



A collaborative project between BlueScope Steel Limited and the Bushfire CRC

**CMIT-2006-193**

# **INVESTIGATION OF THE PERFORMANCE OF STEEL POWER POLE SYSTEMS IN BUSHFIRES**

**Report to  
BlueScope Steel Limited**

N. White, J.E. Leonard and A. Sargeant

**CSIRO - Manufacturing and Infrastructure Technology  
Fire Science and Technology Laboratory  
Bushfire Research**

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SYSTEMS IN BUSHFIRES**

by

N. White, J.E. Leonard and A. Sargeant

BlueScope Steel Limited  
Old Port Road  
PO Box 202  
Port Kembla NSW 2505

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Please address all enquiries to:

The Chief  
CSIRO Manufacturing and Infrastructure Technology  
Private Bag 33  
Clayton South, Victoria 3169

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# **1 INTRODUCTION**

The performance of steel power pole systems in bushfires has been investigated through a series of full-scale fire experiments. This work has been conducted as collaborative project between Bluescope Steel Limited and the Bushfire CRC.

The objective of this work was to investigate experimentally the performance of steel power pole systems produced by Bluescope Steel Limited when exposed to bushfire conditions.

The performance of the bitumastic wrap and sleeves located at the base of the pole was of particular interest as these are intended to inhibit corrosion.

Traditional timber power poles have been observed on occasion to become involved when exposed to bushfires causing either failure of cross arms or failure of the supporting pole. This is supported by much anecdotal and observational evidence. This can result in prolonged failure of electrical service to bush fire affected regions. The steel poles investigated have been developed as an alternative power pole system which offers the potential for improved performance in bushfires.

## **2 POWER POLE SYSTEMS**

Two steel power poles were used in the fire experiments both poles consisted of the same type of steel support pole and cross arms. However different in ground sleeves and insulators were fitted to the two poles.

The steel poles were cylindrical with a length of 12m, and outside diameter of 273mm and a wall thickness of 4.73mm. The poles were hot dip galvanised. A sealed bottom cap and vented top cap, both constructed of powder coated steel were fitted to each pole.

Both poles were fitted with a 1mm thick adhesive bitumastic wrap extending from 0.5 m below ground level to 0.5 m above ground level. This wrap is intended to inhibit corrosion. Beyond 0.5m below ground level the soil oxygen concentration is not considered to be high enough for significant corrosion to occur. On one pole a plastic sleeve constructed of 10 mm thick HDPE was placed over the rap extending from 0.5m below ground level to 0.5m above ground level. On the other pole a experimental steel sleeve constructed of spiral wound sheet steel was placed over the wrap covering the same area. The purpose of these sleeves is to protect the bitumastic wrap from damage caused during installation and by subsequent above ground activities such as brush cutting.

The steel cross arms were 2 m long, 89mm sq rolled hollow section (RHS) with a thickness of 3.5 mm. The cross arms were hot-dip galvanised and powder coated. The cross arms were fitted with steel end caps primarily to prevent birds from nesting inside. Cross arms were mounted on the pole using a 10 mm thick steel, hot-dip galvanised, connecting saddle. The saddle wrapped around the pole and was bolted to the cross arms at both ends and through bolted to the pole. Two cross arms were mounted to each pole at 3m above ground level and 8.5m above ground level.

The cross arm at 3m was intended to allow observation of cross arm performance in flame immersion if sufficient flame height to the top of the pole could not be achieved.

Two electrical insulators were fitted to the top cross arm of each pole.

Bolt on ladder steps were installed at 1m above ground level and at 2 m intervals above that on the rear side of each pole.

The two poles were installed in ground to a depth of 1.8m (leaving 10.2 m above ground level) using lifter borer equipment. The poles were positioned 3m apart directly in front of flame immersion burners. Figure 1 shows the power pole systems installed in front of the bushfire flame front simulator. Diagrams of the power pole systems are provided in Appendix A.



**Figure 1. Power pole systems installed in front of bushfire flame front simulator**

Whilst installing the poles it was noted that the experimental steel sleeve had a looser fit than the polyethylene sleeve exceeding the pole outer diameter by at least 40mm. This resulted in a large air gap between the sleeve and the bitumastic wrap and an inability to tightly pack earth about the base of the pole.

# EXPERIMENTAL APPARATUS

## 2.1 Bush fire flame front simulator

A Bushfire flame front simulator has been constructed in the open at the NSW Rural Fire Service Hot Fire Training Facility south of Mogo, NSW to allow repeatable testing of different materials in bushfire burn over conditions. The bushfire flame front simulator is designed to recreate actual bushfire flame characteristics (e.g. flame temperature profiles and radiant heat flux) using a grid of liquid propane burners

Liquid propane is stored in an 8,000-litre tank permanently installed at the facility. The tank is pressurised by regulated nitrogen to avoid reduction in flow that occurs when the natural vapour pressure of propane is used as a propellant. Safety features fitted to the supply include over-pressure valves and overflow valves.

The pressurised propane is then piped to the simulator grid in a buried 75 mm internal diameter pipe, a distance of approximately 30 metres.

The burner grid consists of 5 separate stages to simulate fire front approach, burn-over and continued advancement. However for this project only the fire front approach was of interest so only two stages, pre-radiation burners and on side immersion burner stages, were used as shown in Figure A4. The poles were built over the top of the unused burner stages. The two burner stages operated as follows.

The pre-radiation stage was arranged in a line of 4 sets of 3 burners at a distance of 5 m from the front of the power poles. This stage simulates the radiant heat exposure from an approaching fire front. Each set of 3 burners could individually be turned on and off via solenoid valves and the burner flow could be controlled via control valves.

On-side immersion stage burners were arranged in 3 rows of 6 burners set back at 350mm, 1.85m and 3.35m from the front of the power poles. During a burn this phase could only be turned on or off. The flow rate could be controlled by fitting differently sized calibrated jets to the burners. When simulating lower fire intensities with shorter flame depths the jets at the rear most rows may be blanked off. The total heat release rate can be estimated by summing the calibrated jets used.

The angle and height of the simulator's flames approaching the power poles was influenced by the ambient wind conditions. Thus, there was a degree of uncontrolled variation in flame angle accordingly to the wind gusts and lulls. The simulator was intended to be used to conduct experiments under the North-easterly sea breeze with wind speeds at 2 metres height in the open of approximately 5-8 km/h. These relatively light breezes are considered to represent the attenuated forest wind under the canopy and to recreate flame angles similar to actual forest fire flames for the appropriate fire line intensity [1]. However all fire experiments on power poles were conducted in as still wind conditions as possible in order to achieve very high flame heights.

While effort was made to accurately simulate critical aspects of a bushfire, there remain fundamental assumptions and limitations associated with attempting to simulate a moving fire on a stationary grid and the use of propane gas to simulate bushfire flames.

## 2.2 Instrumentation

### 2.2.1 Temperature measurement

Temperatures were measured using 1.5 mm Type 'K' MIMS thermocouples. Each thermocouple was identified by a separate thermocouple number as shown in Table 1. The positions of all thermocouples are shown in diagrams presented in Appendix A. Air and surface thermocouples were measured at regular spacings on the front face of the pole and cross arms. Only surface temperatures were measured at regular spacings on the rear face of the poles. Temperatures were measured between the steel post and bitumastic wrap and between the bitumastic wrap and the protective sleeve both above and below ground, front and back. Thermocouples were mounted using self tapping screws and surface thermocouples were mated to the surface with heat sink paste, see Figure 2.



**Figure 2,            Installation of surface thermocouple**

Air temperatures at 1m and 2m in front of power poles on the burner grid were measured by thermocouples mounted on masts at heights up to 3 m above ground level.

### 2.2.2 Heat flux measurement

Heat flux was measured using Medtherm water-cooled Schmidt Boelter total heat flux meters with a sensing range of 0 to 100 kW/m<sup>2</sup>. The total heat flux measured consisted of both radiative



and convective heat. Two heat flux meters were mounted at the front of the burner grid between the two power poles. One of these heat flux meters was horizontal facing the bushfire flame front simulator. The other heat flux meter was vertical facing the open sky. These were used to monitor the heat flux output of the bushfire flame front simulator and control gas flows to pre-radiation burners. For these total heat-flux meters radiative heat was the predominant component measured during pre-radiation exposure however during total flame emersion convective heat was the principal component.

All cables and cooling lines external lines were protected by placing them in silicon coated mineral fibre insulated sheathing or in steel downpipe sections or burying them underneath sand.

### **2.2.3 Data acquisition**

All thermocouples and radiometers were logged at 5-second intervals via a Datataker 505 data logger with up to three expansion modules. The data logger and expansion modules were placed in a steel fireproof box. The data logger had a battery power supply, which was recharged between tests. An RS232 communications link was created by a radio modem transducer connected to the logger and a matching receiver connected to a monitoring computer at the Control area. This allowed for real time observation of data. Data was simultaneously recorded on to the data logger's internal memory card and the PC in the control area to minimise the potential for data loss.

### **2.2.4 Weather measurement**

A range of information relating to climatic conditions was collected prior to and during all experiments. An Oregon WMR112U Cable Free Weather Station and sensors was used to collect weather data and forward it to a base station positioned in the control room, which then logged the information directed to a PC. Data was collected by the sensors at a rate of three recordings per second and logged in the computer data base once a minute. Each record in the data base is an average of the 180 recordings taken in that minute.

Wind speed was measured and recorded in meters per second and the wind direction is displayed as a value between 0° and 359° (Degrees). 0° representing North, 90° representing East, 180° South and 270° West.

This information, in particular the information relating to wind direction and speed, was used to determine appropriate test windows. A North Easterly direction was favoured for testing, which is represented as 45, although testing was carried out under varying wind conditions. Generally the wind conditions are dominated by a local thermally driven sea breeze. This local thermal system produces strong North East winds in the afternoons of warmer days.

This year, 2005, a warmer open ocean current moved further down and closer to the coast. It would appear this increase in sea surface temperature and a slightly lower than average land temperature reduced the frequency and strength of the traditional thermal driven North East sea breeze.

### **2.2.5 Audio-visual recording**

A minimum of two digital video cameras were used to record each test. Digital still pictures before during and after each experiment were also taken and were time stamped for appropriate visual recreation of the exposures.

## **3 PROCEDURE**

The power pole systems were exposed to three different fire exposures in three separate experiments. Temperatures and heat fluxes were logged at 5 second intervals from the start of exposure. At every stage detailed site observations were made relating to the propensity of power pole components to:

- Ignite;
- Loose their integrity or fail to perform as required and
- Act as mechanisms for spreading flame;

The following is a description and procedure for each of the three exposures.

### **3.1 Experiment 1 - Bushfire passage pre-radiation exposure**

This level of exposure represents a radiation profile typical of an advancing bushfire that does not reach a point of direct flame contact occurring on a fire danger day of FDI 40 and fuel load of 15t/ha with sufficient clearing to avoid direct flame contact. Approximately 30 litres of leaf litter consisting of dried eucalypt leaves and small twigs were spread evenly about the base of each pole. The pre-radiation burner stage of the bushfire flame front simulator was then controlled so that the following heat flux measurement readings at horizontal heat flux meter were achieved.

- 5 kW/m<sup>2</sup> for 3 minutes
- 10 kW/m<sup>2</sup> for a further 2 minutes
- 30 kW/m<sup>2</sup> for a further 2 minutes
- 5 kW/m<sup>2</sup> for a further 3 minute and then the burners were turned off

The flame immersion burner stage was not used. The flow rate of the pre-radiation burner stage was manually controlled in response to real time heat flux readings. The experiment was ceased when significant combustion or involvement of the power pole systems ceased.

### **3.2 Experiment 2 - Bushfire passage flame immersion exposure**

This level of exposure represents a bushfire occurring on a high fire danger day of FDI 40 and fuel load of 25t/ha including a flame immersion from a flame front of 15MW/m fire line intensity. Remaining unburnt leaf litter from the previous pre-radiation exposure was left in place but not directly ignited prior to operation of the burner grid. This involved use of the pre-radiation stage similarly as for the pre-radiation exposure. The flame immersion stage was also used as follows:

- 5 kW/m<sup>2</sup> Pre-radiation stage only for 3 minutes

- 10 kW/m<sup>2</sup> Pre-radiation stage only for a further 2 minutes
- 30 kW/m<sup>2</sup> Pre-radiation stage only for a further 2 minutes
- Flame immersion stage on for a further 11seconds
- Flame immersion stage is turned off but takes a further 40 seconds for all gas to burn out of lines for this stage of grid.
- 5 kW/m<sup>2</sup> pre-radiation stage for a further 2 minutes and then the burners were turned off

Leaf litter was applied to timber fences but not ignited prior to operation of the bushfire flame front simulator.

## 4 RESULTS

All graphs of measured temperatures and heat fluxes for each experiment are presented in Appendix B. Peak temperature measurements are summarized in Table 2. Summary results and observations for each test are as follows.

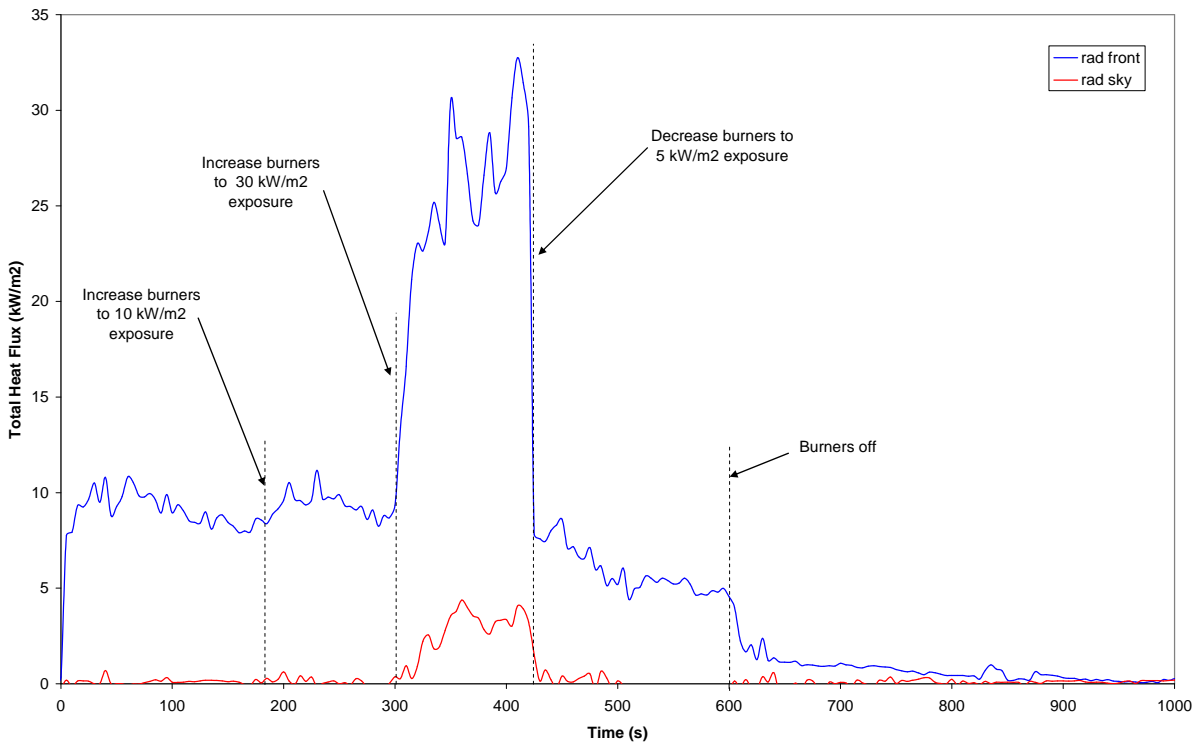
### 4.1 Experiment 1 – Bushfire passage pre-radiation exposure

Pilot burners were ignited prior to the start of the experiment however leaf litter was not ignited. The pre-radiation stage burners were turned on at the start of the experiment. The pre-radiation burners generated a 6m line of flame with flame heights of approximately 3m and flames slightly leaning towards the poles. There was not direct impingement of burner flames on the poles during this experiment, see Figure 3.



**Figure 3. Experiment 1 pre radiation flame exposure**

The measured heat flux for this experiment is shown in Figure 4. Due to the low wind speed creating higher flame heights it was not possible to achieve pre-radiation flame exposures as low as the intended  $5 \text{ kW/m}^2$  and instead  $7\text{-}10 \text{ kW/m}^2$  exposures were achieved. The desired heat flux exposure was achieved for other parts of the exposure profile. No effects were observed on the power pole systems during the early stages of the exposure.



