



Environmentally-Friendly Fire Suppression System for Cargo using Innovative Green Technology

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Overview



- Background and scope of project
- Tests and acceptance criteria
- Experimental rig set up
- Results so far





Background and Scope



- EFFICIENT – (Environmentally Friendly Fire Suppression System for Cargo using Innovative Green Technology)
- Funded by the European Union Clean Sky 2 research program
- Collaboration of several Academic and Industrial partners



Background and Scope



Scope:

- To develop and mature potential fire suppression technology for eventual application in the cargo-cabin architecture of next generation aircraft
- Identify a suitable agent which will replace Halon 1301 and will be able to qualify the FAA MPS



Background and Scope



Objectives:

- Identify a suitable AGENT, or mixture of AGENTs, capable of providing the fire suppression specified in DOT/FAA/TC-TN12/11 MPS - not harmful to human health or the environment
- Develop the EFFICIENT Fire Knockdown System (EFKS) capable of delivering the AGENT(s) under a range of environmental conditions simulating those an aircraft would undergo
- Construct a suitable DEMONSTRATOR capable of showing that the EFKS will fulfil all requirements in terms of fire suppression performance



Tests and Acceptance Criteria

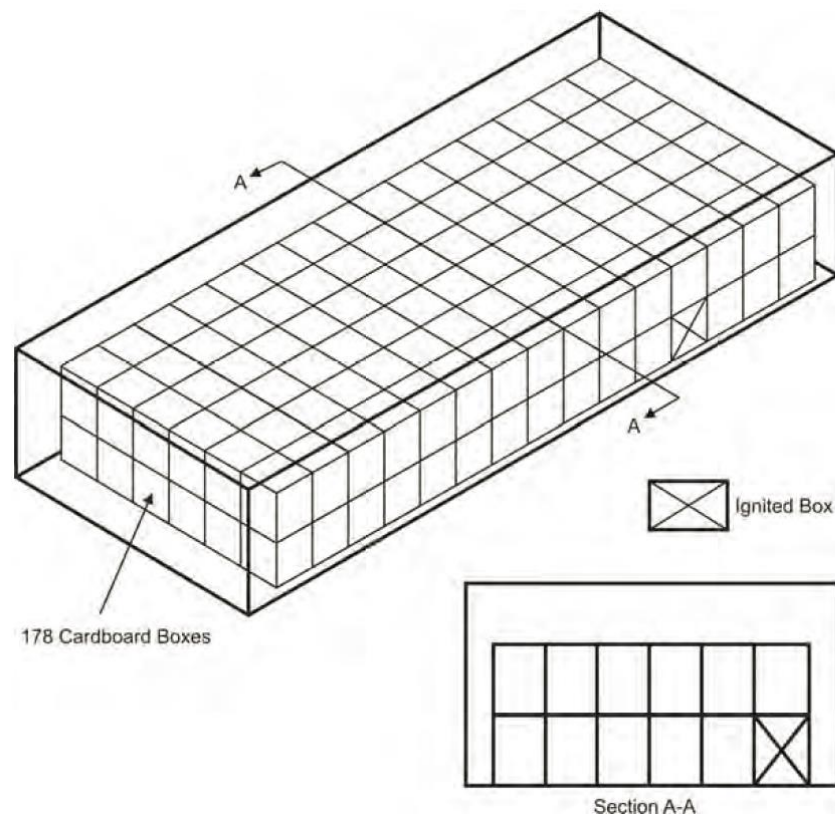


Four test scenarios:

1. Bulk - load fire
2. Containerized load fire
3. Aerosol can explosion (short version)
4. Surface burning fire

Bulk – load fire scenario

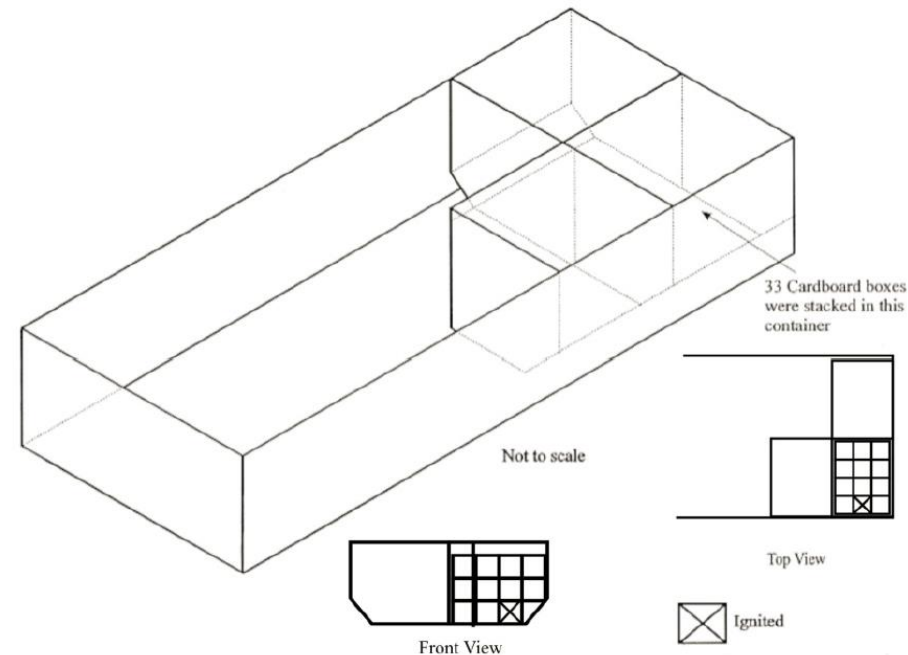
- 178 cardboard boxes filled with shredded paper
- Each box weighs 1.1kg net
- Ignition triggered through a specially perforated box
- Suppression triggered 1 min after ceiling temperature Reaches 93.3 °C
- Temperatures monitored for 28 minutes



Source: FAA MPS

Containerised – load fire scenario

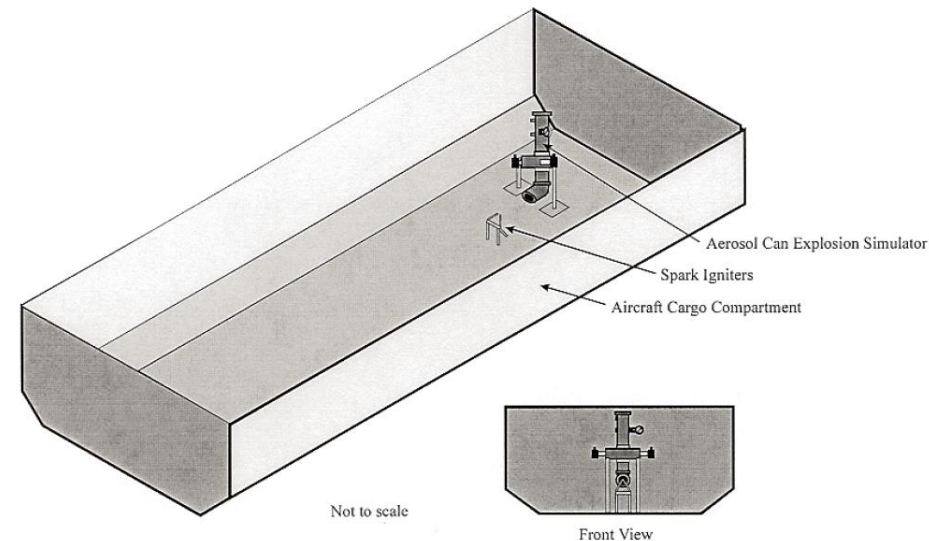
- 3 LD3 containers stacked inside the demonstrator
- One LD3 is filled with 33 boxes
- Ignition triggered through a specially perforated box
- Suppression triggered 1 min after ceiling temperature Reaches 93.3 °C
- Temperatures monitored for 28 minutes



Source: FAA MPS

Aerosol can explosion scenario

- Appropriate pressure vessel containing 20% liquid propane, 60% ethanol and 20% water
- Vessel heated to 240psi
Internal pressure
- Ignition electrodes 3 feet away are charged with 10,000V
- Mixture released within 0.1sec, 2 minutes after suppression activation



Source: FAA MPS

Surface – burning scenario

- Appropriate steel pan containing 0.385l gasoline, 1.9l kerosene and 9.5l water
- Pan located at disadvantaged location
- Ignition electrodes are charged with 10,000V
- Temperatures monitored 2 minutes after suppression activation (60 s after 93.3 °C) for 3 minutes

