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FIELD TEST RESULTS OF EIGHTEEN INDUSTRIAL COAL STOKER FIRED BOILERS FOR EMISSION CONTROL AND IMPROVED EFFICIENCY

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INTRODUCTION

In late 1977, the American Boiler Manufacturers Association (ABMA) was awarded a contract to update specifications and design parameters for coal burning boiler and stoker equipment. The project was jointly funded by the United States Department of Energy and the United States Environmental Protection Agency, with the express purpose of increasing coal usage in an environmentally acceptable manner.

The Need

The need for such a program is clear. In recent years the vast majority of industrial boiler installations have been packaged or shop assembled gas and oil fired units. These boilers could be purchased and installed at substantially lower costs than conventional coal burning boiler-stoker equipment. Because of the declining demand for coal stokers, little or no work has been done in recent years to improve specification data or product information made available to consulting engineers and purchasers of coal burning boiler-stoker equipment.

Furthermore, the market for coal suitable to be fired in industrial boilers is being held back by critical uncertainties in the environmental and energy areas, causing potential customers of coal-fired industrial boilers to shelve plans for capital expansion and conversion. The current implementation of more rigid air pollution regulations has made it difficult for many coal burning installations to comply with required stack emission limits.

It is highly desirable to remove these uncertainties and thereby encourage industrial users to order and install coal fired stoker boilers. This would lead to significantly increased coal usage and decreased dependence upon scarce and imported fuels.

Units Tested

This paper discusses the culmination of an extensive testing effort on eighteen coal-fired stoker boilers. The effort includes 400 tests on 36 boiler-coal combinations conducted over a two year period. The boilers, identified by letter designators, fall into three major stoker classifications: spreader stokers (Sites A, B, C, E, F, G), mass fired overfeed stokers (Sites D, H, I, J, K, L2, L4), and underfeed stokers (Sites L1, L3, L5, L6, L7). The units are described in Table 1 along with the number of coals fired and tests conducted.

TABLE 1

UNIT DESCRIPTION AND DATA BASE

	Stoker Type	Design Capacity lb/hr	Number Coals Tested	Number Test Conditions
Site A	Spreader	300,000	3	68
Site B	Spreader	200,000	4	42
Site C	Spreader	182,500	3	76
Site D	Vibrating Grate	90,000	3	31
Site E	Spreader	180,000	3	25
Site F	Spreader	80,000	2	38
Site G	Spreader	75,000	3	35
Site H	Traveling Grate	45,000	1	24
Site I	Traveling Grate	70,000	2	23
Site J	Chain Grate	70,000	2	13
Site K	Traveling Grate	50,000	3	18
Site L1	Multiple Retort	26,000*	1	1
Site L2	Vibrating Grate	30,000	1	1
Site L3	Single Retort	23,300	1	1
Site L4	Traveling Grate	27,000	1	1
Site L5	Multiple Retort	28,460	1	1
Site L6	Multiple Retort	20,000	1	1
Site L7	Multiple Retort	50,000	1	1

*The Site L1-L7 report expresses steaming capacity in terms of peak, or maximum rating. This paper expresses the Site L1-L7 steaming capacity in terms of maximum continuous ratings so as to be consistent throughout.

OBJECTIVES OF THE TEST PROGRAM

The principle objective of the stoker test program is to generate information which will increase the ability of stoker/boiler manufacturers to design coal-fired units which are economical and environmentally satisfactory alternatives to oil-fired units. Therefore, the units selected for testing represent state-of-the-art designs by several different manufacturers.

This objective was accomplished by measuring boiler emissions and efficiency on a variety of boiler-stoker designs and under a variety of operating conditions. The operating variables included heat release rate, excess air, overfire air, flyash reinjection and coal properties. The measurements included both uncontrolled and controlled particulate loading, nitrogen oxides (NO and NO_2), sulfur oxides (SO_2 and SO_3), oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO), unburned hydrocarbons (HC), combustibles in the flyash and bottom ash, particle size distribution and boiler efficiency. The tests were conducted under steady load conditions.

