LASTFIRE

FIRE TEST SPECIFICATION

REVISION D

MAY 2015

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	DATE: May 2015	DATE: May 2015	DATE: May 2015

CONTENTS

1.0 Introduction

The LASTFIRE Study, an industry project sponsored by 16 oil companies to review the risks associated with fires in large floating roof storage tanks identified the need for a small scale fire test to evaluate the performance of firefighting foam for this special application.

Other tests available were considered to be aimed at different types of incident such as rapid rescue situations.

Consequently a test procedure designed to simulate the special considerations for tank incidents such as forceful foam impact, hot tank walls and distorted tank shells.

Initial test protocols were developed. Based on experience during development and evaluation tests and the need to accelerate the overall test sequence whilst maintaining its criticality and relevance, it was decided that certain aspects of the original protocol should be changed. These changes were:-

i) Increase of nett application rate using the monitor nozzles. This was achieved by increasing the pressure at the nozzle. The purpose of increasing the application rate was to bring it more in line with 50% of the rate proven in incidents with using large capacity monitors.

ii) A test sequence of semi-aspirated nozzle, aspirated nozzle and system nozzle carried out after each other without complete cooling of the test pan and fuel, but keeping the fuel temperature within limits that were not considered to have a significant impact on results.

iii) Adding 100 litres of fuel in between each of the 3 tests on a concentrate. (The test pan was thoroughly cleaned out in between different concentrates and allowed to cool to ambient temperature.)

This test sequence and protocol was successfully used at a major series of tests sponsored by BP and witnessed by industry representations in September 2002 in Norway. Consequently it was adopted as a standard.

The phenomenon of Flashback, which was noted during the September 2002 tests and described in the accompanying report was reviewed further during a second major test series sponsored by BP in June/July 2003. The intensive nature of the June/July 2003 programme meant that a much greater volume of work was carried out than in previous tests, and it was possible to refine burn-back criteria based on the large body of test data now available. In addition, new observations were made.

The decision to adjust burn-back criteria was made by RPI and BP representatives, and reflects observations made over recent LASTFIRE test series, as well as during test development.

Whilst the proportion of marks given to seal tests and burn-back resistance remains as originally specified by end users, minor changes have been made to the scoring in both categories, and more accurate definitions of burn-back behaviour have been applied.

A revision of the original evaluation criteria has therefore been written to include the above changes, and is given in Section 4. The revisions supersede the burn-back criteria given in the September 2002 test specification (Revision A) and users should apply the updated definitions.

The specification has been further updated to address perceived variations in fuel, sea water and third-party test administration. Changes outlined in this document mean that it is the most current as of April 2015.

The main changes from earlier versions are as follows:-

a. **Clarification of fuel (heptane) specification (Section 2.1.4)**

b. **Clarification of simulated sea (salt) water recommended composition (Section 2.3.2)**

c. **Clarification of system nozzle positioning for system nozzle part of test. (Section 2.2.7)**

2.0 Apparatus / Test Specification

2.1 Test Apparatus and Test Conditions

2.1.1 Test apparatus shall be as specified in the drawings given in Appendix A. For immediate reference, the fire pan has the following dimensions:

Inside Diameter :	2.44m
Shell Height :	0.61m
Bottom Thickness :	9.52mm
Shell Thickness :	6.35 - 9.52mm
Material :	Carbon Steel or 304 SS Lined Carbon Steel

Other features :	
Baffles (x 2) :	300mm (w)
Drain fitting :	50mm

The fire test pan shall be located not more than 300mm and not less than 200mm above ground level when supported by suitable legs. The pan shall be thoroughly cleaned prior to a foam concentrate being tested to prevent contamination from previously tested concentrates.

2.1.2 Baffles

Baffles, as specified in Appendix A shall be incorporated into the test pan. The purpose of the baffles is to hinder foam flow and force a longer foam travel distance, thus testing the ability of the foam to spread effectively. Whilst a small-scale test such as this precludes the need for foam to spread over significant distances, this step amounts to a more rigorous test of foam spreading within the confines of a circular tray.

2.1.3 Ambient Conditions

In many respects, there is an advantage to be gained from conducting the test in ‘real’ weather conditions since the objective of the test is to reproduce the expected incident conditions.

Ideally, the fire test shall be conducted outdoors in conditions of no precipitation. Where the test is unavoidably undertaken in conditions of precipitation (i.e. rain, sleet, snow etc.) an experienced person shall decide whether or not the weather conditions are likely to affect the test. Rain and/or high wind speeds or low ambient temperatures will tend to cause the test pan to cool slightly more quickly and therefore allow the foam to seal against the pan walls more effectively. Conversely, in hot environments with still wind conditions, a foam will take longer to seal since the pan walls will retain heat for longer periods. Clearly, if a test series is to be undertaken, then the conditions from test to test should not differ significantly. Any interpretation of test results shall therefore consider these factors.

The fire test shall be undertaken in the following ambient temperatures and wind conditions wherever possible. Measurements of these shall be taken and recorded.

Ambient Temperature:	$5\ ^{o}C < T_a < 20\ ^{o}C$
Wind speed:	*less than 3 m/s , gusts less than 5 m/s*

2.1.4 Test Fuel

The test fuel shall be an aliphatic hydrocarbon mixture having physical properties according to the following specification, commonly referenced in other fire test standards such as EN-1568:

- Distillation range: 84 °C to 105 °C;
- Maximum difference between initial and final boiling points: 10 °C;
- Maximum aromatic content: 1 % w/w;
- Density at 15 °C: (700 ± 20) kg/m3

Typical fuels meeting this specification are certain solvent fractions sometimes referred to as commercial heptane.

300 litres of the fuel shall be floated on a layer of water not less than 100mm deep initially (or approx. 200 litres). The water depth shall be adjusted so that a free-board distance (i.e. from the top of the pan to the liquid surface) of 500mm is obtained. For a full test of one foam (i.e. semi-aspirating, aspirating and system nozzle tests) the fuel and water shall be replenished as necessary. A quantity of 100 litres "top-up" shall be used between each nozzle test for one concentrate.

Fuel and water substrate temperatures shall be within the following limits:-

Fuel Temperature - *10 ^{o}C <T < 30 ^{o}C*

Water Temperature - *10 ^{o}C <T < 30 ^{o}C*

Tank wall temperatures shall be maintained at a level below the maximum temperature above, in between tests.

Note:- If required by an end user, alternative fuels may be used. However, it must be recognised that test assessment criteria may need modification for interpretation.

2.2 Test Nozzles

In order to distinguish between application methods, two nozzle types are used. Specifications for each are given in Appendix B.

A full test series using all three nozzles in the order semi-aspirating, aspirating and system nozzle shall allow the user to evaluate foam performance on the basis of foam/ foam-making equipment combinations. The foam throw and footprint characteristics of individual combinations depend to an extent on the degree of foam aspiration. More importantly, the effectiveness of the foam relies heavily on the amount of foam solution actually reaching the fuel surface. In unaspirated form, ('monitor' application) it is generally accepted that maximum foam throw distances can be achieved. Although it is not possible to quantify foam losses due to the foam stream/fire plume interaction, the observer(s) may wish to consider the advantages and disadvantages of each application method at what is already considered to be a critical application rate.

Notes:- It should be recognized that in the event that only one test nozzle is to be used, then the results of the test cannot necessarily be directly compared to when a series of 3 tests have been carried out.

2.2.1 'Non-system' nozzles

Two 'non-system' nozzles shall be used – 'Semi Aspirating' and 'Aspirating'.

The characteristics of these nozzles are intended to be such that they produce the foam properties typical of commercially available monitors. A wide variety of foam properties can be attained, ranging from non-aspirated to slow draining and low expansion. A table outlining these characteristics is given in Appendix B.

The nozzles are intended to simulate monitor application, but rather than directing foam against a backboard as in many other tests, the foam is thrown directly onto the fuel surface. In this way, the foam blanket is continually disturbed and the tests for post-fire security invariably result in a much sterner test and one that is more akin to real incident application.

The semi-aspirated nozzle is intended to produce foam properties similar to those actual nozzles generally known as "non-aspirating"; the aspirating nozzle to those known as "aspirating". Whenever possible checks should be made on the nozzles actually being used to determine their true characteristics and compare them with the results from the test nozzles.

2.2.2 'System' nozzle

In order to simulate a more gentle foam application, discharge shall be via a 'system nozzle' arrangement. This consists of the nozzle specified in Appendix A held by a suitable support. The nozzle is positioned so that it overhangs the test pan rim. Upon application, the foam runs down into the pan, simulating that from a foam pourer. A lower application rate is used for this configuration, amounting to 2.5 lpm/m^2. This allows the spreading and sealing characteristics of the foam to be assessed, when applied from a pourer at a gentler application rate (See Appendix B).

2.2.3 Nozzle Calibration

The flow rate through the test nozzle in use shall first of all be calibrated. This may be achieved by discharging water into a suitable receptacle and timing the passage of a known volume. (e.g. 10 litres). This will provide the user with a figure for lpm (litres/min). The flowrate may then be adjusted to achieve the desired application rate based on the area of the test pan.

2.2.4 For 'non-system nozzle' application, foam application rates of 3.74 lpm/m^2 (semi-aspirating) and 3.63 lpm/m^2 (aspirating) shall be achieved. (Test pan equal to 4.5 m^2)

2.2.5 For 'system nozzle' (topside pourer) application, a foam application rate of 2.5 lpm/m^2 shall be achieved.

The application rates shall correspond with the foam solution flows as given in Table 2 below.

