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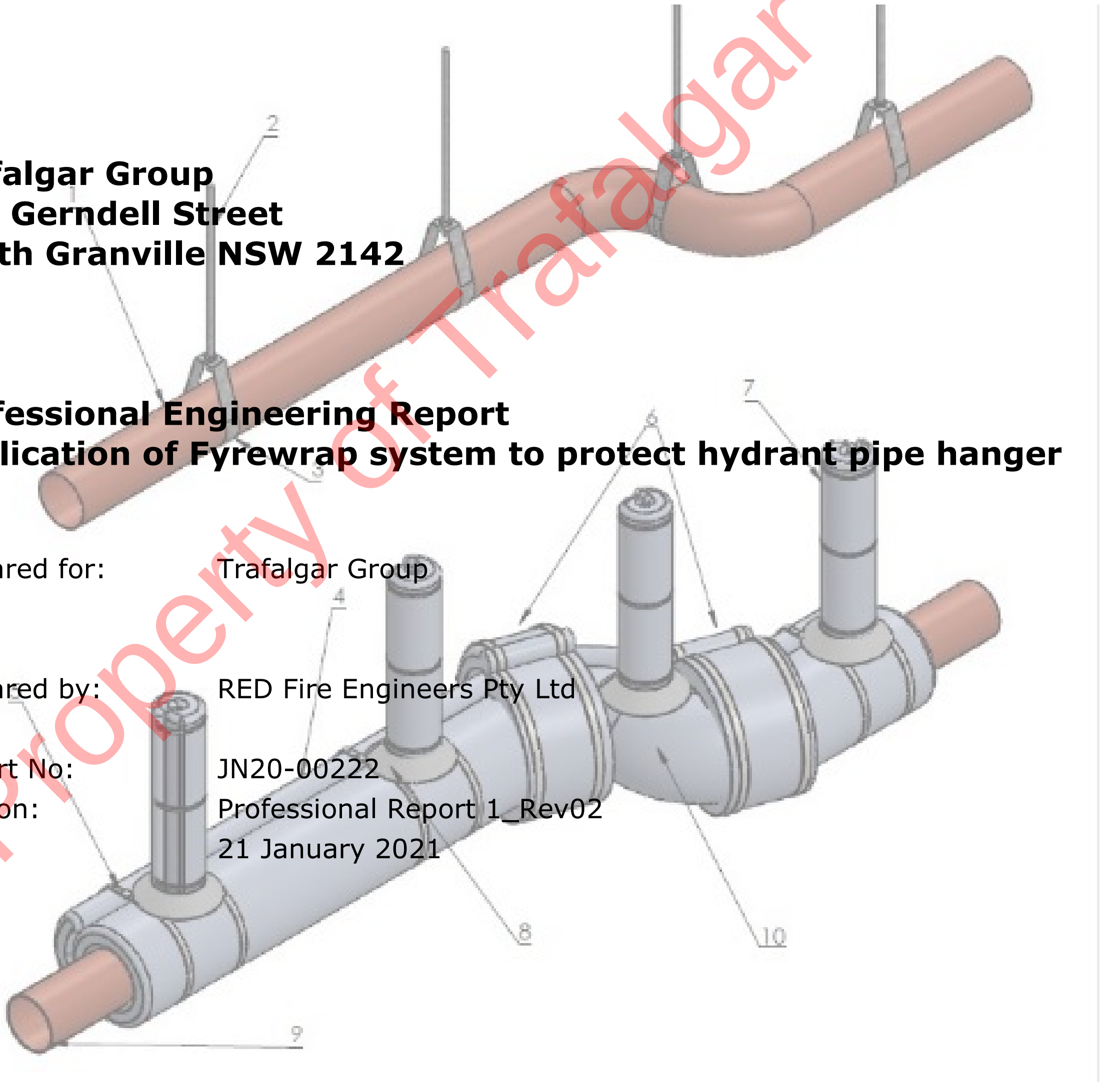

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Professional Engineering Report
Application of Fyrewrap system to protect hydrant pipe hanger

Prepared for: Trafalgar Group

Prepared by: RED Fire Engineers Pty Ltd

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Executive Summary

RED Fire Engineers Pty Ltd has been appointed by Trafalgar Group to prepare a professional engineering report on the application of Trafalgar Fyrewrap fire protection system to protect the fire hydrant system pipe supports when exposed to fire.

