Title	Calorimetry- Box of Lithium Batteries		
Test Type	Custom		
Lab Number	NTSB-2	**Author**	Justin L. Rowe
Test date	8/9/11	**No. Tests**	2

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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

Two calorimetry tests were conducted to examine the fire dynamics of an array of lithium batteries stored in a cardboard container. The container was subject to direct flame impingement from a 30 kW natural gas burner fire, as shown in Figure 1. Instrumentation was installed to measure the heat flux, fire plume temperature, gas species and 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.

Figure 1. Overview of testing arrangement (6552_200464.JPG)

Test Set Up

The 0.22 m x 0.20 x 0.06 m (8.5 x 8 x 2.5 inch) cardboard container was mounted in a 0.48 m (19 inch) high metal stand with a wire mesh base, 0.23 m (9 inch) above the surface of the natural gas burner, as shown in Figure 2. An arrangement of 100 rechargeable lithium batteries (Manufacturer: LG Chem; Model: 18650) were stacked vertically in the cardboard container in a single layer, separated by cardboard inserts, as shown in Figure 3. The batteries had a 3.7 Volt, 2600 mAmp-hour rating. The container was encapsulated by a thin plastic wrapper.

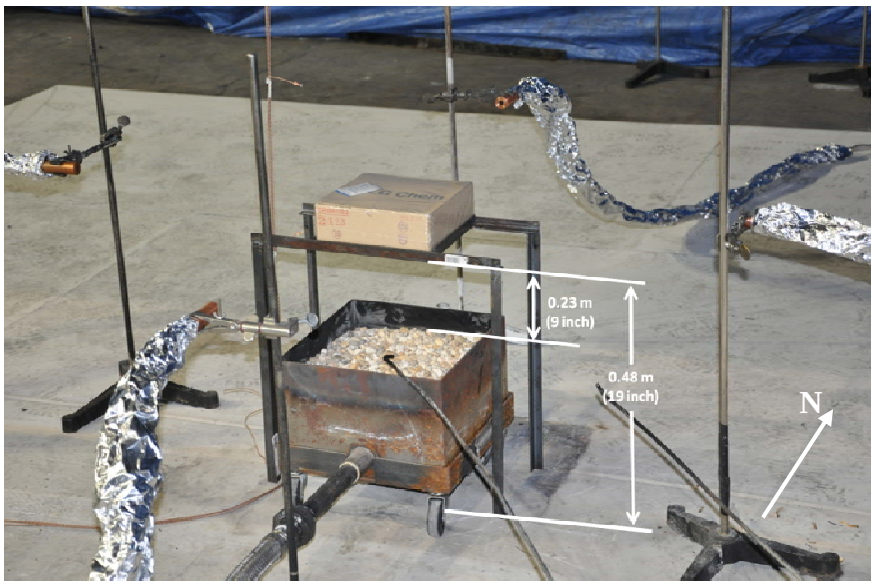

Figure 2. Test setup (6552_200470.JPG)

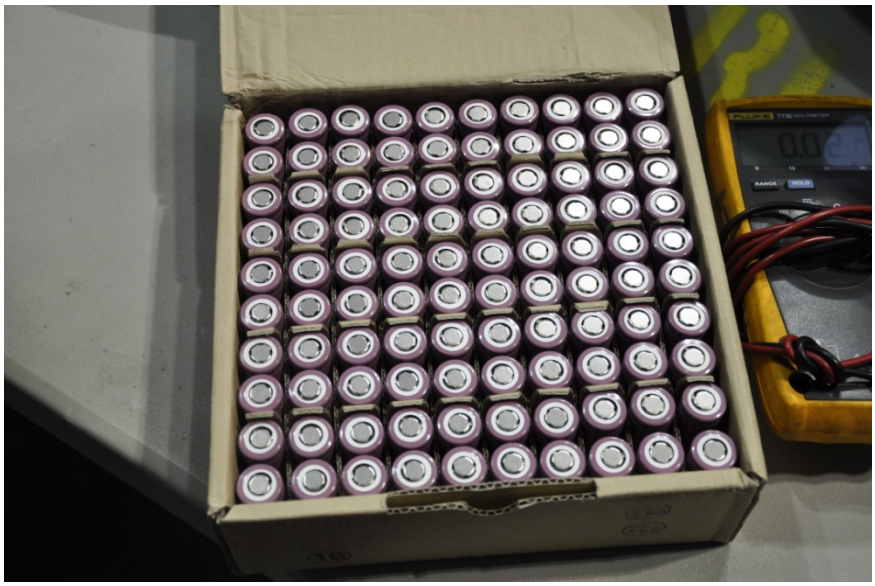

Figure 3. Arrangement of batteries in cardboard container (6552_200488.JPG)

Experiment Details

Ignition Scenario

At the start of the test, natural gas was supplied to the burner to achieve a heat release rate of approximately 30 kW. The natural gas was lit by an open propane pilot flame.

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, gas species production rates of carbon monoxide and carbon dioxide, 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 of the fire plume. There were five thermocouples starting at the base of the cardboard container which extended 1.22m (48 inch) above the container at 0.30m (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 0.51m (20 inch) and an elevation of 0.56m (22 inch).

Elevation distances described in the body of this report are relative to the z-axis defined Figure 4.