One of the secondary objectives of the program is to generate well documented emissions data which will facilitate preparation of attainable national emissions standards for industrial size coal-fired boilers. Therefore, the data generated by the stoker test program are being reviewed by the Office of Air Quality Planning and Standards (OAQPS) of EPA.

Funding for the program has come from the U. S. Department of Energy (DOE), Division of Fossil Fuel Utilization, and from the U. S. Environmental Protection Agency (EPA), Office of Research and Development. KVB, Inc., a Research-Cottrell company, was subcontracted by ABMA to conduct the field tests and write the final reports.

In stoker firing of coal, there are so many variables that even with the extensive amount of testing conducted during this program it was not possible to analyze them all. The interactions between these variables are difficult to assess.

Not all of the parameters were determined on each site nor under the full range of operating variables. For example, the carbon monoxide analyzer was out-of-service during testing at Sites G, I and J. The hydrocarbon analyzer was only operable during testing at four sites, and boiler nameplate rating was not achieved on three of the units due to retrofit equipment on two units and startup problems on a third. In addition, the testing at Sites L1 through L7 was conducted under a separate contract and included a more limited number of test measurements under a single operating condition on each unit.

SUMMARY OF RESULTS

PARTICULATE LOADING

Type of Stoker

Spreader stokers with flyash reinjection from their mechanical dust collectors had by far the highest uncontrolled particulate loadings, ranging from 13 to 36 lb/10^6 Btu. Spreader stokers without reinjection from their dust collectors were next with emissions of 2.1 to 8.8 lb/10^6 Btu, followed by mass fired overfeed stokers with .57 to 2.2 lb/10^6 Btu and underfeed stokers with .25 to .71 lb/10^6 Btu.

Heat Release Rate

It cannot be said that units with higher design heat release rates have higher particulate loadings, but for a given unit the uncontrolled particulate loading always increased as heat release rate, or load, increased. The rate of increase varied from site to site, and at some sites it appeared to accelerate as full load was approached. On spreader stokers with flyash reinjection from mechanical dust collectors, the last 10% increase in heat release rate resulted in a 9 to 20% increase in particulate loading. On spreaders without dust collector reinjection, the increase was 8 to 12%. On mass fired overfeed stokers, particulate loading increased anywhere from 3 to 20% as heat release rate was increased from 90 to 100% of design.

Excess Air

No relationship was established between particulate loading and excess air. This does not foreclose the existence of such a relationship, but rather indicates that such a relationship could not be deciphered from the data due to data scatter and uncontrolled variables.

Overfire Air

Uncontrolled particulate loading was reduced by 20 to 50% on four of six spreader stokers and three of five mass fired overfeed stokers when overfire air pressures were increased. Two sites showed the opposite trend and two sites were unaffected by changes in overfire air pressure.

Coal Ash

Coal ash could be related to particulate loading at only four of the ten test sites at which multiple coals were fired. On three of the spreader stokers it was established that particulate loading increased by .24 to .38 lb/10^6 Btu for each one percent increase in coal ash. Stated in another way, if the coal ash is doubled at these sites, the particulate loading will increase by 15 to 30%. Thus, the relationship between coal ash and particulate loading was not one-to-one on these three units.

On one of the traveling grate stokers, a 4% ash washed coal and a 10% ash unwashed coal from the same mine were tested. The 250% increase in coal ash resulted in a 300% increase in particulate loading. In this case, the dramatic increase in particulate loading can be attributed to the type of ash, a clay like material in the surface of the coal, and to a corresponding increase in coal fines on the unwashed coal.

