TO: Murray Randall, Ben Lariviere

FROM: Steve Schultz

DATE: June 8, 1998

SUBJECT: **Stack gas mass flow measurement for SO_2 C.E.M. System**

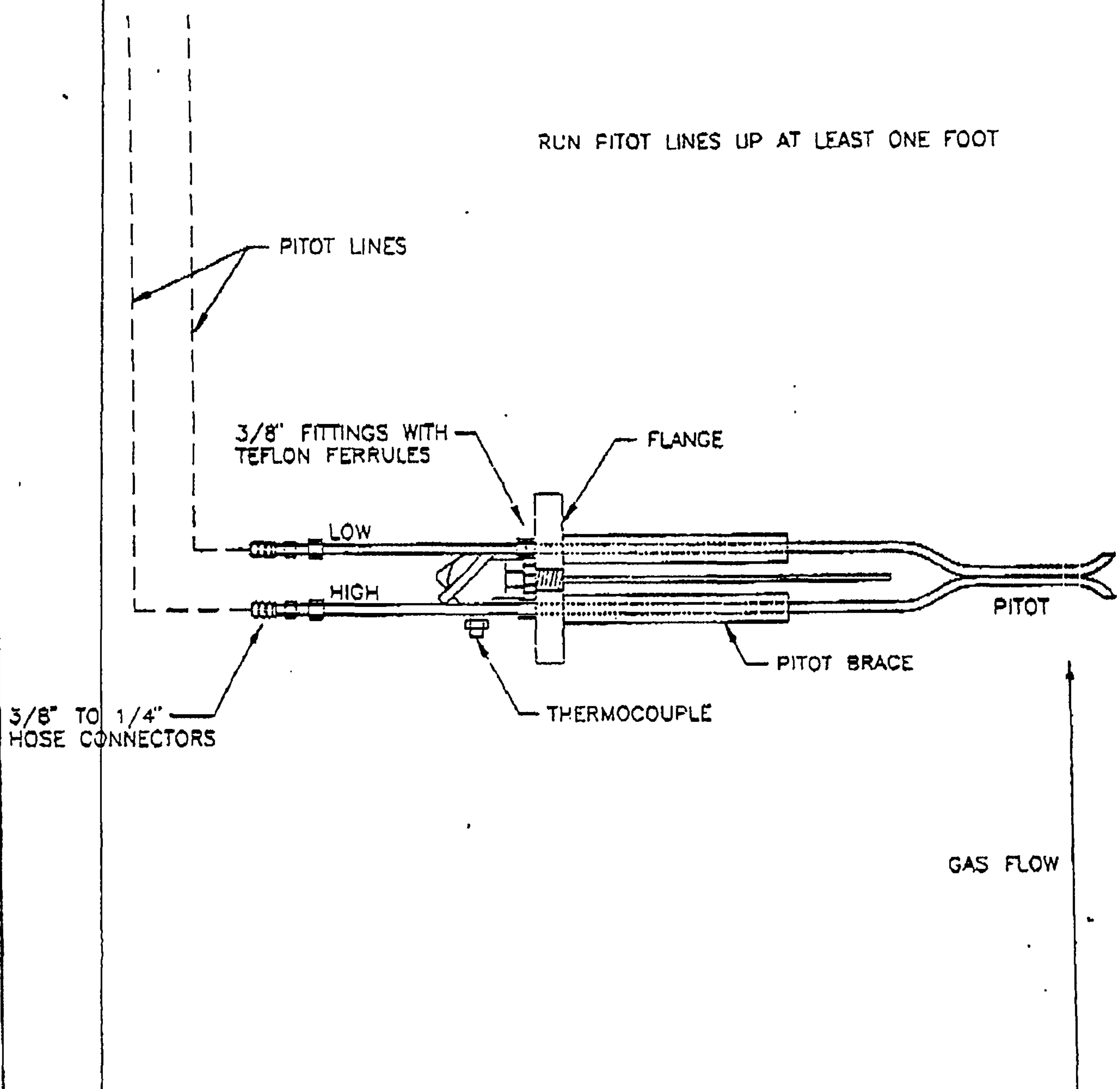
We don't have a lot of info on the gas flow measurement system. This part of the system was supplied by a sub-contractor, not Rosemount. However, it seems pretty simple.

