Title	Calorimetry-Cargo Container Fires		
Test Type	Custom		
Lab Number	NTSB-4	**Author**	Justin L. Rowe
Test dates	8/10/11, 8/11/11	**No. Tests**	4

Table of Contents

NOTE: All dimensional measurements were taken in English units and were later converted to metric units. Any inconsistencies between the two units are due to rounding errors when the English units were converted to metric.

Introduction

Four calorimetry tests were conducted to determine the fire growth rate and energy released from airplane cargo containers loaded with ordinary combustibles. Two types of cargo containers were investigated in the test series: a standard A2N type cargo container of aluminum/Lexan construction, as shown in Figure 1, and a collapsible A2N type cargo container of polypropylene construction with a rain fly and cargo net, as shown in Figure 2. The fuel load in the cargo containers consisted of cardboard boxes filled with shredded paper. The fire was started in one of the boxes using a cartridge type electrical heater to simulate thermal runaway of a lithium-ion battery. Instrumentation was installed to measure the heat flux, fire plume temperature, smoke production, and heat release rate of the fire. Video and photos were taken to document the test series. The test series was conducted using the 4 MW calorimeter in the Medium Burn Room (MBR) of the Bureau of Alcohol, Tobacco, Firearm, and Explosives (ATF) Fire Research Laboratory (FRL) in Beltsville, MD.

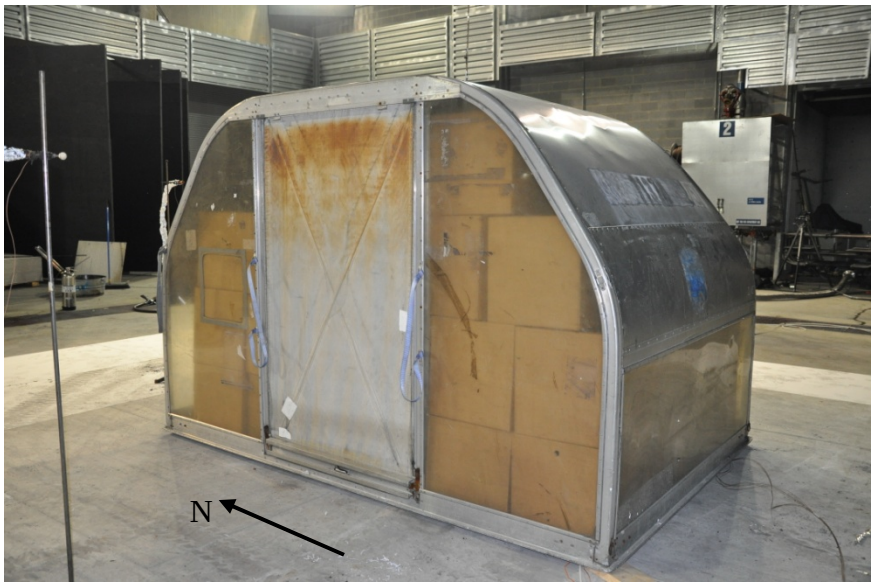

Figure 1. Standard A2N aluminum/Lexan cargo container (6561_2011153.JPG)

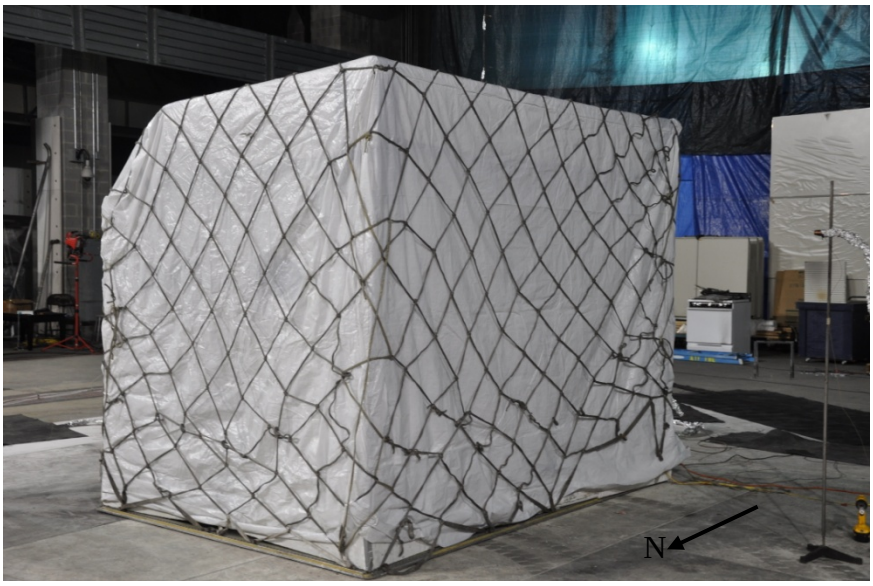

Figure 2. Collapsible A2N container with rain fly and cargo net (6564_201493.JPG)

Test Set Up

A cargo container was placed on one layer of 0.01 m (0.5 inch) thick Durock cement board in an open laboratory environment. A standard A2N cargo container of aluminum/Lexan construction was used in Test 1 (Exp ID. 6561) and Test 2 (Exp ID. 6562). A collapsible polypropylene cargo container covered by a rain fly and cargo net was used in Test 3 (Exp ID. 6564) and Test 4 (Exp ID. 6565). Dimensioning details of the standard A2N and collapsible cargo containers are shown in Figure 3 and Figure 4, respectively.

Seventy-seven 0.46 x 0.46 x 0.46 m (18 x 18 x 18 inch) cardboard boxes were stacked in the container for each test. The top and bottom of each box was closed by alternating the flaps. Each box was filled with 1.13 kg (2.5 lbs) of shredded paper, as shown in Figure 5, for a total of 87.3 kg (192.5 lbs) of paper. The width of the shredded paper was 4 mm (0.16 inch).

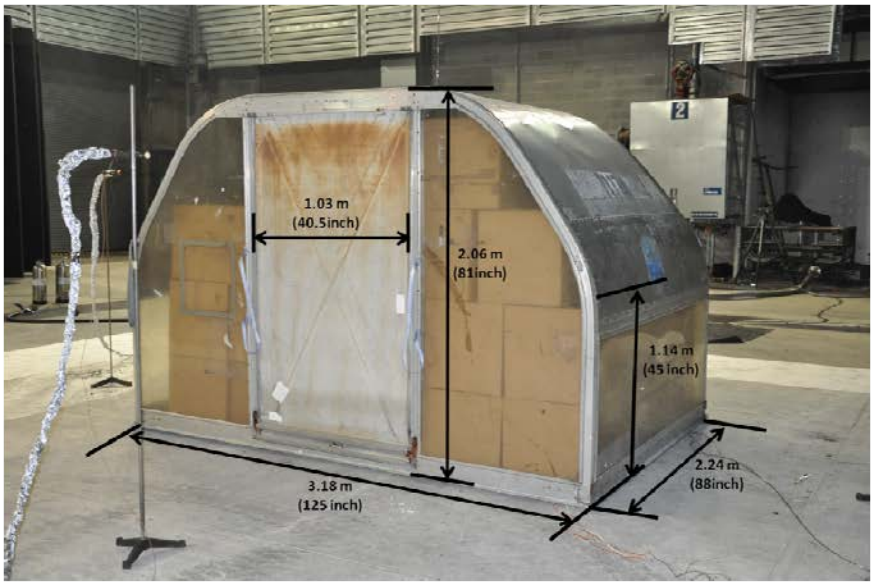

Figure 3. Test setup for Test 1 and Test 2 (6561_201149.JPG)

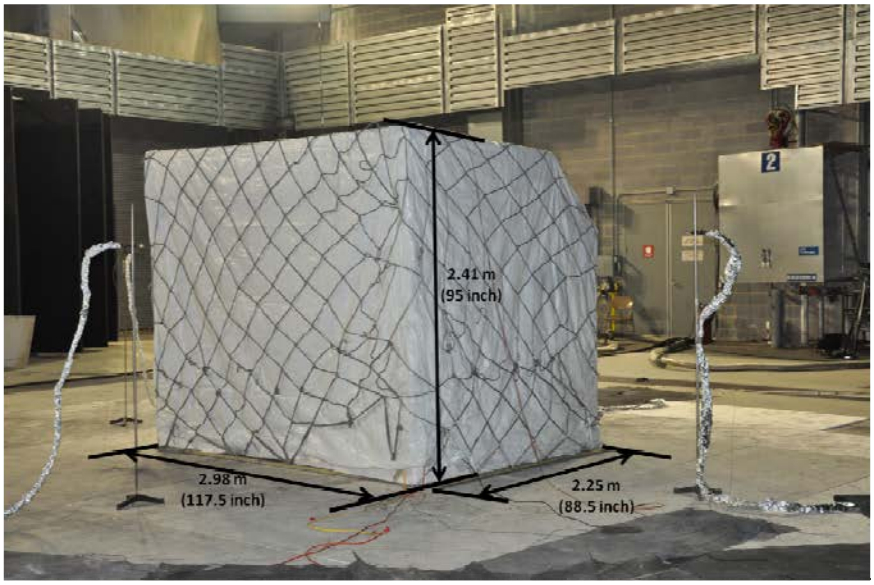

Figure 4. Test setup for Test 3 and Test 4 (6564_201475.JPG)

Figure 5. Shredded paper in cardboard boxes (6561_201176.JPG)

Experiment Details

Ignition Scenario

The fire was started using a remote ignition device in the front right corner box shown in Figure 6. The box was modified by making two vents on each side of the box to facilitate ignition. The 25 mm (1 inch) diameter vents were made 50 mm (2 inch) from the top and bottom edge and 0.23 m (9 inch) from the sides.

Figure 6. Ignition box (6564_201516.JPG)

A cartridge heater, shown in Figure 7, was used as the primary ignition device to simulate thermal runaway of a rechargeable lithium-ion battery. Power was supplied to the cartridge heater using a variable transformer connected to a 115 VAC power supply. The backup ignition device consisted of fifteen large kitchen matches (Manufacturer: Diamond) wrapped around an electric igniter, as shown in Figure 8, and connected to a 6 VDC battery.

The ignition devices were put inside a fire starter block shown in Figure 9 (Manufacturer: Safeway; Model: Fast Start) and embedded into the shredded paper as shown in Figure 10.

At the start of the test, the power to the cartridge heater was turned on. The power was turned off at the onset of flaming ignition.

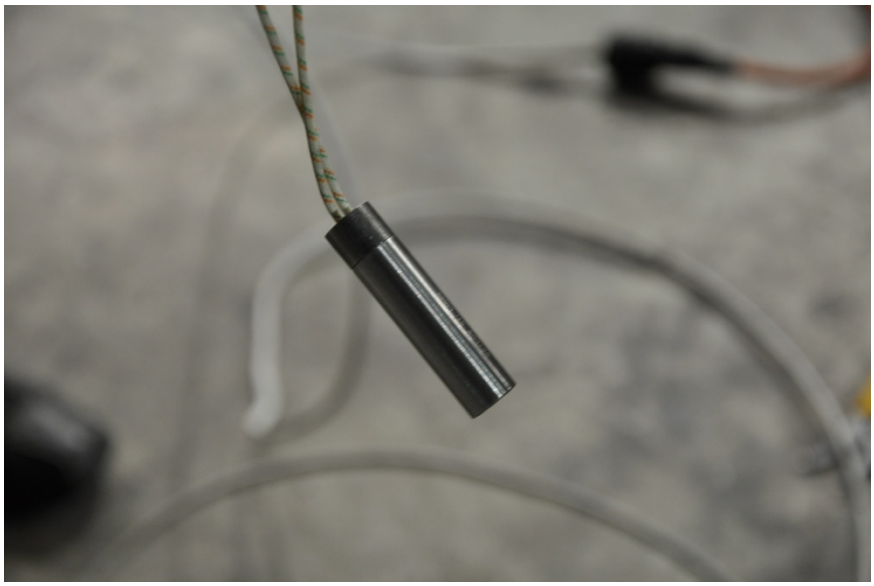

Figure 7. Cartridge heater (6561_212840.JPG)

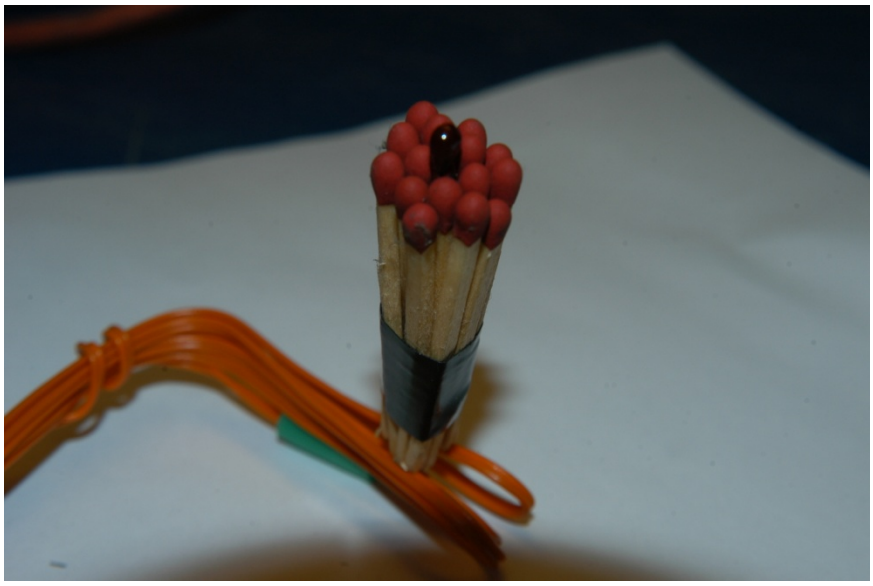

Figure 8. Electric igniter (6561_212839.JPG)

Figure 9. Fire starter (6564_201535.JPG)

Figure 10. Ignition device configuration (6564_201518.JPG)

Instrumentation

The test series was conducted under FRL's 4 MW calorimeter. The calorimeter used in this test series was equipped with instrumentation to measure the following fire properties: total heat release rate, convective heat release rate, combustion gas production rates, and smoke production rates.

Other instrumentation included one thermocouple tree and four heat flux gauges. The thermocouple tree was used to measure a vertical temperature profile along the plume centerline. The tree consisted of five thermocouples starting at the center of the top surface of the container and extending 1.22m (48 inch) above the container at 0.30 m (12 inch) intervals.

The heat flux gauges were used to measure the total energy transfer per unit area. The gauges were centered parallel to each side of the container at a distance of 1.52m (60 inch) at a height of 1.68 m (66 inch).

Elevation distances described in the body of this report are relative to the z-axis defined in Figure 11.

Figure 11. Instrumentation details (6561_201290.JPG)

Laboratory Conditions

The ambient laboratory temperature, barometric pressure, and relative humidity were measured during the experiment(s). The laboratory conditions were measured using an industrial probe and microserver. The probe measures the ambient conditions using capacitive digital sensors. The sensor probe has surface mounted circuitry which responds to changes in the environment and outputs a digital signal. The Laboratory Conditions were measured in accordance with the method defined in FRL Laboratory Instruction "LI017 Laboratory Conditions" [1].

The following table provides a description of the instrumentation used to collect the ambient laboratory conditions measurements during the experiments.

Table 1. Lab Conditions Description

Description	Manufacturer	Model
MBR_01	OMEGA	IBTHX-D

Thermocouples

Thermocouples are temperature measurement sensors that consist of two dissimilar metals joined at one end (a junction) that produces a small thermo-electrical voltage when the wire is heated. The change in voltage is interpreted as a change in temperature [2]. There are many configurations of thermocouples which affect the temperature range, ruggedness, and response time. The information required to identify these factors for the thermocouples that were used during the experiment(s) conducted for this test series is provided in the "Thermocouple Measurement Description" table.

Thermocouples used during this test series were used in accordance with the method defined in FRL laboratory instruction “LI001 Thermocouple” [3].

The following table provides a description of the instrumentation used to collect the temperature measurements during the experiments. The "Description" column describes the location of the temperature measurement. The "Z" location is the height of the thermocouple above the floor. The "Thermocouple Type" describes the characteristics of the thermocouple used.

Table 2. Thermocouple Measurement Description

Description	Location Z (m)	Thermocouple type
Center_105	2.67	Type K, Glass Ins., 24 AWG wire
Center_117	2.97	Type K, Glass Ins., 24 AWG wire
Center_81	2.06	Type K, Glass Ins., 24 AWG wire
Center_93	2.36	Type K, Glass Ins., 24 AWG wire
East		Type K, Glass Ins., 24 AWG wire
Near igniter		Type K, Glass Ins., 24 AWG wire
Near Igniter		Type K, Glass Ins., 24 AWG wire
Near igniter		Type K, Glass Ins., 24 AWG wire
North		Type K, Glass Ins., 24 AWG wire
South		Type K, Glass Ins., 24 AWG wire
TC_81	2.06	Type K, Glass Ins., 24 AWG wire
West		Type K, Glass Ins., 24 AWG wire

Heat Flux Transducers

A heat flux transducer is a device that measures the rate of absorbed incident energy, and expresses it on a per unit area basis. The operating principle of the Schmidt-Boelter heat flux transducer(s) used during this test series is based on one-dimensional heat conduction through a solid. Temperature sensors are placed on a thin, thermally conductive sensor element, and applying heat establishes a temperature gradient across the element. The heat flux is proportional to the temperature difference across the element according to Fourier’s Law [4].

