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INVESTIGATION OF THE PARTICLE SIZE DISTRIBUTION AND
PARTICLE DENSITY CHARACTERISTICS OF DOUGLAS FIR
HOGGED FUEL FLY ASH COLLECTED UNDER KNOWN
COMBUSTION CONDITIONS

TECHNICAL PROGRESS REPORT NO. 2

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CORVALLIS, OREGON 97331

DATE OF REPORT: December, 1978

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
UNDER CONTRACT NO. EY-76-C-06-2227, TASK AGREEMENT NO. 22

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ABSTRACT

The increased interest in wood as a fuel source, coupled with the increasing demand to control the emissions generated by wood combustion, has created a need for information characterizing the emissions that occur for given combustion conditions. This investigation characterizes the carbon char and inorganic fly ash size and density distribution for each of thirty-eight Douglas fir bark samples collected under known conditions of combustion.

SUMMARY OF SIGNIFICANT RESULTS

The analysis of the thirty-eight Douglas fir samples covered two fuel sizes: 1/4" minus and 3/8" to 3/4" bark. The conditions under which the samples had been collected are fully described in "Investigation of the Rate of Combustion of Wood Residue Fuel," Technical Progress Report No. 1, David C. Junge, Ph.D., Oregon State University, September 27, 1977.

1. From the particle size analysis, it was concluded that for conditions of more complete combustion, smaller sized particles were produced. For optimal combustion (a carry over rate of less than 4.54 kg/hr (10 lb/hr)), the mass mean size range was from 0.047mm to 0.31mm. For conditions of less complete combustion (a carry over rate of greater than 15.88 kg/hr (35 lb/hr)), the mass mean size range went from 0.70mm to 1.60mm.
2. A given rate of carry over could be obtained by either high density, small mass mean size particles or by low density, large mass mean size particles.
3. The density was not found to be a function of the size for any of the conditions tested.
4. The density was not a function of the carry over rate for any of the conditions tested.
5. Particle sizes ranged from a maximum of 5.5mm to sizes less than 0.043mm.

I. INTRODUCTION

The increasing interest in wood as a fuel source has stimulated much interest in obtaining data on optimal combustion conditions. As a further extension of the work done by David C. Junge, Oregon State University, in his Technical Report No. 1, "Investigation of the Rate of Combustion of Wood Residue Fuel," analysis was done on thirty-eight samples of Douglas fir carbon char and inorganic ash. All of the samples were collected under known conditions of combustion. This investigation would extend the previously completed work by analyzing the particle size and density characteristics of the char and ash giving design engineers a grasp of the sort of particulate material that could be expected in Douglas fir bark combustion.

II. PURPOSE

The purpose of the investigation was to characterize the carbon char and inorganic fly ash emitted during each of thirty-eight test runs (of known combustion conditions) through the analysis of the particle size and density distribution.

III. INSTRUMENTATION

1. Size Distribution of Ash: A Tyler screen series was used to separate the ash by its particle size. The screens used are listed below:

Tyler Screen Number	Size (mm)
8	2.362
10	1.651
20	0.833
48	0.295
65	0.208
100	0.147
150	0.104
200	0.074
270	0.053
327	0.043

A Ro-Tap Testing Sieve Shaker was used to shake samples down through the various screens used.

2. Weight Distribution: A Mettler top loading balance was used to determine the weight of each of the samples of ash caught upon the individual Tyler screens.
3. Volume Determination: The volume of each of the samples of ash caught on a given Tyler screen was determined using a graduated cylinder. Three sizes were used: 100ml, 25ml, 10ml. The amount of ash on a given screen dictated which cylinder was to be used.

IV. DATA COLLECTED

For each sample, the following data was collected and recorded:

1. The Tyler screen size was recorded.
2. The weight of the ash on a given Tyler screen was determined.
3. The volume of a weighed sample was recorded.

V. PROCEDURE

The procedure used in all of the analyses is outlined below:

1. Align the Tyler screens to the maximum height that the Ro-Tap Testing Sieve Shaker can accomodate. The largest mesh should be placed at the top with successively smaller meshes below it; a pan should be placed at the bottom of the screen column. A cover should be placed over the top Tyler screen prior to being placed on the Ro-Tap.
2. Secure the screen column on the Ro-Tap and shake for two minutes.
3. The material caught in the pan at the end of the two minute shake period should then be placed in the next column of screens that completes the series. After pouring the pan's contents into the top screen, it should again be covered prior to being placed on the Ro-Tap.
4. Secure the remaining screens on the Ro-Tap and shake it for two minutes.
5. Remove the contents of the individual Tyler screens to a tared container. (A common aluminum pie pan is an excellent container to use). To complete the removal of the particles from the Tyler screen, gentle rapping of the sides of the screen and the use of a small paint brush facilitate the transfer.
6. Record the weight of the material and the Tyler screen size from which it was removed.
7. Carefully transfer the weighed material to an appropriate graduated cylinder (the size of the cylinder will depend

upon the quantity of material that was caught on the particular screen). Rap the cylinder gently to compact the material to its minimum volume; the rapping process is completed when no further change is noted in the volume.

8. Record the volume of the ash for the given size Tyler screen.
9. Calculate the density of the material on a given size Tyler screen by dividing the screen's material weight by the material's volume. Record the calculation.
10. Repeat steps 5 through 9 for each of the screens used and for the final pan contents.

VI. EXPERIMENTAL DATA

Data relating the type of combustion conditions producing the given ash sample can be found in Appendix A. The data on particle size and density are found in Appendix B along with graphical presentations of the geometric mass mean size versus density and the cumulative weight percent versus particle size.

VII. PARTICLE DEGRADATION

It was feared that the process of shaking the samples would cause further break-down of the larger particles, biasing the data. In order to check on the possibility of degradation and to determine the minimum time required to shake the samples through the Tyler screen column, sample no. 69 was used in a trial run series.

The material in sample no. 69 was run through the Tyler screens on the Ro-Tap three times using a two minute shaking period. The weight of the sample caught on each of the screens was recorded. Following these two minute trial runs, a four minute shaking period was tested; two runs were completed on the sample material. Appendix C, Figure 1, gives the results of the five trial runs.

As indicated in Figure 1, the weight varied between individual screens; however, the cumulative weight showed little variation. One gram of material was lost during the running of the five tests representing about a 3% loss. Between any two consecutive runs, a maximum loss of approximately 2% occurred. No obvious gain could be readily seen in shaking the sample for four minutes, hence it was decided that the two minute shaking period was sufficient to separate the particles in a sample. Because the weight difference was so small among the three tests run at two minute shaking periods, it was concluded that a two minute shaking period would not cause further degradation of the sample particles.

Figure 2 of Appendix C, shows the data collected for samples no. 66 and 67 which dealt with possible changes in volume measurements for a two minute shaking period. Little change was noted between individual screen volumes and a 2.5% volume change was noted overall.

VIII. RESULTS

The following pages contain a chart with data on the combustion conditions for each sample and the resulting mass mean particle size and mean density for the sample.

