Fire Research Laboratory
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U. S. Department of Justice

Test record

ASCLD/LAB–*International* Testing Accreditation Certificate ALI-217-T

Title	Temperature Characterization of a DeLonghi Type 3107 Oil-Filled Radiant Heater		
Test Type	Custom		
Lab Number	18F0007-2	**Author**	
Test dates	3/20/18, 3/22/18	**No. Tests**	3

Introduction

Three (3) experiments were conducted to characterize the approximate surface temperatures produced by a DeLonghi Type 3107 Oil-Filled Heater. The experiments were documented with thermocouples and digital still photography. The experiments were conducted in the Electrical Engineering Laboratory of the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) Fire Research Laboratory located in Beltsville, MD.

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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.

Experiment Setup

Three (3) experiments were conducted to characterize the approximate surface temperatures produced by a DeLonghi Type 3107 Oil-Filled Heater when run in a controlled environment. The heater was powered by 120 VAC for all three tests.

Heater Details

A picture of the oil-filled heater is shown in Figure 1.

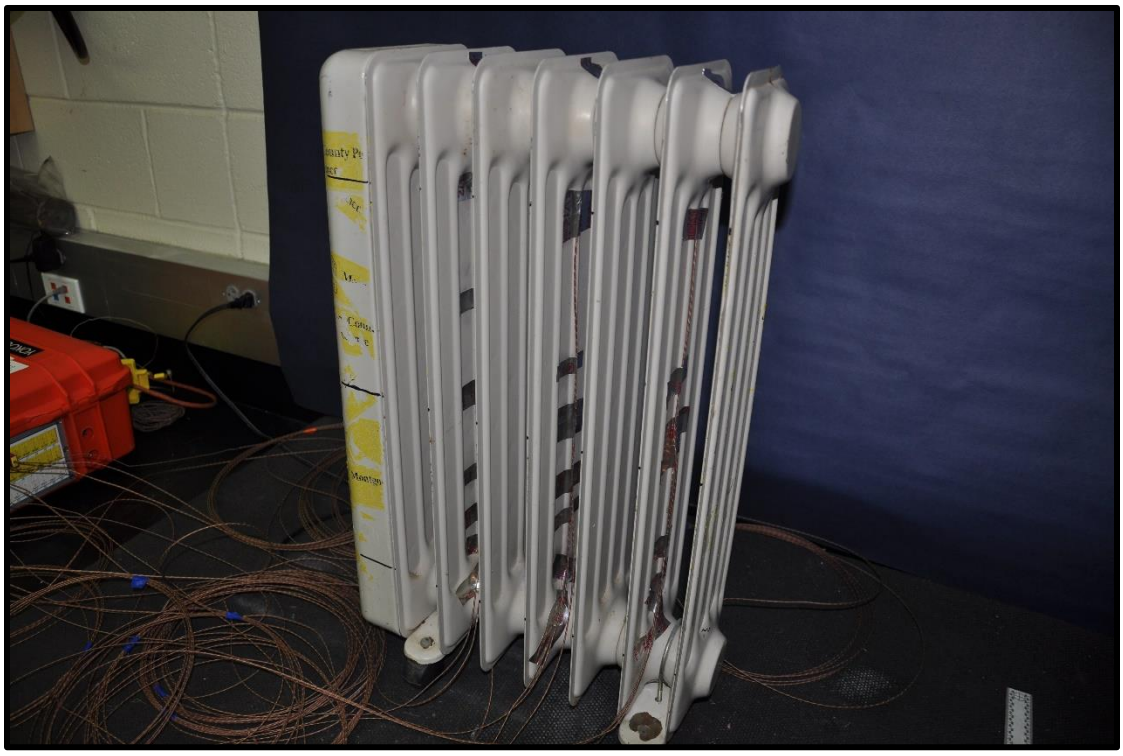


Figure 1. Heater Detail Picture (284707_994431.jpg)

The oil-filled heater had three modes of operation corresponding to heat outputs of 600, 900, and 1500 Watts respectively. The heater used toggle switches to control its heat output. As shown in Figure 2, the 600W setting is activated by toggling the switch on the left, the 900W setting is activated by toggling the switch on the right, and the 1500W setting is activated by toggling both switches together. The heater also used a rotary thermostat switch to set the heat output for every output level. This rotary thermostat switch is shown in Figure 3 and is set to the maximum setting (9).

Figure 2. Adjustable Wattage Toggle Switch (284707_993846.jpg)

Figure 3. Rotary Thermostat Switch (284707_993841.jpg)

The fins of the space heater were labeled 1 through 6. Fins 1, 3, and 5 were selected for measurement, and are shown in Figure 4.

Figure 4. Fin Labeling (284707_993861.jpg)

Experiment Details

Table 1 identifies the Test ID associated with each experiment along with the heater's output mode.

Table 1: Test ID and Heater Output

Experiment	Test ID	Heater Output (W)	Temperature Setting
1	284707	600	9 (maximum)
2	284718	900	9 (maximum)
3	284719	1500	9 (maximum)

Experiment Procedures

The unit was plugged into a 120 VAC source for all experiments. Each experiment started when the heater was switched on to its specified heater output setting. Every experiment was run with the rotary thermostat switch set to its maximum temperature position, as seen in Figure 3. The thermocouple temperatures were then monitored until steady-state temperature was achieved. Steady-state temperature was assumed to be achieved when thermocouple temperatures varied less than one degree over a period of five (5) minutes.

Instrumentation

The experiments were documented using thermocouples and digital still photography. Fifteen (15) type K glass thermocouples were attached to the surface of the oil-filled heater to measure surface temperatures during warm-up and steady-state operation. The thermocouples were attached using OMEGATHERM "201" high thermal conductivity paste, shown in Figure 5. The thermal conductive paste was used to attain better contact between the heater surface and the thermocouple. The thermocouples were then taped to the heater using Nashua 324A Premium Foil Tape to ensure that the thermocouple was in contact with the surface. A pasted thermocouple is documented in Figure 6, followed by a thermocouple that has been pasted and taped shown in Figure 7.

Figure 5. Thermal Paste Description (284707_993887.jpg)

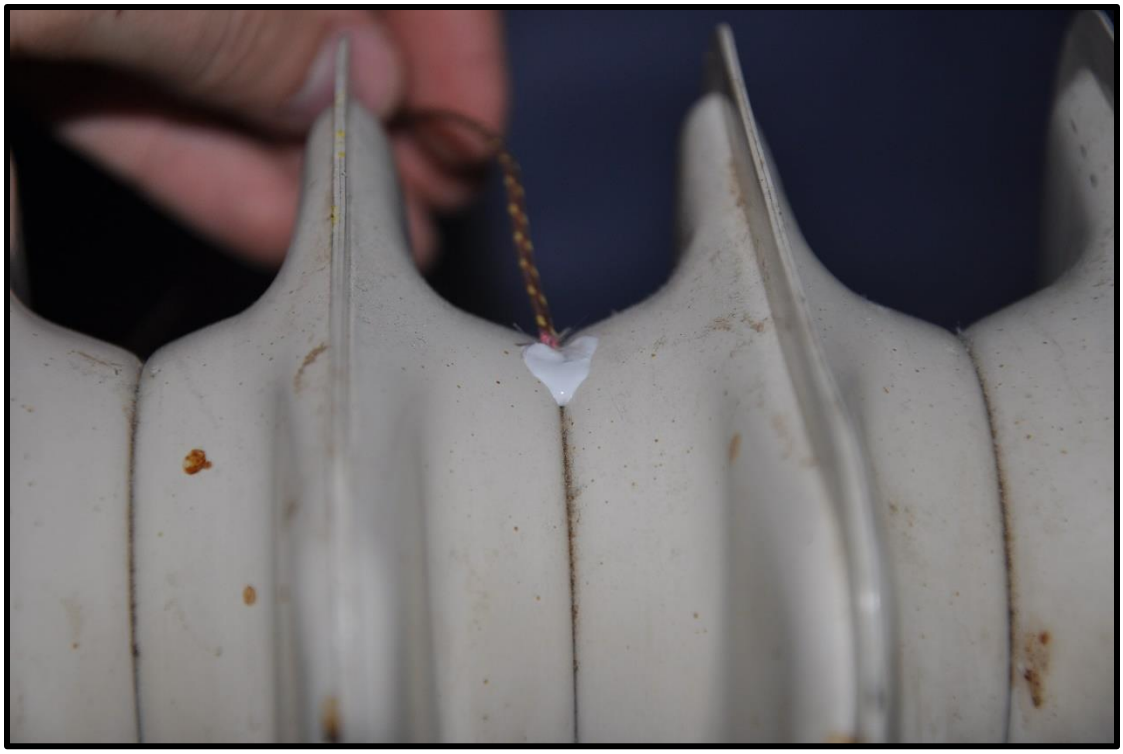


Figure 6. Thermocouple - Thermal Paste Interface (284707_994361.jpg)

Figure 7. Taped Thermocouple (284707_994362.jpg)

The 15 thermocouples were placed on the oil-filled heater in the following locations marked by red points on Figure 8. Figure 9 shows the attached thermocouples.

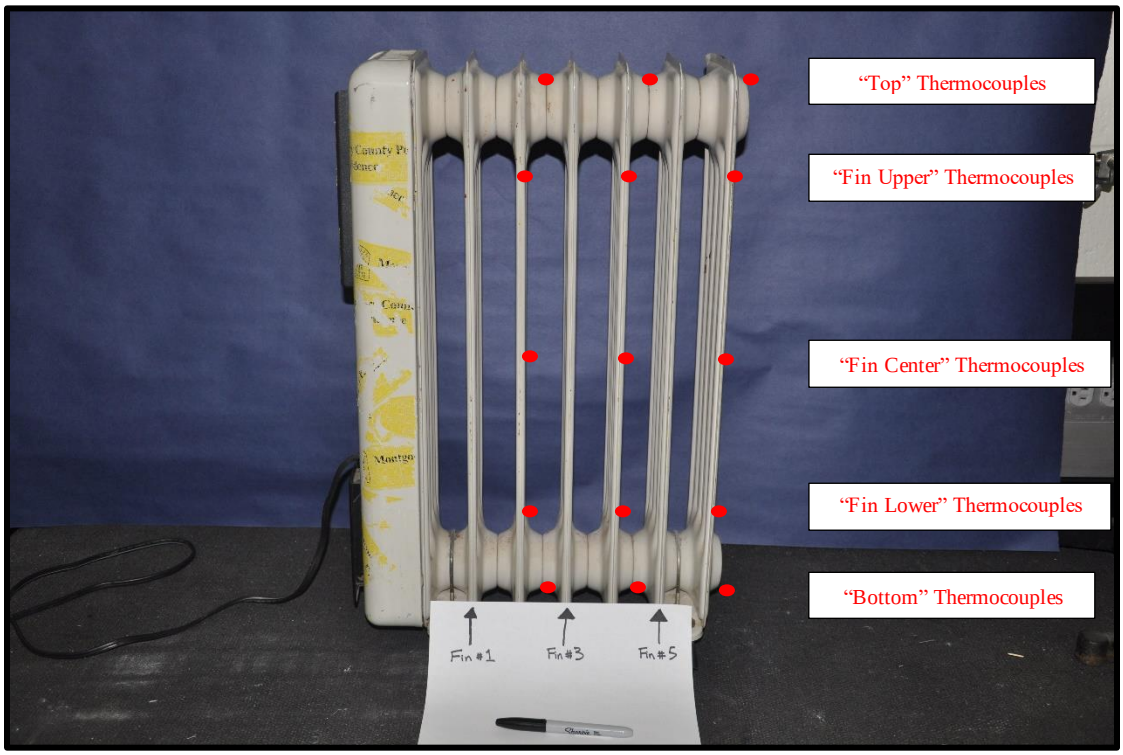


Figure 8. Thermocouple Locations (284707_993861.jpg)