NOZZLE	SOLUTION FLOW (lpm)	NETT SOLUTION FLOW (lpm)	APPLICATION RATE (lpm/m^2)
Semi-Aspirated*	19.0	17.5	3.74
Aspirated	17.0	17.0	3.63
System	11.7	11.7	2.50

Table 2 – Application Rates

**Difference in total solution flow and nett solution flow is caused by drop out from the nozzle through the aspiration holes. (Back pressure is deliberately created in the semi-aspirated nozzle to produce the desired foam properties. This causes some foam solution to be lost through the aspiration holes.)*

2.2.6 Nozzle Positioning

'Non-system nozzles' shall be arranged according to the configuration shown in Appendix A. A suitable nozzle platform shall be constructed to allow such positioning.

2.2.7 The 'System nozzle' shall be held in place by means of a suitable support that will allow the nozzle to be positioned over the test pan rim and the produced foam to flow down the inner wall of the pan.

The system nozzle shall be positioned (ideally) so that the rear edge of the discharge nozzle is against the test pan, so that foam flows partially down the tank inner wall, and the remainder drops directly into the tank. The intention is to simulate a Type II discharge outlet that is designed to lessen submergence of the foam, but for the purposes of a meaningful test, not avoid it completely.

It is recognised that sometimes, test pan/tank distortion makes this positioning difficult but it should be possible to allow a proportion of the foam solution discharge to flow down the "tank" inner wall.

2.2.8 For simulated 'monitor' application (using non-system nozzles) the foam stream shall be directed such that it strikes off-centre (i.e towards the back, but not against the wall) of the pan, or close to the centre. In practice, the distance in-between the nozzle/nozzle platform and the test pan will be variable, since the wind speed and foam expansion will affect the foams' 'throw'. The foam impact zone should be monitored during the test and the nozzle moved to maintain its position if necessary.

2.2.9 For simulated 'pourer' discharge, the system nozzle shall be positioned immediately prior to foam application.

2.3 Foam Apparatus

2.3.1 Foam Premix

All tests shall be conducted with premixed foam solution, transferred to the nozzle at constant pressure by means of a pump or air compression assisted discharge. The application rates given in Table 2 shall be achieved. The arrangement for this shall include the items of equipment similar to those shown in the test schematic. (Appendix A) Two typical configurations are shown. Premix tank(s) of not less than

120 litres capacity in total shall be used since this is the minimum amount of foam required for one test. Ideally an Intermediate Bulk Container (IBC) shall be used, sufficient to hold enough premix for 3 tests for any given foam.

The foam premix shall be prepared immediately prior to the tests.

2.3.2 Salt Water Premix

Where the test is to be conducted using salt water premix, sufficient premix shall be made in a single batch for at least 3 nozzle tests (i.e. semi-aspirating, aspirating and system nozzle tests).

The quantity of salt water premix shall be made with the following simulated sea water (i.e. salt water) composition:-

Component	**% by Weight**
Sodium Chloride (NaC1)	2.5
Magnesium Chloride ($MgC1_2$ x $6H_2O$)	1.1
Calcium Chloride ($CaC1_2$ x $2H_2O$)	0.16
Sodium Sulphate (Na_2SO_4)	0.40
Potable water	95.84

If other simulated sea water compositions are to be used then these shall be subject to approval by the LASTFIRE Coordinator.

2.3.3 Foam Properties

The accurate reproduction of the foam properties achieved on site from real foam-making equipment is a crucial part of the test, and to achieve this, special nozzles have been developed.

Foam quality tests (Expansion and 25% Drainage Time) shall be undertaken to quantify foam properties.

It is recommended that the end user determines the foam properties for the foam solution produced from foam-making equipment on-site, so that these properties can be compared with those achieved during the test.

The collection of foam samples from foam-making equipment shall be undertaken in line with the methods described in NFPA 11, Appendix C.

Where a sample from one of the two non-system nozzles is required, the person undertaking the test shall direct the foam from an appropriate distance from the collection board (typically 2-3 metres) such that a representative sample is obtained.

Where a sample from the ‘system’ nozzle is required, the person undertaking the test shall discharge the foam sample by running foam down the collection board in a gentle manner in order to simulate such application.

3.0 Fire Test Procedure

3.1 To fully evaluate a foam sample, a full test series using the 3 nozzles in the order semi-aspirating, aspirating and system, shall be carried out. (See Table 3 for sequence.)

3.1.1 Ignition and Preburn

The fuel shall be ignited and allowed to burn freely for a period of three (3) minutes after full surface involvement. This extended pre-burn allows high pan and fuel temperatures to develop.

3.1.2 Foam Application

At the end of the 3-minute pre-burn period, foam application shall commence. The nozzle position shall be adjusted prior to application. Steady state operation of the foam stream shall be achieved. The period of application shall be seven (7) minutes.

Foam application shall continue for the full 7-minute period, regardless of whether or not the fire has been extinguished. At the end of this period, the foam supply to the nozzle shall be cut.

An experienced person shall record the times to the following events:

90% fire control

At this point the radiative output from the fire will drop dramatically, enabling the observer to approach the test pan. (donned in suitable protective clothing) Flames will still be visible although a large proportion of the fuel surface will be covered in foam. It is recognized that, to some extent, this is a subjective parameter.

Total Extinguishment

The time for total extinguishment shall be the point at which no visible flames are apparent, including any signs of ‘ghosting’ across the foam surface. The foam blanket shall seal against the tank walls and particularly the baffle plate area where the foam’s sealing ability is tested to the full.

Any failure to control and extinguish the fire during and following the period of foam application shall be noted.

3.1.3 Foam Sample Collection

A foam sample shall be collected following the application period in accordance with 2.3.2 above, and foam quality measurements shall be made.

3.1.4 Vapour Sealing (Torch Tests)

The following tests shall be conducted following foam application, in order to assess the sealing capabilities of the foam.

2 minutes following end of foam application (12 min into test)

Torch Test 1 - A lighted torch shall be passed over the whole of the foam blanket (without contact) The extent of re-involvement (if any) shall be recorded at this stage and assessed against the performance criteria given in Section 4. The test shall ensure that the edges of the blanket and particularly the baffle areas are given attention. The torch shall be passed around the complete circumference of the tray inner edge within 75 mm (3") of the foam blanket and across the centre of the tray. The torch test shall take at least 1 minute to conduct.

13 minutes following end of foam application (23min into test)

Torch Test 2 – A repeat of Torch Test 1 shall be conducted 23 minutes into the fire test.

3.1.5 Burn back Test

The burn-back test shall be conducted by inserting a 300 mm diameter stovepipe (Appendix A) into the area of the blanket as follows:-

- Non-system nozzles – Approximately centrally in the pan half closest to the nozzle location.
- System nozzle – Approximately centrally in the pan half furthest from the nozzle location.

After removing the enclosed portion of the blanket, the exposed fuel shall be re-ignited. Following a further minute, the pipe shall be carefully removed. The burning area shall not increase to more than one quarter of the fuel surface area (approx. 1.16 m^2) within a further 4 minute period. Results shall be assessed against the performance criteria given in Section 4.

Procedure	**Time / Notes**	**Tick Upon Completion**		
Check Flowmeter Calibration / Maintain Charge in Foam Line	Prior to test series			
Aspirating – 17.0 lpm				
Semi-Aspirating – 19.0 lpm				
System – 11.7 lpm				
1. Premix Preparation – 800 litres or enough for test	Prior to test			
2. Install Premix Tank	Prior to test			
3. Adjust nozzle to steady state conditions	Prior to test			
4. Fill test pan with water substrate to mark (~200l)	Prior to test			
5. Record water substrate temperature	Prior to test			
6. Record premix temperature	Prior to test			
7. Measure ambient temperature / wind speed	Prior to test			
8. Add 300 litres of fuel	Prior to test	**1**	**2**	**3**
9. Record fuel temperature	Prior to test			
10. Check freeboard height – 500mm	Prior to test			
FIRE TEST – Ignition / Preburn	0-3 Mins			
11. 7 minutes foam application	3-10 mins			
12. Foam sample collection	10 mins			
Measurement of Expansion / 25% DT	During test			
13. Torch Test 1	12 mins			
14. Torch Test 2	23 mins			
15. Burn back test				
Introduce burn-back pot and remove foam	24 mins			
Ignite burn-back pot	25 mins			
Remove burn-back pot	26 mins			
END OF FIRE TEST				
16. Allow test pan to cool	After test			
17. Remove foam blanket	After test			
18. Refill test pan with fuel – Go to Step 9	After test			
19. Complete pan cleanout following 3rd Test	After 3rd test			
20. Flush lines / pump etc.	After 3rd test			

Table 3: - Fire test procedures for evaluation of single foam sample

4.0 Fire Performance Criteria

Based on end user input, the following is the relative weighting of each aspect of the test:-

- Fire control – 5%
- Extinguishment capability – 65%
- Post-extinguishment vapour suppression to prevent re-ignition – 15%
- Burnback resistance to prevent spreading of the fire in the event that full extinguishment is not achieved or re-ignition occurs – 15%

Potential "scores" are broken down further in Table 4.0. An explanation of each of the criteria is given below, along with guidance and observations. Graphical representations of the scoring method are given in Figures 4a – 4f.

For more guidance on the most desirable foam properties for fighting large storage tank fires, and foam selection and testing, reference should be made to the 'LASTFIRE' Project, 'Review of Foam Properties for Fighting Large Diameter Tank Fires'.

4.1 Evaluation Criteria

Fire Control and Extinguishment

End user polls have confirmed that full extinguishment is a more important indicator of a foam's performance than control. Consequently, only a small proportion of the overall score (maximum 5%) is given to fire control. Marks are awarded for the foam's ability to achieve 90% control up to a maximum of 8 minutes from ignition (i.e. 5 minutes foam application). Foams controlling the fire in 8-10 minutes (5-7 minutes of foam application) are given no marks in this section. Those foams that fail to control the fire once foam application has ceased even after 30 minutes from ignition are deemed to have 'failed' the requirements of the LASTFIRE test and given a resultant 0 overall score.