SUMMARY OF COMBUSTION AND MEAN PARTICLE SIZE AND DENSITY DATA

RUN NUMBER	FUEL SIZE (in)	FUEL MOISTURE (%)	% OVER FIRE AIR	% EXCESS AIR	CARRY OVER RATE (lb/hr)	MASS MEAN PART. SIZE (mm)	MEAN PART. DENSITY (g/cm ³)
40	FINES	55.0	95 ⁺	26.0	17.50	0.76	0.092
41	FINES	55.0	95 ⁺	53.0	10.40	0.31	0.11
42	FINES	55.0	95 ⁺	89.0	6.94	0.17	0.14
43	FINES	55.0	95 ⁺	100.0	8.42	0.16	0.15
44	FINES	55.0	95 ⁺	140.0	8.39	0.12	0.18
45	FINES	55.0	95 ⁺	175.0	7.75	0.12	0.17
47	FINES	56.0	9.40	42.0	28.20	0.62	0.11
48	FINES	56.0	10.90	25.0	26.90	0.64	0.12
49	FINES	56.0	4.40	180.0	72.0	0.50	0.21
50	FINES	56.0	8.19	62.0	31.7	0.42	0.15
51	FINES	56.0	7.79	90.0	32.4	0.68	0.11
52	FINES	56.0	11.25	20.0	24.7	0.65	0.10
53	3/8 - 3/4	41.0	94.04	39.0	10.26	0.63	0.12
54	3/8 - 3/4	41.0	93.66	56.0	10.00	0.36	0.10
55	3/8 - 3/4	41.0	96.46	93.5	9.03	0.16	0.19
56	3/8 - 3/4	41.0	98.11	120.0	7.97	0.047	0.34

SUMMARY OF COMBUSTION AND MEAN PARTICLE SIZE AND DENSITY DATA

RUN NUMBER	FUEL SIZE (in)	FUEL MOISTURE (%)	% OVER FIRE AIR	% EXCESS AIR	CARRY OVER RATE (lb/hr)	MASS MEAN PART. SIZE (mm)	MEAN PART. DENSITY (g/cm ³)
57	3/8 - 3/4	41.0	90.79	145.0	10.36	0.055	0.28
58	3/8 - 3/4	38.0	9.36	19.00	39.00	1.40	0.15
59	3/8 - 3/4	38.0	9.99	25.00	39.50	1.60	0.09
60	3/8 - 3/4	38.0	8.66	50.40	32.90	1.80	0.085
61	3/8 - 3/4	38.0	6.00	81.00	27.50	1.10	0.10
62	3/8 - 3/4	38.0	6.07	120.0	22.10	0.39	0.10
63	3/8 - 3/4	54.0	78.38	10.0	9.15	0.95	0.086
65	3/8 - 3/4	54.0	84.49	27.0	14.20	0.55	0.12
66	3/8 - 3/4	54.0	95 ⁺	45.0	10.60	0.54	0.11
67	3/8 - 3/4	54.0	95 ⁺	90.0	10.20	0.10	0.24
68	3/8 - 3/4	54.0	95 ⁺	65.0	8.80	0.31	0.14
69	3/8 - 3/4	54.0	95 ⁺	120.0	10.48	0.16	--
70	3/8 - 3/4	53.0	12.63	7.5	46.7	1.30	0.11
71	3/8 - 3/4	53.0	11.47	15.0	69.5	1.40	0.14
72	3/8 - 3/4	53.0	9.76	25.0	44.1	1.40	0.14

SUMMARY OF COMBUSTION AND MEAN PARTICLE SIZE AND DENSITY DATA

RUN NUMBER	FUEL SIZE (in)	FUEL MOISTURE (%)	% OVER FIRE AIR	% EXCESS AIR	CARRY OVER RATE (lb/hr)	MASS MEAN PART. SIZE (mm)	MEAN PART. DENSITY (g/cm ³)
73	3/8 - 3/4	53.0	8.09	50.0	39.1	1.30	0.15
74	3/8 - 3/4	53.0	6.55	72.0	31.8	1.50	0.14
75	3/8 - 3/4	53.0	7.56	82.0	27.2	1.10	0.11
76	3/8 - 3/4	53.0	95 ⁺	43.0	12.75	0.48	0.11
77	3/8 - 3/4	53.0	68.71	46.0	25.80	0.94	0.11
78	3/8 - 3/4	53.0	63.88	40.0	32.00	0.64	0.10
79	3/8 - 3/4	53.0	41.69	44.0	35.90	0.70	0.10
66	3/8 - 3/4	54.0	95 ⁺	45.0	10.60	0.54	0.11

The graph which follows, plots carry over rate versus the mass mean particle size. A linear regression model was used to fit the dashed line, shown on the graph, to the data obtained. The line is of the form

$$y = a + bx$$

$$\text{where } a = 9.06$$

$$b = 21.79$$

and the coefficient of determination, r^2 , was 0.43. The analysis indicates a trend for the mass mean particle size to increase as the carry over rate increases (i.e. as the combustion completeness decreases). The low r^2 value reflects the scattered nature of the particle size in relation to the carry over rate.

IX. COLLECTOR DESIGN

From the mass mean particle size and the mean density data, an overall mean value for particle size and density was calculated.

$$\begin{aligned}\bar{X}_s &= \text{mean of the mass mean particle size} \\ &= 0.69\text{mm}\end{aligned}$$

$$\begin{aligned}s_s &= \text{standard deviation of the particle size} \\ &= 0.50\text{mm}\end{aligned}$$

$$\begin{aligned}\bar{X}_d &= \text{mean of the particle density} \\ &= 0.14\text{g/cm}^3\end{aligned}$$

$$\begin{aligned}s_d &= \text{standard deviation of the particle density} \\ &= 0.05\text{g/cm}^3\end{aligned}$$

The large value of the standard deviation, s_s , for the mean particle

PLOT OF CARRY OVER RATE VERSUS MASS MEAN PARTICLE SIZE

size, reflected the wide variation in the individual mass mean particle sizes. (see the table under, VIII. RESULTS)

The maximum size particle encountered was 5.5mm and the smallest were less than 0.043mm and were quite possibly submicron in size. Densities ranged from 0.016g/cm^3 for the larger, less dense particles, to 0.648g/cm^3 for the smaller more dense ash found in the final pan (which contained particles of less than 0.043mm).

For controlled combustion in which the operational parameters are known, the individual particle size and density sheets in Appendix B should be used to obtain more specific range information.

X. CONCLUSIONS

1. Particle Size Analysis: The data on the mass mean particle size, when related to the combustion conditions attained, show that smaller particles were produced when combustion was optimal. The criterion used to determine an optimal combustion, was a carry over rate of less than 4.54kg/hr. It was found that the particles ranged from 0.047mm to 0.31mm if the results of sample no. 63 were disregarded. The mass mean particle size of this sample was so incongruous with the other data that it was felt that the limits should not be based on one such inconsistent run.

As a criterion of poor combustion, a carry over rate of greater than 15.88kg/hr (35 lb/hr) was selected. The mass mean particle size range fell between 0.07mm and 1.60mm, again ignoring the inconsistency of sample no. 49.