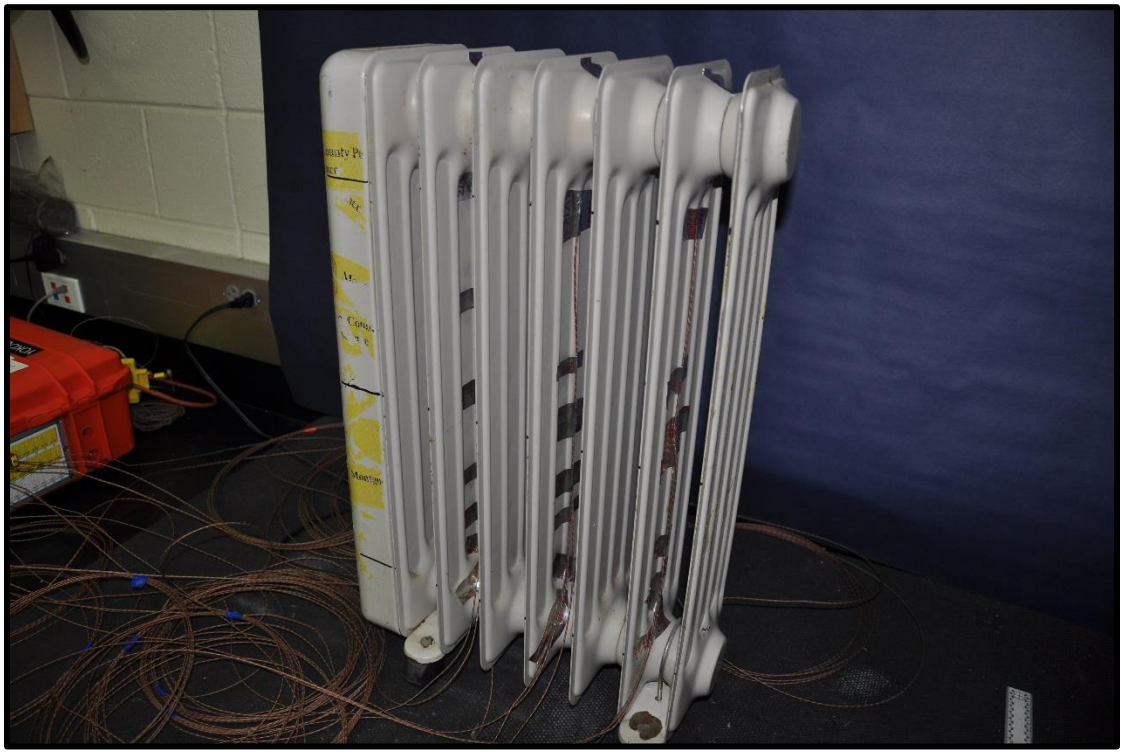


Figure 9. Thermocouples Attached to Heater (284707_994431.jpg)

The fin thermocouples were attached to center of the heater fins. In the center of each fin was an oil channel that ran from the bottom to the top of the heater. The thermocouple was pasted on top of the oil channel as shown in Figure 10.

Figure 10. Thermocouple on Fin Center (284707_994388.jpg)

A thermocouple installed in the row of “Top Thermocouples” is shown in Figure 7. Thermocouples were installed on the body of the heater in the spaces between fins. Figure 11 illustrates a thermocouple installed into the set of bottom thermocouples.

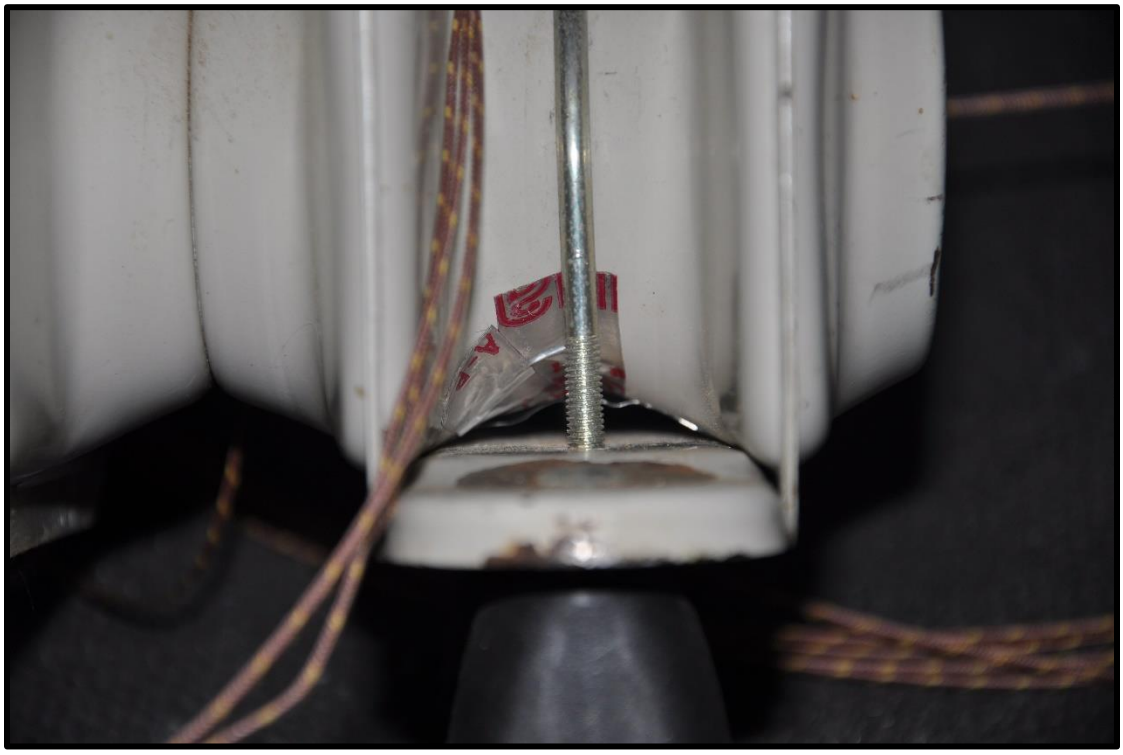


Figure 11. Thermocouple Attached to Bottom Row (284707_994406.jpg)

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 that 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 2. Lab Conditions Description

Experiment ID	Description	Manufacturer	Model
284707	Elec Lab	OMEGA	IBTHP-5
284718	Elec Lab	OMEGA	IBTHP-5
284719	Elec Lab	OMEGA	IBTHP-5

The following table provides a summary of the initial conditions at the start of the experiment(s).The 'Description' column shows the location of the measurements.

Table 3. Ambient Laboratory Condition Summary

Experiment ID	Description	Initial Temperature (C)	Initial Pressure (kPa)	Initial Relative Humidity (%)
284707	Elec Lab	23	100	21
284718	Elec Lab	24	101	17
284719	Elec Lab	24	101	16

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].

Set Up Photos

The following shows photographs of the experiment setup.

Figure 12. 284707_993831

Figure 13. 284707_993832

Figure 14. 284707_993833

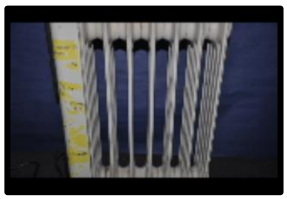


Figure 15. 284707_993834

Figure 16. 284707_993835

Figure 17. 284707_993836

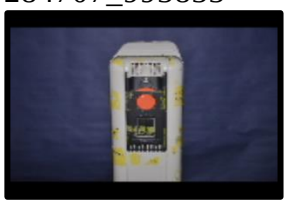


Figure 18. 284707_993837

Figure 19. 284707_993838


Figure 20.
284707_993839


Figure 21.
284707_993840


Figure 22.
284707_993841

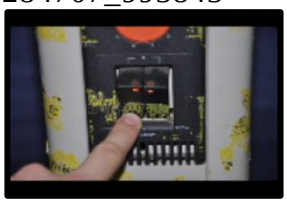

Figure 23.
284707_993842


Figure 24.
284707_993843


Figure 25.
284707_993844


Figure 26.
284707_993845


Figure 27.
284707_993846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284707_993848


Figure 30.
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Figure 31.
284707_993850


Figure 32.
284707_993851

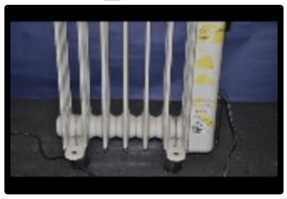
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Figure 34.
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Figure 35.
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Figure 36.
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Figure 37.
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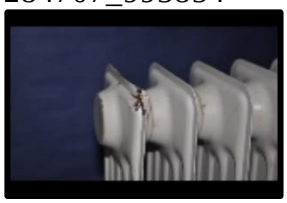
Figure 38.
284707_993857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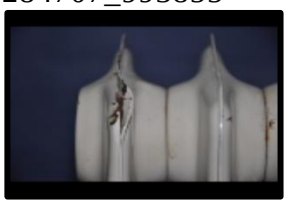
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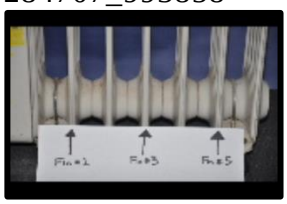
Figure 41.
284707_993860


