SP METHOD 4912

EDITION 2

FIRE SAFETY IN ENGINE COMPARTMENTS

SP Method 4912: Testing of fire suppression system intended for use in compartment with combustion engine.

SP Method 4912: November 2019

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Content

1 Introduction

The test method described in this document is intended for test and rating of suppression performance and limitations of fire suppression systems for installation in engine compartment with a combustion engine. The test method also examines the durability of the system components.

1.1 Scope

This method assesses the fire suppression performance of fire suppression systems under mock-up operational conditions. For this purpose, several different types of fires are ignited and stabilised inside an enclosure with typical engine compartment characteristics before the fire suppression system is activated. After the fire suppression system has been activated and completely discharged, the system is evaluated based on its ability to extinguish various fire sources.
In order to ensure the reproducibility of the test and facilitate its adoption in different laboratories, the method utilizes a standardised mock-up.

The fire suppression system is evaluated both as a complete system and in terms of components.

Durability tests are adapted for harsh vehicle conditions and are adjusted to suit both on-road applications as well as off-road applications.

1.2 Field of application

The test method is applicable to fire suppression systems intended for use in engine compartments, including but not limited to buses, coaches, trucks, wheel loaders, tractors, mining machines and forestry machines. The engine compartment mock-up has a gross volume of 4 m^3. The tested suppression systems can be scaled on the basis of the test results for engine compartments within the range 2 m^3 – 6 m^3. Calculation model for scaling is found in appendix D.

An engine compartment covered by this test method is any enclosure or volume containing an internal combustion engine or heater/ combustion auxiliary heater.

For engine compartments larger than 6 m^3 or smaller than 2 m^3 a separate risk assessment must motivate the extension of the scaling model or the use of another scaling model. For engine compartments larger than 10 m^3, typically found in large heavy-duty mobile machines/equipment, it may be necessary to perform additional measurements of environmental conditions and fire suppression tests to motivate the system size and configuration.

1.3 Disclaimer

The results relate to the performance of fire suppression systems against a variety of tests based on some of the operating conditions and fire hazards associated with engine compartments. The test method is designed to provide some information about the fire suppression performance of the product. This information should be used as input to a risk assessment for real applications but is not intended to be the sole criterion for assessing the potential fire hazard protection of the product in use. It is the responsibility of the fire protection system provider, in collaboration with the vehicle/machine supplier or owner, to carry out a full risk assessment for and of each application and accept full responsibility for the overall performance of the installed suppression system.
Users of this test method should observe the following warning:

Safety warning – in order that suitable precautions may be taken to safeguard health, the attention of all engaged in fire tests shall be drawn to the possibility that toxic or harmful gases may be evolved during combustion of the test fires as well as by activating the suppression system. The potential heat released from the test fires should be considered before the test starts and measures must be taken to avoid any risk of explosion or uncontrolled fire development.

1.4 Tolerances

Below tolerances shall be followed:

- ±5 s for time values
- ±5 % for dimensions, positions, temperatures and other measurements unless explicitly stated otherwise

2 Suppression system durability tests

A representative sample of the complete system shall be tested as specified below. By a representative sample is meant an operable system unit which consists of the same components (mounting brackets inclusively) as the system it represents. If not stated otherwise, it is acceptable for new components to be used for every durability test.

The components of the complete system that can be placed in the engine compartment or equivalent environments shall be tested for durability with exposure to vibration with temperature variations in accordance with ISO 16750-3 and if applicable for protection against ingress of water according to ISO 20653. Corrosion resistance test according to ISO 21207also applies to parts of the system that can be placed on the exterior of the vehicle or in compartments with similar atmospheric conditions.

The listed durability tests are to be considered as additional requirements to legal requirements and requirements imposed by the vehicle manufacturer. It is the responsibility of a suppression system supplier to assure compliance with all applicable requirements.

2.1 Vibration with temperature variations

The object of this test is to ensure the ability of the suppression system to withstand random vibrations induced by rough-road driving with varying ambient temperatures.

2.1.1 Test procedure

The test shall be conducted in accordance with Test VII (Commercial vehicle, sprung masses) in ISO 16750-3. The temperature cycle shall be in accordance with Figure 1 in ISO 16750-3 with T_{min} and T_{max} expressed in the specification of the detector system. The system can either be exposed to the temperature cycle before the vibration test or simultaneously with the vibrations.

Mechanical shock test in accordance with ISO 16750 4.2.2.2 with 20g acceleration (*commercial vehicles, devices on rigid points of the body or frame*) immediately following the vibration test.

2.1.2 Requirements

Following these tests, the representative sample shall be discharged, show no visible signs of leaks or loosened fittings, and the mass of the extinguishing agent discharged shall not be less than 95 % of the highest mass discharged during the fire tests, based upon comparison of extinguishing agent vessel mass or sample mass before and after the test.

2.2 Corrosion resistance

The object of this test is to ensure the ability of the suppression system to withstand the effects of corrosive environment.

2.2.1 Test procedure

The test is made according to ISO 21207, test method 3 with three weeks exposure.

2.2.2 Requirements

Following the test, the representative sample shall be discharged, show no visible signs of leaks or loosened fittings, and the mass of the extinguishing agent discharged shall not be less than 95 % of the highest mass discharged during the fire tests, based upon comparison of extinguishing agent vessel mass or sample mass before and after the test.

2.3 IP-classification

The object of this requirement is to ensure that electric parts in the system that is installed in the engine compartment are protected against ingress of solid foreign objects and water. The degree of protection should ensure protection against high pressure water jets used for cleaning.

2.3.1 Test procedure

The test shall be conducted in accordance with ISO 20653:2013.

2.3.2 Requirements

The system shall fulfil the degree of protection IP6K5/IP6K9K.

Degree of protection IP65 is allowed if the specification of the system explicitly states that the parts cannot be pressure washed.

3 Suppression performance tests

The object of the tests is to ensure system coverage of a complete engine compartment and to test the capability of the suppression system under varying ventilation conditions. If not stated otherwise, the suppression system shall be the same through all tests. The suppression system is to be restored in origin condition before each test with all parts installed as intended. Broken or consumable parts shall be replaced.

The tests are performed in an engine compartment mock-up. Description of the mock-up is found in Appendix A.

3.1 Test scenario openness

The test scenarios can be performed at four different levels of mock-up openness, as listed in Table 1.

Table 1: Levels of mock-up openness

Level	Criteria
1	Fire tests with open mock-up
2	Fire tests without mock-up floor and ceiling
3	Fire tests without mock-up floor
4	Fire tests with enclosed mock-up

3.2 Test scenarios

There are eleven different test scenarios. The test scenarios are described in Annex C and are summarized in Table 2.

Table 2: Test scenarios

Test scenario	Description	Ventilation (m^3/s)	Remarks
1	Low fire load	3	
2	High fire load	3	
3	Hidden fire	3	
4	Hidden fire	1.5	
5	Hidden fire	0	
6	Low fire load	0	Reduced mass of extinguishing agent
7	High fire load	0	At minimum operating temperature
8	High fire load	1,5	
9	Low fire load	1.5	
10	Re-ignition	0	Minimum time to re-ignition: 45 s
11	Class A-fire	0.5	

3.3 Fire sources

Ten different fire sources are used in various configurations in the fire scenarios. Descriptions of the fire sources are found in Appendix B.
Diesel oil, heptane, semi-synthetic engine oil, pine wood and fibre board are used as fuels.

Table 3: Fire sources

Fire source	Description
#1	Pool fire 300 mm × 300 mm
#2	Pool fire 300 mm × 300 mm and fibreboards
#3	Pool fire 200 mm × 300 mm
#4	Pool fire Ø 150 mm
#5	Class A- wood crib fire and pool fire 200 mm × 300 mm
#6	Fibreboard 200 mm × 300 mm
#7	Hidden pool fire 300 mm × 300 mm and fibreboards
#8	Spray fire 0.73 kg/min
#9	Spray fire 0.19 kg/min
#10	Dripping oil fire, 40 droplets/min

3.4 Suppression system

To obtain the minimum discharge rate condition, an extinguishing system is to be assembled using its maximum piping limitations with respect to the number of fittings, sizes and lengths of pipes. The suppression agent cylinder is to be filled to its rated capacity and the cylinder or gas cartridge pressurized with the expellant gas to the normal operating pressure. Other technical suppression system solutions shall be filled or charged in its minimum installation design.

3.4.1 Nozzle positioning

The nozzles may only be positioned inside the mock-up, in two different areas.

3.4.1.1 Nozzle area 1

In the ceiling and at the rear wall. Nozzles positioned in the ceiling must be positioned so that the nozzle outlet is 750 mm or more above floor level. Nozzles shall not be installed inside Obstruction 1. Nozzles shall not be positioned where they prevent the execution of the tests. Nozzles positioned at the rear wall must be positioned so that the nozzle outlet is within 350 mm of the rear wall ($y \geqslant 1150$ mm) and 450 mm or more above floor level, see Figure 1 and Figure 2.

3.4.1.2 Nozzle area 2

Inside the rear box (referred to as Obstruction 4) in the rear side of the mock-up. Nozzles should be located in the ceiling of the box, so that the nozzle outlet is 290 mm or more above floor level, see Figure 2.

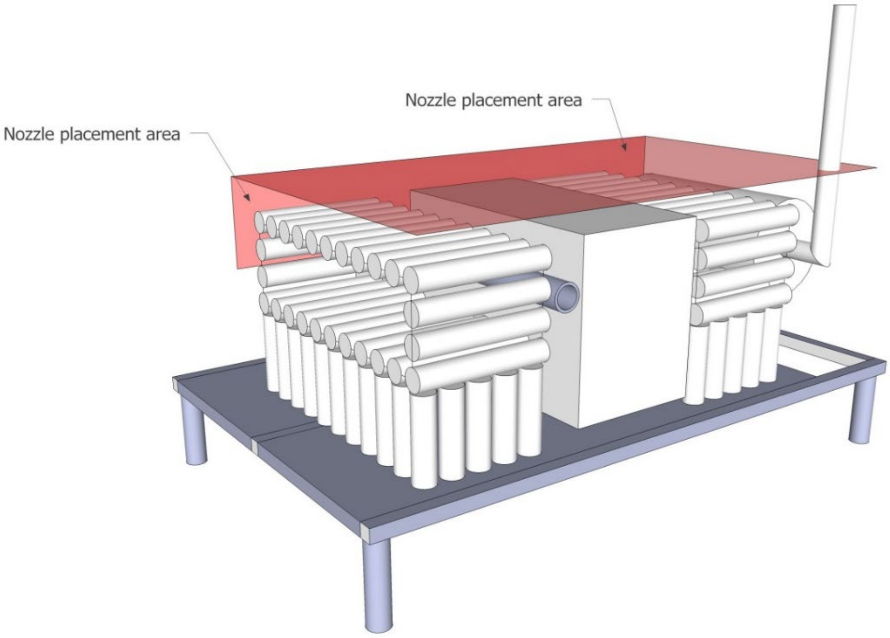

Figure 1 Nozzle positioning seen from the front side of mock-up

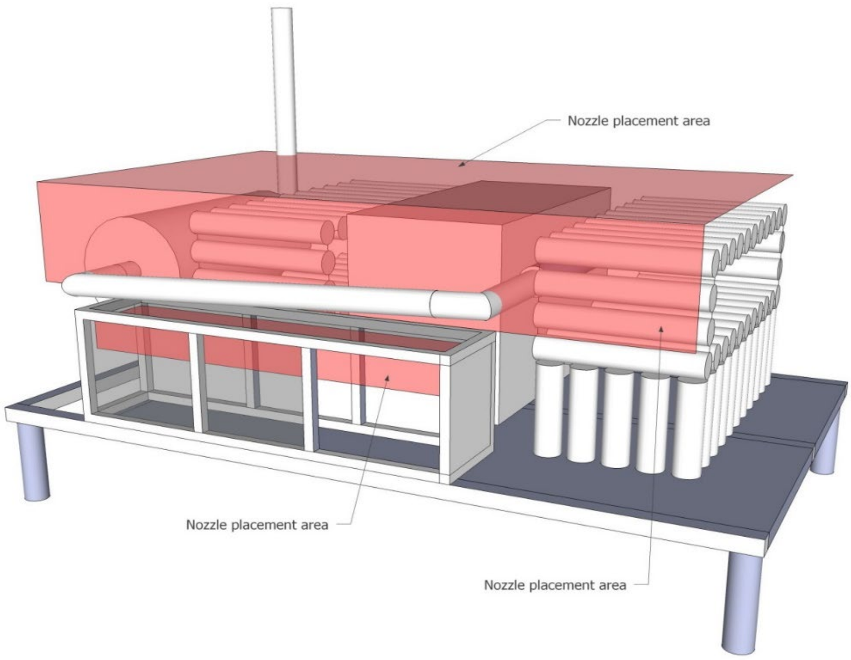

Figure 2 Nozzle positioning seen from the rear side of mock-up

3.5 Verification

The system setup and configuration such as number, type and location of nozzles, length and dimensions of pipes/hoses, number and type of fittings, type and amount of suppression agent, propellant gas and system pressure shall be documented prior to the test. All the parts used in the installed suppression system must be verified to be in compliance with the manufacturers drawings and specifications.

