Technical Publication

Thermal Mass Flow Meter Supports Feedback Control Loop In Boiler System for Thermal Electric Power Generation

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To meet China's growing need for electric power generation, the Guohua Ninghai Power Plant has a total planned operating capacity of 4 x 600 MW [Phase 1] (Figure 1). The plant is located south of Shanghai in Ninghai township, Ningbo city, Zhejiang province and serves the electric power needs in the region.

The Ninghai plant relies on coal-fired steam driven turbine to generate electricity with six sets of HP-983 medium speed coal mills supporting a tangentially corner-fired boiler. The plant's large production operations are complex.

Coal is first fed from silos at the plant to coal mill pulverizers, which grinds the coal to a fine powder. A fan forces a flow of blended primary ambient air and pre-heated air into the coal mill where the air and coal powder are mixed to provide combustion air to a furnace, heating water in a boiler which produces steam to drive power-generating turbines. The plant's sophisticated energy efficient boiler control system requires accurate and responsive air flow measurement.

The Problem

The boiler's steam production efficiency is controlled by adjusting a precise flow of blended primary ambient air and pre-heated air which flow from separate ducts. Each of the duct air flows are controlled by louvered dampers located inside the ducts. The preheated air is blended with the primary ambient air and flows into the coal mills, and afterwards the boiler. Accurate, responsive and reliable air flow measurement is critical to the automated control of the dampers and the efficiency of the boiler, which also ensures safe operation of the boiler and reduces plant operation energy costs.

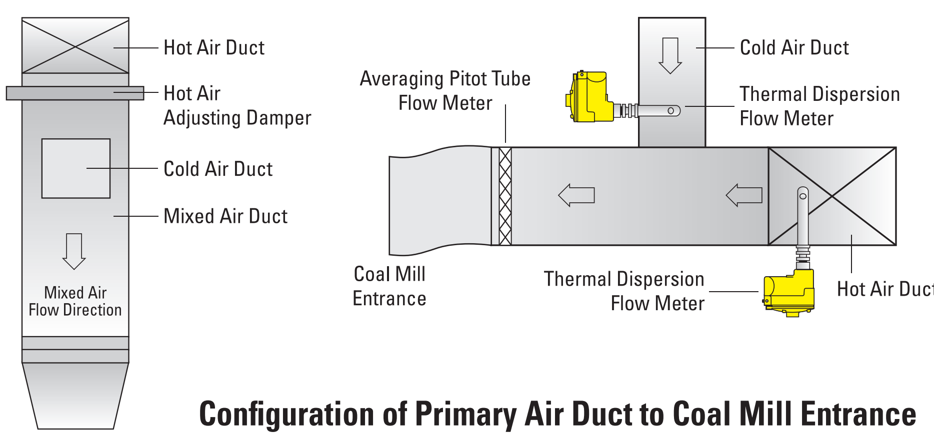
Figure 1: Ninghai Power Plant

The temperature of the pre-heated air fed to the boiler is 518 °F [270 °C[and the primary ambient air temperature is 86 °F [30 °C[. The size of the primary air duct is 47-x-47 inches (1200-x-1200 mm), the pre-heated air duct is also 47-x-47 inches (1200-x-1200 mm), and the ambient forced draft air duct is 20-x-31inches (500-x-800 mm).

The air flow to the coal mills and into the boiler is controlled by the plant's distributed control system (DCS), which requires accurate and responsive air flow measurement data to control the dampers and keep the primary air flow to the coal mill entrance at precise and efficient levels. Figure 2 shows the primary air duct at the coal mill entrance.

Engineers from the China Electric Power Research Institute (CEPRI) and the Guohua Ninghai Power Plant studied several flow meter technologies for optimum accuracy and response, including thermal dispersion and averaging pitot tube, differential pressure (dP). They narrowed their testing to these two technologies based

Figure 2: Primary air duct at coal mill entrance



Configuration of Primary Air Duct to Coal Mill Entrance

on information from installed reference applications at other power plants in China.

The engineers determined that the selected flow meter technology would need to be accurate, responsive and impervious to large temperature fluctuations in order for them to control the air flow automatically via the dampers in the ducts using the plant's DCS. These application criteria can be difficult to achieve because of the large cross sectional area of the air ducts and the temperature stratification in the primary air duct caused by the mixing of the pre-heated and ambient air.

For the flow measurement test program, the two different types of flow meters were installed on Coal Mills C and D that feed Boiler 3. The thermal mass flow meters with multiple sensing points were installed in each of the pre-heated and ambient air ducts. This installation eliminates the large temperature fluctuations that are present in the main primary air duct due to the mixing of the pre-heated and ambient air. It also provides a more precise and responsive damper control within the air ducts. Figure 3 shows the thermal flow meter that was placed in the ambient air duct. The averaging pitot tube flow meter was installed in the main primary air duct downstream from the preheated and ambient air ducts. Figure 4 shows the averaging pitot tube flow meter in the primary air duct.