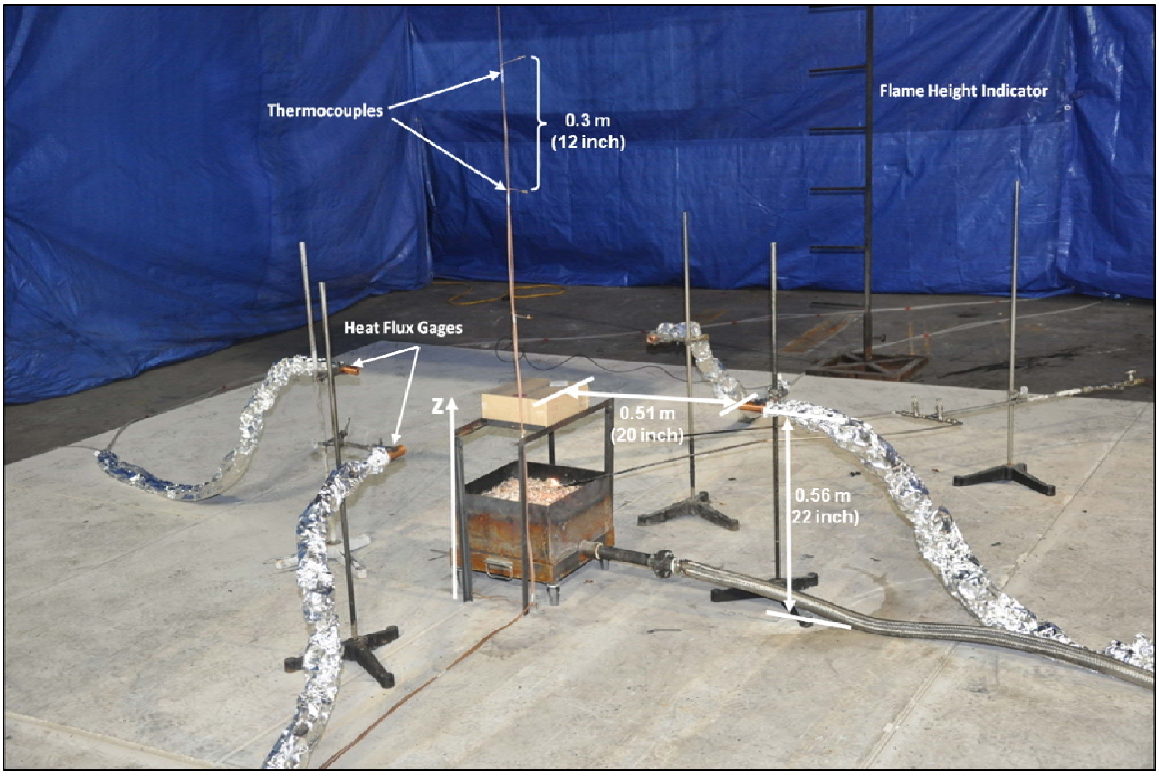

Figure 4. Instrumentation details (6553_200576.JPG)

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
TC_19	0.48	Type K, Glass Ins., 24 AWG wire
TC_31	0.79	Type K, Glass Ins., 24 AWG wire
TC_43	1.09	Type K, Glass Ins., 24 AWG wire
TC_55	1.40	Type K, Glass Ins., 24 AWG wire
TC_67	1.70	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 Over Range (kW/m²)
East	Total	37.50
North	Total	37.50
South	Total	37.50
West	Total	37.50

Gas Train

Natural gas was the fuel that was supplied to the sand burner. The natural gas flow rate was measured and controlled using an Alicat mass flow controller. Figure 5 shows a diagram of the natural gas train. Stainless steel braided hose was used to connect the natural gas train to the natural gas supply and sand burner. Gas trains used during this test series were used in accordance with FRL Laboratory Instruction "LI010 Calibration Burners"[6].

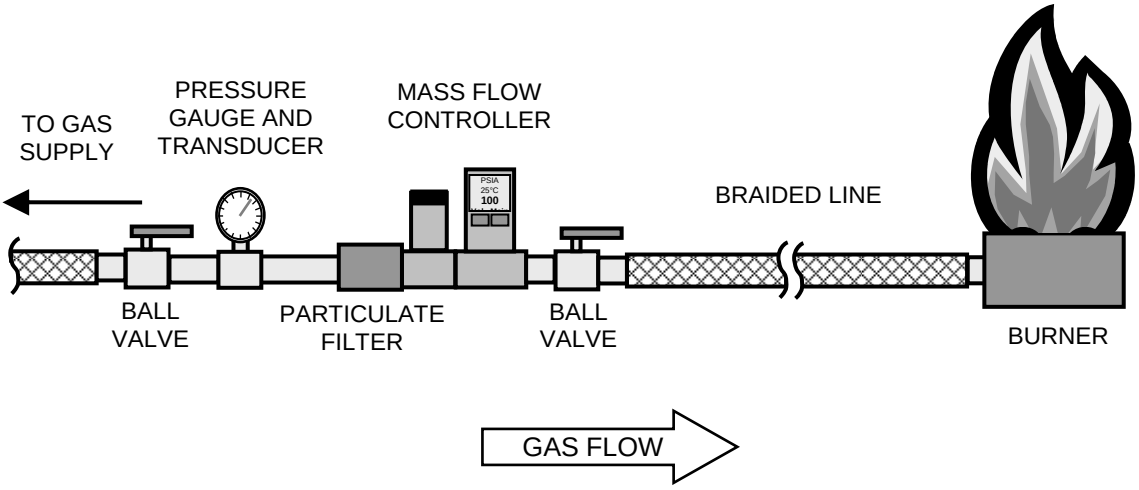

Figure 5. Gas train diagram.

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.

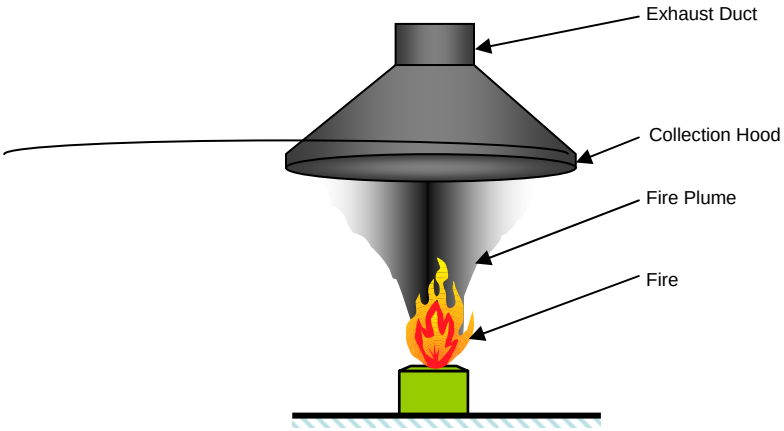

Figure 6. Typical products collector hood

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" [7].

Results for Test 1 (Exp. ID 6552)

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	28.0	27.9	28.3	28.1	28.3

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	99.57	99.54	99.57	99.56	99.56

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	63.9	62.8	63.9	63.4	62.9

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 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)
TC_19	30	758	674	647	625	599
TC_31	27	553	423	385	349	304
TC_43	27	309	241	226	208	190
TC_55	27	208	179	171	155	148
TC_67	27	188	146	138	129	122