There are many configurations of heat flux transducers which affect range, size, mode and sensitivity. The information required to identify these factors for the heat flux transducer(s) that were used during the experiment(s) conducted for this test series is provided in the “Heat Flux Measurement Description” table. Heat flux transducers were used in accordance with the method defined in FRL laboratory instruction “LI002 Heat Flux Transducer” [5].

The following table provides a description of the transducer used to collect heat flux measurements during the experiment(s). The “Description” column typically describes the location of the heat flux transducer. Heat flux mode indicates whether the total heat

flux was measured or just the radiation fraction. Heat flux over range is the maximum measured value reported for this transducer.

Table 3. Heat Flux Measurement Description

Description	Heat Flux Mode	Heat Flux Max Range (kW/m²)
East	Total	75.00
North	Total	75.00
South	Total	75.00
West	Total	75.00

Fire Product Collectors

Fire product collectors, also called heat release calorimeters, are used in fire experiments to measure several characteristics of fires based upon the measured properties of the fire plume. Fire Product collectors consist of a collection hood connected to an exhaust duct placed over a fire as shown in Figure 12. Instrumentation in the exhaust duct measures the properties of the effluent. The fire characteristics that are often calculated from fire products collectors are total heat release rate (HRR), convective heat release rate (CHRR), smoke production rate (SPR), and yield rates of gas species such as carbon monoxide and carbon dioxide.

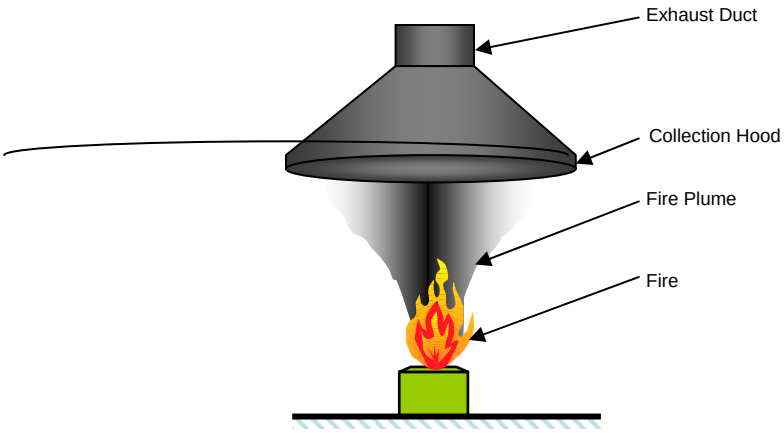

Figure 12. Typical products collector hood

Photographs

Digital Cameras are used within the FRL to record digital still photographs during experiments. Digital Cameras used during this test series were used in accordance with the method defined in FRL Laboratory Instruction "LI003 Digital Cameras" [6].

Results for Test 1 (Exp. ID 6561)

The following table provides a summary of the ambient laboratory temperature during the experiment.

Table 4. Ambient Laboratory Temperature Summary

Description	Initial Value (C)	Minimum (C)	Maximum (C)	Average (C)	Final Value (C)
MBR_01	27.3	27.3	27.7	27.5	27.7

The following table provides a summary of the ambient laboratory pressure during the experiment.

Table 5. Ambient Laboratory Pressure Summary

Description	Initial Value (kPa)	Minimum (kPa)	Maximum (kPa)	Average (kPa)	Final Value (kPa)
MBR_01	99.93	99.90	99.94	99.92	99.92

The following table provides a summary of the ambient laboratory relative humidity during the experiment.

Table 6. Ambient Laboratory Relative Humidity Summary

Description	Initial Value (%)	Minimum (%)	Maximum (%)	Average (%)	Final Value (%)
MBR_01	53.3	52.2	54.5	53.1	52.2

The following table provides a summary of the temperature results. The "Initial Temperature" column provides the measured temperature at the beginning of the test. The maximum temperature recorded during the test is provided in the "Maximum" column. The remaining columns provide the calculated maximum average temperatures.

Table 7. Temperature Value Result Summary

Description	Initial (C)	Maximum (C)	30 second maximum average (C)	60 second maximum average (C)	300 second maximum average (C)	600 second maximum average (C)
Center_105	27	924	802	797	690	657
Center_117	27	877	756	743	691	635
Center_81	27	910	882	855	724	712
Center_93	27	950	843	834	678	670
East	28	90	86	83	71	60
Near igniter	27	751	749	746	732	717
North	28	66	64	61	51	46
South	27	79	77	77	71	60
TC_81	28	941	882	845	738	690
West	27	108	99	96	81	70

The following chart(s) present a time-dependent representation of the instantaneous temperatures measured during the experiment.

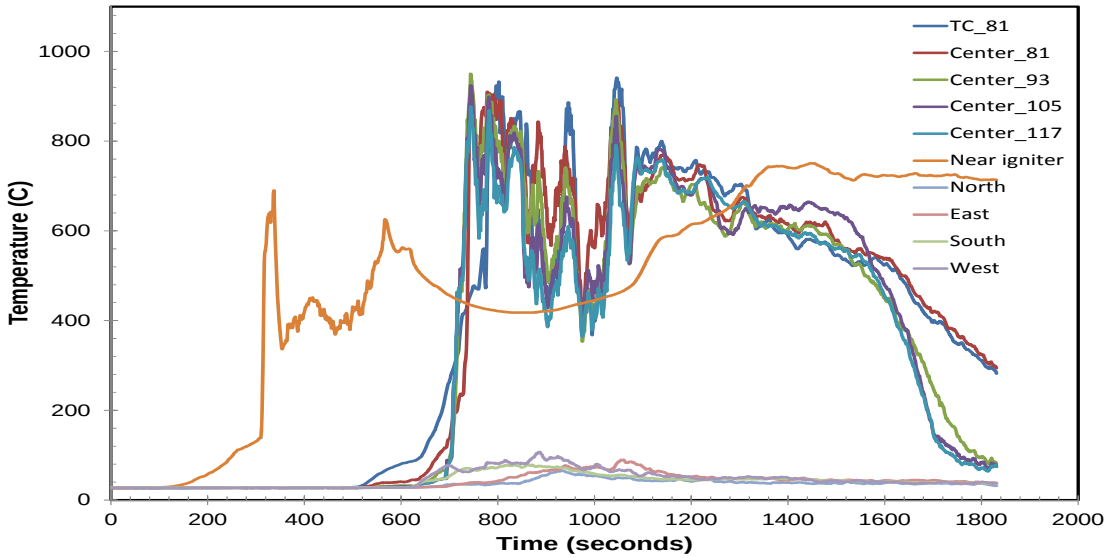

Figure 13. Temperature

The following table provides a summary of the heat flux results. The "Description" column typically describes the location of the heat flux transducer. The time at which the heat flux first changes by a pre-determined amount is provided in the "Time of Initial Change" column. The maximum heat flux recorded during the test is provided in the "Maximum" column. The "Maximum Average" columns are calculated over four pre-determined time spans.

Table 8. Heat Flux Result Summary

Description	Time of Initial Change (s)	Maximum (kW/m²)	30 second maximum average (kW/m²)	60 second maximum average (kW/m²)	300 second maximum average (kW/m²)	600 second maximum average (kW/m²)
East	1	11.0	9.2	8.1	6.4	4.5
North	1	7.1	6.7	6.5	4.0	2.7
South	1	8.3	8.1	7.9	6.5	4.4
West	1	13.7	12.8	12.6	11.2	7.9

The following chart shows a time dependent representation of the instantaneous heat flux measured during the experiment.

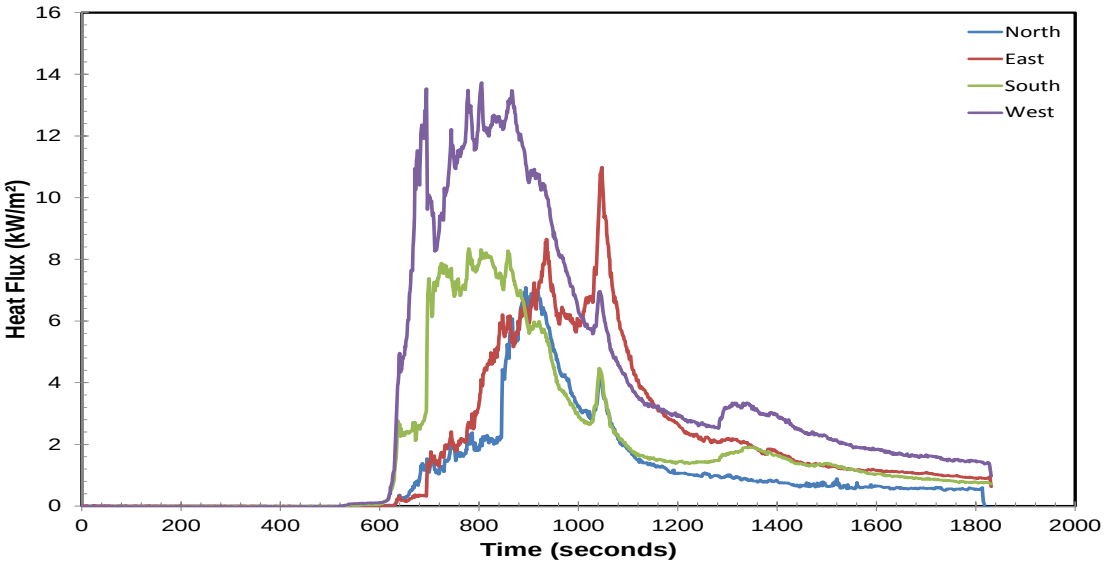

Figure 14. Heat Flux

The following chart provides a time history of the concentration of carbon monoxide and carbon dioxide measured in the exhaust duct during the fire.

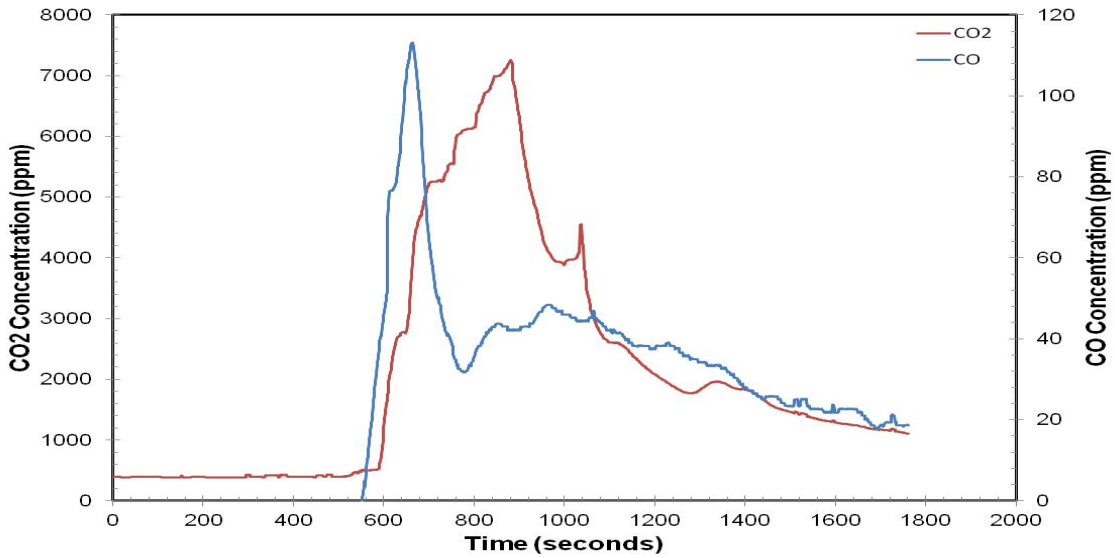

Figure 15. Carbon monoxide and carbon dioxide concentrations

The following chart provides a time history of the concentration of oxygen measured in the exhaust duct during the fire.

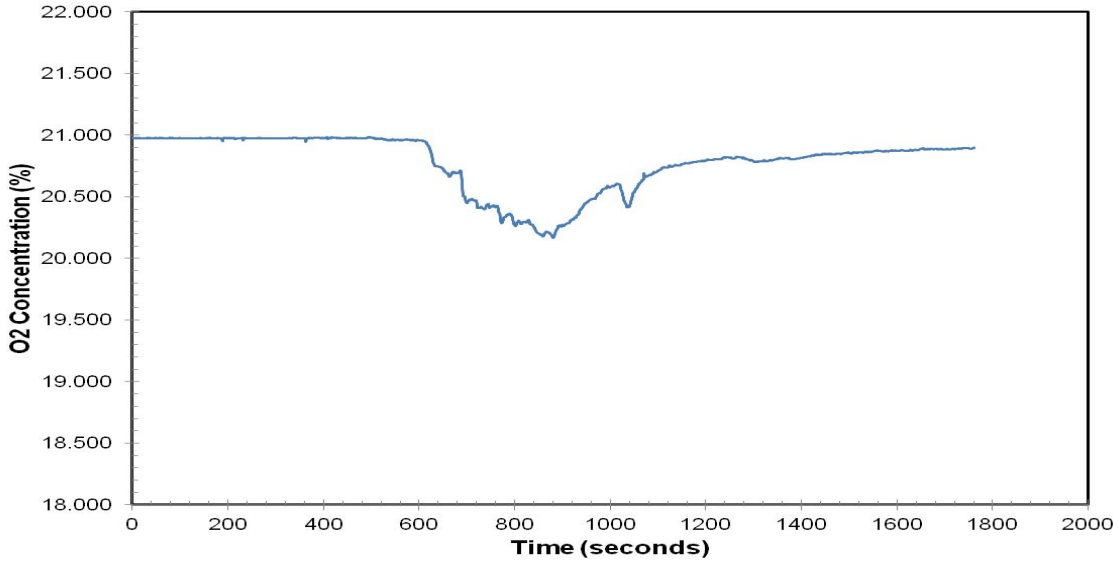

Figure 16. Oxygen Concentration

The following table provides a summary of the heat release rate (HRR) test results. The maximum HRR recorded during the test is provided in the "Maximum" column. The "maximum average" values are calculated from average values of heat release rate over specified time periods. The maximum average values provide a means to compare the severity of different fires over these time spans. The "Total heat released" is calculated from the area under the curve for the duration of the test.

Table 9. Heat Release Rate Result Summary

Maximum (kW)	30 second maximum average (kW)	1 minute maximum average (kW)	5 minute maximum average (kW)	10 minute maximum average (kW)	Total Heat Release (kJ)
3600	3361	3269	3361	1988	1521346

The following chart provides a time history of the heat release rate from the fire.

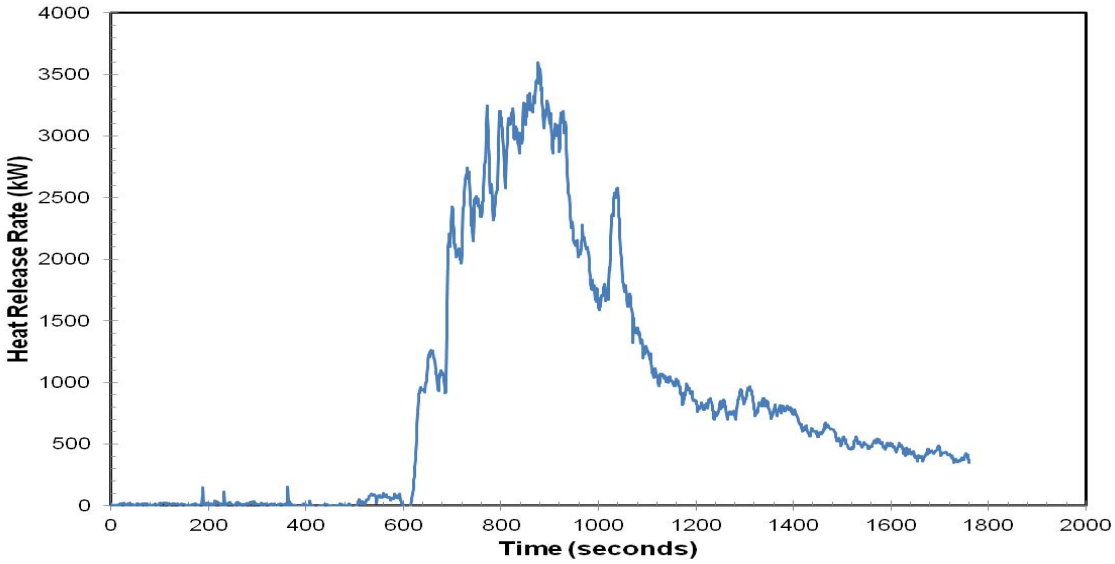

Figure 17. Heat Release Rate

The following table provides a summary of the convective heat release rate (CHRR) test results.

