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## **DSPA AEROSOL GENERATOR ULC WITNESS TESTS**

Prepared for

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# **DSPA Aerosol Generator ULC Witness Tests**

## **1.0 INTRODUCTION**

Hughes Associates, Inc has been working under contract with DSPA with the goal of obtaining an Underwriters Laboratory Canada (ULC) listing for the aerosol generator systems developed by DSPA. The recent tests performed with the U.S. Coast Guard on the “State of Maine” are considered as part of this listing process [1]. The tests covered in this report were performed at the Aberdeen Test Center. These tests consisted of dual wood crib fire tests, n-heptane pan fire tests, and polymeric material array tests. All of these tests had to be successfully performed three consecutive times with a representative of ULC present during the tests. Note that additional testing beyond that included in this project will need to be performed to complete the listing process. These additional tests would include component tests and volume coverage tests for each individual generator to be listed.

These tests were performed in two series at the U.S. Army Aberdeen Test Center in Aberdeen, Maryland. The first series was performed January 14 through 17, 2008 and the second series was performed July 14 through 16. The first series of tests was witnessed by Mr. George Unger of ULC and Mr. Vedad Hasanovic of ULC, Mr. Brian Lancaster of RINA, and Dr. Louise Jackman of BRE. The second series was witnessed by Mr. George Unger of ULC.

## **2.0 APPARATUS**

### **2.1 Test Enclosure**

A 100 cubic meter test enclosure, illustrated in Figures 1 and 2, segregated from a larger metal lined enclosure with two walls constructed from 12mm (0.5 in) plywood over a wooden frame were utilized for these tests. The enclosure has an internal footprint of 4.1 x 7 m (13.5 x 23 ft) and a height of 3.5 m (11.5 ft) and is located at the U.S. Aberdeen Test Center, Aberdeen Proving Ground, MD. It was equipped with a ceiling mounted trap door/pressure relief vent. Access to the enclosure was provided by a plywood door which was also utilized to provide post-test exhaust of the chamber. Air supply ventilation was provided through a floor level damper.



Figure 1 – Photograph of Test Enclosure



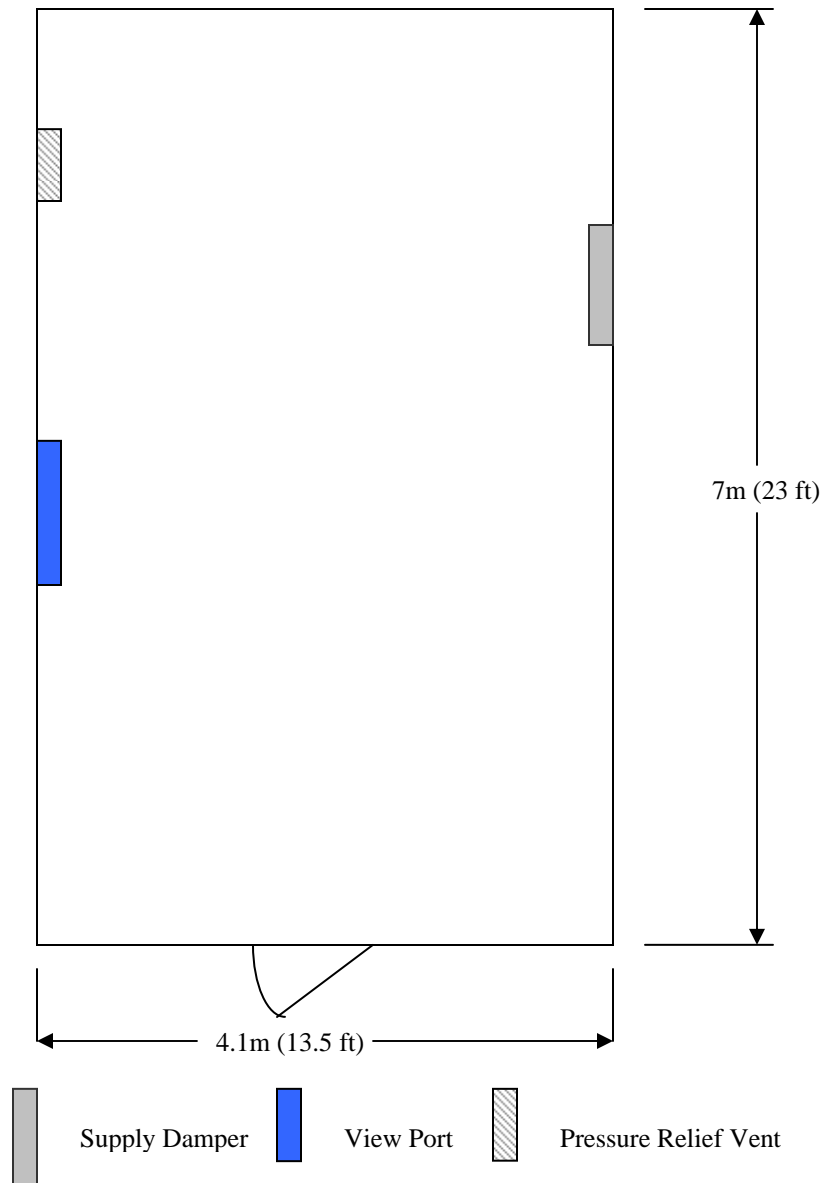


Figure 2 – 3.7 m Test Enclosure

## 2.2 Fire Scenarios

Four fire scenarios were utilized during these tests. The first scenario utilized two wood cribs as described in the draft UL Standard for Condensed Aerosol Extinguishing System Units GEL 8-06 [2] as the Class A compatible wood crib test and also as described in the ISO Standard on Condensed Aerosol Fire Extinguishing Systems, ISO CD 15779 [3]. These cribs were constructed from 32 pieces of trade 5 x 5 cm (2 x 2 in) spruce, 30.5 cm (12 in) in length arranged in eight layers of four members each. This arrangement resulted in a crib that was a cube, 30.5 cm (12 in) on a side. The cribs were placed on top of four bricks, 5 cm (2 in) thick. The cribs were ignited with 113.5 g (0.25 lb) of shredded paper placed underneath each crib and 236 ml of denatured ethyl alcohol poured over each crib. The cribs were pre-conditioned to a moisture content of 9 to 13 % by weight. One of the cribs was located 30.5 cm (1 ft) behind a floor to

ceiling baffle, 0.82 m (2.7 ft) wide and located 1.8 m (5.8 ft) from the back wall of the enclosure. During the second set of tests, the crib and baffle was relocated to 1.8 m (5.8 ft) from the front wall of the enclosure. This was done to remove any influence of the supply air duct from the burning of this crib.

The other crib is located in the center of the test enclosure inside two square baffles, 0.95 m (37.5 in) on a side and 0.3 m (12 in) tall, stacked on top of each other with the top baffle rotated 45° relative to the other. The lower baffle is raised off the floor 9 cm (3.5 in) supported by four bricks, one at each corner. These baffles are identical to those utilized for the Class A polymeric materials tests of GEL-8-06 [2] and ISO 15779 [3]. In addition to these baffles a horizontal baffle measuring 0.76 x 0.76 m (2.5 x 2.5 ft) is placed directly above the crib, 1 m (3.3 ft) above the floor. This set-up is illustrated in Figures 3 and 4.

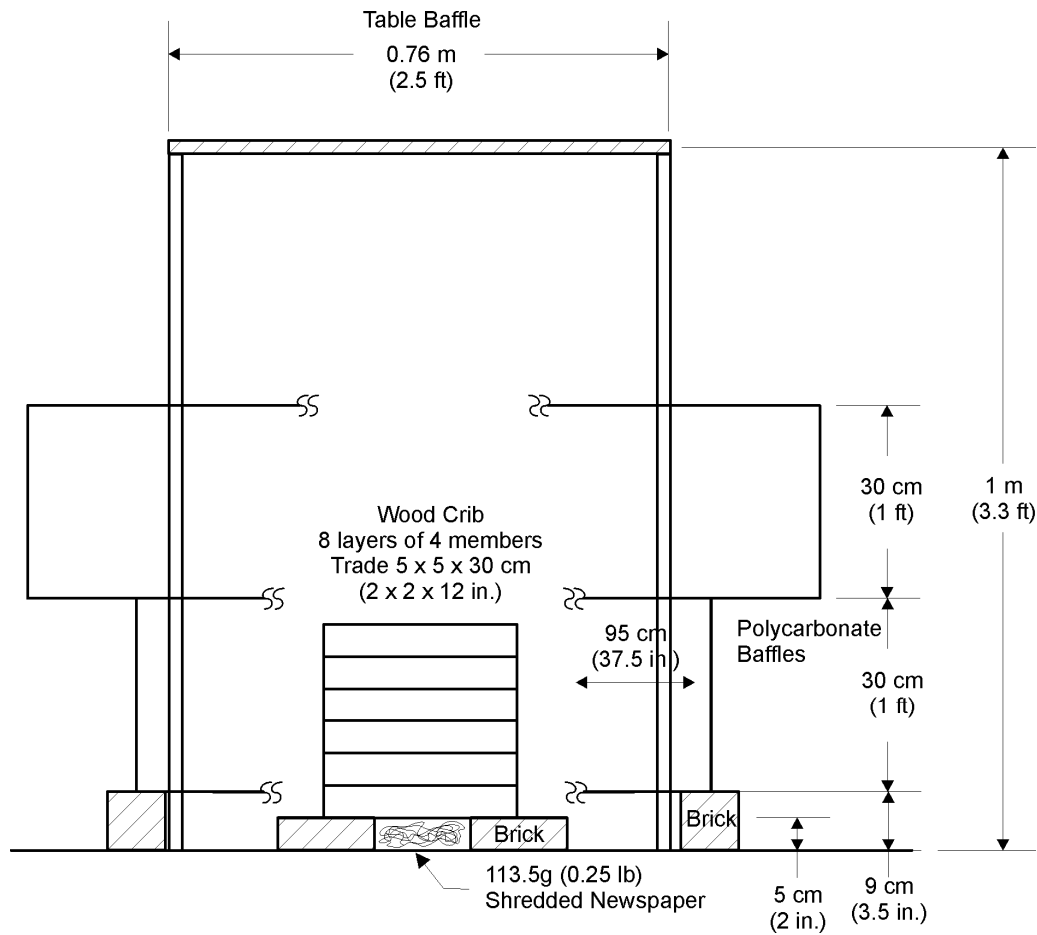


Figure 3 – Center Crib Detail – Elevation View

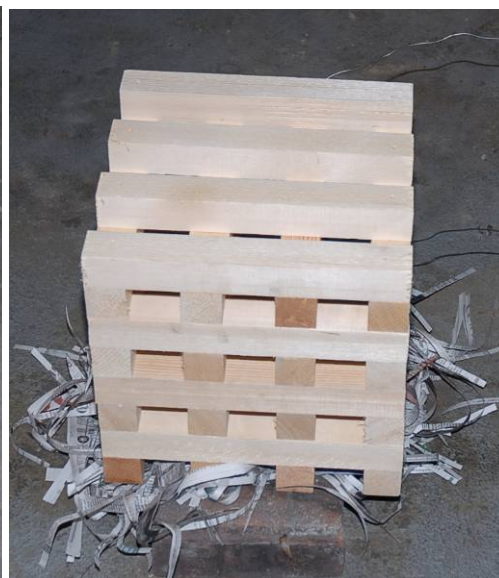


Figure 4 – Photograph of Wood Crib Scenario

During the initial set of wood crib tests, the cribs were constructed from wood purchased at a local (Millersville, MD) lumber yard and fabricated by HAI personnel in Baltimore, MD. The subsequent set of wood crib tests, utilized cribs provided by ULC through their supplier, Carr Lumber and Manufacturing of Bedford Park, IL. Photographs of cribs comparing the two sets of cribs are given in Figure 5. The ULC provided cribs had no cracks or splits in the wood members. There were no gaps or separations between wood members where they crossed each other. The ULC provided crib were held together with smaller nails.



HAI Fabricated Crib



ULC Provided Crib

Figure 5 - Comparison of HAI and ULC provided wood cribs.

The second fire scenario utilized consisted of a polymeric material array as described in the UL test protocol, GEL-8-06 [2]. The array consisted of four sheets of material, each 20 x 40 cm (8 x 16 in) and 0.95 cm (0.38 in) thick, arranged vertically with a center gap of 3.2 cm (1.25 in) and outer gaps of 1.2 cm (0.5 in). The array was suspended 1.2 cm (0.5 in) above a 5.1 x 5.1 cm (2 x 2 in) square 2.2 cm (0.88 in) deep n-heptane pan which was used to ignite the polymeric material array. The pan was fueled with 3.5 ml of n-heptane to provide 90 second of burn duration. The array was shielded on the two sides parallel to the polymeric sheets and on the top by sheet steel attached to an angle iron frame with dimensions of 61 x 38 x 85 cm (24 x 15 x 33.5 in). The array was further shielded by two square baffles, 95 cm (37.5 in) on a side and 30 cm (12 in) tall, placed on top of each other with the upper baffle rotated 45°. The square baffles are raised off the floor 8.9 cm (3.5 in) by four blocks located on the corners of the baffle. This setup is illustrated in Figure 6.

Three polymeric materials were utilized in the scenario: polymethyl methacrylate (PMMA), acrylonitrile butadiene styrene copolymer (ABS) and polypropylene (PP). Properties of these polymers are given in Table 1. Samples of the materials used in these tests were tested utilizing the cone calorimeter with a 25 kW/m<sup>2</sup> radiant exposure to demonstrate conformance to the requirements of GEL-0806 [2] and ISO 15779 [3]. The results of the cone calorimeter tests are given in Table 1. Note that the specification and tolerances given are for GEL-0806 [2]. ISO 15779 has a slightly different specification and tolerance for the polymeric materials, which also met by these materials. Details of cone calorimeter tests are given in Reference 4.

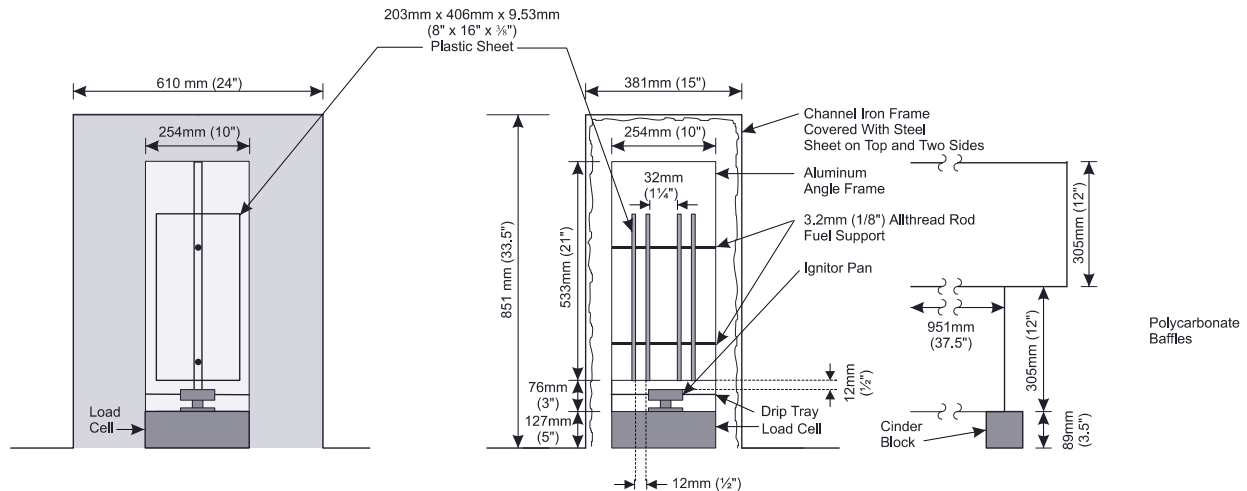


Figure 6 – Polymeric Material Fire Scenario Schematic – Elevation View

Table 1 – Polymeric Fuel Properties

Fuel	Ignition Time (s)			180 Second Average Heat Release Rate (kW/m <sup>2</sup> )			Effective Heat of Combustion (MJ/kg)		
	Tolerance (+/-29%)			Tolerance (+/-26%)			Tolerance (+/-15%)		
	Measured	Specification	Error (%)	Measured	Specification	Error (%)	Measured	Specification	Error (%)
PMMA	86	77	12.0%	237	276	-14.0%	23.7	23.3	1.8%
Polypropylene	107	91	17.6%	186	226	-17.5%	40.5	39.8	1.7%
ABS	101	115	-12.5%	377	484	-22.2%	28.2	28.1	0.2%

The third fire scenario consisted of a square n-heptane pan fire located in the center of the enclosure at an elevation of 76 cm (30 in.) above the floor (lip of the pan). The pan was 0.23 m<sup>2</sup> (2.5 ft<sup>2</sup>) in area and was filled with 5 cm (2 in) of n-heptane on a water substrate to leave a 5 cm (2 in) freeboard between the top of the n-heptane and the lip of the pan. The pan was constructed from 0.64 cm (0.25 in.) steel with the upper edge reinforced with 3.8 x 3.8 x 0.48 cm (1.5 x 1.5 x 0.62 in.) angle iron. The fire was allowed a 30 second pre-burn prior to system activation. This fire scenario was compliant with the GEL 8-06 [2] Class B Fire Extinguishment Test.

ISO 15779 has a n-heptane pan fire test that is similar to that tested. The differences are in the construction of the pan utilized to contain the fuel. The UL compliant pan utilized has an area of 0.23 m<sup>2</sup> (2.5 ft<sup>2</sup>) while the ISO pan is specified to have an area of 0.25 m<sup>2</sup> (2.7 ft<sup>2</sup>) with a dimensional tolerance of  $\pm 5\%$ . The UL pan was constructed of 6.4 mm (0.25 in) thick steel with a 38 cm (1.5 in) wide, 4.8 mm (0.188 in) thick angle iron re-enforcing around the lip of the pan. The ISO pan is to be constructed from 6 mm (0.23 in) thick steel without any re-enforcing around the lip of the pan. The ISO pan is to be located in the enclosure with the bottom of the pan 60 cm above the floor and with a 10 cm (4 in) pan height, the top of the pan would be within the 66 to 76 cm (26 to 30 in) range specified for the UL procedure. The ISO procedure does not mention a water substrate under the n-heptane.

The fourth fire scenario utilized consisted of ten telltale can fires. Eight of these cups were located in the corners of the enclosure, 5 cm (2 in) from each wall (edge of cup to wall), four at floor level and four with the top of the cup 30.5 cm (12 in) from the ceiling. The remaining two cup were located behind the floor to ceiling baffle used in the dual wood crib scenario with one located at floor level and the other located at mid-height of the enclosure. The cups are 7.6 cm (3 in) in diameter and 12.5 cm (5 in) tall and constructed from 6 mm (0.25 in) steel. The cups were filled with 5 cm (2 in) of n-heptane on a water substrate to result in 5 cm (2 in) of freeboard between the lip of the can and the top of the n-heptane fuel.

The location of these fires within the test enclosure is given schematically in Figure 7.

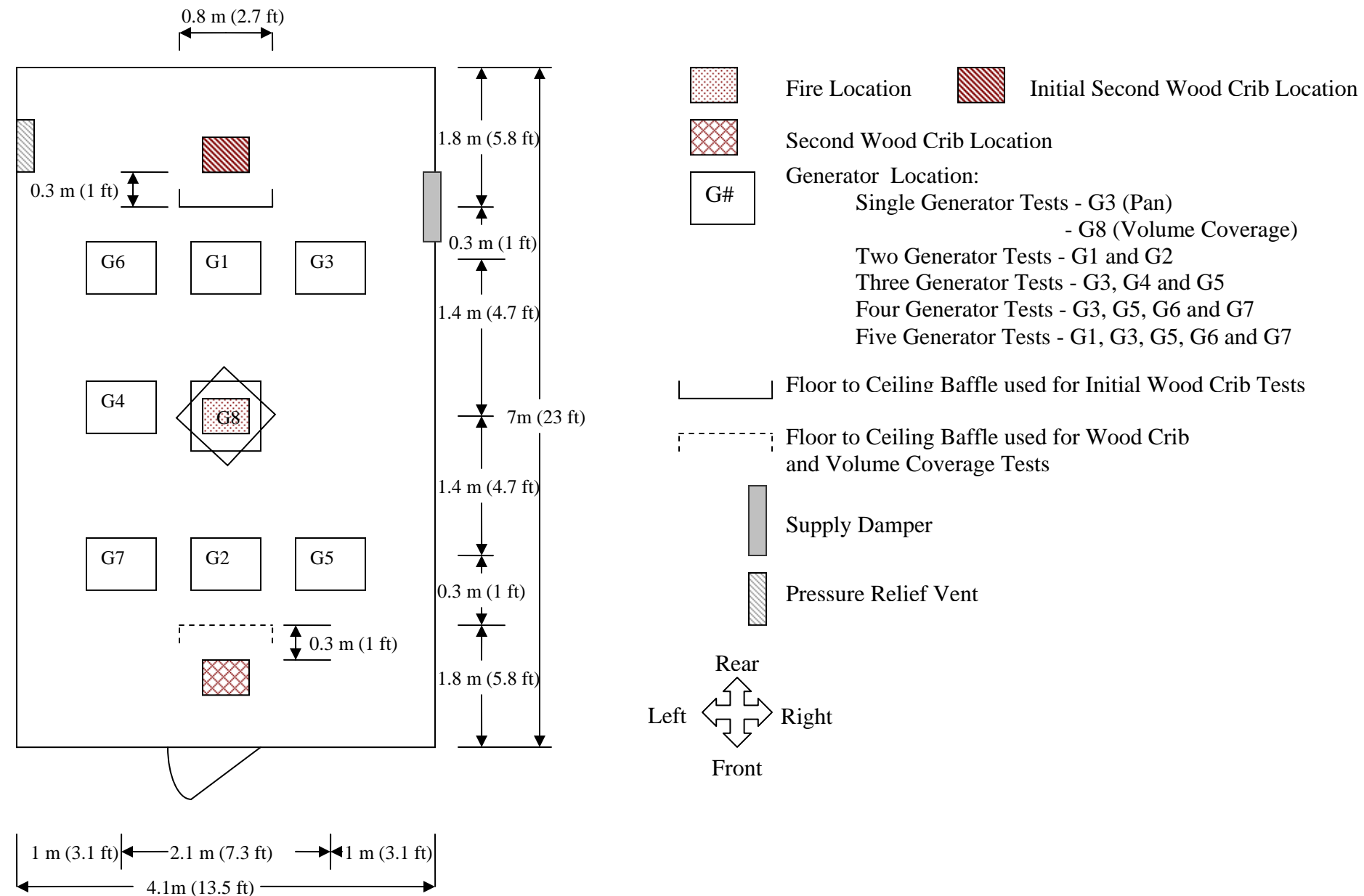


Figure 7 - Fire Scenario and Generator Locations in Test Enclosure

## 2.3 Aerosol Generators

The DSPA aerosol generators utilized the burning of a solid fuel compound to atomize and distribute a powder based extinguishing agent throughout the protected enclosure. The powder based extinguishing agent, representing ~30% of the weight of the solid fuel, was primarily a mixture of ammonium hydrogen carbonate ( $\text{NH}_4\text{HCO}_3$ ), potassium nitrate  $\{\text{KNO}_3\}$ , potassium carbonate  $\{\text{K}_2\text{CO}_3\}$ , and potassium bicarbonate  $\{\text{KHCO}_3\}$ . The burning of the solid fuel generated a gas stream consisting primarily of nitrogen, water vapor, carbon dioxide and carbon monoxide.

The DSPA Generators utilized in these tests are model DSPA 8-1 which contains 3.25 kg of solid fuel propellant and agent. The generated aerosol was discharged vertically downward by this generator. The generators were activated electrically utilizing a variable power supply capable of a 30 amp and 30 VDC. During the initial series of tests, the power supply was set for 14 VDC output for the first 12 of the performed tests and adjusted to 9 VDC for the remaining 6 tests. During the second series of tests, the power supply was set for 4 VDC for the first two tests and was adjusted to 6 VDC for the remaining 11 tests.

One to five generators were utilized per test with aerosol loading factors of 32.2 to 64.3  $\text{g/m}^3$  for the Class B n-heptane pan fire, 96.4  $\text{g/m}^3$  for the polymeric materials fires, 96.4 to 160.7  $\text{g/m}^3$  for the Class A compatible dual wood crib tests and 32.2  $\text{g/m}^3$  for the volume coverage/telltale fire scenario. The location of the generators in the enclosure is illustrated in Figure 7.

## 2.4 Instrumentation

Two type K thermocouples were installed at each generator. One thermocouple was used to monitor the generator casing temperature (Teflon coated type K), and the other to monitor the temperature of the exhaust (stainless steel sheathed type K).

Four stainless steel sheathed type K thermocouples were utilized to monitor the burning of the test fires.

Three additional type K thermocouples were utilized to monitor the temperature inside the enclosure.

A Sartorius Combics Load cell with a full scale range of 15 kg (33 lb) was utilized to monitor the mass loss of the plastic array fires. The scale was calibrated prior to the start of testing and the calibration certificate is included in Appendix A.

A Fairbanks Platform Scale, Number 0435000129 was utilized to weigh the aerosol generators before and after each test. A photograph of the calibration sticker for this scale is also included in Appendix A.

An A&D Model EP-20KA with a full scale range of 20 kg (44 lb) was utilized to weigh the wood cribs and shredded newspaper prior to each dual wood crib test during the second series of tests. A photograph of the calibration sticker is included in Appendix A.

A low range differential pressure transducer, Omega Engineering PX 653-05BD5V, with a full scale range of  $\pm 1.24$  kPa ( $\pm 5$  iwc) was used to monitor the enclosure pressure. The calibration of this device was checked after these tests and found to be outside of the manufacturer's  $\pm 0.25\%$  full scale specifications. The transducer was still found to be within  $\pm 10\%$  full scale. As the measurements taken by this instrument were not critical to the results obtained, this error did not affect the results obtained. The calibration check report is given in Appendix A. A different differential pressure transducer of the same manufacturer and model was utilized during the second test series. As this differential pressure transducer was purchased (March 17, 2008) within a year of conducting these tests, the original manufacturers calibration and certification are still valid.

Three oxygen analyzers, Servomex model 1400, were utilized to monitor the oxygen concentration inside the test enclosure at elevations of 0.37 m (1.2 ft), 0.7 m (2.5 ft) and 1.83 m (6 ft). These analyzers were calibrated prior to each test, utilizing nitrogen as a zero gas and ambient air as the span. The sampled air was drawn through a paper filter to remove the entrained particulate and a Drierite filter to remove the water vapor. The samples were drawn through 8 mm (0.38 in) tubing at a rate of nominally 6 LPM with 1 LPM going to the analyzer and 5 LPM being exhausted through the by-pass. Dwyer flowmeters, Model VFA-22 and VFA-23, with inlet valves were utilized to control and monitor the flow to the analyzers and through the by-pass. The time delay represented by the sampling systems was measured by filling a bag with nitrogen and placing it over the end on the sampling tube in the enclosure. The time from start of the nitrogen flow until the analyzer had reached 50% of the final response was determined to be 29 seconds. The time delay measurements are given in Appendix B.

An Electrophysics pinless wood moisture meter, model CT100, was utilized to measure the moisture content of the wood cribs. Its calibration was checked prior to use utilizing the manufacturer's procedure and calibration plate.

### **3.0 PROCEDURE**

The enclosure was prepared with the generators installed and the fire scenario setup. The power supply was energized upstream of the activation switches after the space was cleared of personnel. The data acquisition system was initiated. After a minimum of ten seconds of background data, the test fires were ignited. The n-heptane pan fire was given 30 seconds of pre-burn prior to activation of the generators. The Telltale cup fires were given 30 seconds of pre-burn prior to activation of the generator. The wood cribs were given 2 minutes of pre-burn prior to activation of the generators. The polymeric material array fire was given 3.5 min (210 sec) of pre-burn prior to activation of the generators. The test enclosure then remained closed for a hold time of ten minutes. At the end of the hold time, the enclosure was purged and the wood cribs were removed from the enclosure to check for any signs of continued burning.

If it was obvious, from the thermocouples monitoring the test fires, that the test fires had not been extinguished by the end of the hold time or would not be extinguished by the end of the hold time, then the enclosure was purged, and the check on the wood crib fires was not performed.



## 4.0 RESULTS AND DISCUSSION

The nine polymeric materials array test fires were successfully extinguished with three installed generators for a loading of  $96.4 \text{ g/m}^3$  as summarized in Table 2. The fires were extinguished in less than the ten minutes allowed by the ULC test protocol with the longest time to extinguishment being 261 seconds from the end of the generator discharge. The mass loss of the polymers from 10 seconds after the end of the generator discharge to the end of the hold time was less than the 15 g allowed with the maximum being 5 g for the 9 tests conducted.

One additional test, Test 7, was conducted with the larger 5.1 x 11.2 cm (2 x 4.5 in) ignition pan. While this test still met the extinguishment time requirement of the ULC test protocol, it exceeded the allowable mass loss requirement over the time period from 10 seconds after the end of the discharge until the end of the hold time. This test did not meet the ISO 15779 extinguishment time requirement of a maximum of 180 seconds after the end of the discharge.

Table 2 - UL Polymer Array Fires Result Summary

Test	Fuel	Total Loading	Pre-burn Time	Discharge Time	Extinguishment Time (From Discharge End)	Fuel Mass Loss (End of Discharge to Min Mass)	Test Result
		[ $\text{g/m}^3$ ]	[sec]	[sec]	[sec]	[g]	[P/F]
Test10	ABS	96.4**	211	75	54	1.0	Pass
Test11	ABS	96.4**	210	75	225	4.5	Pass
Test12	ABS	96.4	211	75	34	1.0	Pass
Test13	PP	96.4	214	75	261	5.0	Pass
Test14	PP	96.4	210	75	0	2.0	Pass
Test15	PP	96.4	210	75	105	2.5	Pass
Test6	PMMA	96.4	210	75	85	4.0	Pass
Test8	PMMA	96.4	210	75	135	4.0	Pass
Test9	PMMA	96.4**	210	75	225	3.5	Pass
Test7*	PMMA*	96.4	210	75	271	19.0	Fail

\* ISO pan utilized to ignite the PMMA array instead of the smaller UL pan

\*\* One of the installed generators failed to actuate - Effective loading less than that stated

During the first series of tests, which utilized wood cribs that were fabricated by HAI with lumber obtained locally, none of five tests conducted with the dual wood crib fire scenario were successful as summarized in Table 3. There was noted a variance in the mass of the cribs utilized beyond that normally attributed with the construction of the cribs. Some of the wood members were noted to have split and chipped in construction. There also appear to be a draft coming from the air supply vent that affected the pre-burn of the crib behind the baffle. All of these effects may have contributed to these tests not showing positive results.

During the second series of tests, wood cribs provided by ULC through their supplier, Carr Lumber and Manufacturing, were utilized and the aerosol was much more successful in causing extinguishment. The baffle was also moved from the rear of the test enclosure to the front of the tests enclosure which move the crib away from the air supply vent which may have also had an

influence on the positive results obtained. The ULC provided wood cribs were noted to be free of cracks or splits, had no gaps or separations between layers where the members crossed, and utilized smaller nails in construction. The cribs were weighed before each test and were found to be within +6.4% and -16.7% of their average mass of 6.93 kg (15.3 lb). The moisture content was similar to that in the previous set of tests ranging from 9 to 13 % by weight.

Table 3 – Dual Wood Crib Test Results Summary

Test Name	Wood Crib Source	Total Loading [g/m <sup>3</sup> ]	Pre-burn Time [sec]	Discharge Time [sec]	Extinguishment Time (From Discharge End) [sec]	Test Result [P/F]
Test19	ULC Prov.	128.6	120	88	-55	Pass
Test20	ULC Prov.	128.6*	124	103 #	285	Pass
Test21	ULC Prov.	128.6	120	104 #	250	Pass
Test22	ULC Prov.	96.4	120	82	3	Pass
Test23	ULC Prov.	96.4	120	79	253	Pass
Test24	ULC Prov.	96.4	120	81	N/E ***	Fail
Test25	ULC Prov.	96.4	120	144 #	-77	Pass
Test26	ULC Prov.	96.4 **	125	90 #	22	Pass
Test27	ULC Prov.	64.3	124	91 #	N/E ***	Fail

\* Two of the installed generators failed to actuate - Effective loading less than that stated

\*\* One of the installed generators failed to actuate - Effective loading less than that stated

\*\*\* Wood crib behind baffle was extinguished - Center wood crib was not

# One or more of the installed generators had delayed activations resulting in longer than normal aerosol discharge times

The results from testing with the Class B n-heptane pan and Telltale fires are summarized in Table 4. As can be seen from this table, the n-heptane pan fires were successfully extinguished with the two installed generators for a loading of 64.3 g/m<sup>3</sup>, with extinguishment times less than the allowed 30 seconds during the first tests series. A single generator configuration corresponding to a loading of 32.1 g/m<sup>3</sup>, with generator located off-set toward the right rear corner of the enclosure, location G3 in Figure 2, was also successful in causing extinguishment of the n-heptane pan fire during the second series of tests.

The volume coverage/telltale test was also successful in causing extinguishment of all of the telltale fires prior to the end of the allowed 30 seconds after the end of the aerosol discharge time as shown in Table 4 and in Figure 8.

Table 4 - Class B n-Heptane Pan and Telltale Fire Test Results

Test Name	Test Fire Scenario	Total Loading	Pre-burn Time	Discharge Time	Extinguishment Time (From Discharge End)	Test Result
		[g/m <sup>3</sup> ]	[sec]	[sec]	[sec]	[P/F]
Test3	UL Pan	64.3	30	75	27	Pass
Test4	UL Pan	64.3	30	75	17	Pass
Test5	UL Pan	64.3	30	75	27	Pass
Test28	UL Pan	32.1	30	79	25	Pass
Test29	UL Pan	32.1	30	75	6	Pass
Test30	UL Pan	32.1	30	78	25	Pass
Test31	Volume Coverage/Telltale	32.1	30	81	-14	Pass

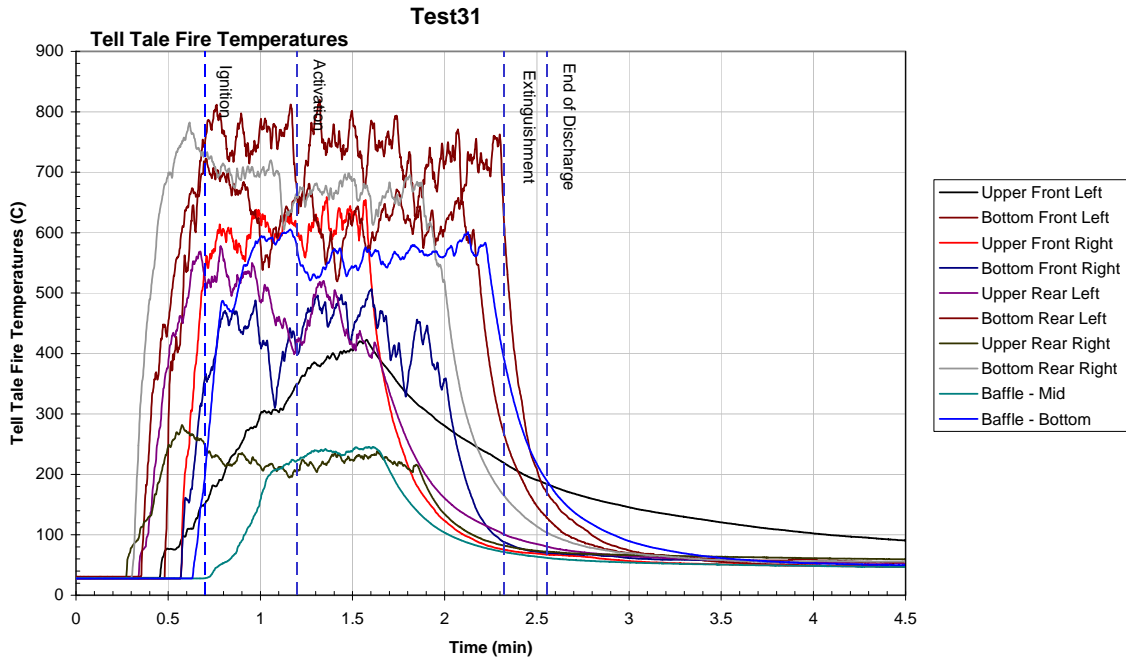


Figure 8 - Temperatures Monitored Above Telltale Fires During Volume Coverage Test with Single Model 8-1 Generator (Test31)

The generator mass loss was on average 3.65 kg, 12% more than the 3.25 kg rating for the generator. This extra mass loss may have been due to a loss of the cooling agent installed in the generators with the aerosol generating compound to reduce the temperature of the aerosol as it exits the generator. This extra mass loss does not contribute to the generation of the aerosol and does not count as adding to the generator loading.

As a result of these tests, the DSPA Aerosol generators have satisfied the extinguishing factor determination test requirements for the ULC Class B n-heptane pan with a nominal loading factor of  $32.1 \text{ g/m}^3$ , and for the ULC Class A compatible materials (polymeric materials and dual wood crib tests) with a nominal loading factor of  $96.4 \text{ g/m}^3$ . The volume coverage test for the model 8-1 generator was also completed with the basic loading factor of  $32.1 \text{ g/m}^3$ . In order to complete the listing process, the distribution verification tests for other models to be included and other component and performance tests are required.

More detailed test DATA are presented in Appendix C.

## 5.0 CONCLUSIONS

These tests demonstrated the effectiveness of the DSPA aerosol to extinguish Class B fuels as the UL/ULC n-heptane pan fire test was successfully completed with a generator loading of  $32.1 \text{ g/m}^3$ . The extinguishment time requirement of 30 seconds or less from the end of the aerosol discharge was successfully met during the three tests conducted with this fire scenario at this generator loading.

The UL/ULC Class A polymeric materials array fires were also successfully completed with a generator loading of  $96.4 \text{ g/m}^3$ . Nine tests were successfully performed, three with each polymeric material meeting both the extinguishment performance requirement of 10 minutes or less from the end of the aerosol discharge and the mass loss requirement of no more than 15 g over the time period from 10 second after the end of the aerosol discharge to 10 minutes after the end of the aerosol discharge.

A fourth test involving the PMMA array was conducted with the larger ISO ignition pan and while the extinguishment performance requirement of the UL/ULC standard was satisfied, the mass loss allowance was exceeded.

The dual wood crib fire scenario, Class A Compatible Wood Crib, was successfully completed with a generator loading of  $96.4 \text{ g/m}^3$  during these tests. Four out of the five tests conducted with this generator loading resulting in successful extinguishment of both cribs.

The volume coverage test with the Model 8-1 Aerosol Generator was successfully completed with a loading factor of  $32.1 \text{ g/m}^3$ .

## 6.0 REFERENCES

1. Back, G.G., Boosinger, M., Beene, D., and Nash, L., "An Evaluation of Aerosol Extinguishing Systems for Machinery Space Applications," U.S. Coast Guard Research and Development Center, Groton, CT, 2005.
2. Underwriters Laboratories Inc. "Proposed Draft UL Test Standard Fixed Condensed Aerosol Extinguishing Units," GEL 8-06, Underwriters Laboratories Inc. Northbrook, IL, 2006.
3. International Standards Organization, "Condensed Aerosol Fire Extinguishing System - Physical Properties and System Design - General Requirements," ISO 15779-1:2005(E), International Standards Organization, Geneva, Switzerland, 2005.
4. Hughes Associates, Inc., "Cone Calorimeter Tests of Class A Plastic Materials," HAI Project Number 1CPH01691.000, Baltimore, MD, January 2008.

## APPENDIX A – INSTRUMENTATION CALIBRATION CERTIFICATES


<b>THE SCALE PEOPLE, INC.</b> <small>SUBSIDIARY OF S.P.I. LTD. 9683-C Gerwig Ln., Columbia, MD 21046 • 410-309-0809 • FAX 410-309-0810</small>		 <small>Visit us on the WEB at <a href="http://www.scalepeople.com">www.scalepeople.com</a></small>	
<b>Customer:</b> Hughes Associates 3610 Commerce Drive Suite 817 Baltimore, MD 21227		<b>Certificate of Calibration</b>	
<b>Manufacturer:</b> Sartorius		<b>Certificate #:</b> 4071-22916	
<b>Model:</b> CISL1		<b>Date of Issue:</b> 12/31/2007	
<b>Serial:</b> 17202385		<b>Due Date:</b> 12/31/2008	
<b>Capacity:</b> 15 kg.		<b>Asset No:</b>	
<b>Readability:</b> .5 g		<b>Location:</b>	
<b>Tolerance:</b> +/- 1.5 g		<b>Attn:</b> Eric Forssell	
		<b>Calibrated By:</b> Merrigan, Pat	
<b>Traceability:</b> Primary standards used for the calibration of equipment are traceable to the National Institute of Standards and Technology. The Scale People, Inc. meets the requirements of ISO/IEC 17025. Calibration Procedures are performed in accordance with SOP # 5 of our Standard Operating Procedure manual.			
<b>Equipment and Enviromental Conditions</b>			
Environmental Conditions	<input type="checkbox"/> Very Good	<input checked="" type="checkbox"/> Good	<input type="checkbox"/> Fair <input type="checkbox"/> Poor
Condition of Equipment	<input type="checkbox"/> Very Good	<input checked="" type="checkbox"/> Good	<input type="checkbox"/> Fair <input type="checkbox"/> Poor
Equipment Calibrated to the following	<input type="checkbox"/> Customer Specifications	<input type="checkbox"/> Handbook 44 (Section 2.20)	<input checked="" type="checkbox"/> Manufacturers Specifations
<b>Comments:</b> Inspected, tested, and calibrated.			
<small>This Certificate may not be reproduced except in full, without the written approval of The Scale People, Inc.</small>			

Figure A.1 – Sartorius Scale Calibration Certificate



Figure A.2 – Fairbanks Scale Calibration Sticker



Figure A 3 - A&D Scale Calibration Sticker



## Maintenance Record

2136395

Certificate Page 1 of 2

### Instrument Identification

Company ID: 121046  
HUGHES ASSOCIATES  
HUGHES ASSOCIATES  
3610 COMMERCE DRIVE  
SUITE 817  
BALTIMORE, MD 21227

PO Number: 1486-C-KBH01691.000

Instrument ID: **40913443**

Model Number: PX653-05BD5V

Manufacturer: OMEGA ENGINEERING  
Description: PRESSURE TRANSDUCER

Serial Number: 40913443

ACCURACY:  $\pm 0.25\%$  OF FULL SCALE

### Certificate Information

Reason For Service: CALIBRATION

Technician: STEPHAN BLITVA

Type of Cal: NORMAL

Cal Date: 03Mar2008

As Found Condition: OUT OF TOLERANCE

As Left Condition: LEFT AS FOUND

Interval: 12 MONTHS

Procedure: 33K6-4-1425-1 PRESSURE TRANSDUCERS

Temperature: 22.0 C

Humidity: 22.0 %

Remarks: Unit was found to be out of tolerance and at the customers request was not adjusted. The unit has been rejected.

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Davis Inotek Instruments Calibration Laboratory is certified to ISO 9001:2000 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994, ISO 10012, 10CFR50 AppxB, and 10CFR21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1121 within the scope for which the lab is accredited.

All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.