The attached drawings show the pitot tube/thermocouple assembly. We have a Rosemount model 3051 DP transmitter and a Rosemount model 3144 temperature transmitter supplied for this system. We will need to send two 4-20 mA signals down the stack to a PC computer to allow continuous calculation of the stack gas flow rate. I guess we can mount the pressure and temp transmitters on the side of the stack, close to the pitot tube port.

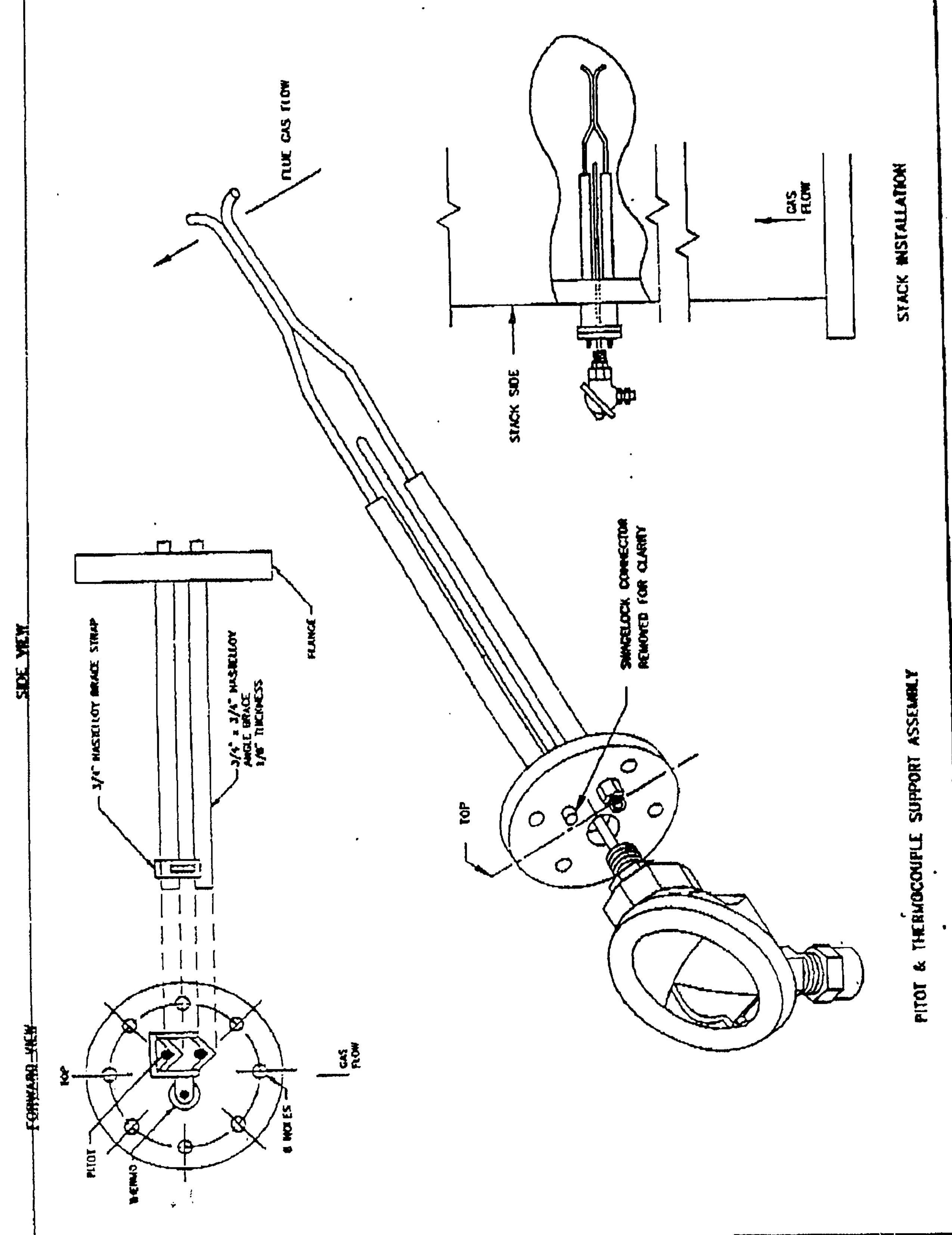
I talked to Rosemount on Friday. They say that the pitot tube assembly should go BELOW the sample probe and sample probe control box (because the pitot tube assembly is shorter than the sample probe, so it will not affect the gas flow around the probe, but the sample probe would affect the readings from the pitot tube if it was mounted below the pitot tube). If we put the pitot tube just below the sample probe box, the two ports will be a little over two feet apart. Also, although the sample probe box has internal heaters and is rated to -45 degrees Celsius, wind chill is a problem and we will have to provide some sort of shelter for the probe box before winter. Because the new stack ports can not be in line with the existing ports, we have no choice but to mount the probe box outside the existing shack.

