Boiler Tune-up for Boiler MACT Compliance and Combustion Improvements

Comparative Study

Sept, 2016

AECOM

Overview

In this presentation, several recent Boiler MACT boiler tune-up projects are summarized, one of which involved three small natural gas fired boilers which were straightforward and involved minimal tuning with no problems encountered. In the second, two multi-fuel fired grate boilers required more extensive tuning, and one of these was equipped with an SNCR that required additional tuning for some off-design operation. While the improved reliability on the gas fired boilers is minimal, the multi-fuel boilers offer immense opportunity for reliability enhancements. This presentation draws a stark contrast between a simple Boiler MACT tune-up and the more complex multi-fuel fired Boiler MACT tune-ups that require additional tuning to meet the current off-design operation, and demonstrates the wide variety of effort that may be required to satisfy the annual Boiler MACT tuning requirements and the benefits of Combustion tuning.

Boiler MACT Requirements

- EPA's Boiler MACT requires Industrial, Commercial, and Institutional Boilers and Process Heaters to meet National Emission Standards for Hazardous Air Pollutants, including CO, PM, mercury, and HCl. Boiler MACT prescribes boiler emission limits, operating limits, and work practice standards including an inspection and boiler tune-up.
- The primary objective of the boiler tune-up is to assure the combustion quality to minimize emissions of organic gases.

Boiler MACT Requirements

- In practice, this requires the owner to optimize the boiler efficiency for heat rate improvement and lower carbon monoxide (CO) emissions.
- The inspection makes sure that the firing equipment is in good operating condition, and that no mechanical issues are found with the combustion equipment or related auxiliary systems which could adversely affect the emissions performance.

Comparing the Three T's of Combustion for tuning Natural Gas vs Multi-Fuel Grate Boiler

Time-Temperature-Turbulence (3 T's)

Natural Gas Fired boilers

1. No fuel handling or disruption problems
2. No complex metering system for fuel
3. No distribution problems
4. No fuel consistency problems
5. Tuning straight forward

Adjusting for combustion is simply a matter of balancing gas flow and secondary air for obtaining optimal residence time, uniform temperature, and perfect turbulence for complete combustion.

Comparing the Three T's of Combustion for tuning Natural Gas vs Multi-Fuel Grate Boiler

Time-Temperature-Turbulence (3 T's)

Multi-Fuel Grate Fired boilers

1. Fuel handling or disruption problems
2. Complex metering system for fuel
3. Distribution problems
4. Fuel consistency problems
5. Tuning is much more complex

As a result of all these problems, a 4th *" T "* must be added for combustion tuning – *TRENDING.*

The 4th T - Trending

It is not enough to simply make an adjustment and assume that the grate will maintain the optimum combustion conditions while the fuel moisture is changing and fuel feed system is having problems. This is where the 4th T – Trending becomes an integral part of the combustion tuning process.

The interactive process of adjusting grate speed, fuel feed, under-grate and above-grate air flow, OFA flow, and under-grate pressure require historical trends to effectively tune combustion. This historical interaction between all these parameters must be monitored empirically to predict the current combustion conditions. These trends will demonstrate how the operator makes adjustments to compensate for these upset conditions and how the boiler reacts to these changes.

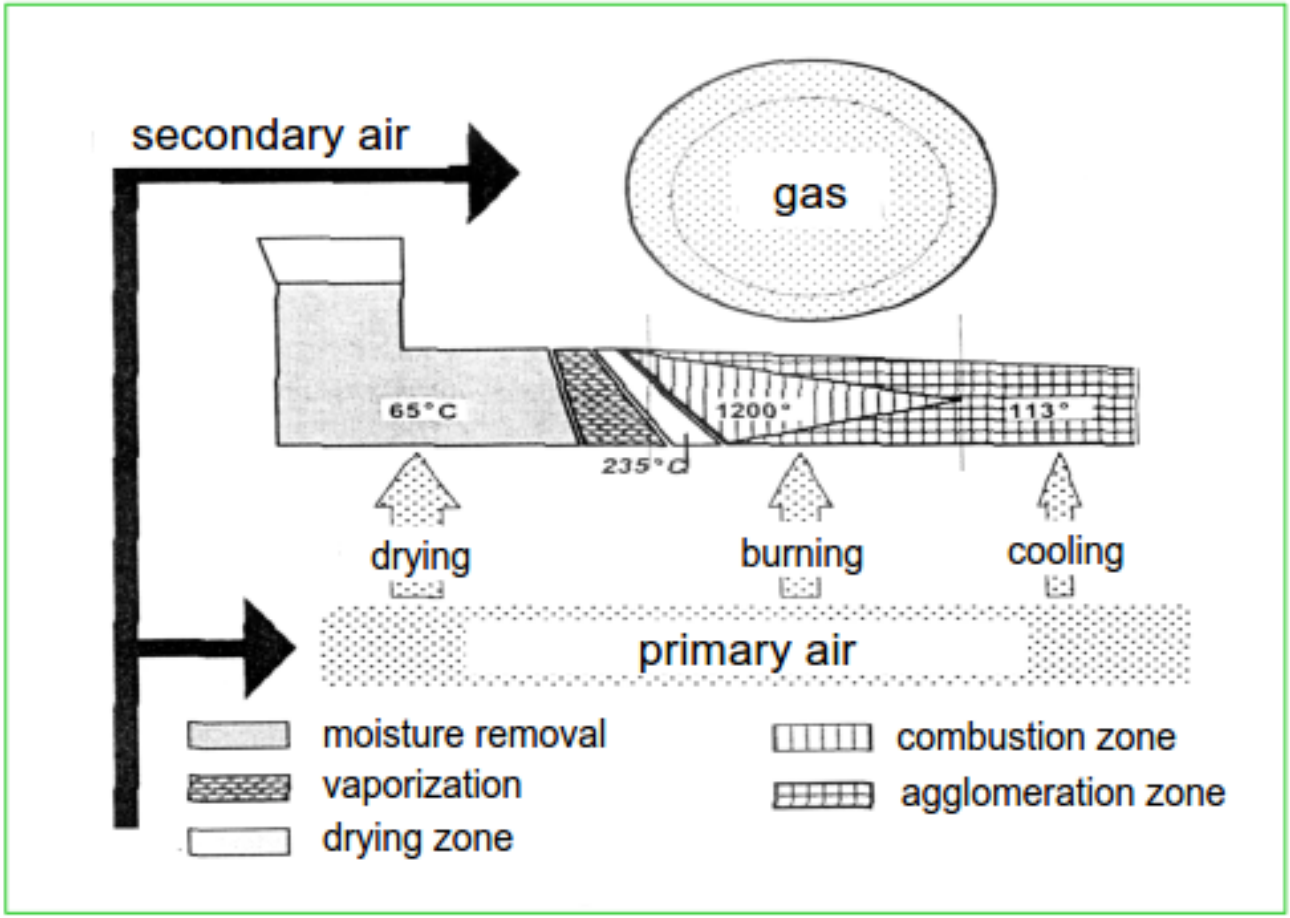
Will can now review the some Boiler MACT reports and more Combustion Theory ……