From the poll of end users it was determined that overall extinguishment is seen as by far the most important fire performance criterion. The scoring system reflects this by apportioning a maximum of 65 % of the total score to it.

Recognising that extinguishment of the fire is the ultimate aim of foam application, and generally speaking the sooner it is achieved the better, scoring shall be based on a 'sliding scale' with full marks given for extinguishment during the first 3 minutes of foam application (up to 6 minutes from ignition). If extinguishment is not achieved within the full 30 minutes test then the foam is classified as "FAIL" and given an overall 0 score.

Vapour Suppression

Vapour suppression performance shall be assessed in the LASTFIRE test by passing a lighted torch around the full circumference and centre of the foam blanket. This shall be done twice during the test and each test given a maximum possible 7.5 % of the total test marks. The extent of re-ignition shall be evaluated and scores given for each ‘torch test’ based on the following observations:-

7.5 marks (7.5 % of total) shall be given if:-

- No re-ignition occurs

5 marks (5 % of total) shall be given if:-

- Only minor edge ignition is observed around part of the tank circumference (<65%), which then subsides and extinguishes. Flames must be less than or approximately equal the test pan height.

2.5 marks (2½ % of total) shall be given if:-

- Re-ignition around > 65 % of the circumference is observed, or minor ‘ghosting’ across the foam blanket occurs.

And

- Ghosting or re-ignition is short lived, extinguishes rapidly, and results in only minor deterioration of the foam blanket (e.g. top layer removal only).

0 marks shall be awarded for vapour sealing capability if:-

- A full surface ‘flashover’ of the foam blanket is observed. If a full flash occurs, flames must subside rapidly.

Or

- Greater than 65% circumference re-ignites

And

- Flames are significantly greater than the test pan height.

- Flaming is prolonged

Or

- Flaming or ghosting occurs, and is prolonged with continued deterioration of the foam blanket. (e.g. multiple layer removal or ‘exfoliation’)

And

- Flames are less than or approximately equal to the test pan height.

NB: If flaming subsides, it may still be possible to conduct a second torch test or burn back test, but no marks shall be given for the current seal test.

OVERALL FAIL shall be deemed if significant, prolonged flaming over a large proportion of the surface (25-50%) is observed, with flames greater than the test pan height. OVERALL FAIL shall be given, even if flaming subsides, and subsequent seal or burn back tests can be conducted.

It is possible that a foam which performs poorly in the first ‘torch test’ may achieve higher marks in the second, once any fuel picked up by the foam has burnt away during the first test.

Burnback Resistance

Different foams are able to resist “burnback” to varying degrees. Upon removal of the burnback pot (and in some cases before removal) foams can exhibit minor or extended reignition of the foam blanket. In some cases, the fuel surface will be exposed as subsequent foam “layers” are burnt and deteriorate.

NB:- Marks for burnback resistance may still be attainable even if extinguishment is delayed and seal tests are not conducted, but full extinguishment must occur before the burn back test is attempted. Similarly, the burn back test can only be attempted once extinguishment of any flames from previous seal tests has occurred.

Marks shall be awarded for burnback resistance as follows:-

Minor flaming or ghosting < 25 % of surface –
15 marks (15 % of total) shall be given if:-

- No more than 25 % of the fuel surface is reignited at any time during the test, or if self-extinguishment occurs.
- No full surface flash is observed
- Minor flickers may be observed, but flames must be no greater than the test pan in height
- Only a minor partial circumference flash is observed – flames must not exceed 65% of the circumference and be limited to test pan height.
- No exposed fuel is observed

Flash over <25 % of surface and edge flickers <65 % circumference -
10 marks (10% of total) shall be given if:-

- No more than 25 % of the fuel surface is flaming at the test end, or self-extinguishment occurs. A brief full surface flash is permitted, but must subside quickly, leaving less than 25 % surface area burning.
- Circumference flickers are no greater than test pan height, and are limited to <65 %
- No exposed fuel is observed

Flash over 25-50 % of surface and edge flickers < 65 % circumference -
5 marks (5 % of total) shall be given if:-

- No more than 25 % of the fuel surface is flaming at the test end. A brief full surface flash is permitted, but must subside quickly, leaving less than 25 % surface area burning.
- Circumference flickers are limited to < 65 %, but are greater than the test pan height.
- No exposed fuel is observed

Full flash over surface with continued ghosting or flaming over significant proportion of surface (25-50 %) -
0 marks shall be given if:-

- 25-50 % of the fuel surface is flaming at the test end.

- Ghosting or flaming is observed over a significant proportion of the surface i.e. 25-50 % and continues until the test end.

- Fuel exposure is evident. Exposure must be limited to < 10 % of the test pan area

Full flash over surface with continued ghosting or flaming over more than 50 % of surface –
An **OVERALL FAIL** shall be deemed if:-

- A full surface flash is accompanied by sustained flaming covering >50% of the surface area, and more than 50% of the surface is burning at the test end.

Or

- Prolonged full surface ghosting or flaming with flames greater than test pan height is observed, without extinguishment or reduction in area.

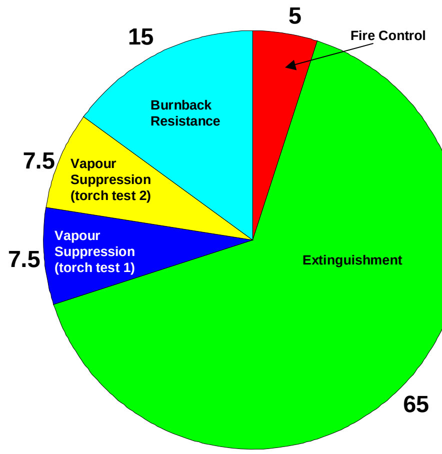
And

- Exposed flaming fuel >10% in area is observed

- Significant foam blanket deterioration or 'iceberging' occurs.

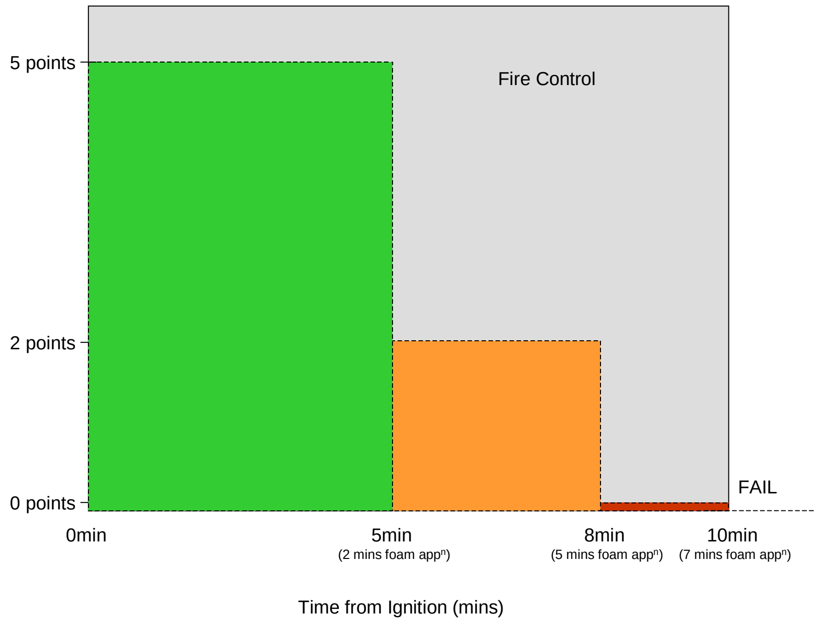
Criteria	Score: (all times from ignition – mins)		Remarks
Fire Control	*0 – 5*	5	
	>5 – 8	2	
	8 – 10	0	
	> 10	FAIL	*OVERALL FAIL*
	Maximum score	***5***	***5 % of total***
Extinguishment	*0 – 6*	65	
	>6 – 10	55	
	>10 – 12	45	
	>12 – 20	25	
	20 – 30	15	
	>30	FAIL	*OVERALL FAIL*
	Maximum score	***65***	***65 % of total***
Vapour Suppression	**Test one**		
		7.5	*No reignition*
		5	*Minor edge ignition only*
		2.5	*Full circumference ignition or single ghosting over surface*
		0	*Full flash and prolonged ghosting over surface*
	Maximum score	***7.5***	***7.5 % of total***
	Test two – scoring as test one		
		7.5	*No reignition*
		5	*Minor edge ignition only*
		2.5	*Full circumference ignition or single ghosting over surface*
		0	*Full flash and prolonged ghosting over surface*
		OVERALL FAIL	*Significant prolonged flaming 25-50%, flames>pan*
	Maximum score	***7.5***	***7.5 % of total***
Burnback Resistance		*15*	*<25 %, minor flaming*
		10	*<25 % flash / <65 % circ.*
		5	*Flash 25-50 % / <65 % circ.*
		0	*Full flash/continued ghosting 25-50 %*
		OVERALL FAIL	*Full flash/sustained flaming or ghosting >50 % / exposed fuel>10 %, iceberging*
	Maximum score	***15***	***15 % of total***
	TOTAL	***100***	

Table 4: Test Criteria / Assessment System



End user relative importance of LASTFIRE Test fire performance criteria
(Developed from poll of end users)

