Fire Suppression in Class-E Cargo Compartments

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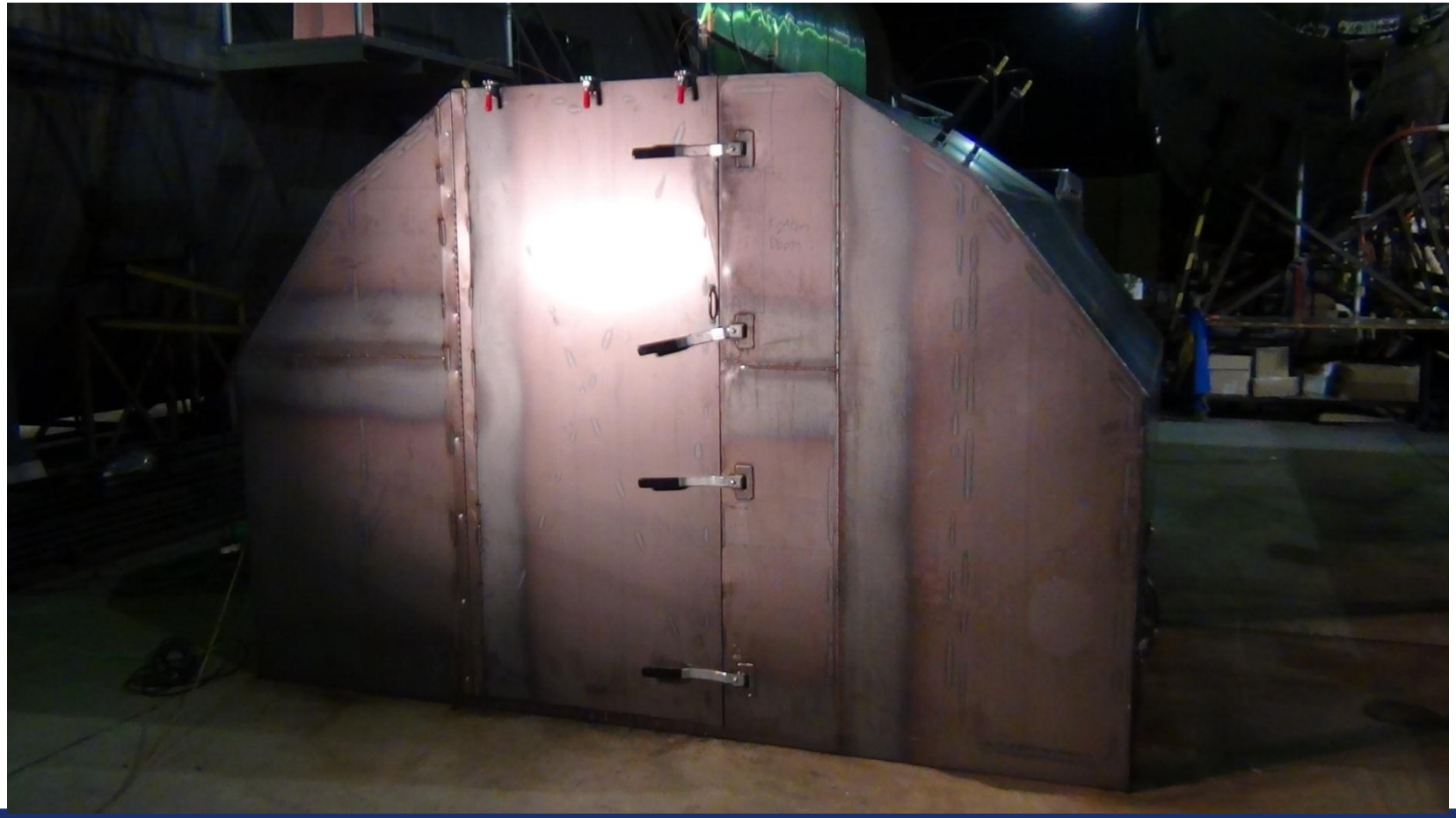
Objective