More Combustion Theory on Grate Boilers

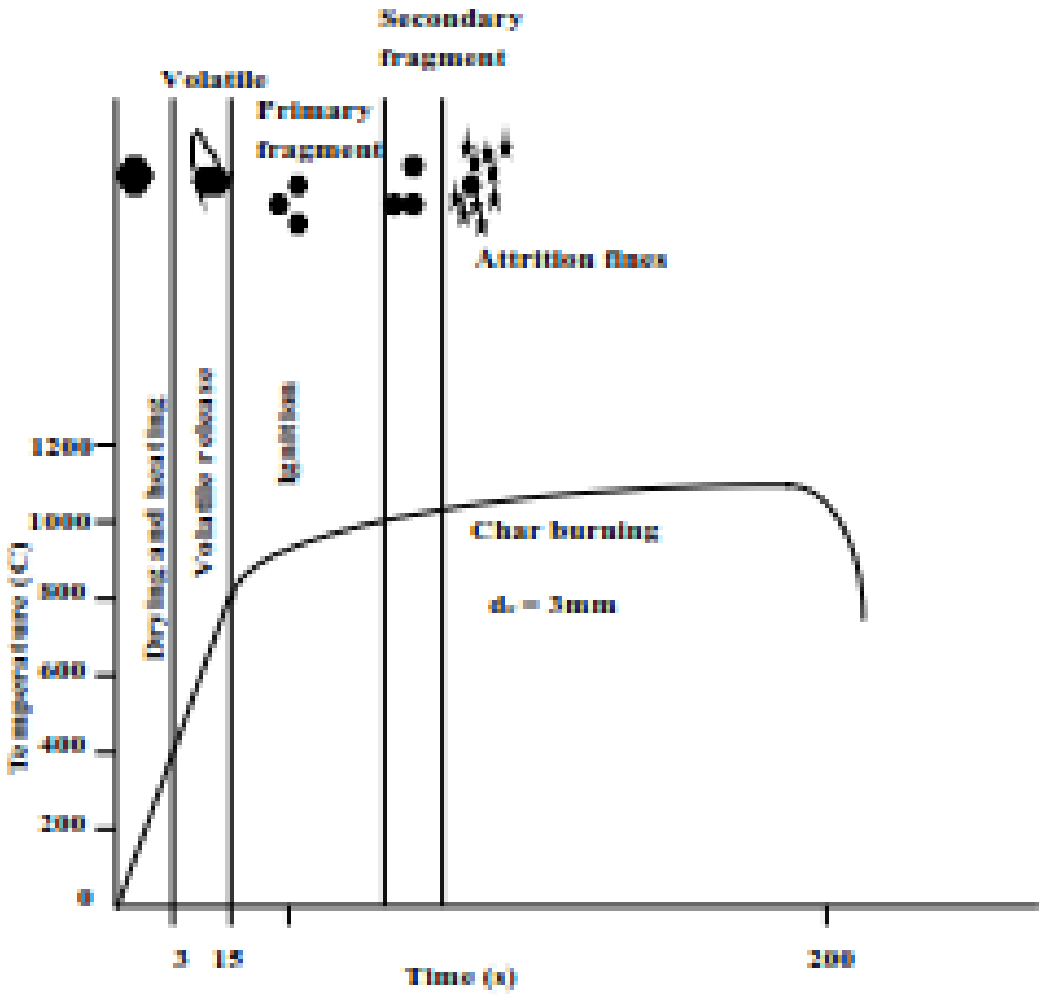
The two major zones of Combustion

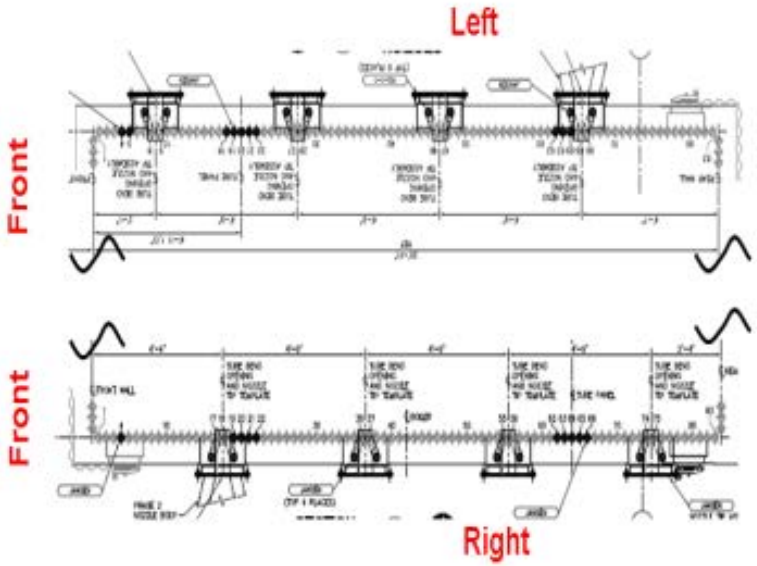
- The Primary Zone is where the combustion is taking place on the surface of the grate
  - To control the grate temperature we use Primary Air
  - Fuel feed
  - Where the majority of fuel is burned to support combustion
- The Secondary Zone or Heat Release Area
  - Controlled by Over-fire Air and Above Grate Air
  - Where emissions for CO and NOx are controlled