The aim of this report is to provide the evidence that, by using the data in a fire-resistance test report, fire safety engineering literature and calculations, the application of Trafalgar Fyrewrap fire protection system can meet the Performance Requirement on preventing early collapse of the pipework and supports when exposed to fire stipulated in Clause 8.7.4 of AS 2419.1-2005 (Amendment 1) and Clause 10.4.1 of AS 2419.1:2017.

This report could be considered as an evidence of suitability as defined in Clause A2.2(a)(iii) of the NCC2016 Volume 1 BCA, Clause A2.2(a)(v) of the NCC2016 Volume 1 Amendment 1 BCA, and Clause A5.2(1)(e) of the NCC2019 Volume 1 BCA.

AS 2419.1 (2005 (Amendment 1) and 2017 versions) requires that where fire hydrant system pipework is likely to be exposed to fire in a building that is not sprinkler protected, the pipe supports shall have an FRL of not less than 60/-/-, while maintaining a pipe-support temperature of not less (which should read 'more') than 500°C when tested in accordance with AS 1530.4, or other measures shall be taken to prevent its early collapse when exposed to fire.

A fire-resistance test to AS 1530.4:2014 has been carried out on 100 mm copper hydrant pipes supported by mild steel hanger rods and pear bands. The copper pipes and pipe support systems were protected with FyreWrap Elite 1.5 and Trafalgar Fire FyreFlex sealant. The aim of this protection was to protect the pipe supports so that they achieve an FRL of not less 60/-/-, while maintaining the pipe support temperature of less than 500°C when tested in accordance with AS 1530.4.

It is understood that the pipe hangers were made of mild steel. Although the yield strength of mild steel is lower than that of normal or high strength steel, its performance in a fire has been evaluated to be as good as those steels. Therefore, reduction factors of steel tensile strength and elasticity at high temperature similar to that of structural steel at high temperature can be applied to mild steel for subsequent calculation. Details of mechanical properties of mild steel are presented in Section 3.

Depending on the types of service pipe (NB 100 mm copper pipe, NB 100 steel pipe or NB 150 steel pipe), the maximum distance between the different size of hangers can be selected from Table 12, provided that spalling of concrete does not occur at the junction between hanger's support and concrete floor slab, and the Fyrewrap fire protection system is installed in full accordance with the manufacturer's technical instruction in Appendix A. This is based on the assumption that the FRLs of the hanger-concrete floor and the hanger-pear band connections are at least equivalent to the hanger's and pear band's FRL.

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1 Introduction

1.1 Project description

1.1.1 RED Fire Engineers Pty Ltd has been appointed by Trafalgar Group to prepare a professional engineering report on the application of Trafalgar Fyrewrap fire protection system to protect the fire hydrant system pipe supports when exposed to fire.

1.1.2 Clause 8.7.4 of the Australian Standard AS 2419.1-2005 (Amendment 1) requires that a non-sprinkler protected building where pipework is likely to be exposed to fire, the pipe supports shall have an FRL of not less than 60/-/- while maintaining a pipe support temperature of not less than (which should read 'not more than') 500 °C when tested in accordance with AS 1530.4; or other measures shall be taken to prevent its early collapse when exposed to fire (AS 2419.1:2005 (Amendment 1), 2005).

1.1.3 The current version of AS 2419.1 is the 2017 edition. Clause 10.4.1 of the 2017 edition has the same pipe supports FRL and temperature limit requirements as per clause 8.7.4 of the 2005 edition (AS 2419.1:2017, 2017). However, it is noted that AS 2419.1:2017 is not called up by the Building Code of Australia (BCA) at the time this report is prepared.

1.1.4 A fire-resistance test of nominally 100 mm copper pipes that were supported by mild steel pipe hangers was undertaken by Warringtonfire on 29 April 2019 in accordance with Sections 2 and 12 of AS 1530.4:2014, with Trafalgar Fire Containment being the test sponsor. The copper pipes and steel pipe hanger were protected with FyreWrap® Elite 1.5 and Trafalgar fire FyreFlex sealant. The test procedure and results were documented in the Warringtonfire report Ref. FRT190004 R4.0 dated 13/10/2020. It is understood that the pipe hangers were made of mild steel.