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

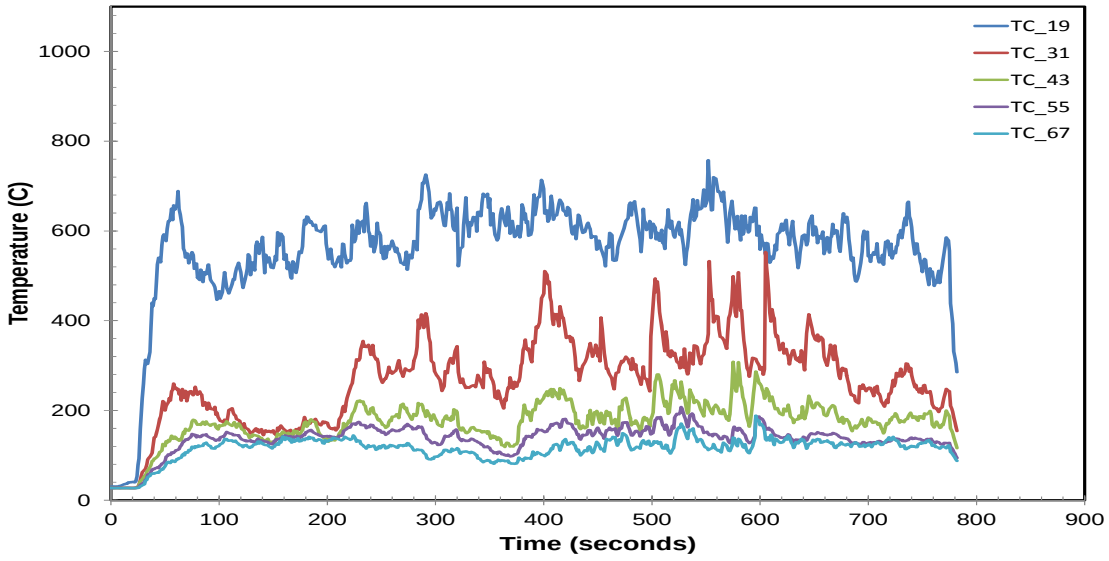

Figure 7. Temperature

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 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	5.4	4.4	4.2	3.4	2.9
North	1	4.5	3.7	3.5	2.7	2.3
South	1	4.9	3.6	3.4	2.7	2.2
West	1	4.4	3.8	3.7	2.9	2.3