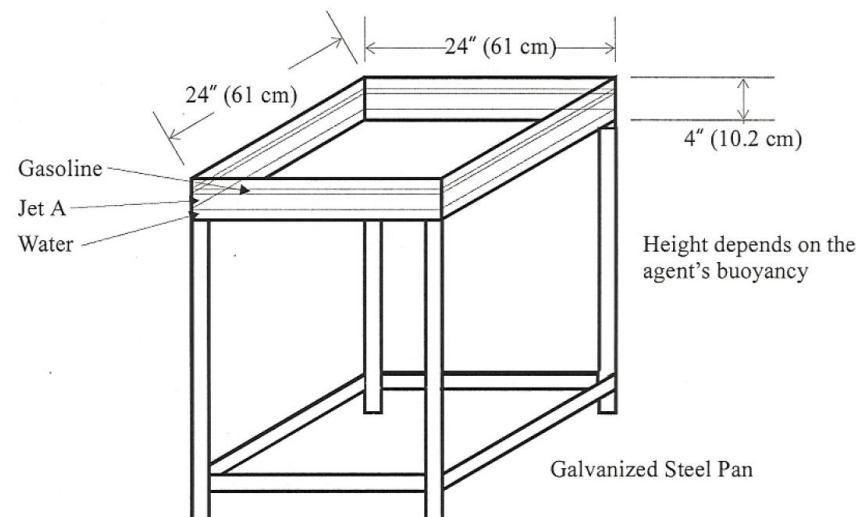


Figure 7. Surface-Burning Fire Pan

Source: FAA MPS



Tests and Acceptance Criteria



Fire Scenario	Maximum Temp. °F (°C)	Maximum Pressure psi (kPa)	Maximum Temp-Time Area °F-min. (°C-min.)	Comments
Bulk Load	710 (377)	Not Applicable	9850 (4974)	Use the data that are between 2 and 30 minutes after suppression system activation.
Containerized Load	650 (343)	Not Applicable	14520 (7569)	Use the data that are between 2 and 30 minutes after suppression system activation.
Surface Fire	560 (293)	Not Applicable	1190 (608)	Use the data that are between 2 and 5 minutes after suppression system activation.
Aerosol Can Explosion Simulation	Not Applicable	0.0	Not Applicable	There shall be no evidence of an explosion. No enhancement of explosion at below inert concentrations.

Synopsis of acceptance criteria - Source: FAA MPS



Experimental Rig Set Up



- Demonstrator manufactured to exact dimensions of wide body aircraft FWD cargo hull (57m³)
- 33 K type thermocouples installed on ceiling and side walls
- Ports for cargo hull door leakage simulation designed according to MPS – Electric fan extracts air at rate of 23l/s
- Adjustable ventilation system installed



