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**An Update on Performance Optimization and Efficiency
Improvement Programs completed at State Electricity Board
Operated Coal Fired Power Plants in India through the Asia Pacific
Partnership on Clean Development and Climate (APP)**

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ABSTRACT

The governments of Australia, Canada, China, India, Japan, Republic of Korea, and the United States have agreed to work with private sector partners under the Asia Pacific Partnership on Clean Development and Climate (APP) to meet goals for energy security, national air pollution reduction, and climate change in ways that promote sustainable economic growth and poverty reduction. The United States Department of Energy's (USDOE's) Office of Fossil Energy and the National Energy Technology Laboratory (NETL) are leading implementation of activities targeted at improving the efficiency of coal-fired power plants in India under the flagship Power Generation Best Practices Project of the Power Generation & Transmission Task Force. NETL has launched a program in India with a few state-owned generating companies to demonstrate some of the best practices used in U.S. power plants.

Under a subcontract with NETL's site support contractor, Research and Development Solutions (RDS), a two-phase combustion optimization and efficiency improvement training project commenced in 2008 - 2009 by Storm Technologies, Inc. This paper reviews the comprehensive approach adopted by Storm Technologies in reviewing power plant performance by inter-relating the variables of performance with fuel quality, and plant reliability and operations. The introduction of the "best practices" through the APP Program is an important paradigm shift in the operation and maintenance of existing fleet and future coal fired generating plants in Asia, as well as the United States. The main objective of the program is to demonstrate the importance and the environmental benefits of combustion and boiler optimization and overall plant efficiency/heat rate improvement.

INTRODUCTION

The reliability and efficiency of many Indian coal-fired power plants suffer due to (1) poor and (in many cases) declining coal quality, (2) deteriorating equipment condition, (3) lack of incentives to maintain or improve efficiency and reliability, (4) inadequate operating budgets, and (5) inadequate knowledge, experience, and operating and maintenance (O&M) practices that adversely affect both plant efficiency and reliability. The inability to sustain plant performance and reliability can be a serious issue for many plants, even if they have been rehabilitated. The lack of appropriate operation and maintenance (O&M) practices results in rapid deterioration of plant efficiency, reliability, and maximum sustainable output (MWs). The introduction of "best practices" for O&M of existing and future coal-fired generating plants in India is critically needed.

Therefore, the main objective of the APP Program is to demonstrate the importance and the environmental benefits of combustion optimization to maximize boiler performance and improve overall plant efficiency. Storm Technologies provided technical assistance to help initiate the adoption of best practices that will reduce fuel consumption, local air pollution, and global carbon dioxide (CO₂) emissions. Under NETL's Program, multiple projects have been strategically designed to promote combustion optimization and efficiency in several Indian coal-fired power plants by including classroom and "hands-on" training.

PHASE I

In Phase 1, combustion optimization and efficiency improvement training, including full-day training workshops emphasizing how to initiate a performance improvement program, covering testing, measurement of heat rate/efficiency, and identify opportunities, and to create lasting awareness at each power plant. At the end of the training, program development and testing protocols were established for each power plant. Testing provisions for each plant were detailed and completed during planned outages. Test ports were installed on the primary air, secondary air, air heater inlet/outlet, and induced draft (ID) fan discharge ducts. Test ports were also installed on the fuel lines to measure and evaluate pulverizer performance. As a part of the program, the participating plants either upgraded and/or optimized their in-house laboratories to enable them to analyze coal proximate analysis, coal fineness, and unburned carbon (i.e., loss on ignition, LOI). Summary illustrations of the comprehensive testing locations utilized on two different boiler variations are shown in Figures 1 and 2.

