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Emission Reduction Measurement and Monitoring Methodology for the Conversion of High-Bleed Pneumatic Controllers in Oil and Natural Gas Systems

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Methodology developed by Verdeo Group, Inc. and Devon Energy Corporation

A nonprofit enterprise of

Winrock International

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1.0 BACKGROUND AND APPLICABILITY

1.1 Background on Pneumatic Controllers in the Oil and Natural Gas Industry

Pneumatic controllers use a pressurized gas, typically natural gas for applications in the oil and gas production industry, to regulate process variables such as pressure, flow rate and liquid level. Pneumatically operated equipment is used in the oil and gas industry because electricity is not readily available at remote production sites.

Most pneumatic instruments and controllers in the natural gas industry are powered by natural gas, and these controllers are designed to discharge methane to the atmosphere as a part of normal operations. Pneumatic controllers can be designed to bleed at both high and low-bleed-rates. Before 1990, all controllers were designed with generally high-bleed rates. Increasing awareness of the extent of wasted resources and potential environmental hazards resulting from higher bleed rates led to the development and introduction of low-bleed pneumatic controllers in the early 1990s.[1] It has now become standard practice to use low-bleed pneumatic controls in *new construction* in the oil and gas industry. Despite the existence of low-bleed technology as well as retrofit solutions such as WellMark's Mizer® Pilot Valve, conversions of existing high-bleed controllers are uncommon. Numerous sources estimate that hundreds of thousands of high-bleed pneumatics still remain in service throughout the oil and gas production segment. As a result, high-bleed pneumatic controllers are among the largest sources of vented methane by equipment type in the domestic oil and natural gas industry.[2]

The objective of this methodology is to provide a method for quantifying baseline emissions from high-bleed pneumatic devices for the purpose of generating tradable GHG emission reduction offsets to incentivize the development of a voluntary, pre-compliance offsets market in the U.S., as well as the rapid adoption and implementation of a technological solution for an important GHG emissions source.

1.2 Applicability

This Baseline Monitoring Methodology for the Conversion of High-Bleed Pneumatic Controllers in Oil and Natural Gas Systems ["Pneumatic Conversion Methodology"] describes the baseline measurement and post-project monitoring procedures for the retrofit or replacement of high-bleed pneumatic controllers with low-bleed alternatives for the purpose of an emission reductions project where emission reductions can be registered.

This methodology is applicable only for the conversion of high-bleed pneumatic controllers to low-bleed pneumatic controllers, where operating conditions and requirements permit such conversions. In some operational applications e.g., the control of very large valves that require fast or precise process

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[1] The EPA defines high-bleed controllers as controllers that bleed in excess of 6 cubic feet per hour, and a low-bleed pneumatic controller is defined as a controller that bleeds at a rate of less than 6 cubic feet per hour. US Environmental Production Agency, "Lessons Learned from Natural Gas STAR Partners: Options for Reducing Methane Emissions from Pneumatic Devices in the Natural Gas Industry", EPA430-B-03-004, Washington, DC, July 2003.

[2] Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2006, USEPA, April, 2008.

changes, high-bleed controllers should not be replaced with low-bleed controllers. In these cases project proponents should investigate the use of new fast-acting devices with lower bleed rates.

This methodology is applicable to continuous bleed pneumatic controllers in level, flow rate, temperature or pressure control applications. Constraints on the applicability of the methodology are as follows:

- This methodology is applicable to the conversion of both snap-acting and throttle acting high-bleed pneumatic controllers to low-bleed pneumatic controllers.
- This methodology is not applicable to projects which deal with the conversion of high-bleed pneumatic controllers in sectors outside of oil and natural gas systems.
- This methodology is only for the conversion of existing high-bleed rate pneumatic controllers, and is not applicable to newly built oil and gas production facilities that are installing low-bleed pneumatic controllers.
- Projects using this methodology will have a crediting period of ten (10) years.

1.3 Periodic Reviews and Revisions

The American Carbon Registry® (ACR) may require revisions to this methodology to ensure that monitoring, reporting, and verification systems adequately reflect changes in the project's activities. An annual attestation and a verification statement, which will include documentation of the findings of a third party verifier applying audit sampling methods, should be submitted by the project entity to ACR. The ACR will then:

- Review the attestation and verification statement and notify the project entity of any required adjustments or corrections to these documents.
- Register verified emission reductions.

This methodology may also be periodically updated to reflect regulatory changes, emission factor revisions, or expanded applicability criteria including new models of eligible high-bleed controllers or additional oil and gas industry segments. Before beginning a project, the project proponent should ensure that they are using the latest version of the methodology.

2.0 BASELINE DETERMINATION

2.1 Project Assessment Boundaries and Emissions Sources

The project boundaries will be confined to all conversions implemented by a single project proponent in a continuous time frame or in contiguous phases.

Because the project implementation, key project data collection and storage, calculation of the project emissions, and total emission reductions will be centrally managed and stored by the project proponent, then it is logical that the GHG emission reduction project assessment boundaries will be the universe of conversions undertaken by the project proponent. However, due to unique operating conditions (i.e. pressure or methane concentration) which could affect emission rates, certain baseline and project emissions will need to be calculated at a basin level in the production sector and at a facility or pipeline level in the transmission and distribution sectors, as described below.

Baseline emissions for the project will be determined through site-specific sampling. The project proponent can establish a manufacturer-specific emission factor for its own population of pneumatic controllers per Sections 3.1.1 & 4.4 and Appendix C below.

Project emission factors will be extrapolated from a series of representative sample measurements of the converted project population. Further information on the measurement and calculation of emissions can be found in the project and baseline emissions calculations as per Sections 3.2 and 4.4 and Appendix C below.

There are no emissions from construction or combustion as a part of the pneumatic retrofit project. Emissions in the project baseline and post-retrofit scenario consist solely of the GHG fraction of natural gas emissions from the pneumatic controllers. These gasses, and their status (included or excluded) within the project are outlined in Table 2.1.

Table 2.1: Baseline and Project Emissions

Gas	Description	Status: (included, excluded)
CH_4	Methane is a major constituent of natural gas. The methane composition of natural gas tends to be between 70% and 90%, but varies depending on the location of the production, transmission or distribution facility. The methane fraction of the gas is an important component in the emission reductions calculation. Facilities will be required to present information from a gas chromatograph or comparable test.	Methane is included as a project and baseline emission.

Gas	Description	Status: (included, excluded)
CO_2	CO_2 constitutes about 5% of most natural gas emissions.	Excluded. While the retrofit of controllers will result in the reduction of CO_2 released bleeding to the atmosphere, no credit will be claimed for this reduction in order to ensure that the project emission reduction claims are conservative.
NMHCs	Non-methane hydrocarbon components of natural gas can include ethane, propane, butane, pentane, or any other non-methane gasses (e.g. nitrogen, helium, and hydrogen sulfide) found in the natural gas.	Excluded

In certain applications, controllers may reach the end of their useful life during the crediting period for the project, such as in cases where a controller is worn down more quickly if the application uses corrosive gas. To determine if any controller included in the project would normally have been replaced with a low-bleed alternative during the crediting period for a reason other than the project activity, the project proponent should provide the following information:

- The project proponent should describe current practice for routine refurbishment of controllers and should provide to the verifier the standard operating procedure, if any, for routine refurbishment of pneumatic controllers, including replacement specifications published by the controller's manufacturer if available.
- Any controllers which would have been so replaced during the crediting period should be identified, the expected date of such replacement should be stated, and no emission reductions credited for that controller after such date.