This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: STEPHAN BLITVA  
Service Representative

### Calibration Standards

NIST Traceable#	Inst. ID#	Description	Model	Cal Date	Date Due
725402	01-0046	6 1/2 DIGIT DIGITAL MULTIMETER	34401A	21May2007	21May2008
1315008	01-0097	DUAL OUTPUT DC POWER SUPPLY	E3620A	03Jul2007	03Jul2008
546522	01-0858	PRESSURE MODULE (10 INCH H <sub>2</sub> O $\pm 0.06\%$ FS)	AQS-1	27Mar2007	27Mar2008
1609050	01-1655	HANDHELD CALIBRATOR	ATE-100	17Oct2007	17Oct2008

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Figure A.4 – Calibration Check of Omega Engineering Low Range Differential Pressure Transducer Utilized during the First Series of Tests (Page 1 of 2)





## Maintenance Record

2136395

Certificate Page 2 of 2

✓ In Tolerance ✗ Out of Tolerance

### Calibration Data

Range	Nominal	As Found		As Left		Min	Max
Pressure Applied in Inches Water with DC Volts Output							
-5.000 inH <sub>2</sub> O	1.000	0.970	✗	0.970	✗	0.987	1.013
-3.000 inH <sub>2</sub> O	1.800	1.787	✓	1.787	✓	1.787	1.813
-1.000 inH <sub>2</sub> O	2.600	2.599	✓	2.599	✓	2.587	2.613
1.000 inH <sub>2</sub> O	3.400	3.148	✗	3.148	✗	3.387	3.413
3.000 in H <sub>2</sub> O	4.200	4.531	✗	4.531	✗	4.187	4.213
5.000 inH <sub>2</sub> O	5.000	5.048	✗	5.048	✗	4.987	5.013

End of Datasheet

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Figure A.5 – Calibration Check of Omega Engineering Low Range Differential Pressure Transducer Utilized during the First Series of Tests (Page 2 of 2)

Table A.1 – Illustration of Effects of Low Pressure Transducer Being Out of Tolerance

Pressure Applied	Output Expected	Output Received	Pressure Measured	Pressure Error	
(iwc)	(VDC)	(VDC)	(iwc)	(iwc)	(% FS)
-5	1	0.97	-5.075	-0.075	-0.8%
-3	1.8	1.787	-3.0325	-0.0325	-0.3%
-1	2.6	2.599	-1.0025	-0.0025	0.0%
1	3.4	3.148	0.37	-0.63	-6.3%
3	4.2	4.531	3.8275	0.8275	8.3%
5	5	5.048	5.12	0.12	1.2%

## APPENDIX B – OXYGEN ANALYZER DELAY MEASUREMENTS

The time delay due to both the response time of the Servomex 1400 oxygen analyzers used and the transit time through the sampling tubes and filters. The time delay was measured by placing a sample bag containing nitrogen over the sample tube in the chamber and monitoring the response of the analyzer. The sample bag was then removed and the analyzer response was monitored during its return to ambient readings. This was done for all three sample points. The delay was found to be similar for all three analyzers and tubes as shown in Table B1 and Figures B1 through B3. An average of all six points was used in recording analyzing the data from the witnessed tests.

Table B.1 – Measured Oxygen Analyzer Response to Step Concentration Changes

		O2-Bottom	O2-Middle	O2-Top
Start N2	[sec]	73.8	228.8	374.3
Min O2	[%]	6.3	1.6	5.6
Half Res	[%]	13.6	11.3	13.3
Half Res Time	[sec]	104.0	255.8	406.0
Delay Time	[sec]	30.2	27.0	31.7
Stop N2	[sec]	155.6	299.7	460.6
Half Res Time	[sec]	185.0	324.5	491.3
Delay Time	[sec]	29.4	24.8	30.7
Average	[sec]	29.8	25.9	31.2
	[sec]		29.0	

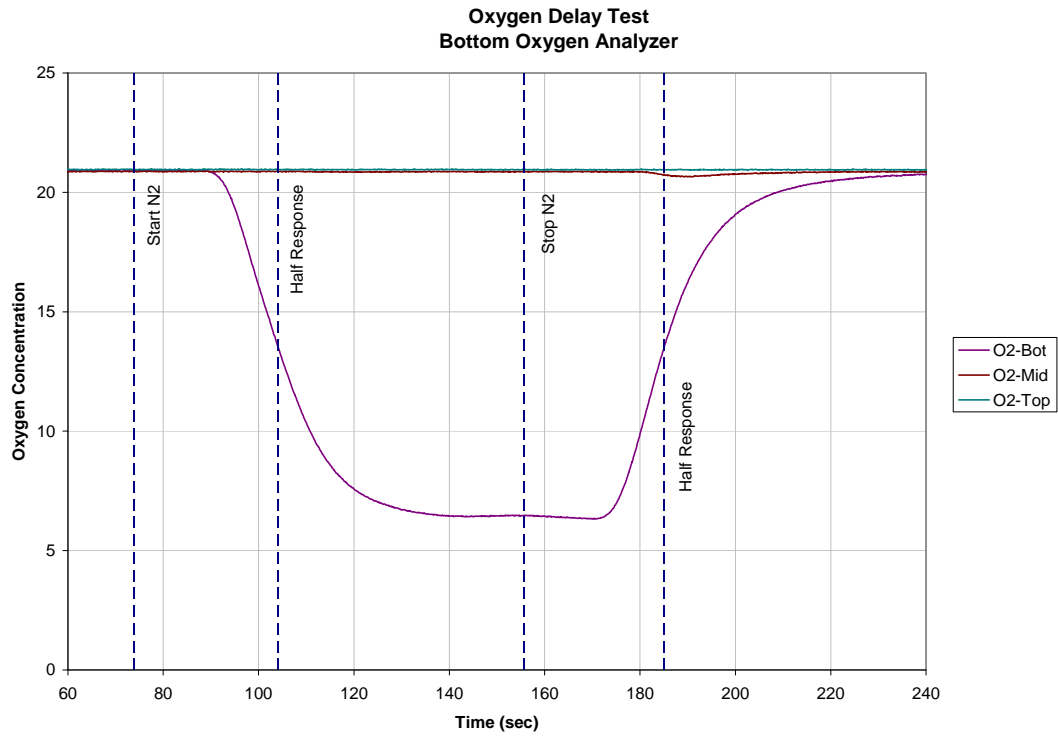


Figure B.1 – Bottom Oxygen Analyzer Response to Step Change

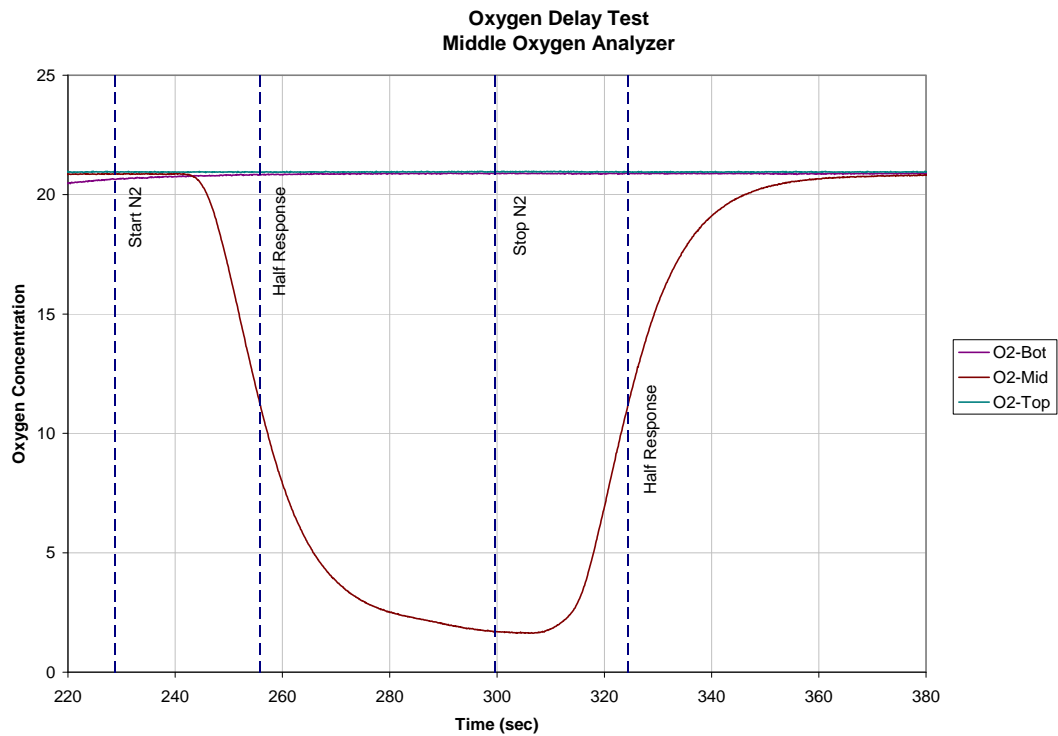


Figure B.2 – Middle Oxygen Analyzer Response to Step Change

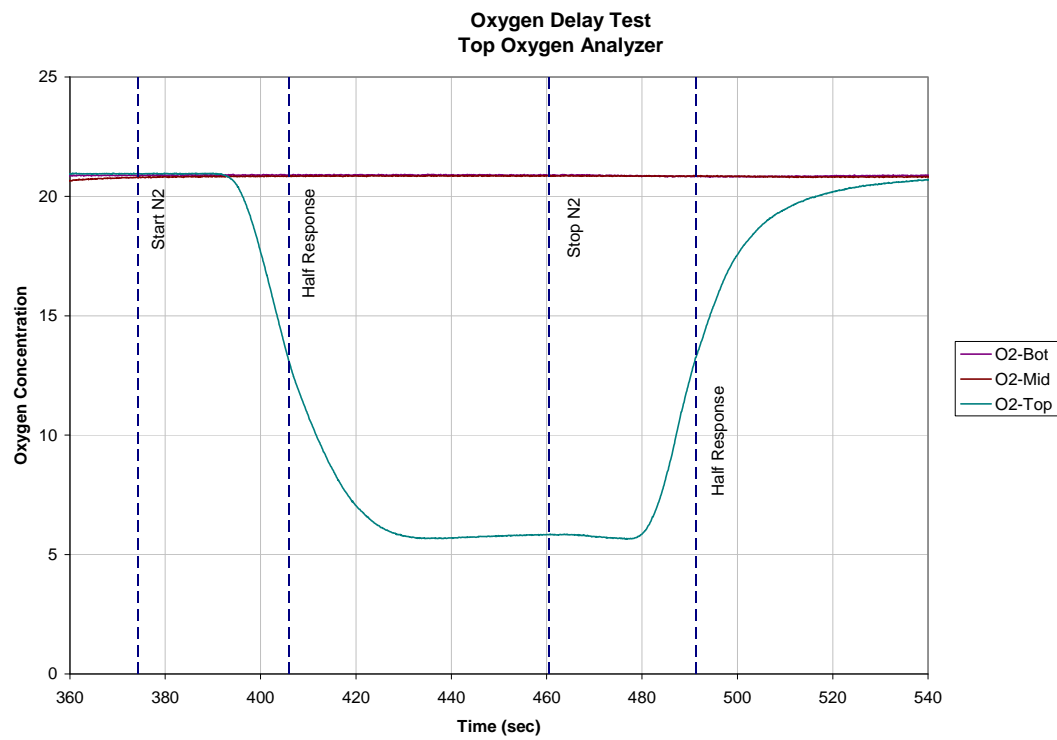


Figure B.3 – Top Oxygen Analyzer Response to Step Change

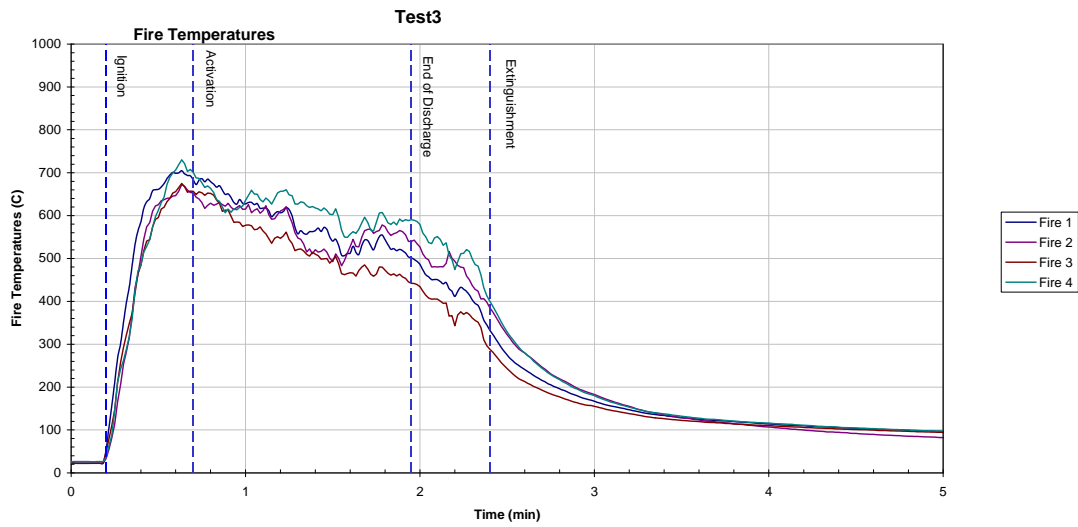


Figure C.10 – Fire Temperatures Measured during UL n-Heptane Pan Fire Test with Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 3)

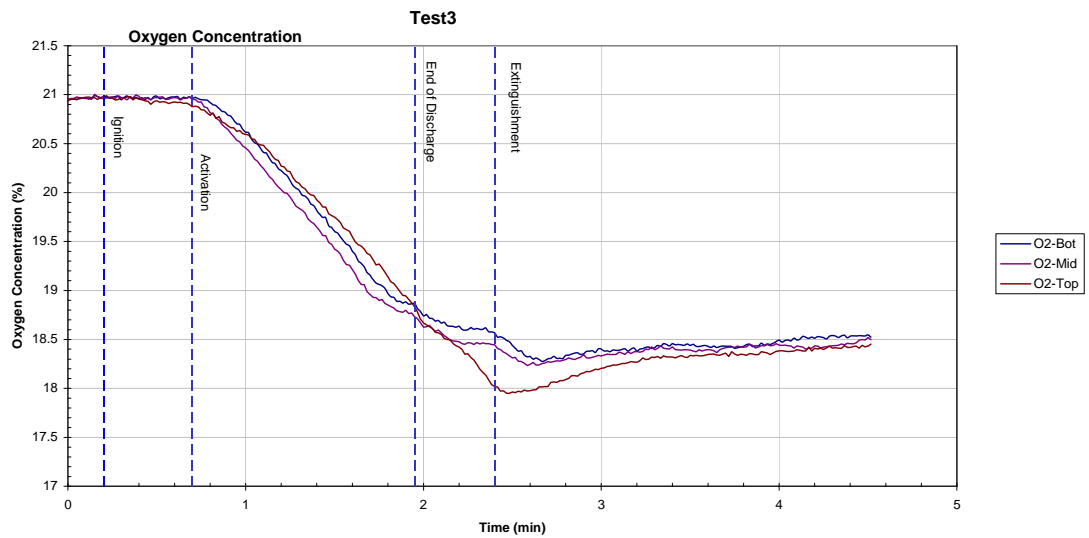


Figure C.11 – Oxygen Concentrations Measured during UL n-Heptane Pan Fire Test with Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 3)

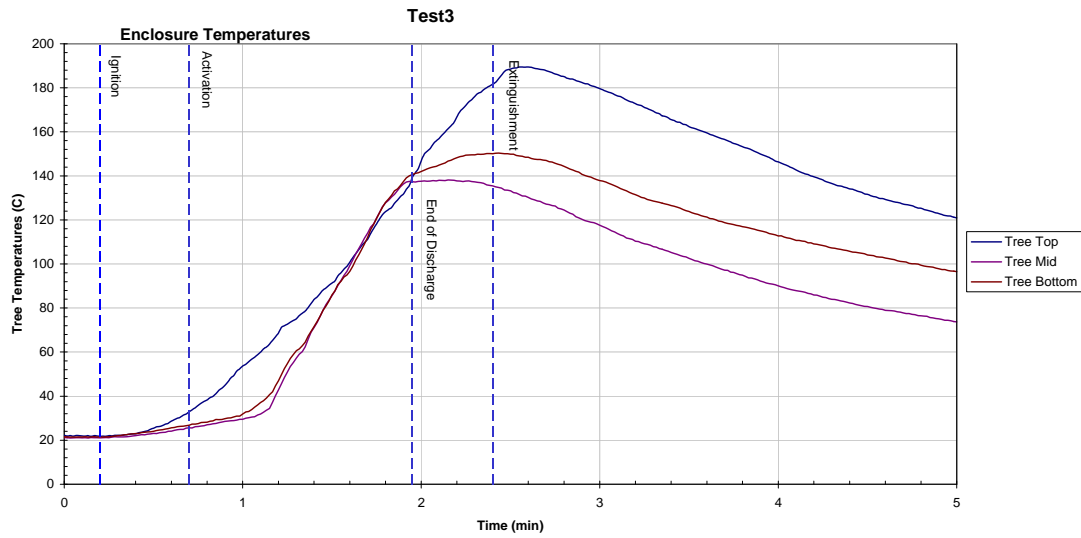


Figure C.12 – Enclosure Temperatures Measured during UL n-Heptane Pan Fire Test with Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 3)

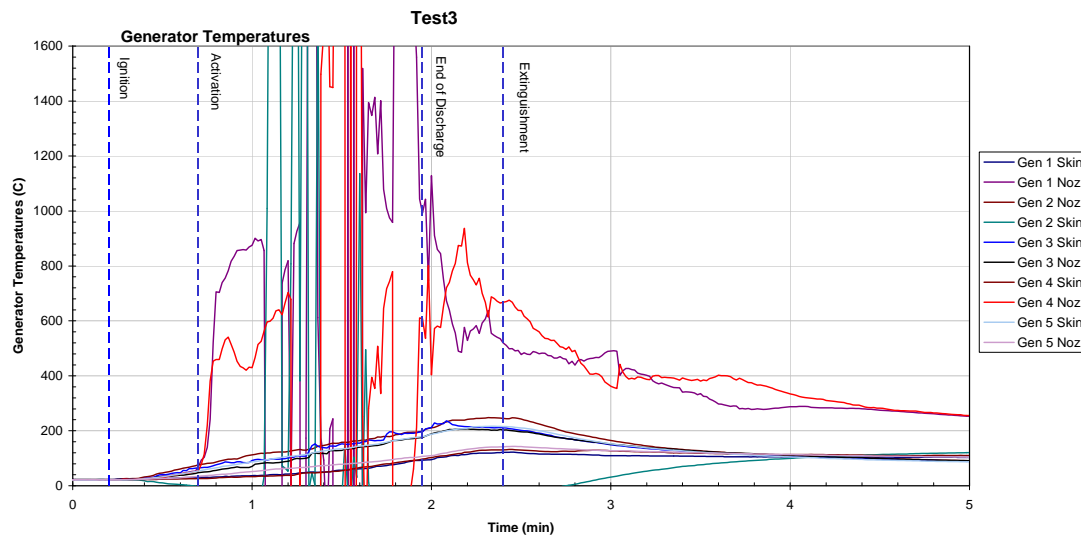


Figure C.13 – Generator Temperatures Measured during UL n-Heptane Pan Fire Test with Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 3)

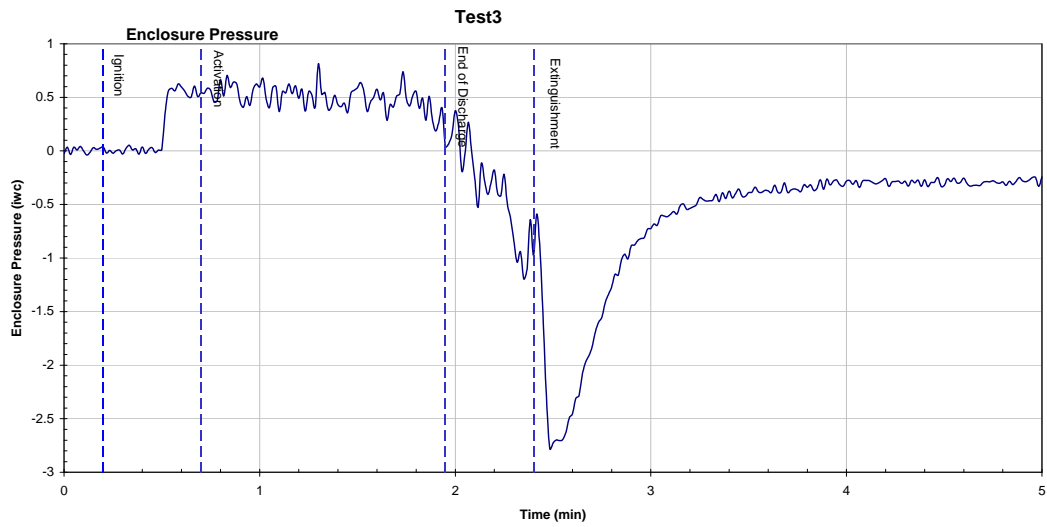


Figure C.14 – Enclosure Pressures Measured during UL n-Heptane Pan Fire Test with Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 3)

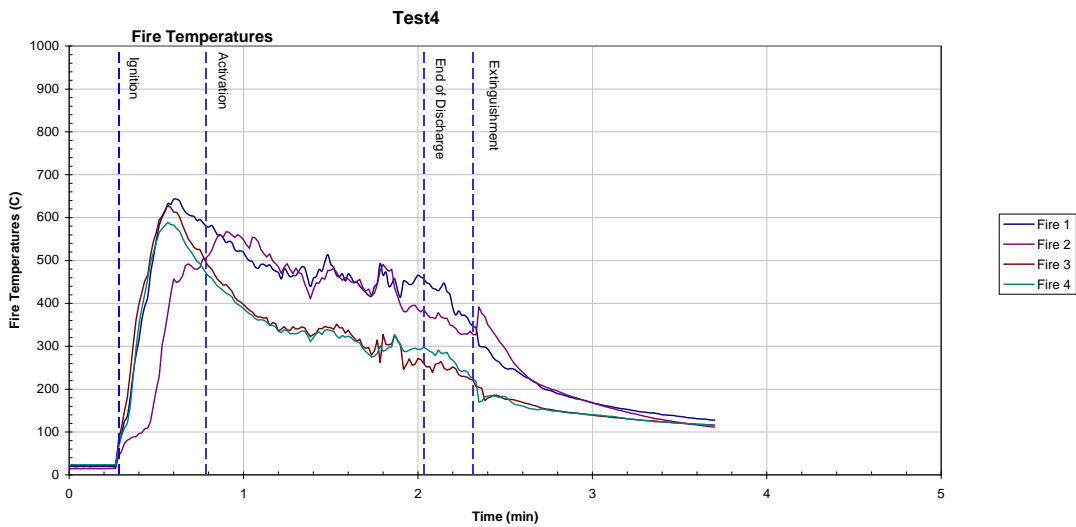


Figure C.15 – Fire Temperatures Measured during UL n-Heptane Pan Fire Test with Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 4)



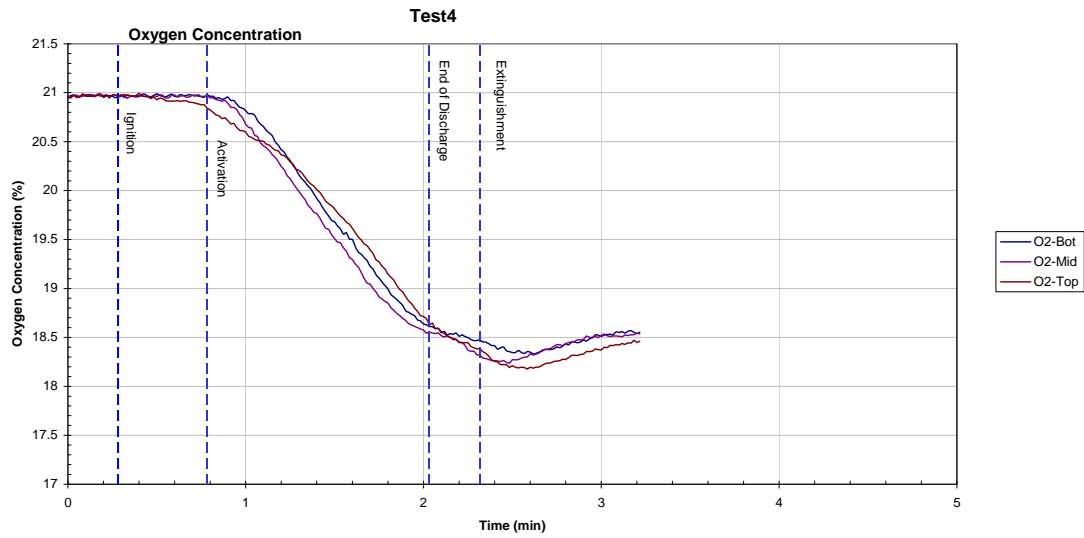


Figure C.16 – Oxygen Concentrations Measured during UL n-Heptane Pan Fire Test with Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 4)

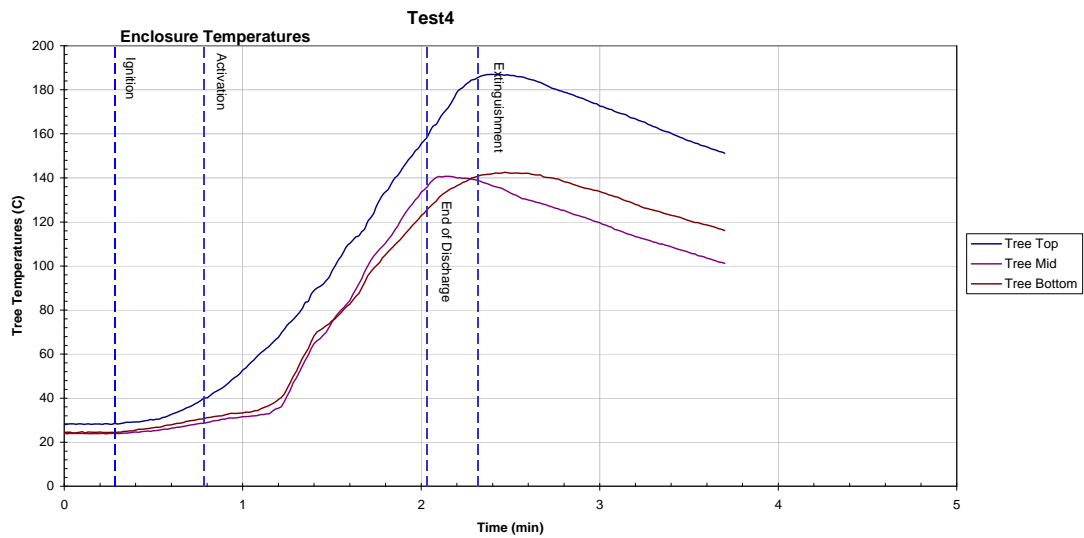


Figure C.17 – Enclosure Temperatures Measured during UL n-Heptane Pan Fire Test with Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 4)

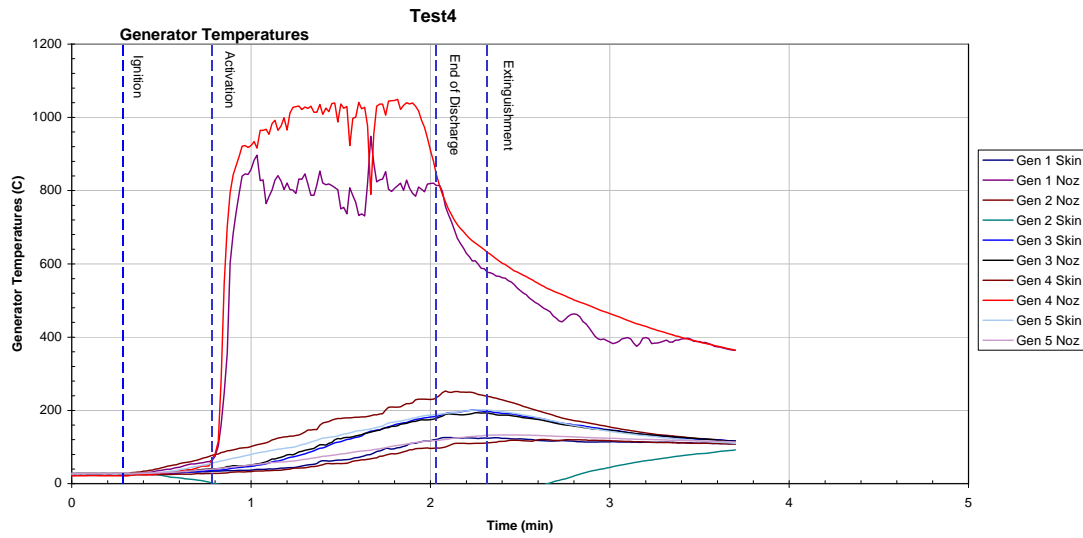


Figure C.18 – Generator Temperatures Measured during UL n-Heptane Pan Fire Test with Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 4)

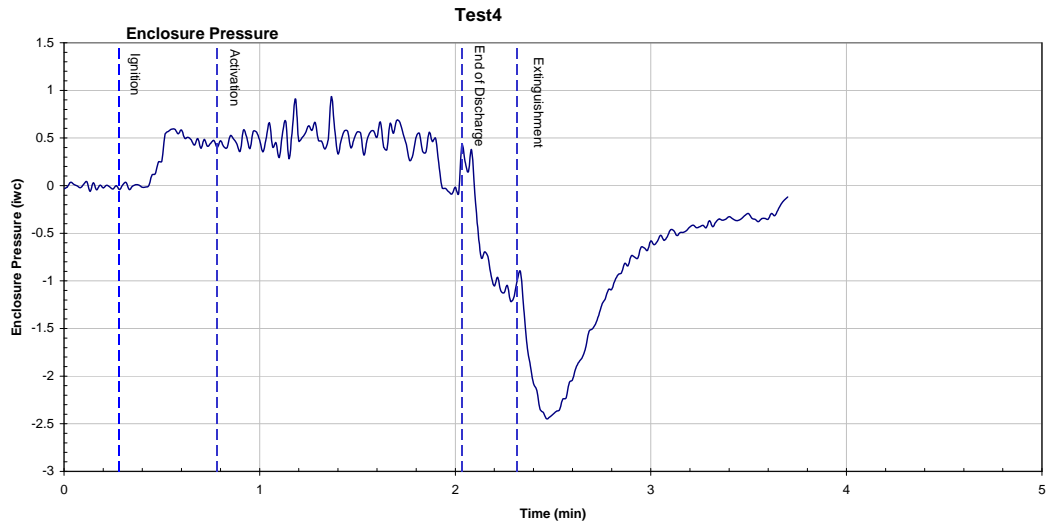


Figure C19 – Enclosure Pressures Measured during UL n-Heptane Pan Fire Test with Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 4)

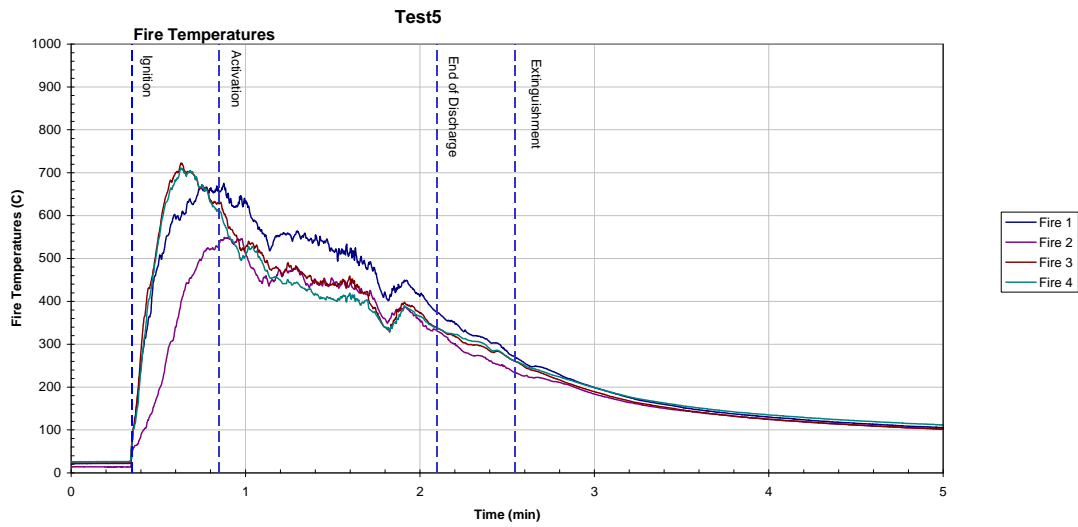


Figure C.20 – Fire Temperatures Measured during UL n-Heptane Pan Fire Test with Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 5)

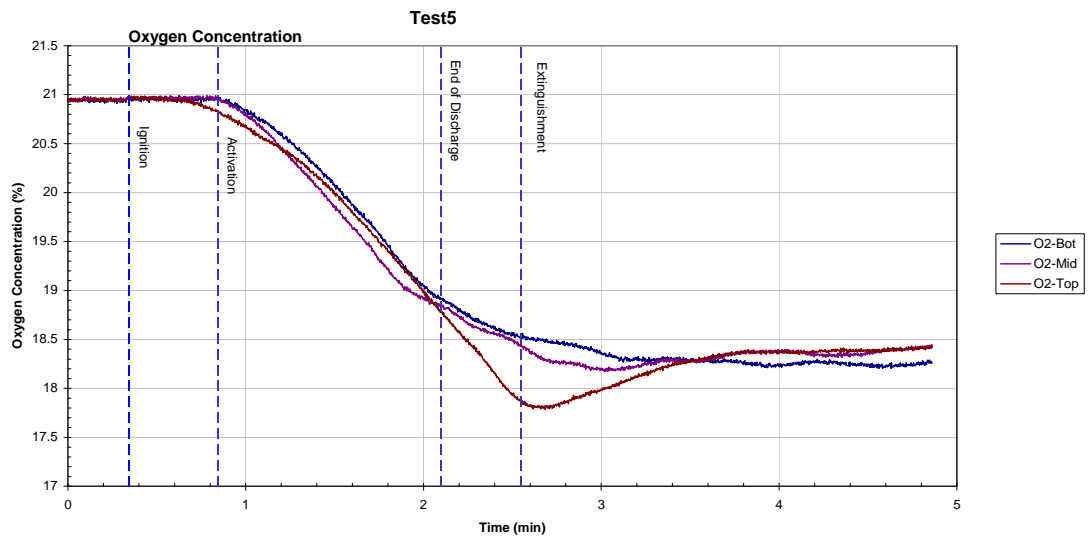


Figure C.21 – Oxygen Concentrations Measured during UL n-Heptane Pan Fire Test with Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 5)

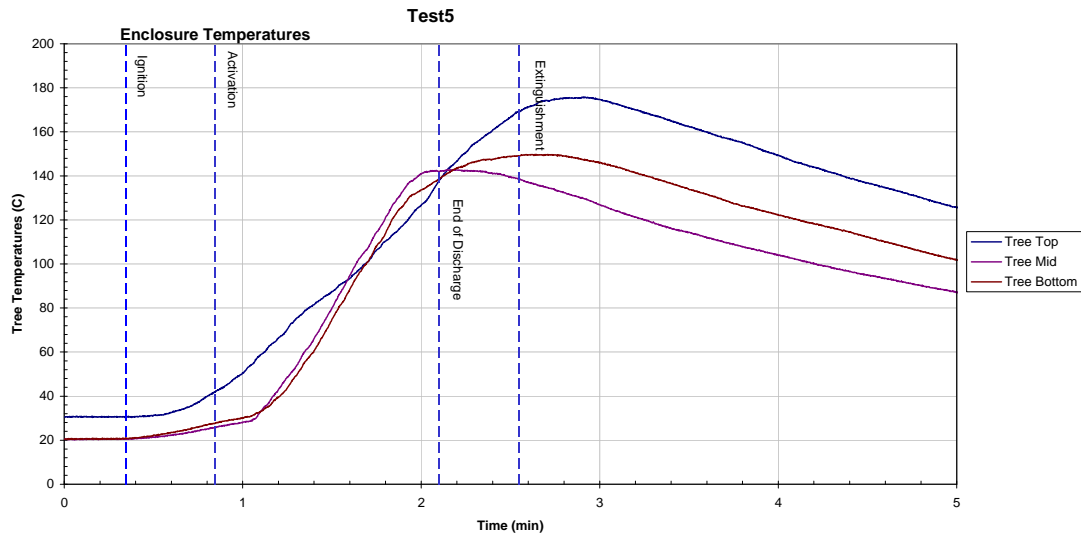


Figure C.22 – Enclosure Temperatures Measured during UL n-Heptane Pan Fire Test with Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 5)

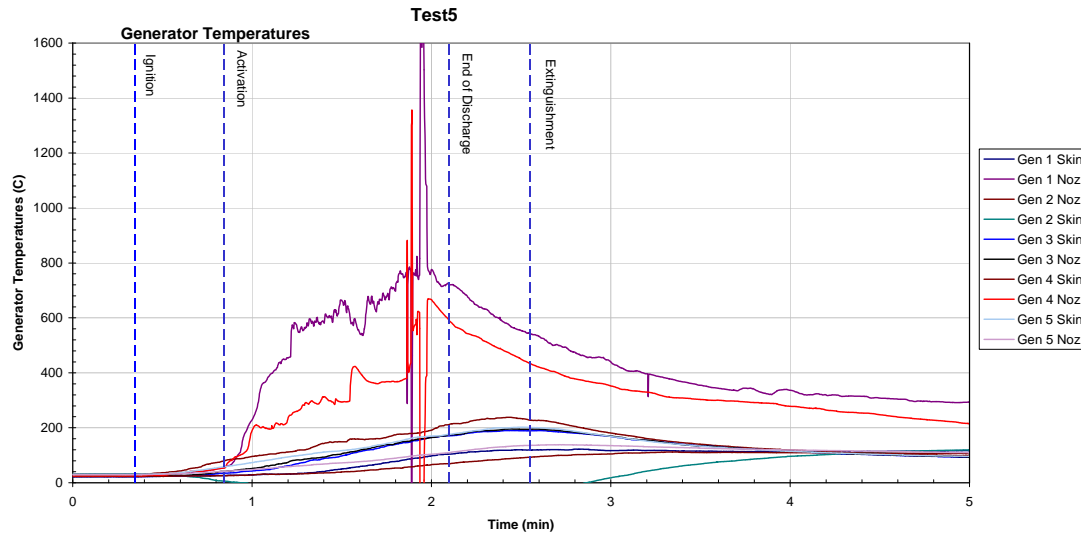


Figure C.23 – Generator Temperatures Measured during UL n-Heptane Pan Fire Test with Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 5)

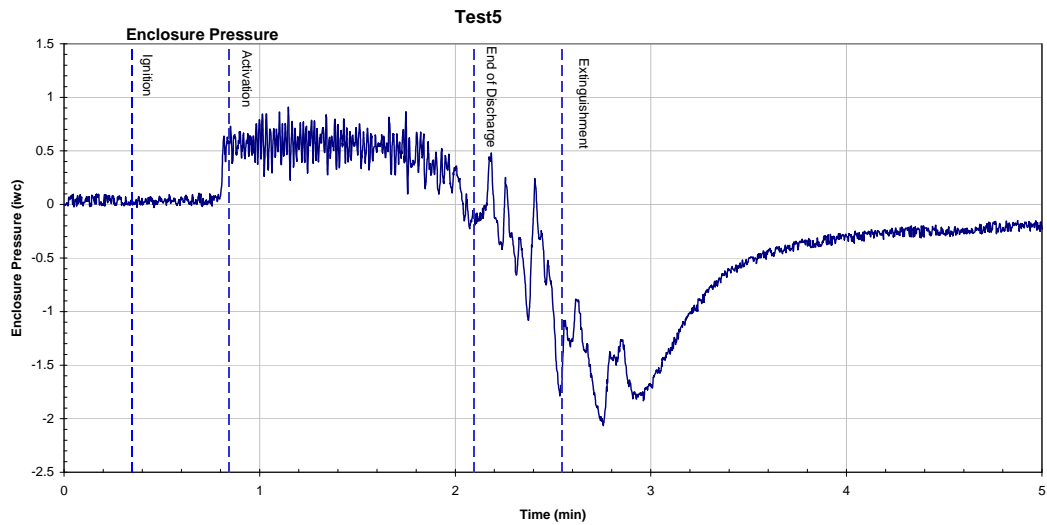


Figure C.24 – Enclosure Pressures Measured during UL n-Heptane Pan Fire Test with Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 5)

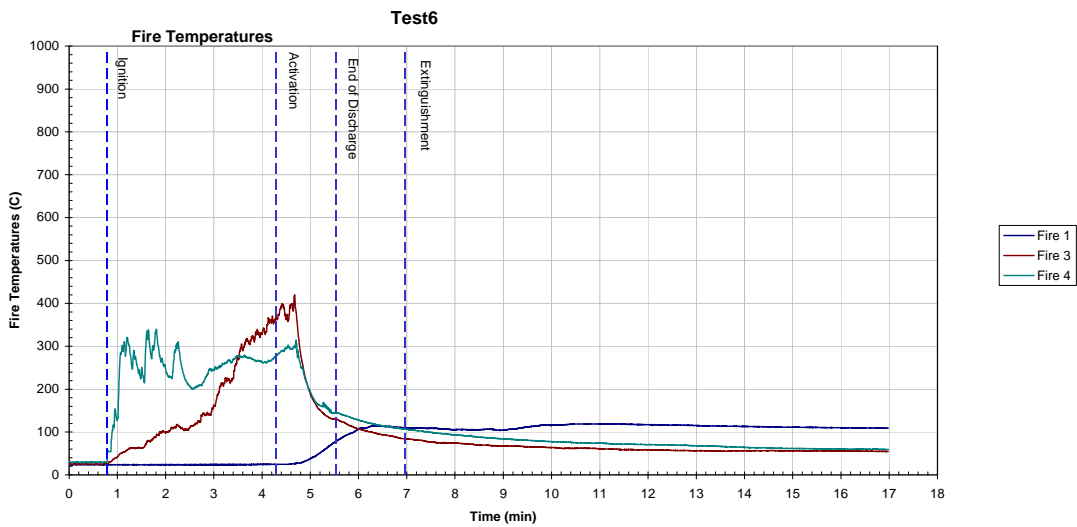


Figure C.25 – Fire Temperatures Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 6)

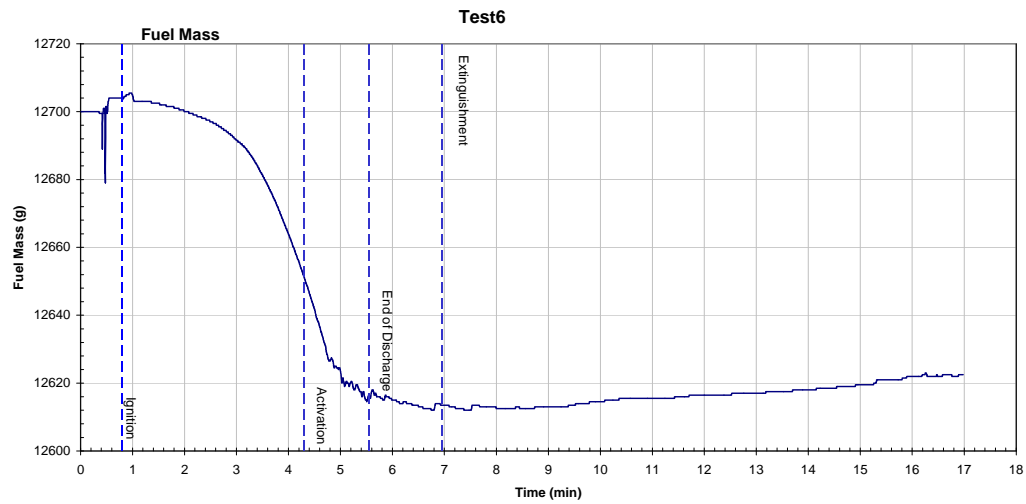


Figure C.26 – Fuel Mass Monitored during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 6)