Cargo hull demonstrator



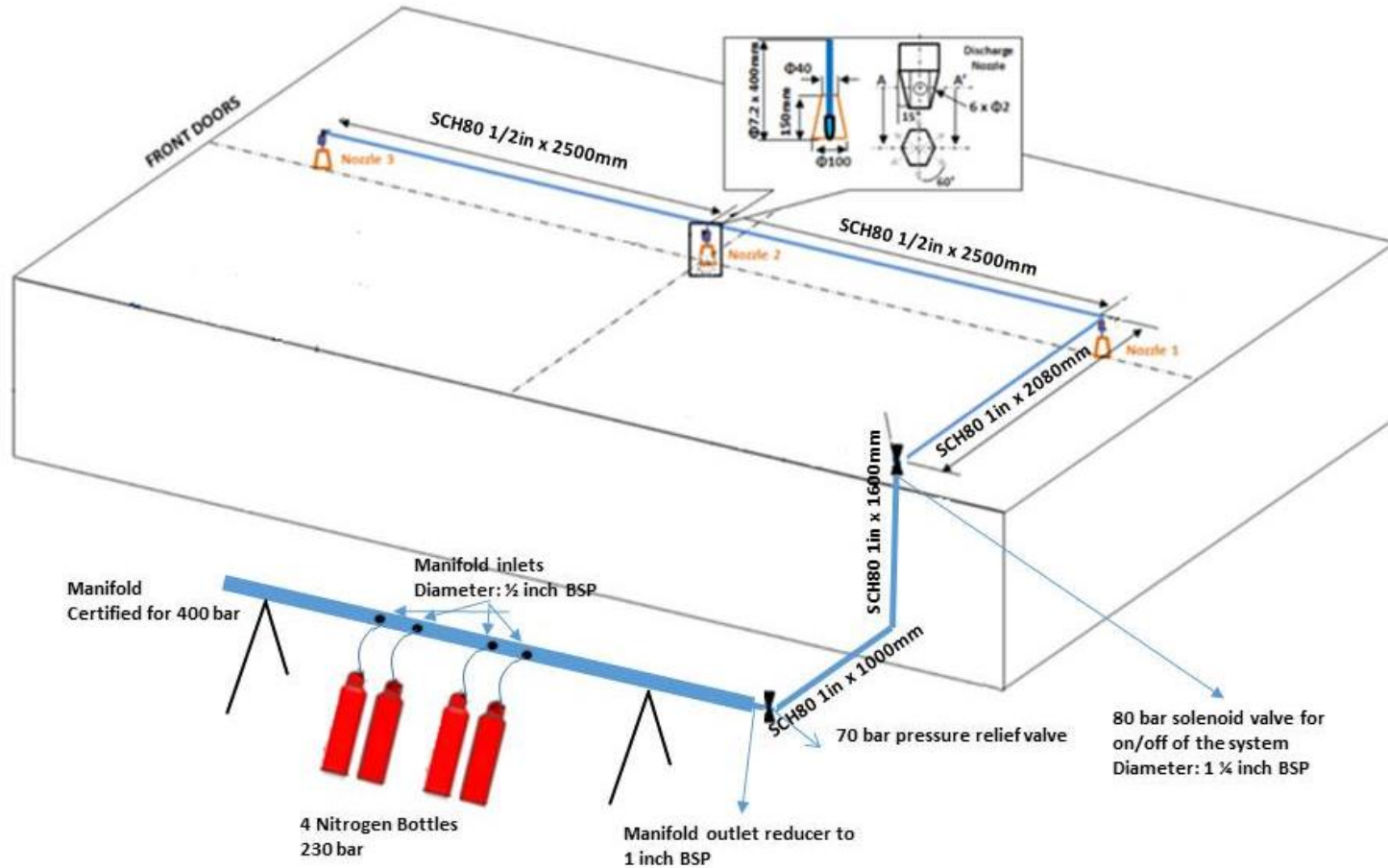
Interior of demonstrator



Leakage simulator



Ventilation and regulation



Schematic representation of nitrogen supply for EKFS



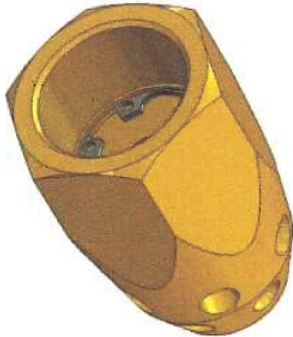
Galvanised steel pipes
1 inch

Spray Nozzles x3

Galvanised steel pipes
 $\frac{1}{2}$ inch

Pressure transducers x3

Nitrogen distribution for EKFS



ASSEMBLY	ORIFICE	Height	A/F	DN	Design Flow rate	Max Flow rate
Part No	RANGE	mm	mm	mm (inch)	Kg/min	Kg/min
NF35150	1.6-10mm	44	24	15 (½")	23	33
NF35200	7-14mm	55	32	20 (¾")	45	66
NF35250	10-18mm	67	41	25 (1")	90	133
NF35320	12-23mm	82	54	32 (1-¼")	118	175
NF35400	15-26mm	93	63	40 (1-½")	158	235

Nitrogen spray nozzles specification



Nitrogen spray nozzle and nitrogen supply arrangement



No	Instrument/sensor	Type	Measurement	Sensor Type	Range Accuracy		Sampling	Output	Units	Usage
1	Thermocouples Type K	Thermocouples with standard head and process connection and weather protection	Temperature	K chrome/alumel	1300 C	1C	10 Samples /s	Low Voltage	35	Temperature measurement inside the demonstrator – One for Ambient temperature measurement
2	Pressure Transducer	OMEGA PXM409	Pressure	Differential Pressure	0-5 psid	0.08%	10 Samples/s	10VDC	2	Pressure drop across orifice plate for leakage simulation flow rate measurement
3	Pressure Transducer	OMEGA PXM409	Pressure	Gauge Pressure	0-70bar psig	0.08%	10 Samples/s	10VDC	3	Static pressure of nitrogen before each spray nozzle
4	Pressure Transducer	Kulite XCQ-093	Pressure	Sealed gauge	0-15 psig	0.1%	3000 Samples/s	100mV	1	Overpressure inside the demonstrator
5	Oxygen analyser	XZR-B2-C2	Oxygen Concentration (v/v)	Zirconium oxide	0-25%	0.55%	10 Samples/s	10V DC	3	Agent concentration,
6	One Weight industrial scale	HFC12	mass (kg)	Load cells – digital output	0-1500kg	0.2kg	10 Samples/s	RS232	1	Mass reduction of nitrogen cylinders during suppression

Basic instrumentation



Experimental Rig Set Up



The interface is divided into several functional areas:

- Temperature Control:** Includes a large graph showing Amplitude vs. Time (00:00 to 00:00). Parameters include TC rate (10), TC number of samples (1), Pressures rate (10), Pressures number of samples (1), Dynamic pressure rate (3000), and Dyn Pr. number of samples (3000). A 'STANDBY' button is visible.
- Pressure and Flow:** Shows Nozzle1_Temp, Nozzle2_Temp, Nozzle3_Temp, Leakage mflow (kg/s) (0.000), Leakage Flow (t/s) (0.00), and Ambient Temperature (C) (0).
- TC (Temperature Controller) Readouts:** Organized by location: Right Wall (TC19-TC24), Ceiling (TC1-TC18), Back Wall (TC25-TC27), and Left (TC28-TC33). Each TC has a current value and a limit value (e.g., TC24: 0.0 / 377).
- Pressure and Oxygen:** Includes Ambient Pressure (kPa) (0.00), Orifice p1 (kPa) (0.00), Orifice p2 (kPa) (0.00), p_Nozzle1 (bar) (0.00), p_Nozzle2 (bar) (0.00), and p_Nozzle3 (bar) (0.00). Oxygen % volume is shown in a graph (8-22) and a list of sensors (O2 UP, MID, LOW, AVG).
- Control and Status:** Features a 'Case Selector' (CONTAINERISED, SURFACE, BULK, AEROSOL), 'Nitrogen Manual Release' (STANDBY), 'Time Target (min)' (1), 'Time has Elapsed' indicator, 'Elapsed Time (min)' (0.00), 'Current time' (00:00:00.000), 'Set override time' (300), 'Rejection limit' (322), 'Time from ignition (s)' (0.0), and 'Ignition' (STANDBY) and 'Heat Gun' (STANDBY) buttons.
- Log Data:** Lists TC measurements file (C:\Users\Efficient\Desktop\Eff_DAQ\data\Surface_run1.lvm) and Dynamic measurements file (C:\Users\Efficient\Desktop\Eff_DAQ\data\compartment_surface_run1.lvm).

