CHARBOSS PROTOTYPE AIR CURTAIN INCINERATOR PILOT TESTING

COMPLIANCE MONITORING & RECORDKEEPING REPORT

IN ACCORDANCE WITH MUTUAL AGREEMENT AND FINAL ORDER NO. AQ/ACPD-ER-2020-18

USDA Forest Service
Pacific Northwest Region
1220 SW Third Avenue
Portland, OR 97204

November 19, 2020

Contents

Introduction 2

Equipment Description 2

Compliance with Paragraph E.11 of the MAO 2

1. Time log of incinerator (burning) operation specifying date and time of startup, nomal operation, and shutdown (end of burning) in the CharBoss. 2

2. Date and time engine is started. 3

3. Time of day the blower is turned on. 3

4. Time of day when the Forest Service ceases feeding the forest wood debris to the CharBoss. 3

5. Time of day when the blower is turned off. 3

6. Mass and each type of forest wood debris fed to the CharBoss each hour. 4

7. Total mass of forest wood debris fed into the CharBoss per day. 4

8. Daily hours of engine operation and fuel usage, including fuel type used. 5

9. Opacity readings during startup, operation between loadings, operations during loadings, and shutdown. 5

10. Moisture Content of Processed Vegetation 6

11. Vegetation Species Processed 6

12. Mass of biochar produced 7

13. Daily start up and shutdown procedures 7

14. Complaint Log. 8

Air Toxics 8

Discussion of Air Toxic Emissions 10

Temperature of Exhaust Stream 11

Figures 12

..... 12

ATTACHEMENTS 15

A. Mutual Agreement and Final Order 15

B. Opacity Testing Report 15

C. Laboratory Analysis of Feedstock Properties 15

D. Startup, Shutdown and operating Plan (SSOP) of September 27, 2020. 15

E. Pile Calculations 15

F. Air Toxics Measurement Plan and Revisions. 15

G. Temperature Traverse Addendum 15

Introduction

In accordance with Mutual Agreement and Final Order (MAO) No. AQ/ACDP-ER-2020-128, the USDA Forest Service (FS) is submitting this report to the Oregon Department of Environmental Quality(DEQ) to fulfil its responsibilities. This report documents all the monitoring and record-keeping information required by paragraph E.11 of the MAO and the air toxic emissions measurement information and result in accordance with the Air Toxics Measurement Plan.

Per paragraph F of the MAO, within 45 days of completing the final pilot test, the FS must submit a final written report to DEQ that includes all of the monitoring and record-keeping information required by Paragraph E.11 of the MAO and the air toxics emissions measurement information and results in accordance with the Air Toxics Measurement Plan. The final pilot test was conducted October 8, 2020. Therefore, this report is due to DEQ by November 23, 2020.

Each item under paragraph E.11 of the MAO is identified in this report along with information which demonstrates compliance with each requirement. Compliance with the Air Toxics Measurement Plan is addressed afterwards.

Equipment Description

The CharBoss is a prototype air curtain incinerator (ACI) under development through a Cooperative Research and Development Agreement (CRADA) between the FS and Air Burners, Inc (ABI), of Palm City, Florida. The CharBoss is an ABI Burn Boss Model T-24 which has been modified to recover biochar. The CharBoss was developed to provide a clean burning alternative to open burning small slash piles. The CharBoss is a BurnBoss with the addition of a moving grate in the bottom which removes the char during operation. A small quantity of ash accumulates beneath the prototype machine. Char is discharged by a mesh conveyor to a water quench tank. Wet char was extracted from the tank. The operation of this prototype was guided by the temperature at a thermocouple below the grate. Operation within temperatures which would not damage equipment provided a consistently clean operation. Figure 1 and 2 are pictures of the CharBoss.

Compliance with Paragraph E.11 of the MAO

1. **Time log of incinerator (burning) operation specifying date and time of startup, nomal operation, and shutdown (end of burning) in the CharBoss.**

Table 1. Time log of Incinerator

Operation	Bandon Dunes	Tollgate	Source
Date	October 5,2020	October 8 2020	Log
Startup	10:23	11:23	Log

Normal Operation	10:28	11:25	Log
Shutdown	16:07	17:00	Log

Figure 3 is a photograph of the elapsed timer on the CharBoss which was required under Paragraph B.3 of the MAO.