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

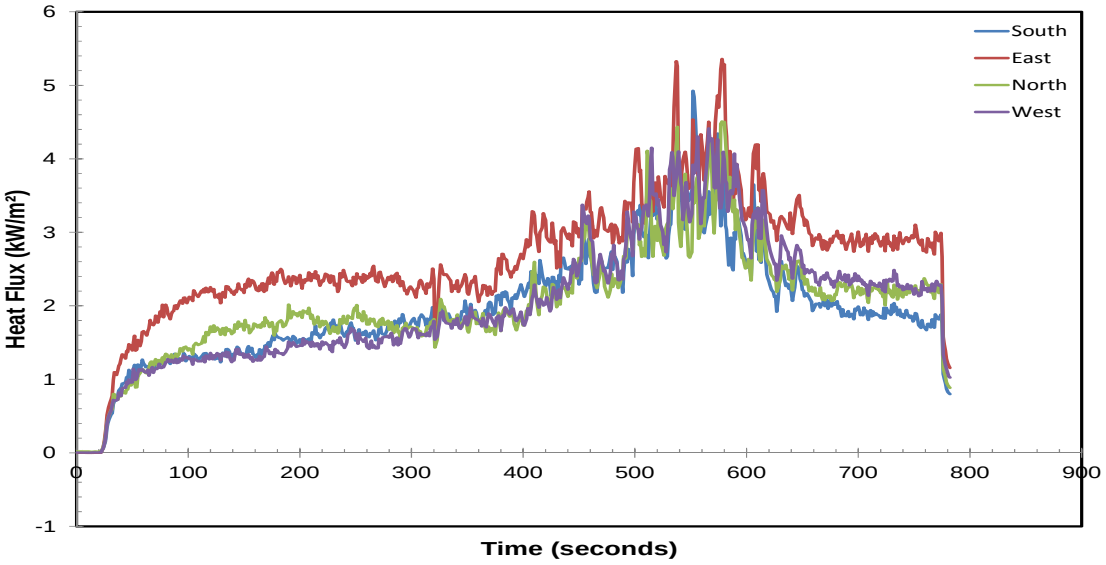

Figure 8. Heat Flux

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

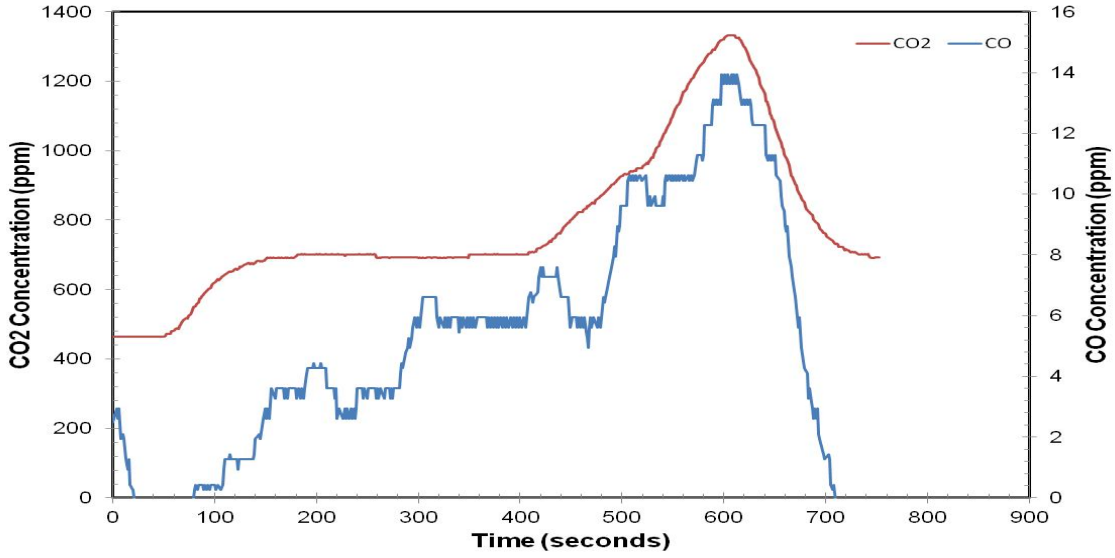

Figure 9. Carbon monoxide and carbon dioxide concentrations

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

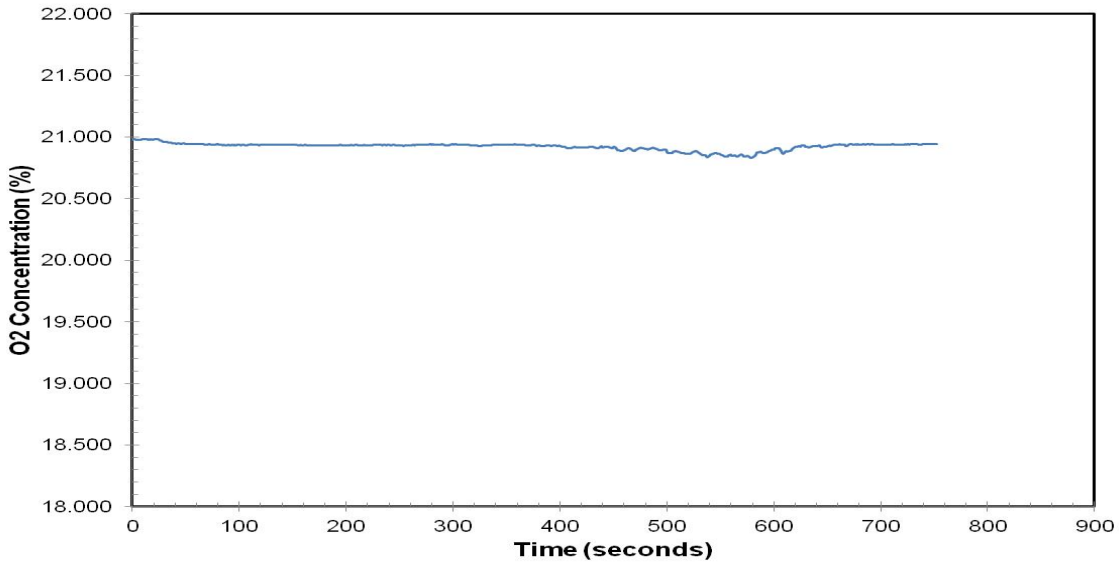

Figure 10. Oxygen Concentration

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)
119	106	103	106	53	35645

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

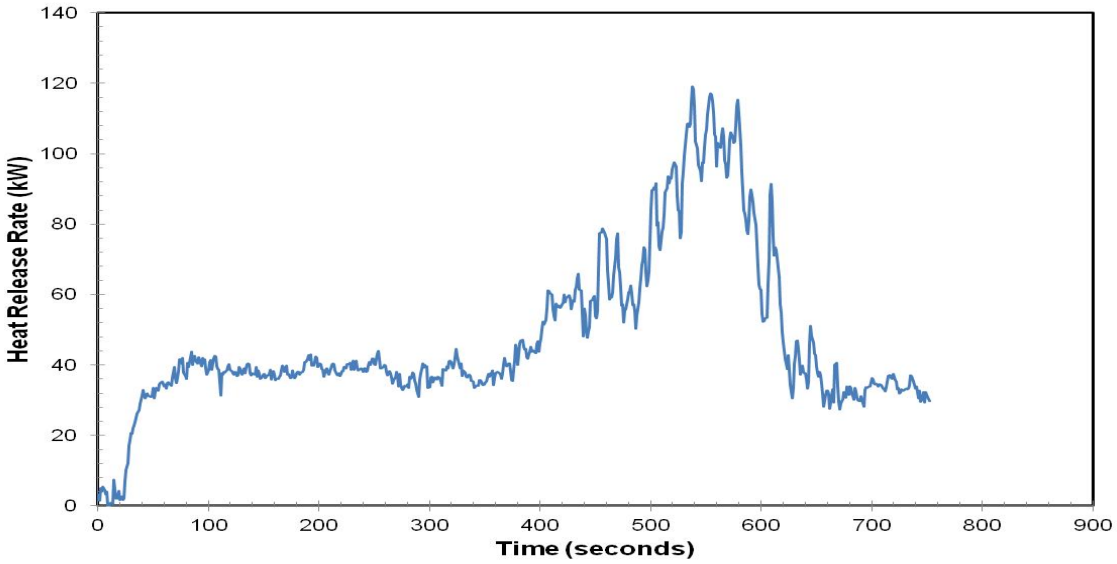

Figure 11. Heat Release Rate

The following table provides a summary of the convective heat release rate (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)
72	66	64	39	27

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

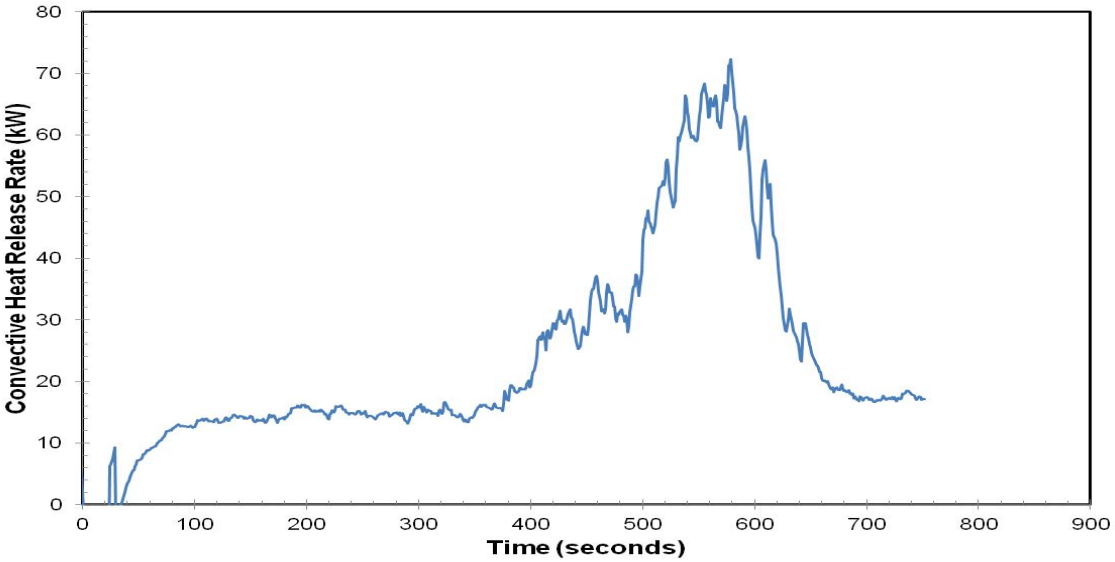

Figure 12. Convective Heat Release Rate

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

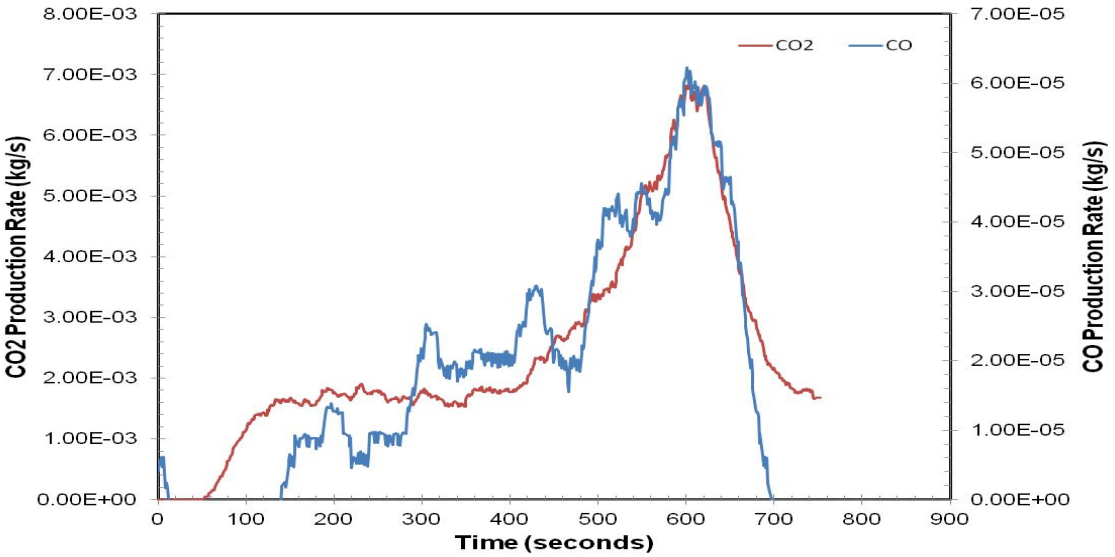

Figure 13. CO and CO2 production rates

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	09:46:07	819	6552_20110809_094607_4.mp4
North East	09:45:57	818	6552_20110809_094557_1.mp4
North West	09:46:00	825	6552_20110809_094600_3.mp4
South West	09:45:58	826	6552_20110809_094558_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 14. Pre test 16 minutes, 6552_200488.jpg