**Figure 4. Experiment 1 pre radiation exposure measured heat fluxes**

After the Pre-radiation burner stage was increased to a  $30 \text{ kW/m}^2$  exposure the leaf litter and sleeves at the base of both poles was observed to emit smoke. At 400 s the leaf litter at the base of pole 2 ignited. Flames spread to involve all leaf litter at the base of pole 2 and also the coated front surface of the steel sleeve, see Figure 5.



**Figure 5. Experiment 1 ignition of leaf litter and sleeve surface coating of pole 2**

The pre-radiation burners were reduced to  $5 \text{ kW/m}^2$  exposure at 420 s. From this time the flames at the base of pole 2 slowly decayed until the pre-radiation burners were turned off at 600s. Inspection of the power pole systems after the test revealed that the leaf litter around the base of pole 1 had not ignited however the front of the polyethylene sleeve had softened and deformed due to predominantly radiant heat, see Figure 6. All leaf litter at the base of pole 2 had been consumed and the front surface coating of the metal sleeve had also been burnt. The Bitumastic wrap was still in tact, see Figure 7. The rest of the pole systems were not significantly affected.

All maximum surface temperatures were achieved at the end of the  $30 \text{ kW/m}^2$  exposure. The maximum front surface temperatures of pole 1 and pole 2 were  $130^\circ\text{C}$  and  $200^\circ\text{C}$  respectively. The peak temperature above ground level beneath the polyethylene sleeve and bitumastic wrap on pole 1 was  $75^\circ\text{C}$ . The polyethylene sleeve was tighter fitting and the leaf litter did not ignite about its base. The peak temperature above ground level beneath the steel sleeve and bitumastic wrap on pole 2 was  $320^\circ\text{C}$ . The steel sleeve was a looser fit and the leaf litter about its base ignited exposing the sleeve to direct flame contact, the bitumastic wrap did not burn itself during this exposure.



**Figure 6.** Experiment 1 resulting damage to polyethylene sleeve on pole 1





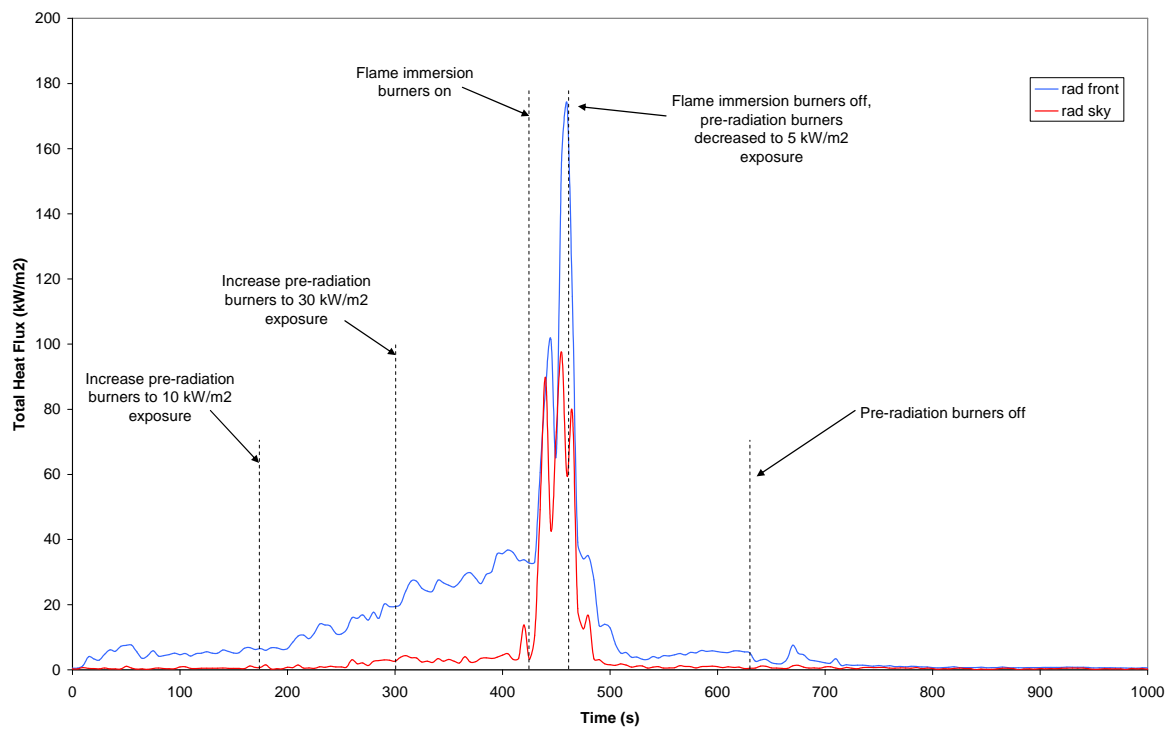
**Figure 7.** Experiment 1 resulting damage to steel sleeve on pole 2

## **4.2 Experiment 2 – Bushfire passage flame immersion exposure**

Prior to the start of the experiment gas burner pilots were ignited. The remaining leaf litter from experiment 1 was left in place but was not directly ignited prior to the start of the experiment. The pre radiation burner stage was turned on at the start of the experiment. At approximately 6:00 the leaf litter and sleeves at the base of both poles were observed to emit smoke. At 7:00 the flame immersion burner stage was turned on and left on for 30 seconds see Figure 8. The total heat flux measurements for this experiment are shown in Figure 9.



**Figure 8. Experiment 2 flame immersion burner stage exposure**



**Figure 9. Experiment 2 total heat flux measurements**



The flame immersion burner stage produced vertical flames with a solid flame height of approximately 6m and flames intermittently reaching heights of 8-10 m. Flames impinged directly on both poles. LPG supply to the flame immersion stage was shut off at 7:30 however the LPG took a further 30 seconds to bleed out of the lines so the flame immersion burners gradually decayed over this period. After the flame immersion burners were shut off it was observed that the leaf litter and polyethylene sleeve at the base of pole 1 had ignited and were burning on the front face. The steel sleeve had been scorched and was smoking but no flaming was observed see Figure 10.



**Figure 10. Experiment 2 ignition of polyethylene sleeve after flame immersion exposure**

The LPG supply to the pre-radiation burner stage was turned off at 10:30 however the LPG took a further 2 minutes to bleed out of the lines. The pre-radiation stage flames gradually decayed over this period. At this time the polyethylene sleeve had become molten and slumped to form a molten pool surrounding the base of pole 1. This molten pool continued to slowly burn for 40 min. A thin film consisting of a mixture of polyethylene and bitumastic wrap coated the circumference over the area previously covered by the sleeve, see Figure 11. Soot from the burning polyethylene marked pole 1 up to a height of 1.5m. The surface coating on the front face of the steel sleeve on pole 2 had been scorched off and the bitumastic wrap beneath had softened and flowed down the pole approximately 100mm leaving behind a thin black film, see Figure 12. The powder coating on the 3m cross arms on both poles had been severely scorched and crazed, see Figure 13. There was no other significant damage to either of the power pole systems. At 50:00 a light spray of water was used to cool the surface of the steel poles prior to the next experiment. All water was evaporated prior to starting the next experiment



**Figure 11.** Experiment 2 resulting damage to polyethylene sleeve on pole1



**Figure 12.** Experiment 2 resulting damage to steel sleeve one pole 2



**Figure 13. Experiment 2 resulting damage to 3m cross arms**

All maximum surface temperatures were achieved at the end of the flame immersion burner exposure at 460 s. The maximum front surface temperatures of pole 1 and pole 2 were 520°C and 465°C respectively. These temperatures are lower than the 650°C melting point of the iron zinc alloy layer that is formed during the hot dip galvanizing metallurgical process of diffusion. The peak temperature above ground level beneath the polyethylene sleeve and bitumastic wrap on pole 1 and pole 2 was 260°C and 575°C respectively.

## **5 CONCLUSIONS**

Based on these experiments the following conclusions are drawn.

When exposed to the bushfire passage involving pre-radiation and ground fuel attack both power pole systems maintained integrity and serviceability. There was only minor damage to the sleeves above ground level however they would still provide an adequate corrosion barrier.

When exposed to the bushfire passage involving flame immersion radiant heat and ground fuel attack both power pole systems maintained integrity and serviceability. There was damage to sleeves and bitumastic wraps on both poles above ground level, replacement of affected materials above ground is required to ensure full pole serviceability, however both sleeves and wraps were in tact below ground level.

The polyethylene sleeve was more easily ignited and damaged than the steel sleeve but maintained its integrity below ground level. The loose fit of the experimental steel sleeve reduced the ability to tightly pack earth about the pole and also resulted in some slumping of the bitumastic wrap in the air gap below ground level when exposed to the structural fire.

## **6 REFERENCES**

- [1] Leonard J., Bushfires in the ACT. Australian Institute of Building Surveyors, 38<sup>th</sup> Annual AIBS State Conference, 2003.



**Table 1. Instrumentation list**

<b>Instrument number</b>	<b>Location</b>	<b>Description</b>	<b>Instrument number</b>	<b>Location</b>	<b>Description</b>
PG1_1	GRID	TC pole 1 m into grid, 1 m above ground	P1_10FS	1	10m above ground, front, surface
PG1_2	GRID	TC pole 1 m into grid, 2 m above ground	P1_10BS	1	10m above ground, back, surface
PG1_3	GRID	TC pole 1 m into grid, 3 m above ground	P1_LIS	1	8.5m cross bar, Left insulator, ceramic, front surface
PG2_1	GRID	TC pole 2 m into grid, 1 m above ground	P1_RIS	1	8.5m cross bar, right insulator, poly, front surface
PG2_2	GRID	TC pole 2 m into grid, 2 m above ground	P2_G-F	2	250mm below ground, front, under bitumen rap
PG2_3	GRID	TC pole 2 m into grid, 3 m above ground	P2_G-B	2	250mm below ground, back, under bitumen rap
Rad1	GRID	rad, 1m above ground, between poles facing grid	P2_G+F	2	400 mm above ground, front, under bitumen rap
Rad2	GRID	rad, 1m above ground, between poles facing sky	P2_G+FF	2	400 mm above ground, front, between bitumen rap and poly sleeve
P1_G-F	1	250mm below ground, front, under bitumen rap	P2_G+B	2	400 mm above ground, back, under bitumen rap
P1_G-B	1	250mm below ground, back, under bitumen rap	P2_G+BB	2	400 mm above ground, back, between bitumen rap and poly sleeve
P1_G+F	1	400 mm above ground, front, under bitumen rap	P2_1FA	2	1m above ground, front, air
P1_G+FF	1	400 mm above ground, front, between bitumen rap and poly sleeve	P2_1FS	2	1m above ground, front, surface
P1_G+B	1	400 mm above ground, back, under bitumen rap	P2_1BS	2	1m above ground, back, surface
P1_G+BB	1	400 mm above ground, back, between bitumen rap and poly sleeve	P2_3FA	2	3m above ground, front, centre cross arm, air
P1_1FA	1	1m above ground, front, air	P2_3FS	2	3m above ground, front, centre cross arm, surface
P1_1FS	1	1m above ground, front, surface	P2_3BS	2	3m above ground, back, pole, air
P1_1BS	1	1m above ground, back, surface	P2_3FLA	2	3m above ground, front, 200mm from left end cross arm, air
P1_3FA	1	3m above ground, front, centre cross arm, air	P2_3FLS	2	3m above ground, front, 200mm from left end cross arm, surface
P1_3FS	1	3m above ground, front, centre cross arm, surface	P2_3FRA	2	3m above ground, front, 200mm from right end cross arm, air
P1_3BS	1	3m above ground, back, pole, air	P2_3FRS	2	3m above ground, front, 200mm from right end cross arm, surface
P1_3FLA	1	3m above ground, front, 200mm from left end cross arm, air	P2_5FA	2	5m above ground, front, air
P1_3FLS	1	3m above ground, front, 200mm from left end cross arm, surface	P2_5FS	2	5m above ground, front, surface
P1_3FRA	1	3m above ground, front, 200mm from right end cross arm, air	P2_5BS	2	5m above ground, back, surface
P1_3FRS	1	3m above ground, front, 200mm from right end cross arm, surface	P2_7FA	2	7m above ground, front, air
P1_5FA	1	5m above ground, front, air	P2_7FS	2	7m above ground, front, surface
P1_5FS	1	5m above ground, front, surface	P2_7BS	2	7m above ground, back, surface
P1_5BS	1	5m above ground, back, surface	P2_8.5FA	2	8.5m above ground, front, centre cross arm, air
P1_7FA	1	7m above ground, front, air	P2_8.5FS	2	8.5m above ground, front, centre cross arm, surface
P1_7FS	1	7m above ground, front, surface	P2_8.5BS	2	8.5m above ground, back, pole, air
P1_7BS	1	7m above ground, back, surface	P2_8.5FLA	2	8.5m above ground, front, 200mm from left end cross arm, air
P1_8.5FA	1	8.5m above ground, front, centre cross arm, air	P2_8.5FLS	2	8.5m above ground, front, 200mm from left end cross arm, surface
P1_8.5FS	1	8.5m above ground, front, centre cross arm, surface	P2_8.5FRA	2	8.5m above ground, front, 200mm from right end cross arm, air
P1_8.5BS	1	8.5m above ground, back, pole, air	P2_8.5FRS	2	8.5m above ground, front, 200mm from right end cross arm, surface
P1_8.5FLA	1	8.5m above ground, front, 200mm from left end cross arm, air	P2_10FA	2	10m above ground, front, air
P1_8.5FLS	1	8.5m above ground, front, 200mm from left end cross arm, surface	P2_10FS	2	10m above ground, front, surface
P1_8.5FRA	1	8.5m above ground, front, 200mm from right end cross arm, air	P2_10BS	2	10m above ground, back, surface
P1_8.5FRS	1	8.5m above ground, front, 200mm from right end cross arm, surface	P2_LIS	2	8.5m cross bar, Left insulator, ceramic, front surface
P1_10FA	1	10m above ground, front, air	P2_RIS	2	8.5m cross bar, right insulator, poly, front surface