2. Date and time engine is started.

Table 2. Startup Dates

Operation	Bandon Dunes	Tollgate	Source
Date	October 5,2020	October 8, 2020	Log
Startup (Engine On)	10:23	11:23	Log

3. Time of day the blower is turned on.

Table 3. Blower On Times

Operation	Bandon Dunes	Tollgate	Source
Date	October 5,2020	October 8 2020	Log
Blower ON	10:32	11:27	Log

4. Time of day when the Forest Service ceases feeding the forest wood debris to the CharBoss.

Table 4. Operation Stop Times

Operation	Bandon Dunes	Tollgate	Source
Date	October 5,2020	October 8 2020	Log
Stop Feed	14:17	17:00	Log

Figure 4 is a photograph of the CharBoss being loaded.

5. Time of day when the blower is turned off.

Table 5. Blower Off Times

Operation	Bandon Dunes	Tollgate	Source
Date	October 5,2020	October 8 2020	Log
Blower OFF	16:07	17:00	Log

6. Mass and each type of forest wood debris fed to the CharBoss each hour.

Table 6. Type and Amount of Forest Wood Debris Feedstocks

Operation	Bandon Dunes	Tollgate	Source
Date	October 5,2020	October 8 2020	Log
Fuel Type	Gorse	White Fir	USFS
Dry fuel start time	10:32	Not applicable. All fuel was green.	
Dry fuel end loading time	11:02		
Total dry fuel time	0 hours 30 min		
Total dry fuel amount burned (tons)	1.2		Pile Calculator
Dry fuel input rate (tons/hr)	2.4*		Log
Dry fuel burned tons/day	1.2		Log
Green fuel start time	11:17	11:25	Log
Green fuel end time	14:17	15:44	Log
Total green fuel time	3 hours 0 min	4 hours 19 min	Log
Total green fuel amount burned (tons)	4.8	6.8	Pile Calculator
Green fuel input rate (tons/hr)	1.6	1.6	Log
Green fuel, tons/day	4.8	6.8	Log

**does not include burn down time.*

7. Total mass of forest wood debris fed into the CharBoss per day.

Forest wood debris consumption was calculated using the University of Washington Piled Fuels Biomass and Emissions calculator (https://depts.washington.edu/nwfire/piles/). The length, width, and height of the pile wood was measured using Loggers Tape immediately before and after the operation of the CharBoss. The difference between the calculated mass was used as the total mass consumed. The input and output of the pile calculations are included in Attachment 5 to this report.

As shown in Table 7, the CharBoss consumed between 6.0 and 6.8 total tons of forest wood debris each day, which was less than the 34 tons permitted.

Table 7. Amount and Type of Forest Wood Debris Burned

Operation	Bandon Dunes	Tollgate	Source
Date	October 5,2020	October 8 2020	Log
Fuel Type	Gorse	White Fir	USFS
Mass (tons)	6.0	6.8	Pile calculator

The calculation of total mass does contain some uncertainties resulting from the imperfect representation of the pile shape (i.e., piles do not have perfectly straight lines as assumed in the pile calculator), assumptions about packing density, human error in measurement, etc. Additionally, it is likely that pile shape, and packing ratio, shifted when material was removed and loaded into the CharBoss. Actual estimates of the amount of uncertainty are difficult if not impossible to calculate.

8. Daily hours of engine operation and fuel usage, including fuel type used.

Table 8. Operational Periods and Fuel Usage

Operation	Bandon Dunes	Tollgate	Source
Date	October 5,2020	October 8 2020	Log
Startup	10:23	11:23	Log
Shutdown	16:07	17:00	Log
Total Hours/Day	5.57 hours	5.62 hours	calculator
Fuel type used	No.2 Diesel S-15	No.2 Diesel S-15	See Figure 5
Fuel usage (gal)	4.7	5.6	Fuel gauge

Prior to testing, diesel fuel was purchased October 4 in Bandon. No. 2 Diesel fuel by rule must contain less than 15 ppm. Figure 5 is a picture of the description of the fuel from the gas station which it was purchased. Figure 6 is a receipt for the diesel fuel purchased for the testing at the two sites. Note, there were no compliance limits specified in the MAO for fuel usage, only reporting requirements.

9. Opacity readings during startup, operation between loadings, operations during loadings, and shutdown.

The table below provides a summary of the opacity readings from the testing at both sites. While this compliance paragraph (11.E.9 of the MAO) specifically mentions opacity between loadings and opacity during loadings, this was not consistent with paragraph B 7 and 8 of the MAO which address visible emission limits. Note, paragraph B 7 addresses operations, but not specifically during loading only or between loading periods, as indicated by paragraph 11.E.9 of the MOA.

The contractor developed a testing plan in accordance with paragraph B7 of the MOA and not during separate periods of loading and between loading. This makes sense because the loading sequence, which happened throughout the day at each testing location only last for a few seconds with the "Peak Visible Emissions" from each loading occur within each 6 minute block average, within the 60 Minute Sampling Run for visible emissions during normal operations.

