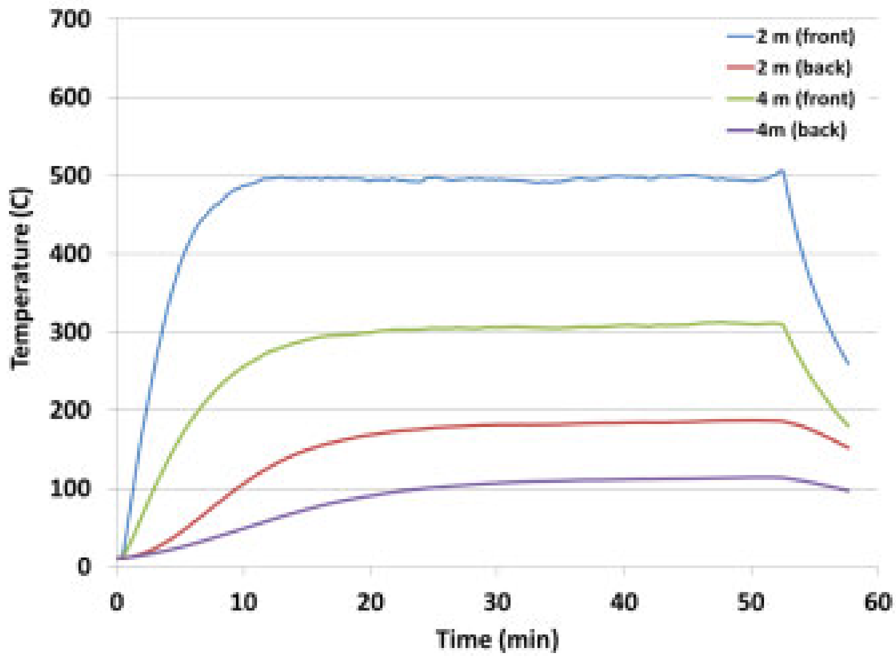


Figure 6-8: Thermocouple temperatures from DFT instruments. Distances are from center of pan (Test 1.1).

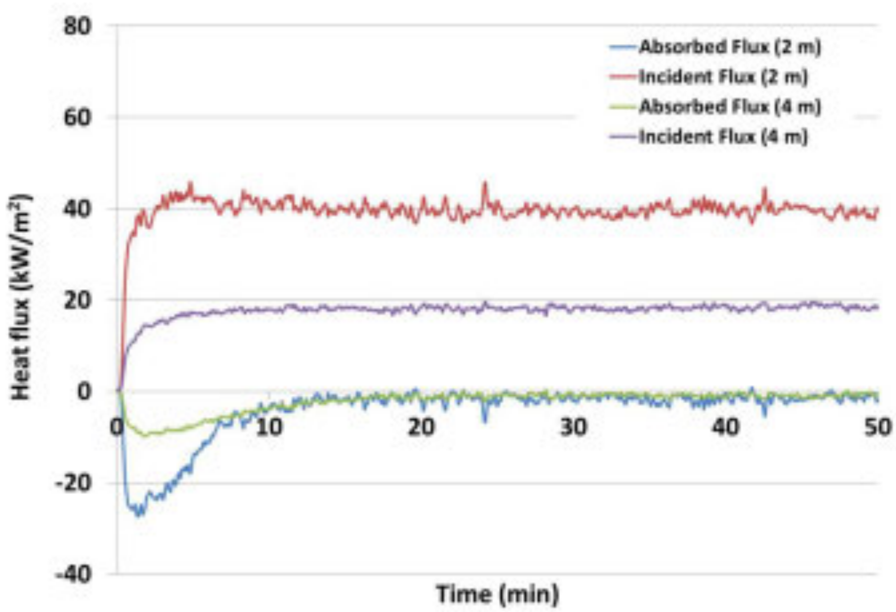


Figure 6-9: Derived heat flux values from DFT measurements. Distances are from center of pan (Test 1.1).

6.1.1.8. Calorimeter TC Temperature and Derived Heat Flux

Figure 6-10 through Figure 6-12 provide temperatures over time from TC measurements placed on the inner and outer cylinders, as well as external to the calorimeter. Some of the TC measurements are much lower than the others, which most likely is an indication that the TC reading is unreliable and thus not included in the analysis. There were six TCs that failed for Test 1.1 and include L-0º (outer), L-270° (outer), L-315° (inner), R-180° (outer), C-0° (exterior), R-45° (exterior), R-180° (exterior), and R-270° (exterior). These thermocouples are not included in the results.

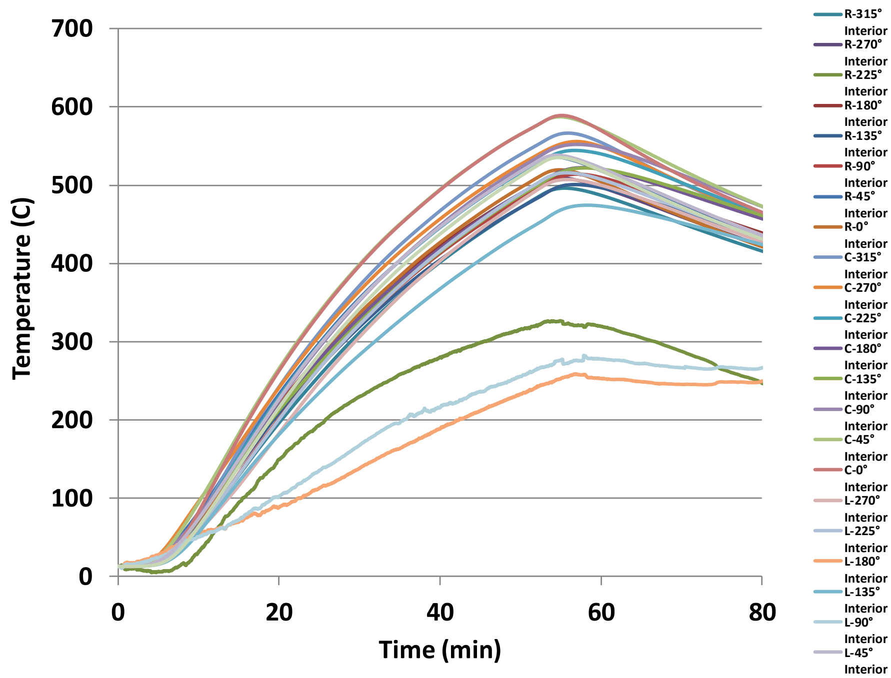


Figure 6-10: Thermocouple temperatures at inner cylinder stations (Test 1.1).

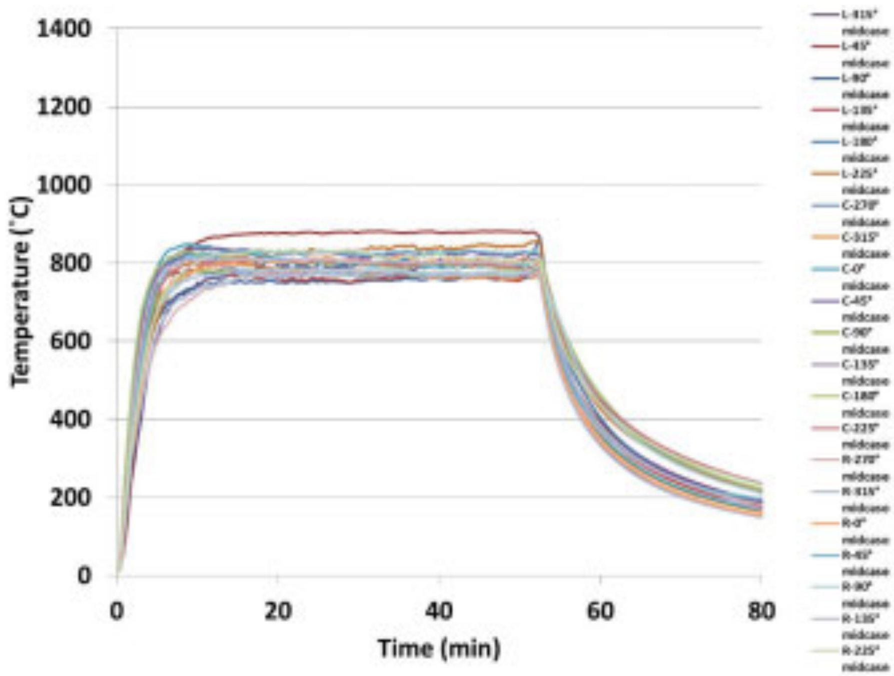


Figure 6-11: Thermocouple temperatures at outer cylinder stations (Test 1.1).

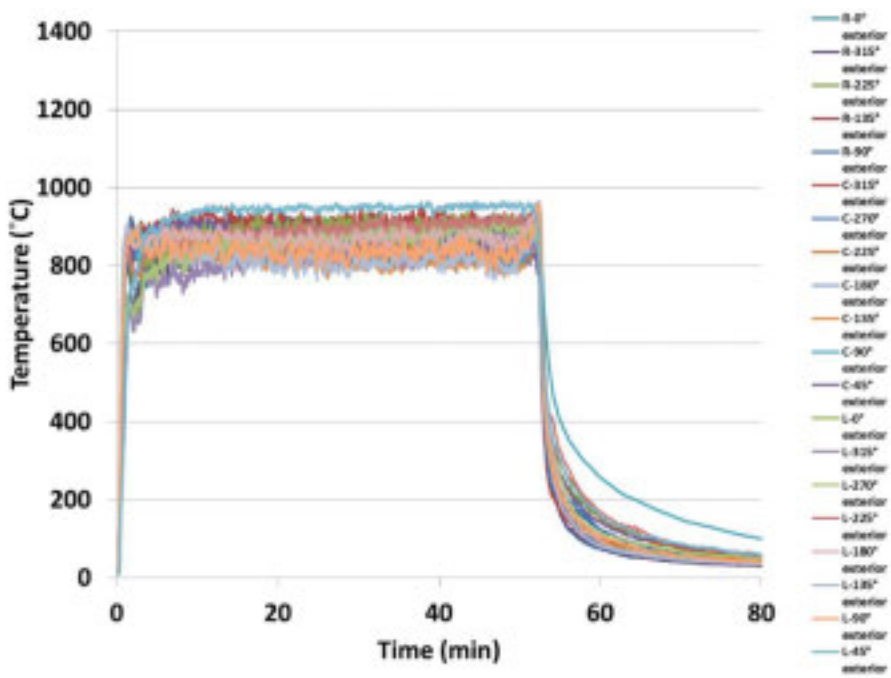


Figure 6-12: Thermocouple temperatures at exterior cylinder stations (Test 1.1).

6.1.1.8.1. Heat Flux to Calorimeter

In Figure 6-13 and Figure 6-14 show the absorbed and total flux to the calorimeter, respectively.

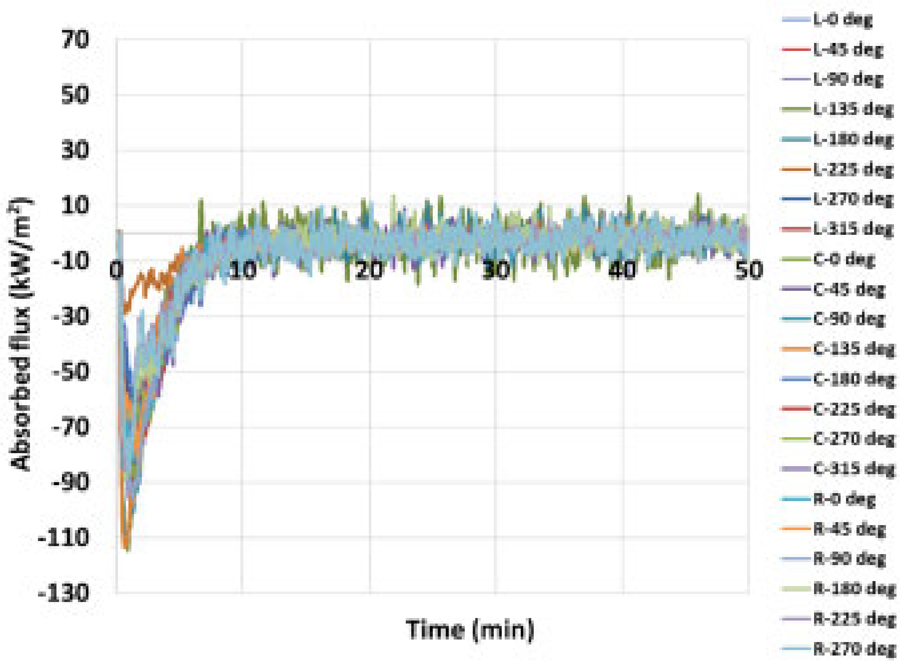


Figure 6-13: Absorbed heat flux to calorimeter (Test 1.1).

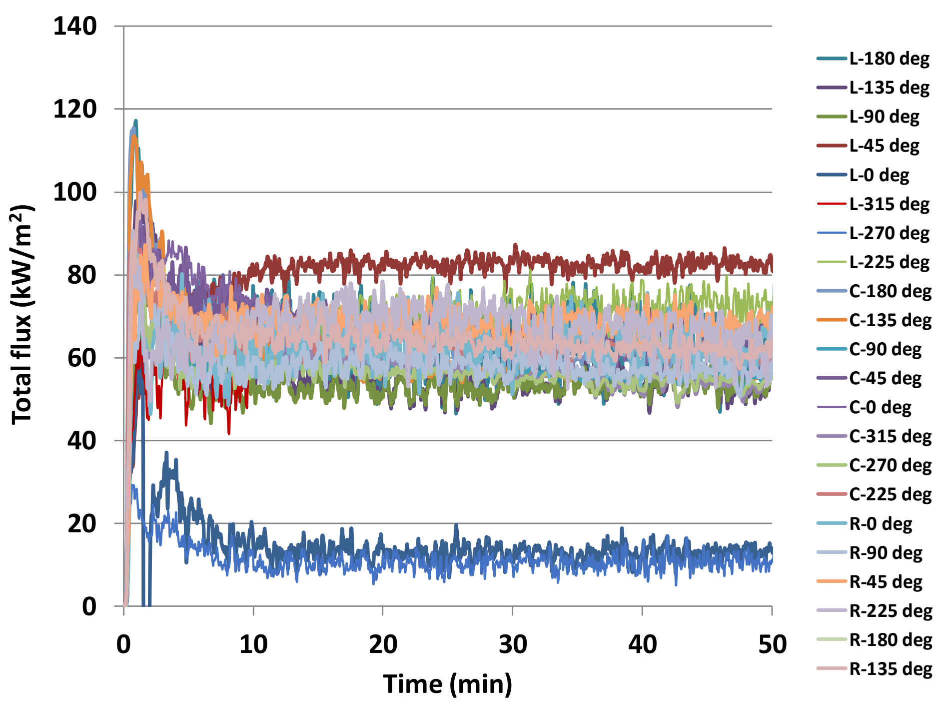


Figure 6-14: Total heat flux to calorimeter (Test 1.1).

6.1.1.9. Heat Release Rate

Figure 6-15 shows the heat release over time from CGA measurements. The average heat release rate, taken between 20-30 minutes, is 4.4 ± 0.2 MW.

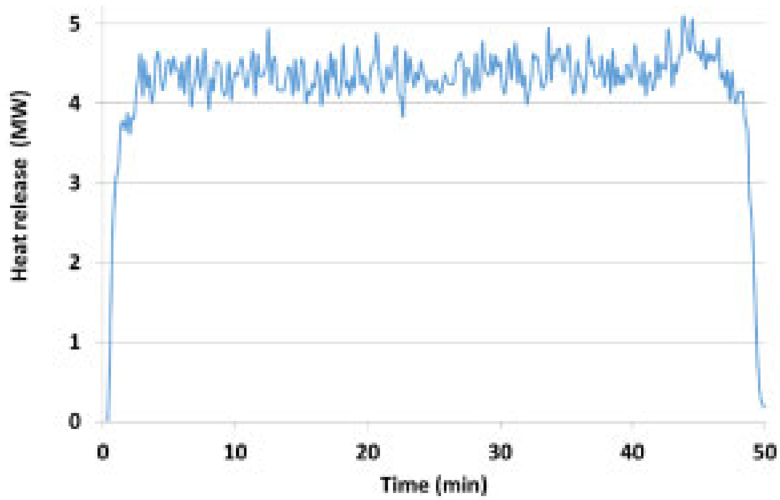


Figure 6-15: Heat release rate (Test 1.1).

6.1.1.10. Flame Height

Figure 6-16 shows the flame height as measured from the IR camera. The average flame height is 5.6 ± 0.88 m. Figure 6-17 shows the average image of the flame in comparison to the stadia board to provide an indication of the average height. The field of view of the camera encompassed up to 7m due to limitation of the radial distance of the test chamber and the camera lens. Thus, the data is clipped at that height.

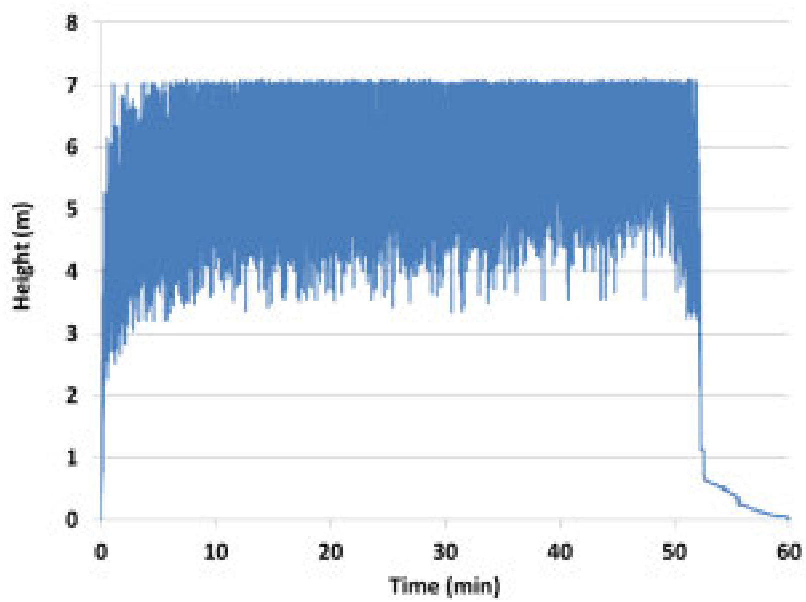


Figure 6-16: Flame height from IR camera measurements (Test 1.1).

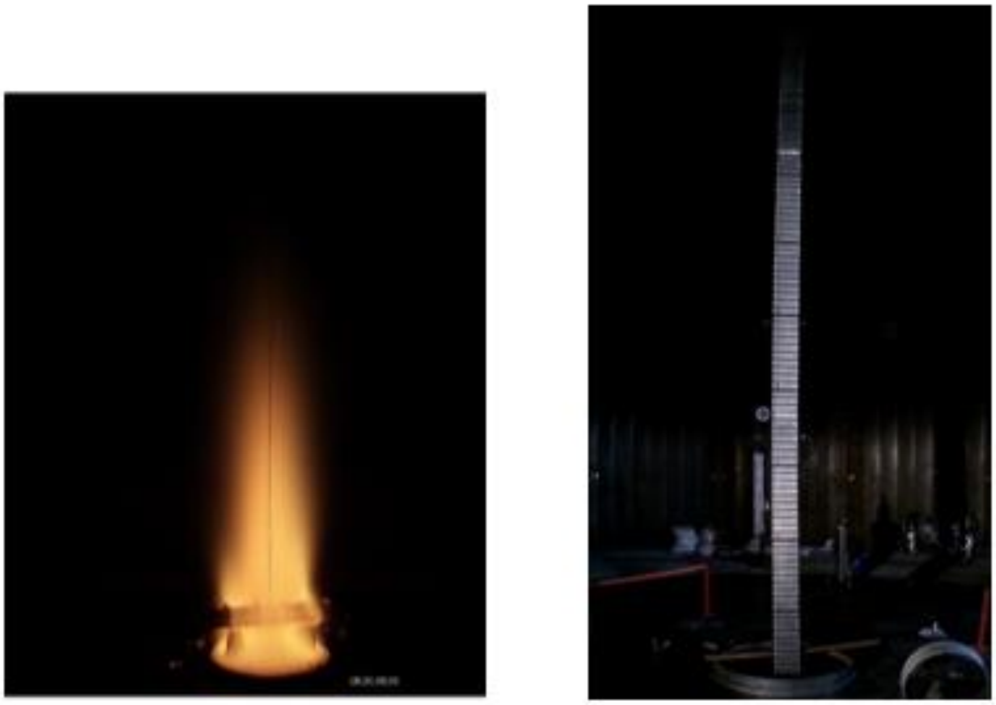


Figure 6-17: Time-averaged image (left). Stadia board (right) (Test 1.1).

6.1.2. Test 1.2

For this test, the heptane was maintained at a supply temperature of 20 ± 5ºC. There was no calorimeter. The duration of test was approximately 37 minutes, during which a constant fuel level of 1.5 inches (3.8 cm) was maintained. After 37 minutes, the fuel supply was terminated, and the fuel was allowed to burn down.

6.1.2.1. Fuel Supply Temperature

Figure 6-18 provides the fuel supply temperature over time. The fuel supply temperature averaged over 10-35 minutes is 24.2 ± 0.3ºC.

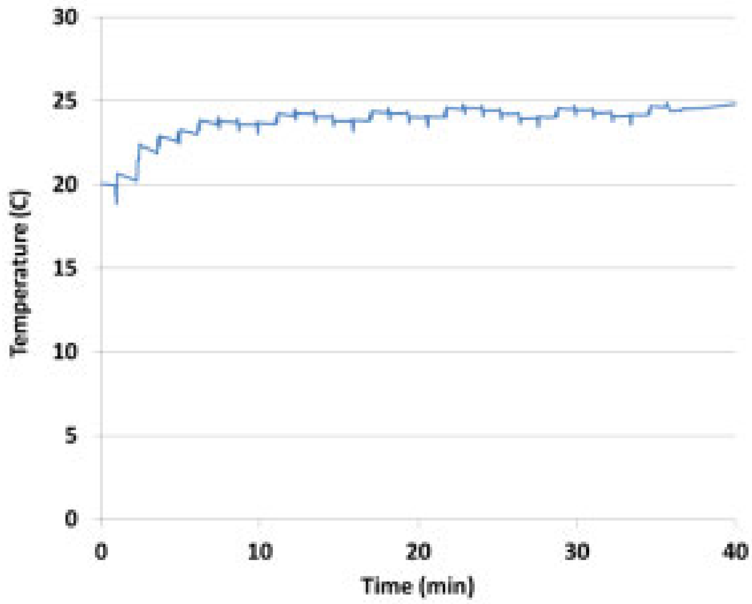


Figure 6-18: Temperature of fuel supply into pan (Test 1.2).

6.1.2.2. Fuel Rake Thermocouple Temperatures

Figure 6-19 shows temperatures from TCs within the liquid fuel. The fuel level was approximately 1.5 inches (3.8 cm) and was held constant over the duration of the test.

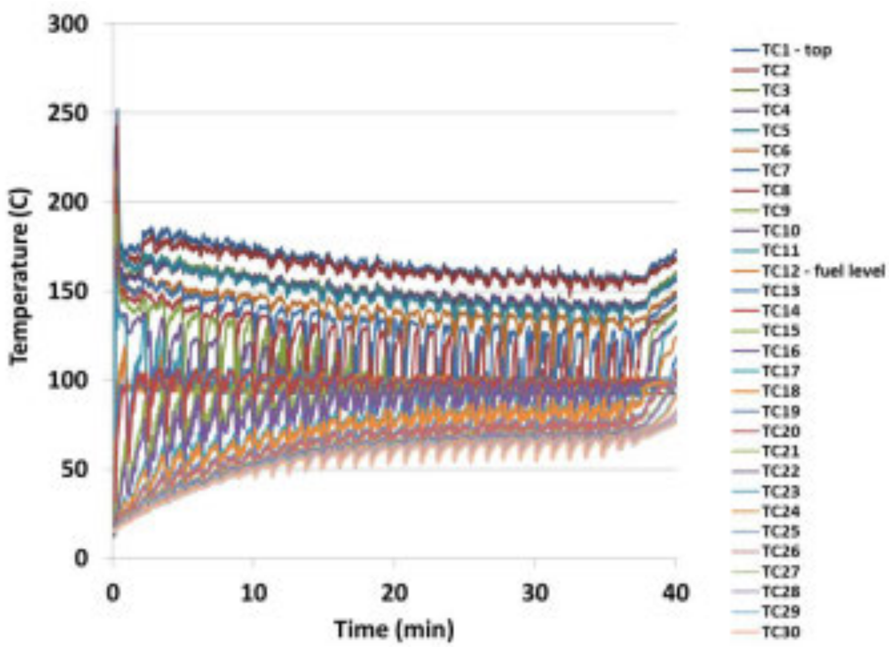


Figure 6-19: Fuel rake thermocouple temperatures (Test 1.2).

6.1.2.3. Burn Rate

Figure 6-20 provides the scale readings over time. The slope of the equation fitted to the data allows for the burn rate to be determined. A slope of 7.5865 kg/min (r^2 = 99%) corresponds to a burn rate of 0.040 kg/m^2s.

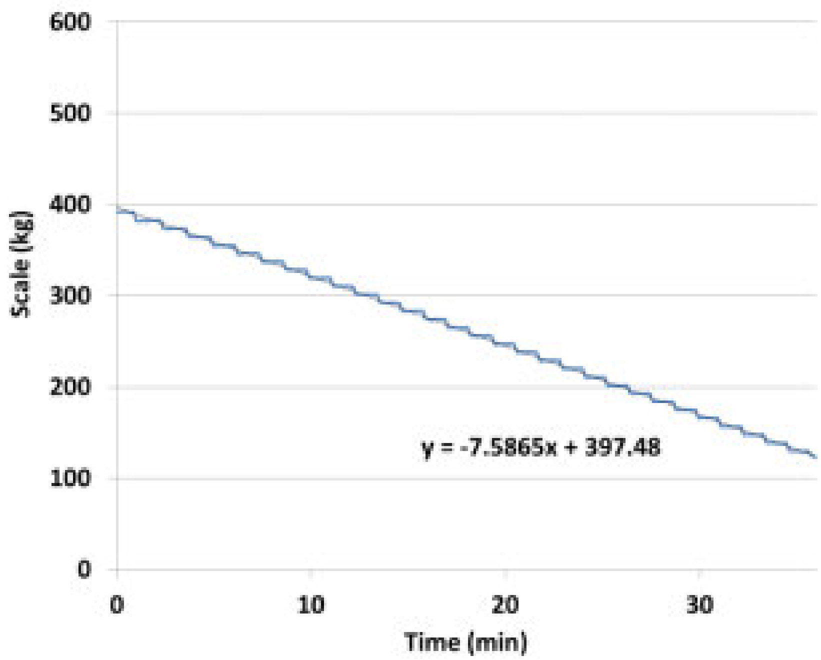


Figure 6-20: Fuel weight over time based on scale measurement (Test 1.2).

6.1.2.4. Radiometers

Figure 6-21 and Figure 6-22 provide the heat flux over time from six narrow-angle and five wide-angle radiometers at the various height locations.

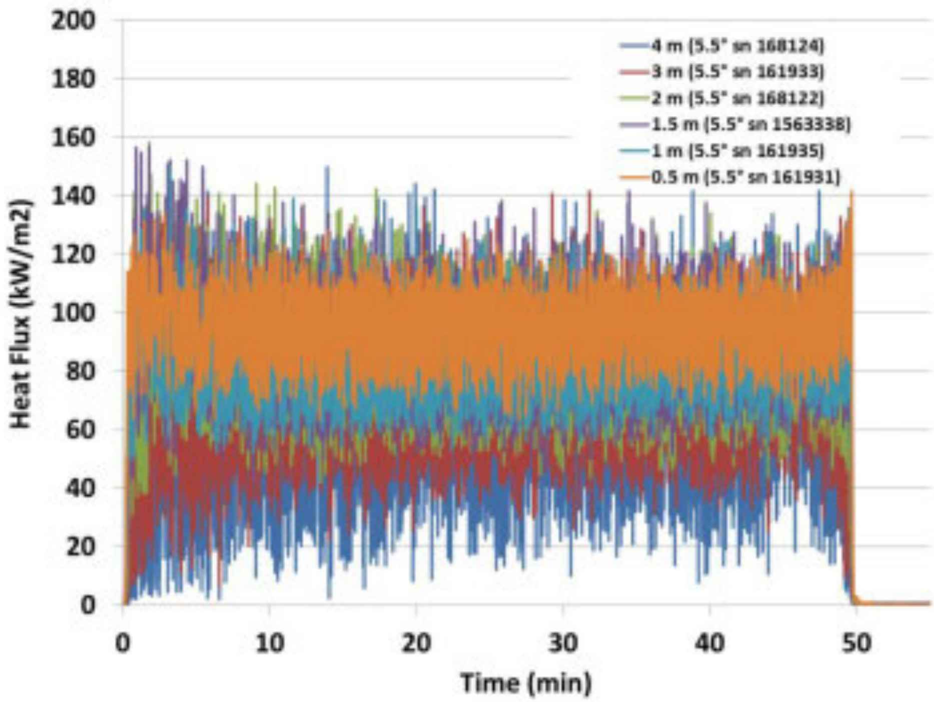


Figure 6-21: Heat flux measurement from narrow view radiometers at different heights (Test 1.2).

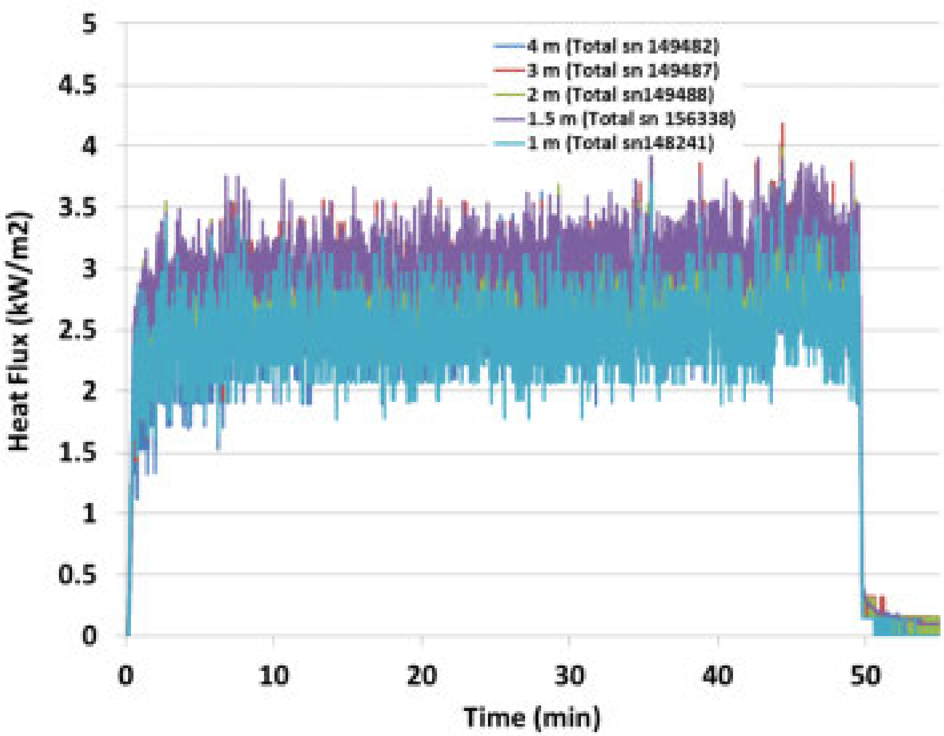


Figure 6-22: Heat flux measurement from wide view radiometers at different heights (Test 1.2).

6.1.2.5. Thermocouple Rake in Fire Plume

Figure 6-23 provides temperature measurements over time from the TCs placed within the fire plume at its vertical centerline.

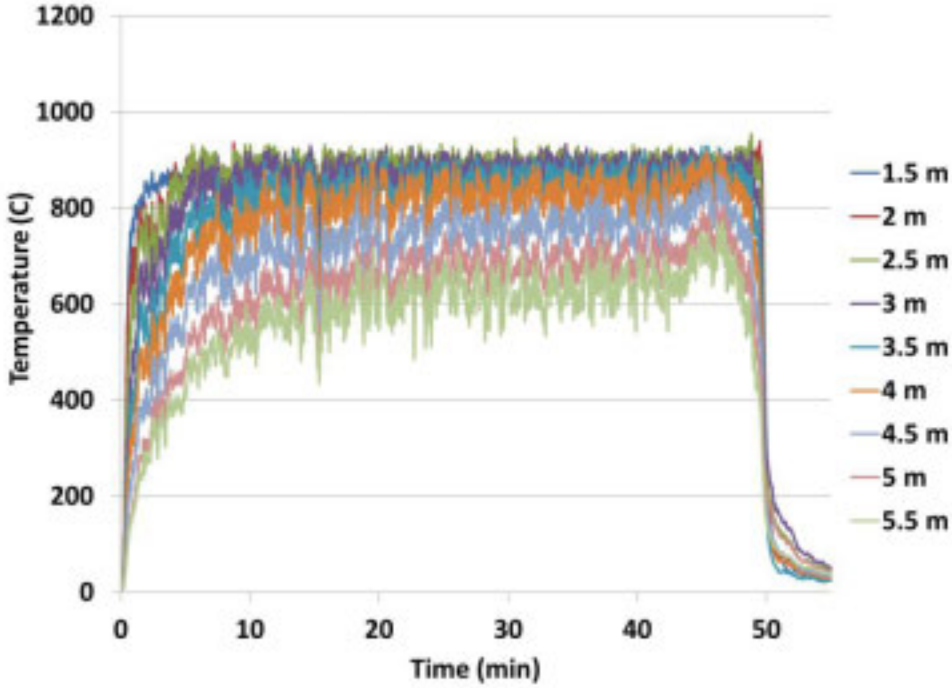


Figure 6-23: Temperature measurements from vertical thermocouple rake in centerline of fire plume (Test 1.2).

6.1.2.6. DFT TC Temperature and Derived Heat Flux

Figure 6-24 and Figure 6-25 provide DFT temperatures and heat flux, respectively. The term 'front' refers to the TC measurement for the plate closest to the fire, while the term 'back' refers to the TC measurement for the plate furthest from the fire.

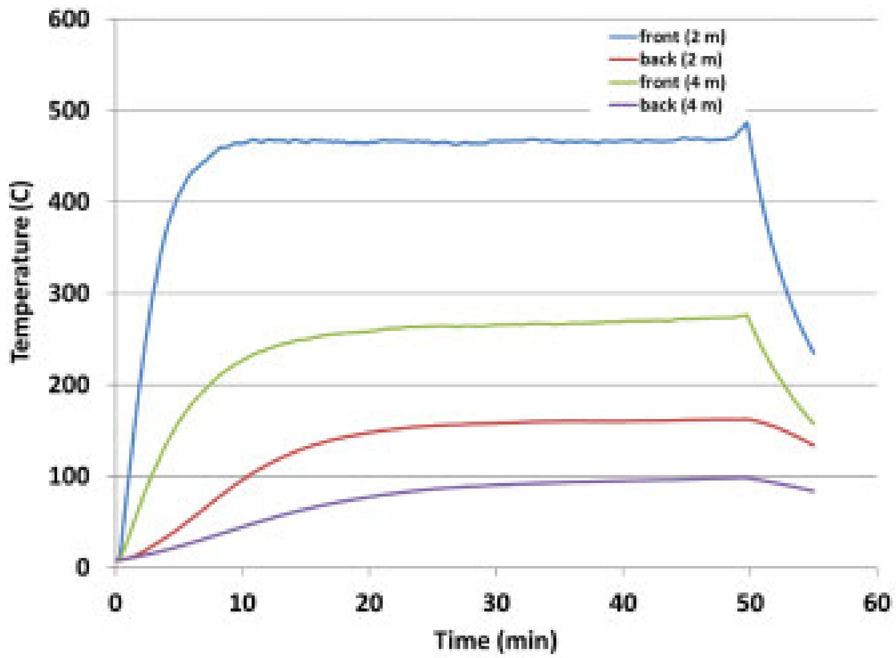


Figure 6-24: Thermocouple temperatures from DFT instruments. Distances are from center of pan (Test 1.2).

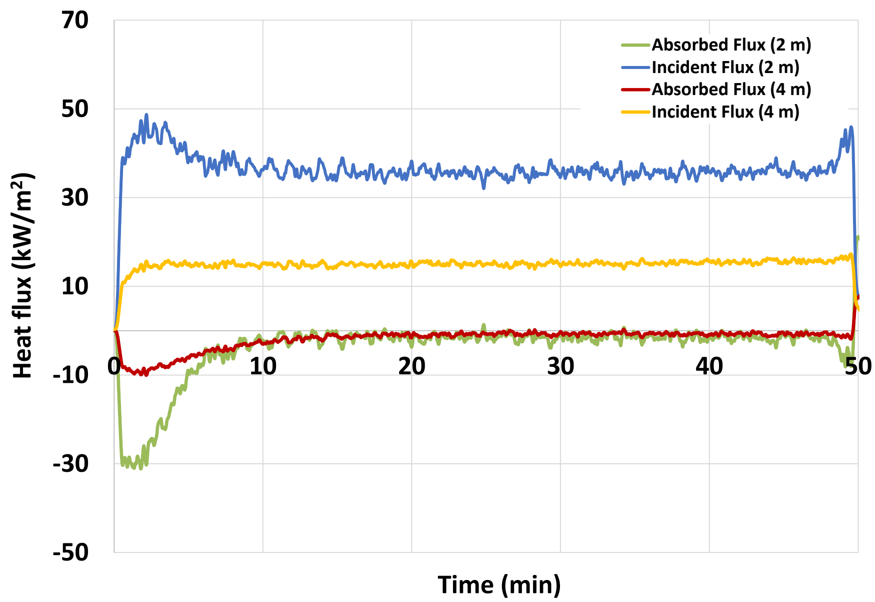


Figure 6-25: Derived heat flux values from DFT measurements. Distances are from center of pan (Test 1.2).

6.1.2.7. Heat Release Rate

Figure 6-26 shows the heat release over time from CGA measurements. The average heat release rate, taken between 20-30 minutes, is 5.2 ± 0.2 MW.

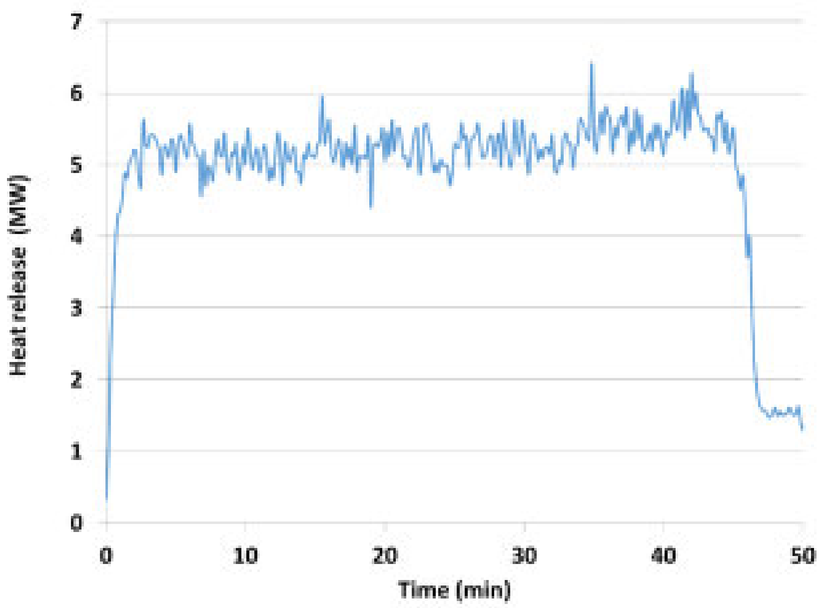


Figure 6-26: Heat release rate (Test 1.2).

6.1.2.8. Flame Height

Figure 6-27 shows an image of the flame as averaged from clips taken from video coverage. Based on this image and comparison to the stadia board, the average flame height is 6.8 m.

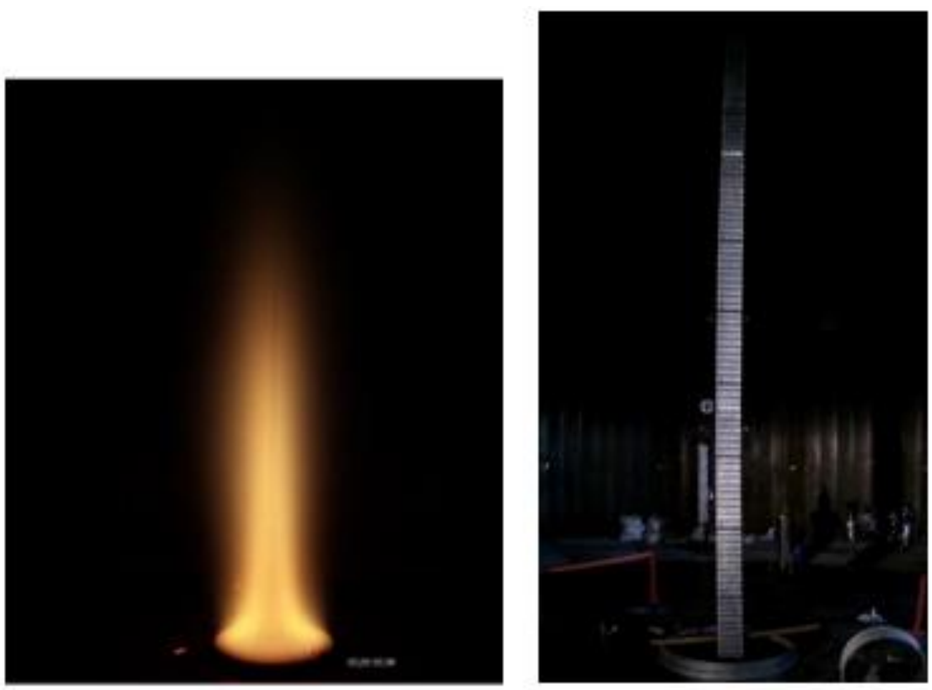


Figure 6-27: Time-averaged image (left). Flame height determined by stadia board marked with 1-m increments (right) (Test 1.2).

