Title	Calorimetry- Single Cardboard Box		
Test Type	Custom		
Lab Number	NTSB-1	Author	Justin L. Rowe
Test dates	8/8/11, 8/9/11	No. Tests	4

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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 examine the fire growth and energy released from a cardboard box containing shredded paper. The fire was started using an open flame ignition source generated inside the cardboard box. The box was closed but small holes were cut out on each side for ventilation. 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 under the 1 MW Square calorimeter in the Medium Burn Room (MBR) of the Bureau of Alcohol, Tobacco, Firearm, and Explosives (ATF) Fire Research Laboratory (FRL) in Beltsville, MD.

Test Set Up

The 0.46 x 0.46 x 0.46 m (18 x 18 x 18 inch) cardboard box was placed on one layer of 13 mm (0.5 inch) thick Durock cement board in an open laboratory environment. The top and bottom of the box were closed by alternating the flaps, as shown in Figure 1. Two 25 mm (1 inch) diameter vents were made on each side of the box at a distance of 50 mm (2 inch) from the top and bottom edge and 0.23 m (9 inch) from the sides. The box contained 1.13 kg (2.5 lbs) of shredded paper. In Test 1 through Test 3, the width of the paper was 4 mm (0.16 inch), as shown in Figure 2. In Test 4, the width of the paper was 6 mm (0.24 inch), as shown in Figure 3.

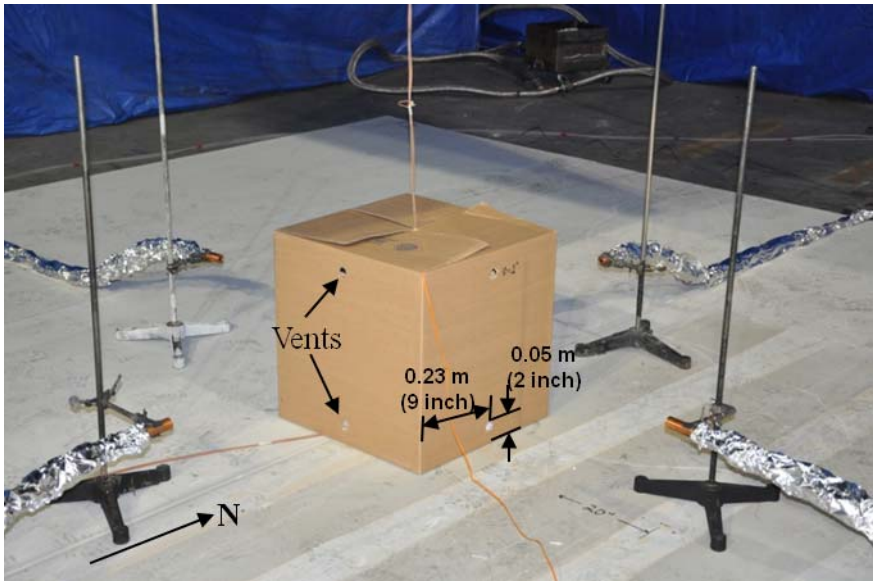

Figure 1. Test setup (6539_199852.JPG)

Figure 2. Shredded paper (4 mm wide) in box for Test 1 through Test 3 (6539_199875.JPG)

Figure 3. Shredded paper (6 mm wide) in box for Test 4 (6555_200689.JPG)

Experiment Details

Ignition Scenario

An open flame ignition source was used to ignite the shredded paper inside the box. The ignition device consisted of fifteen large kitchen matches (Manufacturer: Diamond) wrapped around an electric igniter connected to a 6 VDC battery. The ignition device was placed vertically with the match tips near the top surface of the shredded paper, as shown in Figure 2.

At the start of the test, the power to the electric igniter was switched on, creating a spark which lit the matches and generated an open flame. The ignition device is shown in Figure 4.

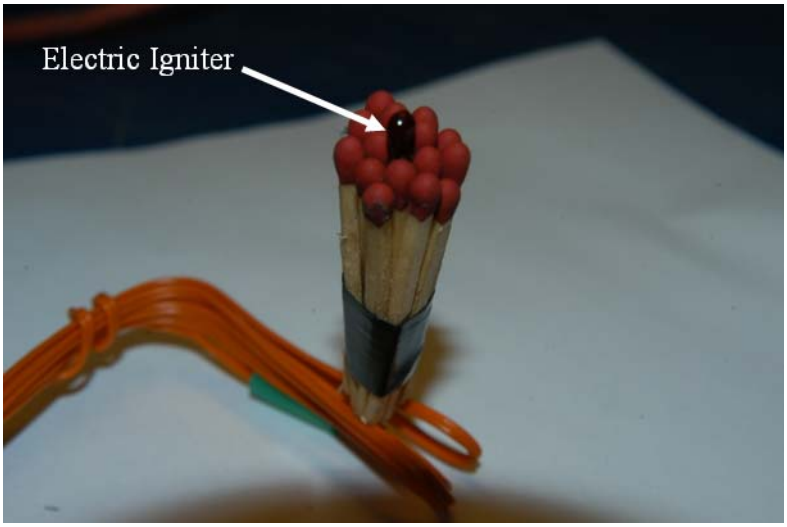

Figure 4. Ignition device (6539_212275.JPG)

Instrumentation

The test series was conducted under FRL's 1 MW Square 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, four heat flux gauges, and a flame height indicator. The thermocouple tree was used to measure a vertical temperature profile along the plume centerline. The tree was mounted through the center of the box as shown in Figure 5. There were five thermocouples starting at the surface inside the top of the box and extending 1.22 m (48 inch) above the box at 0.30 m (12 inch) intervals. The heat flux gauges were used to measure the total energy transfer per unit area on each side of the box. The gauges were centered parallel to each side of the box at a distance of 0.51 m (20 inch) and an elevation of 0.23 m (9 inch).

Elevation distances described in the body of this report are relative to the z-axis defined in Figure 5.

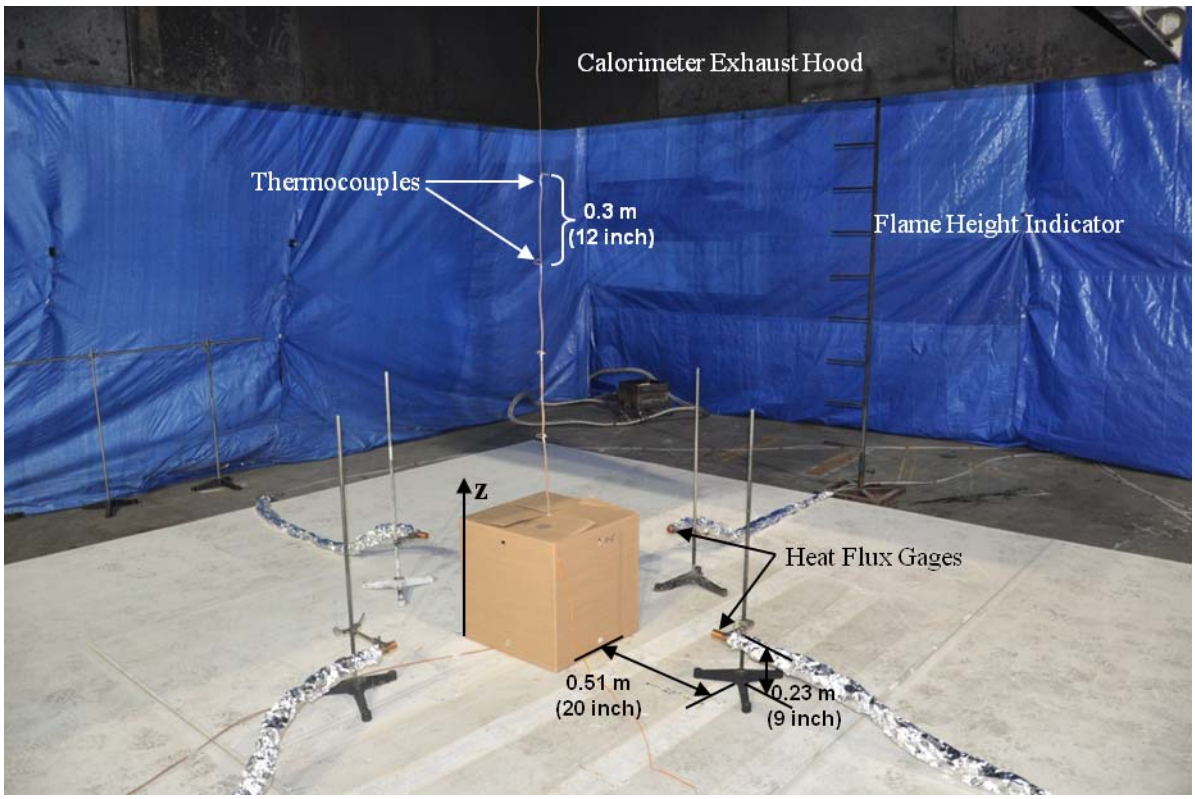

Figure 5. Instrumentation details (6539_199851.JPG)

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_30	0.76	Type K, Glass Ins., 24 AWG wire
Center_42	1.07	Type K, Glass Ins., 24 AWG wire
Center_54	1.37	Type K, Glass Ins., 24 AWG wire
Center_66	1.68	Type K, Glass Ins., 24 AWG wire
Center_Top of box	0.46	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. Location Z is the distance from the floor to the centerline of the 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	Location Z (m)	Heat Flux Mode	Heat Flux Max Range (kW/m²)
East	0.23	Total	37.50
North	0.23	Total	37.50
South	0.23	Total	37.50
West	0.23	Total	37.50

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 6. 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.

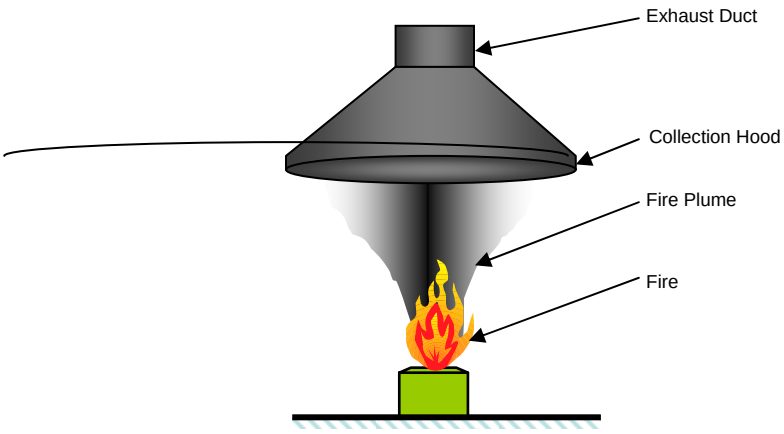

Figure 6. Typical products collector hood

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 6539)

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	27.6	27.6	27.8	27.7	27.8

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	99.79	99.77	99.80	99.79	99.79

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	60.0	59.6	60.2	59.9	59.6

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_30	27	921	830	705	282	165
Center_42	27	854	756	658	299	171
Center_54	27	746	708	664	328	184
Center_66	26	741	664	615	252	145
Center_Top of box	28	847	762	717	510	308