The linear regression model further supports the conclusions on size ranges and carry over rate; however, it should be noted that the scattered nature of the plot clearly depicts the great variability in mass mean particle size.

2. Carry Over Rate: A given carry over rate can be obtained by either high density, small mass mean size particles, or by low density, large mass mean size particles. Great variation occurred in individual results which showed that combustion conditions could produce a given rate by changing the volume of small or large particles. It was not uncommon to find that a moderate carry over rate was achieved by having a large volume of less dense particles collected.
3. Density Analysis: No direct relationships could be found for the density of the collected ash. Density was not a function of size, nor was it a function of the carry over rate for any of the conditions tested.

APPENDIX A

COMBUSTION CONDITIONS FOR EACH SAMPLE TESTED

WOOD TYPE	DOUG FIR
SIZE RANGE	FINES
MOISTURE (%)	55.00
DENSITY (LB/CU FT)	25.99
FUEL FEED (DPY LB/HR)	584.78
OVERFIRE: UNDERFIRE AIR RATIO	122: -22

RUN NO. DATE	40 19MAY77	41 19MAY77	42 19MAY77	43 19MAY77	44 19MAY77	45 19MAY77
%E.A.	26.00	53.00	89.00	100.00	140.00	175.00
%O.F. AIR	111.57	129.69	120.21	133.36	123.37	112.90
FUEL FT3/HR	50.00	50.00	50.00	50.00	50.00	50.00
DRY LB/HR	584.78	584.78	584.78	584.78	584.78	584.78
BTU/HR	5.56	5.56	5.56	5.56	5.56	5.56
BTU/HR/F 12	.56	.56	.56	.56	.56	.56

TEMPERATURES IN DEGREES F

T1	555.00	826.00	867.00	925.00	1004.00	993.00
T2	833.00	873.00	840.00	860.00	836.00	830.00
T3	1019.00	938.00	853.00	848.00	790.00	793.00
T4	535.00	690.00	573.00	540.00	510.00	513.00
FAN OUTLET	66.00	63.00	69.00	71.00	72.00	72.00
UNDERGRATE	281.00	269.00	267.00	275.00	252.00	250.00
FRONT O.F.	0	0	0	0	0	0
REAR O.F.	0	0	0	0	0	0
BYPASS	0	0	0	0	0	0

AIR FLOW RATES IN SCFM

MAIN	2619.01	1757.11	2576.18	3299.27	3629.89	3329.32
FRONT O.F.	962.61	1283.48	802.17	1016.29	1123.04	1149.78
REAR O.F.	0	106.96	802.17	882.39	689.35	1069.56
BYPASS	2460.00	0	1973.70	2095.69	2245.09	1463.91
CONVEYOR	91.66	97.66	99.52	101.62	108.27	109.13
TOTAL	944.97	1147.46	1417.45	1499.95	1799.94	2062.43
LEAKAGE	-694.29	717.30	-320.45	-194.41	-307.93	-67.89

VELOCITIES IN FEET PER SECOND

VEL. AT T1	.34	.43	.44	.46	.40	.40
VEL. AT T2	2.65	3.29	3.94	4.22	4.95	5.63
VEL. AT T3	8.58	9.77	11.25	11.83	13.50	15.45

CARRYOVER DATA

LB/HR	17.50	10.40	6.94	8.42	8.39	7.75
GP/SCF	2.16	1.06	.57	.65	.54	.44
%ASH	17.00	38.30	41.30	38.90	48.00	47.30
%COMB.	83.00	51.70	59.70	61.10	52.00	52.70
OPACITY	<5	<5	<5	<5		0-20

MISCELLANEOUS

BAROMETER	30.29	30.29	30.29	30.29	30.28	30.27
WEATHER	CLOUDY	CLOUDY	CLOUDY	CLOUDY	CLOUDY	CLOUDY

RUN NO. DATE	47 23MAY77	48 23MAY77	49 23MAY77	50 23MAY77	51 23MAY77	52 23MAY77
WE. A.	42.00	25.00	190.00	62.00	90.00	20.00
W. F. AIR	9.40	10.90	4.40	8.19	7.79	11.25
FUEL FT3/HR	50.00	50.00	50.00	50.00	50.00	50.00
DRY LB/HR	584.78	571.78	571.78	571.78	571.78	571.78
BTU/HR	5.56	5.43	5.43	5.43	5.43	5.43
BTU/HR/FT2	.56	.54	.54	.54	.54	.54

TEMPERATURES IN DEGREES F

T1	680.00	645.00	565.00	650.00	626.00	655.00
T2	700.00	700.00	600.00	648.00	626.00	745.00
T3	1005.00	1055.00	650.00	1000.00	850.00	1095.00
T4	705.00	670.00	465.00	670.00	597.00	695.00
FAN OUTLET	56.00	57.00	58.00	61.00	61.00	62.00
UNDERGRATE	275.00	282.00	230.00	275.00	269.00	285.00
FRONT O.F.	0	0	0	0	0	0
REAR O.F.	0	0	0	0	0	0
BYPASS	0	0	0	0	0	0

AIR FLOW RATES IN SCFM

MAIN	1477.91	1617.79	2374.52	1699.81	1889.68	1413.79
FRONT O.F.	0	0	0	0	0	0
REAR O.F.	0	0	0	0	0	0
BYPASS	0	0	0	0	0	0
CONVEYOR	100.12	99.92	90.23	97.27	108.60	98.97
TOTAL	1064.96	916.64	2053.26	1187.96	1393.28	979.97
LEAKAGE	513.06	801.08	411.49	609.12	603.99	632.79

VELOCITIES IN FEET PER SECOND

VEL. AT T1	3.91	3.24	6.59	4.29	4.91	3.14
VEL. AT T2	2.67	2.32	4.60	2.93	3.24	2.31
VEL. AT T3	9.53	8.55	13.63	10.55	11.04	8.44

CARRYOVER DATA

LB/HR	29.20	26.90	72.00	31.70	32.40	24.70
GR/SCF	3.09	3.42	4.09	3.11	2.71	3.28
WASH	16.80	19.80	14.60	23.10	13.20	0
% COAL	83.20	80.20	85.40	76.90	86.80	0
OPACITY	5-10	45	15-80		5-80	5-10

MISCELLANEOUS

BAROMETER	29.84	29.84	29.84	29.84	29.84	29.84
WEATHER	CLOUDY	CLOUDY	CLOUDY	CLOUDY	CLOUDY	CLOUDY

MOON TYPE
SIZE RANGE
MOISTURE (%)
DENSITY (LB/CU FT)
FUEL FEED (OZ/LB/HR)
OVERFIRE UNDERFIRE AIR RATIO

00UG FT2
FINES
56.00
571.79
91.91

WOOD TYPE	DOUG FIR
SIZE RANGE	3/8-3/4
MOISTURE (%)	41.00
DENSITY (LB/CU FT)	22.23
FUEL FEED (DRY LB/HR)	655.78
OVERFIRE: UNDERFIRE AIR RATIO	95: 5

