Infer NO_x emissions from natural-gas fuel flow

To avoid stack-gas measurement, this utility measures fuel flows into its gas-fired boilers, then calculates for NO_x emissions

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To accurately monitor and reduce NO_x emissions from its nine gas-fired powerplants, Southern California Edison Co (SCE) has installed highly accurate gas-flow measurement systems on all incoming natural-gas fuel lines, which range in diameter from 10 to 30 in, depending on unit sizes.

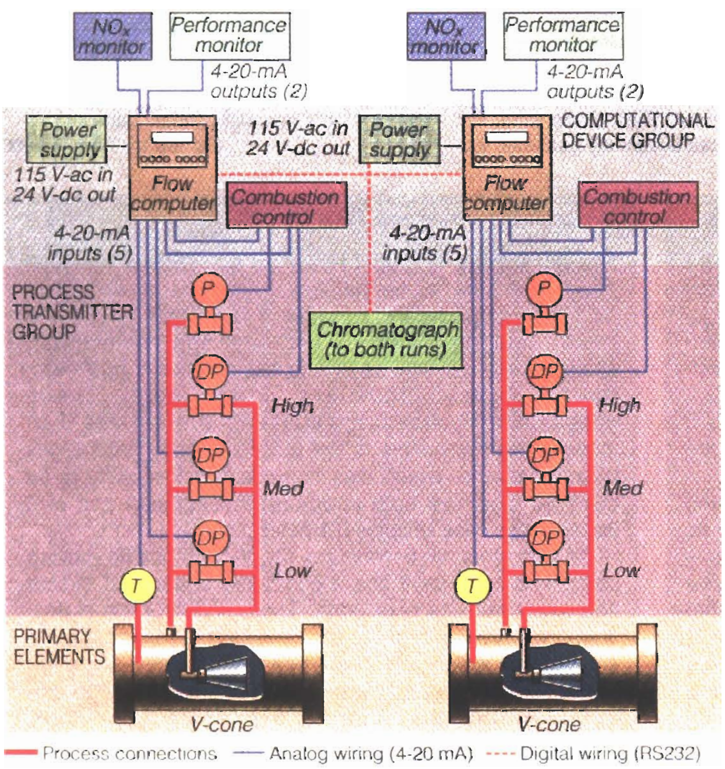
The nine plants comprise 32 boilers (six are supercritical) ranging in size from 100 to 750 MW; gas flow per unit is as high as 7.5-million ft^3/hr in the large units. By installing NO_x-abatement systems on these units, SCE has reduced NO_x emissions from a 140-ppm maximum to as low as 7 ppm in some units—an average reduction across all gas-fired plants of roughly 86%. Flue-gas recirculation, selective catalytic reduction (SCR), and urea injection are the key abatement technologies used to control NO_x.

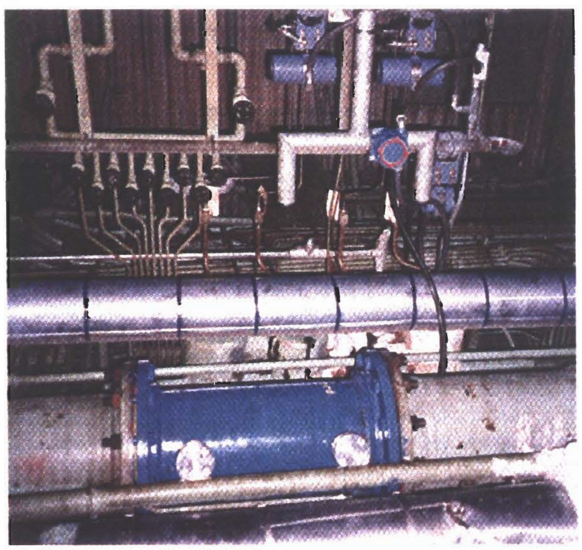
A key part of the story is how NO_x emissions are determined (see box, p 94). It is a technique that shows much promise, especially in multi-plant operations.

System and components

Each of the 36 natural-gas flow-measurement systems (certain boiler-firing methods require two systems per boiler, see Fig 1) include three interconnected components: a concentric, differential-pressure (ΔP) V-cone flowmeter, supplied by McCrometer, a division of Ketema Inc, Hemet, Calif, and a process transmitter group (ΔP/pressure/temperature) and flow computer supplied by ITT Barton, City of Industry, Calif (Fig 2).

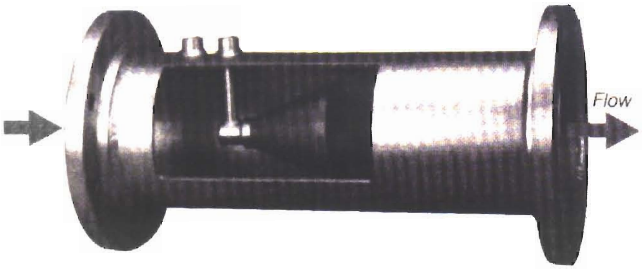
V-cone ΔP flowmeters. These flowmeters operate on the same principle as other ΔP flowmeters, but instead of creating differential pressure by reducing the pipe's inside diameter (ID), a cone is positioned in the center of a constant-diameter, precision-machined metering tube (Fig 3). The cone interacts with the high-velocity center portion of the flow, creating a region of lower pressure immediately downstream of the cone itself. The pressure differential



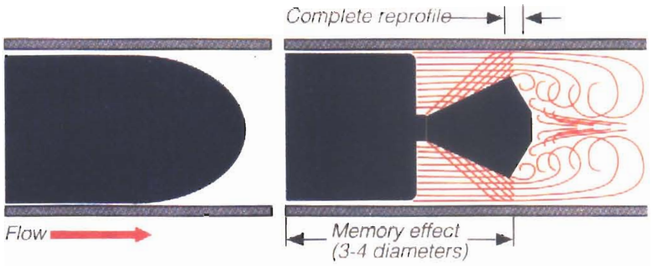


1. Gas-flow measurement system (left) comprises three interconnected components: V-cone flowmeter, process transmitter group, and flow computer