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

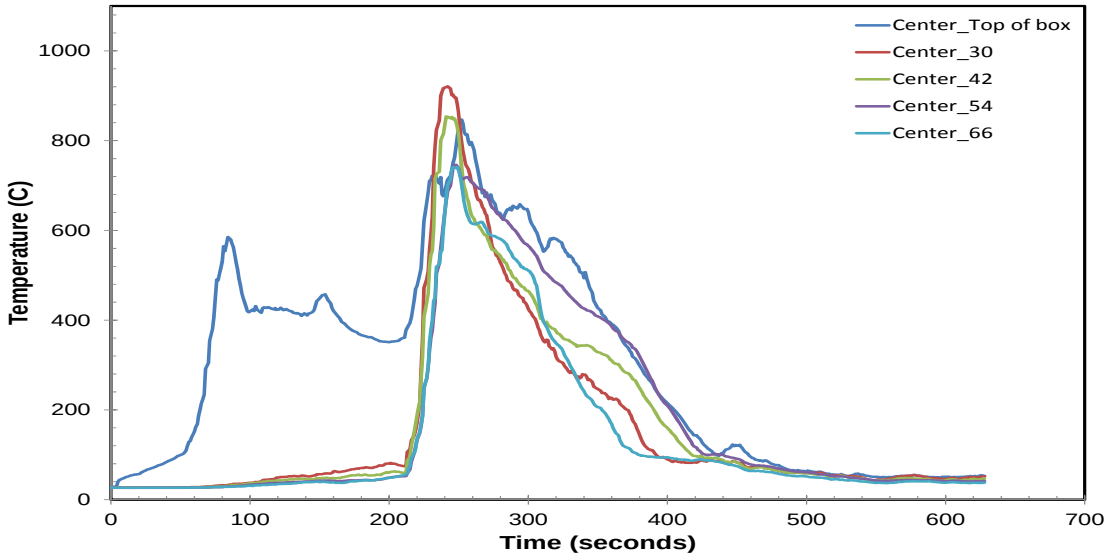

Figure 7. Temperature

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 pre-determined amount of change in heat flux is provided in the "Initial Change Amount" 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)	Initial Change Amount (kW/m^2)	Maximum (kW/m^2)	30 second maximum average (kW/m^2)	60 second maximum average (kW/m^2)	300 second maximum average (kW/m^2)	600 second maximum average (kW/m^2)
East	228	2	5.2	4.6	4.1	2.3	1.3
North	222	2	9.4	7.8	6.5	2.4	1.3
South	222	2	4.6	4.4	4.3	2.5	1.4
West	216	2	9.1	7.9	6.7	2.7	1.5

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

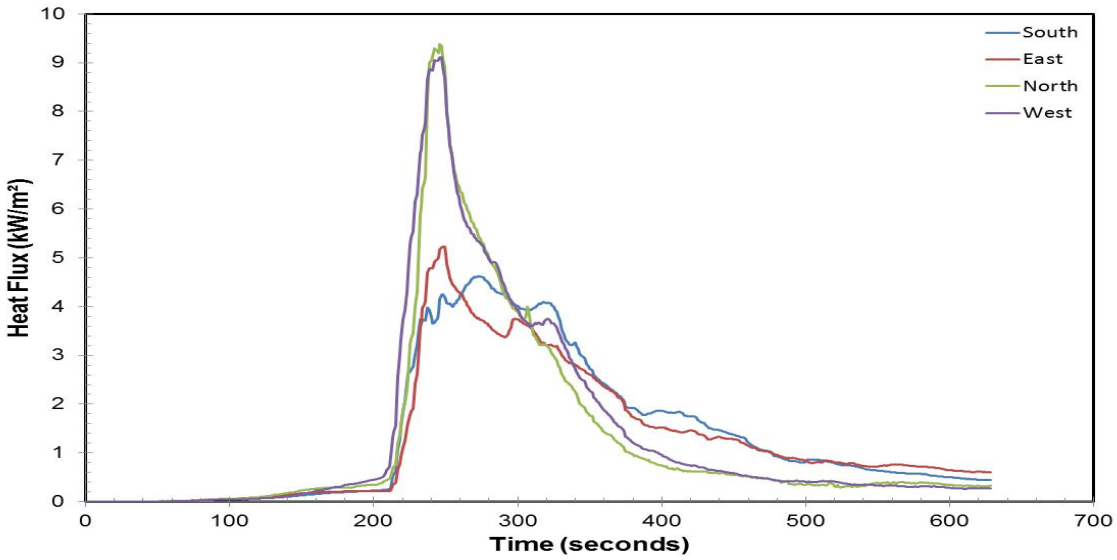

Figure 8. Heat Flux

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

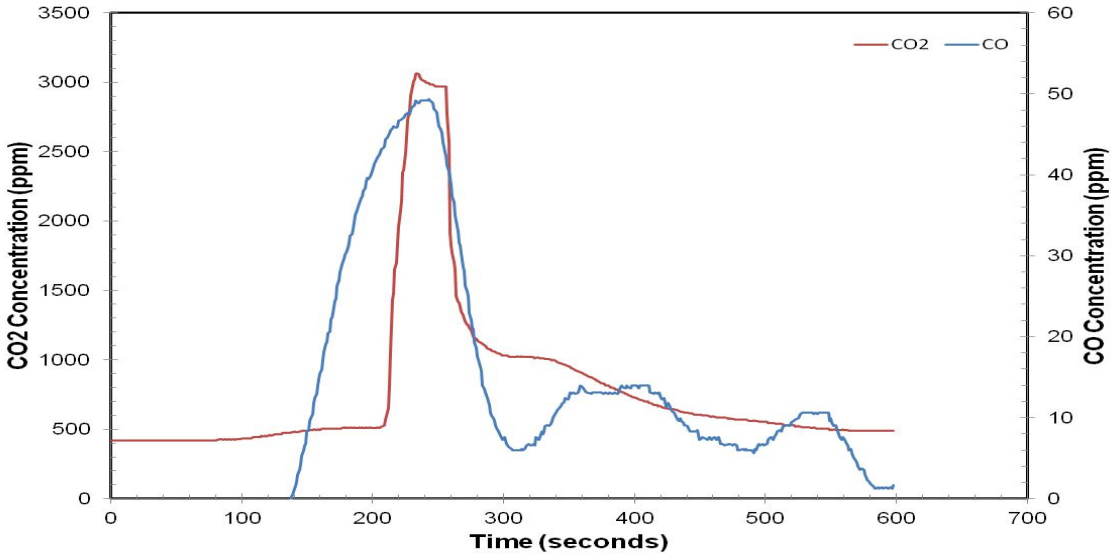

Figure 9. Carbon monoxide and carbon dioxide concentrations

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

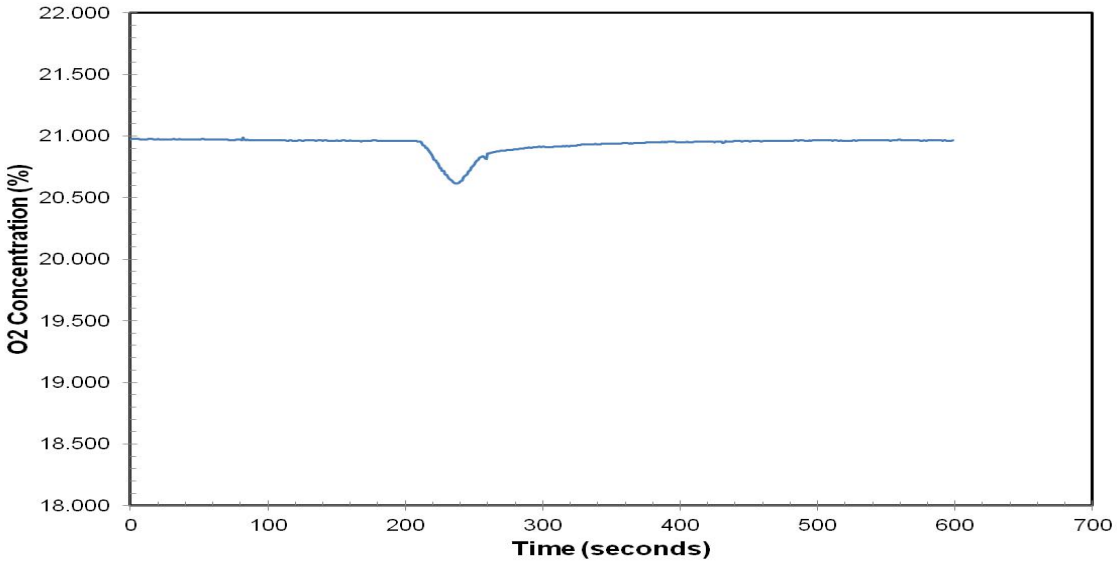

Figure 10. Oxygen Concentration

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)
273	203	141	203	27	15927

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

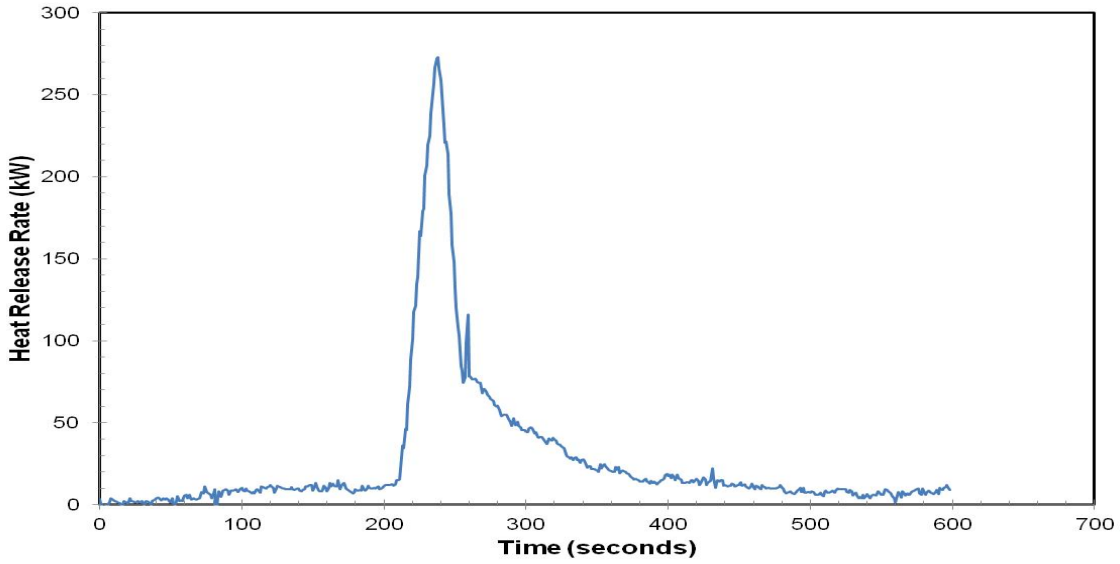

Figure 11. Heat Release Rate

The following table provides a summary of the convective heat release rate (HRR) 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)
146	119	89	30	16

