Technical Guidance for Assuring Measurement Device Data Accuracy

for California's Mandatory Greenhouse Gas Reporting Regulation

Introduction

The Regulation for the Mandatory Reporting of Greenhouse Gas Emissions (MRR) requires that all meters used to calculate covered emissions and covered product data meet prescribed accuracy requirements (§95103(k)). Pursuant to section 95103(k)(6), operators must be able to demonstrate that all such meters were selected, installed, operated, and maintained in a manner that ensures measurement accuracy within +/-5%.

This document provides a technical background on some metering systems, provides examples of what evidence verifiers should request during verification, and how verifiers should document the evaluation and conformance review of metered flow data in their sampling plan. More information on meter accuracy is at: https://www.arb.ca.gov/cc/reporting/ghg-rep/guidance/accuracy-missingdata.pdf.

More information about verification of covered product data reported by refineries is at: https://www.arb.ca.gov/cc/reporting/ghg-rep/guidance/refineries.pdf.

Guidance for Verifiers

Verifiers should seek to understand the reporting entity's system for operating, maintaining, and calibrating meters, and should ensure this is documented in the reporting entity's Greenhouse Gas (GHG) Monitoring Plan, pursuant to §95105(c). Verifiers should gain a general understanding of the processes and controls the operator has put in place to ensure accuracy of metered data, which will inform the verifier's risk assessment, sampling plan, and the resulting targeted review of meter accuracy.

Verifiers are required to document in their sampling plan which meters were evaluated for conformance with measurement accuracy requirements. Because verification of MRR data is primarily risk-based, verifiers are also required to describe why specific meters were chosen for document review and data checks, as described in §95131(b)(7)(D)(1), and why that selection was sufficient for reasonable assurance for both covered emissions and covered product data. CARB will request this information as part of verification audits.

In advance of the site visit, verifiers should confirm that an appropriate engineer or meter technician will be available on-site to answer questions related to flow calculations for specified meters. Verifiers should identify meters used to report covered emissions data and covered product data for a more in-depth review. This review must be described in the sampling plan as part of a detailed conformance check.

At the onset of verification activities, verifiers should request a comprehensive list of the calibration/inspection status of all meters used to measure covered emissions or covered product data. The verifier should seek, at a minimum, a list that contains the dates of the last calibrations and primary element inspections, each meter's role in the reported data, and the postponement status of each meter, if applicable. When verifying conformance with §95103(k), verifiers should, at minimum, request calibration records for pressure and temperature measurement devices, and primary element inspection records. Verifiers should also evaluate other records to ensure that meters were properly installed and maintained, and are appropriate for the application.

CARB highly recommends that all meters and measurement devices subject to postponement requests under section 95103(k)(9) be viewed by the verifier as high risk when conducting the risk assessment and determining a sampling plan. Postponed meters are considered higher risk because they are lacking current inspection and/or calibration results; therefore, accuracy must be assured through other means. Verifiers must verify accuracy consistent with the methods described in the postponement approval letter from CARB and the operator's postponement submittal documentation. All postponement requests that are approved by CARB list each meter that has been approved, the dates for which the postponement is valid, and the method or methods by which the operator must demonstrate accuracy. Operators are required to provide all materials associated with each postponement request to the verifier. This includes the original request letter, supplemental information provided per CARB request during the review process, and the final approval letter for each postponement. For more information about meter calibration postponement, see the Measurement Accuracy and Missing Data Guidance at: https://www.arb.ca.gov/cc/reporting/ghg-rep/guidance/accuracy-missingdata.pdf.

If an operator is reporting throughputs of several different types of process units of varying complexities, the verifier may need to evaluate a higher percentage of meters in order to gain that same amount of confidence that each calculated throughput is based on accurately measured data. In addition to focusing on meters that have a large impact on reported emissions or product data, verifiers should consider how other factors that contribute to the complexity of measurement devices affect their sampling plan, including:

- Liquid throughputs that may be either difficult to quantify, not crucial to overall facility operations (and therefore less closely monitored), or that are not part of an air district's routine air quality inspection program,
- Fuel mixtures whose composition vary depending on process rates,
- High BTU gases, and

- Non-standard meter types where a primary element inspection is not routinely performed by the operator.

As an example, if the reporting entity utilizes 12 different meters to report emissions data, the verifier must justify in the sampling plan which meters were chosen for review, what review was performed, and, if not all meters are evaluated for accuracy, why those other meters were not investigated with that same level of review. The sampling plan should address:

1. The level of confidence the verifier has in the data management system,
2. Whether the meters chosen for detailed review are representative of all meters used to calculate covered emissions, and
3. Whether the other flow measurements not included in a detailed review are expected to have the same type of risks of misreporting as the meters chosen for a more detailed review.