Figure 4a



Fire Control Assessment

Figure 4b

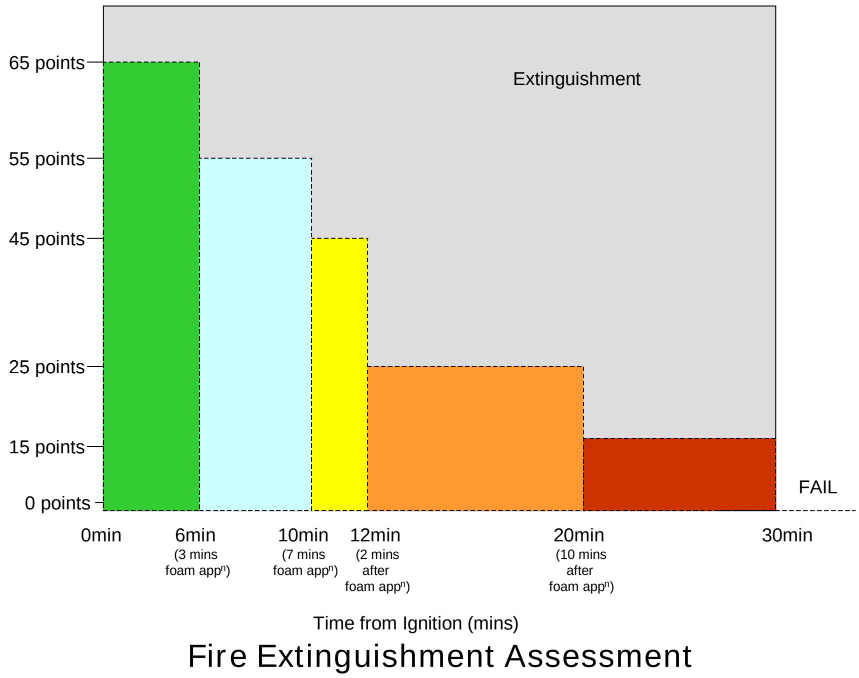
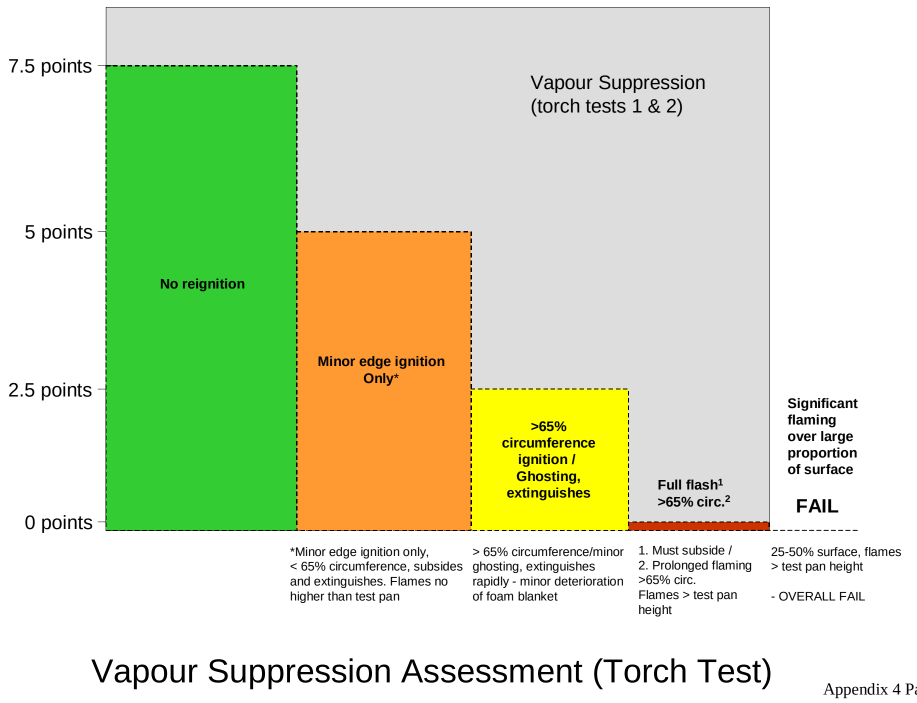
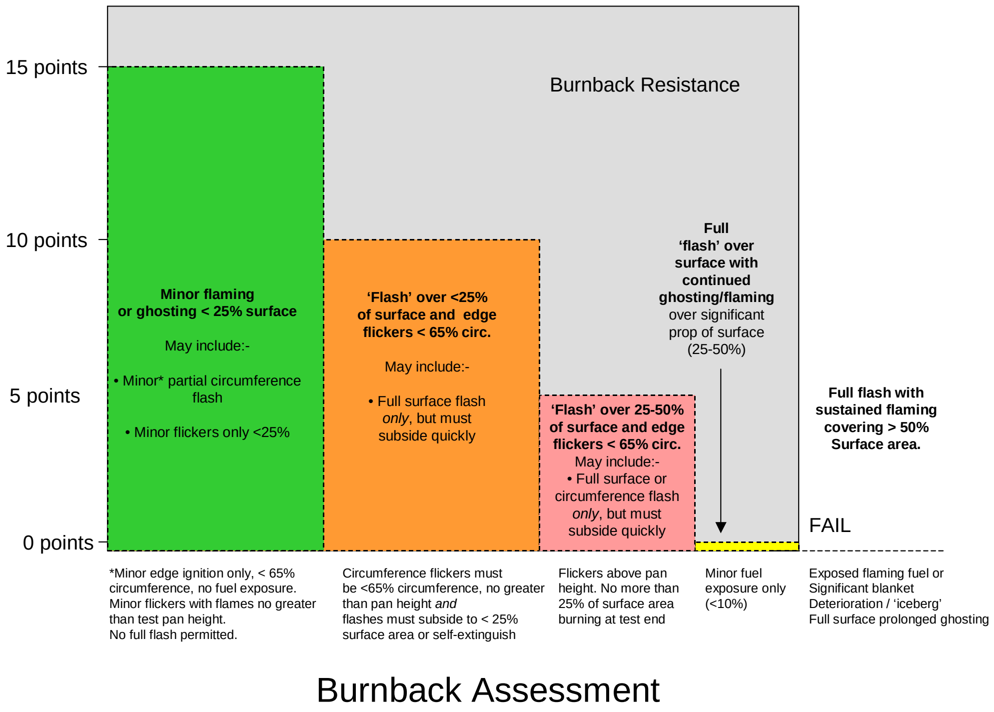


Figure 4c



Appendix 4 Page 4

Figure 4d



Appendix 4 Page 5

Figure 4e

4.2 Overall Scoring

The following overall rating categories are applicable.

Good Fire Performance -	80 – 100 %
Acceptable Fire Performance -	50 – 79.5 % inclusive
Reduced Fire Performance -	25 – 49.5 % inclusive
Poor Fire Performance -	0 – 24.5 % inclusive

The assessment criteria are represented graphically in Figure 4f below.

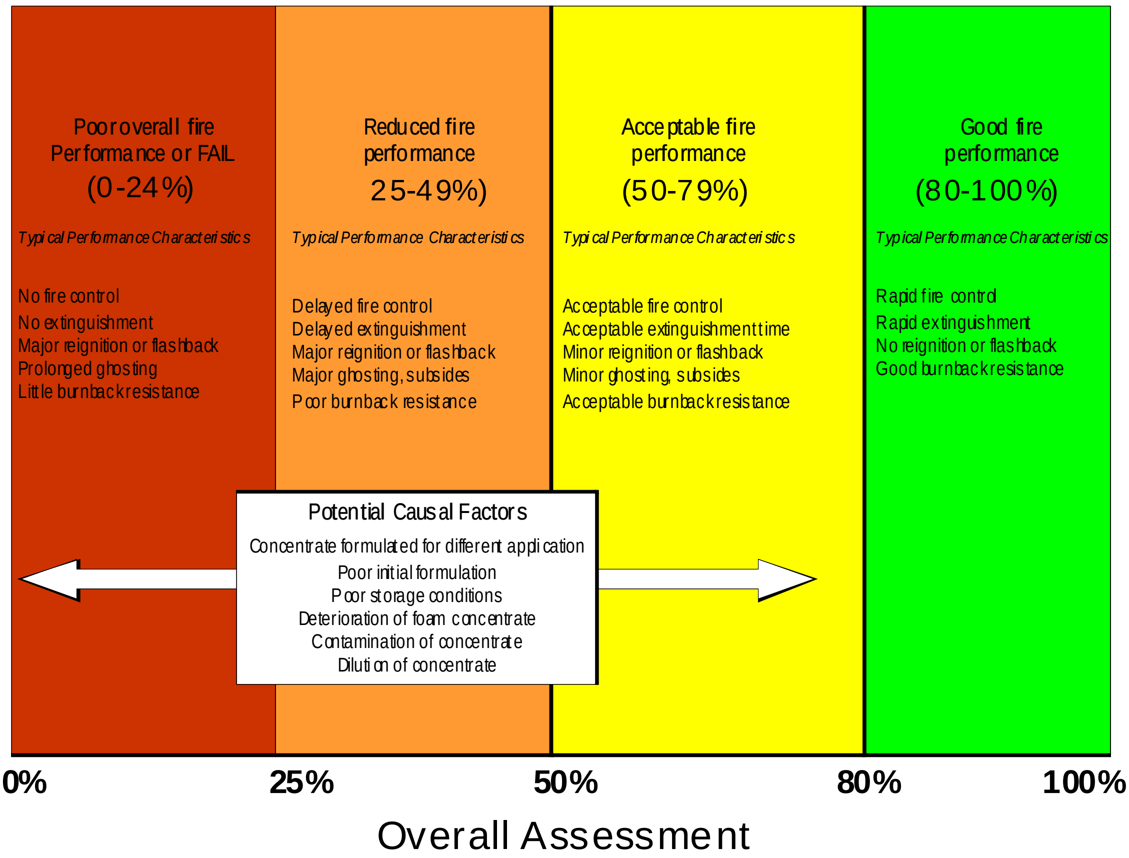


Figure 4f – Overall Assessment

A format for an acceptable results sheet is given in Appendix D.