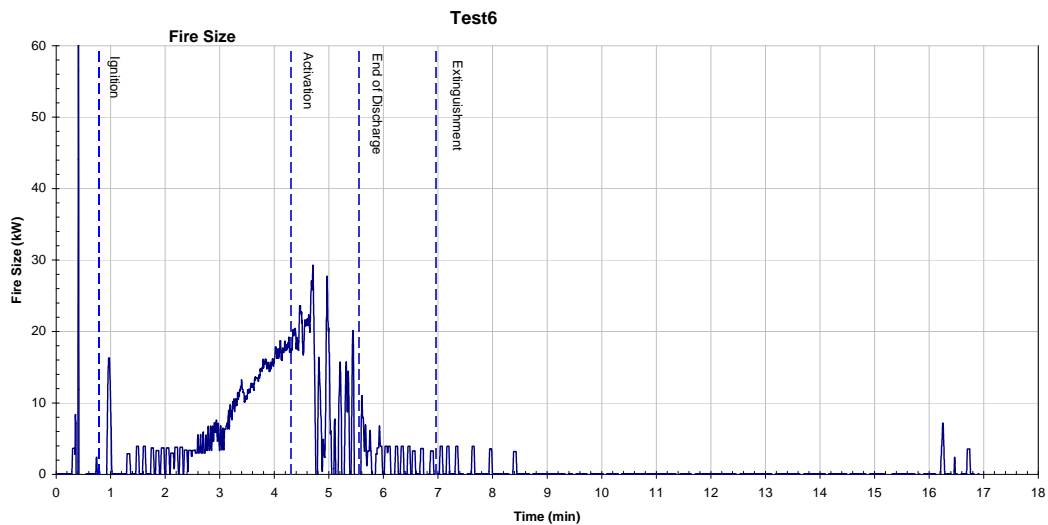


Figure C.27 – Fire Size during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 6)

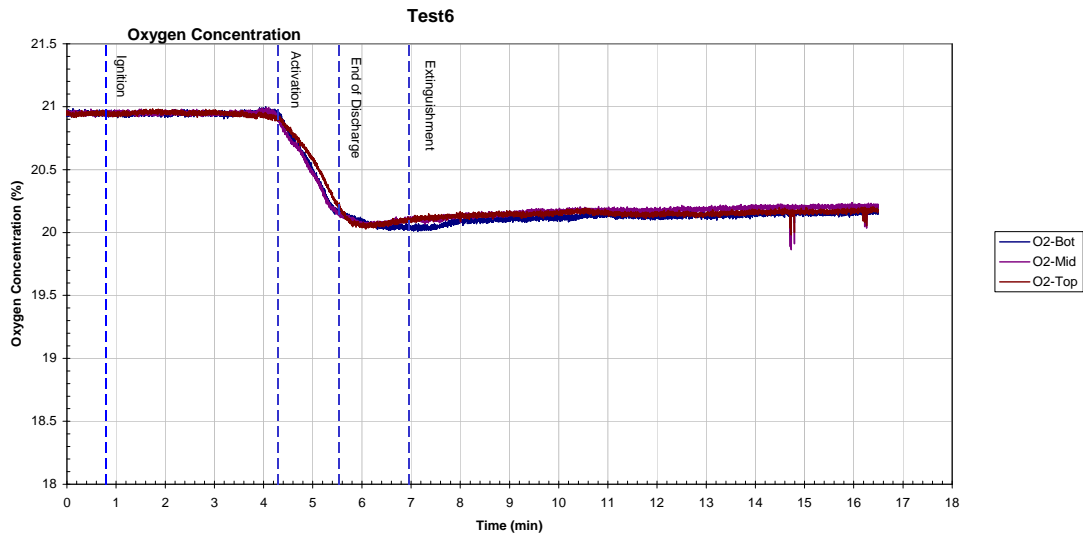


Figure C.28 – Oxygen Concentrations Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 6)

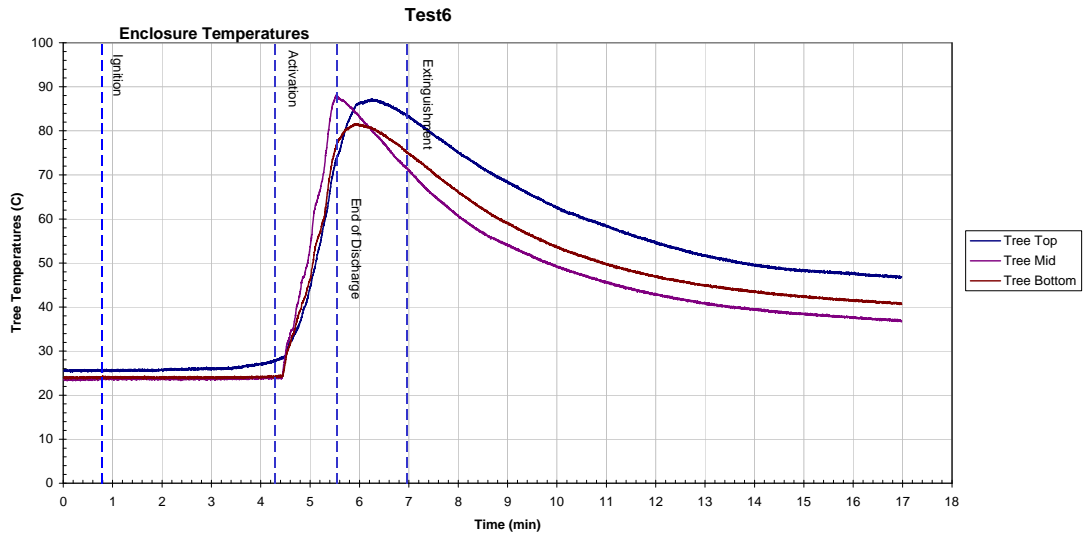


Figure C.29 – Enclosure Temperatures Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 6)

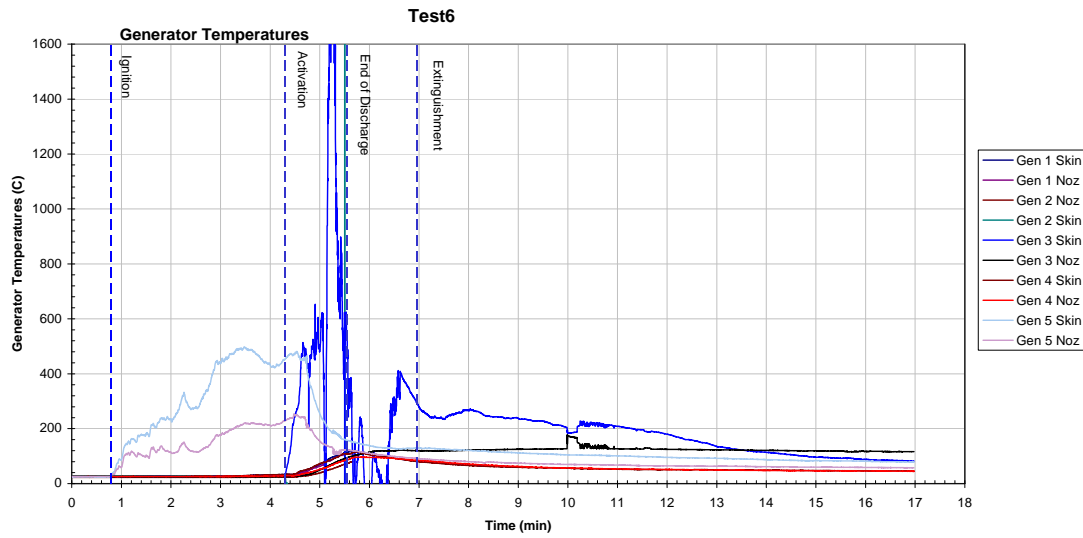


Figure C.30 – Generator Temperatures Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 6)

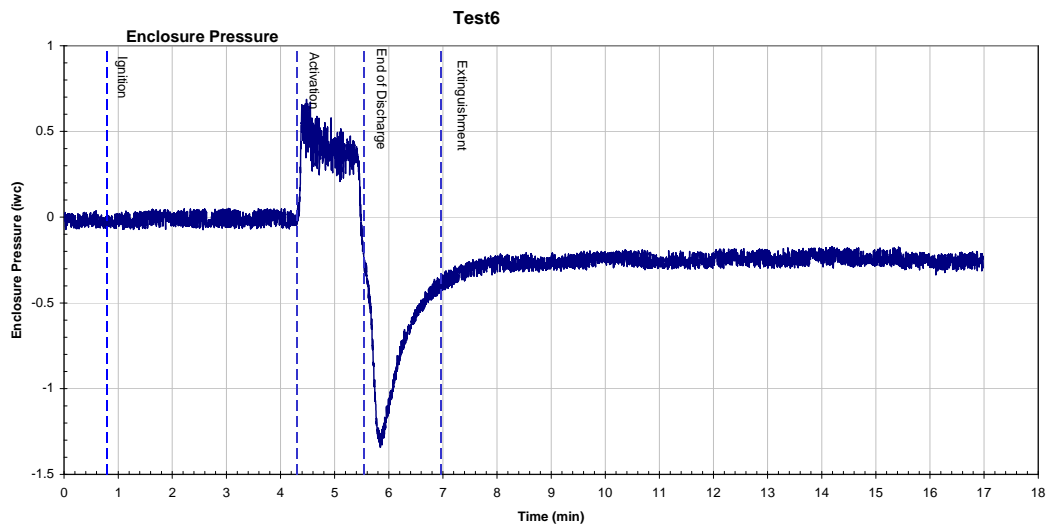


Figure C.31 – Enclosure Pressures Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 6)



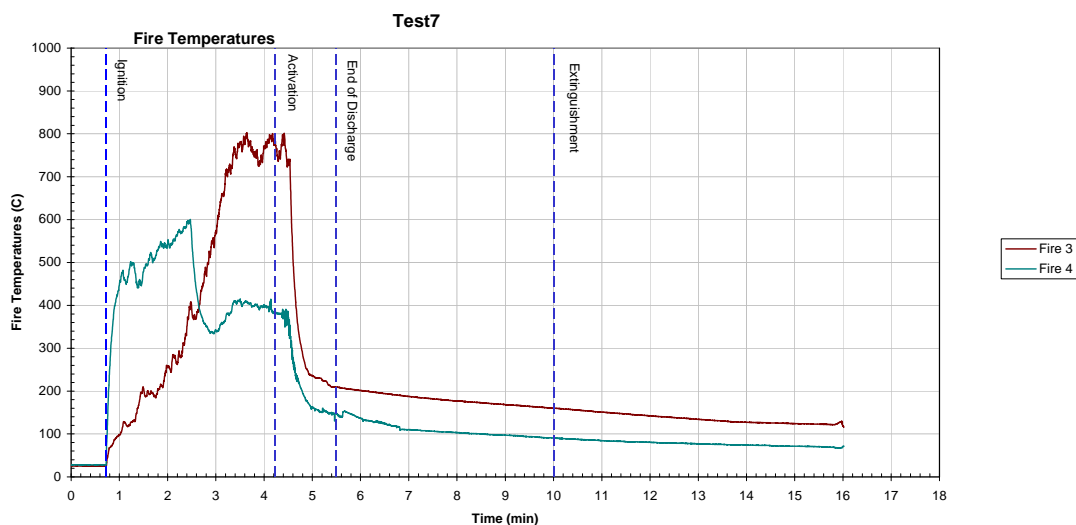


Figure C.32 – Fire Temperatures Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  – ISO Ignition Pan (Test 7)

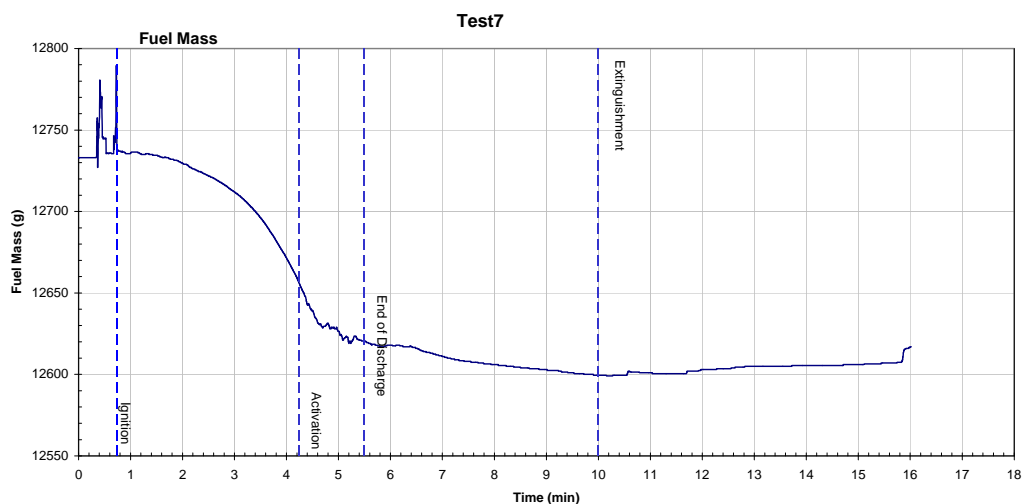


Figure C.33 – Fuel Mass Monitored during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  – ISO Ignition Pan (Test 7)

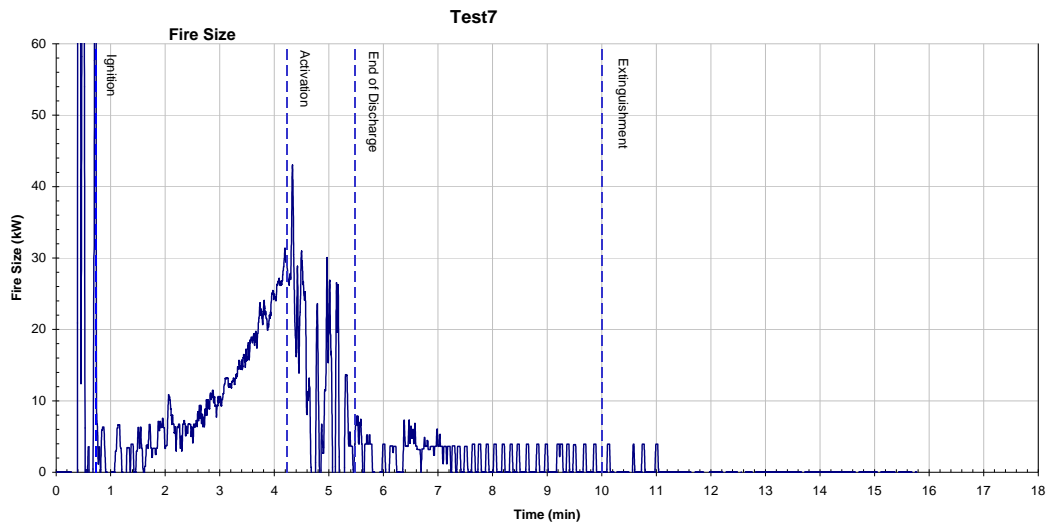


Figure C.34 – Fire Size during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  – ISO Ignition Pan (Test 7)

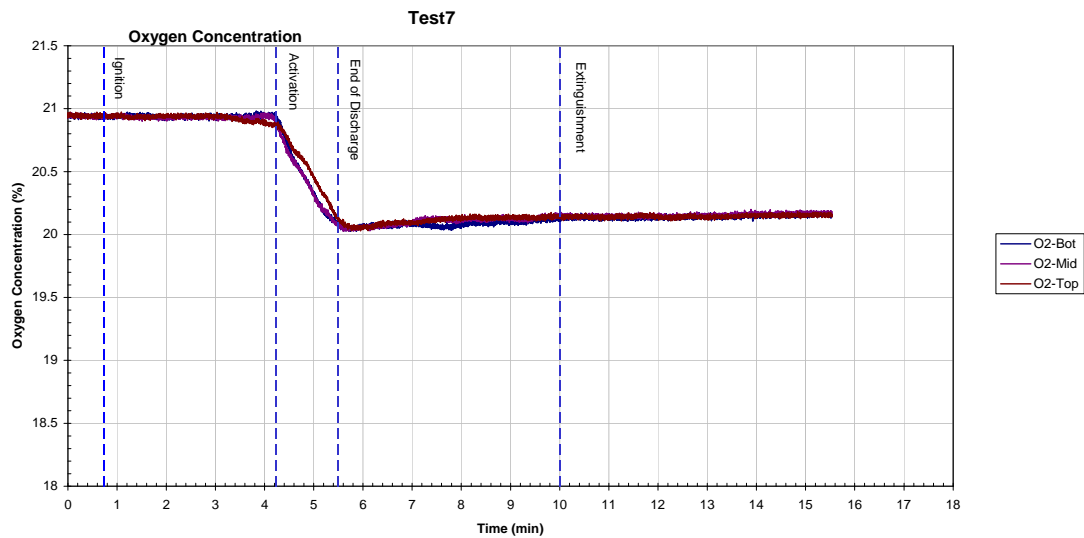


Figure C.35 – Oxygen Concentrations Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  – ISO Ignition Pan (Test 7)

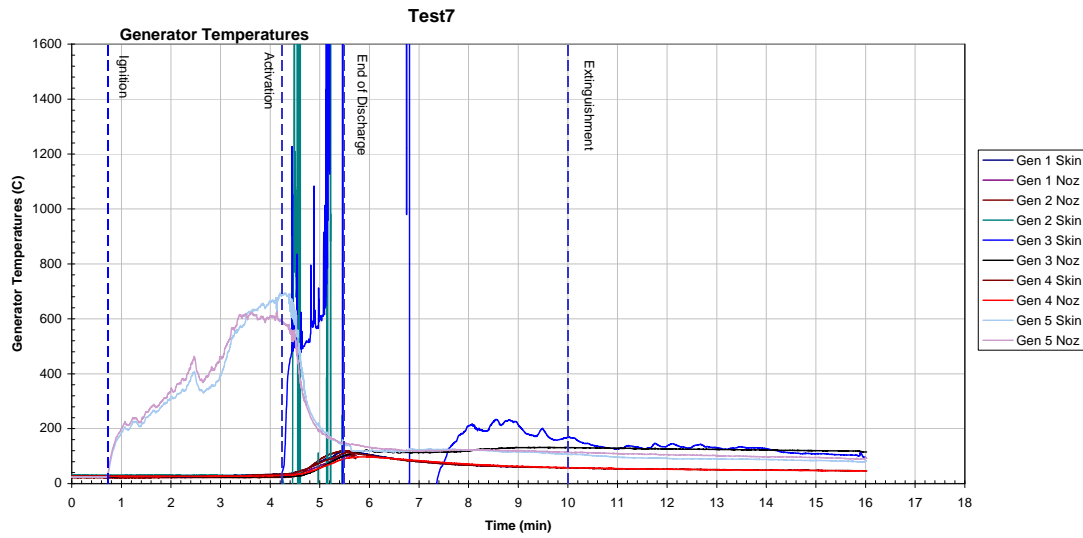


Figure C.36 – Generator Temperatures Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  – ISO Ignition Pan (Test 7)

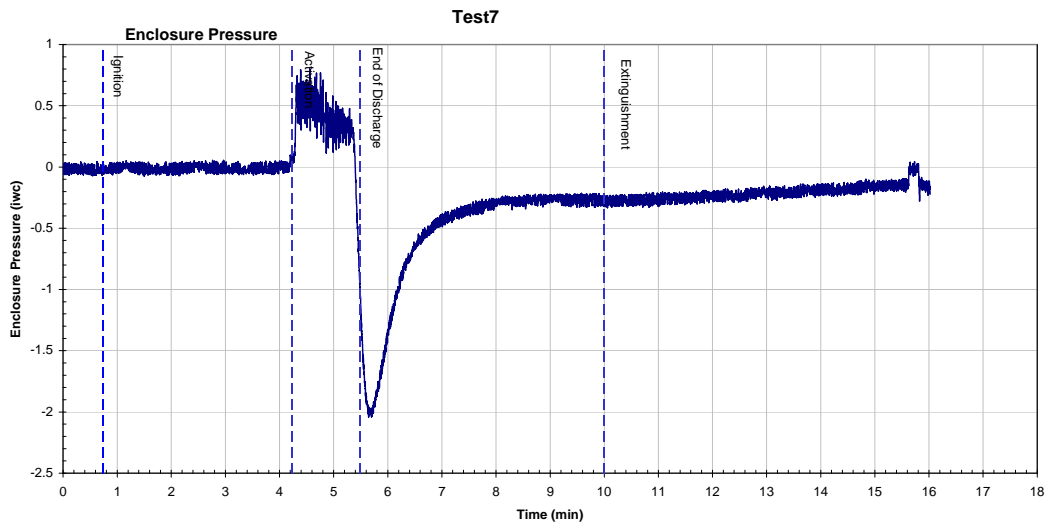


Figure C.37 – Enclosure Pressures Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  – ISO Ignition Pan (Test 7)

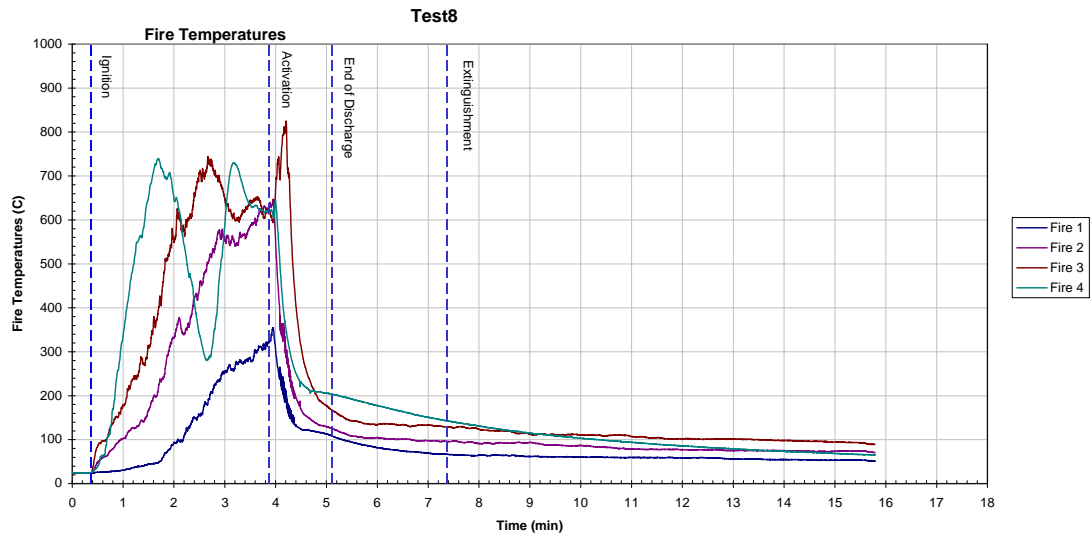


Figure C.38 – Fire Temperatures Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 8)

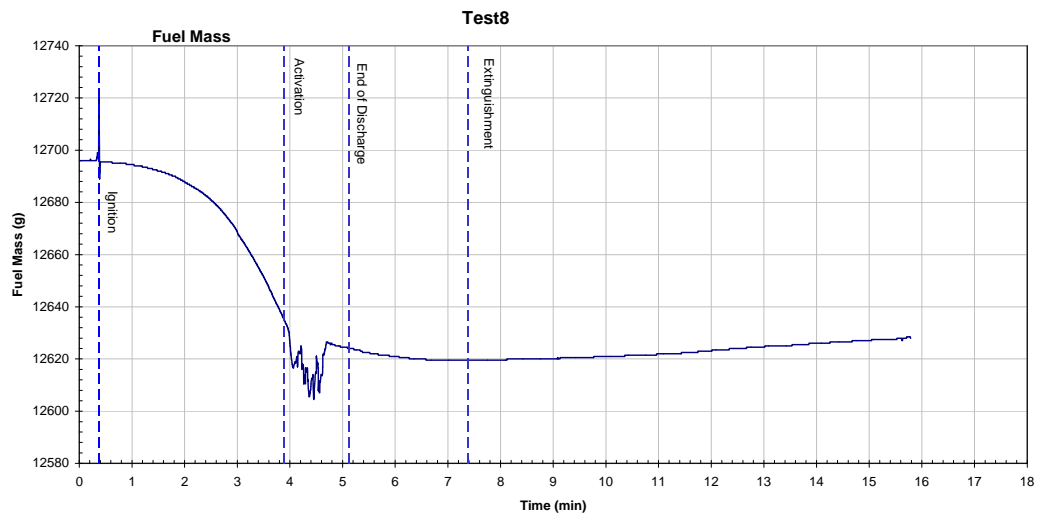


Figure C.39 – Fuel Mass Monitored during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 8)

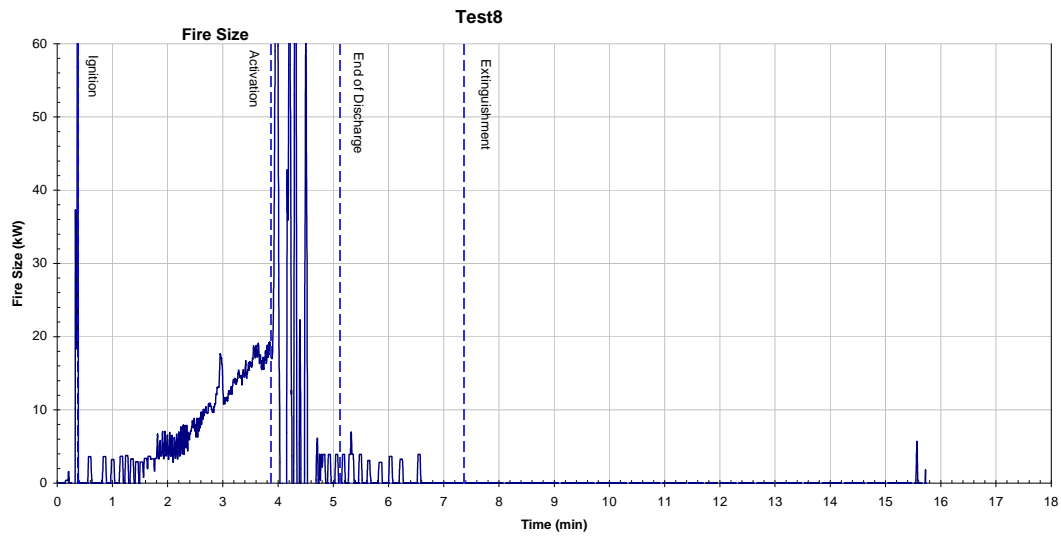


Figure C.40 – Fire Size during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 8)

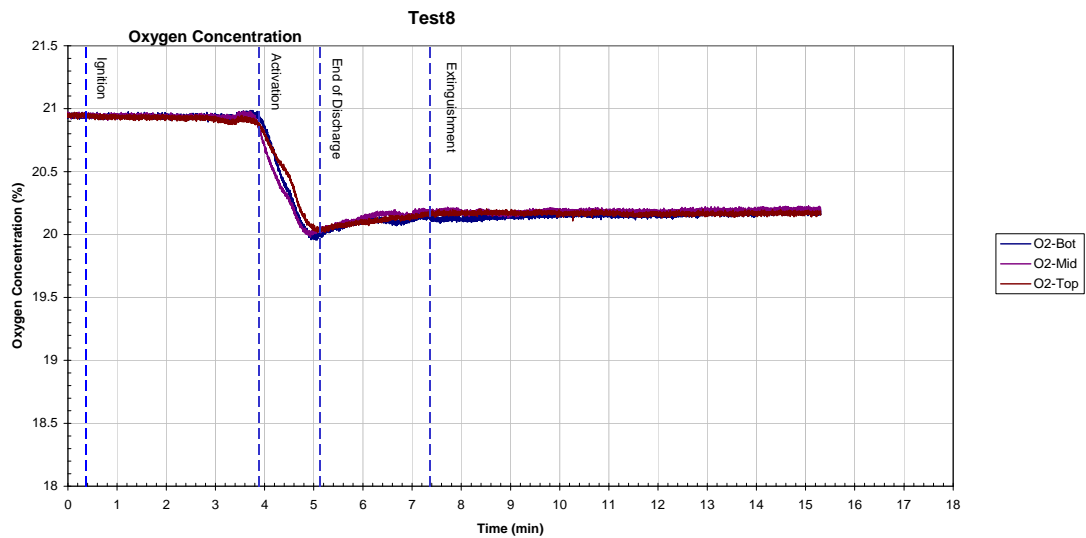


Figure C.41 – Oxygen Concentrations Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 8)

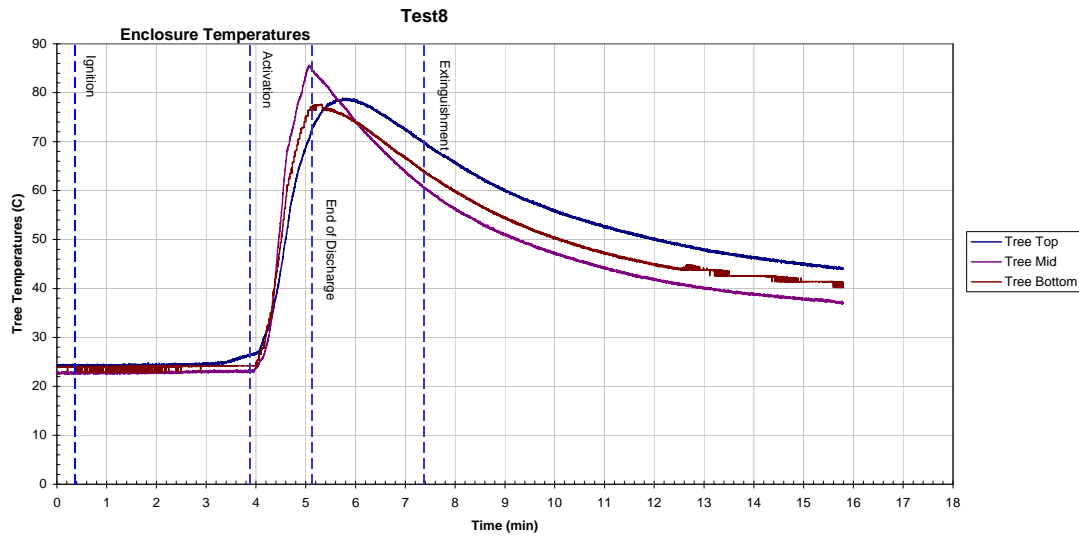


Figure C.42 – Enclosure Temperatures Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 8)

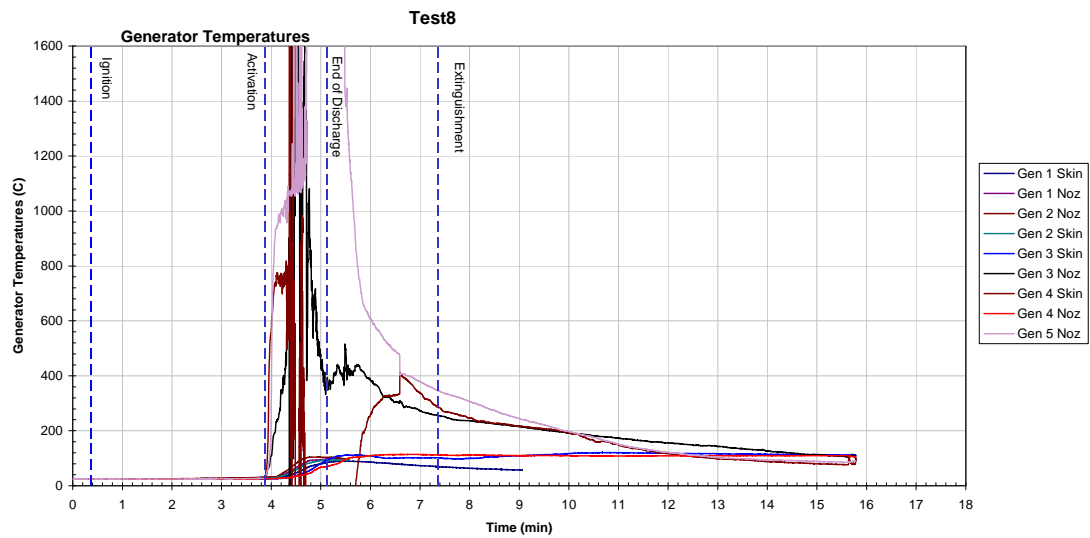


Figure C.43 – Generator Temperatures Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 8)

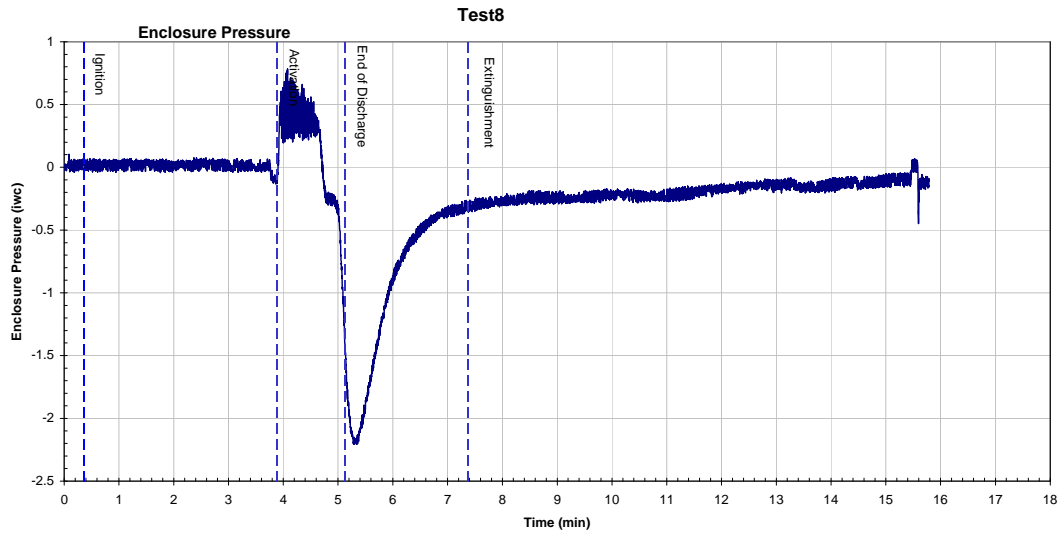


Figure C.44 – Enclosure Pressures Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 8)

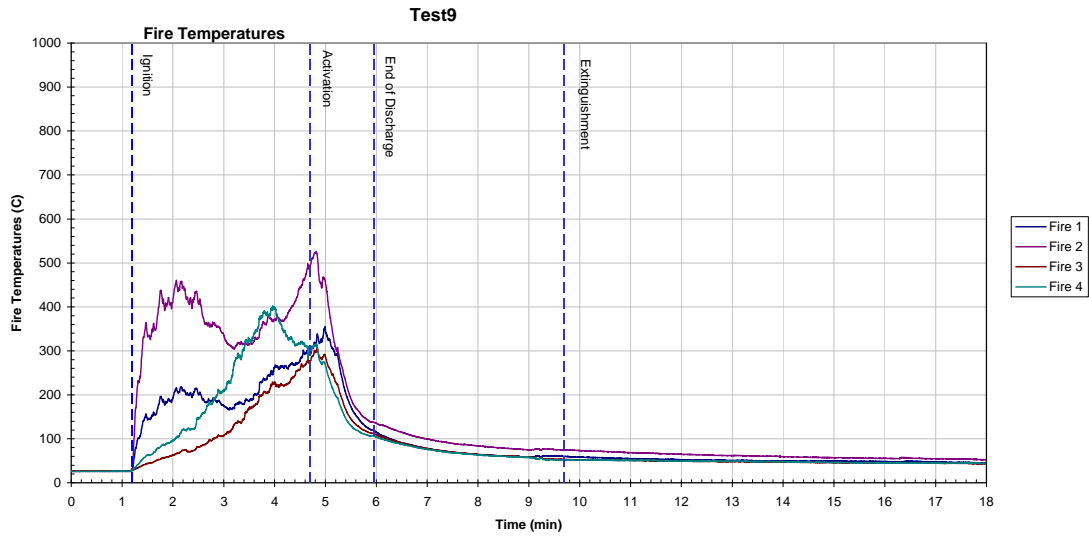


Figure C.45 – Fire Temperatures Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 9)

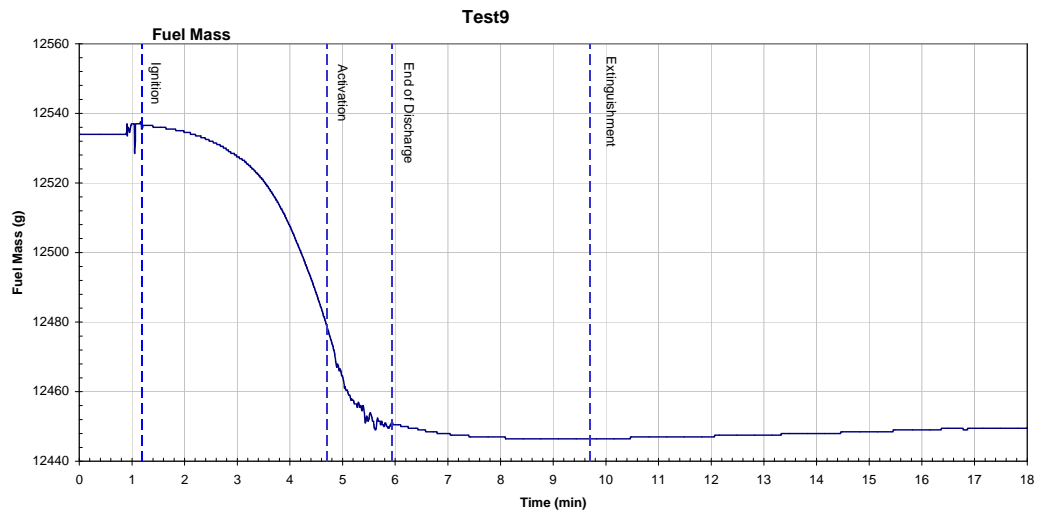


Figure C.46 – Fuel Mass Monitored during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 9)

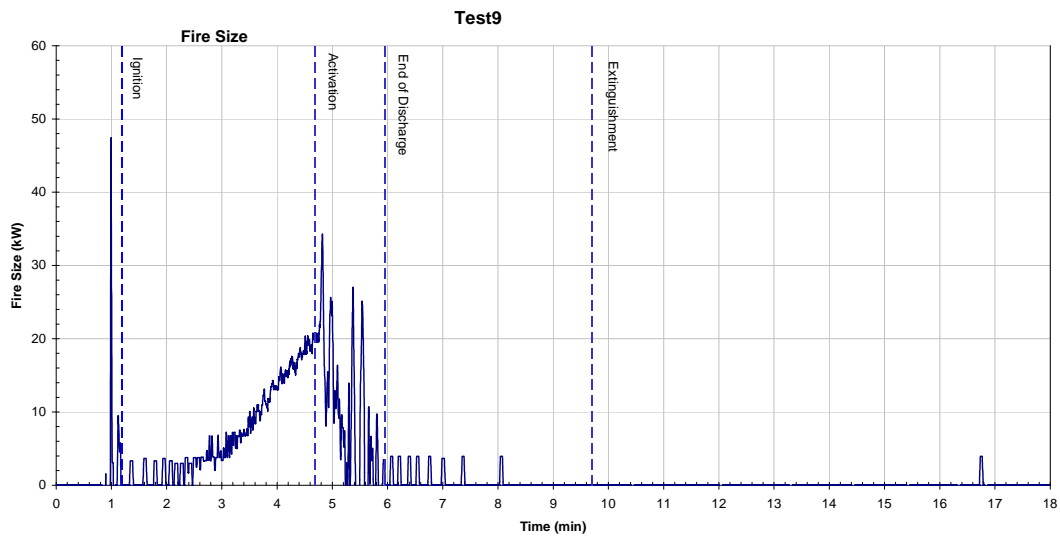


Figure C.47 – Fire Size during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 9)



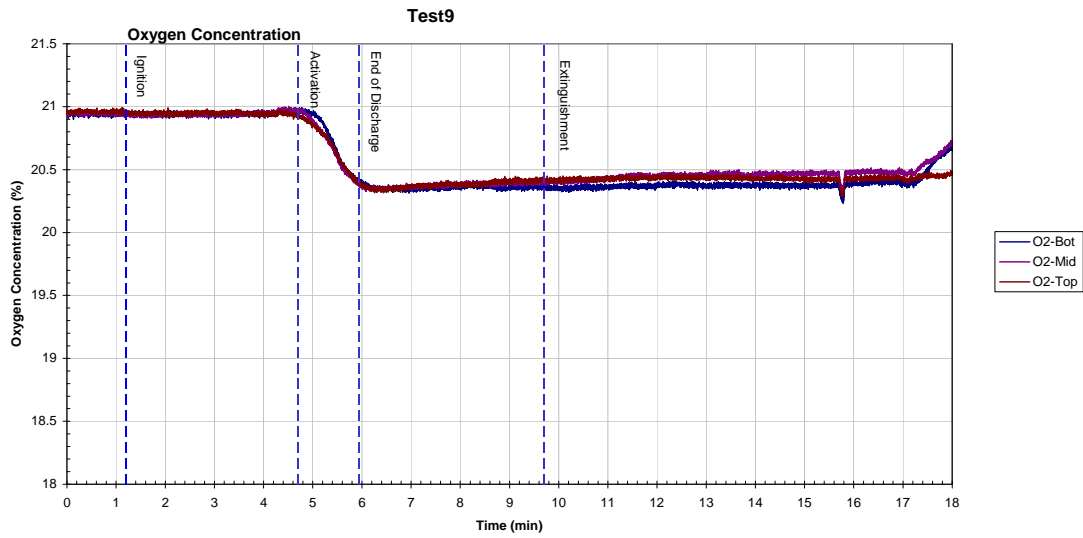


Figure C.48 – Oxygen Concentrations Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 9)

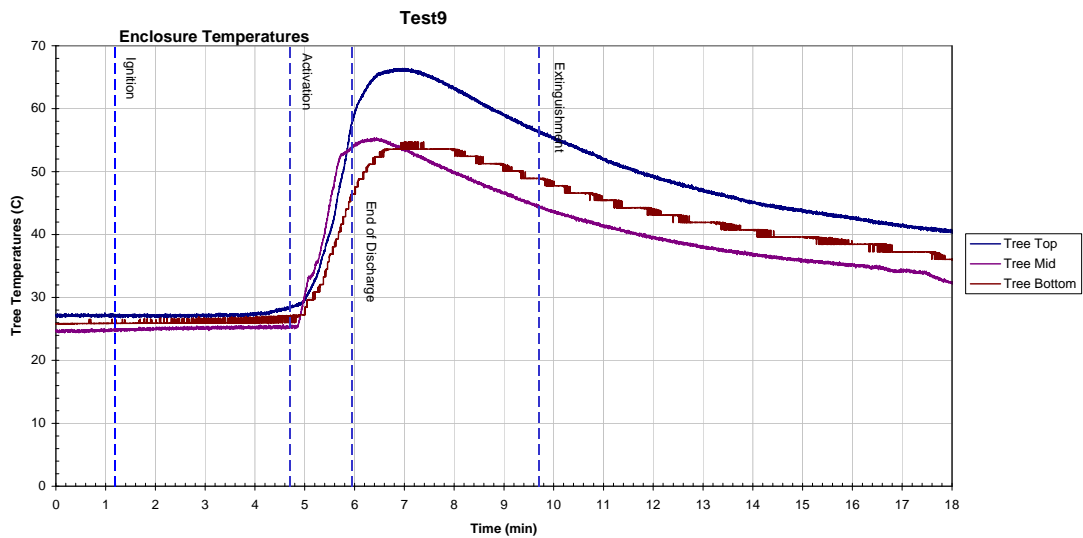


Figure C.49 – Enclosure Temperatures Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 9)