Zones of combustion on grate



Stages of combustion

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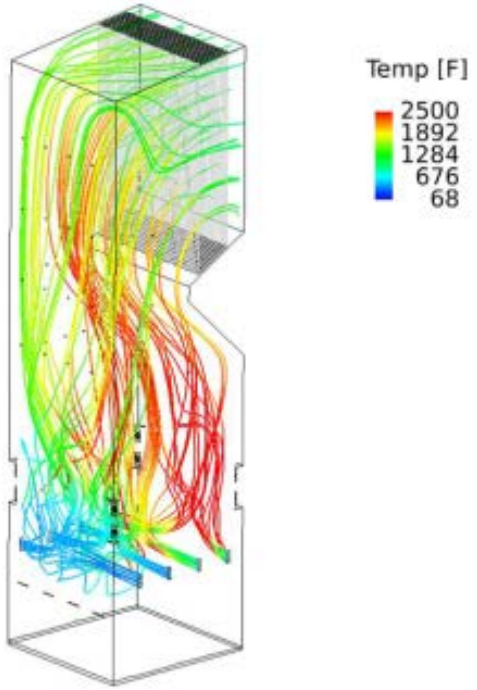
Temp [F]
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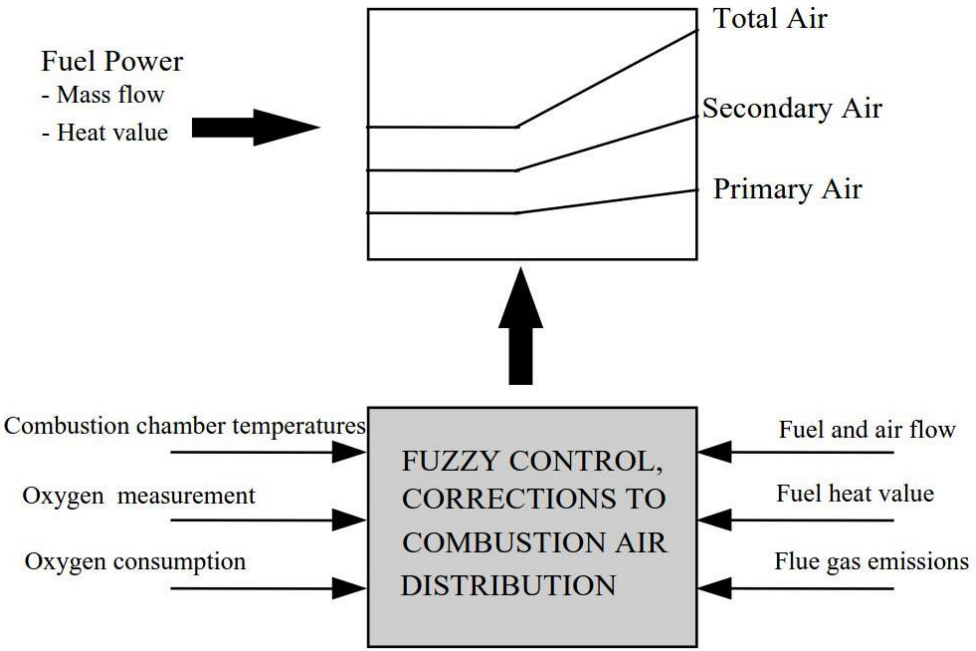
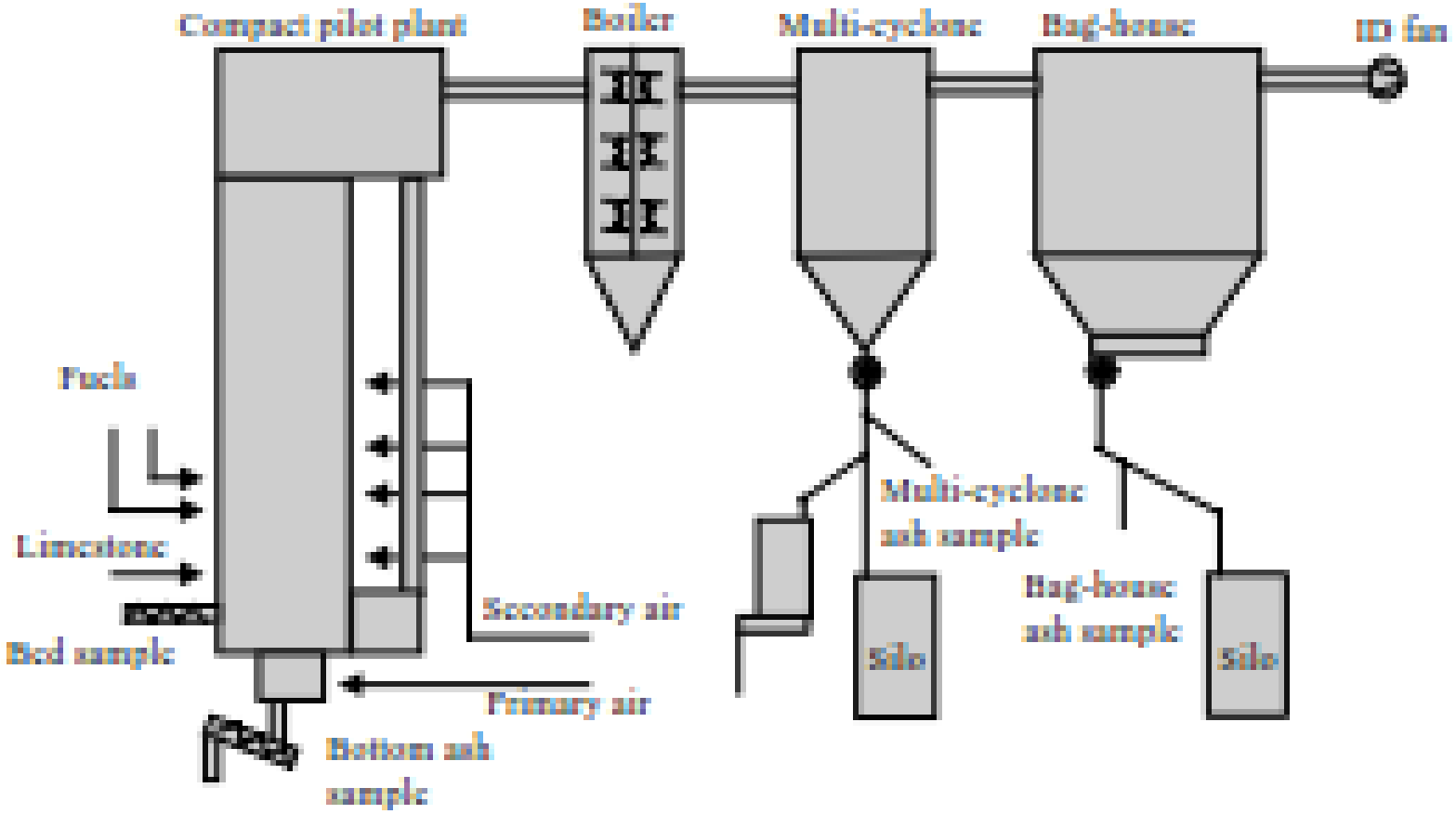
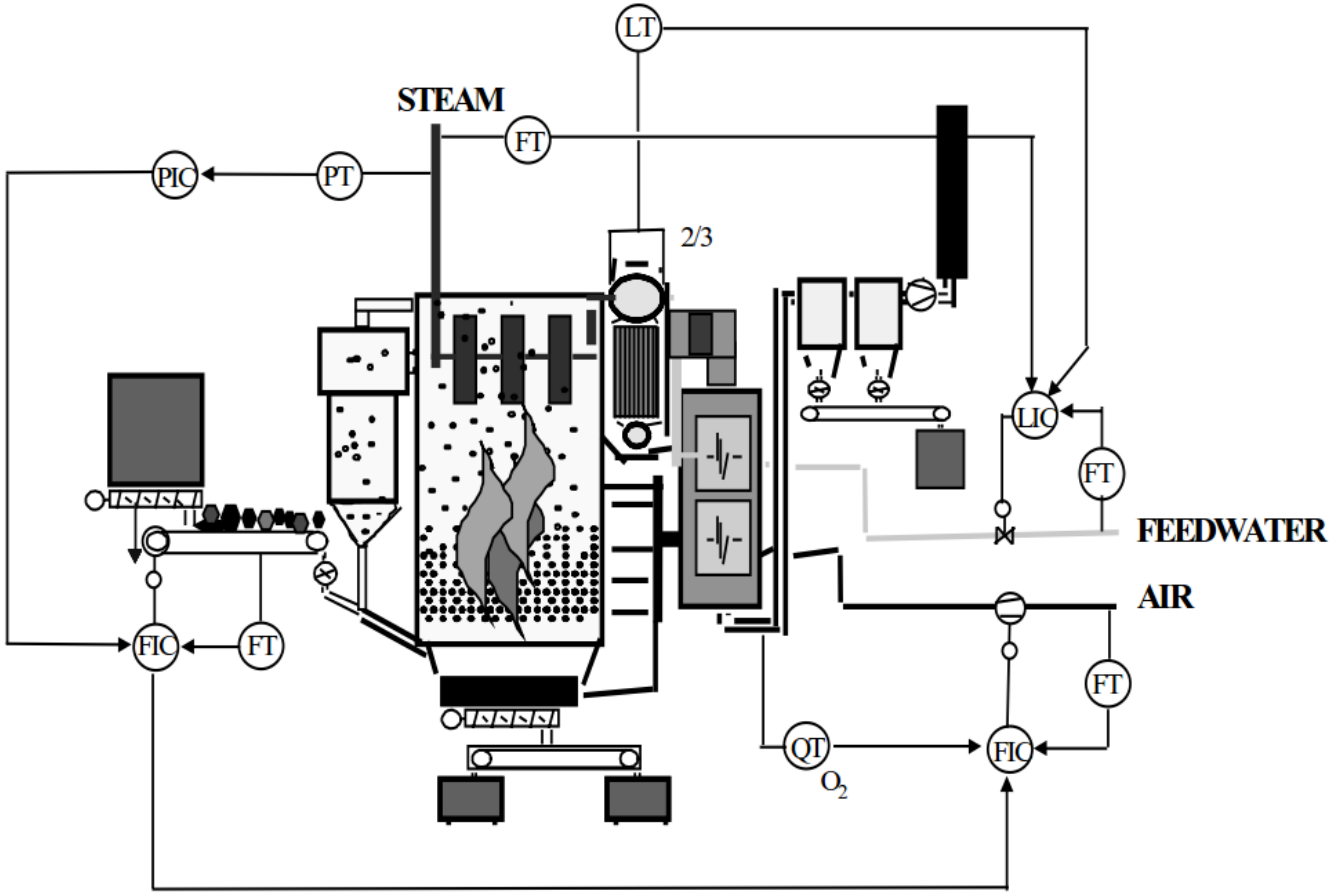
68


