Appendix I. Analysis of Device Performance

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Appendix I. Analysis of Device Performance

To provide a basis to understand the performance of the ESP device, the TEOM and ESP operational data were combined and processed to determine the device’s PM removal efficiency and to permit a graphical display of emissions performance on a consistent basis during the test. This work was performed by Rincon Ranch Consulting under subcontract to Trinity Consultants and is included here at the request of FNSB.

The TEOM PM emission measurements and the ESP operational data were combined and processed to permit a graphical display of emissions performance on a consistent basis during the tests. The TEOM measurements of particulate emissions were reported on a minute basis by ClearStak. For the pellet stove, the data include emission rates measured before and after the ESP device in units of g/h. The ESP operational data are the device’s diagnostic information reported on a second-by-second basis through a data-logging interface to Microsoft Excel. Many different parameters are reported, but for this analysis the key data fields are voltage (V), current (μA), and power (mW). These values indicate whether the ESP is in operation or not and provide the chief measures of its instantaneous operational state.

Arcing events can have a large impact on emissions exiting the ESP. Arcing events are instants in time when the voltage, current and power fall to zero as the high-voltage electrode is shorted to ground. Two types of arcing events were coded. The device itself may report a trouble code of 8 to the data-logging interface to indicate that an event has occurred. In addition to such Reported Arcing Events, Suspected Arcing Events were coded whenever the power fell to zero but a trouble code of 8 was not reported. For either type, an event begins when a second with zero voltage occurs and will continue until such time as power rises above zero. Reported and Suspected Arcing Events are mutually exclusive and both may influence stack emissions.

The TEOM was placed into operation when the ASTM E2779 test procedure began; start and end times were recorded for each test. The ESP datalogging was started independently and could be initiated before the test began, when it began, or shortly thereafter since the ESP turns itself on automatically after a delay of a few to several minutes from starting the test. The first step in the analysis was to align the ESP operational data according to the test start and end times associated with the TEOM data. Then, the second-by-second operational data were reduced to minute or sub-minute averages in order to facilitate graphical display. During the processing, it was determined that the second-by-second data frequently fail to report a second or may report data with a duplicate timestamp. This logging irregularity results in missing 1.8
seconds of each minute on average; most minutes consist of 57-59 entries with duplicated timestamps in some cases. Because of this, the second-by-second entries were treated as generic “entries” that are assumed to be evenly spaced throughout the minute. The difference between this treatment and the true (but unknown) time base of seconds is too small to be detectable in the graphs.

Arcing events are very short-term events that last at most a few seconds. The full second-by-second data show these events clearly along with intra-minute detail on the operational parameters during more normal operation, but the data are unwieldy to display because the ASTM E2779 test spans a total of 25,200 seconds (420 minutes). To address this, while retaining the short-term visualization of arcing events, minute-by-minute averages of voltage, current and power were usually computed to correspond to the TEOM data, but the computation switched to a second-by-second basis whenever an arcing event (of either type) occurs. The data were then reported on a second-by-second basis through the end of the minute in which the arcing event ends. Emissions and operational data were then plotted on an X, Y basis where X can be an integer minute or a decimal value representing a sub-minute average or a single second in time.

Four different graphs were created to display a range of operational parameters, emission rates, and computed emission removal rates and removal efficiencies for the device. The set of four graphs were produced for the entire test cycle and for its four phases: Startup (minutes 0-60); High Burn (minutes 61-120); Medium Burn (minutes 121-240); and Low Burn (minutes 241-419).

The graphs and variables displayed in them are the following:

- **ESP Operational Parameters**: graph of ESP Power, Voltage and Current during the test. Arcing events are indicated by black and red diamonds and overlaid on the graph at the level of 5,000V (an arbitrary position chosen for clarity).

- **Pre and Post Emission Rate with ESP Power**: graph of PM emissions measured before and after the ESP to show the pollutant removal by the device. Power and arcing events are also shown as in the first graph.