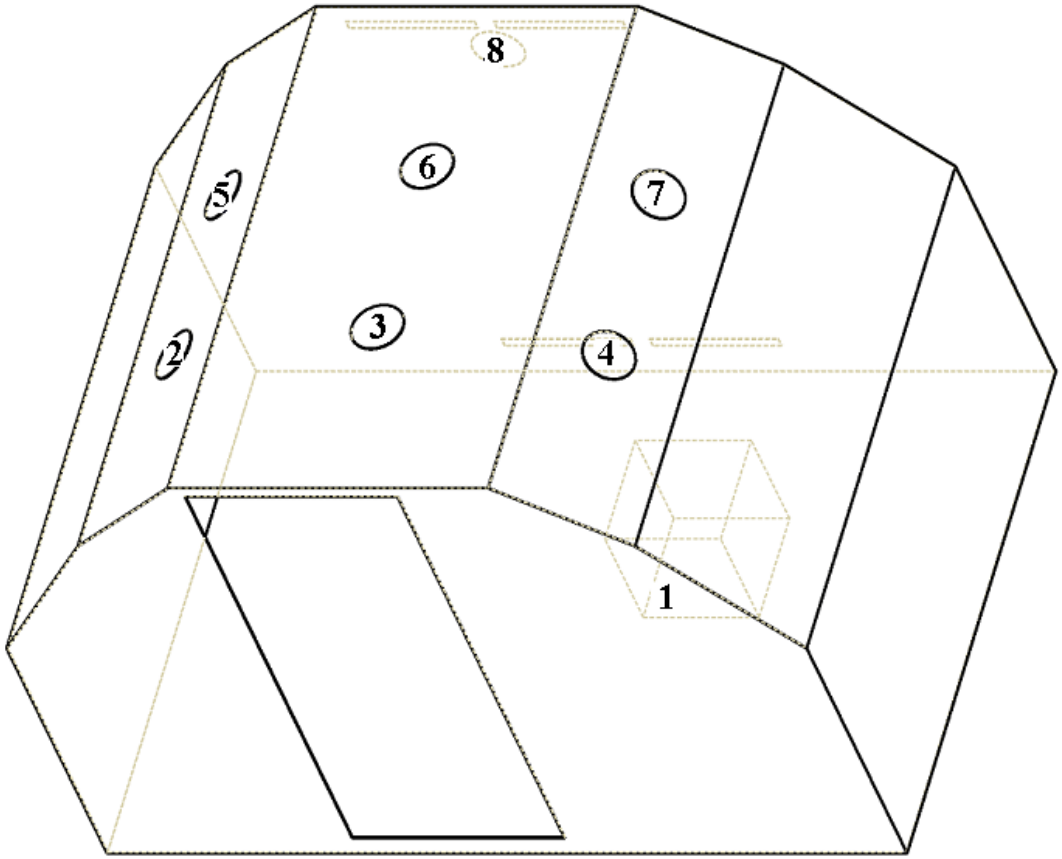
Test a variety of Fire Suppression Options

- Oxygen Starvation
- Aerosol based agents
- Fire Containment Covers (FCC)
- Medium Expansion Foams
- Zone based Water mist systems

Test Article



Instrumentation Location for the FAA Technical Center AAY Test Article



Location 1: Ignition Box - Inbox, Outbox, TC3

Location 8: TC10, Oxygen Concentration Sample Measurement

Location #: TC Inside Ceiling, TC Outside Roof

Location 2: TC4, TC11
Location 3: TC6, TC 13
Location 4: TC8, TC15
Location 5: TC5, TC12
Location 6: TC7, TC14
Location 7: TC9, TC 16