Figure 15. Pre test 16 minutes, 6552_200489.jpg

Figure 16. Pre test 16 minutes, 6552_200487.jpg

Figure 17. Pre test 15 minutes, 6552_200486.jpg

Figure 18. Pre test 15 minutes, 6552_200485.jpg

Figure 19. Pre test 15 minutes, 6552_200484.jpg

Figure 20. Pre test 15 minutes, 6552_200483.jpg

Figure 21. Pre test 14 minutes, 6552_200482.jpg

Figure 22. Pre test 14 minutes, 6552_200481.jpg

Figure 23. Pre test 14 minutes, 6552_200480.jpg

Figure 24. Pre test 14 minutes, 6552_200479.jpg

Figure 25. Pre test 14 minutes, 6552_200478.jpg

Figure 26. Pre test 13 minutes, 6552_200477.jpg

Figure 27. Pre test 13 minutes, 6552_200476.jpg

Figure 28. Pre test 13 minutes, 6552_200475.jpg

Figure 29. Pre test 13 minutes, 6552_200474.jpg

Figure 30. Pre test 13 minutes, 6552_200473.jpg

Figure 31. Pre test 13 minutes, 6552_200472.jpg

Figure 32. Pre test 13 minutes, 6552_200471.jpg

Figure 33. Pre test 13 minutes, 6552_200470.jpg

Figure 34. Pre test 12 minutes, 6552_200469.jpg

Figure 35. Pre test 12 minutes, 6552_200468.jpg

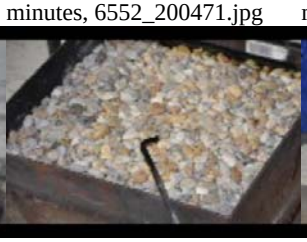

Figure 36. Pre test 12 minutes, 6552_200467.jpg

Figure 37. Pre test 22 seconds, 6552_200466.jpg

Figure 38. 25 seconds, 6552_200465.jpg

Figure 39. 31 seconds, 6552_200464.jpg

Figure 40. 42 seconds, 6552_200463.jpg

Figure 41. 50 seconds, 6552_200462.jpg

Figure 42. 61 seconds, 6552_200461.jpg

Figure 43. 80 seconds, 6552_200460.jpg

Figure 44. 101 seconds, 6552_200459.jpg

Figure 45. 127 seconds, 6552_200458.jpg

Figure 46. 143 seconds, 6552_200457.jpg

Figure 47. 150 seconds, 6552_200456.jpg

Figure 48. 203 seconds, 6552_200455.jpg

Figure 49. 215 seconds, 6552_200454.jpg

Figure 50. 293 seconds, 6552_200453.jpg

Figure 51. 350 seconds, 6552_200452.jpg

Figure 52. 409 seconds, 6552_200451.jpg

Figure 53. 412 seconds, 6552_200450.jpg

Figure 54. 420 seconds, 6552_200449.jpg

Figure 55. 427 seconds, 6552_200448.jpg

Figure 56. 437 seconds, 6552_200447.jpg

Figure 57. 441 seconds, 6552_200446.jpg

Figure 58. 449 seconds, 6552_200445.jpg

Figure 59. 470 seconds, 6552_200444.jpg

Figure 60. 474 seconds, 6552_200443.jpg

Figure 61. 511 seconds, 6552_200442.jpg

Figure 62. 515 seconds, 6552_200441.jpg

Figure 63. 528 seconds, 6552_200440.jpg

Figure 64. 539 seconds, 6552_200439.jpg

Figure 65. 563 seconds, 6552_200438.jpg

Figure 66. 567 seconds, 6552_200437.jpg

Figure 67. 573 seconds, 6552_200436.jpg

Figure 68. 580 seconds, 6552_200435.jpg

Figure 69. 609 seconds, 6552_200434.jpg

Figure 70. 639 seconds, 6552_200433.jpg

Figure 71. 739 seconds, 6552_200432.jpg

Figure 72. 741 seconds, 6552_200431.jpg

Figure 73. Post test 0 minutes, 6552_200430.jpg

Figure 74. Post test 0 minutes, 6552_200429.jpg

Figure 75. Post test 0 minutes, 6552_200428.jpg

Figure 76. Post test 1 minutes, 6552_200427.jpg

Figure 77. Post test 1 minutes, 6552_200426.jpg

Figure 78. Post test 2 minutes, 6552_200425.jpg

Figure 79. Post test 2 minutes, 6552_200424.jpg

Figure 80. Post test 2 minutes, 6552_200423.jpg

Figure 81. Post test 2 minutes, 6552_200422.jpg

Figure 82. Post test 2 minutes, 6552_200421.jpg

Figure 83. Post test 2 minutes, 6552_200420.jpg

Figure 84. Post test 3 minutes, 6552_200419.jpg

Figure 85. Post test 3 minutes, 6552_200418.jpg

Figure 86. Post test 3 minutes, 6552_200417.jpg

Figure 87. Post test 3 minutes, 6552_200416.jpg

Figure 88. Post test 3 minutes, 6552_200415.jpg

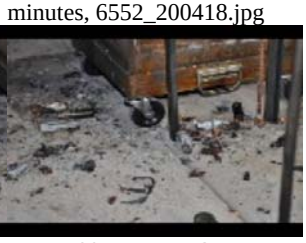

Figure 89. Post test 3 minutes, 6552_200414.jpg

Figure 90. Post test 3 minutes, 6552_200413.jpg

Figure 91. Post test 3 minutes, 6552_200412.jpg

Figure 92. Post test 3 minutes, 6552_200411.jpg

Figure 93. Post test 4 minutes, 6552_200410.jpg

Figure 94. Post test 4 minutes, 6552_200409.jpg

Figure 95. Post test 4 minutes, 6552_200408.jpg

Figure 96. Post test 4 minutes, 6552_200407.jpg

Figure 97. Post test 4 minutes, 6552_200406.jpg

Figure 98. Post test 5 minutes, 6552_200405.jpg

Figure 99. Post test 5 minutes, 6552_200404.jpg

Figure 100. Post test 7 minutes, 6552_200403.jpg

Figure 101. Post test 7 minutes, 6552_200402.jpg

Figure 102. Post test 8 minutes, 6552_200401.jpg

Results for Test 2 (Exp. ID 6553)