4.3 General Guidance and Observations

4.3.1 Extent of Re-involvement – Observations

The observer(s) should be aware that it is sometimes the case that there will be a period of re-involvement, even though the fire may have been extinguished successfully during the seven-minute foam application period. Re-involvement may be *full* in some circumstances. The observer(s) shall therefore remain at a safe distance and approach only when necessary to record results.

In some cases re-extinguishment may occur following a period of full re-involvement, the flames subsiding relatively quickly. Erratic behaviour such as this shall be noted in detail, along with associated times. Observers shall be aware that there is always a possibility that re-involvement may become severe at any stage.

4.3.2 'Ghosting'

'Ghosting' is a phenomenon exhibited with some foams during a period of relatively stable sealing. The fire cannot be deemed 'fully extinguished' since small transient flames will be observed on the foam surface, and sometimes around the blanket edge. This is caused by pockets of fuel vapour forming, which easily ignite. Periods of ghosting shall therefore be recorded, along with the extent and duration.

4.3.3 Burnback Test – Observations

During the burn-back test, removal of the stovepipe will either:

- Cause the fire to spread across the extent of the foam blanket.
- Result in no further spread of flame across the foam blanket – the foam will successfully contain the fire within the removed portion.
- Result in a period of containment, followed by gradual re-involvement, including phenomena such as ghosting. The extent of re-involvement may subside and the fire may self-extinguish.
- Show a period of containment, followed by a gradual closing of the foam blanket around the exposed area, and eventual extinguishment.

The timing and nature of these events shall be recorded on a suitable proforma.

4.3.4 Other Observations

Wind effects, causing 'lift-off' of the foam blanket at the pan edge shall be noted. Any restriction to foam flow resulting in the foam blanket being unable to seal effectively shall be recorded. The test shall be conducted under conditions of very little, or no wind at all, if wind effects are shown to play a major part in rendering foam application ineffective.

During foam application and when assessing post-fire security, several events may occur simultaneously and the observer(s) shall use their experience to determine the most important phenomena. The composition of fire test data will be both quantitative and qualitative, as both times to events and their nature shall be recorded. The observer(s) shall make their own decisions as to the nature of this data, and whether foam performance can be deemed acceptable on the basis of such results.

4.3.5 Further Guidance

When conducting the fire test the user shall be aware of the following foam properties and how each contributes to effective performance.

Cohesion

It must be such that the foam bubbles cling together and form a tough cohesive blanket that does not split up to allow pockets of uncovered fuel.

Vapour Suppression

The foam shall ideally be capable of suppressing flammable vapours and prevent them percolating through the bubbles to burn on the foam surface.

Stability/Water Retention

The foam shall ideally have the ability to retain water in order to continue to perform its cooling function as long as possible. The method of assessing this is to measure the 25 % drainage time (or ”quarter life”) of the foam. This is the time taken for 25% of the solution in a foam to drain from it after it has been aerated.

Flowability/Flame Knockdown

In order to knock down the flame front and control a fire as quickly as possible, the foam shall ideally flow rapidly across the fuel surface and around any obstructions in the hazard. This property is particularly important if we consider that foam will sometimes have to travel large distances, or flow over a sunken roof when applied to a large diameter tank fire.

Heat Resistance

The foam must be able to resist the destructive effects of heat radiated from any remaining fire or from the hot tank walls. To some extent, this property is related to water retaining ability, but this, in itself, is insufficient.

Sealing Capability

It is important that the foam has the ability to seal against any obstruction in the fire otherwise vapours will rise in the gap created and continue to burn.

Burnback Resistance

The foam must have the ability to resist burning back after the majority of the fire has been extinguished. Testing for this property is usually a vital part of a critica1 fire test for a foam. When the fire has been extinguished in such a test it is normal practice to re-ignite a small area and then see how long the foam layer remains to assess its burnback resistance.

Fuel Tolerance

It is good general practice to apply foam as gently as possible and minimise fuel pick-up within the foam. However, this is not always possible. Any foam, if totally saturated with fuel, will obviously burn, but some foam types have the ability to resist fuel pick-up better than others. Such foams are said to be oleophobic and the bubbles actually try to reject any fuel within their structure.

4.4 Foam Concentrate Physical Properties

In order to provide a reference against manufacturer's data and to facilitate comparison of other samples against those actually tested, some physical properties of the foam concentrate shall be measured as follows:-

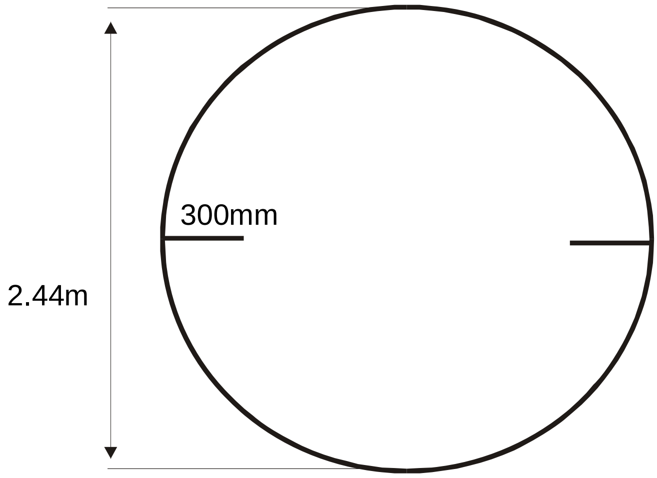
- pH
- Refractive Index
- Viscosity
- Specific Gravity

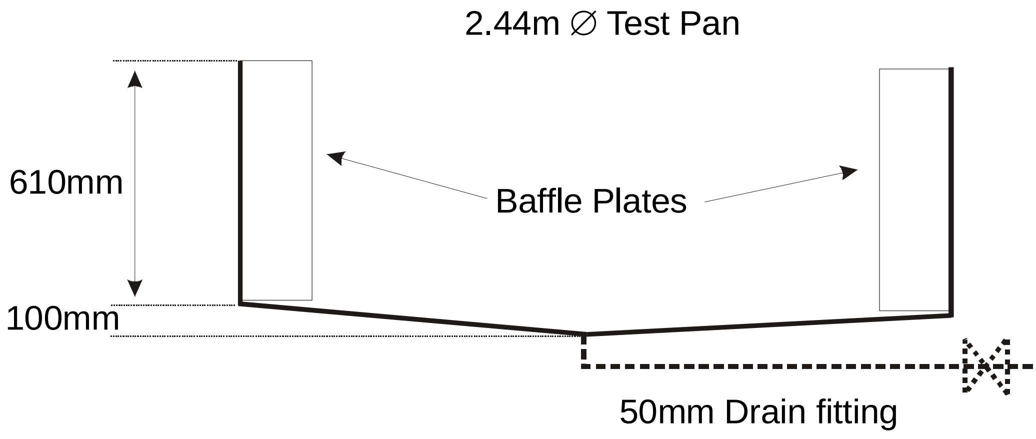
In addition, the surface and interfacial tensions of each foam solution shall be determined.

Test methodologies shall be recorded.

Appendix A

Specification of Test Apparatus





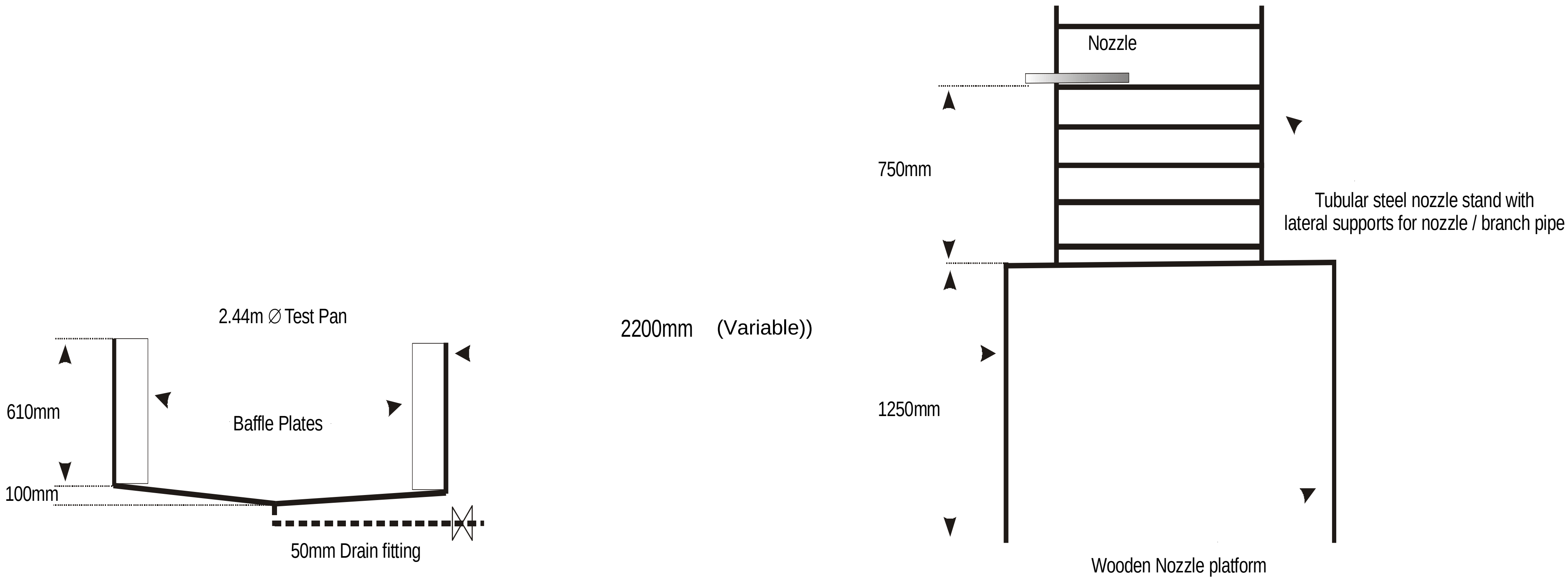
Material : Carbon steel or 304 SS lined carbon steel