6.1.3. *Test 1.3*

For this test, the heptane was maintained at a supply temperature of 60 ± 5ºC. The calorimeter was elevated 1 m from its centerline to the bottom of the fuel pan. The duration of test was approximately 44 minutes, during which a constant fuel level of 1.5 inches (3.8 cm) was maintained. After 44 minutes, the fuel supply was terminated, and the fuel was allowed to burn down.

6.1.3.1. Fuel Supply Temperature

Figure 6-28 shows fuel supply temperature over time. The temperature averaged over 24-44 minutes is 58°C.

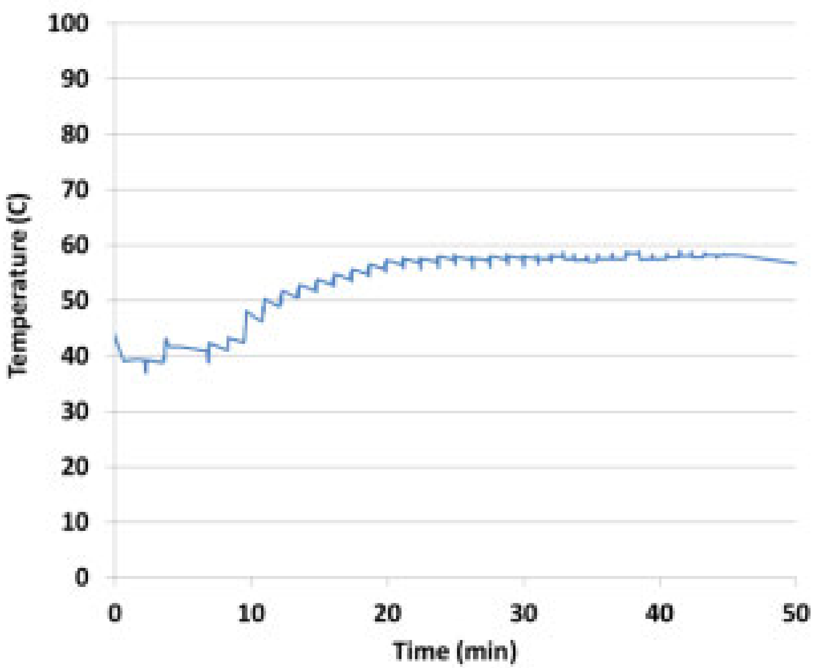


Figure 6-28: Temperature of fuel supply into pan (Test 1.3).

6.1.3.2. Fuel Rake Thermocouple Temperatures

Figure 6-29 shows temperatures from TCs within the liquid fuel. The fuel level was approximately 1.5 inches (3.8 cm) and was held constant over the duration of the test.

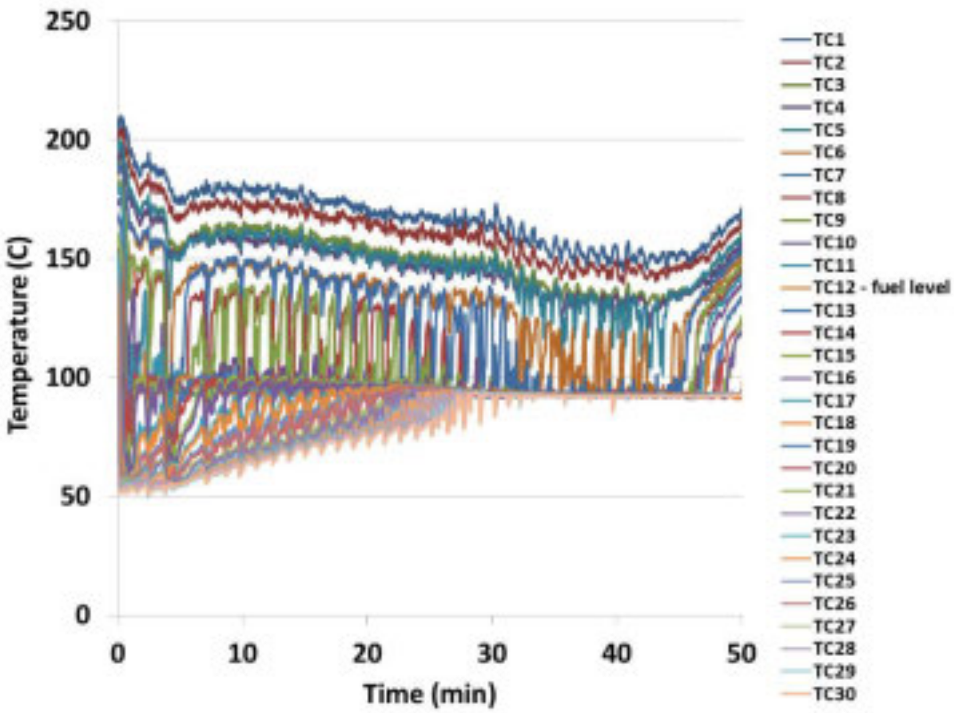


Figure 6-29: Fuel rake thermocouple temperatures (Test 1.3)

6.1.3.3. Burn Rate

Figure 6-30 provides the scale readings over time. The slope of the equation fitted to the data allows for the burn rate to be determined. For the duration when the average fuel temperature was below 58°C, the average burn rate was 0.037 kg/m^{2}s, corresponding to a slope of 6.9087 kg/min (r^2 = 99%). For the duration when the average fuel temperature was an average of 58°C, the average burn rate was 0.040 kg/m^{2}s, corresponding to a slope of 7.5399 kg/min (r^2 = 99%).

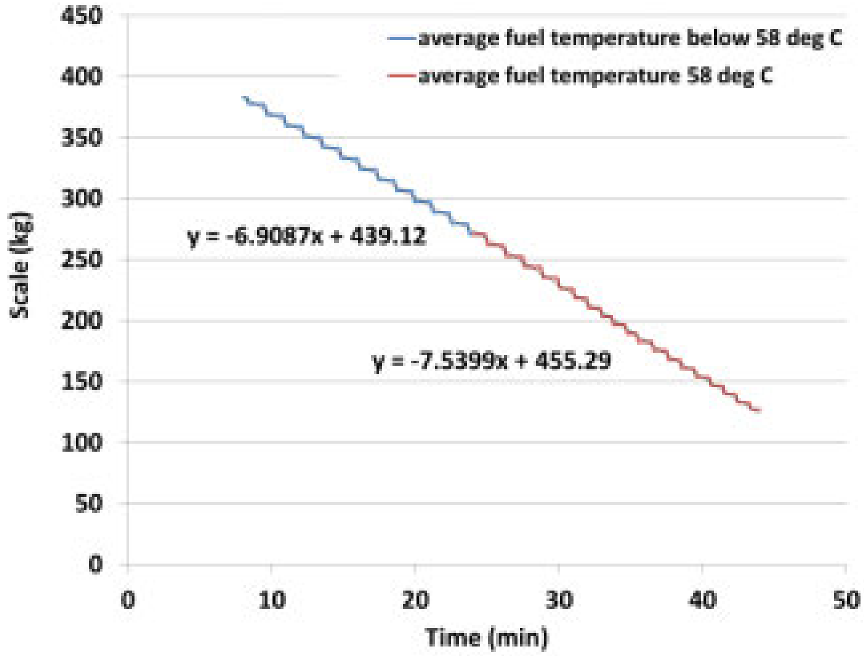


Figure 6-30: Fuel weight over time based on scale measurement (Test 1.3).

6.1.3.4. Radiometers

Figure 6-31 and Figure 6-32 provide the heat flux over time from six narrow-angle and five wide-angle radiometers at the various height locations.

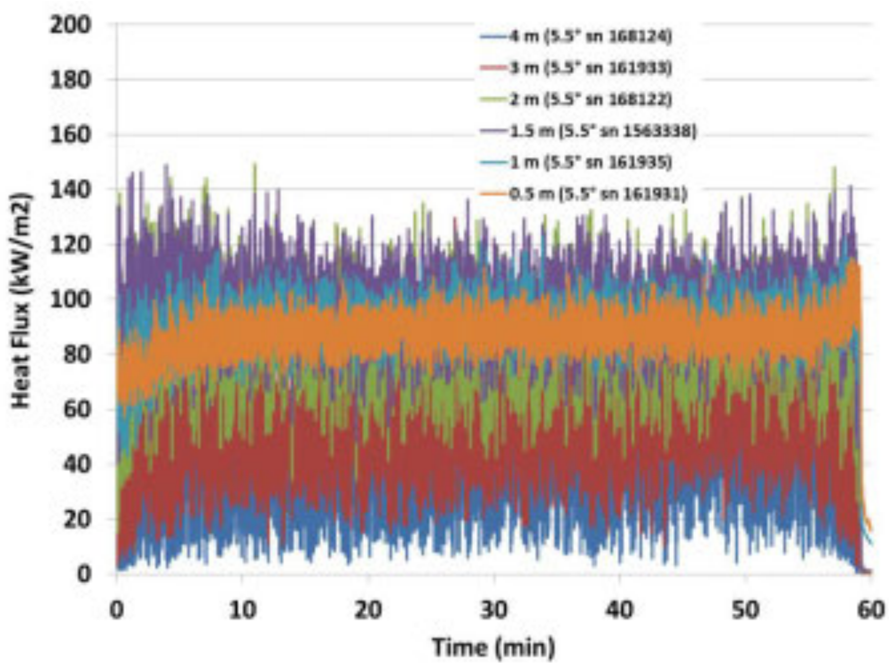


Figure 6-31: Heat flux measurement from narrow view radiometers at different heights (Test 1.3).

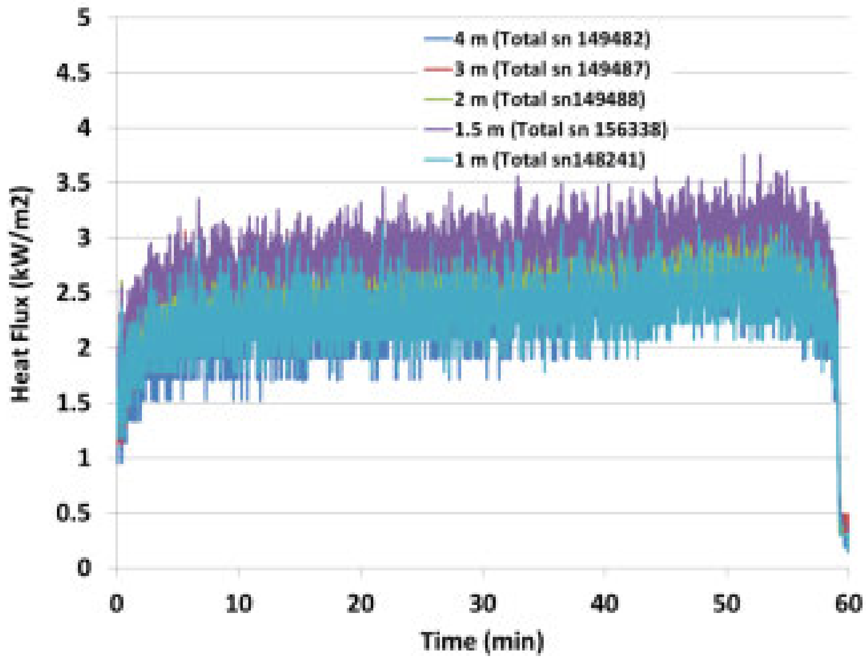


Figure 6-32: Heat flux measurement from wide view radiometers at different heights (Test 1.3).

6.1.3.5. Thermocouple Rake in Fire Plume

Figure 6-33 provides temperature measurements over time from the TCs placed within the fire plume at its vertical centerline.

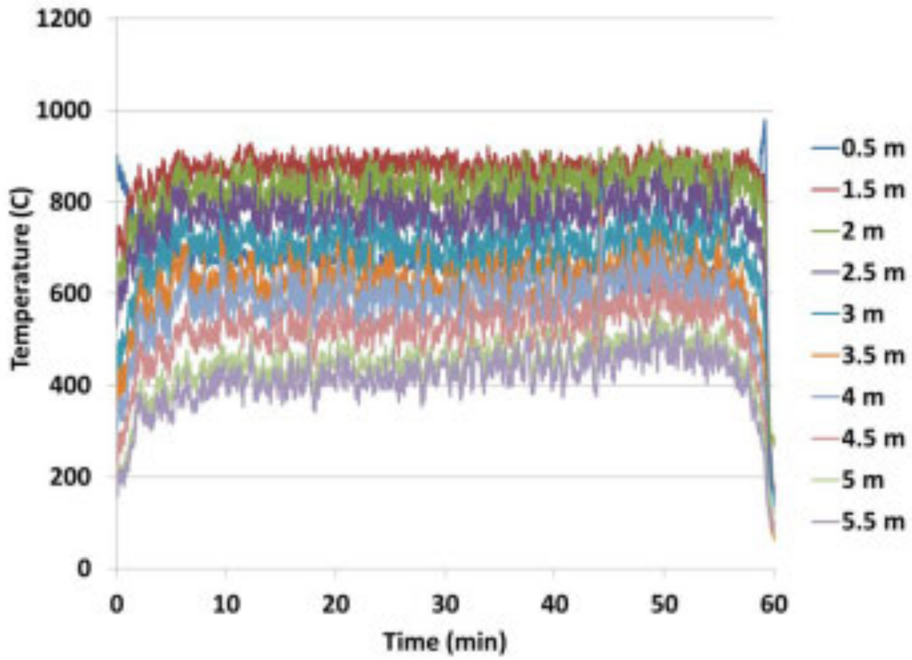


Figure 6-33: Temperature measurements from vertical thermocouple rake in centerline of fire plume (Test 1.3).

6.1.3.6. DFT TC Temperature and Derived Heat Flux

Figure 6-34 and Figure 6-35 provide DFT temperatures and heat flux, respectively. The term 'front' refers to the TC measurement for the plate closest to the fire, while the term 'back' refers to the TC measurement for the plate furthest from the fire. Each TC is mounted on the face that is unexposed and in its center.

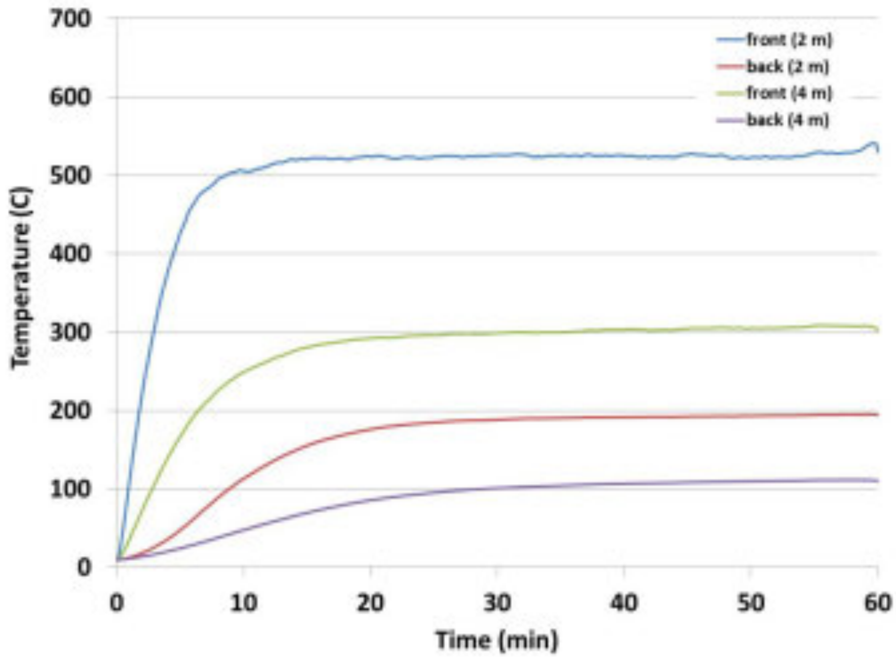


Figure 6-34: Thermocouple temperatures from DFT instruments. Distances are from center of pan (Test 1.3).

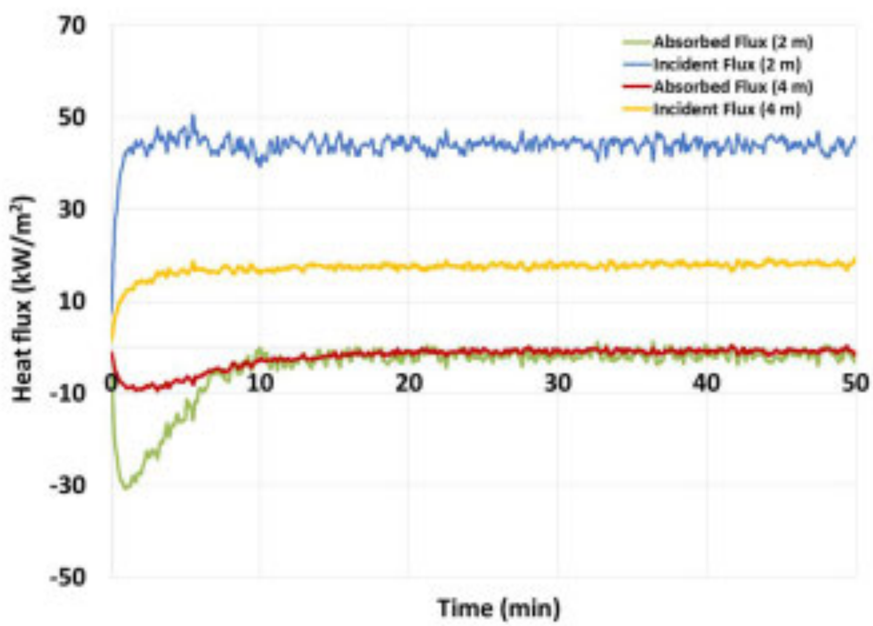


Figure 6-35: Derived heat flux values from DFT measurements. Distances are from center of pan (Test 1.3).

6.1.3.7. Calorimeter TC Temperature and Derived Heat Flux

The number of TCs that failed for Test 1.1 was sufficiently low that NRCC did not feel that replacement was necessary. Thus, Test 1.3 had the same identified failed TCs as Test 1.1 except L-0 ° (outer), but did include three additional TCs that failed, namely C-270° (inner), C-225° (outer) and C-315° (outer), to give a total of ten out of seventy-two TCs that failed. The cause of why the thermocouple at location L-0 ° (outer) provided measurements for test 1.3 and not test 1.1 is unknown. Four out of the ten TCs that failed were exterior. Note that the exterior TCs do not play a role in determining the heat flux to the calorimeter.

Figure 6-36 through Figure 6-38 provide temperatures over time from TC measurements placed on the inner and outer cylinders, as well as external to the calorimeter. Some of the TC measurements are much lower than the others, which most likely is an indication that the TC reading is unreliable, and therefore were not included in the analysis.

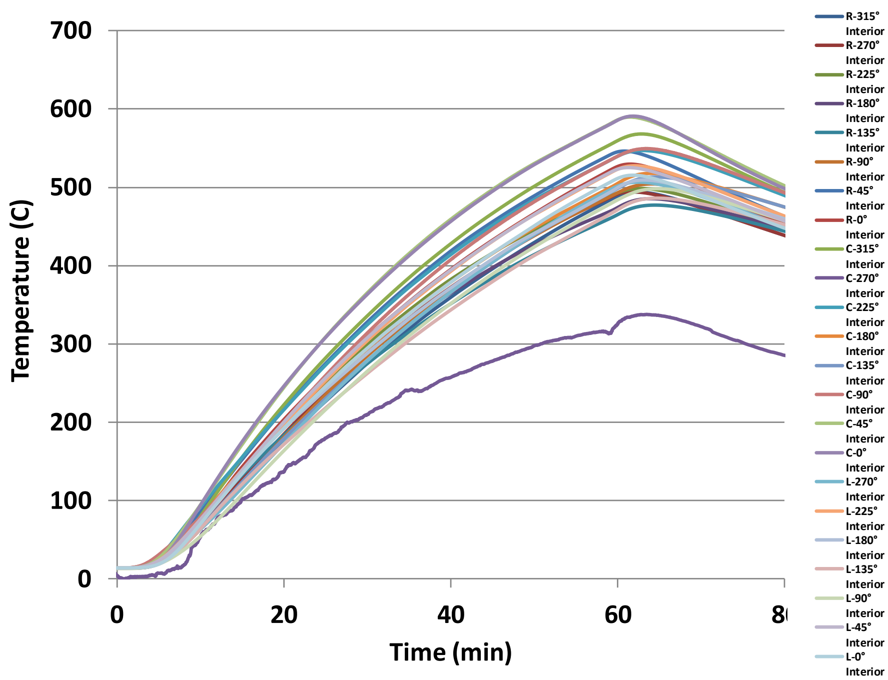


Figure 6-36: Thermocouple temperatures at inner cylinder (Test 1.3).

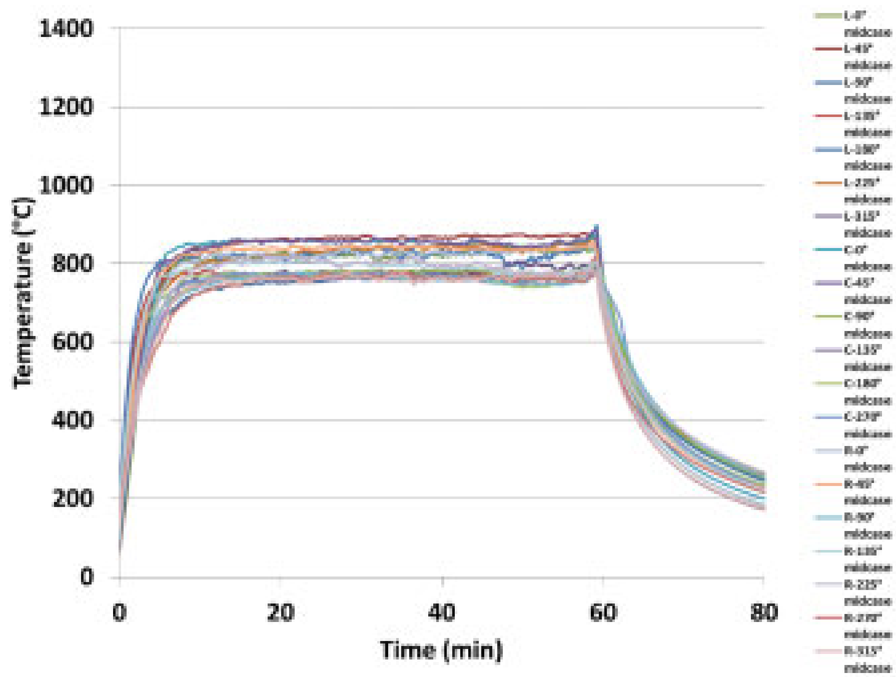


Figure 6-37: Thermocouple temperatures at outer cylinder stations (Test 1.3).

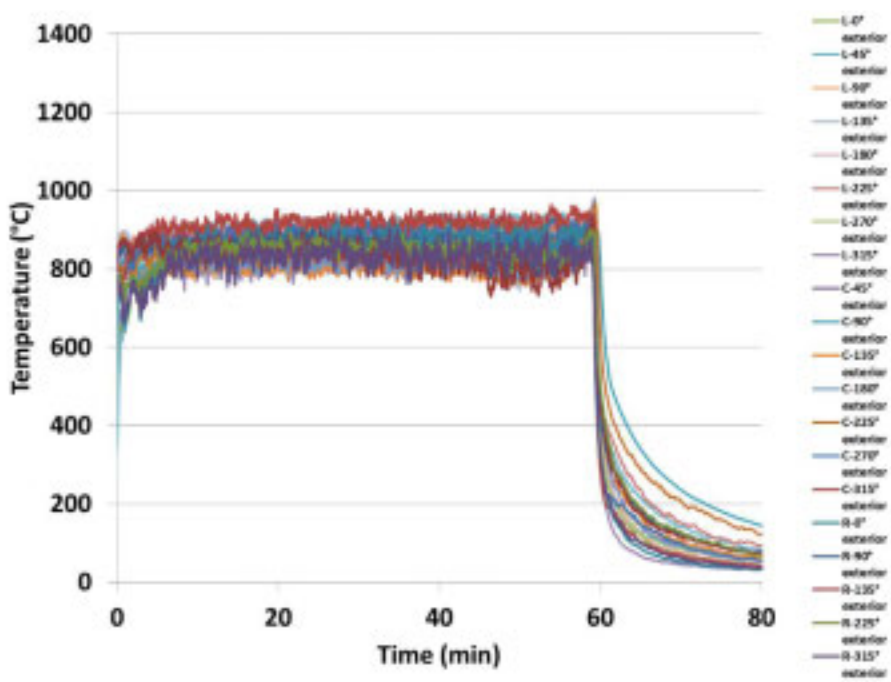


Figure 6-38: Thermocouple temperatures at exterior cylinder stations (Test 1.3).

6.1.3.7.1. Heat Flux to Calorimeter

Figure 6-39 and Figure 6-40 show the absorbed and total flux to the calorimeter, respectively.

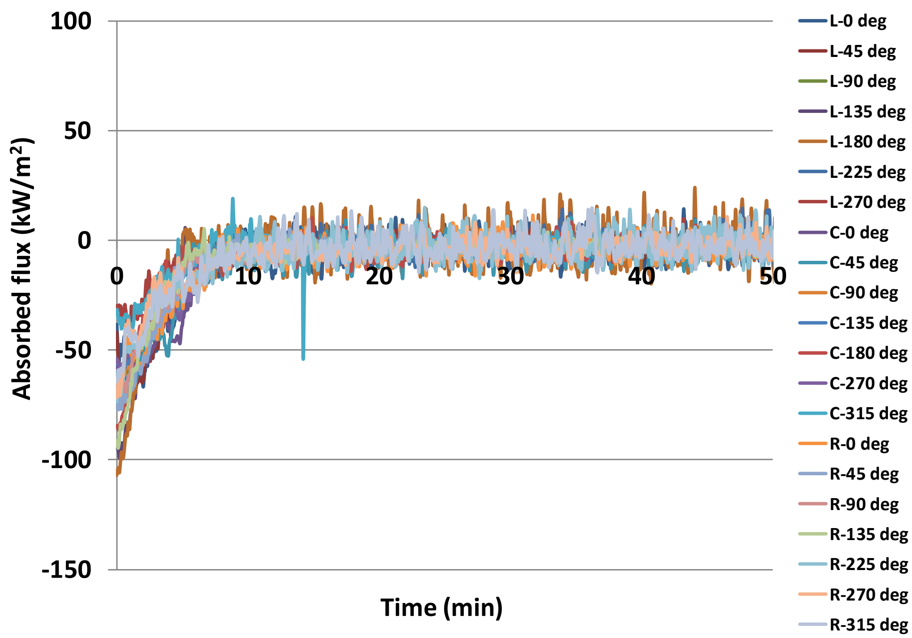


Figure 6-39: Absorbed heat flux to calorimeter (Test 1.3).

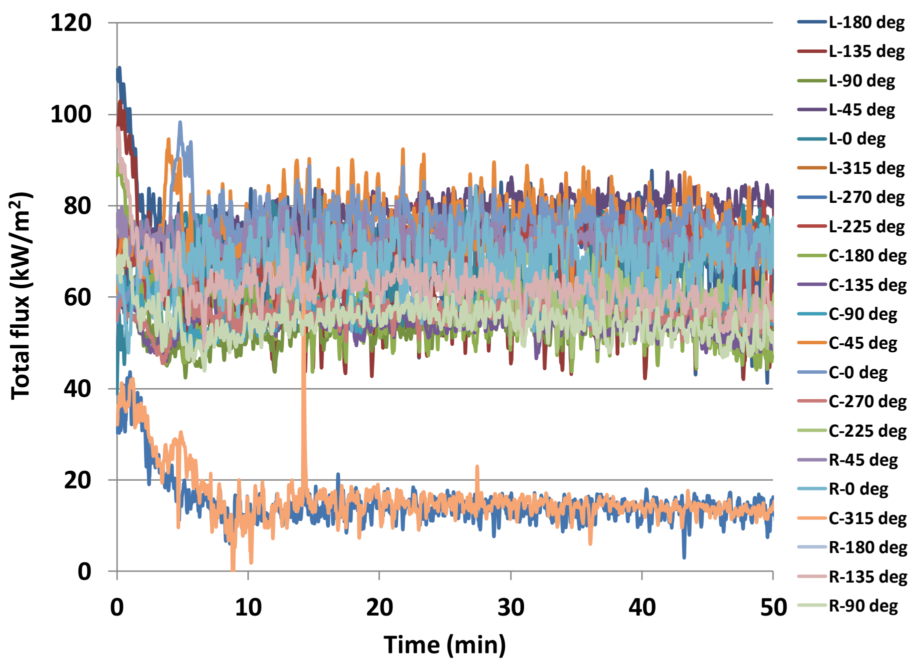


Figure 6-40: Total heat flux to calorimeter (Test 1.3).

6.1.3.8. Heat Release Rate

Figure 6-41 shows the heat release over time from CGA measurements. Before the fuel reached an average temperature of 58°C, the heat release rate averaged over 8-24 minutes is 5.0 ± 0.3 MW. After the fuel reached an average temperature of 58°C, the heat release rate averaged over 24-44 minutes is 5.4 ± 0.3 MW.

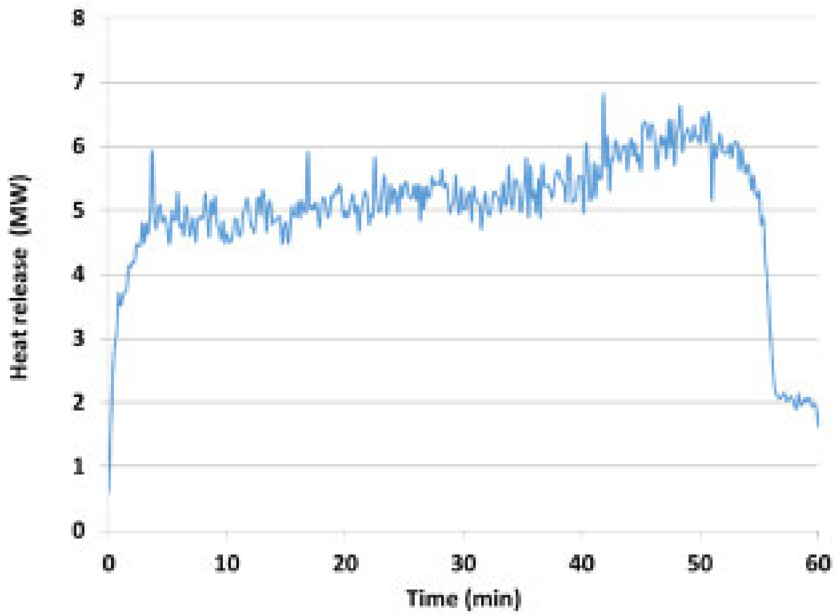
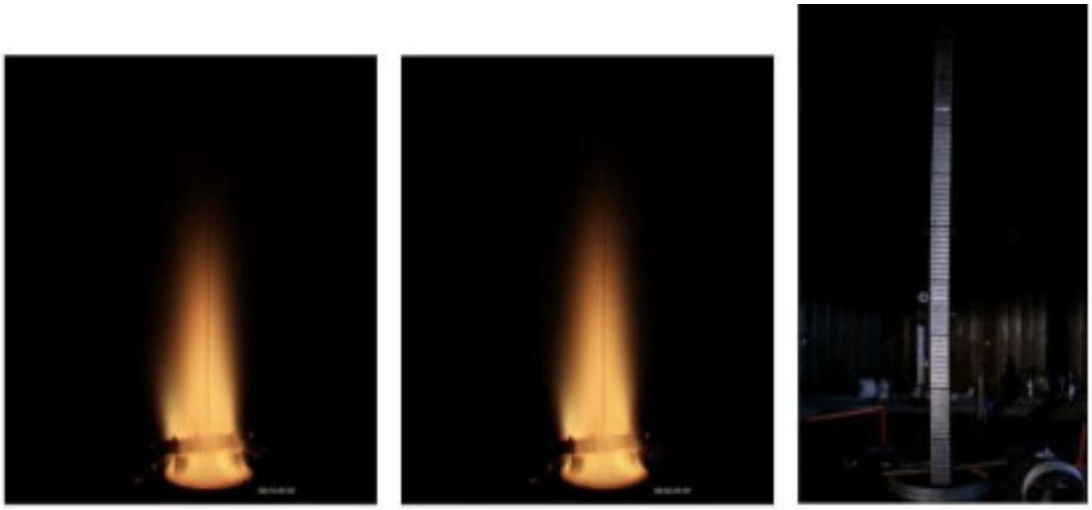


Figure 6-41: Heat release rate (Test 1.3).

6.1.3.9. Flame Height

Figure 6-42 shows images of the flame as averaged from clips taken from video coverage and compared to the stadia board to determine the average flame height. The average flame height is 5.5 m and 5.8 m, before and after the time when the fuel reached 58°C, respectively.



(a) (b) (c)

Figure 6-42: Time-averaged image (a) before fuel reached average temperature 58ºC (b) fuel reached average temperature 58ºC. (c) Flame height determined by stadia board marked with 1-m increments (Test 1.3).

6.2. Bakken Crude Oil Pool Fire Tests

Six 2-m Bakken crude oil pool fire tests were conducted. The propane torches were ignited before the fuel was released into the pan, rather than filling the pan with fuel to the desired level and then initiating the torches. This was done to minimize any light end vapor loss from the crude oil and to minimize the potential for an overpressure event. For all the tests (except Test 2.3), the burn rate was determined by readings from a scale that measured the weight of the water tote supplying water to the tanker. For Test 2.3, a flow meter designed for crude oils was used but malfunctioned. Thus, the burn rate was estimated by observing the level of the water in the tote before and after the test. After Test 2.3, it was then decided to place a scale under the water tote to determine the burn rate. The IR camera was used to determine the flame height. The field of view of the camera encompassed up to 7 m due to limitation of the radial distance of the test chamber and the camera lens. Thus, the data is clipped at that height, but is considered to not have a significant effect on the average flame height since the amount clipped is minor.

6.2.1. Test 2.1

For this test, the Bakken crude oil was maintained at a supply temperature of 21.0 ± 0.9°C. There was no calorimeter above the fuel pan. The duration of test was approximately 37 minutes, during which a constant fuel level of 1.1 inches (3 cm) was maintained. This level is slightly below that used for heptane but was chosen due to the previous experience with a boil-over event in FLAME involving a test for the DOE/DOT sponsor. This level was chosen to allow minimal clearance of the diffuser in the center of the pan. The intent of working with the minimal level was to prevent the fuel boiling over into the basement of FLAME by the ability to shorten the time required to drain the fuel into holding tanks underneath flame. The drain down allows for evacuation of the fuel in case of emergencies. After 37 minutes, the fuel supply was terminated, and the fuel was allowed to burn down.

6.2.1.1. Fuel Supply Temperature

Figure 6-43 provides the fuel supply temperature over time. The fuel supply temperature averaged over 5-35 minutes is 21.0 ± 0.9°C.

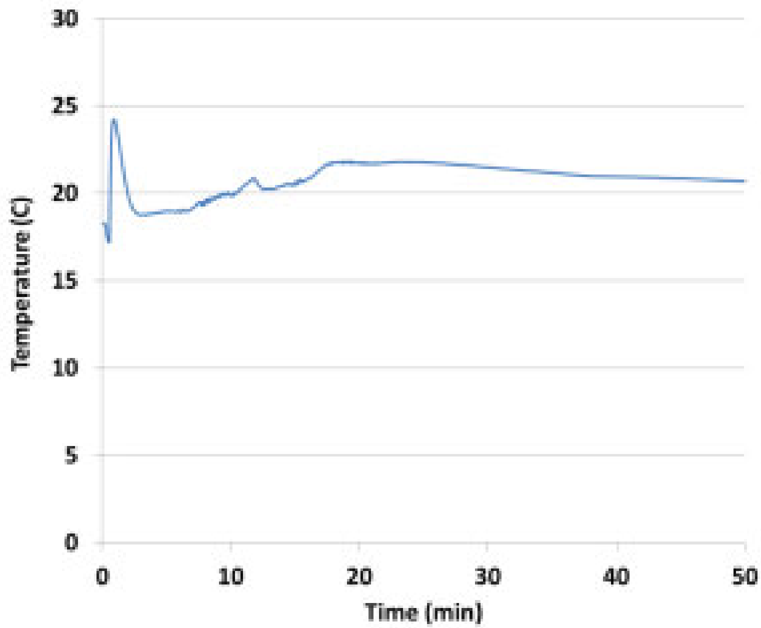


Figure 6-43: Temperature of fuel supply into pan (Test 2.1).

6.2.1.2. Fuel Rake Thermocouple Temperatures

Figure 6-44 shows temperatures from TCs within the liquid fuel. The fuel level was approximately 1.1 inches (2.8 cm) and was held constant over the duration of the test.

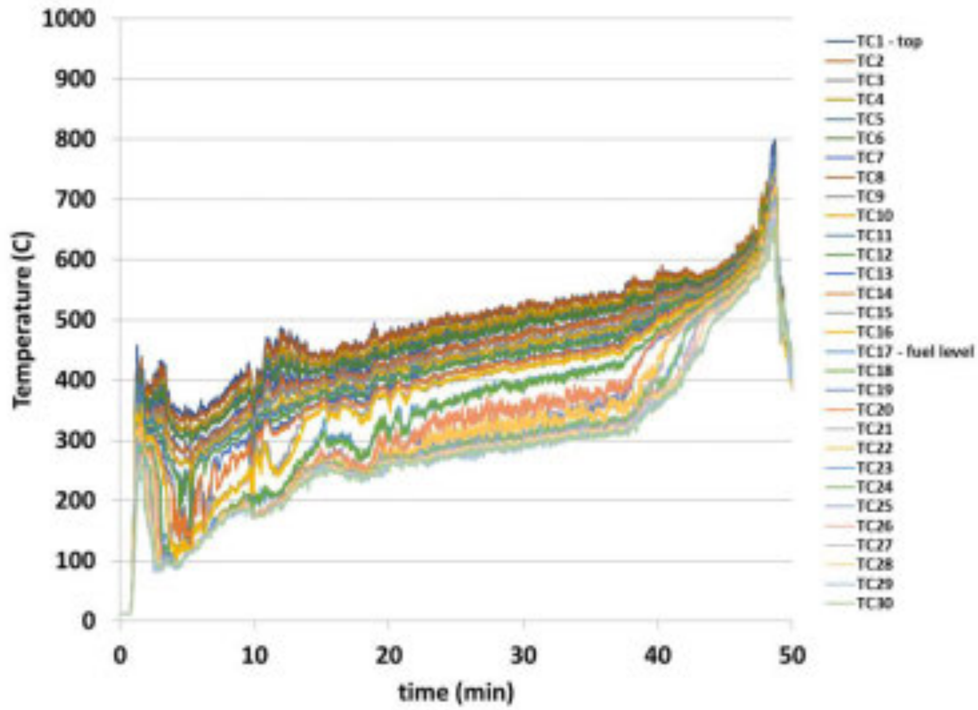


Figure 6-44: Fuel rake thermocouple temperatures (Test 2.1).

6.2.1.3. Burn Rate

Figure 6-45 provides the scale readings over time. The slope of the equation fitted to the data during a steady-state duration (red line) allows for the burn rate to be determined. The slope of 7.0179 kg/min ($r^2 = 99\%$) corresponds to a burn rate of 0.030 kg/m^2s.

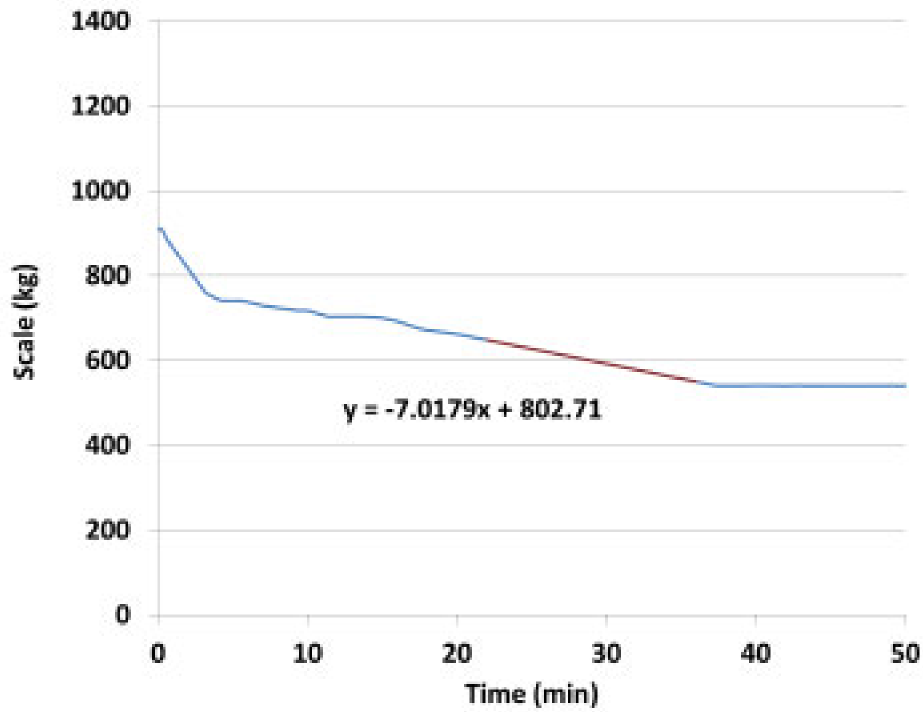


Figure 6-45: Fuel weight over time based on scale measurement (Test 2.1).

6.2.1.4. Radiometers

Figure 6-46 and Figure 6-47 provide the heat flux over time from six narrow-angle and five wide-angle radiometers at the various height locations.