2.2 Baseline Description

The baseline scenario is the continued use of high-bleed pneumatic controllers. Project entities must use the procedures outlined below to justify that the pneumatic conversion project is not common practice for the project entity and the industry.

2.3 Additionality Assessment

Emission reductions from the project must be additional, or deemed not to occur in the business-as-usual scenario. Assessment of the additionality of a project will be made based on passing the three tests cited below. Project proponents utilizing this methodology should consult the latest version of the American Carbon Registry's Technical Standard, which may be updated from time to time. At the time of the drafting of this methodology, the three additionality tests include:

1. Regulatory Surplus Test
2. Common Practice Test, and
3. Implementation Barriers Test

Further guidance on these tests is given below:

TEST 1: Regulatory Surplus

In order to pass the regulatory surplus test, a project must not be mandated by existing laws, regulations, statutes, legal rulings, or other regulatory frameworks in effect now, or as of the project start date, that directly or indirectly affect the credited GHG emissions associated with a project.

The project proponent must demonstrate that there is no existing regulation that mandates the project or effectively requires the GHG emission reductions associated with the retrofit of high-bleed pneumatic controllers with low or no-bleed alternatives.

TEST 2: Common Practice Analysis

The common practice test is designed to demonstrate that the conversion of high-bleed pneumatic controllers is not already being undertaken as a matter of common practice. It is to answer the question of whether, in the industry/sector, there is widespread deployment of this project, technology, or practice.

The project document should demonstrate within reason why the conversion of high-bleed pneumatic controllers with low-bleed alternatives is not common practice in the market. For example, this assessment could include a review and updated assessment of the assumptions on regulations and pneumatic devices populations described below.

National and regional market information and data should be collected from various government agencies (federal, state, local), equipment vendors, and trade associations, as available, to support this market penetration assessment. This assessment should demonstrate that market conditions have not created, nor resulted in, a common practice conversion rate for high-bleed pneumatic devices that is significantly greater than that which the project proponent is undertaking in the project.

More Background Specific to Pneumatic Controllers and Common Practice: Because pneumatic controllers are numerous and dispersed throughout the oil and gas production, gathering, and transmission segments, and no organization has undertaken a comprehensive inventory, it is impossible to have a precise estimate of the number of pneumatic controllers or their aggregate emissions. However, as guidance for project proponents using this methodology, it is important to note that the U.S. EPA, for its annual Inventory on Greenhouse Gas Emissions and Sinks, routinely performs top-down estimations of pneumatic populations and emissions using available industry activity data and emission factors. Based on this EPA data and further analysis of population size and penetration rates it is estimated that less than 10% of the pneumatic high-bleed controller population has been replaced with low-bleed pneumatic devices.

According to the EPA's study, emissions from pneumatic controllers in the oil and gas sector account for 48 billion cubic feet of natural gas emissions per annum.[3] In the same study, the EPA also estimated that there were approximately 498,000 pneumatic controllers in the oil and gas sectors. This number includes high and low-bleed pneumatic controls. Additionally, using the EPA's estimate of total emissions and estimates of average emissions from each high-bleed controller (~140,000 cf/year) and low-bleed controllers (~8,000

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[3] US Environmental Production Agency (EPA), "Lessons Learned from Natural Gas STAR Partners: Options for Reducing Methane Emissions from Pneumatic Devices in the Natural Gas Industry", EPA430-B-03-004, Washington, DC, July 2003.

cf/year) the total number of pneumatic controllers is estimated at closer to 525,650.

Further, the U.S. EPA undertook a study in 2002 that estimated that the ratio of high-bleed to low-bleed pneumatic controls in the oil and gas sector was 66% to 34%.[4] The study also implied that the number of existing high-bleed pneumatics was diminishing at a very low rate; this is essentially because few replacements are occurring. These ratios, along with total population figures, imply that the total number of remaining high-bleed population in the United States is currently between 328,680 and 346,930 controllers.

Like the total number of pneumatic controllers, the number of retrofits/replacements that have occurred is equally difficult to determine precisely. However, data from the EPA and industry vendors and equipment suppliers suggest that the market penetration rate for high-bleed conversion in the production sector remains low.

Since 1993, the EPA has run a voluntary program called Gas STAR to educate natural gas companies about opportunities to reduce emissions from their operations. There are over 100 Gas STAR members, of which more than 30 are natural gas production companies, including 21 of the 25 largest domestic producers. These members submit annual reports to Gas STAR describing the annual emission reduction projects completed during the year. According to the EPA data, members have reported replacing approximately 34,000 high-bleed devices *since 1990* (this figure includes both transmission and distribution companies as well as production companies).

Combining the above estimate of 328,680 – 346,930 high-bleed controllers (in the oil and gas sectors) with the EPA figure that 34,000 high-bleed conversions have occurred (in *both* production and transmission sectors since 1990) would suggest that the market penetration of low-bleed conversions in the industry is below 10%

This penetration rate is further supported by discussions with vendors. Though vendors do not track whether their low-bleed devices are sold for conversion projects or new installations, anecdotal evidence suggests that such replacement projects are uncommon. Vendor surveys indicate that approximately 20,000 devices have been retrofitted since 2000, implying a market penetration rate well below 10% and ‘natural conversion’ rate of less than 1%.

In summary, despite superior technology having been available in the market for 20 years, a very large number of high-bleed pneumatic controllers still exist. The rate of conversion of these controllers, either through the retirement of the equipment on which they operate, or through retrofits, is extremely slow. Anecdotal evidence from industry professionals and field operators indicates that there are a number of reasons for this slow natural rate of conversion, including lack of understanding of the new technology among field operators, a pervasive “if it ain’t broke, don’t fix it” attitude, scarcity of capital and human resources for non-core projects, and corporate budgeting practices that do not account for lifecycle efficiency costs. Additionally, operators are reluctant to act on emission reduction activities before there is a clear path forward on U.S. GHG regulations and law and are adopting a “wait and see” attitude.

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[4] More information on this study may be accessed by contacting the EPA’s Natural Gas STAR program.

TEST 3: Implementation Barrier Analysis

The project proponent should establish that the project overcomes at least one prohibitive financial, technological, or institutional barrier. Further guidance on these barriers is provided below.

In order to demonstrate that there are prohibitive barriers to the project being implemented, the project proponent will provide documented evidence, and offer conservative interpretations of this evidence, as to how the project is overcoming the identified barrier. Anecdotal evidence can be included, but alone is not sufficient proof of barriers. Demonstration of the project facing at least one of the three barriers below is required for approval of the project.

Financial Barriers

The financial barriers test is intended to answer the following question: Does the project face capital constraints that carbon revenues can potentially address; or is carbon funding reasonably expected to incentivize the project's implementation; or are carbon revenues a key element to maintaining the project action's ongoing economic viability after its implementation?