Coal Fines

Because of the movement of air through the grate and the upward movement of combustion gases through the furnace, the smallest coal and ash particles are carried out of the furnace by the gases rather than staying on the grate. This is called particle entrainment and is a problem from both a pollution and an efficiency standpoint. The likelihood of a particle being entrained is a function of its size and density, and the velocities in the furnace. The test data from this program showed a mathematical correlation between coal fines and particulate loading on five stokers. Particulate loading increased by .10 to .55 $lb/10^6$ Btu whenever the percent of coal passing a 16 mesh screen increased by one percent. No correlation was found in studies of six other stokers.

Flyash Reinjection

Flyash from the dust collector was reinjected to the furnace of three of the six spreader stokers. In each case it was demonstrated that uncontrolled particulate loading was increased as a result of re-entrainment of a portion of the reinjected ash. At one site, reinjection was completely eliminated for test purposes. As a result, uncontrolled particulate loading was reduced by 70 to 80% and controlled particulate loading was reduced by 40 to 50%. Reducing the degree of flyash reinjection reduced the percentage of larger particles in the flyash. This in turn reduced the mechanical dust collector efficiency.

Particle Size Distribution

Particle size distribution of the flyash was determined by a variety of methods including cascade impactor, Bahco classifier, SASS cyclones and sieve analysis. The results varied from one method of measurement to another, but clearly showed that spreader stokers emit a higher percentage of coarse, more easily collected particles than mass fired overfeed and underfeed stokers.

NITRIC OXIDE

Type of Stoker

As a class, spreader stokers emitted higher concentrations of nitric oxide than did mass fired overfeed stokers. Under full load conditions, spreader stokers emitted between .30 and .61 $lb/10^6$ Btu NO_x corrected to NO_2 while mass fired overfeed stokers emitted between .21 and .50 $lb/10^6$ Btu NO_x. However, overfeed stokers operated at higher excess air levels than did spreader stokers. When compared at the same excess air levels the difference in NO_x levels is even greater.

Heat Release Rate

For spreader stokers, an increase in heat release rate equivalent to 10% of capacity resulted in an average increase in nitric oxide emissions of .025 $lb/10^6$ Btu as NO_2 at constant excess air. For mass fired overfeed stokers, the relationship ranged from zero to .026 $lb/10^6$ Btu per 10% increase in capacity at constant excess air. In all cases, nitric oxide emissions were invarient with load at normal firing conditions because the effects of decreasing excess air effectively canceled the effects of increasing load. Although NO_x increased with heat release rate on each given unit, it was not true that units with higher design heat release rates emitted higher concentrations of NO_x.

Excess Air

On four spreader stokers without air preheat and one with air preheat, nitric oxide increased by .021 to .036 $lb/10^6$ Btu for each increase of 10% excess air. The sixth spreader stoker used air preheat and its NO_x increased by .067 $lb/10^6$ Btu per increase of 10% excess air. On five mass fired overfeed stokers, NO_x increased by .016 to .027 $lb/10^6$ Btu.

Overfire Air

Nitric oxide emissions were not influenced by changes in overfire air pressure when considered at constant excess air.

Fuel Nitrogen

Variations in fuel nitrogen from .75% to 1.50% by weight had no measurable effect on nitric oxide emissions. This may simply reflect difficulties in sorting out the other variables.

Flyash Reinjection

Flyash reinjection from the mechanical dust collector had no measurable effect on nitric oxide emissions.

SULFUR OXIDES

Type of Stoker

The spreader stokers retained an average five percent of the fuel sulfur in the ash, while the mass fired overfeed stokers retained an average two percent. The remainder was emitted as SO_2 and SO_3, with SO_3 comprising less than two percent of the total.

Fuel Sulfur

Although good sulfur balances were difficult to obtain, the data indicates that fuel sulfur conversion efficiencies of 95 to 98% are reasonable assumptions.