Table 10. Convective Heat Release Rate Result Summary

Maximum (kW)	30 second maximum average (kW)	Peak 60 sec avg (kW)	5 minute maximum average (kW)	Peak 600 sec avg (kW)
2228	2094	2027	1649	1255

The following chart provides a time history of the convective heat release rate from the fire.

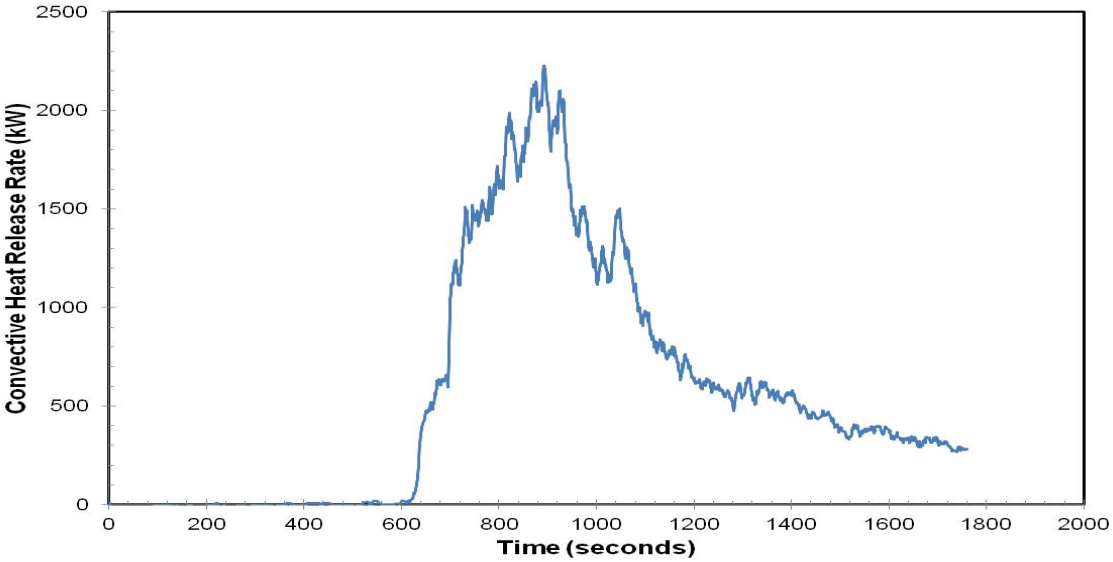

Figure 18. Convective Heat Release Rate

The following chart displays the production rates of CO and CO2.

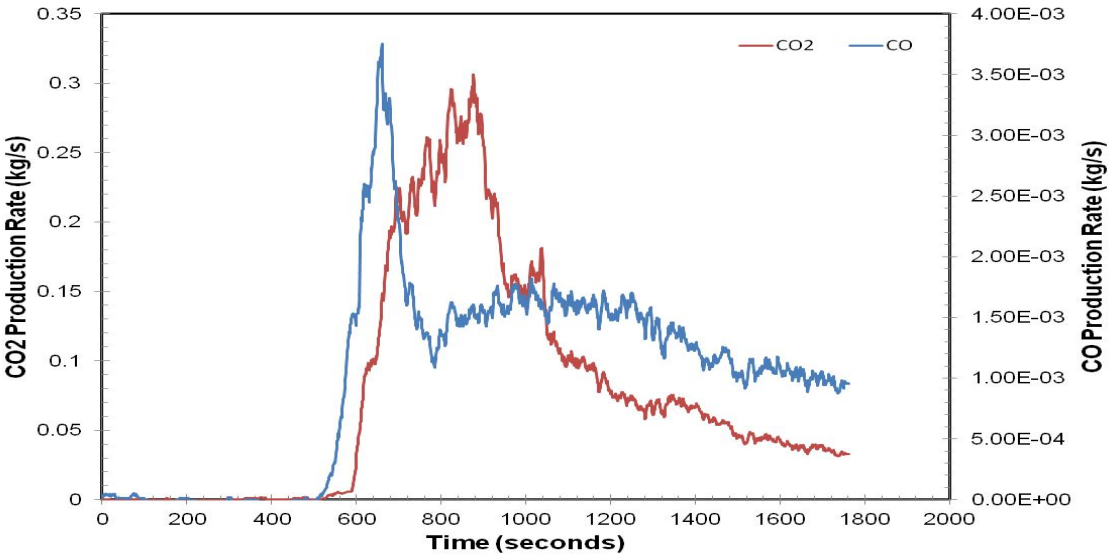

Figure 19. CO and CO2 production rates

The following table provides a description of the video(s) taken during this experiment.

Table 11. Video Log

Description	Start Time	Duration (s)	Filename
1	12:25:15	1859	6561_20110810_122515_1.mp4
2	12:25:16	1859	6561_20110810_122516_2.mp4
3	12:25:18	1858	6561_20110810_122518_3.mp4
4	12:25:20	1857	6561_20110810_122520_4.mp4

The following figures show all of the still photographs uploaded into the FireTOSS system. The caption below each figure provides the picture's filename as well as any description and elapsed test time associated with the picture.

Figure 20. Pre test 2:00 hr:min, 6561_201184.jpg

Figure 21. Pre test 2:00 hr:min, 6561_201183.jpg

Figure 22. Pre test 2:00 hr:min, 6561_201182.jpg

Figure 23. Pre test 1:59 hr:min, 6561_201181.jpg

Figure 24. Pre test 1:49 hr:min, 6561_201180.jpg

Figure 25. Pre test 1:49 hr:min, 6561_201179.jpg

Figure 26. Pre test 1:49 hr:min, 6561_201178.jpg

Figure 27. Pre test 1:49 hr:min, 6561_201177.jpg

Figure 28. Pre test 1:49 hr:min, 6561_201176.jpg

Figure 29. Pre test 1:45 hr:min, 6561_201175.jpg

Figure 30. Pre test 1:45 hr:min, 6561_201174.jpg

Figure 31. Pre test 1:43 hr:min, 6561_201173.jpg

Figure 32. Pre test 1:43 hr:min, 6561_201172.jpg

Figure 33. Pre test 1:35 hr:min, 6561_201171.jpg

Figure 34. Pre test 1:35 hr:min, 6561_201170.jpg

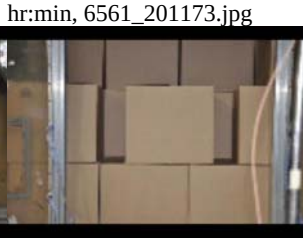

Figure 35. Pre test 1:35 hr:min, 6561_201169.jpg

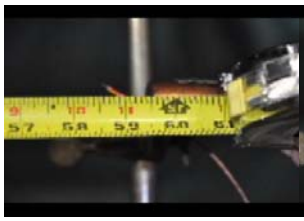

Figure 36. Pre test 1:34 hr:min, 6561_201168.jpg

Figure 37. Pre test 1:34 hr:min, 6561_201167.jpg

Figure 38. Pre test 1:34 hr:min, 6561_201166.jpg

Figure 39. Pre test 1:33 hr:min, 6561_201165.jpg

Figure 40. Pre test 1:33 hr:min, 6561_201164.jpg

Figure 41. Pre test 1:32 hr:min, 6561_201163.jpg

Figure 42. Pre test 1:32 hr:min, 6561_201162.jpg

Figure 43. Pre test 1:32 hr:min, 6561_201161.jpg

Figure 44. Pre test 1:32 hr:min, 6561_201160.jpg

Figure 45. Pre test 1:32 hr:min, 6561_201159.jpg

Figure 46. Pre test 1:32 hr:min, 6561_201157.jpg

Figure 47. Pre test 1:32 hr:min, 6561_201158.jpg

Figure 48. Pre test 1:31 hr:min, 6561_201156.jpg

Figure 49. Pre test 1:31 hr:min, 6561_201155.jpg

Figure 50. Pre test 1:31 hr:min, 6561_201154.jpg

Figure 51. Pre test 1:31 hr:min, 6561_201153.jpg

Figure 52. Pre test 1:31 hr:min, 6561_201152.jpg

Figure 53. Pre test 1:31 hr:min, 6561_201151.jpg

Figure 54. Pre test 1:27 hr:min, 6561_201150.jpg

Figure 55. Pre test 1:27 hr:min, 6561_201149.jpg

Figure 56. Pre test 1:27 hr:min, 6561_201148.jpg

Figure 57. Pre test 1:27 hr:min, 6561_201147.jpg

Figure 58. Pre test 1:27 hr:min, 6561_201146.jpg

Figure 59. Pre test 1:27 hr:min, 6561_201145.jpg

Figure 60. Pre test 1:27 hr:min, 6561_201144.jpg

Figure 61. Pre test 1:27 hr:min, 6561_201143.jpg

Figure 62. Pre test 1:27 hr:min, 6561_201142.jpg

Figure 63. Pre test 1:27 hr:min, 6561_201141.jpg

Figure 64. Pre test 1:26 hr:min, 6561_201140.jpg

Figure 65. Pre test 1:26 hr:min, 6561_201139.jpg

Figure 66. Pre test 1:25 hr:min, 6561_201138.jpg

Figure 67. Pre test 1:25 hr:min, 6561_201137.jpg

Figure 68. Pre test 1:25 hr:min, 6561_201136.jpg

Figure 69. Pre test 1:25 hr:min, 6561_201135.jpg

Figure 70. Pre test 1:25 hr:min, 6561_201134.jpg

Figure 71. Pre test 1:24 hr:min, 6561_201133.jpg

Figure 72. Pre test 1:24 hr:min, 6561_201132.jpg

Figure 73. Pre test 1:24 hr:min, 6561_201131.jpg

Figure 74. Pre test 1:24 hr:min, 6561_201130.jpg

Figure 75. Pre test 1:24 hr:min, 6561_201129.jpg

Figure 76. Pre test 1:24 hr:min, 6561_201128.jpg

Figure 77. Pre test 1:24 hr:min, 6561_201127.jpg

Figure 78. Pre test 1:24 hr:min, 6561_201126.jpg

Figure 79. Pre test 1:24 hr:min, 6561_201125.jpg

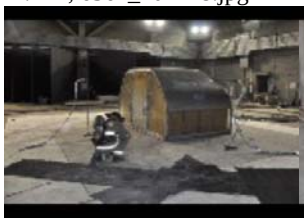

Figure 80. Pre test 1 seconds, 6561_201124.jpg

Figure 81. 20 seconds, 6561_201123.jpg

Figure 82. 76 seconds, 6561_201122.jpg

Figure 83. 125 seconds, 6561_201121.jpg

Figure 84. 162 seconds, 6561_201120.jpg

Figure 85. 195 seconds, 6561_201119.jpg

Figure 86. 220 seconds, 6561_201118.jpg

Figure 87. 231 seconds, 6561_201117.jpg

Figure 88. 236 seconds, 6561_201116.jpg

Figure 89. 259 seconds, 6561_201115.jpg

Figure 90. 264 seconds, 6561_201114.jpg

Figure 91. 281 seconds, 6561_201113.jpg

Figure 92. 287 seconds, 6561_201112.jpg

Figure 93. 299 seconds, 6561_201111.jpg

Figure 94. 307 seconds, 6561_201110.jpg

Figure 95. 312 seconds, 6561_201109.jpg

Figure 96. 328 seconds, 6561_201108.jpg

Figure 97. 333 seconds, 6561_201107.jpg

Figure 98. 352 seconds, 6561_201089.jpg

Figure 99. 363 seconds, 6561_201088.jpg

Figure 100. 383 seconds, 6561_201087.jpg

Figure 101. 446 seconds, 6561_201086.jpg

Figure 102. 450 seconds, 6561_201085.jpg

Figure 103. 454 seconds, 6561_201084.jpg

Figure 104. 461 seconds, 6561_201083.jpg

Figure 105. 474 seconds, 6561_201082.jpg

Figure 106. 491 seconds, 6561_201081.jpg

Figure 107. 494 seconds, 6561_201080.jpg

Figure 108. 497 seconds, 6561_201079.jpg

Figure 109. 504 seconds, 6561_201078.jpg

Figure 110. 514 seconds, 6561_201077.jpg

Figure 111. 525 seconds, 6561_201076.jpg

Figure 112. 537 seconds, 6561_201075.jpg

Figure 113. 552 seconds, 6561_201074.jpg

Figure 114. 558 seconds, 6561_201073.jpg

Figure 115. 567 seconds, 6561_201072.jpg

Figure 116. 569 seconds, 6561_201071.jpg

Figure 117. 582 seconds, 6561_201070.jpg

Figure 118. 592 seconds, 6561_201069.jpg

Figure 119. 594 seconds, 6561_201068.jpg

Figure 120. 616 seconds, 6561_201067.jpg

Figure 121. 618 seconds, 6561_201066.jpg

Figure 122. 622 seconds, 6561_201065.jpg

Figure 123. 628 seconds, 6561_201064.jpg

Figure 124. 637 seconds, 6561_201063.jpg

Figure 125. 645 seconds, 6561_201062.jpg

Figure 126. 661 seconds, 6561_201061.jpg

Figure 127. 665 seconds, 6561_201060.jpg

Figure 128. 671 seconds, 6561_201059.jpg

Figure 129. 673 seconds, 6561_201058.jpg

Figure 130. 685 seconds, 6561_201057.jpg

Figure 131. 688 seconds, 6561_201056.jpg

Figure 132. 695 seconds, 6561_201055.jpg

Figure 133. 706 seconds, 6561_201054.jpg

Figure 134. 719 seconds, 6561_201053.jpg

Figure 135. 729 seconds, 6561_201052.jpg

Figure 136. 742 seconds, 6561_201051.jpg

Figure 137. 754 seconds, 6561_201050.jpg

Figure 138. 769 seconds, 6561_201049.jpg

Figure 139. 771 seconds, 6561_201048.jpg

Figure 140. 791 seconds, 6561_201047.jpg

Figure 141. 810 seconds, 6561_201046.jpg

Figure 142. 815 seconds, 6561_201045.jpg

Figure 143. 822 seconds, 6561_201044.jpg

Figure 144. 823 seconds, 6561_201043.jpg

Figure 145. 826 seconds, 6561_201042.jpg

Figure 146. 844 seconds, 6561_201041.jpg

Figure 147. 848 seconds, 6561_201040.jpg

Figure 148. 866 seconds, 6561_201039.jpg

Figure 149. 890 seconds, 6561_201038.jpg

Figure 150. 893 seconds, 6561_201037.jpg

Figure 151. 906 seconds, 6561_201036.jpg

Figure 152. 907 seconds, 6561_201035.jpg

Figure 153. 930 seconds, 6561_201034.jpg

Figure 154. 954 seconds, 6561_201033.jpg

Figure 155. 974 seconds, 6561_201032.jpg

Figure 156. 979 seconds, 6561_201031.jpg

Figure 157. 984 seconds, 6561_201030.jpg

Figure 158. 999 seconds, 6561_201029.jpg

Figure 159. 1013 seconds, 6561_201028.jpg

Figure 160. 1030 seconds, 6561_201027.jpg

Figure 161. 1032 seconds, 6561_201026.jpg

Figure 162. 1084 seconds, 6561_201025.jpg

Figure 163. 1135 seconds, 6561_201024.jpg

Figure 164. 1161 seconds, 6561_201023.jpg

Figure 165. 1164 seconds, 6561_201022.jpg

Figure 166. 1186 seconds, 6561_201021.jpg

Figure 167. 1256 seconds, 6561_201020.jpg

Figure 168. 1286 seconds, 6561_201019.jpg

Figure 169. 1306 seconds, 6561_201018.jpg

Figure 170. 1348 seconds, 6561_201017.jpg

Figure 171. 1380 seconds, 6561_201016.jpg

Figure 172. 1409 seconds, 6561_201015.jpg

Figure 173. 1427 seconds, 6561_201014.jpg

Figure 174. 1445 seconds, 6561_201013.jpg

Figure 175. 1460 seconds, 6561_201012.jpg

Figure 176. 1467 seconds, 6561_201011.jpg

Figure 177. 1486 seconds, 6561_201010.jpg

Figure 178. 1543 seconds, 6561_201009.jpg

Figure 179. 1604 seconds, 6561_201008.jpg

Figure 180. 1668 seconds, 6561_201007.jpg

Figure 181. 1763 seconds, 6561_201006.jpg

Figure 182. 1803 seconds, 6561_201005.jpg

Figure 183. 1809 seconds, 6561_201004.jpg

Figure 184. 1828 seconds, 6561_201003.jpg

Figure 185. Post test 1 minutes, 6561_201002.jpg

Figure 186. Post test 1 minutes, 6561_201001.jpg

Figure 187. Post test 1 minutes, 6561_201000.jpg

Figure 188. Post test 1 minutes, 6561_200999.jpg

Figure 189. Post test 1 minutes, 6561_200998.jpg

Figure 190. Post test 1 minutes, 6561_200997.jpg

Figure 191. Post test 1 minutes, 6561_200996.jpg

Figure 192. Post test 2 minutes, 6561_200995.jpg

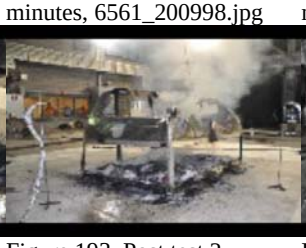

Figure 193. Post test 2 minutes, 6561_200994.jpg

Figure 194. Post test 2 minutes, 6561_200993.jpg

Figure 195. Post test 2 minutes, 6561_200992.jpg

Figure 196. Post test 2 minutes, 6561_200991.jpg

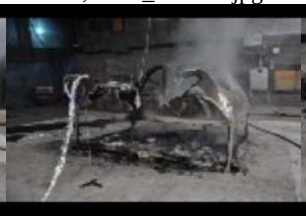

Figure 197. Post test 2 minutes, 6561_200990.jpg

Figure 198. Post test 2 minutes, 6561_200989.jpg

Figure 199. Post test 2 minutes, 6561_200988.jpg

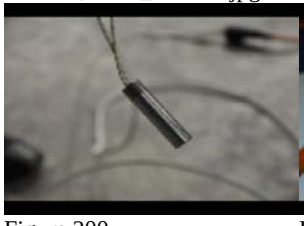

Figure 200. 6561_212840.jpg

Figure 201. 6561_212839.jpg

Results for Test 2 (Exp. ID 6562)

The following table provides a summary of the ambient laboratory temperature during the experiment.