To pass the financial barriers test, the project should face capital constraints that carbon revenue will play a significant role in helping it overcome. Financial constraints can include, but are not limited to:

- High costs – material and personnel costs associated with retrofit process, production losses, etc.
- Immaterial or low returns – project IRR does not meet company thresholds, revenue from gas savings is linked to volatile commodity pricing
- Limited access to capital or capital constraints due to the non-core nature of the project
- High risks from unproven technologies or business models
- Poor credit rating of project partners or high project financial failure risk

If the financial barriers test is selected for the project, the project proponent should both explain the financial barriers and provide sufficient supporting documentation at the time of the project validation. The project proponent should also consider the economic life of the controllers and the costs associated with refurbishment or replacement of these units at the end of this economic life. Project proponents can use a default value for controller replacement of 7 years or use a project-specific estimate in their financial analyses. Additionally, if applicable, economic analysis to demonstrate financial barriers should also account for the dispersion of value from gas savings from the project activity (e.g. passing of savings on to customers or increased royalties to gas lease holders).

Technological Barriers

The technological barriers test is intended to answer the following question: Is a primary reason for implementation of the technology in question its GHG reduction capabilities or benefits, and is the reduction of GHG emissions one of the goals of the project at the start date?

Technological barriers can include high R&D costs, deployment risk of new technologies, and lack of trained personnel available on-site to install, maintain, or properly operate the equipment or any other relevant technical barriers. If the technical barriers test is selected for the project, the project entity should both explain the technical barriers and provide, at the time of the project validation, sufficient supporting documentation.

Institutional Barriers

The institutional barriers test is intended to answer the following question: Does the project face significant organizational, cultural, or social barriers to achieving GHG emission reductions that the accrual of benefits from the project action will help to overcome?

Institutional barriers can include a scarcity of human resources for technology implementation, lack of support from management or operations personnel for new technology practices, an aversion to investment in an area where risks and returns are unfamiliar (as opposed to actual capital constraints), lack of awareness or concern with the benefits of the project, or any other relevant institutional barriers. If the institutional barriers test is selected for the project, the project entity should both explain the institutional barriers and provide, at the time of the project validation, sufficient supporting documentation.

3.0 QUANTIFICATION METHODOLOGY

3.1 Baseline Emissions

Quantification of project emission reductions will require baseline emissions and project emissions, which are calculated from emission factors derived through statistical sampling and analysis of the project proponent's population of pneumatic controllers as follows:

Within the project boundary, an emission factor for calculating baseline emissions will be developed from site-specific measurements using procedures outlined in Appendix C. A representative sample, of not less than 30 direct measurements, must be taken to estimate the average emissions of each manufacturer's controllers to be converted in the project. As there is a statistically significant difference between the average emissions of different manufacturer's controllers (Appendix A) sampling and emission factors should be manufacturer-specific. Using the data from the sample of measurements the lower bound 95% confidence interval for the average emissions will be used as the emission factor to calculate the baseline. By using the lower bound of the confidence level, the uncertainty around sampling is automatically discounted, thereby providing a conservative result.

All measurements will be made using one of the techniques described in Section 4.4 – Measurement Techniques.

Calculation of the emission reductions for this methodology is based on an emission factor approach. The emissions calculations will be made according to the following approach:

$$E_{TB} = \sum_{i=1}^{N} E_{Ti} \quad (1)$$

$$E_{Ti} = E_{Tis} + E_{Tit} \quad (2)$$

$$E_{Tis} = 365 \times EF_i \times GC \times CF \times GWP \times (1 - AT_{s,j}) \times \sum O_{iTime,s} \quad (3)$$

$$E_{Tit} = 365 \times EF_i \times GC \times CF \times GWP \times \sum O_{iTime,t} \quad (4)$$

Where:

E_{TB}	=	Total baseline emissions across all manufacturers (tonnes CO_2e/yr)
E_{Ti}	=	Total baseline emissions from the i^{th} manufacturer (tonnes CO_2e/yr)
N	=	Number of manufacturers in the project assessment boundary
E_{Tis}	=	Emissions from high-bleed controllers configured for snap-acting control from the i^{th} manufacturer for each identified piece of equipment
E_{Tit}	=	Emissions from high-bleed controllers configured for throttle control from the i^{th} manufacturer for each identified piece of equipment
EF_i	=	Emission factor at 95% lower bound for the i^{th} manufacturer (scfd produced gas/controller)
GC	=	Gas composition of methane in produced gas (mole fraction CH_4). If a representative sample of GC data is used, this data should be discounted by a margin-of-error analysis, which can follow the same procedure in Appendix B.
CF	=	Conversion factor for methane volume to mass (0.00001926497 tCH_4/scf CH_4)
GWP	=	Methane global warming potential (21 tonnes CO_2e/tonnes CH_4)
$AT_{s,j}$	=	Actuation time of snap-acting controllers in basin or facility *j* (see 3.1.1 below)
$O_{iTime,s}$	=	Percent annual operating time for the i^{th} manufacturer's snap-acting high-bleed controller (operation hours/total hours per year)
$O_{iTime,t}$	=	Percent annual operating time for the i^{th} manufacturer's throttle acting high-bleed controller (operation hours/total hours per year)

3.1.1 Calculating the actuation rate for snap-acting controllers

An important concept with certain kinds of pneumatic controllers called snap-acting controllers is the actuation time (AT). When snap-acting controllers are operating and conducting their intended function, natural gas is run through the device and is thus not bled to the atmosphere. This period of functioning, when no bleeding occurs, is called actuation. Only in their "inactive" state are snap-acting controllers – whether high-bleed or low-bleed – bleeding gas. Most snap-acting controllers are inactive, and thus bleeding, the vast majority of the time (greater than 95%). However, the project proponent should still take into account the time the device is active and not bleeding gas, so this time can be discounted from overall baseline emissions. For this methodology, the project proponent will develop a default actuation rate to apply to the snap-acting controllers in the project boundary. The default will be based on gathering data from all controllers to be retrofitted and should provide the most conservative result for each distinct facility included in the project boundary.

- For the production sector a basin-by-basin approach is necessary because the actuation rates are directly related to liquid production volumes and therefore tend not to vary much across a basin, but may differ significantly between different basins.
- For the transmission sector a facility by facility (e.g. each compressor station) is necessary because actuation rates could vary significantly between facilities depending on where in the transmission process the facility is positioned.

The project proponent will collect the following data to determine the default actuation rate for snap-acting controllers within a specific facility. The following data needs only to be collected for sites that utilize snap-acting controllers, and this data can be collected at any time:

☐ Port Size. The project proponent will determine port size for the snap-acting control valves that are managed by the controllers to be retrofitted. Port size can be determined by physical inspection and should conform to manufacturers' standard port sizes. For the purposes of determining the most conservative default actuation rate, the smallest port size will be used as representative of the entire retrofit population. If the smallest size is used, this will be conservative because the smaller the port size, the longer the estimated actuation time would be. Because this time is deducted from the baseline emissions, the longer the time, the lower (and thus more conservative) the baseline will be.

☐ Differential Pressure. The project proponent will determine the lowest differential pressure (DP) across the snap-acting control valves within the population to be retrofitted. A common example of this is the pressure drop across a dump valve dumping from separator pressure down to storage tank pressure. Again, using the lowest determined DP in the population to be retrofitted will yield the most conservative result because lower DP results in a decreased driving force for flow through the valves, resulting in a slower flow rate and decreased liquid capacity through the control valves; hence, longer actuation time.