Figure 42.
284707_993861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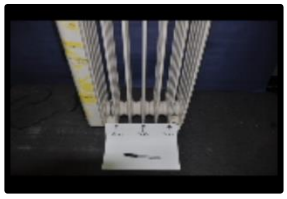
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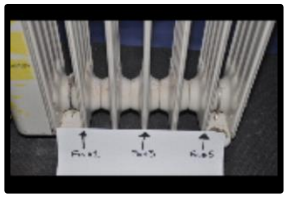
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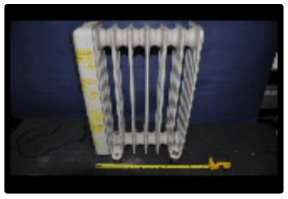
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Figure 47.
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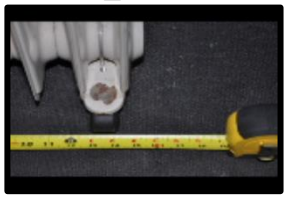
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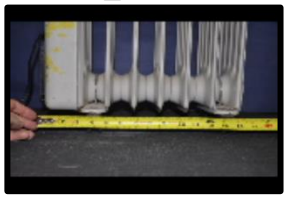
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Figure 50.
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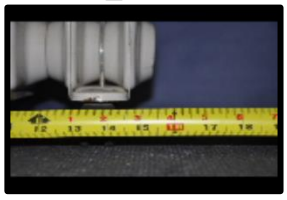
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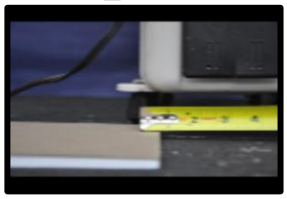
Figure 52.
284707_993871


Figure 53.
284707_993872


Figure 54.
284707_993873


Figure 55.
284707_993874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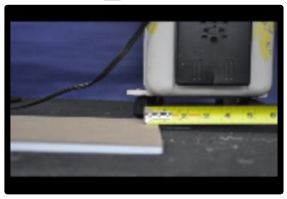
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Figure 58.
284707_993877


Figure 59.
284707_993878


Figure 60.
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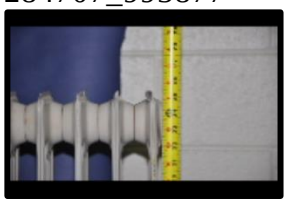
284707_993880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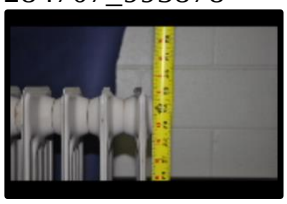
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Figure 64.
284707_993883


Figure 65.
284707_993884


Figure 66.
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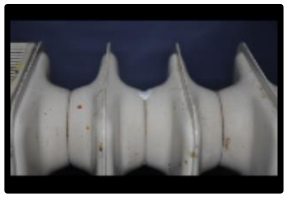
Figure 68.
284707_993887

Figure 69.
284707_993888

Figure 70.
284707_994359



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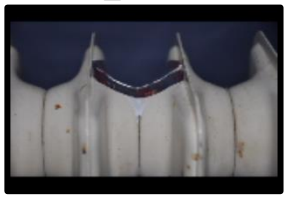

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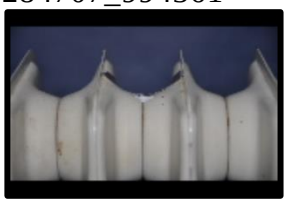

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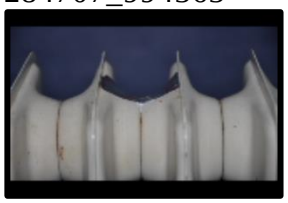

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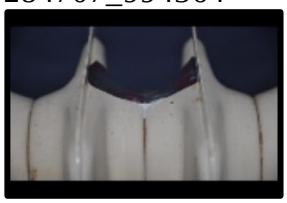

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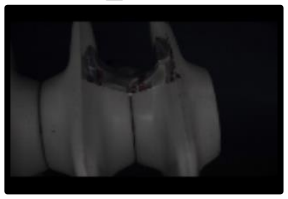

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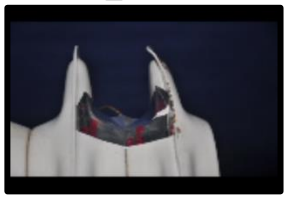

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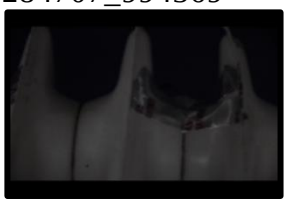

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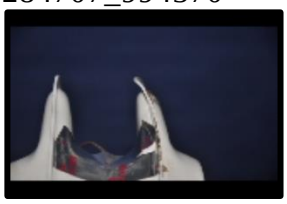

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284707_994376

Figure 88.
284707_994377

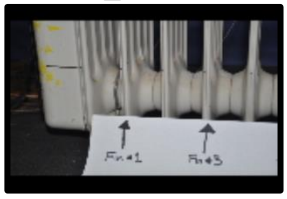

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Figure 90.
284707_994379

Figure 91.
284707_994380

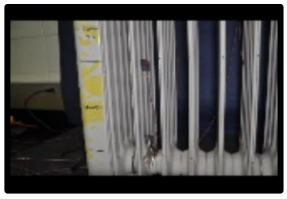
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Figure 93.
284707_994382


Figure 94.
284707_994383

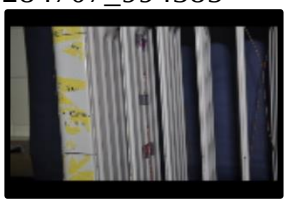

Figure 95.
284707_994384


Figure 96.
284707_994385


Figure 97.
284707_994386


Figure 98.
284707_994387


Figure 99.
284707_994388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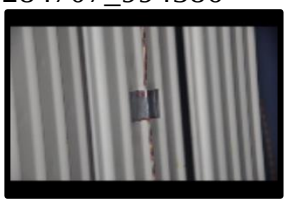
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Figure 102.
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284707_994393


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Figure 106.
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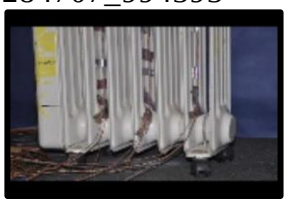
Figure 107.
284707_994396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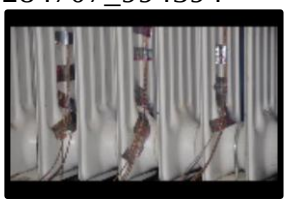
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Figure 110.
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Figure 111.
284707_994400

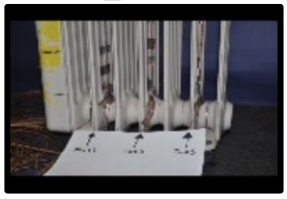
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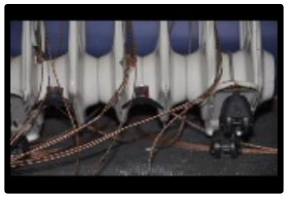
Figure 113.
284707_994402


Figure 114.
284707_994403


Figure 115.
284707_994404



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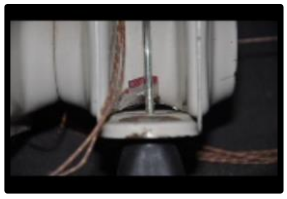

Figure 117.
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Figure 118.
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Figure 119.
284707_994408

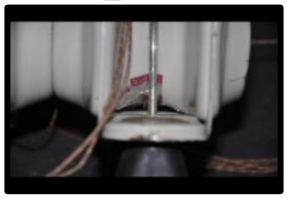

Figure 120.
284707_994409

Experiment 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” [4].

Results for Test 1 (ID 284707)

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

Table 4. Temperature Value Result Summary

Description	Initial (C)	Max (C)	30 second max average (C)	1 minute max average (C)	5 minute max average (C)	10 minute max average (C)
Top1	25.5	78.7	78.6	78.6	78.5	78.4
Top 2	25.1	78.1	78.0	78.0	77.6	77.5
Top 3	24.7	76.1	76.0	75.9	75.8	75.7
Fin 1 Lower	24.0	94.6	94.4	94.3	94.2	94.1
Fin 1 Center	24.3	82.0	81.9	81.9	81.8	81.8
Fin 1 Upper	25.1	83.2	83.1	83.1	82.9	82.9
Fin 3 Lower	24.1	96.4	96.3	96.2	96.2	96.1
Fin 3 Center	24.4	83.2	83.1	83.1	83.0	83.0
Fin 3 Upper	24.9	83.1	83.0	83.0	82.9	82.8
Fin 5 Lower	24.6	69.9	69.8	69.8	69.6	69.6
Fin 5 Center	24.9	73.9	73.9	73.9	73.7	73.7
Fin 5 Upper	25.1	83.6	83.5	83.5	83.5	83.4
Bottom 1	23.5	60.9	60.9	60.8	60.7	60.7
Bottom 2	23.6	59.3	59.2	59.2	59.1	59.0
Bottom 3	23.8	56.7	56.6	56.6	56.5	56.4