RUN NO.	53	54	55	56	57
DATE	26MAY77	26MAY77	26MAY77	26MAY77	26MAY77
%E.A.	39.00	56.00	93.50	120.00	145.00
%O.F. AIR	94.84	93.66	96.46	98.11	97.70
FUEL FT3/HR	50.00	50.00	50.00	50.00	50.00
DRY LB/HR	655.78	655.78	655.78	655.78	655.78
BTU/HR	6.23	6.23	6.23	6.23	6.23
BTU/HR/FT2	.62	.62	.62	.62	.62

TEMPERATURES IN DEGREES F

T1	988.00	1160.00	1505.00	1662.00	1750.00
T2	1142.00	1202.00	1112.00	1075.00	1053.00
T3	1119.00	1092.00	1035.00	1000.00	963.00
T4	728.00	682.00	682.00	738.00	740.00
FAN OUTLET	62.00	63.00	64.00	64.00	65.00
UNDERGRATE	280.00	275.00	275.00	275.00	275.00
FRONT O.F.	240.00	260.00	286.00	361.00	350.00
REAR O.F.	200.00	260.00	265.00	250.00	220.00
BYPASS	720.00	518.00	539.00	490.00	463.00

AIR FLOW RATES IN SCFM

MAIN	2262.07	3410.13	3403.63	2675.95	2605.14
FRONT O.F.	527.14	574.00	745.25	868.94	877.49
REAR O.F.	484.55	545.67	719.34	838.48	882.71
BYPASS	312.71	1257.67	1108.11	107.00	0.00
CONVEYOR	87.65	103.18	105.16	107.98	110.58
TOTAL	1169.05	1312.03	1627.42	1850.30	2060.56
LEAKAGE	867.96	948.62	773.26	933.63	955.17

VELOCITIES IN FEET PER SECOND

VEL. AT T1	.50	.63	.59	.58	1.55
VEL. AT T2	3.97	4.61	5.39	5.96	6.34
VEL. AT T3	11.06	12.18	14.48	16.04	17.38

CARRYOVER DATA

LB/HR	10.26	10.00	9.03	7.97	10.36
GR/SCF	1.02	.89	.65	.50	.59
%ASH	14.80	39.30	43.40	62.50	49.70
%COMB.	85.20	60.70	56.60	37.50	50.30
OPACITY	<5	<5	5.00	5.00	<5

MISCELLANEOUS

BAROMETER	29.91	29.91	29.92	29.91	29.91
WEATHER	CLOUDY	CLOUDY	CLOUDY	CLOUDY	CLOUDY

WOOD TYPE	DOUG FIR
SIZE RANGE	3/8-3/4
MOISTURE (%)	38.00
DENSITY (LB/CU FT)	22.23
FUEL FEED (DRY LB/HR)	689.13
OVERFIRE: UNDERFIRE AIR RATIO	31.92

RUN NO.	58	59	60	61	62
DATE	31 MAY 77	31 MAY 77	31 MAY 77	31 MAY 77	31 MAY 77
%E.A.	19.30	25.00	50.40	81.00	120.00
%O.F. AIR	9.36	9.99	8.66	6.00	6.07
FUEL FT3/HR	50.00	50.00	50.00	50.00	50.00
DRY LB/HR	689.13	689.13	689.13	689.13	689.13
BTU/HR	6.55	6.55	6.55	6.55	6.55
BTU/HR/FT2	.65	.65	.65	.65	.65

TEMPERATURES IN DEGREES F

T1	1560.00	1673.00	1575.00	1385.00	1298.00
T2	1405.00	1410.00	1300.00	1148.00	1003.00
T3	1202.00	1175.00	1125.00	1095.00	1055.00
T4	690.00	708.00	678.00	698.00	758.00
FAN OUTLET	65.00	66.00	66.00	68.00	69.00
UNDERGRATE	256.00	295.00	281.00	281.00	271.00
FRONT O.F.	246.00	266.00	278.00	251.00	260.00
REAR O.F.	280.00	280.00	277.00	222.00	202.00
BYPASS	650.00	629.00	571.00	558.00	527.00

AIR FLOW RATES IN SCFM

MAIN	2249.14	2525.48	3088.69	3307.95	2743.67
FRONT O.F.	0	0	0	0	0
REAR O.F.	0	0	0	0	0
BYPASS	952.97	1061.71	1121.44	1087.43	118.12
CONVEYOR	98.40	110.37	115.05	95.98	118.12
TOTAL	1051.73	1104.76	1329.25	1599.89	1944.38
LEAKAGE	342.84	469.38	751.06	716.81	917.40

VELOCITIES IN FEET PER SECOND

VEL. AT T1	6.72	7.39	8.57	9.58	11.05
VEL. AT T2	4.16	4.38	4.94	5.41	6.96
VEL. AT T3	10.49	10.82	12.57	14.79	17.46

CARRYOVER DATA

LB/HR	39.00	39.50	32.90	27.50	22.10
GF/SCF	4.33	4.17	2.89	2.01	1.33
%ASH	18.70	6.80	7.60	24.40	28.60
%COMB.	81.30	93.20	92.40	75.60	71.40
OPACITY	5.00	5.00	5.00	10-15	10-15

MISCELLANEOUS

BAROMETER	30.03	30.03	30.03	30.03	30.03
WEATHER	CLOUDY	CLOUDY	CLOUDY	CLOUDY	CLOUDY

WOOD TYPE	DOUG FIR
SIZE RANGE	3/8-3/4
MOISTURE (%)	54.00
DENSITY (LB/CU FT)	27.12
FUEL FEED (DRY LB/HR)	623.76
OVERFIRE:UNDERFIRE AIR RATIO	101: -1

RUN NO.	53	65	66	67	68	69
DATE	2JUN77	14JUN77	14JUN77	14JUN77	14JUN77	14JUN77
%E.A.	10.00	27.00	45.00	90.00	65.00	120.00
%O.F. AIR	78.38	97.49	112.39	111.86	115.63	109.21
FUEL FT3/HR	50.00	50.00	50.00	50.00	50.00	50.00
DRY LB/HR	623.76	623.76	623.76	623.76	623.76	623.76
BTU/HR	5.93	5.93	5.93	5.93	5.93	5.93
BTU/HR/FT2	.59	.59	.59	.59	.59	.59

TEMPERATURES IN DEGREES F

T1	615.00	772.00	692.00	945.00	766.00	1113.00
T2	965.00	1035.00	1084.00	1012.00	1005.00	950.00
T3	1190.00	1100.00	1385.00	988.00	1030.00	928.00
T4	730.00	695.00	695.00	710.00	715.00	733.00
FAN OUTLET	62.00	65.00	65.00	68.00	71.00	74.00
UNDERGATE	275.00	261.00	278.00	274.00	278.00	269.00
FRONT O.F.	245.00	260.00	279.00	300.00	301.00	363.00
REAR O.F.	200.00	210.00	259.00	268.00	276.00	240.00
BYPASS	635.00	572.00	540.00	568.00	593.00	495.00