☐ Liquid Capacity: The project proponent will determine the liquid capacity (LC) from the valve manufacturer using the lowest differential pressure (DP) and smallest port size. The manufacturer of the valve should provide the information (sometimes in a chart called the Liquid Capacity Chart) in its literature. LC should be expressed in barrels per day of water flow rate. By using barrels per day of water, and NOT correcting for oil gravity, the calculations will remain conservative since water is denser than oil and will result in slightly longer actuation times. As an example, a company may have a Kimray valve located in an area where the DP is 200 psi and the port size is 1/4 inch. According to Kimray, in this case, the liquid capacity would be 650 barrels per day.

☐ Barrels of Production per Controller (BPC): The project proponent will determine the 30-day average combined (oil or water) production per day for the well sites with controllers to be retrofitted. The 30-day averages will be added together to determine the total combined average volume per day per controller across all of the controllers to be retrofitted.

Any controller for which 30 days worth of production data is not available should be excluded from the calculation of the actuation rate.

The percentage of time the actuator is operating daily (AT) and the snap-acting controller is NOT bleeding can be expressed as:

$AT_{s,j}$ = (BPC / LC) where

$AT_{s,j}$ = the default actuation rate in facility *j* for snap-acting (s) controllers

$AT_{s,j}$ is expressed as a percentage or fraction. Thus, the adjusted baseline bleed rate for a particular snap-acting controller in *facility j* would be the bleed rate * (1-$AT_{s,j}$). If $AT_{s,j}$ were 3%, that means that controller is bleeding 97 percent of the time, and the adjusted baseline emissions would be 97% of the original baseline calculation.

For pneumatic controllers in the transmission sector e.g., compressor scrubber dump valves, the actuation rate should be calculated by facility e.g., compressor station. The production rate and therefore the controller's actuation rate could vary significantly between facilities depending on where the facility is located in the transmission network.

3.1.2 The case of throttle pneumatic controllers

Calculating actuation times, as described above, is not necessary in the case of throttle controllers. With these types of controllers, the actuator is using a portion of the instrument supply gas and the remainder is bleeding through the high-bleed controller pilot, which provides intermediate valve travel and controls the process variable (such as level) at a steady point. Since the actuator is in continuous use, the atmospheric emissions consist of combined actuator vent gas and pilot bleed gas that cannot be delineated from each other. Throttle configured controllers are used in liquid service applications as well as gas service applications, such as flow control or pressure control. As with the snap-acting controllers, the bleed rate can be determined as described in Section 4.4. However, no discount for applying an actuation rate will be required. Thus, the variable $AT_{s,j}$ in equation (3) does not apply for throttle controllers.

3.2 Project Emissions

An emission factor for estimating project emissions will be developed from site-specific measurements taken before each annual GHG emission reduction verification activity. A sample of site-specific measurements will be performed, using procedures outline in Appendix C, to test the post-project emissions of 30 different converted controllers. Using the data from the 30 measurements, a t-test will be performed, and the emission factor will be selected as the upper boundary of the 95% confidence interval. By using the upper bound of the confidence interval, the uncertainty around sampling is automatically discounted, thereby providing a conservative result.

If a single technology has been used to retrofit or replace all devices, a single project emission factor can be developed. However, if a number of different low-bleed technologies are being used for the replacement, then a separate emission factor must be used for each low-bleed technology.

The equation to determine project emissions is as follows:

$$E_{TP} = \sum_{i=1}^{N} E_{Pi} \qquad (9)$$

$$E_{Pi} = 365 \times EF_p \times GC \times CF \times GWP \times \sum O_{iTime} \qquad (10)$$

Where:

E_{TP}	=	Total project emissions across all manufactures (tonnes CO_2e/yr)
E_{Pi}	=	Total project emissions for the i^{th} manufacturer (tonnes CO_2e/yr)
EF_P	=	Calculated emission factor at 95% upper bound for the i^{th} manufacturer (scf/day)
N_i	=	Total number of controllers from the i^{th} manufacturer
GWP	=	Methane global warming potential (21 tonnes CO_2e/tonne CH_4)
GC	=	Gas composition of methane in produced gas (mole fraction CH_4). If a representative sample of GC data is used, this data should be discounted by a margin-of-error analysis, which can follow the same procedure in Appendix B.
CF	=	Conversion factor for methane volume to mass (0.00001926497 tCH_4/scf CH_4)
O_{iTime}	=	Percent annual operating time for the i^{th} identified piece of equipment (%)

Note: Actuation time is not included in project emissions. This is conservative because by not calculating the actuation time, project emissions are not discounted. Thus project emissions would be higher and the emission reductions lower.

3.3 Leakage

Leakage is defined as an increase in emissions outside the project boundary which is attributable to the implementation of the project. In cases where leakage occurs, it must be accounted for and subtracted from the overall emission reductions for the specific verification period.

Project proponents should consider two types of leakage when determining if there is any leakage attributable to the project. These are system leakages and upset leakages, described as follows:

a) ***System Leakage*** is the estimate of fugitive emissions created elsewhere in the facility as a result of implementing the project. As operating practices at individual companies will vary, each project proponent will provide a conservative method for accounting for any material system leakage that could be reasonably expected from the project.

b) ***Upset Leakage*** is the estimate of leakage due to an increase in upset conditions as a result of implementing the project. The project proponent should consider whether the project is likely to cause increased malfunctions of the pneumatic controllers and other components which would result in leakage. The project proponent will provide a conservative method for accounting for any material upset leakage that could be reasonably expected from the project.

Alternatively, if the project proponent deems that there is neither material system nor upset leakage, the project proponent may support this assertion using qualitative and/or quantitative analysis.

3.4 Emission Reductions

Total emission reductions will be calculated as the difference between the baseline emissions and the project emissions.

Emission reductions created by a project will be calculated according to the following equation:

$$ER_y = E_{TB,y} - E_{TP,y} \qquad (11)$$

Where:

ER_y	=	Emission reductions during the year *y* (tonnes CO_2e/yr)
$E_{TB,y}$	=	Baseline emissions in year *y* (tonnes CO_2e/yr)
$E_{TP,y}$	=	Project emissions in year *y* (tonnes CO_2e/yr)

4.0 DATA COLLECTION AND MONITORING

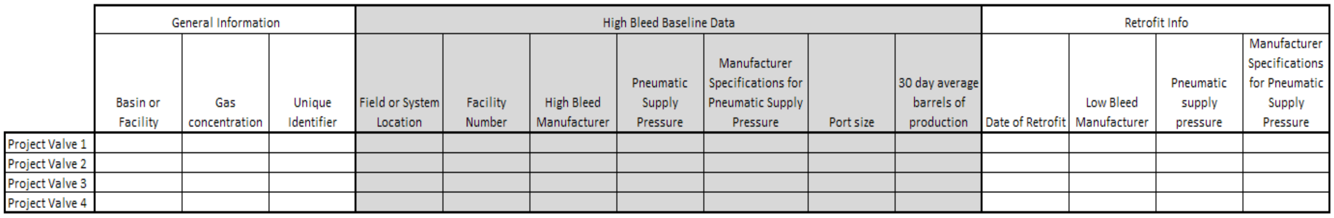
This section outlines procedures for data collection and monitoring. The section discusses instrument calibration and necessary parameters for monitoring.

