed rates for pneumatic controllers, as well as the dump cycles for pneumatic pumps and level controllers, to be captured. The Hawk uses a positive displacement diaphragm meter that detects flow rates down to zero, and can also effectively measure any type of vent gas (methane, air, or propane). In addition, the Hawk uses a precision pressure sensor, an external temperature probe and industry standard gas flow measurement algorithms to accurately measure the gas rates. As a result, flow measurement accuracies within ±2%[4].

3.2 Data Collection and Transfer

To manage the large amount of data that will be collected during this sampling program, Cap-Op has designed a software application (app) to be used in the field in order to reduce data quality and tracking issues, and eliminate manual data recording.

All parameters will be transferred into the app at the sampling location. Where appropriate, the APP has dropdown menus to increase efficiency in compiling data. Numeric input fields have expected ranges of values and options for the units, so that if a value is entered outside of the range a message appears for the user to ensure the input is correct. For further details, refer to Appendix C for the field sample guide.

When the user has access to internet, the APP will sync with the Cap-Op Energy cloud-based Distributed Energy Efficiency Project Platform (DEEPP). The DEEPP will provide various functionalities for managing the data collected in the field including:

- Data storage; and
- Organizing the data into the desired output format of a download-able Excel files.

3.3 Opportunistic Sampling Approach

The sampling approach used for this project is a non-probability technique called opportunistic sampling. This means that sampling locations will be chosen purposefully, instead of random sampling. With the cooperation of CAPP members, the sampling locations will be chosen based on several criteria:

1. Relative contribution to total BC production by volume

In the absence of information on the apportionment of devices between oil and gas companies operating in BC, natural gas production has been used as an initial proxy for occurrence of pneumatic devices. The ten producers that comprise the majority of production were identified (see Figure 3). Some producers were excluded from the sample as, based on the professional experience of the team, it was known that pneumatics were not a significant contributor to those companies' GHG inventory. These were replaced with a selection of other producers to ensure a reasonable cross-section and attempt to capture a greater range of fields and device vintages. **Error! Reference source not found.**

[4] The meter is calibrated from -40°C to +60°C anduses "Gas Rate Algorithm AGA7" and "Equation of State AGA8".

outlines the 15 companies included in the sample. This list is subject to change due to logistical or access reasons as well as the frequency of high bleed controllers in operation based on device inventory.

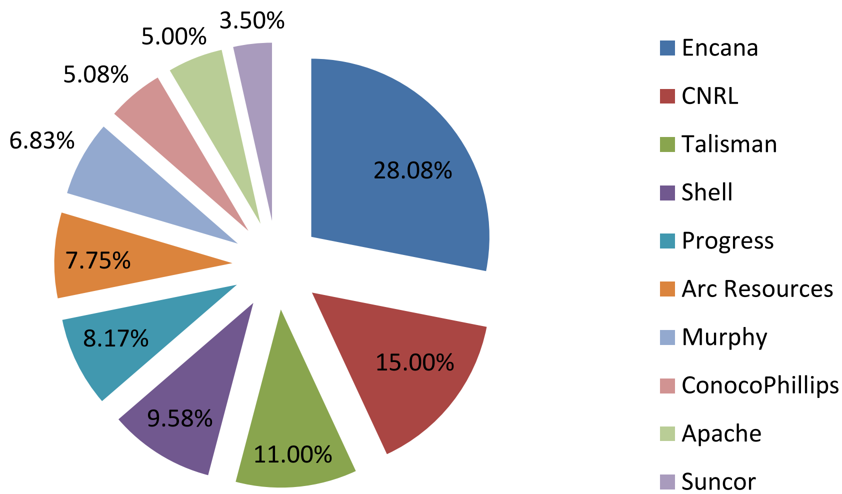

Figure 3: Top 10 Natural Gas Producers in BC (BC Oil and Gas Commission, 2013)

Table 1: Initial List of Producers Included in the Sample

Companies		
EnCana	Apache	Penn West
CNRL	Bonavista	Husky
ConocoPhillips	NuVista	Imperial Oil
Talisman	TAQA	Devon
Progress	Murphy	Nexen