3.6 Test procedure

The suppression system is to be restored in origin condition before each test with all parts installed as intended without any modifications made to the installation.

The fire sources are prepared according to specifications in Appendix B.

The fire sources are placed in the locations as specified in Appendix C for each test scenario.

A pre-burn time is required before the suppression system is activated. The time for pre-burn starts from the time when the first fire source is ignited. All fire sources in the test scenario must be ignited within the time limit for ignition; specifications for each test scenario are found in Appendix C.

In test scenarios where ventilation is required, the ventilation shall remain active until the test has been terminated.

In test scenarios with spray fire, the spray shall be active until the test has been terminated.

Minimum operating temperature fire test is performed with extinguishing agent and propellant gas vessel or suppression agent generator cooled to the lowest operating temperature.

In test with reduced mass of extinguishing agent, the mass used is 83 % of the nominal, (nominal mass of agent is divided with 1.2).

In test scenario for re-ignition, the exhaust manifold mock-up tube is pre-heated prior to the test. A sustained flame on the tube must be observed before the suppression system is activated. The oil shall continue to drip for 300 s after flames are extinguished or until re-ignition occurs.

The tests can be performed in an arbitrary sequence.

3.7 Temperature measurement

Temperature shall be measured and recorded during the re-ignition test at locations specified in Appendix A

3.8 Test criteria

Pool fires shall be extinguished within 60 s after activation of the suppression system or upon end of the discharge of the suppression system if discharge time exceeds 60 s.

Spray fires shall be extinguished within 60 s after activation of the suppression system or upon end of the discharge of the suppression system if discharge time exceeds 60 s. The spray shall be active until test is terminated.

Class A fire shall be extinguished within 60 s after activation of the suppression system or upon end of the discharge of the suppression system if discharge time exceeds 60 s and not re-ignite within 300 s after activation of the suppression system.

Fibre board fires shall be extinguished within 60 s after activation of the suppression system or upon end of the discharge of the suppression system if discharge time exceeds 60 s

Glowing at termination of test is acceptable for Class A and fibre board fires.

Dripping oil fire shall be extinguished within 15 s after activation of the suppression system and not re-ignite within 45 s after fire is supressed.

A test scenario is considered as passed if the first attempt to test is successful or if two out of three attempts is successful.

3.9 Test report

The test report shall as a minimum include the following information:

- Name and address of the testing laboratory
- Date and identification number of the test report
- Name and address of the sponsor
- Date of test
- Name or other identification marks of the tested product
- Description and drawing of the test setup
- Specification, description and drawing of the suppression system
- Configuration of the suppression system used in the tests.
- Identification of the test equipment and used instruments
- Deviations from the test method, if any
- Photos from the test
- Test results
- Date and signature

Appendix A: Engine compartment mock-up

A1 Mock-up construction

A1.1 General

The mock-up is constructed of steel plate. The thickness of the steel plate shall be in accordance with Table A 3. Figure A1 shows the mock-up from the front side and Figure A2 from the rear side. Note that the front side of the mock-up simulates the rear side of a real engine compartment.

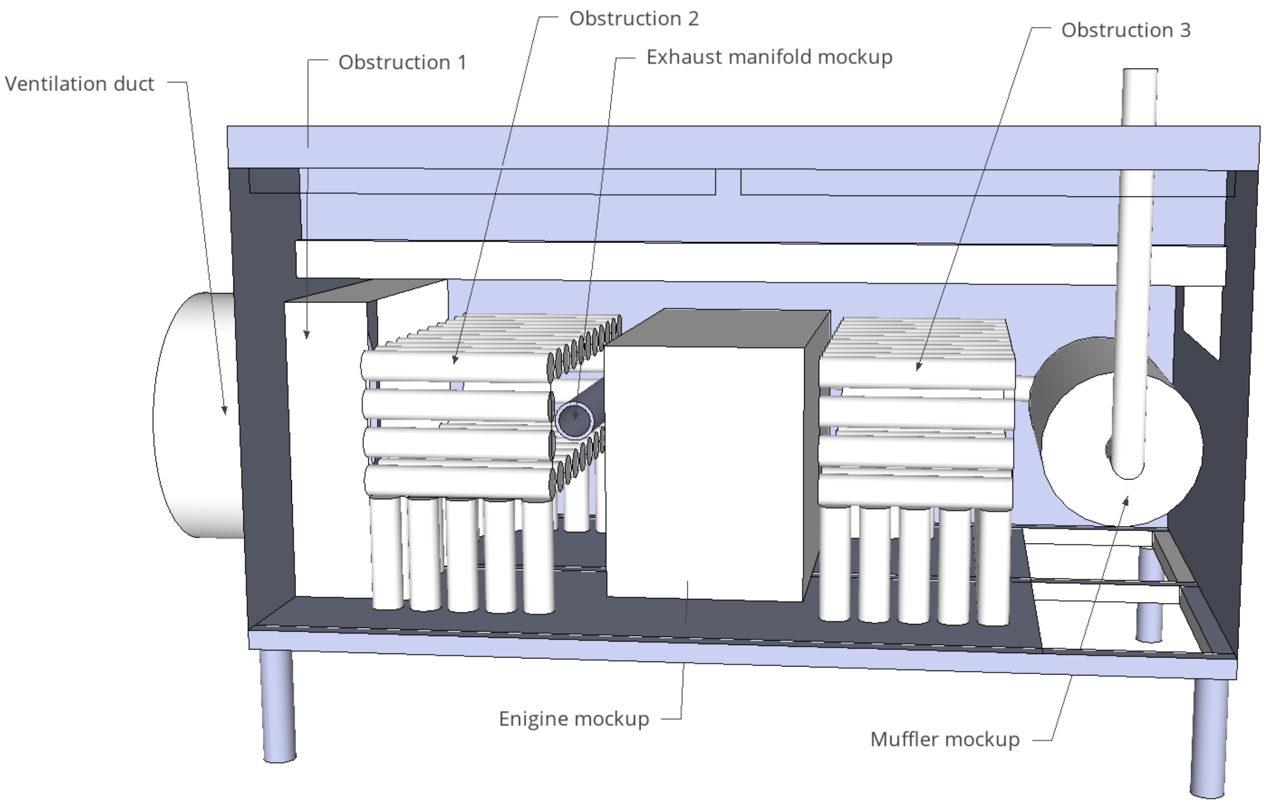

Figure A1 Mock-up as seen from the front side

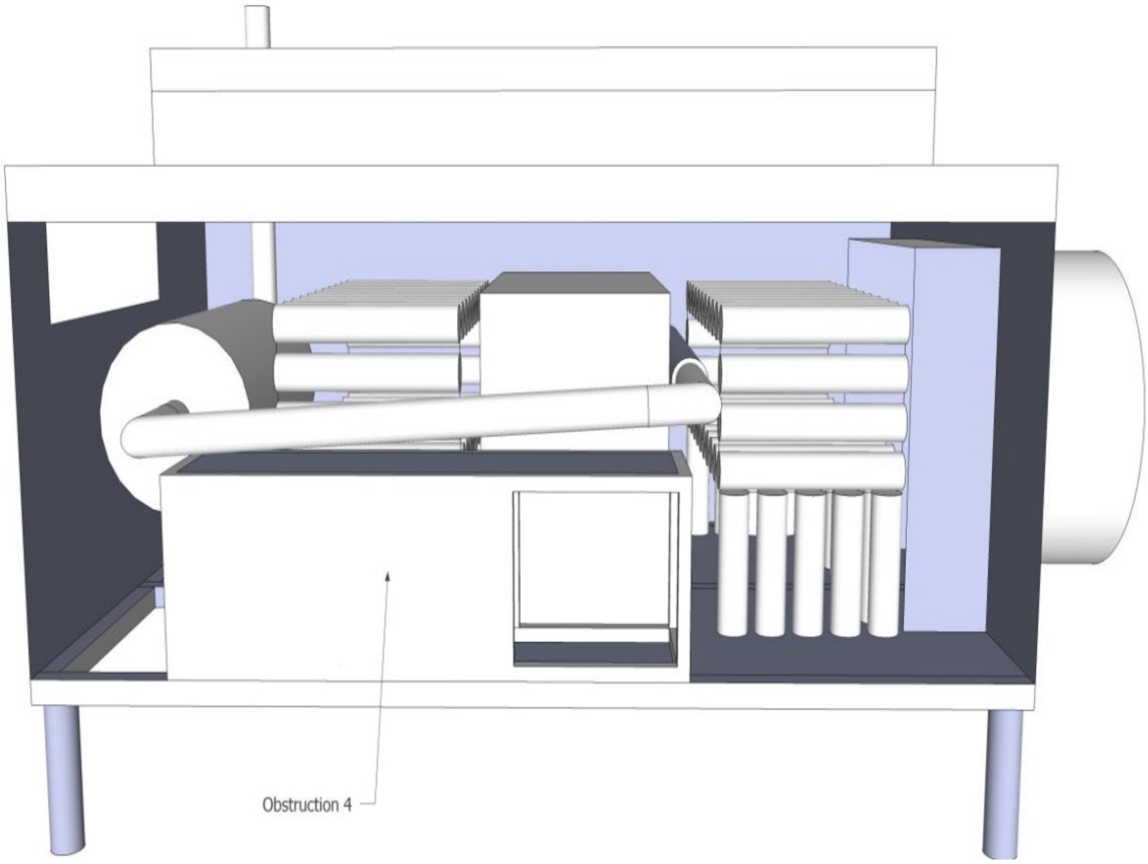

Figure A2 Mock-up as seen from the rear side

A1.2 Framework

The framework of the mock-up shall be constructed according to Figure A3. The sizes of the beams are 50 mm × 50 mm and 100 mm × 50 mm respectively.

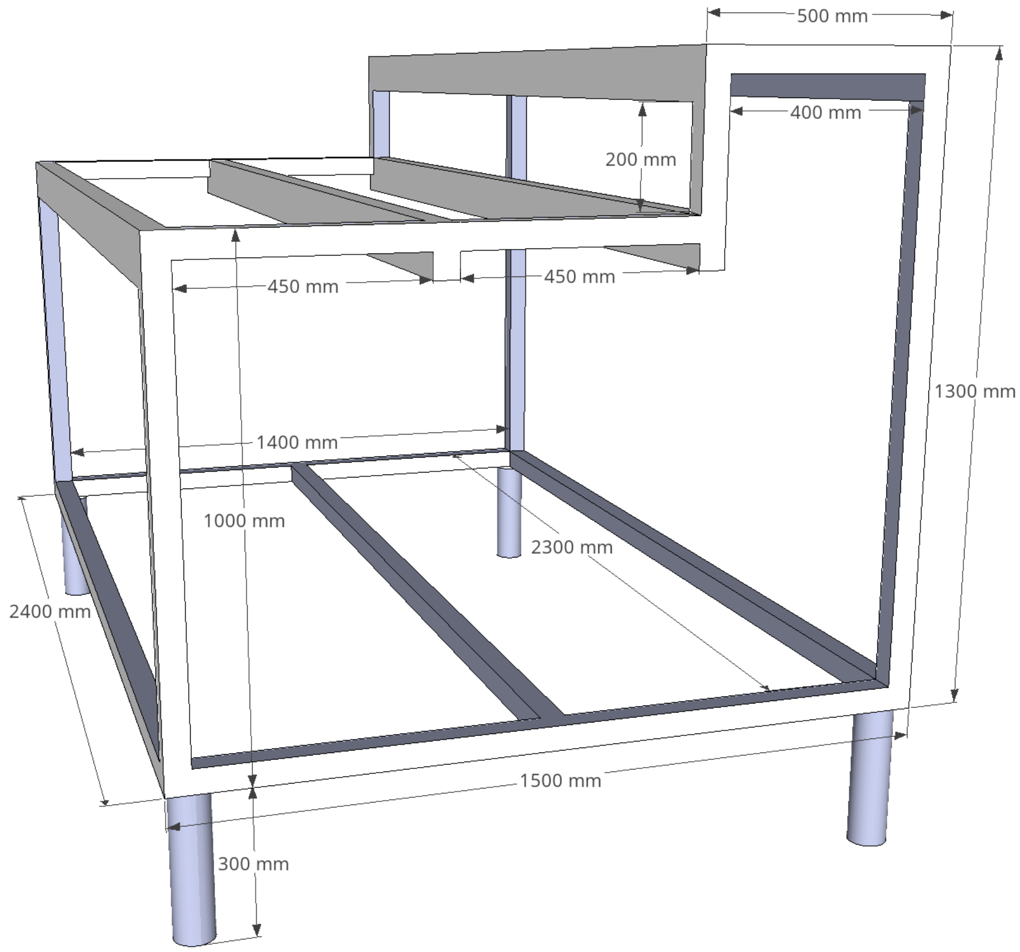

Figure A3 Framework for the mock-up

A1.3 Apertures

In addition to the opening for the ventilation, the mock-up includes six apertures, according to Figure A4. Note that all objects inside the mock-up are hidden Figure A5 in order to more clearly show the apertures. The dimensions and positions of the apertures are according to the coordinates in Table A1

The positions are given by referring to two diagonally opposite corners as all openings are rectangular in shape. However as opening D1 is slightly obstructed by Obstruction 4 resulting in a non-rectangular aperture, the corresponding coordinates describe the two rectangles of which this aperture can be thought to consist of.