PITOT INSTALLATION

Brian



EMRC GAS FLOW MONITOR



Temp. transmitter — Model 3144

D.P. transmitter — 3051

directly into the measurement cavity, an excellent assessment can be obtained of the instrument performance. Chapter 10 discusses this procedure further.

FLUE-GAS VELOCITY (FLOW) MONITORS

Emission standards that specify the continuous monitoring of pollutant mass emission rates imply that velocity monitors are to be part of the CEM system. This can be seen by examining the following relation:

$$\mathrm{pmr}_s = c_s Q_s \tag{6-11}$$

$$Q_s = A_s v_s \tag{6-12}$$

where pmr_s = pollutant mass rate (in kilograms per hour, pounds per hour, or tons per year)
c_s = pollutant concentration (in grams per dry standard cubic meter or pounds per cubic foot)
A_s = stack or duct area (in cubic meters or cubic feet)
v_s = stack-gas velocity (in meters per second or feet per second)

with the application of appropriate conversion factors (e.g., seconds to hours, etc.).

The first U.S. federal requirement for continuous pollutant mass rate determinations appeared with the promulgation of Subpart LLL (Standards of Performance for Onshore Natural Gas Processing: SO_2 Emissions) in 40 FR 40160 October 1, 1985. Continuous rate monitoring requirements are more common in Europe, but have also begun to appear in U.S. state permits and other regulations. However, the allowance trading policy of the 1990 U.S. Clean Air Act Amendments—Title IV provides the greatest impetus for application of velocity monitors for the measurement of emission rates in the United States.

A number of techniques are currently available to monitor flue-gas volumetric flow rate. Although techniques that correlate gas velocity with parameters such as steam flow rate, combustion stoichiometry, or fan horsepower have been used for this purpose, they may be neither particularly accurate nor practical (Richards 1989). Monitors used to measure flue-gas velocity are inherently in-situ monitors, because a dynamic gas measurement must be made. The methods vary in complexity from the use of pitot tubes to transmitting ultrasonic signals across the stack (Table 6-1). Other instrumentation, such as orifice meters, venturi meters, vane anemometers, and flow tubes, are more appropriate to air-handling ducts or specialized gas streams free of particulate matter.

TABLE 6-1 Flow-Monitoring Techniques

Technique	Instrumentation or Sensor
differential pressure sensing	Head meters, pitot tube, averaging probe
	Fluidic sensors
Thermal sensing	Heated sensors
Acoustic velocimetry	Ultrasonic transducers

To obtain a value for the volumetric flow, the differential pressure and thermal techniques require the measurement of stack temperature and/or flue-gas density. An averaging probe can be designed to measure at centers of equal areas across a stack or duct, whereas the ultrasonic method measures velocity on a line average. The other methods measure at one point only, although arrays of sensors can be used to measure at centers of equal areas on a cross section. This discussion of flow-rate monitoring techniques is not intended to be exhaustive of all methods currently available. It emphasizes those that have been or are being used for monitoring flow in industrial or utility stacks or flues.

