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DESCRIPTIVE OUTLINE

The EMRC Gas Flow Monitor is designed to measure the dynamic pressure of gas flow in a stack. This discussion will outline the basic measurement principles employed and how the system measures gas flow. Maintenance requirements are covered under separate sections for ease of reference.

General Description of Measurement System

The EMRC Gas Flow Monitoring System was initially developed for the sole purpose of measuring gas flow in a sulfur plant stack or gas stream. It is designed to tolerate high temperatures (~1,500-2,000°F), a corrosive environment, and a nominal particulate loading. In addition, the techniques employed meet regulatory (EPA and State) measurement criteria.[1]

Gas Flow

The gas flow system consists of an "insitu" S-type pitot located at a representative location in the stack or duct. (Representative siting is determined by taking a gas flow profile during normal operations.) The resultant dynamic pressure (Delta P "$H_2$0) is transmitted via open tubes to an instrument enclosure located on site or at another report location (up to ~1,000 ft.). Each open tube is directly connected to a signal conditioning module (mechanical adsorption and damping). After signal conditioning the gas flow signal is channeled to the signal transducer module. The signal transducer produces a DC output which is routed to an electronic conditioner and interface.

Temperature

The temperature measurement system consists of an "insitu" Type K thermocouple probe (isolated). This is wired to a thermocouple voltage transmitter which produces an electrical output leading to an electronic interface.

Calculation of Gas and Mass Flow Data (optional)

The electronic package is designed to receive input from each of three sources: (1) Gas flow. (2) Temperature and chemical species concentration (ppm or any signal of interest). (3) Produce an output signal which represents the gas flow of the chemical species under consideration.

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[1] Federal Register, Vol. 36, No. 247, 12/23/71, and as further amended.

This discussion does not concern itself with the species monitor(s) and electronic functions, however, the standard equation and assumptions to calculate gas flow and species mass flow are outlined as follows.

Stack Flow Analyzer Equations

Stack Velocity - Calculate the velocity of the stack gas using stack temperature and delta P measurements.

Reference: 40 CFR 60, Appendix A, Method 2, Equation 2-9

$$v_S = K_p \times C_p \times \sqrt{\Delta P_S} \times \sqrt{\frac{T_S}{P_S \times MW_S}}$$

Volumetric Stack Flow STP conversion – Calculate volumetric stack flow using stack velocity.

Reference: 40 CFR 60 Appendix A, Method 2, Equation 2-10

$$Q_{sd} = 60\ (1 - \mathrm{B_{ws}})\ v_S\ A \left(\frac{P_S}{P_{STD}}\right)\left(\frac{T_{STD}}{T_S}\right)$$

where:

Q_{sd}	- Dry standard volumetric stack flow, dscf/min
v_S	- Stack velocity, ft/sec (calculated)
T_S	- Stack temperature, °R = °F + 460 (measured)
T_{STD}	- Absolute stack temperature, fixed value of 528 °R
ΔP_S	- Stack differential pressure, in. H_2O. (measured)
K_p	- Pitot Constant, fixed value of 85.49, dimensionless
C_p	- Pitot Coefficient, fixed value of 0.84 (typical for S-pitot type)
P_S	- Stack barometric pressure, in. Hg (operator entered constant)
P_{STD}	- Standard absolute pressure, fixed value of 29.92 in. Hg
MW_S	- Gas density, lb/lb-mole (operator entered constant)
$Area_S$	- Cross-sectional area of the stack, sq. ft (operator entered constant)
B_{ws}	- Proportion by volume of water vapor in gas stream,(%H_2O/100) (operator entered constant)
60	- Conversion factor, sec/min

Volumetric Flow is calculated as follows:

a. AWCFM = (FPS) (Stack Area) (60)

b. $SWCFM = (AWCFM)\left(\frac{528}{TS + 460}\right)\left(\frac{PS''Hg''}{29.92}\right)$

A more comprehensive look, at the equations involved, is listed as follows:

Data Input:

(1) Stack or Duct Dimensions ____________ ft.