Visible emissions were well below the opacity limits during all phases of operation. As stated in previous conversations with DEQ, compliance with the opacity limit will also demonstrate compliance with the paragraph B.9 of the MAO (must not allow the emissions of particulate matter from the CharBoss in excess of 0.10 grains per dry standard cubic foot).

Table 9. Summary of Opacity Testing Results

Phase of Operation	Opacity at Bandon	Opacity at Tollgate	Opacity Limit
Startup	7.13%	3.5%	≤ 20%
Operation • Run1 • Run 2 • Run 3	 5.31% 4.46% 2.40%	 1.63% 2.38% 2.90%	 ≤10%
Shutdown	0.04%	0.00%	≤10%

For more details about the opacity testing and results, please refer to the Visible Emissions Report prepared by Artic Engineering, in the attachments to this report.

10. Moisture Content of Processed Vegetation

Table 10. Moisture Content of Vegetation

Operation	Bandon Dunes	Tollgate	Source
Moisture Content			
Dry WB*/DB	17.4/19-25	Not applicable	Laboratory Analysis
Green WB/DB	43-46/74-85	17/21	Laboratory Analysis

**WB = wet basis: percentage equivalent of the ratio of the weight of water (W_W) to the total weight of the material. DB = dry basis: percentage equivalent of the ratio of the weight of water (WW) to the weight of the dry matter.*

The laboratory results of the moisture content of the fuels are including in an attachment to this report

11. Vegetation Species Processed

Table 11. Vegetation Species Processed

Operation	**Bandon Dunes**	**Tollgate**	**Source**
Date	October 5,2020	October 8 2020	Log
Fuel Type	*Ulex europea* (Gorse)	*Abies concolor* (White Fir)	USFS

Gorse (Ulex europeaus) is an invasive species which can be transported and is normally open burned in place to destroy volunteer seeds. Figures 7 and 8 are photographs of green and dry Gorse, respectively. Gorse has become very prolific throughout Bandon. Approximately 35,000 acres of Gorse surround the city and have twice caused the city to burn. Testing at the Bandon site is part of an effort to explore ways to utilize this material.

The Bandon Dunes Resort prepared piles of Gorse for testing. Fuels were identified and sampled by USFS personnel. Gorse at Bandon is "plucked" from the soil and is not contaminated. The Gorse contained sand or dirt which the loader shook off the fuel prior to loading. The sand in the dry Gorse is screened from the char by the machine and is reflected in the weight of the ash in

the Bandon samples. Green fuel appeared to be relatively free of sand. The slash pile was inspected by USFS personnel prior to the burn to ensure only clean wood was used for the burn.

The Bandon Dunes Resort test burn was started for the first 1.5 hours with Gorse (21% MC db/17.4% wb) which had been allowed to dry followed by "wet" Gorse (74-85% db/42.5-45.9%wb) for four hours. Gorse is known to burn hot with smokey emissions in an open pile. Observers were impressed by the clean burn. Gorse seeds appeared to have been incinerated in the burn.

White Fir (Abies concolor) slash was the material used in the testing at theTollgate site on the Umatilla National Forest. The slash resulted from thinning to reduce hazardous fuels and improve forest health. The slash is composed of solid wood, branches and needles and is usually burned in open piles. The slash had been piled alongside a logging road during thinning and was left for testing as shown in Figure 9. Figure 10 is a close up view of the White Fir feedstock. Forest slash at Tollgate was piled during harvest and had little or no rocks, dirt or other non-wood components. The slash pile was inspected by USFS personnel prior to the burn to ensure only clean wood was used.

12. Mass of biochar produced

Table 12. Mass of Biochar Produced

Operation	Bandon Dunes	Tollgate	Source
Date	October 5,2020	October 8 2020	Log
Biochar produced (lbs)	129	129	Log

Figures 11-14 are photographs showing the biochar being produced from CharBoss. The discussion of the biochar production rate is presented later in this report, under the Air Toxics section.

13. Daily start up and shutdown procedures

The tests were conducted in according to the Startup Shutdown and Operating Plan (SSOP) of September 27, 2020 (see attachment 4). They were conducted at two sites: one which was hosted by Bandon Dunes Resort, in Bandon, Oregon, and the second which occurred within the Umatilla National Forest near Tollgate, Oregon. The Char Boss was delivered and set up at Bandon Dunes Resort on Sunday, October 4, 2020. Operating personnel arrived with a fire truck on October 5 and the test burn was conducted by FS, ABI and Bandon Dunes Resort personnel. The equipment cooled down and was loaded for transport to the Tollgate site. The CharBoss was delivered and setup at the tollgate site in the Umatilla National Forest on Wednesday, October 7. The test burn was conducted by FS and ABI personnel on Thursday, October 8, 2020. Following the burn the CharBoss was transported to Florida. Both testing sites were located more than 750 from an occupied dwelling, occupied commercial or institutional established, or other occupied structure.