- **Pre and Post Emission Rate with Mass Removal**: graph of the instantaneous mass removal rate (g/h) on the left axis, with running averages of the pre- and post- emission rates and mass removal rate on the right axis. For the graphs of the entire test, the running averages begin with minute 0 and end with minute 419. For the graphs of phases of the test, the running averages begin and end with the minutes that define the phase. Arcing events are overlaid at the 1 level (arbitrary).
Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

- **Removal Efficiency**: graph of instantaneous removal efficiency (blue circles) and running average removal efficiency (black line) along with an overlay of arcing events. The running average begins and ends with the test segment shown in the graph.
Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

Step 2 Pellet Appliance with ESP, Run 2, Entire Run

*Step 2 Pellet Appliance with ESP, Run 2, Entire Run (minutes 0-419)*

**ESP Operating Parameters**

- **Power (mW)**
- **Voltage (V)**
- **Arcing Event (Reported)**
- **Arcing Event (Suspected)**
- **Current (µA)**

**Step 2 Pellet Appliance with ESP, Run 2, Entire Run (minutes 0-419)**

**Pre and Post Emission Rate with ESP Power**

- **Power (mW)**
- **Emission Rate (g/h)**

**Graphs and Data Analysis**
Step 2 Pellet Appliance with ESP, Run 2, Entire Run (minutes 0-419)

Pre and Post Emission Rate with Mass Removal

Running Average

Emission Rate (g/h)

Mass Removal (g/h)

Arcing Events

Step 2 Pellet Appliance with ESP, Run 2, Entire Run (minutes 0-419)

Removal Efficiency

Arcing Events

Removal Efficiency (%)

Arcing Event (Reported)

Arcing Event (Suspected)

Instantaneous Removal Efficiency

Running Avg Pre_ESP (g/h)

Running Avg Post_ESP (g/h)

Running Avg Mass Removal (g/h)
Step 2 Pellet Appliance with ESP, Run 2, Startup

**ESP Operating Parameters**

- Total Power (mW)
- Voltage (V)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Current (μA)

**Pre and Post Emission Rate with ESP Power**

- Total Power (mW)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Pre ESP diluter (g/h)
- Post ESP diluter (g/h)
Step 2 Pellet Appliance with ESP, Run 2, Startup (minutes 0-60)

Pre and Post Emission Rate with Mass Removal

Mass Removal (g/h)

Arcing Events

Running Average Emission Rate (g/h)

Mass Removal (g/h)

Arcing Event (Reported)

Running Avg Pre_ESP (g/h)

Running Avg Post_ESP (g/h)

Running Avg Mass Removal (g/h)

Instantaneous Removal Efficiency

Running Avg Removal Efficiency

Arcing Event (Reported)

Arcing Event (Suspected)

Instantaneous Removal Efficiency

Running Avg Removal Efficiency

Removal Efficiency (%)
Step 2 Pellet Appliance with ESP, Run 2, High Burn

**ESP Operating Parameters**

- **Total Power (mW)**
- **Voltage (V)**
- **Arcing Event (Reported)**
- **Arcing Event (Suspected)**
- **Current (μA)**

**Pre and Post Emission Rate with ESP Power**

- **Emission Rate (g/h)**
- **Pre ESP diluter (g/h)**
- **Post ESP diluter (g/h)**

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<th>Time (minutes)</th>
<th>Power (mW)</th>
<th>Voltage (V)</th>
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<th>Current (μA)</th>
<th>Pre ESP diluter (g/h)</th>
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Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

**Step 2 Pellet Appliance with ESP, Run 2, High Burn (minutes 61-120)**

**Pre and Post Emission Rate with Mass Removal**

**Running Average Emission Rate (g/h)**

**Mass Removal (g/h)**

**Arcing Events**

**Instantaneous Mass Removal Efficiency**

**Running Avg Pre_ESP (g/h)**

**Running Avg Post_ESP (g/h)**

**Running Avg Mass Removal (g/h)**

**Arcing Event (Reported)**

**Arcing Event (Suspected)**

**Removal Efficiency (%)**

**Arcing Events**

**Instantaneous Removal Efficiency**

**Running Avg Removal Efficiency**
Step 2 Pellet Appliance with ESP, Run 2, Medium Burn

**Mass Removal (g/h)**

**Arcing Events**

**Pre and Post Emission Rate with Mass Removal**

**Running Average Emission Rate (g/h)**

**Power (mW)**

**Pre and Post Emission Rate with ESP Power**

**Emission Rate (g/h)**

**Total Power (mW)**

**Arcing Event (Reported)**

**Arcing Event (Suspected)**

**Pre ESP diluter (g/h)**

**Post ESP diluter (g/h)**
Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

![Graph showing emission rates and removal efficiency over time.]