Composite Test Article

Tests Conducted

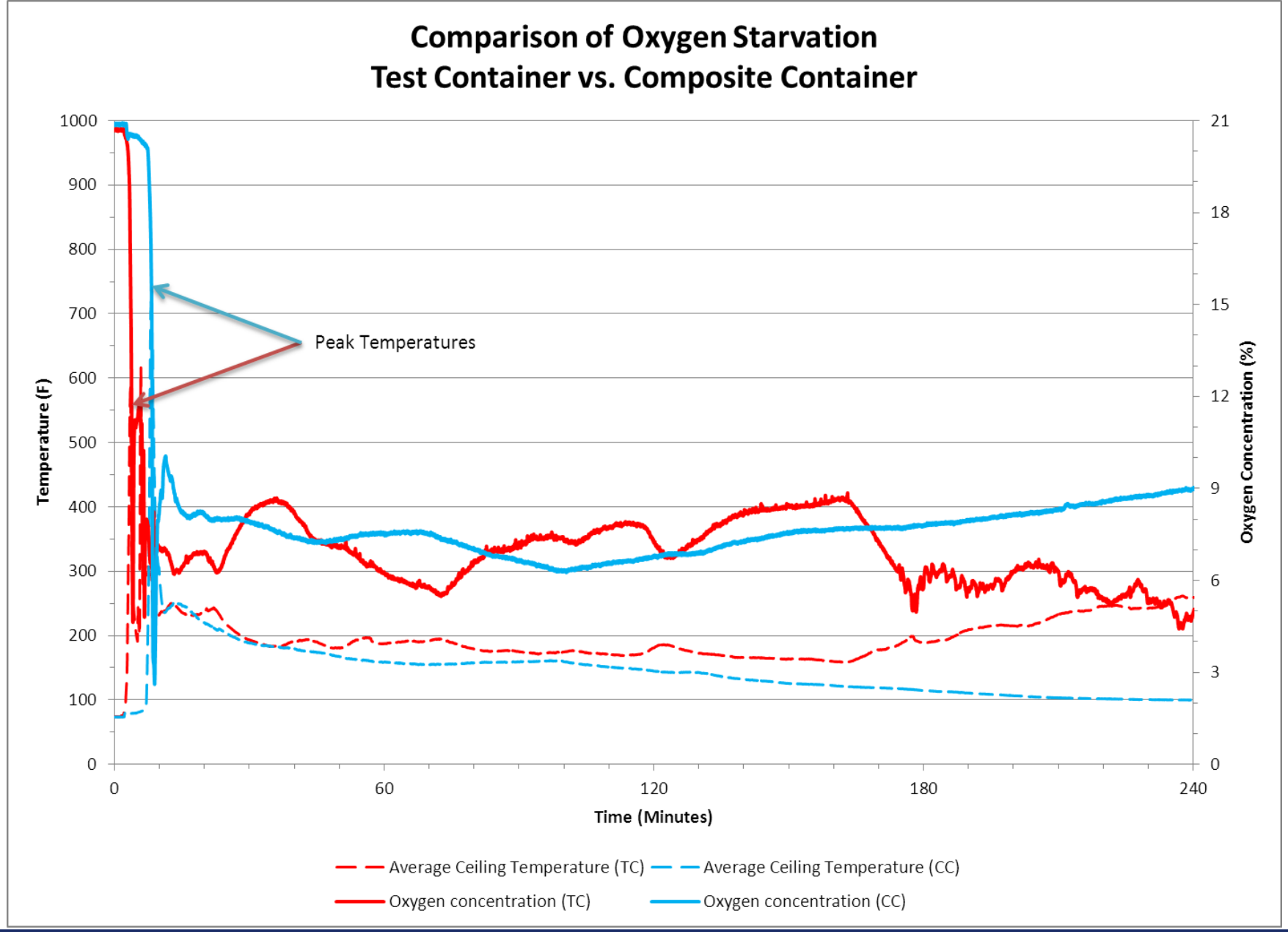
	Test Container		Composite Container	
	Full Load	Half load	Full Load	Half Load
Oxygen Starvation	X	X	X	X
Aerosol Based Suppression Agent	X	X	X	X

Test Procedure: Oxygen Starvation

- The air exchange rates of each container was measured prior to testing.
- Ignition box was lit in the front left corner of the container. (Worst case scenario)
- Observe ceiling temperatures and oxygen concentration over a period of 4 hours.