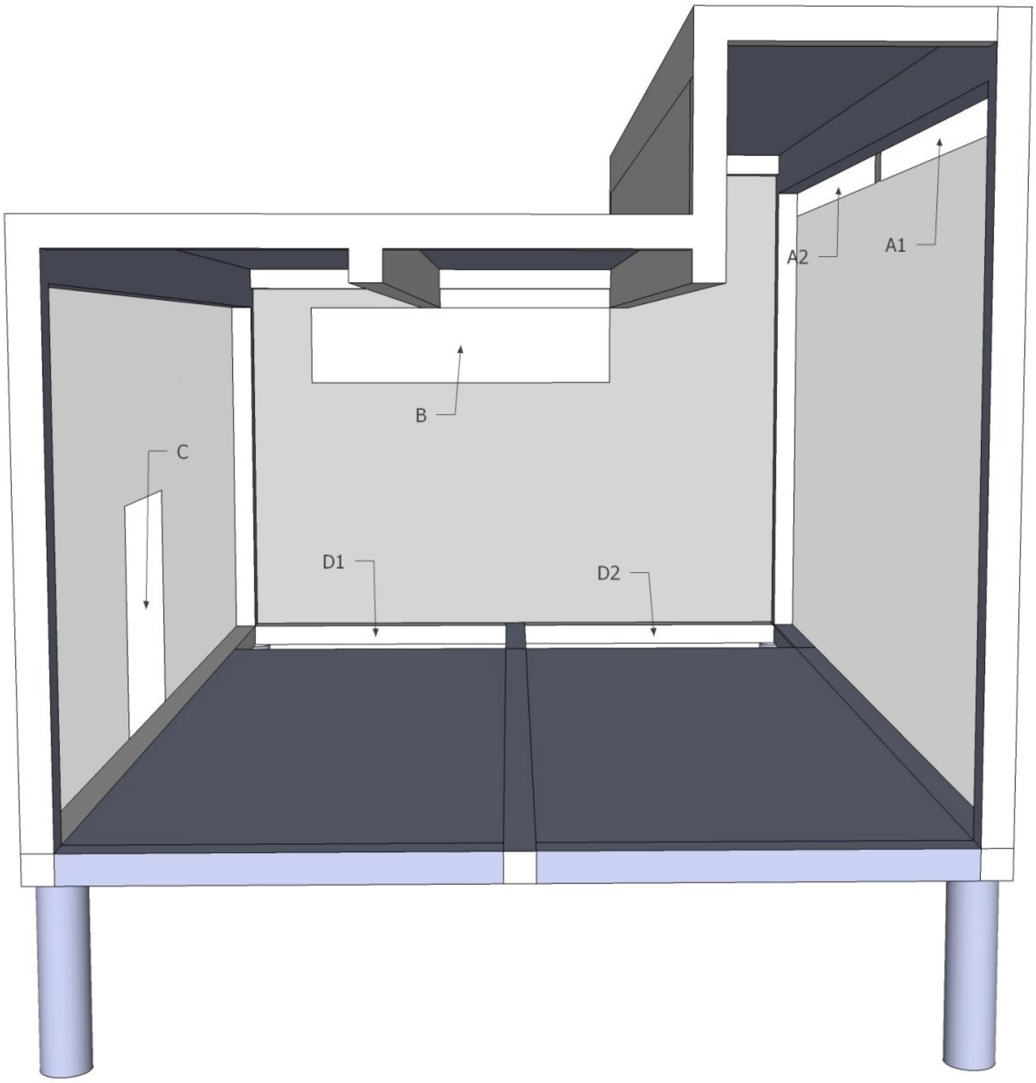

Figure A4 Apertures in the mock-up

Table A 1 Coordinates of apertures in the mock-up

Aperture	Coordinates, mm (x, y, z – x, y, z)	Area of aperture
A1	30, 0, 1080 – 1180, 0, 1130	0.06 m²
A2	1220, 0, 1080 – 2370, 0, 1130	0.06 m²
B	2400, 500, 700 – 2400, 1300, 900	0.16 m²
C	850, 1500, 30 – 1240, 1500, 360	0.13 m²
D1	2000, 780, 0 – 2350, 1200, 0 2071, 1200, 0 – 2350, 1450, 0	0.22 m²
D2	2000, 50, 0 – 2350, 730, 0	0.24 m²
	Total area of apertures:	0.86 m²

Note: The area values are only for information purpose.

A1.4 Doors and walls

The front and rear side of the mock-up shall be equipped with doors. The front doors shall include windows enabling observation of the progress in extinguishment during the tests. The remaining framework shall be covered with walls, ceiling and floor of steel sheet as specified in Table A 3. Walls and ceiling or parts of them may be in the form of closable hatches. The doors and hatches are to be mounted on the outside of the framework in such a way that no parts extend to the interior of the mock-up defined as: $0 < x < 2400$ mm; $0 < y < 1500$ mm; $0 < z < 1250$ (if $y < 500$ mm) and $0 < z < 950$ mm (if $y > 500$ mm). The doors shall extend no further than 60 mm from the mock-up

A2 Mock-up components

All objects in the mock-up are positioned according to coordinates with reference to the lower left corner as in Figure A5. X - from side wall, Y – from front wall, Z – from floor. Coordinates of components in the mock-up are found in Table A2.

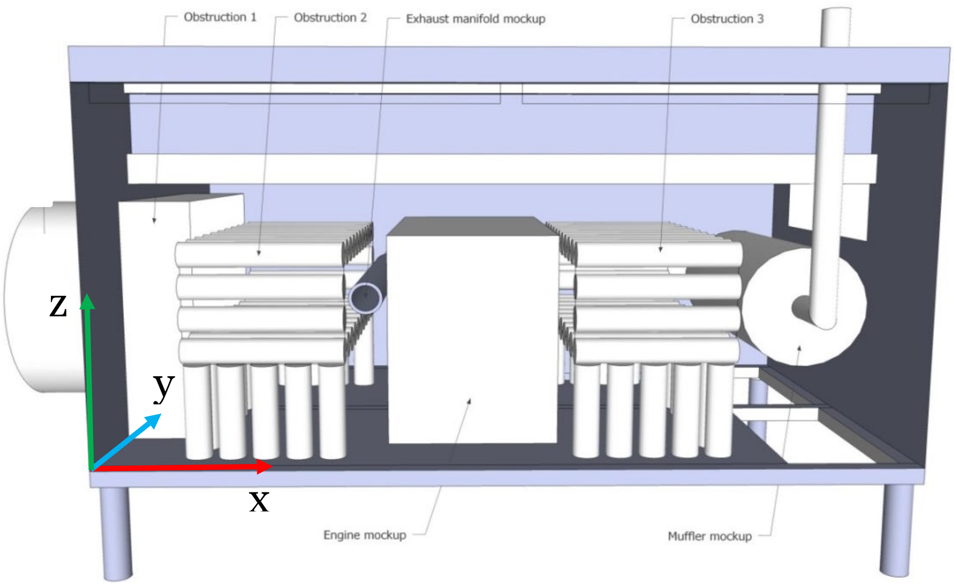

Figure A5 Coordinate system for the position of objects in mock-up.

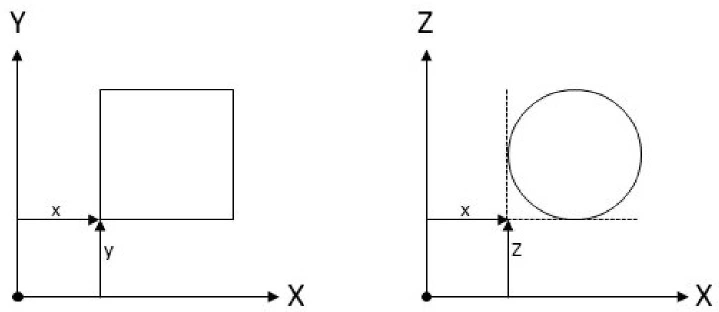

Figure A6 Measuring principle of coordinates

Table A 2 Coordinates of objects

Object	Coordinates (x,y,z) (mm)
Ventilation duct	(-600, 400, 100)
Obstruction 1	(0, 260, 0)
Obstruction 2	(260, 50, 20)
Exhaust manifold	(760, 50, 470)
Engine	(870, 50, 40)
Obstruction 3	(1440, 50, 20)
Obstruction 4	(820, 1200, 0)
Muffler	(2000, 280, 230)

Table A 3 Steel thickness of objects

Object	Plate thickness (mm)
Ventilation duct	1.5 – 3
Obstructions	1.5 – 3
Exhaust manifold	8
Engine	2 – 3
Muffler	2 – 3
Exhaust pipe	2 – 3
Connection pipe	2 – 3
Walls, ceiling and floor	1,5 – 3

A2.1 Engine and exhaust system

The dimensions of the Engine is 1000 mm × 650 mm × 500 mm. The dimensions of the Muffler is Ø 400 mm × 800 mm. The Muffler and the Engine shall be hollow. The Exhaust manifold tube has an inner diameter of Ø 80 mm and a length of 900 mm. The Exhaust manifold tube is connected to the centre of the Muffler through a connection pipe with an outer diameter of Ø 76 mm, running at a y = 1400 mm. The bends on the connection pipe and exhaust pipe should have a radius of 165±10 mm. A pipe with outer diameter of Ø 76mm shall be used to transport the hot gases vertically up and out from the Muffler . It shall be connected to the centre of the Muffler front side and run at a y = 120 mm, see Figure A7. The whole exhaust gas system from the propane burner inlet to the exhaust gas outlet should be smoke tight.

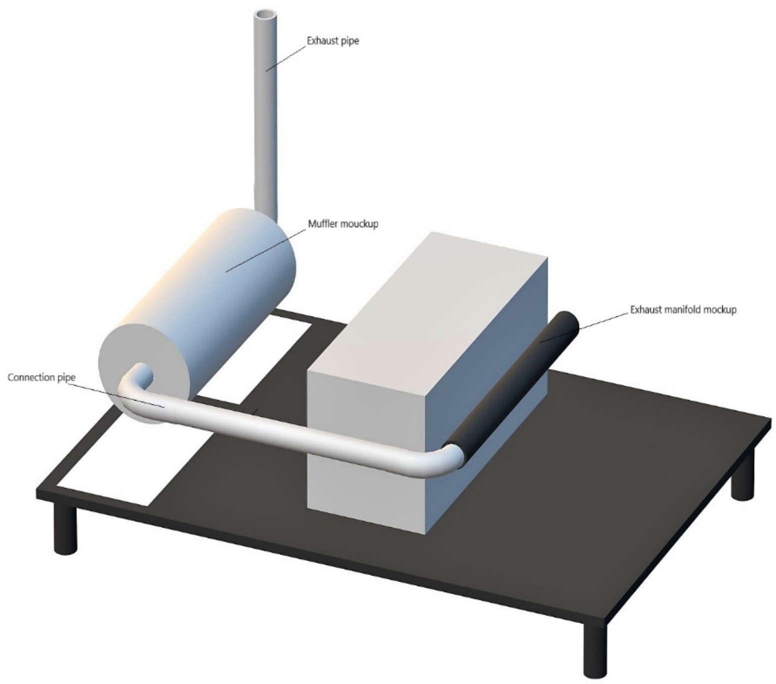

Figure A7 The exhaust system to be pre-heated for the re-ignition test.

A2.2 Obstruction 1

Obstruction 1 has the dimensions of 230 mm × 900 mm × 840 mm, see Figure A8.

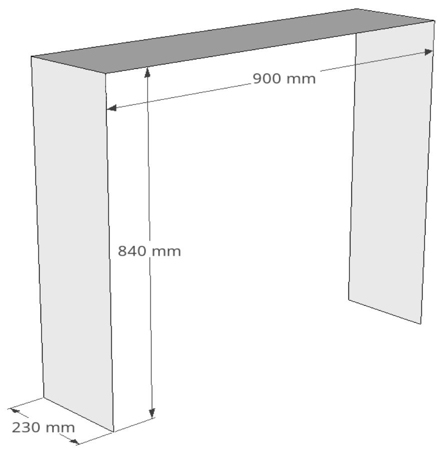

Figure A8 Obstruction 1

A2.3 Obstructions 2 and 3

Obstructions 2 and 3 consist of tubes as shown in Figure . The outer diameter of the tubes is 80 mm and wall thickness is 2,5 mm. The horizontal obstruction tubes are closed in both ends and have a length of 480 mm. The vertical tubes are only closed in the top and have a height of 230 mm. The open distance between each tube (both horizontal and vertical) is 20 mm. The distance between the open bottom of the vertical tubes and apparatus floor is 20 mm. The distance between top of the vertical tubes and the horizontal tubes is 30 mm. The first horizontal tube layer from the bottom forms a storey which is 360 mm above the apparatus floor level.