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	28.2	28.2	28.5	28.3	28.5

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	99.55	99.53	99.57	99.55	99.55

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	63.4	61.9	63.4	62.6	61.9

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 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)
TC_19	37	934	885	844	761	750
TC_31	28	557	450	394	320	301
TC_43	27	384	315	293	251	237
TC_55	27	238	189	177	150	141
TC_67	27	163	142	137	115	110

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

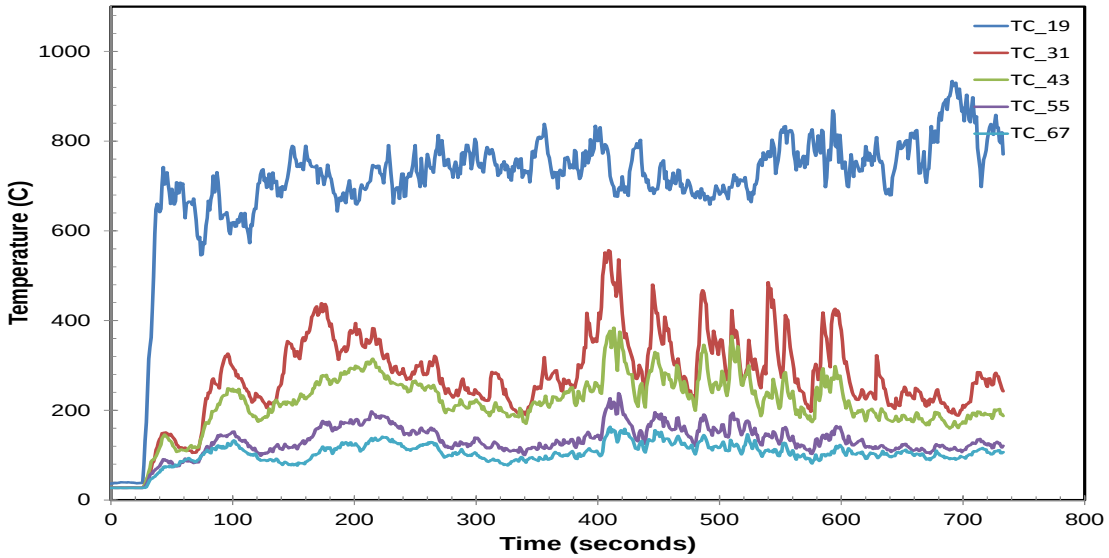

Figure 103. Temperature

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	5.1	3.6	3.5	3.0	2.5
North	1	4.4	3.3	3.2	2.6	2.2
South	1	3.9	3.3	3.2	2.6	2.2
West	1	5.0	4.2	4.0	3.4	2.8

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

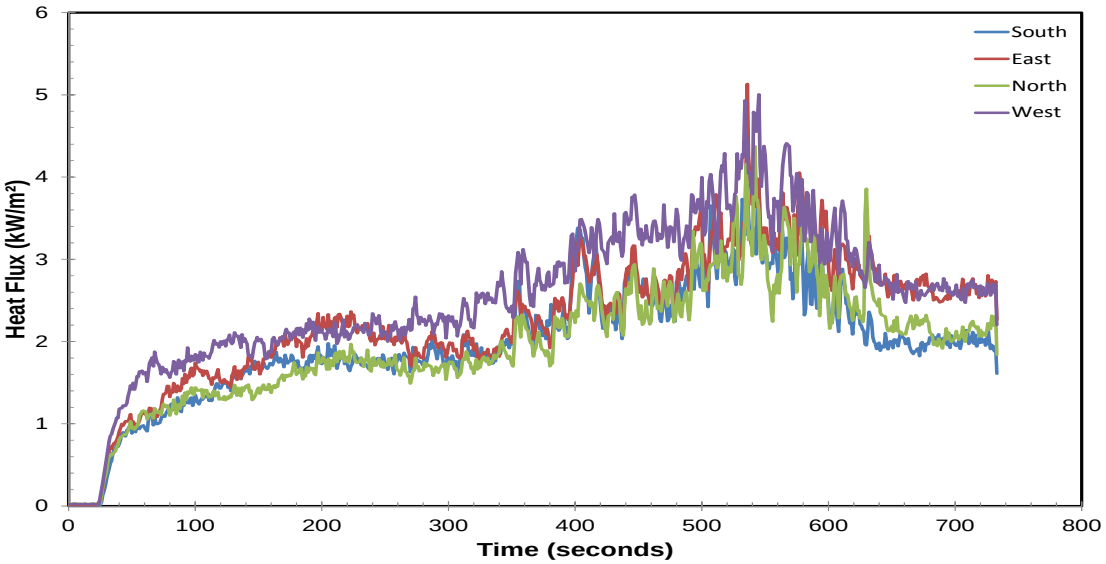

Figure 104. Heat Flux

The following table provides a description of the gas trains used during the experiments.