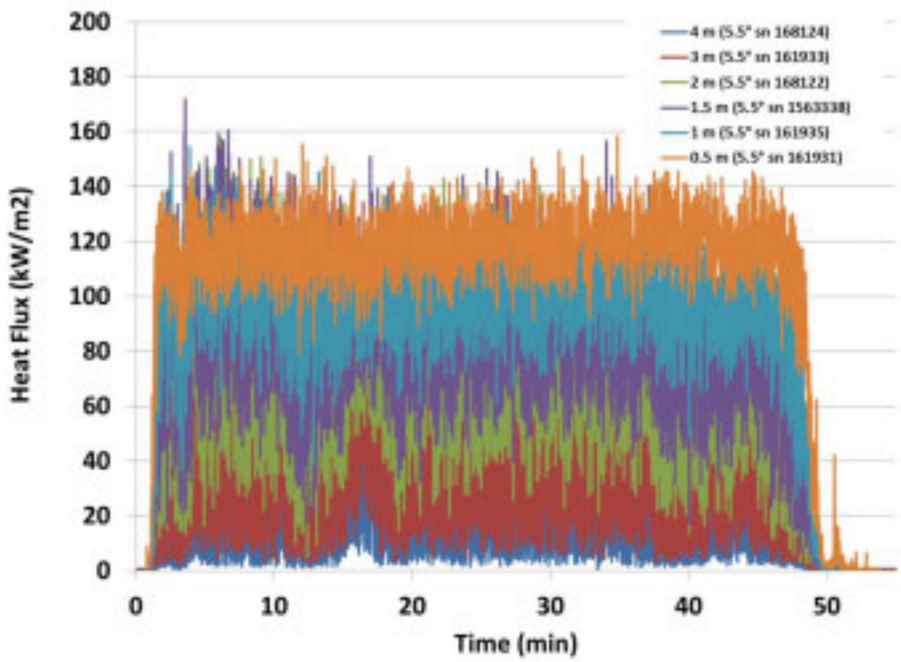


Figure 6-46: Heat flux measurement from narrow view radiometers at different heights (Test 2.1).

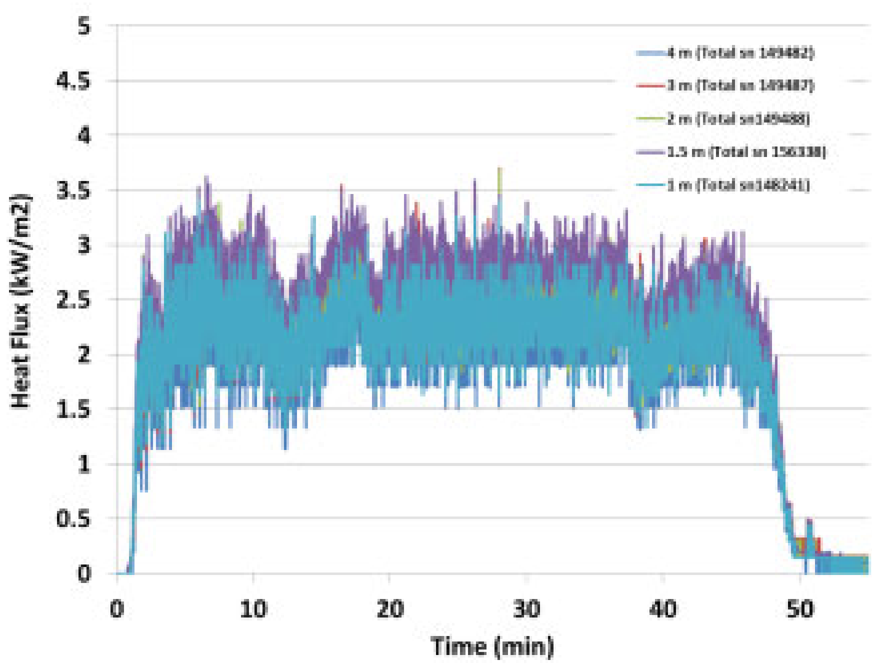


Figure 6-47: Heat flux measurement from wide view radiometers at different heights (Test 2.1).

6.2.1.5. Thermocouple Rake in the Fire Plume

Figure 6-48 provides temperature measurements over time from the TCs placed within the fire plume at its vertical centerline.

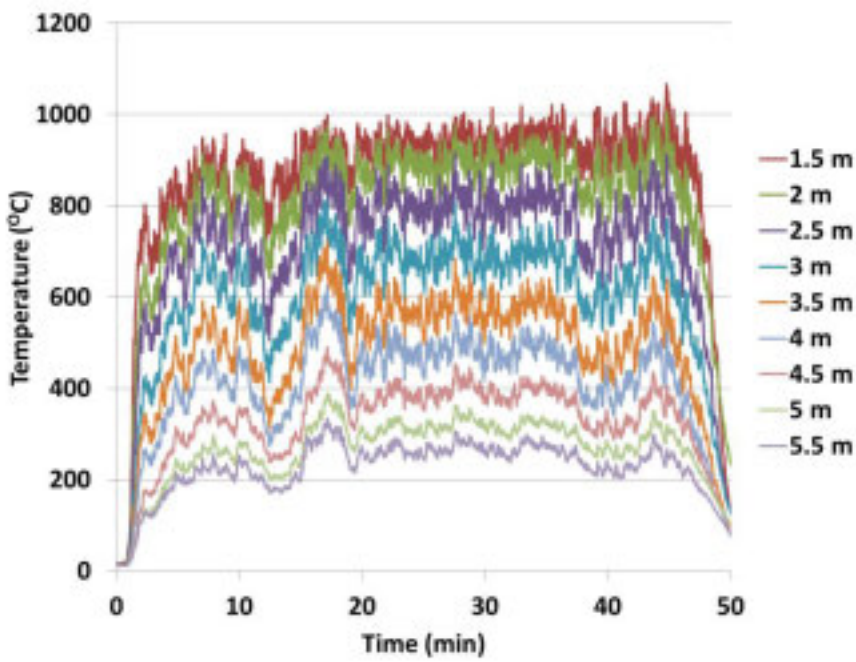


Figure 6-48: Temperature measurements from vertical thermocouple rake in centerline of fire plume (Test 2.1).

6.2.1.6. Plume Temperatures and Surface Emissive Power

Figure 6-49 provides surface temperatures of the fire plume and surface emissive power taken from IR camera measurements.

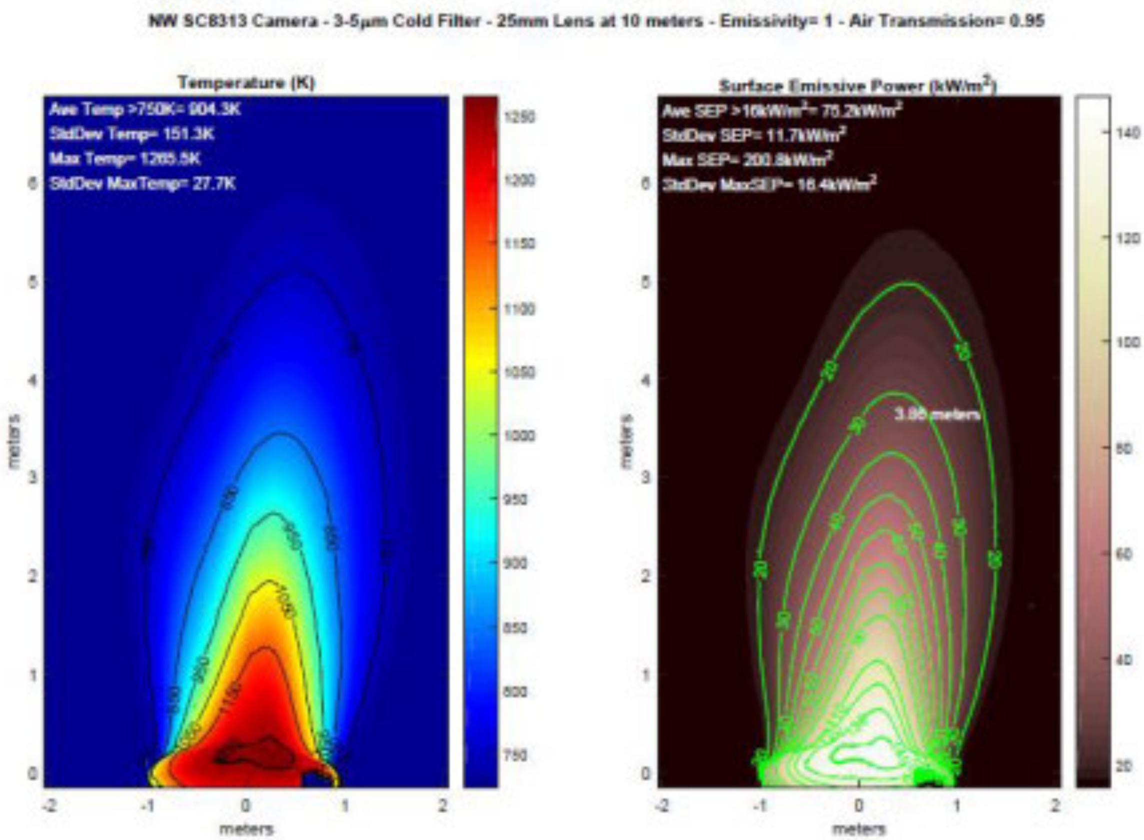


Figure 6-49: Fire plume temperatures and surface emissive power values from IR camera measurements (Test 2.1).

6.2.1.7. DFT TC Temperatures and Derived Heat Flux

Figure 6-50 and Figure 6-51 provide DFT temperatures and heat flux, respectively. The term 'front' refers to the TC measurement for the plate closest to the fire, while the term 'back' refers to the TC measurement for the plate furthest from the fire.

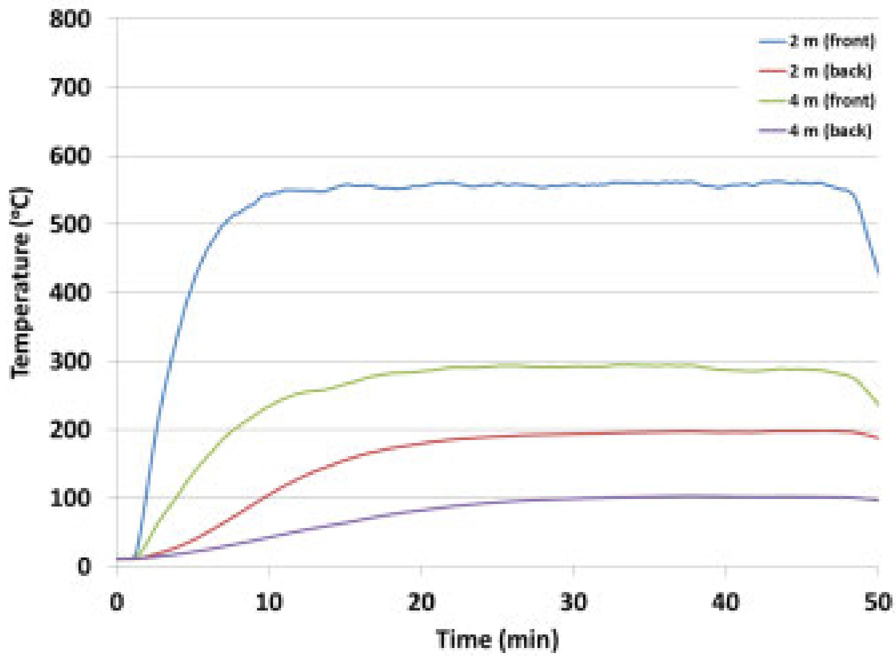


Figure 6-50: Thermocouple temperatures from DFT instruments. Distances are from center of pan (Test 2.1).

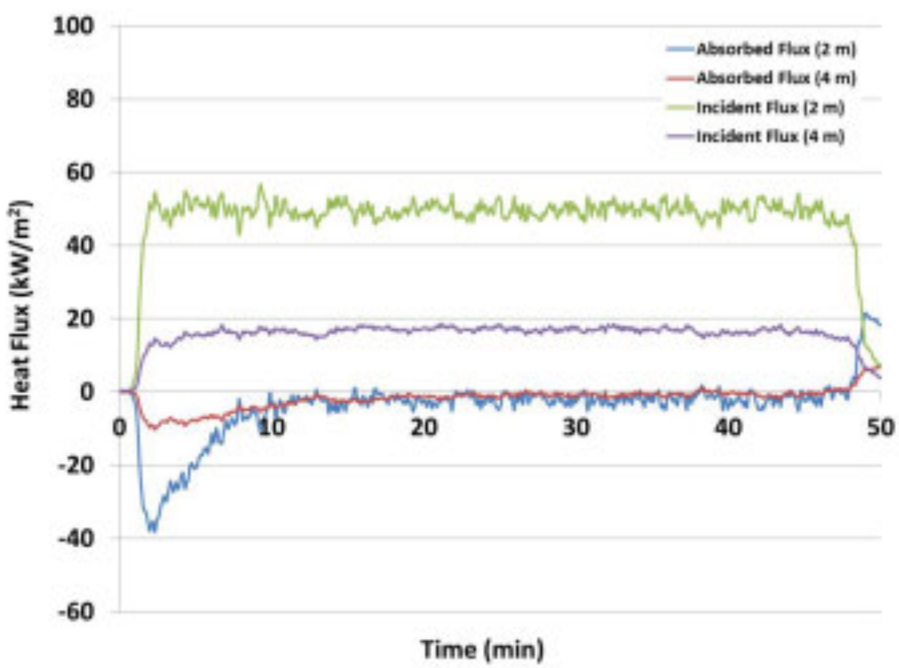


Figure 6-51: Derived heat flux values from DFT measurements. Distances are from center of pan (Test 2.1).

6.2.1.8. Heat Release Rate

Figure 6-52 shows the heat release over time from CGA measurements. The average heat release rate, taken between 22-32 minutes, is 4.8 ± 0.9 MW.

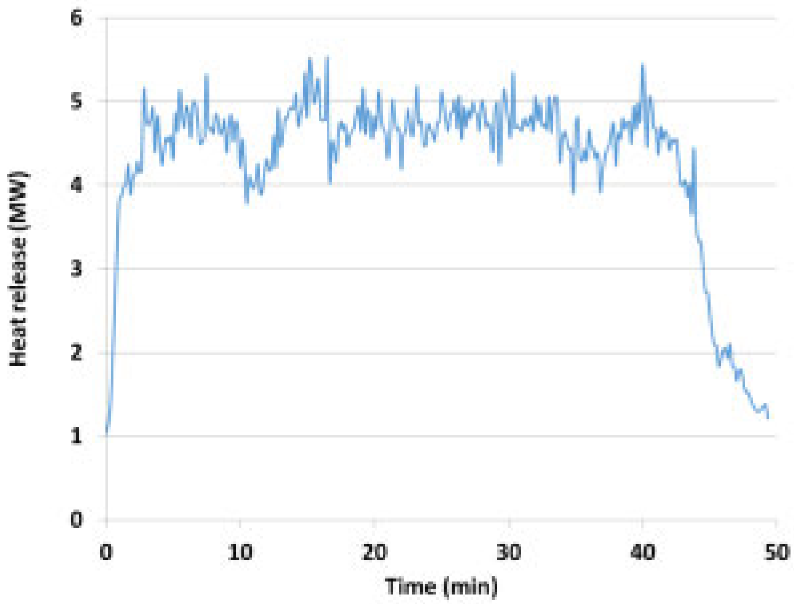


Figure 6-52: Heat release rate (Test 2.1).

6.2.1.9. Flame Height

Figure 6-53 shows the flame height as measured from the IR camera. The flame height averaged over 10 to 20 minutes is 4.5 ± 1.1 m.

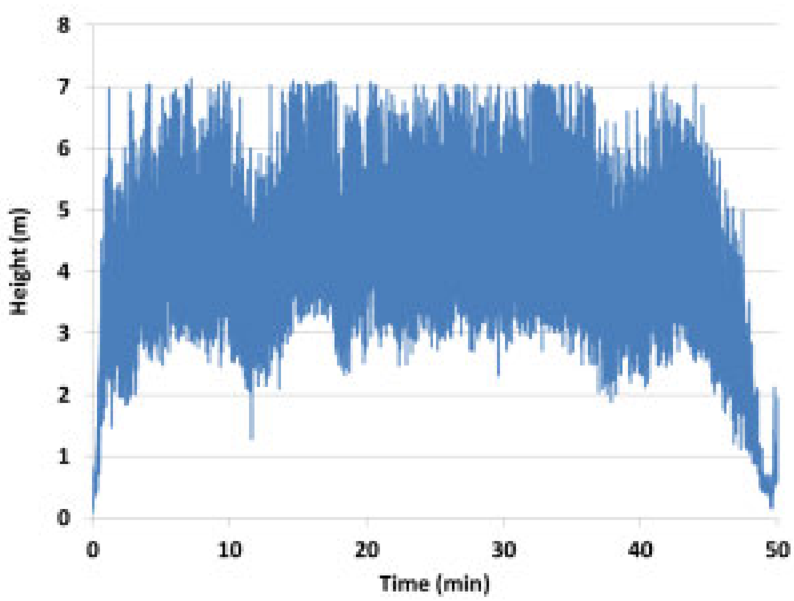


Figure 6-53: Flame height from IR camera measurements (Test 2.1).

6.2.2. *Test 2.2*

For this test, the Bakken crude oil was maintained at a supply temperature of 21.7 ± 0.5ºC. The calorimeter was elevated 0.5 m from its centerline to the bottom of the fuel pan. The original intent was to have the calorimeter just above the fuel surface; however, the calorimeter could not fit within the 12-in lip pan. Thus, the calorimeter was placed above the lip by about 2 inches to provide a total distance of 0.5 m from the calorimeter's centerline to the bottom of the pan. The duration of test was approximately 40 minutes, during which a constant fuel level of 1.1 inches (3 cm) was maintained. After 40 minutes, the fuel supply was terminated, and the fuel was allowed to burn down.

6.2.2.1. Fuel Supply Temperature

Figure 6-54 provides the fuel supply temperature over time. The temperature averaged over 10-40 minutes is 21.7 ± 0.5ºC.

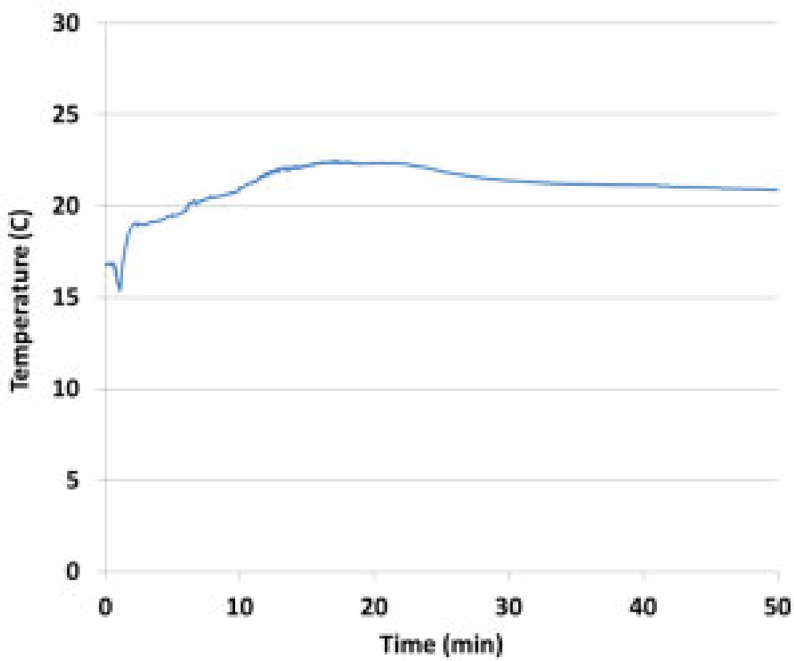


Figure 6-54: Temperature of fuel supply into pan (Test 2.2).

6.2.2.2. Fuel Rake Thermocouple Temperatures

Figure 6-55 shows temperatures from TC within the liquid fuel. The fuel level was approximately 1.1 inches (3 cm) and was held constant over the duration of the test.

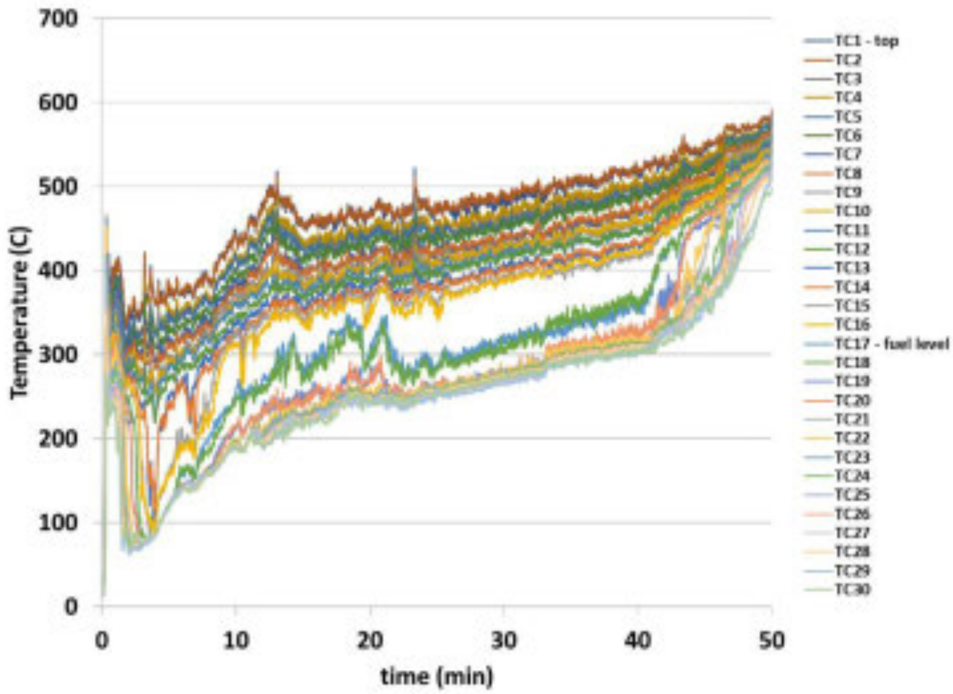


Figure 6-55: Fuel rake thermocouple temperatures (Test 2.2).

6.2.2.3. Burn Rate

Figure 6-56 provides the scale readings over time. The slope of the equation fitted to the data (red line) allows for the burn rate to be determined. A slope of 5.9333 kg/min ($r^2 = 99\%$) corresponds to a burn rate of 0.026 kg/m^{2}s.

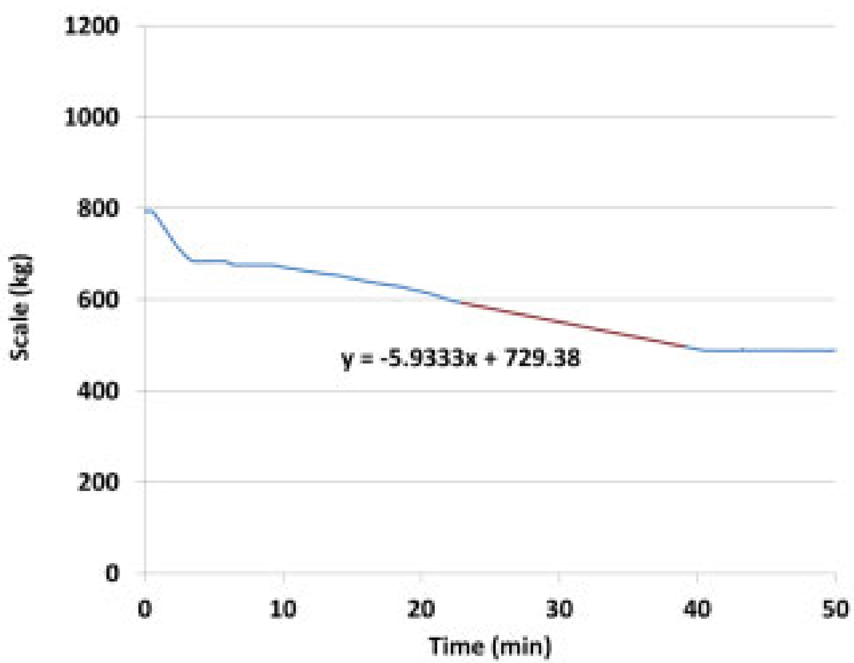


Figure 6-56: Fuel weight over time based on scale measurement (Test 2.2).

6.2.2.4. Radiometers

Figure 6-57 and Figure 6-58 provide the heat flux over time from six narrow-angle and five wide-angle radiometers at the various height locations.

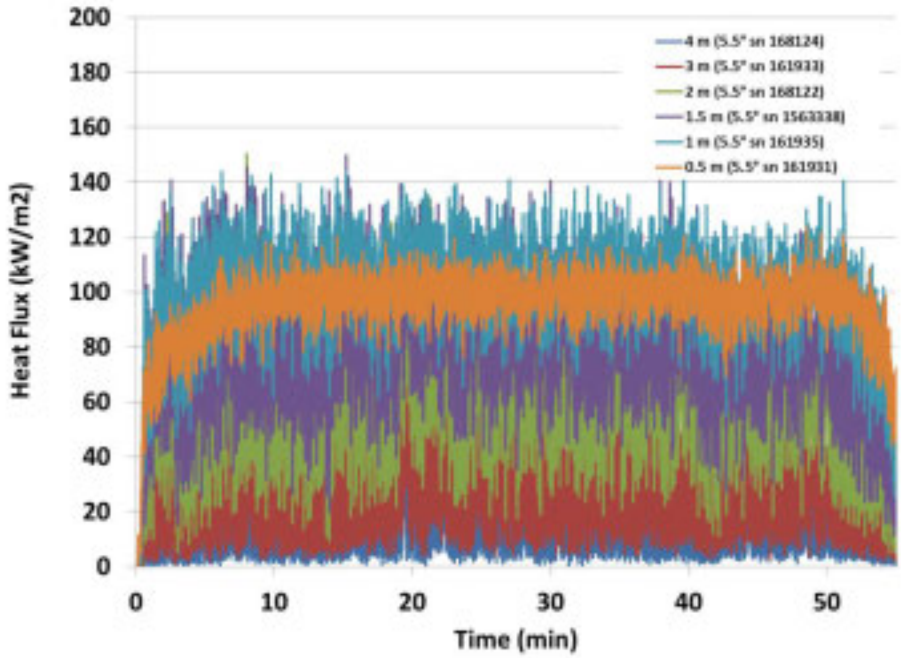


Figure 6-57: Heat flux measurement from narrow view radiometers at different heights (Test 2.2).

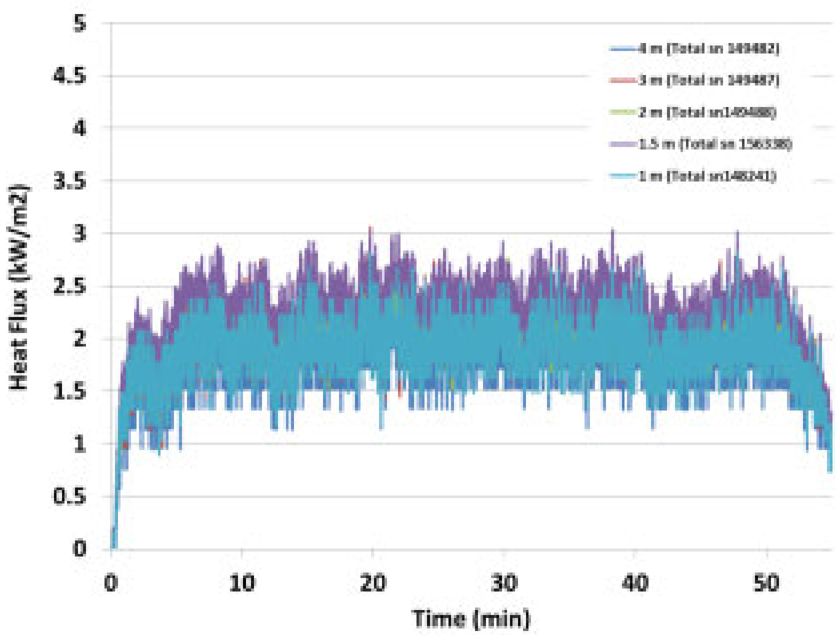


Figure 6-58: Heat flux measurement from wide view radiometers at different heights (Test 2.2).

6.2.2.5. Thermocouple Rake in the Fire Plume

Figure 6-59 provides temperature measurements over time from the TCs placed within the fire plume at its vertical centerline.

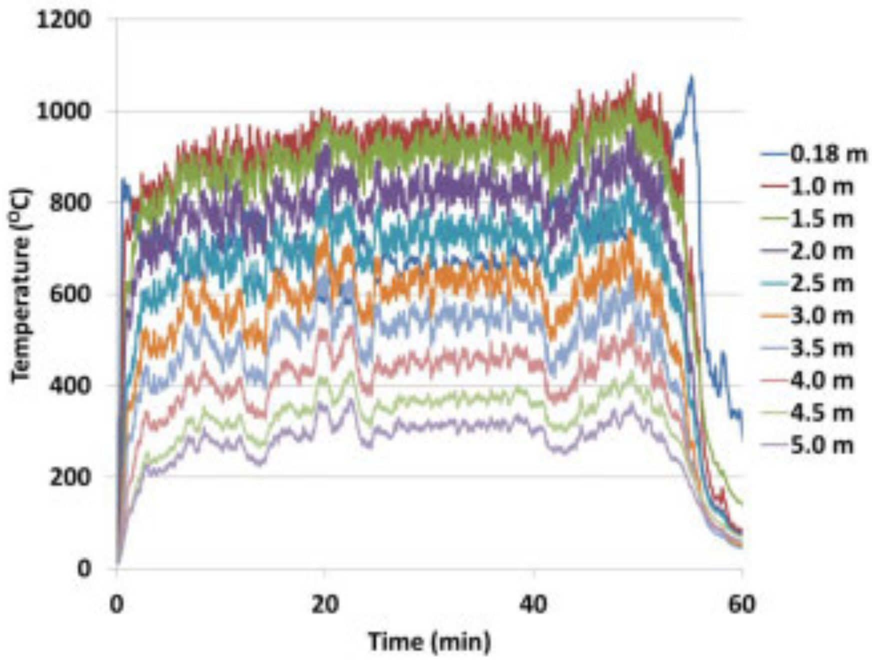


Figure 6-59: Temperature measurements from vertical thermocouple rake in centerline of fire plume (Test 2.2).

6.2.2.6. Plume Temperatures and Surface Emissive Power

Figure 6-60 provides surface temperatures of the fire plume and surface emissive power taken from IR camera measurements.

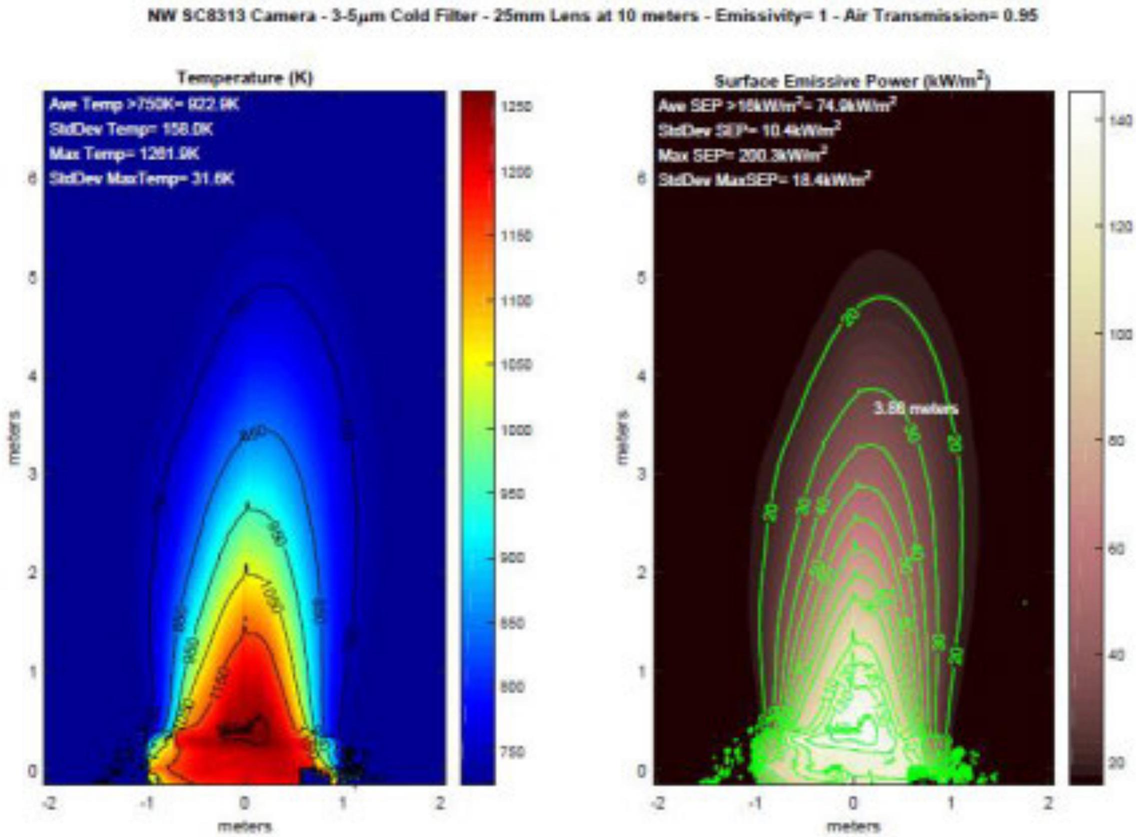


Figure 6-60: Fire plume temperatures and surface emissive power values from IR camera measurements (Test 2.2).

6.2.2.7. DFT TC Temperatures and Derived Heat Flux

Figure 6-61 and Figure 6-62 provide DFT temperatures and heat flux, respectively. The term 'front' refers to the TC measurement for the plate closest to the fire, while the term 'back' refers to the TC measurement for the plate furthest from the fire.

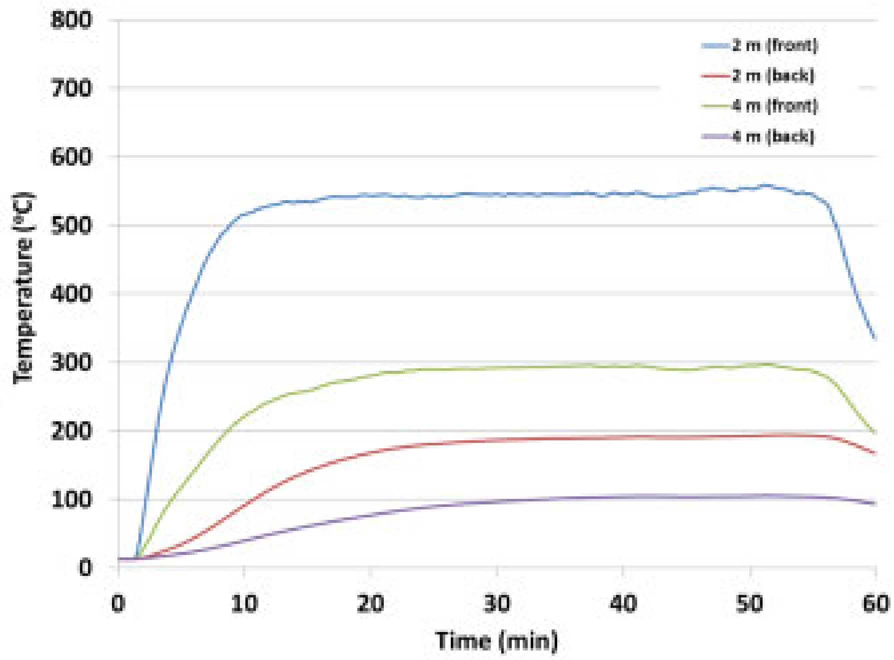


Figure 6-61: Thermocouple temperatures from DFT instruments. Distances are from center of pan (Test 2.2).

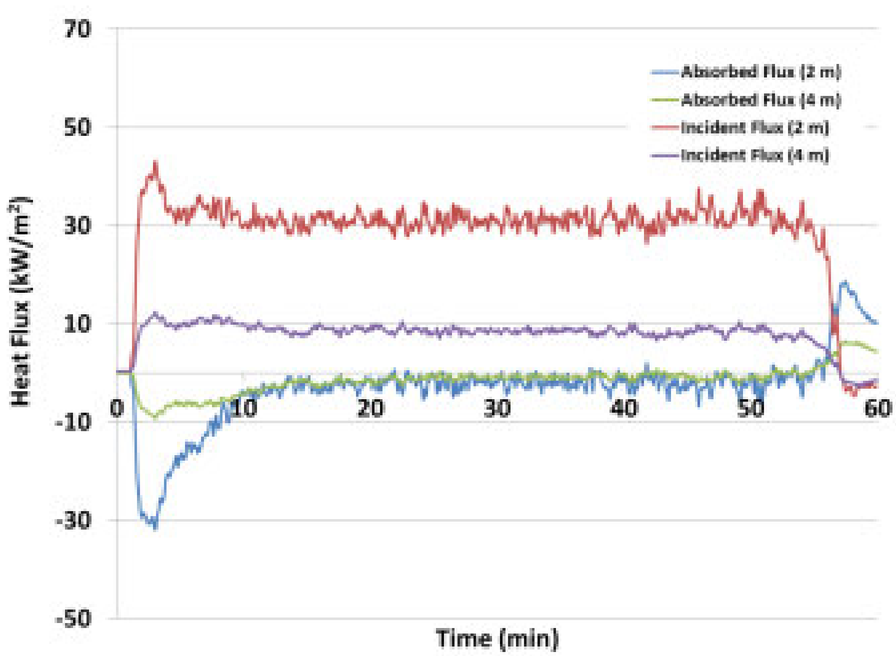


Figure 6-62: Derived heat flux values from DFT measurements. Distances are from center of pan (Test 2.2).

6.2.2.8. Calorimeter TC Temperature and Derived Heat Flux

Figure 6-63 through Figure 6-65 provide temperatures over time from TC measurements placed on the inner and outer cylinders, as well as external to the calorimeter. There were seven TCs that failed for Test 2.2 and include L-180° (inner), R-0° (inner), R-225° (inner), L-0° (outer), L-45° (outer), C-90° (exterior), and R-0° (exterior).

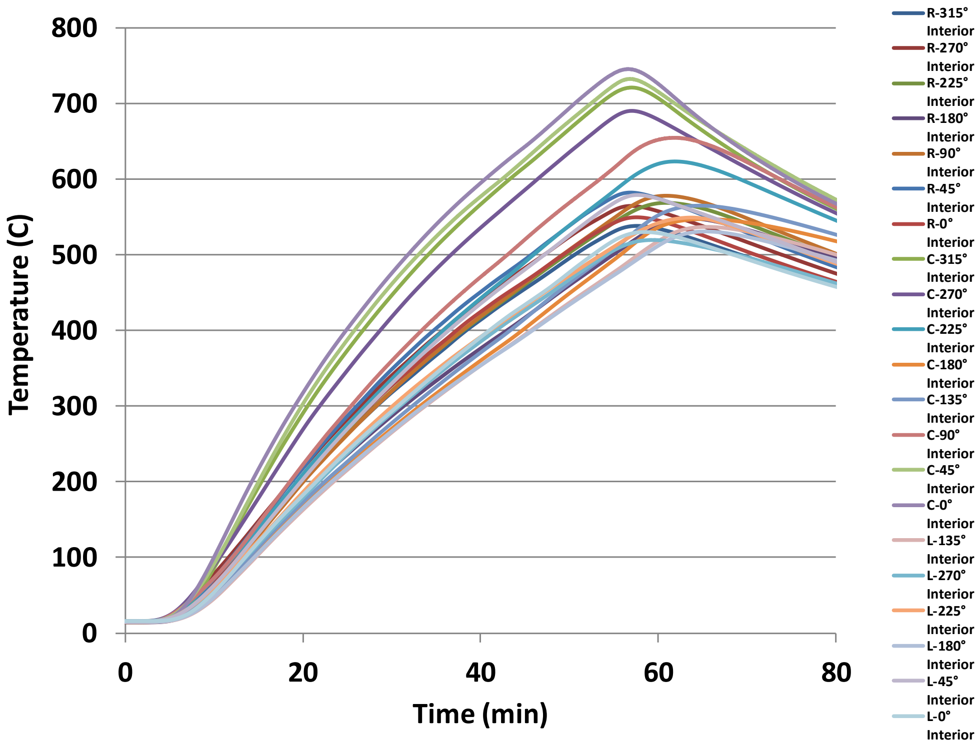


Figure 6-63: Thermocouple temperatures at inner cylinder stations (Test 2.2).

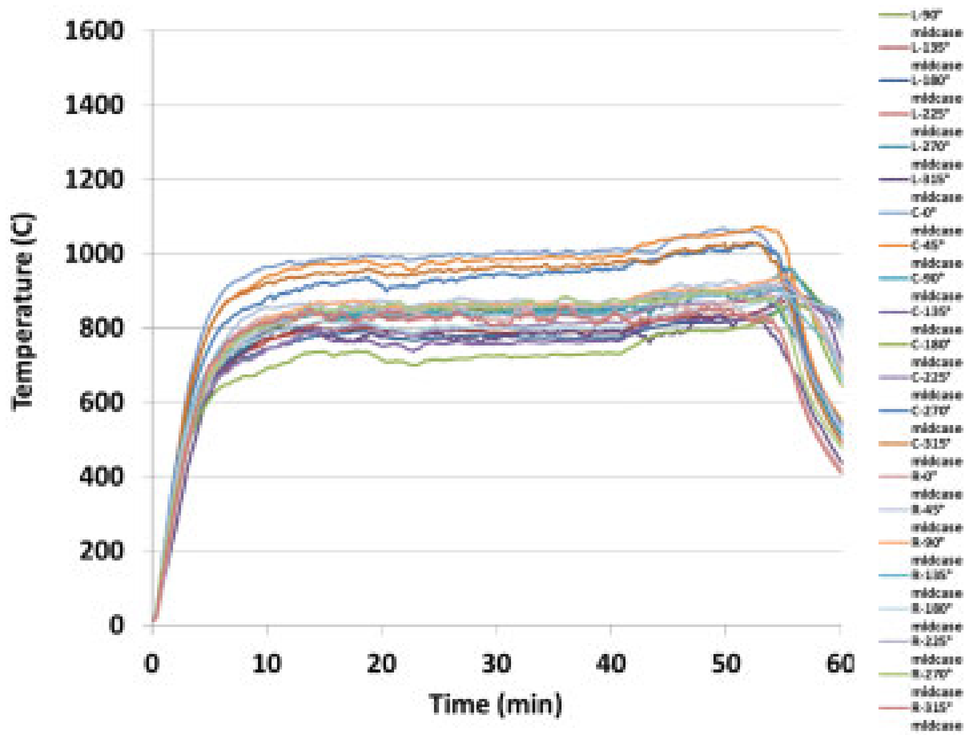


Figure 6-64: Thermocouple temperatures at outer cylinder stations (Test 2.2).