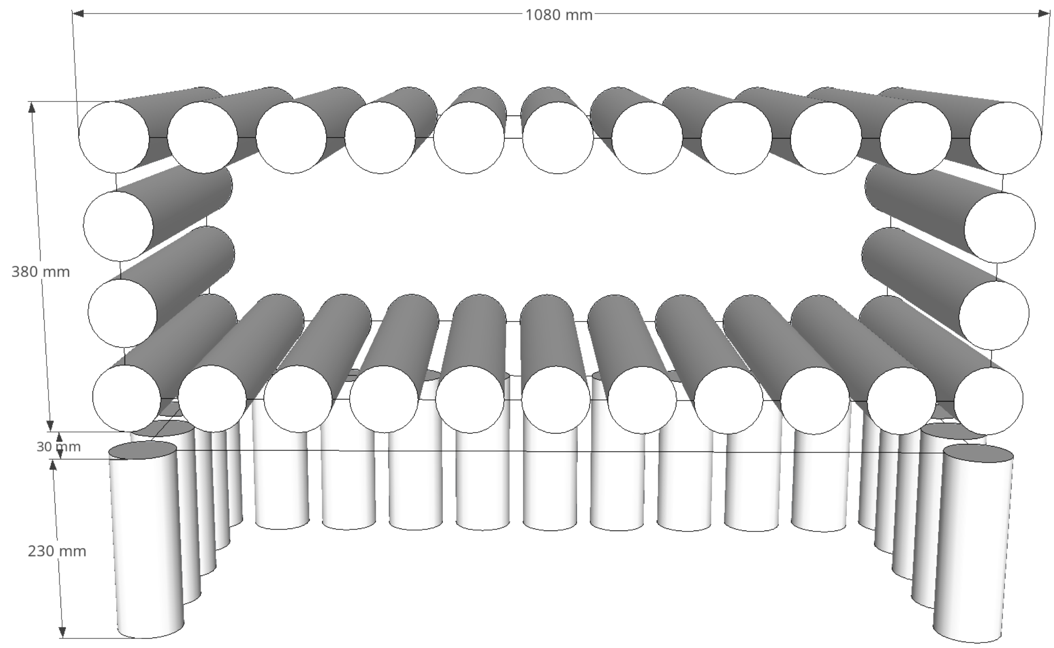

Figure A9 Obstructions 2 and 3

A2.4 Obstruction 4

Obstruction 4 is a box measuring 1250 mm × 300 mm × 390 mm, see Figure A10. Obstruction 4 includes two apertures. The first, on the right short side (240 mm x 330 mm) is open to the interior of the mock-up, while the other on the rear long side (390 mm x 330 mm) is in conjunction with mock-up Aperture C, thus being an opening to the outside, see Figure A4.

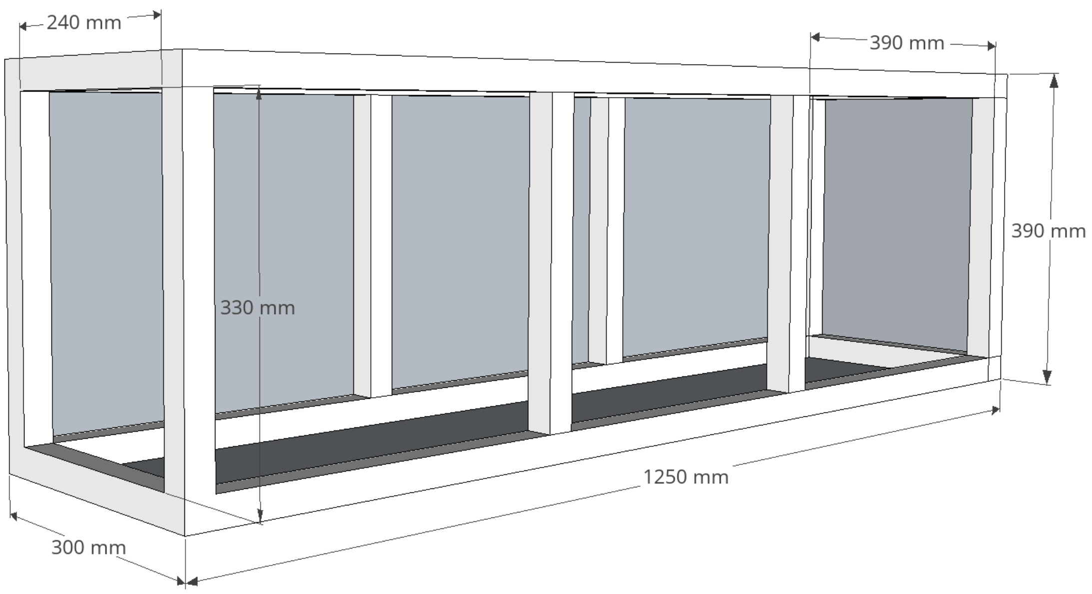

Figure A10 Obstruction 4, view from backside

A2.5 Ventilation

A ventilation duct with inner diameter of 710 mm and a length of 600 mm is installed to the ventilation opening on the mock-up. An axial fan with a diameter of 710 mm (+0 mm, -3 mm) shall be mounted to the ventilation duct. The fan shall produce a certain air flow rate through the duct according to the test scenarios in Appendix C. Frequency converter may be used to adjust the fan speed. In tests without ventilation the duct and fan should be left in its installed position, alternatively a concealing plate with the same diameter as the ventilation opening may be positioned in front of the ventilation duct opening at a distance not closer than 50 mm.

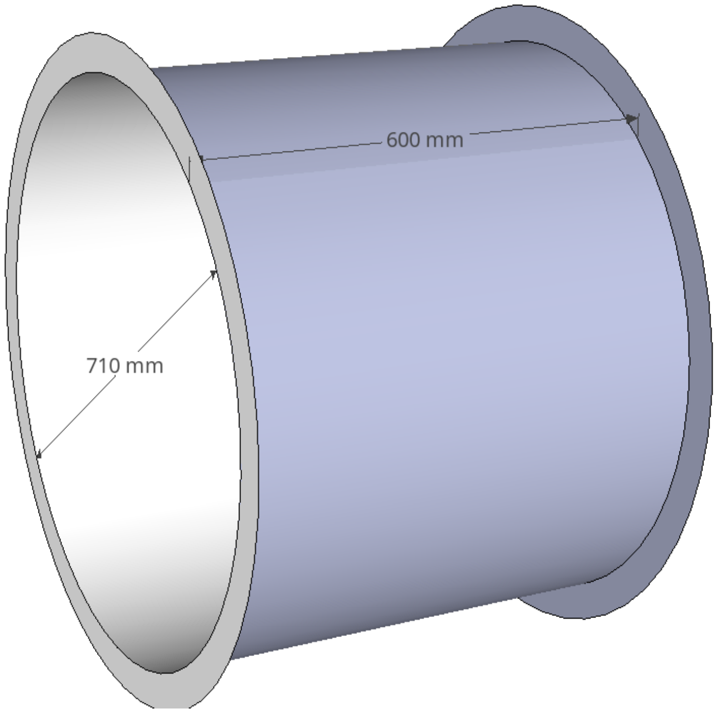

Figure A11 Ventilation duct

A2.6 Temperature measurement

Seven thermocouples shall be mounted on the exhaust manifold pipe. The thermocouples are installed in 2 mm deep holes on the outside of the pipe. The location of the thermocouples shall be in accordance with FigureA12 and FigureA13 . Tc1 – Tc4 shall be located on top of the tube and Tc5 – Tc7 around the tube, on the same distance from the tube opening as Tc2 (300 mm).

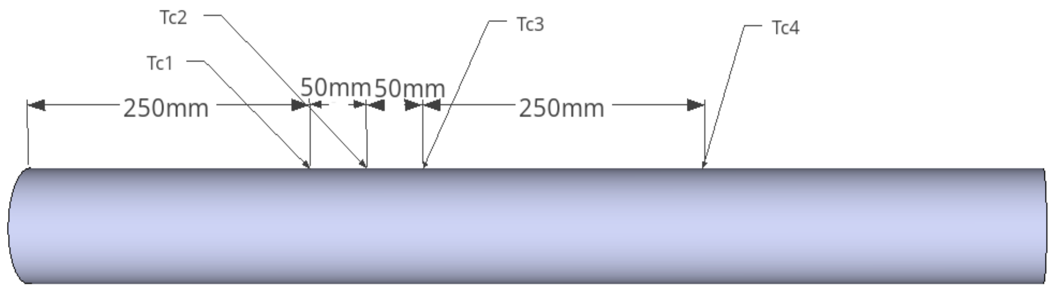

Figure A12 Thermocouples on the exhaust manifold mock-up

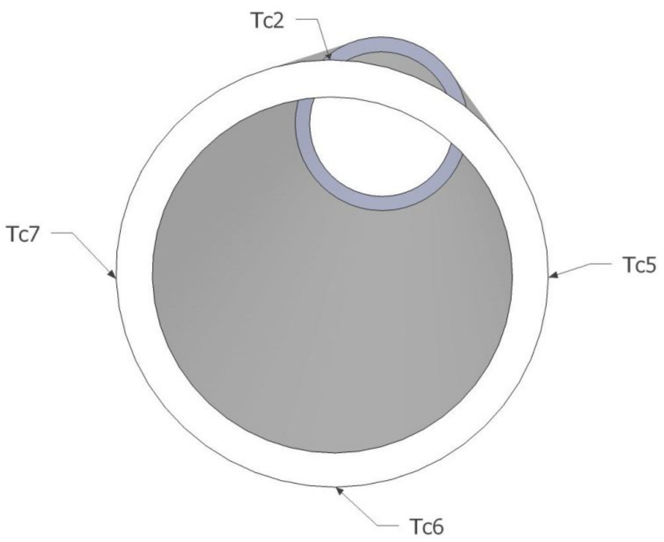

Figure A13 Thermocouples on the exhaust manifold mock-up, viewed from inlet side.

A2.7 Propane burner

A propane burner is used to pre heat the exhaust system and shall be capable to fulfil the requirements on achieved temperatures specified in Appendix B. Pressurized air may be added to the flame for better combustion and to create higher volume flowrate through the exhaust manifold.

Appendix B: Fire sources

B1 Fire sources

Diesel oil, engine oil, heptane, pine wood and fibre board are used as fuels in the test sources described in Table B1.

Table B1: The fire sources used in the test scenarios.

Fire source	Description
#1	Pool fire 300 mm × 300 mm
#2	Pool fire 300 mm × 300 mm and fibreboards
#3	Pool fire 200 mm × 300 mm
#4	Pool fire Ø 150 mm
#5	Class A- wood crib fire and pool fire 200 mm × 300 mm
#6	Fibreboard 200 mm × 300 mm
#7	Hidden pool fire 300 mm × 300 mm and fibreboards
#8	Spray fire 0.73 kg/min
#9	Spray fire 0.19 kg/min
#10	Dripping oil fire, 40 droplets/min

B1.1 Fire source #1

Fire tray of 1.5 mm thick steel.

Table B2: Tray for fire source #1

Dimension (mm)	Rim height (mm)	Water (l)	Diesel (l)	Heptane (l)
300 × 300	70	1.0	0.5	0.2

B1.2 Fire source #2

Fire tray of 1.5 mm thick steel. Two fibre boards.

Table B3: Tray for fire source #2

Dimensions (mm)	Rim height (mm)	Water (l)	Diesel (l)	Heptane (l)
300 × 300	70	1.0	0.5	0.2

The fibre boards shall be conditioned prior to the test at a temperature of 105 °C (±5 °C) for not less than 16 h.

Fibre boards with dimensions 190 mm × 290 mm and thickness of 12 mm are completely immersed in diesel oil for at least 10 min prior to the test.

The fibre boards are mounted vertically in the pool fire tray not more than 10 min before the start of the test, see Figure B1. Supports for keeping the fibre boards in position in the fire tray are needed.

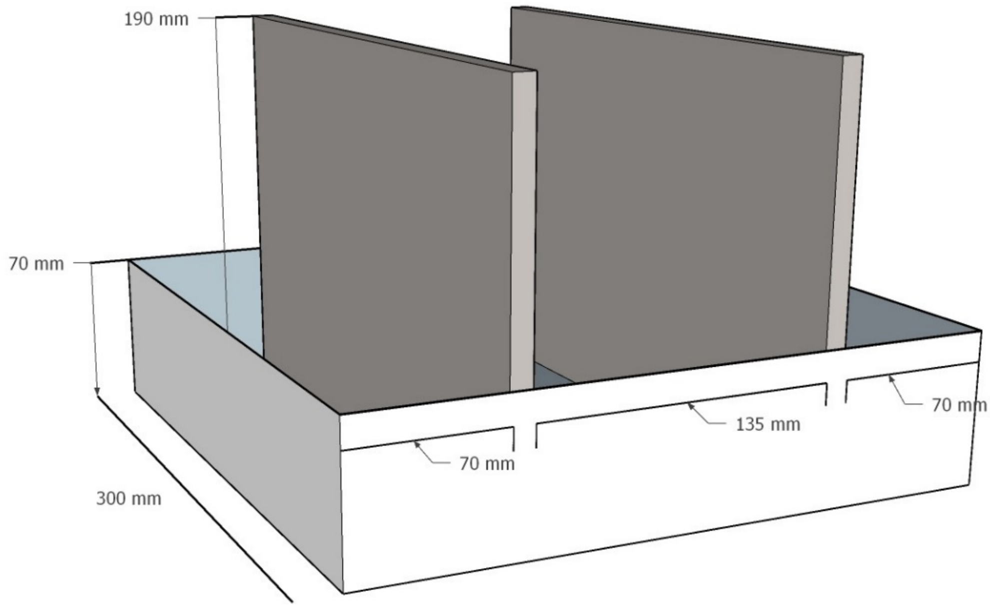

Figure B1: Perpendicular orientation of the fire tray with fibreboards.