2. Location in proximity to Fort St. John
   - Fort St. John is arguably a hub of Oil and Gas production within the province, with a majority of activity found within 500 km. In order to determine pneumatic controller and pump bleed rates in an efficient and cost-effective manner, field sampling crews will be based out of the Fort St. John region of British Columbia. Focusing the sampling in this area means that the majority of producers and production activities will be well represented within this sampling effort.
   - The choices of specific locations must be in accordance with the producers' permissions.
   - The choice of sampling locations will aim to sample 30 devices of each common type, based on producer's knowledge of the equipment based at their sites. The vintage of the controllers and pumps will be considered, as the year of facility commissioning and year of manufacturing will be determined where possible. The sites will be chosen to maximize sampling efficiency and minimize travel time and/or expense; i.e., sites accessible by vehicle are preferable to those accessible by air. Seasonality may play a role in determining which sites are

accessible during the project sampling timeframe. Field locations that are accessed only by winter roads will not be covered.

Opportunistic sampling has known limitations, including that there is no way to know the probability of any one device being included in the sample, and some devices will have zero probability. The statistical consequence is that the sampling error[5] cannot be estimated, and that exclusion bias may arise from the non-random choice of sampling locations. However, random sampling is logistically impractical, given the budget and timeline of this project and so all efforts to minimize exclusion bias will be made, by choosing sampling locations that are representative of producers operating in BC, and geographical production regions.

3.4 Second Round Sampling Rationale

The project methodology has made contingency for a second round of sampling for the following reasons:

- If the initial list is not validated by what is actually in the field, some additional devices may require sampling.
- If the preliminary analysis of first round samples shows a skewed distribution, more samples will be taken during second round sampling to achieve the required confidence interval. To achieve a mean bleed rate with the desired 95% confidence interval, 30 samples will be taken for each type of pneumatic device.
- For the less common devices, natural gas, air and propane samples will be permitted. A conversion factor will be used to convert the air and propane back to natural gas equivalent. After first round sampling is completed, it will be ascertained whether the generic conversion factors are valid or if new factors need to be generated in second round sampling.
- If the distribution of pneumatic devices differs in Northern BC, sampling may be required to determine if there are significant differences between the two areas.

After the first round of sampling, the BC samples taken using Calscan will be compared with DEEPP database that have been sampled using high-flow sampler. This will be used to compare the differences between the types of samples, but will not be used directly to make statistical comparisons. The data will be accessed by TPG staff everyone to three days as it is being collected. This ongoing data management will serve as both a quality assurance-quality control measure, as well as allow TPG to verify that the samples represent a diversity of producers, producing basins, and vintages of devices.

4. Analytical Approach

The analytical methods are described below according to four general areas. As data is collected, it will be processed through the DEEP Platform and the data will be analyzed to the following four questions:

1. *What is the average bleed rate, the standard deviation, and the confidence interval for each type of controller or pump?* These will be completed in Excel®.
2. *Is the measured bleed rate for each controller/pump type normally distributed?* A Shapiro-Wilks test may be used, along with a Q-Q plot, in order to determine whether the data is normally distributed. These tests will be

[5] *Sampling error* is an estimation of the difference between the true population mean and the sample mean, usually expressed in terms of standard error. Standard error cannot be reliably calculated using non-probability sampling techniques, although a mean, standard deviation, and confidence interval can be calculated with large (>30) sample numbers.

performed with Excel® statistical applications, the statistical software "R", or other software. However, the output results will be reported in an Excel® document.