Table 12. Ambient Laboratory Temperature Summary

Description	Initial Value (C)	Minimum (C)	Maximum (C)	Average (C)	Final Value (C)
MBR_01	27.6	27.6	28.2	27.9	28.2

The following table provides a summary of the ambient laboratory pressure during the experiment.

Table 13. Ambient Laboratory Pressure Summary

Description	Initial Value (kPa)	Minimum (kPa)	Maximum (kPa)	Average (kPa)	Final Value (kPa)
MBR_01	99.88	99.85	99.90	99.88	99.87

The following table provides a summary of the ambient laboratory relative humidity during the experiment.

Table 14. Ambient Laboratory Relative Humidity Summary

Description	Initial Value (%)	Minimum (%)	Maximum (%)	Average (%)	Final Value (%)
MBR_01	49.2	47.8	50.5	49.1	48.1

The following table provides a summary of the temperature results. The "Initial Temperature" column provides the measured temperature at the beginning of the test. The maximum temperature recorded during the test is provided in the "Maximum" column. The remaining columns provide the calculated maximum average temperatures.

Table 15. Temperature Value Result Summary

Description	Initial (C)	Maximum (C)	30 second maximum average (C)	60 second maximum average (C)	300 second maximum average (C)	600 second maximum average (C)
Center_105	27	887	842	812	656	605
Center_117	28	890	862	838	693	650
Center_81	28	909	891	867	690	632
Center_93	27	898	873	849	712	675
East	28	114	109	106	97	85
Near igniter	28	668	663	660	590	513
North	28	70	69	66	55	48
South	28	87	83	79	71	61
TC_81	29	884	850	845	727	669
West	27	121	115	109	97	82

The following chart(s) present a time-dependent representation of the instantaneous temperatures measured during the experiment.

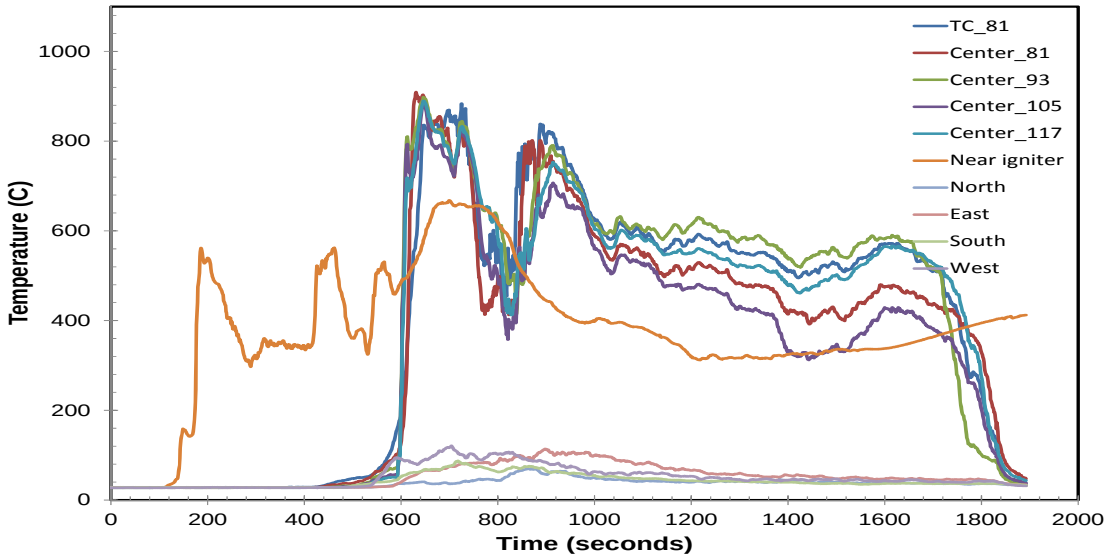

Figure 202. Temperature

The following table provides a summary of the heat flux results. The "Description" column typically describes the location of the heat flux transducer. The time at which the heat flux first changes by a pre-determined amount is provided in the "Time of Initial Change" column. The maximum heat flux recorded during the test is provided in the "Maximum" column. The "Maximum Average" columns are calculated over four pre-determined time spans.

Table 16. Heat Flux Result Summary

Description	Time of Initial Change (s)	Maximum (kW/m²)	30 second maximum average (kW/m²)	60 second maximum average (kW/m²)	300 second maximum average (kW/m²)	600 second maximum average (kW/m²)
East	1	17.1	15.7	14.7	12.9	9.9
North	1	5.7	5.3	5.1	3.4	2.4
South	1	11.2	10.7	10.4	7.9	5.1
West	1	15.0	13.0	12.9	11.4	8.1

The following chart shows a time dependent representation of the instantaneous heat flux measured during the experiment.

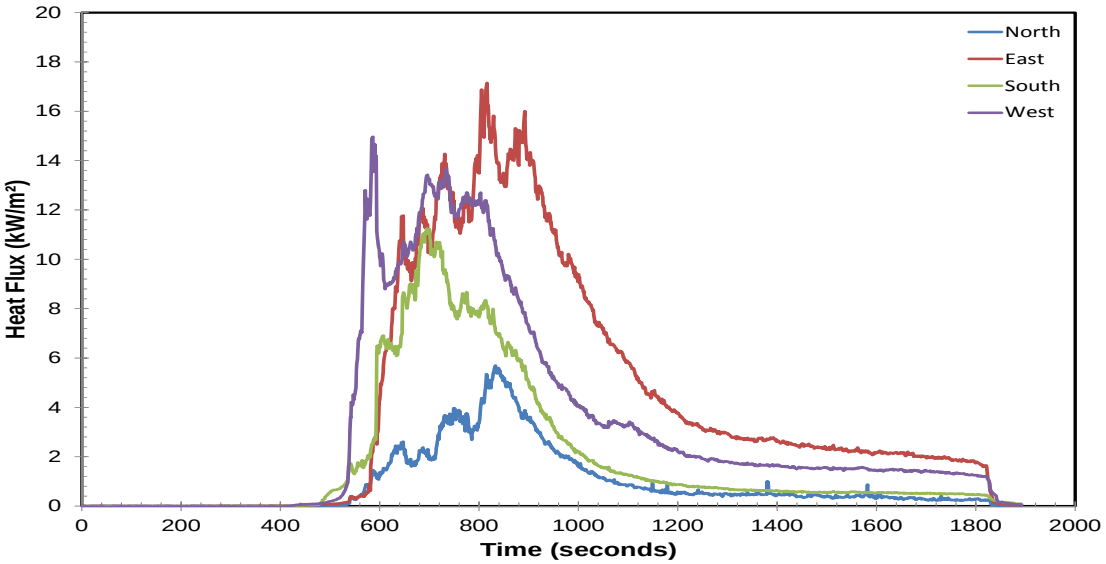

Figure 203. Heat Flux

The following chart provides a time history of the concentration of carbon monoxide and carbon dioxide measured in the exhaust duct during the fire.

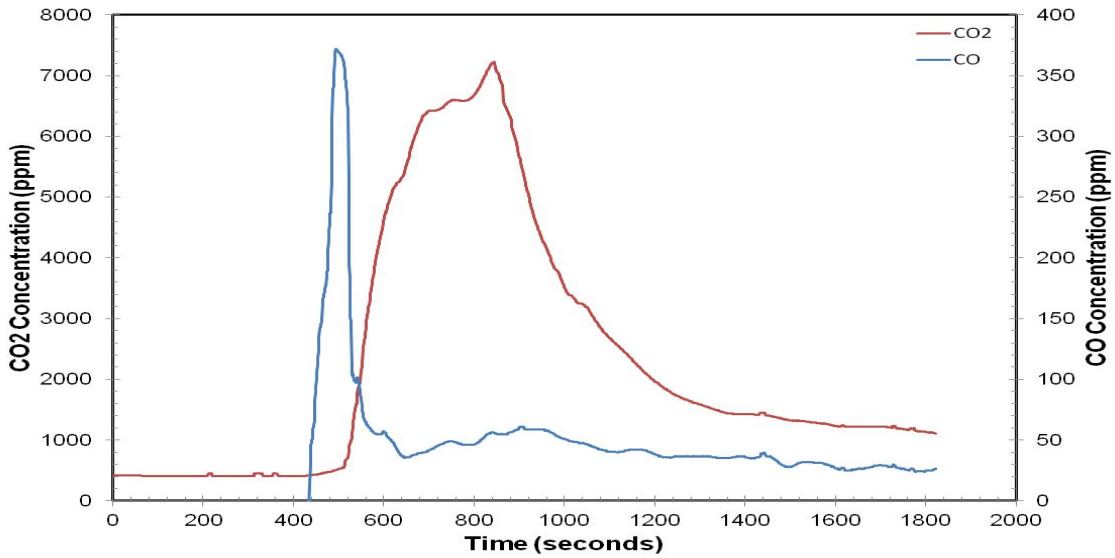

Figure 204. Carbon monoxide and carbon dioxide concentrations

The following chart provides a time history of the concentration of oxygen measured in the exhaust duct during the fire.

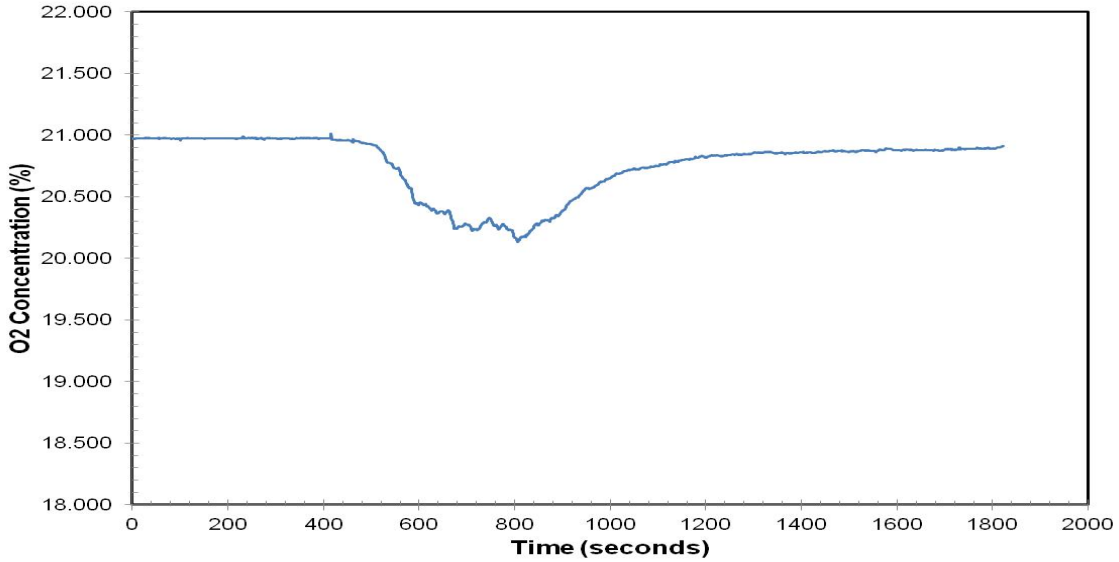

Figure 205. Oxygen Concentration

The following table provides a summary of the heat release rate (HRR) test results. The maximum HRR recorded during the test is provided in the "Maximum" column. The "maximum average" values are calculated from average values of heat release rate over specified time periods. The maximum average values provide a means to compare the severity of different fires over these time spans. The "Total heat released" is calculated from the area under the curve for the duration of the test.

Table 17. Heat Release Rate Result Summary

Maximum (kW)	30 second maximum average (kW)	1 minute maximum average (kW)	5 minute maximum average (kW)	10 minute maximum average (kW)	Total Heat Release (kJ)
3728	3518	3326	3518	2187	1685370

The following chart provides a time history of the heat release rate from the fire.

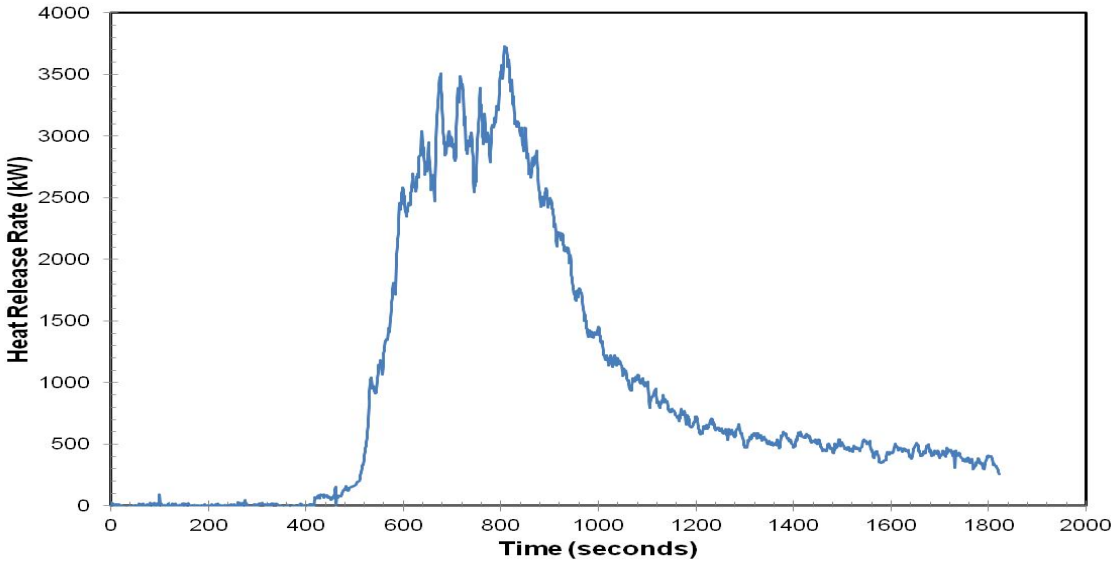

Figure 206. Heat Release Rate

The following table provides a summary of the convective heat release rate (CHRR) test results.

Table 18. Convective Heat Release Rate Result Summary

Maximum (kW)	30 second maximum average (kW)	Peak 60 sec avg (kW)	5 minute maximum average (kW)	Peak 600 sec avg (kW)
2264	2107	2047	1791	1371

The following chart provides a time history of the convective heat release rate from the fire.

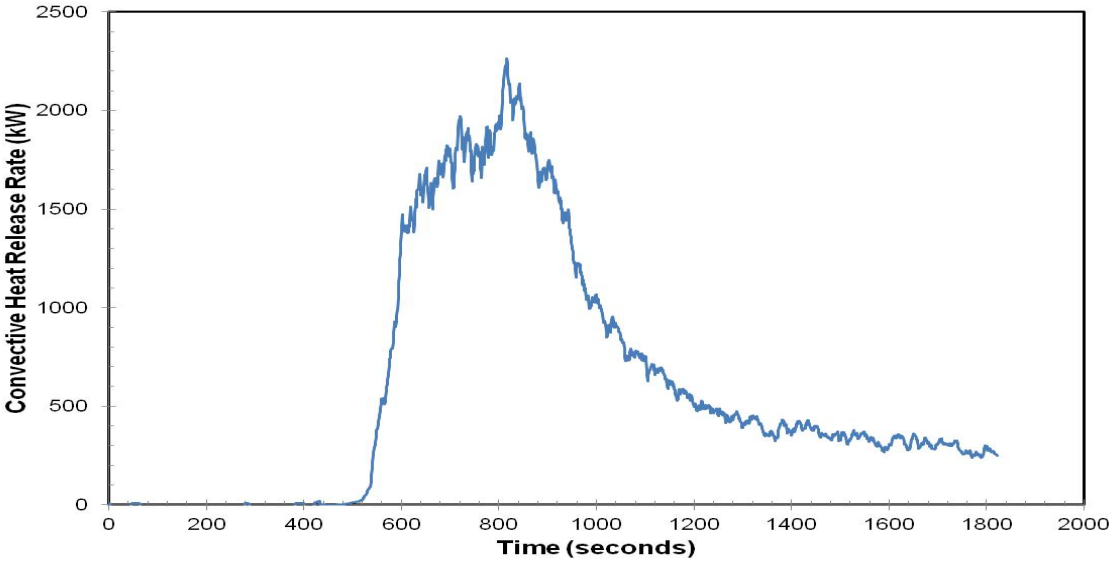

Figure 207. Convective Heat Release Rate

The following chart displays the production rates of CO and CO2.