**Table 2. Summary peak temperature measurements**

		<b>Experiment 1</b>		<b>Experiment 2</b>	
		<b>Pole 1</b>	<b>Pole 2</b>	<b>Pole 1</b>	<b>Pole 2</b>
Maximum air temperature	Temperature (°C)	90	260	590	675
	Time (s)	365	410	465	450
	Height (m)	1m	5 m	1m	1m
Maximum front surface temperature of pole	Temperature (°C)	130	200	520	475
	Time (s)	420	420	465	460
	Height (m)	1m	1m	1m	1m
Maximum surface temp of 3 m cross arm	Temperature (°C)	150	210	320	350
	Time (s)	420	420	465	460
Maximum surface temp of 8.5 m cross arm	Temperature (°C)	72	120	150	110
	Time (s)	420	420	465	445
Maximum rear pole surface temp	Temperature (°C)	45	60	130	96
	Time (s)	1200	1200	1200	950
Maximum front temperature between sleeve and bitumastic wrap above ground	Temperature (°C)	75	320	290	620
	Time (s)	680	560	700	525
Maximum front temperature under bitumastic wrap above ground	Temperature (°C)	59	340	260	575
	Time (s)	1000	580	700	520
Maximum front temperature under bitumastic wrap below ground	Temperature (°C)	16	20	70	32
	Time (s)	constant	constant	3200	2500
Maximum insulator temperature	Temperature (°C)	83	160	290	140
	Time (s)	395	420	455	465
Pre-dominant wind direction		N		NNW	
Average wind speed		0		1.06	
Maximum wind gust		0		2.40	

a – maximum temperature prior to thermocouple ceasing to work

b – Thermocouple did not function properly from start of experiment

# APPENDIX A. DIAGRAMS

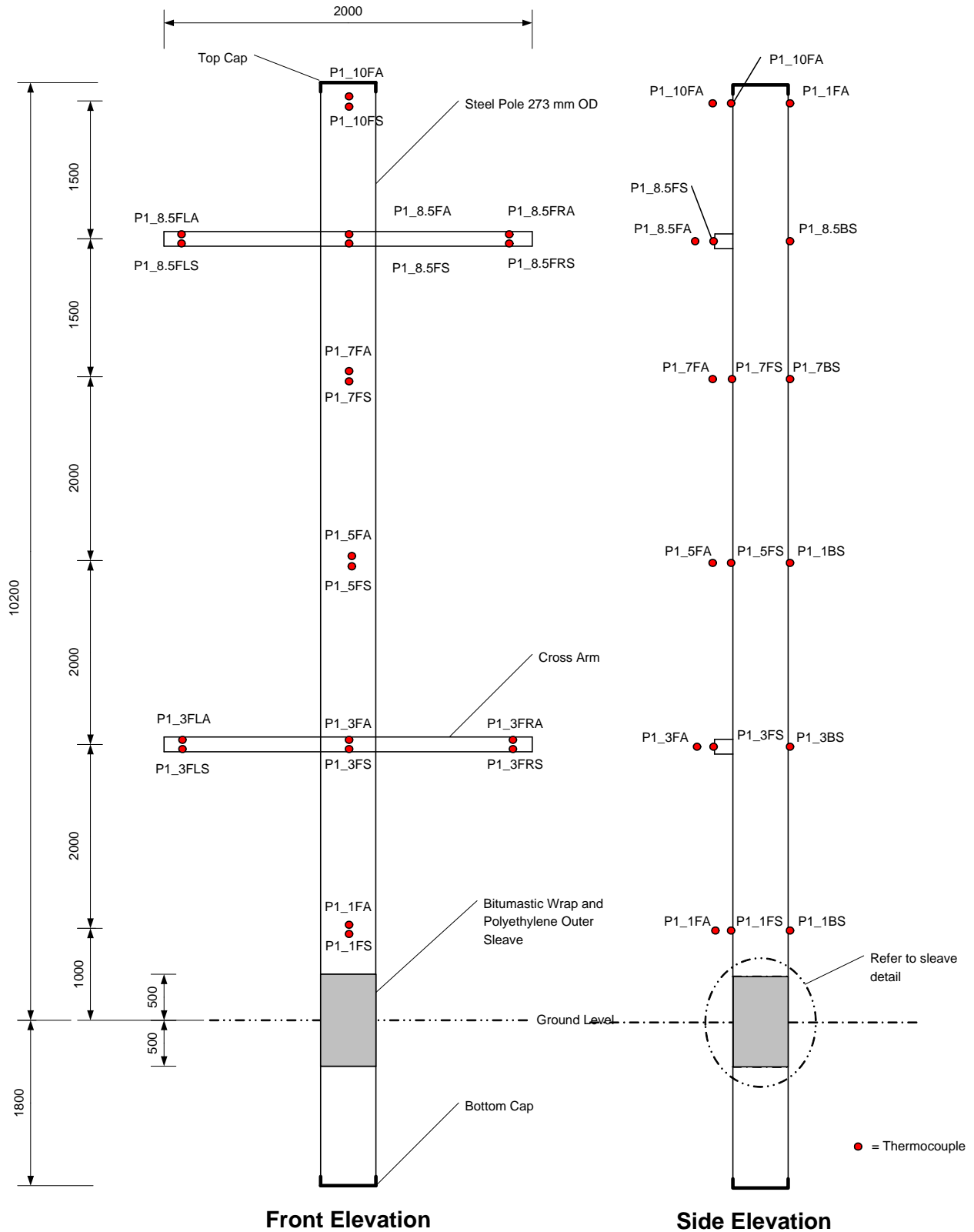
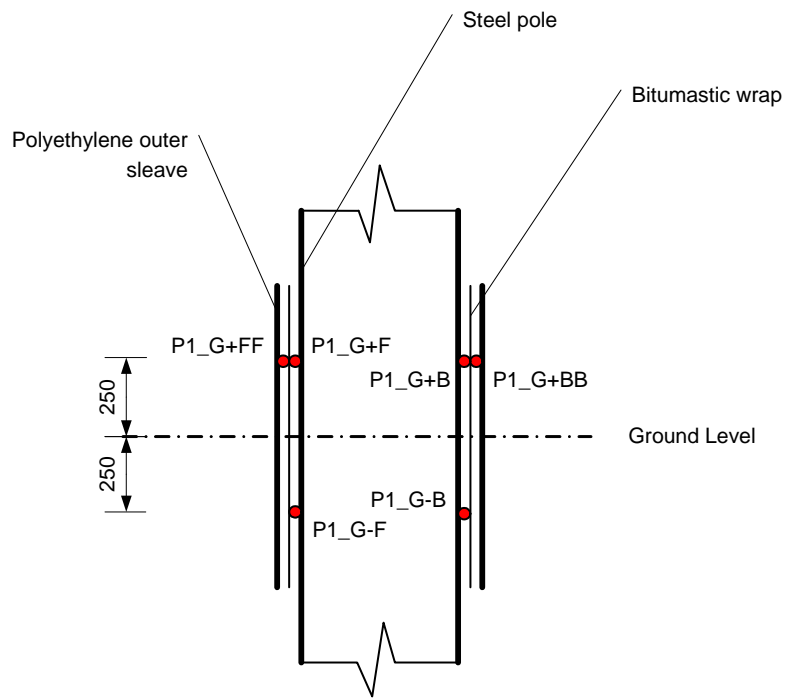


Figure A 1. Front and side elevations of power poles



## Sleeve Detail

Figure A 2. Detail of polyethylene sleeve on pole 1

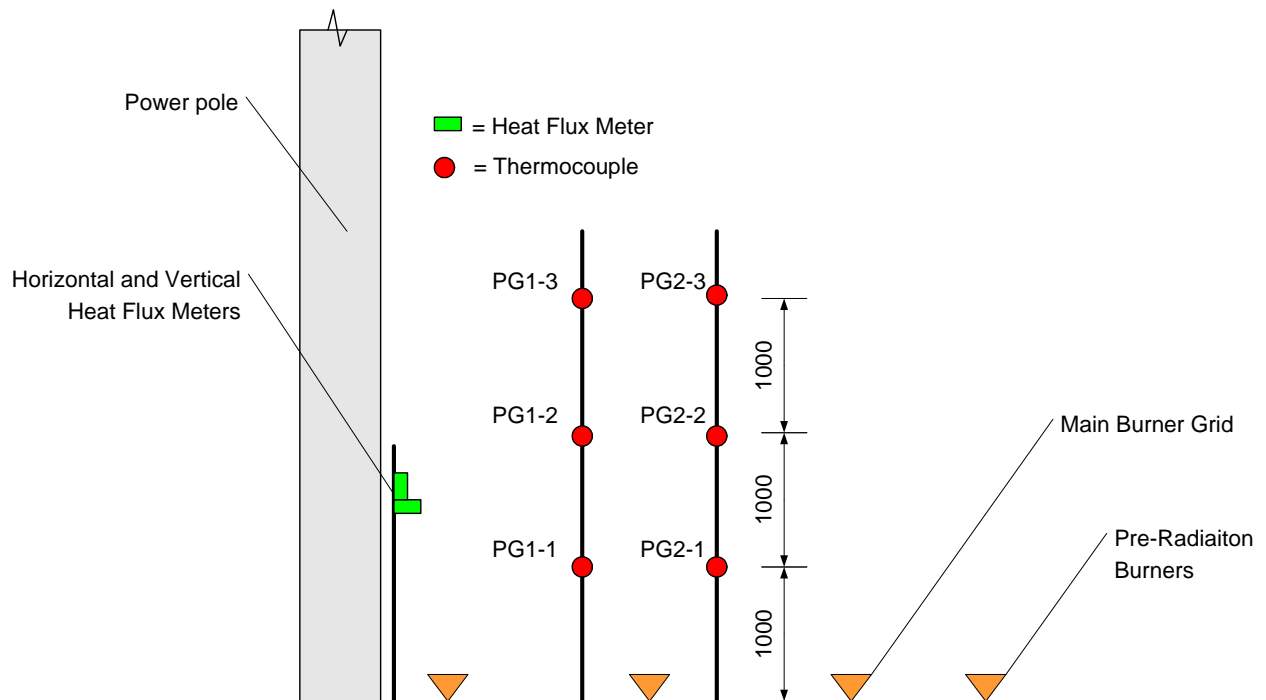
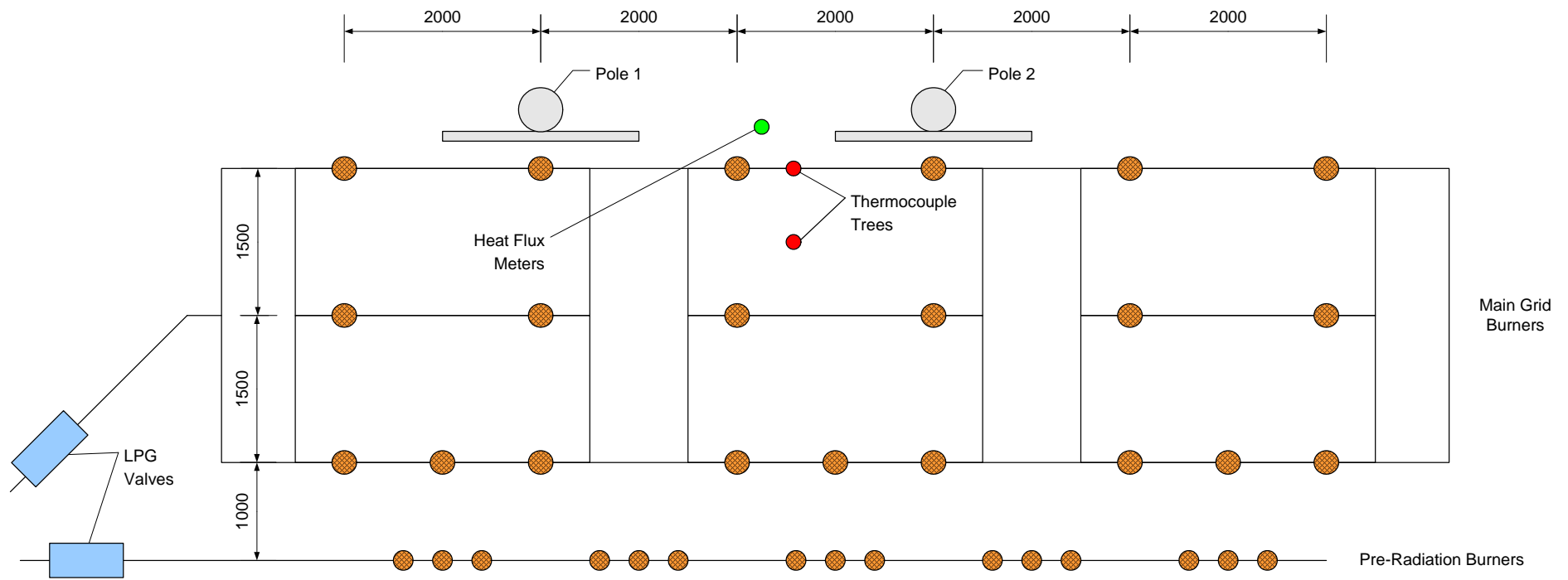


Figure A 3. Side elevation of power poles positioned in front of bushfire flame front simulator