**Step 2 Pellet Appliance with ESP, Run 2, Medium Burn (minutes 121-240)**

- **Mass Removal (g/h)**
- **Arcing Events**
- **Pre and Post Emission Rate with Mass Removal**
- **Running Average Emission Rate (g/h)**

**Removal Efficiency (%)**

- **Arcing Event (Reported)**
- **Arcing Event (Suspected)**
- **Instantaneous Removal Efficiency**
- **Running Avg Removal Efficiency**

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Step 2 Pellet Appliance with ESP, Run 2, Low Burn

ESP Operating Parameters

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<th>Total Power (mW)</th>
<th>Voltage (V)</th>
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Pre and Post Emission Rate with ESP Power

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Step 2 Pellet Appliance with ESP, Run 2, Low Burn (minutes 241-419)

Pre and Post Emission Rate with Mass Removal

Running Average Emission Rate (g/h)

Mass Removal (g/h)

Arcing Events

Running Avg Pre_ESP (g/h)

Arcing Event (Reported)

Running Avg Post_ESP (g/h)

Arcing Event (Suspected)

Running Avg Mass Removal (g/h)

Removal Efficiency (%)

Arcing Events

Arcing Event (Reported)

Instantaneous Removal Efficiency

Arcing Event (Suspected)

Running Avg Removal Efficiency
Step 2 Pellet Appliance with ESP, Run 3, Entire Run

### ESP Operating Parameters

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<th>Time (minutes)</th>
<th>Total Power (mW)</th>
<th>Voltage (V)</th>
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### Pre and Post Emission Rate with ESP Power

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Step 2 Pellet Appliance with ESP, Run 3, Startup

![Graph showing ESP operating parameters and emission rates](image-url)
Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

Step 2 Pellet Appliance with ESP, Run 3, Startup (minutes 0-60)

**Mass Removal (g/h)**

**Arcing Events**

**Pre and Post Emission Rate with Mass Removal**

**Running Average Emission Rate (g/h)**

**Mass Removal (g/h)**

**Arcing Event (Reported)**

**Arcing Event (Suspected)**

**Running Avg Pre_ESP (g/h)**

**Running Avg Post_ESP (g/h)**

**Running Avg Mass Removal (g/h)**

**Removal Efficiency (%)**

**Arcing Events**

**Instantaneous Removal Efficiency**

**Running Avg Removal Efficiency**

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Step 2 Pellet Appliance with ESP, Run 3, High Burn

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**Pellet Stove Retrofit Emission Control Device Emission Reduction Testing**

**Step 2 Pellet Appliance with ESP, Run 3, High Burn**
Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

Step 2 Pellet Appliance with ESP, Run 3, High Burn (minutes 61-120)
Pre and Post Emission Rate with Mass Removal

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<th>Arcing Events</th>
<th>Mass Removal (g/h)</th>
<th>Running Average Emission Rate (g/h)</th>
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Running Avg Pre_ESP (g/h)  Running Avg Post_ESP (g/h)  Running Avg Mass Removal (g/h)

Removal Efficiency

<table>
<thead>
<tr>
<th>Instantaneous Removal Efficiency</th>
<th>Running Avg Removal Efficiency</th>
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<td>40%</td>
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<tr>
<td>70%</td>
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<td>10%</td>
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<tr>
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</tr>
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</table>

Step 2 Pellet Appliance with ESP, Run 3, High Burn (minutes 61-120)
Removal Efficiency
Step 2 Pellet Appliance with ESP, Run 3, Medium Burn

ESP Operating Parameters

Pre and Post Emission Rate with ESP Power
Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

Step 2 Pellet Appliance with ESP, Run 3, Medium Burn (minutes 121-240)

Mass Removal (g/h)
Arcing Events

Pre and Post Emission Rate with Mass Removal

Running Average Emission Rate (g/h)

Running Avg Pre_ESP (g/h)
Running Avg Post_ESP (g/h)
Running Avg Mass Removal (g/h)

Removal Efficiency
Arcing Events

Instantaneous Removal Efficiency
Running Avg Removal Efficiency

Arcing Event (Reported)
Arcing Event (Suspected)