B1.3 Fire source #3

Fire tray of 2.0 mm thick steel.

Table B4: Tray for fire source #3

Dimension (mm)	Rim height (mm)	Water (l)	Diesel (l)	Heptane (l)
200 x 300	70	0.5	0.5	0.2

B1.4 Fire source #4

Fire tray of 1.5 mm thick steel.

Table B5: Tray for fire source #4

Diameter (mm)	Rim height (mm)	Water (l)	Diesel (l)	Heptane (l)
150	100	0.2	0.2	0.1

B1.5 Fire source #5

Wood crib and a fire tray of 2.0 mm thick steel.

Table B6: Wood crib for fire source #5

Dimension (mm)	Number of pieces	Dimension of each piece (mm)
100 × 100 × 100	40	10 x 10 x 100

Table B7: Tray for fire source #5

Dimension (mm)	Rim height (mm)	Water (l)	Diesel (l)	Heptane (l)
200 × 300	70	0.5	0.6	0.3

The assembled wood crib shall be conditioned prior to the test at a temperature of 105°C (±5°C) for not less than 16 h.

The wood crib shall be placed in the centre of the fire tray on a steel support with a height of 20 mm (±5 mm). The support should keep the wood crib above the fuel surface.
The wood crib shall consist of five layers of wood pieces. Each layer includes eight pieces of pine wood. Six pieces are aligned in parallel with a mutual distance of 8 mm (±2 mm) in between. The two remaining pieces aligned perpendicularly to the previous and with a mutual distance of 60 mm in between. See Figure B2.

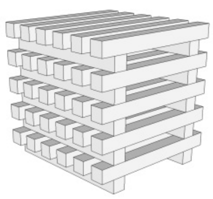

Figure B2: The class A wood crib

B1.6 Fire source #6

One fire tray of 2.0 mm thick steel. Fibre board.

Table B8: Tray for fire source #6

Dimension (mm)	Rim height (mm)	Water (l)	Diesel (l)	Heptane (l)
200 × 300	15	0.0	0.0	(0.1)

The fibre board shall be conditioned prior to the test at a temperature of 105 °C (±5 °C) for not less than 16 h.

One fibre board with dimensions 190 mm × 290 mm and nominal thickness of 12 mm is completely immersed in diesel oil for at least 10 min prior to the test.

The fibre board is placed horizontally in the fire tray not more than 10 min before the start of the test. Heptane (0.1 L) is spread equally over the fibre board surface prior to ignition.

B1.7 Fire source #7

Fire tray of 1.5 mm thick steel. Two fibre boards.

Table B9: Tray for fire source #7

Dimensions (mm)	Rim height (mm)	Water (l)	Diesel (l)	Heptane (l)
300 × 300	70	1.0	0.5	0.2

The fibre boards shall be conditioned prior to the test at a temperature of 105 °C (±5 °C) for not less than 16 h.

Supports for keeping the fibre boards in position in the fire tray are needed.

Fibre boards with dimensions 190 mm × 290 mm and thickness of 12 mm are completely immersed in diesel oil for at least 10 min prior to the test.

The fibre boards are mounted vertically in the pool fire tray not more than 10 min before the start of the test,

The fire source is concealed on one side non parallel with the fibre boards and a cover on the top with the dimensions of 300 mm × 300 mm × 20 mm. see Figure B3.

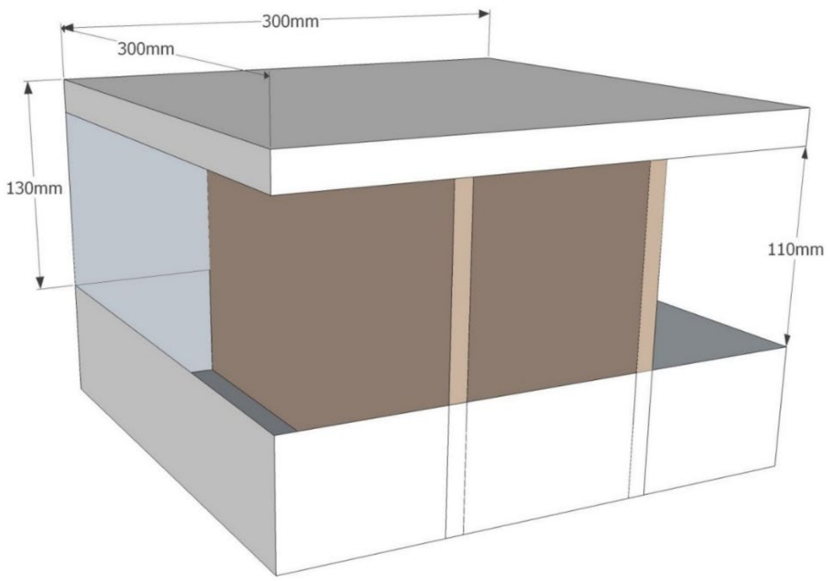

Figure B3 Fire source concealed from the top and from the rear side

B1.8 Fire source #8

Spray fire: Nozzle with 120 ° full cone spray

Table B10: Spray fire properties for fire source #8

Mass flow rate (kg/min)	Tolerance (%)	Nominal pressure (bar)	Fuel
0.73	±10	4.5	Diesel

Table B11: Reference nozzle Lechler 490.368 with 120 ° full cone spray

Flow rate (l/min)	Tolerance (%)	Nominal pressure (bar)	Media
0.74	±10	3.0	Water
0.91	±10	5.0	Water

B1.9 Fire source #9

Spray fire: Nozzle with 80° axial flow hollow cone spray.

Table B12: Spray fire properties for fire source #9

Mass flow rate (kg/min)	Tolerance (%)		Nominal pressure (bar)	Fuel
0.19	±10		4.5	Diesel

Table B13: Reference nozzle Lechler 212.245, 80° axial flow hollow cone spray

Flow rate (l/min)	Tolerance (%)	Nominal pressure (bar)	Media
0.202	±10	3.0	Water
0.261	±10	5.0	Water

B1.10 Fire source #10

Dripping oil fire: Danfoss 0.60X80H or equivalent

Table B12: Dripping oil fire properties for fire source #10

Frequency (drops/min)	Tolerance (%)	Mass flow (g/min)	Fuel
40	-0/ +10	> 2.7	Engine oil

B2 Fuel specifications

B2.1 Diesel oil

Commercial fuel oil or light diesel oil with a density of 0.81 kg/l - 0.85 kg/l.

B2.2 Engine oil

Semi-synthetic engine oil 15W-40 intended use in diesel engine

Reference oil: Statoil MaxWay 15W-40
Base: Mineral oil
Density: 884 kg/m^3 at 15 °C
Viscosity: 107 mm^2/s at 40 °C
Flash point COC: 230 °C

B2.3 Heptane

Product name: Hydrocarbons C7, n-alkanes, iso alkanes, cyclics
Synonyms, tradenames: Exxsol heptane, Heptane shell, Petrosol D heptane, SBP 94/99, Eversol n-paraffin 7, Heptane, Solane 80-110, Essence 80-110.

CAS number: 64742-49-0
Relative density: 0.68 – 0.78 g/cm^3
Initial boiling point and boiling point interval: 83 °C – 105 °C
Auto ignition temperature: >200 °C
Flash point: -5 °C

B2.4 Class A fire

Pine wood is used for the wood cribs. The wood should be stored in dry conditions and have a nominal moisture content of 12 % (±3 %) when assembled.
After the wood crib is assembled and before the fire test, it shall be conditioned at a temperature of 105 °C (±5 °C) for not less than 16 h.

B2.5 Fibre board

Fibreboards with a dry density of 300 kg/m^3 (±10 %). The nominal dimensions of the fibreboards shall be 12 mm × 290 mm × 190 mm. The fibreboards shall consist of at least 90 % raw material from wood. The fibre boards shall be conditioned prior to the test at a temperature of 105 °C (±5 °C) for not less than 16 h. The fibre boards should be used within 8 h after been removed from conditioning.

Appendix C: Fire test procedures

C1 Level of openness

The tests can be performed at four different levels of mock-up openness. The ventilation duct is not closed.

Table C1: Levels of mock-up openness

Level	Criteria
1	Fire tests with open mock-up
2	Fire tests without mock-up floor and ceiling
3	Fire tests without mock-up floor
4	Fire tests with enclosed mock-up

C1.1 Fire tests with open mock-up

Short end sides are installed on the engine compartment mock-up, long end sides, top and floor are removed. Top and back side of elevated part on mock-up is not removed.

C1.2 Fire tests without mock-up floor and ceiling

All sides are installed on the engine compartment mock-up, the top and floor are removed. Top and back side of elevated part on mock-up is not removed.

C1.3 Fire tests without mock-up floor

All sides and top are installed on the engine compartment mock-up, the floor is removed.

C1.4 Fire tests with enclosed mock-up

All sides, floor and top are installed on the engine compartment mock-up.

C2 Test scenarios

Table c2: Fire test scenarios

Test scenario	**Description**	**Ventilation** (m^3/s)	**Remarks**
1	Low fire load	3	
2	High fire load	3	
3	Hidden fire	3	
4	Hidden fire	1.5	
5	Hidden fire	0	
6	Low fire load	0	Reduced mass of extinguishing agent
7	High fire load	0	At minimum operating temperature
8	High fire load	1.5	
9	Low fire load	1.5	
10	Re-ignition	0	Minimum time to re-ignition: 45 s
11	Class A-fire	0.5	

C2.1 Test scenario 1: Low fire load with 3 m³/s ventilation

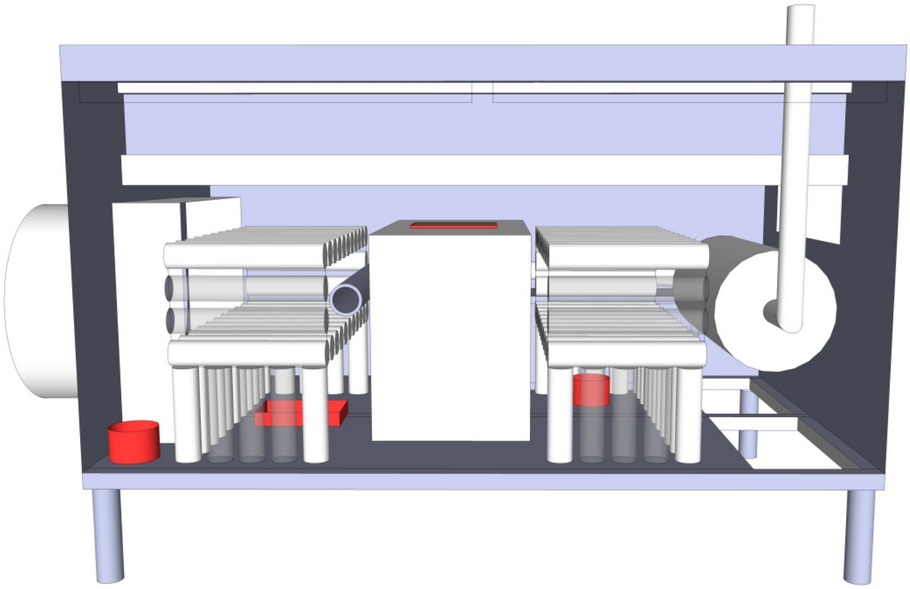

Figure C1: Test scenario 1

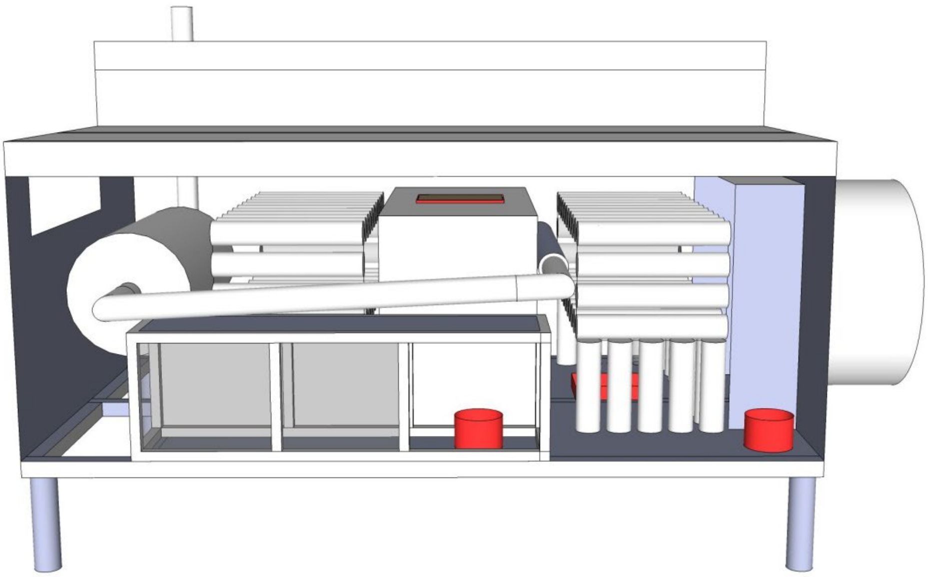

Figure C2: Test scenario 1

Fire source setup:

Table c3: Fire source locations in test scenario 1

Fire source	Description	Placement	Position coordinate (x,y,z)(mm)
#3	Pool fire 300 mm × 200 mm	Obstruction 2 left-central-bottom	(370, 570, 0)
#4	Pool fire Ø 150 mm	Corner left-front-bottom corner	(20, 80, 0)
#4	Pool fire Ø 150 mm	Corner left-rear-bottom corner	(20, 1200, 0)
#4	Pool fire Ø 150 mm	Obstruction 4 central-rearmost-bottom	(970, 1280, 0)
#4	Pool fire Ø 150 mm	Obstruction 3 right-rear-bottom	(1620, 920, 0)
#6	Fibreboard 300 mm × 200 mm	Engine mock-up central-central-top	(970, 450, 700)

Ventilation:

Air volume flow 3.0 m^3/s

Test procedure:

Table c4: Time sequence in test scenario 1

Time	Action
00:00	Start test/ measurement time
01:00	Ignite pool fires
01:30	All pool fires ignited
01:30	Start ventilation
02:00	Activate suppression system

C2.2 Test scenario 2: High fire load with 3 m^3/s ventilation

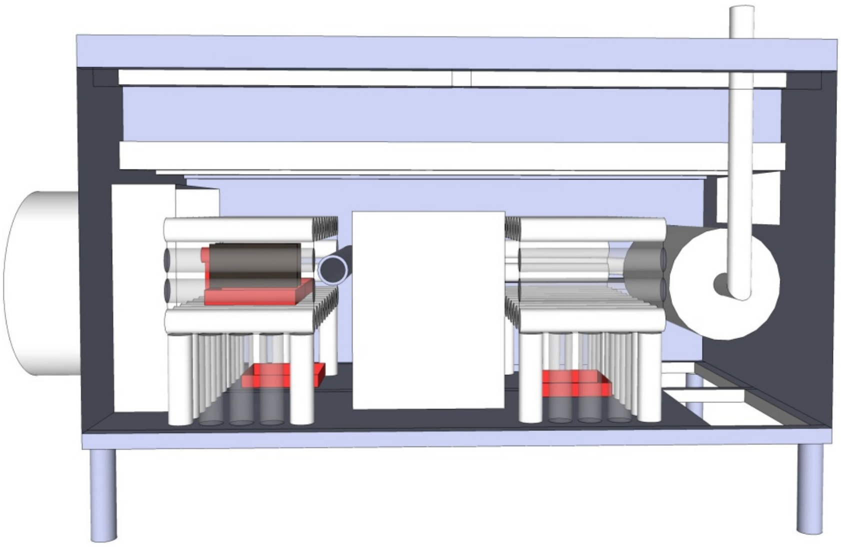

Figure C3: Test scenario 2

Fire source setup:

Table c5: Fire source locations in test scenario 2

Fire source	Description	Placement	Position coordinate (x,y,z) (mm)
#1	Pool fire 300 mm × 300 mm	Obstruction 2 left-central-upper	(370, 470, 360)
#1	Pool fire 300 mm × 300 mm	Obstruction 2 left-rear-bottom	(370, 770, 0)
#1	Pool fire 300 mm × 300 mm	Obstruction 3 right-central-bottom	(1540, 470, 0)
#2	Pool fire 300 mm × 300 mm with 2 Fibreboards	Obstruction 2 left-front-upper	(370, 130, 360)
#8	Spray fire 0.73 kg/min	Obstruction 2 left spray fire	(370, 700, 460)

Ventilation:

Air volume flow 3.0 m^3/s

Test procedure:

The fire trays with fibreboards shall have parallel orientation in relation to the forced air flow.

Table c6: Time sequence in test scenario 2

Time	Action
00:00	Start test/ measurement time
01:00	Ignite pool fires
01:20	All pool fires ignited
01:30	Start ventilation
01:50	Start diesel spray
02:00	Activate suppression system

C2.3 Test scenario 3: Hidden fire with 3 m^3/s ventilation

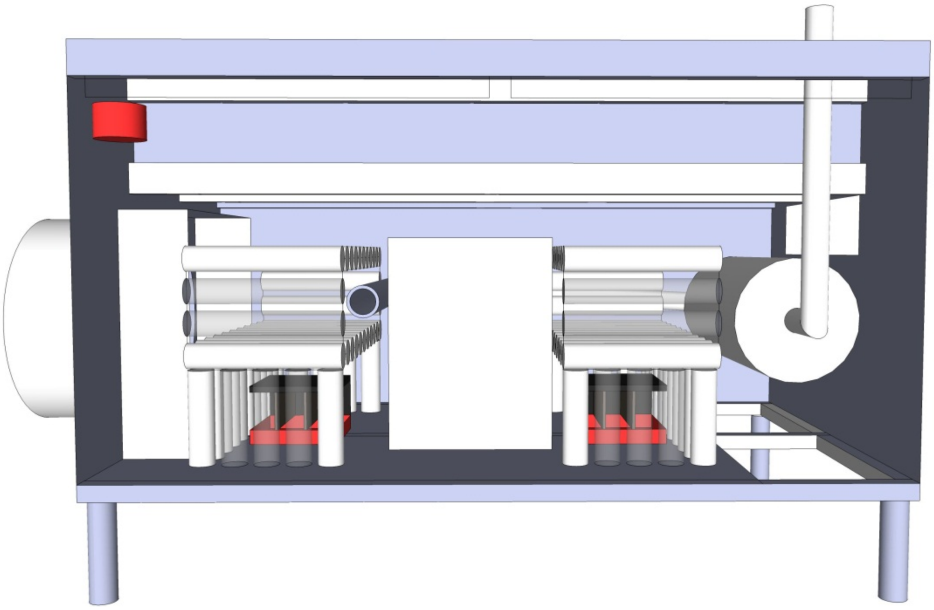

Figure C4: Test scenario 3

Fire source setup:

Table c7: Fire source locations in test scenario 3

Fire source	Description	Placement	Position coordinate (x,y,z) (mm)
#4	Pool fire Ø 150 mm	Corner left-front-top corner	(20, 80, 920)
#7	Hidden pool fire 300 mm × 300 mm with 2 Fibreboards	Obstruction 2 left-central-bottom	(370, 470, 0)
#7	Hidden pool fire 300 mm × 300 mm with 2 Fibreboards	Obstruction 3 right-central-bottom	(1540, 470, 0)

Note: The location of fire sources differs from test without ventilation

Ventilation:

Air volume flow 3.0 m^3/s

Test procedure:

The fire trays with fibreboards shall have perpendicular orientation in relation to the forced air flow.

Table c8: Time sequence in test scenario 3

Time	Action
00:00	Start test/ measurement time
01:00	Ignite pool fires
01:25	All pool fires ignited
01:30	Start ventilation
02:00	Activate suppression system

C2.4 Test scenario 4: Hidden fire with 1.5 m^3/s ventilation

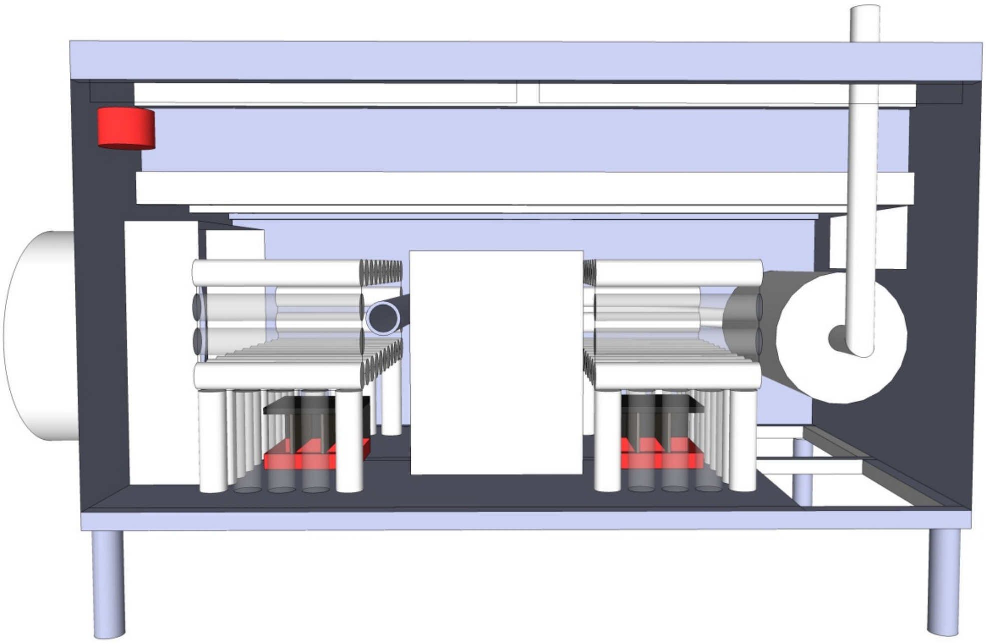

Figure C5: Test scenario 4

Fire source setup:

Table c 9: Fire source locations in test scenario 4

Fire source	Description	Placement	Position coordinate (x,y,z) (mm)
#4	Pool fire Ø 150 mm	Corner left-front-top corner	(20, 80, 920)
#7	Hidden pool fire 300 mm × 300 mm with 2 Fibreboards	Obstruction 2 left-central-bottom	(370, 470, 0)
#7	Hidden pool fire 300 mm × 300 mm with 2 Fibreboards	Obstruction 3 right-central-bottom	(1540, 470, 0)

Note: The location of fire sources differs from test without ventilation

Ventilation:

Air volume flow 1.5 m^3/s

Test procedure:

The fire trays with fibreboards shall have perpendicular orientation in relation to the forced air flow.

Table c 10: Time sequence in test scenario 4

Time	Action
00:00	Start test/ measurement time
01:00	Ignite pool fires
01:25	All pool fires ignited
01:30	Start ventilation
02:00	Activate suppression system

C2.5 Test scenario 5: Hidden fire

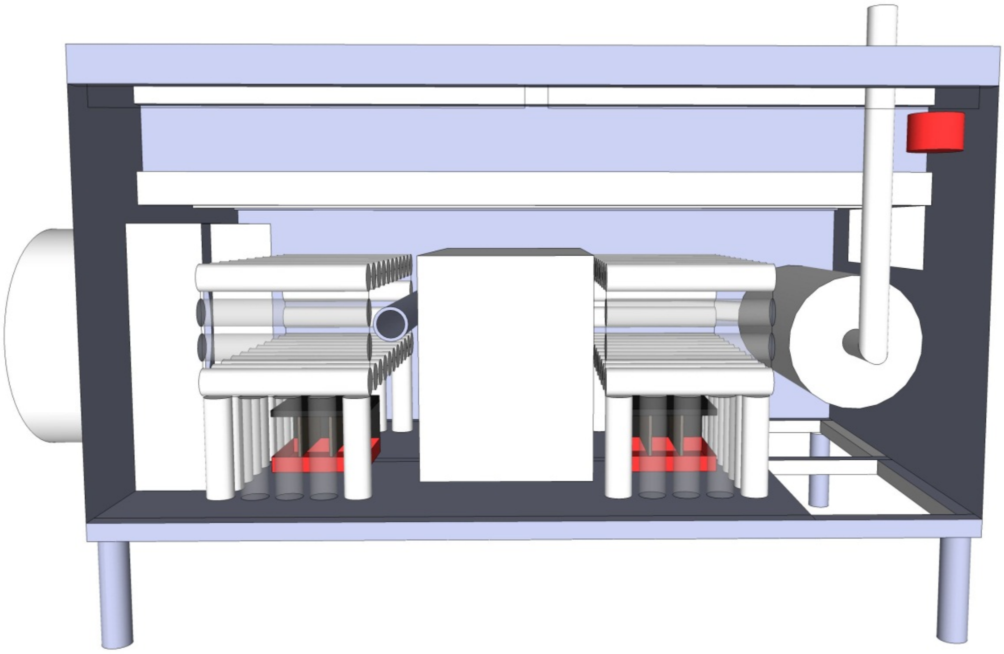

Figure C6: Test scenario 5

Fire source setup:

Table c11: Fire source locations in test scenario 5

Fire source	Description	Placement	Position coordinate (x,y,z) (mm)
#4	Pool fire Ø 150 mm	Corner right-front-top corner	(2230, 80, 920)
#7	Hidden pool fire 300 mm × 300 mm with 2 Fibre boards	Obstruction 2 left-central-bottom	(370, 470, 0)
#7	Hidden pool fire 300 mm × 300 mm with 2 Fibre boards	Obstruction 3 right-central-bottom	(1540, 470, 0)

Ventilation:

No ventilation.