Fuel Power
- Mass flow
- Heat value
Total Air
Secondary Air
Primary Air
Combustion chamber temperatures
Oxygen measurement
Oxygen consumption
FUZZY CONTROL, CORRECTIONS TO COMBUSTION AIR DISTRIBUTION
Fuel and air flow
Fuel heat value
Flue gas emissions


Compact pilot plant
Boiler
Multi-cyclone
Bag-house
ID fan
Fuels
Limestone
Bed sample
Secondary air
Primary air
Bottom ash sample
Multi-cyclone ash sample
Silo
Bag-house ash sample
Silo


LT
STEAM
FT
PIC
PT
2/3
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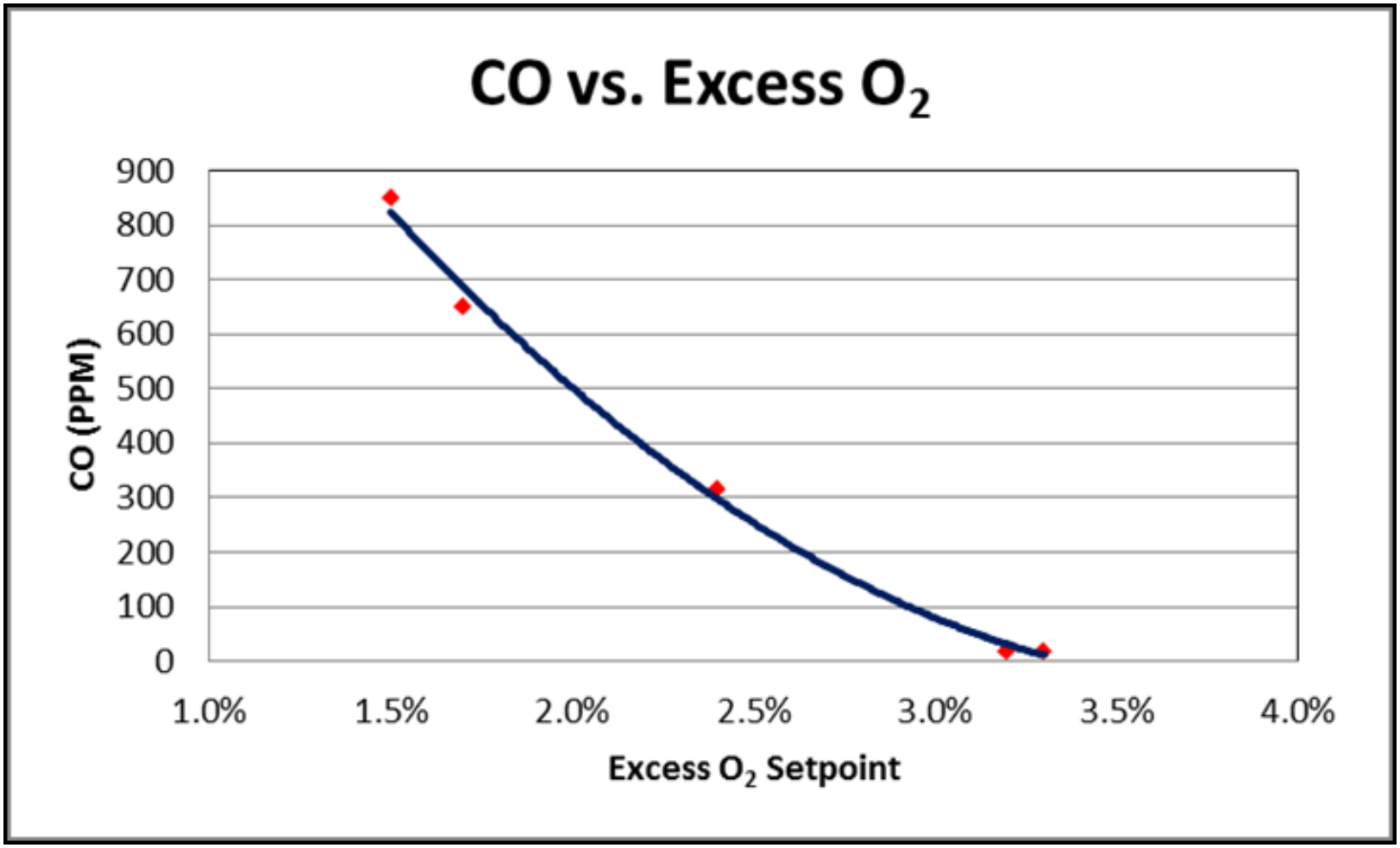
FT
FEEDWATER
AIR
FIC
FT
FT
QT
FIC
O_2

Boiler MACT Reports - Natural Gas Fired

40 CFR 63.7540(a)(10) Requirement(s)	Report Section
(i) Burner Inspections	• Boiler Equipment Overview • Boiler MACT Tune-up Checklist
(i) Flame Pattern Inspection	• Boiler Equipment Overview • Boiler MACT Tune-up Checklist
(i) Air-to-fuel Control System	• Boiler MACT Tune-up Checklist
(i) CO Emissions Optimization	• Boiler Equipment Overview • Optimization Conclusions
(i) CO Measurements	• Boiler Tune-up Summary • Boiler MACT Tune-up Checklist
(i) Report with before/after CO concentrations, corrections actions taken if any, type and amount of fuel used over preceding 12-month period	• Boiler MACT Tune-up Checklist • Test Conditions • January 2015 – December 2015 Boilers 6,7, and 9 Fuel Consumption