3. *What controller/pump parameters are significant determinants of the measured bleed rate?* The data collected in the course of sampling includes other parameters, such as supply pressure, or other field-adjustable variables. If there is a significant effect, further analysis may be conducted in order to determine a more accurate bleed rate based on the creation of parameter categories, for example. Or, no significant effects may be present, and then greater confidence in an average bleed rate can be ascertained. If the data is normally distributed, a General Linear Model will be created to test the significance of each of the parameters. If the data is not normally distributed, a Generalized Liner Model will be used instead. The General(ized) Linear Model will be created using Excel® statistical applications, or the software R, with the results reported in an Excel® document.
4. *Do models of pneumatic devices vary significantly with respect to measured bleed rate?* Certain devices that have interchangeable componentry may have very similar bleed rates. It is worth analyzing whether certain controllers (pumps) exhibit significantly different bleed rates, in order to determine whether one bleed rate can be applied to multiple controller types, perhaps including somewhat less frequent controllers. An Analysis of Variance (ANOVA) test will be used if the bleed rate data is normally distributed, or a Kruskal-Wallis test if the data is not normally distributed, to compare the difference between the means of the different controller (pump) bleed rates. These tests can be performed using Excel® statistical applications.
5. *Is there a trend in variances of measured bleed rates to manufacturers' specifications?* The average measured field bleed rate of each type of device may differ significantly, or predictably, from the manufacturer's specified bleed rate. The average measured field bleed rate of each type of device will be compared to the manufacturers' specified bleed rate using a t-test if the data is normally distributed (or a Mann-Whitney-U test if the data is not normally distributed). A linear regression can also be conducted across controller types in order to determine whether the measured field bleed rate varies predictably from the manufacturers' specified bleed rate. These tests can be performed using Excel statistical applications.

5. Format of Results

The following equations will be used for calculating greenhouse gas emissions from natural gas pneumatic continuous high-bleed controllers and pumps.

5.1 Pneumatic Controllers:

$$E_s = EF_j \times t_j \qquad \text{Equation 350-2}$$

Where:

E_s = Annual GHG emissions for pneumatic high-bleed devices (tCO_2e/y)

EF_j = The emission factor for pneumatic device, j, as provided in Equation 1 (tCO_2e /h/device)

t_j = Total time that the pneumatic device, j, has been in service (i.e. the time that that gas flows to the device) through the reporting period (h). Default is 8760 hours.

$$EF_j = \left(Bleed\ Rate_j * CH_4\% \ * \rho CH_4 \ * GWP_{CH4}\right) + \left(Bleed\ Rate_j * CO_2\% * \rho CO2\ \right) \qquad \text{Equation 1}$$

Where:

Bleed Rate = The average measured bleed rate volume for pneumatic device, j (Sm^3NG/hr)

% CH_4 = The concentration of methane in the natural gas stream (Sm^3CH_4/ Sm^3NG)

ρ CH_4 = The density of methane: 0.66×10^{-3} t CH_4/ Sm^3

GWP_{CH4}	=	The global warming potential of methane: 21 tCO_2e/tCH_4
% CO_2	=	The concentration of carbon dioxide in the natural gas stream (Sm^3CO_2/ Sm^3NG)
ρ CO_2	=	The density of carbon dioxide: 1.98 x 10^{-3} t CO_2/S m^3

5.2 Pneumatic Pumps:

$$E_s = EF_j \times Q_j$$ Equation 350-3

Where:

E_s	=	Annual GHG emissions for pneumatic pumps (tCO_2e/y).
EF_j	=	Natural gas-driven pneumatic pump gas emission factor expressed in "emission per volume of liquid pumped at operating pressure" as provided by Equation 2 for pump j (tCO_2e /litre).
Q_j	=	Volume of liquid pumped annually by pump j (litres/y).

$$EF_j = (Bleed\ Rate_j * CH4\% \ * \rho CH4 \ * GWP_{CH4}) + (Bleed\ Rate_j * C02\% * \rho CO2\ )$$ Equation 1

Where:

Bleed Rate	=	The average measured bleed rate volume for pneumatic pump, j (Sm^3NG/hr)
% CH_4	=	The concentration of methane in the natural gas stream (Sm^3CH_4/ Sm^3NG)
ρ CH_4	=	The density of methane: 0.66 x 10^{-3} t CH_4/ Sm^3
GWP_{CH4}	=	The global warming potential of methane: 21 tCO_2e/tCH_4
% CO_2	=	The concentration of carbon dioxide in the natural gas stream (Sm^3CO_2/ Sm^3NG)
ρ CO_2	=	The density of carbon dioxide: 1.98 x 10^{-3} t CO_2/S m^3

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Appendix A: Compilation of All Known Pneumatic Controllers