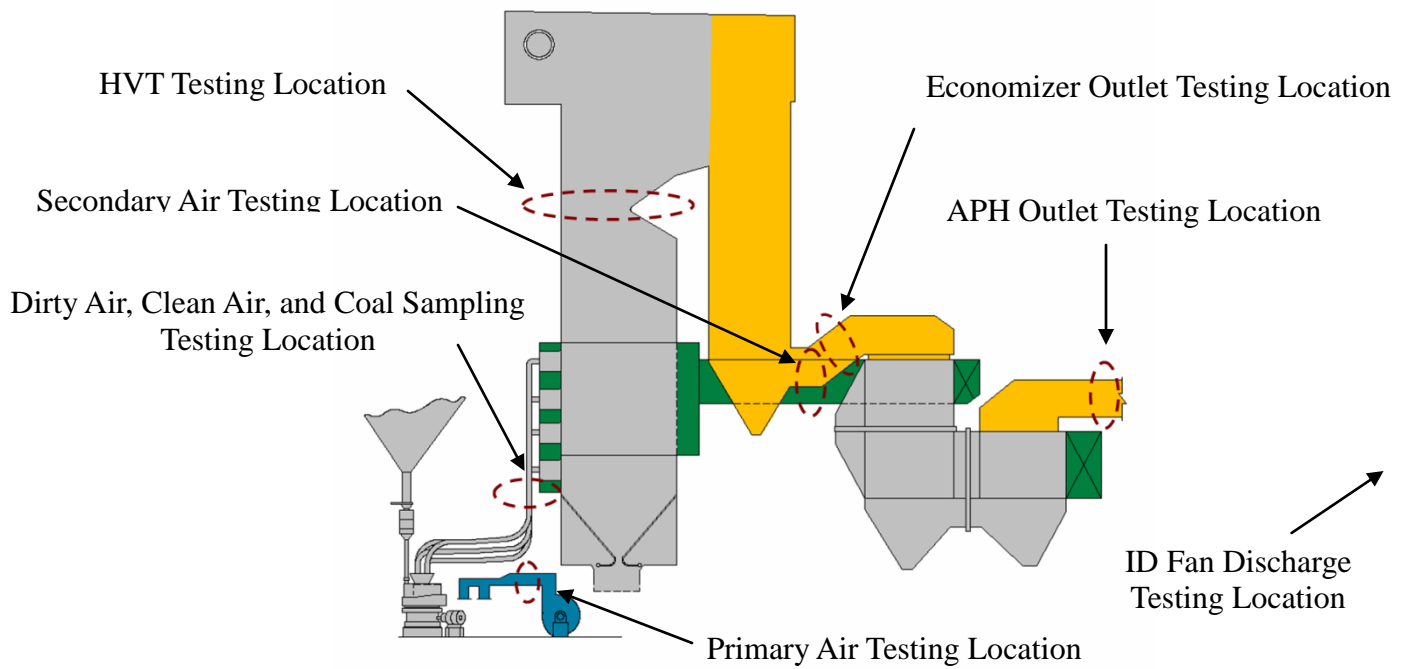


Figure 1: Comprehensive Boiler Testing Locations on Plant "A" (210 MW Wall Fired)