(2) Stack or Duct Area __________ sq. ft.

(3) Gas Constituents: % H2O __________
% CO2 __________
% O2 __________

(4) Gas Density __________lb/lb-mole

(5) Gas Velocity __________fps

(6) Standard Dry (cfh) __________sdcfh

(7) Actual Wet (cfm) __________

(8) Stack Temperature (Ts) __________Deg F
(assumed or measured)

(9) Stack Pressure (Ps) __________"Hg
(assumed or measured)

B_{ws} = Decimal equivalent of percent moisture.

[1]Gas Density (Dry) = 0.44 (_____%CO_2) + 0.32 (_____%02) + 0.28 (_____%N2 + _____ % CO) = __________lb/lb-mole (Dry)

Gas Density (Wet) = (Gas Density {Dry}) (1-B_{ws}) + (18xB_{ws}) = __________lb/lb-mole (Wet)

Use the following for velocity calculations.

[2]$fps = (85.49)\,(cp)\,\sqrt{dp}\;\sqrt{(Ts\,A/Ps''\,Hg\,lb/lb-mole\,wet)}$

[3]sdcfh = 3600 (1-B_{ws}) (fps) (sq.ft.) ({528/TsA} {Ps "Hg/29.92})

[4]$awcfm = \frac{(sdcfh)\,(100/\{100-\%H_2O\})\,(29.92/Ps\ \text{“Hg})\,(TsA/528)}{60}$

(10) Chemical Species (molecular weight) __________MW

(11) Chemical Species (concentration) __________ppm

$$PPH = \frac{(60x10\text{-}6)\ (MW/N/V)\ (AWCFM)\ (ppm)}{N/V = 359\ (TsA/492)\ (29.92/Ps)}$$

N/V = 359 (TsA/492) (29.92/Ps)

OPERATION AND MAINTENANCE

The EMRC Gas Flow Monitor is an extremely simple system to operate and maintain. Please read the following paragraphs prior to working with the gas flow system.

Startup and Calibration

A span check on the pressure transducer can be performed as follows. (1) Use a volt meter to observe voltage or milliamps (depending on PLC or DAS load resistance) off DC output terminals #1 and #2 on TB-2. (2) Use a 4-20 MA simulator on #1 and #2 on TB-1 to simulate a loop test on the differential pressure transducer. (3) Calculate the proper reading for the pressure observed on the Transducer. A span adjustment is available inside the Transducer via adjustment Pots.

A span check on the thermocouple transmitter can be performed as follows. (1) Use a volt meter to observe voltage or milliamps off DC output terminals #3 and #4 on TB-2. (2) Attach a thermocouple simulator to TB-1. A span adjustment is available on the Acromag transmitter module.

System Seal Integrity

If a leak in the gas flow system occurs it will malfunction yielding erroneous transducer output. Seal integrity is essential at all times.

Pitot Alignment

If the instrument appears to be yielding faulty output, after all of the above have been checked, it is possible that the pitot opening planes are out of alignment. The pitot opening planes must be perpendicular to the gas stream.

Proper Tubing Alignment

It is important that the proper tubing connections be made when re-establishing the pitot system. Be certain that the high side pitot line is connected to the high side of the pitot tube (pitot opening facing the gas stream).

Plugging of Pitot Sensor

It is possible that the pitot head could become plugged. The usual plug is caused by particulates depositing on the openings of the pitot. In this case the probe should be removed and cleaned. It is sometimes possible to blow-back the pitot head via the pitot tube lines, however, such back pressure could rupture the tubing and/or open fittings. Therefore, unless the gas flow monitor system has been fitted with a proper probe blow-back set up it is recommended that the probe be cleaned manually if plugged.

INSTALLATION

Thermocouple Probe/Pitot Installation

1. Perform a velocity traverse of the stack using EPA Methods #1 and #2. From this data determine a representative location for insitu placement of the pitot (sensor) head.