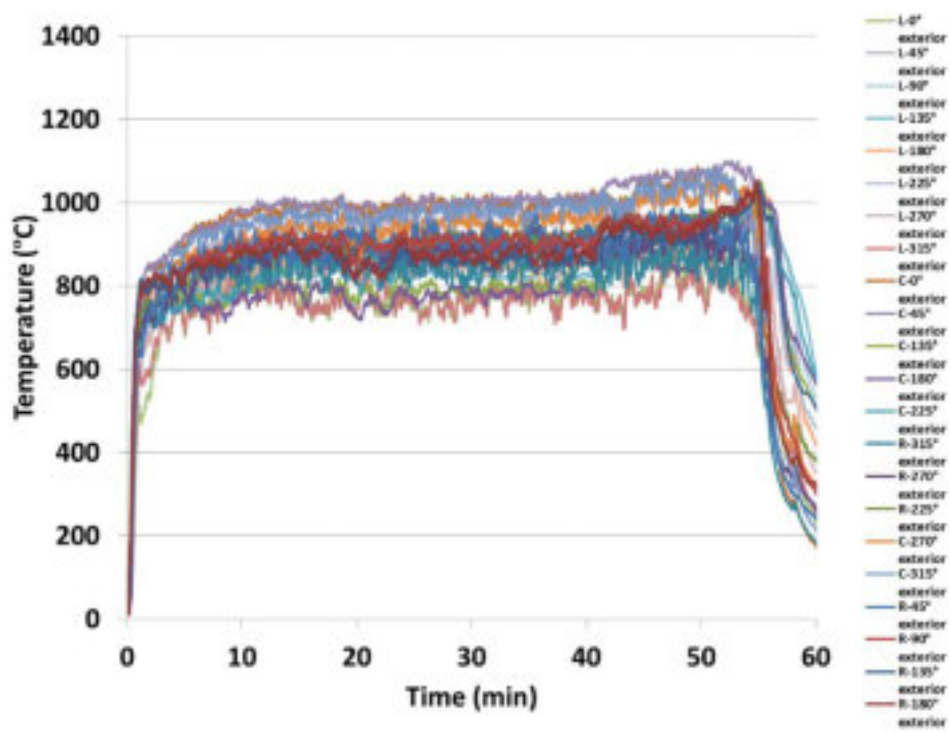


Figure 6-65: Thermocouple temperatures at exterior cylinder stations (Test 2.2).

6.2.2.8.1. *Heat Flux to Calorimeter*

Figure 6-66 and Figure 6-67 show the absorbed and total flux to the calorimeter, respectively.

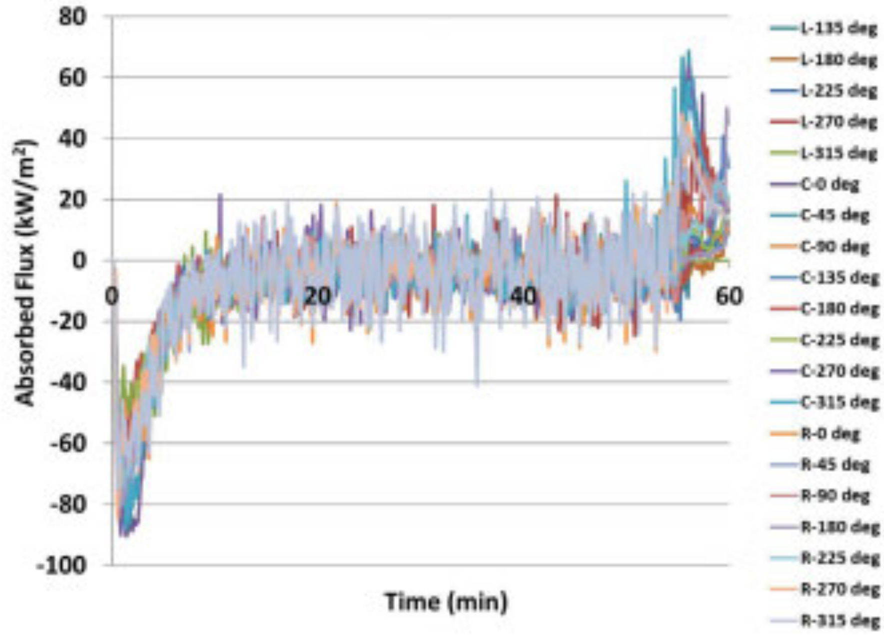


Figure 6-66: Absorbed heat flux to calorimeter (Test 2.2).

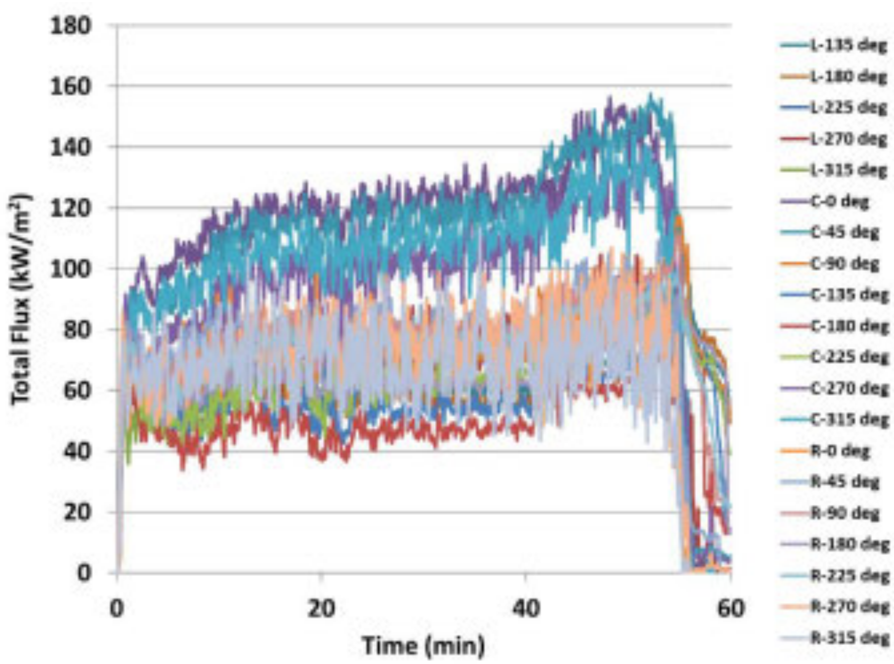


Figure 6-67: Total heat flux to calorimeter (Test 2.2).

6.2.2.9. Heat Release Rate

Figure 6-68 shows the heat release over time from CGA measurements. The average heat release rate, taken between 15-30 minutes, is 3.5 ± 0.7 MW.

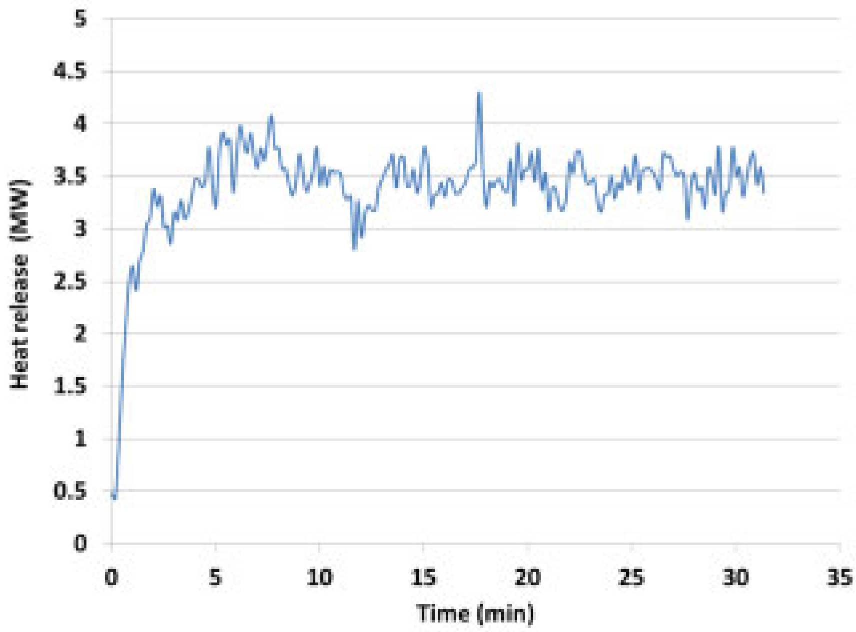


Figure 6-68: Heat release rate (Test 2.2).

6.2.2.10. Flame Height

Figure 6-69 shows the flame height as measured from the IR camera. The flame height averaged over 10 to 20 minutes is 4.25 ± 1.03 m.

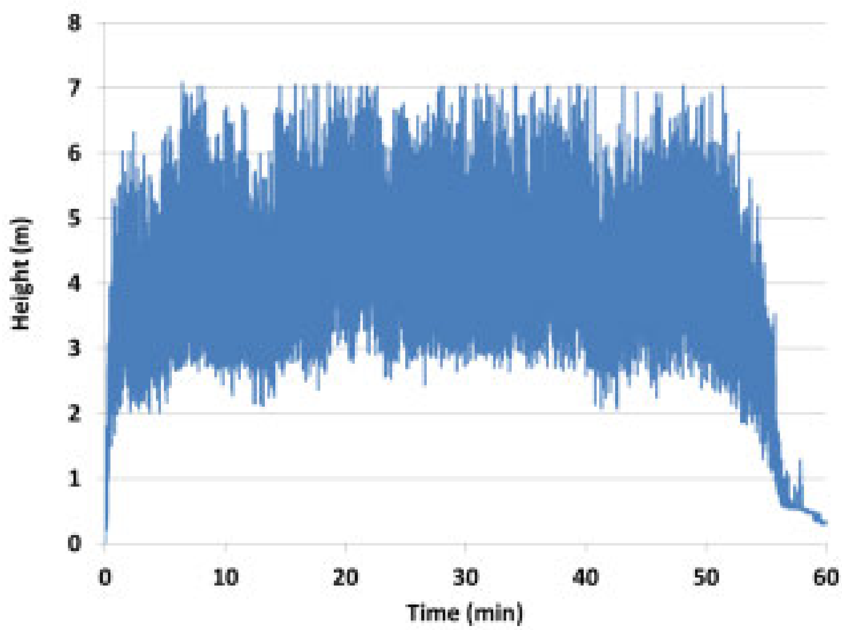


Figure 6-69: Flame height from IR camera measurements (Test 2.2).

6.2.3. Test 2.3

For this test, the Bakken crude oil was maintained at a supply temperature of 22.2 ± 0.5ºC. The calorimeter was elevated 1 m from its centerline to the bottom of the fuel pan. The duration of test was approximately 33 minutes, during which a constant fuel level of 1.1 inches (3 cm) was maintained. After 33 minutes, the fuel supply was terminated, and the fuel was allowed to burn down.

6.2.3.1. Fuel Supply Temperature

Figure 6-70 provides the fuel supply temperature over time. The fuel supply temperature averaged over 10-30 minutes is 22.2 ± 0.5ºC.

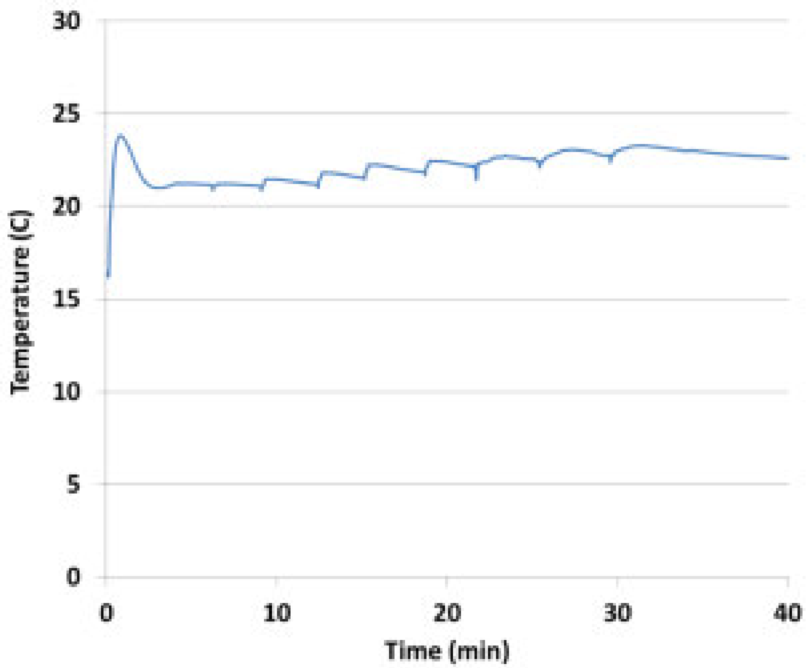


Figure 6-70: Temperature of fuel supply into pan (Test 2.3).

6.2.3.2. Fuel Rake Thermocouple Temperatures

Figure 6-71 shows temperatures from TCs within the liquid fuel. The fuel level was approximately 1.1 inches (2.8 cm) and was held constant over the duration of the test.

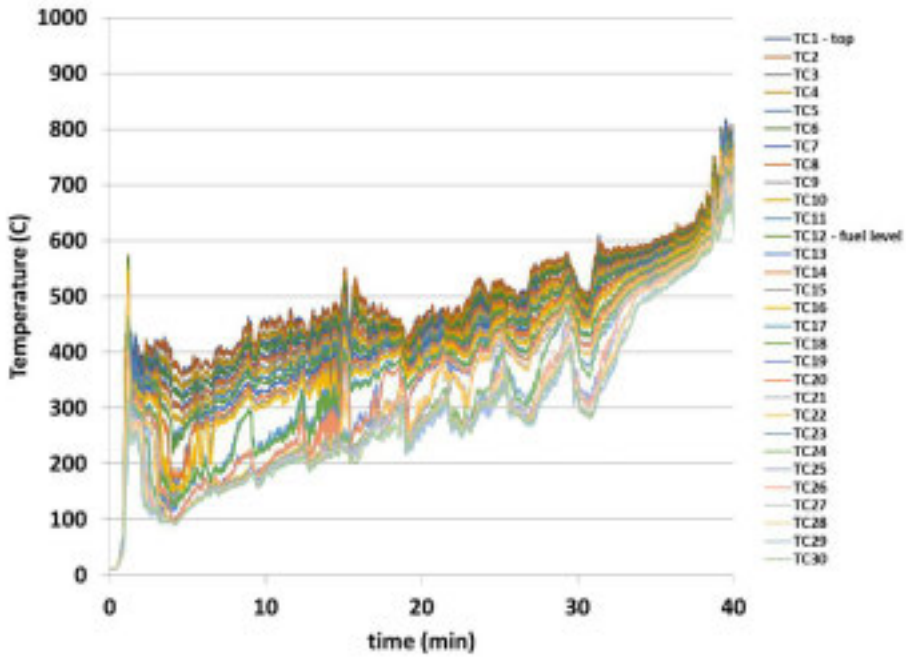


Figure 6-71: Fuel rake thermocouple temperatures (Test 2.3).

6.2.3.3. Burn Rate

A flow meter was used for this test but failed to provide reliable readings. Thus, to determine an estimate of the burn rate, the water level in the 275-gallon tote was noted before and after the test to determine the volume of water that was pushed into the tanker. The level decreased by about 0.3 times the height of the tote, which corresponds to 82.5 gallons (312 L). There were 23.2 gallons (87.8 L) of fuel remaining in the pan once the water pump was turned off, and 6 gallons of oil remaining in the fuel line. Subtracting these two volumes from 82.5 gallons (312 L) results in 53.3 gallons (201.7 L) of oil, which took about 32 minutes to burn. This corresponds to a burn rate of 0.027 kg/m^2s.

6.2.3.4. Radiometers

Figure 6-72 and Figure 6-73 provide the heat flux over time from six narrow-angle and five wide-angle radiometers at the various height locations.

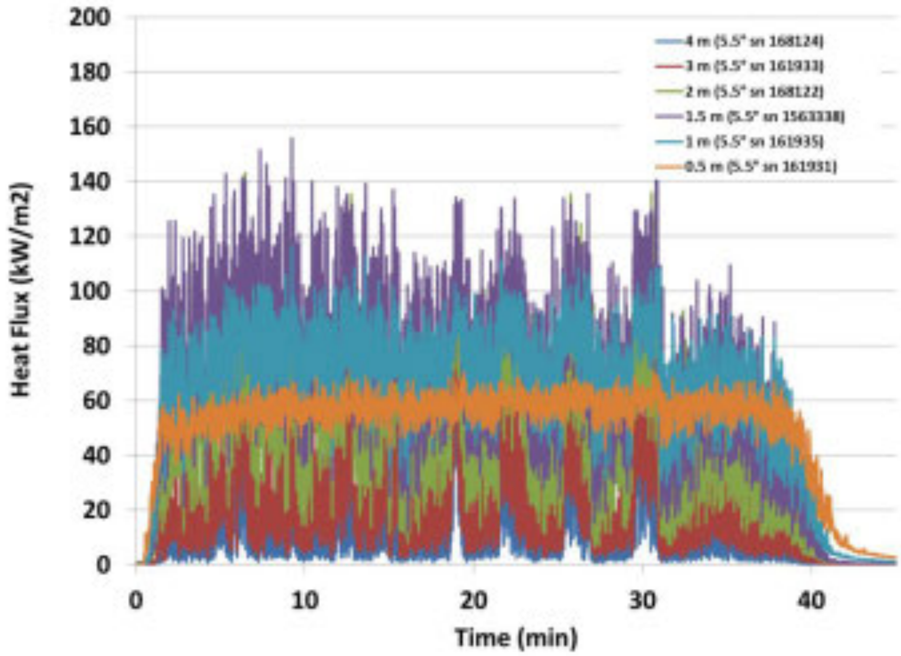


Figure 6-72: Heat flux measurement from narrow view radiometers at different heights (Test 2.3).

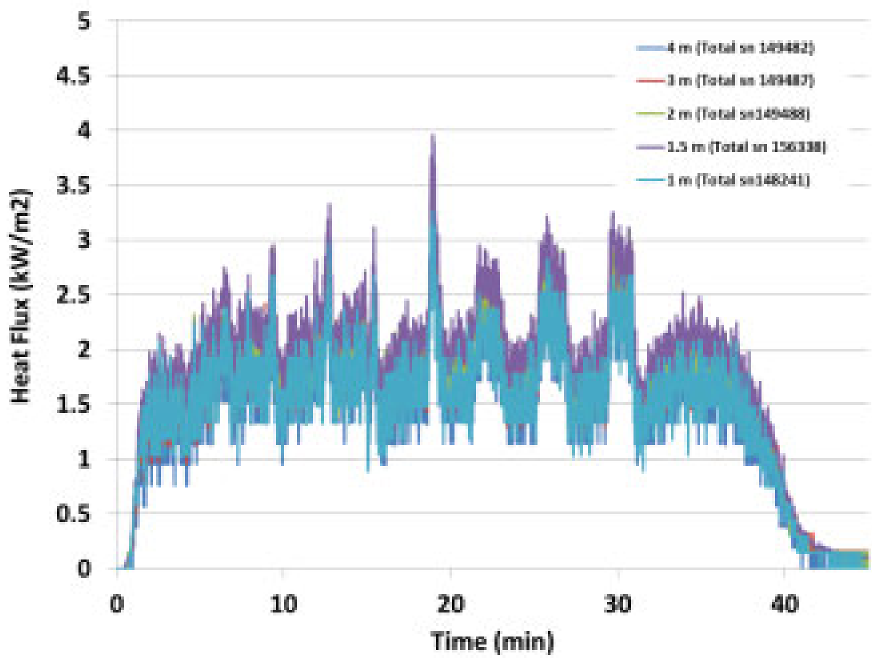


Figure 6-73: Heat flux measurement from wide view radiometers at different heights (Test 2.3).

6.2.3.5. Thermocouple Rake in the Fire Plume

Figure 6-74 provides temperature measurements over time from the TCs placed within the fire plume at its vertical centerline.

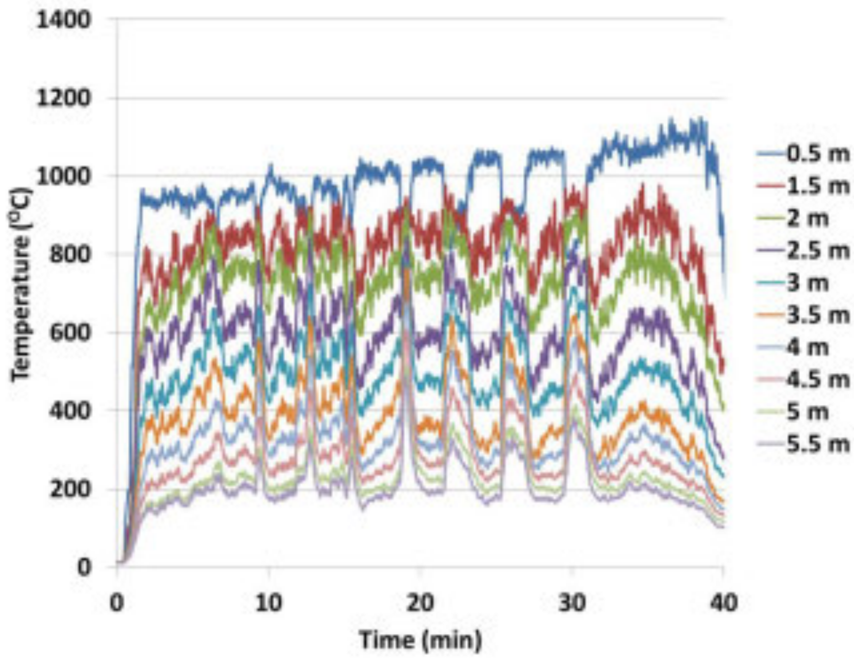


Figure 6-74: Temperature measurements from vertical thermocouple rake in centerline of fire plume (Test 2.3).

6.2.3.6. Plume Temperatures and Surface Emissive Power

Figure 6-75 provides surface temperatures of the fire plume and surface emissive power taken from IR camera measurements.

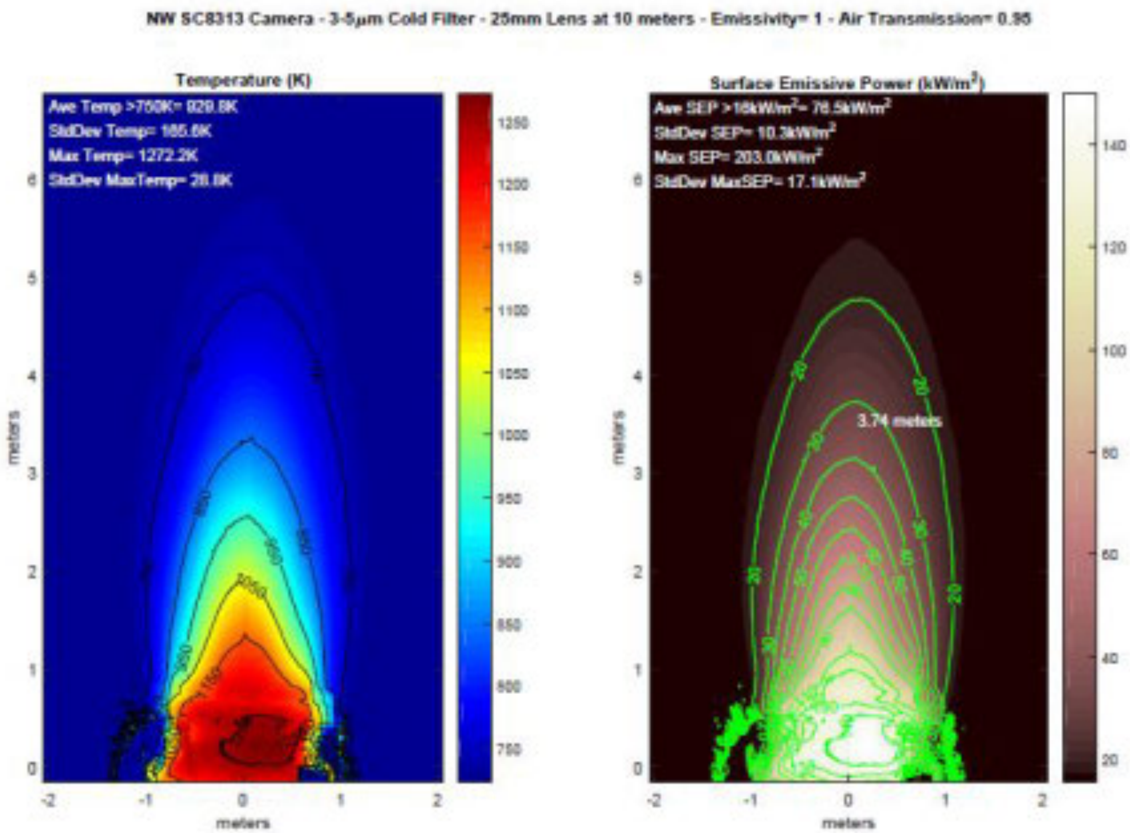


Figure 6-75: Fire plume temperatures and surface emissive power values from IR camera measurements (Test 2.3).

6.2.3.7. DFT TC Temperatures and Derived Heat Flux

Figure 6-76 and Figure 6-77 provide DFT temperatures and heat flux, respectively. The term 'front' refers to the TC measurement for the plate closest to the fire, while the term 'back' refers to the TC measurement for the plate furthest from the fire.

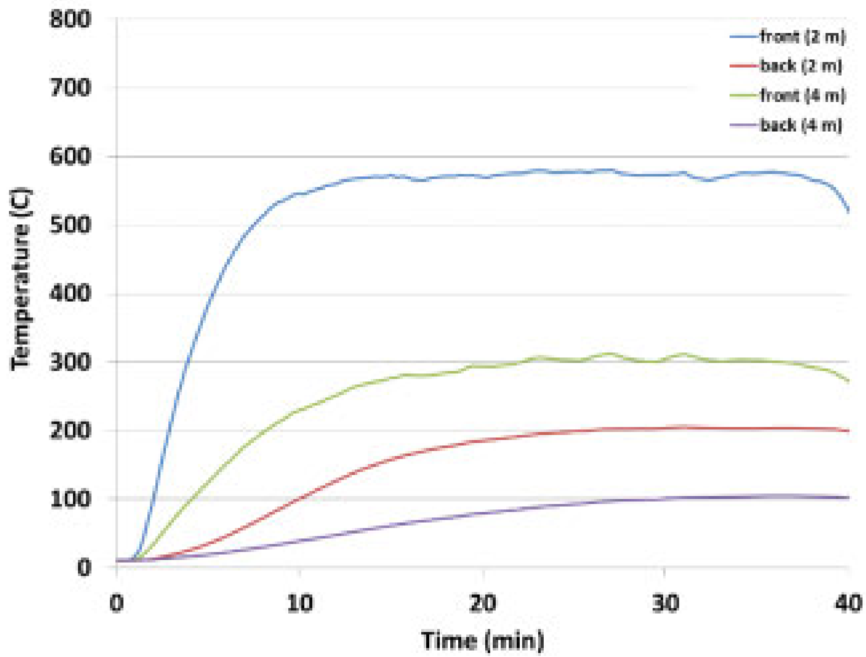


Figure 6-76: Thermocouple temperatures from DFT instruments. Distances are from center of pan (Test 2.3).

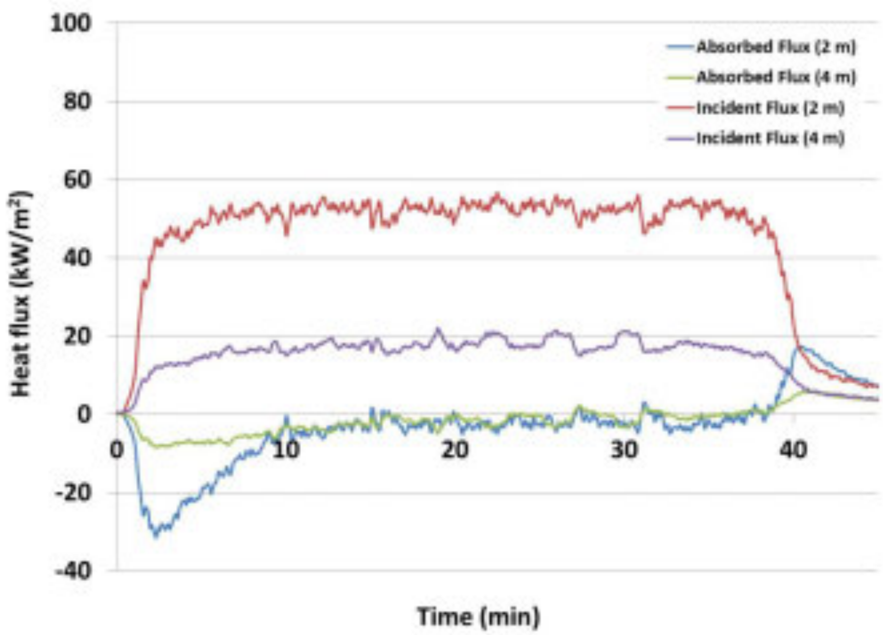


Figure 6-77: Derived heat flux values from DFT measurements. Distances are from center of pan (Test 2.3).

6.2.3.8. Calorimeter TC Temperature and Derived Heat Flux

Figure 6-78 through Figure 6-80 provide temperatures over time from TC measurements placed on the inner and outer cylinders, as well as external to the calorimeter.

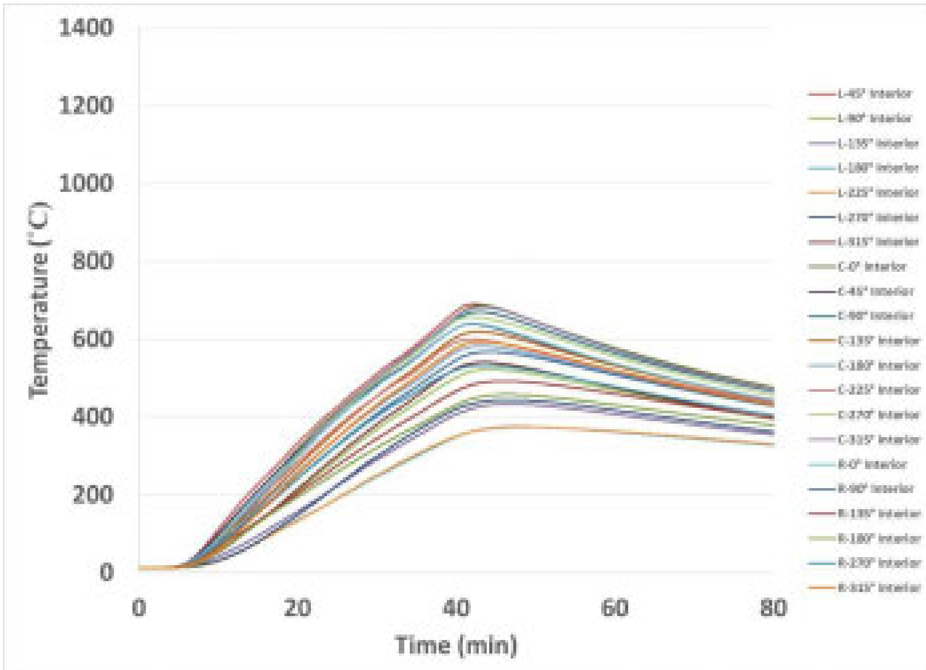


Figure 6-78: Thermocouple temperatures at inner cylinder stations (Test 2.3).

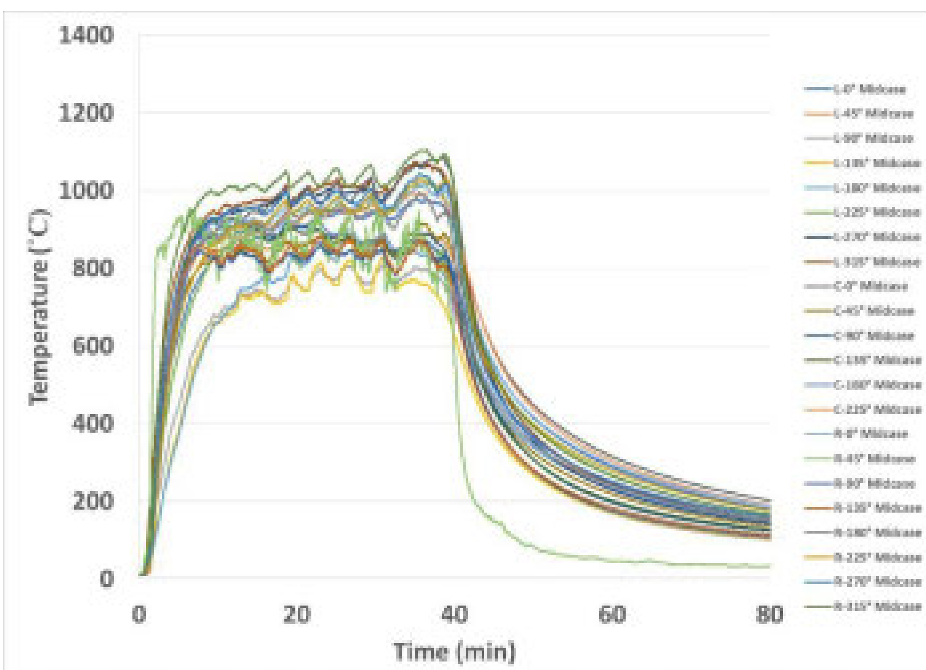


Figure 6-79: Thermocouple temperatures at outer cylinder stations (Test 2.3).

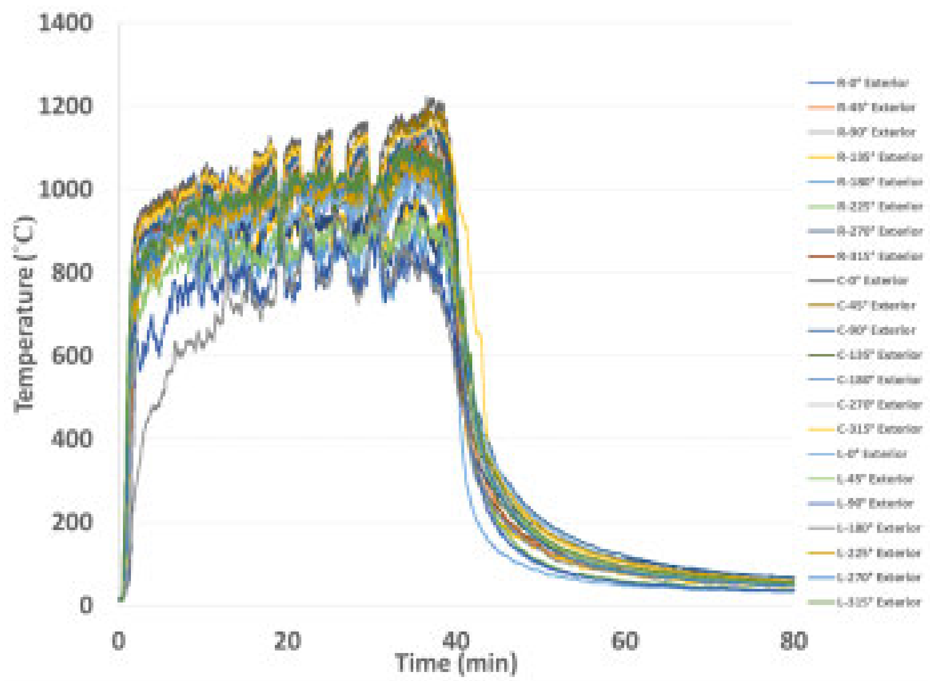


Figure 6-80: Thermocouple temperatures at exterior cylinder stations (Test 2.3).

6.2.3.8.1. Heat Flux to Calorimeter

Figure 6-81 and Figure 6-82 show the absorbed and total flux to the calorimeter, respectively.

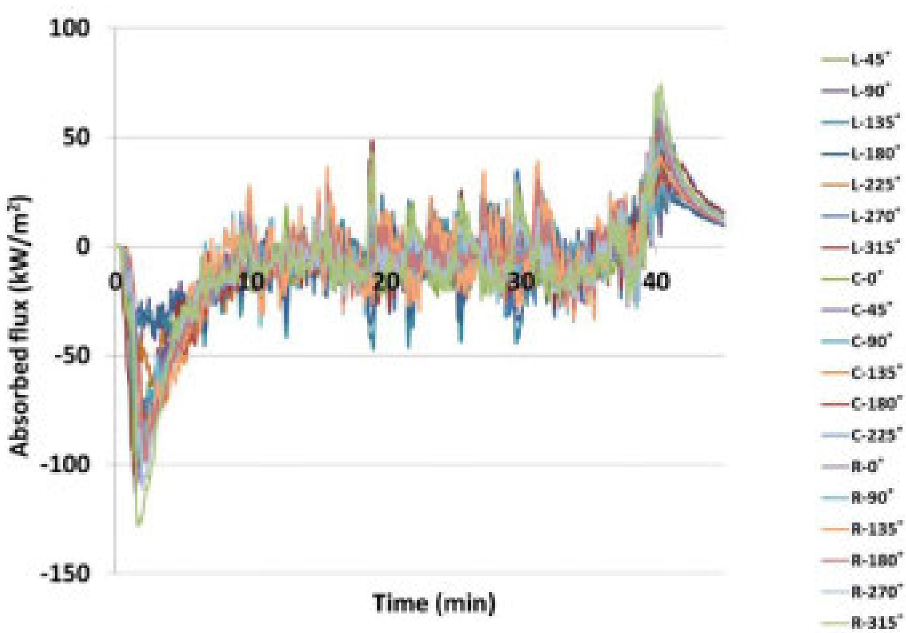


Figure 6-81: Absorbed heat flux to calorimeter (Test 2.3).

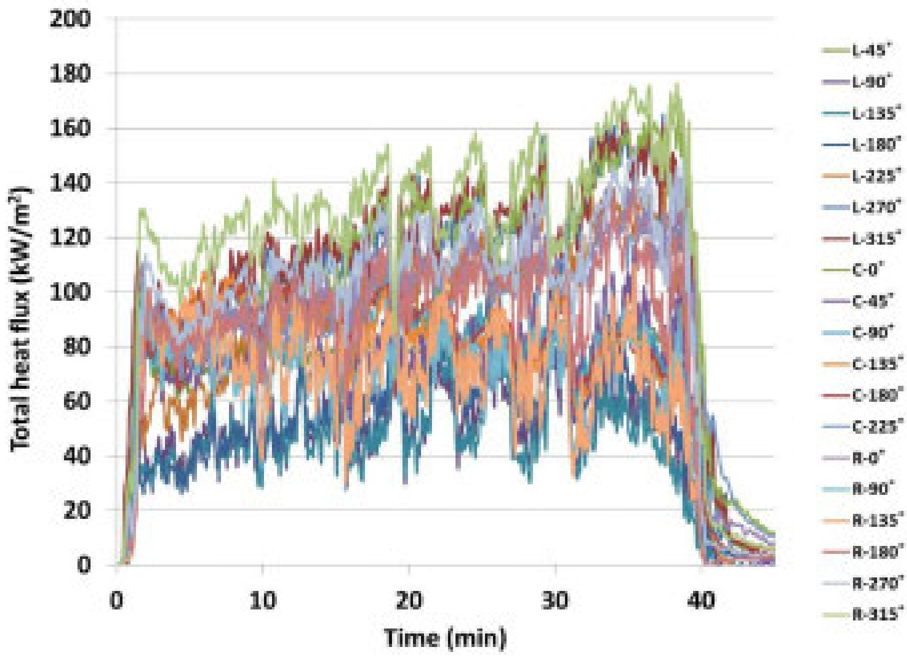


Figure 6-82: Total heat flux to calorimeter (Test 2.3).

6.2.3.9. Heat Release Rate

Figure 6-83 shows the heat release over time from CGA measurements. The average heat release rate, taken between 10-30 minutes, is 3.8 ± 0.9 MW.

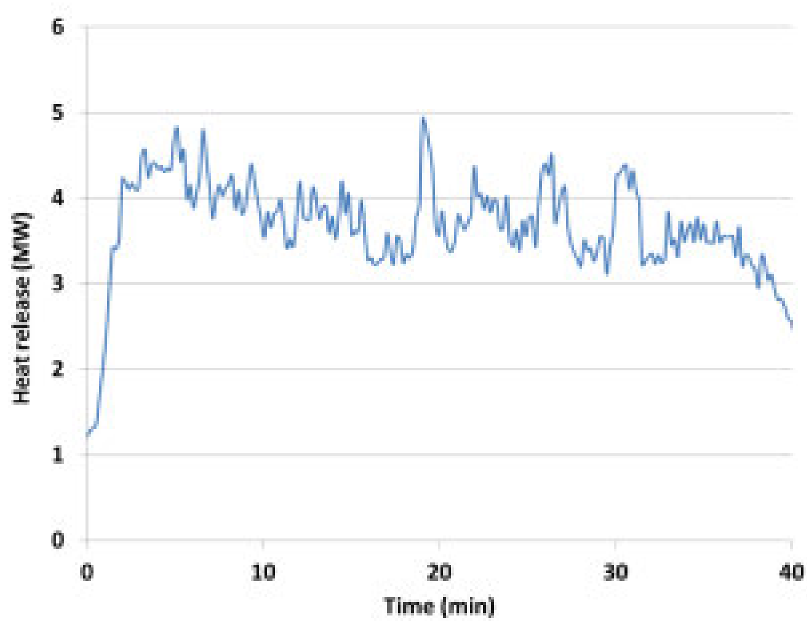


Figure 6-83: Heat release rate (Test 2.3).