The following represent some errors that could be present in flow calculations used by the operator to calculate mass or volume:

- The fuel flow calculation assumes a density for the fuel that differs from the actual density. This type of error that can be addressed by using measured pressure and temperature data from the meter location to compensate for differences in actual density over time and during changes in gas composition or processes.
- The fuel flow calculation inverts a correction factor for density, temperature, and/or pressure, or includes the wrong parameters, or incorrectly uses the square root of the correction factor (e.g., mass flow is proportional to $\sqrt{2\rho\Delta P}$ but volumetric flow is proportional to $\sqrt{2\Delta P/\rho}$).
- The design specifications for the orifice meter are inconsistent with the plates that are currently being used (e.g., different orifice diameter), or the calculations do not reflect the dimensions of the orifice used to produce the data (e.g., uses generic or ideal measurements instead of actual measurements).
- The meter is used qualitatively by staff in the field for process control purposes, but may not be +/-5% accurate. This type of error can be much more difficult to detect during verification. Verifiers should use their professional judgment to appropriately assess uncertainty risk of calculated flow accuracy. Verifiers should trace data used in the flow calculations back to its origin, as required in §95131(b)(8)(D)(1), and be prepared to <u>spend additional time</u> reviewing flow calculations during the site visit. This includes evaluation of the underlying equations used to convert measured pressure and temperature to flow volume, and the source and appropriateness of those equations. If data do not appear to

be verifiable, please consider asking CARB for assistance to help resolve the issue.

If accuracy cannot be determined by the verifier, the data are considered unverifiable. For covered emissions data, that means the operator would be required to use missing data substitution. For covered product data, that means the operator would be required to separately report the data as excluded in Subpart A of Cal e-GGRT.

Orifice Plate Meters

Verifiers that are evaluating the flow equations and calculations related to differential pressure referenced in §95103(k)(6)(A)(1)[1] may use the following as a reference. Verifiers should be aware that metering systems and calculation methods used at facilities may differ from those shown here, but may still be accurate. The equations referenced here are designed to provide verifiers with more information related to flow calculations used in many differential pressure meters. This information may be used to investigate the accuracy and appropriateness of metering systems during verifications and formulate questions of metering technicians when onsite.

Background

An orifice meter measures flow by producing a change in the pressure by forcing the flow through a constricted space. Because mass must be conserved, the flow increases through the constriction, which results in a measured decrease in fluid pressure. By measuring the differential pressure - the difference between the pressure before and after the orifice meter - and applying the appropriate equation, differential pressure metering systems can calculate the appropriate mass or volumetric flow rate. Note that the form of the equation that needs to be used depends heavily on the units of the input data. Conflicting units of measurement between the input values and the equation being used may result in significant error.

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[1] The equations used in this guidance document are contained in AGA Report #3 – Part 1. That document is a reference in AGA Report #3 - Part 2, which is incorporated by reference in MRR §95103(k)(6)(A)(1).

Mass Flow Equation

An equation used by reporters for orifice meters to calculate flows from differential pressure is the mass flow equation which can be represented in Equation (1)[2] as:

$$q_m = C_d E_v Y \left(\frac{\pi}{4}\right) d^2 \sqrt{2g\rho_{t,p}\Delta P} \qquad (1)$$

Where:

q_m = mass flow rate **(lb/s)**, independent of temperature and pressure

C_d = orifice discharge coefficient **(dimensionless)**, *empirically* derived

E_v = velocity approach factor **(dimensionless)**, defined as $\frac{1}{\sqrt{1-\beta^4}}$ where **β** is the dimensionless ratio of the orifice diameter to the internal diameter of the pipe. E_v corrects for the effects produced by the incoming flow rate

Y = expansion coefficient **(dimensionless)**, *empirically* calculated and accounts for fluid compression under the change in pressure. Equal to 1.0 if the fluid is incompressible, < 1.0 if compressible

$\frac{\pi}{4}d^2$ = orifice area **(ft^2)** for orifice bore diameter *d* in ft

g = acceleration due to gravity **($32.2\ ft/s^2$)**

$\rho_{t,p}$ = density of the fluid **(lb/ft^3)** at actual temperature and pressure conditions

ΔP = differential pressure **(lbf/ft^2)**, the difference between the fluid pressure before the orifice meter, and the pressure after the orifice meter.

Simplified Mass Flow Equation

Verifiers may encounter reporters that use a simplified version of the mass flow equation, incorporating $\pi/4$, $\sqrt{2g}$, and any needed unit conversions, shown as "N", in Equation 2.

$$q_m = NC_d E_v Y d^2 \sqrt{\rho_{t,p}\Delta P} \qquad (2)$$

Table 1 lists values of N for some common units of the measured or calculated inputs in Equation 2.

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[2] Based on ISO 5167-2 (2003), referenced in §95103(k)(6)(A)(1), and modified here for imperial units.