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

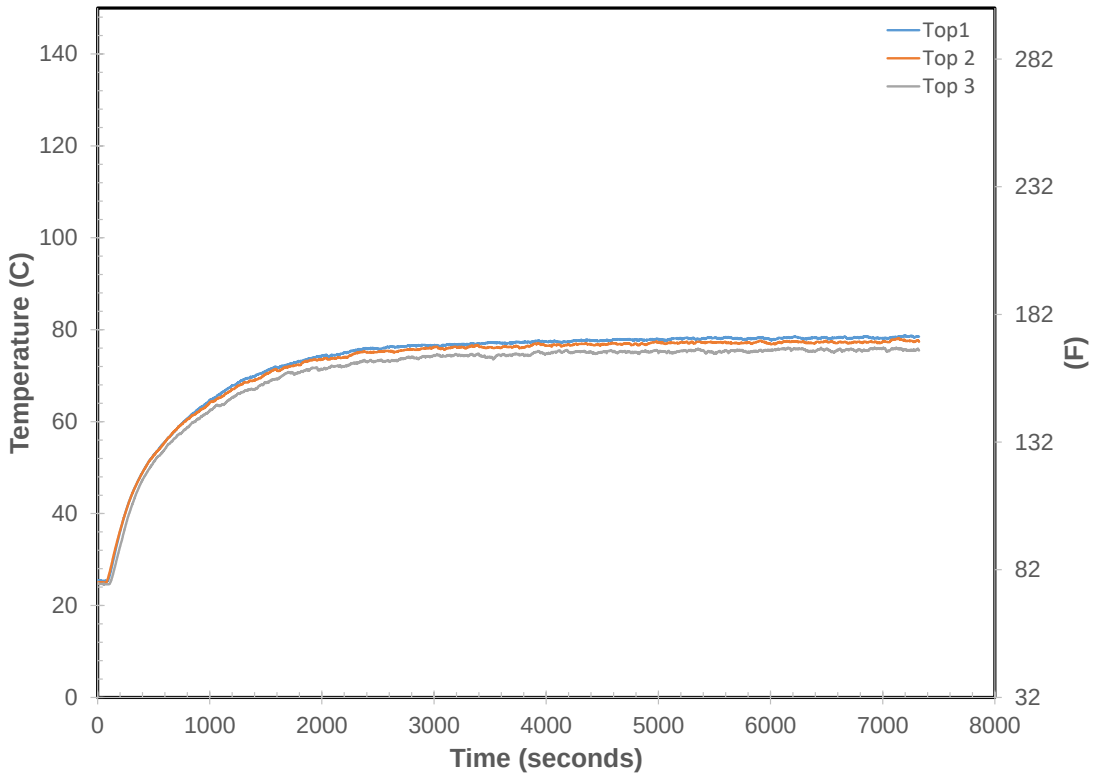

Figure 121. ID 284707 Top Thermocouple Temperatures

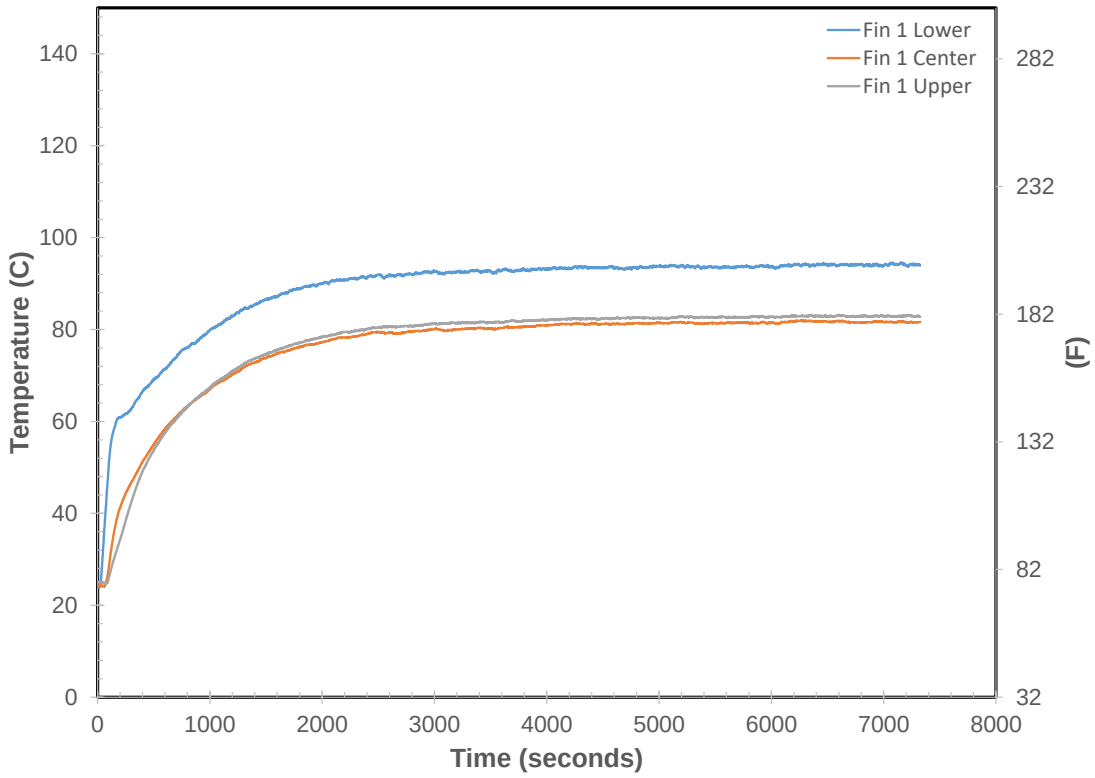

Figure 122. ID 284707 Fin 1 Thermocouple Temperatures

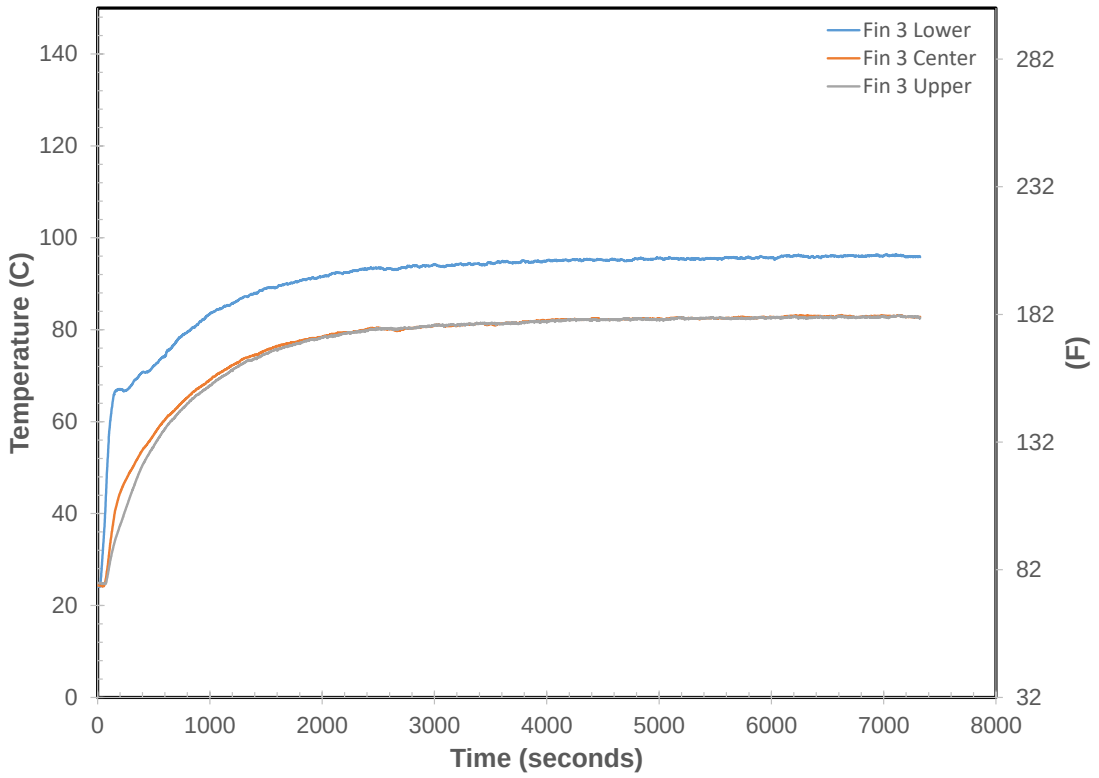

Figure 123. ID 284707 Fin 3 Thermocouple Temperatures

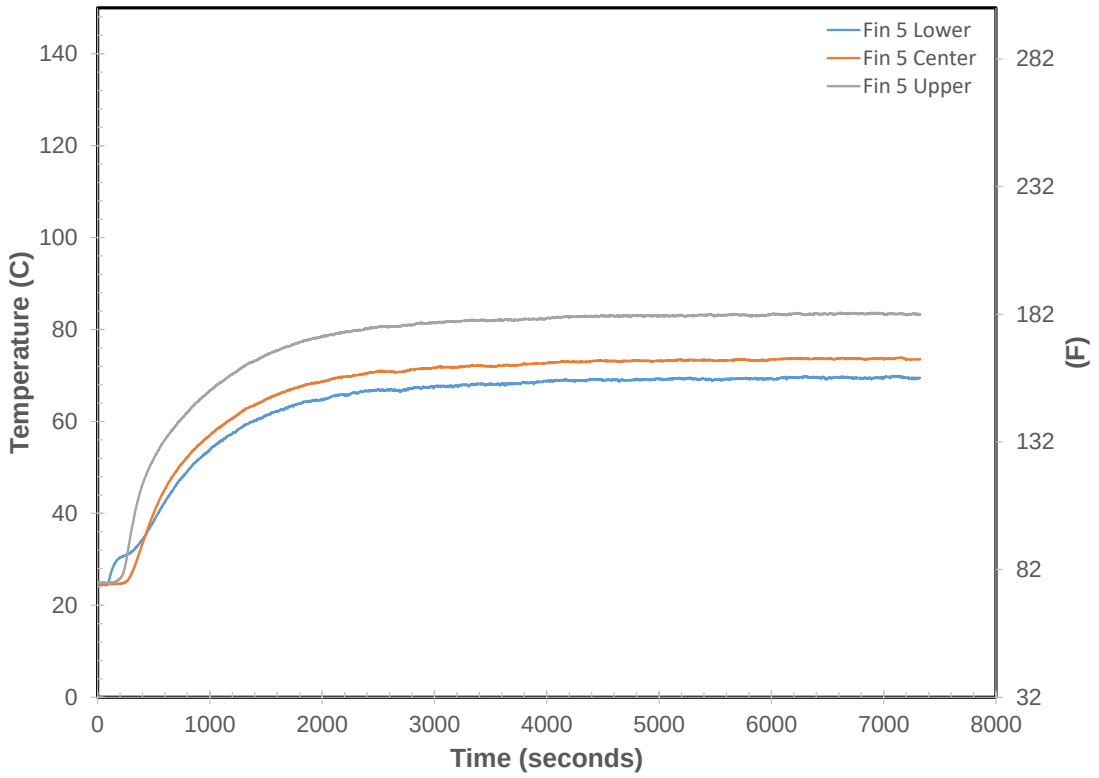

Figure 124. ID 284707 Fin 5 Thermocouple Temperatures

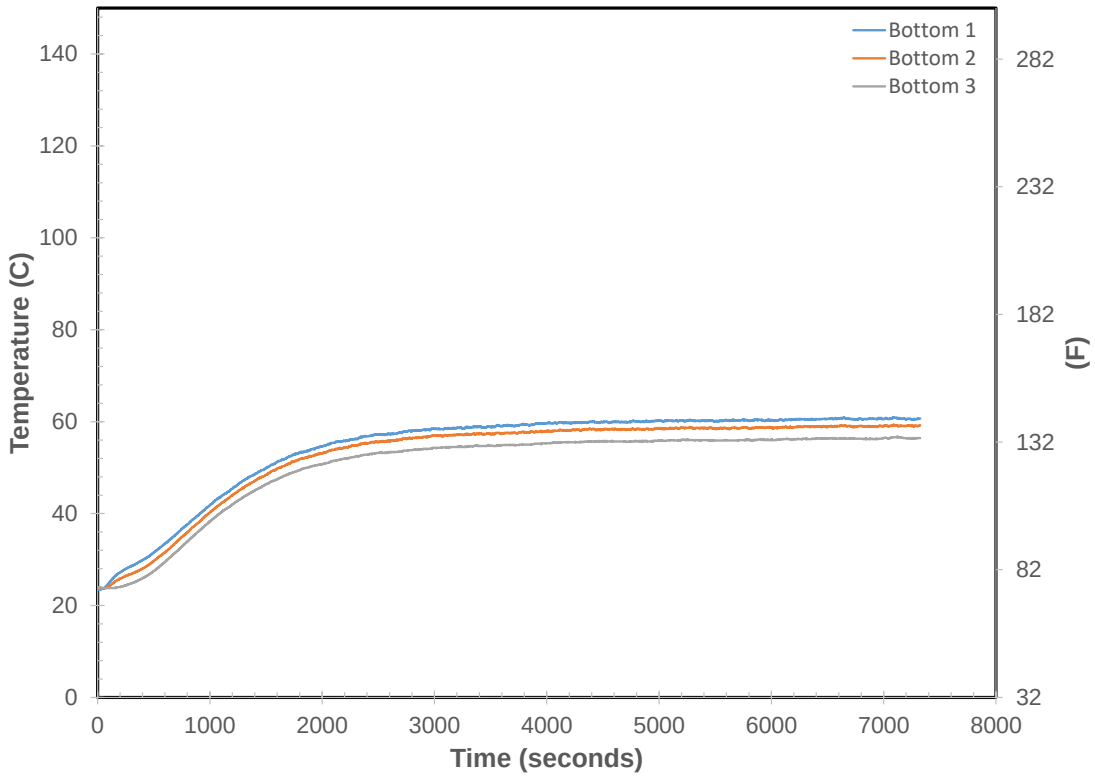

Figure 125. ID 284707 Bottom Thermocouple Temperatures

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 126. Pre test 19 minutes (284707_994410)