AIR FLOW RATES IN SCFM

MAIN	2450.57	2965.14	3233.14	3307.95	2881.58	2787.08
FRONT O.F.	600.17	785.83	599.19	822.16	711.17	921.01
REAR O.F.	0	0	593.91	756.92	708.59	999.66
BYPASS	1213.15	1287.21	1377.60	933.27	770.94	0
CONVEYOR	89.54	103.09	110.58	121.14	105.55	101.35
TOTAL	379.97	1015.97	1159.96	1519.95	1319.95	1759.94
LEAKAGE	446.99	705.06	806.17	975.88	897.24	1128.49

VELOCITIES IN FEET PER SECOND

VEL. AT T1	.88	.74	.39	.48	.42	.53
VEL. AT T2	2.74	3.29	3.87	4.77	4.15	5.27
VEL. AT T3	8.91	9.71	10.92	13.28	11.92	14.67

CARRYOVER DATA

LB/HR	9.15	14.20	10.60	10.20	8.80	10.48
GP/SCF	1.21	1.63	1.07	.78	.78	.70
%ASH	28.40	14.20	10.50	45.40	12.90	32.30
%COMB.	71.60	85.80	89.50	54.60	87.10	67.70
OPACITY	3.00	5.00	5.00	4.00	5.00	8.00

MISCELLANEOUS

BAROMETER	30.23	30.08	30.08	30.08	30.11	30.11
WEATHER	CLOUDY	OVERCAST	OVERCAST	ROCKEN	SCATRED	CLEAR

WOOD TYPE DOUG FIR
 SIZE RANGE 3/8-3/4
 MOISTURE (%) 53.00
 DENSITY (LB/CU FT) 27.12
 FUEL FEED (DRY LB/HR) 637.32
 OVERFIRE: UNDERFIRE AIR RATIO 91.91

RUN NO. DATE	70 16JUN77	71 16JUN77	72 16JUN77	73 16JUN77	74 16JUN77	75 16JUN77
%E.A.	7.50	15.00	25.00	50.00	72.00	82.00
%O.F. AIR	12.63	11.47	9.76	8.09	6.55	7.56
FUEL FT3/HR	50.00	50.00	50.00	50.00	50.00	50.00
DRY LB/HR	637.32	637.32	637.32	637.32	637.32	637.32
BTU/HR	6.06	6.06	6.06	6.06	6.06	6.06
BTU/HR/FT2	.60	.60	.60	.60	.60	.60

TEMPERATURES IN DEGREES F

T1	1685.00	1672.00	1634.00	1527.00	1513.00	1258.00
T2	1470.00	1428.00	1362.00	1250.00	1250.00	1114.00
T3	1045.00	1060.00	1075.00	1072.00	1090.00	1082.00
T4	572.00	602.00	651.00	760.00	802.00	820.00
FAN OUTLET	63.00	65.00	68.00	71.00	74.00	78.00
UNDERGATE	276.00	276.00	278.00	290.00	273.00	273.00
FRONT O.F.	238.00	256.00	275.00	299.00	290.00	290.00
REAR O.F.	109.00	210.00	204.00	200.00	200.00	200.00
BYPASS	480.00	480.00	575.00	565.00	579.00	560.00

AIR FLOW RATES IN SCFM

MAIN	2822.18	3092.57	2497.27	2038.42	2220.45	2487.44
FRONT O.F.	0	0	0	0	0	0
REAR O.F.	0	0	0	0	0	0
BYPASS	1491.70	1086.26	831.39	0	0	0
CONVEYOR	111.01	107.77	99.71	99.14	92.13	112.48
TOTAL	878.67	939.97	1021.70	1226.04	1405.86	1487.60
LEAKAGE	562.82	1174.31	743.79	911.52	906.72	1112.32

VELOCITIES IN FEET PER SECOND

VEL. AT T1	5.94	6.36	6.90	7.92	9.11	8.29
VEL. AT T2	3.70	3.86	4.03	4.93	5.14	5.01
VEL. AT T3	8.16	8.78	9.60	11.41	13.17	13.84

CARRYOVER DATA

LB/HR	46.70	69.50	44.10	39.10	31.90	27.20
GR/SCF	6.20	9.63	5.04	3.72	2.64	2.13
%ASH	7.60	12.70	6.80	7.40	9.80	7.00
%COMB.	92.40	67.30	93.20	92.60	90.20	93.00
OPACITY	7.50	7.50	14.00	16.00	23.00	24.00

MISCELLANEOUS

BAROMETER	30.10	30.10	30.10	30.10	30.10	30.10
WEATHER	OVERCAST	SCTCO	CLEAR	CLEAR	CLEAR	CLEAR

WOOD TYPE DOUG FIR
 SIZE RANGE 3/8-3/4
 MOISTURE (%) 53.00
 DENSITY (LB/CU FT) 27.12
 FUEL FEED (DRY LB/HR) 637.32
 OVERFIRE: UNDERFIRE AIR PATTO 69: 31

RUN NO. DATE	76 16JUN77	77 16JUN77	78 16JUN77	79 16JUN77	66 14JUN77
XE.A.	43.00	46.00	40.00	44.00	45.00
XO.F. AIR	102.49	63.71	63.88	41.69	112.39
FUEL FT3/HR	50.00	50.00	50.00	50.00	50.00
DRY LB/HR	637.32	637.32	637.32	637.32	623.76
BTU/HR	6.06	6.06	5.06	6.06	5.93
BTU/HR/FT2	.60	.60	.60	.60	.59

TEMPERATURES IN DEGREES F

	76	77	78	79	66
T1	1150.00	1440.00	1490.00	1557.00	692.00
T2	1330.00	1160.00	1147.00	1233.00	1098.00
T3	1103.00	1075.00	1080.00	1080.00	1085.00
T4	740.00	720.00	703.00	697.00	695.00
FAN OUTLET	79.00	90.00	83.00	84.00	65.00
UNDERGRATE	270.00	273.00	261.00	267.00	278.00
FRONT O.F.	230.00	255.00	228.00	308.00	279.00
REAR O.F.	215.00	200.00	200.00	210.00	269.00
BYPASS	590.00	565.00	560.00	535.00	540.00

AIR FLOW RATES IN SCFM

	76	77	78	79	66
MAIN	3240.44	3280.00	3216.57	3481.99	3233.14
FRONT O.F.	549.04	722.52	407.62	352.34	599.19
REAR O.F.	553.96	0	223.64	0	593.91
BYPASS	1370.57	1368.00	1435.00	1631.76	1377.60
CONVEYOR	94.93	97.49	90.67	138.38	110.58
TOTAL	1168.83	1193.35	1144.31	1177.00	1159.96
LEAKAGE	795.98	816.14	736.94	811.60	806.17

VELOCITIES IN FEET PER SECOND

	76	77	78	79	66
VEL. AT T1	.54	2.72	3.05	5.03	-0.37
VEL. AT T2	4.50	4.16	3.96	4.20	3.87
VEL. AT T3	11.12	11.14	10.73	11.03	10.92

CARRYOVER DATA

	76	77	78	79	66
LB/HR	12.75	25.80	32.00	35.00	10.60
GR/SCF	1.27	2.52	3.26	3.56	1.07
%ASH	17.30	20.50	15.60	10.80	10.58
%COMB.	82.70	79.50	84.40	89.20	89.58
OPACITY	15.00	15.00	17.00	23.00	5.00