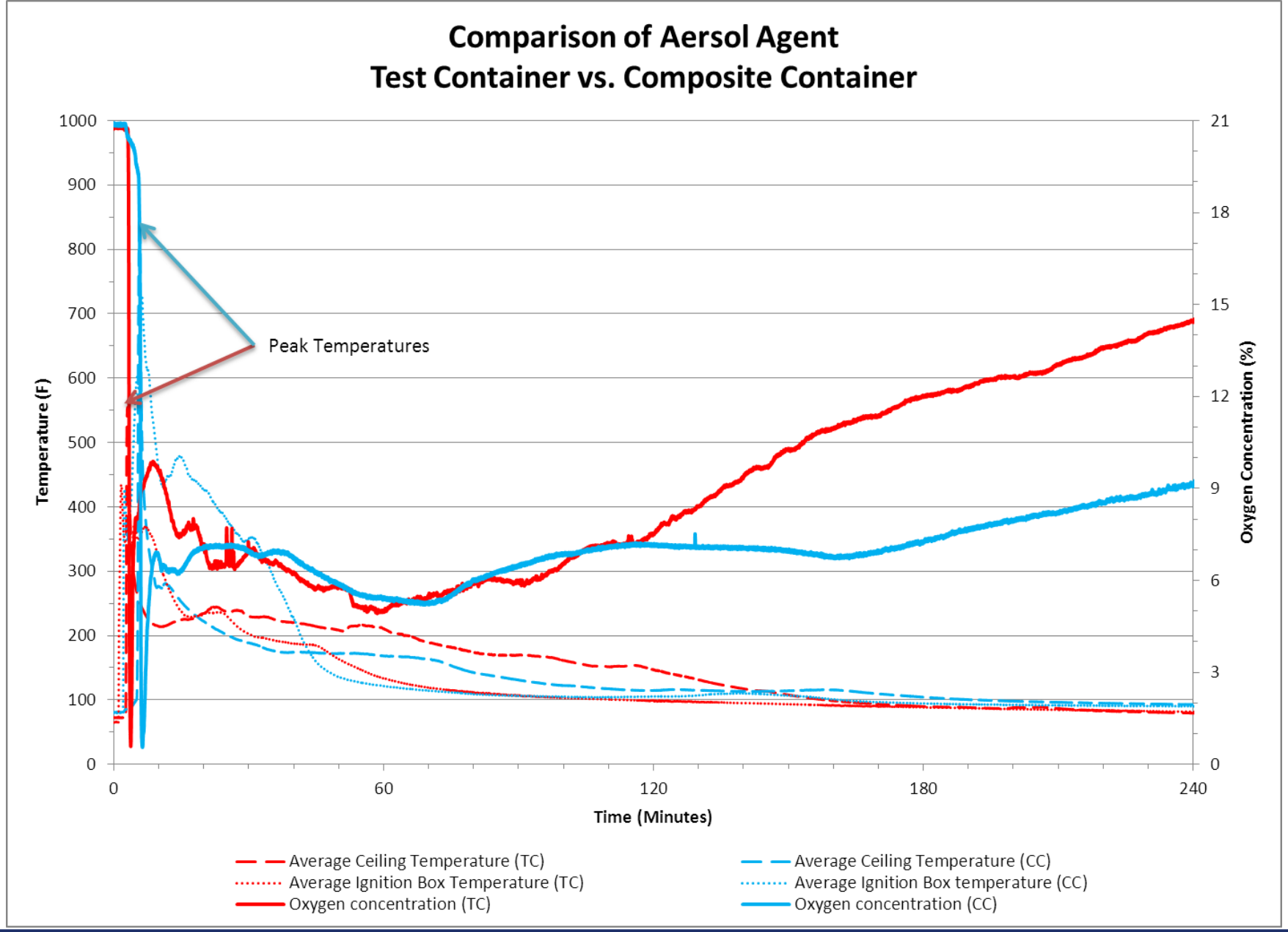
Test Procedure: Aerosol Suppression

- Ignition box was lit in the front left corner of the container. (Worst case scenario)
- The agent was triggered manually when the internal ceiling temperature reached 200°F. (Failure point in a Lexan based AAY)
- Observe ceiling temperatures and oxygen concentration over a period of 4 hours.


Comparison of Oxygen Starvation
Test Container vs. Composite Container
Temperature (F)
Oxygen Concentration (%)
Time (Minutes)
Peak Temperatures
1000
900
800
700
600
500
400
300
200
100
0
21
18
15
12
9
6
3
0
0
60
120
180
240
Average Ceiling Temperature (TC)
Average Ceiling Temperature (CC)
Oxygen concentration (TC)
Oxygen concentration (CC)