2. Screw the thermocouple probe into the flange and through the thermocouple support.

3. Slide the pitot into the front of the support brace and on through the 3/8" bore through fittings at a length matching the representative traverse point as determined in Step 1. Tighten the 3/8" bore through fittings with the pitot tubes protruding. Observe the pitot perpendicular orientation.[2] The pitot will want to rotate when the 3/8" fittings are tightened. Use a vice grip to hold each individual tube when tightening these fittings. Mark the tubes with orientation marks to make sure no rotation has occurred.

4. Cut off any excess pitot tube as necessary. Attach Swagelok connectors to the pitots for pitot hose connection. Pitot lines should be run upward for a short distance (1 ft.) before proceeding to the instrument housing. In the event that a small amount of moisture should diffuse into the pitots the upward run insures that droplets will be kept out of lines away from the instrument housing.

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[2] Refer to "Flange Assembly" diagram.

5. Attach the thermocouple wire to the probe and caulk if necessary. The wire and probe connections are color coded.

    - Red (-)
    - Yellow (+)

Note: If possible check orientation of pitot alignment once installed. Pitots must be installed correctly for accurate flow readings.

TIMING SEQUENCE

The timing signals for zero span and purge are supplied to the gas flow monitor by the customer PLC. The PLC signals are wired into the terminal strip TB-2 and activate the designated 24 VDC relays.

Zero must be activated to allow span or purge. An internal interlock will shut off span or purge is zero is not activated.

Caution: The system must stay in zero for at least 30 seconds after purging the high or low pitot lines. Care must be taken when doing a purge as the lines hold a residual pressure for a short time. Do not connect your purge air until you are sure the sequence allows the required 30 second delay.

The following example demonstrates a satisfactory purge sequence:

906. Zero ON (close internal pitot lines)
907. High Purge ON
908. High Purge OFF
908 Low Purge ON
909. Low Purge OFF
910. Zero OFF (return to normal operation)

The following example demonstrates a zero-span sequence.

900. Zero ON
902 Span ON
904 Span OFF
905 Zero OFF

Representative Placement of Flow Probes

Successful gas flow monitoring is the product of two distinct efforts. They are: (1) Utilization of reliable and accurate gas flow monitor instrumentation and (2) Placement of flow sensors at representative points in each gas stream.

It is #2 that is the concern of this discussion. In order to place the gas flow probe or probes (two or more) so that the total flow of the stack is accurately measured the following procedures must be implemented.

1. A preliminary profile of gas flow must be developed prior to monitor (probe) installation. This profile is conducted utilizing EPA Methods #1 and #2. Standard test methods are acceptable except for stacks having known stratification "problems" or streams having a duct or stack diameter equal to or greater than approximately 10' (feet) For these streams the number of traverse points should be increased by two to four times (12 to 24 or 48 traverse points). The purpose of the increased traverse points is to identify any possible flow anomalies (stratification patterns, flow islands, etc.).

2. Utilize the preliminary profile data to evaluate potential placement "problems." It must be noted that the "test" ports most probably are not the same ports that will be utilized for instrument (monitor) flange/probe placement. As such the monitor probe placement is only partially predictable.

3. Final probe placement must be implemented by placing the monitor probes into a preselected position (based on the preliminary data) and concurrently conducting full stream EPA Methods #1 and #2 profiles to check the representativeness of the probe installation. Note that EPA Methods #1 and #2 profiles must be conducted according to EPA #1 requirements to confirm that points represent the test standard. If this final placement stage is not implemented probe placement cannot be insured or considered necessarily representative.

4. Once the probes are placed conduct an audit test at each required load level. Note the resultant relative accuracy's and if necessary adjust the probe and/or fine tune representative points by adjusting the final output DAS flow volume to best "match" the reference results. This can be done by establishing a "flue factor" (a factor of </> 1) and/or flow dependent (regime) computer regression and adjustment to provide an empirical result bias.