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

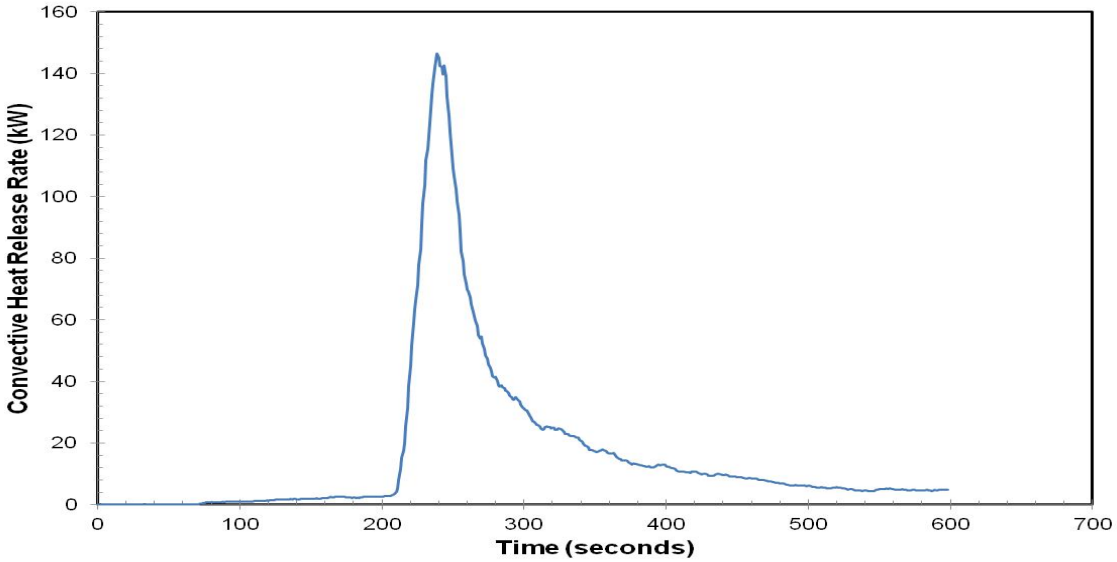

Figure 12. Convective Heat Release Rate

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

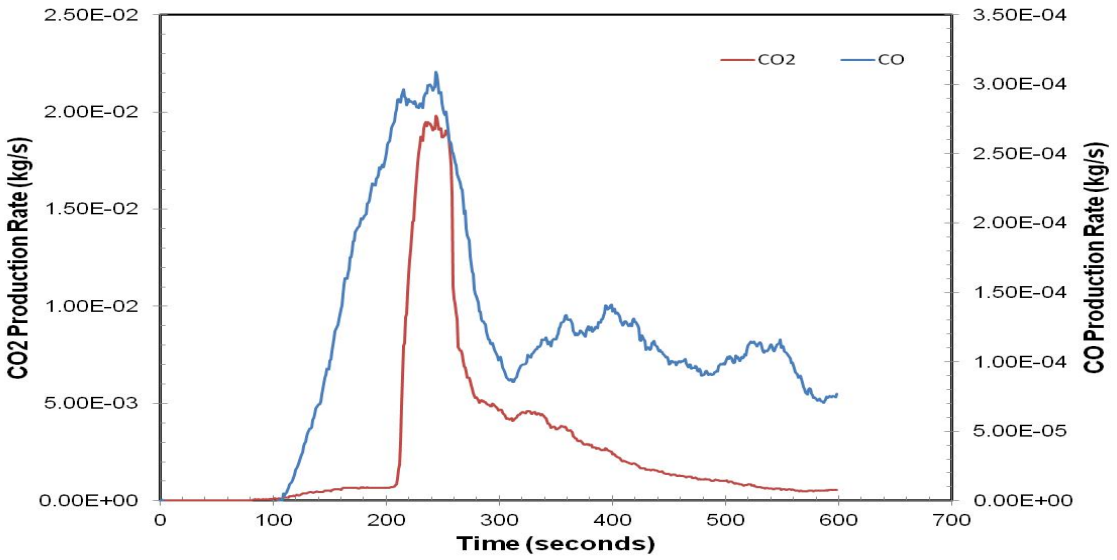

Figure 13. CO and CO2 production rates

Video

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

Table 11. Video Log

Description	Start Time	Duration (s)	Filename
North	09:49:01	666	6539_20110808_094901_2.mp4
North East	09:48:59	667	6539_20110808_094859_1.mp4
North West	09:49:10	659	6539_20110808_094910_4.mp4
South West	09:49:09	659	6539_20110808_094909_3.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 14. Pre test 13 minutes, 6539_199879.jpg

Figure 15. Pre test 13 minutes, 6539_199880.jpg

Figure 16. Pre test 13 minutes, 6539_199878.jpg

Figure 17. Pre test 12 minutes, 6539_199877.jpg

Figure 18. Pre test 12 minutes, 6539_199876.jpg

Figure 19. Pre test 12 minutes, 6539_199875.jpg

Figure 20. Pre test 12 minutes, 6539_199874.jpg

Figure 21. Pre test 12 minutes, 6539_199873.jpg

Figure 22. Pre test 12 minutes, 6539_199872.jpg

Figure 23. Pre test 12 minutes, 6539_199871.jpg

Figure 24. Pre test 11 minutes, 6539_199870.jpg

Figure 25. Pre test 11 minutes, 6539_199869.jpg

Figure 26. Pre test 9 minutes, 6539_199868.jpg

Figure 27. Pre test 7 minutes, 6539_199867.jpg

Figure 28. Pre test 7 minutes, 6539_199866.jpg

Figure 29. Pre test 7 minutes, 6539_199865.jpg

Figure 30. Pre test 7 minutes, 6539_199864.jpg

Figure 31. Pre test 7 minutes, 6539_199863.jpg

Figure 32. Pre test 7 minutes, 6539_199862.jpg

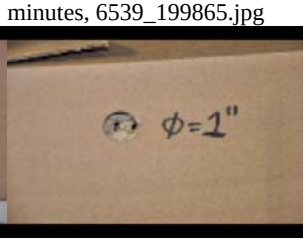

Figure 33. Pre test 6 minutes, 6539_199861.jpg

Figure 34. Pre test 6 minutes, 6539_199860.jpg

Figure 35. Pre test 4 minutes, 6539_199859.jpg

Figure 36. Pre test 4 minutes, 6539_199858.jpg

Figure 37. Pre test 4 minutes, 6539_199857.jpg

Figure 38. Pre test 4 minutes, 6539_199856.jpg

Figure 39. Pre test 4 minutes, 6539_199855.jpg

Figure 40. Pre test 3 minutes, 6539_199854.jpg

Figure 41. Pre test 3 minutes, 6539_199853.jpg

Figure 42. Pre test 3 minutes, 6539_199852.jpg

Figure 43. Pre test 3 minutes, 6539_199851.jpg

Figure 44. Pre test 3 minutes, 6539_199850.jpg

Figure 45. Pre test 3 minutes, 6539_199849.jpg

Figure 46. Pre test 2 minutes, 6539_199848.jpg

Figure 47. 0 seconds, 6539_199847.jpg

Figure 48. 2 seconds, 6539_199846.jpg

Figure 49. 10 seconds, 6539_199845.jpg

Figure 50. 67 seconds, 6539_199844.jpg

Figure 51. 70 seconds, 6539_199843.jpg

Figure 52. 77 seconds, 6539_199842.jpg

Figure 53. 85 seconds, 6539_199841.jpg

Figure 54. 91 seconds, 6539_199840.jpg

Figure 55. 96 seconds, 6539_199839.jpg

Figure 56. 104 seconds, 6539_199838.jpg

Figure 57. 111 seconds, 6539_199837.jpg

Figure 58. 117 seconds, 6539_199836.jpg

Figure 59. 197 seconds, 6539_199835.jpg

Figure 60. 210 seconds, 6539_199834.jpg

Figure 61. 212 seconds, 6539_199833.jpg

Figure 62. 213 seconds, 6539_199832.jpg

Figure 63. 214 seconds, 6539_199831.jpg

Figure 64. 217 seconds, 6539_199830.jpg

Figure 65. 219 seconds, 6539_199829.jpg

Figure 66. 227 seconds, 6539_199828.jpg

Figure 67. 229 seconds, 6539_199827.jpg

Figure 68. 233 seconds, 6539_199826.jpg

Figure 69. 236 seconds, 6539_199825.jpg

Figure 70. 241 seconds, 6539_199824.jpg

Figure 71. 243 seconds, 6539_199823.jpg

Figure 72. 246 seconds, 6539_199822.jpg

Figure 73. 251 seconds, 6539_199821.jpg

Figure 74. 254 seconds, 6539_199820.jpg

Figure 75. 257 seconds, 6539_199819.jpg

Figure 76. 266 seconds, 6539_199818.jpg

Figure 77. 274 seconds, 6539_199817.jpg

Figure 78. 297 seconds, 6539_199816.jpg

Figure 79. 345 seconds, 6539_199815.jpg

Figure 80. 353 seconds, 6539_199814.jpg

Figure 81. 431 seconds, 6539_199813.jpg

Figure 82. 434 seconds, 6539_199812.jpg

Figure 83. 550 seconds, 6539_199811.jpg

Figure 84. 553 seconds, 6539_199810.jpg

Figure 85. Post test 0 minutes, 6539_199809.jpg

Figure 86. Post test 0 minutes, 6539_199808.jpg

Figure 87. Post test 0 minutes, 6539_199807.jpg

Figure 88. Post test 0 minutes, 6539_199806.jpg

Figure 89. Post test 0 minutes, 6539_199805.jpg

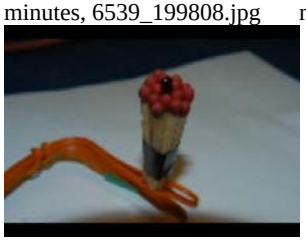

Figure 90. 6539_212275.jpg

Results for Test 2 (Exp. ID 6543)

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	27.7	27.7	27.9	27.8	27.9

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	99.81	99.80	99.83	99.82	99.82

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	60.9	60.2	60.9	60.6	60.2

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 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_30	27	886	843	815	318	174
Center_42	27	846	819	774	296	162
Center_54	27	844	810	749	298	163
Center_66	27	868	839	759	296	162
Center_Top of box	28	1014	930	899	532	294

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

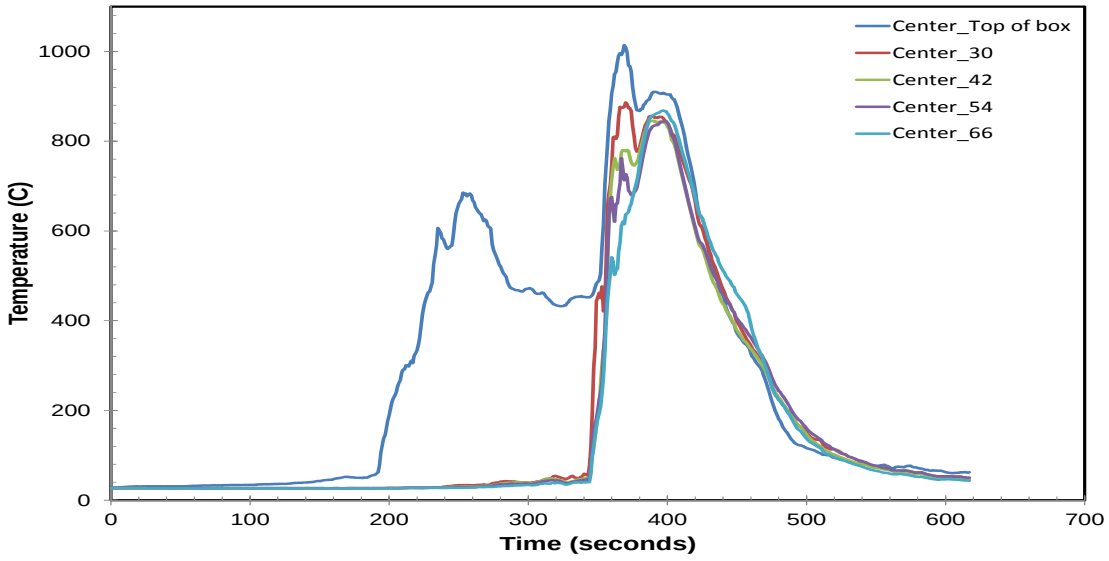

Figure 91. Temperature

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	10.4	8.7	7.6	2.6	1.3
North	1	6.4	6.2	5.9	2.2	1.1
South	1	12.6	9.7	8.1	2.7	1.3
West	1	6.2	5.7	5.4	2.0	1.0