**Figure A 4. Plan view of power poles installed in front of bushfire flame front simulator**

APPENDIX B GRAPHS

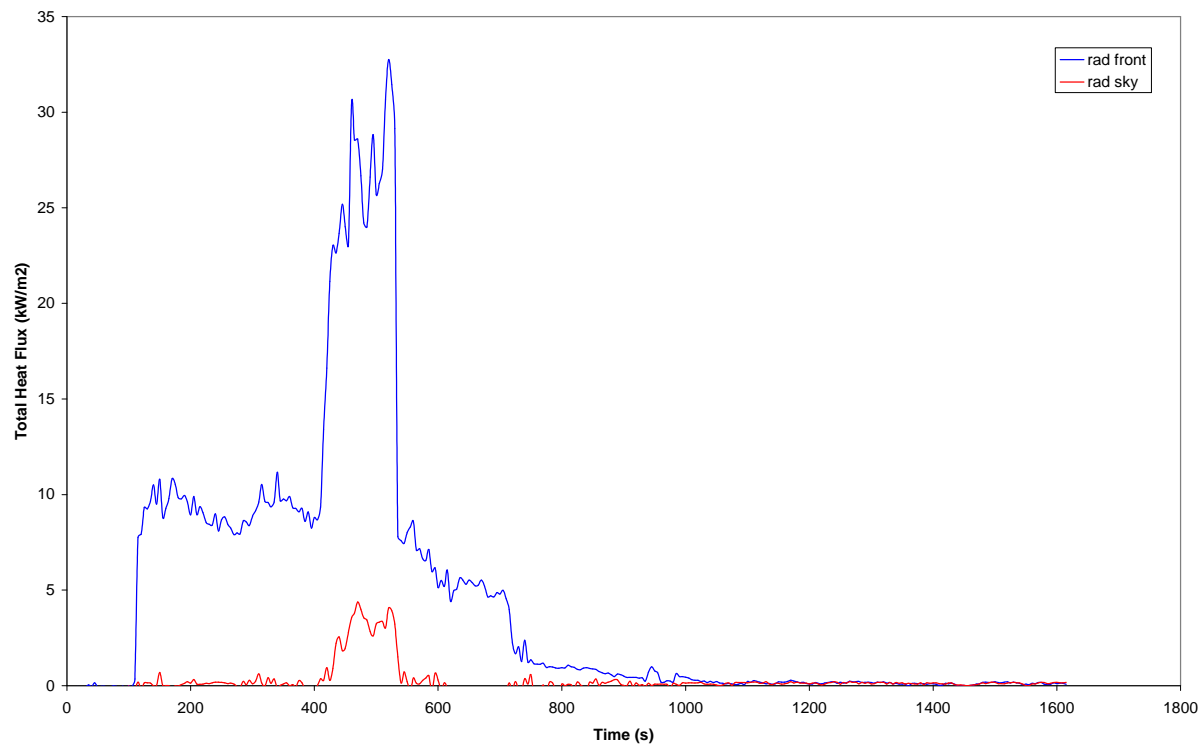


Figure B 1. Test 1 pre-radiation exposure total heat flux measurements

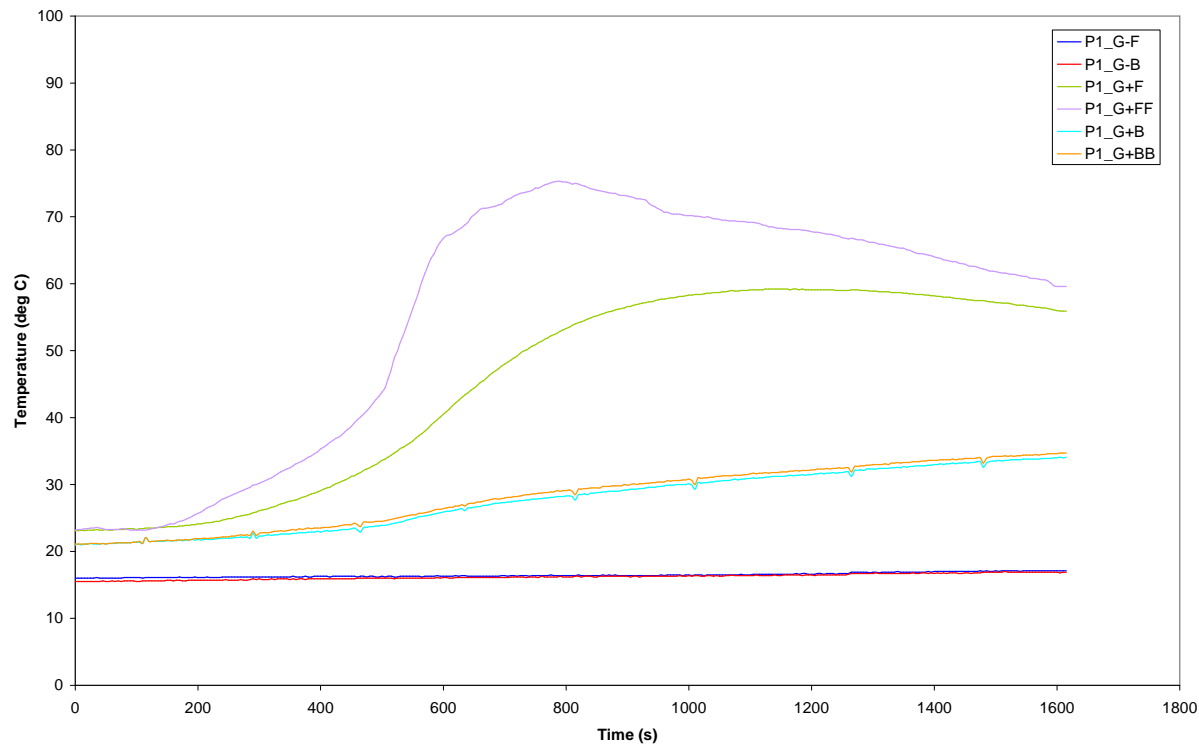
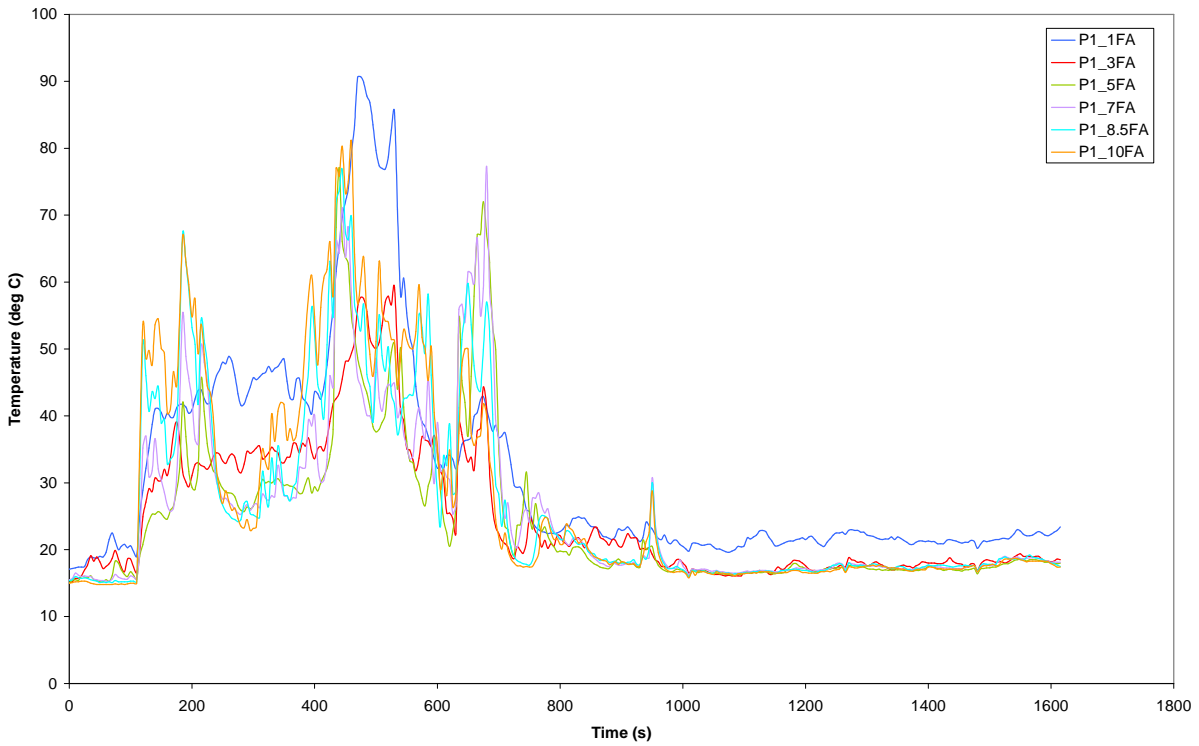
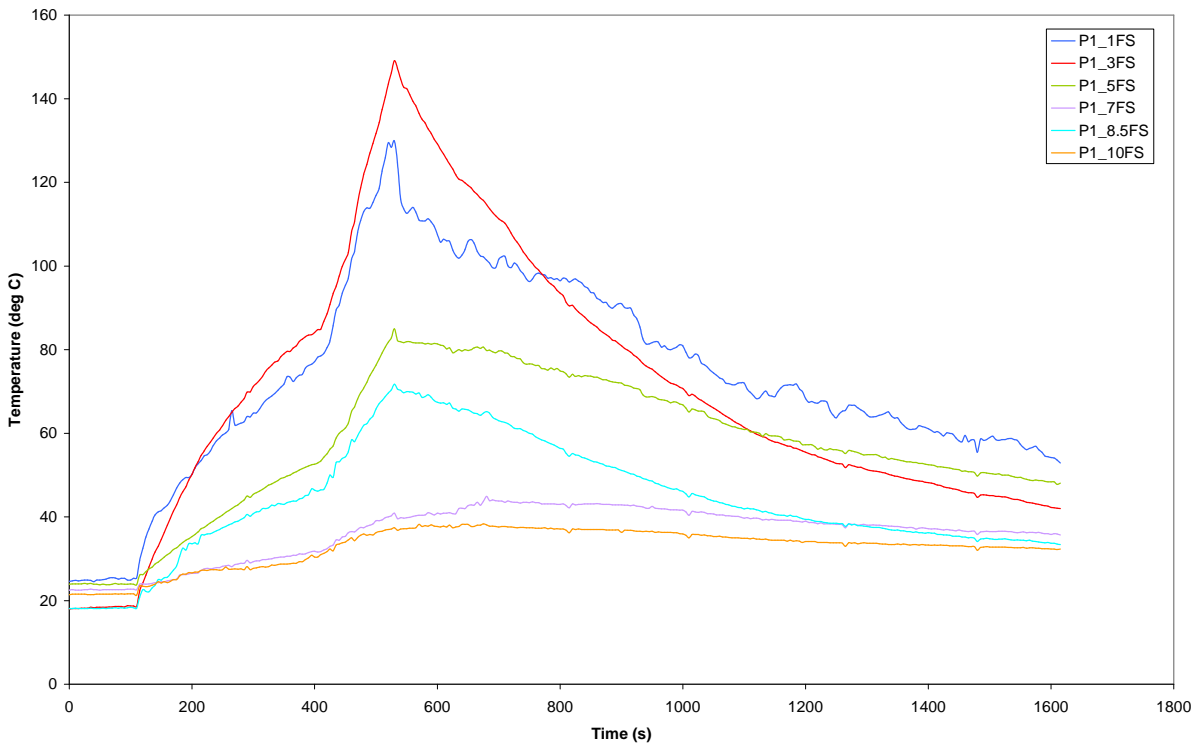


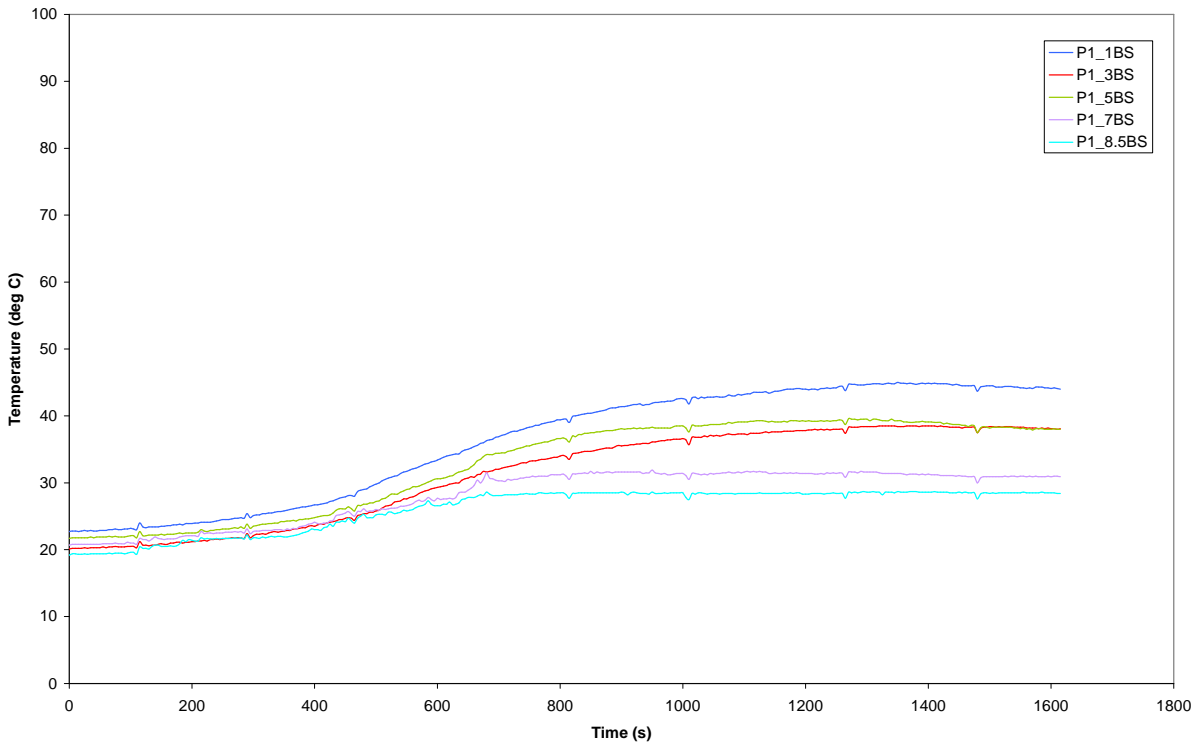
Figure B 2. Test 1 pre-radiation exposure - pole 1 base temperatures



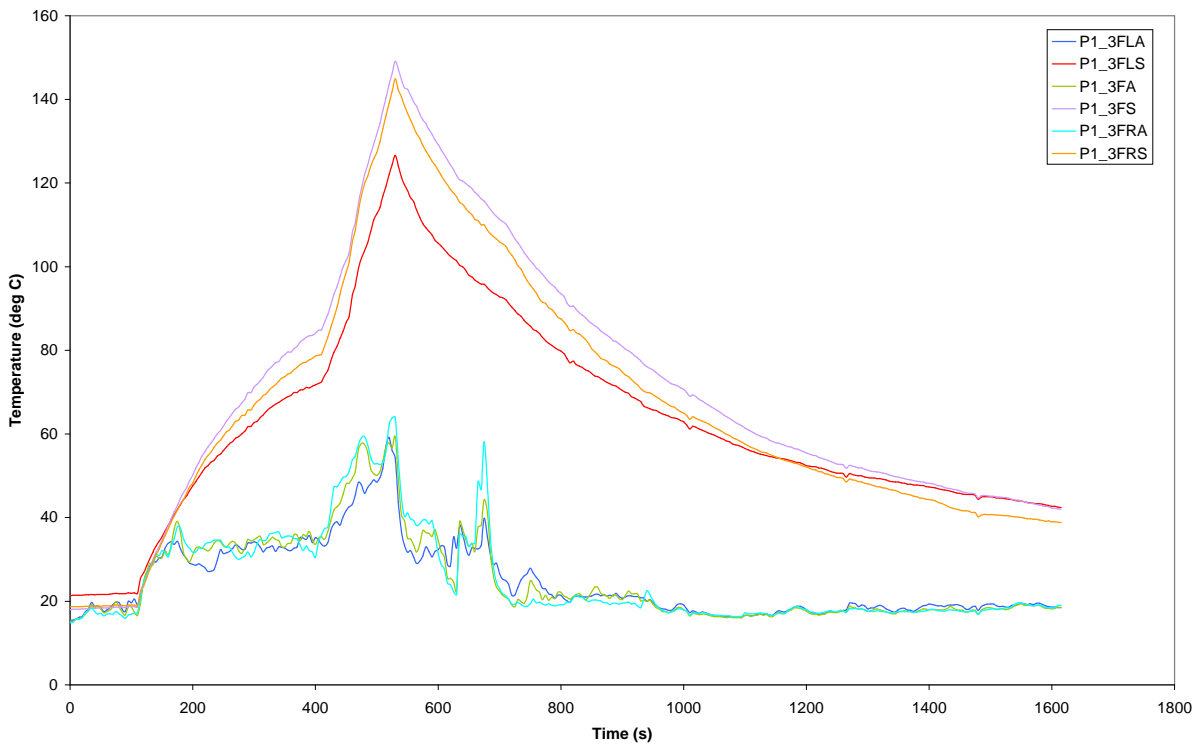
**Figure B 3. Test 1 pre-radiation exposure - pole 1 front air temperatures**



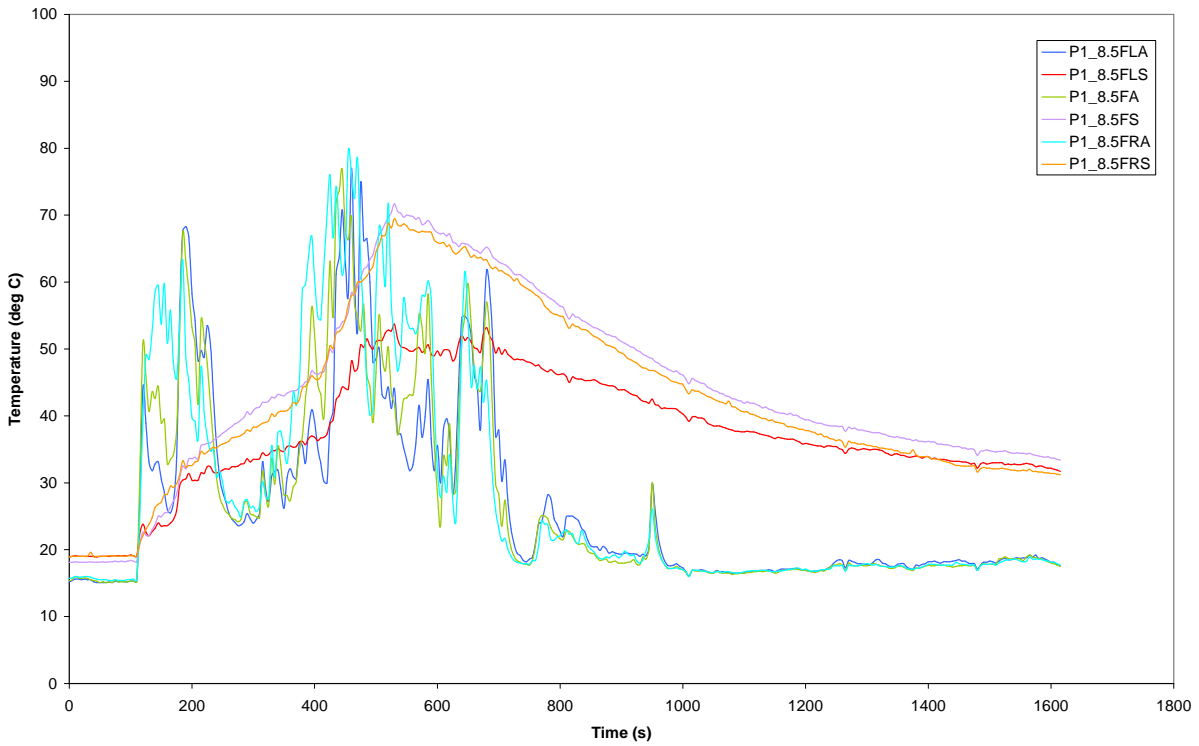
**Figure B 4. Test 1 pre-radiation exposure - pole 1 front surface temperatures**



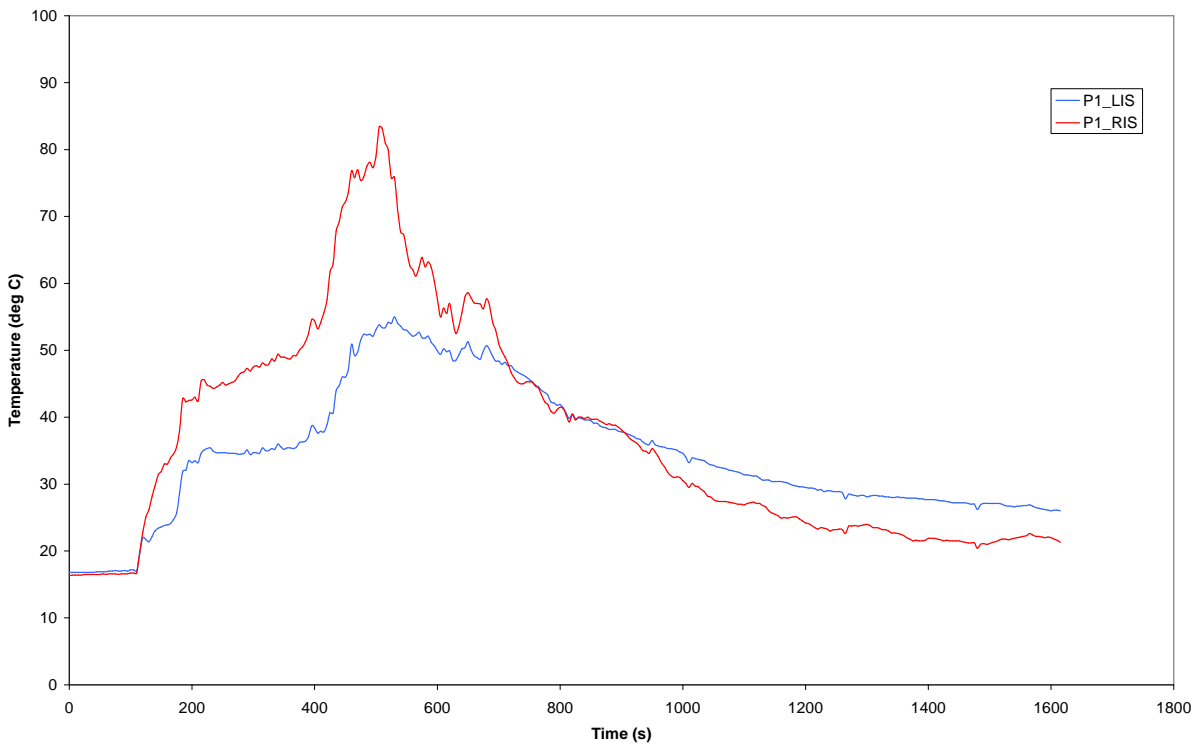
**Figure B 5. Test 1 pre-radiation exposure - pole 1 rear surface temperatures**