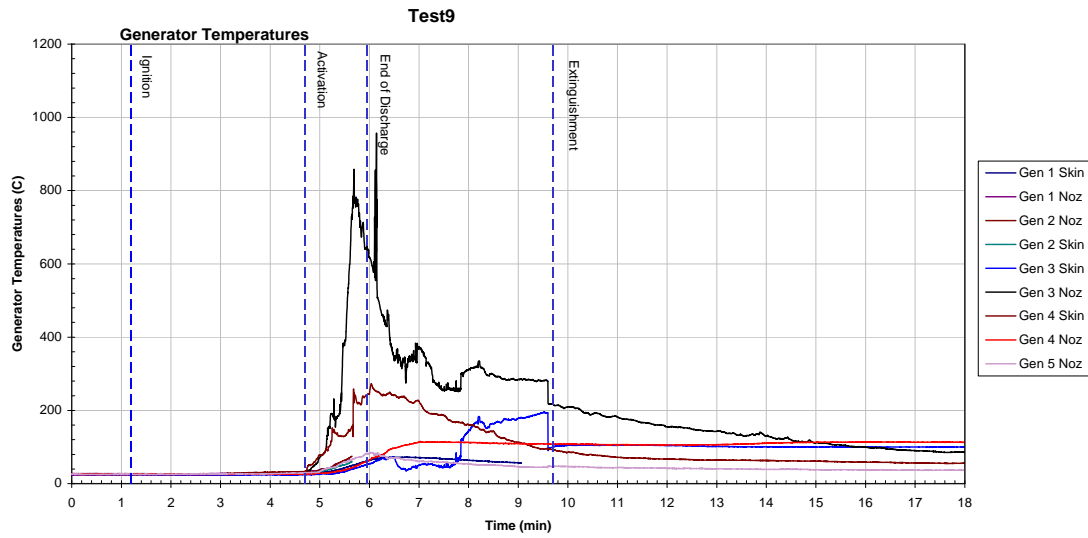


Figure C.50 – Generator Temperatures Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 9)

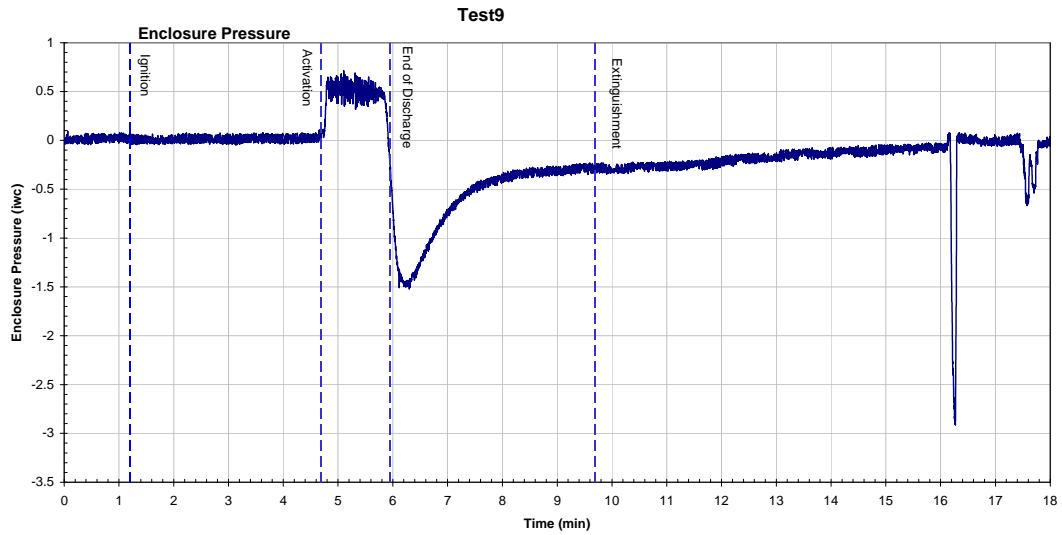


Figure C.51 – Enclosure Pressures Measured during UL Polymeric Materials Test with PMMA and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 9)

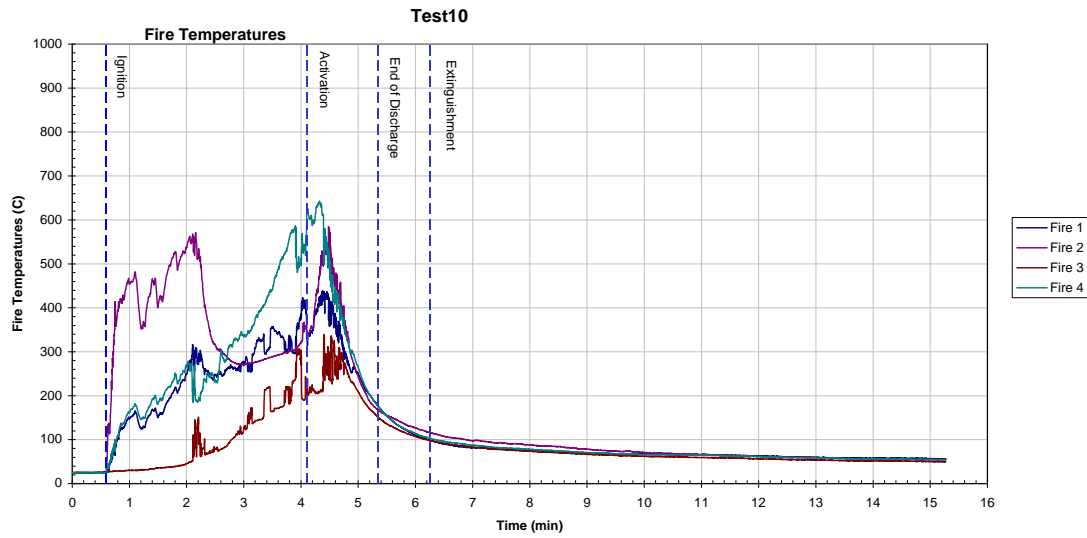


Figure C.52 – Fire Temperatures Measured during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 10)

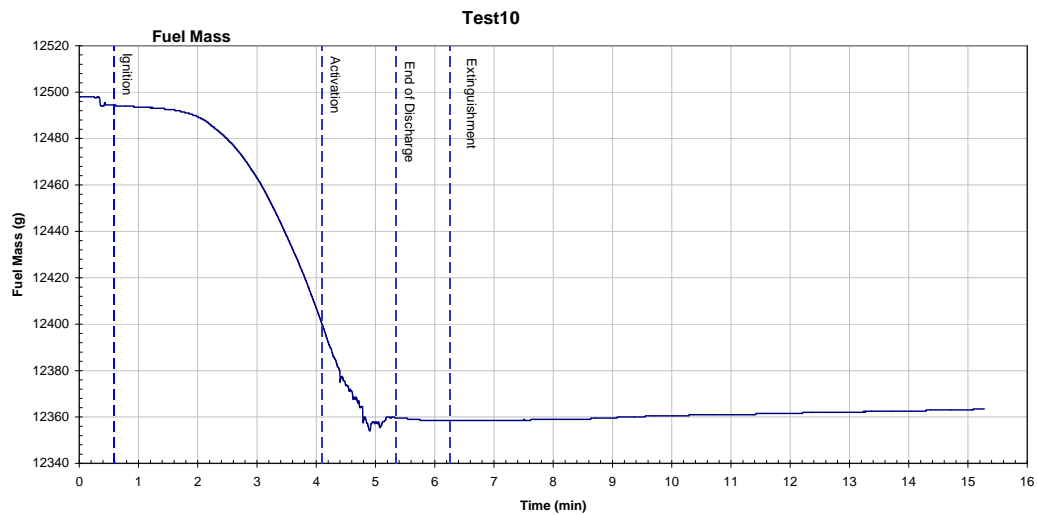


Figure C.53 – Fuel Mass Monitored during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 10)

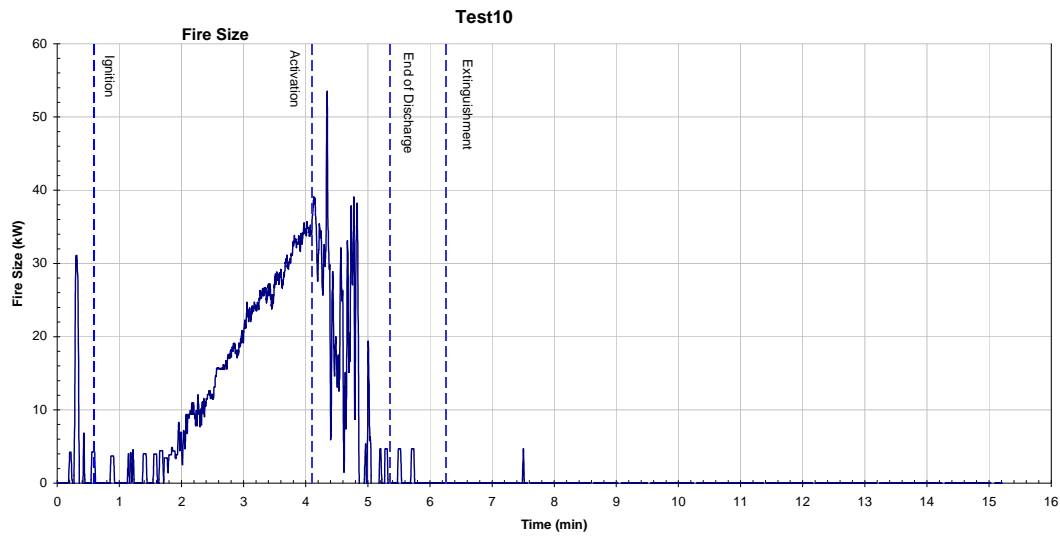


Figure C.54 – Fire Size during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 10)

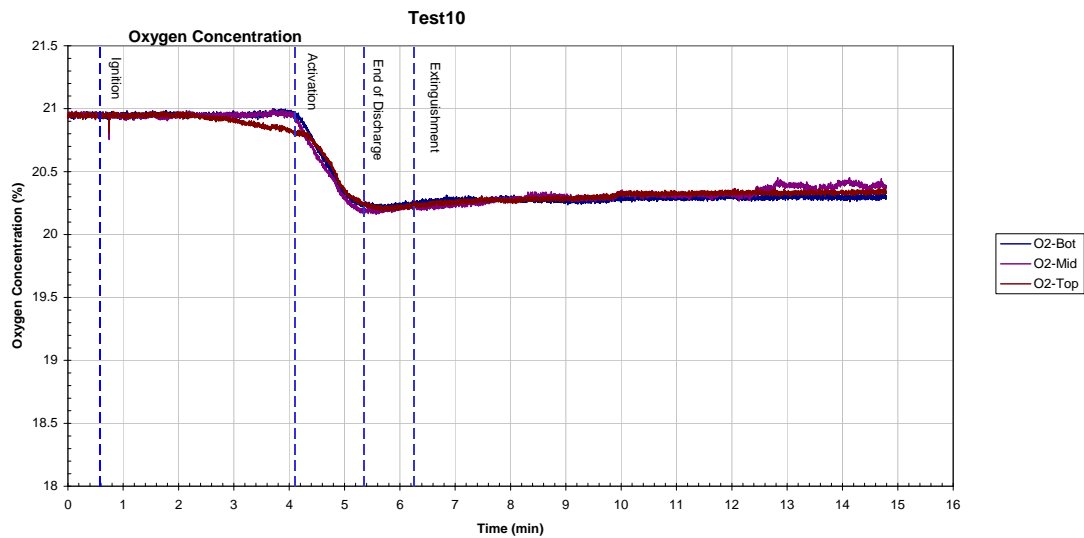


Figure C.55 – Oxygen Concentrations Measured during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 10)

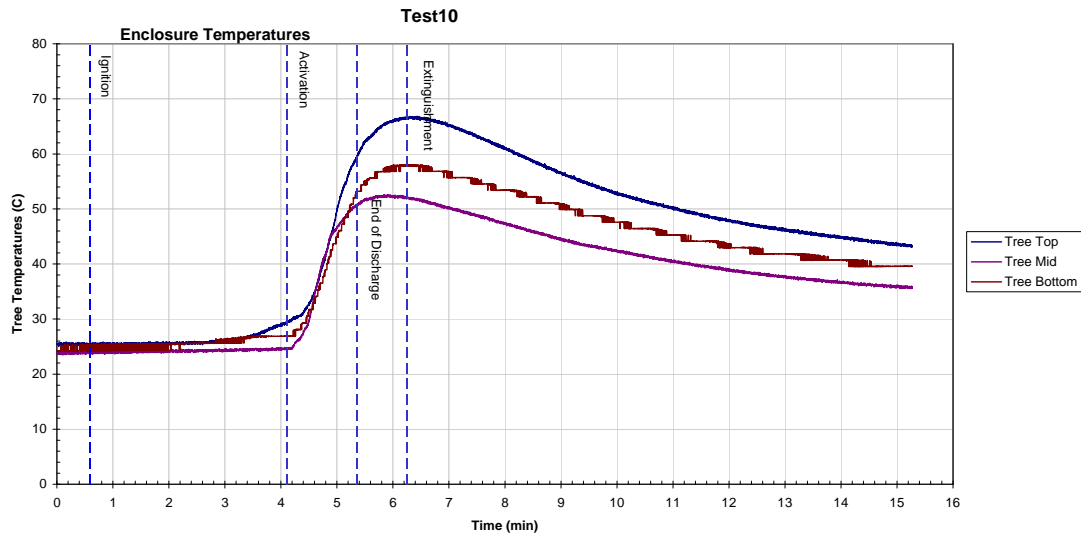


Figure C.56 – Enclosure Temperatures Measured during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 10)

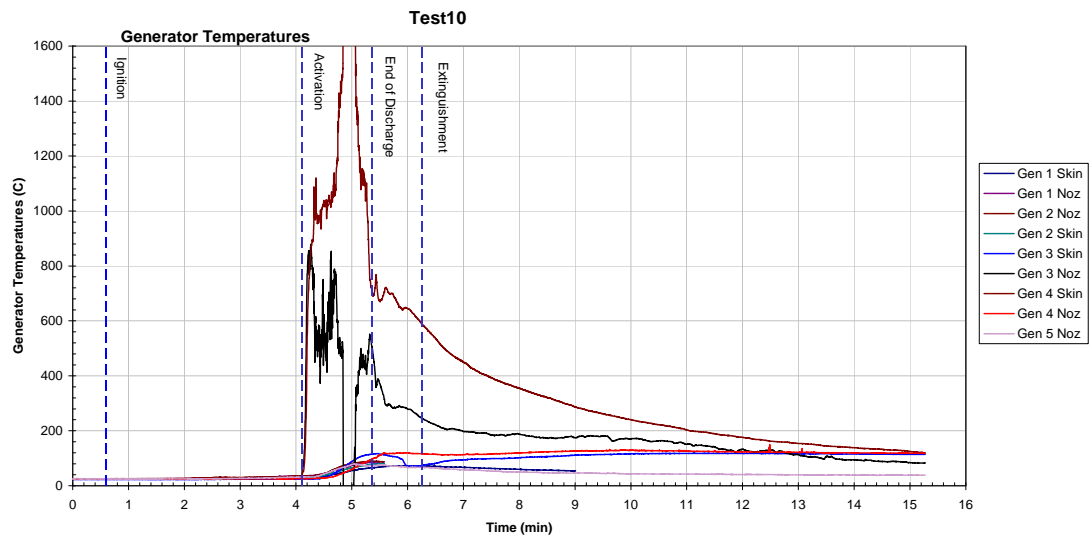


Figure C.57 – Generator Temperatures Measured during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 10)

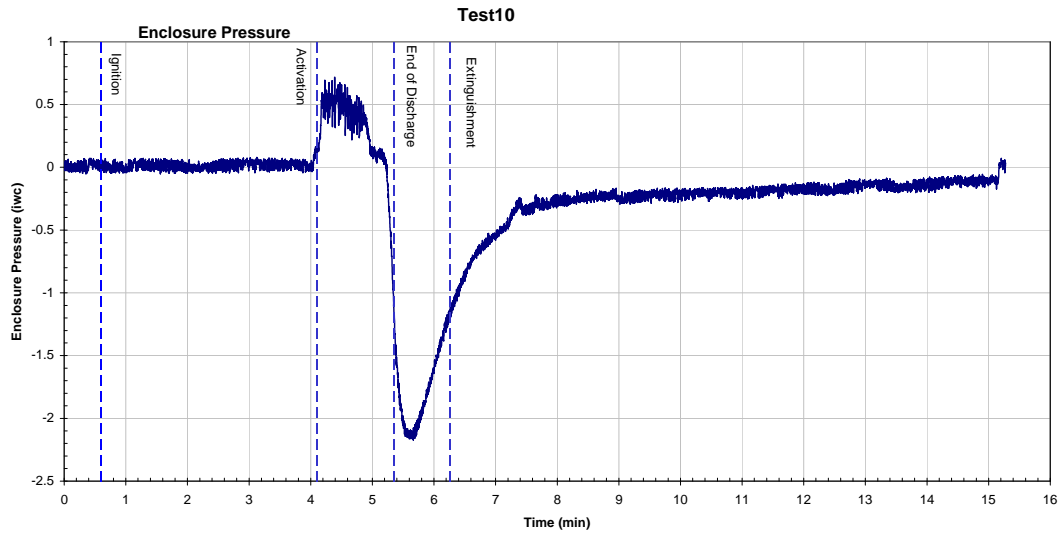


Figure C.58 – Enclosure Pressures Measured during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 10)

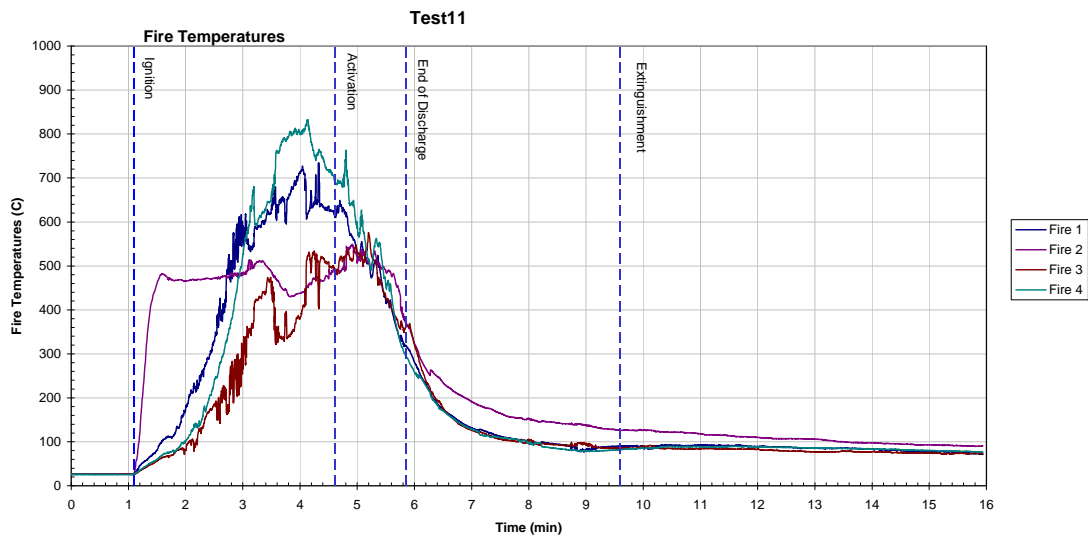


Figure C.59 – Fire Temperatures Measured during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 11)

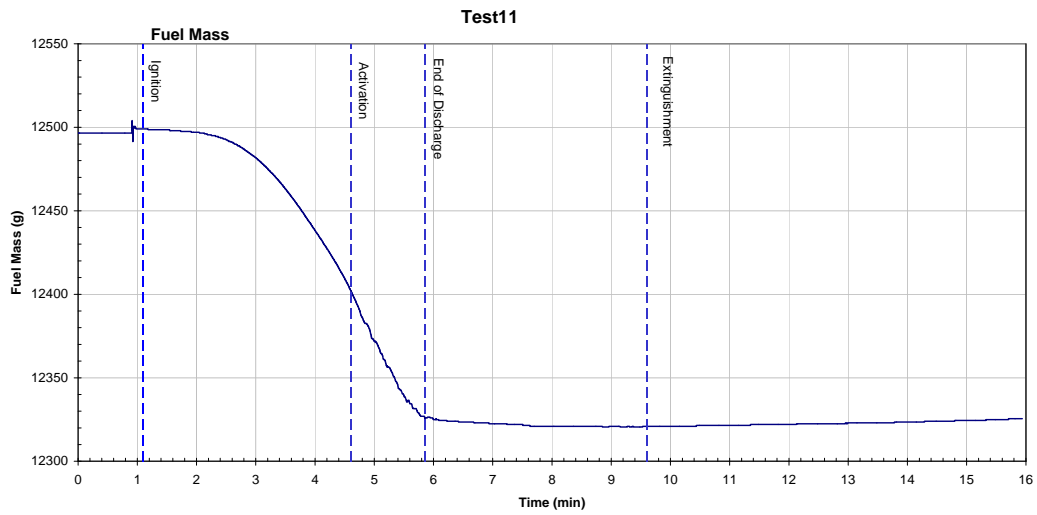


Figure C.60 – Fuel Mass Monitored during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 11)

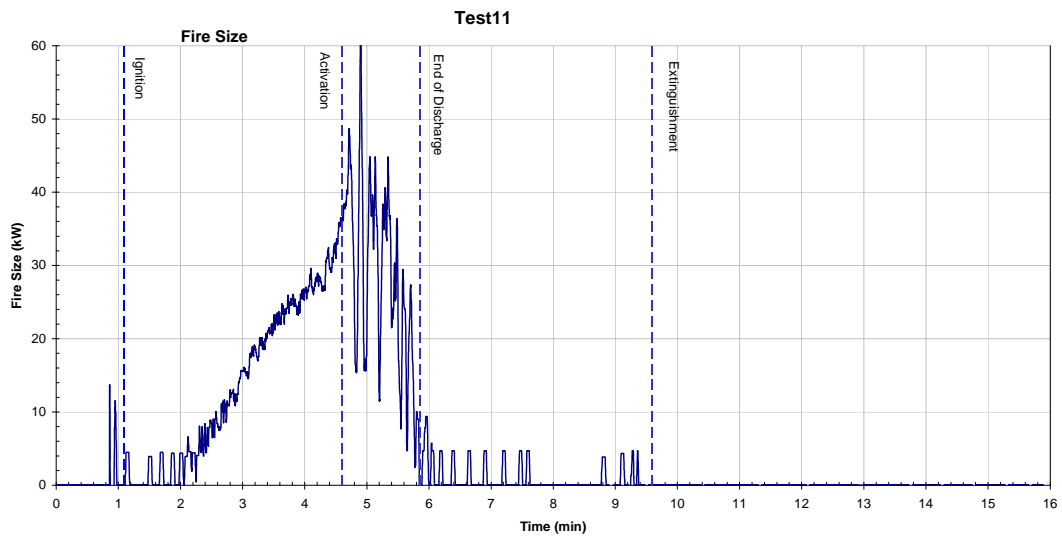


Figure C.61 – Fire Size during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 11)

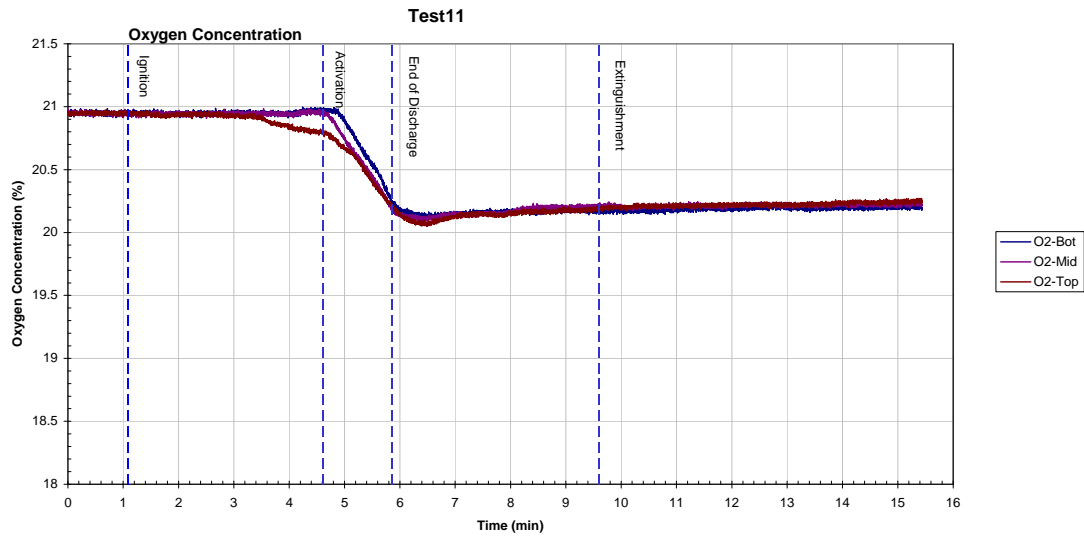


Figure C.62 – Oxygen Concentrations Measured during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 11)

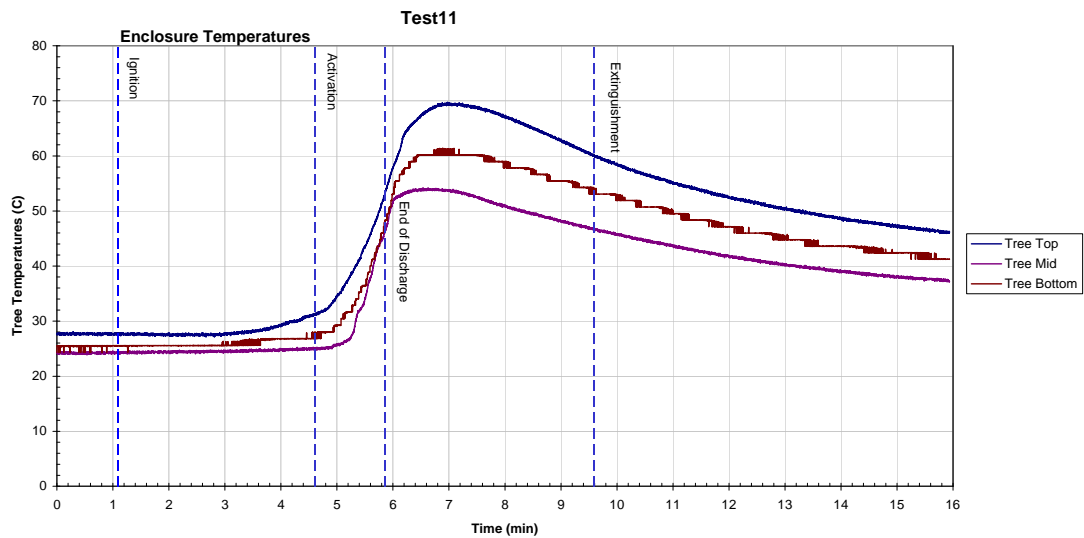


Figure C.63 – Enclosure Temperatures Measured during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 11)



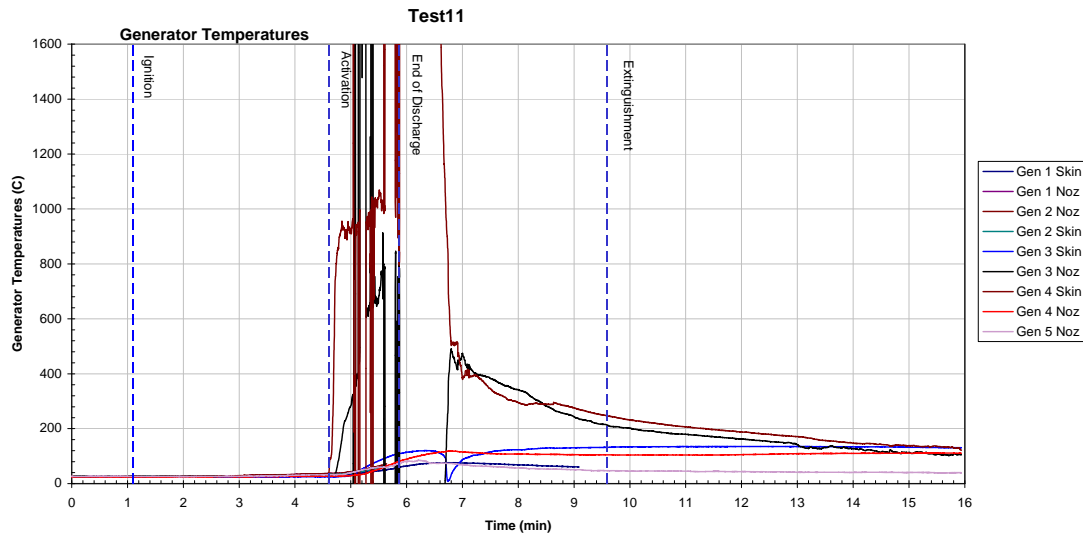


Figure C.64 – Generator Temperatures Measured during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 11)

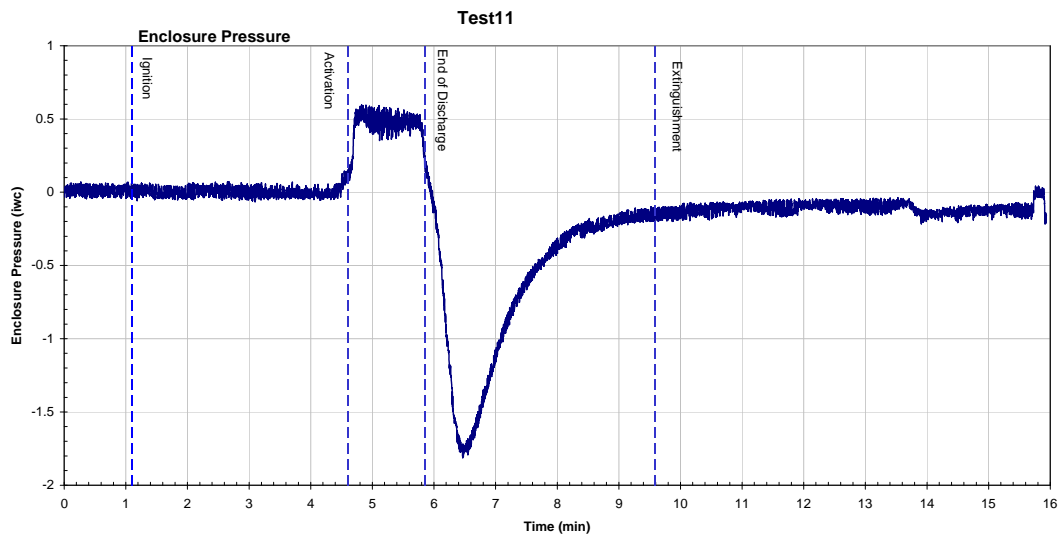


Figure C.65 – Enclosure Pressures Measured during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 11)

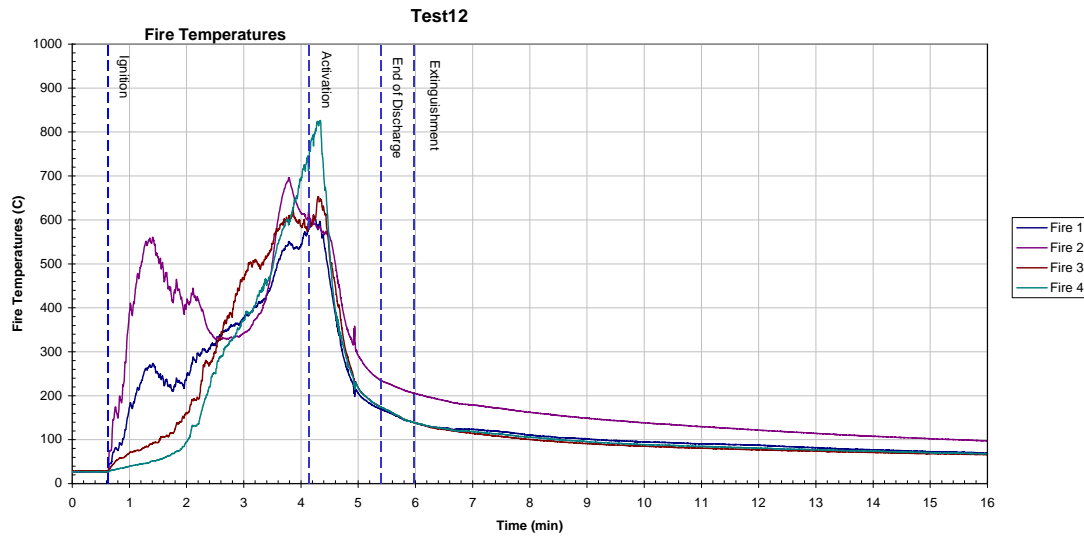


Figure C.66 – Fire Temperatures Measured during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 12)

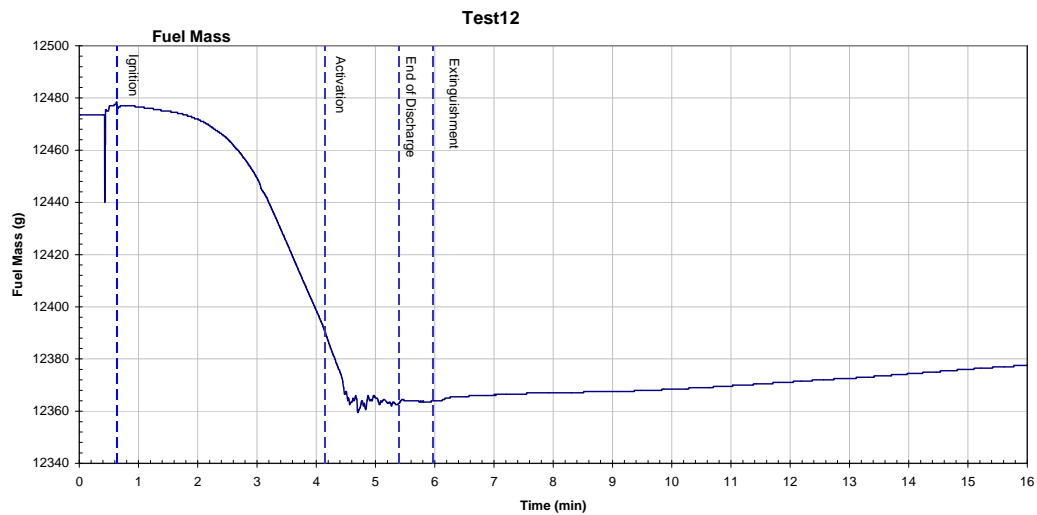


Figure C.67 – Fuel Mass Monitored during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 12)

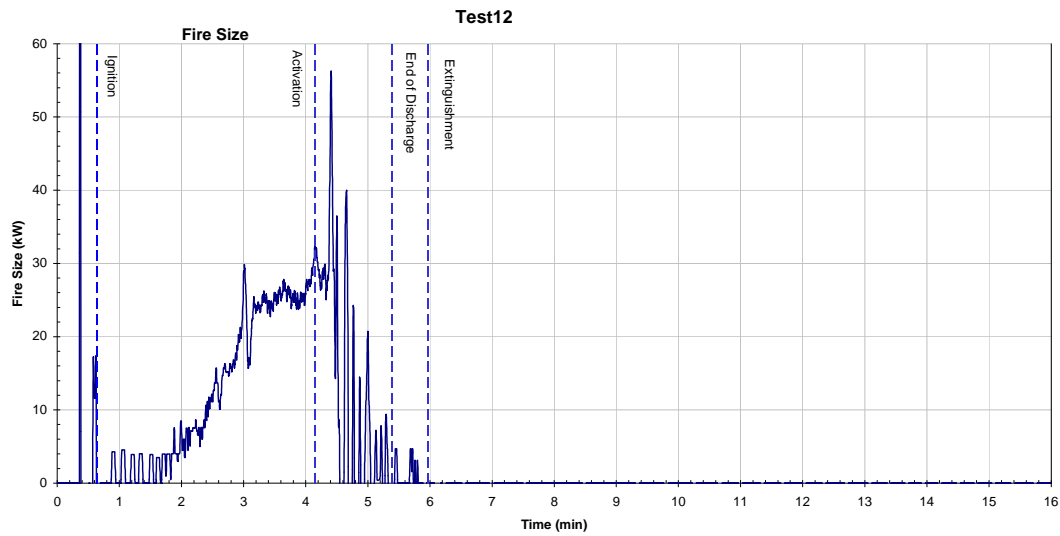


Figure C.68 – Fire Size during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 12)

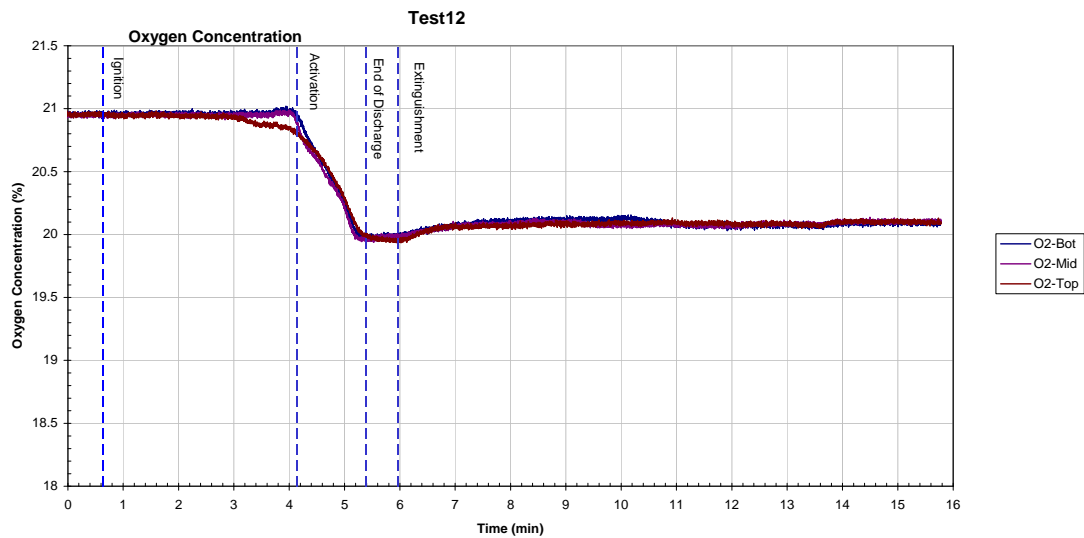


Figure C.69 – Oxygen Concentrations Measured during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 12)

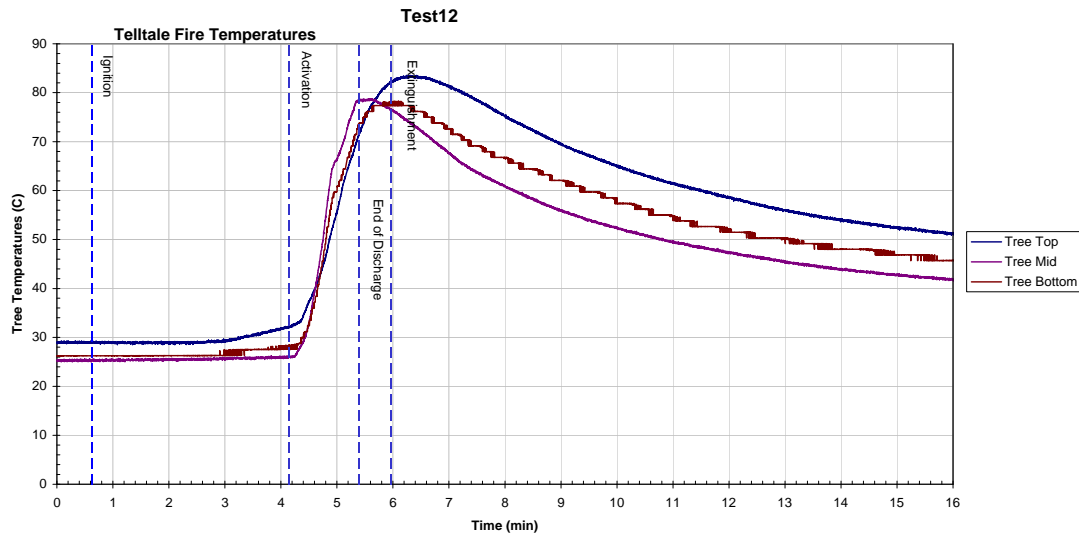


Figure C.70 – Enclosure Temperatures Measured during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 12)

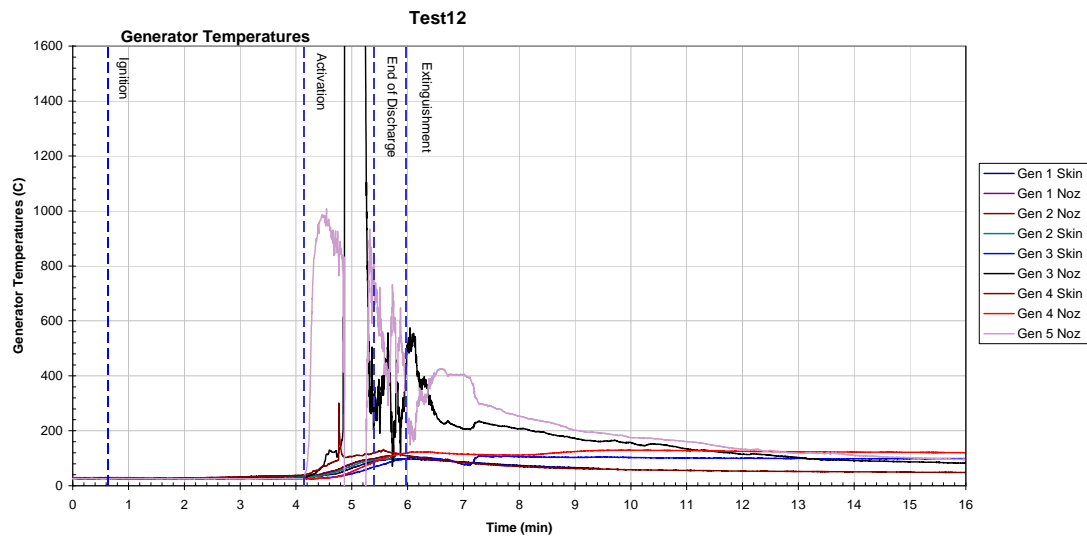


Figure C.71 – Generator Temperatures Measured during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 12)

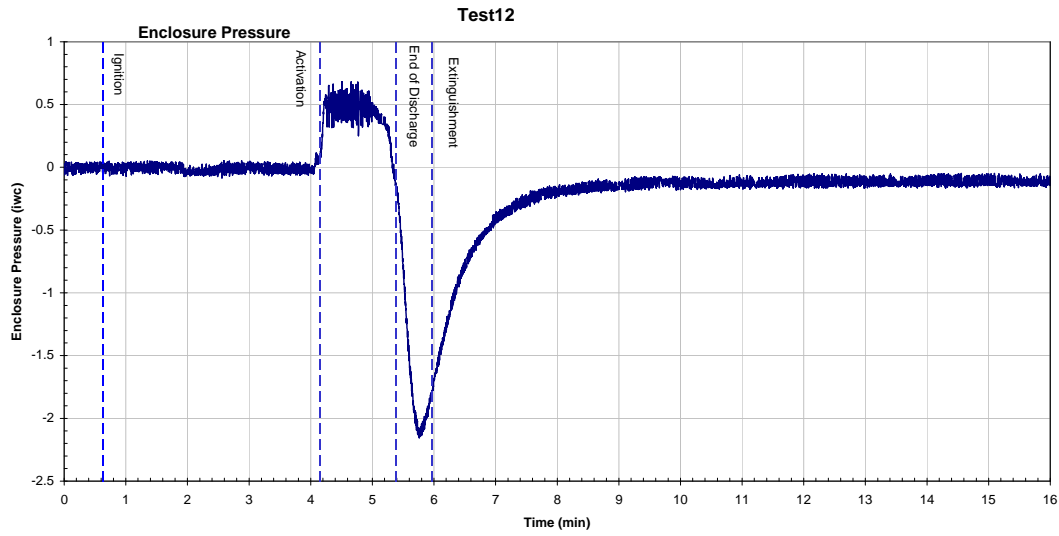


Figure C.72 – Enclosure Pressures Measured during UL Polymeric Materials Test with ABS and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 12)