Description	Manufacturer	Model	Manufacturer Rate (m^3/h NG)	Source	Equivalent Devices	Sample?	Justification
Pressure Controller	Ametek	Series 40	0.22	WCI/CAPP BMP/GAS Star		Yes	High-bleed
Positioner	Becker	HPP-5	0.18	WCI		Yes	High-bleed
Pressure Controller	Bristol Babcock	Series 502 A/D	0.22	WCI/CAPP BMP/GAS Star		Yes	High-bleed
Pressure Controller	Dyna-Flo	4000	0.89	WCI	Dyna-Flo 5000	Yes	High-bleed
Pressure Controller	Dyna-Flo	4000LB	0.13	Dyna-Flo		Yes	High-bleed
Transducer	Fairchild	TXI 7800	0.31	WCI		Yes	High-bleed
Transducer	Fisher	546	1.10	WCI	Fisher 546S Fisher 546	Yes	High-bleed
Transducer	Fisher	646	0.29	WCI		Yes	High-bleed
Transducer	Fisher	846	0.44	WCI/CAPP BMP/GAS Star	Fisher 846S	Yes	High-bleed
Level Controller	Fisher	2500	1.55	WCI	Fisher 2506	Yes	High-bleed
Level Controller	Fisher	2900	0.85	WCI/CAPP BMP/GAS Star	Fisher 2901 Fisher 2900A	Yes	High-bleed
Positioner	Fisher	3582	0.59	WCI		Yes	High-bleed
Positioner	Fisher	3590	1.10	WCI		Yes	High-bleed
Positioner	Fisher	3660	0.26	WCI		Yes	High-bleed
Positioner	Fisher	3661	0.38	WCI		Yes	High-bleed
Pressure Controller	Fisher	4100	1.83	WCI	Fisher 4101	Yes	High-bleed

Description	Manufacturer	Model	Manufacturer Rate (m^3/h NG)	Source	Equivalent Devices	Sample?	Justification
Pressure Controller	Fisher	4150	0.96	WCI	Fisher 4150K Fisher 4160R CVS 4150 Fisher 4150K Fisher 4160	Yes	High-bleed
Temperature Controller	Fisher	4156			Fisher 4156 Fisher 4166	Yes	High-bleed
Pressure Controller	Fisher	4194	0.16	WCI		Yes	High-bleed
Pressure Controller	Fisher	4195	0.16	WCI		Yes	High-bleed
High-Low Pressure Pilot	Fisher	4660	0.18	Gas STAR	Fisher 4660A	Yes	High-bleed
Positioner	Fisher	Fieldvue DVC5000	0.37	WCI/CAPP BMP/GAS Star	FisherDVC5040 FisherDVC5030 FisherDVC5020 FisherDVC5010	Yes	High-bleed
Level Controller	Fisher	2900A			Fisher 2901A	Yes	High-bleed
Positioner	Fisher	3582i	0.76	WCI		Yes	High-bleed
Positioner	Fisher	3620J	0.98	WCI		Yes	High-bleed
Pressure Transmitter	Fisher	C1	0.19	WCI		Yes	High-bleed
Positioner	Fisher	Fieldvue DVC6000	0.52	WCI/CAPP BMP/GAS Star	FisherDVC6030 FisherDVC6020 FisherDVC6010	Yes	High-bleed
Transducer	Fisher	i2P-100	0.37	WCI	Fisher i2P-100, 4-20mA	Yes	High-bleed
Pressure	Foxboro	43AP	0.66	WCI/CAPP BMP/GAS Star		Yes	High-bleed