Both pilot tests were conducted under the supervision of the US Forest Service in collaboration with personnel from Air Burners Inc. The CharBoss was operated and supervised by Air Burner Inc. employees according to their operating procedures. (Operating Manual, BurnBoss T-24, Vers. 06.02.2020 www.airburners.com). The ABI trainer always attended the machine during operation and directed the loader regarding the size, location in the burner, and frequency of fuel loading. The host organizations provided personnel and equipment for fuel loading and fire control.

Additionally, per paragraph B.19a., DEQ stated that "no fires may be started in the CharBoss or material added to existing fires in the CharBoss if the local fire department, the local Forest Protection Association, or Oregon Department of Forestry has banned burning for the test area, unless a written waiver issued by the appropriate authority is received by the Forest Service to DEQ prior to the pilot burn. While a burn ban was in place for Coos County, a waiver was issued by Coos County Forest Protection Association for the operation of the CharBoss at the Bandon Site for the day of testing. This was submitted to DEQ prior to testing at the Bandon Site. No burn bans were in place for the date and location of the testing at the Tollgate site.

DEQ also specified in paragraph B.19b that in the event that DEQ's Air Quality Index (AQI) was greater than 100, within the vicinity of a scheduled test burn, the FS must contact DEQ and obtain approval before proceeding with the pilot burn. Fortunately, he AQI was less than 100 for the location of the pilot tests at both sites on the day of testing.

14. Complaint Log.

No complaints were received.

Air Toxics

Air toxic emissions were quantified using a mass balance approach, as identified in the September 30, 2020 air toxic plan submitted to DEQ and the suggested revisions by Mr. Thomas Rhodes of DEQ (both included in Attachment 7).

The mass balance approach is shown in equation (1).

$$M_x air = M_x In - M_x Out \quad (1)$$

where:

M = mass
x = air toxic pollutant
air = emitted to the atmosphere
In = input material stream (i.e., forest wood debris)
Out = output materials (char, ash, and water)

The amount of input material was quantified as discussed previously in this report (see compliance with paragraph E.7 of the MAO. Material output from the CharBoss consisted of

biochar, ash, and the water used for quenching the char. The mass of the biochar was determined by measuring the volume of material produced in five-gallon buckets and applying the bulk density of biochar (dry weight). The mass of the ash was determined by measuring the dimensions of the ash pile remaining after the CharBoss was moved (see Figure 15). The pile volume was converted to dry mass using the average of the four laboratory measurements of the four-corners of the ash pile at each site. Any metals which remained in the quench water would adhere to any solids in the water. The percent of solids in the quench water was measured in the laboratory, and that value was converted to dry mass. The table below presents the input values and bulk density values needed to determine the mass of three output streams: biochar, ash, and quench water.

Table 13. Calculation of Mass for Input and Output Streams

	Bandon	Tollgate
Input material (forest wood debris)(tons)	6.0	6.8
Output material		
Biochar (buckets).	21	21
Gallons/bucket	5	5
Biochar (gallons)	105	105
Cubic feet/gallon (water)	0.133681	0.133681
Volume of biochar (ft^3)	14.03	14.03
Biochar bulk density (lbs/ft^3) – dry. weight	9.26	9.26
Biochar (lbs) – dry weight	129.18	129.18
Biochar mass (tons) – dry weight	0.0646	0.0646
Ash		
Dimensions (Length, width, depth in inches)	120 x 34x 4	120 x 34 x 3.73
Ash volume (ft^3)	9.44	8.81
Average Ash density (lbs/ft^3)	42.6*	19.3
Ash (lbs)	402.14	170.03
Ash (tons) – dry weight	0.2010	0.0850
Quench Water (solids in the water)		
Volume of water (gallons)	36	36
Percent of solids in the quench water	0.20%	1.06%
Density of water (lbs/gallon)	8.345	8.345
Weight of solids in the quench water (lbs)	0.601	3.184
Weight of solids in the quench water (tons)	0.000301	0.001592

**Ash at Bandon site was denser than that at the Tollgate site. This is because the ash at the Badon site contained sand which sifted through the screen inside the CharBoss. The ash at Tollgate was much lighter because it didn't contain sand.*

The concentration of arsenic (As), cadmium (Cd), manganese (Mn), and lead (Pb) was determined by laboratory analysis. Unfortunately, the University of Idaho Laboratory which was identified as the laboratory of choice in the Air Toxics plan had a large backlog of samples at the time of sample submittal. Because of this backlog, they could not guarantee that the analyses

would be completed before the due date for this compliance report. As such, the University of Minnesota Research Analytical Laboratory (http://ral.cfans.umn.edu/) was able to accommodate our need and performed the laboratory analyses of the samples. Please visit their website for specifics on their analysis procedures.