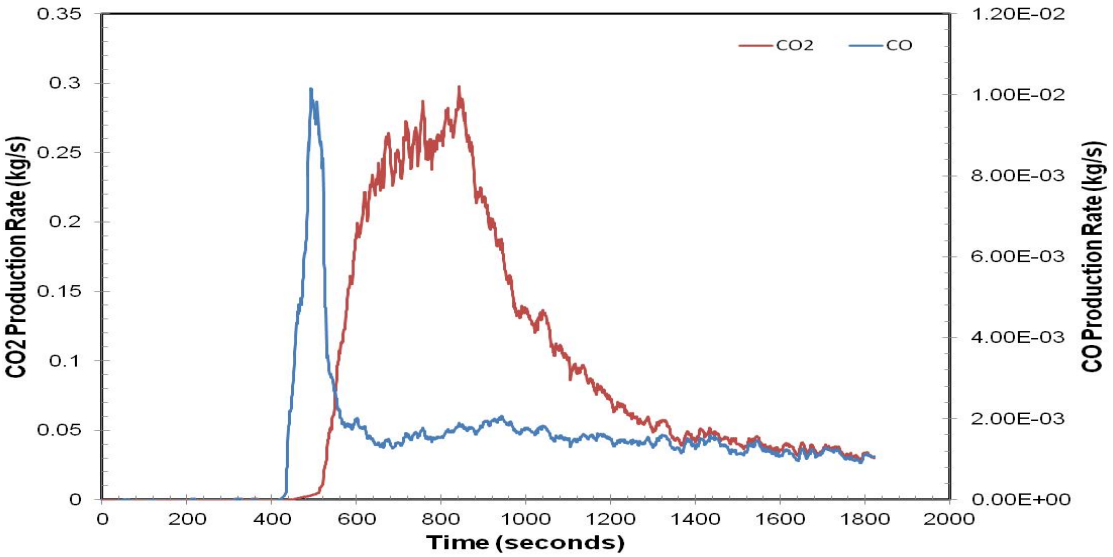

Figure 208. CO and CO2 production rates

The following table provides a description of the video(s) taken during this experiment.

Table 19. Video Log

Description	Start Time	Duration (s)	Filename
1	14:39:42	1854	6562_20110810_143942_1.mp4
2	14:39:44	1853	6562_20110810_143944_2.mp4
3	14:39:52	1846	6562_20110810_143952_3.mp4
4	14:39:54	1846	6562_20110810_143954_4.mp4

The following figures show all of the still photographs uploaded into the FireTOSS system. The caption below each figure provides the picture's filename as well as any description and elapsed test time associated with the picture.

Figure 209. Pre test 8 minutes, 6562_212285.jpg

Figure 210. Pre test 8 minutes, 6562_212286.jpg

Figure 211. Pre test 8 minutes, 6562_212287.jpg

Figure 212. Pre test 8 minutes, 6562_201331.jpg

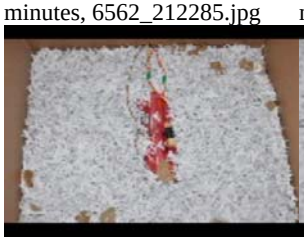

Figure 213. Pre test 8 minutes, 6562_201330.jpg

Figure 214. Pre test 8 minutes, 6562_201329.jpg

Figure 215. Pre test 8 minutes, 6562_201328.jpg

Figure 216. Pre test 8 minutes, 6562_201327.jpg

Figure 217. Pre test 8 minutes, 6562_201326.jpg

Figure 218. Pre test 8 minutes, 6562_201325.jpg

Figure 219. Pre test 7 minutes, 6562_201324.jpg

Figure 220. Pre test 7 minutes, 6562_201323.jpg

Figure 221. Pre test 7 minutes, 6562_201322.jpg

Figure 222. Pre test 7 minutes, 6562_201321.jpg

Figure 223. Pre test 7 minutes, 6562_201320.jpg

Figure 224. Pre test 5 minutes, 6562_201319.jpg

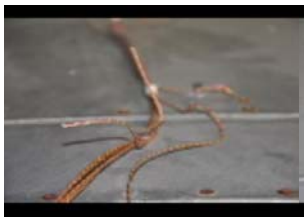

Figure 225. Pre test 5 minutes, 6562_201318.jpg

Figure 226. Pre test 5 minutes, 6562_201317.jpg

Figure 227. Pre test 4 minutes, 6562_201316.jpg

Figure 228. Pre test 4 minutes, 6562_201315.jpg

Figure 229. Pre test 3 minutes, 6562_201314.jpg

Figure 230. Pre test 3 minutes, 6562_201313.jpg

Figure 231. Pre test 3 minutes, 6562_201312.jpg

Figure 232. Pre test 3 minutes, 6562_201311.jpg

Figure 233. Pre test 3 minutes, 6562_201310.jpg

Figure 234. Pre test 3 minutes, 6562_201309.jpg

Figure 235. Pre test 3 minutes, 6562_201308.jpg

Figure 236. Pre test 3 minutes, 6562_201307.jpg

Figure 237. Pre test 3 minutes, 6562_201306.jpg

Figure 238. Pre test 2 minutes, 6562_201305.jpg

Figure 239. Pre test 2 minutes, 6562_201304.jpg

Figure 240. Pre test 2 minutes, 6562_201303.jpg

Figure 241. Pre test 2 minutes, 6562_201302.jpg

Figure 242. Pre test 2 minutes, 6562_201301.jpg

Figure 243. Pre test 2 minutes, 6562_201300.jpg

Figure 244. Pre test 2 minutes, 6562_201299.jpg

Figure 245. Pre test 2 minutes, 6562_201298.jpg

Figure 246. Pre test 2 minutes, 6562_201297.jpg

Figure 247. Pre test 2 minutes, 6562_201296.jpg

Figure 248. Pre test 119 seconds, 6562_201295.jpg

Figure 249. Pre test 27 seconds, 6562_201294.jpg

Figure 250. Pre test 19 seconds, 6562_201293.jpg

Figure 251. 0 seconds, 6562_201292.jpg

Figure 252. 45 seconds, 6562_201291.jpg

Figure 253. 71 seconds, 6562_201290.jpg

Figure 254. 75 seconds, 6562_201289.jpg

Figure 255. 133 seconds, 6562_201288.jpg

Figure 256. 141 seconds, 6562_201287.jpg

Figure 257. 146 seconds, 6562_201286.jpg

Figure 258. 152 seconds, 6562_201285.jpg

Figure 259. 161 seconds, 6562_201284.jpg

Figure 260. 182 seconds, 6562_201283.jpg

Figure 261. 199 seconds, 6562_201282.jpg

Figure 262. 206 seconds, 6562_201281.jpg

Figure 263. 224 seconds, 6562_201280.jpg

Figure 264. 229 seconds, 6562_201279.jpg

Figure 265. 246 seconds, 6562_201278.jpg

Figure 266. 251 seconds, 6562_201277.jpg

Figure 267. 257 seconds, 6562_201276.jpg

Figure 268. 268 seconds, 6562_201275.jpg

Figure 269. 275 seconds, 6562_201274.jpg

Figure 270. 278 seconds, 6562_201273.jpg

Figure 271. 295 seconds, 6562_201272.jpg

Figure 272. 302 seconds, 6562_201271.jpg

Figure 273. 307 seconds, 6562_201270.jpg

Figure 274. 319 seconds, 6562_201269.jpg

Figure 275. 339 seconds, 6562_201268.jpg

Figure 276. 350 seconds, 6562_201267.jpg

Figure 277. 371 seconds, 6562_201266.jpg

Figure 278. 377 seconds, 6562_201265.jpg

Figure 279. 382 seconds, 6562_201264.jpg

Figure 280. 393 seconds, 6562_201263.jpg

Figure 281. 399 seconds, 6562_201262.jpg

Figure 282. 401 seconds, 6562_201261.jpg

Figure 283. 410 seconds, 6562_201260.jpg

Figure 284. 435 seconds, 6562_201259.jpg

Figure 285. 436 seconds, 6562_201258.jpg

Figure 286. 469 seconds, 6562_201257.jpg

Figure 287. 472 seconds, 6562_201256.jpg

Figure 288. 476 seconds, 6562_201255.jpg

Figure 289. 483 seconds, 6562_201254.jpg

Figure 290. 486 seconds, 6562_201253.jpg

Figure 291. 498 seconds, 6562_201252.jpg

Figure 292. 502 seconds, 6562_201251.jpg

Figure 293. 512 seconds, 6562_201250.jpg

Figure 294. 522 seconds, 6562_201249.jpg

Figure 295. 530 seconds, 6562_201248.jpg

Figure 296. 531 seconds, 6562_201247.jpg

Figure 297. 544 seconds, 6562_201246.jpg

Figure 298. 546 seconds, 6562_201245.jpg

Figure 299. 549 seconds, 6562_201244.jpg

Figure 300. 563 seconds, 6562_201243.jpg

Figure 301. 580 seconds, 6562_201242.jpg

Figure 302. 598 seconds, 6562_201241.jpg

Figure 303. 605 seconds, 6562_201240.jpg

Figure 304. 624 seconds, 6562_201239.jpg

Figure 305. 642 seconds, 6562_201238.jpg

Figure 306. 662 seconds, 6562_201237.jpg

Figure 307. 680 seconds, 6562_201236.jpg

Figure 308. 683 seconds, 6562_201235.jpg

Figure 309. 698 seconds, 6562_201234.jpg

Figure 310. 718 seconds, 6562_201233.jpg

Figure 311. 727 seconds, 6562_201232.jpg

Figure 312. 751 seconds, 6562_201231.jpg

Figure 313. 764 seconds, 6562_201230.jpg

Figure 314. 775 seconds, 6562_201229.jpg

Figure 315. 786 seconds, 6562_201228.jpg

Figure 316. 798 seconds, 6562_201227.jpg

Figure 317. 811 seconds, 6562_201226.jpg

Figure 318. 861 seconds, 6562_201225.jpg

Figure 319. 864 seconds, 6562_201224.jpg

Figure 320. 906 seconds, 6562_201223.jpg

Figure 321. 935 seconds, 6562_201222.jpg

Figure 322. 964 seconds, 6562_201221.jpg

Figure 323. 968 seconds, 6562_201220.jpg

Figure 324. 972 seconds, 6562_201219.jpg

Figure 325. 1030 seconds, 6562_201218.jpg

Figure 326. 1042 seconds, 6562_201217.jpg

Figure 327. 1054 seconds, 6562_201216.jpg

Figure 328. 1069 seconds, 6562_201215.jpg

Figure 329. 1073 seconds, 6562_201214.jpg

Figure 330. 1114 seconds, 6562_201213.jpg

Figure 331. 1170 seconds, 6562_201212.jpg

Figure 332. 1250 seconds, 6562_201211.jpg

Figure 333. 1318 seconds, 6562_201210.jpg

Figure 334. 1385 seconds, 6562_201209.jpg

Figure 335. 1435 seconds, 6562_201208.jpg

Figure 336. 1497 seconds, 6562_201207.jpg

Figure 337. 1541 seconds, 6562_201206.jpg

Figure 338. 1652 seconds, 6562_201205.jpg

Figure 339. 1678 seconds, 6562_201204.jpg

Figure 340. 1732 seconds, 6562_201203.jpg

Figure 341. 1799 seconds, 6562_201202.jpg

Figure 342. 1819 seconds, 6562_201201.jpg

Figure 343. 1823 seconds, 6562_201200.jpg

Figure 344. 1892 seconds, 6562_201199.jpg

Figure 345. Post test 0 minutes, 6562_201198.jpg

Figure 346. Post test 0 minutes, 6562_201197.jpg

Figure 347. Post test 0 minutes, 6562_201196.jpg

Figure 348. Post test 0 minutes, 6562_201195.jpg

Figure 349. Post test 0 minutes, 6562_201194.jpg

Figure 350. Post test 0 minutes, 6562_201193.jpg

Figure 351. Post test 0 minutes, 6562_201192.jpg

Results for Test 3 (Exp. ID 6564)

The following table provides a summary of the ambient laboratory temperature during the experiment.

Table 20. Ambient Laboratory Temperature Summary

Description	Initial Value (C)	Minimum (C)	Maximum (C)	Average (C)	Final Value (C)
MBR_01	26.8	26.8	27.9	27.1	27.9

The following table provides a summary of the ambient laboratory pressure during the experiment.

Table 21. Ambient Laboratory Pressure Summary

Description	Initial Value (kPa)	Minimum (kPa)	Maximum (kPa)	Average (kPa)	Final Value (kPa)
MBR_01	100.53	100.51	100.57	100.54	100.54

The following table provides a summary of the ambient laboratory relative humidity during the experiment.

Table 22. Ambient Laboratory Relative Humidity Summary

Description	Initial Value (%)	Minimum (%)	Maximum (%)	Average (%)	Final Value (%)
MBR_01	47.7	45.7	47.8	46.9	46.8

The following table provides a summary of the temperature results. The "Initial Temperature" column provides the measured temperature at the beginning of the test. The maximum temperature recorded during the test is provided in the "Maximum" column. The remaining columns provide the calculated maximum average temperatures.

Table 23. Temperature Value Result Summary

Description	Initial (C)	Maximum (C)	30 second maximum average (C)	60 second maximum average (C)	300 second maximum average (C)	600 second maximum average (C)
Center_105	26	736	653	644	514	325
Center_117	26	736	634	611	497	326
Center_81	26	698	629	617	458	294
Center_93	26	750	657	657	510	323
East	27	91	79	75	58	46
Near Igniter	27	859	770	702	553	467
North	27	134	128	122	108	77
South	27	123	119	112	101	77
TC_81	27	788	686	671	467	301
West	26	193	188	179	144	102

The following chart(s) present a time-dependent representation of the instantaneous temperatures measured during the experiment.

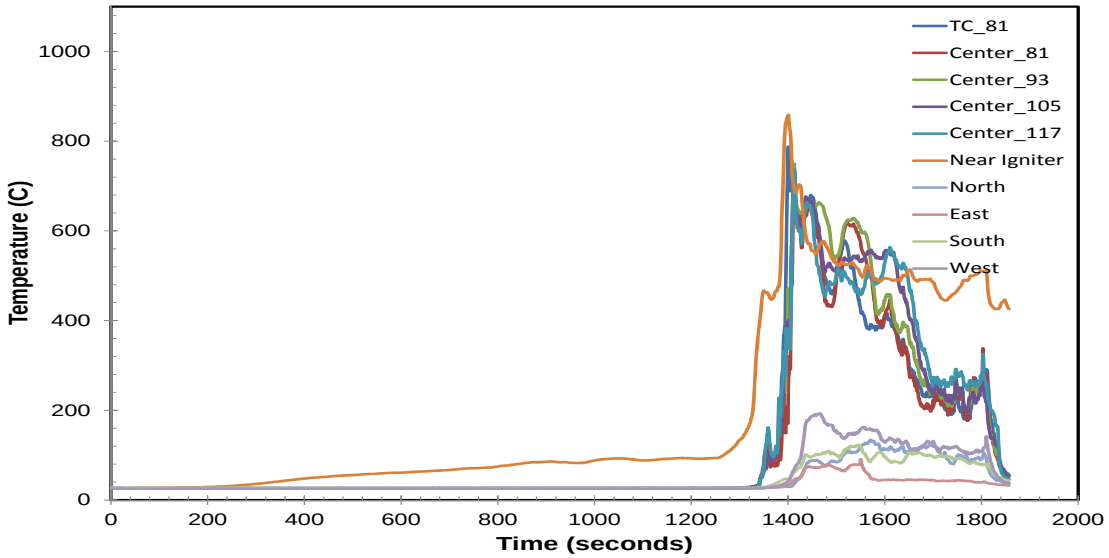

Figure 352. Temperature

The following table provides a summary of the heat flux results. The "Description" column typically describes the location of the heat flux transducer. The time at which the heat flux first changes by a pre-determined amount is provided in the "Time of Initial Change" column. The maximum heat flux recorded during the test is provided in the "Maximum" column. The "Maximum Average" columns are calculated over four pre-determined time spans.

Table 24. Heat Flux Result Summary

Description	Time of Initial Change (s)	Maximum (kW/m²)	30 second maximum average (kW/m²)	60 second maximum average (kW/m²)	300 second maximum average (kW/m²)	600 second maximum average (kW/m²)
East	1	19.7	10.6	9.8	4.6	2.3
North	1	19.5	16.6	15.9	12.6	7.8
South	1	24.8	19.1	17.0	13.9	8.8
West	1	43.9	32.2	27.4	16.8	10.2

The following table shows which heat flux transducers(s) were taken out of service during the experiment(s). The "Description" column typically describes the location of the heat flux transducer. If the heat flux measurement has to be discontinued during a test the "Out of Service Time" and "Out of Service Reason" columns report the test time and reason why the heat flux measurement was removed, respectively.