The process for keeping track of the emission reduction project's parameters includes:

- Identifying and logging high-bleed pneumatic controllers to be converted
- Following the instructions for calibrating measurement instruments
- Selection of the random sampling for the project emissions
- Oversight of project emissions measurements, such as operating time, methane concentration, and bleed rates
- Recording project emissions data and calculating project emission factors

The tables at the end of this section list the key parameters of the emission reductions calculation, and how each parameter should be recorded. All information for the project should be stored electronically and centrally in a single spreadsheet that is easily accessible for the project validator and emission reduction verifiers.

Table 4.0: Example of Pneumatic Retrofit Project Database



	General Information			High Bleed Baseline Data							Retrofit Info			
	Basin or Facility	Gas concentration	Unique Identifier	Field or System Location	Facility Number	High Bleed Manufacturer	Pneumatic Supply Pressure	Manufacturer Specifications for Pneumatic Supply Pressure	Port size	30 day average barrels of production	Date of Retrofit	Low Bleed Manufacturer	Pneumatic supply pressure	Manufacturer Specifications for Pneumatic Supply Pressure
Project Valve 1														
Project Valve 2														
Project Valve 3														
Project Valve 4														

4.1 Verification Period

The verification period can be defined at the discretion of the project proponent, provided it conforms to ACR's guidelines on verification periods.

4.2 Baseline Emissions Measurement

The emission factors are the foundation of the baseline emissions calculations. These baseline emission factors are proscribed by this methodology and are not directly relevant to defining the data collection and monitoring requirements associated with this methodology. Diligent count and record of the number and manufacturer of eligible controllers converted to low-bleed will be required for the methodology's implementation. The section below elaborates on necessary data collection for baseline construction.

#	Parameter	Procedure
1	Number of controllers	Project manager should keep a catalog of all of the controllers intended to be replaced by the project, including manufacturer and controller type. This database will be used for the selection of the project group in subsequent GHG emission reductions verifications.
2	Location	Record of location of the pneumatic controller within the operations infrastructure is critical in order to account for the operational status of the equipment.
3	Low-bleed pneumatic controllers	Each converted pneumatic controller should be given a unique identifying number that shows it to be a part of the project assessment boundary. For each potential retrofit, the project proponent should confirm that the retrofit has taken place. The project proponent is responsible for keeping track of which retrofits have already been used in sampling and use controller and basin data to select subsequent sample groups. Given that the major equipment to which the pneumatic controllers are associated has operations which are monitored routinely; operating hours for each low-bleed pneumatic controller will be recorded. Each controller should include a description of whether it is continuous bleed or interrupted bleed.

4.3 Project Emissions Measurement

4.3.1 Selection of verification sampling group

Quantification of project emissions will require direct measurement of emissions. Direct measurement of emissions will be taken from a random and representative sample of 30 post-retrofit pneumatic controllers, and a project emission factor will be calculated for each verification period.

4.3.2 Identification of verification sampling group

Once a controller has been selected for the verification sampling group, it should be noted in the data base that that the controller has been selected. After the emissions test has been performed, the controller should have a durable identifier (e.g. documented GPS coordinates, unique identifier code, stamped metal tag) so that it is easily identifiable and will be found by the verifier or project manager in subsequent data quality QC spot-checks, GHG emission reduction spot-checks, or verification site visits. Finally, pneumatic controllers in the sample verification group should be excluded from the random selection for the subsequent verification, and then re-included in the pool thereafter.

4.3.3 Data analysis and emission factor derivation for emission factor sampling group

The 30 data points will be used to determine the 95% confidence interval for the average emissions.[5] The value at the upper bound of the 95% confidence interval should be selected as a conservative measure.

4.3.4 Outliers in the verification sample group

All the emissions from all controllers selected for the verification sample group should still be included in the sample mean calculation of the project emission factor. If a control is found to be bleeding gas at an abnormally high rate, the project proponent should determine if the reading is a typographical error or a measurement inaccuracy and take the necessary step to correct this reading. However, if the abnormally high reading is accurate it should still be included in the project emissions calculation. No outliers will be removed unless they are inaccurate measurements and cannot be rectified.

4.3.5 Ensuring consistency in baseline sample measurements

In order to ensure that emissions measurements are in accordance with normal operating parameters, pneumatic gas supply pressure for controllers within the snap-acting sample set must fall within manufacturer's specifications. Controllers for which pneumatic gas supply pressure readings fall outside manufacturer's specifications should be excluded from the sample set.

4.4 MEASUREMENT TECHNIQUES

Measurement of emissions will be performed using one of the following techniques:

4.4.1 A high volume sampling tool

This can include a Hi-Flow Sampler or comparable instrument which meets the instrumentation requirements as outlined below to the satisfaction of the verifier. Due to the low rate of gas flow of individual pneumatic controllers, a Hi-Flow Sampler is uniquely suited to accurately quantify flow rates from low-emissions (several hundred scfd) sources. The Hi-Flow Sampler operates by pulling emissions away from the leaking equipment into a centralized conduit for measurement, automatically correcting for the hydrocarbons in the ambient air that would otherwise contribute to the total leak rate measured.

The Hi-Flow Sampler utilizes dual function catalytic oxidation/ thermal conductivity sensors to measure the rate of gas flow from the leak and ensure the accuracy of the measurement test. The Hi-Flow Sampler measures only combustible gases (methane, propane, butane, etc) and not inert gases like carbon dioxide and nitrogen. Therefore when correcting for gas composition in the afore-mentioned equations 3, 4 and 10, the gas composition correction factor (GC) should be calculated as the volume of methane as a proportion of all combustible gases (methane, propane, butane etc).

The following procedures should be followed in using the Hi-Flow Sampler to measure emissions:

- Calibration on instruments should be checked, at a minimum, according to the procedures and frequency outlined by the manufacturers of the Hi-Flow Sampler.

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[5] Due to the high degree of control on both the calibration of the instruments and the random, representative nature of the sample, a 95% upper bound is appropriate for the development of the project emission factor. A 95% interval is in line with IPCC and UNFCCC CDM best practices when a random and representative sample is taken.

  - For gas concentration, instrument should be calibrated using gas that has been provided by a certified vendor (Approved within ± 2%).
  - For catalytic oxidation, calibrate for 2.5% methane.
  - For thermal conductivity, calibrate for 99% methane.
- Measurements need only be taken once. The test should endure for a minimum of 5 minutes to ensure that the gas emissions are measured at a steady state.

The leak flow rate of methane is calculated as follows:

$$F_{CH_4,i} = F_{Sampler,i} \times \left(C_{Sample,i} - C_{Back,i}\right)$$

Where:

$F_{CH4,i}$	=	The leak flow rate of methane for leak *i* from the leaking component (scfm)
$F_{sampler,\,i}$	=	The sample flow rate of methane for leak *i* (scfm)
$C_{sample,\,i}$	=	The concentration of methane in the sample flow from leak *i* (volume percent)
$C_{back,\,i}$	=	The concentration of methane in the background near the component (volume percent)

4.4.2 In-line turbine meters

Another option for determining leak rates is the use of an in-line turbine meter. In this case, a meter is installed into the system as opposed to an external sniffing device like the Hi-Flow Sampler. The process works by shutting supply pressure off to the controller and isolating it from service. In most cases, there is a regulator line feeding the controller. The meter is installed downstream of the regulator output port by using ¼ inch tubing and fittings compatible with the regulator and the input port of the flow meter. Another ¼ inch length of tubing is installed from put the output port of the flow meter to the input port of the control device being tested. This ensures the flow meter is installed upstream of the device.