6.2.3.10. Flame Height

Figure 6-84 shows the flame height as measured from the IR camera. The flame height averaged over 10-20 minutes is 4.33 ± 1.1 m.

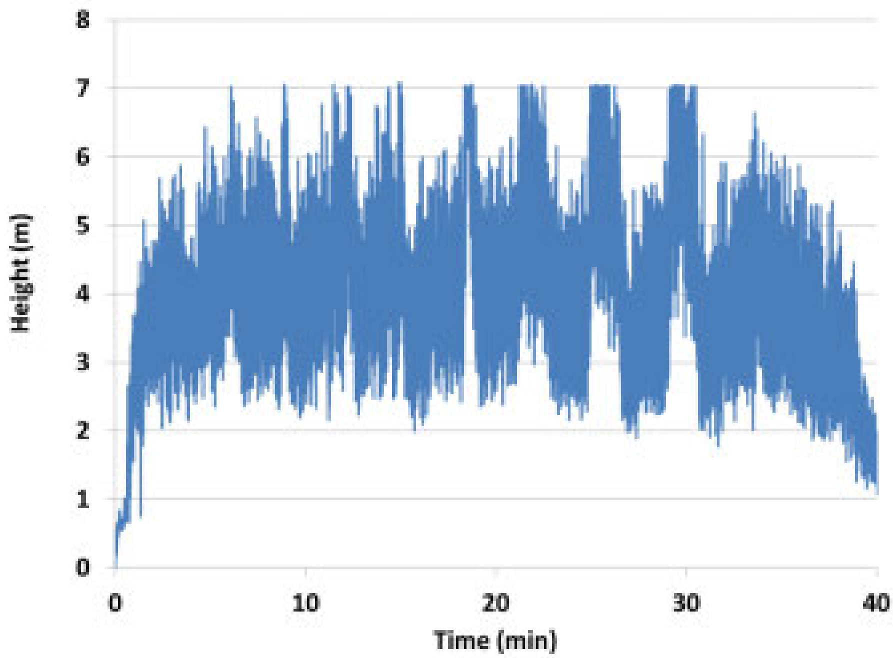


Figure 6-84: Flame height from IR camera measurements (Test 2.3).

6.2.4. Test 2.4

For this test, the Bakken crude oil was maintained at a supply temperature of 58.2 ± 1.0ºC. The calorimeter was elevated 1 m from its centerline to the bottom of the fuel pan. The duration of test was approximately 42 minutes, during which a constant fuel level of 1.1 inches (3 cm) was maintained. After 42 minutes, the fuel supply was terminated, and the fuel was allowed to burn down.

6.2.4.1. Fuel Supply Temperature

Figure 6-85 provides the fuel supply temperature over time. The fuel supply temperature averaged over 23-42 minutes is 58.2 ± 1.0ºC.

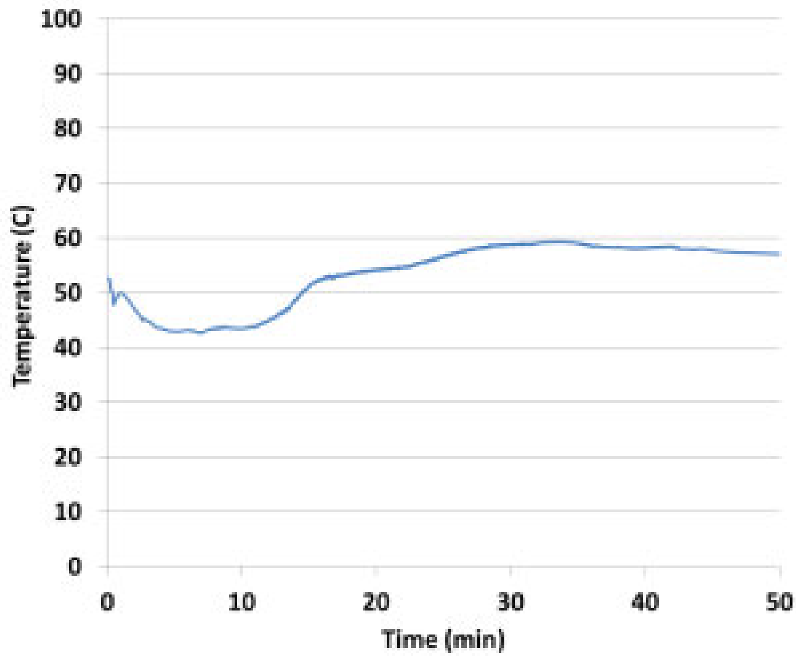


Figure 6-85: Temperature of fuel supply into pan (Test 2.4).

6.2.4.2. Fuel Rake Thermocouple Temperatures

Figure 6-86 shows temperatures from TCs within the liquid fuel. The fuel level was approximately 1.1 inches (2.8 cm) and was held constant over the duration of the test.

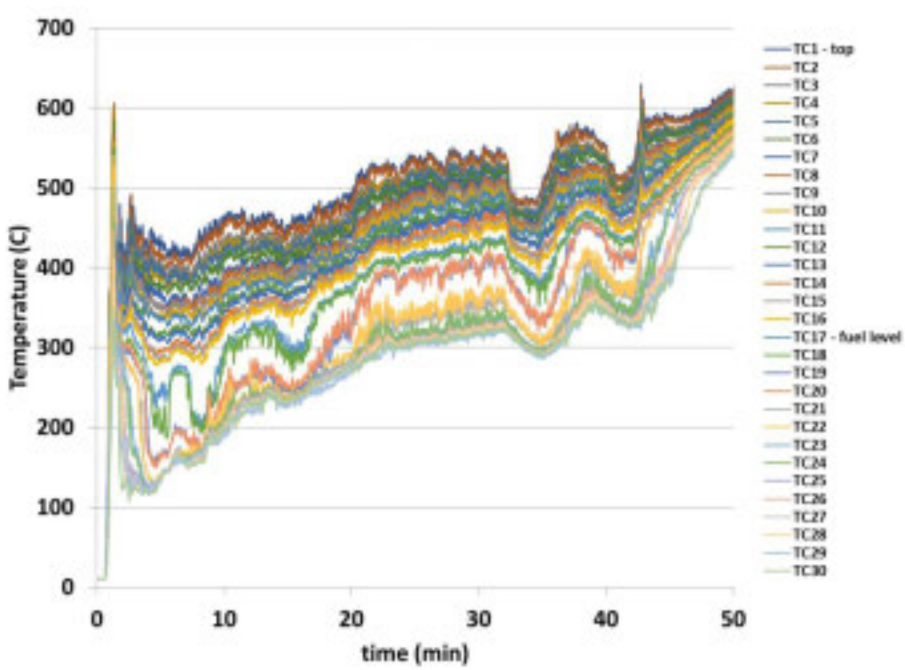


Figure 6-86: Fuel rake thermocouple temperatures (Test 2.4).

6.2.4.3. Burn Rate

Figure 6-87 provides the scale readings over time. The slope of the equation fitted to the data allows for the burn rate to be determined. A slope of 6.6713 kg/min (r^2 = 99%) corresponds to a burn rate of 0.029 kg/m^2s.

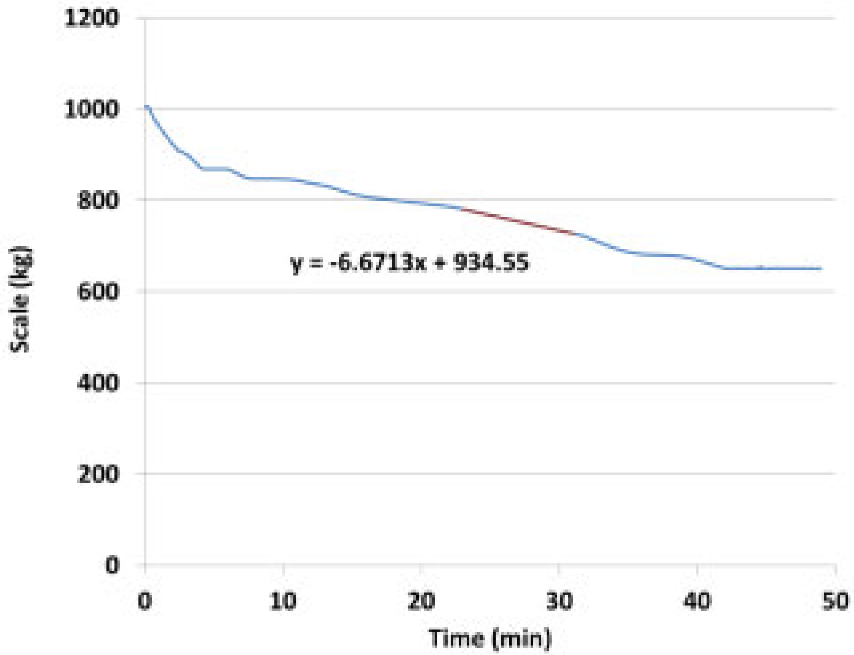


Figure 6-87: Fuel weight over time based on scale measurement (Test 2.4).

6.2.4.4. Radiometers

Figure 6-88 and Figure 6-89 provide the heat flux over time from six narrow-angle and five wide-angle radiometers at the various height locations.

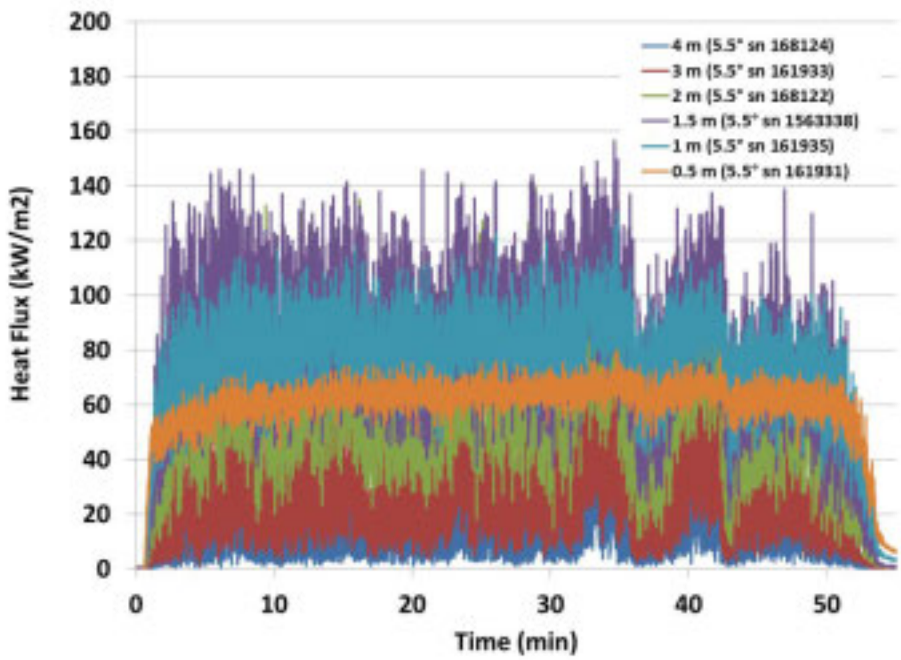


Figure 6-88: Heat flux measurement from narrow view radiometers at different heights (Test 2.4).

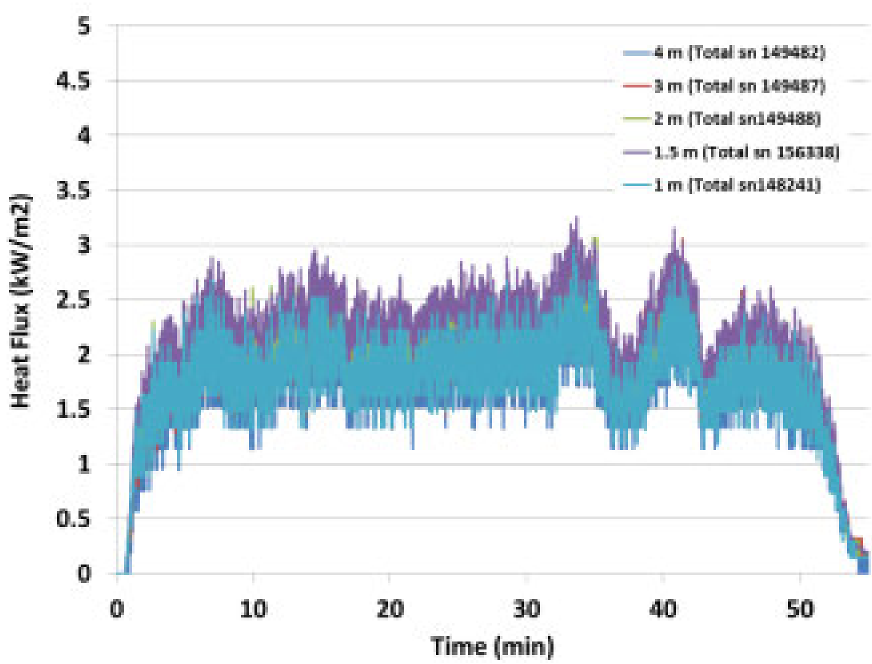


Figure 6-89: Heat flux measurement from wide view radiometers at different heights (Test 2.4).

6.2.4.5. Thermocouple Rake in the Fire Plume

Figure 6-90 provides temperature measurements over time from the TCs placed within the fire plume at its vertical centerline.

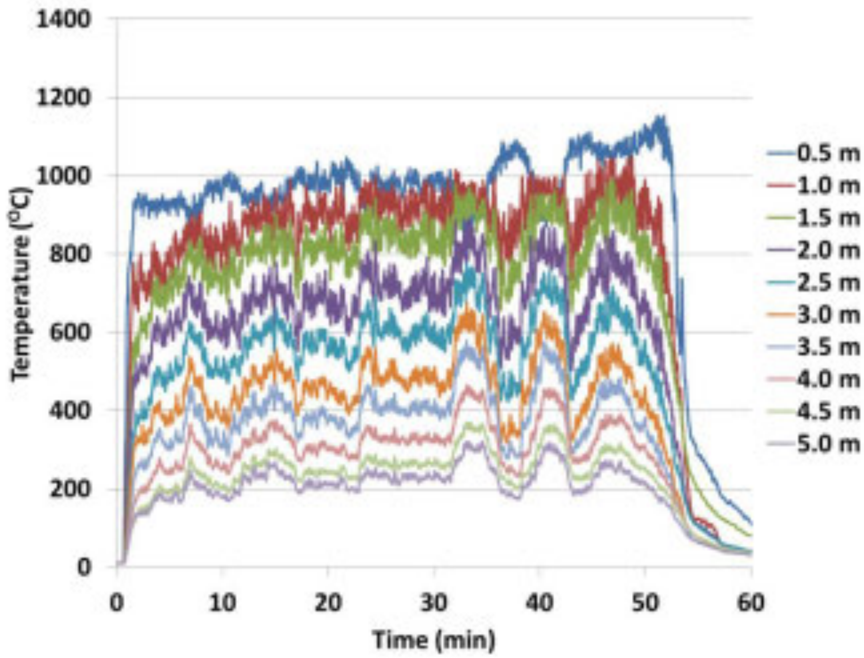


Figure 6-90: Temperature measurements from vertical thermocouple rake in centerline of fire plume (Test 2.4).

6.2.4.6. Plume Temperatures and Surface Emissive Power

Figure 6-91 provides surface temperatures of the fire plume and surface emissive power taken from IR camera measurements.

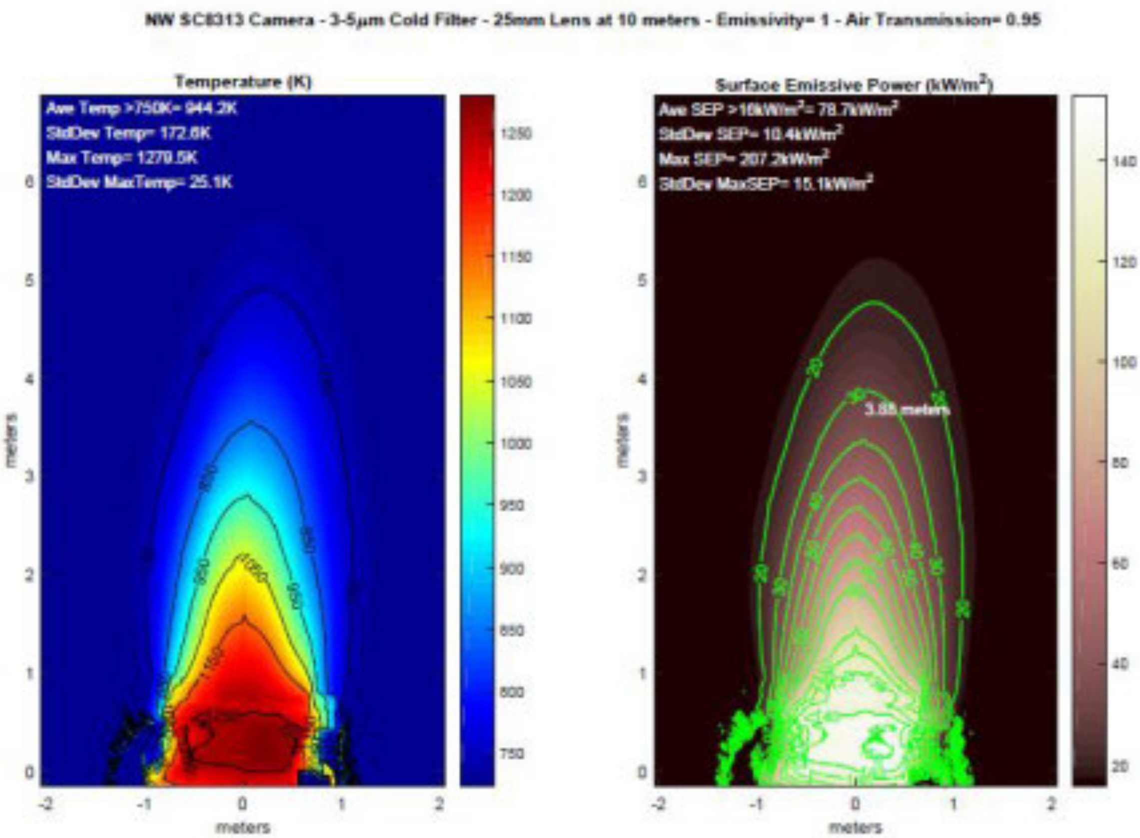


Figure 6-91: Fire plume temperatures and surface emissive power values from IR camera measurements (Test 2.4).

6.2.4.7. DFT TC Temperatures and Derived Heat Flux

Figure 6-92 and Figure 6-93 provide DFT temperatures and heat flux, respectively. The term 'front' refers to the TC measurement for the plate closest to the fire, while the term 'back' refers to the TC measurement for the plate furthest from the fire.

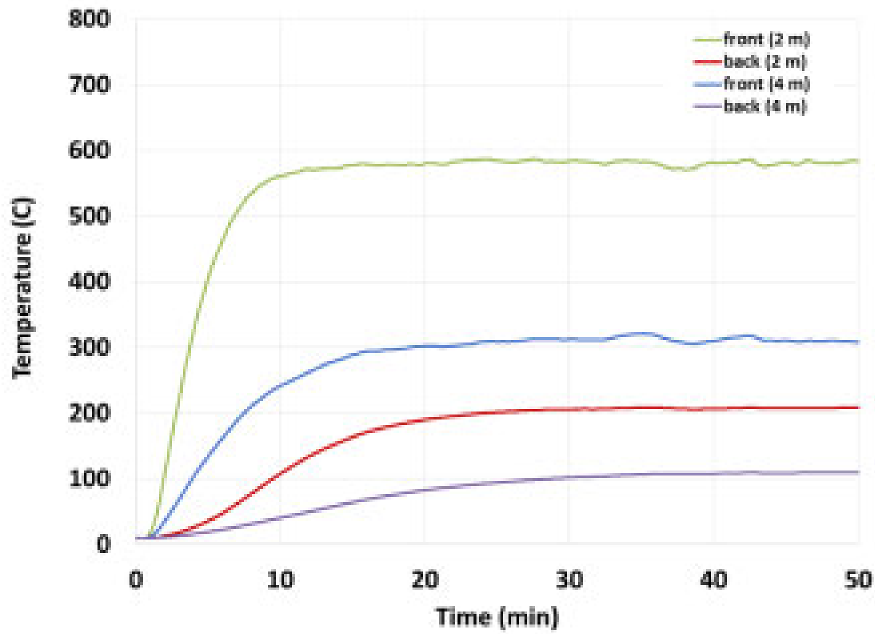


Figure 6-92: Thermocouple temperatures from DFT instruments. Distances are from center of pan (Test 2.4).

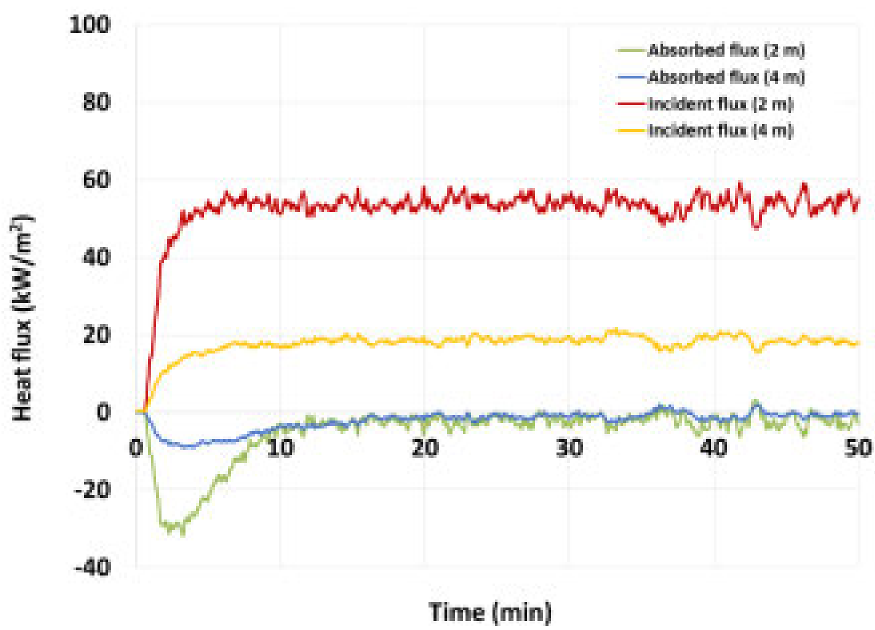


Figure 6-93: Derived heat flux values from DFT measurements. Distances are from center of pan (Test 2.4).

6.2.4.8. Calorimeter TC Temperature and Derived Heat Flux

Figure 6-94 through Figure 6-96 provide temperatures over time from TC measurements placed on the inner and outer cylinders, as well as external to the calorimeter.

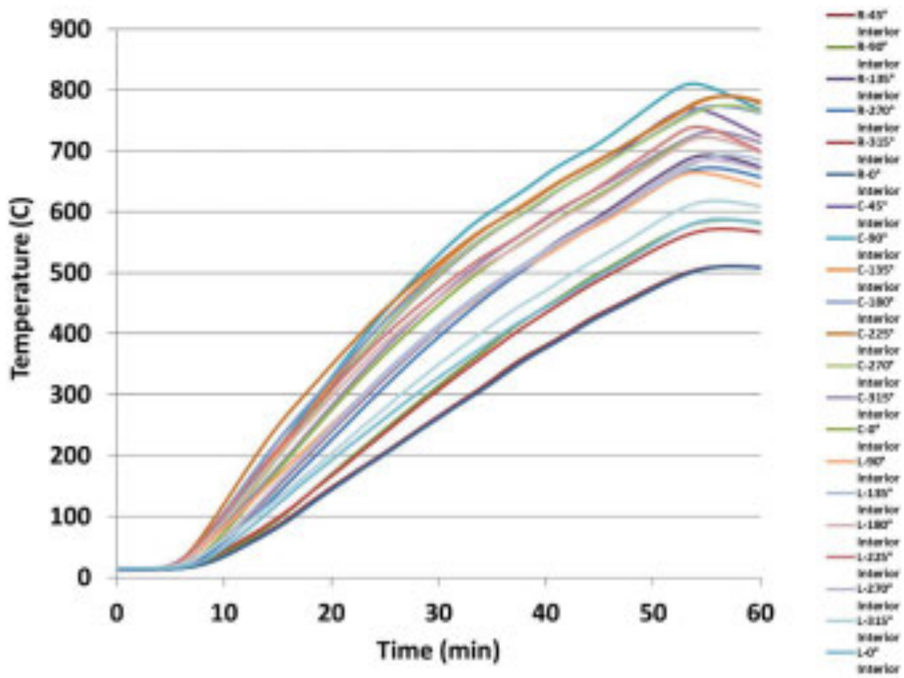


Figure 6-94: Thermocouple temperatures at inner cylinder stations (Test 2.4).

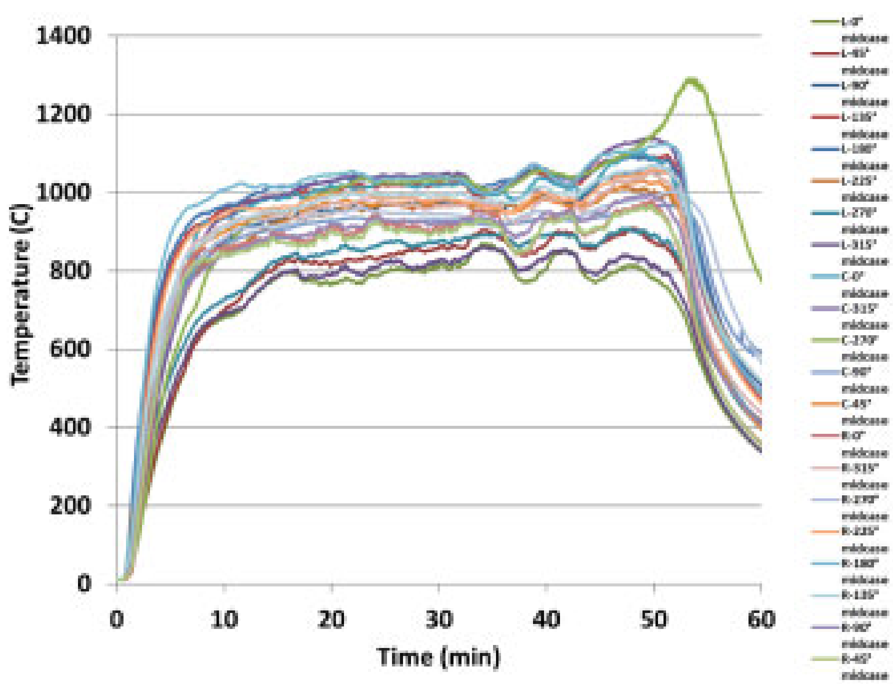


Figure 6-95: Thermocouple temperatures at outer cylinder stations (Test 2.4).

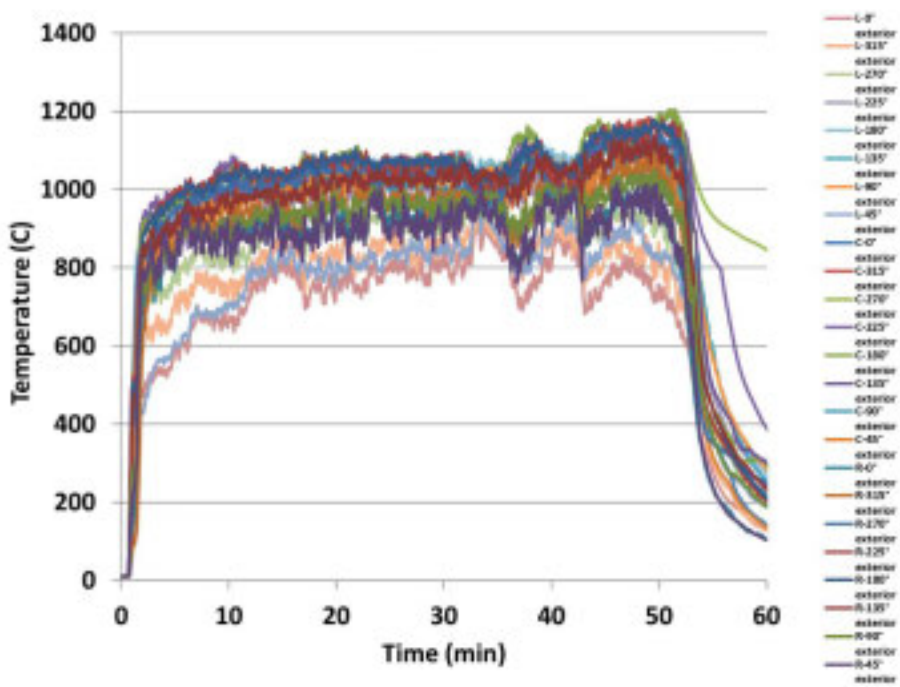


Figure 6-96: Thermocouple temperatures at exterior cylinder stations (Test 2.4).

6.2.4.8.1. Heat Flux to Calorimeter

Figure 6-97 and Figure 6-98 show the absorbed and total flux to the calorimeter, respectively.

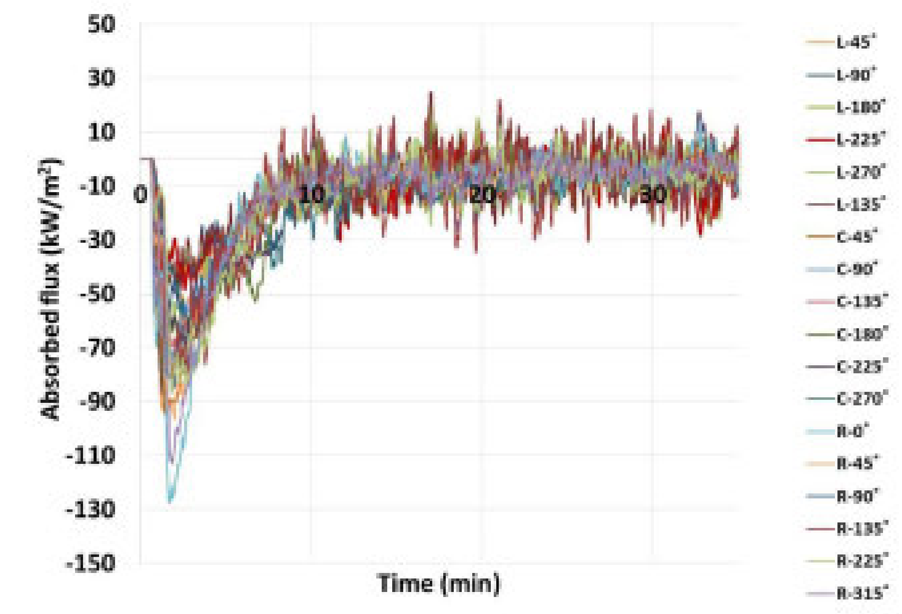


Figure 6-97: Absorbed heat flux to calorimeter (Test 2.4).

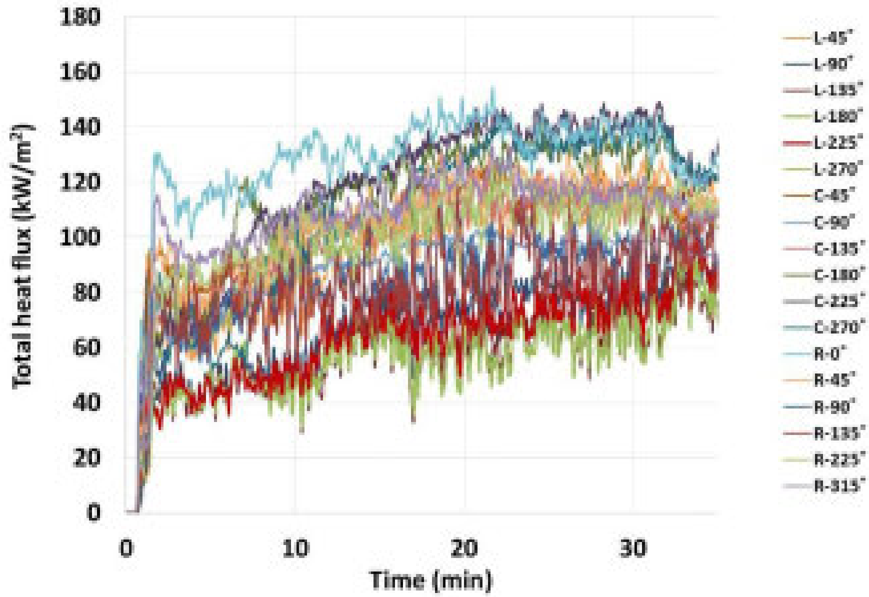


Figure 6-98: Total heat flux to calorimeter (Test 2.4).

6.2.4.9. Heat Release Rate

Figure 6-99 shows the heat release over time from CGA measurements. The average heat release rate, taken between 23-42 minutes, is 3.21 ± 0.8 MW.

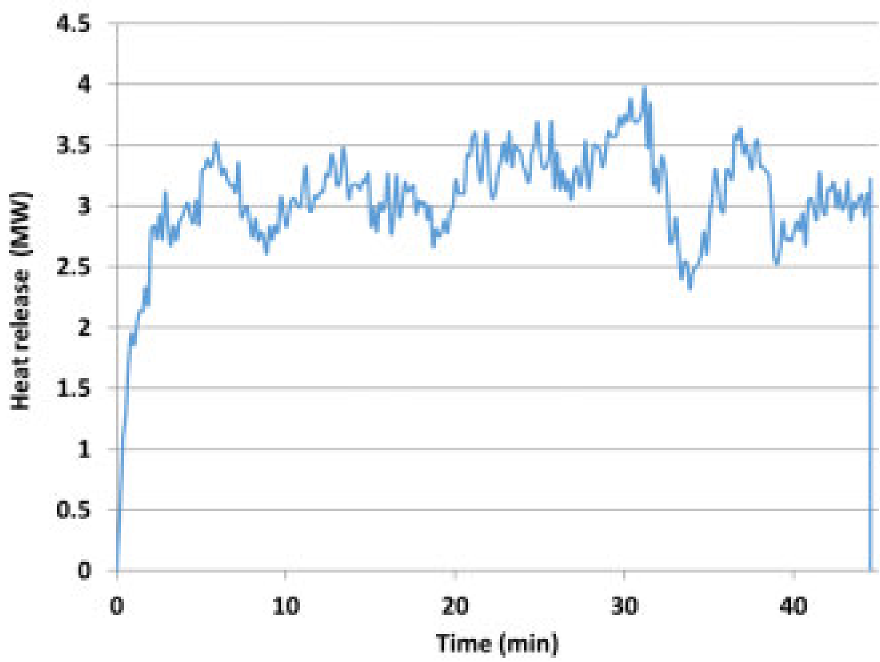


Figure 6-99: Heat release rate (Test 2.4).

6.2.4.10. Flame Height

Figure 6-100 shows the flame height as measured from the IR camera. The flame height averaged over 10 to 20 minutes is 4.51 ± .96 m.

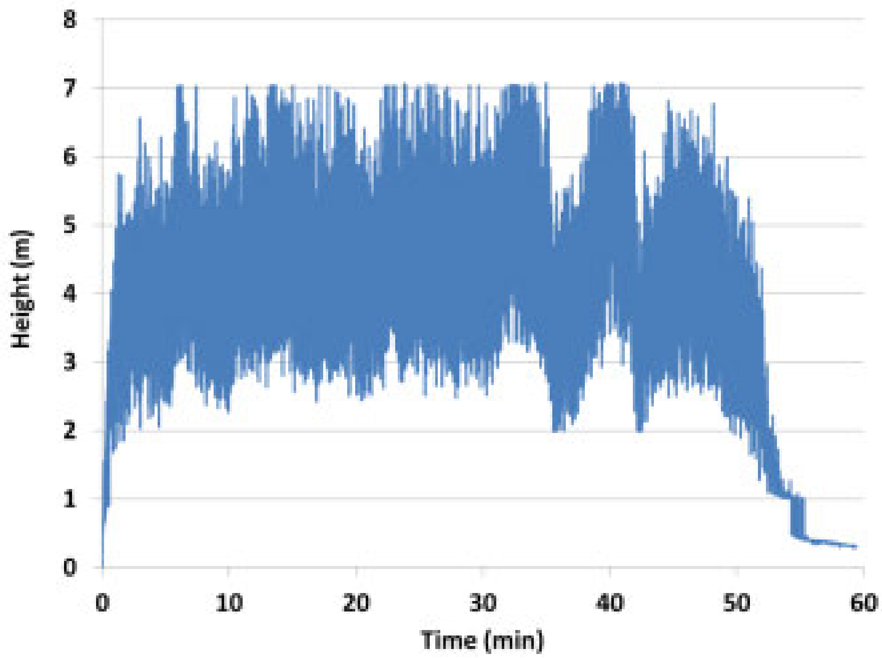


Figure 6-100: Flame height from IR camera measurements (Test 2.4).

6.2.5. Test 2.5

For this test, the Bakken crude oil was maintained at a supply temperature of 21.3 ± 0.6ºC. The calorimeter was elevated 1 m from its centerline to the bottom of the fuel pan. The duration of test was approximately 36 minutes, during which a constant fuel level of 1.1 inches (3 cm) was maintained. After 36 minutes, the fuel supply was terminated, and the fuel was allowed to burn down.

6.2.5.1. Fuel Supply Temperature

Figure 6-101 provides the fuel supply temperature over time. The fuel supply temperature averaged over 10-35 minutes is 21.3 ± 0.6ºC.

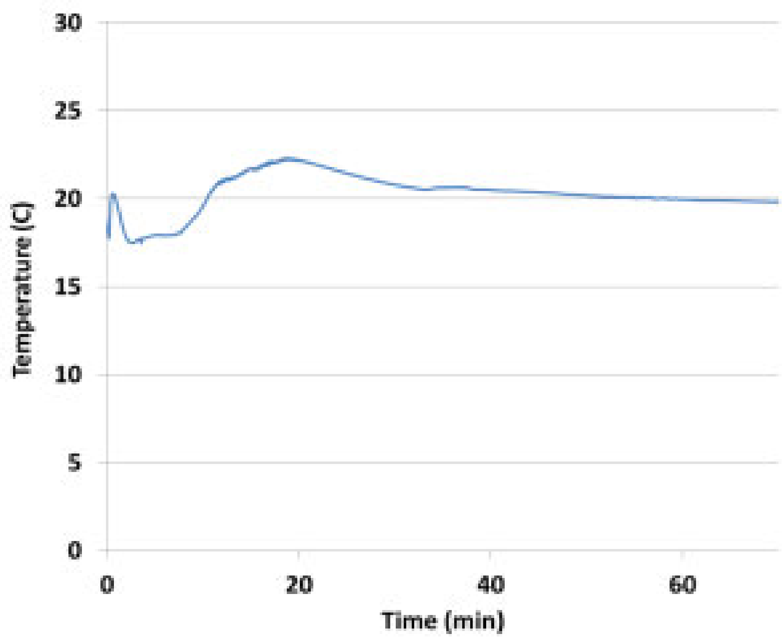


Figure 6-101: Temperature of fuel supply into pan (Test 2.5).

6.2.5.2. Fuel Rake Thermocouple Temperatures

Figure 6-102 shows temperatures from TCs within the liquid fuel. The fuel level was approximately 1.1 inches (2.8 cm) and was held constant over the duration of the test.

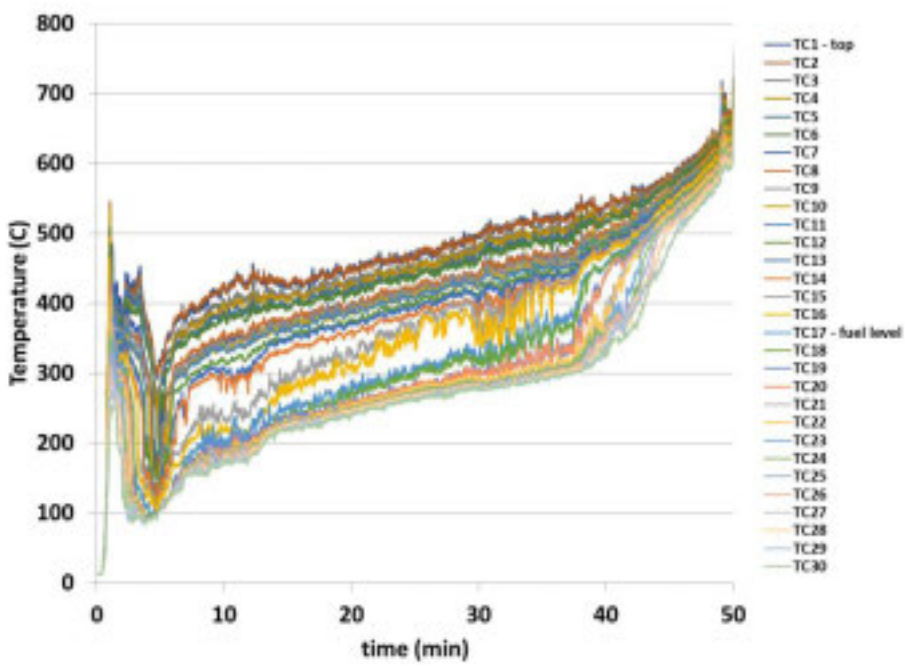


Figure 6-102: Fuel rake thermocouple temperatures (Test 2.5).

6.2.5.3. Burn Rate

Figure 6-103 provides the scale readings over time. The slope of the equation fitted to the data allows for the burn rate to be determined. A slope of 5.9614 kg/min (r^2 = 99%) corresponds to a burn rate of 0.026 kg/m^2s.