Table 25. Out of Service Times

Description	Serial number	Out of service time (s)	Out of service reason
East	1227932	1560	Container knocked HF over

The following chart shows a time dependent representation of the instantaneous heat flux measured during the experiment.

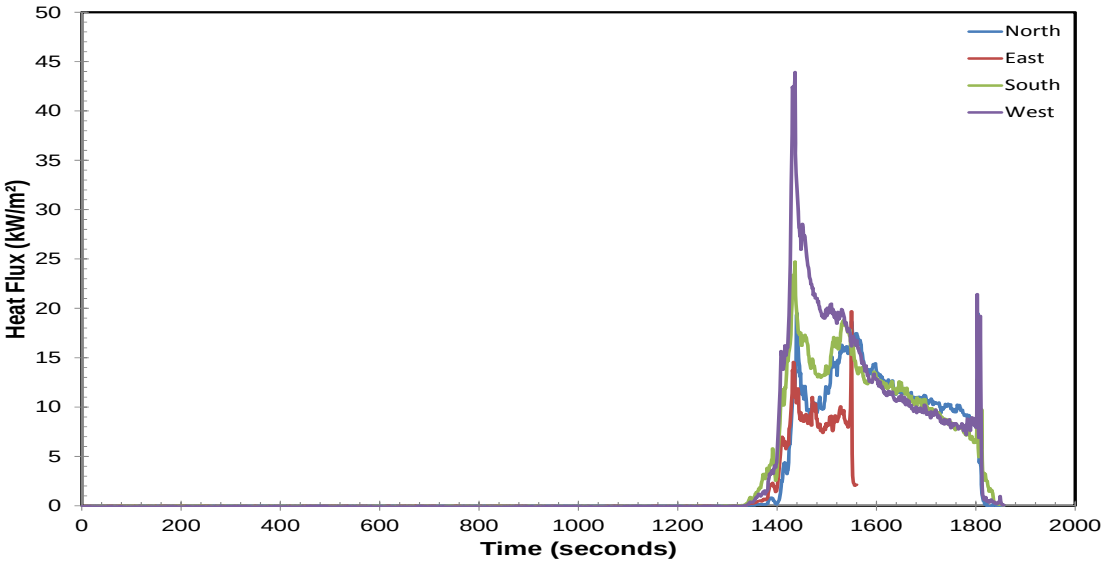

Figure 353. Heat Flux

The following chart provides a time history of the concentration of carbon monoxide and carbon dioxide measured in the exhaust duct during the fire.

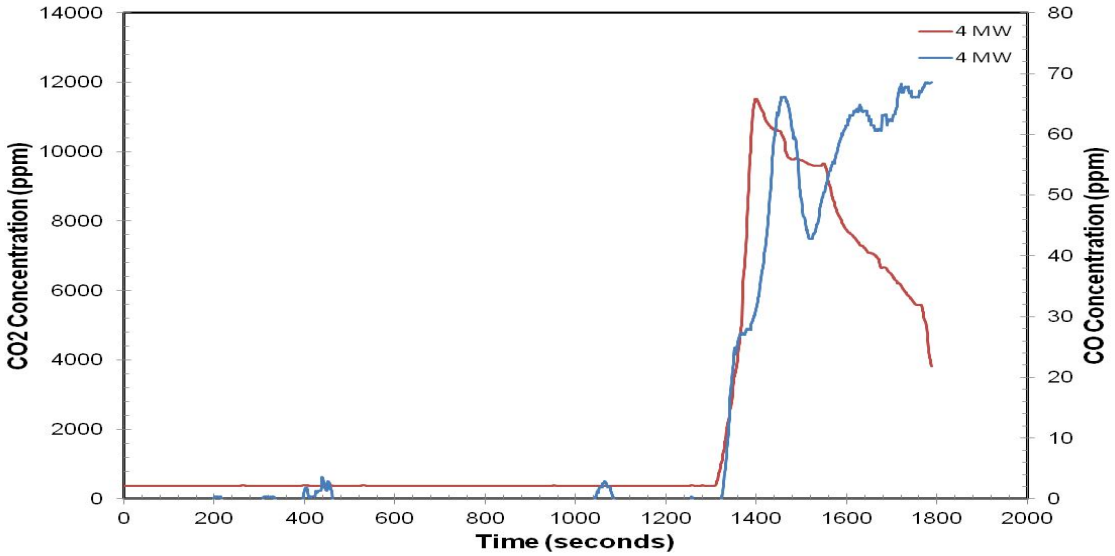

Figure 354. Carbon monoxide and carbon dioxide concentrations

The following chart provides a time history of the concentration of oxygen measured in the exhaust duct during the fire.

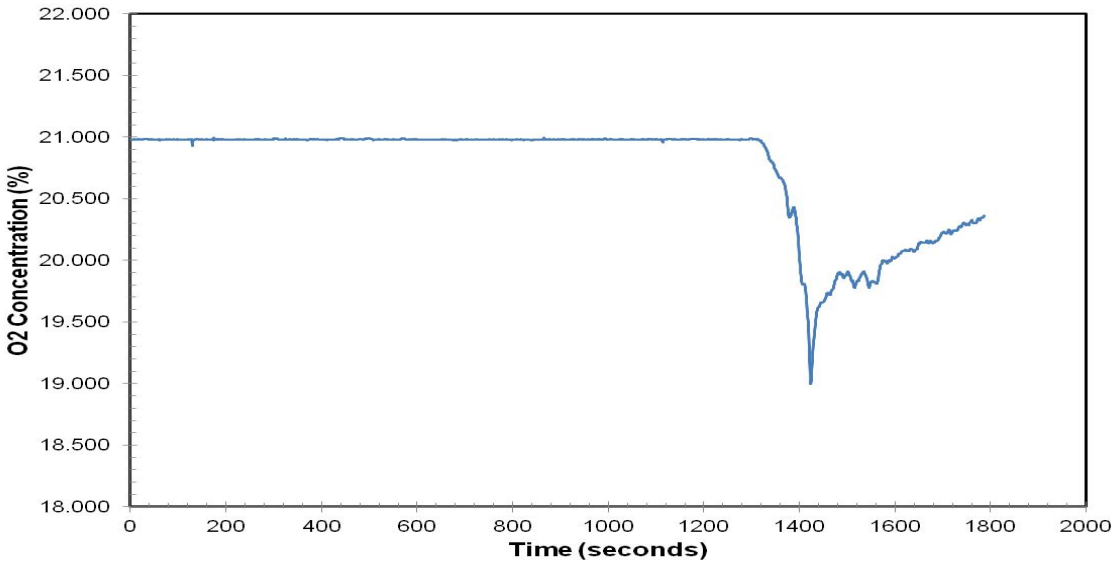

Figure 355. Oxygen Concentration

The following table provides a summary of the heat release rate (HRR) test results. The maximum HRR recorded during the test is provided in the "Maximum" column. The "maximum average" values are calculated from average values of heat release rate over specified time periods. The maximum average values provide a means to compare the severity of different fires over these time spans. The "Total heat released" is calculated from the area under the curve for the duration of the test.

Table 26. Heat Release Rate Result Summary

Maximum (kW)	30 second maximum average (kW)	1 minute maximum average (kW)	5 minute maximum average (kW)	10 minute maximum average (kW)	Total Heat Release (kJ)
8405	6577	5999	6577	2965	1784613

The following chart provides a time history of the heat release rate from the fire.

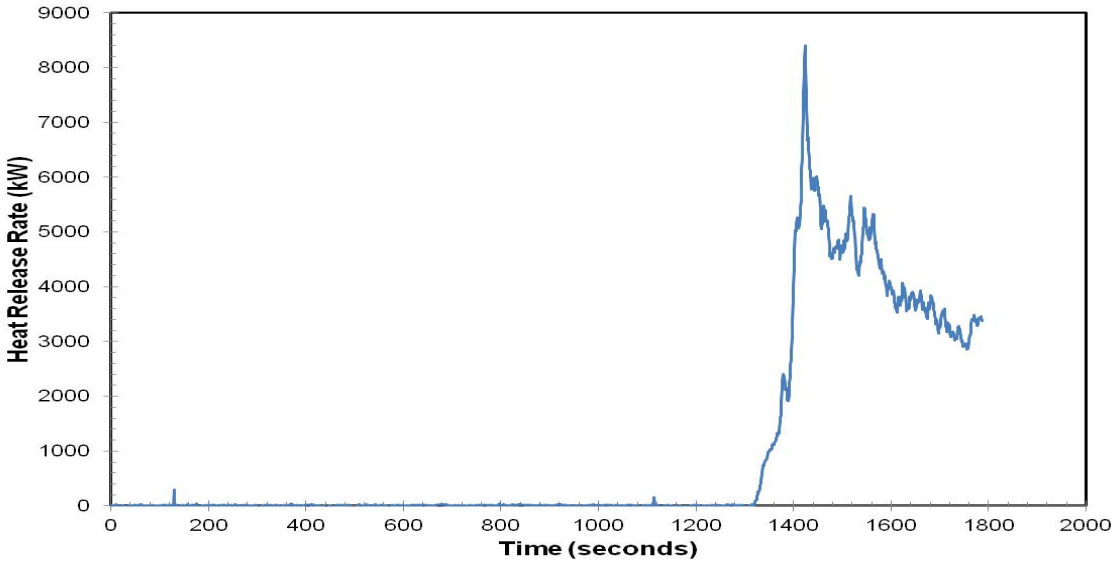

Figure 356. Heat Release Rate

The following table provides a summary of the convective heat release rate (CHRR) test results.

Table 27. Convective Heat Release Rate Result Summary

Maximum (kW)	30 second maximum average (kW)	Peak 60 sec avg (kW)	5 minute maximum average (kW)	Peak 600 sec avg (kW)
4062	3537	3260	2731	1736

The following chart provides a time history of the convective heat release rate from the fire.

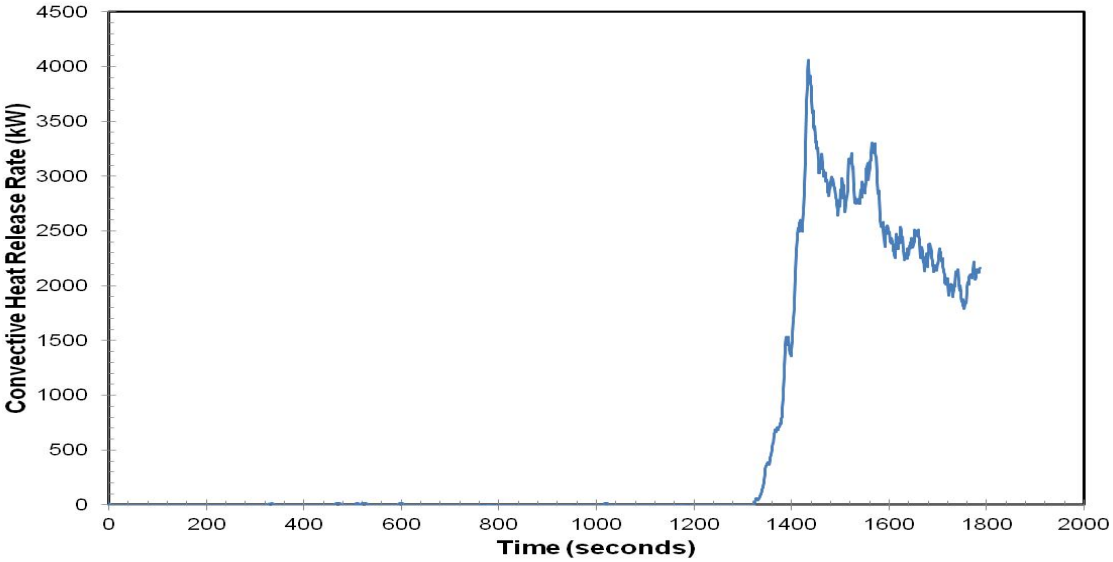

Figure 357. Convective Heat Release Rate

The following chart displays the production rates of CO and CO2.

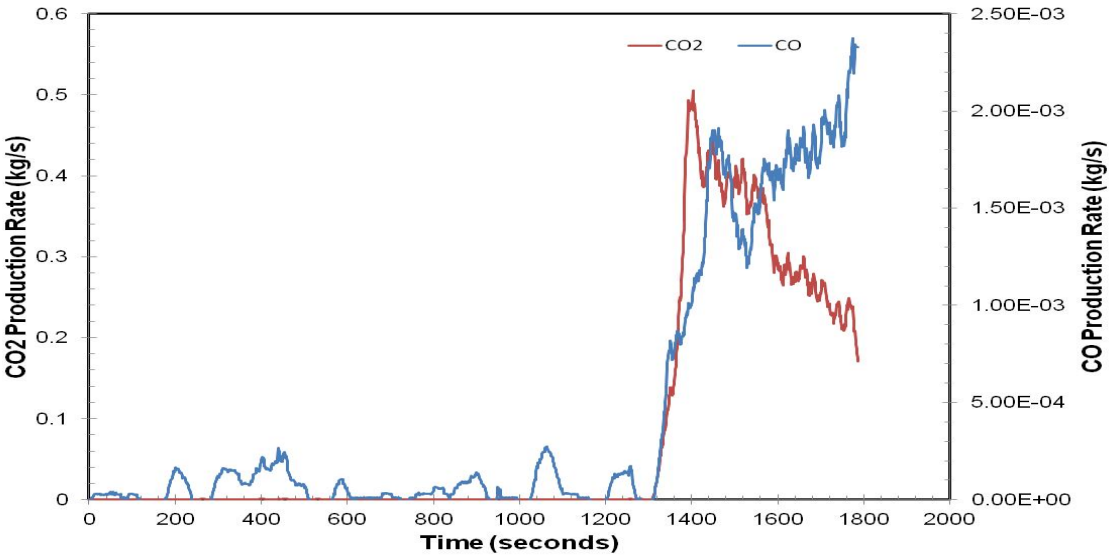

Figure 358. CO and CO2 production rates

The following table provides a description of the video(s) taken during this experiment.

Table 28. Video Log

Description	Start Time	Duration (s)	Filename
1	10:04:35	1889	6564_20110811_100435_1.mp4
2	10:04:37	1888	6564_20110811_100437_2.mp4
3	10:04:45	1881	6564_20110811_100445_3.mp4
4	10:04:47	1887	6564_20110811_100447_4.mp4
5	10:04:48	1887	6564_20110811_100448_5.mp4

The following figures show all of the still photographs uploaded into the FireTOSS system. The caption below each figure provides the picture's filename as well as any description and elapsed test time associated with the picture.