CARBON MONOXIDE

Type of Stoker

Spreader stokers emitted lower concentrations of carbon monoxide than traveling grate stokers while firing Eastern bituminous coals. Emissions from three of the spreader stokers were in the range of 50 to 250 ppm at full load. A fourth was in the range of 200 to 600 ppm. By comparison, two traveling grate stokers emitted 50 to 700 ppm CO at full load, and a vibrating grate stoker emitted between 50 and 2000+ ppm CO. The comparison is limited to these seven stokers. Carbon monoxide emissions were not measured on three other stokers due to instrument failure, and a fourth fired only Western coals. At Test Sites L1 through L7, the carbon monoxide concentration was measured with an Orsat analyzer having a minimum detection limit of 0.1% or 1000 ppm. Significantly, the carbon monoxide emissions were below this detection limit on the Site L stokers.

Heat Release Rate

Carbon monoxide emissions were highest at high heat release rates under low excess air conditions, and at low heat release rates under high excess air conditions. At full load, carbon monoxide emissions could be controlled with proper application of combustion air.

Excess Air

Carbon monoxide was more prevalent as excess air dropped below about 30-40% on spreader stokers and about 60% on mass fired overfeed stokers. Carbon monoxide increased gradually as excess air increased above about 60% on spreader stokers and 100% on mass fired overfeed stokers.

Overfire Air

Carbon monoxide emissions were reduced by the increased use of overfire air.

Coal Rank

Carbon monoxide emissions were greatest while firing Western sub-bituminous coals. On one spreader stoker where both an Eastern and a Western coal was fired, the full load Western coal emissions ranged from 163 to 702 ppm and averaged 342 ppm. By comparison, the full load Eastern coal emissions ranged from 33 to 263 ppm and averaged 71 ppm.

Flyash Reinjection

Flyash reinjection from the mechanical dust collector had no measurable effect upon carbon monoxide emissions.

UNBURNED HYDROCARBON

Type of Stoker

Based on limited data, the spreader stokers emitted lower hydrocarbon emissions than the mass fired overfeed stokers. Full load emissions from the spreader stokers ranged from 0 to 15 ppm for Site F and 35 to 41 ppm for Site G. By comparison, the mass fired overfeed stokers emitted between 5 and 112 ppm for Site H and 80 ppm for a single point on Site J.

Heat Release Rate

Unburned hydrocarbons tended to decrease as heat release rate increased on three of four stokers where this emission was measured. On the fourth stoker, the opposite trend was observed.

Excess Air

Unburned hydrocarbon emissions showed little or no correlation with excess air on spreader stokers. On mass fired overfeed stokers, hydrocarbons increased in almost direct proportion to the excess air.

Overfire Air

Unburned hydrocarbons were reduced 82% by increasing the overfire air pressure on one traveling grate stoker. No correlation was found on one spreader stoker. The other two units where hydrocarbon emissions were measured had insufficient data to make a correlation.

Coal Properties

The site firing the lower volatile coal had the lowest hydrocarbon emissions. The 29% volatile coal yielded 19-41 ppm hydrocarbons while the 41% volatile coal yielded 163 to 702 ppm hydrocarbons. Volatiles are expressed here on a dry, mineral matter free basis.

Carbon Monoxide

Unburned hydrocarbons increased with increasing carbon monoxide emissions on one traveling grate stoker. No correlation was found on one spreader stoker.

EXCESS AIR

Type of Stoker

At full load, most spreader stokers were capable of operating at 30% excess air (5% O_2). By comparison, the mass fired overfeed stokers generally required 50% excess air (7% O_2).

Size of Stoker

With one exception, the excess air operating level was inversely proportional to the size of the stoker. The larger the stoker, the lower the excess air requirement.

Heat Release Rate

The excess air requirement drops as heat release rate increases on stoker boilers. The excess air requirement levels off as 30% excess air is approached.

Coal Properties

Coal properties were not found to alter excess air requirements on these stoker boilers.