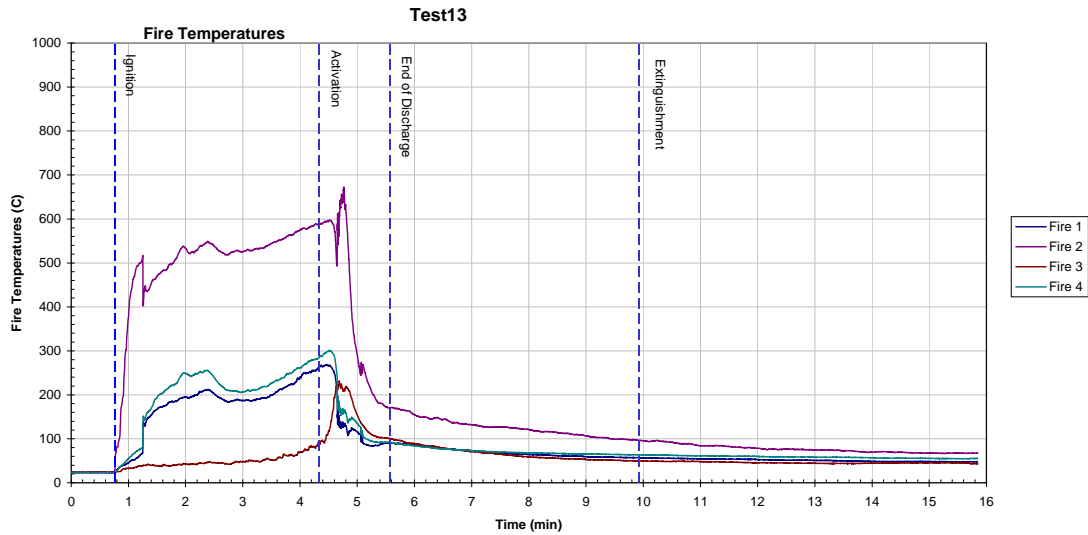


Figure C.73 – Fire Temperatures Measured during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 13)

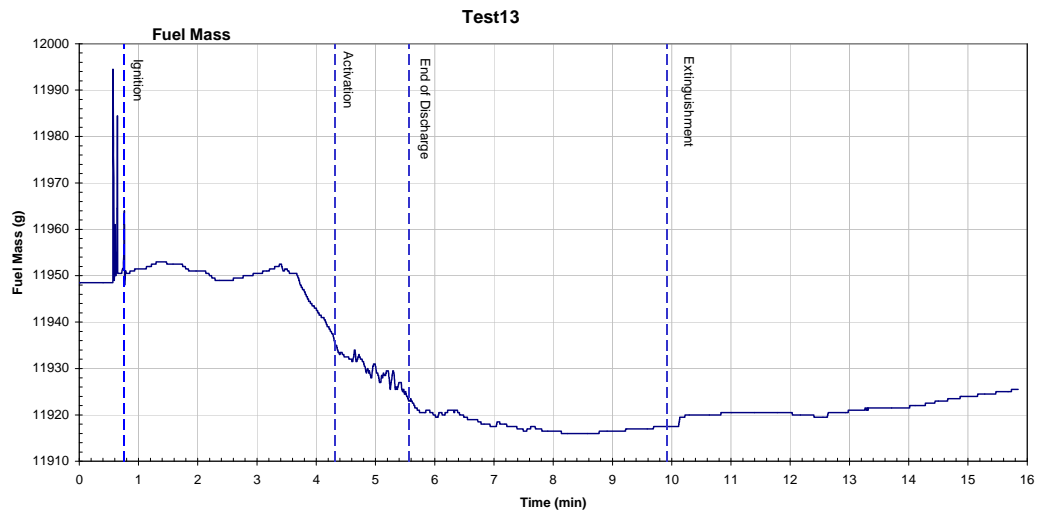


Figure C.74 – Fuel Mass Monitored during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 13)

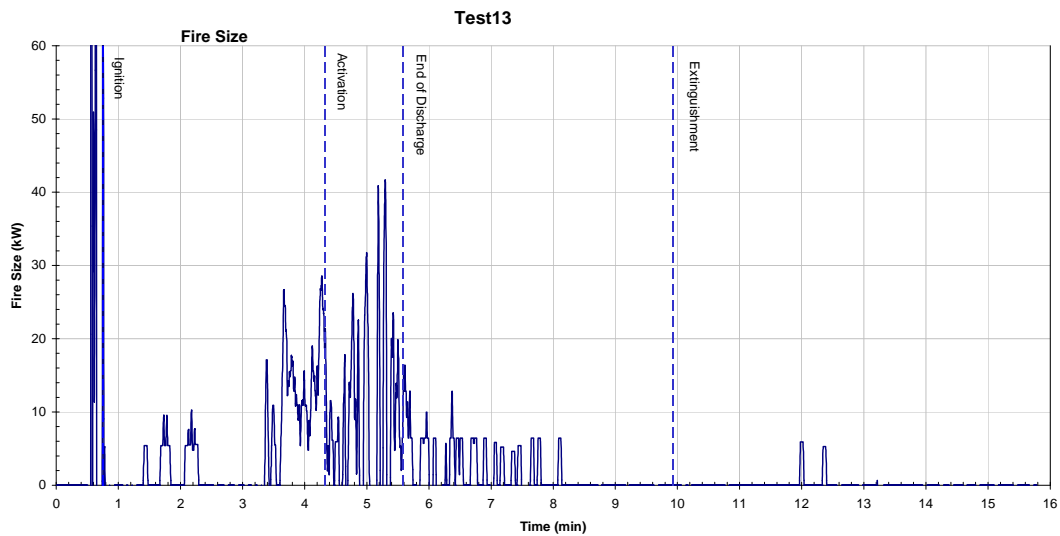


Figure C.75 – Fire Size during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 13)

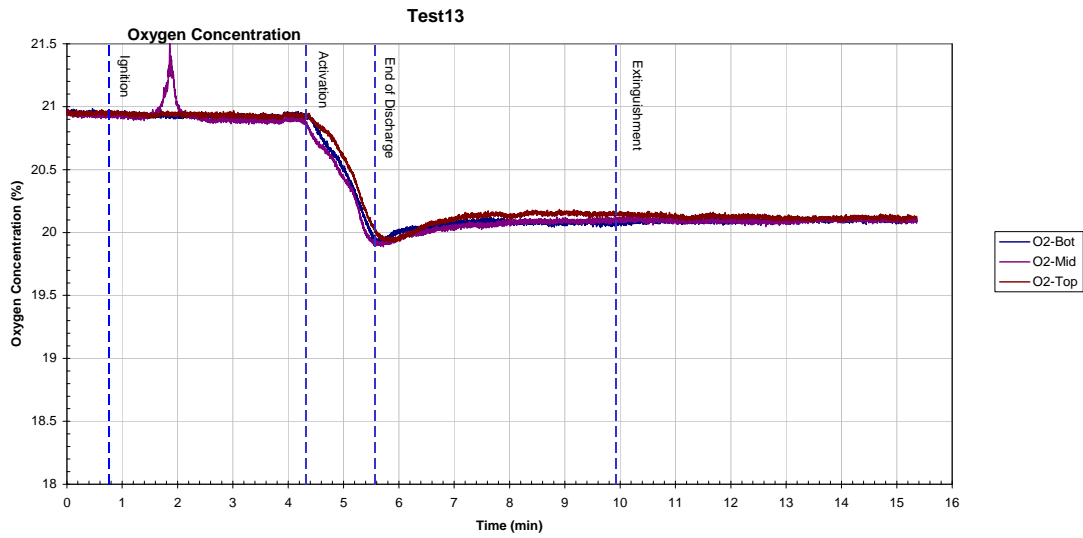


Figure C.76 – Oxygen Concentrations Measured during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 13)

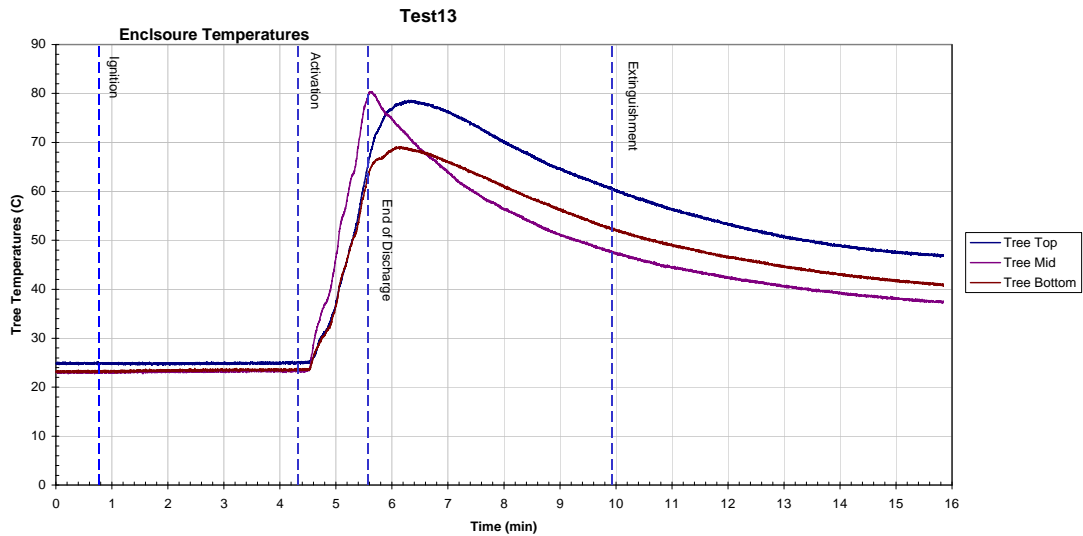


Figure C.77 – Enclosure Temperatures Measured during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 13)

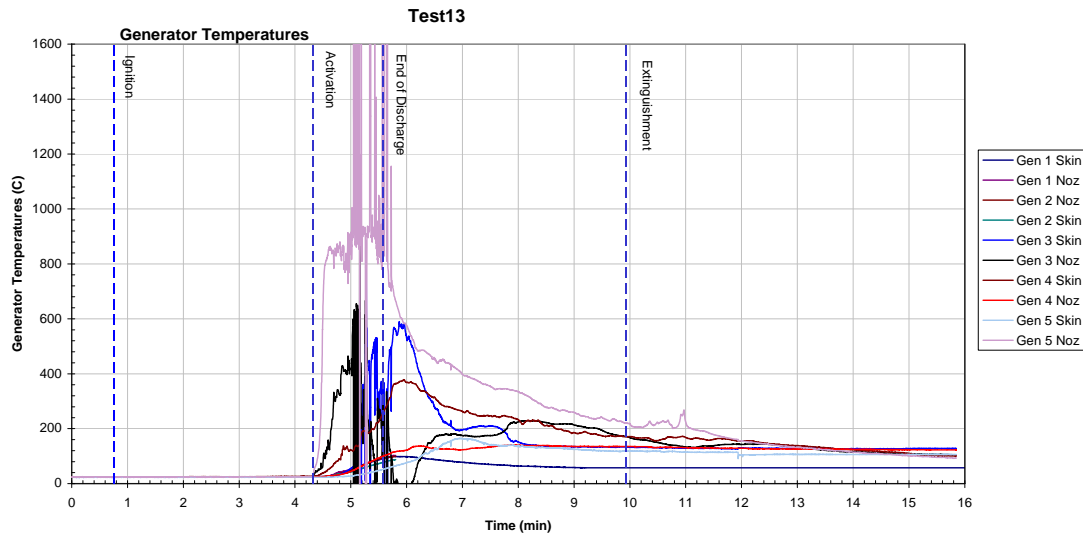


Figure C.78 – Generator Temperatures Measured during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 13)

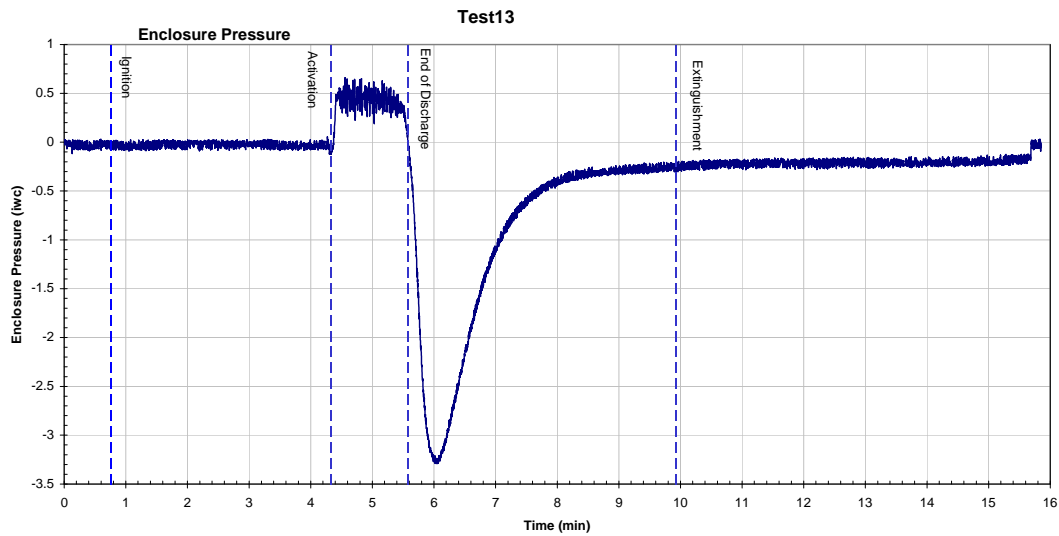


Figure C.79 – Enclosure Pressures Measured during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 13)



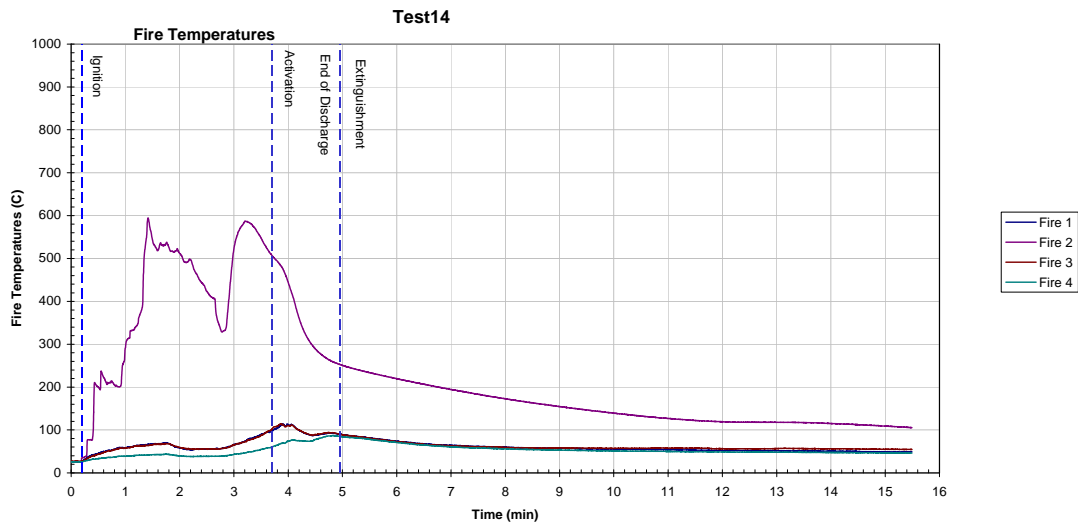


Figure C.80 – Fire Temperatures Measured during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 14)

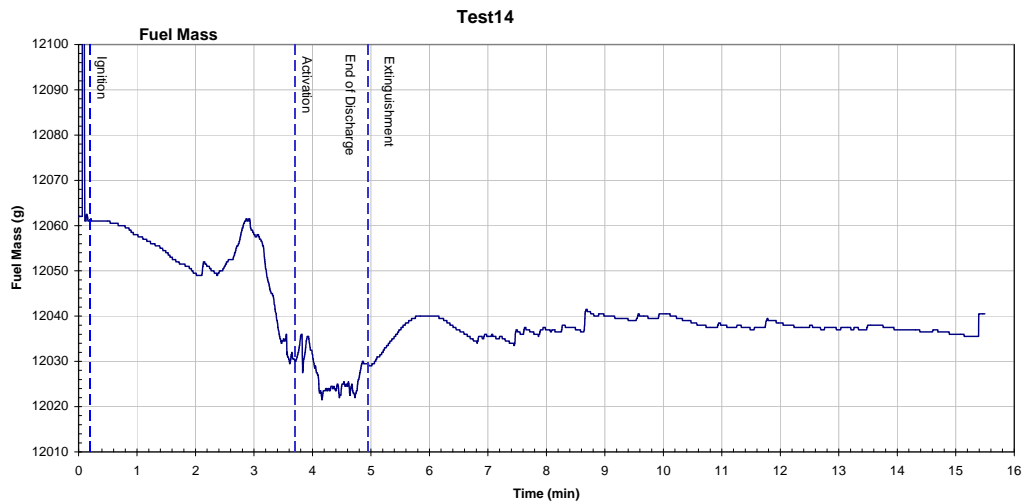


Figure C.81 – Fuel Mass Monitored during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 14)

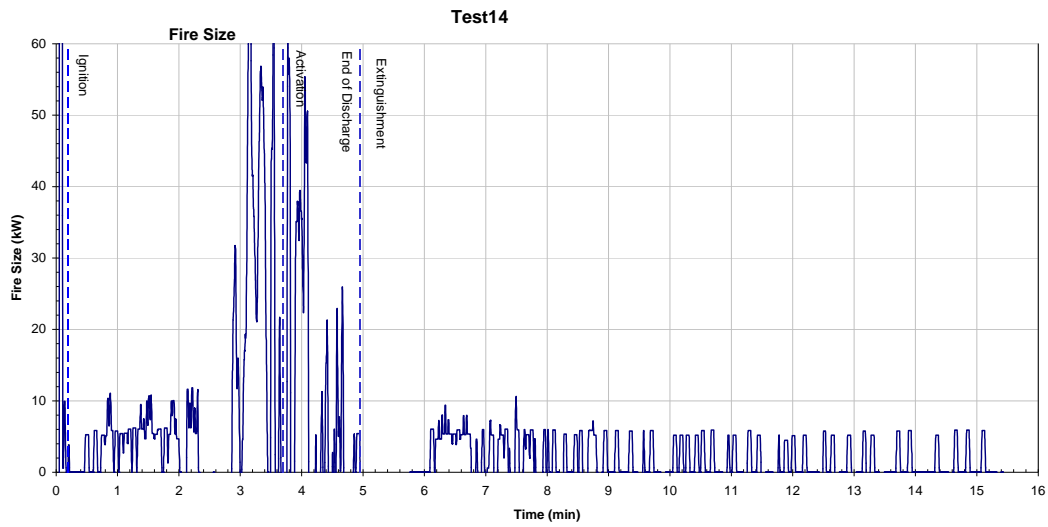


Figure C.82 – Fire Size during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 14)

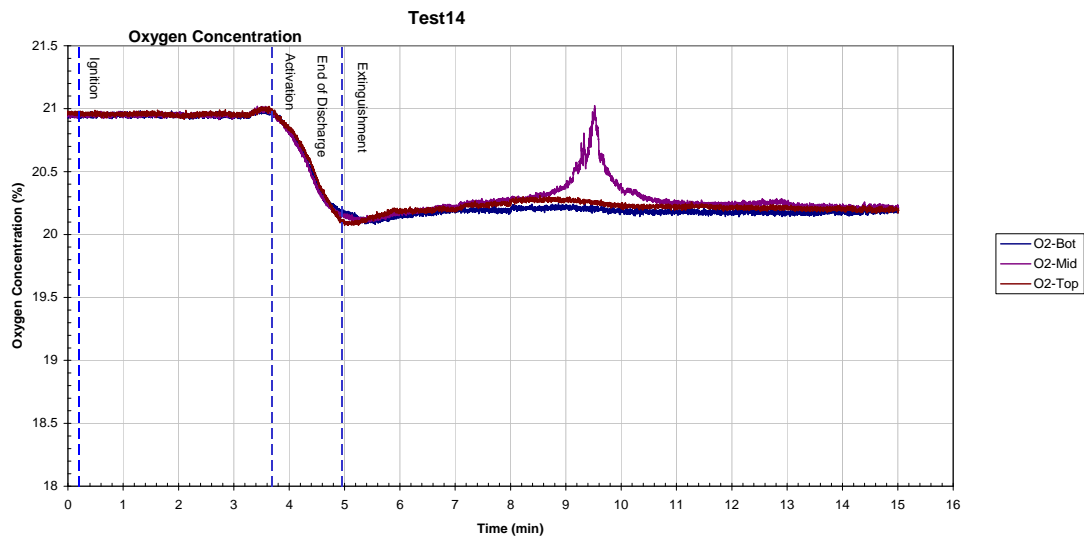


Figure C.83 – Oxygen Concentrations Measured during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 14)

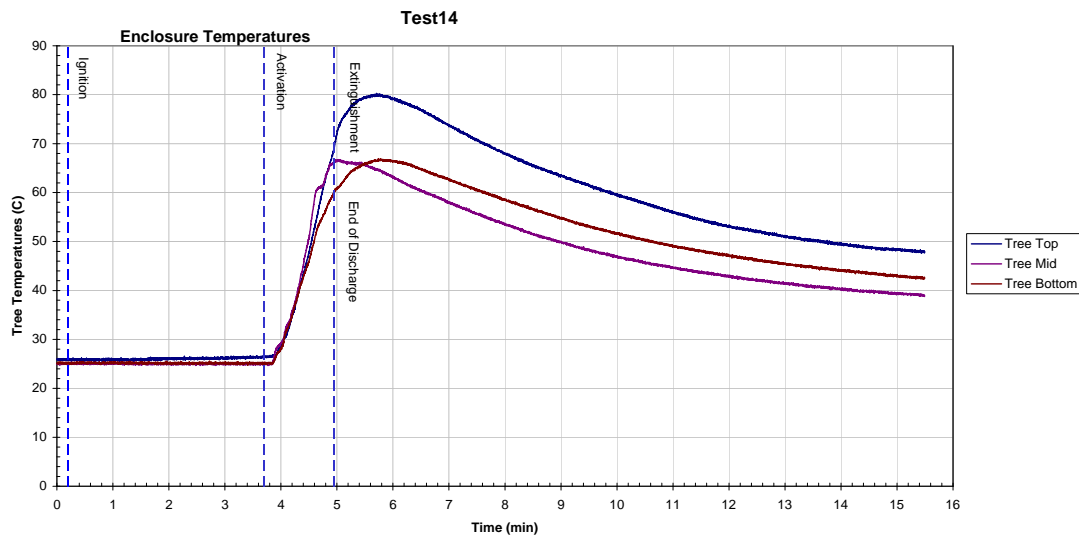


Figure C.84 – Enclosure Temperatures Measured during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 14)

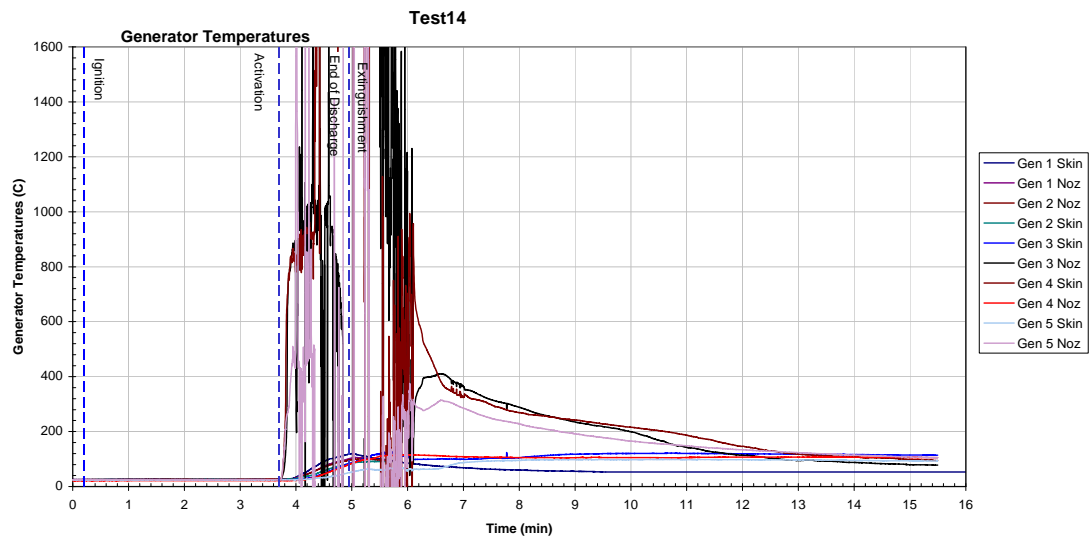


Figure C.85 – Generator Temperatures Measured during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 14)

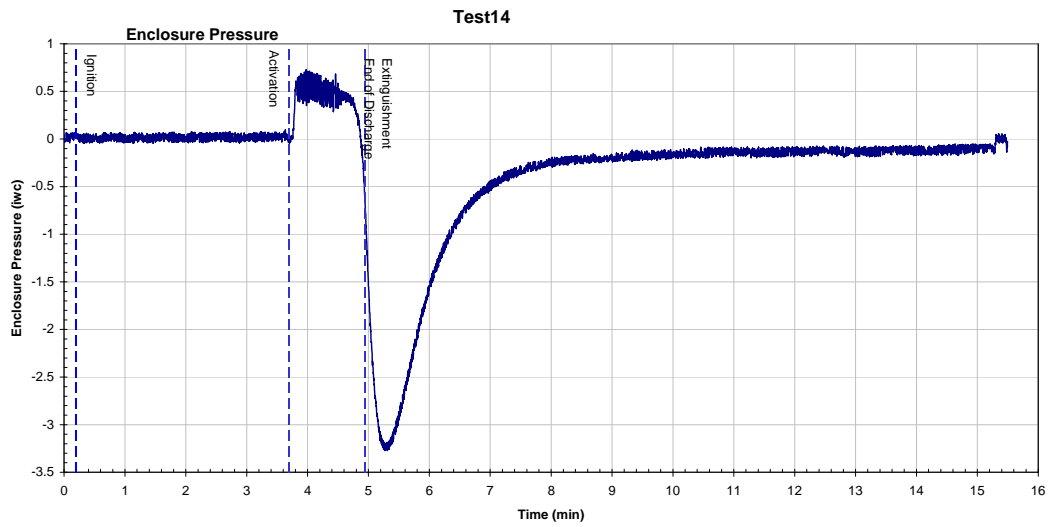


Figure C.86 – Enclosure Pressures Measured during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 14)

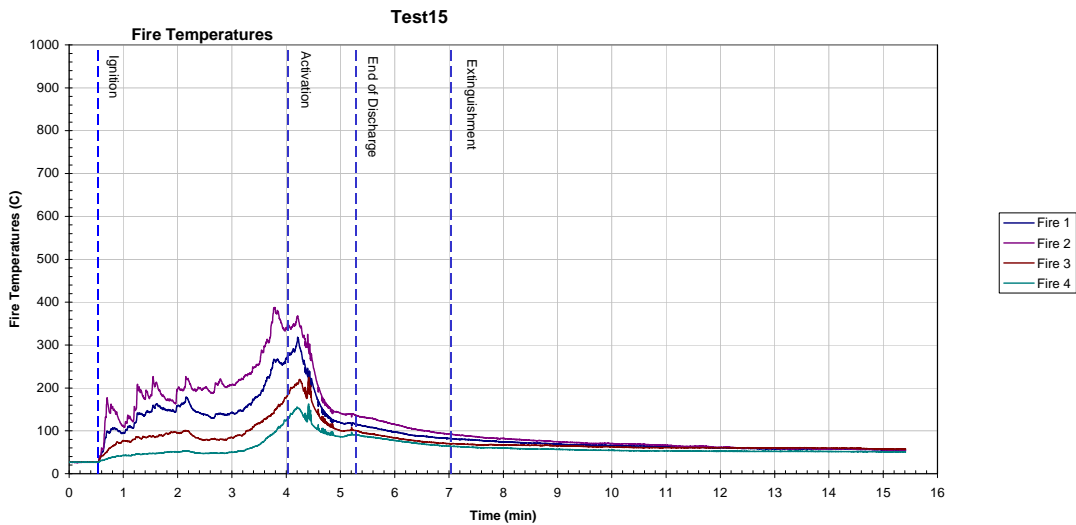


Figure C.87 – Fire Temperatures Measured during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 15)

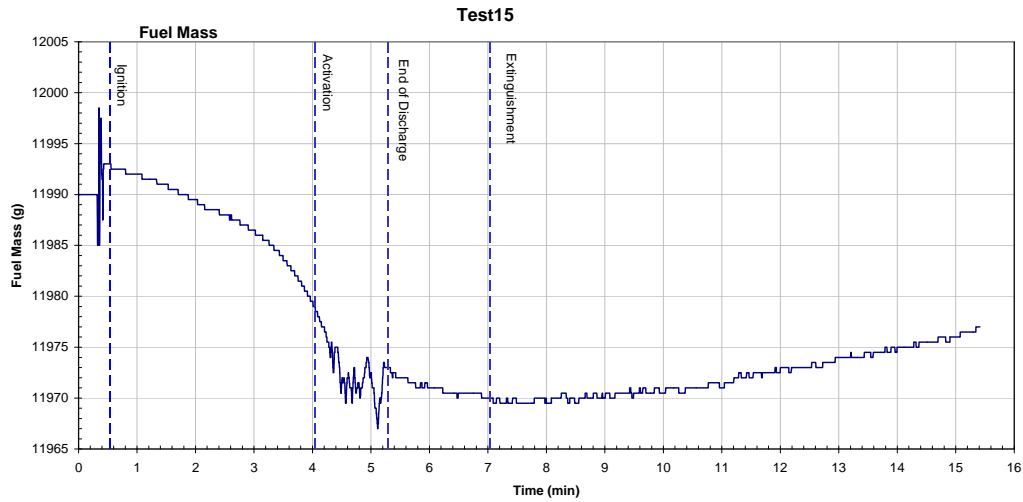


Figure C.88 – Fuel Mass Monitored during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 15)

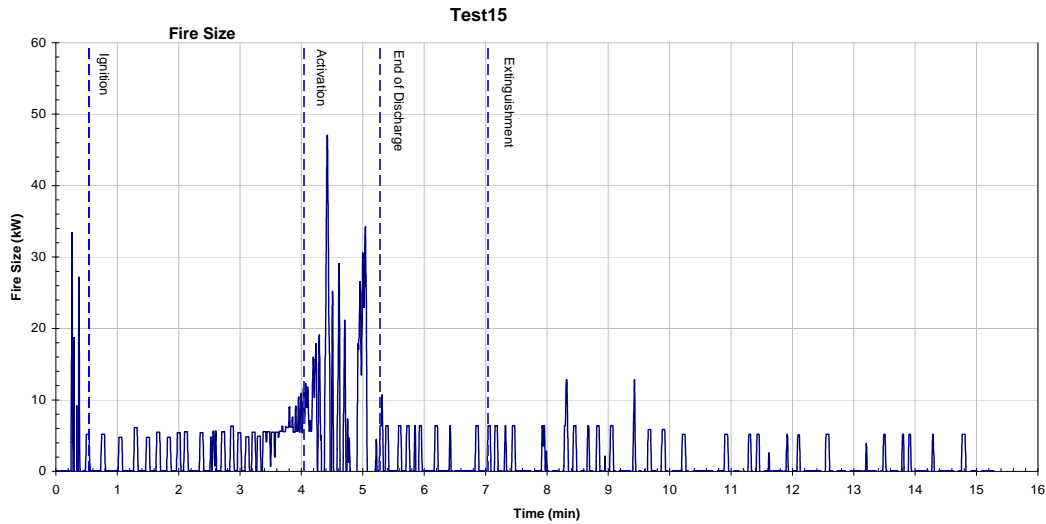


Figure C.89 – Fire Size during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 15)

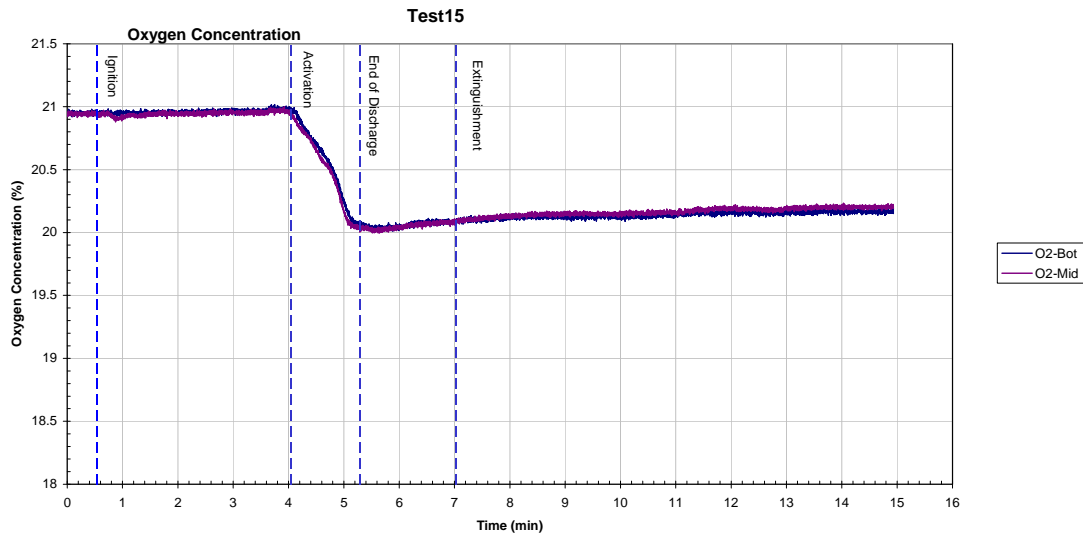


Figure C.90 – Oxygen Concentrations Measured during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 15)

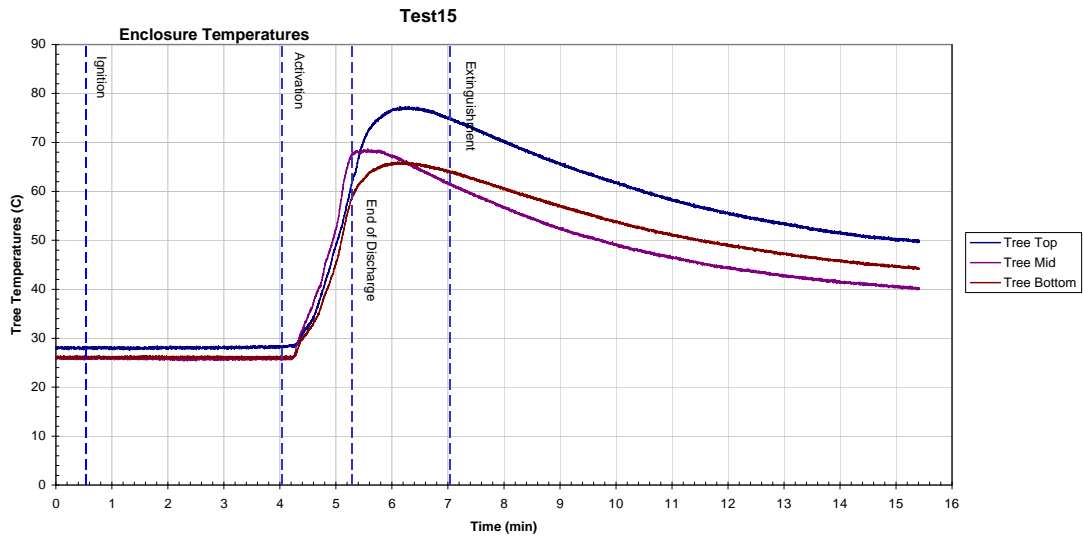


Figure C.91 – Enclosure Temperatures Measured during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 15)

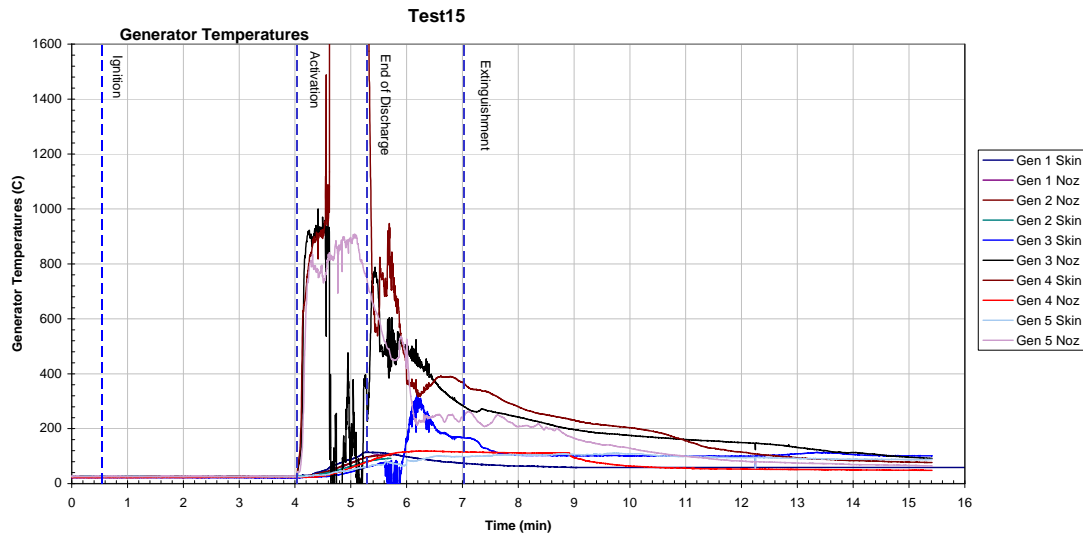


Figure C.92 – Generator Temperatures Measured during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 15)

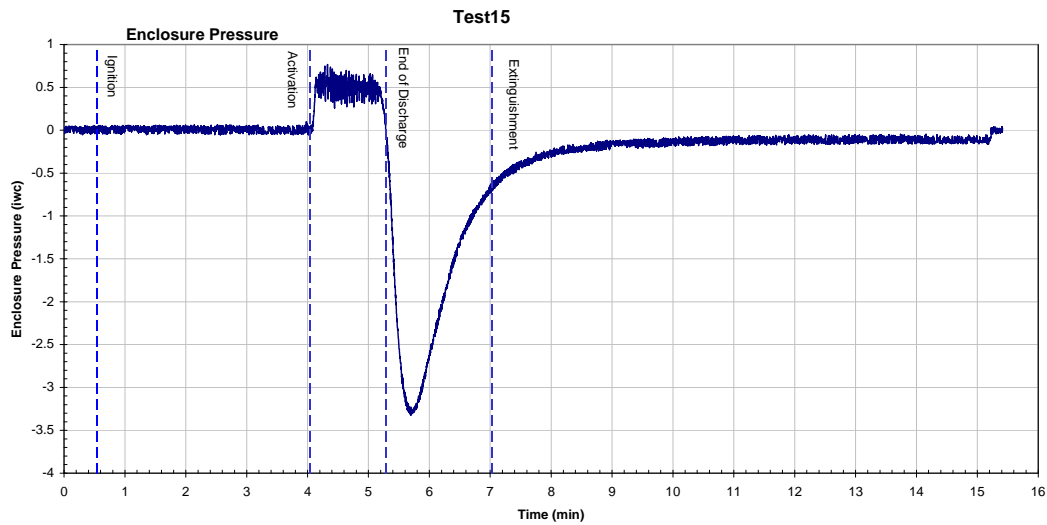


Figure C.93 – Enclosure Pressures Measured during UL Polymeric Materials Test with Polypropylene and Three DSPA Model 8-1 Aerosol Generators for a Loading of  $96.4 \text{ g/m}^3$  (Test 15)

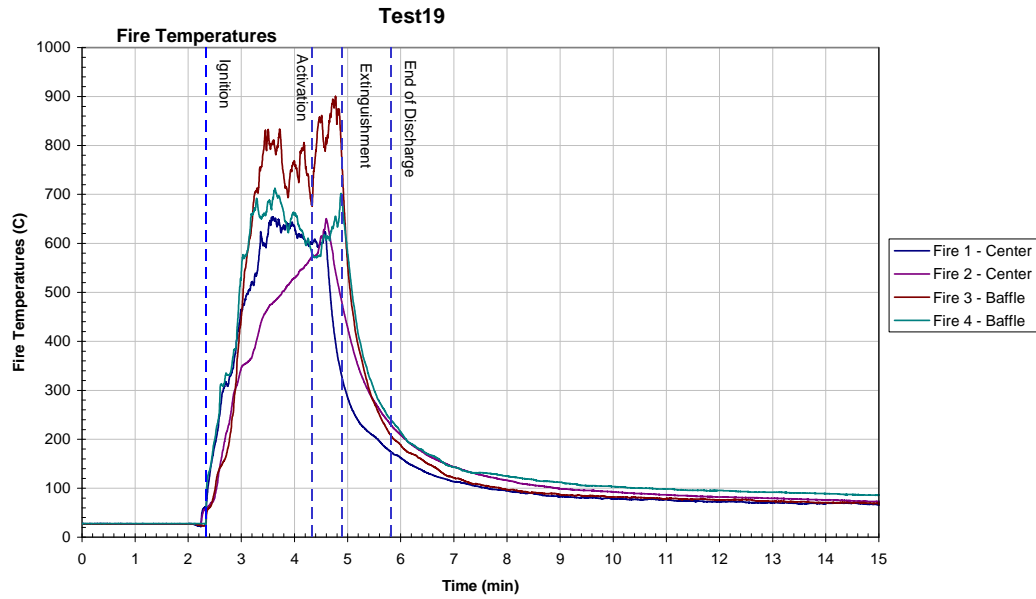


Figure C 109 - Fire Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Four DSPA Model 8-1 Aerosol Generators for a Loading of 128.6  $\text{g/m}^3$  (Test 19)



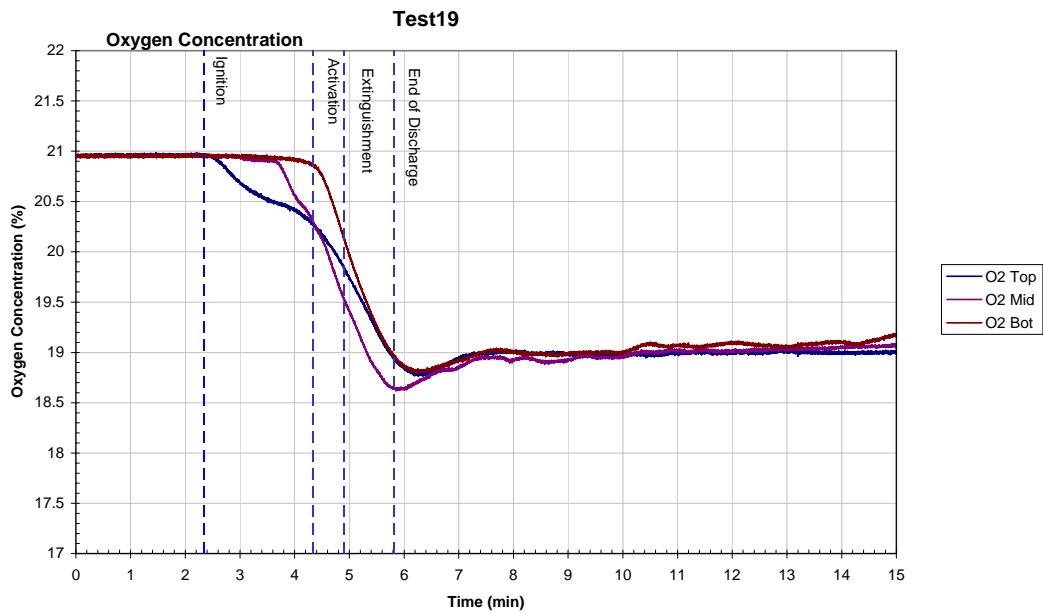


Figure C 110 - Oxygen Concentrations Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Four DSPA Model 8-1 Aerosol Generators for a Loading of 128.6 g/m<sup>3</sup> (Test 19)