I-21
### Step 2 Pellet Appliance with ESP, Run 3, Low Burn

#### ESP Operating Parameters

<table>
<thead>
<tr>
<th>Total Power (mW)</th>
<th>Voltage (V)</th>
<th>Arcing Event (Reported)</th>
<th>Arcing Event (Suspected)</th>
<th>Current (μA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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#### Pre and Post Emission Rate with ESP Power

<table>
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<th>Power (mW)</th>
<th>Emission Rate (g/h)</th>
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<tr>
<td></td>
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</tbody>
</table>

Graphs showing power, voltage, current, and emission rate measurements over time.
Step 2 Pellet Appliance with ESP, Run 3, Low Burn (minutes 241-419)

- Mass Removal (g/h)
- Arcing Events

Pre and Post Emission Rate with Mass Removal

- Running Average Emission Rate (g/h)

Mass Removal Efficiency (%)

- Arcing Event (Reported)
- Arcing Event (Suspected)

Instantaneous Removal Efficiency

- Running Avg Pre_ESP (g/h)
- Running Avg Post_ESP (g/h)
- Running Avg Mass Removal (g/h)
Step 2 Pellet Appliance with ESP, Run 7, Entire Run

---

**Pellet Stove Retrofit Emission Control Device Emission Reduction Testing**

**Step 2 Pellet Appliance with ESP, Run 7, Entire Run**

---

**ESP Operating Parameters**

- Total Power (mW)
- Voltage (V)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Current (μA)

---

**Pre and Post Emission Rate with ESP Power**

- Power (mW)
- Emission Rate (g/h)

---

---
Step 2 Pellet Appliance with ESP, Run 7, Entire Run (minutes 0-419)

Pre and Post Emission Rate with Mass Removal

Running Average Emission Rate (g/h)

Mass Removal (g/h)

Arcing Events

Instantaneous Removal Efficiency

Running Avg Removal Efficiency

Arcing Event (Reported)

Running Avg Pre_ESP (g/h)

Running Avg Post_ESP (g/h)

Running Avg Mass Removal (g/h)

Removal Efficiency (%)

0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

0
15
30
45
60
75
90
105
120
135
150
165
180
195
210
225
240
255
270
285
300
315
330
345
360
375
390
405
420

Arcing Event (Reported)

Arcing Event (Suspected)

Removal Efficiency

0
1
2
3
4
5

0 15 30 45 60 75 90 105 120 135 150 165 180 195 ... Event (Reported) Arcing Event (Suspected)

Running Avg Removal Efficiency

I-25
Step 2 Pellet Appliance with ESP, Run 7, Startup
Step 2 Pellet Appliance with ESP, Run 7, Startup (minutes 0-60)
Pre and Post Emission Rate with Mass Removal

- Mass Removal (g/h)
- Arcing Events
- Running Average Emission Rate (g/h)

Removal Efficiency

- Arcing Event (Reported)
- Instantaneous Removal Efficiency
- Arcing Event (Suspected)
- Running Avg Removal Efficiency
Step 2 Pellet Appliance with ESP, Run 7, High Burn

ESP Operating Parameters

- Total Power (mW)
- Voltage (V)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Current (μA)

Pre and Post Emission Rate with ESP Power

- Total Power (mW)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Pre ESP diluter (g/h)
- Post ESP diluter (g/h)
Pellet Stove Retrofit Emission Control Device Emission Reduction Testing
Step 2 Pellet Appliance with ESP, Run 7, Medium Burn

![Graph showing ESP operating parameters, including power (mW), voltage (V), current (μA), and arcing event (reported and suspected).]

![Graph showing pre and post emission rate with ESP power, including total power (mW), arcing event (reported and suspected), pre ESP diluter (g/h), and post ESP diluter (g/h).]
Step 2 Pellet Appliance with ESP, Run 7, Medium Burn (minutes 121-240)

Pre and Post Emission Rate with Mass Removal

Running Average

Removal Efficiency (%)

Arcing Events
Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

**Step 2 Pellet Appliance with ESP, Run 7, Low Burn**

![Graph showing ESP Operating Parameters](image1)

- **Power (mW)**
- **Voltage (V)**
- **Arcing Event (Reported)**
- **Arcing Event (Suspected)**
- **Current (μA)**

![Graph showing Pre and Post Emission Rate with ESP Power](image2)