COMBUSTIBLES IN THE BOTTOM ASH

Type of Stoker

Combustible levels were lower in the bottom ash of spreader stokers than they were for mass fired overfeed stokers or underfeed stokers. The average for each of six spreader stokers fired at full load ranged from 9% to 14%. By comparison, mass fired overfeed stokers ranged from 16% to 26% with one unit averaging 43%, and underfeed stokers ranged from 19 to 25% with one unit averaging 8%.

Heat Release Rate

Heat release rate had very little effect on combustibles in the bottom ash.

Excess Air

No correlation was found between excess air and combustibles in the bottom ash.

Coal Properties

Small differences in bottom ash combustible levels were observed which appeared to be related to coal properties at some sites. However, the particular coal properties causing these differences were not identified.

Ash Balance

It was found that 65% to 85% of the coal ash remained on the grate in spreader stokers as compared to 80% to 90% for mass fired overfeed stokers. For the purposes of computing combustible heat losses, 75% and 85% are good estimates for spreaders and mass fired overfeed stokers, respectively.

COMBUSTIBLES IN THE FLYASH

Type of Stoker

Combustible levels in the flyash were higher in the spreader stokers than in either the mass fired overfeed stokers or the underfeed stokers. With the exception of Test Site C, the spreader stoker data ranged from 47% to 84% and averaged 60%. On the other hand, the mass fired overfeed stoker data ranged from 22% to 56% and averaged 28%. Flyash samples taken from the dust collector hoppers of two underfeed stokers revealed 20.2% and 20.5% combustibles.

Heat Release Rate

Combustibles in the flyash tended to increase slightly as heat release rate increased on spreader stokers. On mass fired overfeed stokers, no significant trend was observed.

Excess Air

No correlation was found between combustibles in the flyash and excess air level on either spreader stokers or mass fired overfeed stokers.

Overfire Air

Increasing overfire air pressure effectively reduced the combustible content of the flyash by an average 40% in 74% of the overfire air tests. This resulted in an average efficiency gain of 1.70% of heat input for spreader stokers and 0.27% of heat input for the mass fired overfeed stokers. 26% of the tests gave the opposite result.

Coal Properties

At Test Site C, the combustibles in the flyash were 2 to 4 times higher while firing an Eastern bituminous coal than while firing a Western sub-bituminous coal. This was the only site where flyash combustibles could be directly related to coal properties. The particular property of the coal responsible for the difference was not identified.

Flyash Reinjection

Combustibles in the flyash at the boiler outlet increased by 23% to 63% when the rate of flyash reinjection was reduced. At the dust collector outlet, similar increases were observed.

Particle Size

The largest flyash particles contain the largest combustible fractions. Flyash samples from two spreader stokers and two mass fired overfeed stokers were analyzed.

BOILER EFFICIENCY

Type of Stoker

Boiler efficiencies were determined by the ASME Abbreviated Efficiency Test (PTC 4.1). At or near full load, the measured boiler efficiencies ranged from 72.5 to 83.5% for six spreader stokers, 71.0 to 84.8% for seven mass fired overfeed stokers, and 64.1 to 76.8 for five mass fired underfeed stokers.

Heat Release Rate

In most cases, boiler efficiencies were relatively constant with changing heat release rates. At a few sites, efficiency dropped as heat release rate dropped because increasing dry gas heat losses predominated.

Excess Air

Boiler efficiency decreased as excess air increased on all of the extensively tested stokers. Dry gas heat losses dominated this trend, overshadowing any effects due to combustible heat losses. For each 10% excess air decrease, boiler efficiency increased by .33% to 1.0%.

Overfire Air

Boiler efficiency improved by an average one percent when overfire air was increased on spreader stokers as a result of reduced carbon carryover. However, on mass fired overfeed stokers, efficiency was reduced by an average 2.75% when overfire air was increased due to increased dry gas losses and increased bottom ash combustible heat losses.

Coal Properties

Coal properties affected boiler efficiencies on two occasions. At Test Site C, the high moisture western coal produced efficiencies which were 3 to 4% lower than similar tests on low moisture eastern coals. At Test Site K, the unwashed coal produced lower boiler efficiencies than either of the others because this coal led to a greater combustible heat loss.