Boiler MACT Reports – Natural Gas Fired



Boiler MACT Reports – Natural Gas Fired

Boiler MACT Tune Up Checklist		
UNIT **Power Boiler 6** WO# _____ Date(s) of Inspection 1/8/2016 Person(s) performing Inspection Aletto (AECOM) If unit not operating on required date of tune-up, indicate as such under Observations.		
Component Inspected	**Observations**	**Corrective Actions, if required**
Burners (clean or replace components)	Inspected during the outage and checked during startup	No adjustments required
Flame Pattern (make adjustments for optimization)	Good ignition point and excellent flame pattern	No adjustments required
Air-to-Fuel Ratio (Calibrated & functioning per the manufacturer's recommendations?)	Excess air was adjusted for optimal CO readings using the Testo 340XL	CO was optimized above 2.5% O2 when firing 100% Natural Gas and CO < 10ppm
Measure CO concentration in the effluent stream corrected to 3% O_2 before tuning:	CO concentration ppm_{vd} at stack O_2: <11ppm Stack oxygen concentration %: 3% CO ppm_{vd} corrected to 3% O_2: 11 ppm	
Measure CO concentration in the effluent stream corrected to 3% O_2 after tuning:	CO concentration ppm_{vd} at stack O_2: 0 ppm Stack oxygen concentration %: 5.5 % CO ppm_{vd} corrected to 3% O_2: 0 ppm	

Boiler MACT Reports – Natural Gas Fired

Boiler MACT Tune Up Checklist

UNIT **Power Boiler 7** WO# _____

Date(s) of Inspection 1/9/2016

Person(s) performing Inspection Aletto (AECOM)

If unit not operating on required date of tune-up, indicate as such under Observations.

Component Inspected	Observations	Corrective Actions, if required
Burners (clean or replace components)	Inspected during the outage and checked during startup	No adjustments required
Flame Pattern (make adjustments for optimization)	Good ignition point and excellent flame pattern	No adjustments required
Air-to-Fuel Ratio (Calibrated & functioning per the manufacturer's recommendations?)	Excess air was adjusted for optimal CO readings using the Testo 340XL	CO was optimized above 2.5% O2 when firing 100% Natural Gas and CO < 10ppm
Measure CO concentration in the effluent stream corrected to 3% O_2 before tuning:	CO concentration ppm_{vd} at stack O_2: <28ppm Stack oxygen concentration %: 5.5% CO ppm_{vd} corrected to 3% O_2: 33 ppm	
Measure CO concentration in the effluent stream corrected to 3% O_2 after tuning:	CO concentration ppm_{vd} at stack O_2: 0 ppm Stack oxygen concentration %: 6 % CO ppm_{vd} corrected to 3% O_2: 0 ppm	

Boiler MACT Reports – Natural Gas Fired

Boiler MACT Tune Up Checklist

UNIT **Power Boiler 9** WO# _____

Date(s) of Inspection 1/13/2016

Person(s) performing Inspection Aletto (AECOM)

If unit not operating on required date of tune-up, indicate as such under Observations.

Component Inspected	Observations	Corrective Actions, if required
Burners (clean or replace components)	Inspected during the outage and checked during startup	No adjustments required
Flame Pattern (make adjustments for optimization)	Good ignition point and excellent flame pattern	No adjustments required
Air-to-Fuel Ratio (Calibrated & functioning per the manufacturer's recommendations?)	Excess air was adjusted for optimal CO readings using the Testo 340XL	CO was optimized above 2.5% O2 when firing 100% Natural Gas and CO < 10ppm
Measure CO concentration in the effluent stream corrected to 3% O_2 before tuning:	CO concentration ppm_{vd} at stack O_2: <30 ppm Stack oxygen concentration %: 7.1 % CO ppm_{vd} corrected to 3% O_2: 39 ppm	
Measure CO concentration in the effluent stream corrected to 3% O_2 after tuning:	CO concentration ppm_{vd} at stack O_2: 0 ppm Stack oxygen concentration %: 9.74 % CO ppm_{vd} corrected to 3% O_2: 0 ppm	

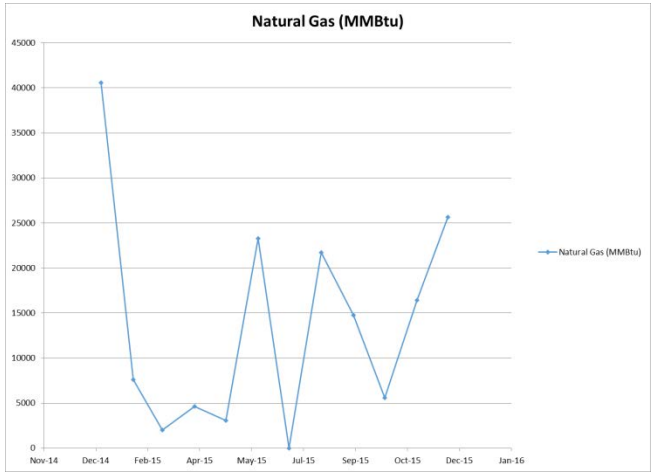
Boiler MACT Reports – Natural Gas Fired

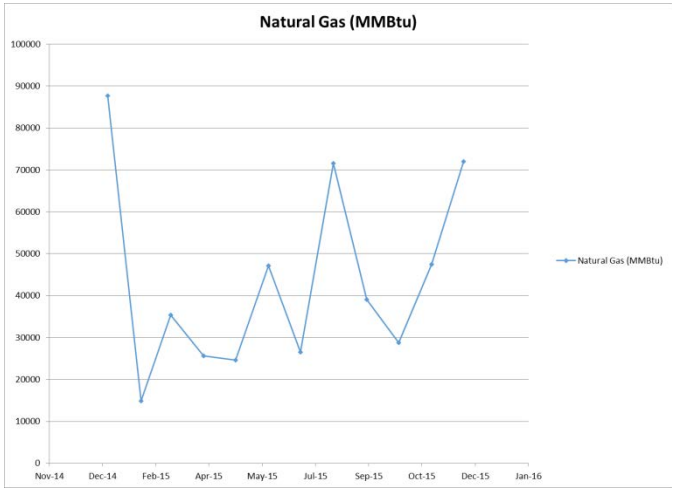
PB 6	Natural Gas (MMBtu)
January 2015	40556
February 2015	7604
March 2015	1990
April 2015	4649
May 2015	3052
June 2015	23287
July 2015	0
August 2015	21743
September 2015	14751
October 2015	5574
November 2015	16421
December 2015	25660
12-Month Total	165291

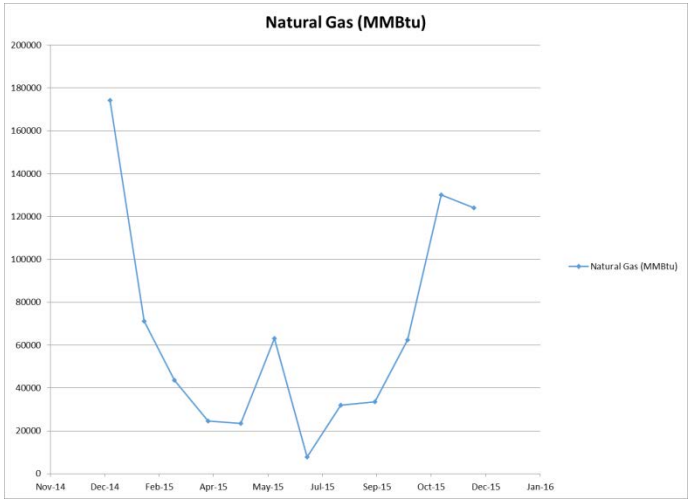
PB 7	Natural Gas (MMBtu)
January 2015	87704
February 2015	14878
March 2015	35391
April 2015	25596
May 2015	24611
June 2015	47197
July 2015	26476
August 2015	71524
September 2015	39054
October 2015	28796
November 2015	47441
December 2015	72027
12-Month Total	520693