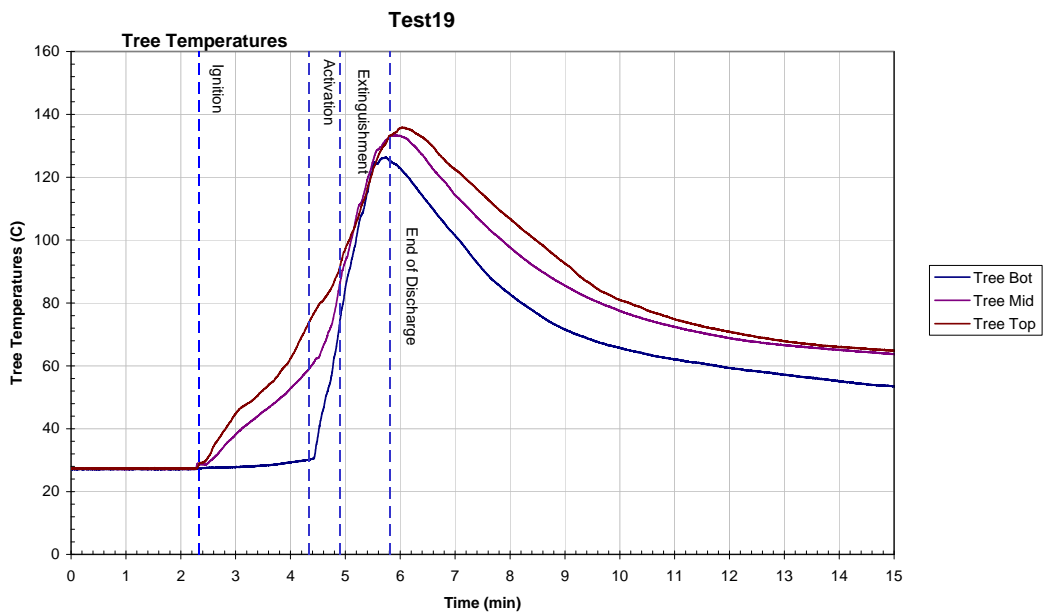


Figure C 111 - Enclosure Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Four DSPA Model 8-1 Aerosol Generators for a Loading of 128.6 g/m<sup>3</sup> (Test 19)

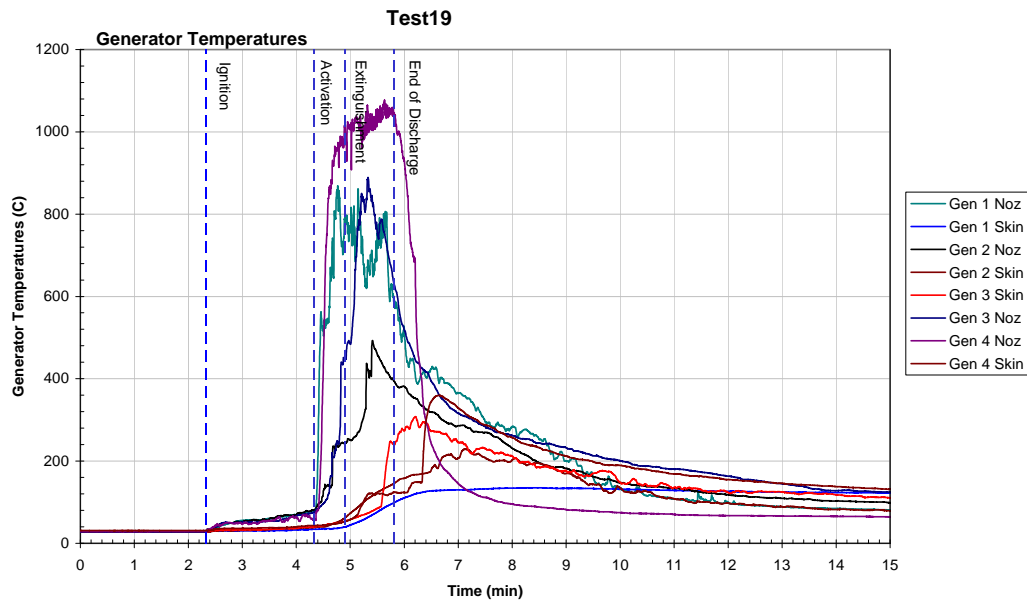


Figure C 112 - Generator Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Four DSPA Model 8-1 Aerosol Generators for a Loading of 128.6 g/m<sup>3</sup> (Test 19)

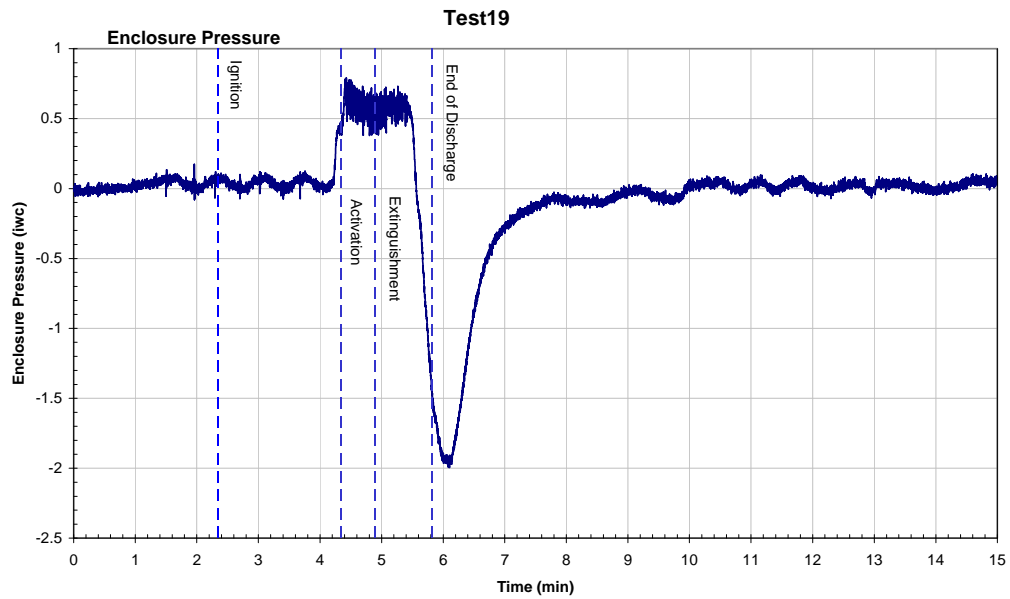


Figure C 113 - Enclosure Pressure Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Four DSPA Model 8-1 Aerosol Generators for a Loading of 128.6 g/m<sup>3</sup> (Test 19)

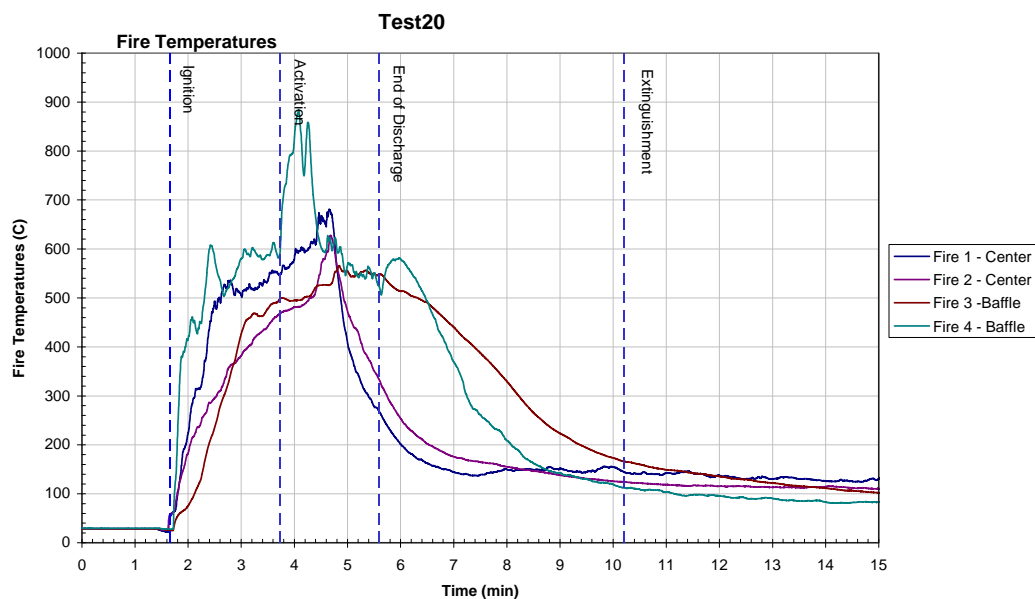


Figure C 114 - Fire Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Four DSPA Model 8-1 Aerosol Generators for a Loading of 128.6 g/m<sup>3</sup> (Test 20)

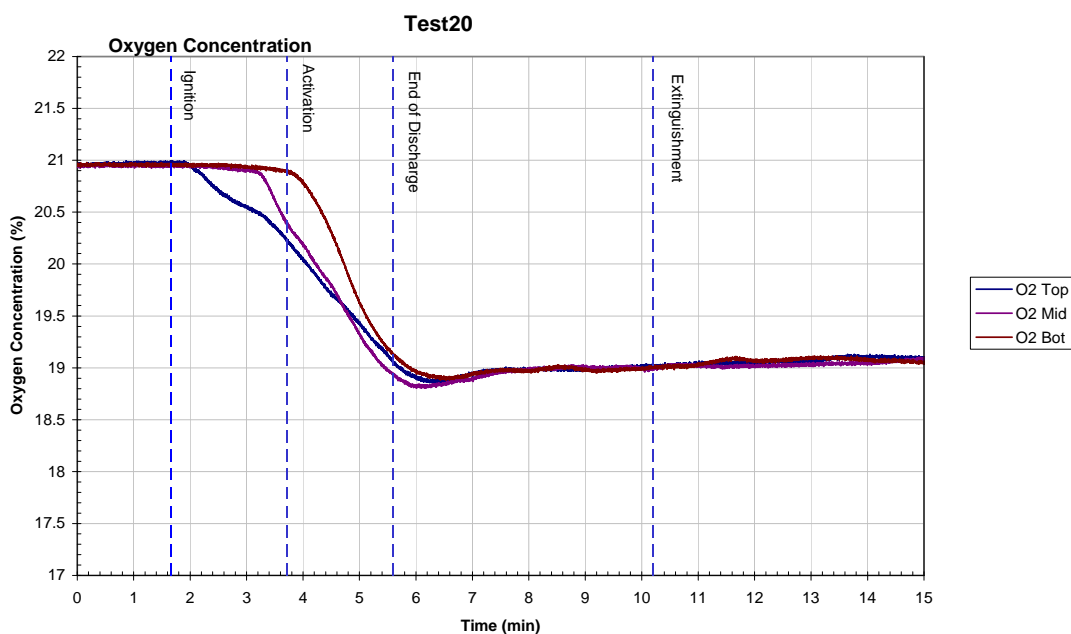


Figure C 115 - Oxygen Concentrations Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Four DSPA Model 8-1 Aerosol Generators for a Loading of 128.6 g/m<sup>3</sup> (Test 20)

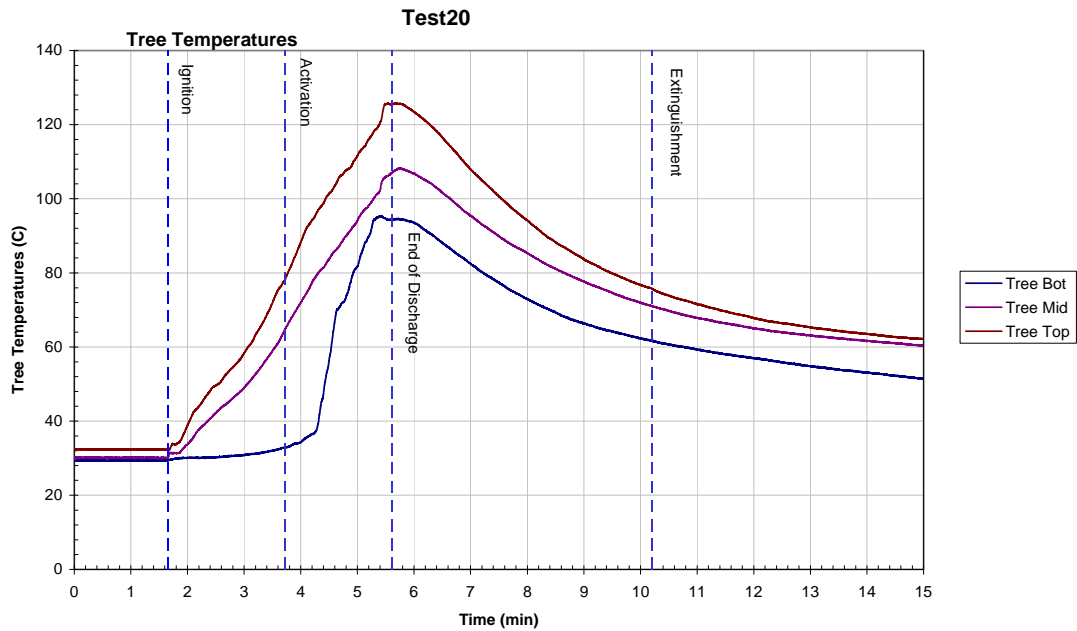


Figure C 116 - Enclosure Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Four DSPA Model 8-1 Aerosol Generators for a Loading of 128.6 g/m<sup>3</sup> (Test 20)

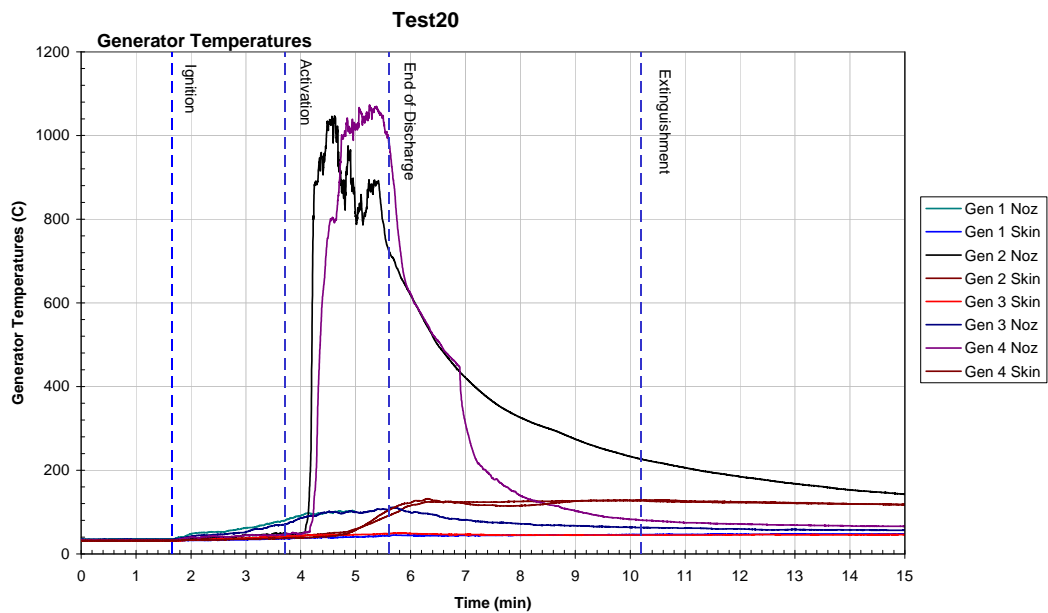


Figure C 117 - Generator Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Four DSPA Model 8-1 Aerosol Generators for a Loading of 128.6 g/m<sup>3</sup> (Test 20)

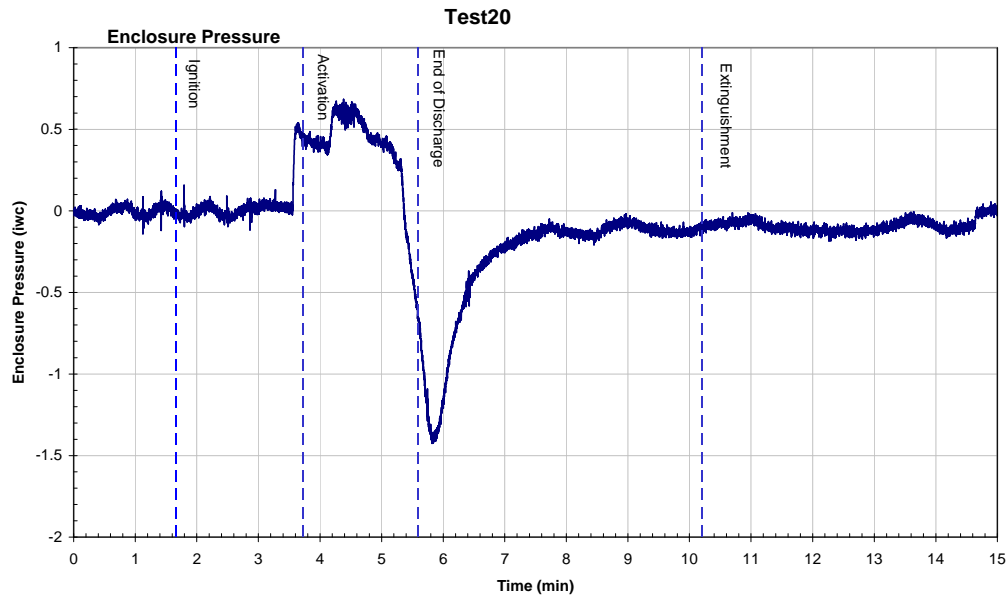


Figure C 118 - Enclosure Pressure Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Four DSPA Model 8-1 Aerosol Generators for a Loading of 128.6  $\text{g/m}^3$  (Test 20)

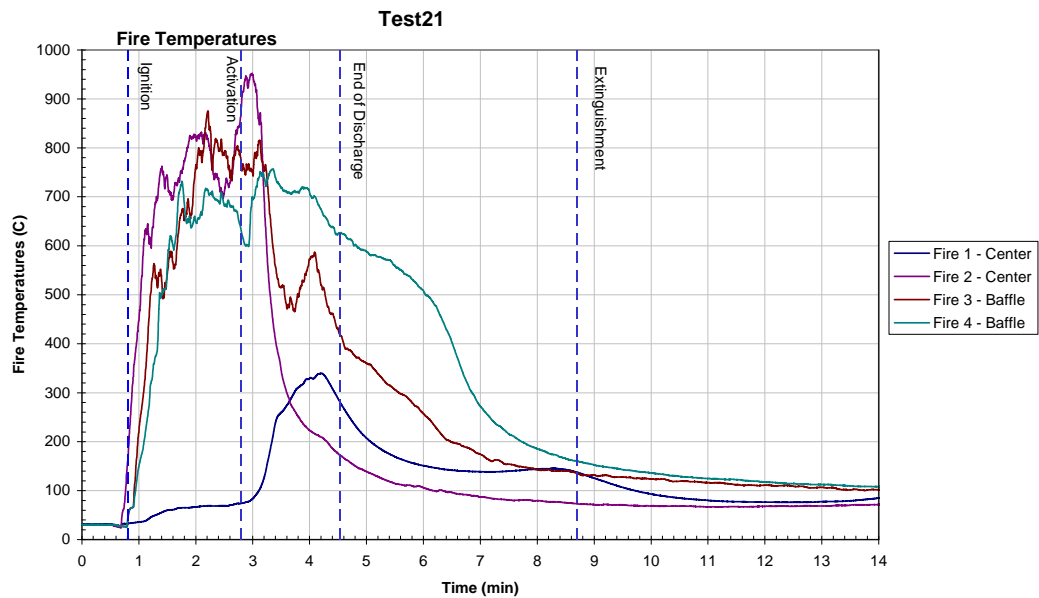


Figure C 119 - Fire Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Four DSPA Model 8-1 Aerosol Generators for a Loading of 128.6  $\text{g/m}^3$  (Test 21)

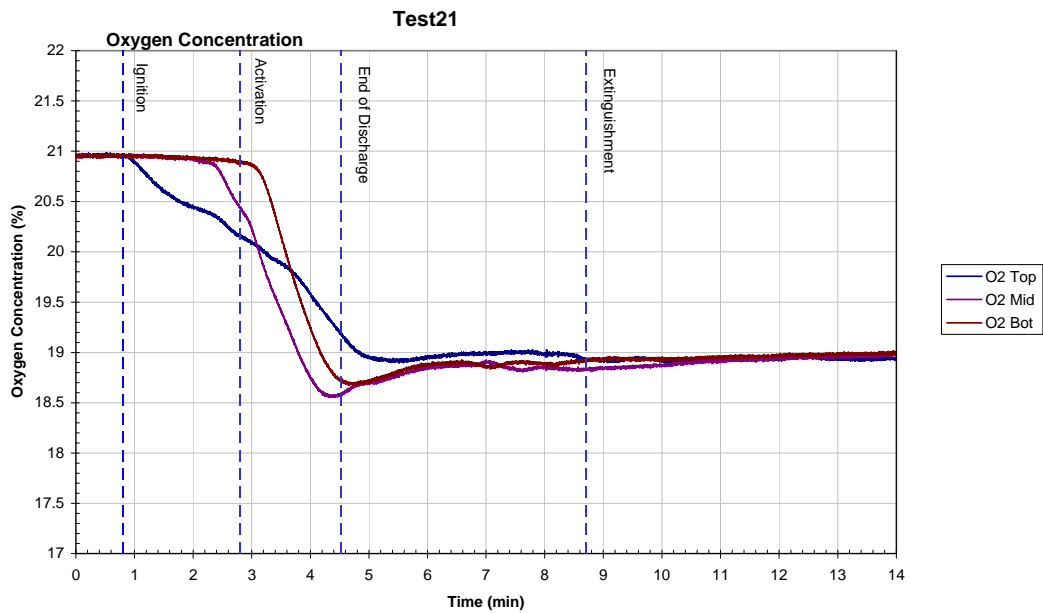


Figure C 120 - Oxygen Concentrations Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Four DSPA Model 8-1 Aerosol Generators for a Loading of 128.6 g/m<sup>3</sup> (Test 21)

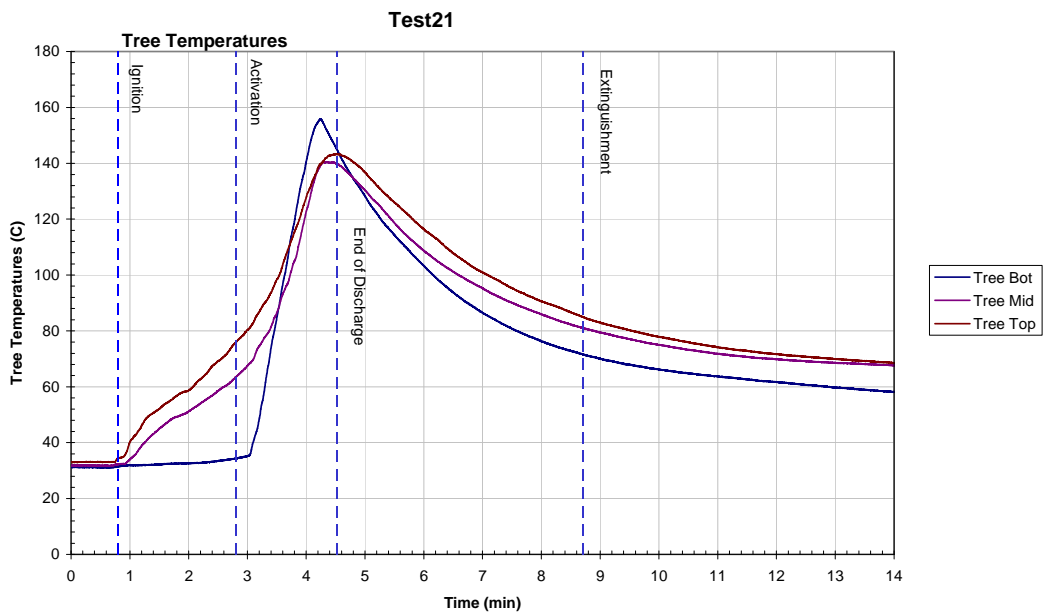


Figure C 121 - Enclosure Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Four DSPA Model 8-1 Aerosol Generators for a Loading of 128.6 g/m<sup>3</sup> (Test 21)

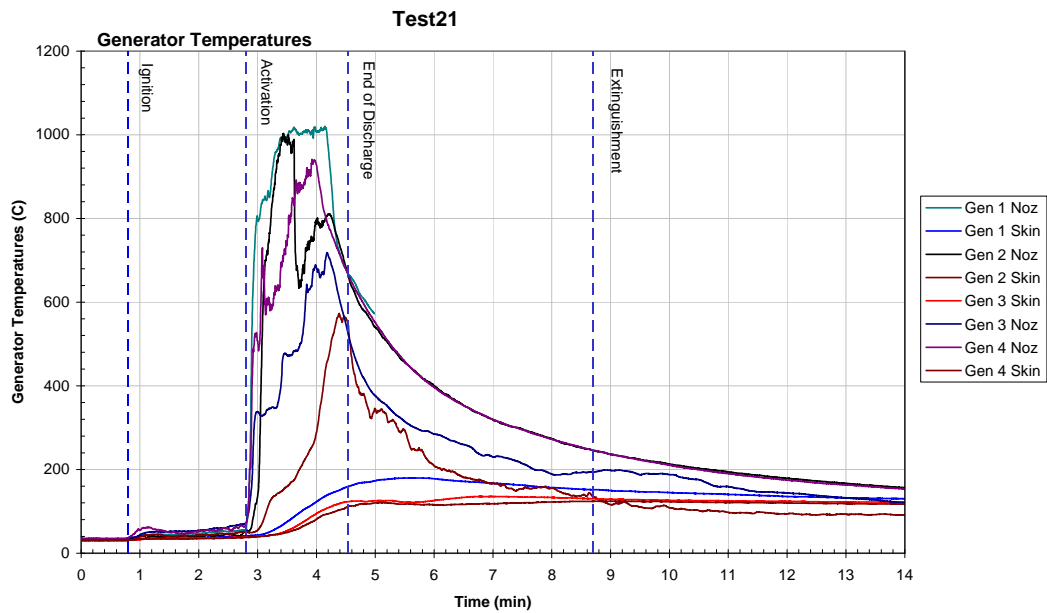


Figure C 122 - Generator Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Four DSPA Model 8-1 Aerosol Generators for a Loading of 128.6 g/m<sup>3</sup> (Test 21)

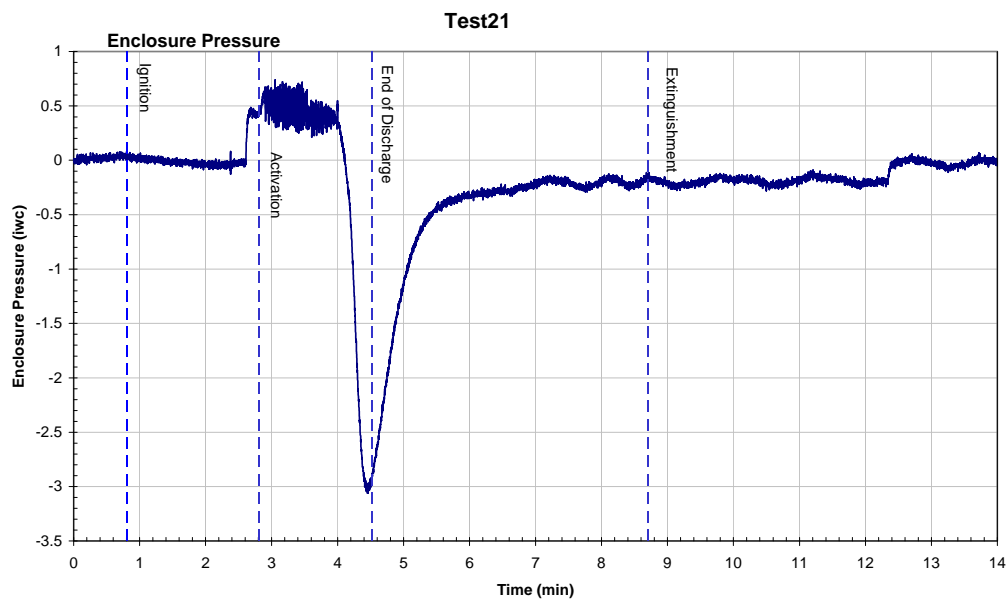


Figure C 123 - Enclosure Pressure Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Four DSPA Model 8-1 Aerosol Generators for a Loading of 128.6 g/m<sup>3</sup> (Test 21)

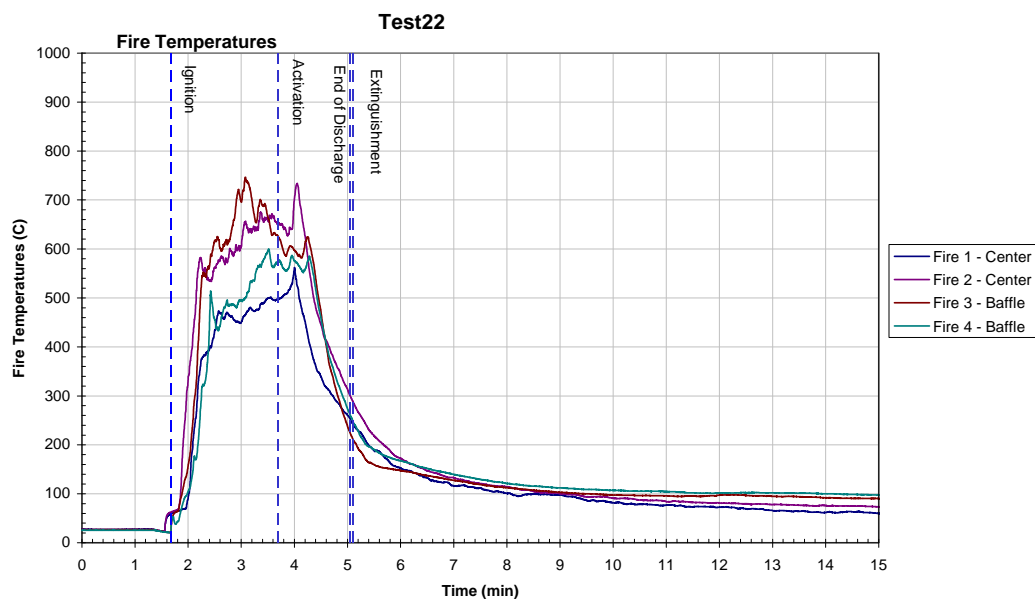


Figure C 124 - Fire Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 22)

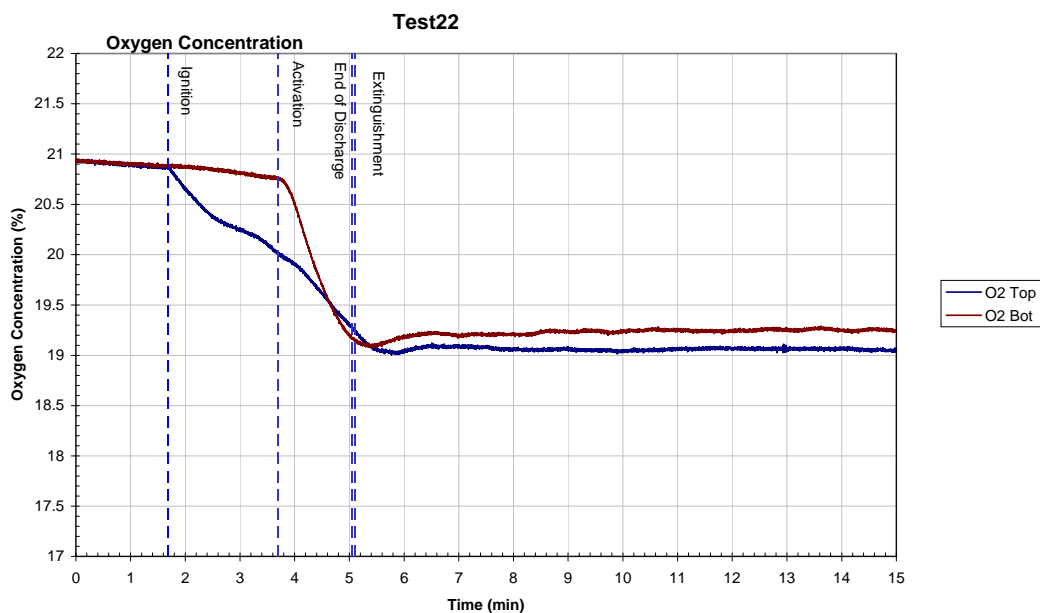


Figure C 125 - Oxygen Concentrations Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 22)



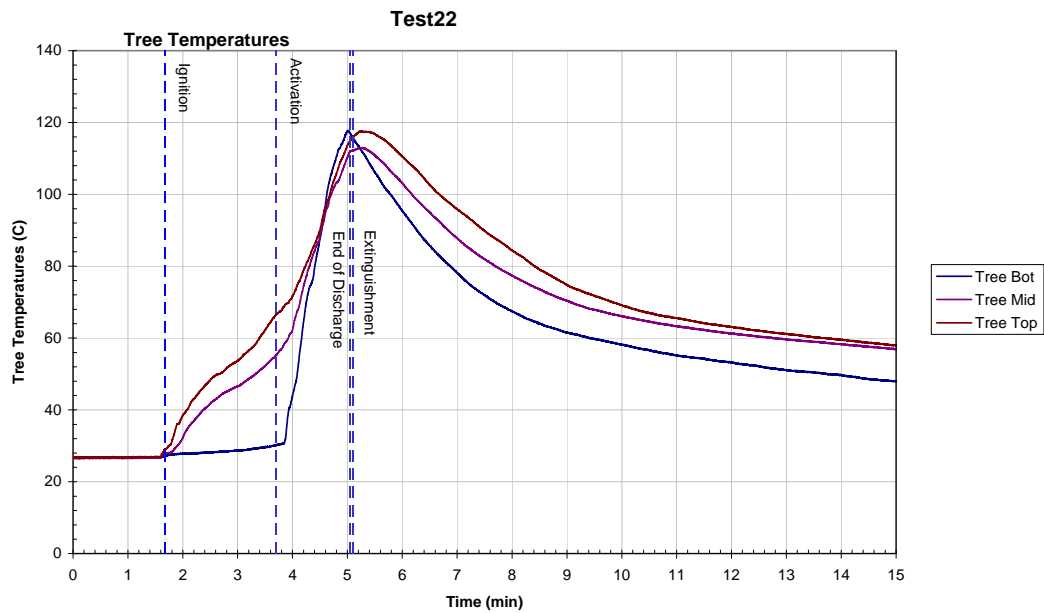


Figure C 126 - Enclosure Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 22)

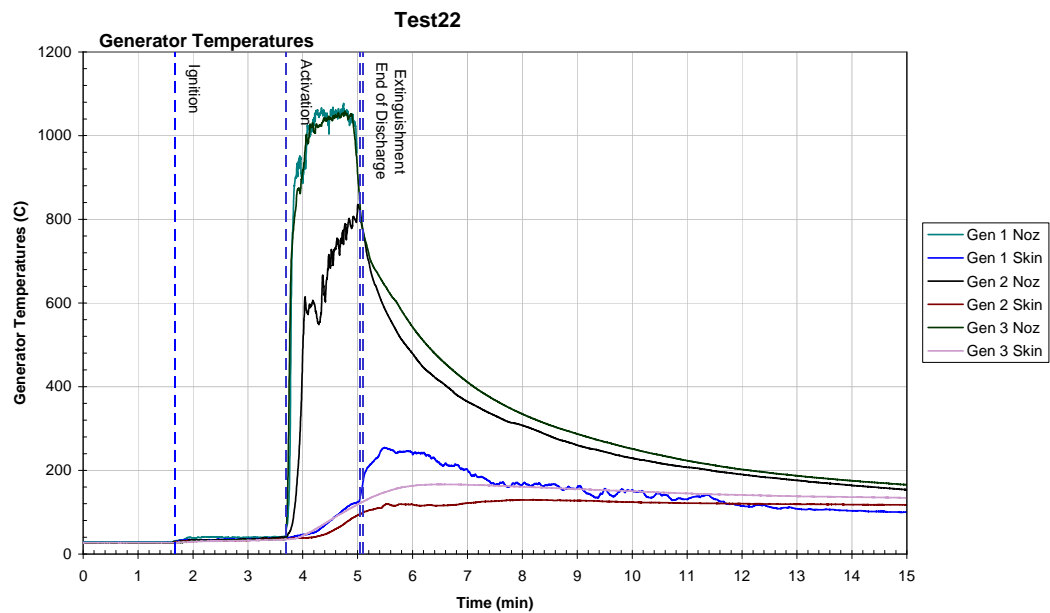


Figure C 127 - Generator Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 22)

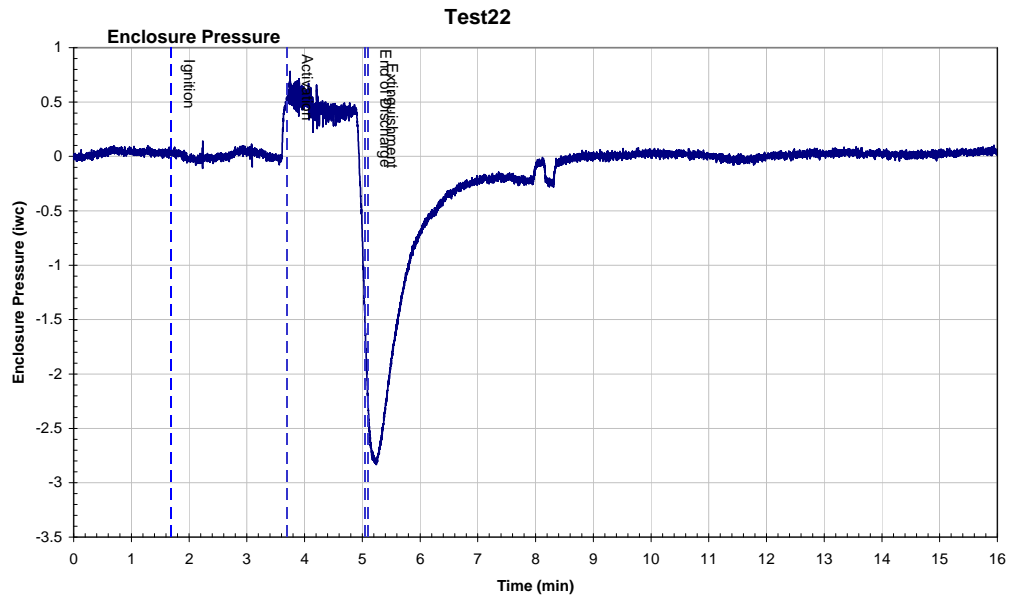


Figure C 128 - Enclosure Pressure Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4  $\text{g/m}^3$  (Test 22)

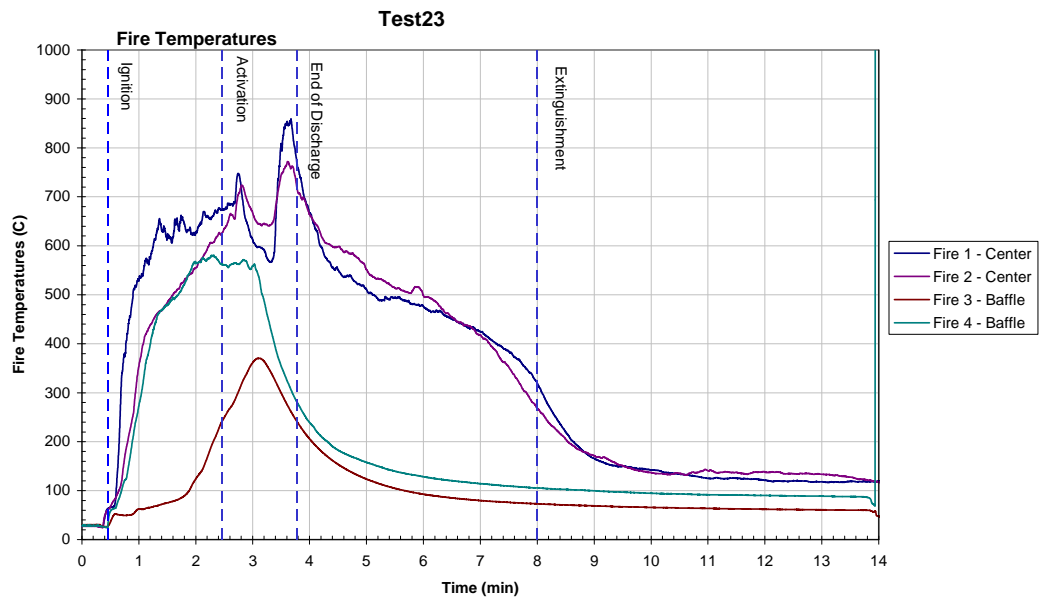


Figure C 129 - Fire Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4  $\text{g/m}^3$  (Test 23)

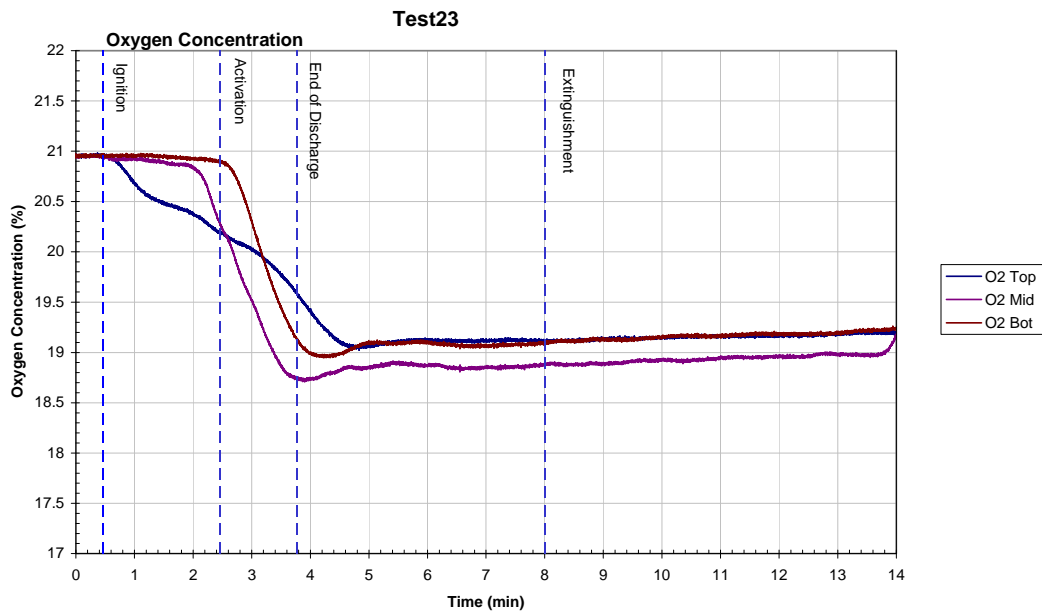


Figure C 130 - Oxygen Concentrations Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 23)

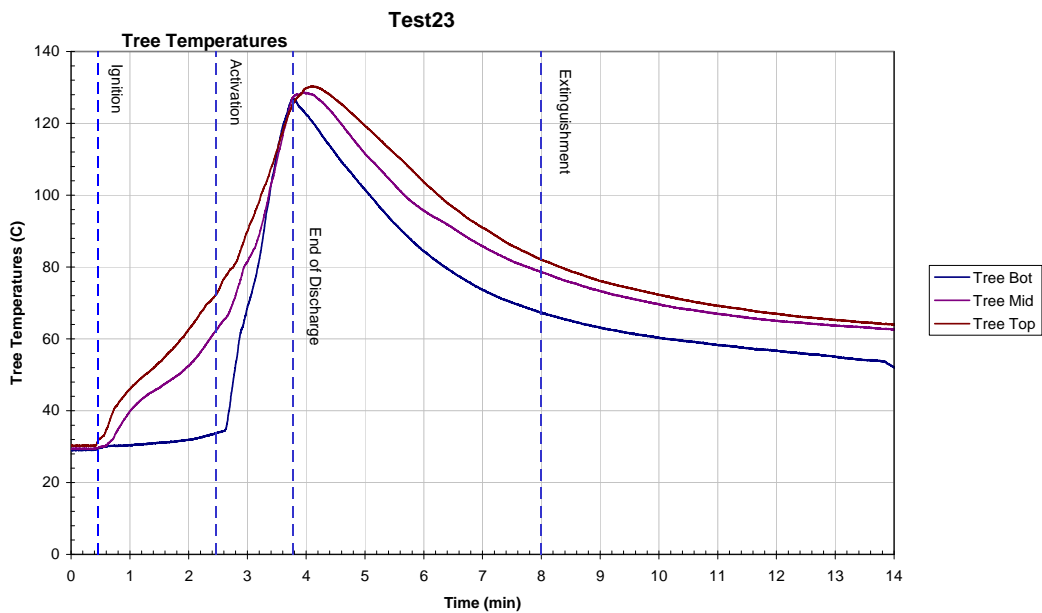


Figure C 131 - Enclosure Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 23)