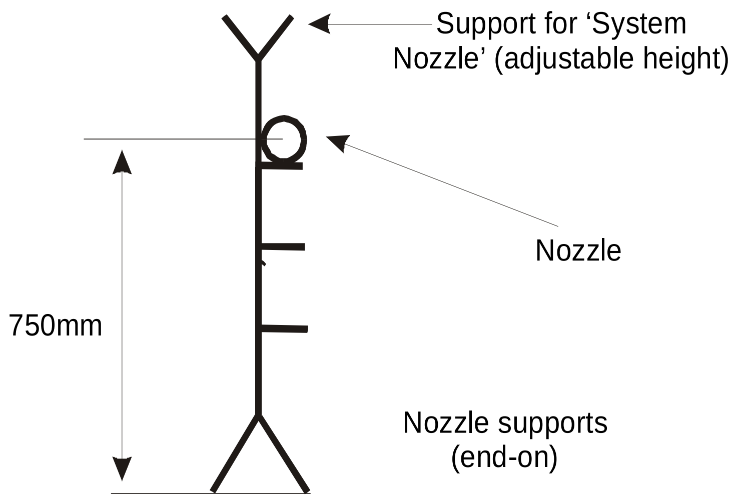
Shell thickness : 6.35 - 9.52mm

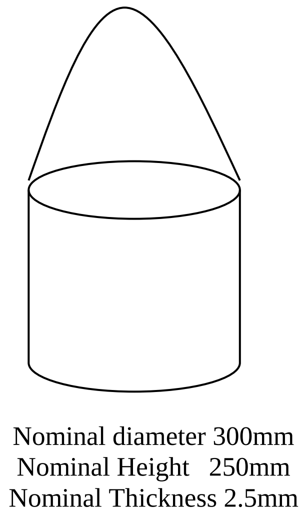
Baffle plates (x2) : 300mm width, 600mm height (approx)
clamped and / or bolted to pan sides

Pan should be supported approx 300mm above ground by means of suitable legs.

Test Pan / Nozzle Arrangement

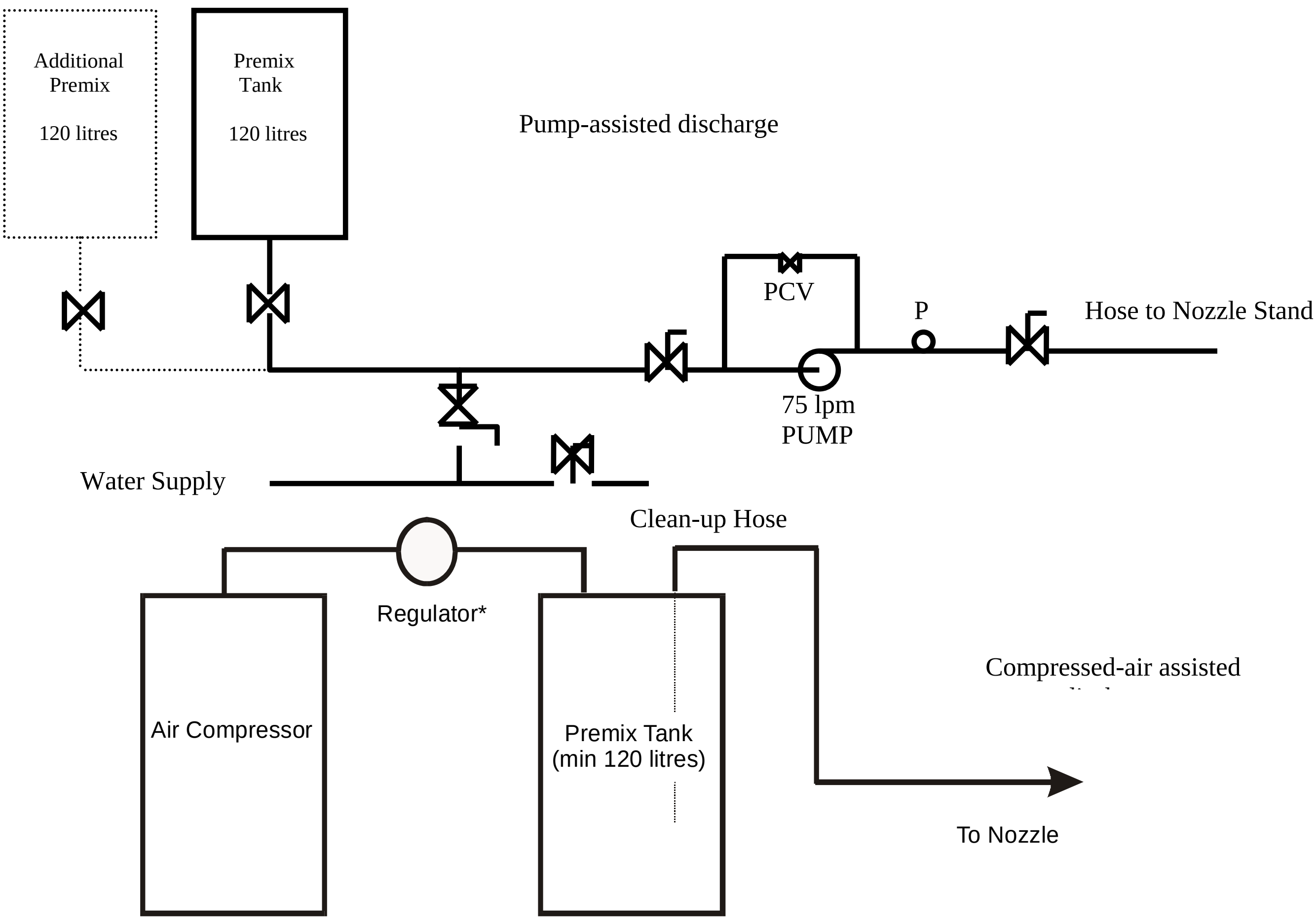






Nozzle Support Structure

Burn-back Pot



* e.g. Nullmatic Pressure Regulator 3-200 psig range Approx 110 psig for Aspirating (4 USG) Nozzle / 85 psig for system nozzle

Typical Piping Arrangements

Appendix B

Test Nozzle Specification

B.1.0 The following pages detail the nozzles, which should be used for this fire test. No other nozzles should be used.

B.1.1 Both aspirating and non-aspirating versions are used. These nozzles were developed in line with the requirements of fire test UL 162 to provide foam quality (expansion and drainage time) similar to that produced from the application equipment actually used at incidents. (Essentially monitors in this case) Where this specification outlines the use of a 'Semi-Aspirated' nozzle, a distinction between this and 'true' non-aspirated nozzles should be made. Essentially, the 'semi-aspirated' nozzle will provide such foam, although a small degree of aspiration will occur by virtue of the foam emerging from the nozzle and entraining air.

B.1.2 The simulation of topside foam pourers is achieved through the use of a foam 'system' nozzle, specified in drawing B-3. This nozzle produces fully aspirated foam, and is able to be hooked over the rim of the test pan, providing suitable supports are available. (Appendix A)

Drawing **B-1** Semi-Aspirating foam nozzle and detail

Drawing **B-2** Aspirating foam nozzle and detail

Drawing **B-3** Foam 'system' nozzle (aspirating)

B.1.3 The foam characteristics of these nozzles are summarised below based on best current data available.

Nozzle	Emulation	Foam Quality	Foam Properties
B-2	Titan/Colossus/Mega †	Good quality	Expansion 5-10 ; 25 % Drainage 3 mins
B-1	Williams monitors ‡	Average quality	Expansion 3-5 ; 25 % Drainage 2 mins
B-3	Fixed system (Foam Pourer)	Variable quality	Range of expansion ratios and drainage times