- **Power (mW)**
- **Emission Rate (g/h)**
- **Pre ESP diluter (g/h)**
- **Post ESP diluter (g/h)**
Step 2 Pellet Appliance with ESP, Run 8, Entire Run

Pellet Stove Retrofit Emission Control Device Emission Reduction Testing
Step 2 Pellet Appliance with ESP, Run 8, Startup

**ESP Operating Parameters**

- Total Power (mW)
- Voltage (V)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Current (μA)

**Pre and Post Emission Rate with ESP Power**

- Total Power (mW)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Pre ESP diluter (g/h)
- Post ESP diluter (g/h)
Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

Step 2 Pellet Appliance with ESP, Run 8, High Burn

**ESP Operating Parameters**

- **Total Power (mW)**
- **Voltage (V)**
- **Arcing Event (Reported)**
- **Arcing Event (Suspected)**
- **Current (μA)**

**Pre and Post Emission Rate with ESP Power**

- **Pre ESP diluter (g/h)**
- **Post ESP diluter (g/h)**

---

I-38
Step 2 Pellet Appliance with ESP, Run 8, High Burn (minutes 61-120)

Latitude: 43.65643
Longitude: -79.38101
Height: 648 feet

Pre and Post Emission Rate with Mass Removal

Running Average Emission Rate (g/h)

Instantaneous Removal Efficiency

Running Avg Pre_ESP (g/h)
Running Avg Post_ESP (g/h)
Running Avg Mass Removal (g/h)

Arcing Events

Removal Efficiency (%)

0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

0
1
2
3
4
5
61 66 71 76 81 86 91 96 101 106 111 116

Mass Removal (g/h)

Arcing Events

Pre and Post Emission Rate with Mass Removal

Running Average Emission Rate (g/h)

Removal Efficiency (%)

0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

0
1
2
3
4
5
61 66 71 76 81 86 91 96 101 106 111 116

Arcing Events

Removal Efficiency (%)
Step 2 Pellet Appliance with ESP, Run 8, Medium Burn

---

**Step 2 Pellet Appliance with ESP, Run 8, Medium Burn (minutes 121-240)**

**ESP Operating Parameters**
- Total Power (mW)
- Voltage (V)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Current (μA)

**Pre and Post Emission Rate with ESP Power**
- Total Power (mW)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Pre ESP diluter (g/h)
- Post ESP diluter (g/h)
Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

Step 2 Pellet Appliance with ESP, Run 8, Medium Burn (minutes 121-240)

<table>
<thead>
<tr>
<th>Mass Removal (g/h)</th>
<th>Arcing Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre and Post Emission Rate with Mass Removal</td>
<td></td>
</tr>
<tr>
<td>Running Average Emission Rate (g/h)</td>
<td></td>
</tr>
</tbody>
</table>

- Mass Removal (g/h)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Running Avg Pre_ESP (g/h)
- Running Avg Post_ESP (g/h)
- Running Avg Mass Removal (g/h)

Removal Efficiency (%)

- Arcing Event (Reported)
- Arcing Event (Suspected)
- Instantaneous Removal Efficiency
- Running Avg Removal Efficiency
Step 2 Pellet Appliance with ESP, Run 8, Low Burn

**ESP Operating Parameters**

- Total Power (mW)
- Voltage (V)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Current (μA)

**Pre and Post Emission Rate with ESP Power**

- Total Power (mW)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Pre ESP diluter (g/h)
- Post ESP diluter (g/h)
Step 2 Pellet Appliance with ESP, Run 8, Low Burn (minutes 241-419)

Pre and Post Emission Rate with Mass Removal

Running Average

Emission Rate (g/h)

Mass Removal (g/h)

Arcing Events

Arcing Event (Reported)

Arcing Event (Suspected)

Running Avg Pre_ESP (g/h)

Running Avg Post_ESP (g/h)

Running Avg Mass Removal (g/h)

Removal Efficiency (%)

Arcing Events

Instantaneous Removal Efficiency

Running Avg Removal Efficiency
Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

**Step 2 Pellet Appliance with ESP, Run 9, Entire Run**

![Graph of Step 2 Pellet Appliance with ESP, Run 9, Entire Run (minutes 0-419)](image)