Figure 127. Pre test 18 minutes (284707_994411)

Figure 128. Pre test 18 minutes (284707_994412)

Figure 129. Pre test 18 minutes (284707_994413)

Figure 130. Pre test 18 minutes (284707_994414)

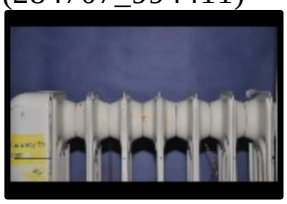

Figure 131. Pre test 18 minutes (284707_994415)

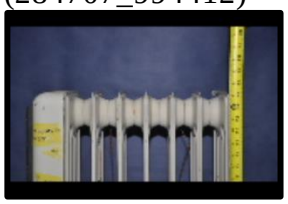

Figure 132. Pre test 18 minutes (284707_994416)

Figure 133. Pre test 18 minutes (284707_994417)

Figure 134. Pre test 18 minutes (284707_994418)

Figure 135. Pre test 17 minutes (284707_994419)

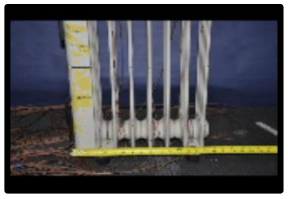

Figure 136. Pre test 17 minutes (284707_994420)

Figure 137. Pre test 13 minutes (284707_994421)

Figure 138. Pre test 12 minutes (284707_994422)

Figure 139. Pre test 8 seconds (284707_994423)

Figure 140. Pre test 6 seconds (284707_994424)

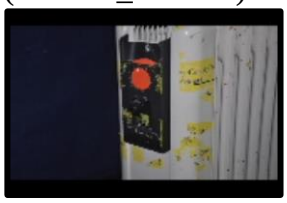

Figure 141. 8 seconds (284707_994425)

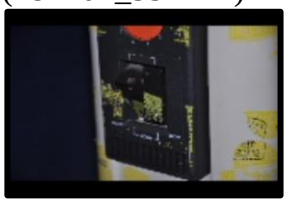

Figure 142. 10 seconds (284707_994426)

Figure 143. 64 seconds (284707_994427)

Figure 144. 66 seconds (284707_994428)

Figure 145. 80 seconds (284707_994429)

Figure 146. 3416 seconds (284707_994430)

Figure 147. 3422 seconds (284707_994431)

Figure 148. 3430 seconds (284707_994432)

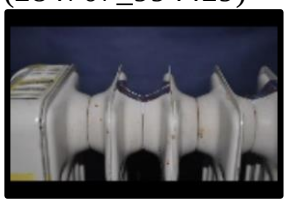

Figure 149. 3446 seconds (284707_994433)

Figure 150. 3470 seconds (284707_994434)

Figure 151. 3476 seconds (284707_994435)

Figure 152. 5232 seconds (284707_994436)

Figure 153. 5236 seconds (284707_994437)

Figure 154. 5250 seconds (284707_994438)

Figure 155. 5260 seconds (284707_994439)

Figure 156. 5266 seconds (284707_994440)

Figure 157. Post test 0 minutes (284707_994441)

Figure 158. Post test 0 minutes (284707_994442)

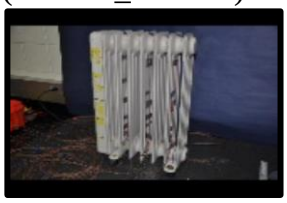

Figure 159. Post test 0 minutes (284707_994443)

Results for Test 2 (ID 284718)

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

Table 5. Temperature Value Result Summary

Description	Initial (C)	Max (C)	30 second max average (C)	1 minute max average (C)	5 minute max average (C)	10 minute max average (C)
Top1	23.2	83.0	82.9	82.9	82.7	82.6
Top 2	23.0	81.7	81.6	81.5	81.4	81.2
Top 3	22.8	79.4	79.3	79.3	79.1	79.1
Fin 1 Lower	22.6	97.6	97.4	97.4	97.1	97.0
Fin 1 Center	22.6	85.5	85.5	85.4	85.3	85.3
Fin 1 Upper	22.6	86.9	86.8	86.8	86.7	86.7
Fin 3 Lower	22.5	97.2	97.0	97.0	96.8	96.8
Fin 3 Center	22.7	85.1	85.1	85.1	85.0	84.9
Fin 3 Upper	22.8	87.6	87.5	87.5	87.4	87.4
Fin 5 Lower	22.8	73.8	73.6	73.6	73.5	73.4
Fin 5 Center	23.0	77.5	77.4	77.4	77.2	77.2
Fin 5 Upper	22.8	87.4	87.4	87.3	87.2	87.2
Bottom 1	22.6	65.8	65.7	65.7	65.6	65.5
Bottom 2	22.5	64.2	64.1	64.1	64.0	64.0
Bottom 3	22.5	60.7	60.7	60.6	60.6	60.5