It must be recognized that probe placement is critical to the success of any Gas Flow Monitoring System. The art of such placement requires knowledge of each and every stream. The EMRC Gas Flow Monitor has been routinely achieving relative accuracy values of <5% in a wide variety of applications.

If problems of application are encountered the factory is available for assistance including field testing and data evaluation.

Procedure for Sensing Plugging of Flow Probes

Section 2.2.2.2. requires a means to sense plugging of the flow probe sensors on a daily basis. The EMRC Gas Flow Monitoring System accomplishes this by one technique.

1. Plugging or indication of plugging is "sensed" by noting the difference of the stack flow signal prior to and after the probe purge cycle. If the pre-purge Delta P signal deviates ~3% of normal scale without a similar change in unit production a plugging scenario may have occurred. This can be verified by implementing a non-routine purge. If plugging or indication of plugging is "sensed" increase the purge cycle accordingly (12 to 6 hours, etc.).

   The DAS can be programmed to warn the operator if the Delta threshold has been achieved or exceeded.

   Total plugging results in erratic data output. The operator, upon observation of such erratic output, would "command" a backpurge and note the return to normal operations. If normal operations are not achieved the problem would be elsewhere.

   If "plugging" is noted the backpurge frequency should be increased (24 to 12 to 6 hours accordingly) until indications of plugging is absent.

Procedure for Detecting Line Leaks

Section 2.2.2.2. requires that a leak check be performed on the pitot lines on a quarterly basis. This can be done manually with reference to EPA Method #2. This procedure requires two instrument personnel and a means of communication between them. Care must be taken not to over pressurize the system and cause damage to the DP transducer.

Leak Check for a One Pitot System

1. Disconnect the pitot lines from the pitot hose connectors at the stack flange. Make note of which one is the high and the low pressure line.

2. Identify the high side hose. Using a separate line and valve connected to the high side of the system, apply a slight pressure to the high side hose while a second person observes the differential pressure readout in the cabinet. When

the display reaches a reading near 100% of the transducer range seal the hose off. After a slight drop while sealing the hose the reading should hold steady for 15 seconds. Release the seal.

3. Identify the low side hose. Apply a slight vacuum to the low side hose and proceed with the leak check as in step 2.

4. Reconnect the pitot lines.

Leak Check for a Two Pitot System

1. Identify the flange with the manifold tees used to join the two pitots together.

2. Make note of the two high side hoses and the two low side hoses.

3. Remove both high side hoses and temporarily join them together using a hose mender or other connector. Remove both low side hoses and join them as above.

4. Move to second flange location.

5. Proceed with leak check method for a one pitot system, steps 1-4.

Gas Flow Monitor Requirements 40 CFR, Part 75, Section 2.2.2.2.

Procedure for Sensing Plugging of Flow Probes

Previously provided.

Procedure for Detecting Line Leaks

Previously provided.

Procedure for Eliminating Moisture Interference with Pitot Tubes

One of the most critical parts of installation is to insure moisture condensation droplets do not enter the pitot lines. In the measurement of differential pressure stack gas does not flow through the lines. Condensation will be the result of a small amount of moisture that may hit the pitot openings. When the pitot lines are connected to the pitot they must be run upwards at least one foot (1') to insure that condensate moisture does not "roll" down the lines. Any collection of moisture will be blown out the pitot openings during the purge cycle.

Provision for Sensor Purge

The EMRC Gas Flow Monitor is equipped with purge capabilities. The pitot lines are purged on a regular basis with high pressure air. This high pressure air will blow back any moisture that may condensate in the pitot or any particulate that may collect on the pitot openings.

Provision for Detecting Temperature Sensor Failure

The temperature transmitter will upscale on thermocouple failure. The transmitter will output full scale or 20 MA with a failed thermocouple input. The DAS must be programmed to flag an alarm should this occur.