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Project Summary

Three-Stage Combustion (Reburning) on a Full Scale Operating Boiler in the U.S.S.R.

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This report gives results of a program to complete the preliminary design of a three-stage combustion (reburn) system for NO_x emissions control on an operating boiler in the U.S.S.R. This project was sponsored by the U.S. Environmental Protection Agency (EPA) in support of the protocol of the Eleventh Meeting of the Stationary Source Air Pollution Control Technology Working Group, Moscow, U.S.S.R., November 1988.

The program to design the reburn system consisted of five tasks: visiting the Ladyzhinskaya host site to exchange design and operating information; translating Soviet documents into English; performing process calculations; conducting physical flow modeling; and developing a preliminary system design which included general arrangement drawings and furnace performance analyses.

The overall preliminary reburn system design was presented to and accepted by Soviet representatives during a June 1989 meeting at the EPA's Air and Energy Engineering Research Laboratory (AEERL) in Research Triangle Park, N.C. It appears that reburning would be a viable NO_x reduction technology for the type of boiler that the host Ladyzhinskaya steam generating unit represents.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering Information at back).

Introduction

The objective of this program was to systematically develop a preliminary design for a three-stage combustion (reburn) system for the 300 MWe type Tππ-312 Ladyzhinskaya steam generating unit located in Vinnitsa, U.S.S.R. This objective has been met and the preliminary design was accepted by the Soviet representatives monitoring this program during a meeting at EPA/AEERL in June 1989.

Acceptance was qualified, however, in that the Soviets requested that a supplemental thermal performance sensitivity analysis be conducted on the key reburn process parameters in order to even further quantify any impacts that the reburn system would have on normal boiler operation. In addition, during the June 1989 meeting the Soviet representatives presented additional information and clarification on the design and operational assumptions that were used in developing the preliminary reburn system design.

Future work on the three-stage combustion (reburning) demonstration will include the Soviet side's completing the detailed design of the system, then fabricating, retrofitting, and finally testing the system at the Ladyzhinskaya power station. Currently, the U.S. side would be involved in these phases in review and consultative roles.

Design Elements

The statements below summarize major elements of the preliminary design. (Key findings related to the supplemental recommendations for the jointly accepted U.S.S.R. preliminary reburn system design are included).

- The design is based on: information transmitted from the Soviet to the U.S. side during the Ladyzhinskaya plant tour hosted by the Soviet side in November 1988; public domain reburning technology technical literature; and Combustion Engineering boiler design methodologies.
- The preliminary design employs natural gas as the reburn fuel and coal as the main. burner fuel. The report highlights potential advantages and disadvantages of using fuel oil and coal as reburn fuels.
- The preliminary design meets design criteria for maximizing NO_x reductions for the process.
- To the extent possible. the preliminary design was developed consistent with the Soviet side directive that reburn system operation cannot affect slag tapping (wet slag removal from the furnace bottom), that temperature growth (with the reburn system in operation) must be within tube design limits, and that furnace slagging/ fouling characteristics should not change. As designers of the Ladyzhinskaya unit, the Soviet side must corroborate the above through application of their own design methodologies prior to establishing the final reburn system design.
- The preliminary design identifies major process flows for the main burners, reburn fuel injectors, and burnout air injectors. The total number of injectors, as well as their elevational and planar locations and their approximate free areas (cross sectional exit areas), have been established based on stoichiometric/ residence time calculations, physical flow modeling, and boiler performance calculations. Detailed mechanical design of the system is the responsibility of the Soviet side.
- The preliminary design generally consisted of 12 reburn fuel injector windboxes located at elevation 20.3 m, and 12 burnout air injector windboxes located at elevation 29.2 m (Figure I). The reburn fuel (natural gas) represented 20% of the total heat input into the boiler. Recirculated flue gas (FGR) has been employed as a reburn fuel propelling medium; the quantity of FGR required was defined to be 10% by weight of the total boiler flue gas.
- The reburn fuel and burnout air injectors identified in the preliminary design are capable of vertically tilting and horizontally yawing. This design feature will enhance system performance optimization in the host boiler. Down-tilt of the nozzles significantly enhanced mixing, as demonstrated by physical flow modeling.
- The reburn fuel nozzle configuration should be designed to achieve a jet velocity at the nozzle exit of 146-183 ft/sec(45-56 m/sec).
- The burnout air nozzle configuration should be designed to achieve a jet velocity at the nozzle exit of 183-229 ft/sec(56-70 m/sec).
- When reburning is employed, gas temperature in the furnace hopper should decrease by 50 to l00°F (28 to 56°C) and the furnace exit gas temperature should increase by 60 to 70°F (35 to 40°C).