**Figure 9. Step 2 Pellet Appliance with ESP, Run 9, Entire Run (minutes 0-419)**

- **Pre and Post Emission Rate with ESP Power**
- **ESP Operating Parameters**

---

**Total Power (mW)**

**Voltage (V)**

**Arcing Event (Reported)**

**Arcing Event (Suspected)**

**Current (μA)**
Figure ES-2. Step 2 Pellet Appliance with ESP, Run 9, Entire Run (minutes 0-419)

<table>
<thead>
<tr>
<th>Mass Removal (g/h)</th>
<th>Arcing Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Startup</td>
<td>High Burn</td>
</tr>
<tr>
<td>Medium Burn</td>
<td>Low Burn</td>
</tr>
</tbody>
</table>

Pre and Post Emission Rate with Mass Removal

Running Average Emission Rate (g/h)

Removal Efficiency (%)

Arcing Events

Instantaneous Removal Efficiency

Running Avg Removal Efficiency

Arcing Event (Reported)

Arcing Event (Suspected)
Step 2 Pellet Appliance with ESP, Run 9, Startup

**Step 2 Pellet Appliance with ESP, Run 9, Startup (minutes 0-60)**

**ESP Operating Parameters**
- Total Power (mW)
- Voltage (V)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Current (μA)

**Pre and Post Emission Rate with ESP Power**
- Total Power (mW)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Pre ESP diluter (g/h)
- Post ESP diluter (g/h)
Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

**Graph 1:**
- *Step 2 Pellet Appliance with ESP, Run 9, Startup (minutes 0-60)*
- **Pre and Post Emission Rate with Mass Removal**
- **Running Average Emission Rate (g/h)**

**Legend:**
- Mass Removal (g/h)
- Arcing Events
- Running Avg Pre_ESP (g/h)
- Running Avg Post_ESP (g/h)
- Running Avg Mass Removal (g/h)

**Graph 2:**
- *Step 2 Pellet Appliance with ESP, Run 9, Startup (minutes 0-60)*
- **Removal Efficiency**

**Legend:**
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Instantaneous Removal Efficiency
- Running Avg Removal Efficiency

**Table:**
- Mass Removal (g/h)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Instantaneous Removal Efficiency
- Running Avg Removal Efficiency
Step 2 Pellet Appliance with ESP, Run 9, High Burn

**Graph 1:**
- **Power (mW)** vs. Time (minutes 61-120)
- **Voltage (V)** vs. Time (minutes 61-120)
- **Current (μA)** vs. Time (minutes 61-120)

**Graph 2:**
- **Power (mW)** vs. Time (minutes 61-120)
- **Emission Rate (g/h)** vs. Time (minutes 61-120)
Step 2 Pellet Appliance with ESP, Run 9, Medium Burn

![Graph showing ESP Operating Parameters and Emission Rate with ESP Power](image-url)
Step 2 Pellet Appliance with ESP, Run 9, Medium Burn (minutes 121-240)

Mass Removal (g/h)
Arcing Events

Running Average Pre_ESP (g/h)
Running Avg Post_ESP (g/h)
Running Avg Mass Removal (g/h)

Removal Efficiency (%)
Arcing Events

Instantaneous Removal Efficiency
Running Avg Removal Efficiency

Arcing Event (Reported)
Arcing Event (Suspected)
Step 2 Pellet Appliance with ESP, Run 9, Low Burn

[Graphs showing ESP operating parameters and emission rate with ESP power.]
Step 2 Pellet Appliance with ESP, Run 9, Low Burn (minutes 241-419)

Pre and Post Emission Rate with Mass Removal

<table>
<thead>
<tr>
<th>Mass Removal (g/h)</th>
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<tbody>
<tr>
<td>Running Avg Pre_ESP (g/h)</td>
<td>Running Avg Post_ESP (g/h)</td>
</tr>
</tbody>
</table>

Removal Efficiency (%)

Arcing Events

Instantaneous Removal Efficiency

Running Avg Removal Efficiency
Step 2 Pellet Appliance with ESP, Run 10, Entire Run

ESP Operating Parameters

Total Power (mW) Voltage (V) Arcing Event (Reported) Arcing Event (Suspected) Current (μA)

Pre and Post Emission Rate with ESP Power

Total Power (mW) Arcing Event (Reported) Arcing Event (Suspected) Pre ESP diluter (g/h) Post ESP diluter (g/h)
Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

Step 2 Pellet Appliance with ESP, Run 10, Entire Run (minutes 0-419)