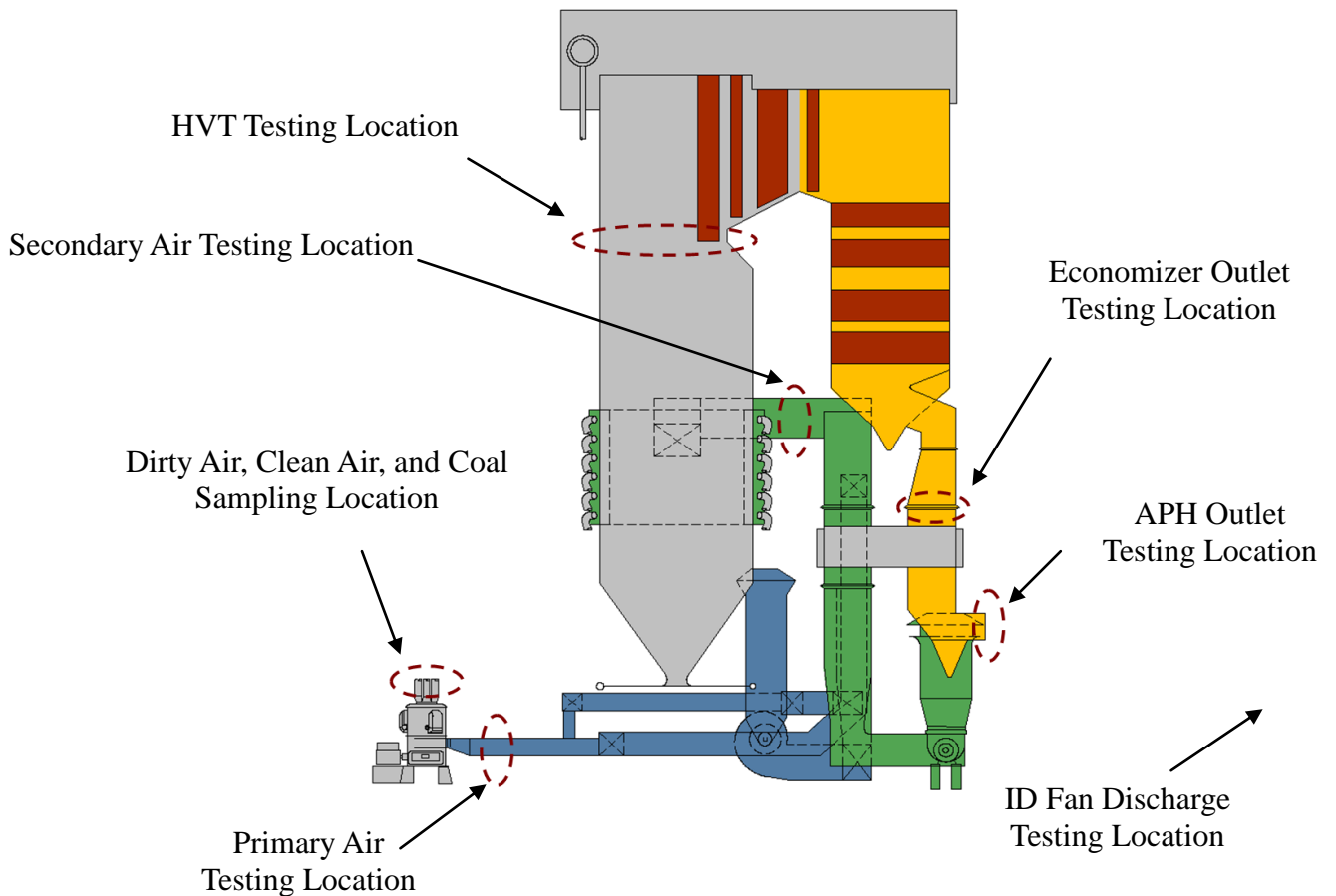


Figure 2: Comprehensive Boiler Testing Locations on Plant "B" (210 MW Corner Fired)

TEST PROGRAM PROTOCOL

1. Fuel Line Clean Airflow Testing
 - a. Balance and distribution evaluation
 - b. Minimum airflow set-point evaluations
2. Primary Airflow Measurements and Calibration Tests
 - a. Evaluation of the transport airflow to the mills, air/fuel ratios and the heat balance for each milling system.
3. Dirty Airflow and Isokinetic Coal Sampling via the STORM Method
 - a. Fuel line distribution, balance and air-fuel ratios
 - b. Representative coal fineness for each fuel pipe
4. Secondary Airflow Measurements and Calibration Tests
 - a. Evaluation of total combustion airflow to the unit
5. Furnace Exit HVT Traverses
 - a. Determination of actual flue gas oxygen, temperature, and carbon monoxide profiles
 - b. Comparison of actual furnace exit gas temperature vs. temperature gun
6. Air In-Leakage Survey (4 Major Regions)
 - a. Furnace exit
 - b. Economizer outlet
 - i. Comparison of actual boiler oxygen vs. control indicated
 - c. Air heater outlet
 - d. ID fan discharge
7. Flue Gas Flow Measurement
8. Boiler Efficiency
9. Fly Ash Particle Size and Bottom Ash LOI Analyses
10. Tuning and Optimization
11. Fly-Ash and Bottom-Ash LOI Results
12. Radiant Losses/Survey with Temperature Gun
13. Control Indications Evaluation
14. Analytical Evaluation
 - a. Minimum airflow calculation and review
 - b. Mill heat balance calculations vs. actual
 - c. Fuel loading curves
 - d. Review of control indications (hand recordings)
 - i. Evaluation of instrumentation issues/deviations
 - ii. Review of the plant equipment and design operating curves
 - iii. Review all motor nameplates
 - e. Fuel analyses summary (current)
 - f. Review of the plant performance sheets and boiler design
 - g. Review of the “design” vs. “as found” performance
 - h. Review of all performance improvements completed to date
 - i. Review of combustion performance
 - i. Furnace exit gas temperature and carbon monoxide profiles
 - ii. Measured Stoichiometry (air and flue gas evaluation)
 - iii. Design vs. actual performance