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

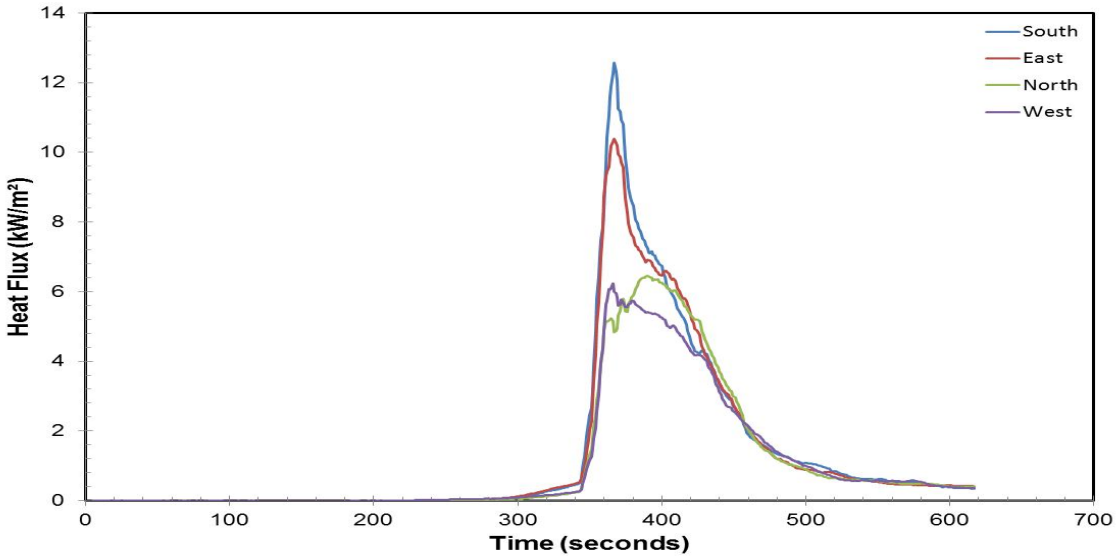

Figure 92. Heat Flux

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

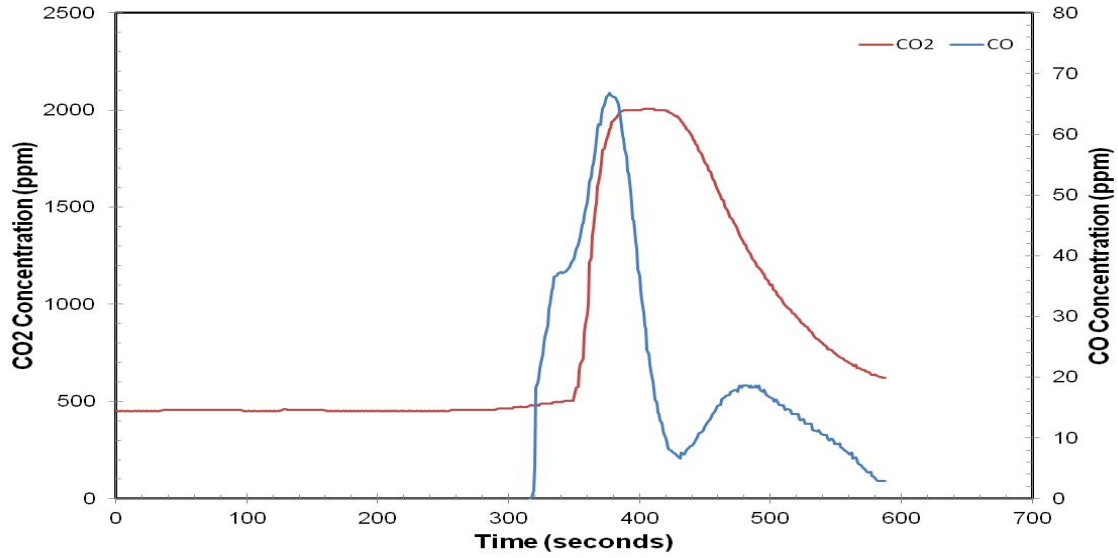

Figure 93. Carbon monoxide and carbon dioxide concentrations

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

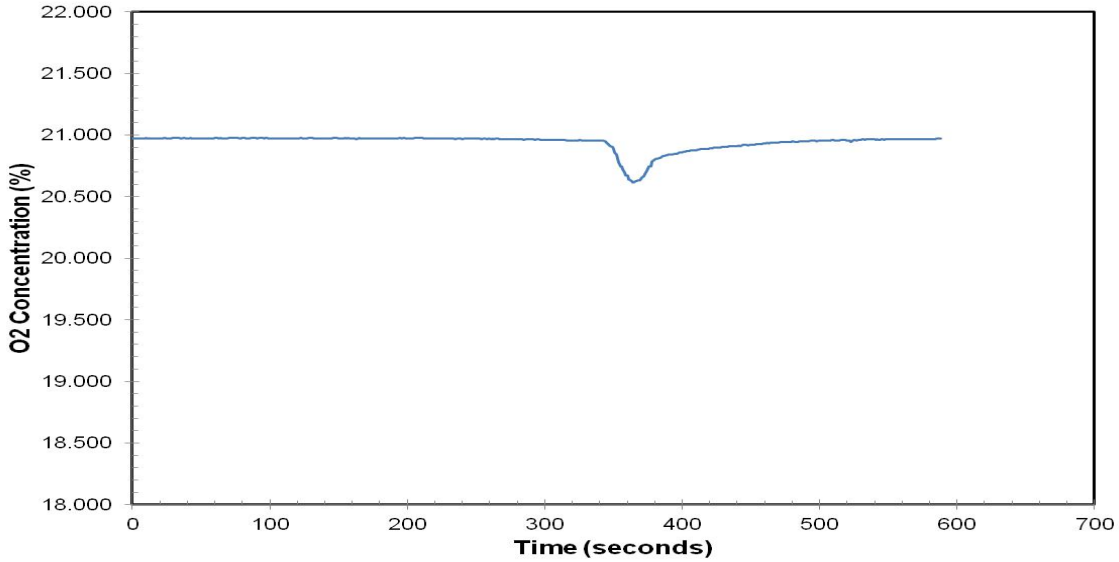

Figure 94. Oxygen Concentration

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)
323	236	162	236	23	13873

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

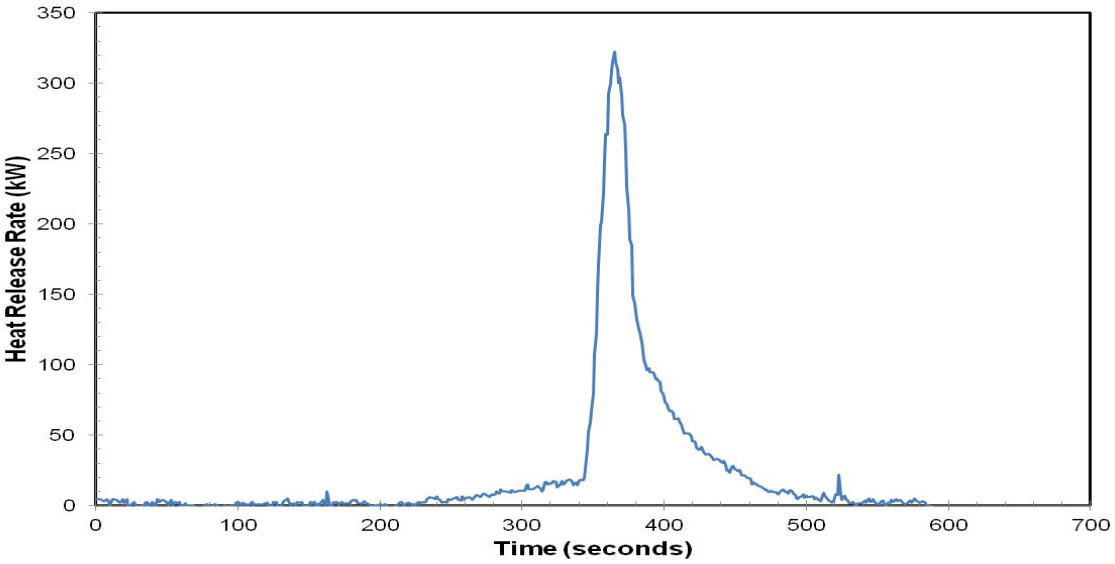

Figure 95. Heat Release Rate

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)
174	138	100	31	15

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

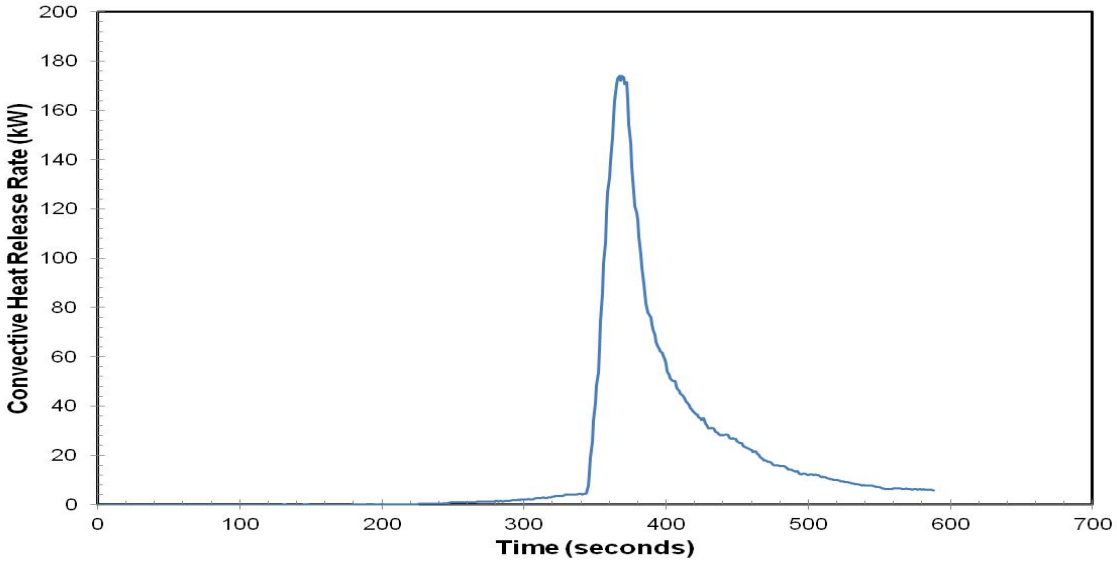

Figure 96. Convective Heat Release Rate

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

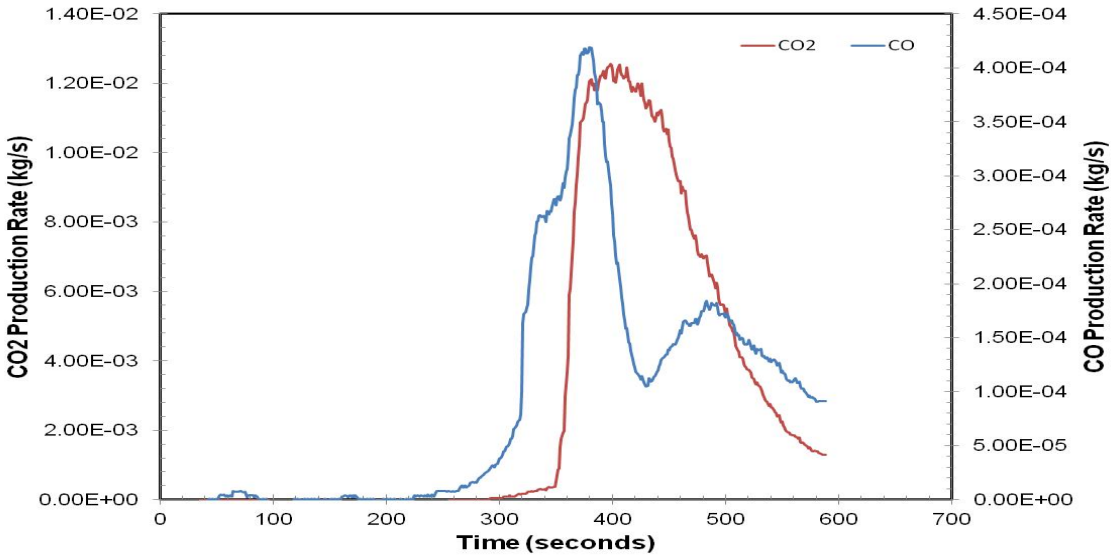

Figure 97. CO and CO2 production rates

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

Table 19. Video Log

Description	Start Time	Duration (s)	Filename
North	10:59:22	641	6543_20110808_105922_2.mp4
North East	10:59:20	642	6543_20110808_105920_1.mp4
North West	10:59:32	634	6543_20110808_105932_4.mp4
South West	10:59:30	634	6543_20110808_105930_3.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 98. Pre test 34 minutes, 6543_200023.jpg