Flyash Reinjection

Some but not all of the carbon in the reinjected flyash was recovered at Site A, B and C. There was insufficient data to calculate carbon recovery rates with any accuracy.

TABLE 2

RANGE OF DATA ENCOUNTERED AT HIGH LOAD*

	Spreader Stokers With Reinjection from Dust Collectors **	Spreader Stokers W/O Reinjection from Dust Collectors	Mass Fired Overfeed Stokers	Mass Fired Underfeed Stokers
Uncontrolled Particulate, $lb/10^6$ Btu	12.7 - 36.4	2.1 - 8.8	0.57 - 2.2	0.25 - 0.71
Controlled Particulate, $lb/10^6$ Btu	0.60 - 3.5	.17 - 3.8	0.11 - 0.75	0.46 - 0.58
Mechanical Collector Efficiency, %	94.9 - 98.0	40.6 - 96.0	10.9 - 92.7	26.6 - 42.9
Excess Air, %	18 - 113	19 - 82	30 - 97	33 - 186
Nitric Oxide, $lb/10^6$ Btu as NO_2	.30 - .60	.36 - .61	.21 - .50	No Data
Carbon Monoxide, ppm dry @ 3% O_2	22 - 1600	33 - 702	39 - 2300	<1000
Unburned Hydrocarbons, ppm wet @ 3% O_2	No Data	0 - 41	5 - 112	No Data
Combustibles in Flyash, %	7.1 - 65.6	26.6 - 83.5	21.8 - 56.0	20.2 - 20.5
Combustibles in Bottom Ash, %	0.0 - 34.4	0.3 - 27.2	7.1 - 69.1	8.1 - 25.0
Flyash Combustibles Heat Loss, %	.54 - 5.5	.51 - 9.2	.26 - 1.1	.07 - .21
Bottom Ash Combustibles Heat Loss, %	.00 - 3.0	.04 - 3.4	.42 - 8.1	1.2 - 3.9
Boiler Efficiency, %	75.79 - 83.43	73.59 - 83.94	69.75 - 84.10	64.13 - 76.81

* Underfeed Stokers were Tested at Loads Ranging from 55-100% of Capacity. Data from the other Stokers were Obtained within the Upper 10% of the Obtainable Load Range.

** Does not Include Tests in which Reinjection from the Mechanical Collector was Reduced.

DIFFERENCES BETWEEN STOKER TYPES

It may be constructive to compare the differences in emissions among the several types of stokers included in the program. These are covered as follows:

Excess Air

At full load, most spreader stokers were capable of operating at 30% excess air (5% O_2). By comparison, the mass fired overfeed stokers generally required 50% excess air (7% O_2).

With one exception, the excess air operating level was inversely proportional to the size of the stoker. The larger the stoker, the lower the excess air requirement.

Particulate Loading

Spreader stokers with flyash reinjection from their mechanical dust collectors had by far the highest uncontrolled particulate loadings, ranging from 13 to 36 lb/10^6 Btu. Spreader stokers without reinjection from their dust collectors were next with emissions of 2.1 to 8.8 lb/10^6 Btu, followed by mass fired overfeed stokers with .57 to 2.2 lb/10^6 Btu and underfeed stokers with .25 to .71 lb/10^6 Btu.

Combustibles in the Flyash

Combustible levels in the flyash were higher in the spreader stokers than in either the mass fired overfeed stokers or the underfeed stokers. With the exception of Test Site C, the spreader stoker data ranged from 47% to 84% and averaged 60%. On the other hand, the mass fired overfeed stoker data ranged from 22% to 56% and averaged 28%. Flyash samples taken from the dust collector hoppers of two underfeed stokers revealed 20.2% and 20.5% combustibles.