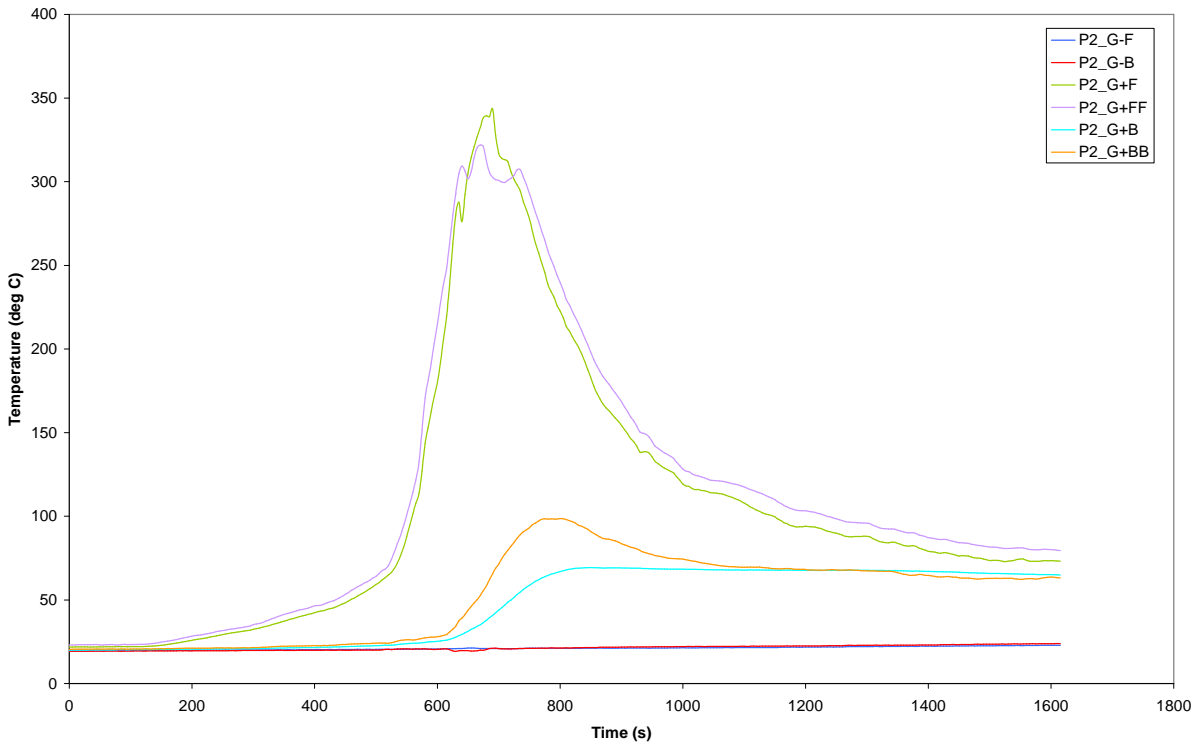
**Figure B 6. Test 1 pre-radiation exposure - pole 1 air and surface temperatures on 3 m cross-arm**



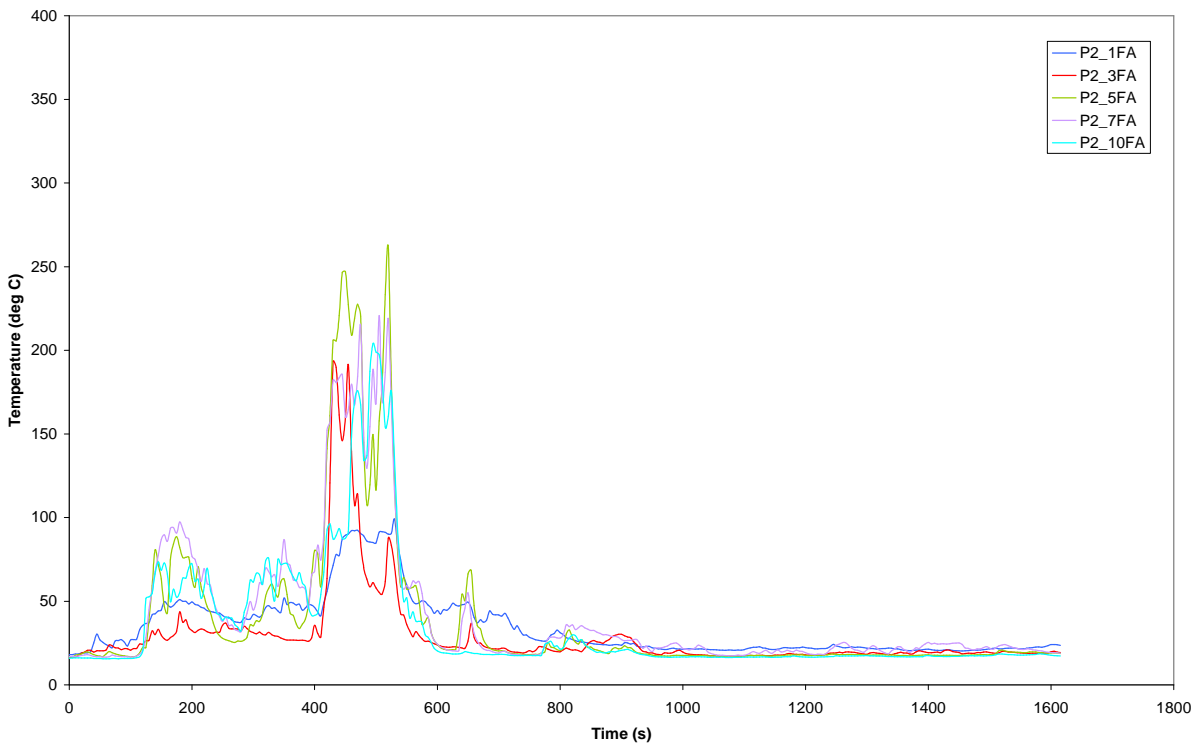
**Figure B 7. Test 1 pre-radiation exposure - pole 1 air and surface temperatures on 8.5m cross arm**



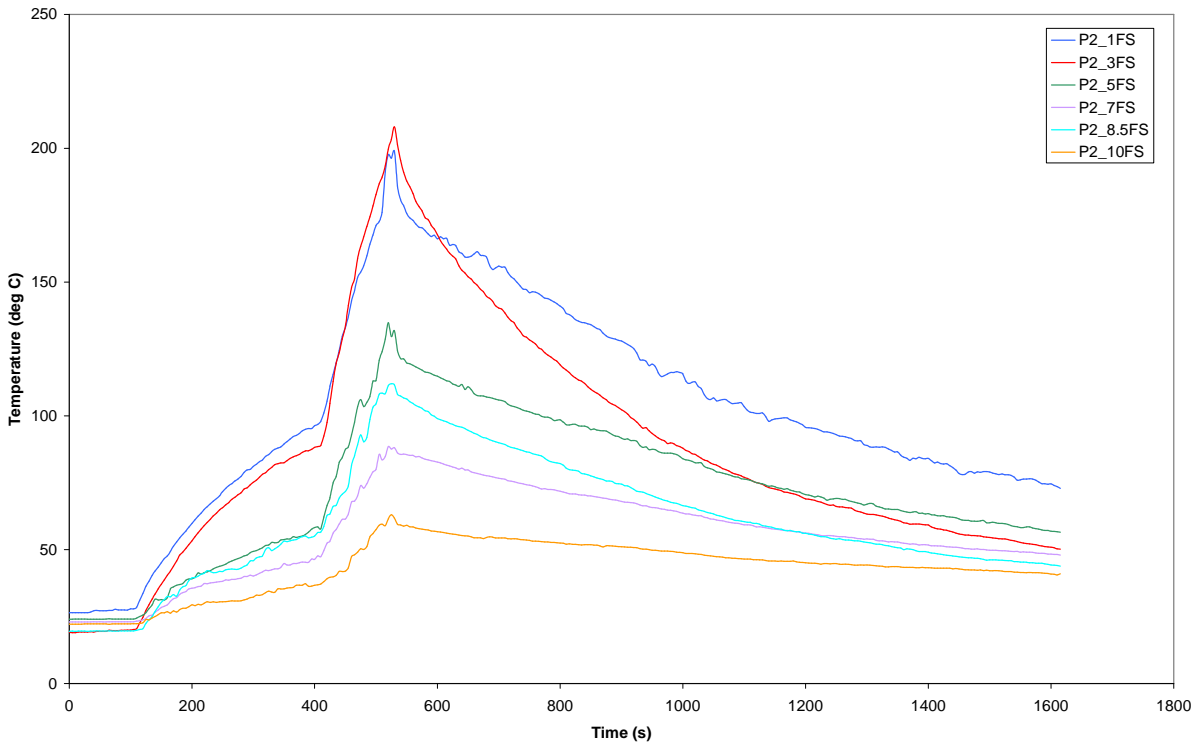
**Figure B 8. Test 1 pre-radiation exposure – pole 1 insulator surface temperatures**



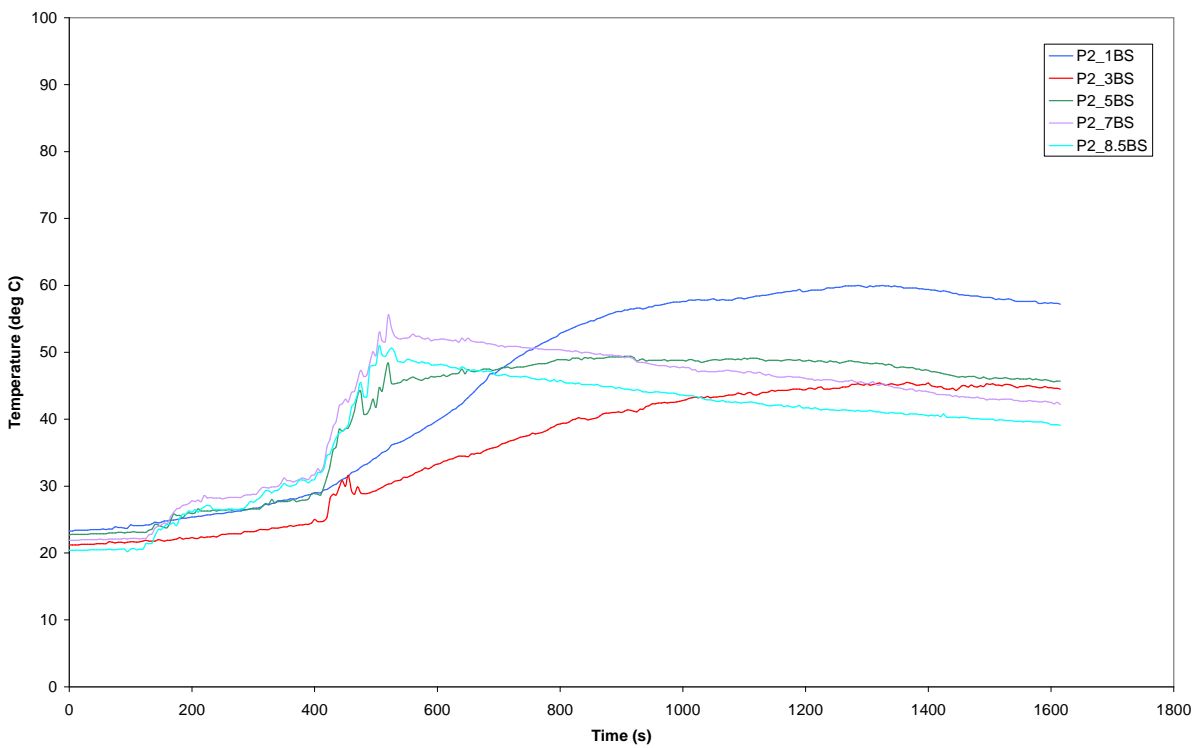
**Figure B 9. Test 1 pre radiation exposure – pole 2 base temperatures**



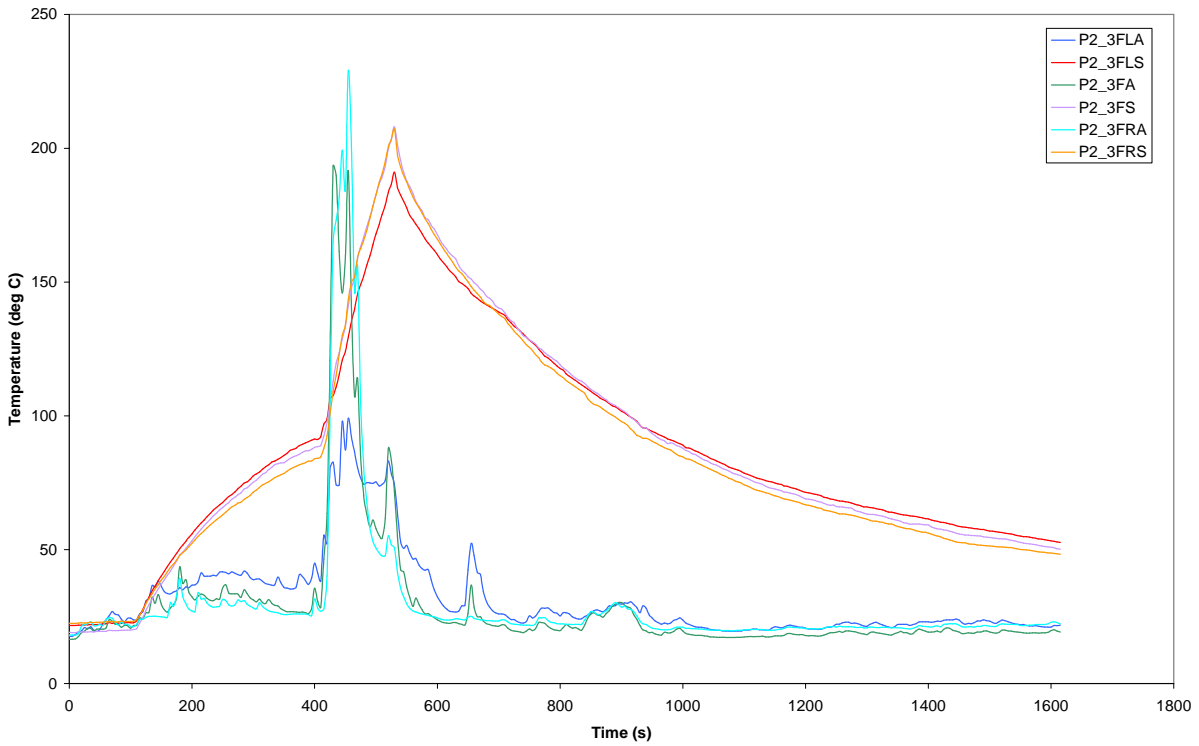
**Figure B 10. Test 1 pre radiation exposure –pole 2 front air temperatures**