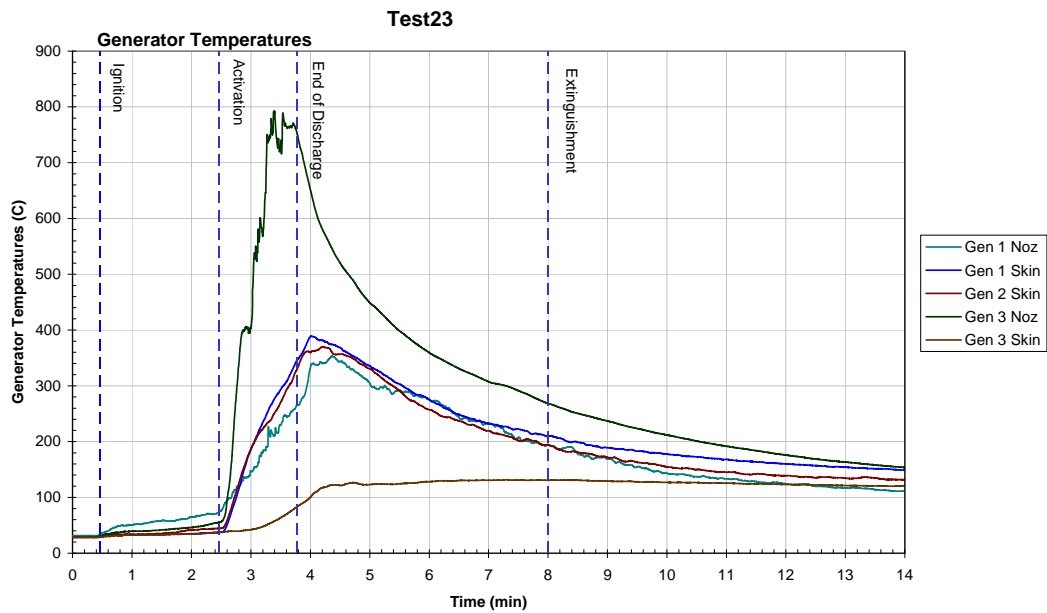


Figure C 132 - Generator Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 23)

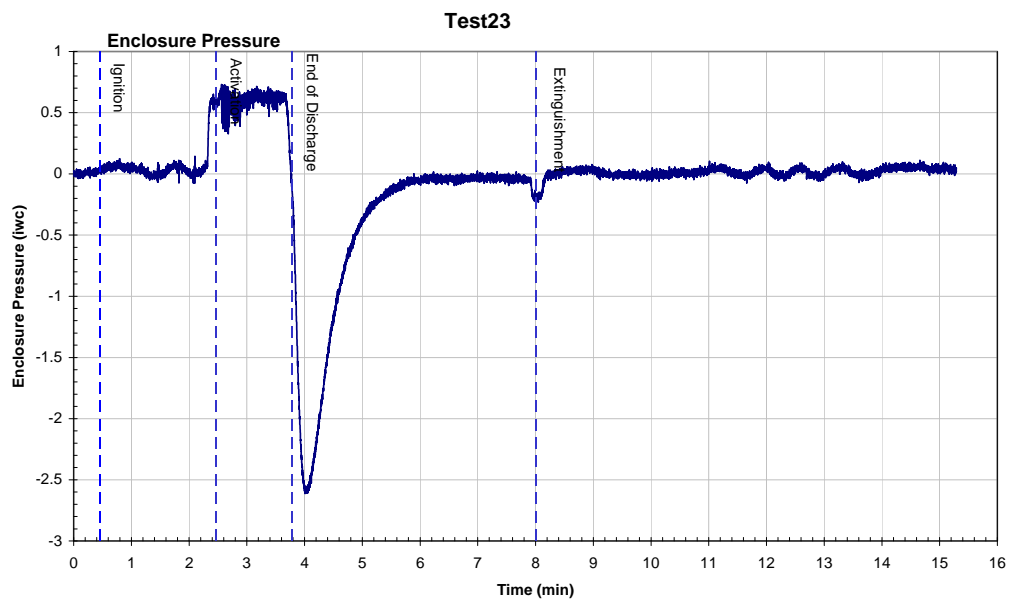


Figure C 133 - Enclosure Pressure Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 23)

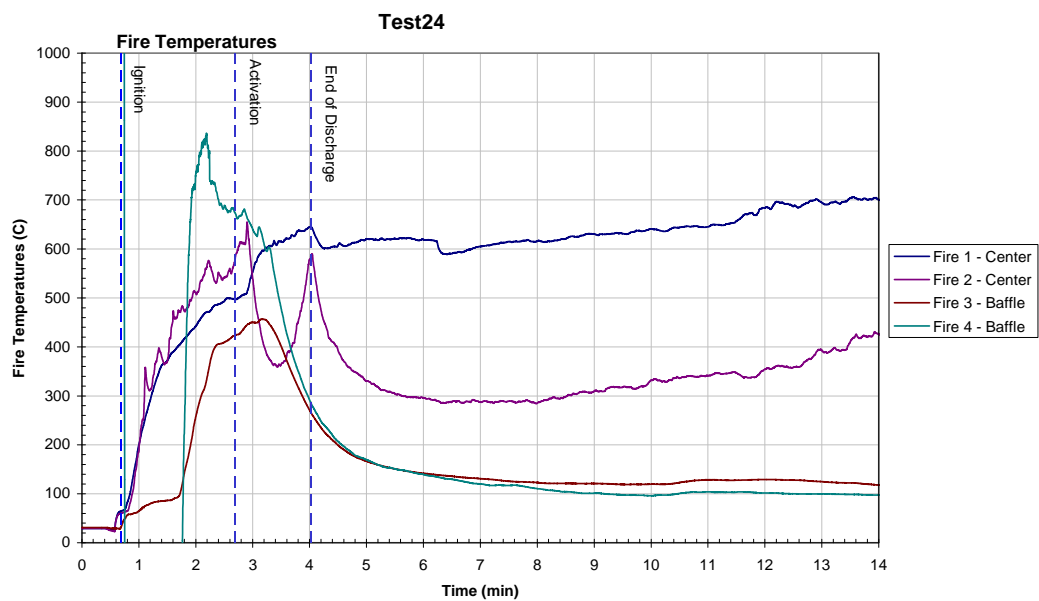


Figure C 134 - Fire Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 24)

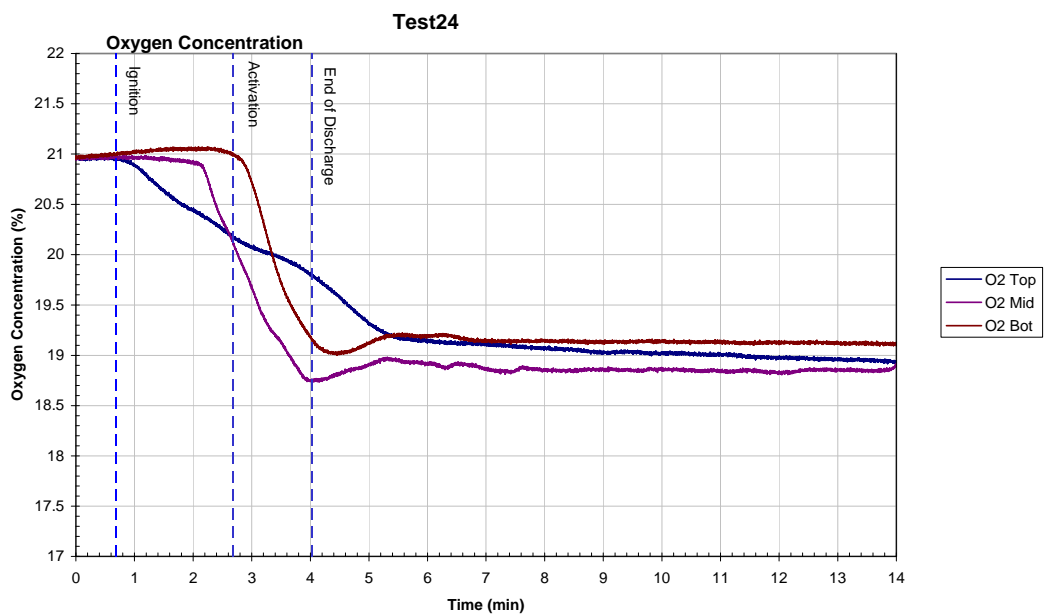


Figure C 135 - Oxygen Concentrations Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 24)

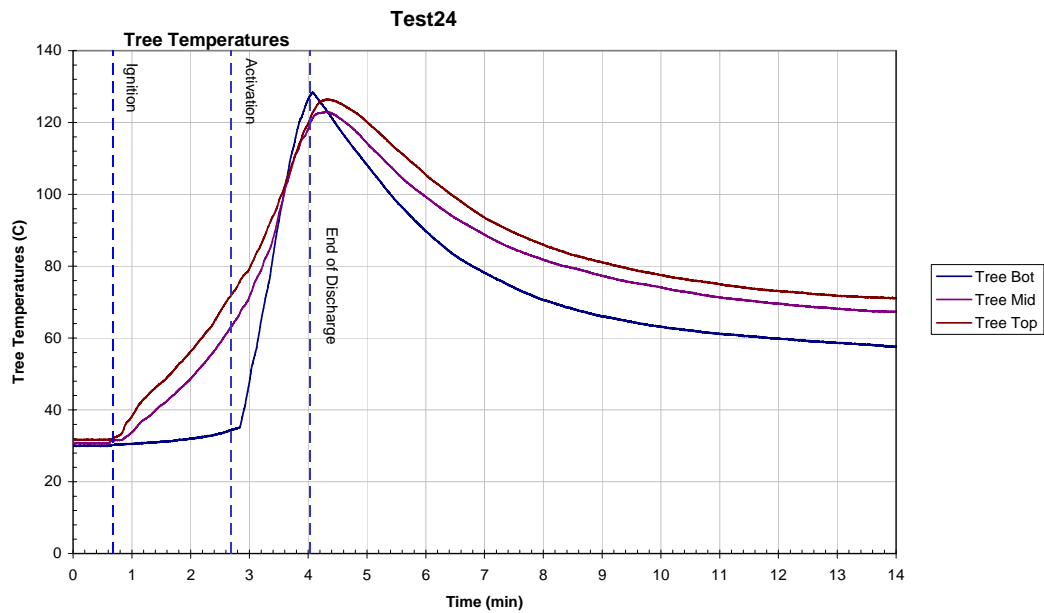


Figure C 136 - Enclosure Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 24)

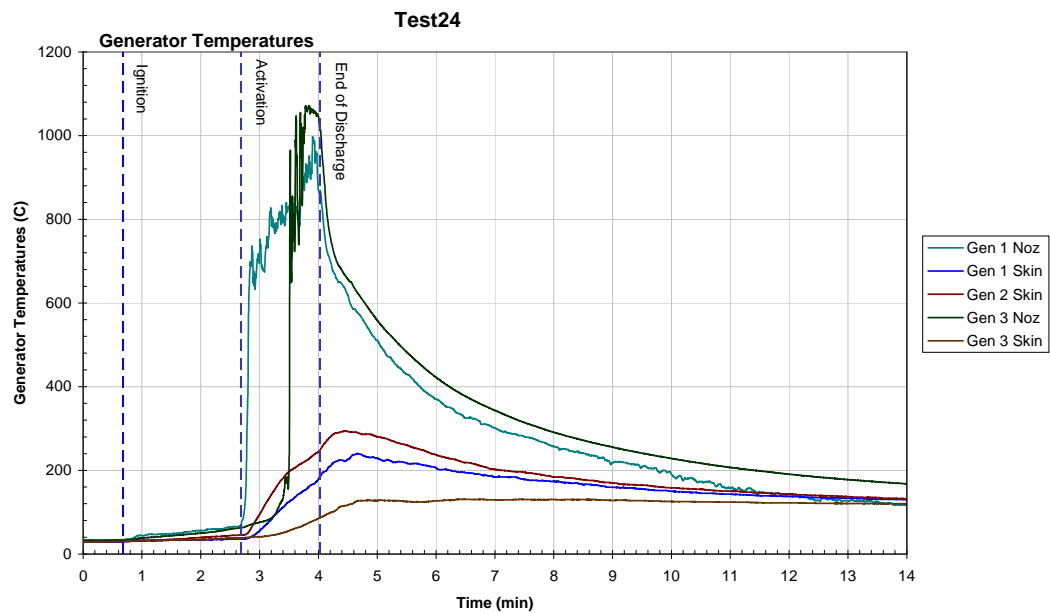


Figure C 137 - Generator Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 24)

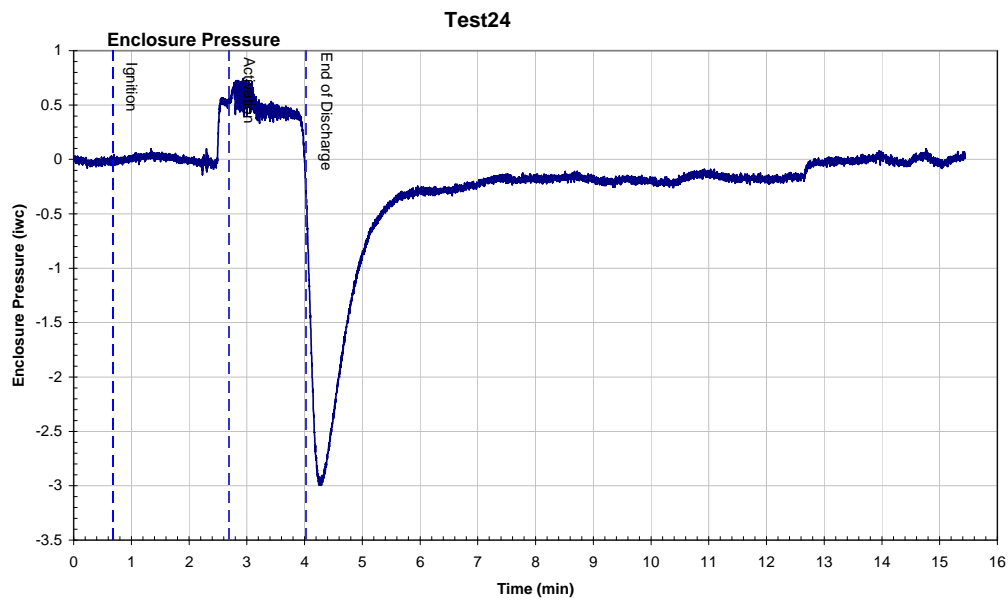


Figure C 138 - Enclosure Pressure Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 24)

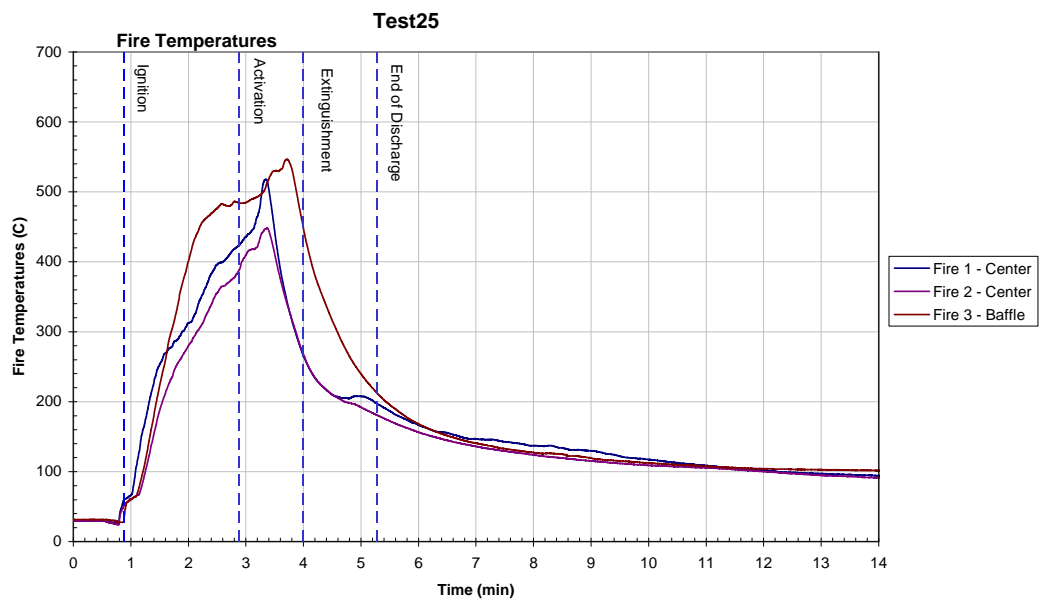


Figure C 139 - Fire Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 25)

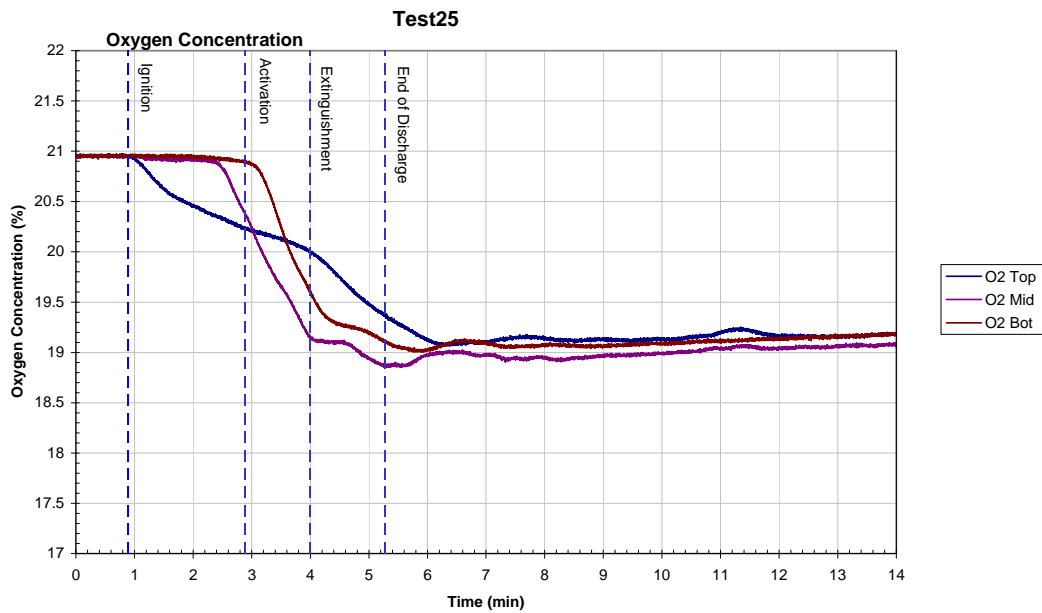


Figure C 140 - Oxygen Concentrations Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 25)

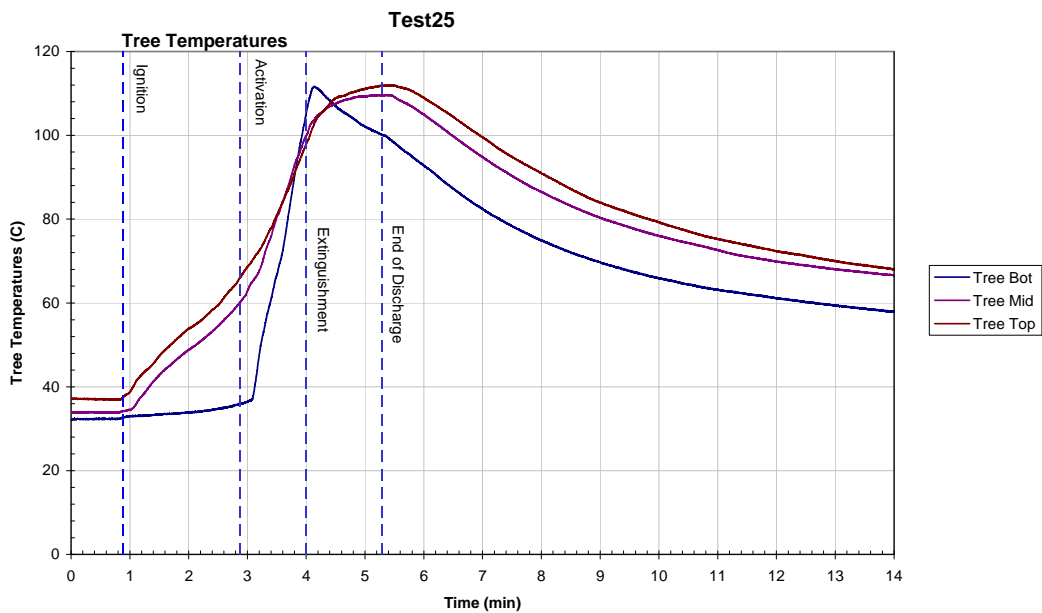


Figure C 141 - Enclosure Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 25)



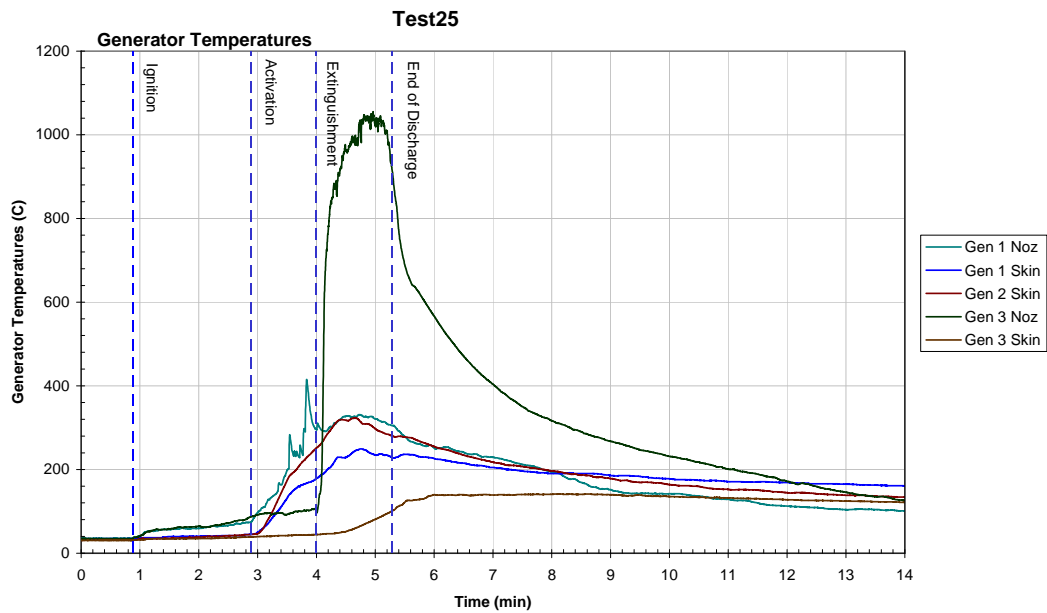


Figure C 142 - Generator Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 25)

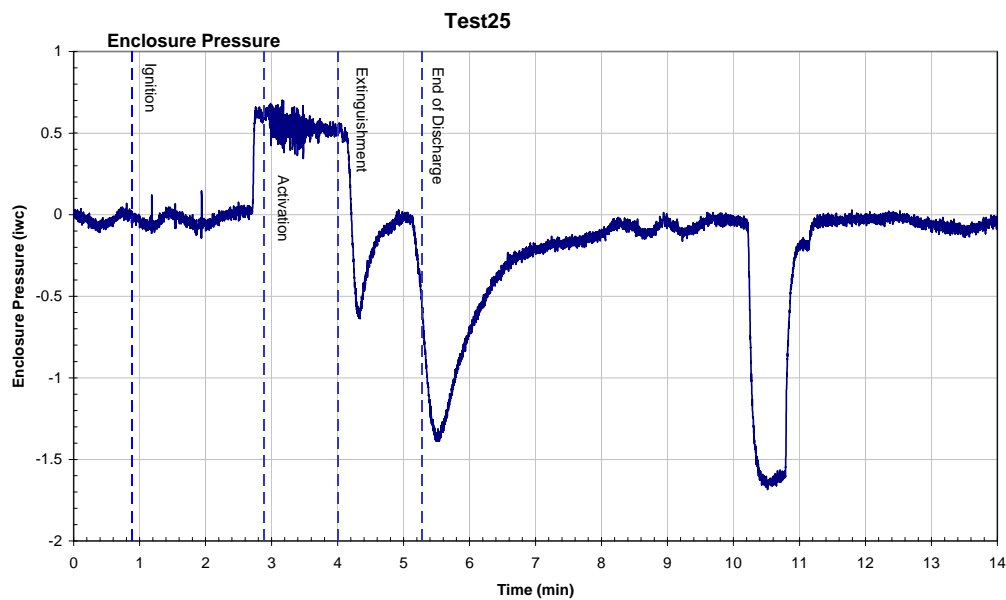


Figure C 143 - Enclosure Pressure Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 25)

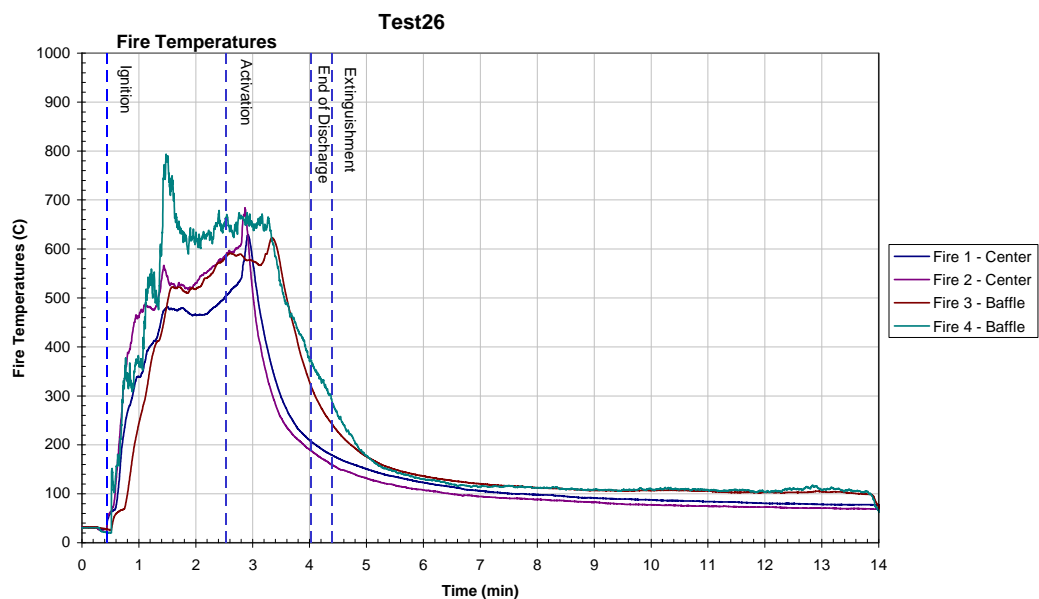


Figure C 144 - Fire Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 26)

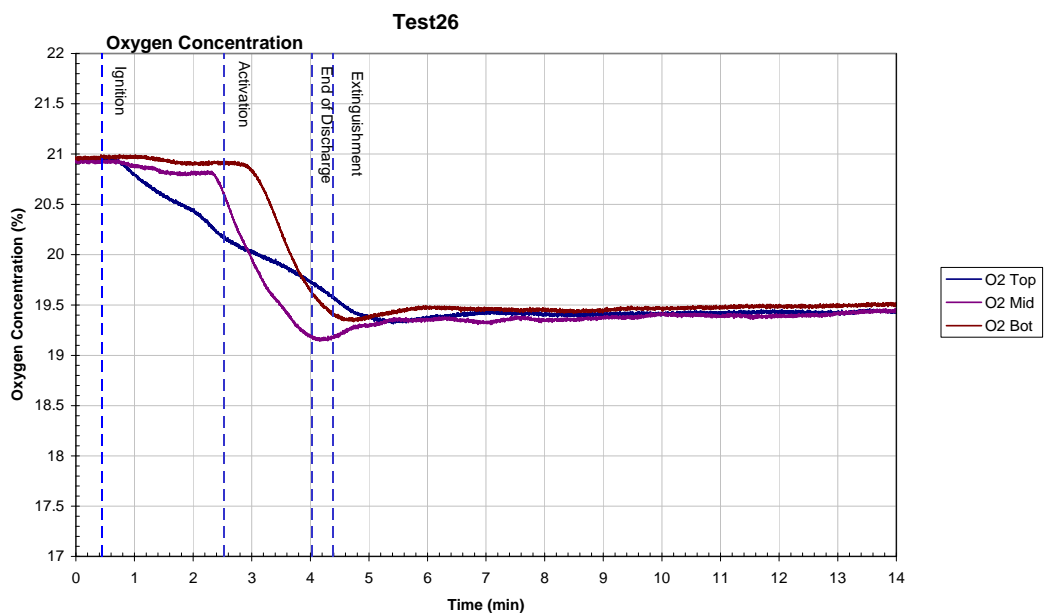


Figure C 145 - Oxygen Concentrations Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 26)

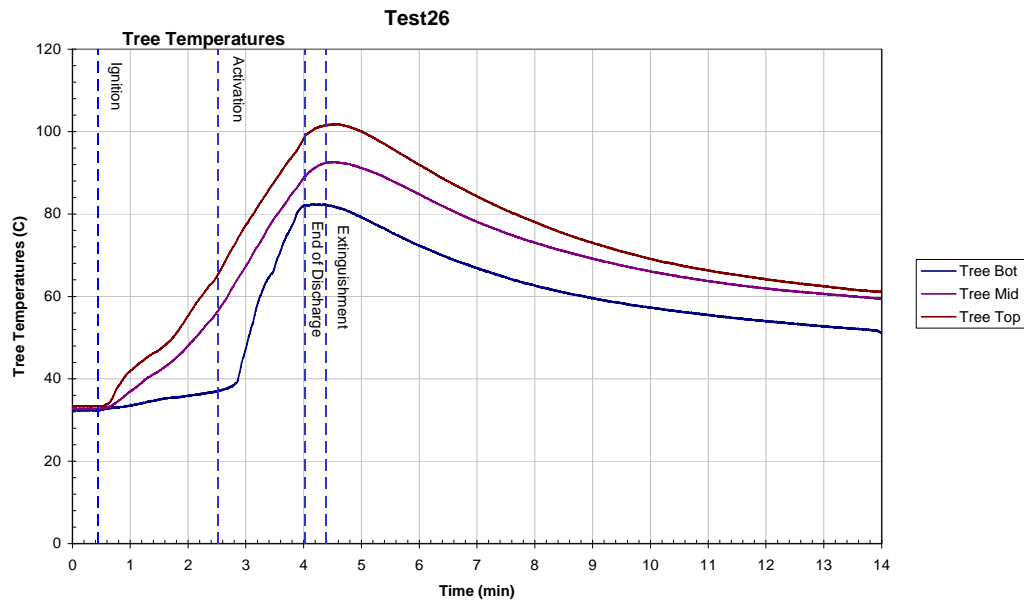


Figure C 146 - Enclosure Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 26)

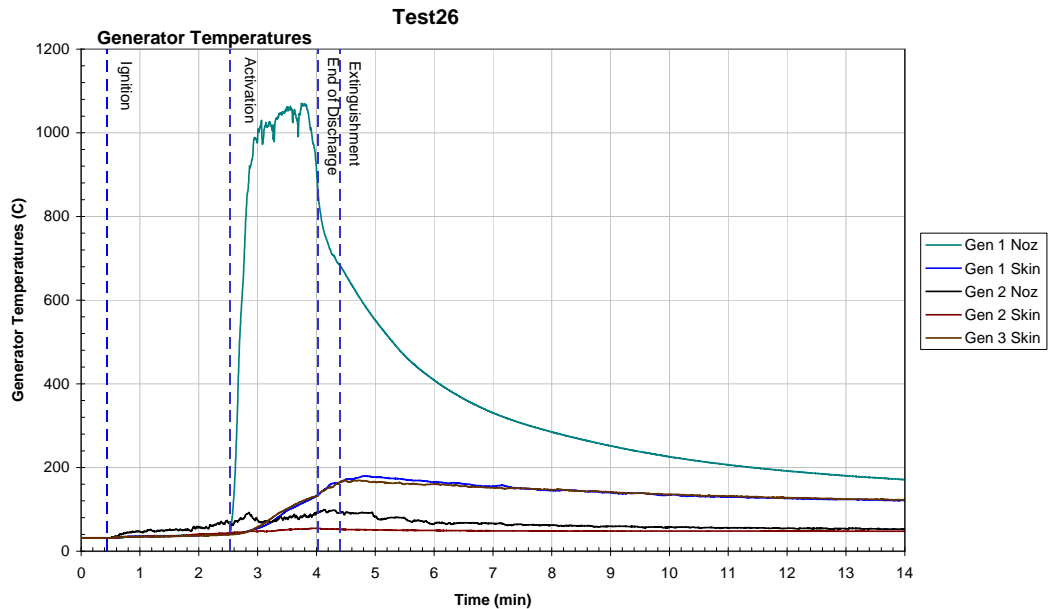


Figure C 147 - Generator Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 26)

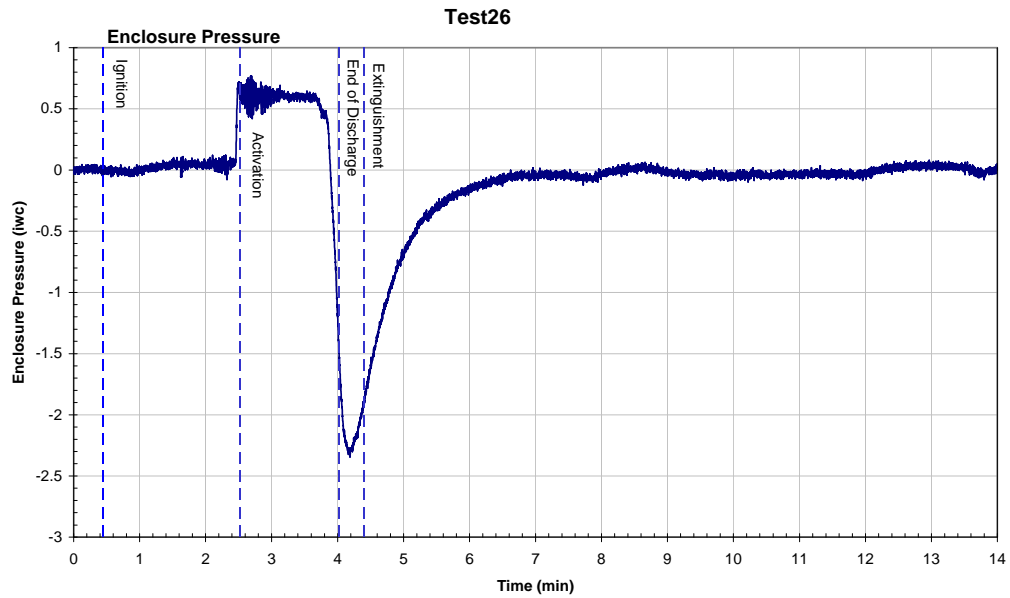


Figure C 148 - Enclosure Pressure Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Three DSPA Model 8-1 Aerosol Generators for a Loading of 96.4 g/m<sup>3</sup> (Test 26)

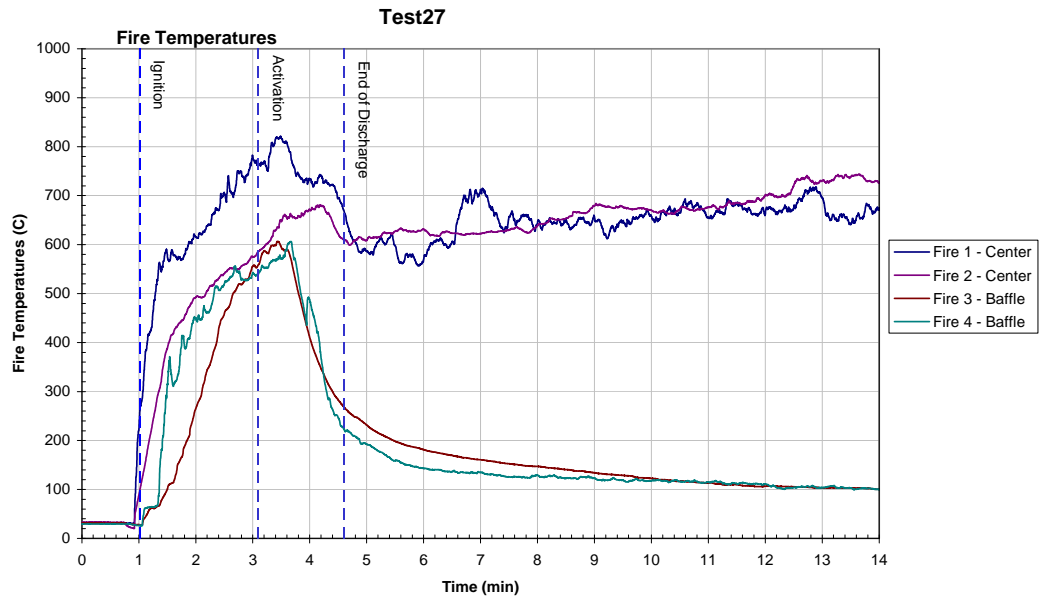


Figure C 149 - Fire Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 27)

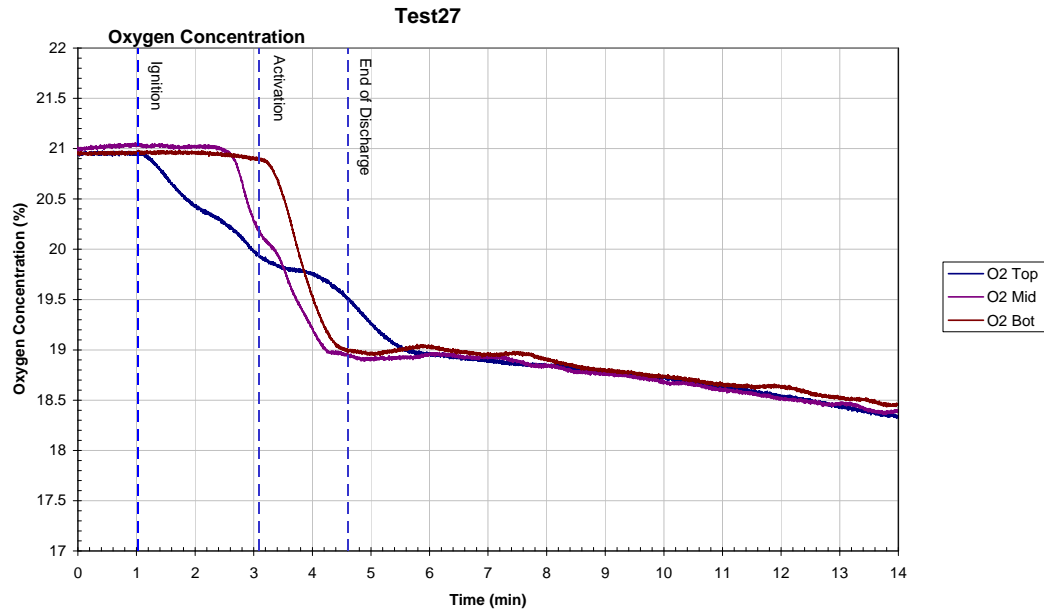


Figure C 150 - Oxygen Concentrations Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 27)

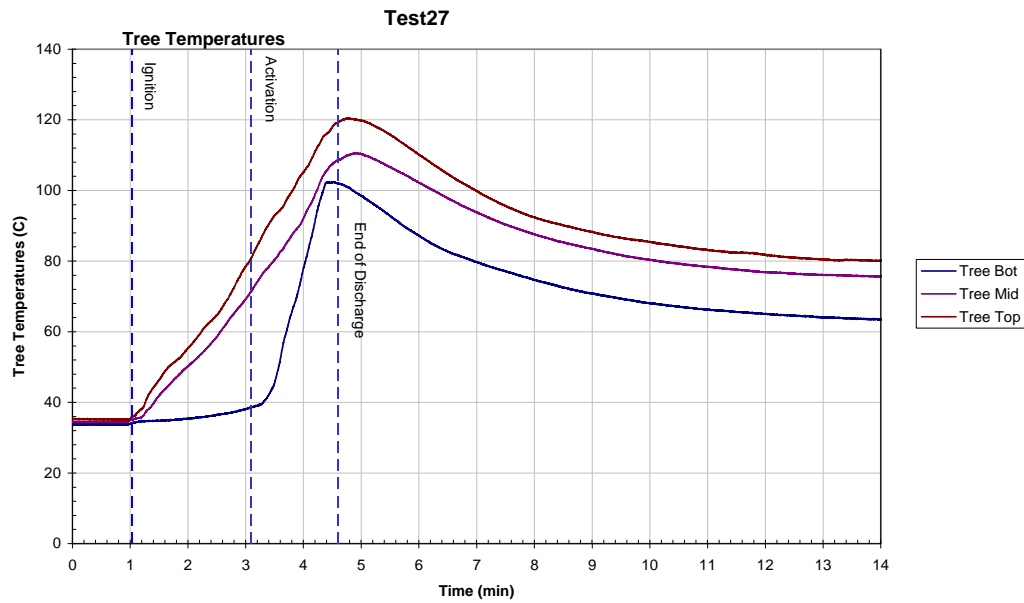


Figure C 151 - Enclosure Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 27)

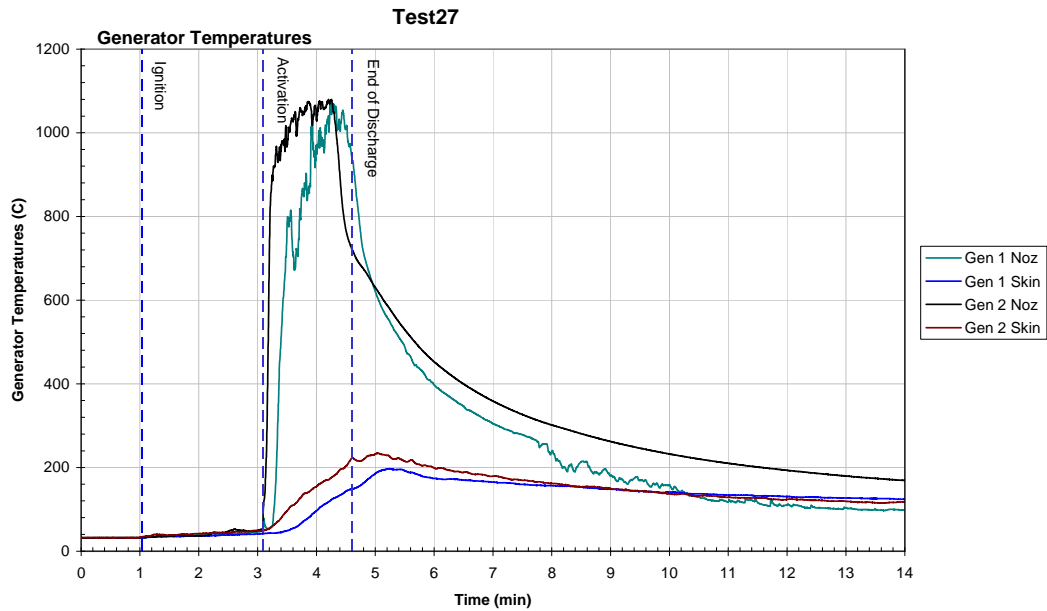


Figure C 152 - Generator Temperatures Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 27)