Description	Manufacturer	Model	Manufacturer Rate (m^3/h NG)	Source	Equivalent Devices	Sample?	Justification
Controller							
Level Controller	Invalco	AE-155	1.95	WCI		Yes	High-bleed
Level Controller	Invalco	CT Series	1.47	WCI/CAPP BMP/GAS Star	NATCO Flextube (CT Series)	Yes	High-bleed
Positioner	Invalco	Flextube (CT Series)	1.47	WCI	NATCO Flextube (CT Series)	Yes	High-bleed
Pressure Controller	ITT Barton	338	0.22	WCI/CAPP BMP/GAS Star		Yes	High-bleed
Pressure Controller	ITT Barton	4195	0.13	Gas Star		Yes	High-bleed
Pressure Controller	ITT Barton	335P	0.22	WCI/CAPP BMP/GAS Star		Yes	High-bleed
Level Controller	Kimray	Gen2	0.54	Manufacturer's website[6]		Yes	High-bleed
Temperature Controller	Kimray	HT-12				Yes	High-bleed
Level Controller	Mallard	3201				Yes	High-bleed
Positioner	Masoneilan	4600B Series	0.88	WCI		Yes	High-bleed
Positioner	Masoneilan	4700B Series	0.88	WCI		Yes	High-bleed
Positioner	Masoneilan	7400 Series	1.36	WCI		Yes	High-bleed
Positioner	Moore Products	73N-B PtoP	1.33	WCI/CAPP BMP/GAS Star		Yes	High-bleed

[6] http://mobile.kimray.com/downloads/instruction/GENIIBACKmount.pdf

Description	Manufacturer	Model	Manufacturer Rate (m^3/h NG)	Source	Equivalent Devices	Sample?	Justification
Positioner	Moore Products	750P	1.55	WCI/CAPP BMP/GAS Star		Yes	High-bleed
Transducer	Moore Products	IPX2				Yes	High-bleed
Pressure Controller	Natco	CT	1.55	WCI		Yes	High-bleed
Pressure Controller	Norriseal	4900				Yes	High-bleed
Level Controller	Norriseal	1005PI				Yes	High-bleed
Pressure Controller	Time Mate	2000				Yes	High-bleed
Level Controller	Wellmark	2001A	0.13	CAPP		Yes	High-bleed
Positioner	YTC	YT-2400				Yes	High-bleed
Level Controller	Fisher	2660	0.04	CAPP BMP	Fisher 2660A	Yes	PCT
Level Controller	Fisher	2680	0.04	CAPP BMP	Fisher 2680A	Yes	PCT
Level Controller	Fisher	L2	0.06	WCI		Yes	PCT
Pressure Transmitter	ITT Barton	273A	0.11	Gas Star	274A 284B 285B	Yes	PCT
Positioner	Sampson	3780 Digital	0.04	WCI		Yes	PCT
Positioner	Becker	ERP-2.0	0.00	WCI/CAPP BMP/GAS Star		No	Low-bleed
Controller	Becker	VRP-SB	0.00	Gas Star		No	Low-bleed
Pressure Controller	Bristol Babcock	358	0.07	Gas Star		No	Low-bleed

Description	Manufacturer	Model	Manufacturer Rate (m^3/h NG)	Source	Equivalent Devices	Sample?	Justification
Pressure Controller	Bristol Babcock	359	0.07	Gas Star		No	Low-bleed
Pressure Controller	Bristol Babcock	5455 Model 624-III	0.09	WCI		No	Low-bleed
Pressure Controller	Bristol Babcock	Series 5453-Model 624 - II	0.11	Gas STAR		No	Low-bleed
Pressure Controller	Bristol Babcock	Series 5455 Model-624 10F	0.11	WCI/CAPP BMP/GAS Star		No	Low-bleed
Pressure Transmitter	Bristol Babcock	Series 5457-70F	0.11	Gas STAR		No	Low-bleed
Transducer	Bristol Babcock	Series 9110-00A	0.02	WCI/CAPP BMP/GAS Star		No	Low-bleed
Level Controller	Fisher	2100	0.04	WCI/CAPP BMP/GAS Star		No	Low-bleed
Positioner	Masoneilan	SVI Digital	0.04	CAPP		No	Low-bleed
Level Controller	Norriseal	1001	0.07	WCI	1001A	No	Low-bleed
Level Controller	Norriseal	1001XL	0.07	WCI		No	Low-bleed
Positioner	VRC	VP700G	0.04	WCI/CAPP BMP/GAS Star		No	Low-bleed

Appendix B: Initial List of Pneumatic Devices Included in the Sample

Pneumatic Controller List

This list was developed by analyzing the frequency each controller make/model appeared in Cap-Op's field sample database. These 15 controllers make up 97% of the database.