The output readings from the two thermal mass flow meters were compared to the averaging pitot tube flow meter and to the changes in the dampers. Based on the result of the test program, the thermal mass flow meters provided the best system control. The thermal mass flow meters on the duct for Boiler 3 provided an accurate and responsive output of the air flow rate, which was consistent with the damper positioning. See Figure 5 for the Mill D recorded air flow measurements.

Both the averaging pitot tube and thermal mass flow meters tracked the damper positioning changes in this test and their air flow readings were within 1 percent accuracy of each other. While the averaging pitot tube flow meter provided a similar accuracy and was responsive, its accuracy was negatively affected when the air flow pressure dropped. See Figure 6 for the Boiler 3 Mill C recorded air flow measurements at low pressures.

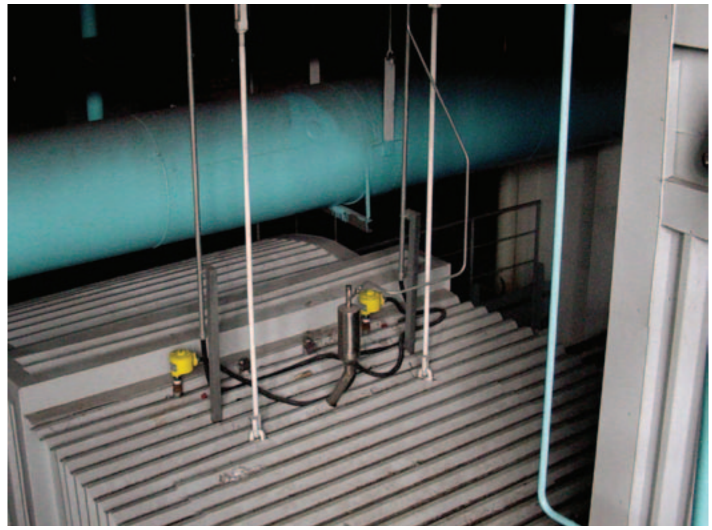


Figure 3: Thermal mass flow meter in cold air duct

Figure 4: Averaging pitot tube flow meter in primary air duct

The tests showed the flow rate output of the thermal mass flow meters matched the set position of the preheated/ambient air dampers, and the thermal mass flow meter provided the response time required of the automatic control feedback loop within the DCS. The thermal mass flow meters responsiveness was enhanced by an anticipator algorithm in the DCS. The DCS PID parameter proportion factor was adjusted from 0.3 to 0.4 and the integration factor was reduced from 300 to 150. The accuracy performance of the averaging pitot tube flow meters, however, was greatly affected by low air pressure conditions and low air flows.

Due to the low pressure in test shown in Figure 6 – Mill C, the averaging pitot tube flow meter did not track well with the damper position changes. In addition, averaging pitot flow meters require higher maintenance because their sensor design includes small air inlets, which clog in the fly ash laden air flow inside the ducts. Whereas the thermal mass flow meters do not have small air inlets, nor mechanical moving parts, and therefore it's impervious to the fly ash laden air flow conditions.

The Solution

After completion of the test program, thermal mass flow measurement supplier Fluid Components International LLC (FCI) provided its Model MT86 Series Multi-Point Thermal Mass flow meters (Figure 7) for use at the Guohua Ninghai Power Plant. These precision air flow meters are installed around the world in numerous electric power generation plants because of their accurate, stable and reliable measurement over wide temperatures and variable pressures.

The FCI Model MT86 Series Multi-Point Thermal Mass flow meter is designed with up to 8 independent thermal mass flow sensor arrays placed in a variable length assembly. The MT Series is ideal for applications in thermal and nuclear electric power generation and other heavy process or manufacturing industries. It provides excellent flow measurement inside the large line sizes found in combustion air systems, HVAC units, large ducts, flue stacks and wherever unstable process conditions make other flow meter technologies ineffective.