PB 9	Natural Gas (MMBtu)
January 2015	174280
February 2015	71285
March 2015	43629
April 2015	24653
May 2015	23512
June 2015	63048
July 2015	7804
August 2015	31989
September 2015	33622
October 2015	62405
November 2015	130190
December 2015	124087
12-Month Total	790504

Natural Gas Boilers 6,7, and 9 – Fuel







Boiler MACT Reports –Multi-Fuel Grate Boiler

40 CFR 63.7540(a)(10) Requirement(s)	Report Section
(i) Grate Inspections	• Boiler Equipment Overview • Boiler MACT Tune-up Checklist
(i) Combustion Distribution Pattern Inspection	• Boiler Equipment Overview • Boiler MACT Tune-up Checklist
(i) Air-to-fuel Control System	• Boiler MACT Tune-up Checklist
(i) CO Emissions Optimization	• Boiler Equipment Overview • Optimization Conclusions
(i) CO Measurements	• Boiler Tune-up Summary • Boiler MACT Tune-up Checklist
(i) Report with before/after CO concentrations, corrections actions taken if any, type and amount of fuel used over preceding 12-month period	• Boiler MACT Tune-up Checklist • Test Conditions • June 2015 – May 2016 Boiler 11 Fuel Consumption

Boiler MACT Reports –Multi-Fuel Grate Boiler

Boiler MACT Tune Up Checklist

UNIT **Power Boiler 11** WO# _____

Date(s) of Inspection 6/25/2016

Person(s) performing Inspection Aletto (AECOM)

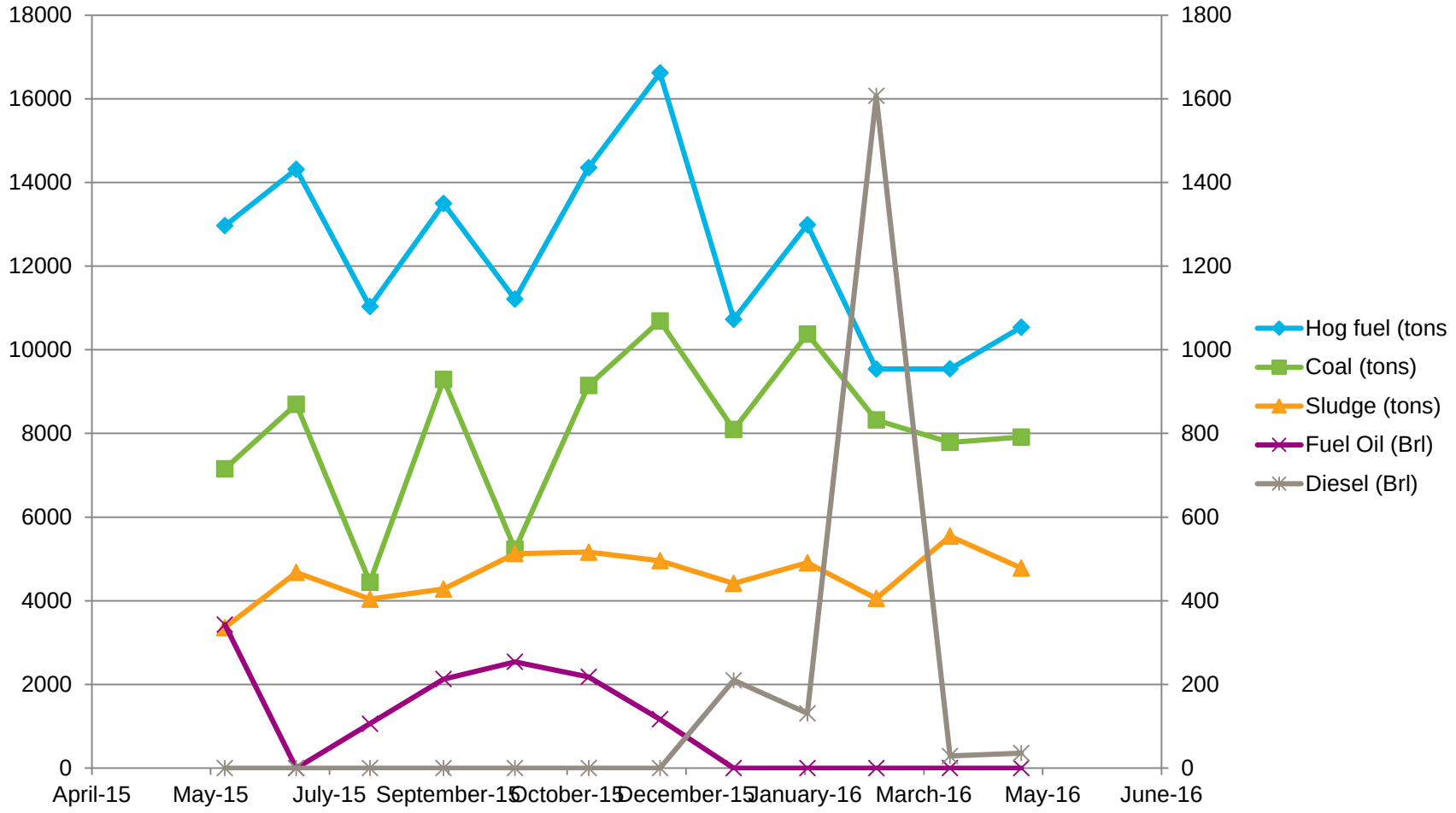
If unit not operating on required date of tune-up, indicate as such under Observations.

Component Inspected	Observations	Corrective Actions, if required
Grates (clean or replace components)	Visually Inspected during the operation at several different load ranges.	Should be inspected during the fall outage and any damage repaired
Bed Depth (make adjustments for optimization)	Grate speed could be increased slightly to reduce CO at higher steam flows	Monitor grate temperatures during operation and adjust the grate speed
Air-to-Fuel Ratio (Calibrated & functioning per the manufacturer's recommendations?)	Excess air was adjusted for optimal CO readings using the Testo 340	CO was optimized above 4% O2 when firing coal and biomass and CO fluctuated between 100 ppm and 300 ppm
Measure CO concentration in the effluent stream corrected to 3% O_2 before tuning:	CO concentration ppm_{vd} at stack O_2: <3000ppm >1000 Stack oxygen concentration %: 5 % CO ppm_{vd} corrected to 3% O_2: 3377 ppm	
Measure CO concentration in the effluent stream corrected to 3% O_2 after tuning:	CO concentration ppm_{vd} at stack O_2: < 200 ppm Stack oxygen concentration %: 7 % CO ppm_{vd} corrected to 3% O_2: 257 ppm	