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

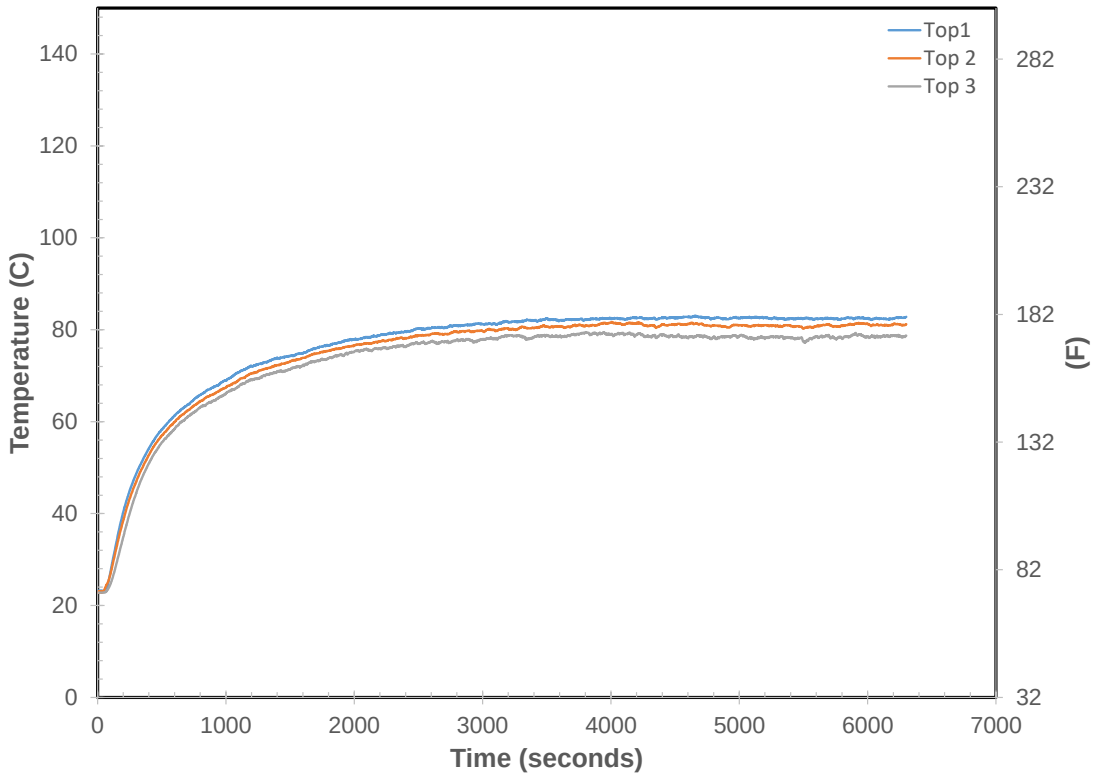

Figure 160. ID 284718 Top Thermocouple Temperatures

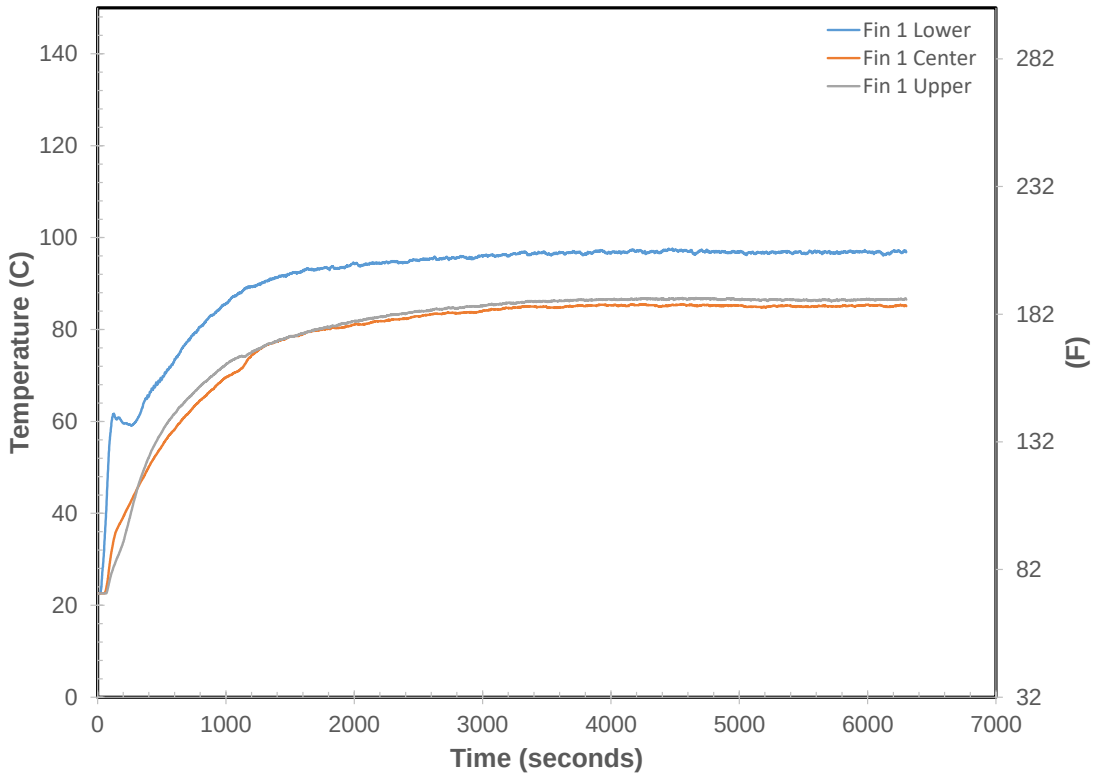

Figure 161. ID 284718 Fin 1 Thermocouple Temperatures

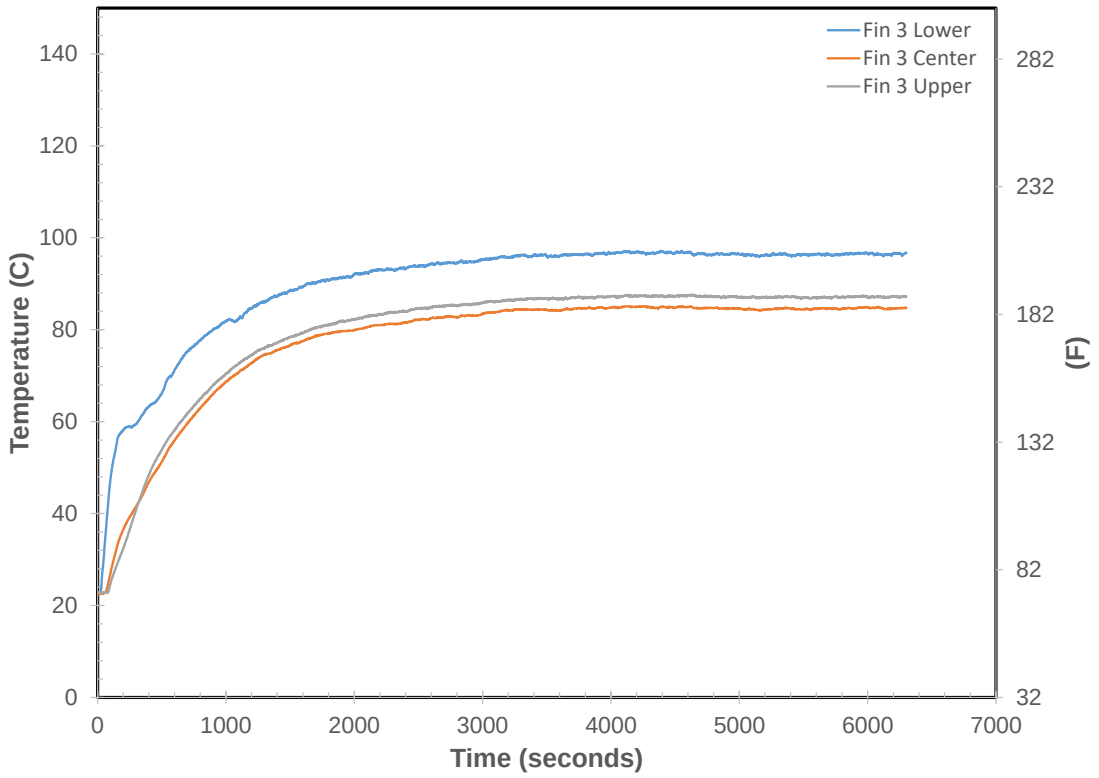

Figure 162. ID 284718 Fin 3 Thermocouple Temperatures

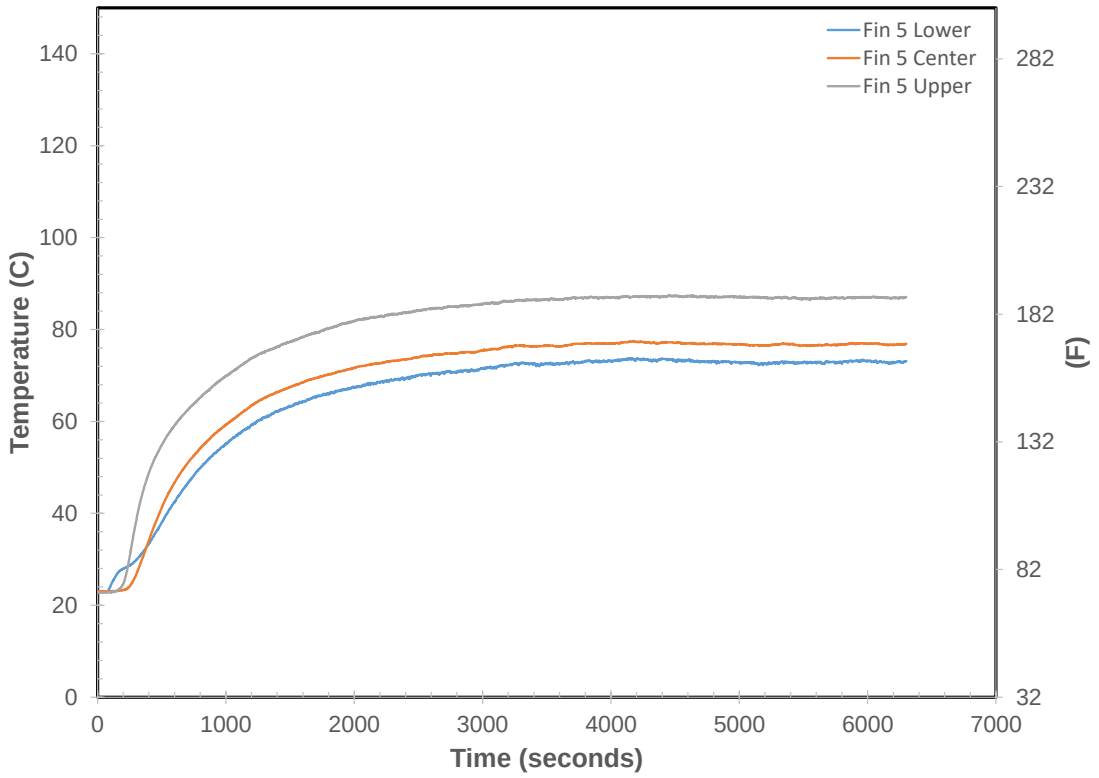

Figure 163. ID 284718 Fin 5 Thermocouple Temperatures

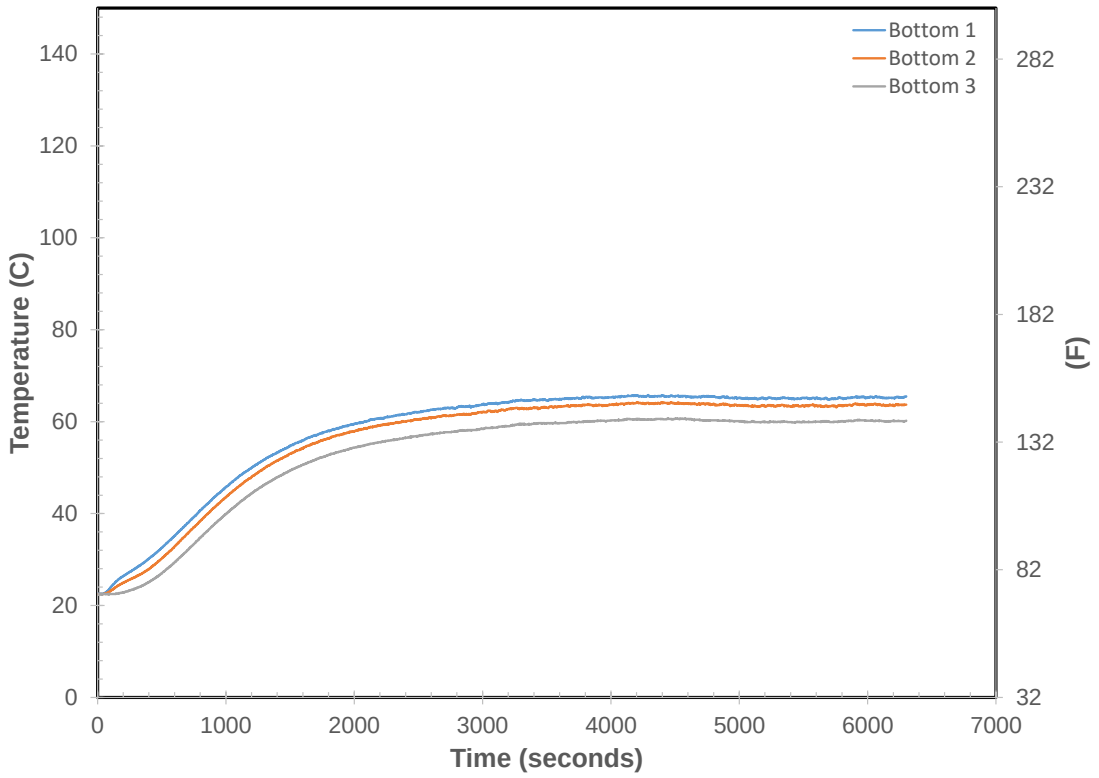

Figure 164. ID 284718 Bottom Thermocouple Temperatures

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 165. Pre test 72 seconds (284718_994464)

Figure 166. Pre test 64 seconds (284718_994465)

Figure 167. Pre test 54 seconds (284718_994466)

Figure 168. Pre test 44 seconds (284718_994467)

Figure 169. Pre test 42 seconds (284718_994468)

Figure 170. 6 seconds (284718_994469)

Figure 171. 8 seconds (284718_994470)

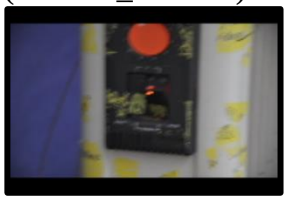

Figure 172. 16 seconds (284718_994471)

Figure 173. 22 seconds (284718_994472)

Figure 174. 32 seconds (284718_994473)

Figure 175. 378 seconds (284718_994474)

Figure 176. 384 seconds (284718_994475)

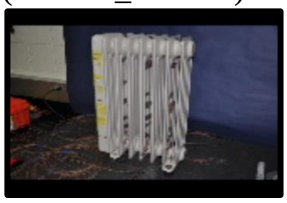

Figure 177. 392 seconds (284718_994476)