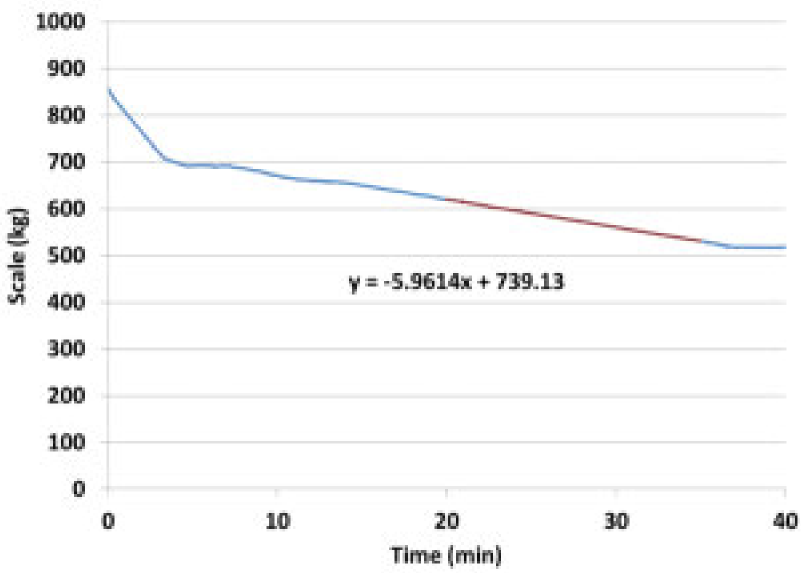


Figure 6-103: Fuel weight over time based on scale measurement (Test 2.5).

6.2.5.4. Radiometers

Figure 6-104 and Figure 6-105 provide the heat flux over time from six narrow-angle and five wide-angle radiometers at the various height locations.

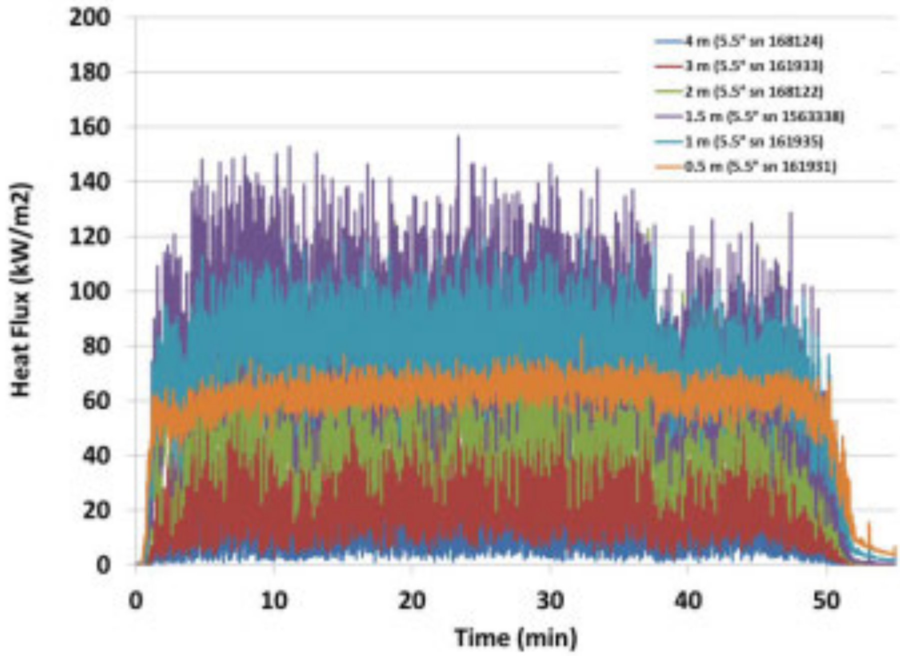


Figure 6-104: Heat flux measurement from narrow view radiometers at different heights (Test 2.5).

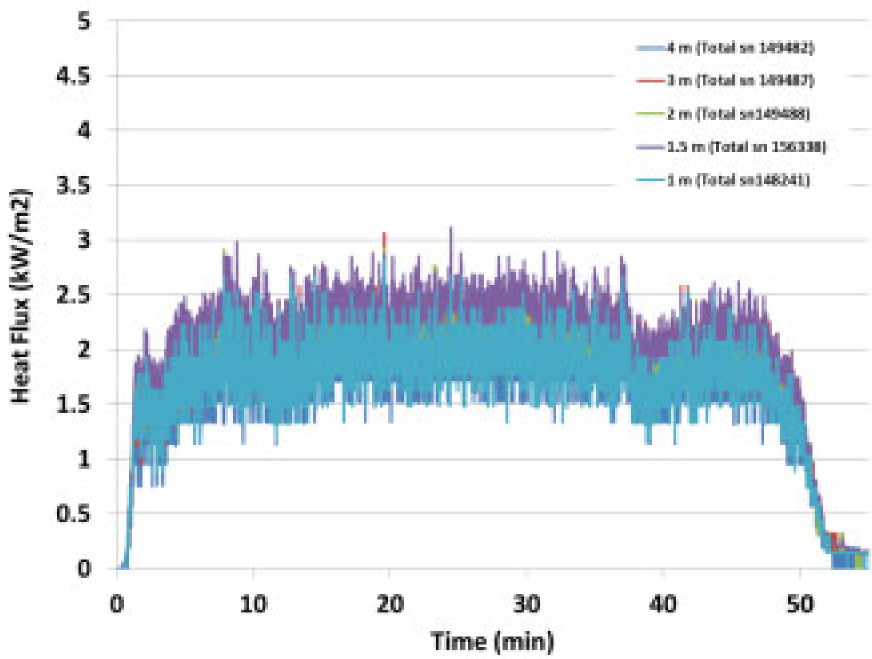


Figure 6-105: Heat flux measurement from wide view radiometers at different heights (Test 2.5).

6.2.5.5. Thermocouple Rake in the Fire Plume

Figure 6-106 provides temperature measurements over time from the TCs placed within the fire plume at its vertical centerline.

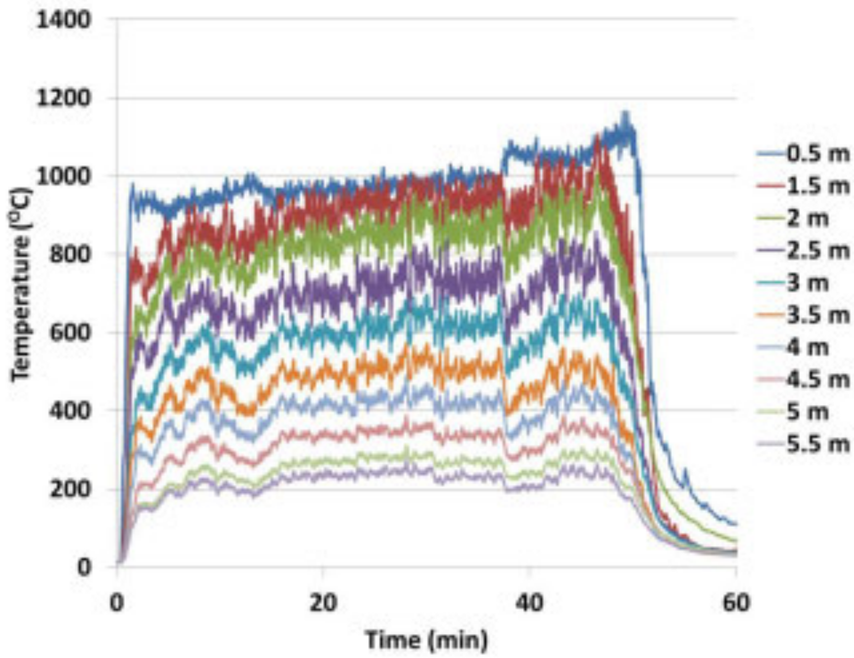


Figure 6-106: Temperature measurements from vertical thermocouple rake in centerline of fire plume (Test 2.5).

6.2.5.6. Plume Temperatures and Surface Emissive Power

Figure 6-107 provides surface temperatures of the fire plume and surface emissive power taken from IR camera measurements.

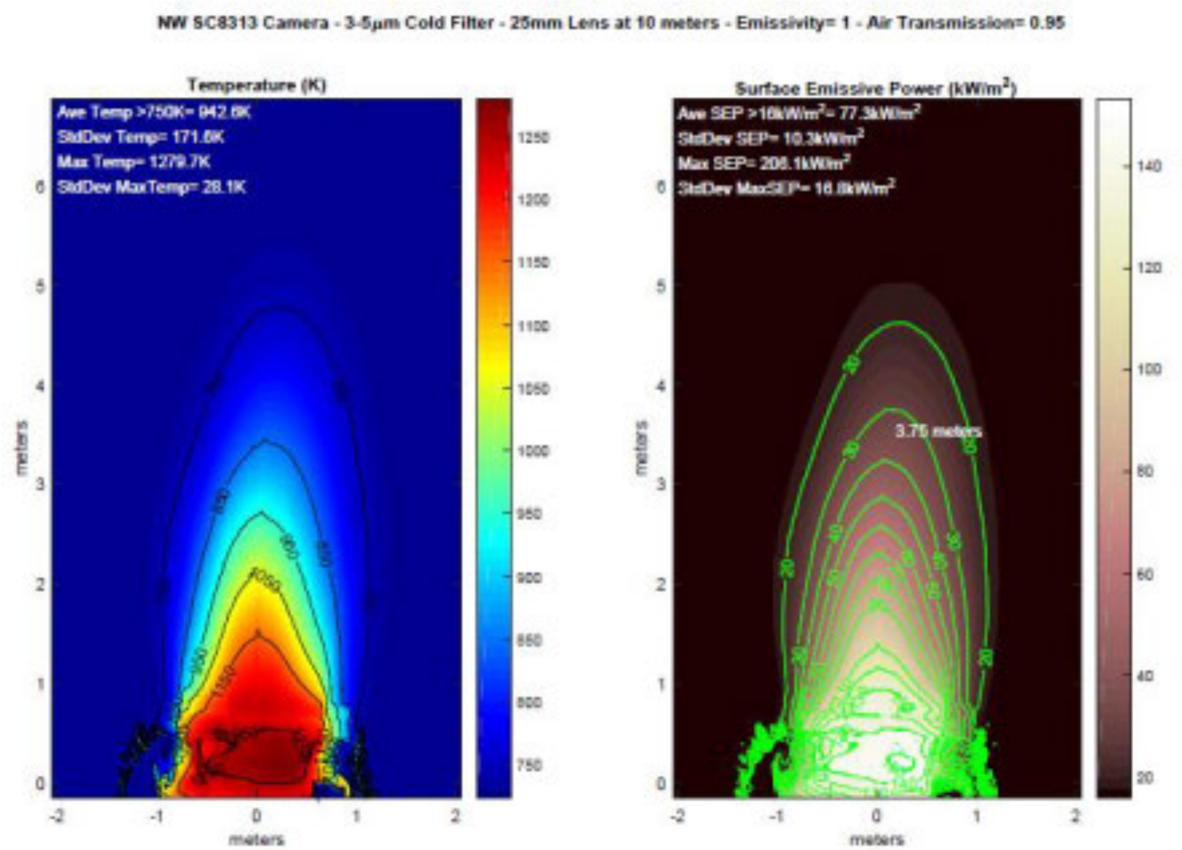


Figure 6-107: Fire plume temperatures and surface emissive power values from IR camera measurements (Test 2.5).

6.2.5.7. DFT TC Temperatures and Derived Heat Flux

Figure 6-108 and Figure 6-109 show DFT temperatures and heat flux, respectively. The term 'front' refers to the TC measurement for the plate closest to the fire, while the term 'back' refers to the TC measurement for the plate furthest from the fire.

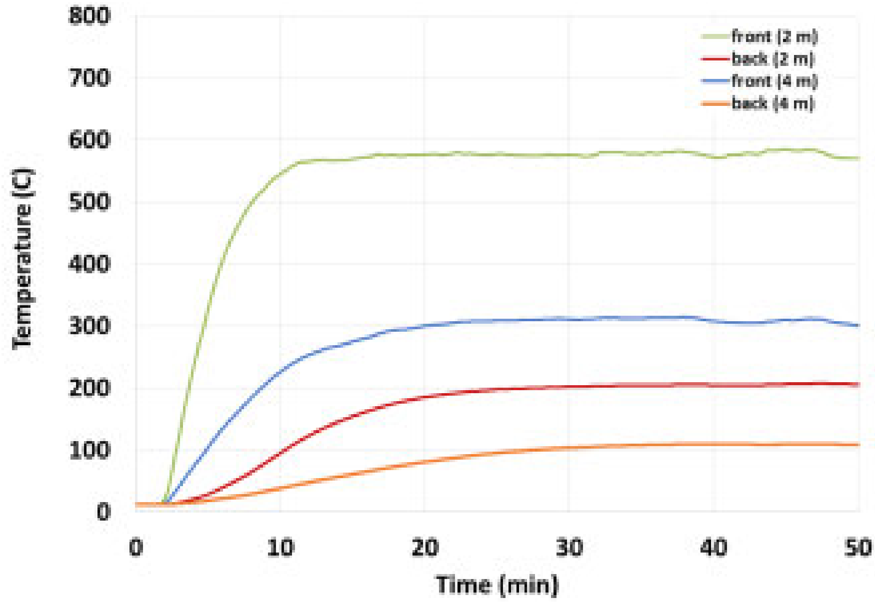


Figure 6-108: Thermocouple temperatures from DFT instruments. Distances are from center of pan (Test 2.5).

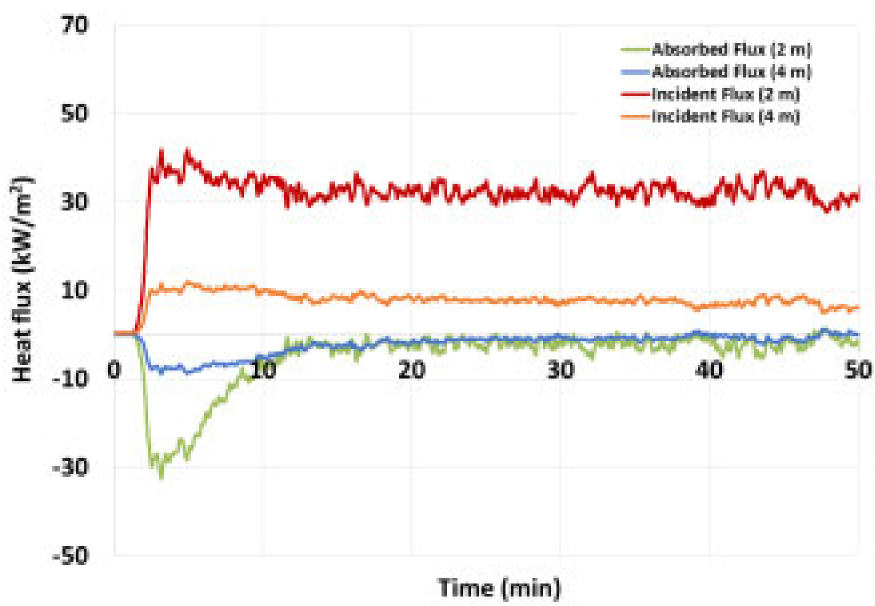


Figure 6-109: Derived heat flux values from DFT measurements. Distances are from center of pan (Test 2.5).

6.2.5.8. Calorimeter TC Temperature and Derived Heat Flux

Figure 6-110 through Figure 6-112 provide temperatures over time from TC measurements placed on the inner and outer cylinders, as well as external to the calorimeter.

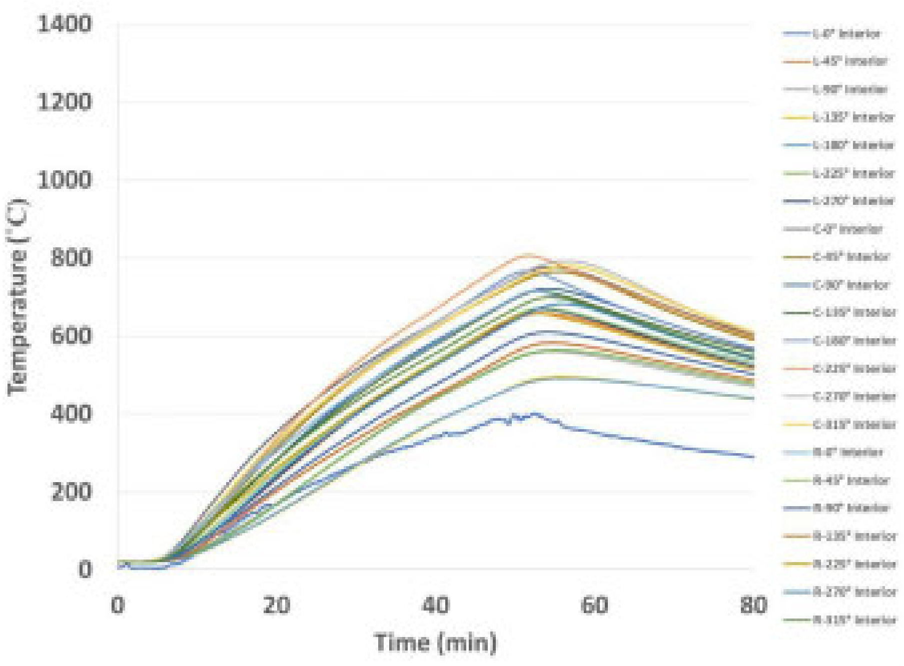


Figure 6-110: Thermocouple temperatures at inner cylinder stations (Test 2.5).

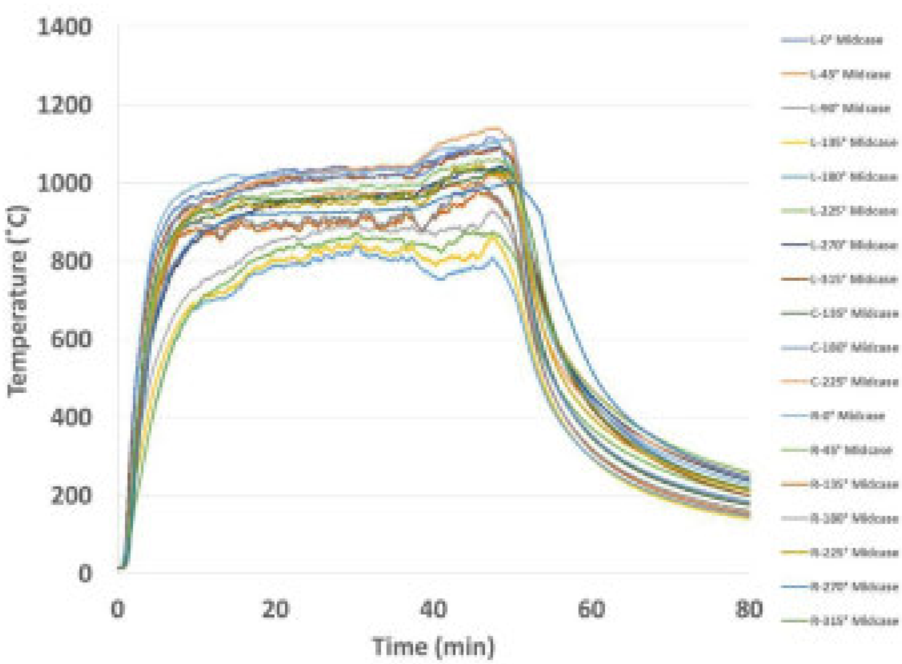


Figure 6-111: Thermocouple temperatures at outer cylinder stations (Test 2.5).

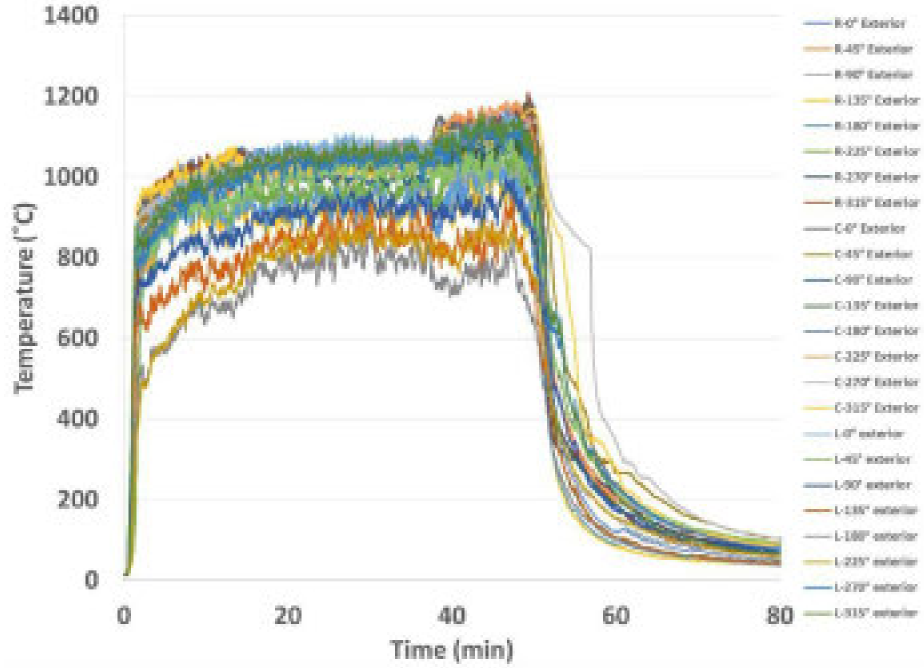


Figure 6-112: Thermocouple temperatures at exterior cylinder stations (Test 2.5).

6.2.5.8.1. Heat Flux to Calorimeter

Figure 6-113 and Figure 6-114 show the absorbed and total flux to the calorimeter, respectively.

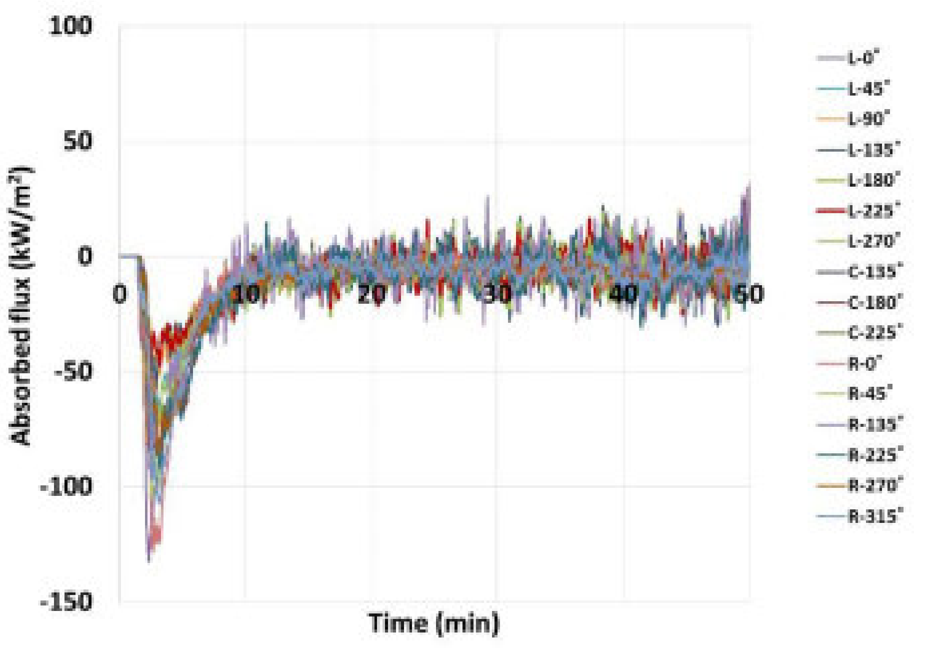


Figure 6-113: Absorbed heat flux to calorimeter (Test 2.5).

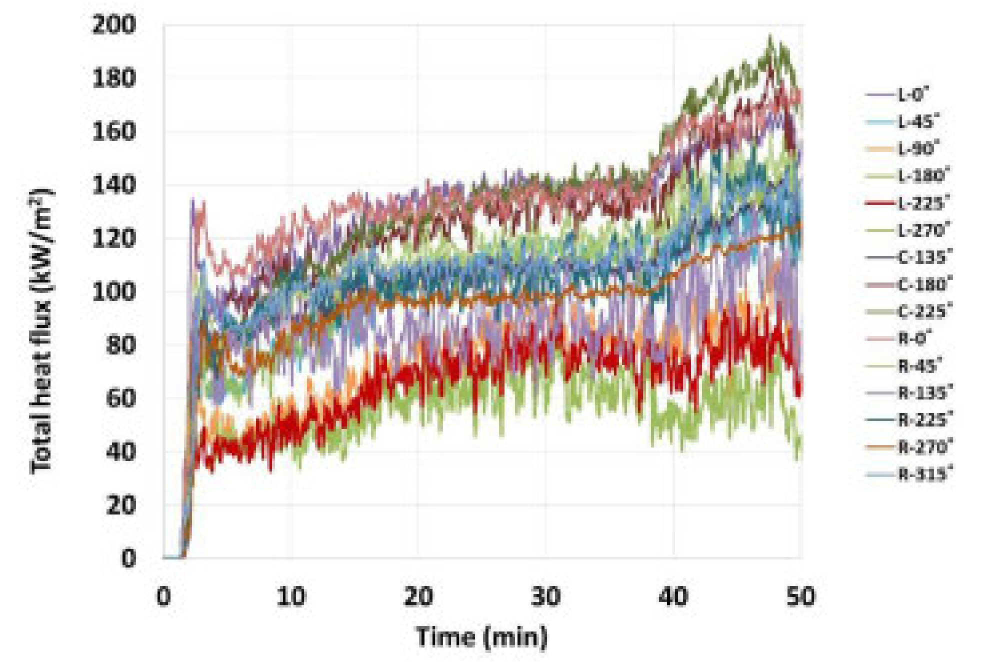


Figure 6-114: Total heat flux to calorimeter (Test 2.5).

6.2.5.9. Heat Release Rate

Figure 6-115 shows the heat release over time from CGA measurements. The average heat release rate, taken between 20-30 minutes, is 3.6 ± 0.8 MW.

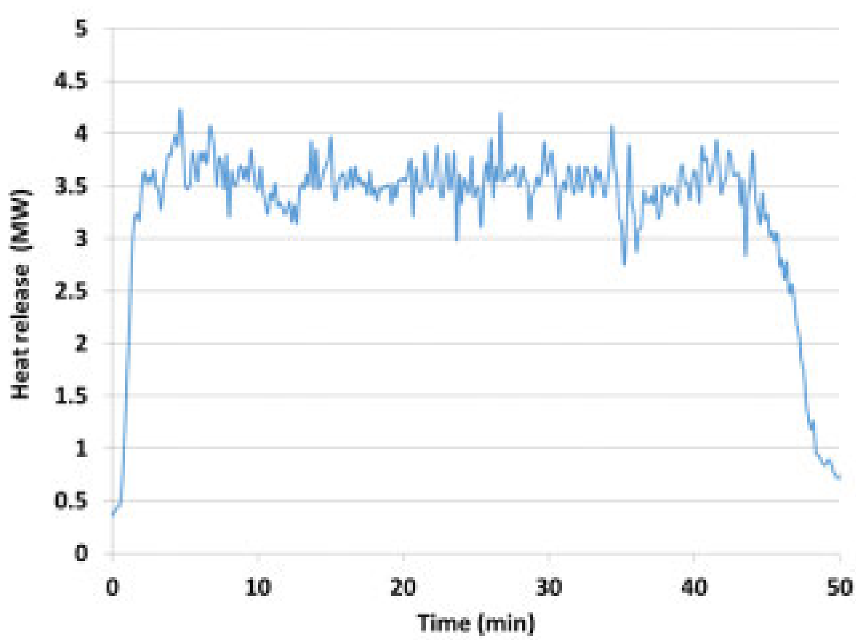


Figure 6-115: Heat release rate (Test 2.5).

6.2.5.10. Flame Height

Figure 6-116 shows the flame height as measured from the IR camera. The flame height averaged over 10 to 20 minutes is 4.46 ± 0.94 m.

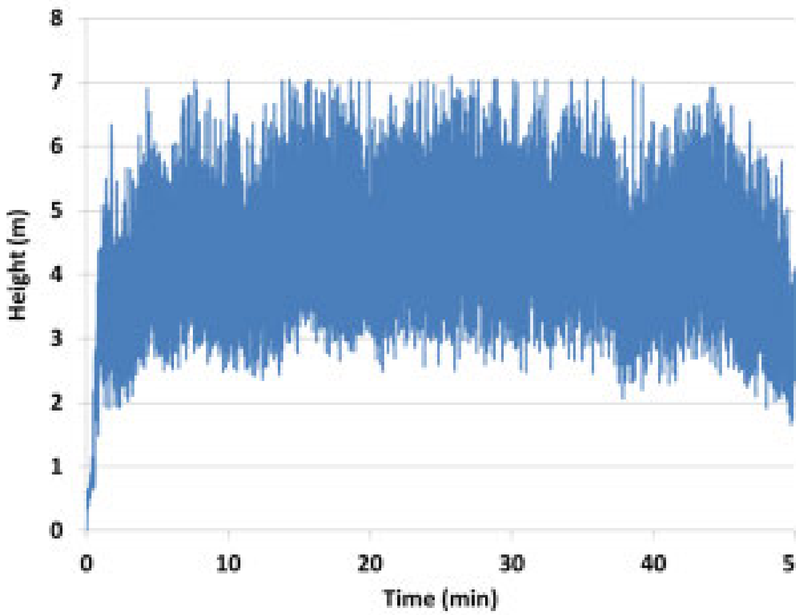


Figure 6-116: Flame height from IR camera measurements (Test 2.5).

6.2.6. Test 2.6

For this test, there was no calorimeter above the fuel pan and the Bakken crude oil was allowed to burn down, rather than maintain a constant fuel level. The duration to fill the pan with fuel to a level of 3 inches (7.6 cm) was 4.63 minutes. The average temperature of the fuel fed into the pan was 20.0 ± 1.7°C. The duration of test was approximately 36 minutes.

6.2.6.1. Fuel Supply Temperature

Figure 6-117 provides the fuel supply temperature during the time that fuel was supplied to the plan. The fuel supply temperature averaged over 0-4.63 minutes is 20.0 ± 1.7°C.

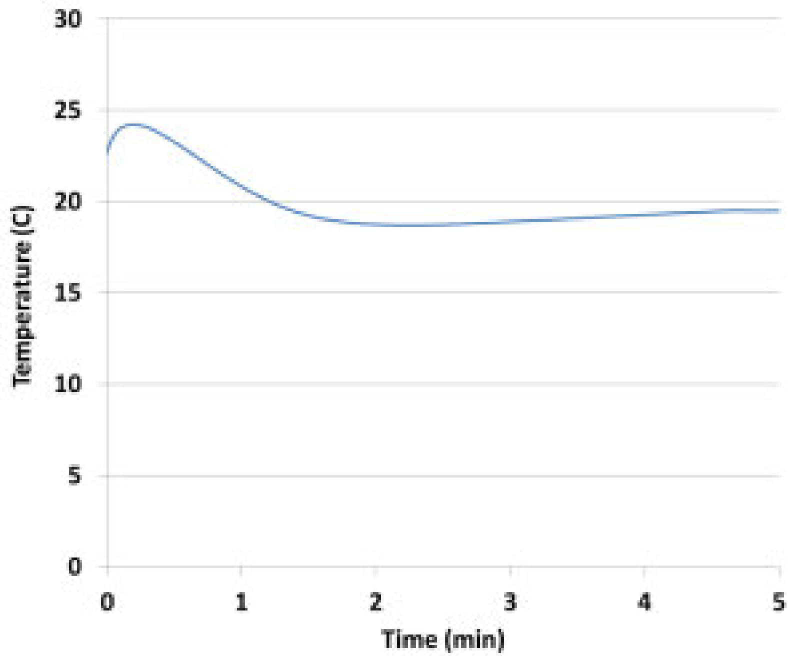


Figure 6-117: Temperature of fuel supply into pan (Test 2.6).

6.2.6.2. Fuel Rake Thermocouple Temperatures

Figure 6-118 shows temperatures from TCs within the liquid fuel. The fuel level was not held constant but allowed to burn down over the duration of the test.

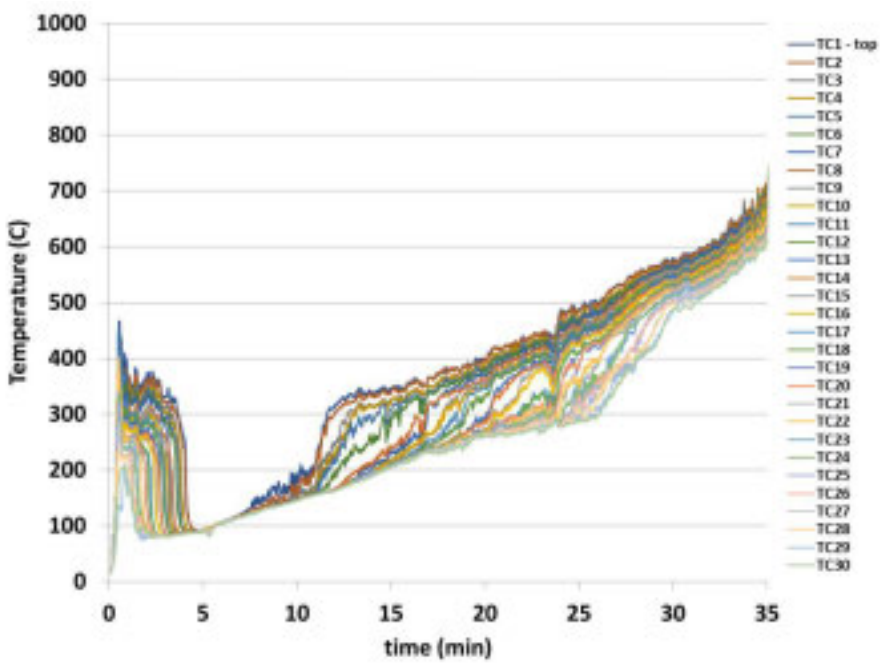


Figure 6-118: Fuel rake thermocouple temperatures (Test 2.6).

6.2.6.3. Burn Rate

For this test, the fuel was ignited immediately upon entry into the pan and then was filled to 3 inches (7.6 cm), taking approximately 4.63 minutes (Figure 6-119). This level was determined by using the results from the previous tests for burn rate in order to provide at least 30 minutes of burn time. The burn rate was determined by considering the total fuel volume introduced into the pan minus that left in the line and potential residue (Table 6-1) divided by the burn duration of 36 minutes. This value was then divided by the burn duration to result in an average burn rate of 0.030 kg/m^{2}s.

Table 6-1: Values used to determine burn rate.

Specification	gallons (L)
Initial volume	221 (837)
Final volume after fill	147 (556)
Volume in line	6 (23)
Residue	2 (8)
Volume burned	66 (250)

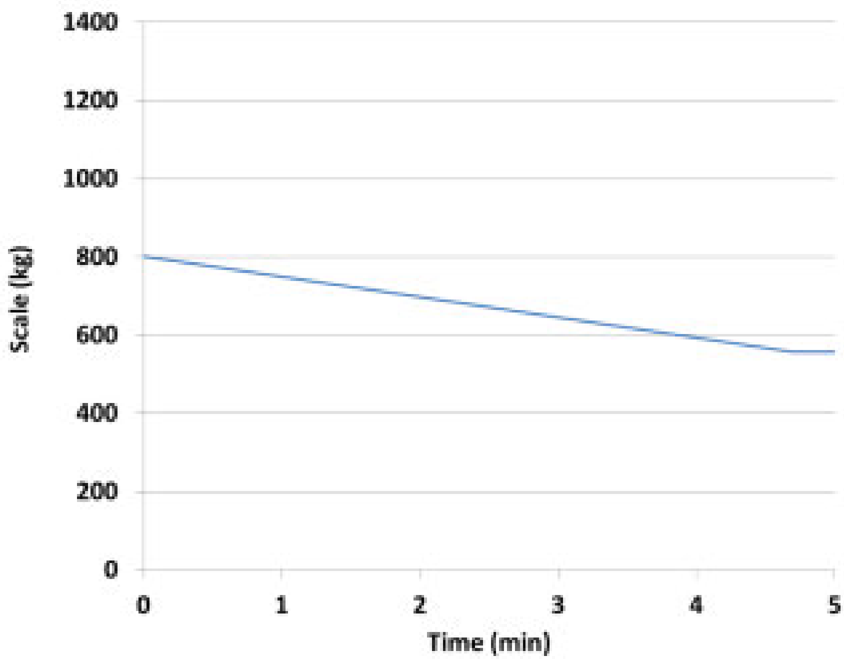


Figure 6-119: Fuel weight over time based on scale measurement (Test 2.6).

6.2.6.4. Radiometers

Figure 6-120 and Figure 6-121 provide the heat flux over time from six narrow-angle and five wide-angle radiometers at the various height locations.

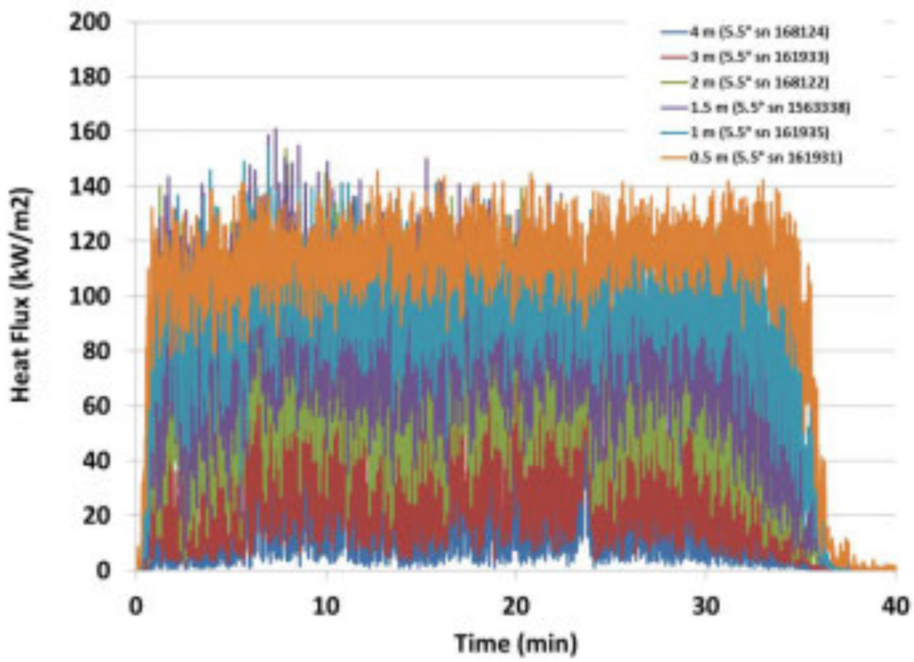


Figure 6-120: Heat flux measurement from narrow view radiometers at different heights (Test 2.6).

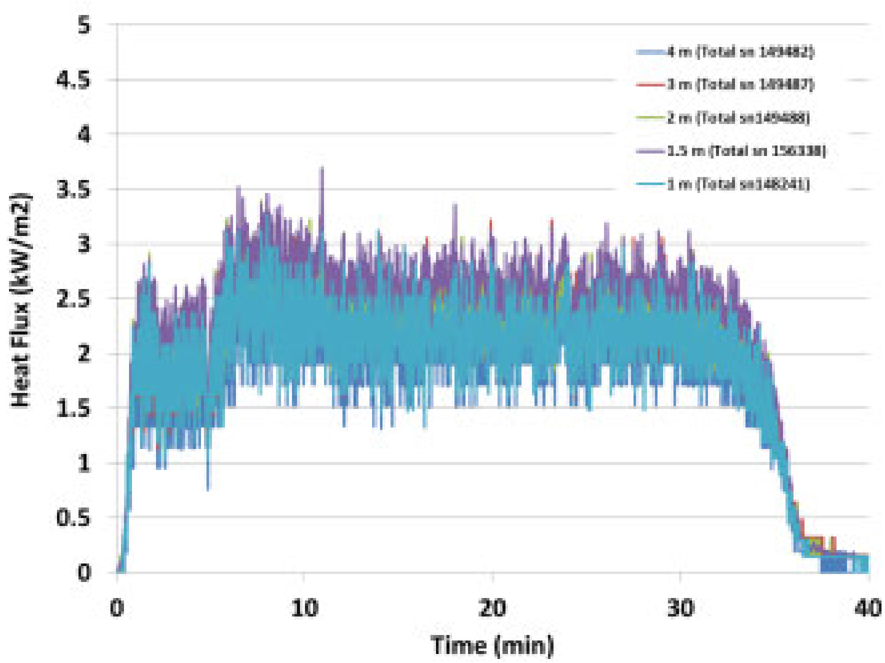


Figure 6-121: Heat flux measurement from wide view radiometers at different heights (Test 2.6).

6.2.6.5. Thermocouple Rake in the Fire Plume

Figure 6-122 provides temperature measurements over time from the TCs placed within the fire plume at its vertical centerline.

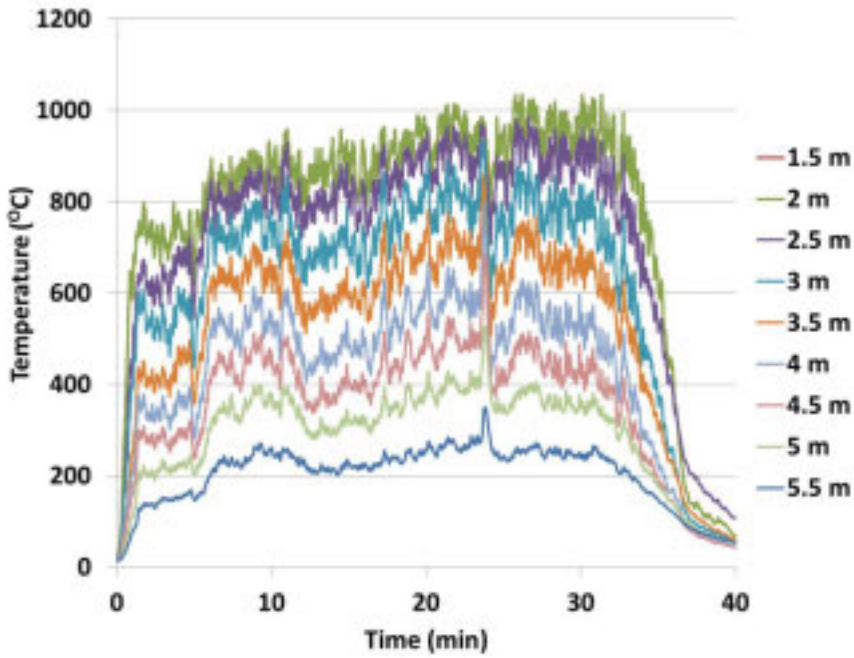


Figure 6-122: Temperature measurements from vertical thermocouple rake in centerline of fire plume (Test 2.6).