1.2 Scope of this report

1.2.1 The aim of this report is to provide the evidence that, by using the data in the aforementioned fire-resistance test report, fire safety engineering literature and calculations on the performance of mild steel at high temperature, the application of Trafalgar Fyrewrap fire protection system can meet the Performance Requirements as stipulated in Clause 8.7.4 of AS 2419.1-2005 (Amendment 1) and Clause 10.4.1 of AS 2419.1:2017.

1.2.2 This report could be, therefore, used as an evidence of suitability as defined in Clause A2.2(a)(iii) of the NCC2016 Volume 1 BCA, Clause A2.2(a)(v) of the NCC2016 Volume 1 Amendment 1 BCA, Clause A5.2(1)(e) of the NCC2019 Volume 1 BCA (ABCB, 2018; ABCB, 2018; ABCB, 2019).

1.2.3 The scope of this report is to, based on the results of the aforementioned fire test, demonstrate that Fyrewrap can be used to protect the pipe support systems for hydrant system pipework to prevent early collapse when exposed to fire and to determine the minimum pipe hanger size and maximum pipe hanger spacing.

1.2.4 To carry out the tasks above, a literature search on the properties and performance of mild steel at elevated temperature has been carried out because the Australian Standard was developed for structural steel members rather than mild-steel members. Therefore, the formula in AS 4100 may not be applied to mild steel directly.

1.2.5 Investigation of the restrained condition between the pipe hangers and the concrete floor slab is beyond the scope of this report. It should be noted that the restrained condition between hangers and concrete floor slab was not mentioned in the aforementioned fire resistance test report, and the failure of the restrained condition in case of fire could lead to the failure of a service system regardless of the FRL achieved by the protected hangers.

2 Summary of the fire resistance test

2.1 Background

2.1.1 The relevant documents and drawings on which this report is based are listed in Table 1.

Table 1: Relevant documentation

Organisation	Title	Project number/ ref	Date	Revision
Warringtonfire	Fire resistance test report	FRT190004	13/10/2020	R4.0
Trafalgar	Fyrewrap ® Fire Protection for Copper Hydrant Pipe	Published by Trafalgar Fire on 16/07/19. (Refer to Appendix A for manufacturer's instruction).		

2.2 Test setup

2.2.1 Two critical service systems (A and B) have been included in the fire resistance test report. While the critical service system A was tested with water-filled copper pipe and pressurised to 1000 kPa, system B was tested with an empty copper pipe to assess its ambient capacity.

2.2.2 The details of installation using Fyrewrap are shown in Figure 1. The hydrant pipe is made of DN100 Type B copper. The installation of these hydrant pipes was advised by Trafalgar to have been in accordance with the Australian Standard AS 4809 requirements as per Fyrewrap critical datasheet 16072019 (Refer to Appendix A).

2.2.3 The copper hydrant pipes (both systems A and B) were hanged to concrete floor slab using four pipe supports in the form of M10 mild steel rod (Ø 10 mm x 340 mm long). The size of the concrete floor slab was 1760 mm long x 1200 mm wide x 120 mm thick with the strength of concrete being 51 MPa at 28 days and density of 2420 kg/m^3. Pipe hangers (pear bands) were used to hang the copper hydrant pipe to the four pipe supports using M10 nuts (Ø 16 mm) (Refer to item 3 in Figure 1). The positions of hangers were at approximately 100 mm from the edge of the AAC wall (Figures 7 and 8), at the elbows and then at 350 mm centres along the straight section of pipe on the exposed side.

2.2.4 The AAC wall was made of Hebel Power Panel with a size of 600 mm high x 1200 mm wide x 75 mm thick. This wall was positioned below the concrete slab and located at the east and west edges of the fire resistance test furnace.

2.2.5 Pipe hangers were made of powder-coated steel of 32 mm wide x 2.0 mm thick.

2.2.6 The copper pipe was wrapped with 38 mm thick Fyrewrap blanket with 75 mm overlaps through the entire length of copper pipe along with the furnace.

2.2.7 The Fyrewrap blanket was tied using 4.6 mm stainless steel cable ties. The distance between cable ties was maximum 200 mm.

2.2.8 The elbows of the copper pipe (Refer to item 10 in Figure 1) were wrapped with the 38 mm FyreWrap blanket, as shown in Figure 2.

2.2.9 At the junction between the hydrant pipe and the AAC wall (Section 2.2.4), the copper pipe penetration through the wall was fire stopped using the Trafalgar Fire FyreFlex sealant applied to either side of the backing rod and finished flush at the ACC wall and pipe interface along the east and west ends. A 20 mm bead was further applied between the wraps (item 4) at the junction of the hanger and pipe (Refer to Figure 3).