Table 17. Gas Train Description

Description	MFC Model Name	Fuel Type
Gas Train A	MCR-1000slpm-d	natural gas

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

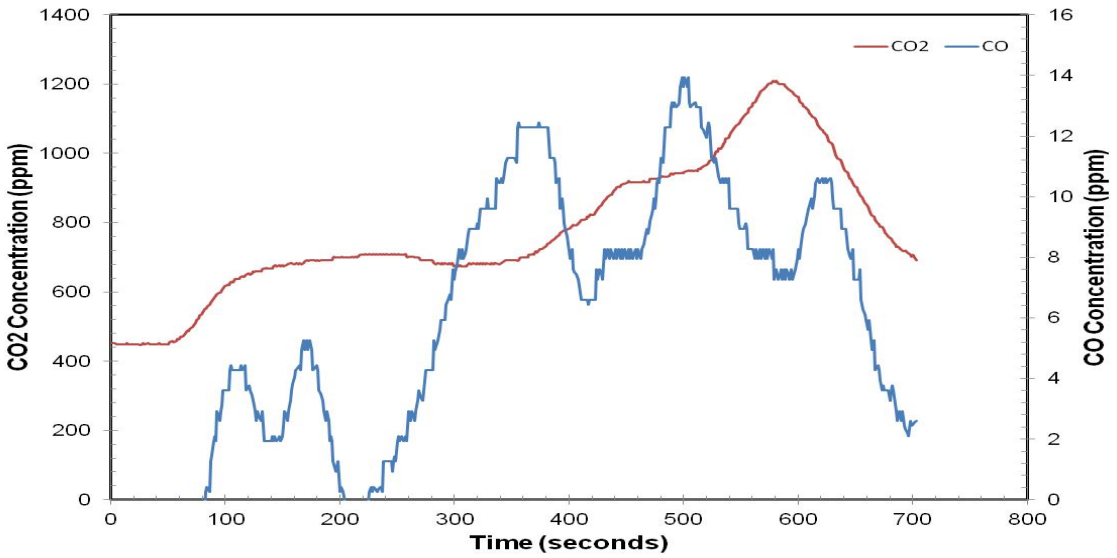

Figure 105. Carbon monoxide and carbon dioxide concentrations

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

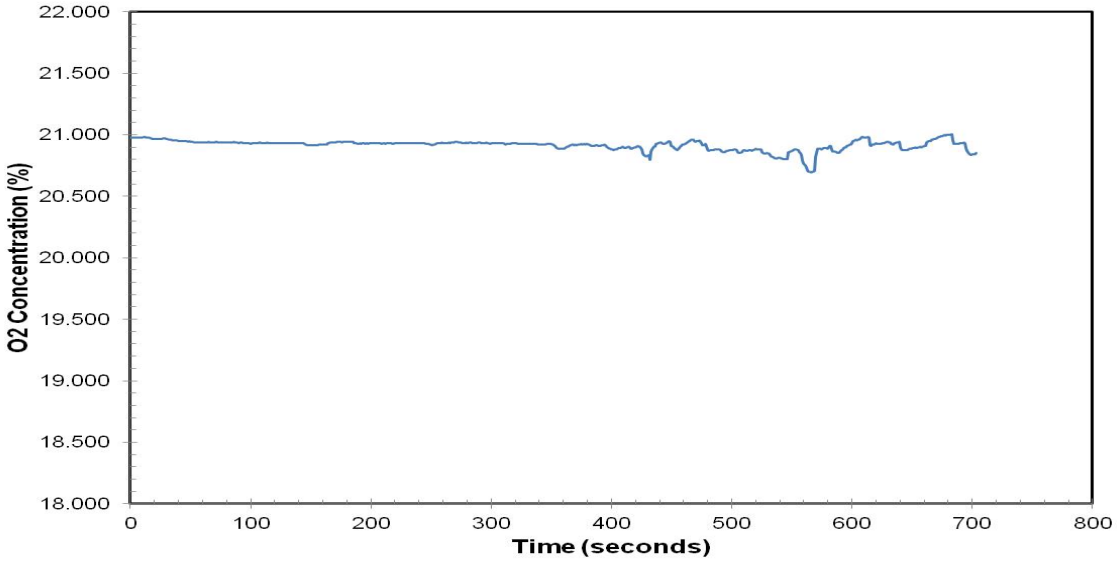

Figure 106. Oxygen Concentration

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 18. 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)
243	147	123	147	56	35783