Figure 178. 400 seconds (284718_994477)

Figure 179. 412 seconds (284718_994478)

Figure 180. 416 seconds (284718_994479)

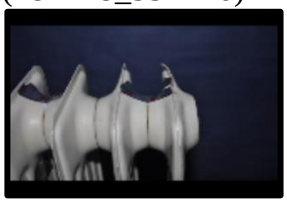

Figure 181. 422 seconds (284718_994480)

Figure 182. 3484 seconds (284718_994481)

Figure 183. 3490 seconds (284718_994482)

Figure 184. 3498 seconds (284718_994483)

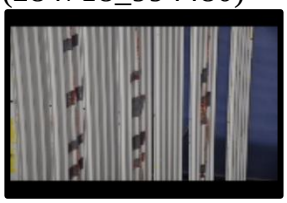

Figure 185. 3500 seconds (284718_994484)

Figure 186. 3502 seconds (284718_994485)

Figure 187. 3510 seconds (284718_994486)

Figure 188. 4992 seconds (284718_994487)

Figure 189. 4996 seconds (284718_994488)

Figure 190. 5006 seconds (284718_994489)

Figure 191. Post test 0 minutes (284718_994490)

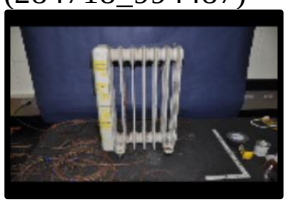

Figure 192. Post test 0 minutes (284718_994491)

Figure 193. Post test 0 minutes (284718_994492)

Figure 194. Post test 0 minutes (284718_994493)

Results for Test 3 (ID 284719)

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

Table 6. Temperature Value Result Summary

Description	Initial (C)	Max (C)	30 second max average (C)	1 minute max average (C)	5 minute max average (C)	10 minute max average (C)
Top1	23.3	113.0	112.8	112.8	112.6	112.6
Top 2	23.0	111.4	111.3	111.2	110.9	110.7
Top 3	22.8	108.7	108.5	108.3	108.1	107.9
Fin 1 Lower	23.0	134.6	134.3	134.1	133.9	133.9
Fin 1 Center	22.8	117.0	116.9	116.9	116.7	116.7
Fin 1 Upper	22.7	123.6	123.5	123.4	123.3	123.2
Fin 3 Lower	22.9	138.9	138.6	138.5	138.2	138.1
Fin 3 Center	22.8	121.2	121.1	121.1	120.9	120.9
Fin 3 Upper	22.9	122.2	122.1	122.1	121.9	121.9
Fin 5 Lower	23.1	108.8	108.5	108.3	108.0	107.9
Fin 5 Center	23.1	112.5	112.4	112.4	112.2	112.1
Fin 5 Upper	22.9	122.8	122.7	122.6	122.5	122.5
Bottom 1	23.1	94.9	94.8	94.8	94.6	94.5
Bottom 2	22.9	91.5	91.4	91.4	91.3	91.3
Bottom 3	22.8	87.9	87.9	87.8	87.7	87.6