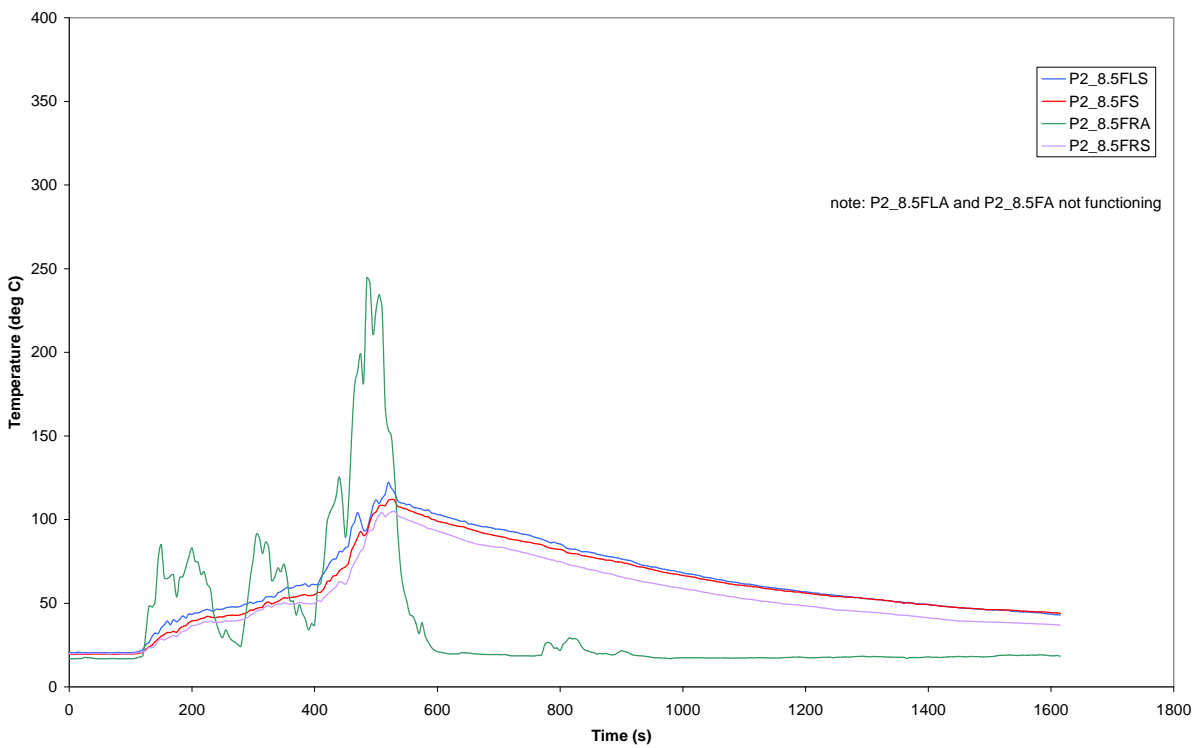
**Figure B 11. Test 1 pre radiation exposure – pole 2 front surface temperatures**



**Figure B 12. Test 1 pre radiation exposure – pole 2 back surface temperatures**

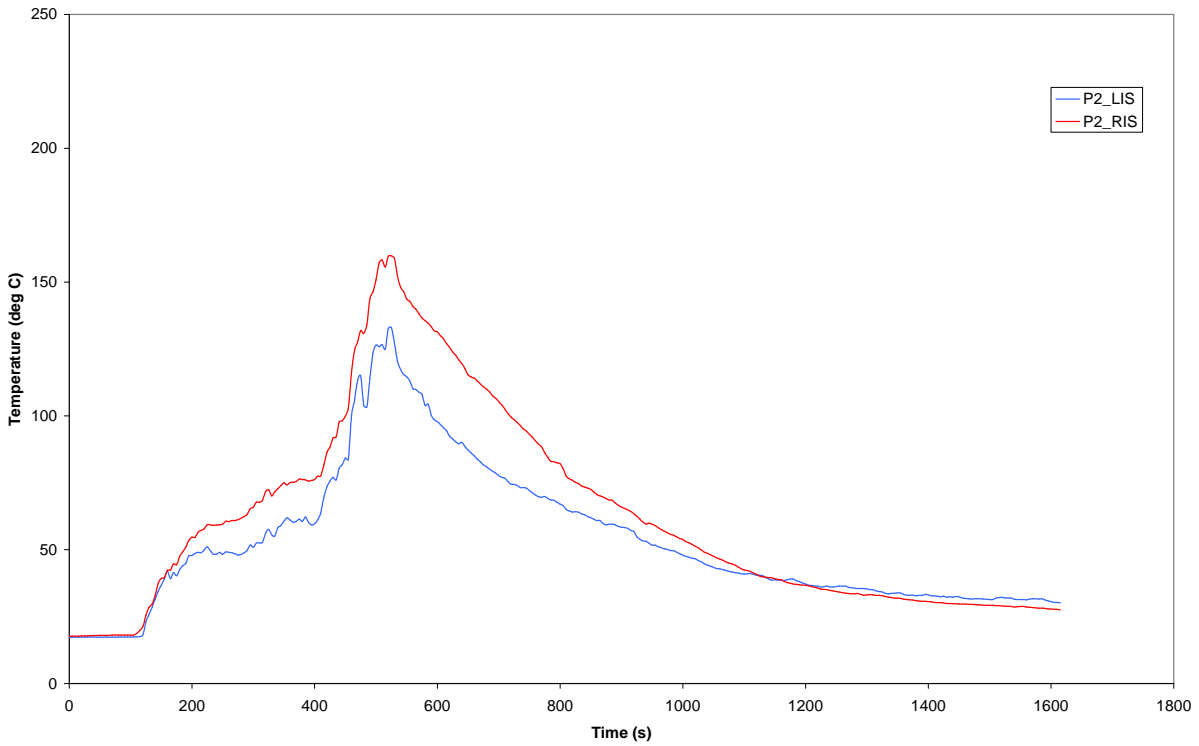


**Figure B 13. Test 1 pre radiation exposure – pole 2 air and surface temperatures at 3m cross arm**

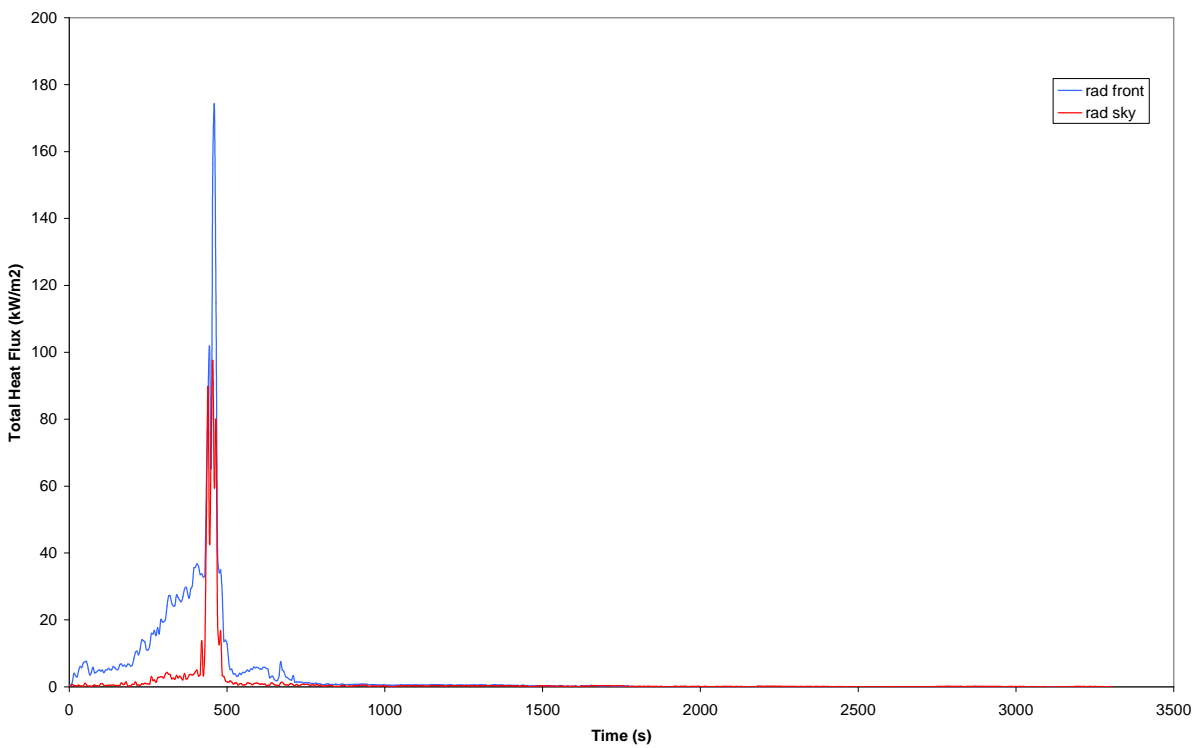


**Figure B 14. Test 1 pre radiation exposure – pole 2 air and surface temperatures at 8.5m cross arm**

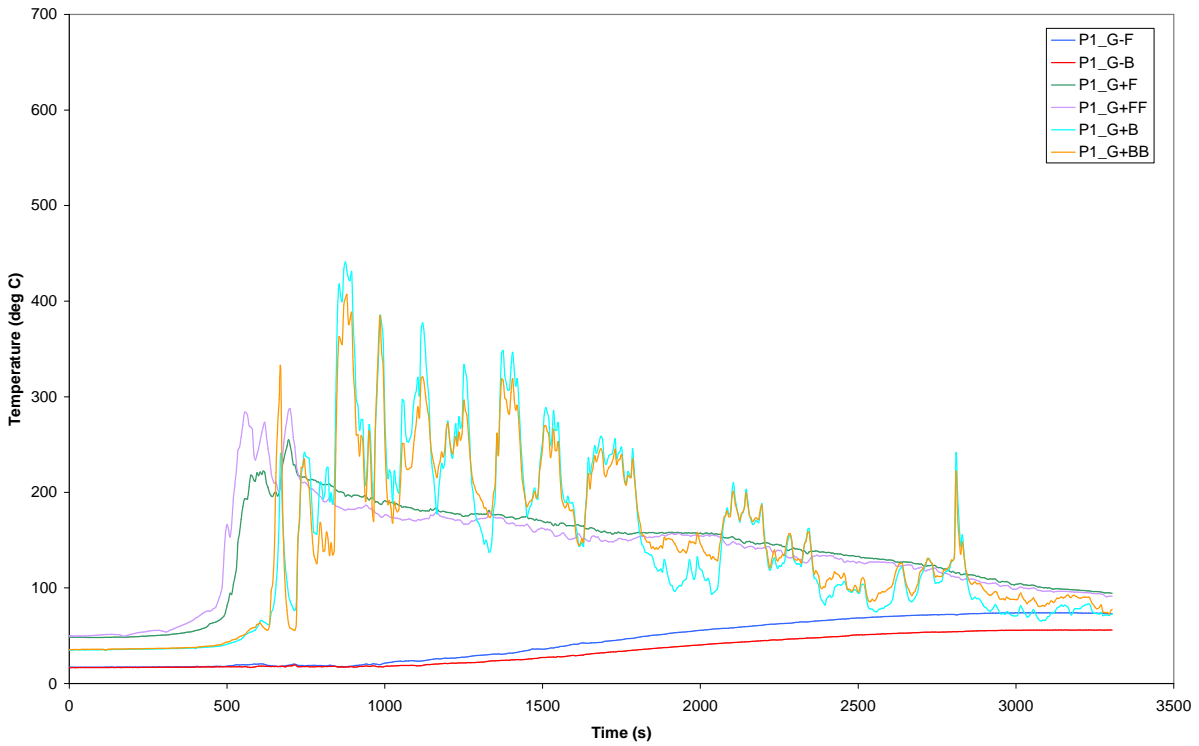




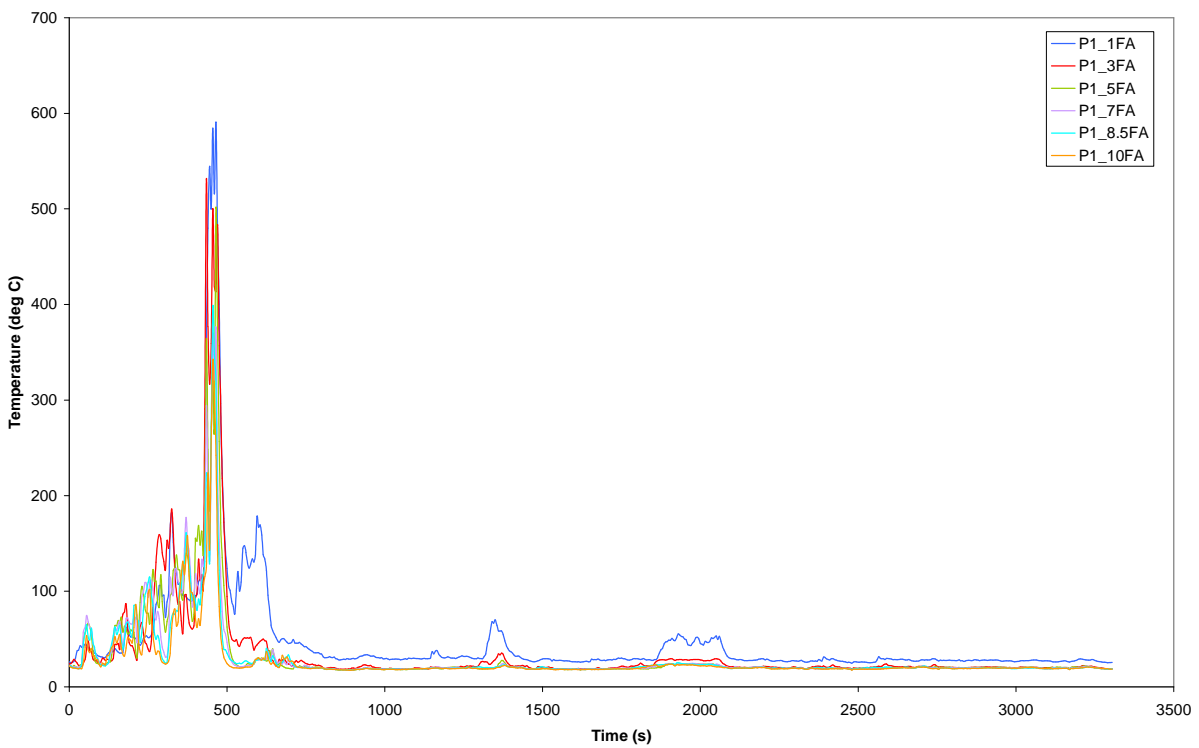
**Figure B 15. Test 1 pre radiation exposure – pole 2 insulator surface temperatures**



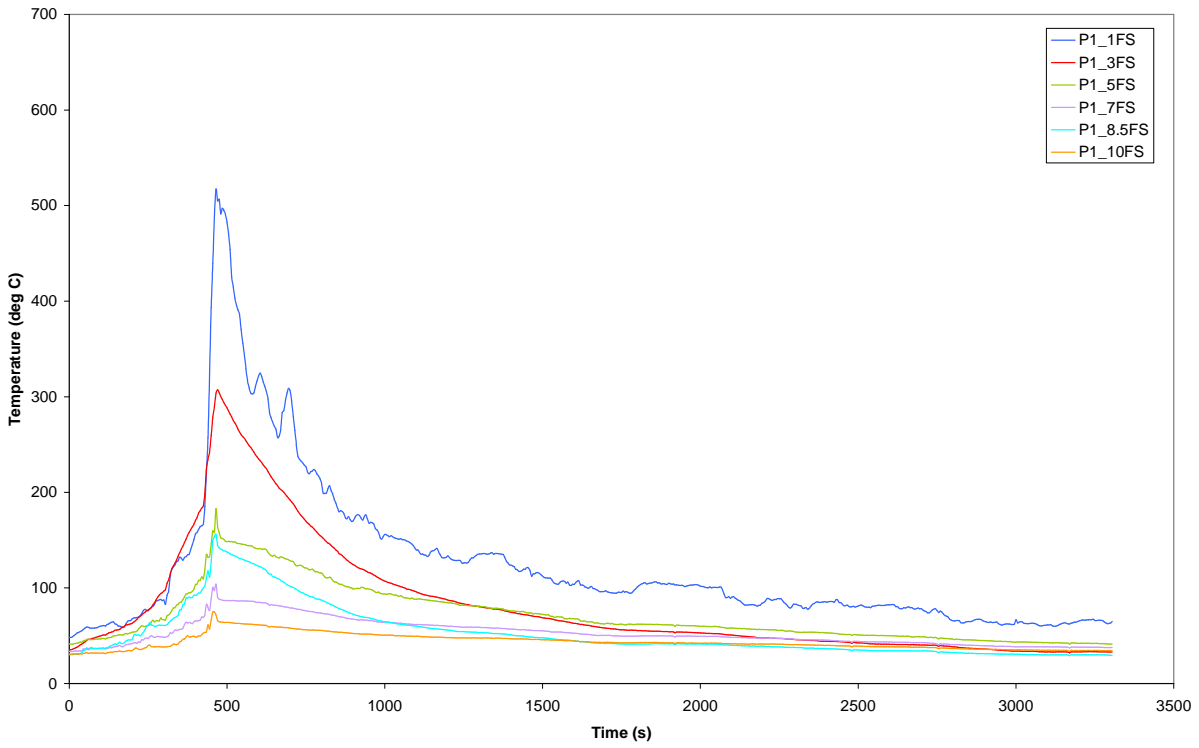
**Figure B 16. Test 2 flame immersion exposure – total heat flux measurements**



