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EXECUTIVE SUMMARY

IMPACTS OF COFIRING HYDROGEN IN A COAL-FIRED STEAM BOILER

Numerical Modeling Assessment of 35%, 50%, and 100% Hydrogen Firing

Utility-scale, coal-fired steam boilers for power generation are significant sources of man-made CO_2. Accordingly, a timely opportunity exists to determine the technical challenges of cofiring low-carbon fuels such as hydrogen in these boilers. Doing so would leverage existing power plant infrastructure and help initiate the transition of the power industry to a low-carbon future. A 2018 study developed a computational fluid dynamics (CFD) model of a coal-fired furnace to gain insights into the benefits and issues associated with various coal and natural gas cofiring options.[1] That same furnace model was modified in 2022 to assess the impacts of cofiring hydrogen at a 10% heat input level. The furnace model simulates a 700MWg, tangentially fired unit fueled with a blend of eastern bituminous coals fed through six mills. Details of that model and the modifications implemented for hydrogen cofiring can be found in reference.[2] With the focus on industry-wide decarbonization, the current project utilized an incremental modeling approach to expand the hydrogen cofiring fraction with coal, including up to 100% hydrogen firing. The objective of the project was to identify potential combustion performance and operability issues when cofiring hydrogen at 35, 50, and solely firing 100% hydrogen (by heat input) on the previously described tangential-design coal furnace. Key performance indicators of interest within the furnace domain included the following:

- Flue gas temperature and distribution
- Waterwall heat transfer
- Changes in flue gas velocity vectors and uniformity
- Changes to major combustion product species
- Changes to NOx generation
- Changes to carbon-in-ash for those cases that cofire with coal

Note that the model predictions are relevant for the radiative section of the boiler up to the furnace exit at the nose arch. Effects on the downstream convective pass, steam side calculations, and downstream environmental control equipment were not included as part of these simulations. When appropriate, both cofiring scenarios and full hydrogen firing scenarios are discussed jointly. For the 100% hydrogen simulations, two parametric studies were conducted: excess air sensitivity and flue gas recirculation (FGR). Key insights from all the simulations in the full report include:

Flue Gas Temperature Distribution: Hydrogen combustion was shown to increase both average and peak flue gas temperatures within the furnace plenum and at the furnace exit. Within the lower furnace burner zone, flue gas temperatures for cases that cofired hydrogen experienced a more stratified thermal profile, with zones exhibiting higher temperatures near the waterwalls and cooler temperatures toward the furnace center.

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[1] *Studies on Coal and Natural Gas Cofiring: Simulation of Tangentially Fired Furnace Cofiring Strategies.* EPRI, Palo Alto, CA: 2018. 3002013004. https://www.epri.com/research/products/000000003002013004.

[2] *Impacts of Cofiring Hydrogen in a Coal-Fired Boiler: Numerical Modeling Assessment.* EPRI, Palo Alto, CA: 2022. 3002023986. https://www.epri.com/research/products/000000003002023986.

Flue Gas Velocity Magnitude and Distribution: Increased hydrogen co-firing created higher flue gas velocities within the furnace plenum and at the furnace exit than the coal baseline. This increased velocity is a concern for cases where fly ash particles, especially for relatively higher erosive coals, are present, as these may increase the potential for abrasion or erosion damage to downstream convective heat transfer surfaces.

Changes in Major Flue Gas Species Concentrations: CO_2 concentrations in the hydrogen cofiring cases were reduced proportionally to the level of hydrogen cofiring. Respectively, the H_2O concentration, as the only hydrogen combustion product, increased its flue gas concentration to 17.6% at 35% H_2 cofiring and 21% at 50% H_2 cofiring. At 100% hydrogen firing, moisture levels reached 35% by volume.

Changes in NOx: NOx predictions for cofiring at 35 and 50% levels indicated differences derived primarily from the reduction of fuel-bound nitrogen in coal. NOx emissions at the furnace exit showed reductions at all hydrogen cofiring levels. For the 50% cofiring cases, NOx predictions were sensitive to the hydrogen injection configuration. These differences, albeit at the same hydrogen cofiring level, indicate sensitivities with respect to flue gas thermal profiles, near-flame temperature, and oxygen availability in the lower furnace.

Waterwall Heat Transfer: Predictions of the total wall heat-flux on the furnace waterwalls, from the ash hopper to the furnace exit at the nose arch, indicated a decrease in heat absorption when compared to the coal baseline. In all 100% hydrogen firing cases, the hydrogen injector location affected the heat release distribution along the furnace height and the respective heat absorption.

Parametric Excess Air Sensitivity at 100% Hydrogen Firing: To alleviate the higher velocities observed in the initial 15.5% excess air simulation, two parametric cases with reduced air at 10 and 5% were conducted. Note that hydrogen's quicker kinetics and elimination of the need to oxidize both CO and char enabled reduced excess air levels without operating issues. Results indicate velocity reductions at the furnace exit, although these were still higher than the coal-only baseline simulation.

Flue Gas Recirculation (FGR) Simulation: Although FGR induced a cooling effect on the furnace gases, temperatures remained higher than the coal baseline. Flue gas velocities also remained higher than the case without FGR. Another prediction of the FGR case was a reduction in waterwall absorption. A more detailed model, including convection section impacts, is needed to better predict the outcome of FGR on steam cycle impacts. One predicted benefit from FGR was the 98% NOx reduction with respect to the baseline coal-only case.

Specific details of each respective simulation, along with detailed plots, contour maps, and tables, are described in the full report (3002028439).

The Low-Carbon Resources Initiative

This report was published under the Low-Carbon Resources Initiative (LCRI), a joint effort of EPRI and GTI Energy addressing the need to accelerate development and deployment of low- and zero-carbon energy technologies. The LCRI is targeting advances in the production, distribution, and application of low-carbon energy carriers and the cross-cutting technologies that enable their integration at scale. These energy carriers, which include hydrogen, ammonia, synthetic fuels, and biofuels, are needed to enable affordable pathways to economy-wide decarbonization by mid-century. For more information, visit www.LowCarbonLCRI.com.

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