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

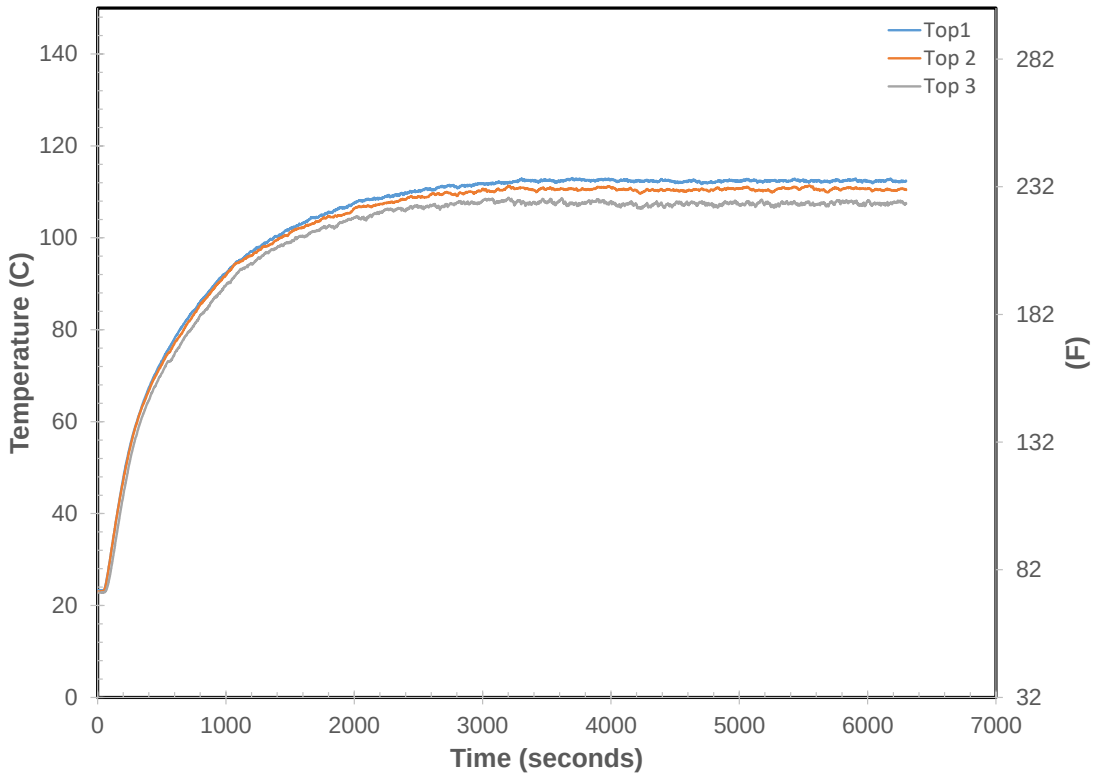

Figure 195. ID 284719 Top Thermocouple Temperatures

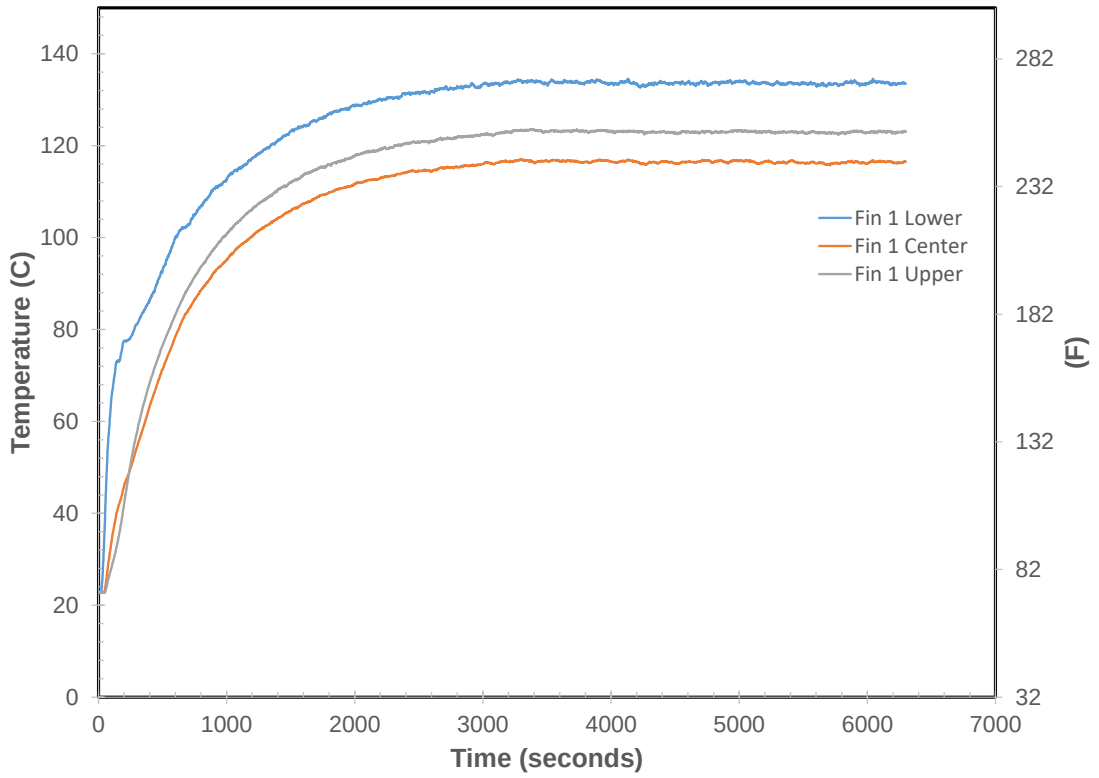

Figure 196. ID 284719 Fin 1 Thermocouple Temperatures

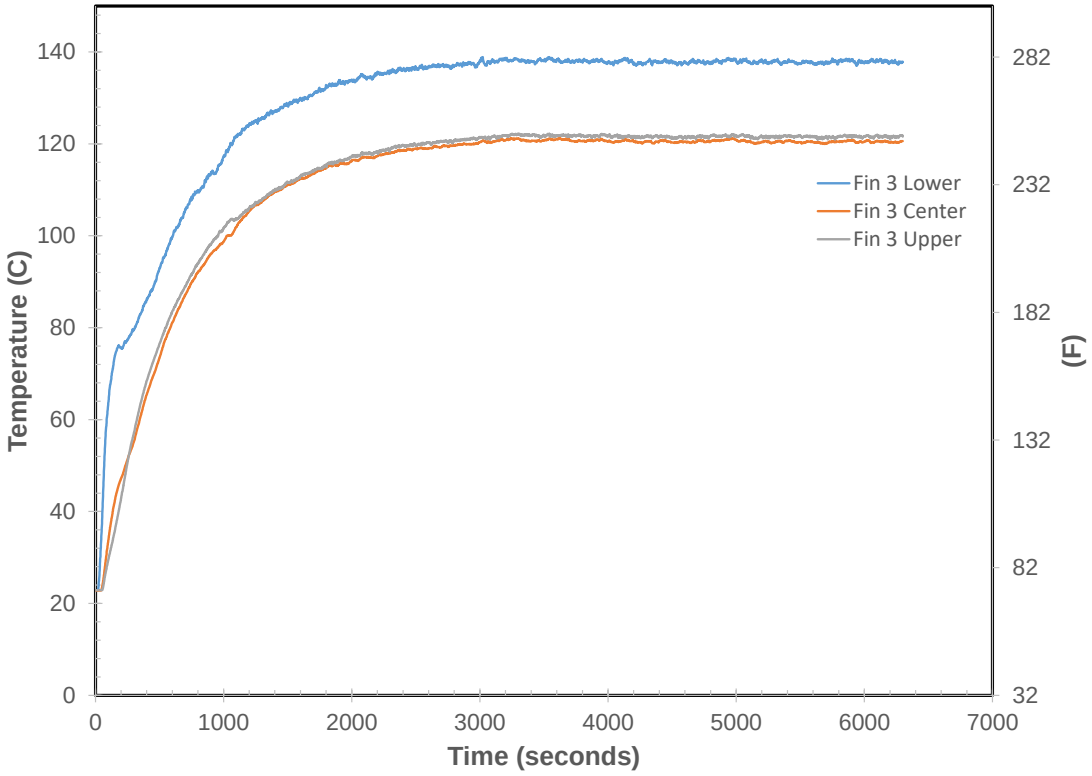

Figure 197. ID 284719 Fin 3 Thermocouple Temperatures

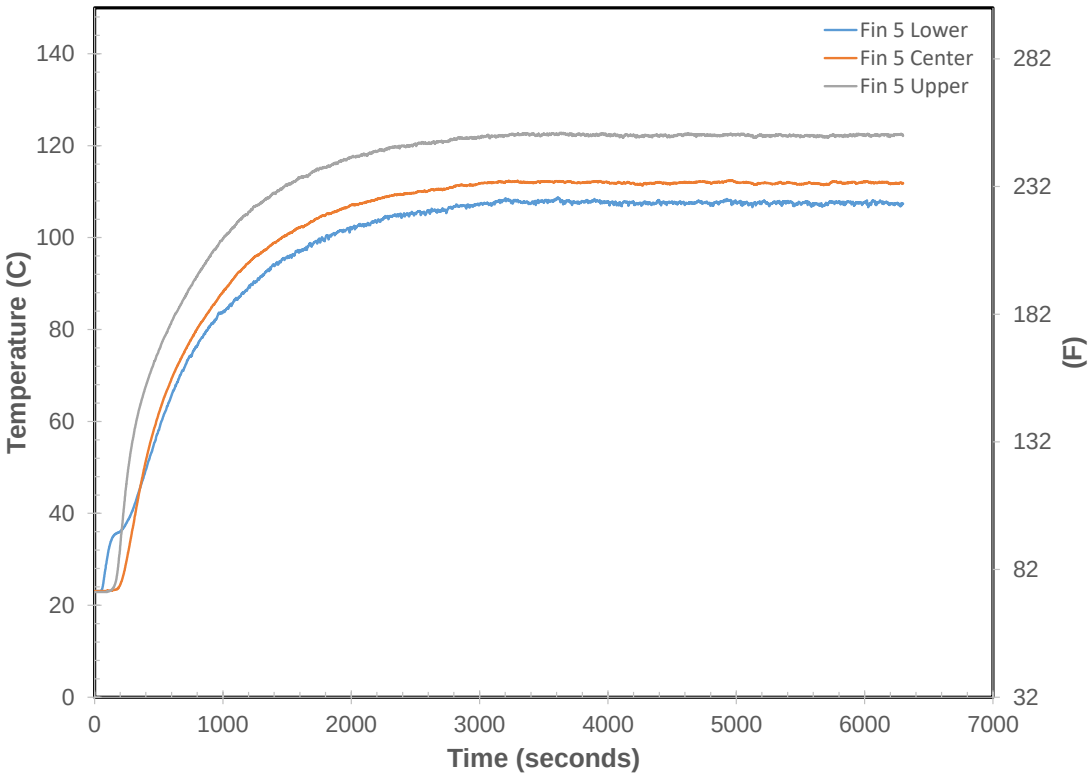

Figure 198. ID 284719 Fin 5 Thermocouple Temperatures

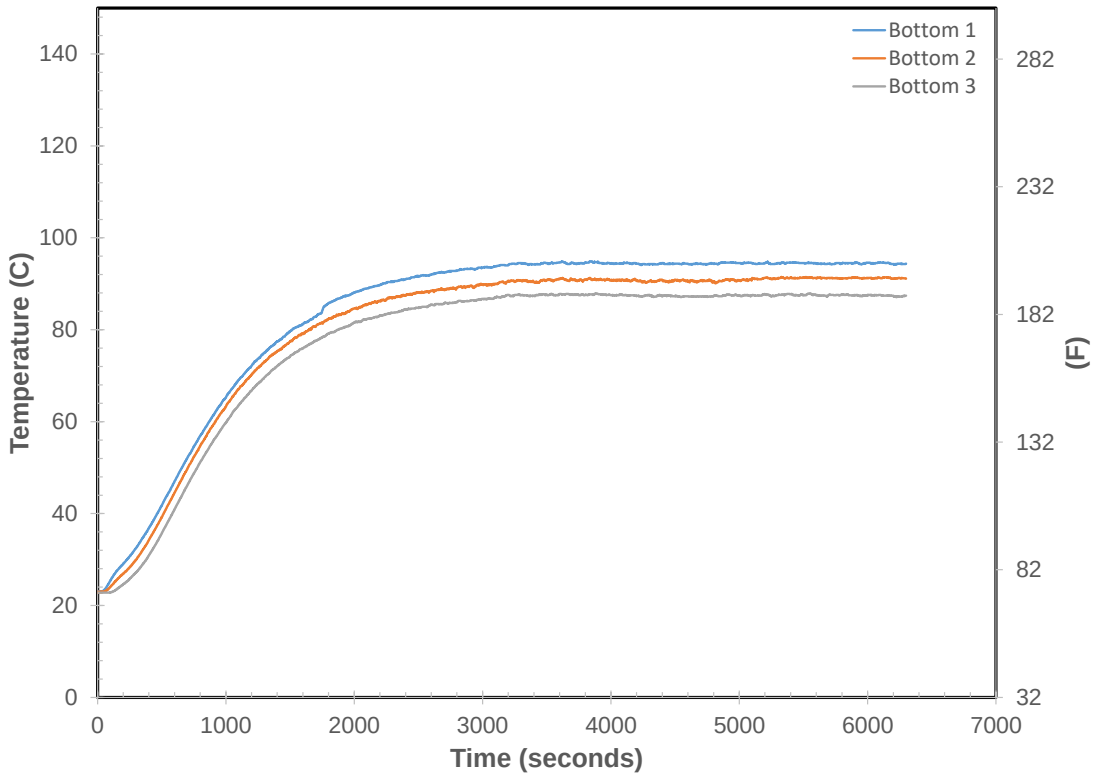

Figure 199. ID 284719 Bottom Thermocouple Temperatures

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 200. Pre test 92 seconds (284719_994512)

Figure 201. Pre test 88 seconds (284719_994513)

Figure 202. Pre test 78 seconds (284719_994514)

Figure 203. Pre test 74 seconds (284719_994515)

Figure 204. 4 seconds (284719_994516)

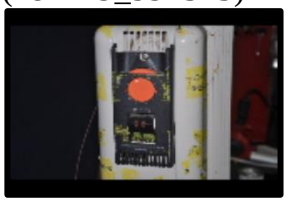

Figure 205. 8 seconds (284719_994517)

Figure 206. 10 seconds (284719_994518)

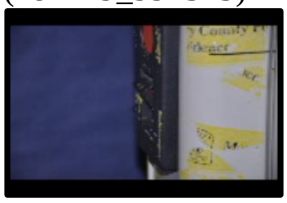

Figure 207. 14 seconds (284719_994519)

Figure 208. 18 seconds (284719_994520)

Figure 209. 22 seconds (284719_994521)

Figure 210. 676 seconds (284719_994522)

Figure 211. 680 seconds (284719_994523)

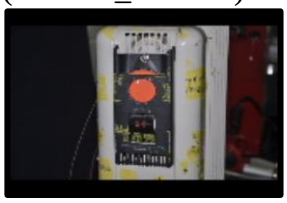

Figure 212. 686 seconds (284719_994524)

Figure 213. 688 seconds (284719_994525)

Figure 214. 1996 seconds (284719_994526)

Figure 215. 2002 seconds (284719_994527)

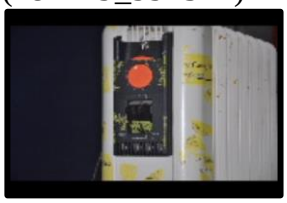

Figure 216. 2010 seconds (284719_994528)

Figure 217. 2012 seconds (284719_994529)

Figure 218. 2018 seconds (284719_994530)

Figure 219. 2638 seconds (284719_994531)

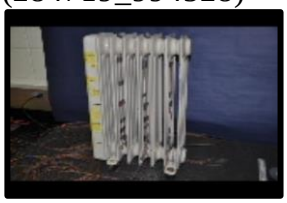

Figure 220. 2640 seconds (284719_994532)

Figure 221. 2648 seconds (284719_994533)

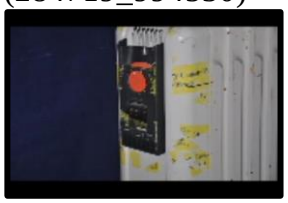

Figure 222. 2652 seconds (284719_994534)

Figure 223. 2658 seconds (284719_994535)

Figure 224. 2664 seconds (284719_994536)

Figure 225. 2670 seconds (284719_994537)

Figure 226. 4182 seconds (284719_994538)

Figure 227. 4188 seconds (284719_994539)

Figure 228. 4192 seconds (284719_994540)

Figure 229. 4202 seconds (284719_994541)

Figure 230. 4212 seconds (284719_994542)

Figure 231. 4216 seconds (284719_994543)

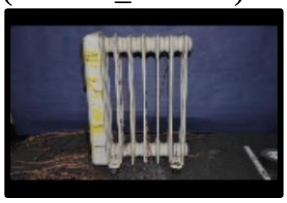

Figure 232. 5562 seconds (284719_994544)

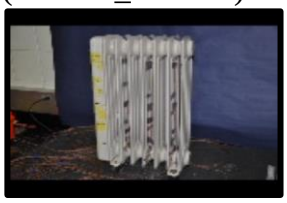

Figure 233. 5564 seconds (284719_994545)

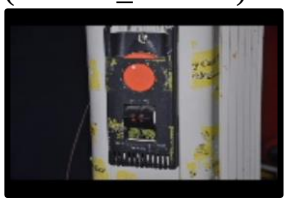

Figure 234. 5572 seconds (284719_994546)

Figure 235. 5574 seconds (284719_994547)

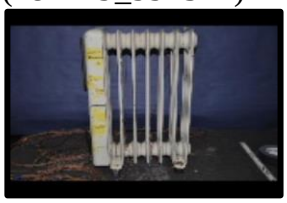

Figure 236. Post test 0 minutes (284719_994548)

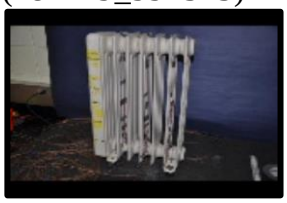

Figure 237. Post test 0 minutes (284719_994549)

Figure 238. Post test 0 minutes (284719_994550)

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