Test procedure:

Table c12: Time sequence in test scenario 5

Time	Action
00:00	Start test/ measurement time
01:00	Ignite pool fires
01:25	All pool fires ignited
02:00	Activate suppression system

C2.6 Test scenario 6: Low fire load with reduced mass of extinguishing agent

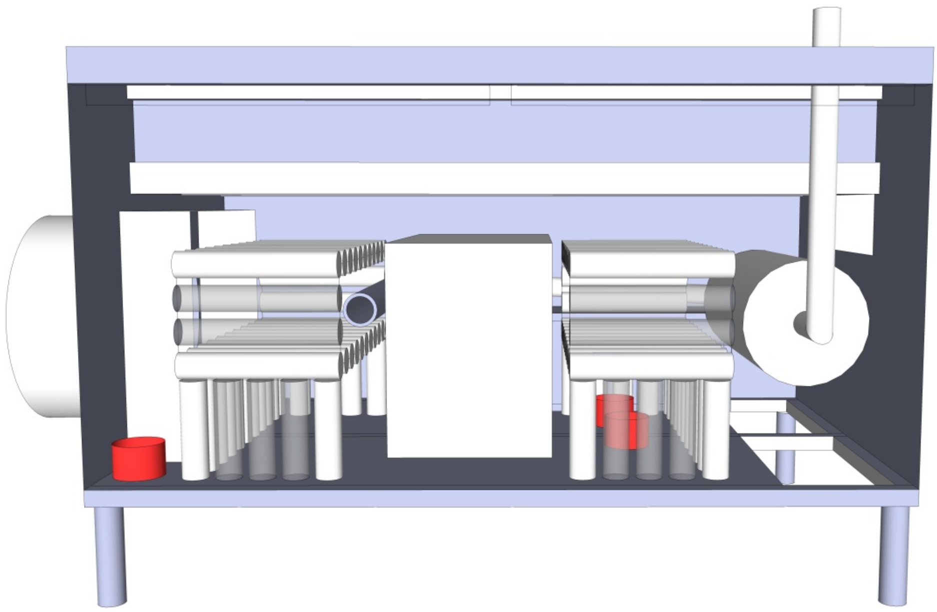

Figure C7: Test scenario 6

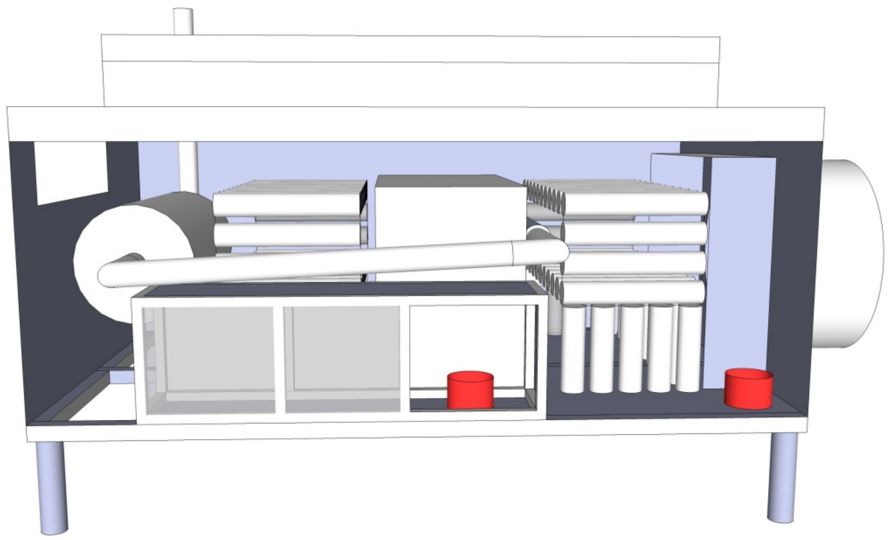

Figure C8: Test scenario 6

Fire source setup:

Table c 13: Fire source locations in test scenario 6

Fire source	Description	Placement	Position coordinate (x,y,z) (mm)
#4	Pool fire Ø 150 mm	Corner left-front-bottom corner	(20, 80, 0)
#4	Pool fire Ø 150 mm	Corner left-rear-bottom corner	(20, 1200, 0)
#4	Pool fire Ø 150 mm	Obstruction 4 central-rearmost-bottom	(970, 1280, 0)
#4	Pool fire Ø 150 mm	Obstruction 3 right-central-bottom	(1620, 570, 0)
#4	Pool fire Ø 150 mm	Obstruction 3 right-rear-bottom	(1620, 920, 0)

Ventilation:

No ventilation.

Test procedure:

The mass of extinguishing agent used is reduced to 83 % of the nominal mass.

Table c14: Time sequence in test scenario 6

Time	Action
00:00	Start test/ measuring time
01:00	Start igniting pool fires
01:10	All pool fires ignited
02:00	Activate suppression system

C2.7 Test scenario 7: High fire load test at minimum operating temperature

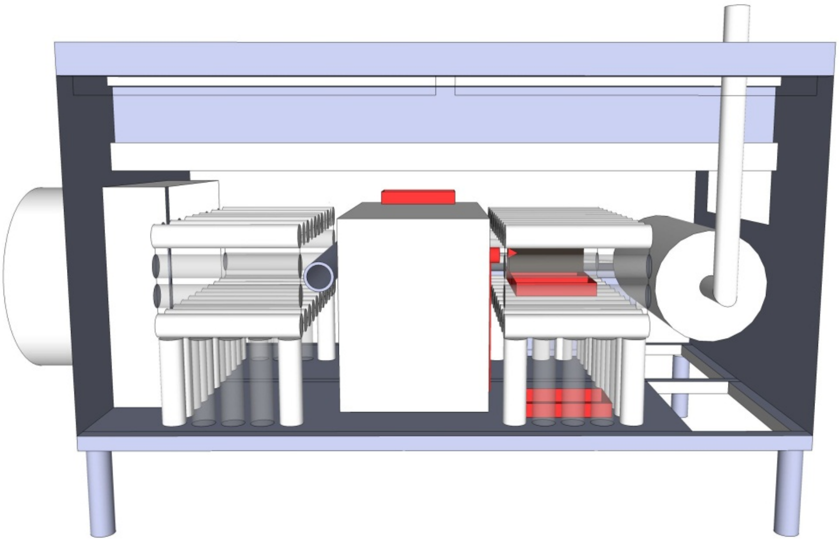

Figure C9: Test scenario 7

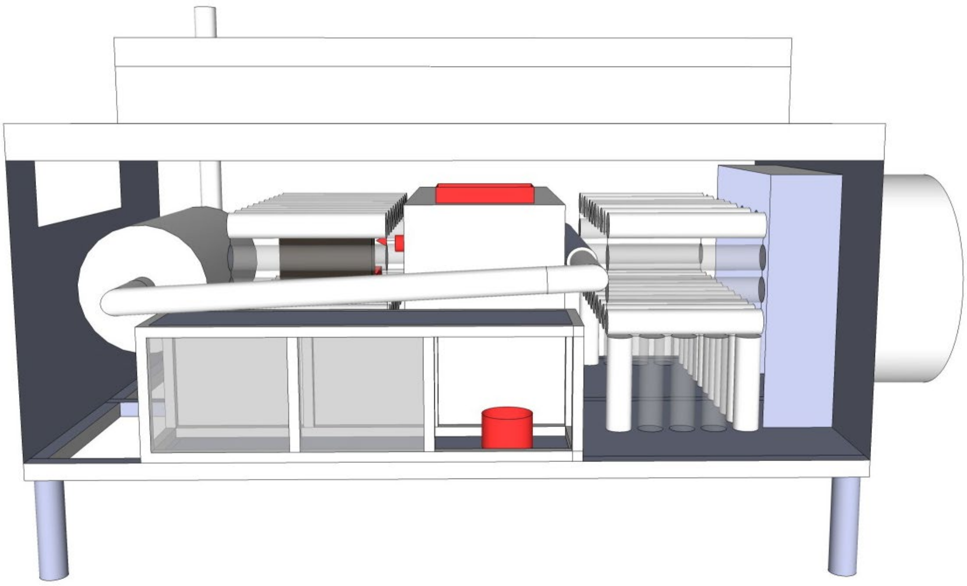

Figure C10: Test scenario 7

Fire source setup:

Table c15: Fire source locations in test scenario 7

Fire source	Description	Placement	Position coordinate (x,y,z) (mm)
#2	Pool fire 300 mm × 300 mm with 2 Fibre boards	Obstruction 3 right-rear-upper	(1540, 770, 360)
#3	Pool fire 200 mm × 300 mm	Engine mock-up central-rear-top	(970, 850, 700)
#3	Pool fire 200 mm × 300 mm	Obstruction 3 right-central-upper	(1540, 570, 360)
#3	Pool fire 200 mm × 300 mm	Obstruction 3 right-front-bottom	(1540, 130, 0)
#4	Pool fire Ø 150 mm	Obstruction 4 central-rearmost-bottom	(970, 1280, 0)
#9	Spray fire 0.19 kg/min	Obstruction 3 right spray fire	(1470, 730, 460)

Ventilation:

No ventilation.

Test procedure:

The extinguishing agent container and propellant gas vessel or extinguishing agent generator are conditioned at the lowest desired operating temperature for at least 16 h prior to test.

Table c16: Time sequence in test scenario 7

Time	Action
-05:00	Extinguishing agent container and propellant gas vessel or extinguishing agent generator is picked out from the cold chamber
00:00	Start test/ measurement time
01:20	Start igniting pool fires
01:40	All pool fires ignited
01:50	Start spray fire
02:00	Activate suppression system

C2.8 Test scenario 8: High fire load with 1.5 m3/s ventilation

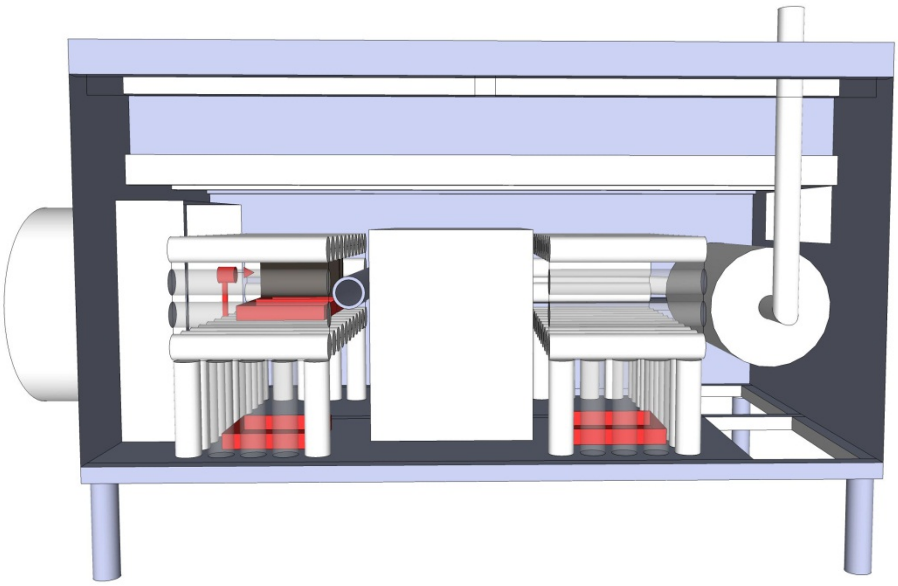

Figure C11: Test scenario 8

Fire source setup:

Table c17: Fire source locations in test scenario 8

Fire source	Description	Placement	Position coordinate (x,y,z) (mm)
#1	Pool fire 300 mm × 300 mm	Obstruction 2 left-central-upper	(370, 470, 360)
#1	Pool fire 300 mm × 300 mm	Obstruction 2 left-front-bottom	(370, 130, 0)
#1	Pool fire 300 mm × 300 mm	Obstruction 3 right-front-bottom	(1540, 130, 0)
#2	Pool fire 300 mm × 300 mm with 2 Fibre boards	Obstruction 2 left-rear-upper	(370, 770, 360)
#8	Spray fire 0.73 kg/min	Obstruction 2 left spray fire	(370, 700, 460)

Ventilation:

Air volume flow 1.5 m^3/s

Test procedure:

The fire trays with fibreboards shall have parallel orientation in relation to the forced air flow.