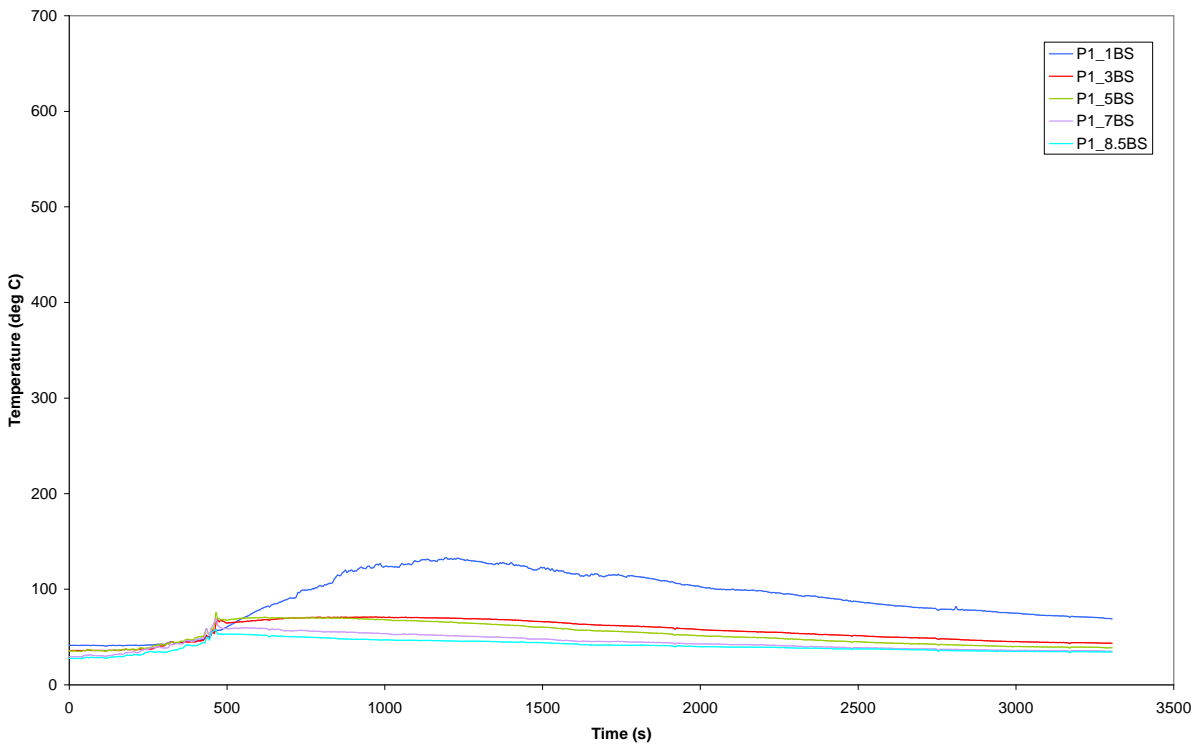
**Figure B 17. Test 2 flame immersions exposure – pole 1 base temperatures**



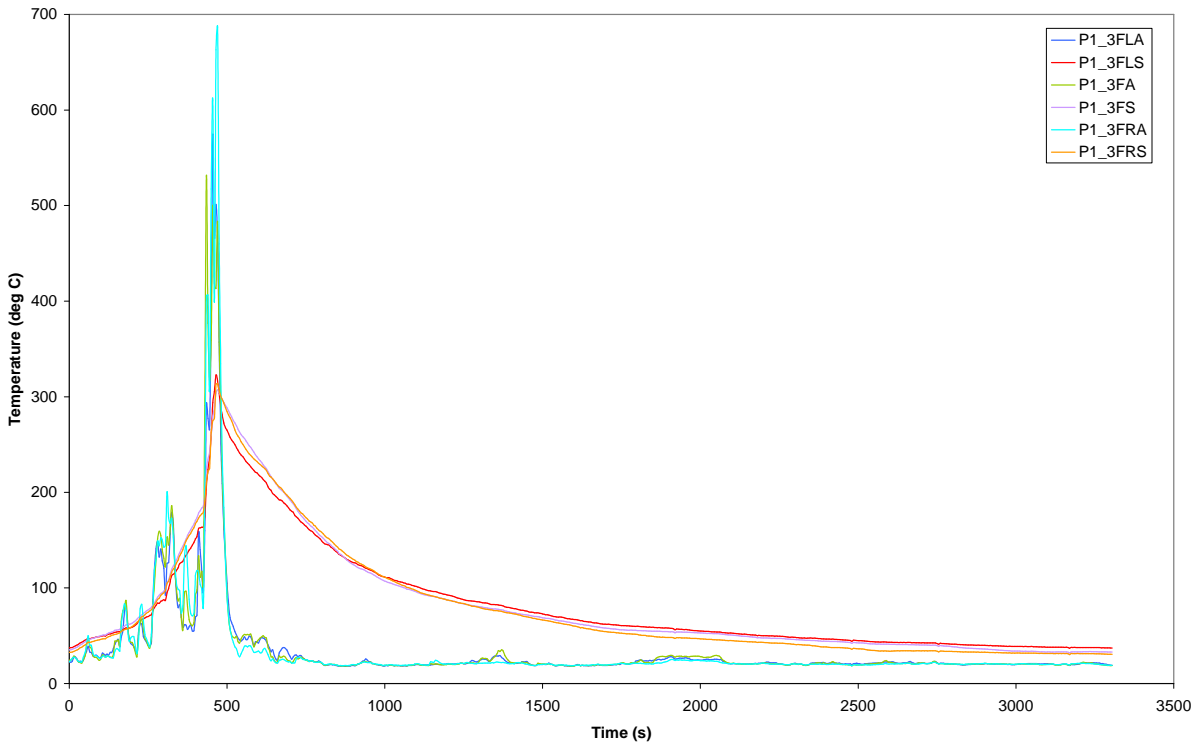
**Figure B 18. Test 2 flame immersion exposure – pole 1 front air temperatures**



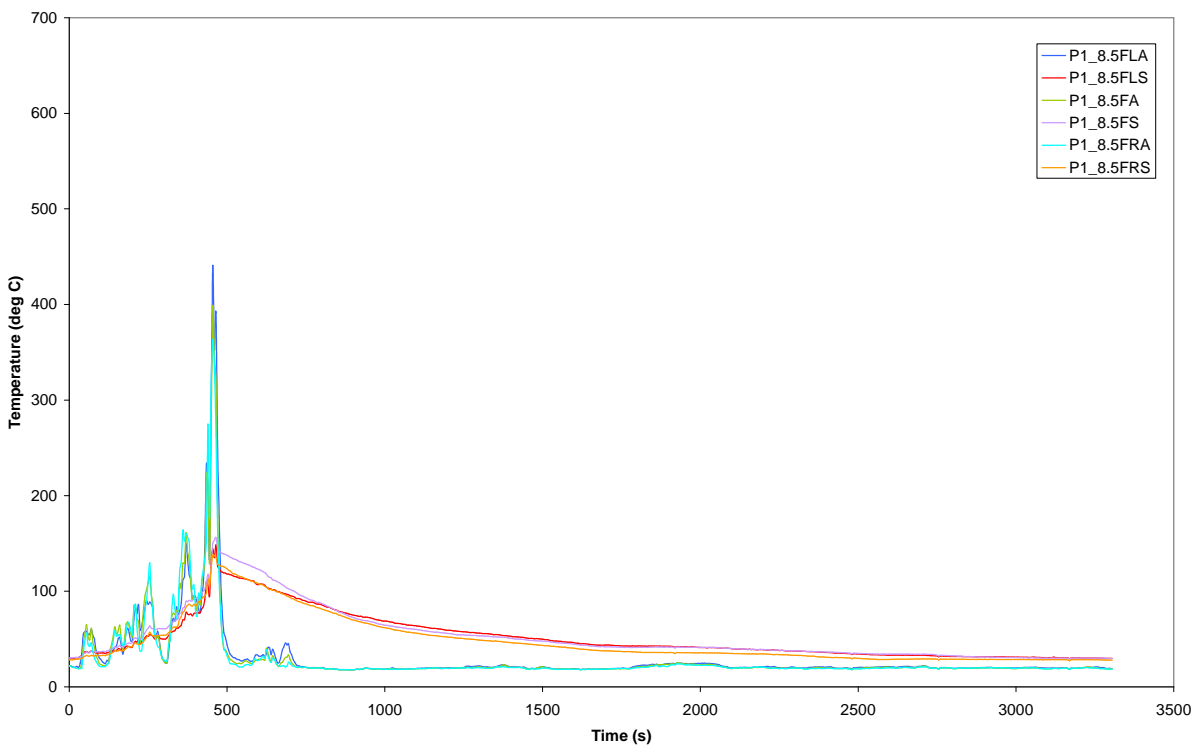
**Figure B 19. Test 2 flame immersion exposure – pole 1 front surface temperatures**



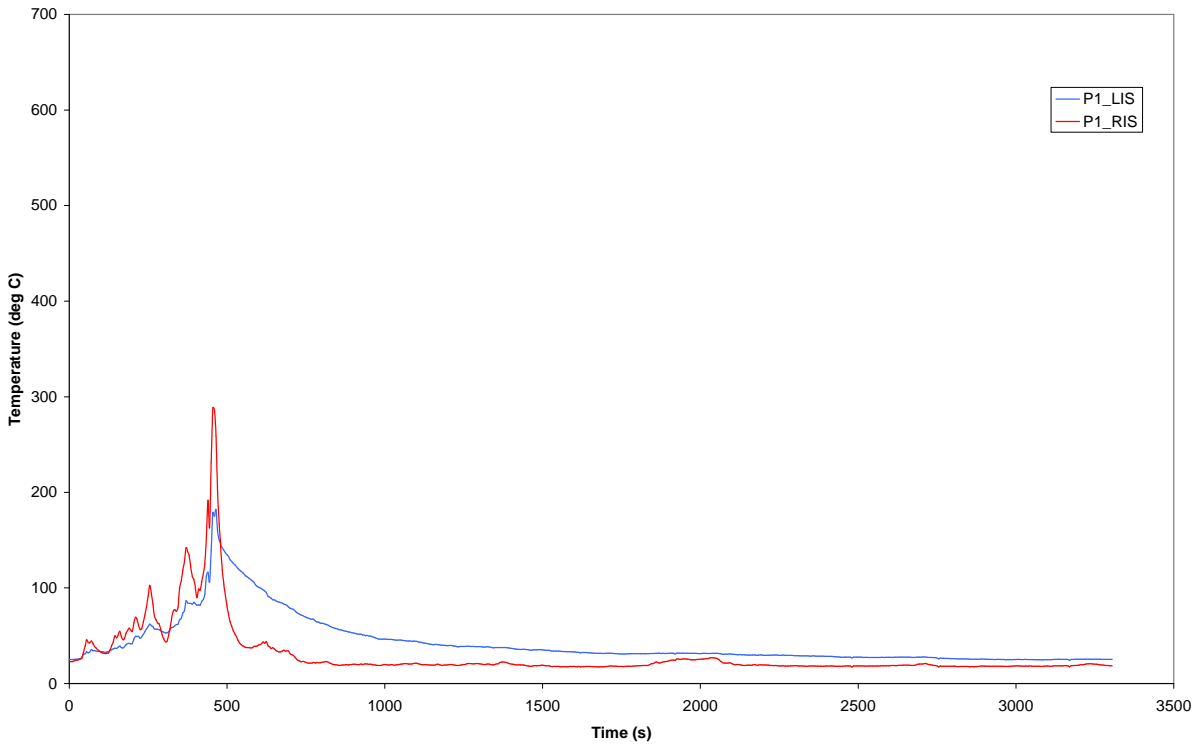
**Figure B 20. Test 2 flame immersion exposure – pole 1 back surface temperatures**



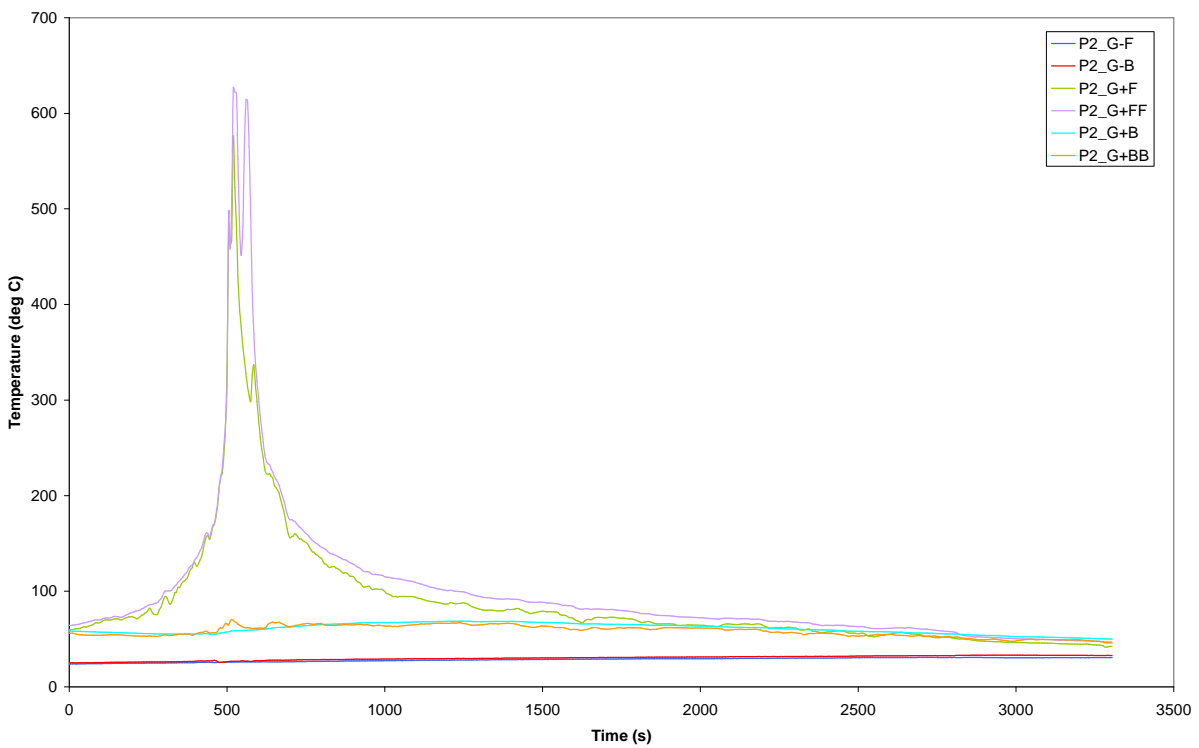
**Figure B 21.** Test 2 flame immersion exposure - pole 1 air and surface temperatures on 3m cross arm