- j. Efficiency and heat rate evaluation
 - i. Preliminary (onsite)
 - ii. Final (upon completion of a thorough review of all the fuel analyses and control indications)
- k. Review of plant equipment issues (if any)
 - i. For example:
 1. Coal feeders
 2. Mills
 3. Soot blowers
 4. Boiler casing, expansion joints, and insulation
 5. Air heaters
 6. Draft losses due to plugging and/or internal alignment issues
 7. Air and flue gas ductwork
 8. Fans
 9. Controls instrumentation
 10. Cycle losses

PHASE II

As a part of Phase II and prior to completion of testing in India, two engineers each from power plant visited three U.S. coal-fired power plants to observe best practices and participate in hands-on demonstration of various testing techniques. The three plants were Nevada Power's Reid Gardner Power Station near Moapa, Nevada, featuring front wall-fired Foster Wheeler boilers; Orlando Utilities Commission's Stanton Energy Center (OUC/SEC) near Orlando, Florida, featuring opposed wall-fired Babcock and Wilcox units rated at 450 MW; and E.ON-U.S.'s Trimble County Station, near Bedford, Kentucky, featuring a tangentially fired boiler. Hands-on testing demonstration and training were conducted at OUC/SEC to take advantage of the plant's excellent O&M practices that have led to consistent heat rate improvement and documented reduced CO₂ emissions reduction.

PHASE III

Throughout the program, testing efforts at these participating power plants has been supported by NTPC Limited's (NTPC) Center for Power Efficiency and Environmental Protection (CenPEEP). CenPEEP was established in 1994 by NTPC and the India Mission of the U.S. Agency for International Development (USAID/India) through the Greenhouse Gas Pollution Prevention (GEP) Project to reduce greenhouse gas emissions by improving the overall performance of existing Indian coal-fired power plants and sustaining this improvement through modern performance monitoring and reliability-maintenance practices. CenPEEP functions as a resource center for the acquisition, demonstration, and dissemination of state-of-the-art technologies and practices for performance improvement of coal-fired power plants across NTPC's coal-fired power plant fleet and throughout all of India.

Steam turbine test conducted by CenPEEP revealed heat rate performance degradation. Multiple areas were identified by CenPEEP personnel to address the turbine performance, including leaking drains, condenser leaks, and turbine degradation. Within the initial site assessment

report, details were outlined to be completed during the scheduled outages at each facility. Recommendations that were readily acted upon by plant staff during the outage and led to an average reduction of ~75kcal/kWh(293Btu/kWh) in each plant’s heat rate. Improvements were also completed to each unit and the efficiency improvements and CO₂ reductions were easily identified. Improvements in Dry Gas Losses were greatly decreased by reducing the amount of Air In-Leakage on the units. Other areas of improvement were completed to reduce UBC levels, and reductions in auxiliary horsepower consumption.

A graphical representation of the pre-outage improvements is given in following figure.

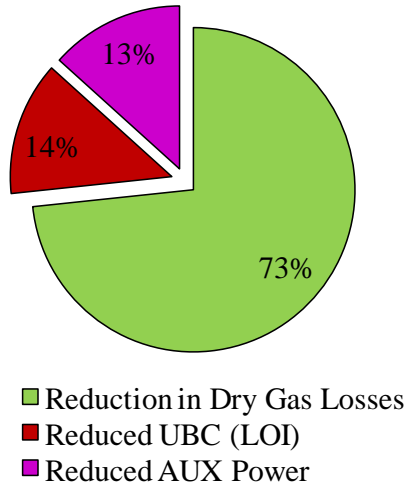


Figure No. 3

EVALUATION OF EFFICIENCY

Understanding efficiency improvement opportunities has been a significant part of the program being implemented by NETL. For example, let’s review a few of the basic efficiency penalties. Dry gas loss improvement comes from utilizing the heat within the process, rather than expelling it to the atmosphere through the flue stack. By optimizing the “inputs” and/or the fundamental ingredients of a steam generators combustion process, UBC, primary air flow optimization, reduction of coal dribble through the pyrite hoppers, and overall mill performance can significantly improve boiler performance, efficiency, and reliability and indirectly reduce CO₂ emissions by lowering furnace exit flue gas temperatures and de-superheating spray flows. Lowering air heater leakage and furnace leakage upstream of the air heater inlet also contributes to CO₂ emissions because of the losses associated with this stealth penalty. Furthermore, it should be noted that within the program, the fuels being fired had a substantial influence on negative CO₂ emission deviations from design. The following chart displays the average efficiency opportunities measured during the evaluations of these units.