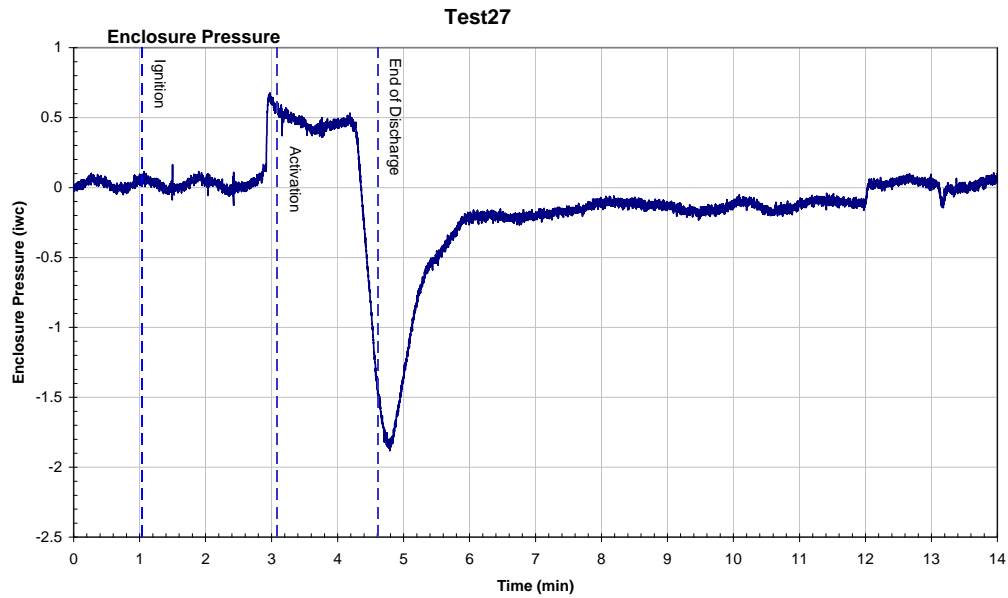


Figure C 153 - Enclosure Pressure Measured during the Dual Wood Crib Test with ULC Provided Wood Cribs and Two DSPA Model 8-1 Aerosol Generators for a Loading of  $64.3 \text{ g/m}^3$  (Test 27)

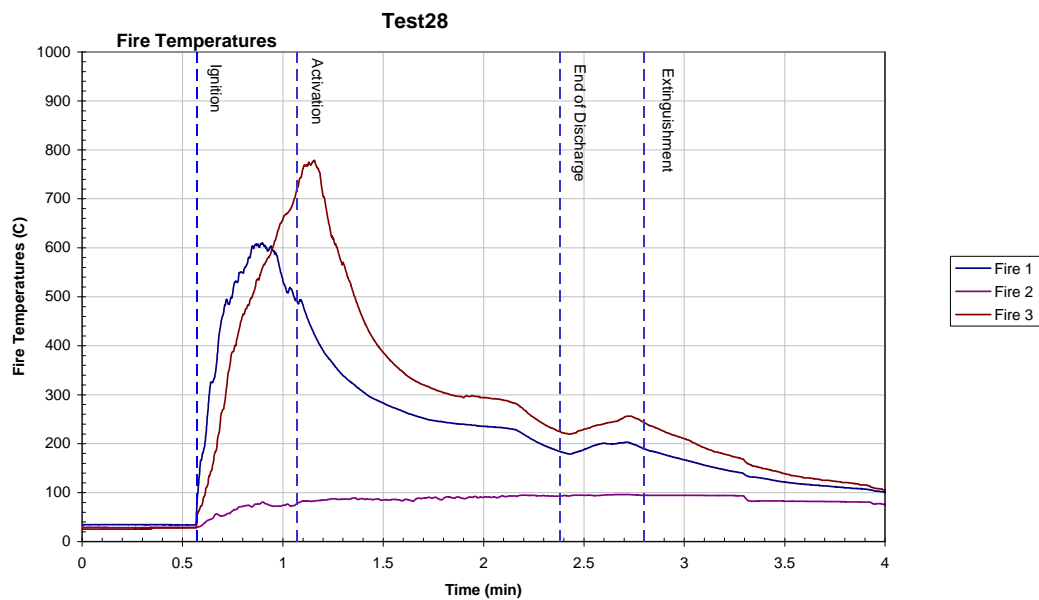


Figure C 154 - Fire Temperatures Measured during the UL n-Heptane Pan Fire Test with One DSPA Model 8-1 Aerosol Generator for a Loading of  $32.1 \text{ g/m}^3$  (Test 28)

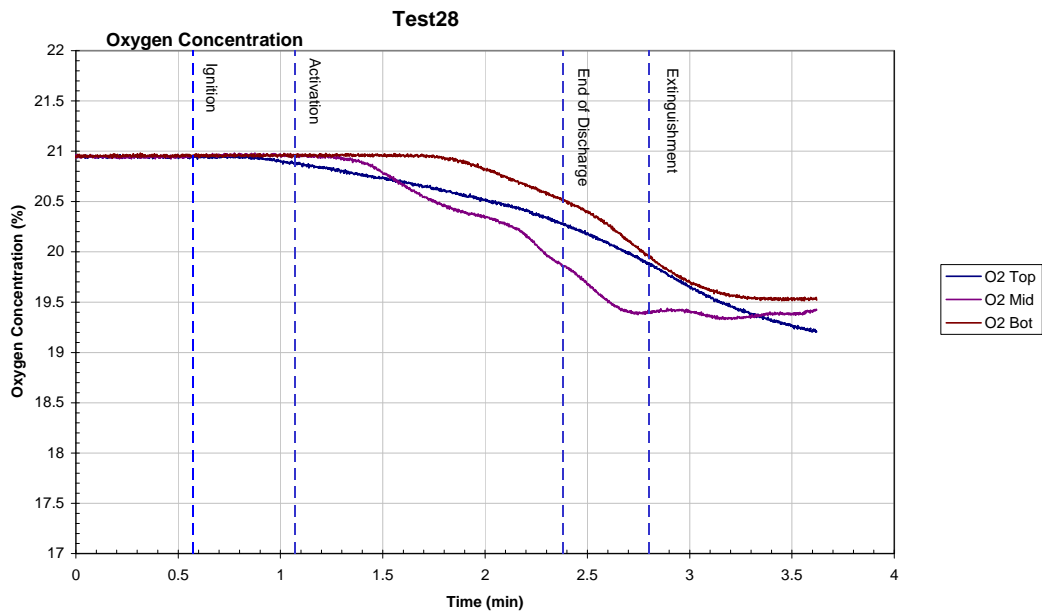


Figure C 155 - Oxygen Concentrations Measured during the UL n-Heptane Pan Fire Test with One DSPA Model 8-1 Aerosol Generator for a Loading of  $32.1 \text{ g/m}^3$  (Test 28)

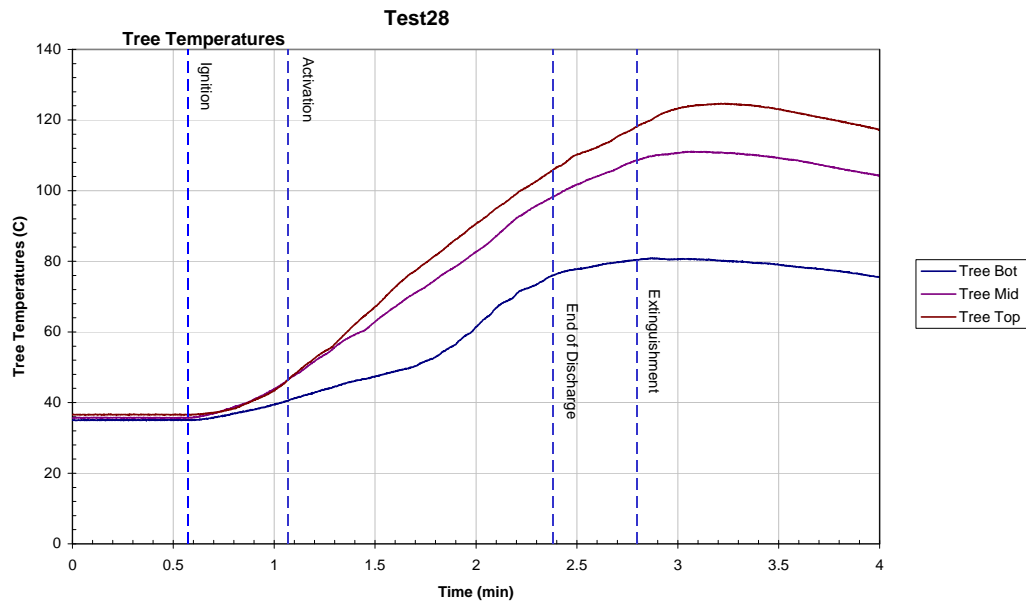


Figure C 156 - Enclosure Temperatures Measured during the UL n-Heptane Pan Fire Test with One DSPA Model 8-1 Aerosol Generator for a Loading of  $32.1 \text{ g/m}^3$  (Test 28)



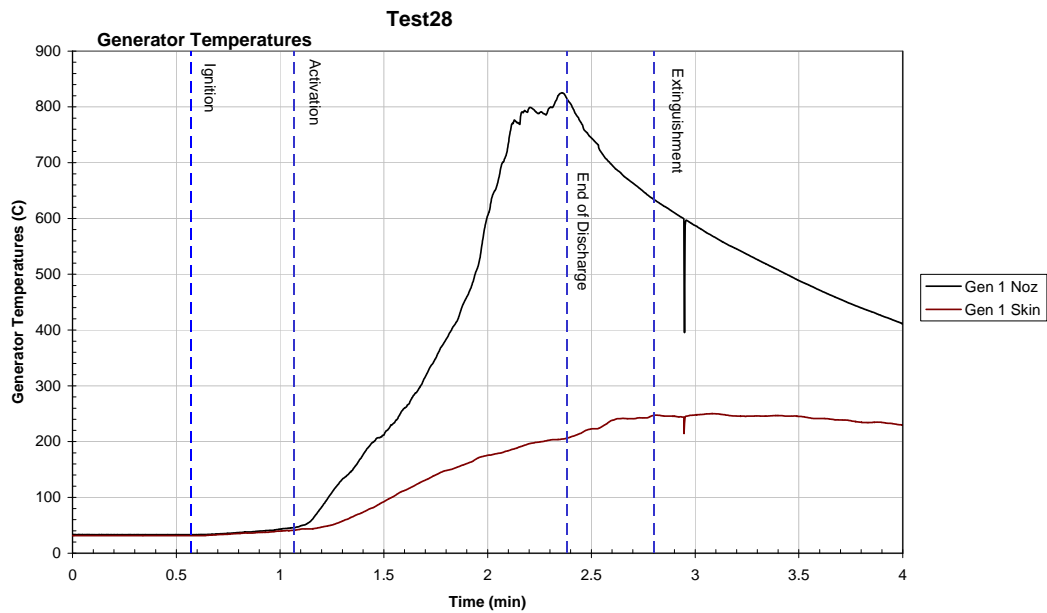


Figure C 157 - Generator Temperatures Measured during the UL n-Heptane Pan Fire Test with One DSPA Model 8-1 Aerosol Generator for a Loading of  $32.1 \text{ g/m}^3$  (Test 28)

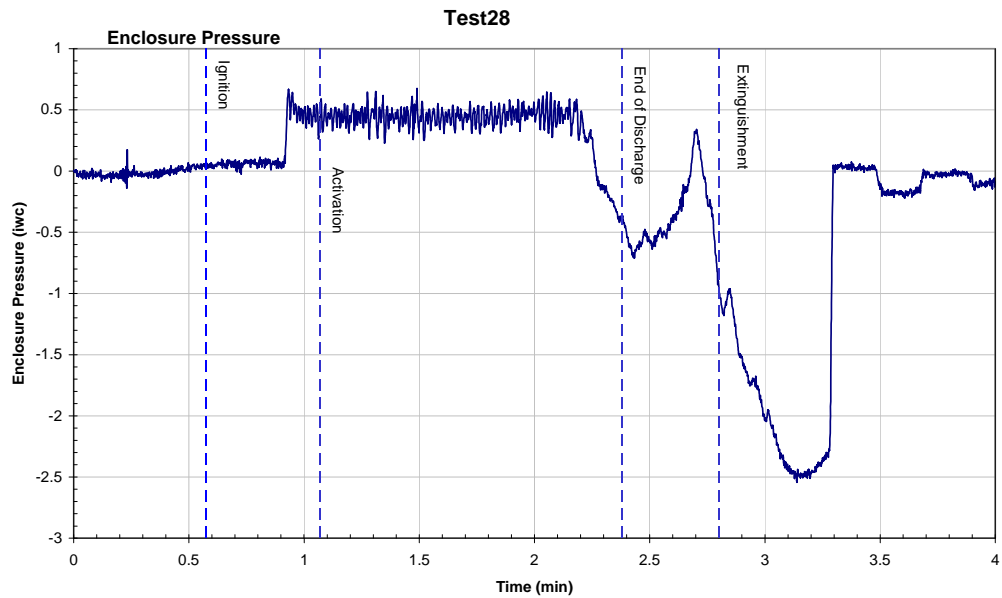


Figure C 158 - Enclosure Pressure Measured during the UL n-Heptane Pan Fire Test with One DSPA Model 8-1 Aerosol Generator for a Loading of  $32.1 \text{ g/m}^3$  (Test 28)

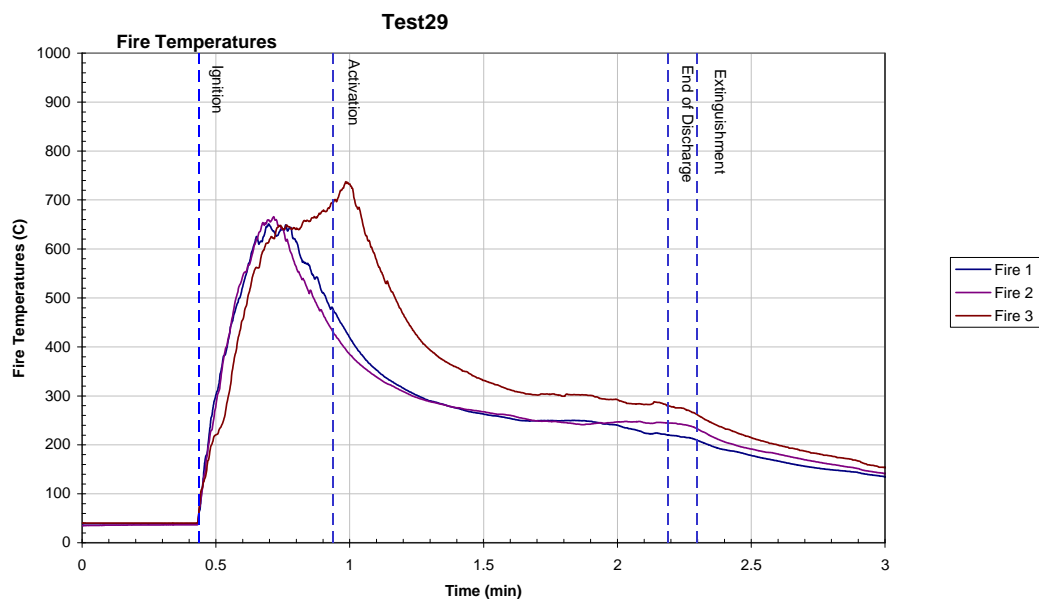


Figure C 159 - Fire Temperatures Measured during the UL n-Heptane Pan Fire Test with One DSPA Model 8-1 Aerosol Generator for a Loading of  $32.1 \text{ g/m}^3$  (Test 29)

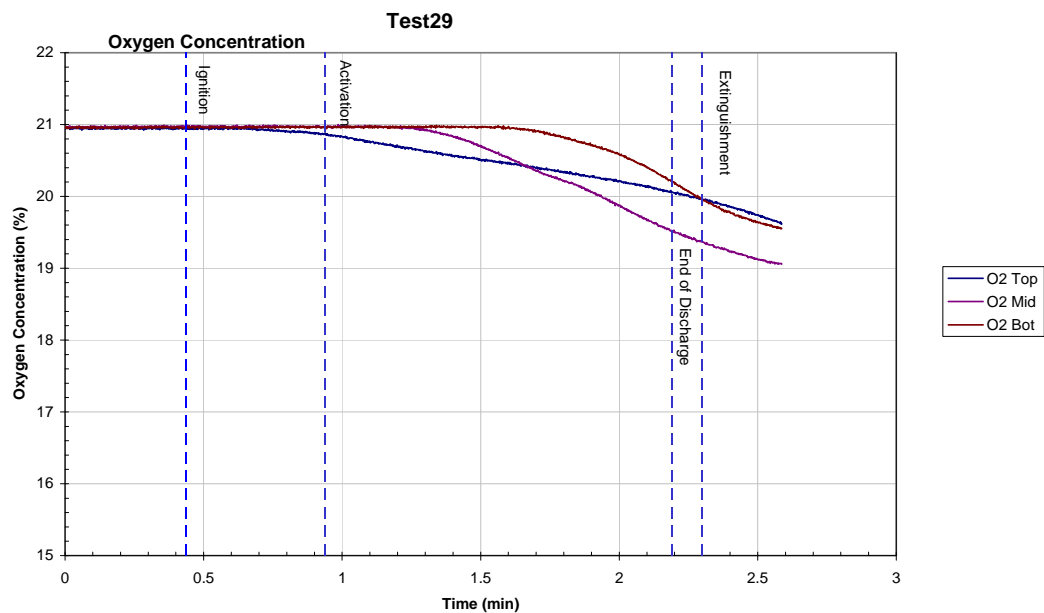


Figure C 160 - Oxygen Concentrations Measured during the UL n-Heptane Pan Fire Test with One DSPA Model 8-1 Aerosol Generator for a Loading of  $32.1 \text{ g/m}^3$  (Test 29)

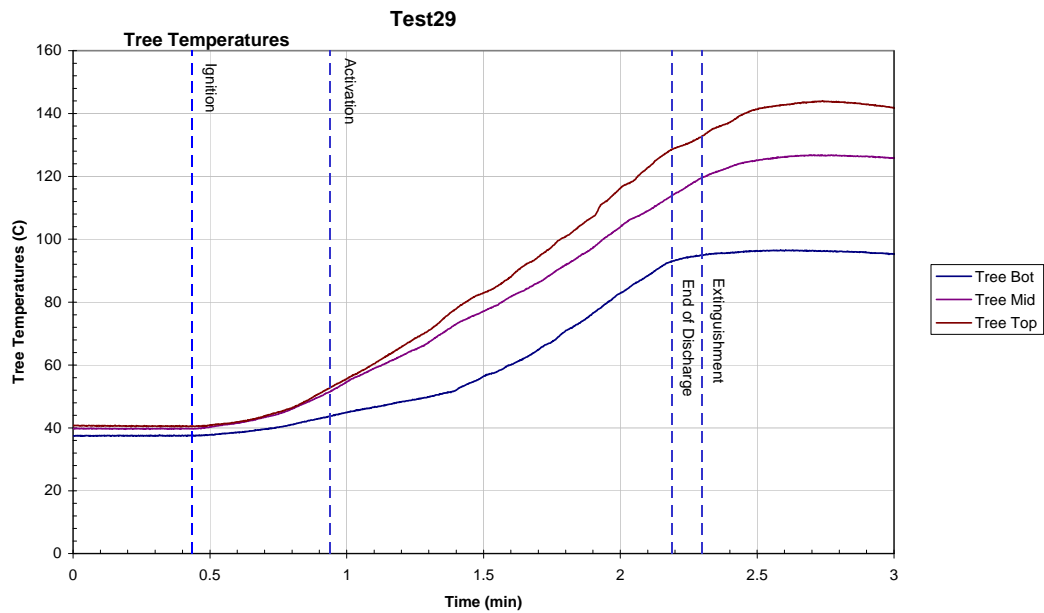


Figure C 161 - Enclosure Temperatures Measured during the UL n-Heptane Pan Fire Test with One DSPA Model 8-1 Aerosol Generator for a Loading of  $32.1 \text{ g/m}^3$  (Test 29)

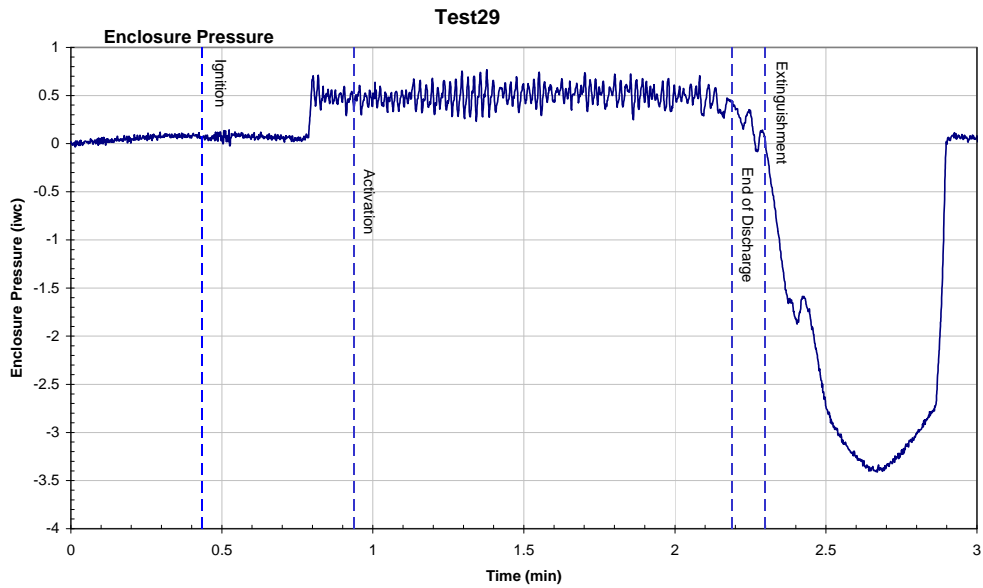


Figure C 162 - Enclosure Pressure Measured during the UL n-Heptane Pan Fire Test with One DSPA Model 8-1 Aerosol Generator for a Loading of  $32.1 \text{ g/m}^3$  (Test 29)

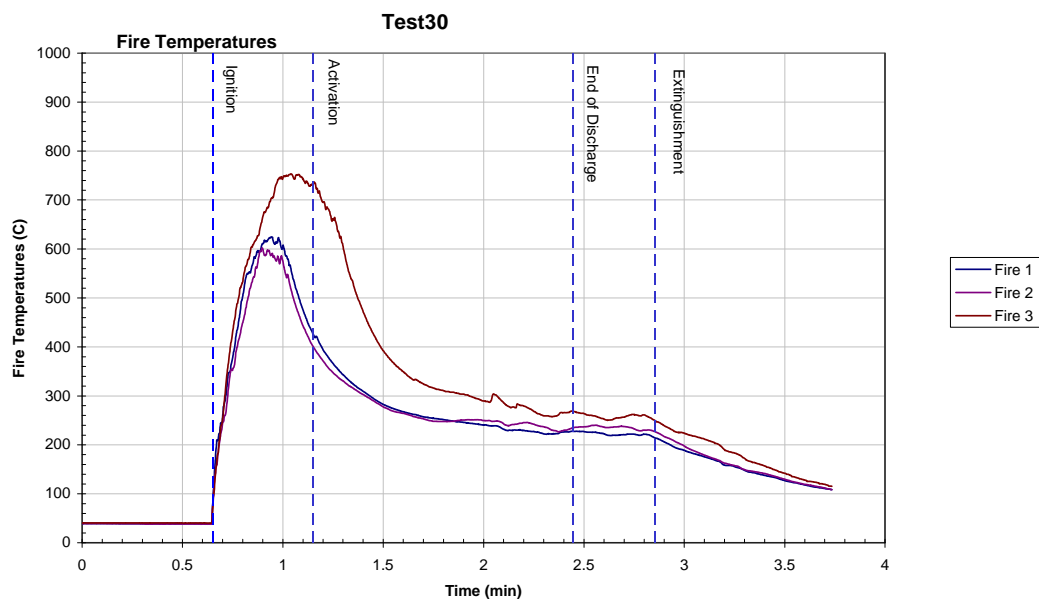


Figure C 163 - Fire Temperatures Measured during the UL n-Heptane Pan Fire Test with One DSPA Model 8-1 Aerosol Generator for a Loading of  $32.1 \text{ g/m}^3$  (Test 30)

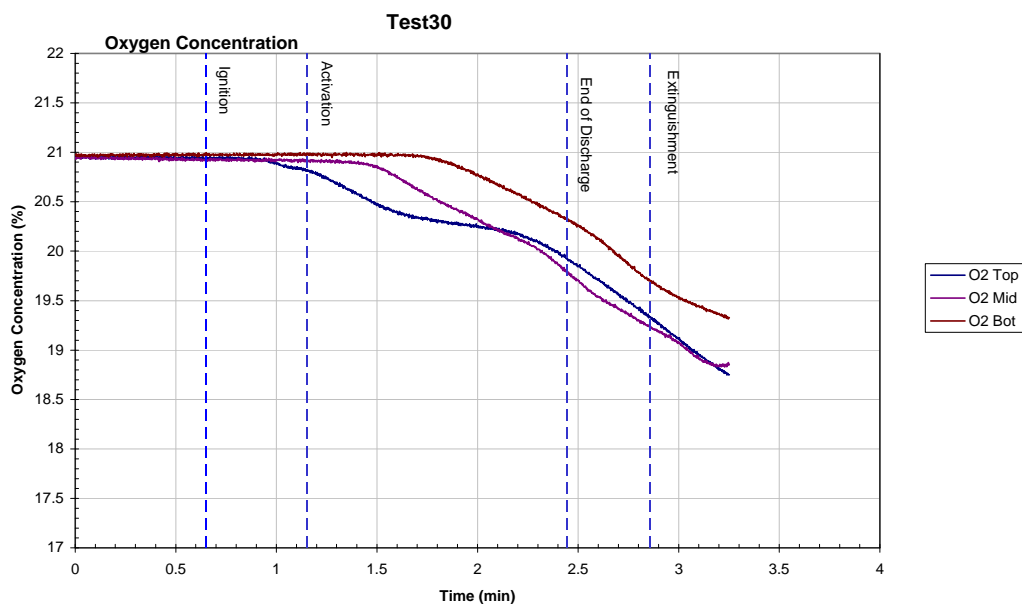


Figure C 164 - Oxygen Concentrations Measured during the UL n-Heptane Pan Fire Test with One DSPA Model 8-1 Aerosol Generator for a Loading of  $32.1 \text{ g/m}^3$  (Test 30)

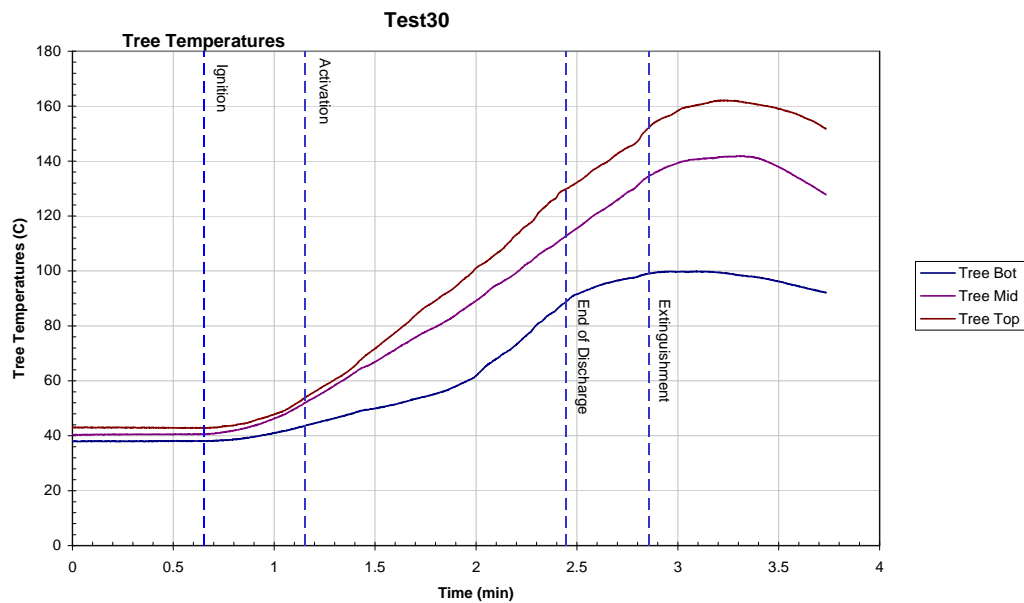


Figure C 165 - Enclosure Temperatures Measured during the UL n-Heptane Pan Fire Test with One DSPA Model 8-1 Aerosol Generator for a Loading of  $32.1 \text{ g/m}^3$  (Test 30)

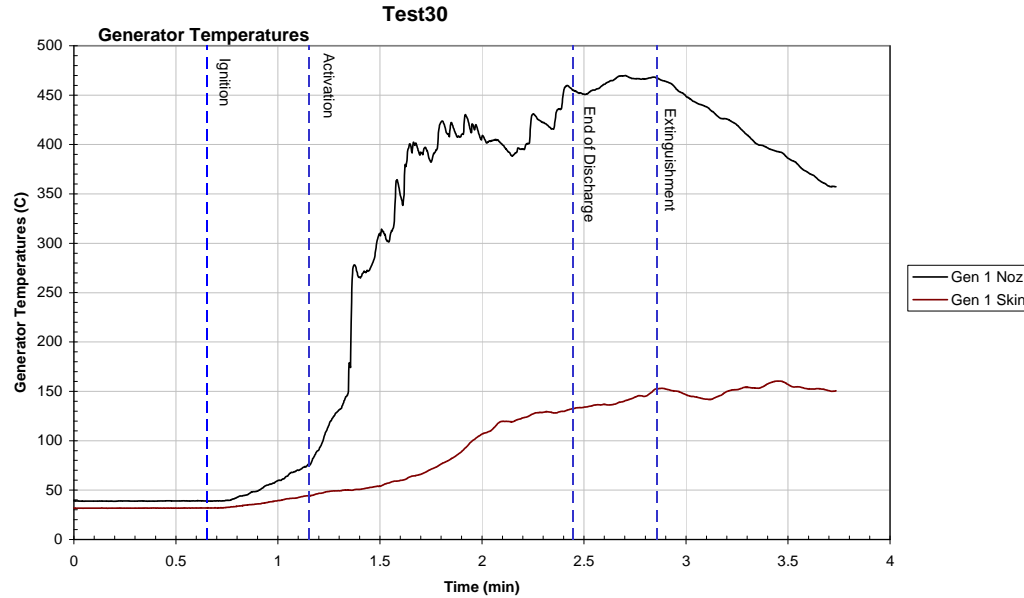


Figure C 166 - Generator Temperatures Measured during the UL n-Heptane Pan Fire Test with One DSPA Model 8-1 Aerosol Generator for a Loading of  $32.1 \text{ g/m}^3$  (Test 30)

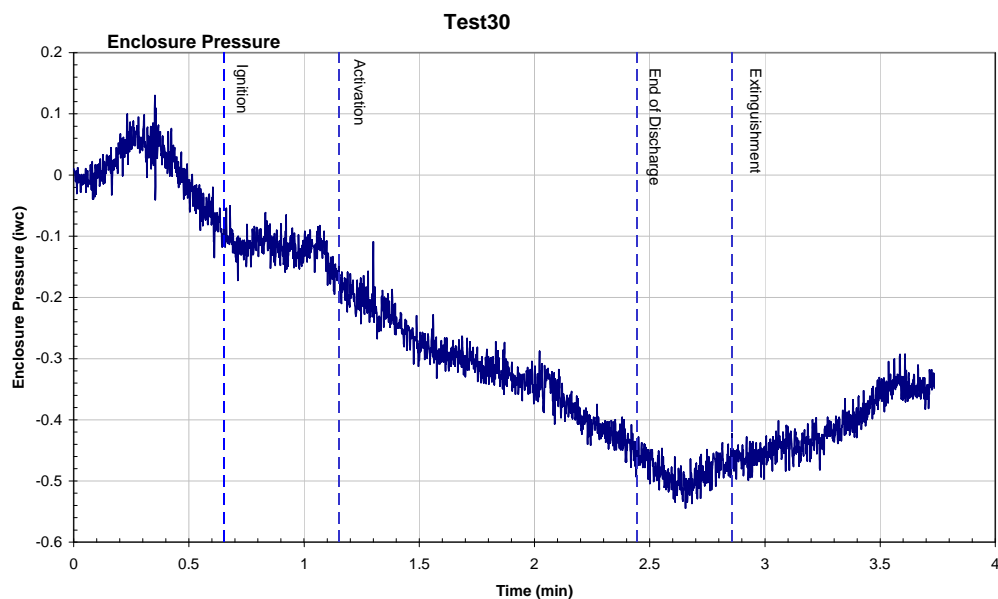


Figure C 167 - Enclosure Pressure Measured during the UL n-Heptane Pan Fire Test with One DSPA Model 8-1 Aerosol Generator for a Loading of  $32.1 \text{ g/m}^3$  (Test 30)

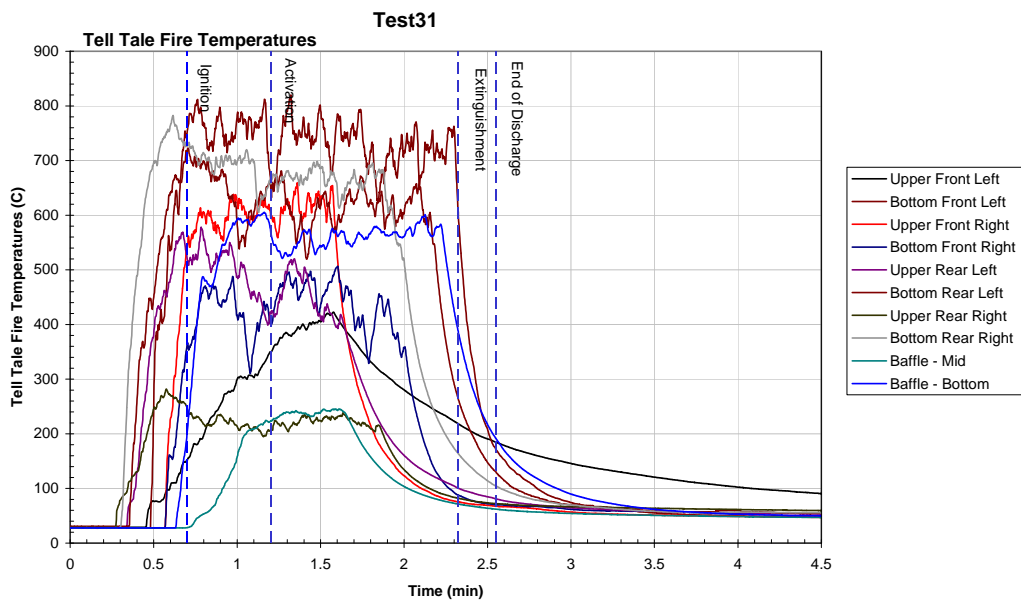


Figure C 168 - Telltale Fire Temperatures Measured during the Volume Coverage Test with DSPA Model 8-1 Aerosol Generator and a Loading of  $32.1 \text{ g/m}^3$  (Test 31)

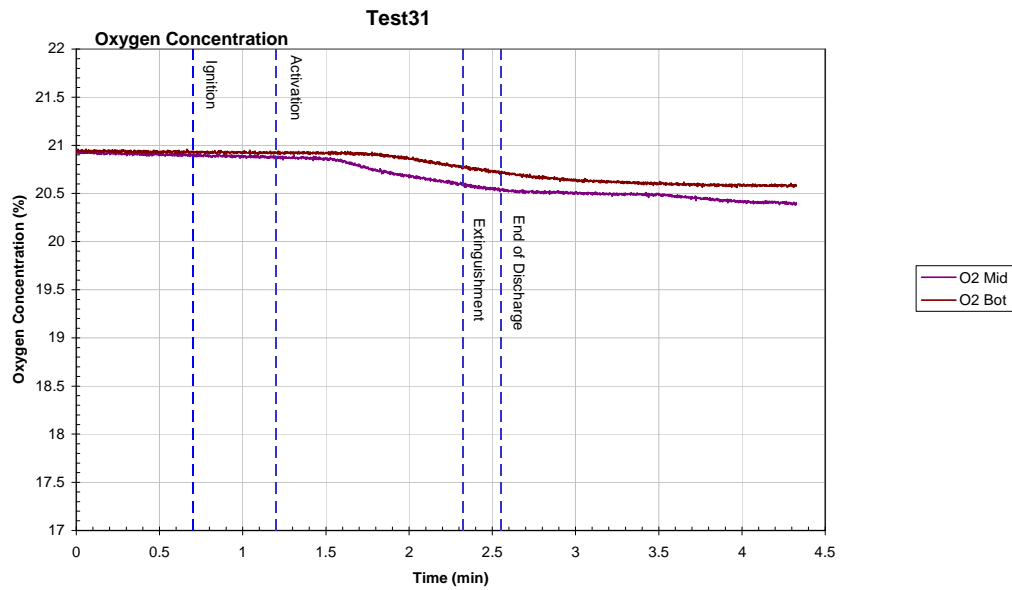


Figure C 169 - Oxygen Concentrations Measured during the Volume Coverage Test with DSPA Model 8-1 Aerosol Generator and a Loading of  $32.1 \text{ g/m}^3$  (Test 31)

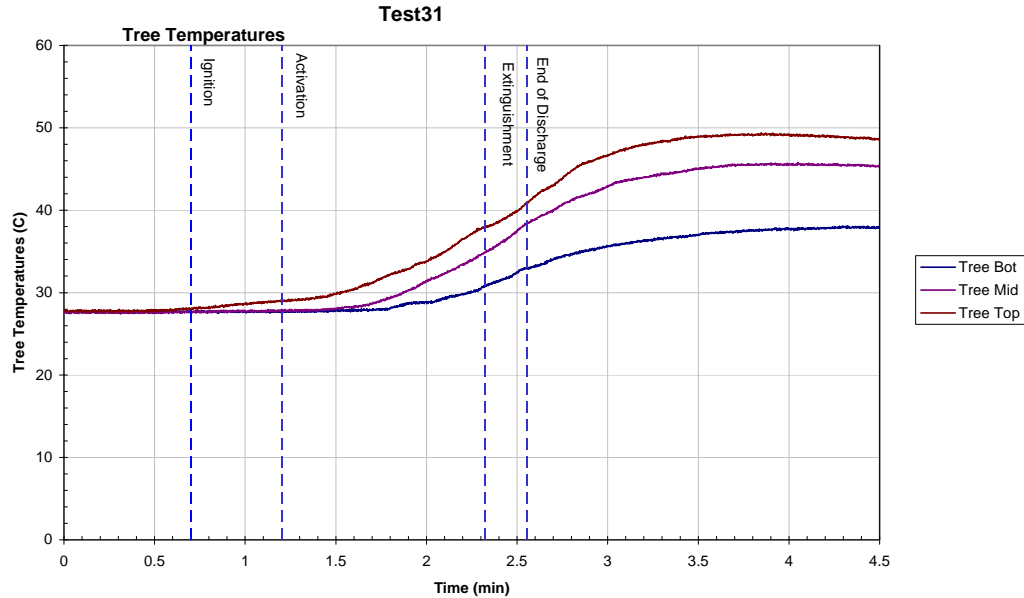


Figure C 170 - Enclosure Temperatures Measured during the Volume Coverage Test with DSPA Model 8-1 Aerosol Generator and a Loading of  $32.1 \text{ g/m}^3$  (Test 31)

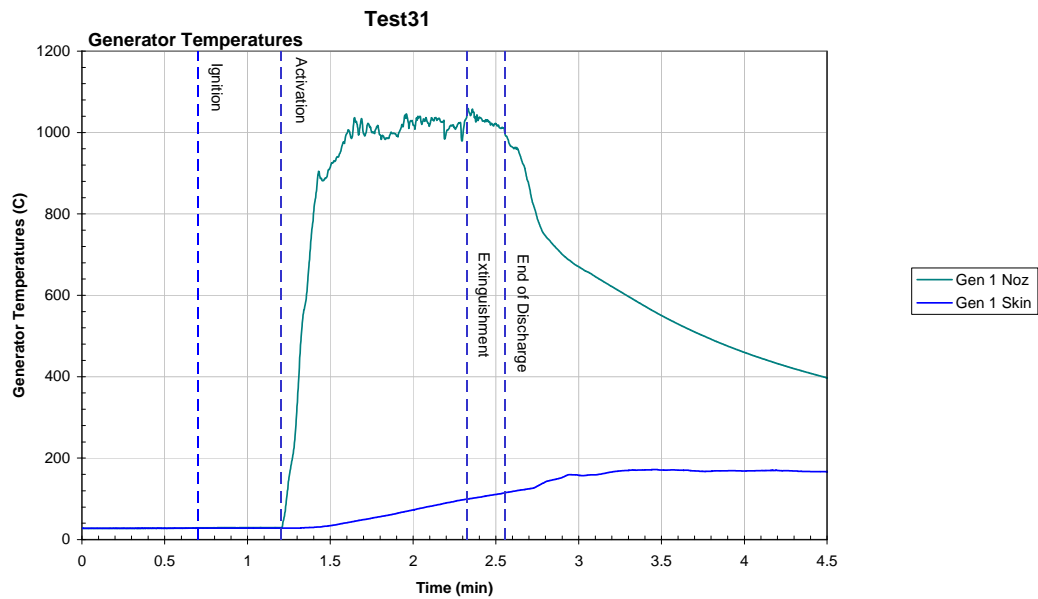


Figure C 171 - Generator Temperatures Measured during the Volume Coverage Test with DSPA Model 8-1 Aerosol Generator and a Loading of  $32.1 \text{ g/m}^3$  (Test 31)

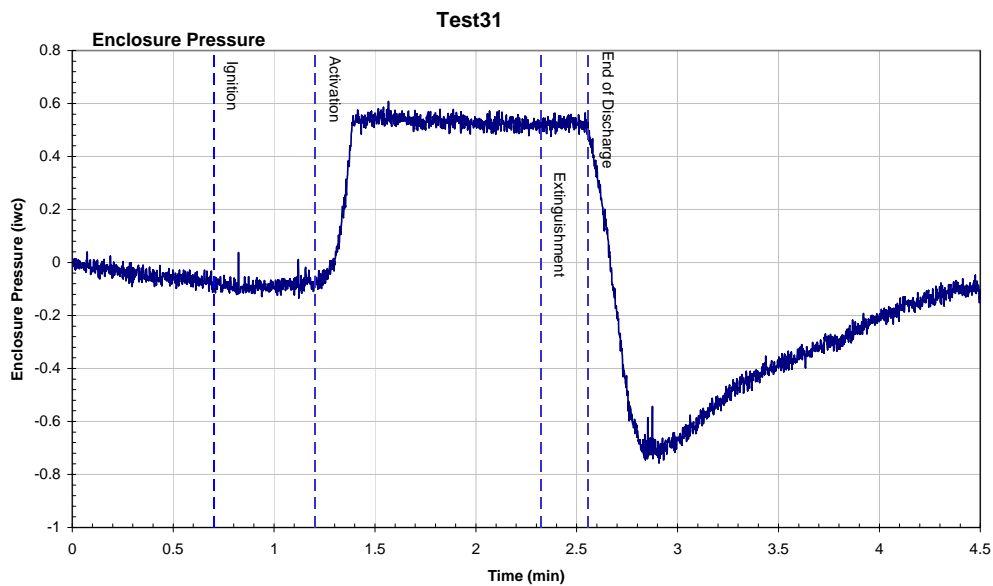


Figure C 172 - Enclosure Pressure Measured during the Volume Coverage Test with DSPA Model 8-1 Aerosol Generator and a Loading of  $32.1 \text{ g/m}^3$  (Test 31)