Before the retrofit from high-bleed to low-bleed, the system pressure is turned on, slowly allowing the controller to stabilize to its operating condition. The flow meter will register and record the flow of supply gas, which is being used by the controller. Once the test is completed, the inlet and outlet shutoff valves are closed again, isolating the controller from supply pressure. After the retrofit program the same test procedure is performed on a different sample set. The difference between the pre-retrofit and post-retrofit measurements indicates the bleed savings opportunity. Once the testing is completed, the flow meter is uninstalled and the system is returned to its original configuration.

All in-line turbine meters shall be calibrated according to the manufacturer's specifications prior to measurement.

4.4.3 Calibrated bagging

Calibrated bag measurements use anti-static bags of known volume (e.g. 0.085 m^3 or 0.227 m^3) with a neck shaped for easy sealing around the vent. Measurement is made by timing the bag expansion to full capacity while also employing a technique to completely capture the leak while the inflation is being timed. The measurement is repeated on the same leak source numerous times (at least 7, typically 7 to 10 times) in order to ensure a representative average for the fill times (outliers or problem times should be omitted and the tests rerun until a representative average rate is established). The temperature of the gas is measured to allow correction of volume to standard conditions. Additionally, gas composition is measured to verify the proportion of methane in the vented gas, since in some cases air may also be vented, resulting in a mixture of natural gas and air. Calibrated bags allow for reliable measurement of leak flow rates of more than 250 m^3/h. The leak flow rate of methane is calculated as follows:

$$F_{CH4,i} = V_{bag} \times w_{sampleCH4,i} \times 3600 / t_{aver,i}$$

Where:

$F_{CH4,i}$	=	The leak flow rate of methane for leak *i* from the leaking component (m^3/h)
V_{bag}	=	Volume of calibrated bag used for measurement (m^3)
$w_{sampleCH4,i}$	=	The concentration of methane in the sample flow from leak *i* (volume percent)
$t_{aver,i}$	=	Average bag fill time for leak *i* (seconds)

4.5 Data and Analysis for Verification

Table 4.5 below details the data to be collected or calculated.

Table 4.5: Data to be Collected or Calculated

Parameter	Description	Data Unit	Calculated [c], Measured [m], Reference [r], Operating records [o]	Measurement frequency	Comment
E_{TB}	Total annual emissions across all manufacturers in the baseline	tCO_2e	[c]	Calculated once	In cases where only one brand of high-bleed controller is replaced, $E_{TB} = E_{Ti}$
E_{Ti}	Total annual baseline emissions from the from the i^{th} manufacturer	tCO_2e	[c]	Calculated once	
N	Number of manufacturers in the project assessment boundary	#	[c]	Calculated once	
TN_i	Total number of controllers from the i^{th} manufacturer across the project	#	[m]	Logged at the beginning of the project. Changes and updates made during each verification period.	The total populations of each manufacturer's continuous high-bleed pneumatic controllers to be replaced in this project (TN_i) will be inventoried by the project proponent. The location, manufacturer brand, and date of conversion of each controller replaced should be recorded electronically and centrally stored.
EF_i	Baseline emission factor at 95% lower bound for i^{th} manufacturer	scfd	[c]	Calculated once	

Parameter	Description	Data Unit	Calculated [c], Measured [m], Reference [r], Operating records [o]	Measurement frequency	Comment
GC	Gas composition of methane	%	[m]	Frequency determined by well operator	The methane composition of the produced natural gas is a key calculation element in estimating the baseline and project emissions of the GHG emission reduction project. Methane is the primary constituent of natural gas, and its concentration in natural gas produced in the U.S. is found to be on the order of 60-95%.[6] GC can be determined by gas chromatography or other gas analysis technology. Depending on the measurement technique used (see Section 4.4), GC may represent either the methane concentration of the total gas composition or of only combustible gases. Methane concentration testing may occur at a frequency determined by the well operator according to the characteristics of gas production at a particular well. In this case, the most recent recorded gas composition analysis will be used in baseline or project emission calculations. If a sampling approach is used, it should be discounted by a margin-of-error analysis, which can follow the same procedure in Appendix B. Project proponent may also want to reference the National Institute of Standards and Technology (NIST) traceable calibration gases.
$\mathbf{GWP}_{CH4}$	Global warming potential of CH_4	21	[r]	N/A	21 was determined in the 1996 IPCC Second Annual Assessment Report to be the Global Warming Potential of Methane. The 2001 Third Annual Assessment Report determined the global warming potential to be 23. Common industry practice and conservatism dictated that 21 should be used as the global warming potential for methane in the future.
$\mathbf{O}_{iTime}$	Operating hours of the production equipment relating to the pneumatic controllers	%	[o] [c]	Data to be taken from operating records of company	Hours of operation used to calculate total emissions, as only controllers on operating equipment are assumed to emit gas.

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[6] Foss, M.M., “Interstate Natural Gas – Quality Specifications and Interchangeability”, University of Texas Bureau of Economic Geology, Austin, TX, December 2004.

Parameter	Description	Data Unit	Calculated [c], Measured [m], Reference [r], Operating records [o]	Measurement frequency	Comment
E_{TP}	Total project emissions across all manufactures	tCO_2e	[c]	Each validation period	Note that in the event that only one conversion technology is used, $E_{TP} = E_{Pi}$
E_{Pi}	Total annual project emissions for the i^{th} manufacturer	tCO_2e	[c]	Each validation period	
EF_P	Emission factor for the project taken at the upper bound of the 95% confidence interval	scfd	[m] [c]	Calculated for each verification period	
E_{TP}	Total annual emissions for the project	tCO_2e	[m] [c]	Calculated for each verification period	
BPC	Barrels of water produced per controller	Average barrels per day/ controller	[c]	Once	Can be measured at any time. Used to determine actuation time or period of time snap-acting controller is active and thus not bleeding.
LC	Liquid capacity	Barrels per day of water flow rate	[r]	Once	Can be measured at any time. Used to determine actuation time or period of time snap-acting controller is active and thus not bleeding.
DP	Differential pressure	Psi	[r]	Once	Can be measured at any time. Used to determine actuation time for snap-acting controllers.
Port size	Port size of controller	Inches	[r]	Once	Can be measured at any time. Used to determine actuation time for snap-acting controllers.

5.0 EMISSIONS OWNERSHIP AND QUALITY

5.1 Statement of Direct Emissions

The project proponent should attest that all emission reductions occur on the property owned and/or controlled by the project proponent and that none of the emissions claimed by the project are indirect emissions.

5.2 Permanence

Project proponents should demonstrate that the emissions reduced by the project are permanently reduced.

5.3 Title

Project proponents should provide evidence that they have title or contractual rights to the emission reductions claimed in the project document prior to ACR registration and that no other entity has a conflicting claim over the emission reduction claimed in the in the project document.

5.4 Community and Environmental Impacts

It is unlikely that this particular type of project – the simple replacement of controllers at various and remote oil-production locations – would have any significant environmental or social impacts. The retrofitting of controllers are not capital-intensive projects requiring any kind of environmental impact statement, and no new infrastructure is put in place. Retrofitting pneumatic controllers only replaces a tiny part of a large infrastructure already on the ground, with the environmental impacts having been incurred long before the retrofit project.