Experiment control interface



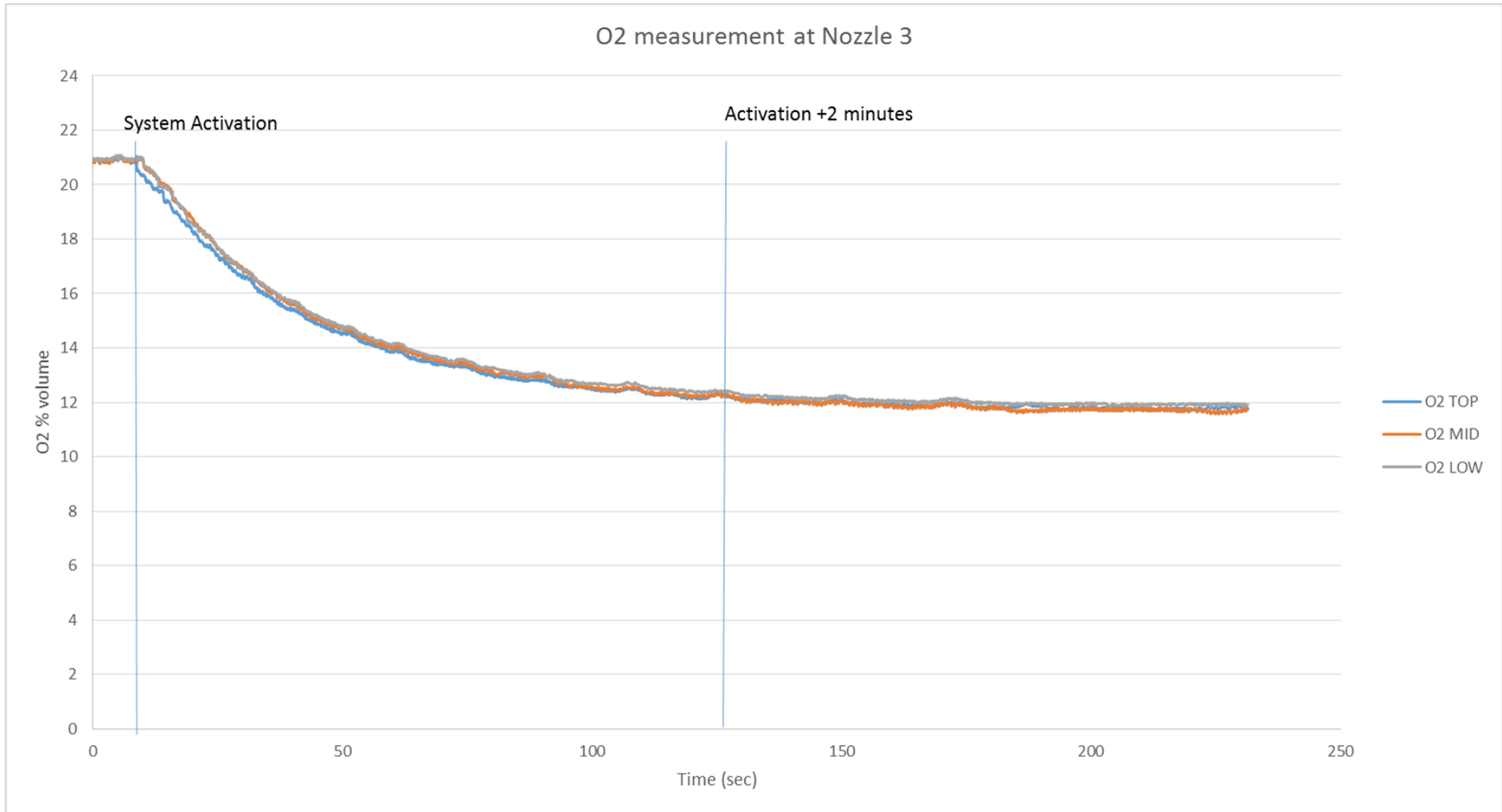
Aerosol can explosion simulation



Results so Far

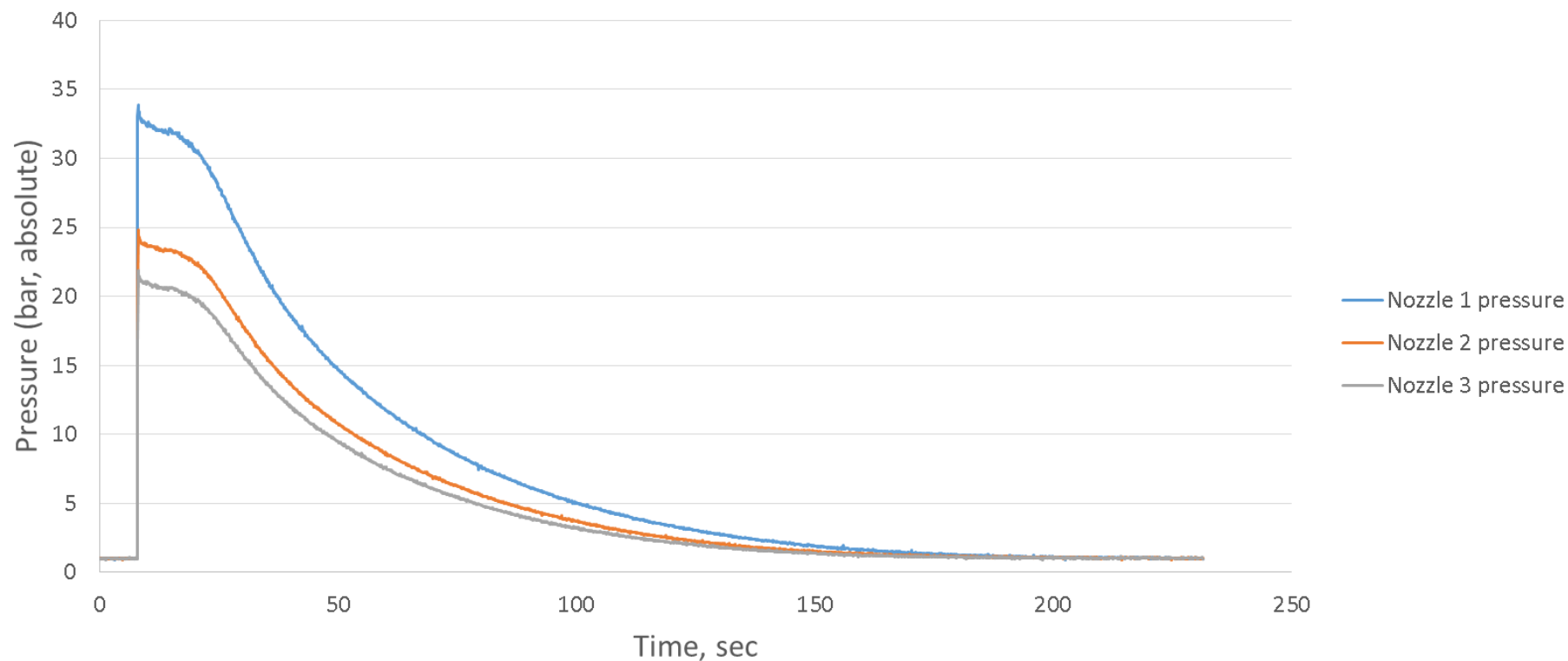


- Baseline nitrogen concentration tests for EKFS
- Nozzles configured at orifice diameters 5mm, 8.5mm and 8.5mm respectively
- Pressure of nitrogen distribution system regulated at 50bar
- Approximately 45kg of nitrogen consumed
- Peak pressure increase inside chamber at 0.4psi
- Oxygen concentration reduced below 12% volume within 2 minutes