Combustibles in the Bottom Ash

Combustible levels were lower in the bottom ash of spreader stokers than they were for mass fired overfeed stokers or underfeed stokers. The average for each of six spreader stokers fired at full load ranged from 9% to 14%. By comparison, mass fired overfeed stokers ranged from 16% to 26% with one unit averaging 43%, and underfeed stokers ranged from 19 to 25% with one unit averaging 8%.

Sulfur Oxides

The spreader stokers retained an average five percent of the fuel sulfur in the ash, while the mass fired overfeed stokers retained an average two percent. The remainder was emitted as SO_2 and SO_3, with SO_3 comprising less than two percent of the total.

Nitric Oxide

As a class, spreader stokers emitted higher concentrations of nitric oxide than did mass fired overfeed stokers. Under full load conditions, spreader stokers emitted between .30 and .61 lb/10^6 Btu NO_x corrected to NO_2 while mass fired overfeed stokers emitted between .21 and .50 lb/10^6 Btu NO_x. However, overfeed stokers operated at higher excess air levels than did spreader stokers. When compared at the same excess air levels the difference in NO_x levels is even greater.

Carbon Monoxide

Spreader stokers emitted lower concentrations of carbon monoxide than traveling grate stokers while firing Eastern bituminous coals. Emissions from three of the spreader stokers were in the range of 50 to 250 ppm at full load. A fourth was in the range of 200 to 600 ppm. By comparison, two traveling grate stokers emitted 50 to 700 ppm CO at full load, and a vibrating grate stoker emitted between 50 and 2000+ ppm CO. The comparison is limited to these seven stokers. Carbon monoxide emissions were not measured on three other stokers due to instrument failure, and a fourth fired only Western coals. At Test Sites L1 through L7, the carbon monoxide concentration was measured with an Orsat analyzer having a minimum detection limit of 0.1% or 1000 ppm. Significantly, the carbon monoxide emissions were below this detection limit on the Site L stokers.

Unburned Hydrocarbons

Based on limited data, the spreader stokers emitted lower hydrocarbon emissions than the mass fired overfeed stokers. Full load emissions from the spreader stoker ranged from 0 to 15 ppm for Site F and 35 to 41 ppm for Site G. By comparison, the mass fired overfeed stokers emitted between 5 and 112 ppm for Site H and 80 ppm for a single point on Site J.

Boiler Efficiency

Boiler efficiencies were determined by the ASME Abbreviated Efficiency Test (PTC 4.1). At or near full load, the measured boiler efficiencies ranged from 72.5 to 83.5% for six spreader stokers, 71.0 to 84.8% for seven mass fired overfeed stokers, and 64.1 to 76.8 for five mass fired underfeed stokers.

CONCLUSION

Results of the test program have been summarized in this paper. More complete details will be available in a final report titled "Emissions and Efficiency Performance of Industrial Coal Stoker Fired Boilers" which will be published by EPA and available early this summer. Availability of individual site reports are shown in Appendix A. Table 2 displays the range of data obtained from the project.

These data represent averages by site therefore, the lowest number represents the lowest average while the highest numbers represent the highest average. Care must be taken in utilizing this data which only summarizes the extensive tests. The reader is directed to the site reports, their data supplements and the final report for complete data and conclusions.

This paper does not mention the names of the equipment manufacturers. The authors felt that such information could lead to false association of unit performance with a specific manufacturer when, in fact, unit performance can relate to any number of variables including fuel properties and operating procedures. Any superficial association between unit performance and manufacturer would be a grievous mistake.

Two additional reports are being prepared by ABMA under this contract. One report will be addressed to stoker boiler operators, identifying operating procedures which lead to increased combustion efficiency and reduced emissions. The other report will summarize the results of EPA Level 1 chemical analysis on test sites A through K for polynuclear aromatic hydrocarbons and trace elements. These will be available later this year.

NOTE TO EDITORS

CONTROL OF GASEOUS POLLUTANTS FROM INDUSTRIAL COMBUSTION BY CHEMICAL REACTION

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