BAROMETER	76	77	78	79	66
WEATHER	30.08	30.05	30.05	30.05	30.03
	CLOUDY	CLOUDY	CLEAR	CLEAR	OVERCAST

APPENDIX B

PARTICLE SIZE DISTRIBUTION AND PARTICLE DENSITY

VERSUS SIZE DISTRIBUTION

(Data for each of 38 samples listed by run numbers)

RUN NUMBER: 40

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.08		0.032
1.651	0.56	99.45	0.047
0.833	5.31	95.57	0.074
0.295	4.77	58.85	0.106
0.208	0.81	25.86	0.119
0.147	0.73	20.26	0.143
0.104	0.38	15.21	0.158
0.074	0.31	12.59	0.163
0.053	0.36	10.44	0.180
0.043	0.34	7.95	0.243
pan	0.81	5.60	0.506

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

23

RUN NUMBER: 40

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 40

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 41

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.29		0.016
1.651	0.73	98.10	0.024
0.833	3.06	93.30	0.043
0.295	3.33	73.21	0.076
0.208	0.75	51.35	0.107
0.147	0.96	46.42	0.147
0.104	0.58	40.12	0.157
0.074	0.74	36.31	0.161
0.053	0.70	31.45	0.159
0.043	0.64	26.86	0.229
pan	3.45	22.65	0.556

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 41

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 41

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 42

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.07		0.018
1.651	0.32	99.67	0.025
0.833	2.80	98.14	0.045
0.295	4.98	84.82	0.077
0.208	1.22	61.11	0.097
0.147	1.65	55.31	0.135
0.104	1.28	47.45	0.160
0.074	1.16	41.36	0.176
0.053	1.25	35.84	0.198
0.043	1.12	29.89	0.303
pan	5.16	24.56	0.600

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

29

RUN NUMBER: 42

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 42

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 43

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.18		0.019
1.651	0.51	98.96	0.026
0.833	2.60	96.00	0.059
0.295	3.30	80.92	0.067
0.208	0.92	61.78	0.115
0.147	1.30	56.44	0.155
0.104	1.10	48.90	0.164
0.074	0.91	42.52	0.186
0.053	1.09	37.24	0.210
0.043	1.06	30.92	0.331
pan	4.27	24.77	0.628

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PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 43

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 43

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 44

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.03		0.020
1.651	0.17	99.88	0.032
0.833	1.59	99.21	0.053
0.295	5.24	92.92	0.085
0.208	2.12	72.18	0.128
0.147	2.89	63.79	0.166
0.104	1.67	52.36	0.186
0.074	1.50	45.75	0.203
0.053	1.44	39.81	0.218
0.043	1.27	34.11	0.302
pan	7.35	29.09	0.613

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

36

RUN NUMBER: 44

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 44

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 45

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.05		0.017
1.651	0.21	99.79	0.026
0.833	1.85	98.88	0.044
0.295	4.92	90.94	0.075
0.208	2.02	69.83	0.116
0.147	2.02	61.16	0.142
0.104	1.22	52.49	0.174
0.074	1.27	47.25	0.190
0.053	1.08	41.80	0.193
0.043	1.15	37.17	0.288
pan	7.51	32.23	0.606

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 45

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 45

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 47

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.17		0.043
1.651	0.85	99.12	0.068
0.833	6.46	94.71	0.090
0.295	5.72	61.18	0.114
0.208	1.17	31.50	0.124
0.147	1.23	25.43	0.141
0.104	0.68	19.05	0.151
0.074	0.60	15.52	0.133
0.053	0.55	12.40	0.183
0.043	0.53	9.55	0.241
pan	1.31	6.80	0.409

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 47

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 47

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 48

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	4.5		0.024
1.651	8.8	99.23	0.067
0.833	4.59	95.12	0.096
0.295	4.42	63.11	0.113
0.208	0.90	32.29	0.129
0.147	0.77	26.01	0.143
0.104	0.38	20.64	0.173
0.074	0.44	17.99	0.176
0.053	0.39	14.92	0.177
0.043	0.33	12.20	0.206
pan	1.42	9.90	0.394

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

45

RUN NUMBER: 48

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 48

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 49

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.46		0.054
1.651	1.48	98.45	0.085
0.833	4.60	93.44	0.115
0.295	12.84	77.89	0.207
0.208	3.57	34.48	0.241
0.147	2.20	22.41	0.244
0.104	0.78	14.98	0.300
0.074	0.60	12.34	0.194
0.053	0.72	10.31	0.200
0.043	0.64	7.88	0.237
pan	1.69	5.71	0.393

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 49

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 49

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 50

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.19		0.043
1.651	0.82	99.15	0.075
0.833	5.52	95.47	0.094
0.295	6.65	70.70	0.136
0.208	2.22	40.87	0.176
0.147	1.82	30.91	0.172
0.104	0.83	22.75	0.180
0.074	0.72	19.02	0.180
0.053	0.71	15.79	0.178
0.043	0.57	12.61	0.219
pan	2.24	10.05	0.339

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 50

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 50

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 51

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.48		0.044
1.651	1.67	97.27	0.070
0.833	5.63	87.76	0.085
0.295	4.90	55.70	0.117
0.208	1.06	27.79	0.151
0.147	0.96	21.75	0.145
0.104	0.49	16.29	0.153
0.074	0.36	13.50	0.150
0.053	0.49	11.45	0.163
0.043	0.42	8.66	0.233
pan	1.10	6.26	0.423

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 51

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 51

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 52

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.19		0.036
1.651	1.02	98.85	0.060
0.833	5.70	92.69	0.084
0.295	4.87	58.25	0.097
0.208	1.08	28.82	0.119
0.147	0.89	22.30	0.133
0.104	0.48	16.92	0.141
0.074	0.44	14.02	0.169
0.053	0.35	11.36	0.159
0.043	0.36	9.25	0.212
pan	1.17	7.07	--

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 52

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 52

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 53

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.09		0.025
1.651	0.51	99.21	0.060
0.833	4.06	94.72	0.090
0.295	2.64	58.98	0.107
0.208	0.43	35.74	0.139
0.147	0.56	31.95	0.175
0.104	0.37	27.03	0.218
0.074	0.34	23.77	0.213
0.053	0.42	20.78	0.191
0.043	0.48	17.08	0.300
pan	1.46	12.85	0.562

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

60

RUN NUMBER: 53

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 53

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 54

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.67		0.018
1.651	0.75	93.00	0.024
0.833	1.96	85.16	0.044
0.295	1.46	64.68	0.072
0.208	0.24	49.26	0.093
0.147	0.34	46.71	0.126
0.104	0.27	43.16	0.159
0.074	0.38	40.33	0.173
0.053	0.39	36.36	0.163
0.043	0.45	32.29	0.250
pan	2.64	27.59	0.539