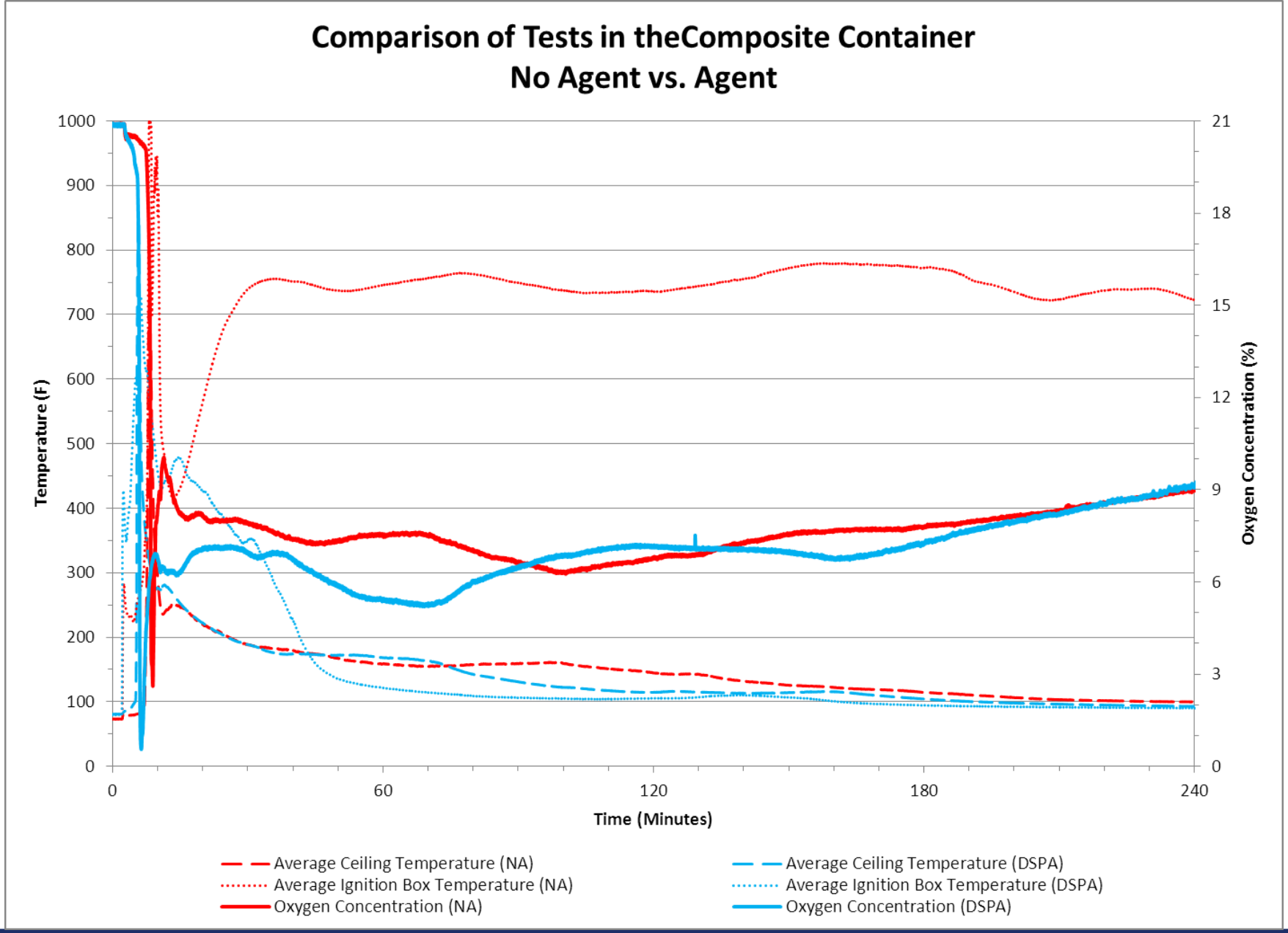
Observations: Oxygen Starvation

- Air exchange rates in the test and composite container were approximately 26 cfm and 5 cfm respectively.
- Temperatures within the test container suggest failure.
- Test container also shows an upper bound of air exchange rate at which oxygen starvation could starve a fire.
- The composite container effectively deprived the fire while being able to withstand the initial surge in high temperatures.
- There was a flashover in the composite container once the doors were opened at the end of the test.


Comparison of Aersol Agent
Test Container vs. Composite Container
Temperature (F)
Oxygen Concentration (%)
Time (Minutes)
Peak Temperatures
0
60
120
180
240
100
200
300
400
500
600
700
800
900
1000
3
6
9
12
15
18
21
Average Ceiling Temperature (TC)
Average Ignition Box Temperature (TC)
Oxygen concentration (TC)
Average Ceiling Temperature (CC)
Average Ignition Box temperature (CC)
Oxygen concentration (CC)

Observations: Aerosol suppression

- The aerosol agent in combination with oxygen starvation successfully suppressed the fire.
- ~85% of the boxes were undamaged.
- There was no flashover at the end of the test.


Comparison of Tests in theComposite Container
No Agent vs. Agent
Temperature (F)
Oxygen Concentration (%)
Time (Minutes)
0
60
120
180
240
100
200
300
400
500
600
700
800
900
1000
3
6
9
12
15
18
21
Average Ceiling Temperature (NA)
Average Ignition Box Temperature (NA)
Oxygen Concentration (NA)
Average Ceiling Temperature (DSPA)
Average Ignition Box Temperature (DSPA)
Oxygen Concentration (DSPA)

Significance of Fire Suppression in Tandem with Oxygen Starvation

- The agent extinguishes the fire in the container.
- Oxygen starvation allows the aerosol to remain within the container to maintain an inert environment.
- There is a smaller probability of a flashover when the container is opened.