6.2.6.6. Plume Temperatures and Surface Emissive Power

Figure 6-123 provides surface temperatures of the fire plume and surface emissive power taken from IR camera measurements.

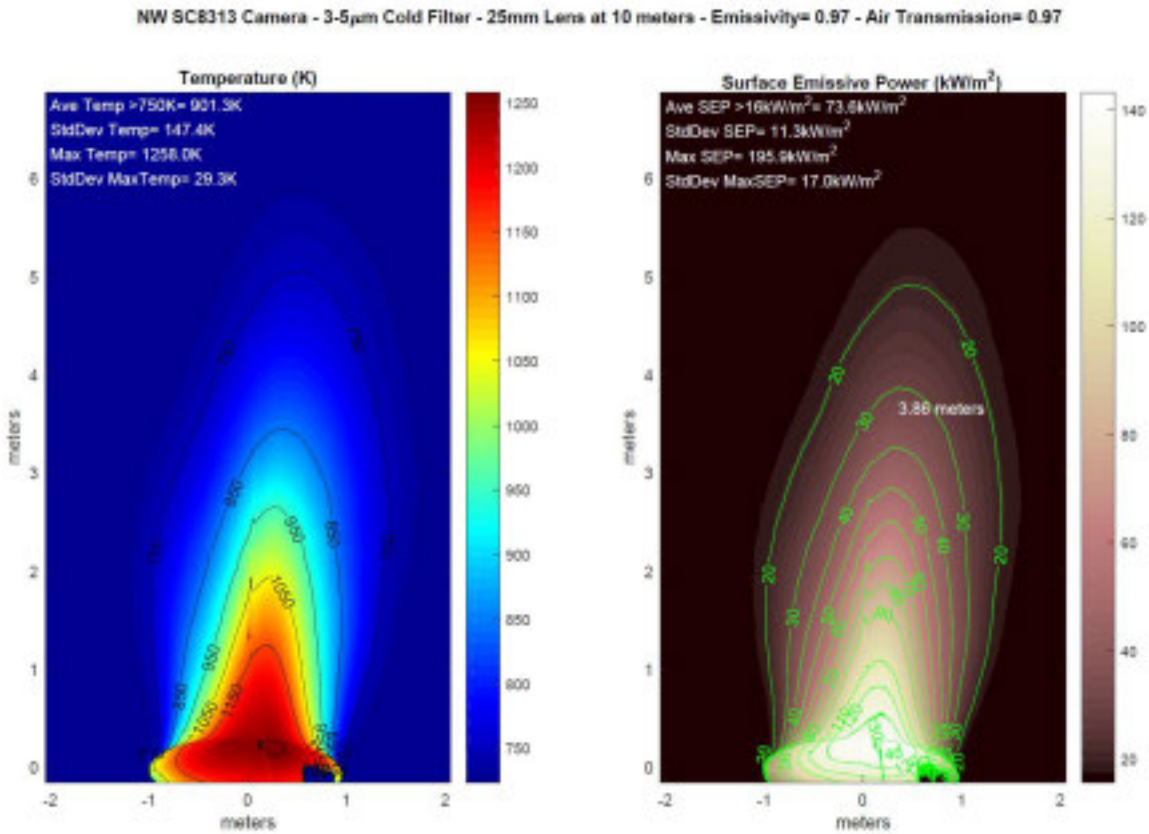


Figure 6-123: Fire plume temperatures and surface emissive power values from IR camera measurements (Test 2.6).

6.2.6.7. DFT TC Temperatures and Derived Heat Flux

Figure 6-124 and Figure 6-125 provide DFT temperatures and heat flux, respectively. The term 'front' refers to the TC measurement for the plate closest to the fire, while the term 'back' refers to the TC measurement for the plate furthest from the fire.

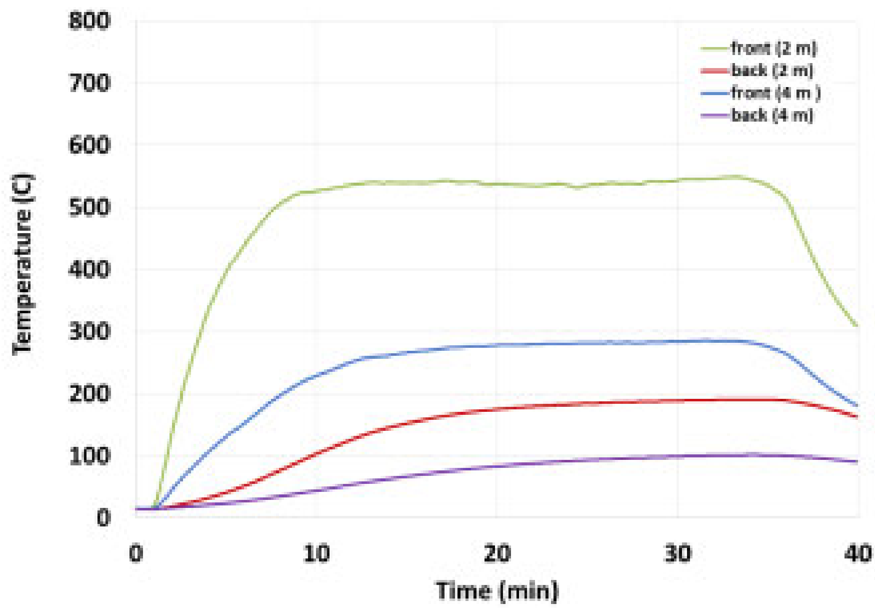


Figure 6-124: Thermocouple temperatures from DFT instruments. Distances are from center of pan (Test 2.6).

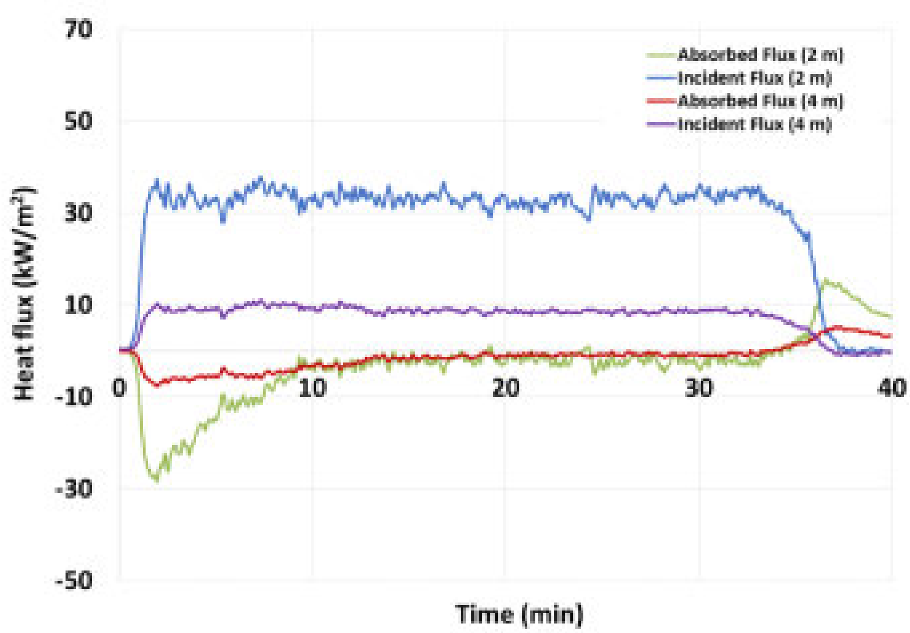


Figure 6-125: Derived heat flux values from DFT measurements. Distances are from center of pan (Test 2.6).

6.2.6.8. Heat Release Rate

Figure 6-126 shows the heat release over time from CGA measurements. The average heat release rate, taken between 15-30 minutes, is 3.5 ± 0.7 MW.

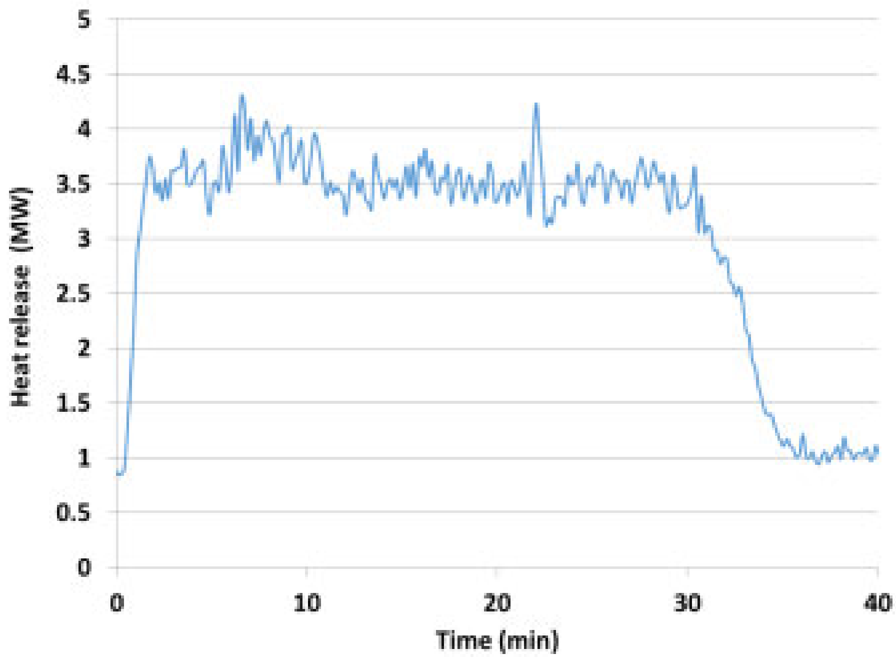


Figure 6-126: Heat release rate (Test 2.6).

6.2.6.9. Flame Height

Figure 6-127 shows the flame height as measured from the IR camera. The flame height averaged over 10 to 20 minutes is 4.5 ± 1.0 m.

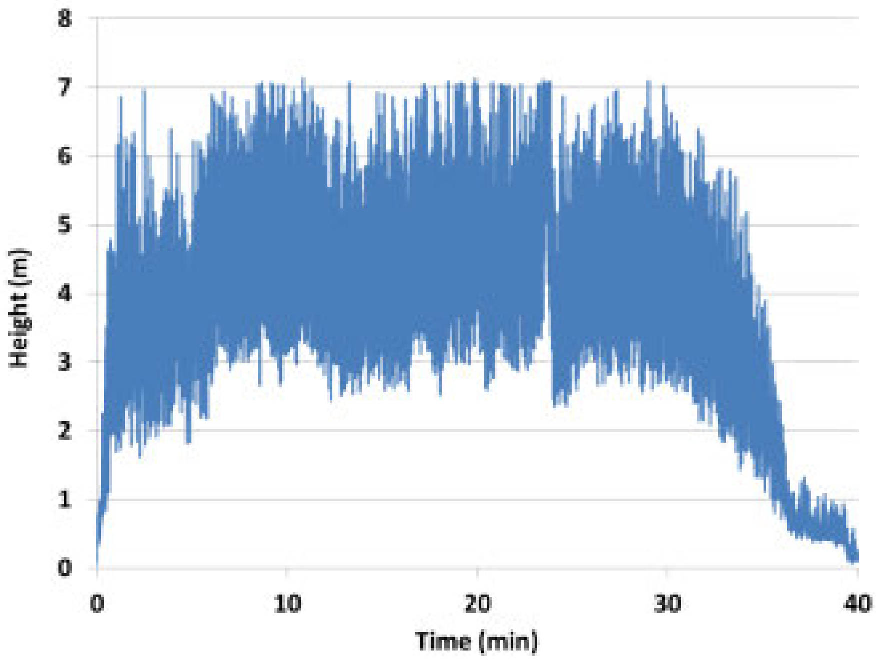


Figure 6-127: Flame height from IR camera measurements (Test 2.6).

6.3. Dilbit Crude Oil Pool Fire Tests

In contrast to the heptane and Bakken crude oil tests, the dilbit crude oil did not reach an identifiable unique steady state over the duration of a test. Based on indications of the flame height, the burn rate varied over the course of a test. For all tests the burn rate was determined by readings from a scale that measured the weight over time. Since the dilbit is composed of a mixture in which a condensate diluent is added, preferential burning could be occurring to explain this behavior. Measurements from other instruments also reflected the behavior of the flame height as will be evident in the test results presented in the following sections.

6.3.1. Test 3.1

For this test, the calorimeter was elevated 1 m from its centerline to the bottom of the fuel pan and the dilbit was maintained at a supply temperature of 20 ± 5ºC. The dilbit fuel was supplied and maintained at a constant fuel level of about 30 mm (1.2 inches) for about 25 minutes. After 25 minutes, the dilbit fuel supply was terminated and Jet-A fuel was introduced for approximately 5 minutes.

6.3.1.1. Fuel Supply Temperature

Figure 6-128 shows fuel supply temperature over time. The temperature averaged over 5-25 minutes is 21.7± 0.5ºC.

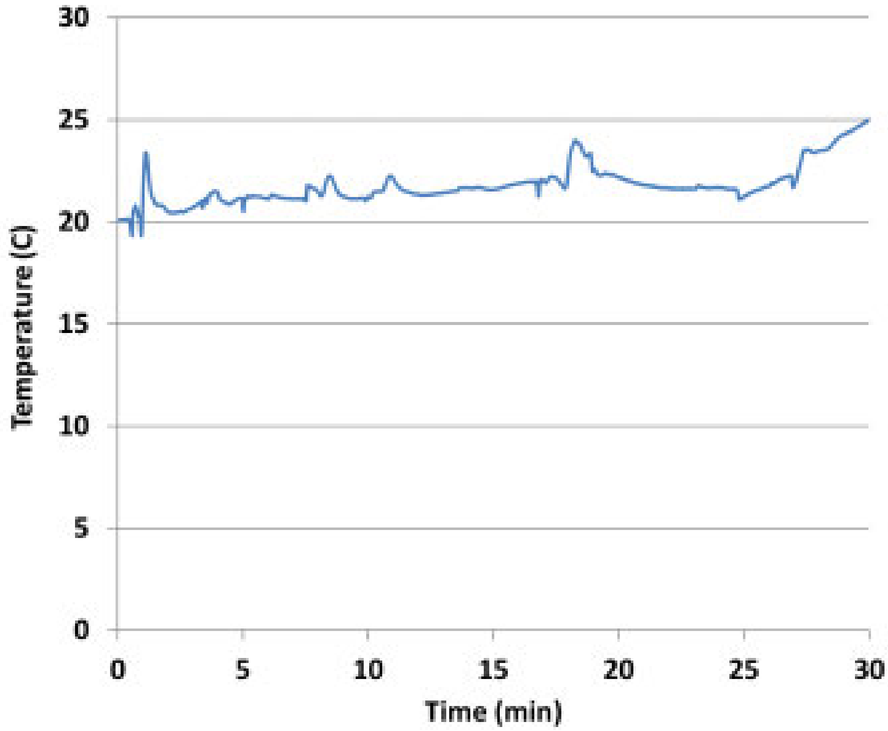


Figure 6-128: Temperature of fuel supply into pan (Test 3.1).

6.3.1.2. Fuel Rake Thermocouple Temperatures

Figure 6-129 shows temperatures from thermocouples within the liquid fuel during the test. The pan was prefilled to the desired height before ignition. The fuel level at approximately 30 mm (1.2 inches) is indicated at TC16. At around 12.5 minutes all thermocouples rapidly increased by 200ºC indicating that heat from the flame was transferred throughout the pool.

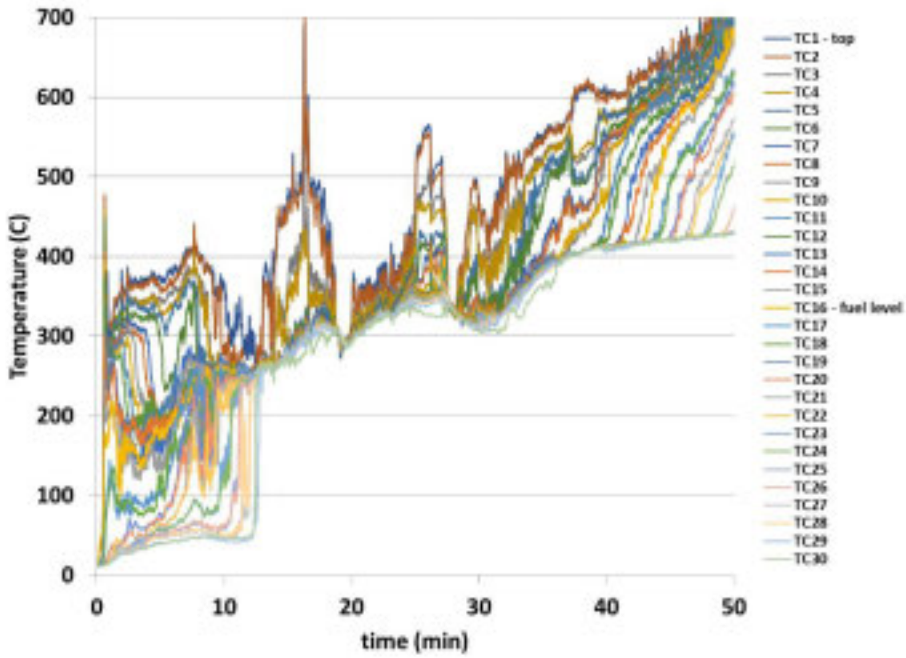


Figure 6-129: Fuel Rake thermocouple temperatures (Test 3.1).

6.3.1.3. Burn Rate

The burn rate is determined by identifying a period in which the differential pressure gauge reading is nearly constant and determining the slope of the change in weight of the fuel tank during that period. Since this was our first test using the system configuration, the difficulty of maintaining a constant fuel level through manual valve control of the fuel feed and nitrogen pressure was unknown. Once experience was gained with this first test, achieving longer periods of constant fuel level for subsequent tests were more successful.

Due to the difficulty in maintaining a constant fuel level only short intervals could be identified, namely, from 9.8 to 10.6 minutes and 16.6 to 17.4 minutes (Figure 6-130 and Figure 6-131). The dP gauge failed about 20 minutes into the test thereby the burn rate could not be determined beyond that time. Note that the fuel level for the interval of 9.8-10.6 minutes was not constant but is sufficient to provide an estimate of the burn rate during this time.

The slope of the curve over the identified periods indicates burn rate values of 9.31 kg/min (0.049 kg/m^2s) during 9.8 to 10.6 minutes and 6.32 kg/min (0.034 kg/m^2s) during 16.6 to 17.4 minutes. Note that this test configuration was repeated for the fifth test in this series. Thus, a more reliable measurement was obtained in test 3.5 allowing for a more accurate indication of the burn rate. Description of the fifth test is provided in section 6.5. The weight of the post-test residue in the pan for Test 3.1 was 31.5 kg (69.3 lbs).

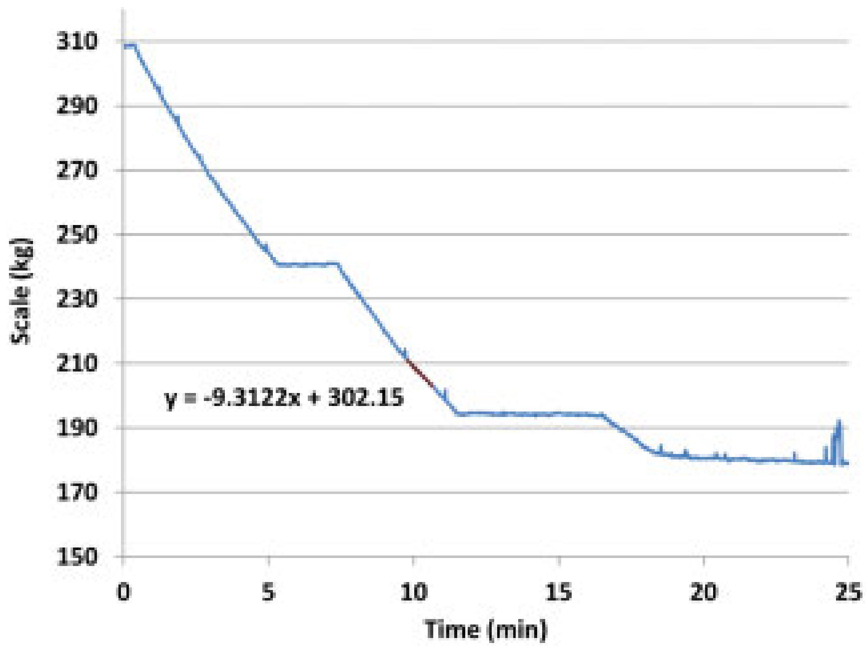


Figure 6-130: Fuel weight over time based on scale measurement (9.8-10.6 minutes) (Test 3.1).

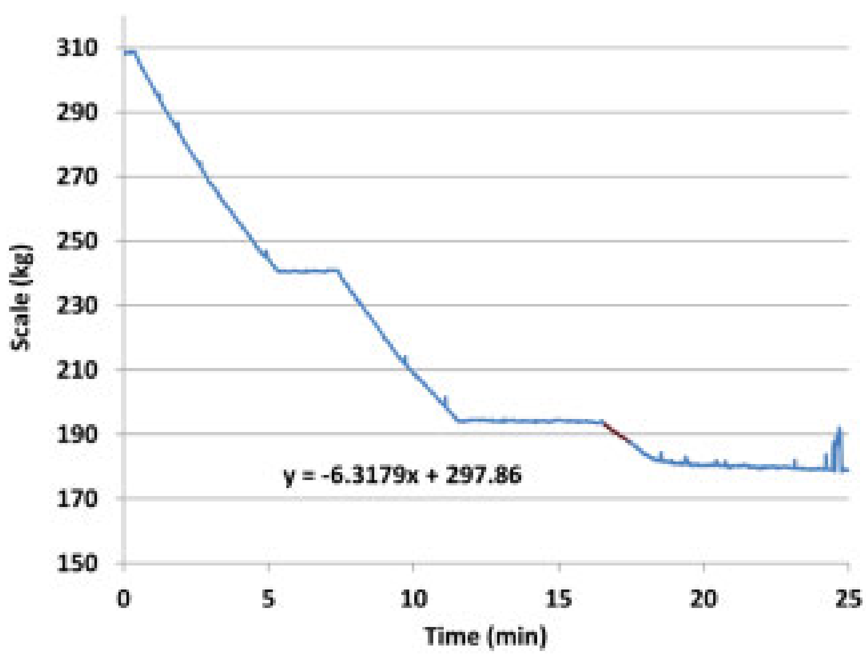


Figure 6-131: Fuel weight over time based on scale measurement (16.6-17.4 minutes) (Test 3.1).

6.3.1.4. Radiometers

Figure 6-132 and Figure 6-133 provide the heat flux over time from the six narrow-angle and five wide-angle radiometers mounted vertically at different elevations at the facility wall, approximately 9 m from the center of the pan. Note that there is a spike in temperature at about 19 minutes after the beginning of the test which lasted under a minute. Review of video footage indicates that the flame height momentarily increased at this time, the cause of which is unknown.

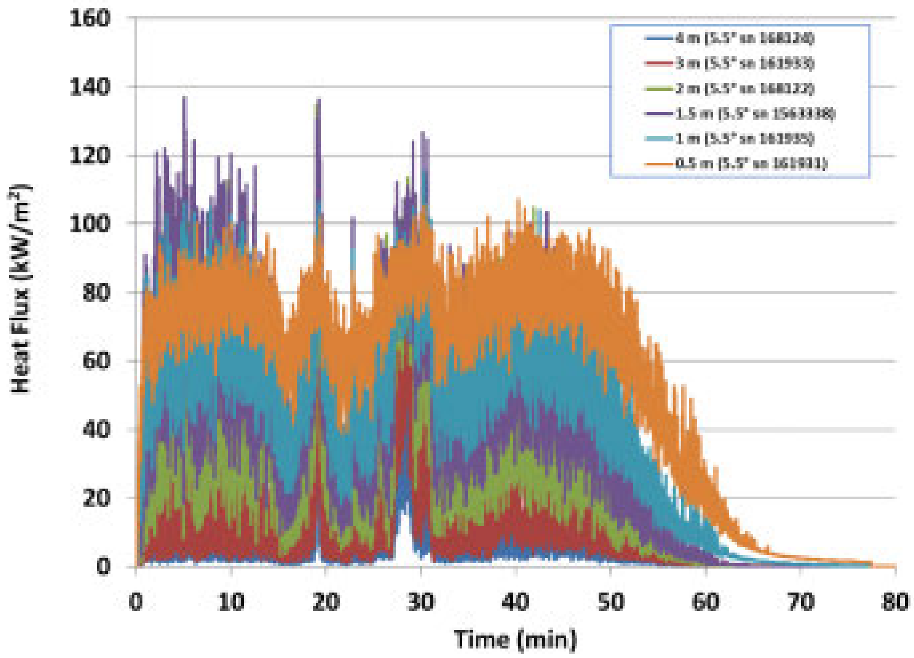


Figure 6-132: Heat flux measurement from narrow view radiometers at different heights (Test 3.1).

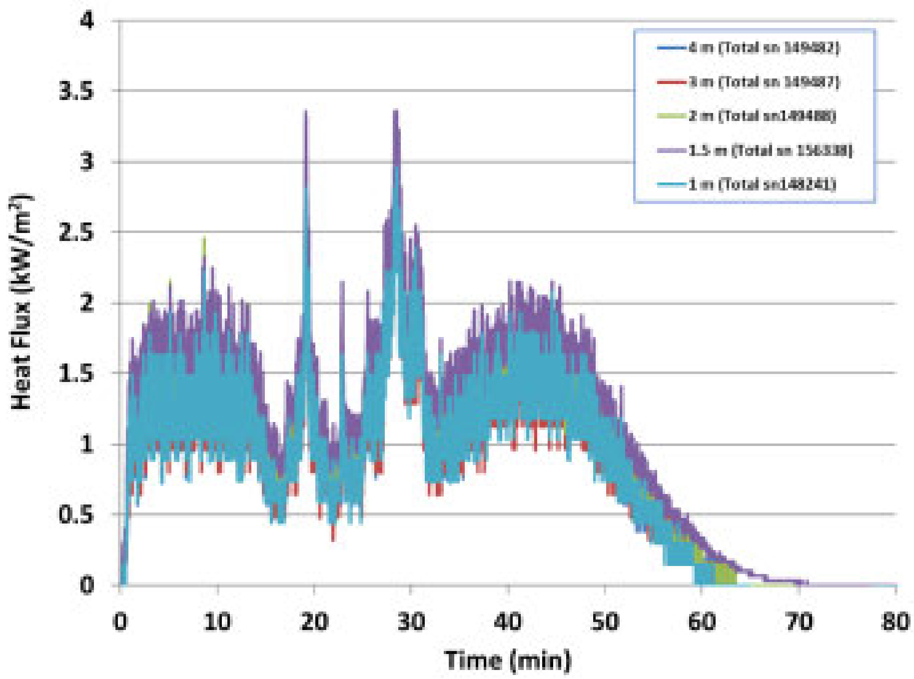


Figure 6-133: Heat flux measurement from wide view radiometers at different heights (Test 3.1).

6.3.1.5. Thermocouple Rake in Fire Plume

Figure 6-134 provides temperature measurements over time from thermocouples placed within the fire plume at its vertical centerline. When the Jet-A fuel was introduced at 25 minutes after the start of the test all temperatures increased except at the 0.5 m location which decreased. It can be anticipated that the temperatures would be altered since the flame height increased with the introduction of Jet-A fuel.

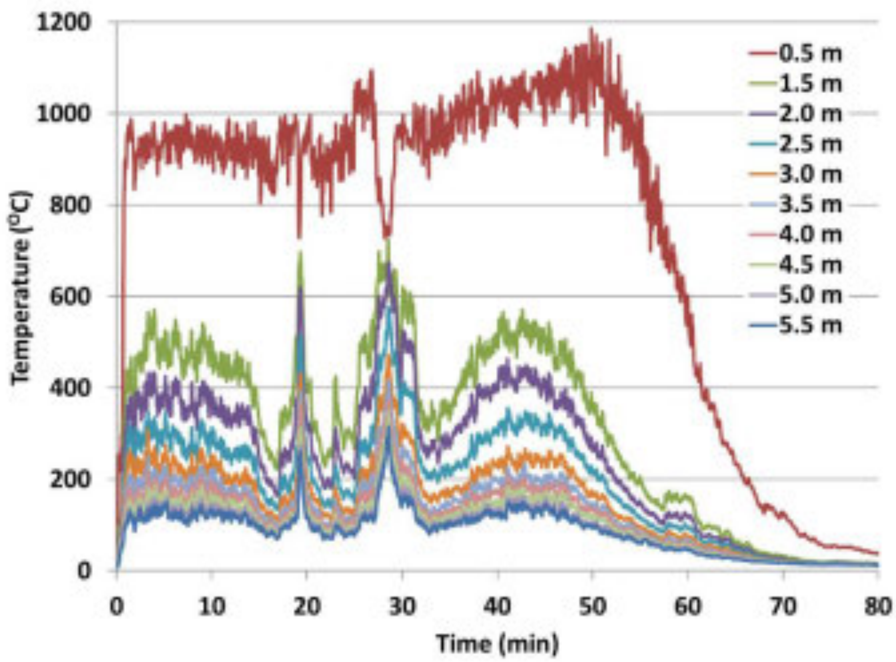


Figure 6-134: Temperature measurements from vertical thermocouple rake in centerline of fire plume (Test 3.1).

6.3.1.6. Plume Temperature and Surface Emissive Power

Figure 6-135 provides IR camera measurements of surface temperatures of the fire plume and surface emissive power averaged over the time during which the dilbit crude oil was burning. The time and spatially averaged SEP is 77.7 ± 7.4 kW/m^2 and the time-averaged local maximum SEP is 194.3 ± 20.3 kW/m^2.

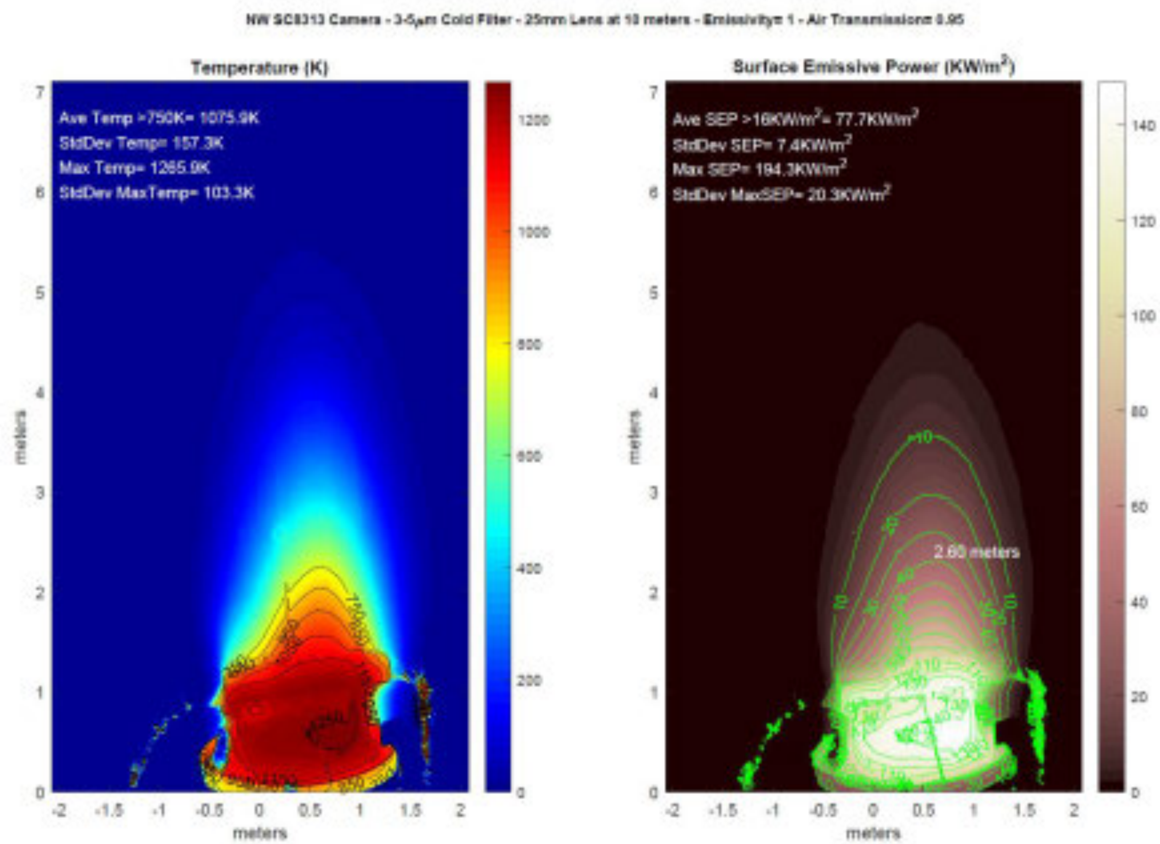


Figure 6-135: Fire plume temperatures and surface emissive power values from IR camera measurements (Test 3.1).

6.3.1.7. DFT TC Temperature and Derived Heat Flux

Figure 6-136 and Figure 6-137 provide DFT temperatures and heat flux, respectively. The term 'front' refers to the thermocouple measurement for the plate closest to the fire, while the term 'back' refers to the thermocouple measurement for the plate furthest from the fire.

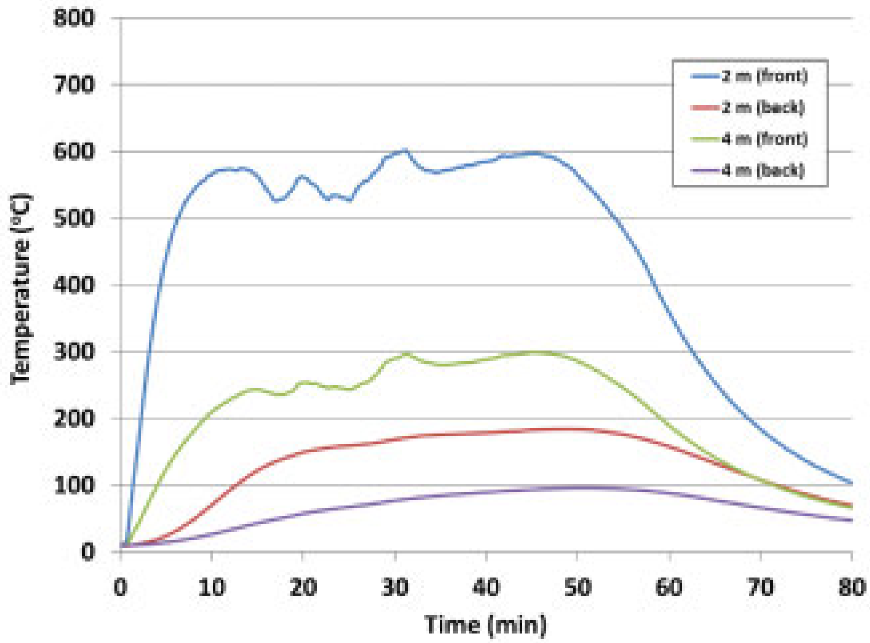


Figure 6-136: Thermocouple temperatures from DFT instruments. Distances are from center of pan (Test 3.1).

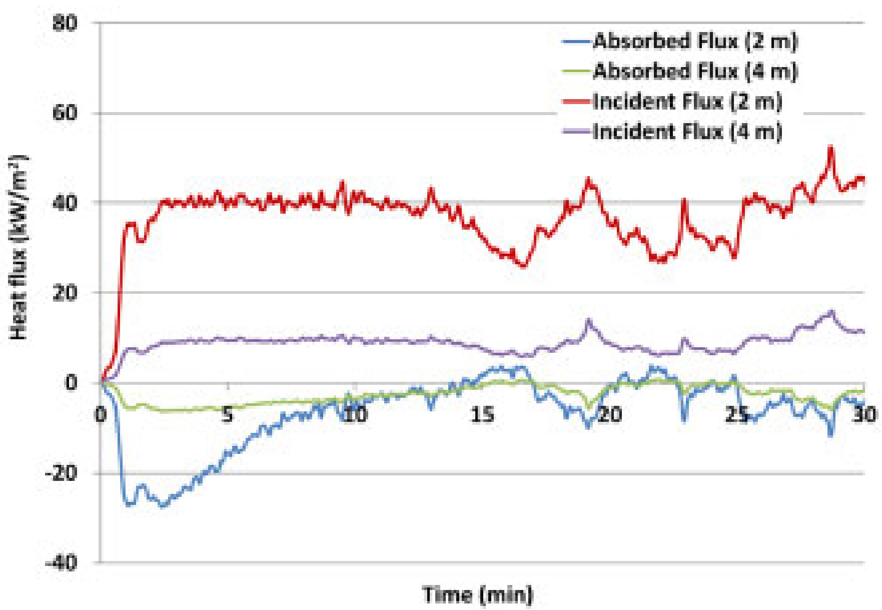


Figure 6-137: Derived heat flux values from DFT measurements. Distances are from center of pan (Test 3.1).

6.3.1.8. Calorimeter TC Temperature and Derived Heat Flux

Figure 6-138 through Figure 6-140 provide temperatures over time from TC measurements placed on the inner and outer cylinders, as well as external to the calorimeter. Figure 6-138 provides thermocouple temperatures on the outer surface of the inner cylinder. None of the inner thermocouples failed. Figure 6-139 provides thermocouple temperatures from the inner surface of the outer shell (midcase) of the calorimeter. The thermocouple location 2L135° failed and is not included in the figure. Figure 6-140 provides thermocouple temperatures on the exterior of the outer cylinder. None of the exterior thermocouples failed.

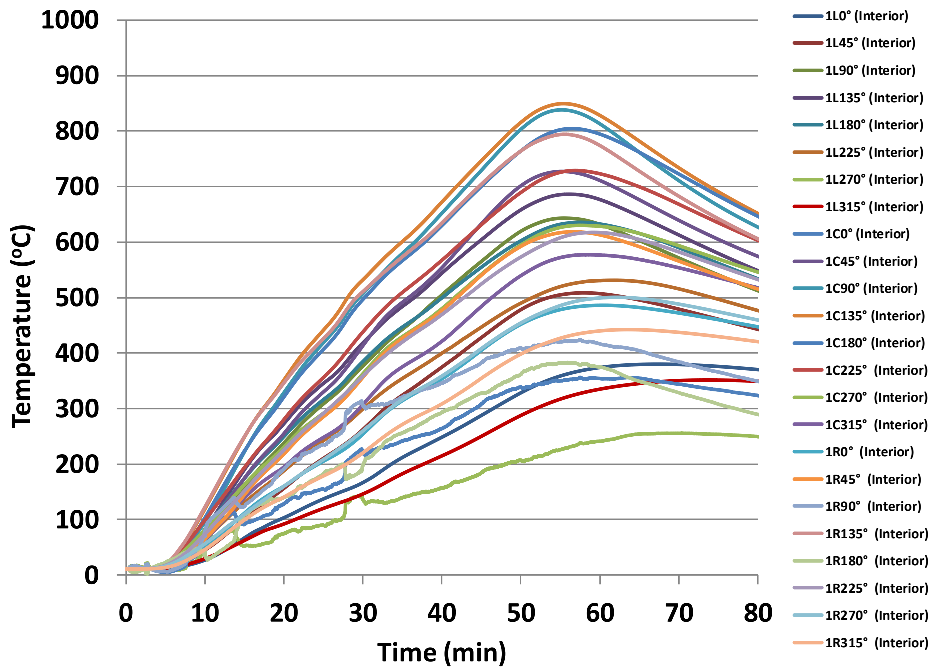


Figure 6-138: Thermocouple temperatures at inner cylinder stations (Test 3.1).

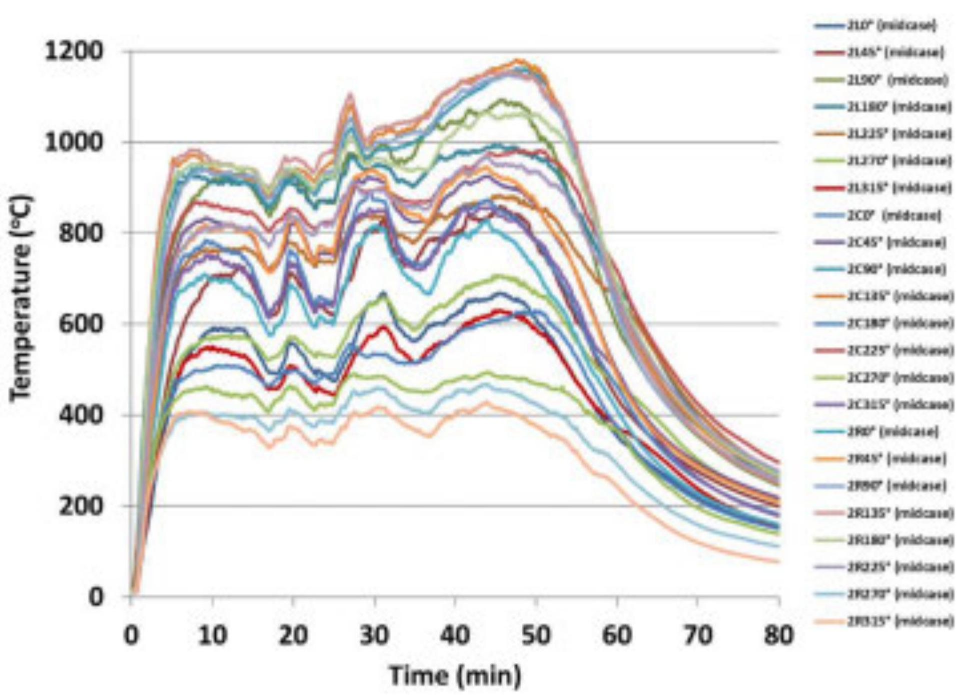


Figure 6-139: Thermocouple temperatures at outer cylinder stations (Test 3.1).