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 54

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 54

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 55

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.24		0.032
1.651	0.85	98.84	0.053
0.833	4.67	94.73	0.074
0.295	3.14	72.17	0.085
0.208	0.58	57.01	0.116
0.147	0.89	54.20	0.189
0.104	0.82	49.90	0.228
0.074	0.84	45.94	0.221
0.053	1.02	41.88	0.227
0.043	1.29	36.96	0.323
pan	6.36	30.73	0.612

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

66

RUN NUMBER: 55

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 55

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 56

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.25		0.029
1.651	0.67	99.12	0.048
0.833	3.31	96.75	0.074
0.295	1.99	85.03	0.085
0.208	0.71	77.99	0.154
0.147	1.28	75.48	0.237
0.104	1.18	70.95	0.281
0.074	1.44	66.77	0.267
0.053	1.43	61.68	0.298
0.043	2.10	56.62	0.328
pan	13.90	48.19	0.615

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

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RUN NUMBER: 56

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 56

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 57

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.27		0.033
1.651	0.75	98.75	0.061
0.833	2.55	95.28	0.082
0.295	1.32	83.48	0.098
0.208	0.75	77.37	0.234
0.147	1.32	73.90	0.293
0.104	1.19	67.79	0.298
0.074	1.25	62.29	0.260
0.053	1.35	56.50	0.260
0.043	1.53	50.26	0.340
pan	9.33	43.18	0.648

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 57

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 57

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 58

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	2.76		0.080
1.651	3.71	81.75	0.100
0.833	3.29	97.21	0.100
0.295	1.81	35.45	0.106
0.208	0.42	23.48	0.114
0.147	0.47	20.70	0.142
0.104	0.36	17.59	0.150
0.074	0.33	15.21	0.165
0.053	0.41	13.03	0.186
0.043	0.39	10.32	0.260
pan	1.17	7.74	0.468

DOUGLAS FIR BARK

RUN NUMBER: 58

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 58

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 59

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	2.42		0.071
1.651	3.11	78.99	0.094
0.833	2.72	52.0	0.091
0.295	1.12	28.39	0.088
0.208	0.18	18.66	0.095
0.147	0.19	17.10	0.106
0.104	0.16	15.45	0.123
0.074	0.18	14.06	0.138
0.053	0.21	12.50	0.150
0.043	0.21	10.68	0.191
pan	1.02	8.85	0.425

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 59

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 59

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 60

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	3.42		0.059
1.651	2.44	66.96	0.084
0.833	1.70	43.38	0.083
0.295	0.66	26.96	0.085
0.208	0.15	20.58	0.083
0.147	0.22	19.13	0.100
0.104	0.11	17.01	0.092
0.074	0.18	15.94	0.113
0.053	0.20	14.20	0.125
0.043	0.18	12.27	0.150
pan	1.09	10.53	0.363

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 60

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 60

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 61

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	1.56		0.087
1.651	2.95	89.70	0.098
0.833	3.97	70.23	0.102
0.295	1.33	44.03	0.098
0.208	0.31	35.25	0.107
0.147	0.60	33.20	0.135
0.104	0.41	29.90	0.164
0.074	0.47	27.20	0.157
0.053	0.53	24.09	0.161
0.043	0.55	20.59	0.229
pan	2.57	16.96	0.476

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

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RUN NUMBER: 61

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 61

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 62

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	1.51		0.052
1.651	2.58	92.14	0.072
0.833	4.04	78.72	0.081
0.295	1.60	57.70	0.084
0.208	0.53	49.38	0.115
0.147	0.86	46.62	0.134
0.104	0.59	42.14	0.134
0.074	0.82	39.07	0.152
0.053	0.86	34.81	0.162
0.043	0.98	30.33	0.228
pan	4.85	25.23	0.511

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 62

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 62

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 63

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	1.23		0.031
1.651	1.90	90.54	0.054
0.833	3.88	75.92	0.078
0.295	1.70	46.08	0.100
0.208	0.44	33.00	0.126
0.147	0.53	29.62	0.166
0.104	0.38	25.54	0.165
0.074	0.39	22.62	0.163
0.053	0.40	19.62	0.154
0.043	0.37	16.54	0.231
pan	1.78	13.69	0.468

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 63

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 63

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 65

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.22		0.034
1.651	0.77	98.12	0.057
0.833	3.62	91.55	0.084
0.295	2.28	60.63	0.112
0.208	0.57	41.16	0.154
0.147	0.85	36.29	0.202
0.104	0.51	29.04	0.243
0.074	0.48	24.68	0.218
0.053	0.43	20.58	0.215
0.043	0.38	16.91	0.271
pan	1.60	13.66	0.471

1 cond

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

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RUN NUMBER: 65

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 65

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 66

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.46		0.038
1.651	2.38	98.90	0.085
0.833	13.94	93.24	0.082
0.295	7.50	60.03	0.103
0.208	1.89	42.16	0.152
0.147	2.66	37.66	0.218
0.104	1.84	31.32	0.279
0.074	1.69	26.94	0.264
0.053	1.46	22.92	0.232
0.043	1.52	19.44	0.287
pan	6.64	15.82	0.544

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

96

RUN NUMBER: 66

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 66

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 67

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.22		0.044
1.651	1.00	99.62	0.063
0.833	10.09	97.91	0.086
0.295	8.43	80.59	0.095
0.208	2.59	66.13	0.146
0.147	4.00	61.69	0.187
0.104	2.84	54.82	0.233
0.074	2.87	49.95	0.250
0.053	3.35	45.02	0.243
0.043	4.07	39.28	0.318
pan	18.82	32.29	0.570

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

99

RUN NUMBER: 67

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 67

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 68

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.72		0.031
1.651	1.61	97.17	0.045
0.833	6.19	90.83	0.060
0.295	4.56	66.48	0.063
0.208	1.0	43.54	0.114
0.147	1.58	44.61	0.170
0.104	1.21	38.40	0.195
0.074	1.15	33.64	0.198
0.053	1.29	29.11	--
0.043	1.26	24.04	0.274
pan	4.85	19.08	0.527

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 68

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 68

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 69

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.62		
1.651	1.66	98.20	
0.833	8.51	93.37	
0.295			
0.208	6.42	68.61	
0.147	1.73	49.93	
0.104	1.33	44.89	
0.074	1.31	41.02	
0.053	1.71	37.21	
0.043	2.17	32.24	
pan	8.91	25.92	

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

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RUN NUMBER: 69

RUN NUMBER: 70

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	4.75		0.054
1.651	5.93	81.89	0.076
0.833	6.49	59.28	0.074
0.295	4.21	34.54	0.083
0.208	1.03	18.49	0.099
0.147	0.84	14.56	0.111
0.104	0.46	11.36	0.121
0.074	0.41	9.60	0.137
0.053	0.42	8.04	0.162
0.043	0.47	6.44	0.235
pan	1.22	4.65	0.421

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 70

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 70

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 71

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	6.69		0.092
1.651	9.66	83.23	0.103
0.833	9.18	59.01	0.103
0.295	5.62	36.00	0.108
0.208	1.34	21.91	0.119
0.147	1.20	18.55	0.141
0.104	0.77	15.54	0.154
0.074	0.77	13.61	0.183
0.053	0.77	11.68	0.179
0.043	0.77	9.75	0.226
pan	3.12	7.82	0.433