Fire Containment Covers

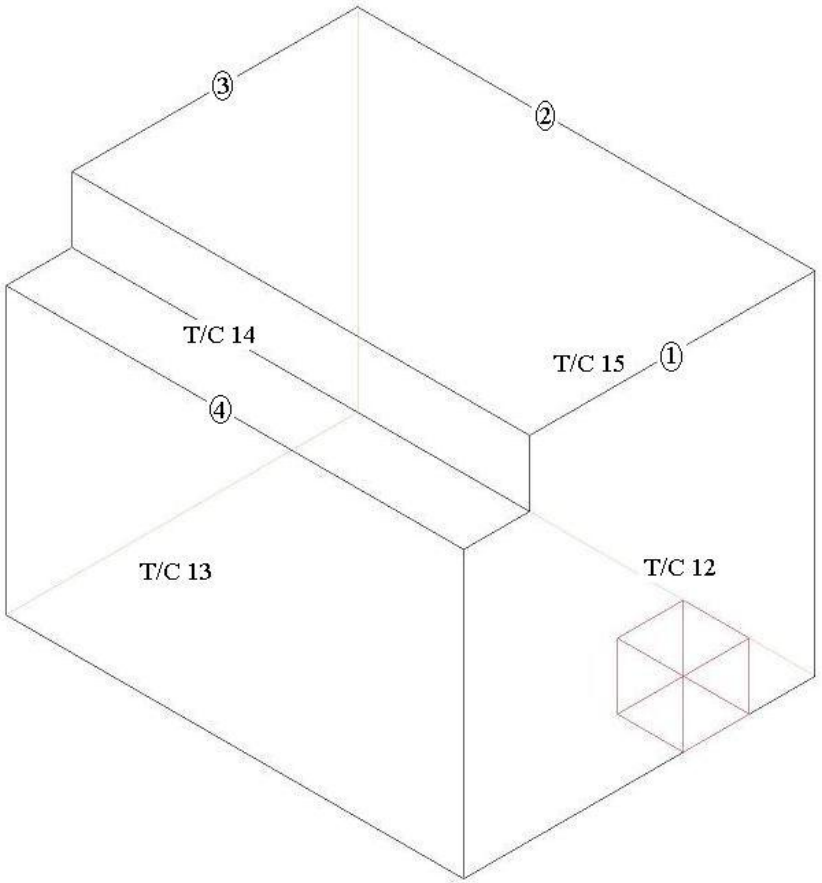
Test Setup

- 114 cardboard boxes filled with 2.5 lbs of shredded paper used as fire load.

Test Criteria

- Test will be considered a failure if any thermocouple placed 4” away from the FCC exceeds 400°F