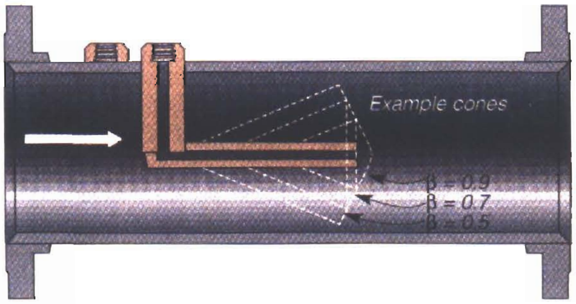
2. Typical gas-flow system installed at SCE generating stations is shown (above)



3. V-cone flowmeter has cone fixed in center of a constant-diameter, precision-machined metering tube



4. Flattening effect is produced by V-cone flowmeter on velocity profile by engaging high-velocity flow in pipe's center



5. Graphic relationship between typical V-cone beta ratios can range from less than 0.4 to 0.9

between the region upstream at the tube wall and downstream at the V-cone face is measured with pressure taps. These V-cones can accurately measure flows described by Reynolds numbers of less than 8000.

The position and shape of the cone in the flow stream as well as the locations of the pressure taps optimize performance. By engaging the high-velocity flow in the pipe's center, the cone conditions and reshapes (flattens) the fluid's velocity profile (Fig 4). These two aspects combined create a more uniform velocity profile over the meter's cross-section.

Diameter of the cone in any given pipeline size varies as determined by the specific application. Beta ratios—the ratio between diameter of the orifice bore (or any restriction) and pipe ID—can range from less than 0.4 to 0.9 (Fig 5). If high resolution and/or wide turndown are required, a small beta ratio can be selected; if minimum permanent pressure loss is more important, a larger beta ratio is selected. At SCE, beta ratios range from 0.39 to 0.65, depending on the interrelationships between gas flows and pipe sizes. This was done to optimize accurate operation throughout the wide turndowns required (see box below, right).

Three process transmitters—one for high ΔPs in excess of 120-in. H_2O, another for intermediate ΔPs, and a third for draft-range pressures—cover the 15:1 turndown required. The combination produces the desired system accuracy of ±2% of rate throughout the turndown range. The transmitters output to a flow computer and overlap, so that the entire turndown range is covered.

The process transmitter group includes pressure and temperature (thermocouple) transmitters that also feed the flow computer. All ΔP/pressure/temperature transmitters are calibrated semiannually.

Flow computers provide for a live chromatograph input from the gas line serving each pair of boilers. With these data, the flow computers can accurately calculate gas mass flow which, in turn, is the basis for the NO_x emissions calculation.

The flow computers incorporate a library of specific gas-flow calculations. One of these is the American Gas Assn (AGA) calculation from AGA Report No. 8 "Compressibility and Super-Compressibility for Natural Gas and Other Hydrocarbon Gas Transmission Measurements," which is built into the flow computers. This complex algorithm is the basis for the gas-volume and -mass calculation. It is an iterative algorithm that requires processing power equivalent to that of an Intel 8086-based personal computer.

More than sufficient analog inputs (six) are provided to handle the five transmitter input signals; that is, three ΔPs, one pressure, and one temperature signal. To maximize accuracy, the flow computer selects the appropriate transmitter for the flow rate.

Multiple real-time, mass-flow information is provided to the NO_x and performance monitors. Additional archived documentation supplies the user with a time/date stamped record of significant activities affecting the flow data. These activities may include unit calibration, configuration changes, and diagnostic or process alarms. With this audit trail, the user or regulatory agency can evaluate the cause of any unusual process data.

Edited by Tom Elliott

Utility opts to measure gas flows at front end

All available gas-flow measurement technologies were reviewed for Southern California Edison by an independent consultant with expertise in flow measurement. The evaluation took into account all aspects of the utility's monitoring-systems goals, including high accuracy, reliability, and turndown capability; minimum-length metering runs to reduce real-estate needs; and O&M considerations. Most important: The systems had to ensure that applicable emissions regulations were met.

Based on the evaluation, the utility chose to determine flue-gas flows inferentially, measuring fuel-gas flows into its boilers and stochiometrically calculating NO_x emissions—rather than relying on less dependable and more expensive stack-gas flow measurement techniques. The inferential technique meets the requirements of EPA's 40CFR, Parts 72 et al, and regulations for accuracy across the flow range (within ±2%). Also, it is permissible under Rule 1135 of the South Coast Air Quality Management District, which has jurisdiction over the region's air emissions.

V-cone flowmeters fill the bill

The flowmeters at SCE display an accuracy of between ±0.75 and ±1%, while yielding a turndown in excess of 15:1. The application produces a repeatability of 0.1% while requiring minimum upstream and downstream straight runs—as little as one to two diameters upstream, three to five diameters downstream. These upstream/downstream requirements are far less than those already available in the utility's existing natural-gas piping systems, which was important to the utility in its quest to minimize both structural investments and real estate in the case of large-diameter piping.

As with other ΔP flowmeters, the V-cone has no moving parts. The cone itself has a contoured shape that directs flow away from its beta edge. Thus, unlike orifice plates, beta-edge erosion and the accumulation of foreign material—both of which adversely affect accuracy—are minimized. Thus, V-cone flowmeters can be expected to uniformly reduce the need for expensive inspection, maintenance, and possible replacement.