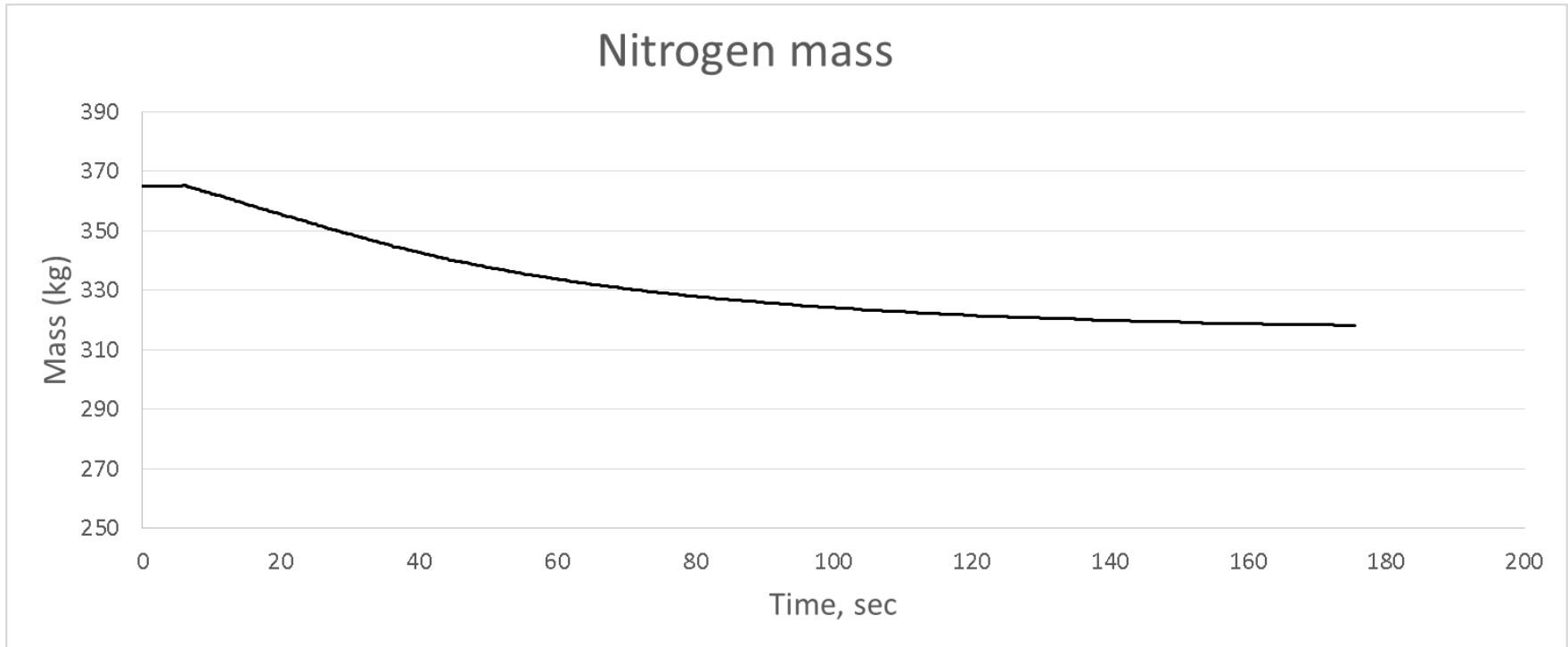


Oxygen concentration reduction

Spray Nozzles Pessure



Discharge nozzles pressure



Nitrogen mass consumption during EKFS



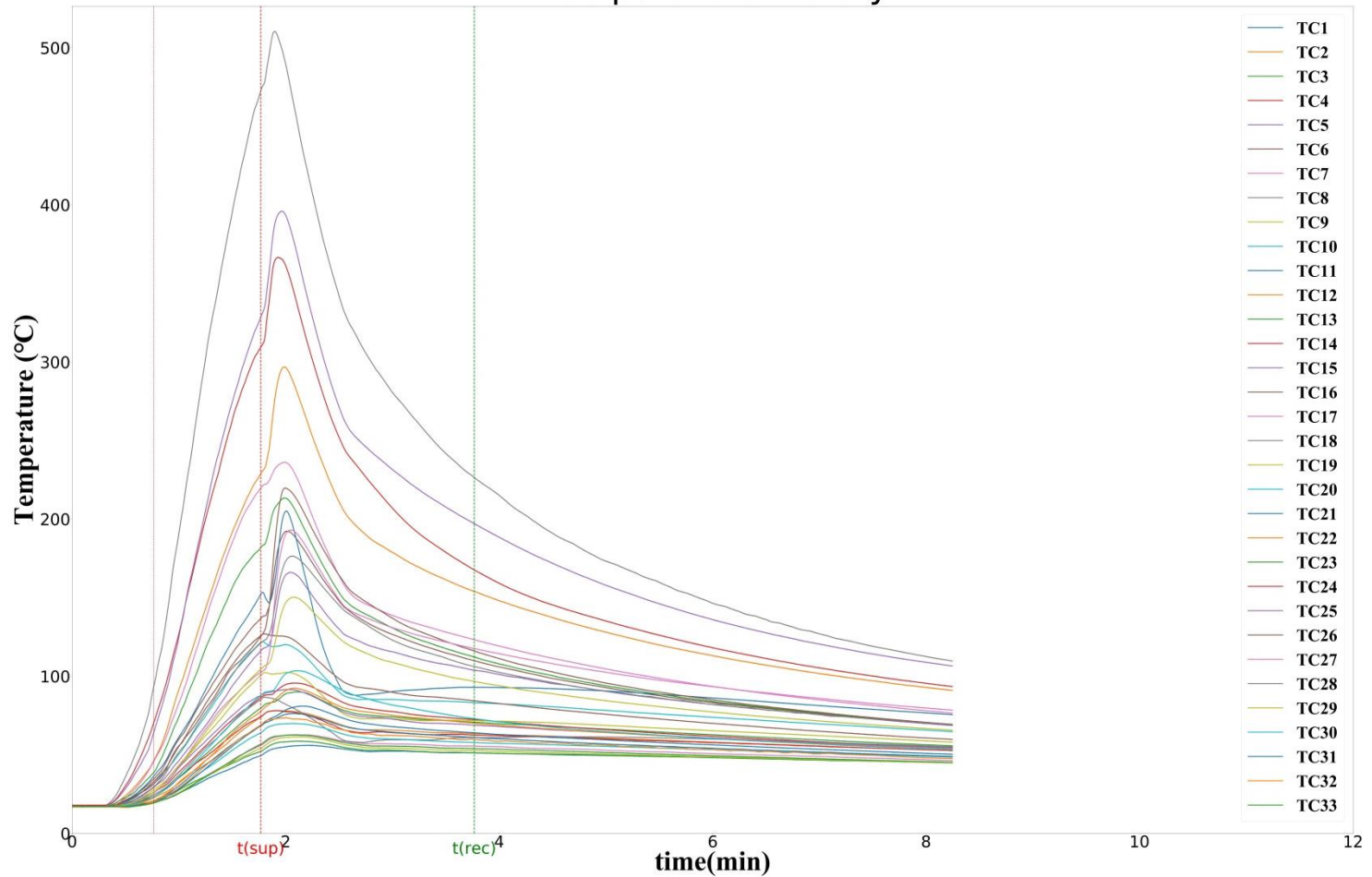
Location of Surface Burning pan

Cylinder_weight (kg)	TC1	TC23	TC22	TC21	TC20	TC19
117.8	20.2	19.8	19.7	19.8	19.4	25.1
Leakage inflow (kg/s)	TC4_Limit	TC23_Limit	TC22_Limit	TC21_Limit	TC20_Limit	TC19_Limit
NaN	93.2	93.2	93.2	93.2	93.2	93.2
Leakage Flow (kg/s)	Ceiling					
NaN	TC17	TC16	TC15	TC14	TC13	
Ambient Temperature (C)	22.7	22.1	21.2	21.6	20.2	20.9
26.4	TC25_Limit	TC17_Limit	TC16_Limit	TC15_Limit	TC14_Limit	TC13_Limit
Back Wall	93.2	93.2	93.2	93.2	93.2	93.2
TC25_Limit	TC26	TC11	TC10	TC9	TC8	TC7
93.2	19.4	21.3	21.1	22.7	23.8	22.8
TC26_Limit	TC11_Limit	TC10_Limit	TC9_Limit	TC8_Limit	TC7_Limit	
93.2	93.2	93.2	93.2	93.2	93.2	
TC27_Limit	TC5	TC4	TC2	TC2	TC1	
93.2	19.7	22.8	22.8	21.4	25.1	
Ambient Pressure (kPa)	TC5_Limit	TC4_Limit	TC2_Limit	TC2_Limit	TC1_Limit	
88.95	93.2	93.2	93.2	93.2	93.2	
Office p1 (kPa)	Left					
88.94	TC28	TC29	TC30	TC31	TC32	TC33
Office p2 (kPa)	19.6	21.3	21.3	22.2	21.6	22.3
88.83	TC28_Limit	TC29_Limit	TC30_Limit 2	TC31_Limit	TC32_Limit	TC33_Limit
p_Nozzle1 (kPa)	88.8	93.2	93.2	93.2	93.2	93.2
p_Nozzle2 (kPa)	88.8					
p_Nozzle3 (kPa)	88.8					

Nearest thermocouples

Surface Burning scenario pan location

Temperature history



Temperature distribution for Surface Burning scenario



Results so Far



- Oxygen concentration reduced to $\approx 10\%$
- Approximately 34kg Nitrogen discharged

Location	Max temp (°C)	Max temp limit (°C)	Max temp over time (°C)	Max temp over time Limit (°C)	Result
TC18	205.83	293	475.42	608	PASS
TC18	226.55	293	509.46	608	PASS



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