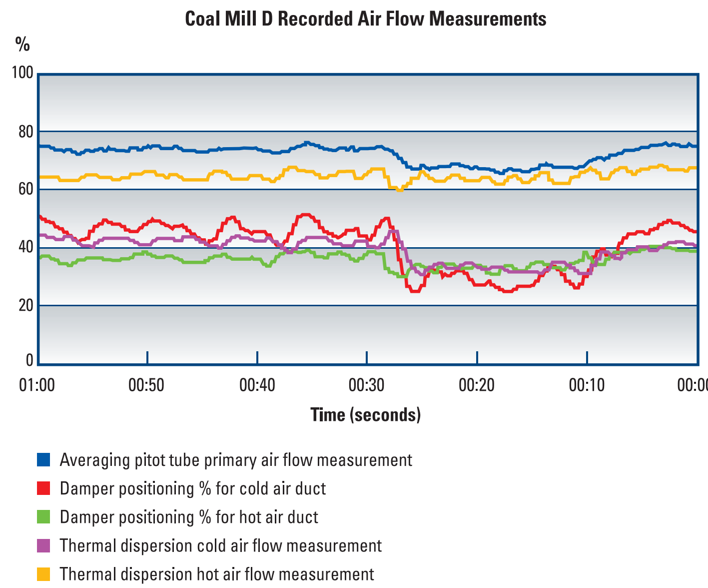


Figure 5: Test data for thermal mass flow meter

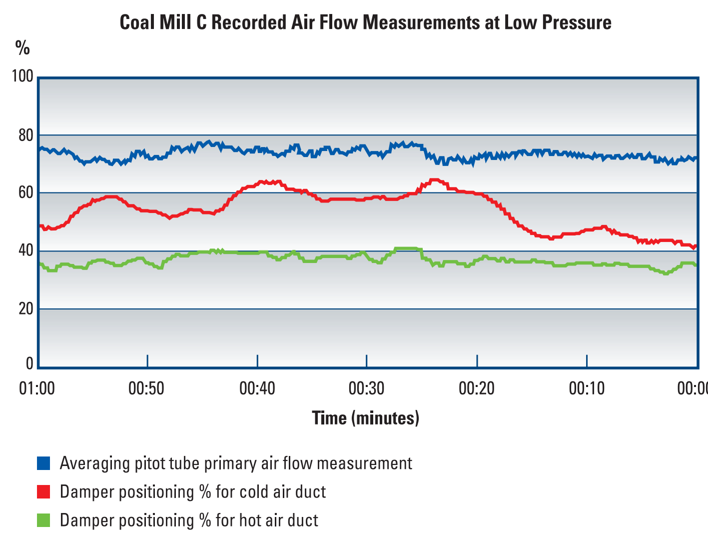


Figure 6: Test data for averaging pitot tube flow meter

MT Series flow meters are highly versatile, with a wide turndown range available from 5:1 to 1000:1 and flow sensitivity from 0.25 SFPS (0.08 NMPS) to 150 SFPS (45.7 NMPS). With its smart digital flow transmitter and advanced thermal dispersion flow sensing element(s), the MT86 Series meets a wide range of environmental monitoring requirements worldwide.

With a no-moving parts design and no orifices to plug or foul the Model MT86 Series flow meters incorporate a fully temperature-compensated thermal dispersion mass flow sensor design that is highly stable and repeatable. FCI's thermal mass flow sensing technology places two thermowell protected platinum RTD temperature sensors in the process stream. One RTD is heated while the other senses the actual process temperature. The temperature differential between these two sensors is measured and is directly proportional to the mass flow rate of the fluid (Figure 8).

Figure 7: FCI MT86 Series Flow Meters

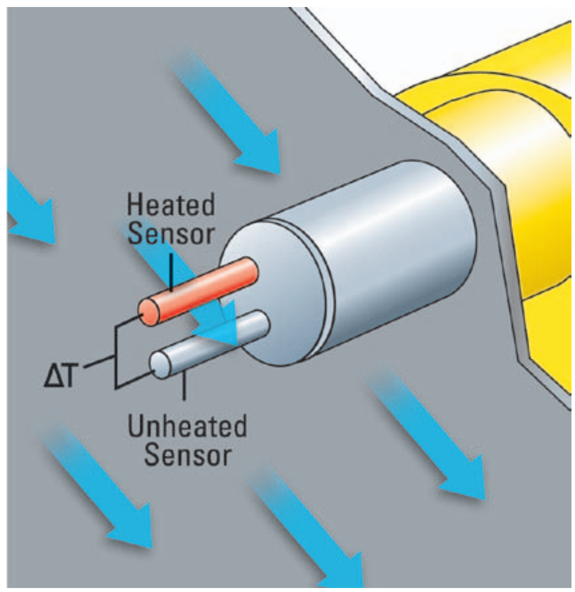


Figure 8: Thermal dispersion principle of operation

Conclusions

After testing and evaluating both flow meter technologies, the engineers from CEPRI and the Guohua Ninghai Power Plant solved the challenge of finding the most accurate air flow measurement technology which would be responsive enough for automatic damper control of the mix of preheated and ambient air flowing into the coal mills. The FCI thermal mass flow meters air flow accuracy and responsiveness provided the necessary flow data to automatically control the dampers and maximize the efficiency of Boiler 3. ■