**Mass Removal (g/h)**
- Pre and Post Emission Rate with Mass Removal
  - Running Average Emission Rate (g/h)

**Arcing Events**
- Instantaneous Removal Efficiency
- Running Average Removal Efficiency

**Removal Efficiency (%)**
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Instantaneous Removal Efficiency
- Running Avg Pre_ESP (g/h)
- Running Avg Post_ESP (g/h)
- Running Avg Mass Removal (g/h)
Step 2 Pellet Appliance with ESP, Run 10, Startup

**Step 2 Pellet Appliance with ESP, Run 10, Startup (minutes 0-60)**

**ESP Operating Parameters**
- Total Power (mW)
- Voltage (V)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Current (μA)

**Pre and Post Emission Rate with ESP Power**
- Total Power (mW)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Pre ESP diluter (g/h)
- Post ESP diluter (g/h)
Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

Step 2 Pellet Appliance with ESP, Run 10, Startup (minutes 0-60)

- Mass Removal (g/h)
- Arcing Events

Pre and Post Emission Rate with Mass Removal

- Running Average Emission Rate (g/h)

Removal Efficiency

- Removal Efficiency (%)
Step 2 Pellet Appliance with ESP, Run 10, High Burn

### ESP Operating Parameters

<table>
<thead>
<tr>
<th>Total Power (mW)</th>
<th>Voltage (V)</th>
<th>Arcing Event (Reported)</th>
<th>Arcing Event (Suspected)</th>
<th>Current (μA)</th>
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### Pre and Post Emission Rate with ESP Power

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<th>Emission Rate (g/h)</th>
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<td>10,000</td>
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<td>14,000</td>
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</tr>
<tr>
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<tr>
<td>18,000</td>
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Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

Step 2 Pellet Appliance with ESP, Run 10, High Burn (minutes 61-120)

<table>
<thead>
<tr>
<th>Mass Removal (g/h)</th>
<th>Arcing Events</th>
</tr>
</thead>
<tbody>
<tr>
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<td>20%</td>
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<td>30%</td>
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</tr>
<tr>
<td>5</td>
<td>50%</td>
</tr>
<tr>
<td>6</td>
<td>60%</td>
</tr>
<tr>
<td>7</td>
<td>70%</td>
</tr>
<tr>
<td>8</td>
<td>80%</td>
</tr>
<tr>
<td>9</td>
<td>90%</td>
</tr>
<tr>
<td>10</td>
<td>100%</td>
</tr>
</tbody>
</table>

Pre and Post Emission Rate with Mass Removal

Running Average Emission Rate (g/h)

Removal Efficiency (%)

Arcing Events

Instantaneous Removal Efficiency

Running Avg Removal Efficiency
Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

Step 2 Pellet Appliance with ESP, Run 10, Medium Burn

![Graph 1: ESP Operating Parameters](image1)

![Graph 2: Pre and Post Emission Rate with ESP Power](image2)
Pellet Stove Retrofit Emission Control Device Emission Reduction Testing

Step 2 Pellet Appliance with ESP, Run 10, Medium Burn (minutes 121-240)

<table>
<thead>
<tr>
<th>Mass Removal (g/h)</th>
<th>Arcing Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre and Post Emission Rate with Mass Removal</td>
<td></td>
</tr>
</tbody>
</table>

Running Average Emission Rate (g/h)

Removal Efficiency

Removal Efficiency (%)
Step 2 Pellet Appliance with ESP, Run 10, Low Burn

ESP Operating Parameters

- Total Power (mW)
- Voltage (V)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Current (μA)

Pre and Post Emission Rate with ESP Power

- Total Power (mW)
- Arcing Event (Reported)
- Arcing Event (Suspected)
- Pre ESP diluter (g/h)
- Post ESP diluter (g/h)
Step 2 Pellet Appliance with ESP, Run 10, Low Burn (minutes 241-419)

Pre and Post Emission Rate with Mass Removal

Running Average Emission Rate (g/h)

Mass Removal (g/h)

Arcing Events

Instantaneous Removal Efficiency

Running Avg Pre_ESP (g/h)

Running Avg Post_ESP (g/h)

Running Avg Mass Removal (g/h)

Removal Efficiency (%)

Arcing Events

Arcing Event (Reported)

Arcing Event (Suspected)

Running Avg Removal Efficiency

Removal Efficiency (%)