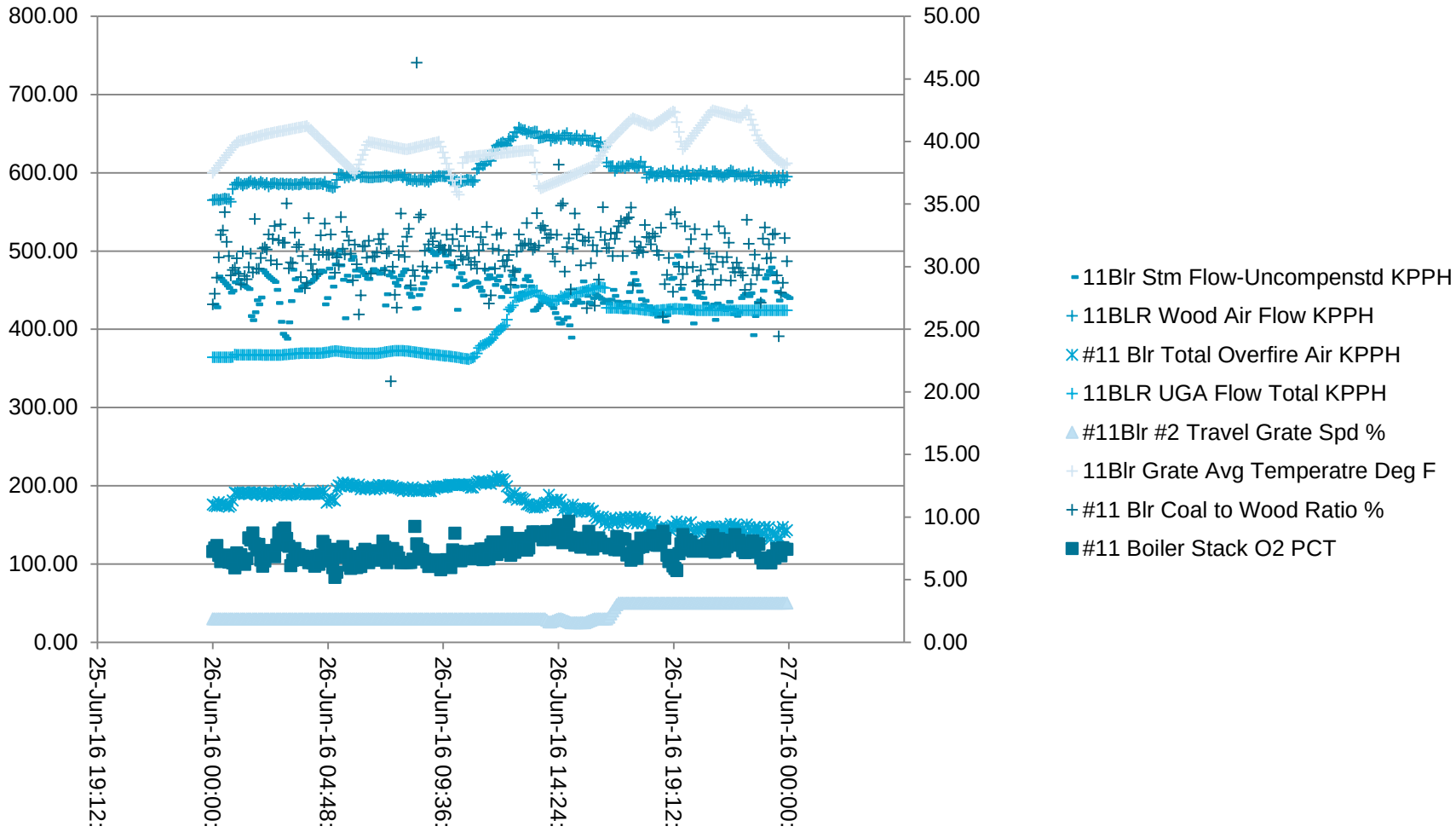
Boiler MACT Reports –Multi-Fuel Grate Boiler

	Hog Fuel (tons)	*Coal (tons)*	*Sludge (tons)*	*Fuel Oil (barrels)*	*Diesel (Barrels)*
June 2015	12966	7155	3359	343	0
July 2015	14316	8697	4677	0	0
August 2015	11033	4443	4040	106	0
September 2015	13496	9287	4281	213	0
October 2015	11208	5233	5128	254	0
November 2015	14353	9149	5164	218	0
December 2015	16616	10690	4957	117	0
January 2016	10730	8093	4415	0	210
February 2016	12989	10375	4908	0	131
March 2016	9540	8321	4057	0	1607
April 2016	9544	7785	5544	0	29
May 2016	10538	7912	4780	0	36

Boiler MACT Reports –Multi-Fuel Grate Boiler



Boiler MACT Reports –Multi-Fuel Grate Boiler



Boiler MACT Reports –Multi-Fuel Grate Boiler

Looking at the trends we were able to keep the stack O2 the same but went from >3000 ppm CO to < 200 ppm

1. Decreased the bed height, which increase grate temperature and decreased CO
2. Increased the OFA air flow and decreased the under-grate air the same portion which decreased CO
3. Since NOx compliance was not a concern the incremental increase in NOx was not an issue in this report

***** Please note that the other Multi-Fuel Grate Boiler has a SNCR and has a stringent NOx requirement of < .13 lbs/mmbtu ******

Boiler MACT Reports –Multi-Fuel Grate Boiler with Mobotec SNCR

40 CFR 63.7540(a)(10) Requirement(s)	Report Section
(i) Burner Inspections	• Boiler Equipment Overview • Boiler MACT Tune-up Checklist
(i) Flame Pattern Inspection	• Boiler Equipment Overview • Boiler MACT Tune-up Checklist
(i) Air-to-fuel Control System	• Boiler MACT Tune-up Checklist
(i) CO Emissions Optimization	• Boiler Equipment Overview • Optimization Conclusions
(i) CO Measurements	• Boiler Tune-up Summary • Boiler MACT Tune-up Checklist
(i) Report with before/after CO concentrations, corrections actions taken if any, type and amount of fuel used over preceding 12-month period	• Boiler MACT Tune-up Checklist • Test Conditions • October 2014 – September 2015 20 Boiler Fuel Consumption

Boiler MACT Reports –Multi-Fuel Grate Boiler with Mobotec SNCR

Boiler MACT Tune Up Checklist

UNIT **Power Boiler 11** WO# _____

Date(s) of Inspection 6/25/2016

Person(s) performing Inspection Aletto (AECOM)