The laboratory results of the air toxics analysis for both the input and the output streams are presented in Attachment F. The mass balance results for each air toxic are presented below for Bandon.

Table 14. Air Toxic Mass Balance and Emission Rates at the Bandon Test Site

In/Out Stream	Ar	Cd	Mn	Pb
Gorse (mg)	BDL	BDL	74,608	919
Biochar (mg)	311	BDL	8,245	BDL
Ash (mg)	702	BDL	67,653	543
Water (mg)	BDL	BDL	150	BDL
Mass Balance In – Out (mg)	-1013	0	-1440	376
Mass burned (tons)	6.0	6.0	6.0	6.0
Emission Rate (mg/ton)	0	0	0	63

Table 15. Air Toxic Mass Balance and Emission Rates at the Tollgate Test Site

In/Out Stream	Ar	Cd	Mn	Pb
White Fire (mg)	BDL	435	470,798	1459
Biochar (mg)	386	BDL	29,749	BDL
Ash (mg)	BDL	BDL	492,403	877
Water (mg)	BDL*	BDL*	150*	BDL
Mass Balance In – Out (mg)	-386	435	-51,504	1459
Mass burned (tons)	6.8	6.8	6.8	6.8
Emission Rate (mg/ton)	0	64	0	215

Discussion of Air Toxic Emissions

Of the pollutants of principal concern the arsenic and lead were often very low or below detection limits. In all cases there was little or slightly more metal in the biochar, ash and water than in the incoming fuel. This may have been due to the problems of developing a mass balance in a system of this nature. Manganese (Mn) had the highest concentration of the metals in both the Gorse and the White Fir. For the testing at the Bandon site, about 10% of the Mn appeared in the biochar and 90% in the ash with a minor amount in the water. For the testing at the Tollgage

site, about 5% of the Mn appeared in the biochar and about 5% in ash of the White Fir. Based upon these two pilot tests, only Pb appears to be emitted from the CharBoss and only in a small amount.

Temperature of Exhaust Stream

At the request of DEQ, the exhaust temperature was measured at one of the pilot testing sites. The methodology and test result are presented in Attachment F to this report. The testing was conducted at the Tollgate site where White Fir was burned. The average exhaust temperature was 370.7 °F. For more details, please refer to the test report.

Figures

Figure 1 ABI CharBoss.

Figure 2. Setup with Biochar Discharge in lower right.

Figure 3 CharBoss Control with Hour Meter (noted by the red oval)

Figure 4. Loading the CharBoss

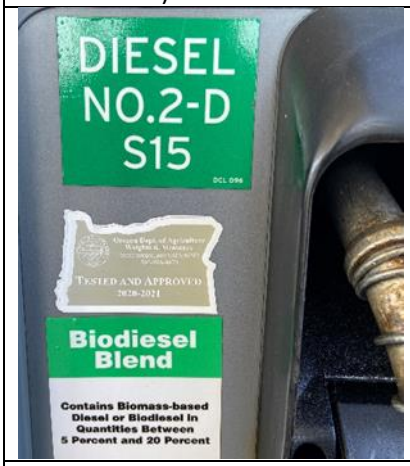

Figure 5. Diesel Type purchased

Figure 6. Fuel Receipt

Figure 7 Green Gorse Pile

Figure 8. Dry Gorse Pile (close up)

Figure 9. Feedstock pile of White Fir at Tollgate

Figure 10. White Fir feedstock

Figure 11. Biochar Discharge to Water Bath

Figure 12. Unloading Biochar

Figure 13. Biochar

Figure 14. Close-up view of Biochar

Figre 15. Ash pile under the CharBoss.

ATTACHEMENTS

A. Mutual Agreement and Final Order

B. Opacity Testing Report

C. Laboratory Analysis of Feedstock Properties

D. Startup, Shutdown and operating Plan (SSOP) of September 27, 2020.

E. Pile Calculations

F. Air Toxics Measurement Plan and Revisions.

G. Temperature Traverse Addendum