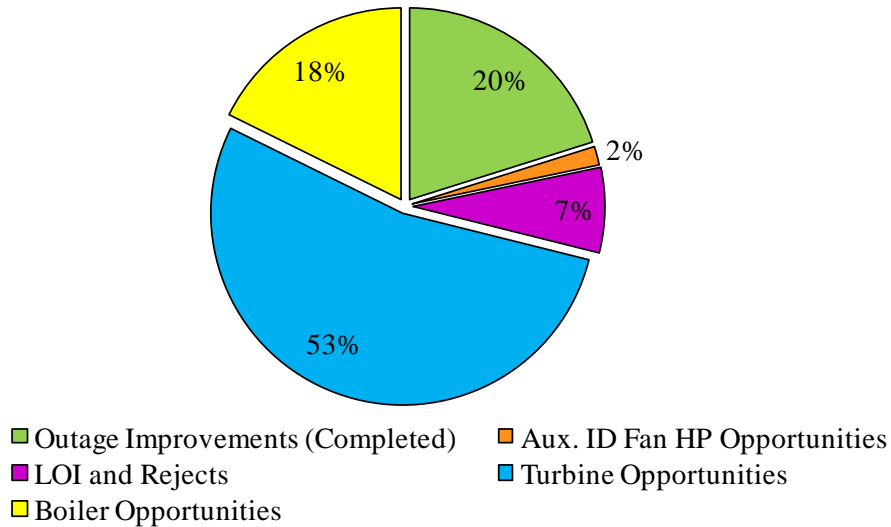


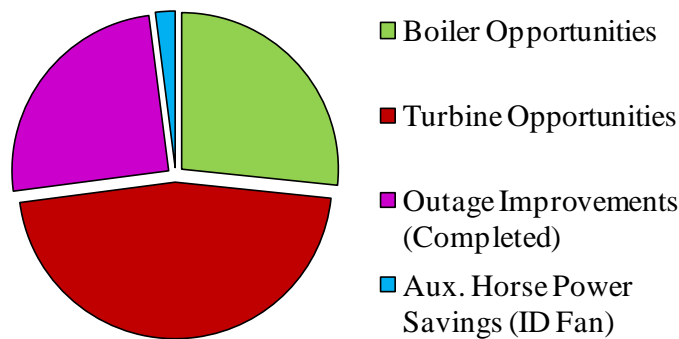
Figure No. 4

It should be noted that average plant thermal efficiency results were measured at around 30-31%, implying that hundreds of kcals (~1,000-2,000Btu's) are available for heat rate improvement.

PERFORMANCE IMPACT ON CO₂ EMISSIONS

On average in this program, if the turbine drains on these units were repaired and the HP/IP turbine efficiencies were improved upon at each plant, there could be an average reduction of ~74,000 tonnes per year of CO₂ emissions alone. Operating at full load and at a target heat rate of 2,400 kcal/kWh, and firing typical Indian coal, CO₂ average emissions reductions of ~124,000 tonnes per year is achievable. It should be noted that each of the plants selected were super thermal power stations with at least six units. Thus, assuming the other units have similar losses, potentially, CO₂ emissions reductions of ~744,000 tonnes/year might be achievable at each unit. To illustrate the impact on efficiency on greenhouse gas (GHG) emissions, the following figure displays the average increased CO₂ production.

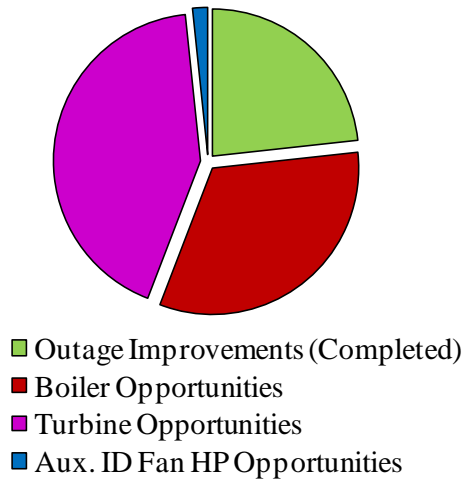
Average CO₂ Emissions



PERFORMANCE IMPACT ON FUEL COST

As a part of the program, fuel quality was evaluated and found to have a significant impact on boiler and pulverizer performance and fuel costs. To illustrate the impact of efficiency on fuel cost, the following graph illustrates the approximate averages evaluated and/or improved as a part of the program.