  The cumulative waterwall steam heat absorption was predicted to decrease by about 4% with natural gas reburning. The fly ash carbon content was anticipated to decrease slightly with natural gas reburning. And finally, no significant changes were predicted for the furnace waterwall metal temperatures.
- A supplemental thermal performance analysis and sensitivity study, based on information exchanged by the U.S./Soviet sides in June 1989, resulted in several key design recommendations. These recommendations, if implemented in the Soviet final system design, will potentially improve NO_x reduction performance and further minimize the operational impacts of reburning on the Ladyzhinskaya boiler.

In particular, it was determined that it would be desirable to: minimize the main burner excess air level; minimize the reburn fuel flow while maintaining the desired reburn zone stoichiometry; minimize the reburn injector flue gas recirculation (FGR) flow while maintaining effective mixing; and maintaining or increasing the upper furnace FGR flow and approximate location.

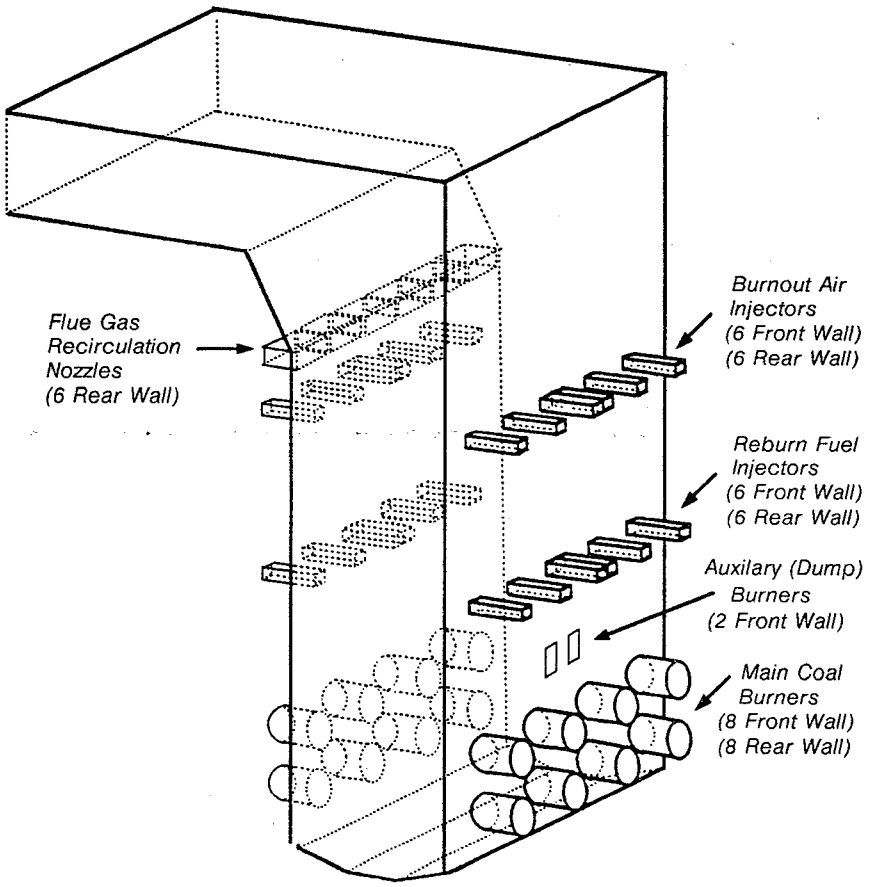

Figure 1. *Preliminary reburn system design, Ladyzhinskaya Power Station, Vinnitsa, U.S.S.R.*

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Robert E. Hall is the EPA Project Officer (see below).
The complete report, entitled "Three-Stage Combustion (Reburning) on a Full Scale Operating Boiler in the U.S.S.R.," (Order No. PB 90-181 322AS; Cost: $23.00, subject to change) will be available only from:
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