Description	Manufacturer	Model	Equivalents	Name	Count	Percentage
Pressure Controller	Fisher	4150	Fisher 4150K Fisher 4160R CVS 4150 Fisher 4150K Fisher 4160	Fisher 4150	380	26.44%
Transducer	Fisher	i2P-100	Fisher i2P-100, 4-20mA	Fisher i2P-100	177	12.32%
Level Controller	Norriseal	1001	1001A	Norriseal 1001	170	11.83%
Level Controller	Fisher	2900	Fisher 2901 Fisher 2900A Fisher 2901A	Fisher 2900	163	11.34%
Transducer	Fisher	546	Fisher 546S Fisher 546	Fisher 546	94	6.54%
Level Controller	Fisher	L2		Fisher L2	84	5.85%
Level Controller	Fisher	2680	Fisher 2680A	Fisher 2680	78	5.43%
High-Low Pressure Pilot	Fisher	4660	Fisher 4660A	Fisher 4660	73	5.08%
Positioner	Fisher	Fieldvue DVC6000	FisherDVC6030 FisherDVC6020 FisherDVC6010	Fisher Fieldvue DVC6000	39	2.71%
Temperature Controller	Kimray	HT-12		Kimray HT-12	27	1.88%
Level Controller	Fisher	2660	Fisher 2660A	Fisher 2660	24	1.67%
Level Controller	Fisher	2500	Fisher 2506	Fisher 2500	23	1.60%
Level Switch	SOR	1530		SOR 1530	23	1.60%
Pressure Transmitter	Fisher	C1		Fisher C1	19	1.32%
Level Controller	Norriseal	1001XL		Norriseal 1001XL	19	1.32%
Total						97%

Pneumatic Pump List

This is a comprehensive list that was developed by surveying multiple sources (industry, manufacturers, etc.). This list is subject to change as sampling progresses as we get a picture of how frequently each device occurs in reality.

Manufacturer	Model
Arrow	548
Arrow	5100
Bruin	5000
Bruin	BR113LP
Checkpoint	1250
COE	5100
CVS	5100
CVS	51
CVS	C-252
Flowmore	5100
Graco	716
Ingersoll Rand	MUA0178
Linc	84-T Series
Linc	282
Morgan	4500
Morgan	HD312-3K
Plainsman	
Texstream	5100
Texstream	5000
Texstream	MK2
Timberline	2500, 5000, 1560 Series
Western Chemical Pump	ACE Series
Wilden	02-5000-01
Williams	MK2
Williams	Mark XIIA
Williams	WRA1112MNNBB

Appendix C: Field Sampling Guide

The subsequent guidelines will be followed by the GreenPath field sample team:

What to Sample On-Site

- Sample the list of controllers found in Appendix B.
- Take an Inventory (Create Controllers and Pumps in the APP), but do not sample controllers that are not on this list.
- For each Make and Model (including their equivalents), limit sampling to 10 for each Producer.
- Sample all pumps.
- The top 10 controllers represent 89% of the surveyed controllers in the Cap-Op database. For these very common devices we plan to take all natural gas samples.
- The top 15 controllers represent 97% of the surveyed controllers in the Cap-Op database. For these additional 5 less common devices, we plan to sample whatever we can find: natural gas, air or propane. A conversion factor will be used to convert the air and propane samples to natural gas equivalent to ensure we are comparing apples to apples. Once we have completed the first round of sampling we can ascertain whether the conversion factors are valid to compare these samples or if new factor needs to be generated in second round sampling.
- Rare devices are those that comprise the remaining 3% of the surveyed controllers in the Cap-Op database. They will be sampled only during the second round sampling process, if they prove to be more common than initially thought. Analytical options vary, and are discussed below in the section entitled “Rare Devices.”

Duration of Sampling

All samples need to:

- be taken for at least **10 min**, or
- until **2 ft^3** of gas has been collected, or
- until at least 2 dump cycles have been collected (for level controllers)

Sampling Pumps

- Sample all pumps.
- If pumps are turned off and you have the permission of the operator to turn on, take **separate samples** of the pump at different operating speeds. Limit different operating speeds to speeds that the pump would function under **normal operating conditions**.