If there are any significant impacts from pneumatic retrofits, however, project proponents should take into account ACR’s Community and Environmental Impacts criteria when applying this methodology to specific projects. These criteria require analysis of any adverse environmental or social impacts on the communities near the project boundary. If there are any adverse environmental problems that may result from the project itself, project proponents should conduct stakeholder meetings with community groups or other appropriate NGOs to ensure that any concerns associated with the project are addressed.

6.0 QA/QC

As part of the Pneumatic Conversion Protocol, the number of continuous high-bleed pneumatic controllers to be converted in the project will be monitored by the project proponent, with all pneumatic controllers that are converted being identified and numbered. As a QA/QC check on the retrofit of pneumatic controllers, purchasing invoice and shipping receipt information or other documentation from the low-/no-bleed pneumatic controller equipment supplier for the pneumatic controller conversions should be available. More details on the specific QA/QC activities required by the Pneumatic Conversion Methodology are summarized in Table 7.1 in the following section.

In addition, in order to ensure that controllers are retrofitted correctly and to minimize any chance of future “upset” conditions resulting from the retrofit, project proponents should review the manufacturer’s recommended retrofit procedures and the manufacturer’s recommended post-retrofit QA/QC checklist.

7.0 UNCERTAINTIES

The emission reduction calculations in this methodology are designed to understand possible emissions, and to minimize the possibility of overestimation and over crediting of GHG emission reductions, due to various uncertainties, primarily associated with emission factors and representative sampling populations.

Nonetheless, there are a number of uncertainties related to estimates of methane emission reductions from continuous high-bleed pneumatic controller conversion projects. Some of these uncertainties are more easily quantified than others. These sources and relative magnitude of uncertainties (and changes thereof) should be explicitly addressed and discussed by the project proponent as part of the GHG emissions calculation and reporting process, and described in the project document as part of the GHG emissions calculation and reporting process.

These potential sources of uncertainty include but are not limited to: emission factors, methane gas composition, operating time, actuation time and conversion rates. Each of these potential sources of uncertainty, and the associated QA/QC program elements designed to minimize them is summarized in Table 7-1. Other factors as stated above (e.g. equipment overhaul frequency, instrument settings) have a bearing on uncertainty. Overall uncertainty can be assessed by using the uncertainties of each element in a calculation.

The accuracy and precision of measurement equipment, such as the high flow meter and gas composition analyzer, are readily quantified and the uncertainties associated with each measurement are considered to be quite low.

The extrapolation of gas composition measurements to the total bleed rate of methane gas can introduce some uncertainty, depending upon the variability of the methane content of the gas (geographically and temporally) and the frequency of samples taken.

Operating outages in the baseline and the project activity will be recorded, if and when they occur, though the contribution of this variation to the overall uncertainty is not expected to be large and conservative estimates of durations will be made.

Table 7.1: Uncertainties in the Reported Data

Data Parameter	Uncertainty Level of Data	QA/QC Procedures Risk Mitigation
Emission Factors **($EF_{i,B}$ and EF_P)**	Low/Medium	***$EF_{i,B}$*** -Field instruments calibrated before use, statistical analyses at 95% confidence interval, and project emission factor at lower bound ***EF_P*** -Field instruments calibrated before use, statistical analyses at 95% confidence interval, and project emission factor at upper bound

Data Parameter	Uncertainty Level of Data	QA/QC Procedures Risk Mitigation
Operating Parameters	Low/Medium	**Supply Pressure** – Pneumatic gas supply pressure of controllers sampled for the purposes of determining the baseline and project emissions will be recorded at the time of sampling and must be within manufacturer recommended specifications **Maintenance Conditions** – After retrofits have been completed, overhauls to correct upset conditions should be documented. Additionally, estimates of emissions resulting from the upset condition should also be recorded under Leakage as described in Section 3.3
Instrument Parameters	Low/Medium	**Actuation Rate** – Sampling must only be conducted when the controller is in a steady state and not actuating. Additionally, sample measurements need to be taken for a time period in excess of 5 minutes to ensure stabilization of the gas emissions and avoid any spikes **Liquid levels and Proportional Band** – Controllers must be installed and configured to operate within manufacturers' specifications e.g. within manufacturers' specified bands and levels
Number of High and Low-Bleed Pneumatic Controllers **($N_{i,}$)**	Low	Each replaced controller should be tagged with a durable unique identifier (e.g. stamped metal, GPS coordinates etc) capable of lasting several years and inspected in field, with count confirmed with equipment supplier sales/installation records
Methane Gas Composition **(GC)**	Low	Multiple measurements sources; historical tract/field/reservoir/basin/compressor station data for validation
Operating Time **(O_{iTime})**	Low	Project entity maintains detailed and continuous information on the operation of the equipment
Actuation time for snap-acting controllers **(AT)**	Low	AT is calculated with data that should be available to all oil companies, including port size of the controllers to be retrofitted, the differential pressure and barrels of production. All are basic data parameters that would either be available centrally or by observing in the field. Liquid capacity is provided by the manufacturer of the valves.

APPENDIX A

This annex presents a summary of the data, summarized in Table A.1, used to prove that there are statistically significant differences associated with manufacturer design differences in continuous high-bleed pneumatic controllers. This observation is also confirmed in the vendor literature for low-/no-bleed pneumatic controllers.[7] Based on that, as part of the statistical analysis of the baseline sampling test data, stratified data sets (by manufacturer) were also evaluated.

Table A.1[8]: High-Bleed Pneumatic Controller Emissions Data Summary

Manufacturer	Model	Baseline Bleed Rate, scfd	Data Source
Cemco	6900	367.0	Producer 3
Wellmark/Cemco	6900	432.0	Producer 3
Cemco	6900	528.0	Producer 3
Cemco	6900	732.0	Producer 3
Cemco	--	463.2	Producer 3
Cemco	6900 @ 25 psi	576	Producer 3
Cemco	6900 @ 35 psi	696	Producer 3
Cemco	6900	535.2	Producer 3
Cemco	6900	726.7	Producer 2
Cemco	6900	851.5	Producer 2
Cemco	Snap-acting	401.3	Producer 1
Cemco	Throttle	386.0	Producer 1
Cemco	Throttle w/ snap head	441.9	Producer 1
Cemco	Throttle w/ snap head	355.6	Producer 1
Cemco	Snap-acting	401.3	Producer 1
Cemco	Snap-acting	447.0	Producer 1
Cemco	Throttle w/ snap head	441.9	Producer 1
Cemco	Throttle w/ snap head	406.4	Producer 1
Invalco	Throttling	518.1	Producer 1
Invalco	Snap-acting	274.3	Producer 1

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[7] Wellmark, Mizer Pilot Control, "Continuous Bleed Controllers – Lost Gas." www.wellmarkco.com

[8] Table A-1 summarizes the high-bleed emissions data points take from the measurement of 35 Cemco (18) and Invalco (17) controllers. Data was provided by two (2) oil and gas production companies and the low-/no-bleed pneumatic controller manufacturer, with sampling measurements taken by their field technicians for two different oil and gas companies representing 8 different production fields in 4 states.