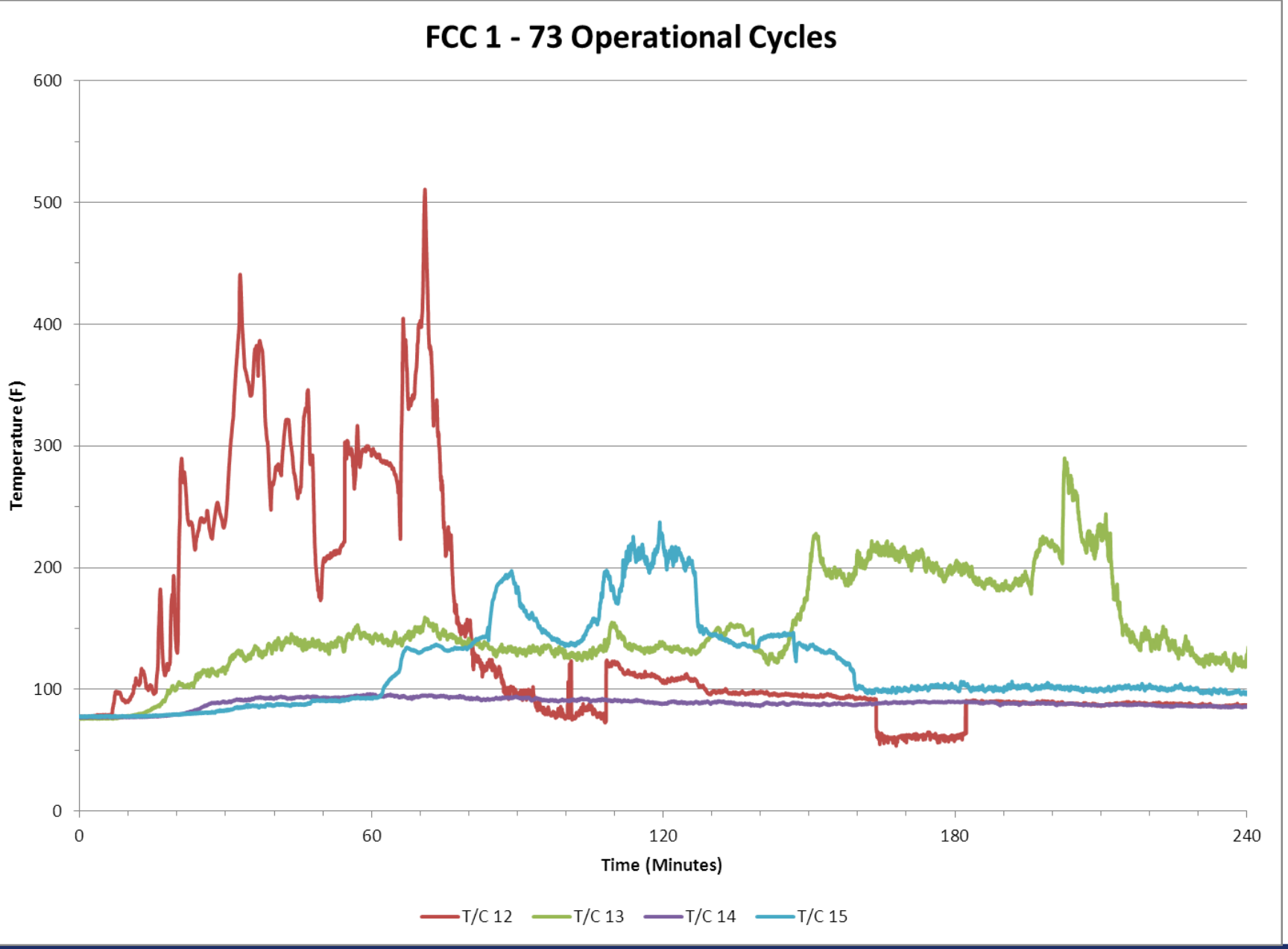
FCC T/C Location Chart

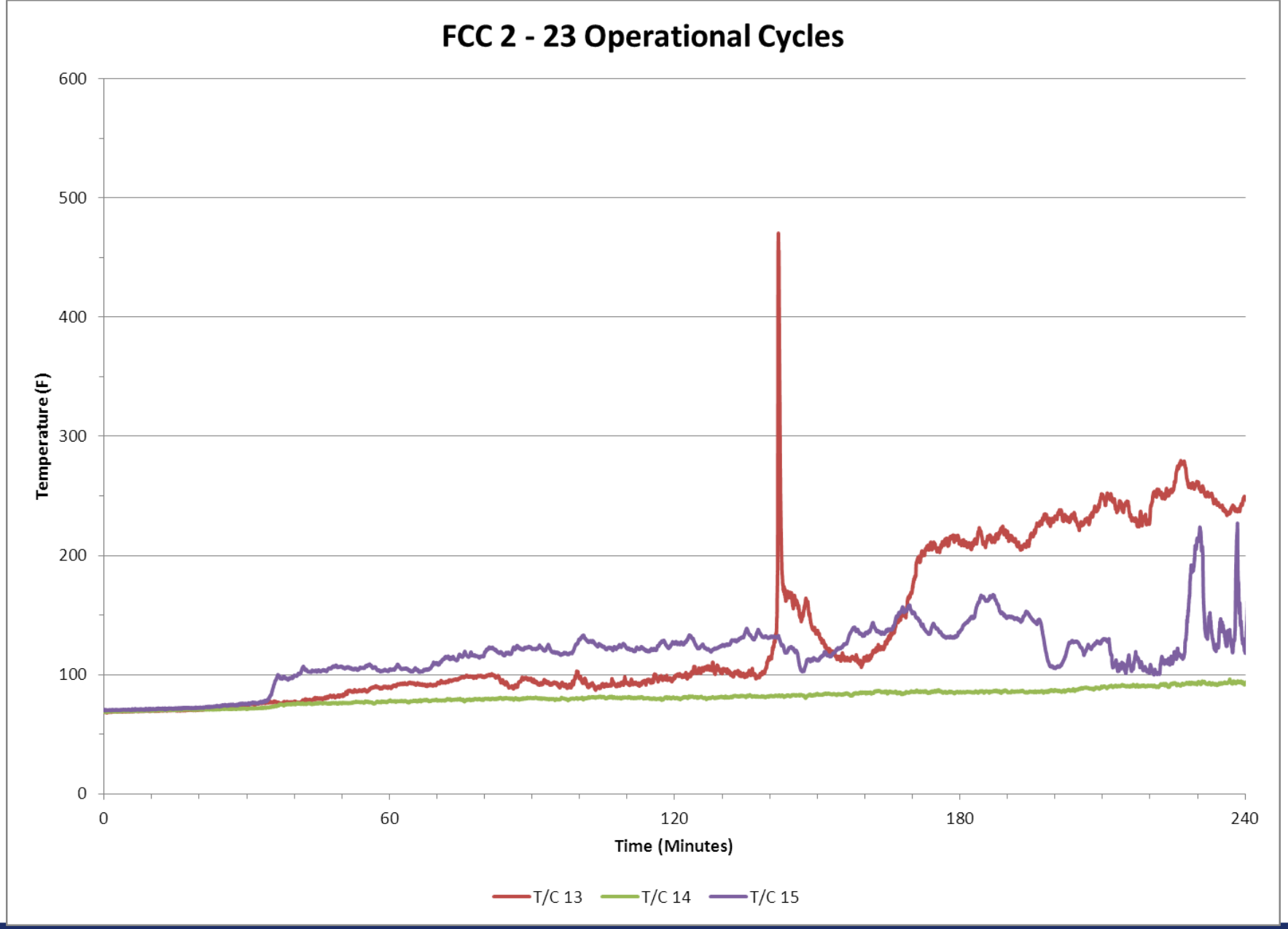


Ignition Box: T/C Inbox, Outbox, 3

Location #: T/C Inside, T/C Outside
Location 1: T/C 4, T/C 8
Location 2: T/C 5, T/C 11
Location 3: T/C 6, T/C 10
Location 4: T/C 7, T/C 9

T/C 12-15 are located 4 inches away from the outside of the FCC cover, 48 inches of the ground.


FCC 1 - 73 Operational Cycles
600
500
400
300
200
100
0
Temperature (F)
0
60
120
180
240
Time (Minutes)
T/C 12
T/C 13
T/C 14
T/C 15


FCC 2 - 23 Operational Cycles
600
500
400
300
200
100
0
Temperature (F)
0
60
120
180
240
Time (Minutes)
T/C 13
T/C 14
T/C 15

Observations: FCC

- Both FCC covers failed to the standards of ISO 14186.
- The FCCs were able to contain the fire within itself.
- The FCCs displayed a behavior that was explained as "offgassing". When the temperature inside the FCC rose, the material on the FCC decomposed to release a gas that spontaneously combusted on the external surface of the FCC. This did not affect the performance of the cover, but could lead to failing the ISO standard.