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

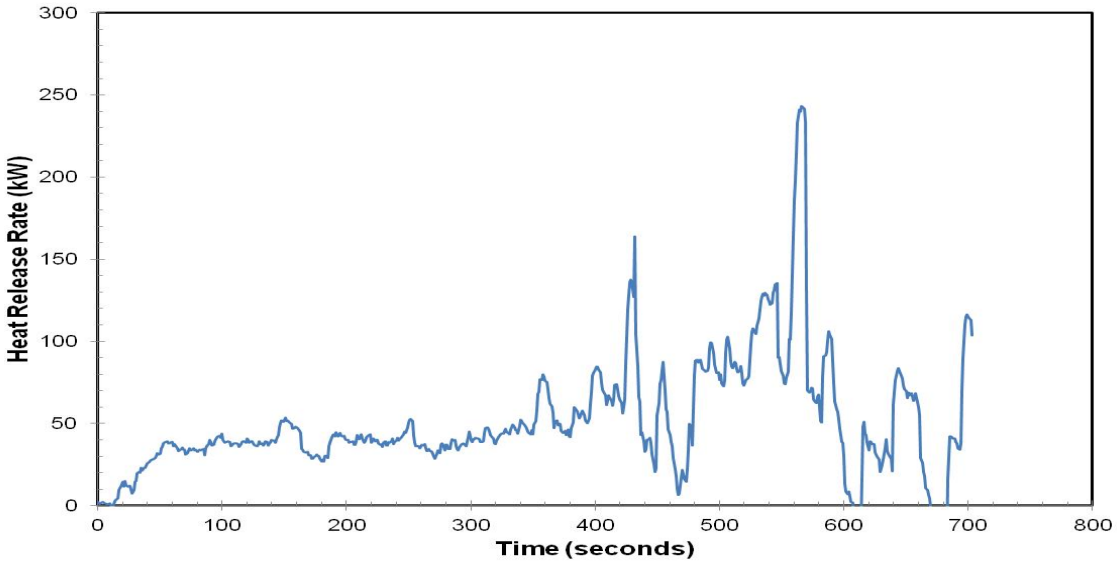

Figure 107. Heat Release Rate

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

Table 19. 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)
64	59	58	42	31

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

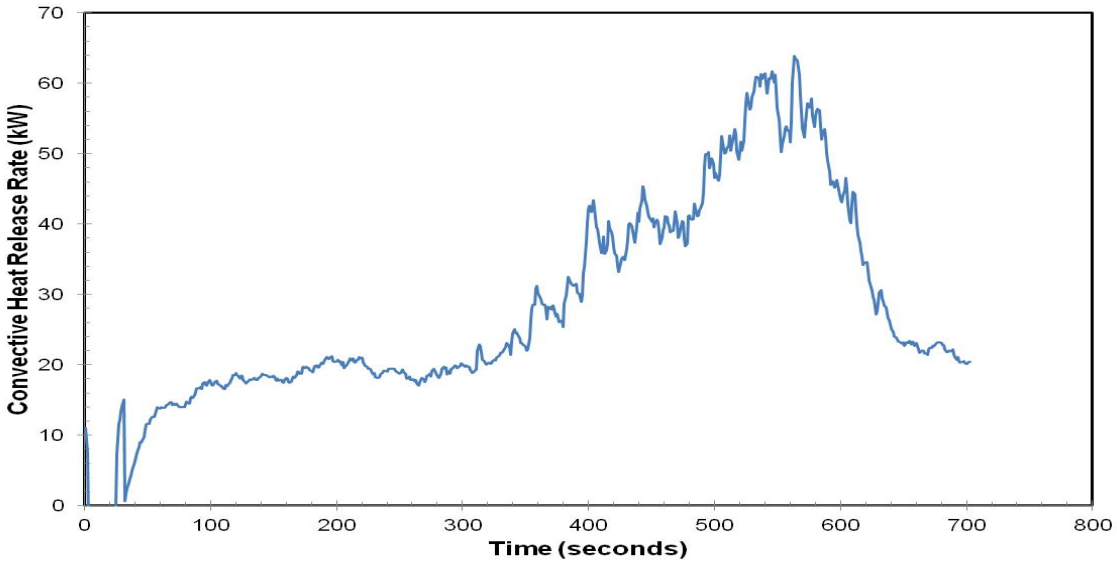

Figure 108. Convective Heat Release Rate

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

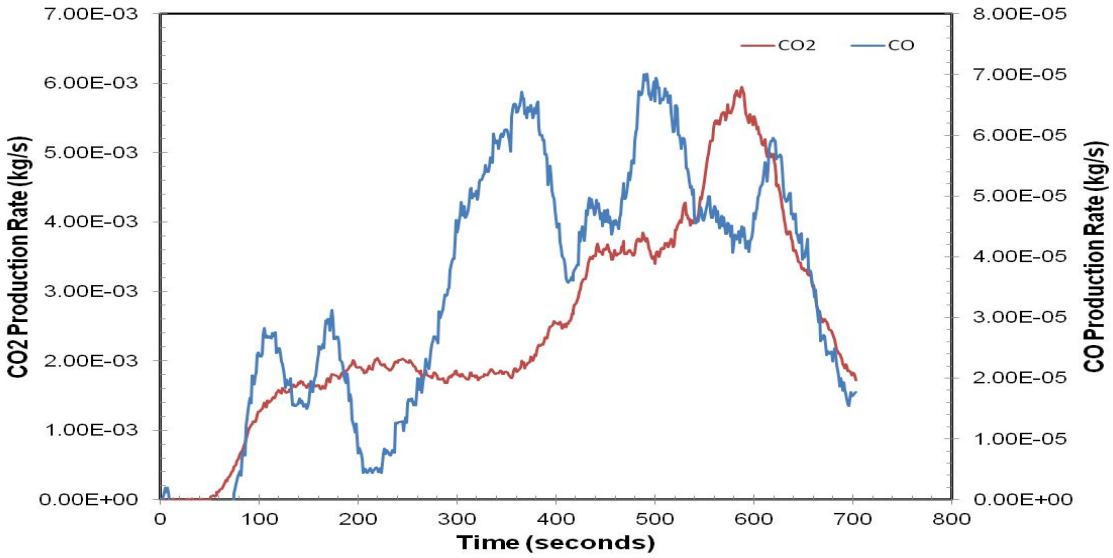

Figure 109. CO and CO2 production rates

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

Table 20. Video Log

Description	Start Time	Duration (s)	Filename
North	10:39:02	755	6553_20110809_103902_4.mp4
North East	10:38:57	757	6553_20110809_103857_1.mp4
North West	10:39:00	756	6553_20110809_103900_3.mp4
South West	10:38:58	757	6553_20110809_103858_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.

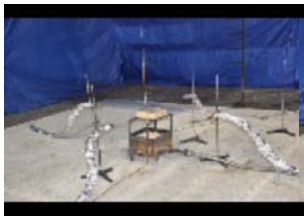

Figure 110. Pre test 3 minutes, 6553_200576.jpg

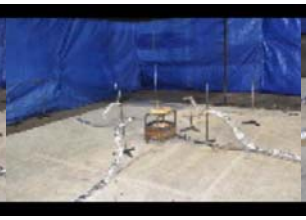

Figure 111. Pre test 3 minutes, 6553_200575.jpg

Figure 112. Pre test 3 minutes, 6553_200574.jpg

Figure 113. Pre test 3 minutes, 6553_200573.jpg

Figure 114. Pre test 3 minutes, 6553_200572.jpg

Figure 115. Pre test 3 minutes, 6553_200571.jpg

Figure 116. Pre test 3 minutes, 6553_200570.jpg

Figure 117. Pre test 3 minutes, 6553_200569.jpg

Figure 118. Pre test 2 minutes, 6553_200568.jpg

Figure 119. Pre test 2 minutes, 6553_200567.jpg

Figure 120. Pre test 16 seconds, 6553_200566.jpg

Figure 121. 30 seconds, 6553_200565.jpg

Figure 122. 45 seconds, 6553_200564.jpg

Figure 123. 63 seconds, 6553_200563.jpg

Figure 124. 93 seconds, 6553_200562.jpg

Figure 125. 99 seconds, 6553_200561.jpg

Figure 126. 118 seconds, 6553_200560.jpg

Figure 127. 130 seconds, 6553_200559.jpg

Figure 128. 186 seconds, 6553_200558.jpg

Figure 129. 236 seconds, 6553_200557.jpg

Figure 130. 292 seconds, 6553_200556.jpg

Figure 131. 317 seconds, 6553_200555.jpg

Figure 132. 334 seconds, 6553_200554.jpg

Figure 133. 336 seconds, 6553_200553.jpg

Figure 134. 349 seconds, 6553_200552.jpg

Figure 135. 392 seconds, 6553_200551.jpg

Figure 136. 400 seconds, 6553_200550.jpg

Figure 137. 413 seconds, 6553_200549.jpg

Figure 138. 422 seconds, 6553_200548.jpg

Figure 139. 433 seconds, 6553_200547.jpg

Figure 140. 447 seconds, 6553_200546.jpg

Figure 141. 456 seconds, 6553_200545.jpg

Figure 142. 475 seconds, 6553_200544.jpg

Figure 143. 477 seconds, 6553_200543.jpg

Figure 144. 486 seconds, 6553_200542.jpg

Figure 145. 507 seconds, 6553_200541.jpg

Figure 146. 513 seconds, 6553_200540.jpg

Figure 147. 521 seconds, 6553_200539.jpg

Figure 148. 526 seconds, 6553_200538.jpg

Figure 149. 530 seconds, 6553_200537.jpg

Figure 150. 538 seconds, 6553_200536.jpg

Figure 151. 559 seconds, 6553_200535.jpg

Figure 152. 580 seconds, 6553_200534.jpg

Figure 153. 583 seconds, 6553_200533.jpg

Figure 154. 617 seconds, 6553_200532.jpg

Figure 155. 627 seconds, 6553_200531.jpg

Figure 156. 682 seconds, 6553_200530.jpg

Figure 157. 693 seconds, 6553_200529.jpg

Figure 158. Post test 1 minutes, 6553_200528.jpg

Figure 159. Post test 1 minutes, 6553_200527.jpg

Figure 160. Post test 1 minutes, 6553_200526.jpg

Figure 161. Post test 1 minutes, 6553_200525.jpg

Figure 162. Post test 1 minutes, 6553_200524.jpg

Figure 163. Post test 1 minutes, 6553_200523.jpg

Figure 164. Post test 1 minutes, 6553_200522.jpg

Figure 165. Post test 2 minutes, 6553_200521.jpg

Figure 166. Post test 2 minutes, 6553_200520.jpg

Figure 167. Post test 2 minutes, 6553_200519.jpg

Figure 168. Post test 2 minutes, 6553_200518.jpg

Figure 169. Post test 2 minutes, 6553_200517.jpg

Figure 170. Post test 2 minutes, 6553_200516.jpg

Figure 171. Post test 2 minutes, 6553_200515.jpg

Figure 172. Post test 2 minutes, 6553_200514.jpg

Figure 173. Post test 3 minutes, 6553_200513.jpg

Figure 174. Post test 3 minutes, 6553_200512.jpg

Figure 175. Post test 3 minutes, 6553_200511.jpg

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