JUPITER OXYGEN-NETL PROJECT UPDATE, January 2009

Tests of Jupiter Oxygen's instrumented 15 MWth oxyfuel boiler have been run from October 2007 to December 2008. Testing has included 100% oxyfuel firing with and without recycle of flue gases, to test both untempered high flame temperature oxy-fuel firing and lowered temperature oxy-fuel firing. Tests were run with air firing as well for comparison.

Testing has been conducted with both natural gas and coal (Illinois No. 6) as the fossil fuel source for high flame temperature (~5000ºF) oxyfuel combustion with no flue gas recycling (termed 'untempered' operation). Tests were also run with recycling of flue gas (tempered operation) aimed at achieving flame temperatures in the 3000°F range, roughly equivalent to the temperature of air firing. This is useful for the study of both retrofit and new boiler designs. Comparisons have been made between the heat transfer distribution of the predominately non-luminous (infrared emitting) natural gas flame with the heat transfer distribution of the more luminous (significant visible component) coal flame. The luminous component of the coal flame allows radiant heat transfer over a broader range of the electromagnetic spectrum and results in more radiant heat transfer at a given flame temperature.

Measurements in the test boiler with untempered, high flame temperature oxy-fuel combustion have shown that the efficiency of heat transfer from fuel to steam increased by 6.4% compared to air firing. This resulted in a 6.7% reduction in fuel usage, consistent with the expected range of gains based on past testing and modeling. Although this fuel savings does not include the fuel required to meet the parasitic power loads for oxygen production and carbon capture, research to date suggests that heat recovery from the oxygen plant and Integrated Pollutant Removal compressors will allow Jupiter's approach to attain significant fuel savings compared to other oxyfuel approaches. This will lead to closed loop systems in which heat recovery lowers net heat losses. Research to date has not yet determined whether a closed loop heat recovery system with full carbon capture will or will not narrow the percentage of fuel savings for Jupiter's untempered high flame temperature approach compared to other oxyfuel approaches.

Test data indicates that heat deposition (transfer of heat from the hot combustion products, i.e. gas and, for coal, particulate, to the water/steam) in the boiler can be controlled by use of recycled flue gases. In Jupiter's approach, these recycled gases are not mixed with the oxygen or the flame. This means that the volume of flue gas recycle can be used to change the amount of heat absorbed in the radiant zone and the remaining amount of heat available in the convective zone. Note that this heat transfer improvement occurs in an oxy-fuel CO_2/water vapor internal atmosphere, which both has improved emissivity (thermal energy emitting strongly in the infrared) and little nitrogen compared to air but which also is an active gas that interacts with bands of infrared thermal radiation through absorption and emission for improved radiant heat transfer.

Test data indicates that untempered high flame temperature oxy-fuel can produce boiling in the tubes that is within design parameters, and confirms model predictions that heat transfer in the radiant zone is improved. The test boiler has operated at measured flame temperatures of about 5000°F without any evidence of tube or refractory damage in a 1984 boiler with original tube and wall materials. Tube and steam temperatures have been maintained within the specifications without material or tube design changes. Preliminary screening of boiler samples shows no adverse affect from oxy-firing in terms of slagging and fouling.

Test data from untempered high flame temperature oxy-fuel combustion has shown the ability to capture at least 95% of the CO_2 with the Integrated Pollutant Removal system. Testing also suggested that 100% capture can be achieved if the grid is used to power the capture system during power plant start-up and shut-down. Measured data is consistent with extensive modeling and technical literature, which suggests that carbon capture from oxyfuel combustion systems is simpler than for air fired combustion.

Oxyfuel combustion also significantly lowers NO_X, since oxygen is used instead of air so that the only nitrogen is from the fossil fuel and any air in-leakage. The testing has shown removal of essentially all of the H_2O, particulate, low thermal combustion NO_X, and SO_X, i.e. only trace H_20 remains while the remaining parts of the three pollutants are below instrument detection ranges when using IPR.

Computer models have been built based on these test results, past Jupiter Oxygen-NETL testing, and predictive modeling, regarding heat distribution in the boiler, capture of heat from the combustion products, and recovery of heat from compression of the treated gases.

The understanding of convective and radiative heat transfer in the oxy-fuel boiler has been significantly advanced in the following respects:

- The luminous component of coal fired flames is clearly shown, through infrared analysis of the flame output, to be an important factor that must be considered in any modeling efforts. This leads to modeling issues related to particulate contribution to the flame intensity (black body component);
- Modeling showing the redistribution of heat between the radiant and convective zones during oxy-firing (as opposed to air firing) has been shown to be correct in direction and magnitude; and
- Analysis of the combustion products confirms the strong interaction of the oxy-fuel combustion products with the infrared components of the flame.

Newly-built oxyfuel power plants designed for this improved radiant heat transfer have the potential for smaller size (less capital cost) and lower operating costs compared with other oxyfuel systems as well as air fired power plants. Retrofits of power plants using the high-temperature oxyfuel approach have the potential for reduced capital and operating costs when compared with other oxyfuel approaches. Control of heat transfer at the tube surfaces is needed to ensure trouble free operation at the high radiant heat flux rates. However, this can be controlled through engineering of furnace heat release rate and the furnace liberation rate.