THE IMPORTANCE OF
MASS-WEIGHTED AVERAGE TEMPERATURE
FOR CONTROLLING PRIMARY AIR IN COAL PULVERIZERS

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I. INTRODUCTION:

With the introduction of the K-BAR 2000, for which each sensing element measures the mass velocity (SFPM or SMPS) and air temperature (°F or °C), one can easily compute the mass- weighted average temperature of the flowing process stream. The calculation routine is embedded into the Series 155 Mass Flow Computer and is very useful in flows that have non-uniform velocity and temperature profiles.

II. APPLICATION TO COAL-BURNING POWER PLANTS:

The mass-weighted average air temperature is a much more useful and representative measurement of air temperature for air streams having non-uniform air velocity and air temperature profiles. If the temperature profile is flat, or if the velocity profile is flat, the mass weighted temperature profile is the same as the arithmetic temperature average. The mass-weighted temperature is important because it is the temperature reading needed to accurately compute the enthalpy of the air. Although rarely used and not fully appreciated, knowing the energy content of the primary air allows one to more accurately control the hot and cold air flow rate ratio used in coal pulverizers for major power boilers. By knowing the mass flow rate, the mass-weighted average air temperature and the specific heat of the air, one can make feed-forward calculations to anticipate the mass-weighted air temperature of the coal duct/air mixture into the burner. The temperature of this mixture is critical for combustion efficiency and for preventing "puffs" (coal dust explosions) which can be very expensive and constitute a serious safety issue at most coal burning power plants. Because "puffs" normally occur at start-up and shut-down, the measurement of the mass-weighted temperature and the air mass flow rate are extremely important measurements and if properly used, can provide a safe, highly controlled, accurate coal/air ratio to maintain the air temperature and fuel/air ratio with safe limits. Furthermore, since the Kurz Thermal Mass Flow Sensors have exceptional low velocity sensitivity (nearly down to zero velocity at all temperatures as opposed to differential pressure devices which are rarely able to measure accurately below about 700 SFPM), a pulverizer control system can be made to safely operate from start-up to shut-down and provide the highest level of flow, temperature and air velocity control.

BASIC EQUATION:

$$\overline{T_M} = \frac{V_1 \times T_1 + V_2 \times T_2 \ldots\ldots V_N \times T_N}{V_1 + V_2 \ldots\ldots V_N} = \frac{\sum_{i=1}^{N} V_i \times T_i}{\sum_{i=1}^{N} V_i}$$

$$\overline{V_M} = \sum_{i=1}^{N} V_i / N$$

$$\overline{T_A} = \sum_{i=1}^{N} T_i/N$$

Where:

$\overline{T_M} = \text{Mass-Weighted Average Temperature } [°F, °C]$

$\overline{V_M} = \text{Average Mass Velocity } [SFPM]$

$V_i = \text{The mass velocity of Point } i \text{ of a Kurz MFT Series Sensor } [SFPM]$

$T_i = \text{The air temperature at Point } i \text{ on a Kurz MFT Series Sensor } [°F, °C]$

$\overline{T_A} = \text{Arithmatic mean temperature } [°F, °C]$

$i = \text{The identifier for the ith sensor where } i = 1, 2, ...N$

$N = \text{The identifier for the number of sensors in the multi-point array}$

INTEGRATION WITH "FLOW PERFECT":

As discussed in Technical Brief (DCN 368030), Flow Perfect is a Kurz proprietary automatic sensor configuration correction factor algorithm. Thus in the event that one or more of the independent Kurz mass flow/temperature sensors is damaged, has failed, or the power has been disconnected for maintenance, etc., Flow Perfect will "Kick-Out" the problem sensor. If a velocity/temperature (FD) sensor is removed from the array based upon the "Kick-Out" criteria (normally between -1% to 110% of the full scale calibration range) then the Model 155 mass Flow Computer will re-compute the correction factor using the remaining velocity/temperature sensors, based upon the Flow Perfect data obtained from customer's in-situ calibrations, or from the initial set-up data. Since the velocity and temperature measurements are related, a "Kick-Out" signal from either measurement will initiate the Flow Perfect Correction feature routine, and the resulting mass-weighted temperature reading will reflect what the temperature reading would have been had the same sensors been used to obtain the baseline data. The display will show "Kick-Out" and by pressing "C" the location of the offending sensor and its output and input readings may be observed.

EXAMPLE:

The following data was measured for a 5' x 5' duct having nine (9) "FD" sensors placed at equal area locations:

Sensor	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Velocity [SFPM]	4000	4500	5000	5500	6000	6500	7000	7500	8000
Temperature [°F]	650	625	600	575	550	525	500	475	450

Results of Calculations:

$$\overline{V} = 6000\ SFPM$$

$$\overline{T_M} = 536°F$$

$$\overline{T_A} = 550$$

Thus, the mass-weighted average temperature is 12°F less than the arithmetic average temperature, which causes a substantial error in the air stream enthalpy.

CONCLUSION:

The mass-weighted temperature $(\overline{T_M})$ is a more accurate method for use in calculating the energy content of the air stream and can be important especially in coal pulverizer applications in which the tempering air is poorly mixed with the hot air, which is typical for most installations.

Another important advantage of the K-BAR 2000 is that the individual temperature for each velocity sensor is used instead of the arithmetic average temperature for making the VTM (velocity/temperature/mapping) calculations. This allows the Series 155 Mass Flow Computers to obtain more accurate mass velocity and mass flow calculations resulting in better air/fuel ratio control and safety (no "Puffs").