Figure 99. Pre test 33 minutes, 6543_200022.jpg

Figure 100. Pre test 33 minutes, 6543_200021.jpg

Figure 101. Pre test 33 minutes, 6543_200020.jpg

Figure 102. Pre test 33 minutes, 6543_200019.jpg

Figure 103. Pre test 33 minutes, 6543_200018.jpg

Figure 104. Pre test 27 minutes, 6543_200017.jpg

Figure 105. Pre test 27 minutes, 6543_200016.jpg

Figure 106. Pre test 27 minutes, 6543_200015.jpg

Figure 107. Pre test 27 minutes, 6543_200014.jpg

Figure 108. Pre test 6 minutes, 6543_200013.jpg

Figure 109. Pre test 6 minutes, 6543_200012.jpg

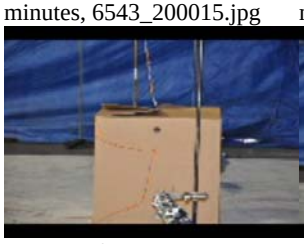

Figure 110. Pre test 1 seconds, 6543_200011.jpg

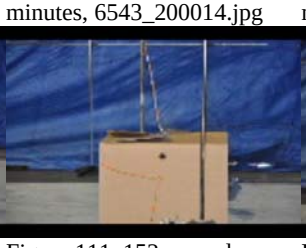

Figure 111. 152 seconds, 6543_200010.jpg

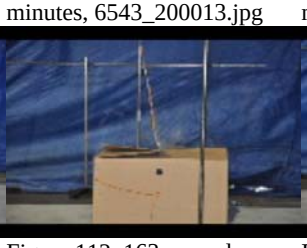

Figure 112. 163 seconds, 6543_200009.jpg

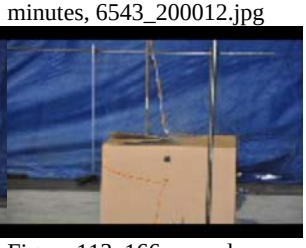

Figure 113. 166 seconds, 6543_200008.jpg

Figure 114. 180 seconds, 6543_200007.jpg

Figure 115. 192 seconds, 6543_200006.jpg

Figure 116. 197 seconds, 6543_200005.jpg

Figure 117. 214 seconds, 6543_200004.jpg

Figure 118. 231 seconds, 6543_200003.jpg

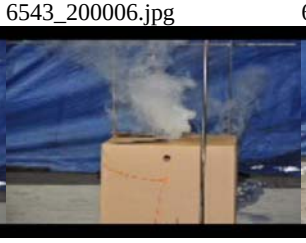

Figure 119. 235 seconds, 6543_200002.jpg

Figure 120. 244 seconds, 6543_200001.jpg

Figure 121. 247 seconds, 6543_200000.jpg

Figure 122. 267 seconds, 6543_199999.jpg

Figure 123. 297 seconds, 6543_199998.jpg

Figure 124. 300 seconds, 6543_199997.jpg

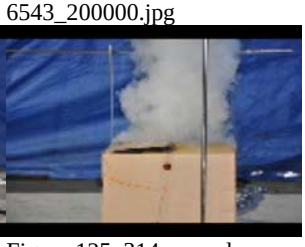

Figure 125. 314 seconds, 6543_199996.jpg

Figure 126. 327 seconds, 6543_199995.jpg

Figure 127. 333 seconds, 6543_199994.jpg

Figure 128. 336 seconds, 6543_199993.jpg

Figure 129. 343 seconds, 6543_199992.jpg

Figure 130. 346 seconds, 6543_199991.jpg

Figure 131. 348 seconds, 6543_199990.jpg

Figure 132. 351 seconds, 6543_199989.jpg

Figure 133. 354 seconds, 6543_199988.jpg

Figure 134. 357 seconds, 6543_199987.jpg

Figure 135. 361 seconds, 6543_199986.jpg

Figure 136. 366 seconds, 6543_199985.jpg

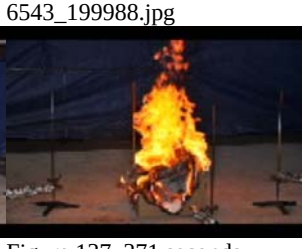

Figure 137. 371 seconds, 6543_199984.jpg

Figure 138. 376 seconds, 6543_199983.jpg

Figure 139. 378 seconds, 6543_199982.jpg

Figure 140. 382 seconds, 6543_199981.jpg

Figure 141. 389 seconds, 6543_199980.jpg

Figure 142. 396 seconds, 6543_199979.jpg

Figure 143. 400 seconds, 6543_199978.jpg

Figure 144. 411 seconds, 6543_199977.jpg

Figure 145. 424 seconds, 6543_199976.jpg

Figure 146. 445 seconds, 6543_199975.jpg

Figure 147. Post test 0 minutes, 6543_199974.jpg

Figure 148. Post test 0 minutes, 6543_199973.jpg

Figure 149. Post test 0 minutes, 6543_199972.jpg

Figure 150. Post test 0 minutes, 6543_199971.jpg

Figure 151. Post test 0 minutes, 6543_199970.jpg

Figure 152. Post test 0 minutes, 6543_199969.jpg

Results for Test 3 (Exp. ID 6544)

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	27.9	27.9	28.0	27.9	28.0

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	99.81	99.79	99.82	99.81	99.80

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	60.3	60.0	60.4	60.3	60.2

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 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_30	27	604	484	434	159	94
Center_42	27	616	481	402	143	86
Center_54	27	576	489	396	144	86
Center_66	27	569	474	361	126	76
Center_Top of box	29	942	804	670	370	205

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

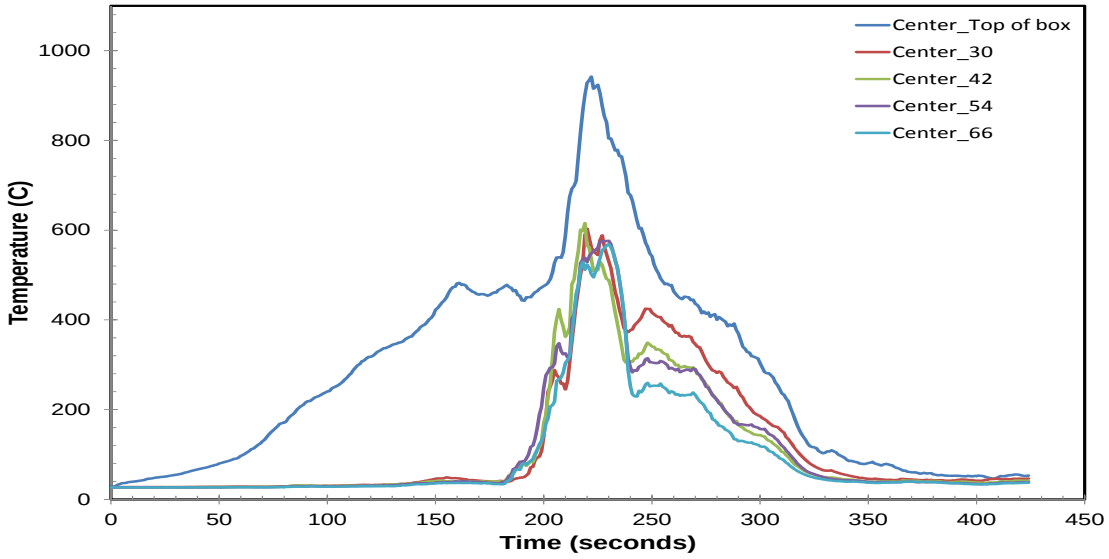

Figure 153. Temperature

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	12.1	9.1	7.4	2.6	1.3
North	1	8.2	7.0	6.3	2.2	1.1
South	1	10.7	8.7	7.3	2.3	1.2
West	1	6.6	6.2	5.7	2.0	1.0