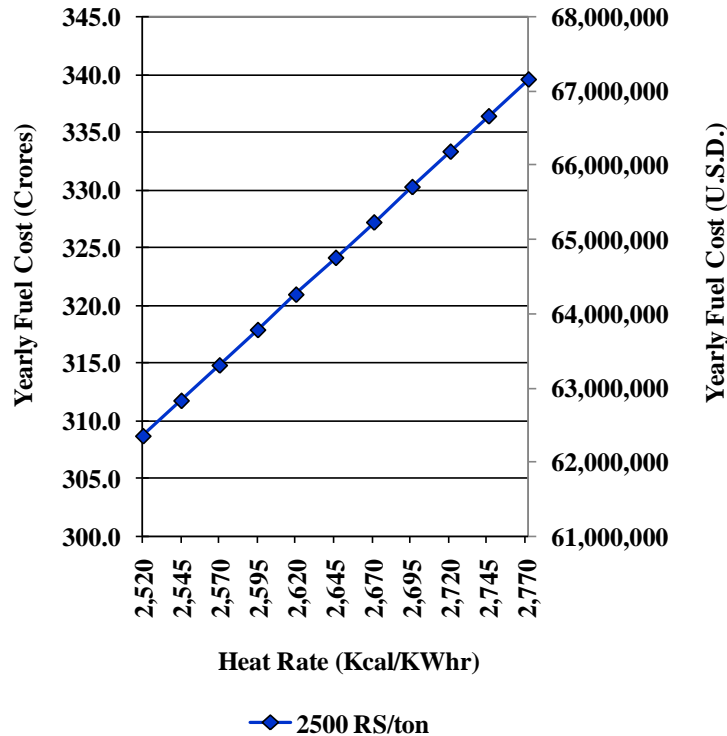
**Increased Fuel Cost
(Average from each unit)**



Each of the demonstrations completed as a part of the program have demonstrated potential fuel savings of US\$5-15 million. To illustrate, fuel costs for a typical 210-MW unit are shown for varying heat rates.

Given

Parameter	Value
Load	210 MW (gross)
Operation	7,000 hrs
Fuel GCV	3,000 kcal/kg
Coal Cost	2,500 Rs./Ton
Ash Content	50%



CONCLUSION

As demonstrated in this project, there are tremendous opportunities for significant CO₂ emissions reduction through improvements in boiler and turbine operation. Replication of the testing performed in one of the units in the other units at each power plant and at other similar units through the utilities and elsewhere in India will reduce GHG emissions. The APP Program, and this project in particular, will not only promote CO₂ emissions reduction, it will decrease fuel consumption, improve reliability, and increase plant generation capacity.

The testing program that was established identified 14 major areas of concern which, when improved upon, will increase boiler efficiency and overall unit and plant thermal efficiency. Below are suggested key points that can be utilized to simultaneously increase performance, heat rate and reduce CO₂ emissions on pulverized coal-fired units.

KEY POINTS

1. Team training and commitment is essential
2. Installation of the testing ports and a performance program is essential
3. Excess O₂ at the furnace exit and economizer outlet must be optimized
4. Pulverized coal fineness must be optimized
 - 75% minimum passing 200 mesh with a 0.1% maximum on 50 mesh

5. Balance and supply adequate secondary air flow. This must be controlled with validated and proven total airflow metering devices within each of the main supply ducts.
6. Wind box to furnace differential must be optimum
7. Mill air to fuel ratios should be optimum and controlled
 - Controlled with gravimetric coal feeders and mill inlet primary airflow measurement
8. Fuel flow should be balanced to $\pm 10\%$ of the mean
9. Clean air velocities balanced within $\pm 2\%$
10. Burner tolerances within $\pm 1/4$ inch (6 mm)
11. Boiler efficiency and air in-leakage assessments and optimization
12. Air in-leakage maintained at a minimum