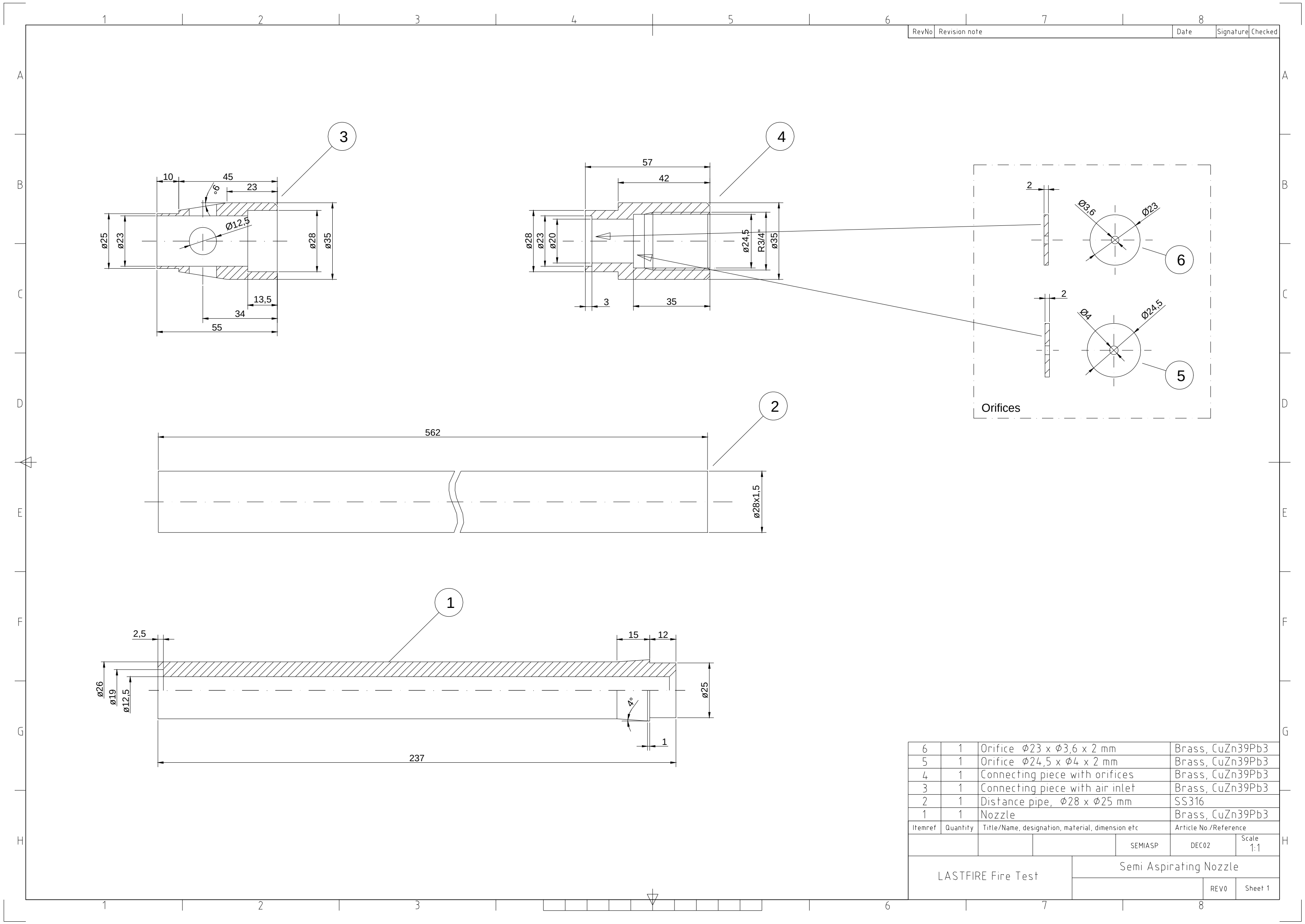
† Typical aspirating monitors
‡ Producing 'semi-aspirated' foam

B.1.4 'Semi-aspirating' nozzles were developed to produce foam of the same drainage time and expansion as 'non-aspirating' large throughput monitors.

B.1.5 'Aspirating' nozzles were considered to represent large throughput monitor nozzles designed to aspirate foam in the order of 6:1.

Drawing B-1

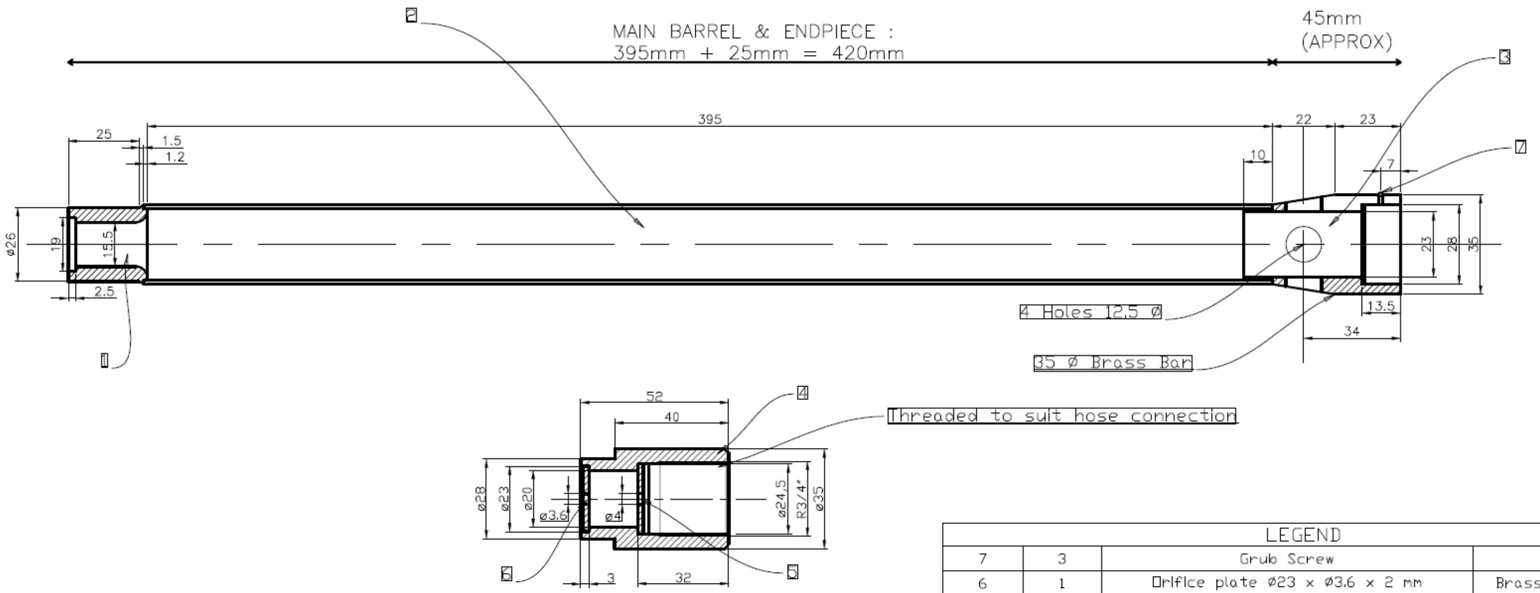
Semi-Aspirating Nozzle and Detail



Itemref	Quantity	Title/Name, designation, material, dimension etc	Article No./Reference
6	1	Orifice Φ23 x Φ3,6 x 2 mm	Brass, CuZn39Pb3
5	1	Orifice Φ24,5 x Φ4 x 2 mm	Brass, CuZn39Pb3
4	1	Connecting piece with orifices	Brass, CuZn39Pb3
3	1	Connecting piece with air inlet	Brass, CuZn39Pb3
2	1	Distance pipe, Φ28 x Φ25 mm	SS316
1	1	Nozzle	Brass, CuZn39Pb3

Drawing B-2

Aspirating Nozzle and Detail



ALL DIMENSIONS IN mm UNLESS OTHERWISE STATED

TOTAL LENGTH : 465–470mm (± 5mm TOLERANCE)

ORIFICE TOLERANCE ±0.02mm (Item Ref 5 & 6)

LEGEND

Item ref	Quantity	Title/Name, Designation, Dimensions etc	Material
7	3	Grub Screw	
6	1	Orifice plate Ø23 x Ø3.6 x 2 mm	Brass, CuZn39Pb3
5	1	Orifice plate Ø24.5 x Ø4 x 2 mm	Brass, CuZn39Pb3
4	1	Connecting piece with orifices	Brass, CuZn39Pb3
3	1	Connecting piece with air inlets	Brass, CuZn39Pb3
2	1	Distance pipe Ø28 x Ø25 mm	SS316
1	1	Nozzle	Brass, CuZn39Pb3

Resource Protection International

Resource Protection International
Walker House, George Street,
Aylesbury, Bucks, HP20 2HU, United Kingdom.
Tel: (01296) 399311 Fax (01296) 395669
Email: ramsden@resprotint.co.uk
Web: www.resprotint.co.uk