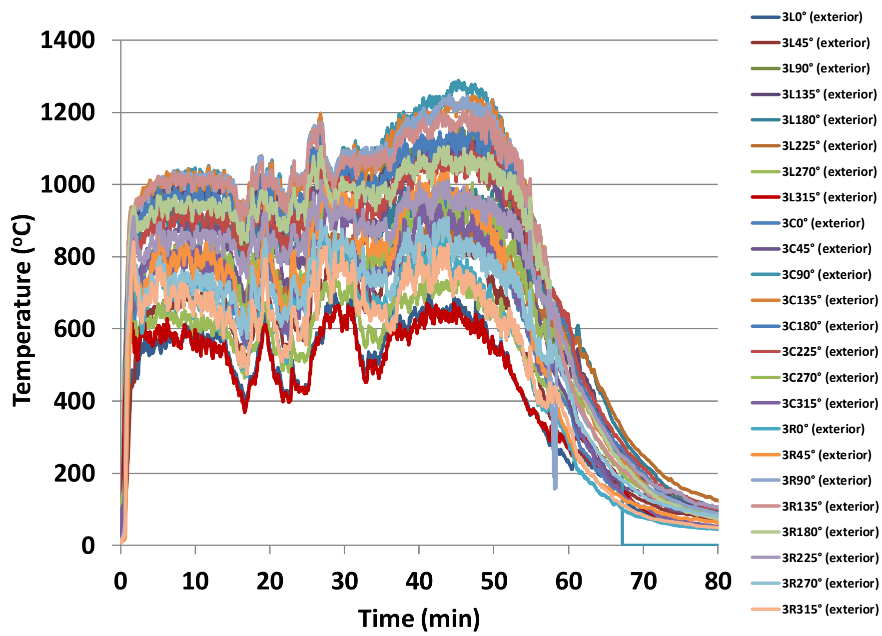


Figure 6-140: Thermocouple temperatures at exterior cylinder stations (Test 3.1).

6.3.1.8.1. Heat Flux to Calorimeter

Figure 6-141 and Figure 6-142 provide the absorbed and total heat flux to the calorimeter, respectively. The location at 135° left is not included in Figure 6-141 because it provided non-physical values. Note that there were temporary spikes from a few locations which seemed to continue to provide reliable readings after the spike. The cause of the spikes at these thermocouple locations is unknown.

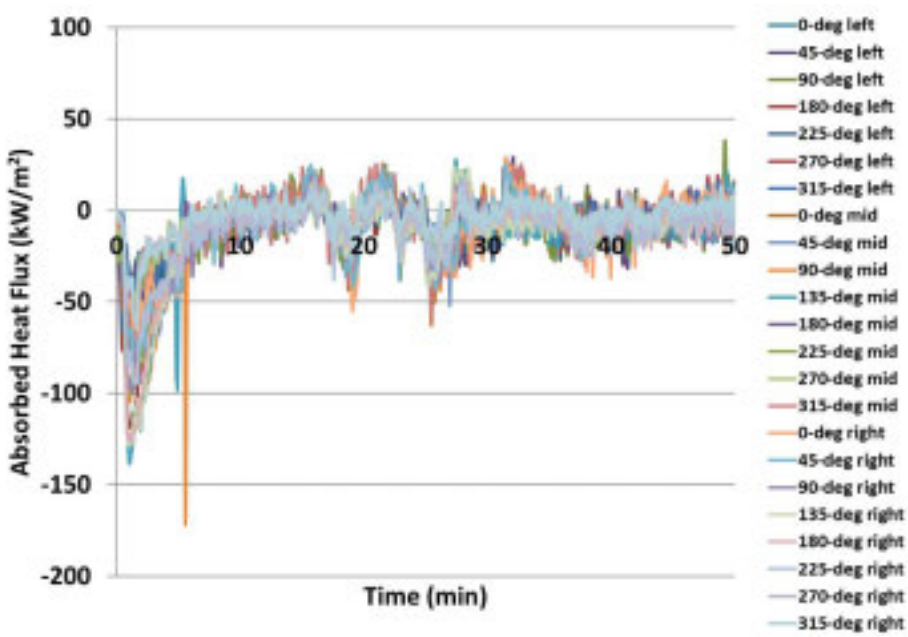


Figure 6-141: Absorbed heat flux to calorimeter (Test 3.1).

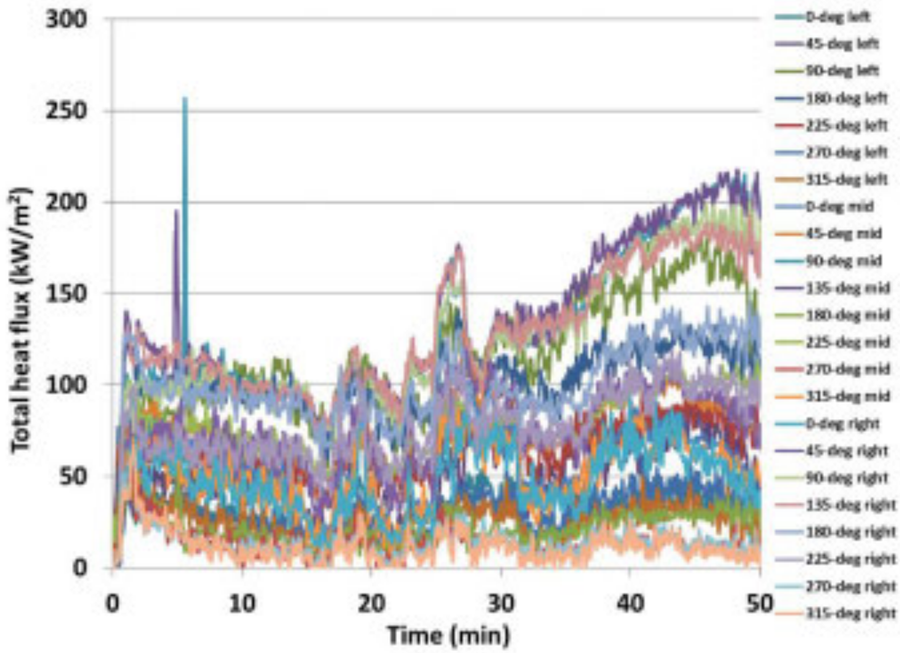


Figure 6-142: Total heat flux to calorimeter (Test 3.1).

6.3.1.9. Heat release rate

Data from the combustion gas analyzer was not collected since there was equipment failure that required investigation and thus was not available for the test. The heat release rate based on evaluating the product of the heat of combustion (43.275 MJ/kg), mass flux (0.034 kg/m^{2}s), and pan area (3.14 m^2) is 4.62 MW.

6.3.1.10. Flame Height

Figure 6-143 shows the flame height as measured from the IR camera. The flame height averaged over 5 to 25 minutes is 3.5 $\pm$ 0.9 m. Note that when the Jet-A was introduced at approximately 25 minutes the flame height increased to an average height of about 5 m. The field of view of the camera did not encompass above 7 m due to limitation of the radial distance of the test chamber and the camera lens. Thus, the data is clipped at that height.

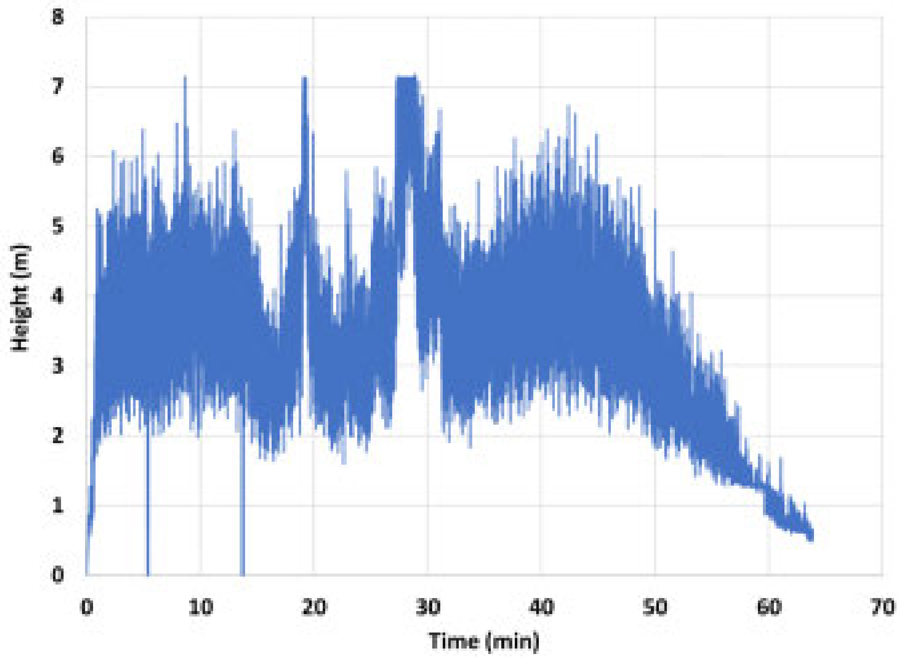


Figure 6-143: Flame height from IR camera measurements (Test 3.1).

6.3.2. Test 3.2

For this test, the calorimeter was elevated 0.5 m from its centerline to the bottom of the fuel pan and the dilbit was maintained at a supply temperature of 20 ± 5ºC. The dilbit fuel was supplied and maintained at a constant fuel level of about 30 mm (1.2 inches) for approximately 30 minutes. After 30 minutes, the dilbit fuel supply was terminated and Jet-A fuel was introduced for about 7 minutes.

6.3.2.1. Fuel Supply Temperature

Figure 6-144 provides the fuel supply temperature over time. The fuel supply temperature averaged over 0-30 minutes is 22.1 ± 1.2ºC.

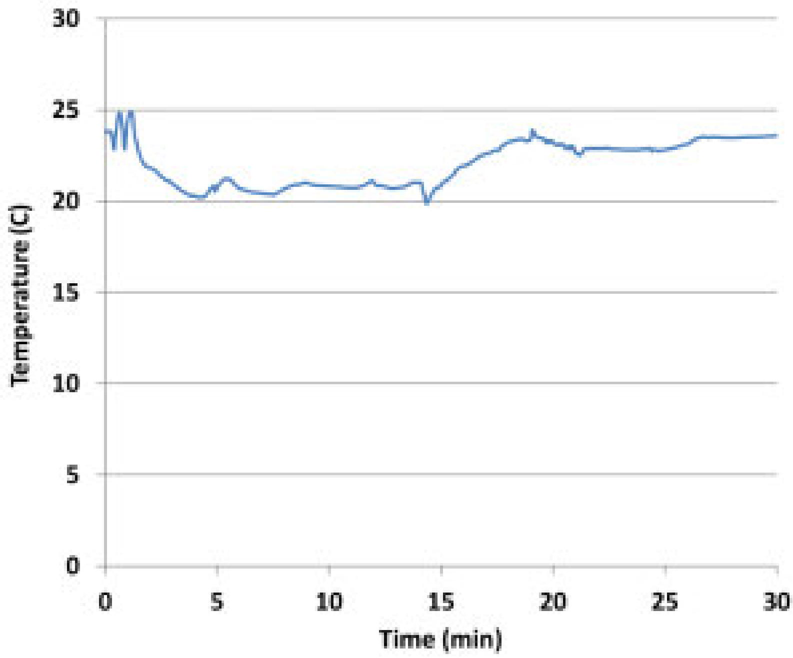


Figure 6-144: Temperature of fuel supply into pan (Test 3.2).

6.3.2.2. Fuel Rake Thermocouple Temperatures

Figure 6-145 shows temperatures from TCs within the liquid fuel. The fuel level at approximately 30 mm (1.2”) is indicated at TC16. For this test the fuel was ignited as it entered the pan and it took approximately 10 minutes to fill to the target differential pressure. Due to this delay in reaching the desired fill level, subsequent tests pre-filled the pan to the desired height before ignition. Also, the temperature readings from the rake are much higher than that for Test 3.1 because of flame engulfment occurring right from the beginning of the test.

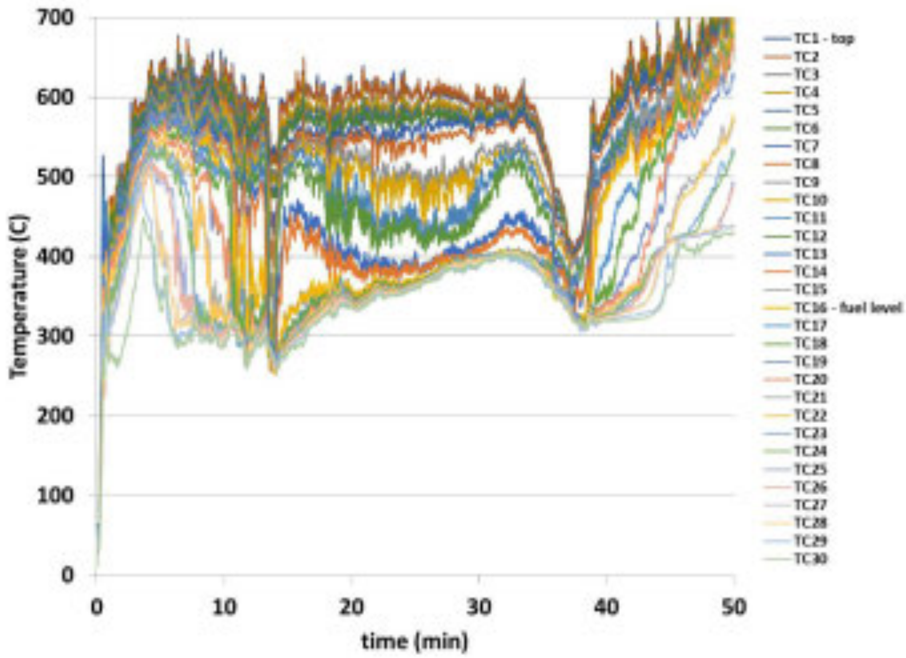


Figure 6-145: Fuel rake thermocouple temperatures (Test 3.2).

6.3.2.3. Burn Rate

The burn rate is determined by identifying a period in which the differential pressure gauge reading is nearly constant and determining the slope of the change in weight of the fuel tank during that period. For the first portion of the test, a constant fuel level could not be identified but the burn rate could be somewhat estimated by evaluating from 11.9 to 12.7 minutes. During this period the slope indicated 11.3 kg/min (r^2 = 99%) which corresponds to a mass flux of 0.06 kg/m^2s (Figure 6-146). For the second portion of the test, the period of 17.3 to 18.3 minutes was chosen to determine the burn rate since it provided the longest duration over which the dP gauge was constant (Figure 6-147). There was another steady period around 20 minutes, but the gauge was near failure and thus may not have been as accurate. The slope of the curve over 17.3 to 18.3 minutes is 4.26 kg/min (r^2 = 99%) which corresponds to a mass flux of 0.023 kg/m^2s. The weight of the post-test residue in the pan was 28.4 kg (62.6 lbs).

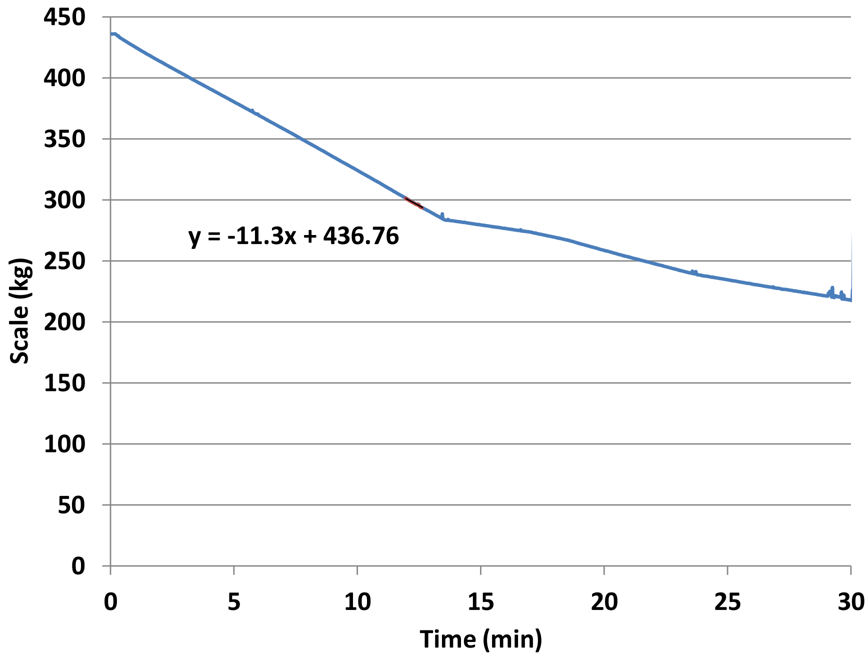


Figure 6-146: Fuel weight over time based on scale measurement (11.9 to 12.6 minutes) (Test 3.2).

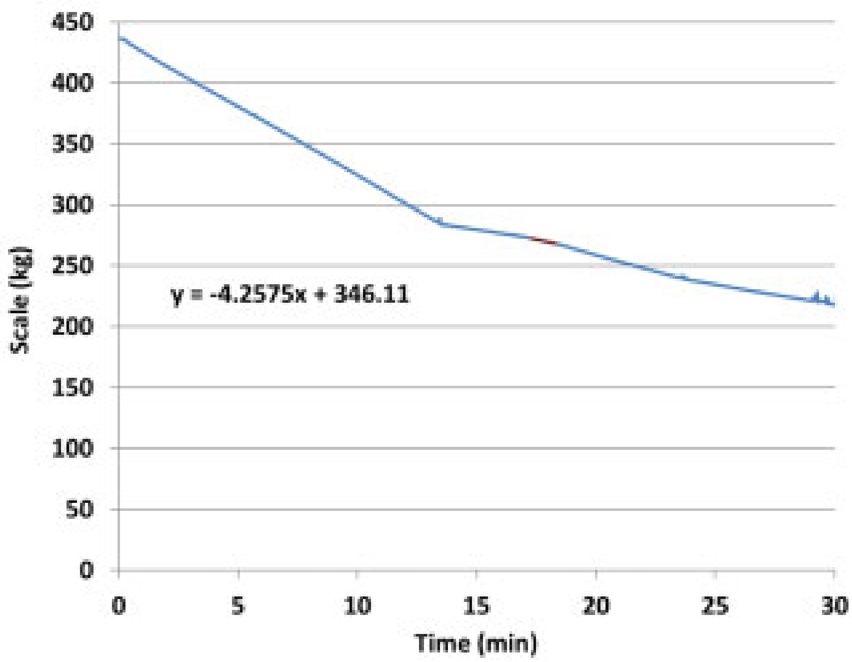


Figure 6-147: Fuel weight over time based on scale measurement (17.3 to 18.3 minutes) (Test 3.2).

6.3.2.4. Radiometers

Figure 6-148 and Figure 6-149 provide the heat flux over time from six narrow-angle and five wide-angle radiometers at the various height locations. At around 14 minutes the heat flux reading from both the narrow-angle and wide-angle gauges decrease. This is the time at which the fuel reached a constant level.

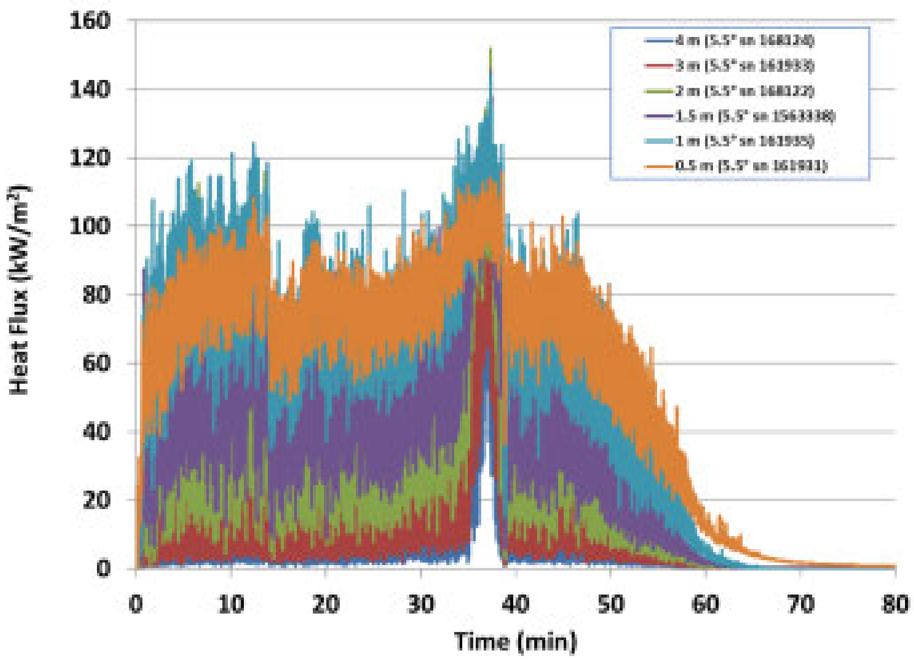


Figure 6-148: Heat flux measurement from narrow view radiometers at different heights (Test 3.2).

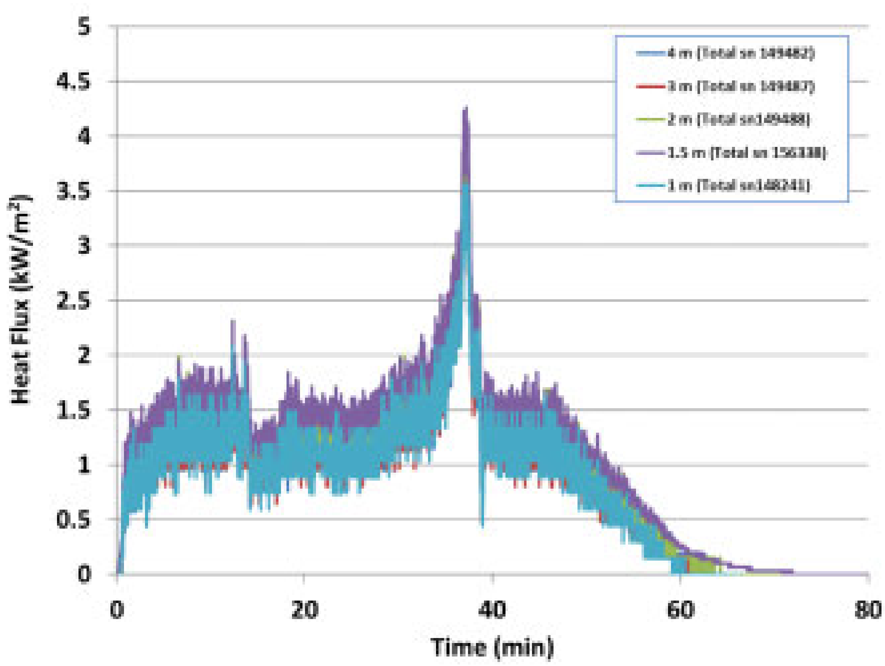


Figure 6-149: Heat flux measurement from wide view radiometers at different heights (Test 3.2).

6.3.2.5. Thermocouple Rake in Fire Plume

Figure 6-150 provides temperature measurements over time from the TCs placed within the fire plume at its vertical centerline.

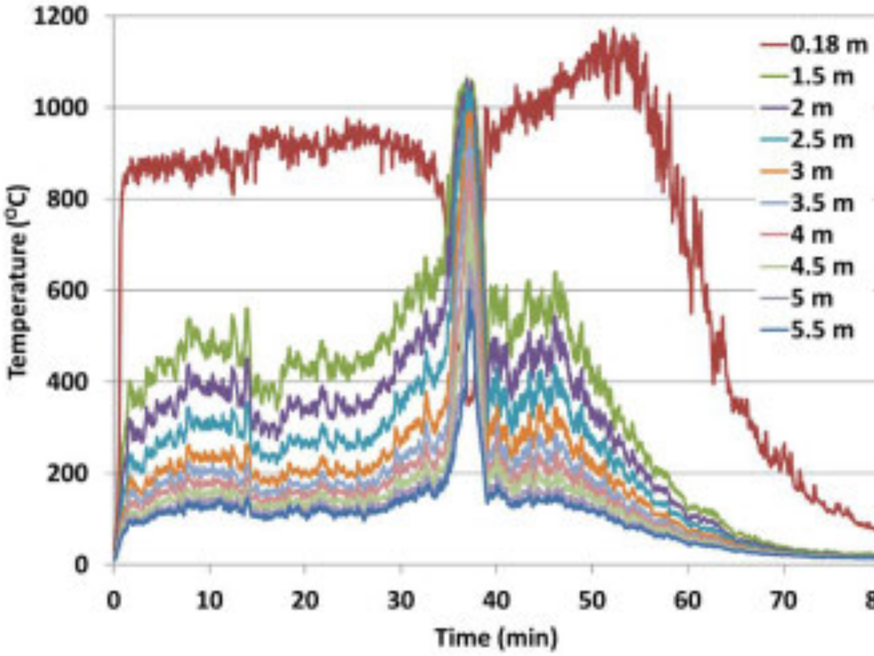


Figure 6-150: Temperature measurements from vertical thermocouple rake in centerline of fire plume (Test 3.2).

6.3.2.6. Plume Temperature and Surface Emissive Power

Figure 6-151 provides IR camera measurements of surface temperatures of the fire plume and surface emissive power averaged over the time during which the Dilbit crude oil was burning. The time and spatially averaged SEP is 69.8 ± 8.2 kW/m^2 and the time-averaged local maximum SEP is 173.3 ± 13.7 kW/m^2.

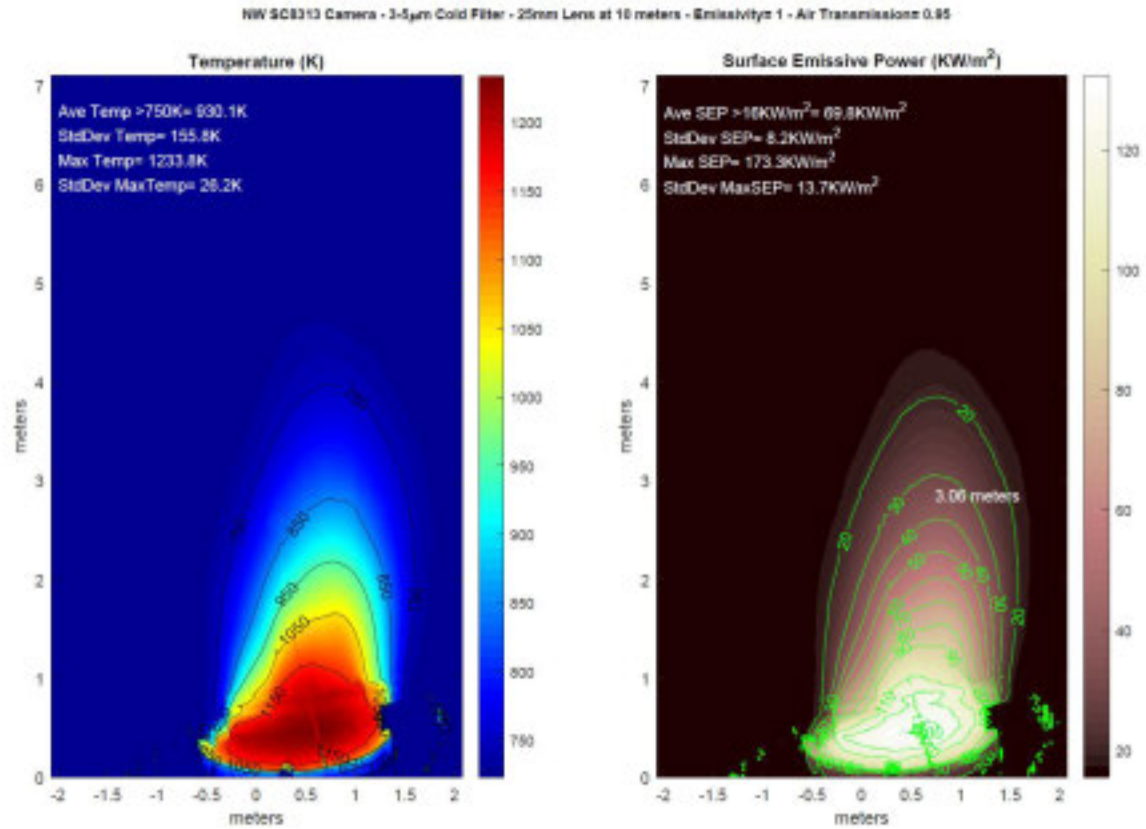


Figure 6-151: Fire plume temperatures and surface emissive power values from IR camera measurements (Test 3.2).

6.3.2.7. DFT TC Temperature and Derived Heat Flux

Figure 6-152 and Figure 6-153 provide DFT temperatures and heat flux, respectively. The term 'front' refers to the thermocouple measurement for the plate closest to the fire, while the term 'back' refers to the thermocouple measurement for the plate furthest from the fire.

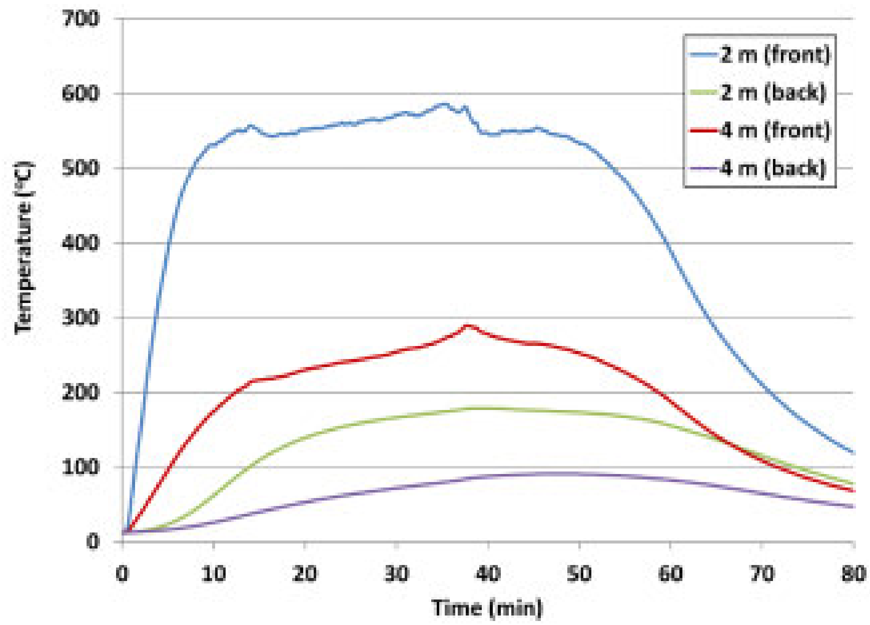


Figure 6-152: Thermocouple temperatures from DFT instruments. Distances are from center of pan (Test 3.2).

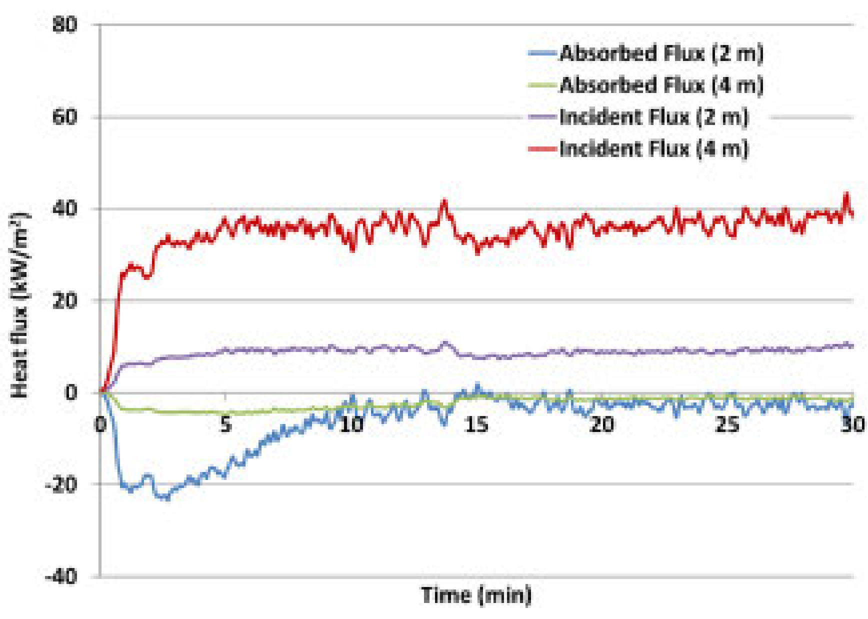


Figure 6-153: Derived heat flux values from DFT measurements. Distances are from center of pan (Test 3.2).

6.3.2.8. Calorimeter TC Temperature and Derived Heat Flux

Figure 6-154 through Figure 6-156 provide temperatures over time from TC measurements placed on the inner and outer cylinders, as well as external to the calorimeter. Figure 6-154 provides thermocouple temperatures on the outer surface of the inner cylinder. None of the inner thermocouples failed. Figure 6-155 provides thermocouple temperatures from the inner surface of the outer shell (midcase) of the calorimeter. The temperature reading from the thermocouple at location 2R315° is much lower than the other readings, indicating that it was near failure. Figure 6-156 provides thermocouple temperatures on the exterior of the outer cylinder. The thermocouples that failed include the locations of 3C90°, 3R90^0, 3R135° and are not included in the figure.

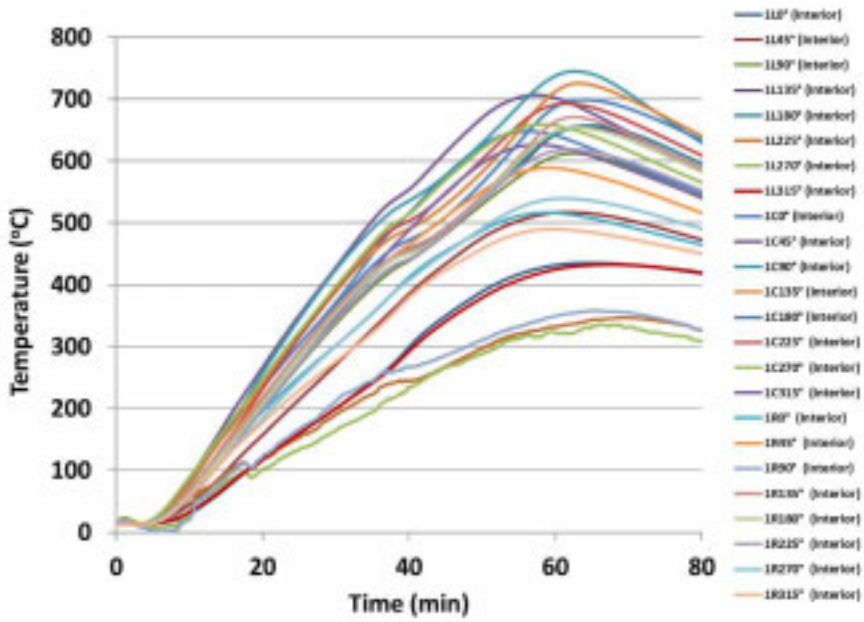


Figure 6-154: Thermocouple temperatures at inner cylinder stations (Test 3.2).

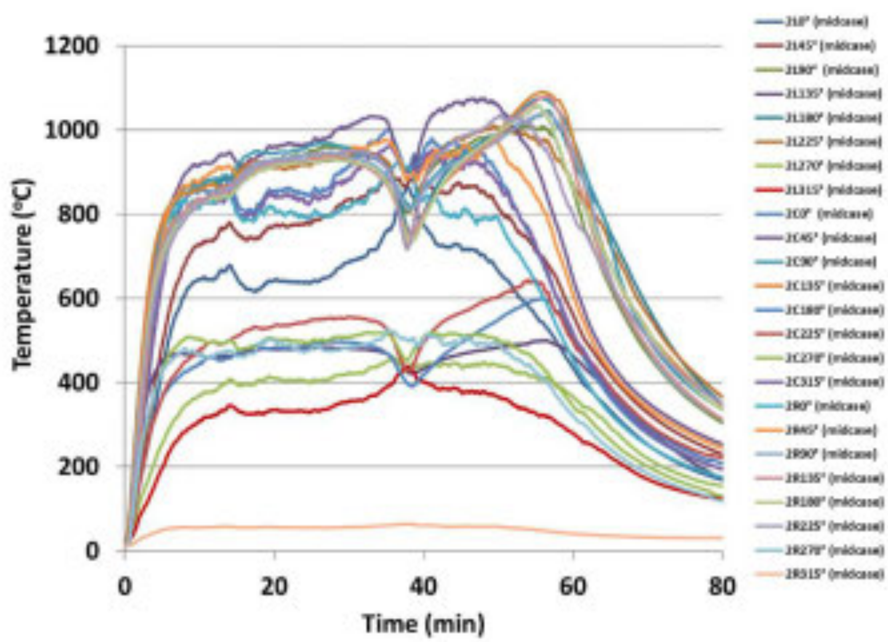


Figure 6-155: Thermocouple temperatures at outer cylinder stations (Test 3.2).

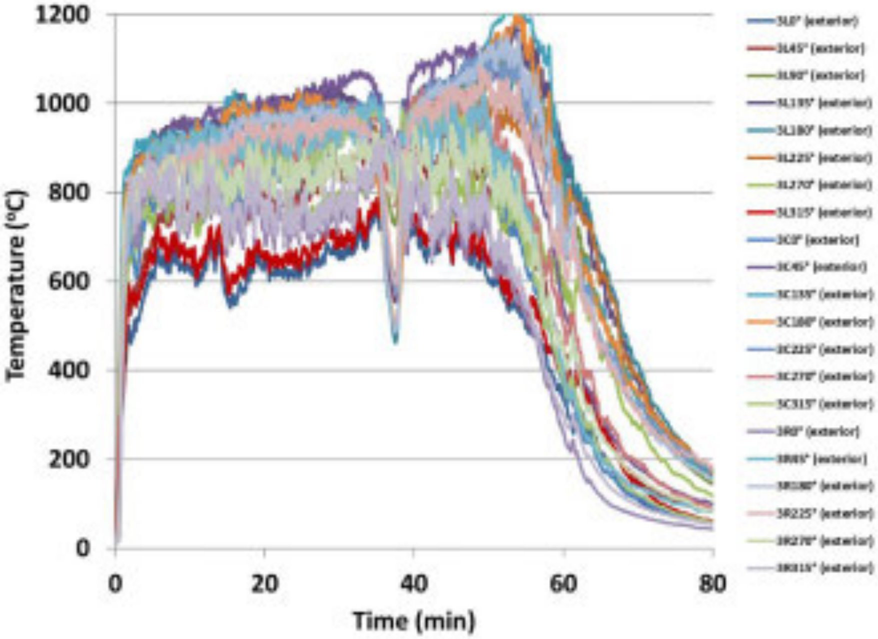


Figure 6-156: Thermocouple temperatures at exterior cylinder stations (Test 3.2).

6.3.2.8.1. Heat Flux to Calorimeter

Figure 6-157 and Figure 6-158 provide the absorbed and total heat flux to the calorimeter, respectively. The absorbed and total heat flux at location R315° is close to zero which confirms that the thermocouple reading was not reliable.

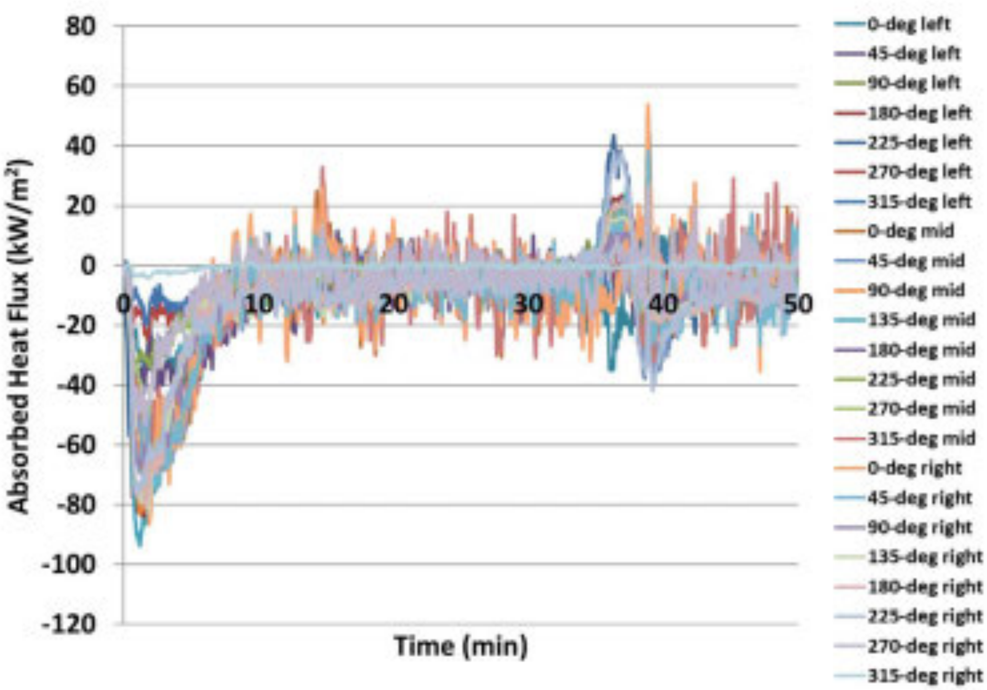


Figure 6-157: Absorbed heat flux to calorimeter (Test 3.2).