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

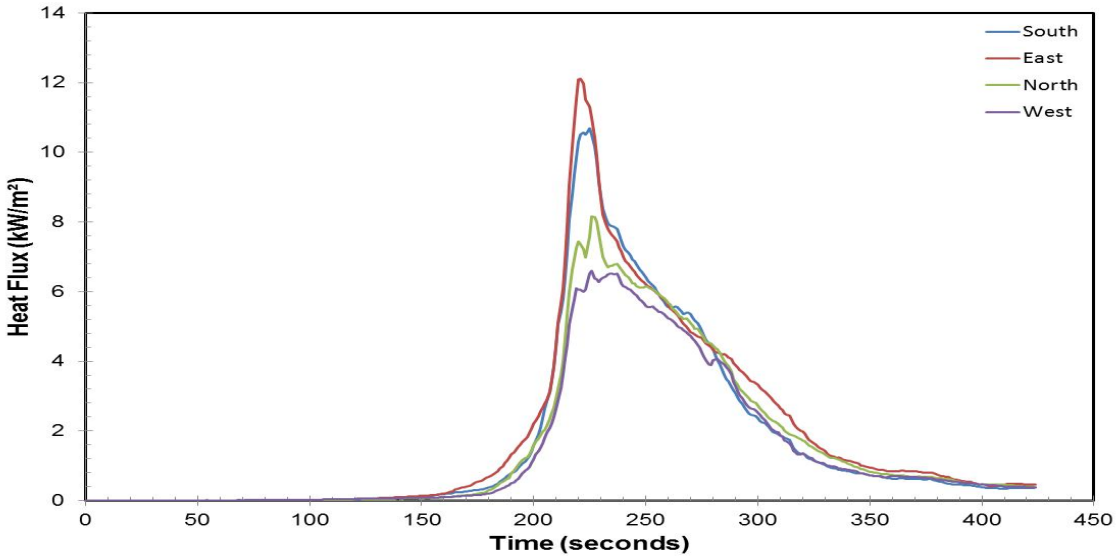

Figure 154. Heat Flux

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

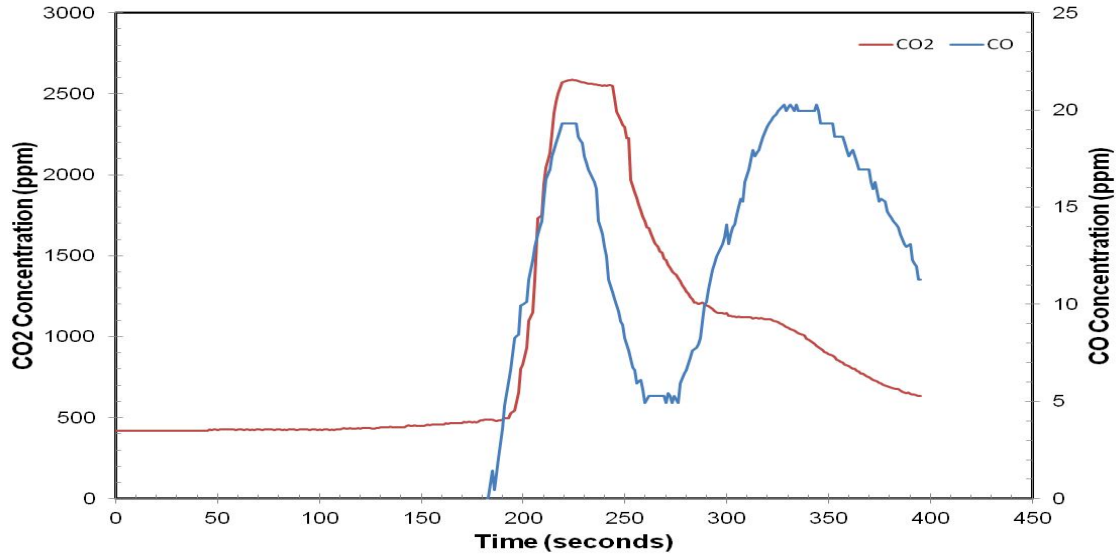

Figure 155. Carbon monoxide and carbon dioxide concentrations

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

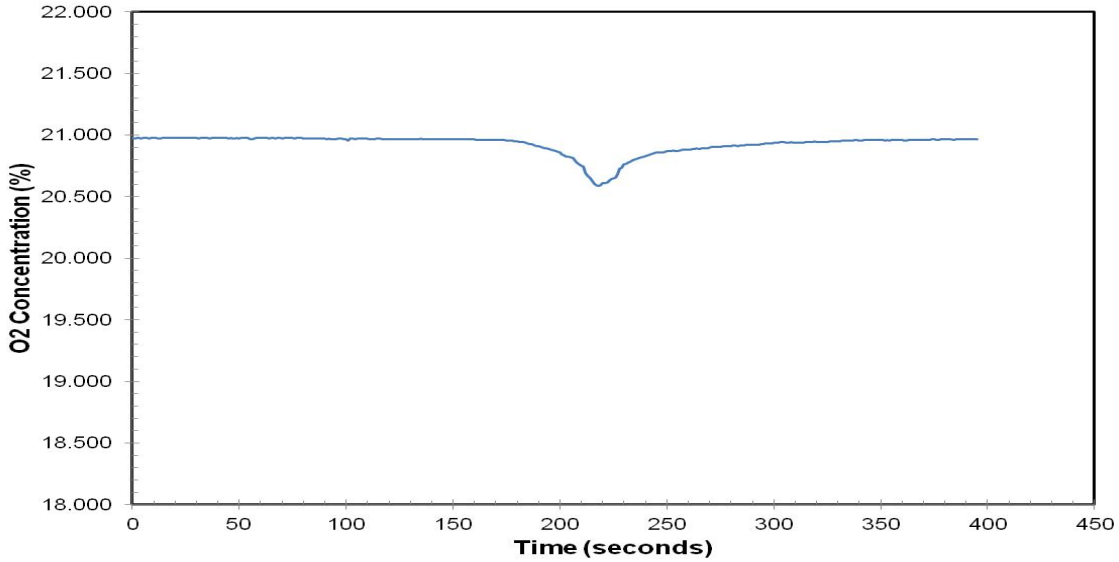

Figure 156. Oxygen Concentration

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 25. 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)
326	227	160	227	25	14678

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

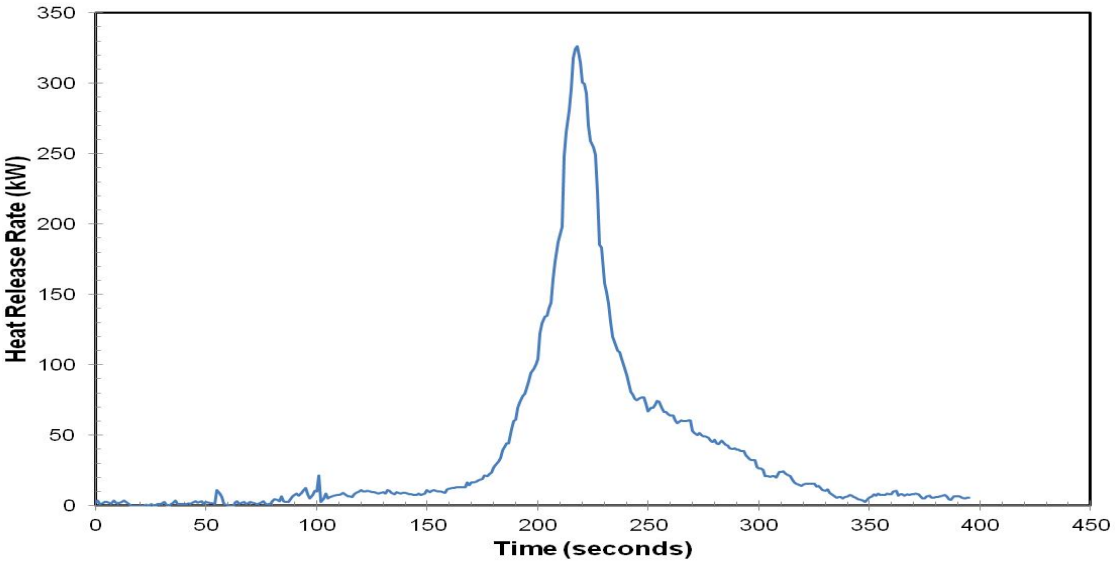

Figure 157. Heat Release Rate

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

Table 26. 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)
176	139	101	31	16

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

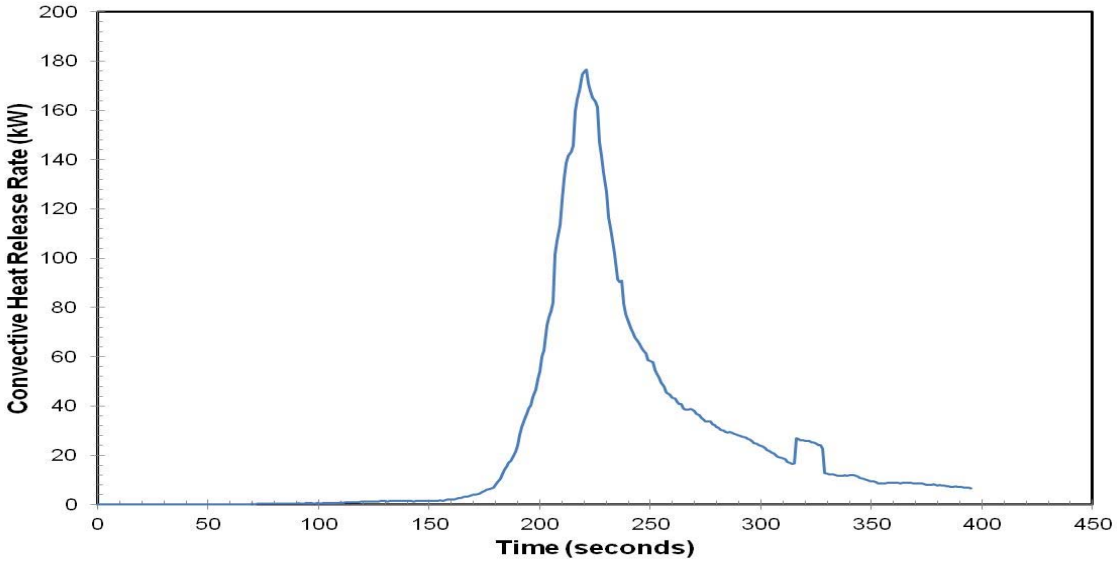

Figure 158. Convective Heat Release Rate

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

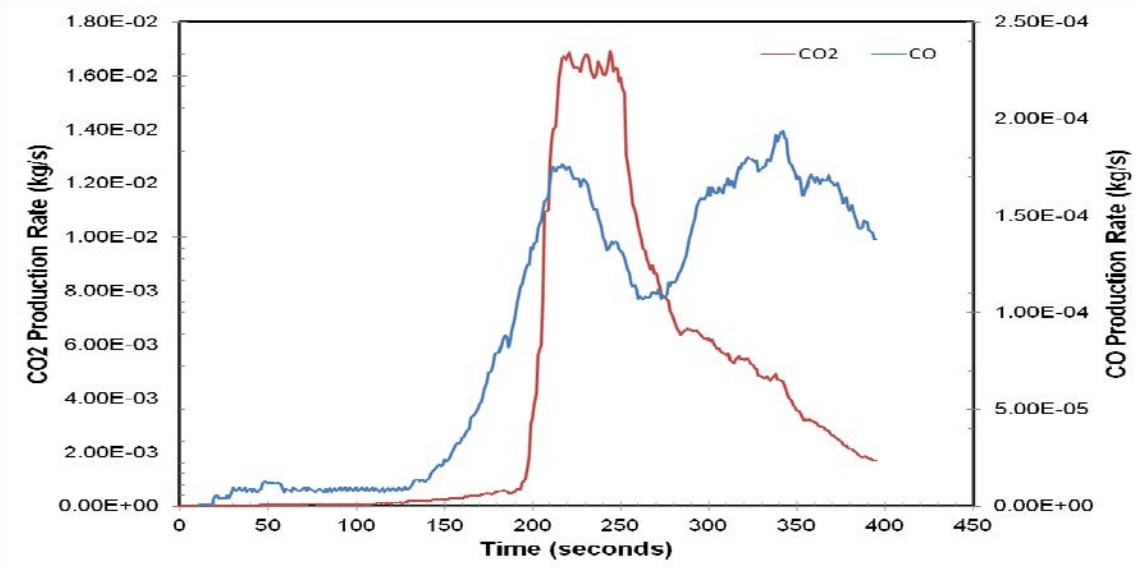

Figure 159. CO and CO2 production rates

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 160. Pre test 35 seconds, 6544_200096.jpg

Figure 161. Pre test 29 seconds, 6544_200095.jpg

Figure 162. Pre test 26 seconds, 6544_200094.jpg

Figure 163. Pre test 21 seconds, 6544_200093.jpg

Figure 164. Pre test 18 seconds, 6544_200092.jpg

Figure 165. Pre test 13 seconds, 6544_200091.jpg

Figure 166. Pre test 4 seconds, 6544_200090.jpg

Figure 167. Pre test 2 seconds, 6544_200089.jpg

Figure 168. 0 seconds, 6544_200088.jpg

Figure 169. 87 seconds, 6544_200087.jpg

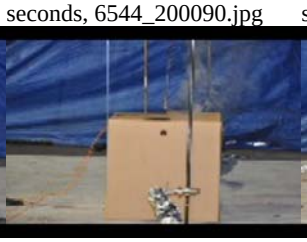

Figure 170. 96 seconds, 6544_200086.jpg

Figure 171. 116 seconds, 6544_200085.jpg

Figure 172. 124 seconds, 6544_200084.jpg

Figure 173. 127 seconds, 6544_200083.jpg

Figure 174. 154 seconds, 6544_200082.jpg

Figure 175. 156 seconds, 6544_200081.jpg

Figure 176. 157 seconds, 6544_200080.jpg

Figure 177. 160 seconds, 6544_200079.jpg

Figure 178. 162 seconds, 6544_200078.jpg

Figure 179. 164 seconds, 6544_200077.jpg

Figure 180. 166 seconds, 6544_200076.jpg

Figure 181. 169 seconds, 6544_200075.jpg

Figure 182. 172 seconds, 6544_200074.jpg

Figure 183. 175 seconds, 6544_200073.jpg

Figure 184. 177 seconds, 6544_200072.jpg

Figure 185. 179 seconds, 6544_200071.jpg

Figure 186. 182 seconds, 6544_200070.jpg

Figure 187. 185 seconds, 6544_200069.jpg

Figure 188. 188 seconds, 6544_200068.jpg

Figure 189. 191 seconds, 6544_200067.jpg

Figure 190. 195 seconds, 6544_200066.jpg

Figure 191. 199 seconds, 6544_200065.jpg

Figure 192. 205 seconds, 6544_200064.jpg

Figure 193. 210 seconds, 6544_200063.jpg

Figure 194. 212 seconds, 6544_200062.jpg

Figure 195. 228 seconds, 6544_200061.jpg

Figure 196. 230 seconds, 6544_200060.jpg

Figure 197. 238 seconds, 6544_200059.jpg

Figure 198. 238 seconds, 6544_200058.jpg

Figure 199. 244 seconds, 6544_200057.jpg

Figure 200. 247 seconds, 6544_200056.jpg

Figure 201. 259 seconds, 6544_200055.jpg

Figure 202. 261 seconds, 6544_200054.jpg

Figure 203. 271 seconds, 6544_200053.jpg

Figure 204. 276 seconds, 6544_200052.jpg

Figure 205. 383 seconds, 6544_200051.jpg

Figure 206. 396 seconds, 6544_200050.jpg

Figure 207. Post test 0 minutes, 6544_200049.jpg

Figure 208. Post test 0 minutes, 6544_200048.jpg

Figure 209. Post test 0 minutes, 6544_200047.jpg

Figure 210. Post test 0 minutes, 6544_200046.jpg

Figure 211. Post test 0 minutes, 6544_200045.jpg

Figure 212. Post test 0 minutes, 6544_200044.jpg

Figure 213. Post test 0 minutes, 6544_200043.jpg

Results for Test 4 (Exp. ID 6555)