Table c18: Time sequence in test scenario 8

Time	Action
00:00	Start test/ measuring time
01:00	Ignite pool fires
01:20	All poolfires ignited
01:30	Start ventilation
01:50	Start spray fire
02:00	Activate suppression system

C2.9 Test scenario 9: Low fire load with 1.5 m^3/s ventilation

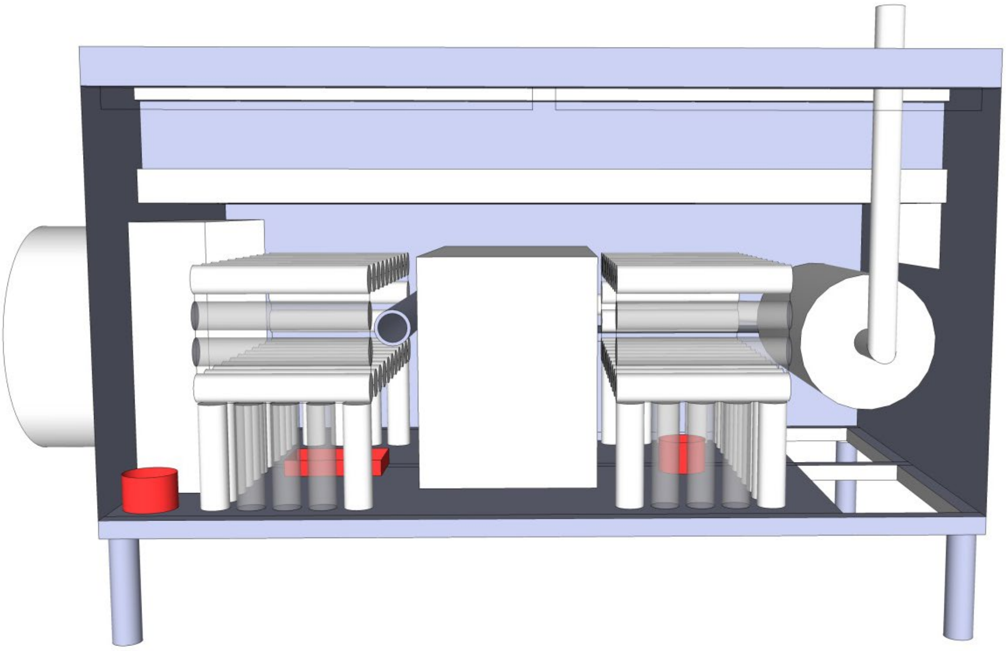

Figure C12: Test scenario 9

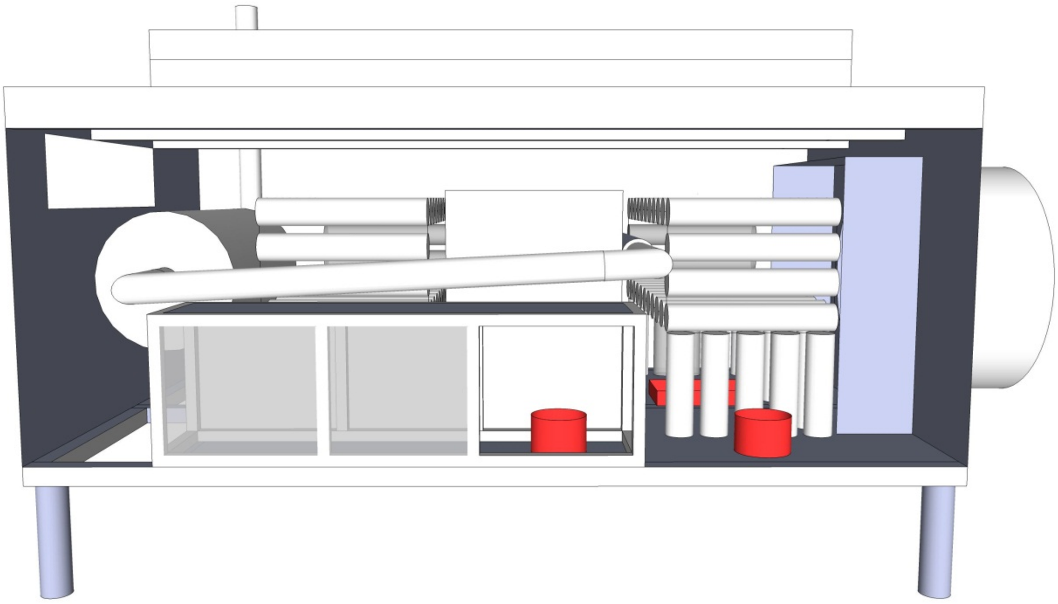

Figure C13: Test scenario 9

Fire source setup:

Table c19: Fire source locations in test scenario 9

Fire source	Description	Placement	Position coordinate (x,y,z) (mm)
#3	Pool fire 300 mm × 200 mm	Obstruction 2 left-central-bottom	(370, 570, 0)
#4	Pool fire Ø 150 mm	Corner left-front-bottom corner	(20, 80, 0)
#4	Pool fire Ø 150 mm	Obstruction 2 left-rearmost-bottom, just outside the rear wall	(450, 1200, 0)
#4	Pool fire Ø 150 mm	Obstruction 4 central-rearmost-bottom	(970, 1280, 0)
#4	Pool fire Ø 150 mm	Obstruction 3 right-central-bottom	(1540, 570, 0)

Ventilation:

Air volume flow 1.5 m^3/s

Test procedure:

Table c20: Time sequence in test scenario 9

Time	Action
00:00	Start test/ measurement time
01:00	Ignite pool fires
01:30	All pool fires ignited
01:30	Start ventilation
02:00	Activate suppression system

C2.10 Test scenario 10: Re-ignition test

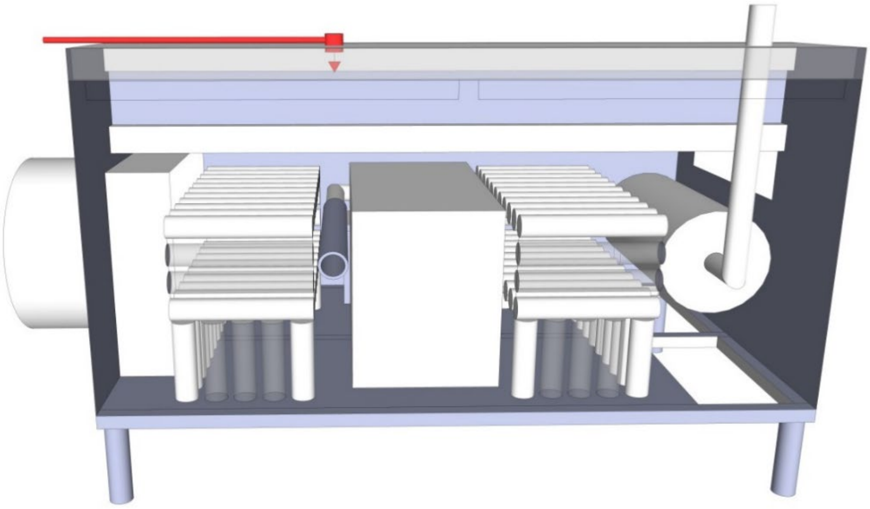

Figure C14: Test scenario 10

Fire source setup:

Table c21: Fire source location at re-ignition test

Fire source	Description	Placement	Position coordinate (x,y,z) (mm)
#10	40 droplets oil/ minute	--	(820, 280, 1220)

Ventilation: No ventilation.

Test procedure:

Prior to test: The area on exhaust pipe where drops fall shall be cleaned with emery cloth.

Pre heating: The tube shall be heated from the inner side until the temperature of Tc2 > 600°C, Tc1 > 570 °C and Tc5, Tc6 & Tc7 > 520°C. When the predefined temperatures are reached the pre-heating procedure stops and the burner is removed (time 0:00).

Table c22: Time sequence in test scenario for determining re-ignition delay

Time	Action
-15:00 ±5 min	Start of pre-heating the tube and measuring the temperature
t(T=600°C)= 0:00	End of pre-heating
00:30	Start of dripping oil
00:40	Sustained flaming must have commenced
00:45	Activate suppression system
t ext	Extinction of flames
t reignition	Time of re-ignition
t ext +05:00	End of test

C2.11 Test scenario 11: Class A-fire

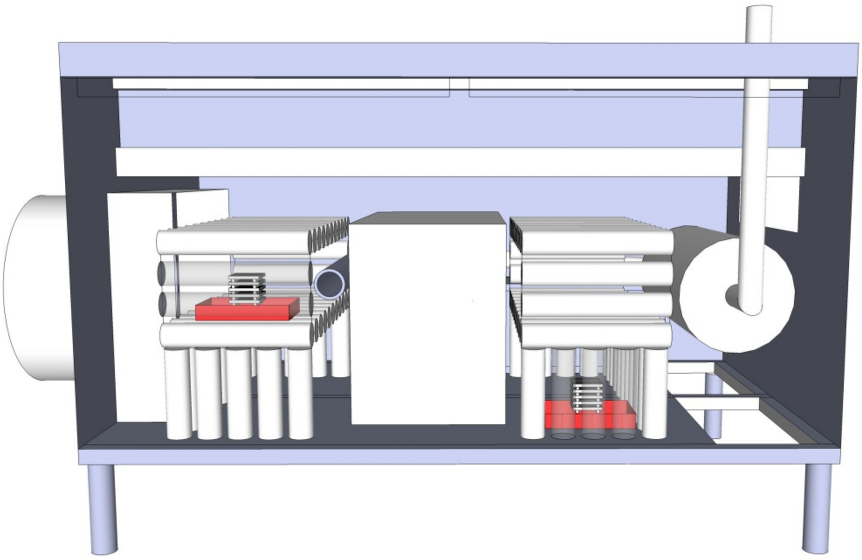

Figure C15: Test scenario 11

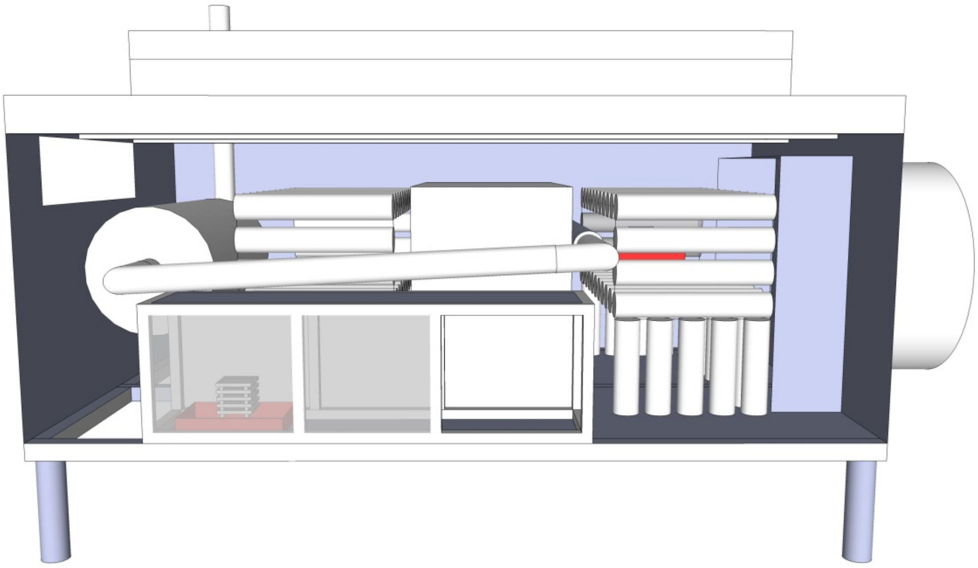

Figure C16: Test scenario 11

Fire source setup:

Table c23: Fire source locations in test scenario 11

Fire source	Description	Placement	Position coordinate (x,y,z) (mm)
#5	Class A- wood crib fire and pool fire 200 mm × 300 mm	Obstruction 2 left-front-upper	(370, 130, 360)
#5	Class A- wood crib fire and pool fire 200 mm × 300 mm	Obstruction 3 right-front-bottom	(1540, 130, 0)
#5	Class A- wood crib fire and pool fire 200 mm × 300 mm	Obstruction 4 right-rearmost-bottom	(1740, 1250, 0)

Ventilation:

Air volume flow 0.5 m^3/s

Test procedure:

Table c24: Time sequence in test scenario 11

Time	Action
00:00	Start test/ measuring time
01:00	Start igniting pool fires
01:10	All pool fires ignited
03:00	Start ventilation
04:00	Activate suppression system
09:00	End of test

Appendix D Classification

D1 Performance classification

Table D1:

Test scenario rating	Level of openness	Class A fire
A+ ↑ E	1 ↑ 4	A or -

Re ignition delay (s)	(time in seconds)

D1.1 Test scenario rating

Table D2:

Rating	Test scenario	Description	Ventilation Flowrate (m^3/s)	
A+	1	Low fire load	3	**A+**
A+	2	High fire load	3	**A+**
A+	3	Hidden fire	3	**A+**
A	4	Hidden fire	1.5	**A**
B	5	Hidden fire	0	**B**
C	1	Low fire load	3	**C**
C	2	High fire load	3	**C**
D	6	Low fire load	0	**D**
E	7	High fire load	0	**E**
E	8	High fire load	1.5	**E**
E	9	Low fire load	1.5	**E**
E	10	Re-ignition > 45 s	0	**E**

Test scenarios 1 and 2 for rating **C** is not required to pass for **B** and **A** rating.

D1.2 Level of openness

Table D3:

Level	Criteria
1	Fire tests passed with open mock up
2	Fire tests passed without mock up floor and ceiling
3	Fire tests passed without mock up floor
4	Fire tests passed with all sides closed on mock up

D1.3 Class A fire

Table D4:

Description	**Ventilation Flowrate** (m^3/s)	**Remarks**
Class A fire	0.5	Extinguished within 60 s after activation of the suppression system.

D2 Scaling

Measurement and calculation of engine compartment gross volume is made before scaling a tested suppression system. The volume of components in the engine compartment should not be subtracted. In case the engine compartment is not fully enclosed the boundaries is set to 500 mm from the nearest component that is supposed to be protected, alternatively the outer frame of the engine compartment, whichever is shortest. The calculated gross volume is rounded to one decimal when expressed in m^3.

The suppression system can be scaled for engine compartment gross volume in the range of 2 $m^3 \leq 6$ m^3 using equation $S_x = 0{,}1 \cdot x + 0{,}6$.

The equation gives a scaling factor that can be used for scaling the tested suppression system.
This includes the mass of the suppression agent, all discharge points and the mass of the propellant gas container, if applicable.

The total discharge time of the system shall as a minimum remain the same.
The scaled number of nozzles may be rounded to closest integer.
The mass of suppression agent is rounded to one decimal when expressed in kg.

Table D1: Nomenclature for equation

S_x	Scaling factor for suppression system
x	The gross volume of the engine compartment, [m^3]

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