REV	DATE	DESCRIPTION	BY	CHK	APP
0		ISSUED FOR COMMENT			

PERMIT | STAMP | SCALE: NONE

DRAWN SK DATE 10/02/2011
CHECKED BC DATE 10/02/2011
APPROVED DATE
CLIENT DATE

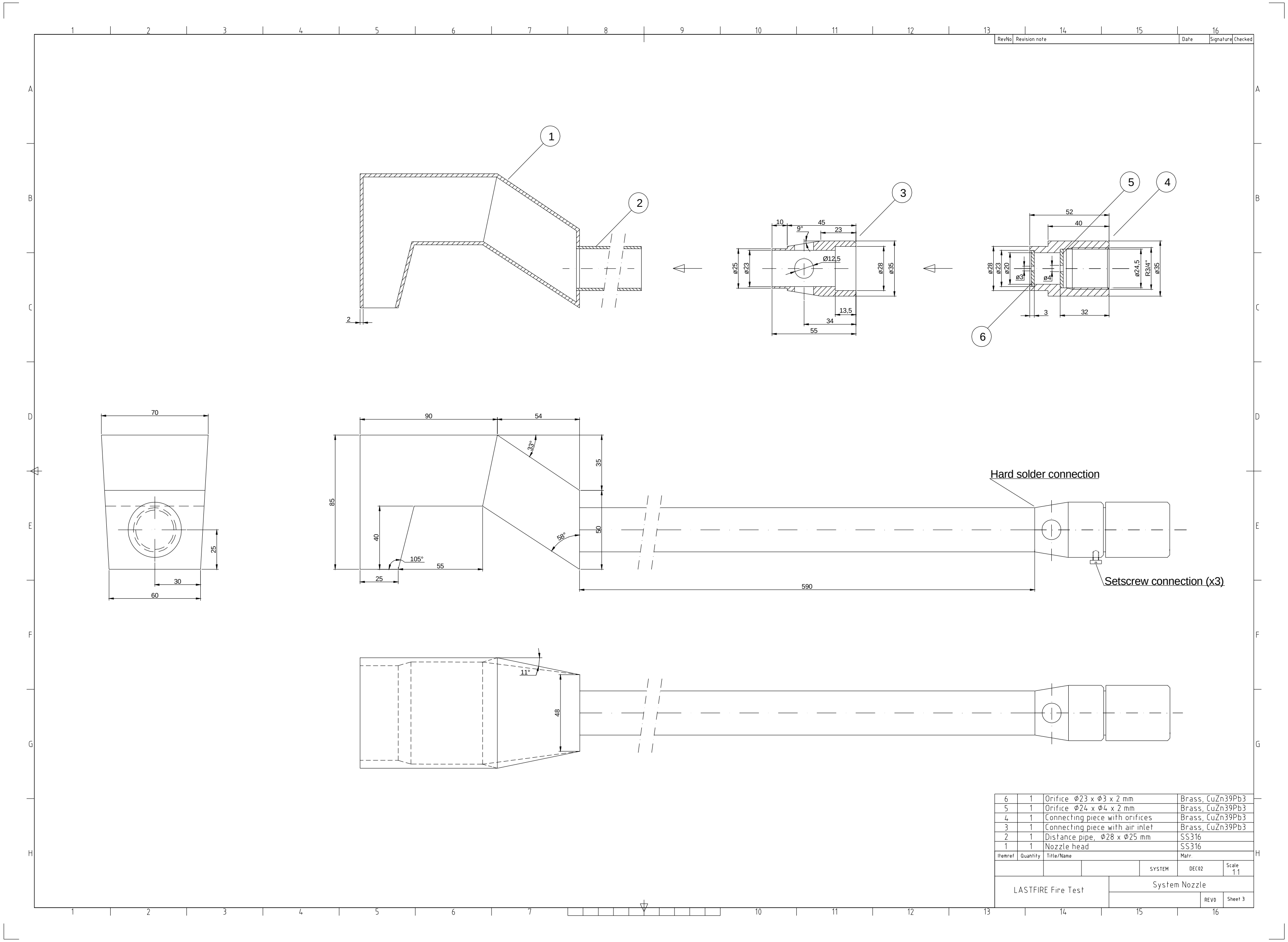
LASTFIRE

LASTFIRE
ASPIRATED NOZZLE

PROJECT No. LASTFIRE | DWG. No. LASTFIRE-001 | SHT. No 01 | REV 0

Drawing B-3

'System' Nozzle


Hard solder connection
Setscrew connection (x3)
6 | 1 | Orifice Ø23 x Ø3 x 2 mm | Brass, CuZn39Pb3
5 | 1 | Orifice Ø24 x Ø4 x 2 mm | Brass, CuZn39Pb3
4 | 1 | Connecting piece with orifices | Brass, CuZn39Pb3
3 | 1 | Connecting piece with air inlet | Brass, CuZn39Pb3
2 | 1 | Distance pipe, Ø28 x Ø25 mm | SS316
1 | 1 | Nozzle head | SS316
Itemref | Quantity | Title/Name | Matr.
SYSTEM
DEC02
Scale 1:1
LASTFIRE Fire Test
System Nozzle
REV0
Sheet 3

Appendix C

Foam Collection Apparatus

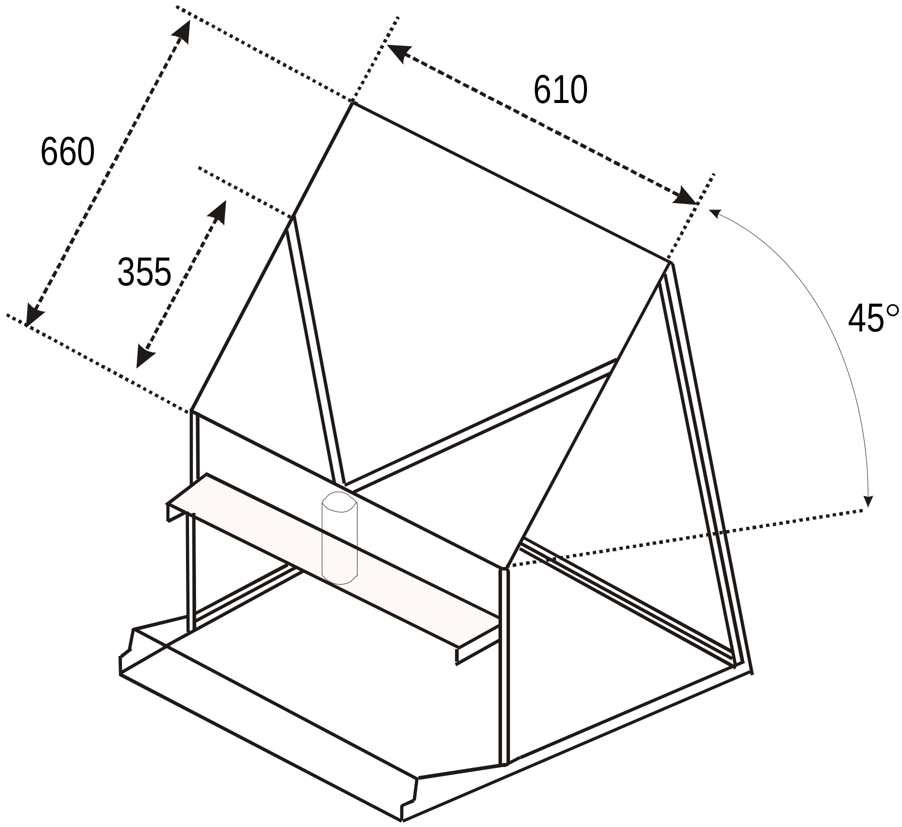
C.1.0 The collection of expanded foam samples forms an important part of the fire test procedure.

Firstly, a representative sample should be collected from the foam/equipment combination so that expansion and drainage time measurements can be made.

C.1.1 The apparatus used for the collection of expanded foam samples, necessary for the determination of Expansion Ratio and 25% Drainage Time consists of:

- Collection Board (Drawing **C-1**)
- 1,600 ml Drainage Pan (Drawing **C-2**)

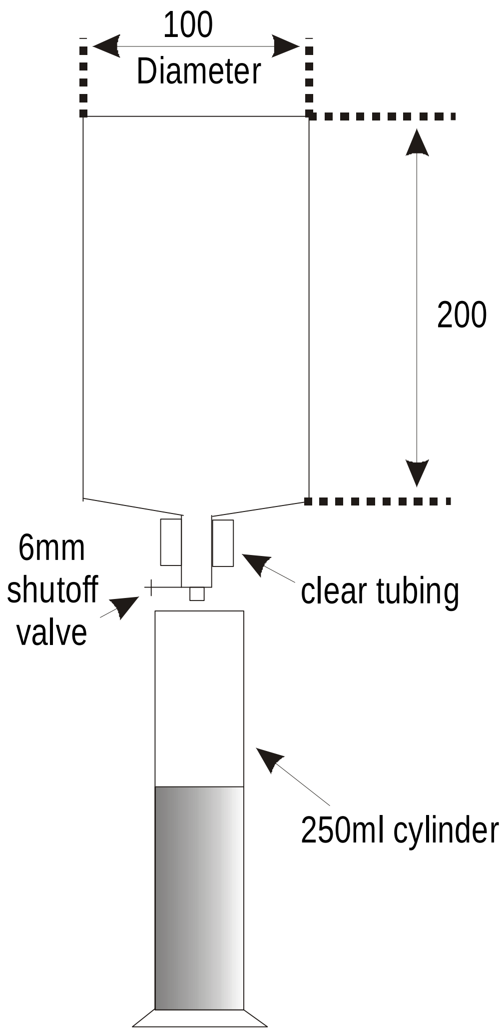
C.1.2 More information on the collection of expanded foam samples and the measurement of parameters such as expansion and 25 % drainage time can be found by referring to NFPA 11.



Drawing C-1

Foam Collection Board

All dimensions in millimetres



Drawing C-2

1,600 ml Drainage Pan

All dimensions in millimetres

Appendix D – Example Record Sheet / Certificate

LASTFIRE
Large Atmospheric Storage Tank Fires

Lastfire Foam Test Results

Manufacturer/Site .... Date: ....

Foam Concentrate Characteristics

Type:	....	pH at 20°C	....	S.T. at 1%	....
Concentration:	....	S.G. at 20°C	....		
Water type	....	R.I. at 20°C	....	Viscosity at 20°C	....
Batch No.	....				

Foam Quality

	Expansion	25 % Drainage Time
Semi-Aspirated	....	....
Aspirated	....	....
System	....	....

Test Conditions

	Ambient Temp: °C	Wind Velocity: m/s
Semi-Aspirated	....	....
Aspirated	....	....
System	....	....

Fuel Type / Tank Temps °C

Type	Fuel	Water/substrate
Heptane	....	....
	....	....
	....	....

Nozzle Calibration

	Source	Specified	Actual
Semi-Aspirated	*Lastfire*	19.0 lpm	19.0 lpm
Aspirated	*Lastfire*	17.0 lpm	17.0 lpm
System	*Lastfire*	11.7 lpm	11.7 lpm

Fire Performance Data

	Semi-Asp.	*Marks*	Aspirated	*Marks*	System	*Marks*
'Control' Time	....		....		....	
Extinguishment Time	....		....		....	
Torch Test @ 12min:		....		....		....
Torch Test @ 23 min:		....		....		....
Burnback Resistance		....		....		....
Overall Rating		0		0		0

Notes / Comments

Purpose of Test ....
Test Location: ....
Initial of Tester ....
Ref ....
Note: This certificate is valid for these batches only

Test Reference

Signed:

Lastfire Project Co-ordinator

Appendix E

References

[1] [LASTFIRE] 'A Joint Oil Industry Project to Review the Fire Related Risks of Large Open-top Floating Roof Storage Tanks' *Project Co-ordinators: Resource Protection International; 1997*

[2] [OF555C] 'Federal Specification: Foam Liquid, Fire Extinguishing, Mechanical' *1969*

[3] [UL162] 'Standard for Foam Equipment and Liquid Concentrates

[4] [NFPA11] 'Standard for Low, Medium and High Expansion Foam,' *National Fire Protection Association Inc. ; 1998*