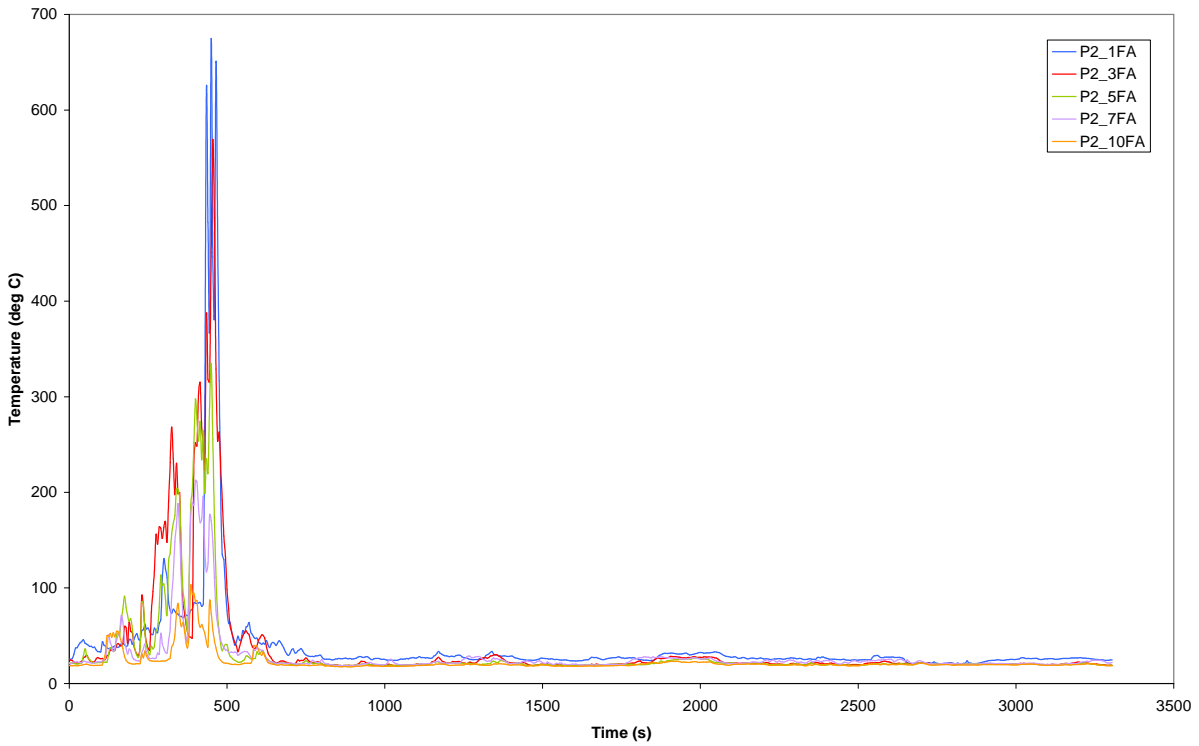
**Figure B 22.** Test 2 flame immersion exposure – pole 1 air and surface temperatures on 8.5m cross arm



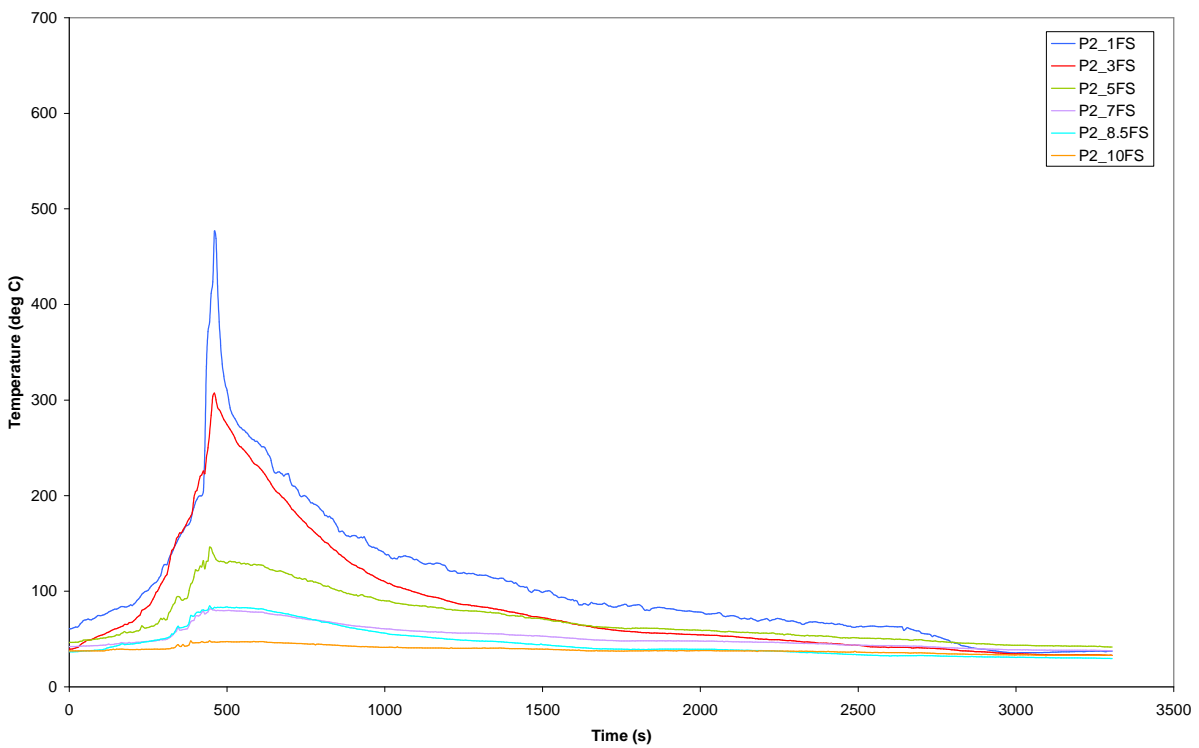
**Figure B 23. Test 2 flame immersion exposure – pole 1 insulator surface temperatures**



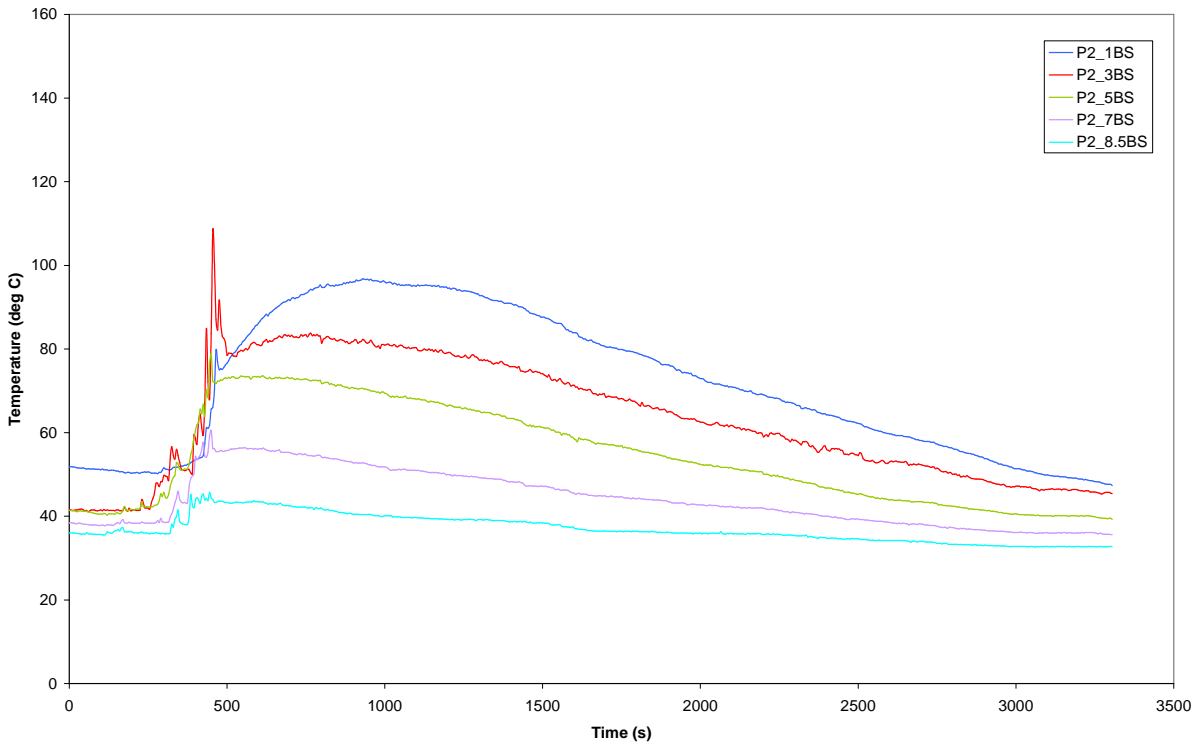
**Figure B 24. Test 2 flame immersion exposure – pole 2 base temperatures**



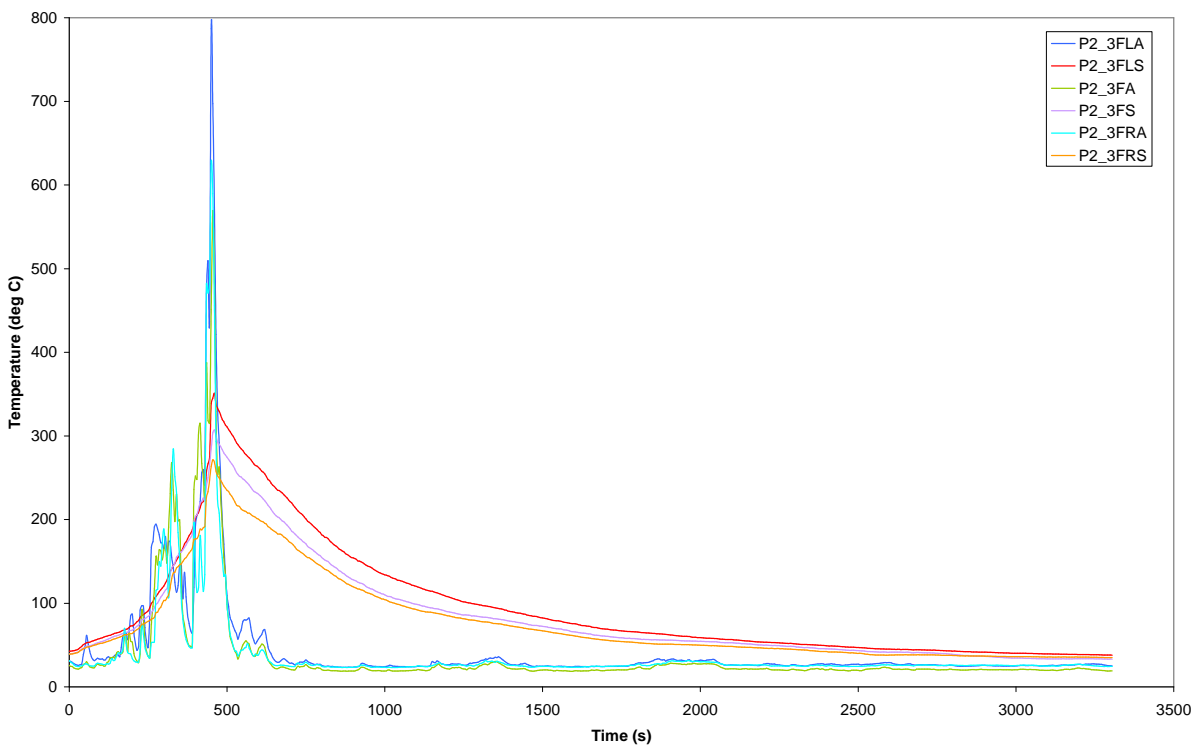
**Figure B 25. Test 2 flame immersion exposure – pole 2 front air temperatures**



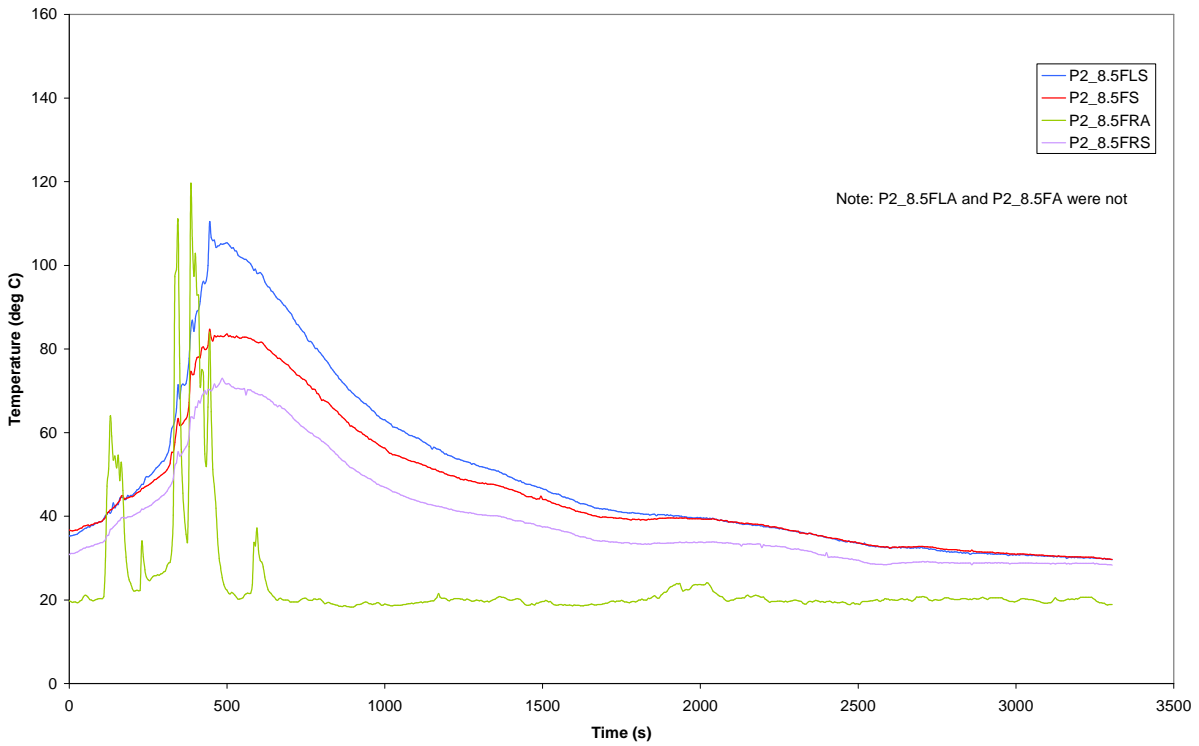
**Figure B 26. Test 2 flame immersion exposure – pole 2 front surface temperatures**



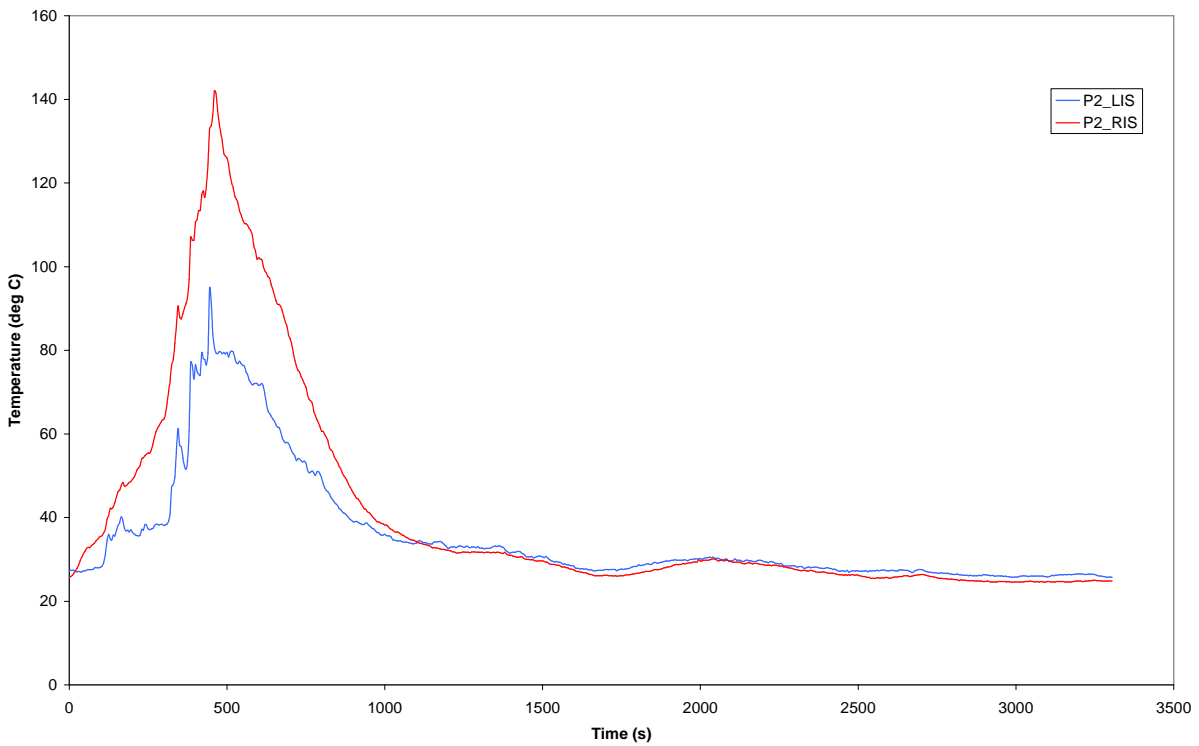
**Figure B 27. Test 2 flame immersion exposure – pole 2 rear surface temperatures**



**Figure B 28. Test 2 flame immersion exposure – pole 2 air and surface temperatures on 3m cross arm**



**Figure B 29. Test 2 flame immersion exposure – pole 2 air and surface temperatures on 8.5m cross arm**



**Figure B 30. Test 2 flame immersion exposure – pole 2 insulator surface temperatures**