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 71

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 71

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 72

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	5.82		0.083
1.651	8.98	83.54	0.102
0.833	9.37	58.15	0.103
0.295	5.13	31.65	0.112
0.208	1.06	17.14	0.129
0.147	1.05	14.14	0.150
0.104	0.55	11.17	0.172
0.074	0.63	9.62	0.180
0.053	0.53	7.83	0.177
0.043	0.47	6.34	0.235
pan	1.77	5.01	0.421

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 72

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 72

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 73

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	6.13		0.090
1.651	9.42	83.97	0.105
0.833	9.63	59.34	0.099
0.295	4.07	34.15	0.113
0.208	0.92	23.51	0.128
0.147	1.15	21.10	0.139
0.104	0.82	18.10	0.161
0.074	0.87	15.95	--
0.053	0.85	13.68	--
0.043	0.89	11.45	0.228
pan	3.49	9.13	0.447

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 73

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 73

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 74

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	6.45		0.088
1.651	9.71	84.03	0.102
0.833	11.12	59.98	0.105
0.295	3.71	32.44	0.106
0.208	0.92	23.25	0.128
0.147	1.08	20.98	0.137
0.104	0.72	18.30	0.150
0.074	0.86	16.52	0.191
0.053	0.81	14.39	0.156
0.043	0.87	12.38	0.218
pan	4.13	10.23	0.430

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 74

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 74

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 75

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	3.19		0.094
1.651	7.96	92.13	0.105
0.833	12.65	72.50	0.103
0.295	4.75	41.29	0.110
0.208	1.22	29.58	0.139
0.147	1.44	26.57	0.157
0.104	1.14	23.01	0.170
0.074	1.19	20.20	0.183
0.053	1.10	17.27	0.190
0.043	1.11	14.55	0.247
pan	4.79	11.82	0.470

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 75

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 75

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 76

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	0.37		0.026
1.651	1.73	98.65	0.048
0.833	9.35	92.34	0.075
0.295	5.08	58.26	0.092
0.208	0.85	39.74	0.116
0.147	1.33	36.64	0.175
0.104	0.94	31.79	0.214
0.074	1.00	28.36	0.200
0.053	0.89	24.72	0.189
0.043	0.93	21.47	0.251
pan	4.96	18.08	0.477

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 76

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 76

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 77

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	1.66		0.069
1.651	6.69	95.76	0.094
0.833	12.75	78.68	0.104
0.295	5.26	46.12	0.107
0.208	1.19	32.69	0.134
0.147	1.52	29.65	0.169
0.104	1.13	25.77	0.198
0.074	1.26	22.88	0.203
0.053	1.14	19.66	0.190
0.043	1.23	16.75	0.251
pan	5.33	13.61	0.485

DOUGLAS FIR BARK

RUN NUMBER: 77

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 77

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 78

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	2.69		0.044
1.651	5.06	92.21	0.077
0.833	7.73	77.55	0.087
0.295	5.26	55.16	0.094
0.208	1.43	39.92	0.112
0.147	1.71	35.78	0.140
0.104	1.26	30.82	0.166
0.074	1.23	27.17	0.181
0.053	1.25	23.61	0.179
0.043	1.29	19.99	0.248
pan	5.61	16.25	0.464

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

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RUN NUMBER: 78

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 78

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

RUN NUMBER: 79

SIZE (mm)	SCREEN WEIGHT (g)	CUMULATIVE % WEIGHT	DENSITY (g/cm ³)
2.362	4.50		0.063
1.651	7.46	90.57	0.091
0.833	9.86	74.94	0.094
0.295	6.89	54.28	0.098
0.208	1.99	39.84	0.116
0.147	2.12	35.67	0.214
0.104	1.52	31.22	0.155
0.074	1.72	28.04	0.187
0.053	1.77	24.43	--
0.043	1.94	20.73	0.269
pan	7.95	16.66	0.476

PLOT OF PARTICLE SIZE DISTRIBUTION--COLLECTED ASH
DOUGLAS FIR BARK

RUN NUMBER: 79

PLOT OF PARTICLE DENSITY VERSUS GEOMETRIC MEAN SIZE

RUN NUMBER: 79

▲ = Density of material collected in pan, i.e. particles less than 0.043mm.

APPENDIX C

COMPARATIVE DATA ON PARTICLE DEGRADATION STUDIES

TWO MINUTE SHAKE PERIOD

TYLER SCREEN SIZE (mm)	TEST RUN 1		TEST RUN 2		TEST RUN 3	
	WEIGHT	CUM WT	WEIGHT	CUM WT	WEIGHT	CUM WT
2.362	0.62	0.62	0.63	0.63	0.58	0.58
1.651	1.66	2.28	1.55	2.18	1.62	2.20
0.833	8.51	10.79	8.64	10.82	8.50	10.70
0.295	—	—	5.65	16.47	5.86	16.56
0.208	6.42	17.21	1.12	17.59	1.22	17.78
0.147	1.73	18.94	1.69	19.28	1.63	19.41
0.104	1.33	20.27	1.21	20.49	1.21	20.62
0.074	1.31	21.58	1.29	21.78	1.31	21.93
0.053	1.71	23.29	1.56	23.34	1.68	23.61
0.043	2.17	25.46	1.85	25.19	2.19	25.80
pan	8.91	34.37	8.87	34.06	8.17	33.97

Figure 1a. Comparison of Screen Weights; Sample no. 69

FOUR MINUTE SHAKE PERIOD

TYLER SCREEN SIZE (mm)	TEST RUN 1		TEST RUN 2	
	WEIGHT	CUM WT	WEIGHT	CUM WT
2.362	0.56	0.56	0.54	0.54
1.651	1.41	1.97	1.41	1.95
0.833	8.19	10.16	8.47	10.42
0.295	5.84	16.00	5.97	16.39
0.208	1.06	17.06	1.07	17.46
0.147	1.63	18.69	1.45	18.91
0.104	1.22	19.91	1.38	20.29
0.074	1.27	21.18	1.20	21.49
0.053	1.50	22.68	1.34	22.83
0.043	1.61	24.29	1.45	24.28
pan	8.87	33.16	9.11	33.39

Figure 1b. Comparison of Screen Weights
Sample no. 69

TWO MINUTE SHAKE PERIOD

TYLER SCREEN SIZE (mm)	SAMPLE #66		SAMPLE #67	
	RUN #1	RUN #2	RUN #1	RUN # 2
2.362	12	11	5	4.5
1.651	28	27	16.0	16.8
0.833	169	168	118	114
0.295	73	77	89	85
0.208	12.4	12.0	17.8	16.6
0.147	12.2	13.0	21.4	24.0
0.104	6.6	6.8	12.2	14.8
0.074	6.4	7.0	11.5	11.0
0.053	6.3	6.3	13.8	12.2
0.043	5.3	5.1	12.8	9.8
pan	12.2	11.8	33.0	33.0

Figure 2. Volume Comparison