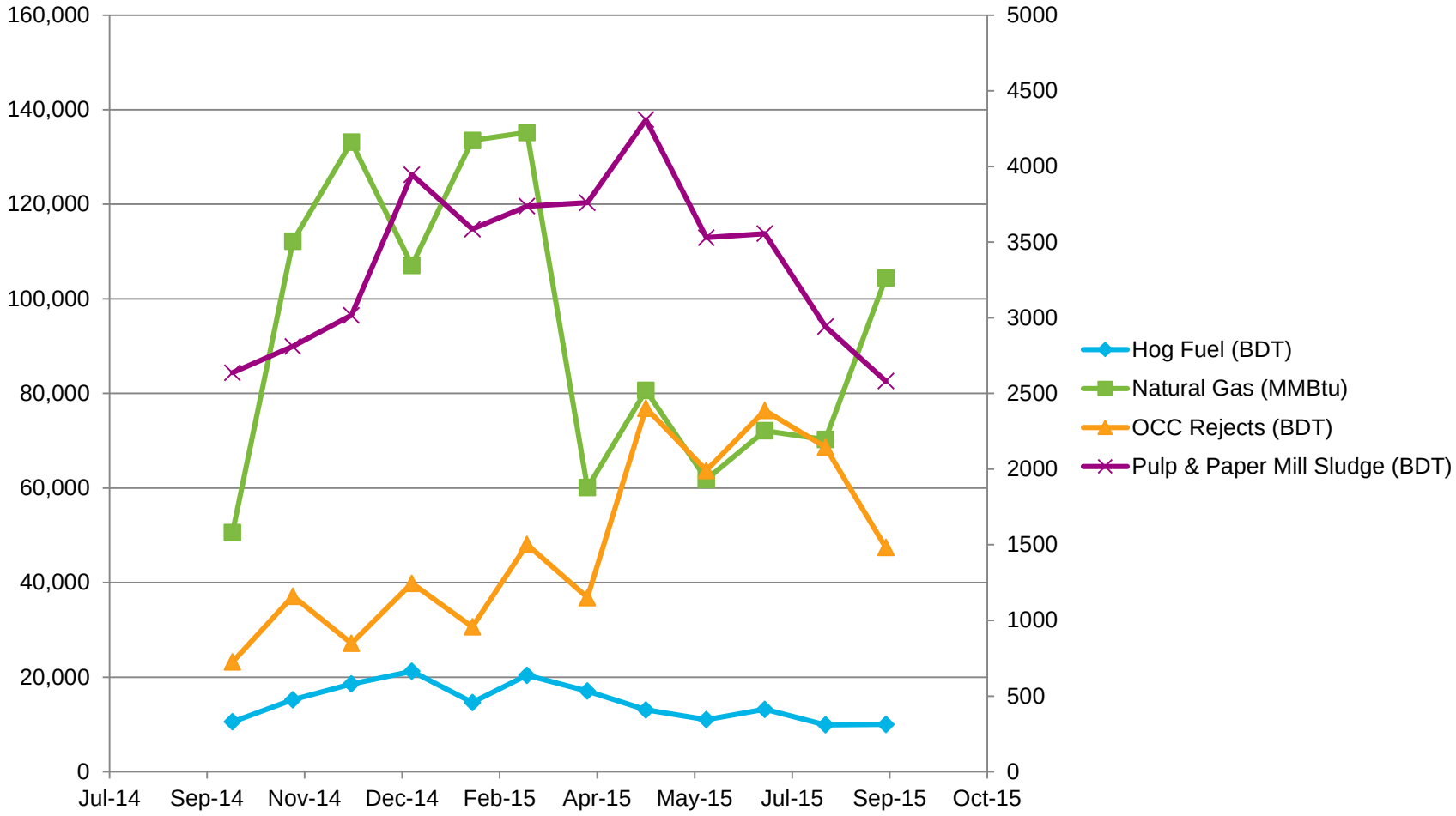
If unit not operating on required date of tune-up, indicate as such under Observations.

Component Inspected	Observations	Corrective Actions, if required
Grates (clean or replace components)	Visually Inspected during the operation at several different load ranges.	Should be inspected during the fall outage and any damage repaired
Bed Depth (make adjustments for optimization)	Grate speed could be increased slightly to reduce CO at higher steam flows	Monitor grate temperatures during operation and adjust the grate speed
Air-to-Fuel Ratio (Calibrated & functioning per the manufacturer's recommendations?)	Excess air was adjusted for optimal CO readings using the Testo 350xl	CO was optimized above 4% O2 when firing biomass and natural gas and CO dropped to < 20 when operating at 100% natural gas
Measure CO concentration in the effluent stream corrected to 3% O_2 before tuning:	CO concentration ppm_{vd} at stack O_2: >500 ppm Stack oxygen concentration %: 10.5 % CO ppm_{vd} corrected to 3% O_2: 861 ppm	
Measure CO concentration in the effluent stream corrected to 3% O_2 after tuning:	CO concentration ppm_{vd} at stack O_2: < 10 ppm Stack oxygen concentration %: 12.5 % CO ppm_{vd} corrected to 3% O_2: 0 ppm	

Boiler MACT Reports –Multi-Fuel Grate Boiler with Mobotec SNCR

	Hog Fuel (BDT)	Natural Gas (MMBtu)	OCC Rejects (BDT)	Pulp & Paper Mill Sludge (BDT)
October 2014	10,574	50,580	726	2,637
November 2014	15,229	112,191	1,160	2,811
December 2014	18,564	133,152	849	3,016
January 2015	21,230	107,104	1,245	3,945
February 2015	14,646	133,513	958	3,586
March 2015	20,411	135,189	1,502	3,738
April 2015	17,063	60,078	1,151	3,760
May 2015	13,086	80,656	2,403	4,309
June 2015	11,034	61,792	1,991	3,530
July 2015	13,196	72,122	2,388	3,556
August 2015	9,919	70,252	2,145	2,942
September 2015	10,010	104,425	1,482	2,582
12-Month Total	174,962	1,121,054	18,000	40,412

Boiler MACT Reports –Multi-Fuel Grate Boiler with Mobotec SNCR



Boiler MACT Reports –Multi-Fuel Grate Boiler with Mobotec SNCR

The controlling method to reduce CO on this boiler when the biomass was extremely wet was to co-fire with natural gas, however this created a problem controlling NOx.

– This Boiler was suppled with a Mobotec SNCR to control NOx.

– SNCR reactions only take place in a narrow temperature window.

– When firing 100% Natural Gas the temperature was too high for NOx reduction with urea injection.

– Solutions
  - Reduce steam flow
  - Increase OFA
  - ????

Boiler MACT Reports –Multi-Fuel Grate Boiler with Mobotec SNCR

Outside the Box Solutions

– Use the decommissioned heavy oil firing system's steam atomizer to stage the natural gas combustion and decrease the temperature in the upper furnace for Urea injection to be effective.

– It WORKED !!

Boiler MACT Reports

Natural Gas	Muti-fuel grate boiler	Multi-fired grate boiler w SNCR
No fuel feed problems	Constant fuel feed problems	Constant fuel feed problems
No fuel metering problems	Most have volumetric measurements and inaccurate feed blending	Most have volumetric measurements and inaccurate feed blending
No Fuel distribution across the boiler	Constantly monitoring feeders and distribution between feeders	Constantly monitoring feeders and distribution between feeders
No fuel consistency problems	Constant blending issues and fluctuating moisture levels	Constant blending issues and fluctuating moisture levels
No NOx Requirements	No NOx Requirements	<.13 lbs/mmbtu
No Trending Historical Data Required	Historical Data Required for tuning for effective tuning	Historical Data Required for tuning for effective tuning

Boiler MACT Tune up

– From the simplest natural gas fired boiler to the most complex multi-fuel fired grate boilers with SNCR the required Boiler MACT tune up is an opportunity for the owners to not only improve efficiency but to also improve the boiler's reliability and increase productivity. By either educating the control board operators or enhancing the control system, the overall performance and reliability can be greatly improved and still meet the EPA's requirements.

Questions ?

Comments ?

Thank you

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