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

Table 27. Ambient Laboratory Temperature Summary

Description	Initial Value (C)	Minimum (C)	Maximum (C)	Average (C)	Final Value (C)
MBR_01	28.3	28.3	28.6	28.4	28.5

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

Table 28. Ambient Laboratory Pressure Summary

Description	Initial Value (kPa)	Minimum (kPa)	Maximum (kPa)	Average (kPa)	Final Value (kPa)
MBR_01	99.59	99.57	99.60	99.59	99.59

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

Table 29. Ambient Laboratory Relative Humidity Summary

Description	Initial Value (%)	Minimum (%)	Maximum (%)	Average (%)	Final Value (%)
MBR_01	63.7	63.1	63.7	63.5	63.1

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 30. 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_30	27	890	849	740	358	195
Center_42	27	839	780	658	293	162
Center_54	27	651	554	497	235	132
Center_66	27	551	521	493	217	123
Center_Top of box	28	696	677	601	411	235

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

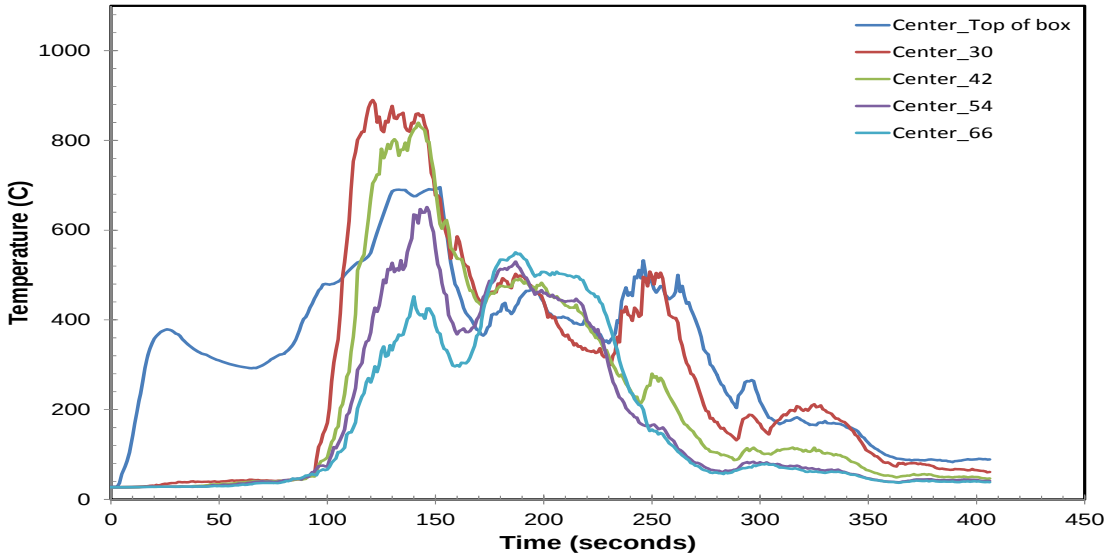

Figure 214. Temperature

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 31. 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	5.2	5.1	5.0	2.5	1.3
North	1	7.7	6.9	6.4	2.9	1.5
South	1	5.8	5.5	5.1	2.8	1.4
West	1	5.8	5.7	5.3	2.7	1.4

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

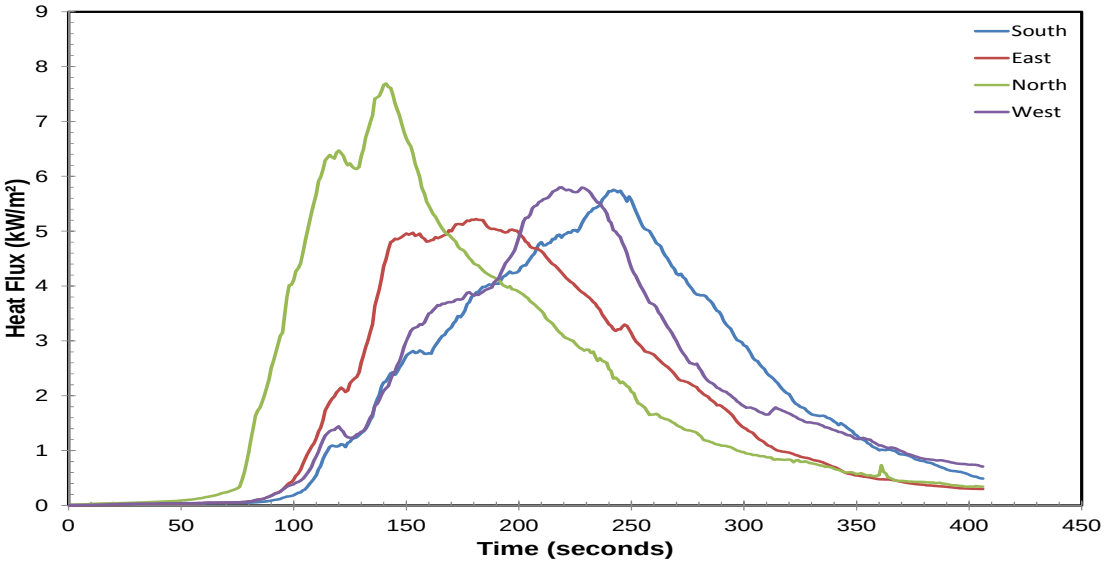

Figure 215. Heat Flux

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

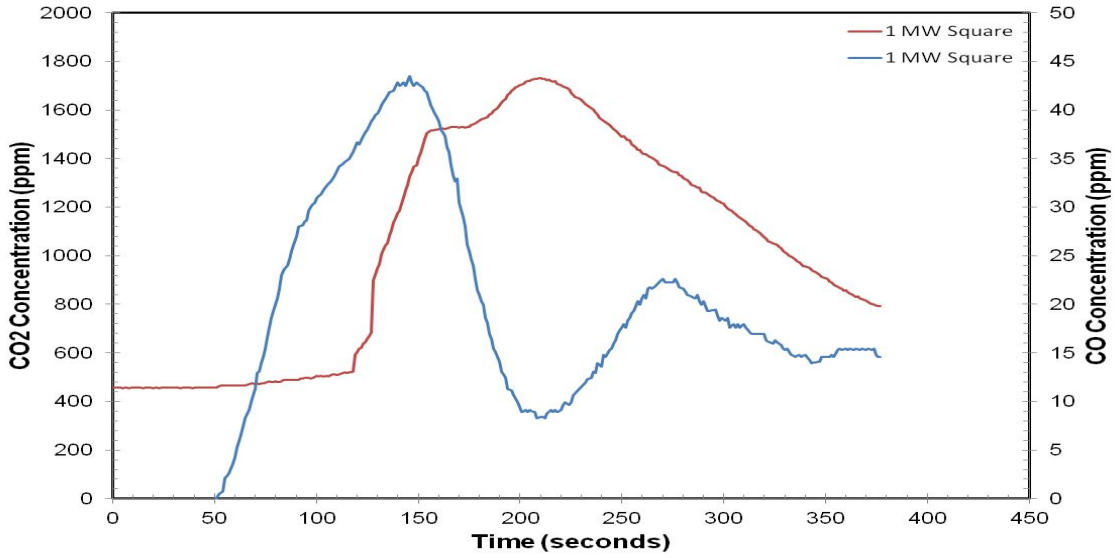

Figure 216. Carbon monoxide and carbon dioxide concentrations

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

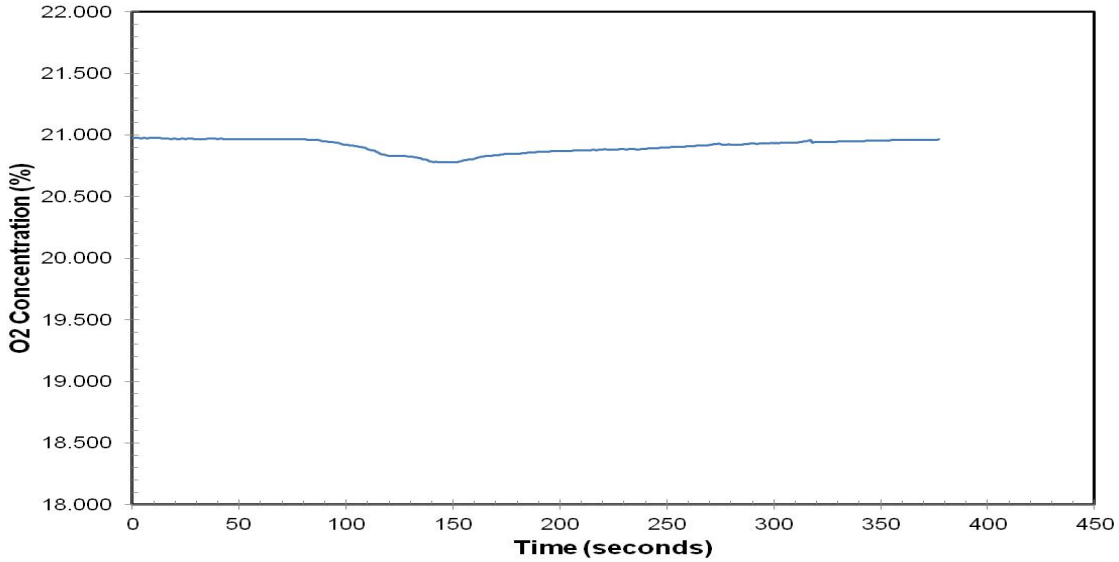

Figure 217. Oxygen Concentration

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 32. 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)
179	160	142	160	31	18850