Medium Expansion Foam

Objective:

- To determine the expansion ratio of ANSUL foam with and without using a medium foam expansion nozzle.
- To obtain the same expansion ration as mentioned above without using the nozzle and using an inert gas to drive the foam.

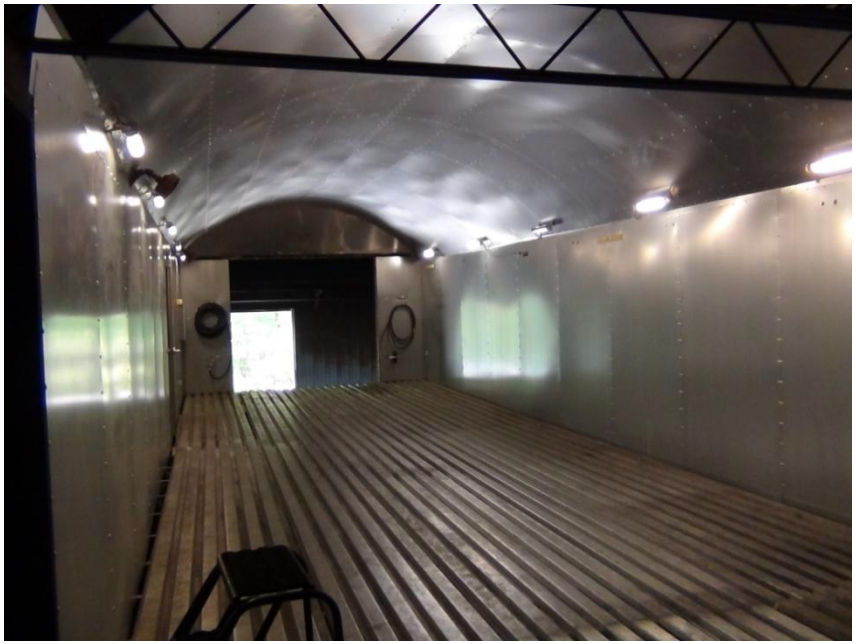
Medium Expansion Foam: Setup

Zone Based Water Mist System

Objective:

- To determine the effectiveness of a water mist system as a viable fire suppression system in a Class-E cargo deck.

Zone Based Water Mist System



- The DC-10 cargo deck has been rebuilt to perform fire testing within.
- Ducting systems are being installed to replicate air exchange rates similar to a real world scenario.

Future Work

- Conduct tests to determine a worst case scenario fire load that contains lithium batteries.
- Conduct tests with medium expansion foam driven by an inert gas in the test container.
- Conduct tests with zone based water mist systems on a standard fire load and on lithium battery fires in the main cargo deck.