Manufacturer	Model	Baseline Bleed Rate, scfd	Data Source
Invalco	CTS-215	655.0	EPA
Invalco	CTU-215	1052.2	Producer 2
Invalco	CTU-415	597.6	Producer 3
Invalco	CTU-415	559.2	Producer 3
Invalco	CTU-415	415.2	Producer 3
Invalco	CTU-415	636.0	Producer 3
Invalco	CTU-215	744.0	Producer 3
Invalco	CTU-215	540.0	Producer 3
Invalco	CTU-215	285.0	Producer 3
Invalco	CTU-215	984.0	Producer 3
Invalco	CTU-215	1034.0	Producer 3
Invalco	CTU-215	712.0	Producer 3
Invalco	CTU-215	657.0	Producer 3
Invalco	CTU-215	703.0	Producer 3
Invalco	CTU-215	324.0	Producer 3

Statistically Significant Difference between Average Emissions for Cemco and Invalco

The sample average for Cemco controllers was 511 scfd and the sample average for Invalco controllers was 629 scfd. Given that the emissions from the different manufacturers are different, it becomes imperative to assess if there is a statically significant difference between the emissions from Cemco controllers and Invalco controllers.

- If there is a statistically significant difference in the sample means then it indicates that the differences between the sample means is not due to chance, but rather due to real differences in controllers, e.g. design. The implication of this is that baseline sampling must be carried out for each controller manufacturer independently (i.e. 30 samples of Cemco controllers and 30 samples of Invalco controllers).
- If however, there is not a significant difference between sample means, then it indicates that the difference between the sample means is likely due to chance and not as a result of real differences. Therefore the Cemco and Invalco controllers can be considered as one population from a baseline estimation point of view (i.e. 30 samples of controllers).

Analysis: To assess statistical significance a two sample *t* test for independent samples was conducted. Assuming unequal variances, $t_{\text{calculated}} = 1.76$ with a *p*-value = .091. This *p*-value is less than the significance level of .10 which leads to the conclusion that there is a statistically significant difference between the Cemco and Invalco average emissions.

In other words, the difference in sample means is *not* due to chance but is the result of real differences in the controllers. Therefore the standard baseline emission factors for high-bleed controls cannot be directly applied without manufacturer specific measurement data and the project proponent must sample different manufacturer's controllers as separate populations.

Estimating the Average Emissions for Cemco and Invalco

Table A.2 summarizes the results of the confidence interval calculations for the individual manufacturers. Margins of error and confidence intervals were calculated using the standard method assuming a normal population distribution and an unknown population variance. See Appendix B for a detailed explanation of confidence interval calculation methods. The resulting values are summarized in the table below.

Table A.2: 95% Confidence intervals for mean emissions of Cemco and Invalco controllers

	Mean Value (scfd)	Stdev	Margin of Error	Lower Bound	Upper Bound
Cemco	511	147	73	437	584
Invalco	629	238	122	507	751

APPENDIX B

This appendix defines the procedure for calculating an interval estimate for the population mean, μ. Because it is rarely possible to take a census of a population of items, we must rely on the results of a sample data set to estimate the mean of a population. The interval estimate is called a *confidence interval*. The typical form of any confidence interval is to add and subtract a *margin of error* from a sample statistic.

When estimating a population mean, the sample statistic used is the sample mean, $\bar{x}$. The margin of error of any interval estimate is dependent on three factors: the level of confidence chosen by the analyst, the variation within the population, and the size of the sample used for estimation.

The formula for calculating a confidence interval for μ is:

$$\bar{x} \pm t\frac{s}{\sqrt{n}} \qquad (1)$$

where $t\frac{s}{\sqrt{n}}$ is the margin of error, t is the statistic used to guarantee the confidence of the estimate, s is the sample standard deviation, and n is the sample size. The margin of error of any interval estimate is dependent on these three values.

The order in which one proceeds in the estimation process is the following:

- Choose a confidence level. Typically, the confidence level used is 95%. By choosing a higher confidence one would be increasing the margin of error, all things being equal. By choosing a lower confidence one would decrease the margin of error, all things being equal. In other words, greater confidence leads to wider intervals, lesser confidence leads to more narrow intervals.
- Determine the appropriate sample size. The size of the sample should be determined by the precision level desired (expressed as the margin of error) and confidence level desired and will be dependent on the amount of variation in the population. Depending on how these three factors change, the appropriate sample size could go up or down. For example, we can use the sample standard deviation calculated from the Invalco data in App A (s = 238 scfd) as an estimate of the population variation. If we choose a confidence level of 95%, and choose a margin of error of ± 100 scfd, the appropriate sample size would be n = 22. If one were to use a larger sample size, the margin of error would be less than ± 100 scfd, as long as the population variation has not increased.
- Collect the sample and calculate the sample mean, $\bar{x}$ and the sample standard deviation, s.
- Determine the value of t, the statistic matched to the desired confidence level. For example, if using a sample size of 30 and a desired confidence level of 95%, the t statistic value is 2.045. The value of the t statistic is based on a parameter called *degrees of freedom* where $df = n - 1$. The t statistic value can be found on any standard Student's t table of critical values.
- Calculate the confidence interval limits using formula (1).

Example calculations: Refer back to the sample data provided for the baseline emissions of the Cemco and Invalco controllers shown in Appendix A. A confidence level of 95% was used in the calculations. There are many off-the-shelf statistical software packages that will perform these routine calculations with the appropriate sample data input on a spreadsheet.

Manufacturer	Cemco	Invalco
Sample size, *n*	18	17
Sample mean, $\bar{x}$	510.5	628.9
Sample Std Dev, *s*	147.2	237.9
t statistic	2.110	2.120
Margin of Error	73.2	122.3
95% Confidence Interval	(437 to 584)	(507 to 751)

APPENDIX C

This appendix defines the procedure for sampling emissions during the estimation of the baseline and project emissions. The project proponent will take direct measurements, using measurement techniques outlined in Section 4.4 above, from a sample of a minimum of 30 pneumatic controllers that are correctly installed and operating under manufacturers' recommended guidelines. In addition to emissions measurements the project proponent will also collect the following information at the time of measurement:

- Unique controller identifier
- Supply pressure across the controller
- Port size (snap-actuating only)

In addition to the data collection, the project proponent will, at the time of sampling, do the following:

- Visual observation of correct installation of the pneumatic controller
- Observed successful operation of the controller, which might require physically triggering the controller

Additionally, the project proponent may choose to increase the size of the sample measurements to a number greater than 30. By doing this the project proponent will get a more accurate estimate of the population average emissions and a smaller margin of error at the 95% confidence level, which could mean a higher lower bound for the baseline emissions estimate and a lower upper bound for the project emissions estimate and therefore potentially a greater net overall emission reduction value. This is illustrated in Appendix B and by the following table.

Sample size (n)	Minimum size: 30	Greater than 30 (e.g. 50)
Degrees of Freedom (n-1)	29	49
t statistic at 95% confidence level	2.045	2.012
Margin of error formula	$t\frac{s}{\sqrt{n}}$	$t\frac{s}{\sqrt{n}}$
Margin of error	0.373 S_{30}	0.284 S_{50}

S_{30} is the standard deviation of a random set of 30 emissions measurements and S_{50} is the standard deviation of a random set of 50 emissions measurements. Typically, $S_{50} > S_{30}$ due to the larger sample size and therefore the margin of error for the 50 random sample will be less than that for the random sample of 30 measurements.