Figure 359. Pre test 1:11 hr:min, 6564_201535.jpg


Figure 360. Pre test 1:09 hr:min, 6564_201534.jpg


Figure 361. Pre test 1:08 hr:min, 6564_201533.jpg


Figure 362. Pre test 1:08 hr:min, 6564_201532.jpg


Figure 363. Pre test 1:08 hr:min, 6564_201531.jpg


Figure 364. Pre test 1:08 hr:min, 6564_201530.jpg


Figure 365. Pre test 1:07 hr:min, 6564_201529.jpg


Figure 366. Pre test 1:07 hr:min, 6564_201528.jpg


Figure 367. Pre test 1:06 hr:min, 6564_201527.jpg


Figure 368. Pre test 1:06 hr:min, 6564_201526.jpg


Figure 369. Pre test 1:06 hr:min, 6564_201525.jpg


Figure 370. Pre test 1:06 hr:min, 6564_201523.jpg

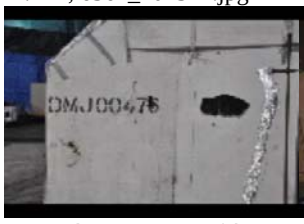
Figure 371. Pre test 1:06 hr:min, 6564_201524.jpg


Figure 372. Pre test 1:03 hr:min, 6564_201522.jpg


Figure 373. Pre test 1:03 hr:min, 6564_201521.jpg


Figure 374. Pre test 1:03 hr:min, 6564_201520.jpg

Figure 375. Pre test 59 minutes, 6564_201519.jpg

Figure 376. Pre test 59 minutes, 6564_201518.jpg

Figure 377. Pre test 58 minutes, 6564_201517.jpg

Figure 378. Pre test 57 minutes, 6564_201516.jpg

Figure 379. Pre test 55 minutes, 6564_201515.jpg

Figure 380. Pre test 55 minutes, 6564_201514.jpg

Figure 381. Pre test 54 minutes, 6564_201513.jpg

Figure 382. Pre test 54 minutes, 6564_201512.jpg

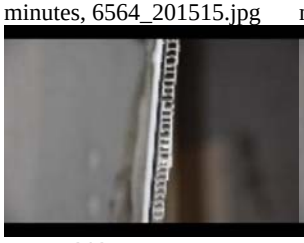

Figure 383. Pre test 54 minutes, 6564_201511.jpg

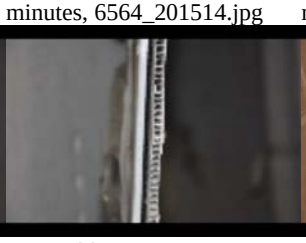

Figure 384. Pre test 52 minutes, 6564_201510.jpg

Figure 385. Pre test 48 minutes, 6564_201509.jpg

Figure 386. Pre test 48 minutes, 6564_201508.jpg

Figure 387. Pre test 48 minutes, 6564_201507.jpg

Figure 388. Pre test 48 minutes, 6564_201506.jpg

Figure 389. Pre test 48 minutes, 6564_201505.jpg

Figure 390. Pre test 29 minutes, 6564_201504.jpg

Figure 391. Pre test 29 minutes, 6564_201503.jpg

Figure 392. Pre test 29 minutes, 6564_201502.jpg

Figure 393. Pre test 29 minutes, 6564_201501.jpg

Figure 394. Pre test 28 minutes, 6564_201500.jpg

Figure 395. Pre test 28 minutes, 6564_201499.jpg

Figure 396. Pre test 28 minutes, 6564_201498.jpg

Figure 397. Pre test 28 minutes, 6564_201497.jpg

Figure 398. Pre test 27 minutes, 6564_201496.jpg

Figure 399. Pre test 27 minutes, 6564_201495.jpg

Figure 400. Pre test 25 minutes, 6564_201494.jpg

Figure 401. Pre test 14 minutes, 6564_201493.jpg

Figure 402. Pre test 14 minutes, 6564_201492.jpg

Figure 403. Pre test 14 minutes, 6564_201491.jpg

Figure 404. Pre test 14 minutes, 6564_201490.jpg

Figure 405. Pre test 14 minutes, 6564_201489.jpg

Figure 406. Pre test 13 minutes, 6564_201488.jpg

Figure 407. Pre test 13 minutes, 6564_201487.jpg

Figure 408. Pre test 13 minutes, 6564_201486.jpg

Figure 409. Pre test 12 minutes, 6564_201485.jpg

Figure 410. Pre test 12 minutes, 6564_201484.jpg

Figure 411. Pre test 12 minutes, 6564_201483.jpg

Figure 412. Pre test 12 minutes, 6564_201482.jpg

Figure 413. Pre test 11 minutes, 6564_201481.jpg

Figure 414. Pre test 11 minutes, 6564_201480.jpg

Figure 415. Pre test 11 minutes, 6564_201479.jpg

Figure 416. Pre test 11 minutes, 6564_201478.jpg

Figure 417. Pre test 10 minutes, 6564_201477.jpg

Figure 418. Pre test 10 minutes, 6564_201476.jpg

Figure 419. Pre test 10 minutes, 6564_201475.jpg

Figure 420. Pre test 10 seconds, 6564_201474.jpg

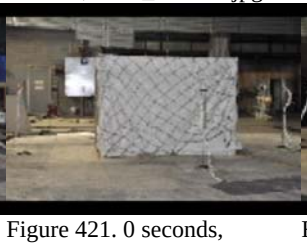

Figure 421. 0 seconds, 6564_201473.jpg

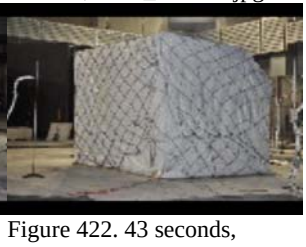

Figure 422. 43 seconds, 6564_201472.jpg

Figure 423. 56 seconds, 6564_201471.jpg

Figure 424. 81 seconds, 6564_201470.jpg

Figure 425. 143 seconds, 6564_201469.jpg

Figure 426. 256 seconds, 6564_201468.jpg

Figure 427. 326 seconds, 6564_201467.jpg

Figure 428. 449 seconds, 6564_201466.jpg

Figure 429. 493 seconds, 6564_201465.jpg

Figure 430. 500 seconds, 6564_201464.jpg

Figure 431. 524 seconds, 6564_201463.jpg

Figure 432. 547 seconds, 6564_201462.jpg

Figure 433. 553 seconds, 6564_201461.jpg

Figure 434. 560 seconds, 6564_201460.jpg

Figure 435. 641 seconds, 6564_201459.jpg

Figure 436. 649 seconds, 6564_201458.jpg

Figure 437. 677 seconds, 6564_201457.jpg

Figure 438. 684 seconds, 6564_201456.jpg

Figure 439. 719 seconds, 6564_201455.jpg

Figure 440. 746 seconds, 6564_201454.jpg

Figure 441. 837 seconds, 6564_201453.jpg

Figure 442. 839 seconds, 6564_201452.jpg

Figure 443. 850 seconds, 6564_201451.jpg

Figure 444. 854 seconds, 6564_201450.jpg

Figure 445. 896 seconds, 6564_201449.jpg

Figure 446. 902 seconds, 6564_201448.jpg

Figure 447. 912 seconds, 6564_201447.jpg

Figure 448. 976 seconds, 6564_201446.jpg

Figure 449. 998 seconds, 6564_201445.jpg

Figure 450. 1000 seconds, 6564_201444.jpg

Figure 451. 1016 seconds, 6564_201443.jpg

Figure 452. 1053 seconds, 6564_201442.jpg

Figure 453. 1108 seconds, 6564_201441.jpg

Figure 454. 1151 seconds, 6564_201440.jpg

Figure 455. 1241 seconds, 6564_201439.jpg

Figure 456. 1268 seconds, 6564_201438.jpg

Figure 457. 1280 seconds, 6564_201437.jpg

Figure 458. 1292 seconds, 6564_201436.jpg

Figure 459. 1297 seconds, 6564_201435.jpg

Figure 460. 1304 seconds, 6564_201434.jpg

Figure 461. 1314 seconds, 6564_201433.jpg

Figure 462. 1319 seconds, 6564_201432.jpg

Figure 463. 1327 seconds, 6564_201431.jpg

Figure 464. 1337 seconds, 6564_201430.jpg

Figure 465. 1339 seconds, 6564_201429.jpg

Figure 466. 1345 seconds, 6564_201428.jpg

Figure 467. 1349 seconds, 6564_201427.jpg

Figure 468. 1353 seconds, 6564_201426.jpg

Figure 469. 1359 seconds, 6564_201425.jpg

Figure 470. 1369 seconds, 6564_201424.jpg

Figure 471. 1371 seconds, 6564_201423.jpg

Figure 472. 1381 seconds, 6564_201422.jpg

Figure 473. 1386 seconds, 6564_201421.jpg

Figure 474. 1391 seconds, 6564_201420.jpg

Figure 475. 1401 seconds, 6564_201419.jpg

Figure 476. 1405 seconds, 6564_201418.jpg

Figure 477. 1421 seconds, 6564_201417.jpg

Figure 478. 1431 seconds, 6564_201416.jpg

Figure 479. 1440 seconds, 6564_201415.jpg

Figure 480. 1451 seconds, 6564_201414.jpg

Figure 481. 1460 seconds, 6564_201413.jpg

Figure 482. 1493 seconds, 6564_201412.jpg

Figure 483. 1524 seconds, 6564_201411.jpg

Figure 484. 1537 seconds, 6564_201410.jpg

Figure 485. 1569 seconds, 6564_201409.jpg

Figure 486. 1593 seconds, 6564_201408.jpg

Figure 487. 1610 seconds, 6564_201407.jpg

Figure 488. 1631 seconds, 6564_201406.jpg

Figure 489. 1635 seconds, 6564_201405.jpg

Figure 490. 1657 seconds, 6564_201404.jpg

Figure 491. 1695 seconds, 6564_201403.jpg

Figure 492. 1707 seconds, 6564_201402.jpg

Figure 493. 1714 seconds, 6564_201401.jpg

Figure 494. 1720 seconds, 6564_201400.jpg

Figure 495. 1740 seconds, 6564_201399.jpg

Figure 496. 1746 seconds, 6564_201398.jpg

Figure 497. 1785 seconds, 6564_201397.jpg

Figure 498. 1799 seconds, 6564_201396.jpg

Figure 499. Post test 0 minutes, 6564_201395.jpg

Figure 500. Post test 0 minutes, 6564_201394.jpg

Figure 501. Post test 1 minutes, 6564_201393.jpg

Figure 502. Post test 1 minutes, 6564_201392.jpg

Figure 503. Post test 1 minutes, 6564_201391.jpg

Figure 504. Post test 1 minutes, 6564_201390.jpg

Figure 505. Post test 1 minutes, 6564_201389.jpg

Figure 506. Post test 1 minutes, 6564_201388.jpg

Figure 507. Post test 1 minutes, 6564_201387.jpg

Results for Test 4 (Exp. ID 6565)

The following table provides a summary of the ambient laboratory temperature during the experiment.

Table 29. Ambient Laboratory Temperature Summary

Description	Initial Value (C)	Minimum (C)	Maximum (C)	Average (C)	Final Value (C)
MBR_01	27.0	27.0	28.9	27.7	28.9

The following table provides a summary of the ambient laboratory pressure during the experiment.

Table 30. Ambient Laboratory Pressure Summary

Description	Initial Value (kPa)	Minimum (kPa)	Maximum (kPa)	Average (kPa)	Final Value (kPa)
MBR_01	100.51	100.49	100.52	100.50	100.50

The following table provides a summary of the ambient laboratory relative humidity during the experiment.

Table 31. Ambient Laboratory Relative Humidity Summary

Description	Initial Value (%)	Minimum (%)	Maximum (%)	Average (%)	Final Value (%)
MBR_01	44.2	40.9	44.8	43.3	40.9

The following table provides a summary of the temperature results. The "Initial Temperature" column provides the measured temperature at the beginning of the test. The maximum temperature recorded during the test is provided in the "Maximum" column. The remaining columns provide the calculated maximum average temperatures.

Table 32. Temperature Value Result Summary

Description	Initial (C)	Maximum (C)	30 second maximum average (C)	60 second maximum average (C)	300 second maximum average (C)	600 second maximum average (C)
Center_105	27	707	428	420	368	312
Center_117	27	519	502	500	447	364
Center_81	28	840	551	503	471	446
Center_93	27	845	638	603	517	406
East	28	178	175	174	162	142
Near igniter	28	870	752	681	627	618
North	28	154	137	133	115	99
South	28	128	124	119	107	91
TC_81	28	735	604	602	531	457
West	27	182	175	171	129	110

The following chart(s) present a time-dependent representation of the instantaneous temperatures measured during the experiment.

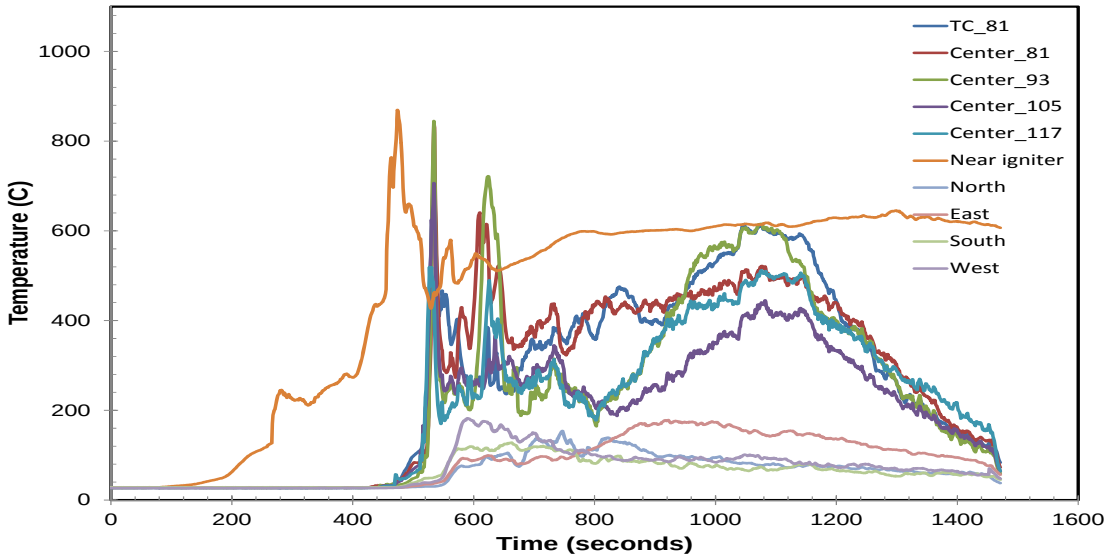

Figure 508. Temperature

The following table provides a summary of the heat flux results. The "Description" column typically describes the location of the heat flux transducer. The time at which the heat flux first changes by a pre-determined amount is provided in the "Time of Initial Change" column. The maximum heat flux recorded during the test is provided in the "Maximum" column. The "Maximum Average" columns are calculated over four pre-determined time spans.

Table 33. Heat Flux Result Summary

Description	Time of Initial Change (s)	Maximum (kW/m²)	30 second maximum average (kW/m²)	60 second maximum average (kW/m²)	300 second maximum average (kW/m²)	600 second maximum average (kW/m²)
East	1	20.5	17.9	17.3	15.3	13.4
North	1	21.3	18.1	17.8	14.3	12.1
South	1	24.2	21.5	20.9	15.6	12.3
West	1	32.5	28.8	27.2	19.2	14.9

The following chart shows a time dependent representation of the instantaneous heat flux measured during the experiment.

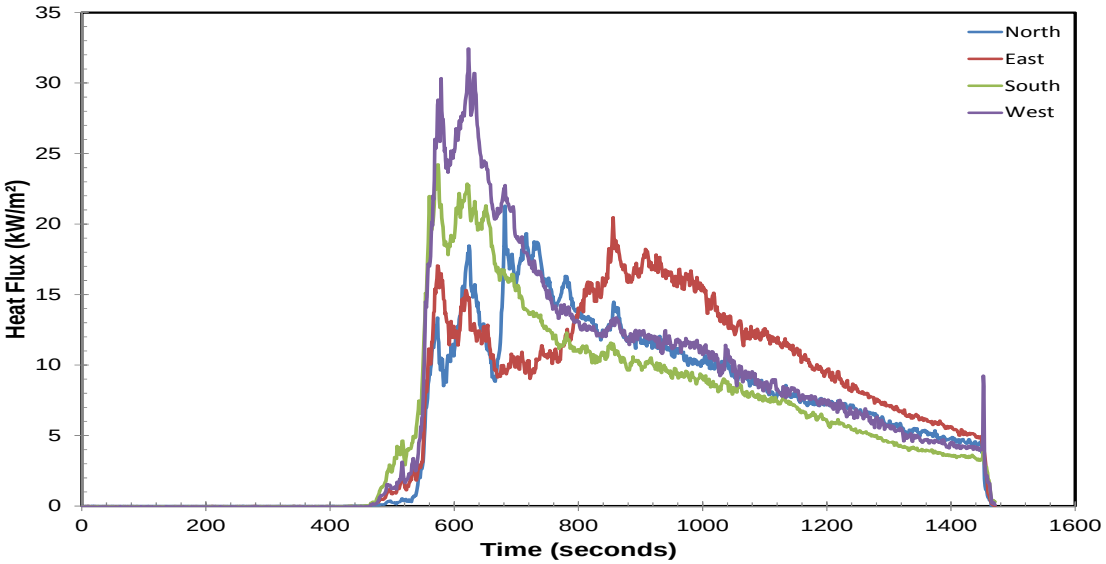

Figure 509. Heat Flux

The following chart provides a time history of the concentration of carbon monoxide and carbon dioxide measured in the exhaust duct during the fire.

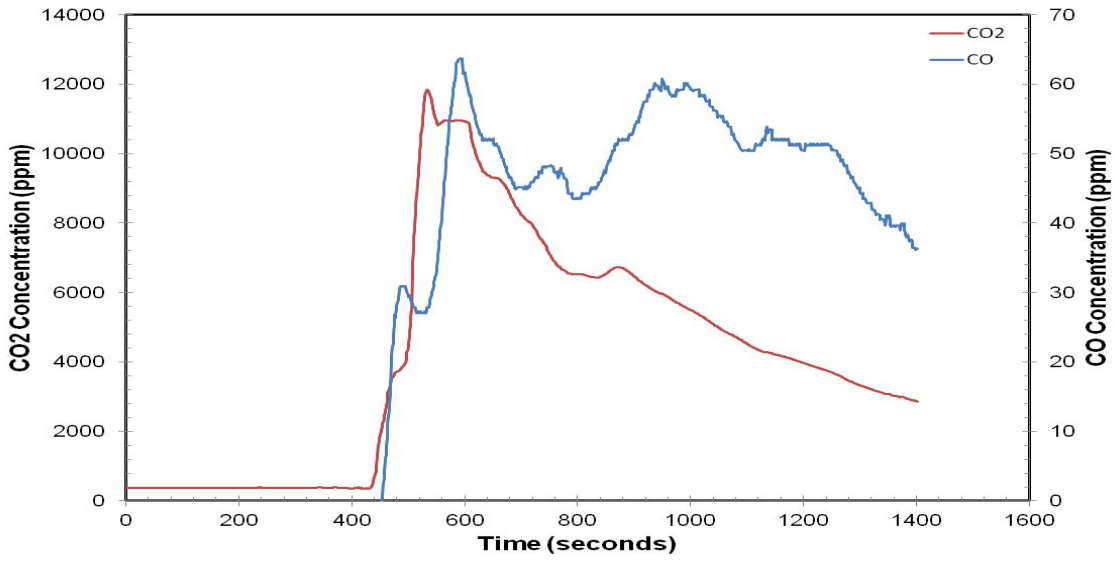

Figure 510. Carbon monoxide and carbon dioxide concentrations

The following chart provides a time history of the concentration of oxygen measured in the exhaust duct during the fire.