Table 1: Common Values of N

	Constants			
π	3.142	3.142	3.142	3.142
g	32.17	32.17	32.17	NA
	Where the following variables are measured in:			
	Imperial	**Imperial**	**Imperial**	**SI**
d	ft	in	in	m
ΔP	lbf/ft^2	lbf/in^2	in H_2O (60 °F)	Pa
$\rho_{t,p}$	lb/ft^3	lb/ft^3	lb/ft^3	kg/m^3
ρ_b	lb/ft^3	lb/ft^3	lb/ft^3	kg/m^3
q_m	lb/s	lb/s	lb/s	kg/s
q_v	ft^3/s	ft^3/s	ft^3/s	m^3/s
	Results in the following values for N:			
N	6.300	0.5250	0.0997	1.111

Simplified Volumetric Flow Equation

MRR requires reporting of some values as a standard volume. To convert the mass flow to the standard volumetric flow ($q_{v,std}$), reporters divide by the base (standard) density (ρ_b) of the fluid at 60 °F, and a standard pressure of either 14.696 psi (1 atm), or 14.73 psi (30 in Hg), as shown in Equation 3. Either of these “standard” pressures is acceptable.

$$q_{v,std} = \frac{q_m}{\rho_b} = \frac{N C_d E_v Y d^2 \sqrt{\rho_{t,p} \Delta P}}{\rho_b} \tag{3}$$

Where $q_{v,std}$ is the volumetric flow under standard conditions.

Flows are commonly measured or aggregated on an hourly basis. To calculate the flow rate per hour, reporters multiply the final value by 3,600 seconds per hour.

Example Calculations[3]

The following two example calculations may be used to verify volumetric flows and total volume for both liquids and gases.

LIQUIDS:

For liquids, the expansion coefficient (Y) is always equal to 1.0, as liquids are incompressible. Taking empirical/measured data to be:

Y	expansion coefficient	= 1.0
C_d	orifice discharge coefficient	= 0.598
d	orifice bore diameter	= 2.00 in
D	internal diameter of pipe	= 4.00 in
$\Delta\boldsymbol{P}$	differential pressure	= 98.0 in H_2O (60 °F)
$\boldsymbol{\rho_{t,p}}$	density of the liquid	= 43.67 lbs/ft^3
$\boldsymbol{\rho_b}$	base (standard) density	= 245.4 lbs/bbl

Based on these units of measurement the correct value of N is **0.0997.** Therefore:

$$\beta = \frac{\mathrm{d}}{\mathrm{D}} = \frac{2.00}{4.00} = 0.500$$

$$\mathrm{E_v} = \frac{1}{\sqrt{1-\beta^4}} = \frac{1}{\sqrt{1-0.500^4}} \approx 1.0328$$

$$\mathrm{q_m} = \mathrm{NC_dE_vYd^2}\sqrt{\rho_{\mathrm{t,p}}\Delta\mathrm{P}}$$

$$= (0.0997) * (0.598) * (1.0328) * (1.0) * (2)^2 * \sqrt{43.67 * 98.0}$$

$$\approx \mathbf{16.1\ \frac{lbs}{second}}$$

Converting from mass flow to volumetric flow:

$$\mathrm{q_v} = \frac{\mathrm{q_m}}{\rho_\mathrm{b}} = \frac{16.1}{245.4} \approx \mathbf{0.0656\ \frac{bbl}{second}}$$

Converting from per second flow to per hour:

$$0.0656\frac{\mathrm{bbl}}{\mathrm{s}} * 3{,}600\ \frac{\mathrm{s}}{\mathrm{hr}} \approx \mathbf{236\ \frac{bbl}{hour}}$$

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[3] These values are for instructional purposes only.

GASES:

For gases, the expansion coefficient (Y) is always less than 1.0, as gases are compressible. Taking empirical/measured data to be:

Y	expansion coefficient	= 0.5
C_d	orifice discharge coefficient	= 0.598
d	orifice bore diameter	= 1.00 in
D	internal diameter of pipe	= 3.00 in
ΔP	differential pressure	= 3.50 lbf/in^2
$\rho_{t,p}$	density of the gas	= 0.0447 lbs/ft^3
ρ_b	base (standard) density	= 0.0417 lbs/ft^3

Based on these units of measurement the correct value of N is 0.0525. Therefore:

$$\beta = \frac{d}{D} = \frac{1.00}{3.00} = \frac{1}{3}$$

$$E_v = \frac{1}{\sqrt{1-\beta^4}} = \frac{1}{\sqrt{1-\left(\frac{1}{3}\right)^4}} \approx 1.006$$

$$q_m = NC_dE_vYd^2\sqrt{\rho_{t,p}\Delta P} = (0.0525) * (0.598) * (1.006) * (0.5) * (1)^2 * \sqrt{0.0447 * 3.50}$$

$$\approx \mathbf{0.0062\ \frac{lbs}{second}}$$

Converting from mass flow to volumetric flow:

$$q_v = \frac{q_m}{\rho_b} = \frac{0.0062}{0.0417} \approx \mathbf{0.150\ \frac{ft^3}{second}}$$

Converting from per second flow to per hour:

$$0.150\ \frac{ft^3}{s} * 3{,}600\ \frac{s}{hr} \approx \mathbf{539\ \frac{ft^3}{hour}}$$