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

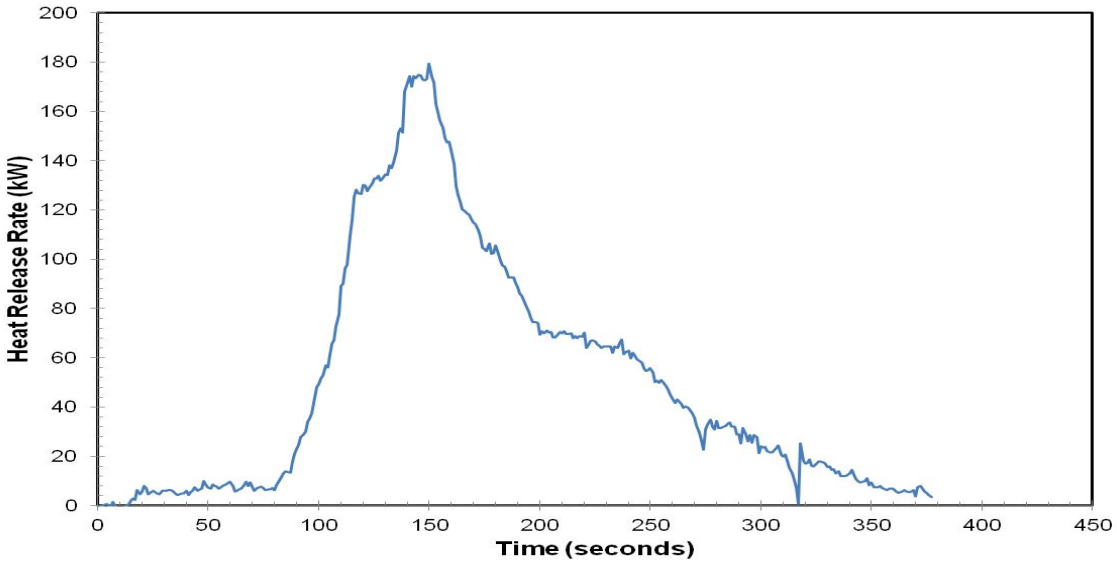

Figure 218. Heat Release Rate

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

Table 33. 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)
111	100	89	42	21

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

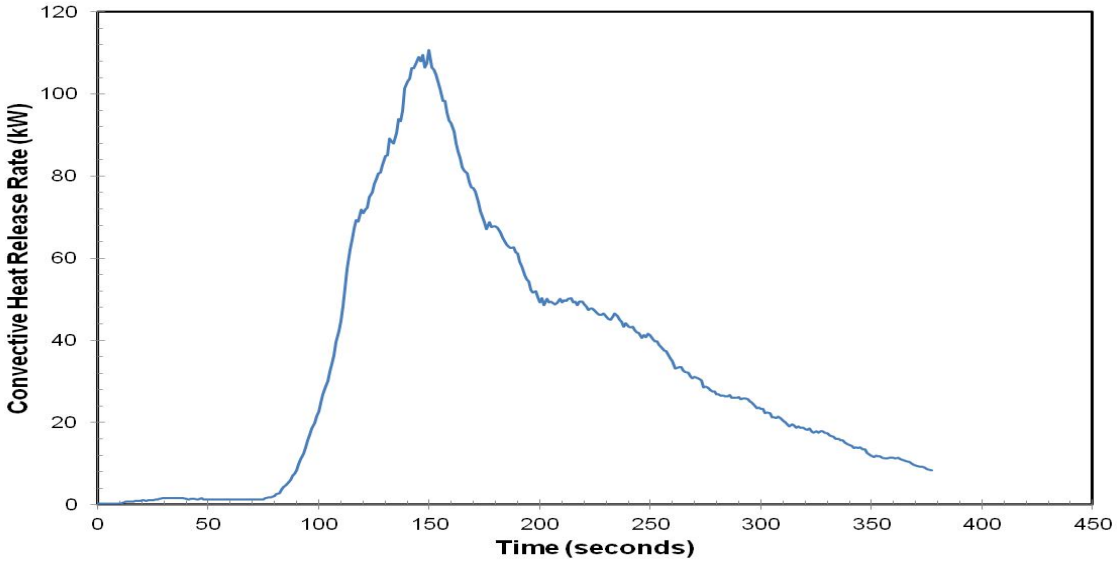

Figure 219. Convective Heat Release Rate

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

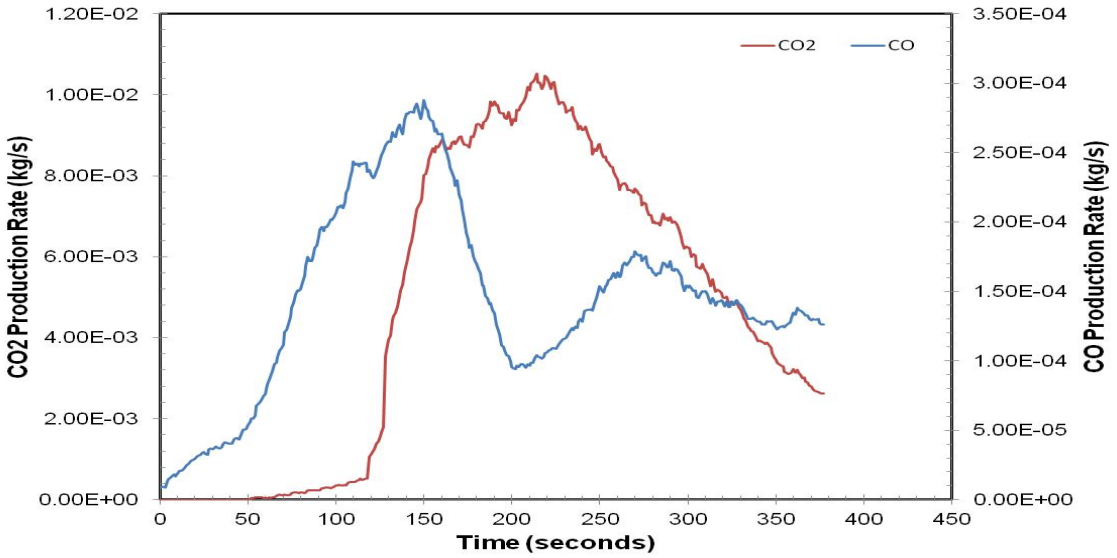

Figure 220. CO and CO2 production rates

Video

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

Table 34. Video Log

Description	Start Time	Duration (s)	Filename
North	11:38:32	430	6555_20110809_113832_4.mp4
North East	11:38:27	432	6555_20110809_113827_1.mp4
North West	11:38:30	431	6555_20110809_113830_3.mp4
South West	11:38:29	431	6555_20110809_113829_2.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 221. Pre test 44 minutes, 6555_200629.jpg

Figure 222. Pre test 44 minutes, 6555_200628.jpg

Figure 223. Pre test 44 minutes, 6555_200627.jpg

Figure 224. Pre test 44 minutes, 6555_200626.jpg

Figure 225. Pre test 43 minutes, 6555_200625.jpg

Figure 226. Pre test 43 minutes, 6555_200624.jpg

Figure 227. Pre test 15 minutes, 6555_200689.jpg

Figure 228. Pre test 15 minutes, 6555_200688.jpg

Figure 229. Pre test 15 minutes, 6555_200687.jpg

Figure 230. Pre test 12 minutes, 6555_200686.jpg

Figure 231. Pre test 12 minutes, 6555_200685.jpg

Figure 232. Pre test 12 minutes, 6555_200684.jpg

Figure 233. Pre test 12 minutes, 6555_200683.jpg

Figure 234. Pre test 11 minutes, 6555_200682.jpg

Figure 235. Pre test 11 minutes, 6555_200681.jpg

Figure 236. Pre test 11 minutes, 6555_200680.jpg

Figure 237. Pre test 11 minutes, 6555_200679.jpg

Figure 238. Pre test 12 seconds, 6555_200678.jpg

Figure 239. Pre test 2 seconds, 6555_200677.jpg

Figure 240. 1 seconds, 6555_200676.jpg

Figure 241. 4 seconds, 6555_200675.jpg

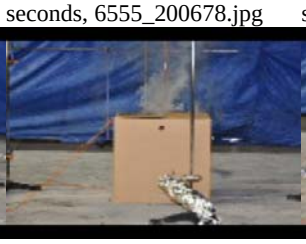

Figure 242. 14 seconds, 6555_200674.jpg

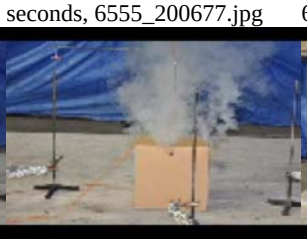

Figure 243. 21 seconds, 6555_200673.jpg

Figure 244. 23 seconds, 6555_200672.jpg

Figure 245. 26 seconds, 6555_200671.jpg

Figure 246. 33 seconds, 6555_200670.jpg

Figure 247. 36 seconds, 6555_200669.jpg

Figure 248. 46 seconds, 6555_200668.jpg

Figure 249. 50 seconds, 6555_200667.jpg

Figure 250. 67 seconds, 6555_200666.jpg

Figure 251. 69 seconds, 6555_200665.jpg

Figure 252. 76 seconds, 6555_200664.jpg

Figure 253. 78 seconds, 6555_200663.jpg

Figure 254. 80 seconds, 6555_200662.jpg

Figure 255. 83 seconds, 6555_200661.jpg

Figure 256. 85 seconds, 6555_200660.jpg

Figure 257. 88 seconds, 6555_200659.jpg

Figure 258. 91 seconds, 6555_200658.jpg

Figure 259. 98 seconds, 6555_200657.jpg

Figure 260. 99 seconds, 6555_200656.jpg

Figure 261. 100 seconds, 6555_200655.jpg

Figure 262. 100 seconds, 6555_200654.jpg

Figure 263. 103 seconds, 6555_200653.jpg

Figure 264. 108 seconds, 6555_200652.jpg

Figure 265. 109 seconds, 6555_200651.jpg

Figure 266. 109 seconds, 6555_200650.jpg

Figure 267. 117 seconds, 6555_200649.jpg

Figure 268. 117 seconds, 6555_200648.jpg

Figure 269. 119 seconds, 6555_200647.jpg

Figure 270. 119 seconds, 6555_200646.jpg

Figure 271. 122 seconds, 6555_200645.jpg

Figure 272. 130 seconds, 6555_200644.jpg

Figure 273. 133 seconds, 6555_200642.jpg

Figure 274. 133 seconds, 6555_200643.jpg

Figure 275. 141 seconds, 6555_200640.jpg

Figure 276. 141 seconds, 6555_200641.jpg

Figure 277. 143 seconds, 6555_200639.jpg

Figure 278. 150 seconds, 6555_200638.jpg

Figure 279. 152 seconds, 6555_200637.jpg

Figure 280. 156 seconds, 6555_200636.jpg

Figure 281. 157 seconds, 6555_200635.jpg

Figure 282. 177 seconds, 6555_200634.jpg

Figure 283. 184 seconds, 6555_200633.jpg

Figure 284. 189 seconds, 6555_200632.jpg

Figure 285. 205 seconds, 6555_200630.jpg

Figure 286. 205 seconds, 6555_200631.jpg

Figure 287. 214 seconds, 6555_200623.jpg

Figure 288. 222 seconds, 6555_200622.jpg

Figure 289. 233 seconds, 6555_200621.jpg

Figure 290. 258 seconds, 6555_200619.jpg

Figure 291. 258 seconds, 6555_200620.jpg

Figure 292. Post test 0 minutes, 6555_200617.jpg

Figure 293. Post test 0 minutes, 6555_200618.jpg

Figure 294. Post test 0 minutes, 6555_200616.jpg

Figure 295. Post test 0 minutes, 6555_200614.jpg

Figure 296. Post test 0 minutes, 6555_200615.jpg

Figure 297. Post test 0 minutes, 6555_200613.jpg

Figure 298. Post test 0 minutes, 6555_200612.jpg

Figure 299. Post test 0 minutes, 6555_200611.jpg

Figure 300. Post test 0 minutes, 6555_200610.jpg

Figure 301. Post test 0 minutes, 6555_200609.jpg

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