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**Computational Modeling and Experimental Studies on NO_x Reduction
Under Pulverized Coal Combustion Conditions**

Technical Progress Report
Sixth Quarter
April 1, 1996 - June 30, 1996

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Technical Progress Report
Sixth Quarter

INTRODUCTION

During this quarter (April-June 1996), the experiments for nitric oxide reburning with a combination of methane and acetylene were conducted successfully. With the failure of ozonator lamp in the NO_x analyzer shortly thereafter, the experimental study of nitric oxide reburning with a combination of methane and ammonia could not be completed. In the meantime, a coal feeder was designed and a purchase order was sent out for the building of the coal feeder. Presented herein are the experimental results of NO reburning with methane/acetylene. The results are consistent with model predictions. Also in this quarter, an internal program update was planned at Rust College.

REBURNING EXPERIMENTS WITH METHANE/ACETYLENE

EXPERIMENTAL

The experimental procedure employed for nitric oxide reburning with methane/acetylene was very similar to the one described in the last quarterly report (employed for reburning with methane). First, the furnace was turned on and with its temperature set point control, a furnace temperature in the neighborhood of 1140 C was set. Slowly, helium, oxygen and carbon dioxide cylinders were opened and the flow levels calculated for a particular reburning stoichiometric ratio (SR₂) were set. Oxygen simultaneously flowed through the NO_x analyzer. The analyzer was turned on and allowed to warm up. The parameters on the analyzer were checked until they reached the normal operating conditions. Then, the nitric oxide flow was adjusted to 1000 ppm which was expressed on the NO_x analyzer digital readout. The Omega probe measured the gas temperature inside the reactor which

was digitized on the thermometer readout. The furnace temperature was adjusted slightly so as to maintain the reactor gas temperature at 1100 C. When all the flow parameters were stable, methane and acetylene were introduced according to the calculated flow rate for the particular SR2 in question. Instantly, the NO_x output decreased and once it reached a steady value, the reading was recorded. A constant check on gas leaks was crucial to the success of the experiments. The procedure was repeated for various SR2 values (0.75-1.0) as well as for four reburn fuel combinations of methane and acetylene. As many as 20 runs were conducted to study the reburning effectiveness of methane/acetylene.

While the gas temperature 3" inside the reactor read 1100 C, the experiment was performed for six SR2 values, namely, 0.75, 0.8, 0.85, 0.9, 0.95 and 1.0. The total flow rate of the gas mixture was 1950 cc/min. Given in Table 1 are the various flow rates of pure gases calculated for NO reburning with 90/10 fuel combination of methane and acetylene. Table 2 lists the actual flow rates, adjusted to accommodate varying gas proportions (that is, percent concentrations) in the cylinders such as oxygen/He, methane/He, acetylene/He and NO/He. These were calibrated for rotameter scales and fed through the respective flow meters. The steady readings on the NO_x analyzer before addition of reburn fuel and after addition of reburn fuel were recorded. The experimental results for four combinations of methane/acetylene, namely, 95/5, 90/10, 85/15 and 80/20 are shown in Table 3. The results from previous quarter for NO reburning with 100% methane are also tabulated for the purpose of comparison.

Table 1. Simulated flow rates of various pure gases for NO reburning with 90/10 combination of methane/acetylene

SR2	CO ₂	O ₂	CH ₄	C ₂ H ₂	NO	He
0.75	313.5	36.0	75.9	8.4	1.95	1514.2
0.80	316.2	36.3	61.4	6.8	1.95	1527.3
0.85	318.6	36.6	48.4	5.4	1.95	1539.1
0.90	320.8	36.8	36.6	4.1	1.95	1549.7
0.95	322.8	37.1	26.0	2.9	1.95	1559.3
1.00	324.6	37.3	16.3	1.8	1.95	1568.1

Table 2. Adjusted flow rates accounting for gas proportions (% concentrations) in the cylinders

SR2	CO ₂	O ₂	CH ₄	C ₂ H ₂	NO	He
0.75	313.5	179.0	377.8	385.3	553.4	141.0
0.80	316.2	180.6	305.5	311.6	553.4	282.7
0.85	318.6	182.0	240.7	245.5	553.4	409.8
0.90	320.8	183.2	182.3	185.9	553.4	524.4
0.95	322.8	184.4	129.3	131.8	553.4	628.3
1.00	324.6	185.4	81.0	82.6	553.4	722.9

Table 3. Experimental results on NO reburning with various combinations of methane and acetylene

Gas Temperature 1100 C

SR2	100/0	95/5	90/10	85/15	80/20
0.75	-	1000/7	1000/8	-	-
0.8	1012/14	1000/7	1000/5	1000/5	1000/5
0.85	1018/10.3	1000/8	1000/6	1000/6	1000/6
0.9	1012/6	1000/8	1000/7	1000/4	1000/5
0.95	956/270	1000/453	1000/452	1000/410	1000/372
1.0	1018/852	1000/785	1000/753	-	-

NO in/out Concentrations are measured in ppm.

DISCUSSION

It can be seen from Table 3 that for the case of 100% methane as reburn fuel, NO reduction increases with increase in SR2 ratio until the optimum SR2 value of 0.9. The reduction is not as high for the cases of $SR2 > 0.9$. This behavior was documented in the previous report and it is consistent with the numerical predictions carried out earlier in the program.

For the case of 95% methane and 5% acetylene, a similar reduction is observed. The inlet concentration of NO (1000 ppm) reduces to mere single digits for the lower SR2 values (0.75-0.9), thus yielding a wider SR2 window that favors NO reduction. The reduction is 55% at $SR2=0.95$ and only 21% at $SR2=1.0$. Again, the experimental results of NO reduction with a combination of methane and acetylene follow the same trend predicted computationally.

It can be noticed also that NO reduction is almost the same for various methane/acetylene combinations. It means that a slight addition of acetylene is enough to strengthen the reductive effectiveness of methane. In effect, the addition of acetylene will enhance the operating window considerably from a narrow 0.85-0.9 SR2 range for methane to 0.75-0.9 SR2 range for all combinations of methane and acetylene.

The above finding is significant in terms of the industry needs. With methane as reburn fuel, the narrow operating window calls for precise cascade control between the primary zone combustion feed inlet, the reburning zone methane inlet and the NOx analyzer in order that the NOx emissions be within permissible limits. However, with addition of acetylene to methane as reburn fuel, the NOx emissions will be within permissible limits as long as a set point control is given to the methane/acetylene reburning feed inlet not to exceed the SR2 of 0.9. With the latter case, the operation is easier to keep the NOx emissions within limits even if there arise some changes in the primary zone combustion feed inlet.

PROJECTIONS

Upon getting the NOx analyzer fixed, the NO reburning experiments with a combination of methane/ammonia will be performed. With the coal feeder being built, it is anticipated that the furnace-reactor arrangement be modified to accommodate the same. The char gasification studies will be commenced once the gaseous reburning experiments are concluded.