Differential Pressure Sensing

The Pitot Tube

Pitot tubes have been used traditionally to measure stack-gas volumetric flow rate and are specified as the EPA reference for measuring flue-gas velocity. A pitot tube consists of two tubes, one facing the direction of flow of the gas, to measure an impact pressure, and the other tube either perpendicular to the flow or in the direction opposite the flow, to measure the static or wake pressure. The pressure differential between the stagnation pressure and the wake pressure is the "velocity pressure" Δp and is measured using a manometer, Magnehelic gauge, or pressure transducer. The velocity pressure Δp is related to the flue-gas velocity by the pitot tube equation:

$$v_s = K_p C_p \sqrt{\frac{T_s \Delta p}{P_s M_s}} \tag{6-13}$$

where v_s = velocity of the gas
K_p = dimensional constant
C_p = pitot tube calibration coefficient
T_s = absolute temperature of the gas
P_s = absolute pressure of the stack gas
M_s = molecular weight of the stack gas

Note that a number of parameters beside the directly measured Δp must be either assumed, calculated, or otherwise determined, to obtain the velocity.

A number of devices have been developed to take advantage of these principles. The simplest is the type-S (Stausscheibe) pitot tube specified in U.S. EPA Reference Method 2. The stagnation and wake pressures can be monitored continuously using pressure transducers (capacitance-type or other) and, by using a thermocouple to monitor stack temperatures, the velocity can be calculated (stack-gas molecular weight is estimated). Plugging of tubes can be avoided by periodically blowing high-pressure air through the tubes (Rollins 1977).

A pitot tube obviously measures at only one point, although multiple tubes can be used to average a flow distribution across the stack or duct. The impact and static tubes can feed into separate, common chambers where the pressures equilibrate to give an average value. However, a simpler averaging technique is employed in the averaging probe.

Averaging Probes

Averaging probes are a modified form of pitot tube, having four or more ports in a pipe, located at the traverse points corresponding to the centers of equal areas of the stack cross section. These ports face the direction of flow and give an average stagnation pressure over the stack diameter. The static pressure is averaged using ports located behind the high-pressure ports. Because the port locations will be different for each installation, stack dimensions must be carefully specified before the probe is constructed.

An averaging probe averages only on one diameter. If two probes were installed perpendicular to each other, the flow would be more completely characterized. The accuracy of an averaging probe is dependent, as is that of the pitot tube, on the constancy of its calibration coefficient (C_p) and assumptions associated with the stack-gas density (molecular weight or composition and temperature).

The pitot tube and averaging probe are less sensitive to low flow rates than to high flow rates because low pressure differentials (Δp) are difficult to measure accurately. Also, agglomerating particulate matter, acid gases, and moisture droplets may cause system failures. However, the use of blow-back techniques can, again, increase availability. There is also a question of cross-flow existing in averaging probes due to different port pressures (Ginesi and Grebe 1987), but the severity of such a problem would become evident when certifying the installation.

Thermal Sensing Systems

Thermal sensing instruments are based on the transfer of heat from a heated body to the flowing gas. This requires the use of two sensors, one heated, the other unheated. In a typical configuration (Figure 6-15), platinum resistance wire is wound on ceramic cylinders, which are then protected by a stainless steel tube. The longer sensor is heated (the velocity sensor); the shorter one (temperature sensor) is not heated. These two resistance elements are connected to a bridge circuit that maintains the temperature of the heated sensor. As the moving stack gas cools the sensor, the current through the element is increased to keep the temperature constant. This current (and the resultant voltage signal that is generated) is related to the heat loss from the sensor. The unheated sensor is used to compensate for temperature changes in the stack gas.

In another configuration, the heated and unheated resistance elements are combined on a single tip. The tip is glass-coated and is typically applied to monitoring flow in noncorrosive atmospheres. A metal-clad

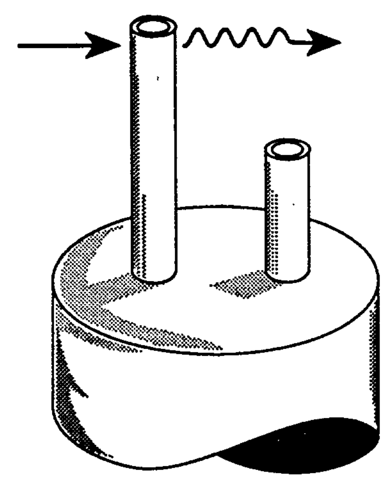


FIGURE 6-15. A thermal probe sensor.