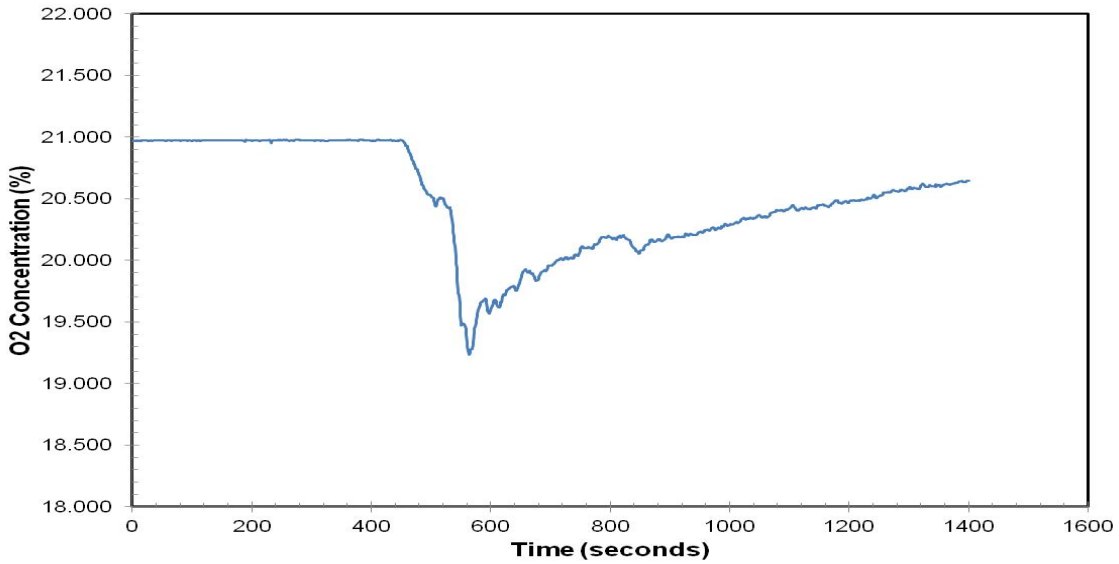

Figure 511. Oxygen Concentration

The following table provides a summary of the heat release rate (HRR) test results. The maximum HRR recorded during the test is provided in the "Maximum" column. The "maximum average" values are calculated from average values of heat release rate over specified time periods. The maximum average values provide a means to compare the severity of different fires over these time spans. The "Total heat released" is calculated from the area under the curve for the duration of the test.

Table 34. Heat Release Rate Result Summary

Maximum (kW)	30 second maximum average (kW)	1 minute maximum average (kW)	5 minute maximum average (kW)	10 minute maximum average (kW)	Total Heat Release (kJ)
7149	6794	6250	6794	3911	2977811

The following chart provides a time history of the heat release rate from the fire.

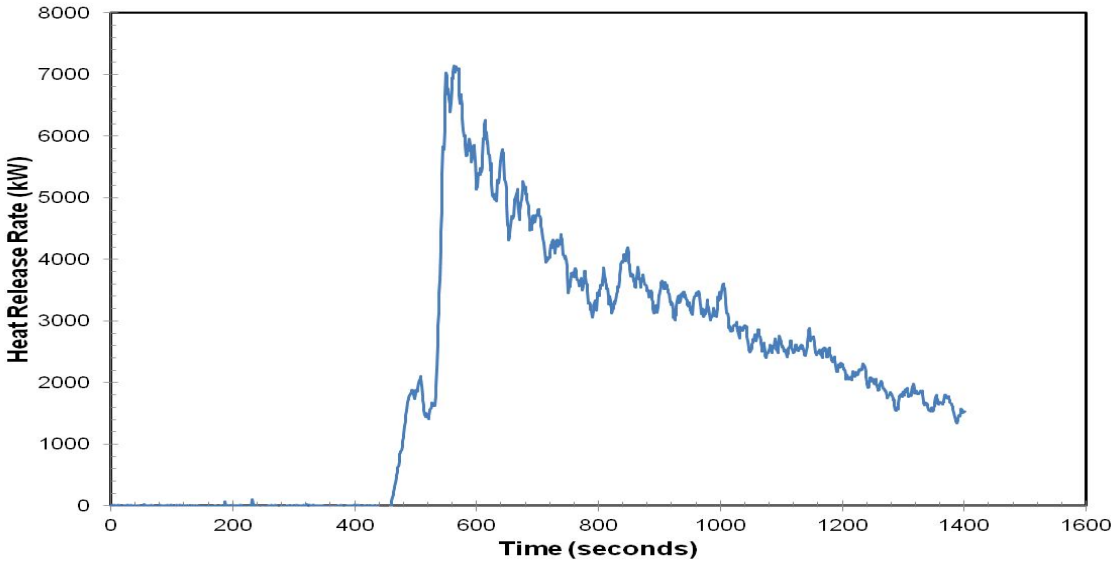

Figure 512. Heat Release Rate

The following table provides a summary of the convective heat release rate (HRR) test results.

Table 35. Convective Heat Release Rate Result Summary

Maximum (kW)	30 second maximum average (kW)	Peak 60 sec avg (kW)	5 minute maximum average (kW)	Peak 600 sec avg (kW)
3844	3445	3299	2730	2335

The following chart provides a time history of the convective heat release rate from the fire.

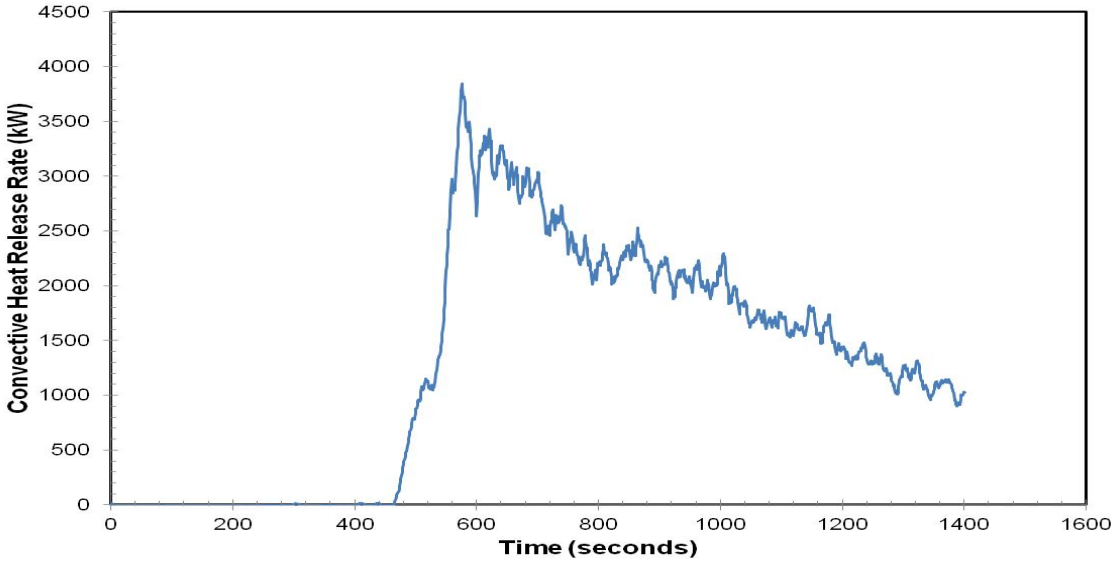

Figure 513. Convective Heat Release Rate

The following chart displays the production rates of CO and CO2.

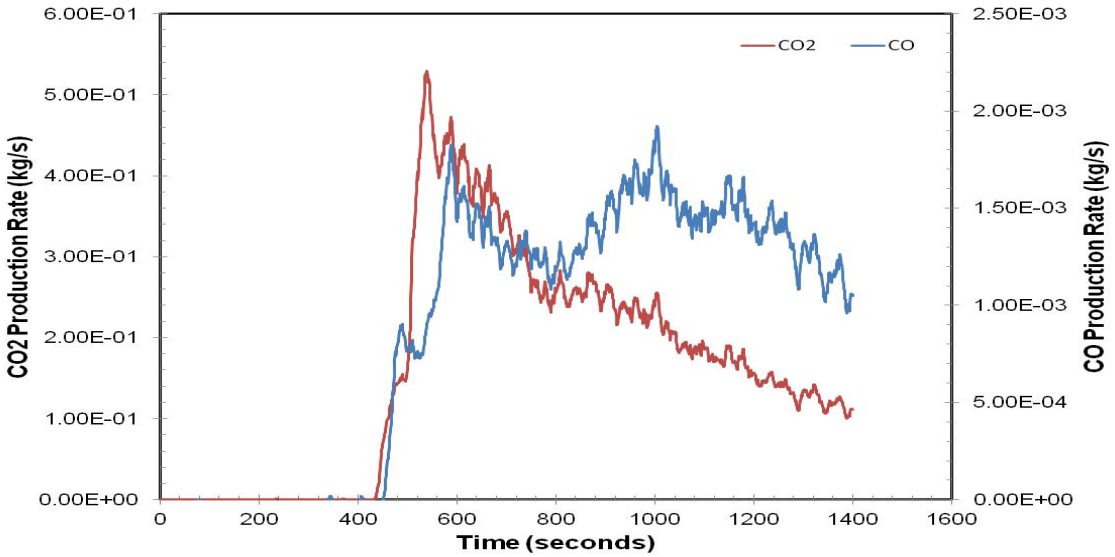

Figure 514. CO and CO2 production rates

The following table provides a description of the video(s) taken during this experiment.

Table 36. Video Log

Description	Start Time	Duration (s)	Filename
1	14:21:34	1498	6565_20110811_142134_1.mp4
2	14:21:36	1497	6565_20110811_142136_2.mp4
3	14:21:37	1505	6565_20110811_142137_3.mp4
4	14:21:44	1499	6565_20110811_142144_4.mp4
5	14:21:46	1498	6565_20110811_142146_5.mp4

The following figures show all of the still photographs uploaded into the FireTOSS system. The caption below each figure provides the picture's filename as well as any description and elapsed test time associated with the picture.

Figure 515. Pre test 38 minutes, 6565_201678.jpg

Figure 516. Pre test 38 minutes, 6565_201677.jpg

Figure 517. Pre test 38 minutes, 6565_201676.jpg

Figure 518. Pre test 38 minutes, 6565_201675.jpg

Figure 519. Pre test 38 minutes, 6565_201674.jpg

Figure 520. Pre test 38 minutes, 6565_201673.jpg

Figure 521. Pre test 37 minutes, 6565_201672.jpg

Figure 522. Pre test 37 minutes, 6565_201671.jpg

Figure 523. Pre test 36 minutes, 6565_201670.jpg

Figure 524. Pre test 36 minutes, 6565_201669.jpg

Figure 525. Pre test 23 minutes, 6565_201668.jpg

Figure 526. Pre test 23 minutes, 6565_201667.jpg

Figure 527. Pre test 23 minutes, 6565_201666.jpg

Figure 528. Pre test 23 minutes, 6565_201665.jpg

Figure 529. Pre test 23 minutes, 6565_201664.jpg

Figure 530. Pre test 23 minutes, 6565_201663.jpg

Figure 531. Pre test 22 minutes, 6565_201662.jpg

Figure 532. Pre test 22 minutes, 6565_201661.jpg

Figure 533. Pre test 22 minutes, 6565_201660.jpg

Figure 534. Pre test 22 minutes, 6565_201659.jpg

Figure 535. Pre test 17 minutes, 6565_201658.jpg

Figure 536. Pre test 15 minutes, 6565_201657.jpg

Figure 537. Pre test 15 minutes, 6565_201656.jpg

Figure 538. Pre test 15 minutes, 6565_201655.jpg

Figure 539. Pre test 14 minutes, 6565_201654.jpg

Figure 540. Pre test 14 minutes, 6565_201653.jpg

Figure 541. Pre test 14 minutes, 6565_201651.jpg

Figure 542. Pre test 14 minutes, 6565_201652.jpg

Figure 543. Pre test 13 minutes, 6565_201650.jpg

Figure 544. Pre test 13 minutes, 6565_201649.jpg

Figure 545. Pre test 13 minutes, 6565_201648.jpg

Figure 546. Pre test 12 minutes, 6565_201647.jpg

Figure 547. Pre test 11 minutes, 6565_201646.jpg

Figure 548. Pre test 11 minutes, 6565_201645.jpg

Figure 549. Pre test 11 minutes, 6565_201644.jpg

Figure 550. Pre test 7 minutes, 6565_201643.jpg

Figure 551. Pre test 6 minutes, 6565_201642.jpg

Figure 552. Pre test 6 minutes, 6565_201641.jpg

Figure 553. Pre test 5 minutes, 6565_201640.jpg

Figure 554. Pre test 5 minutes, 6565_201639.jpg

Figure 555. Pre test 5 minutes, 6565_201638.jpg

Figure 556. Pre test 7 seconds, 6565_201637.jpg

Figure 557. Pre test 1 seconds, 6565_201636.jpg

Figure 558. 96 seconds, 6565_201635.jpg

Figure 559. 132 seconds, 6565_201634.jpg

Figure 560. 245 seconds, 6565_201633.jpg

Figure 561. 370 seconds, 6565_201632.jpg

Figure 562. 384 seconds, 6565_201631.jpg

Figure 563. 389 seconds, 6565_201630.jpg

Figure 564. 394 seconds, 6565_201629.jpg

Figure 565. 420 seconds, 6565_201628.jpg

Figure 566. 431 seconds, 6565_201627.jpg

Figure 567. 457 seconds, 6565_201626.jpg

Figure 568. 462 seconds, 6565_201625.jpg

Figure 569. 465 seconds, 6565_201624.jpg

Figure 570. 485 seconds, 6565_201623.jpg

Figure 571. 504 seconds, 6565_201622.jpg

Figure 572. 509 seconds, 6565_201621.jpg

Figure 573. 513 seconds, 6565_201620.jpg

Figure 574. 518 seconds, 6565_201619.jpg

Figure 575. 523 seconds, 6565_201618.jpg

Figure 576. 528 seconds, 6565_201617.jpg

Figure 577. 534 seconds, 6565_201616.jpg

Figure 578. 545 seconds, 6565_201615.jpg

Figure 579. 556 seconds, 6565_201614.jpg

Figure 580. 568 seconds, 6565_201613.jpg

Figure 581. 580 seconds, 6565_201612.jpg

Figure 582. 584 seconds, 6565_201611.jpg

Figure 583. 602 seconds, 6565_201610.jpg

Figure 584. 606 seconds, 6565_201609.jpg

Figure 585. 633 seconds, 6565_201608.jpg

Figure 586. 650 seconds, 6565_201607.jpg

Figure 587. 660 seconds, 6565_201606.jpg

Figure 588. 672 seconds, 6565_201605.jpg

Figure 589. 693 seconds, 6565_201604.jpg

Figure 590. 707 seconds, 6565_201603.jpg

Figure 591. 732 seconds, 6565_201602.jpg

Figure 592. 774 seconds, 6565_201601.jpg

Figure 593. 797 seconds, 6565_201600.jpg

Figure 594. 808 seconds, 6565_201599.jpg

Figure 595. 813 seconds, 6565_201598.jpg

Figure 596. 817 seconds, 6565_201597.jpg

Figure 597. 861 seconds, 6565_201596.jpg

Figure 598. 901 seconds, 6565_201595.jpg

Figure 599. 921 seconds, 6565_201594.jpg

Figure 600. 950 seconds, 6565_201593.jpg

Figure 601. 996 seconds, 6565_201592.jpg

Figure 602. 1043 seconds, 6565_201591.jpg

Figure 603. 1074 seconds, 6565_201590.jpg

Figure 604. 1096 seconds, 6565_201589.jpg

Figure 605. 1107 seconds, 6565_201588.jpg

Figure 606. 1126 seconds, 6565_201587.jpg

Figure 607. 1204 seconds, 6565_201586.jpg

Figure 608. 1279 seconds, 6565_201585.jpg

Figure 609. 1284 seconds, 6565_201584.jpg

Figure 610. 1302 seconds, 6565_201583.jpg

Figure 611. 1398 seconds, 6565_201582.jpg

Figure 612. 1428 seconds, 6565_201581.jpg

Figure 613. 1431 seconds, 6565_201580.jpg

Figure 614. 1445 seconds, 6565_201579.jpg

Figure 615. 1448 seconds, 6565_201578.jpg

Figure 616. Post test 0 minutes, 6565_201577.jpg

Figure 617. Post test 1 minutes, 6565_201576.jpg

Figure 618. Post test 1 minutes, 6565_201575.jpg

Figure 619. Post test 1 minutes, 6565_201574.jpg

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