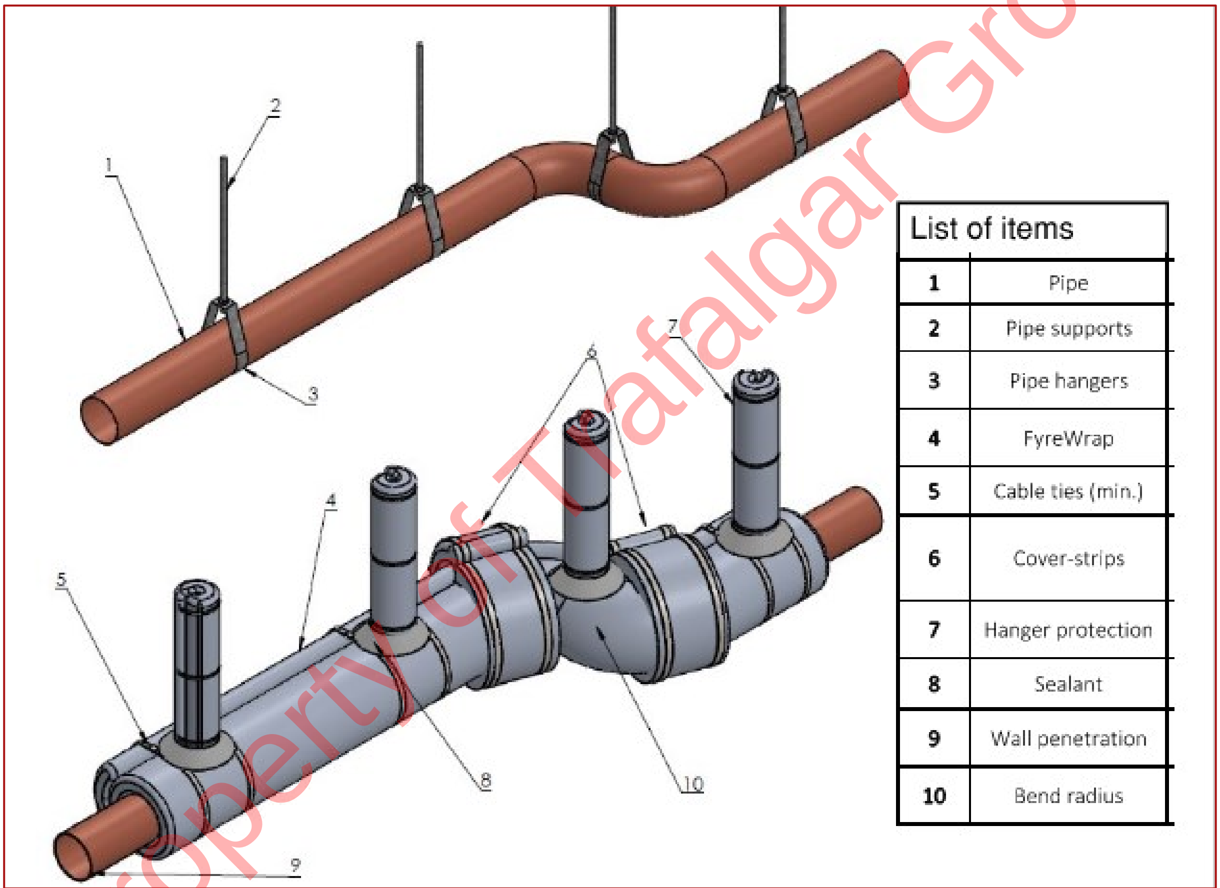

Figure 1: Schematic details of installation of Fyrewrap

2.2.10 The hangers were protected by 38 mm FyreWrap blanket. The blanket wrapped around the steel hangers with 100 mm overlap.

2.2.11 The FyreWrap blanket for the hangers was tied using 4.6 mm stainless steel cable ties with the distance between two ties of maximum 120 mm.

2.2.12 The interface between hangers and hydrant pipe was sealed with Fyreflex acrylic sealant in the form of 20 mm fillet (Refer to item 8 in Figure 1 and Figure 4). Additional information about cross-section and completed the setup for critical system services A and B can be found in Figures 5 and 6.

2.2.13 At the interface between hangers' wrap and concrete floor slab, no sealant was applied.

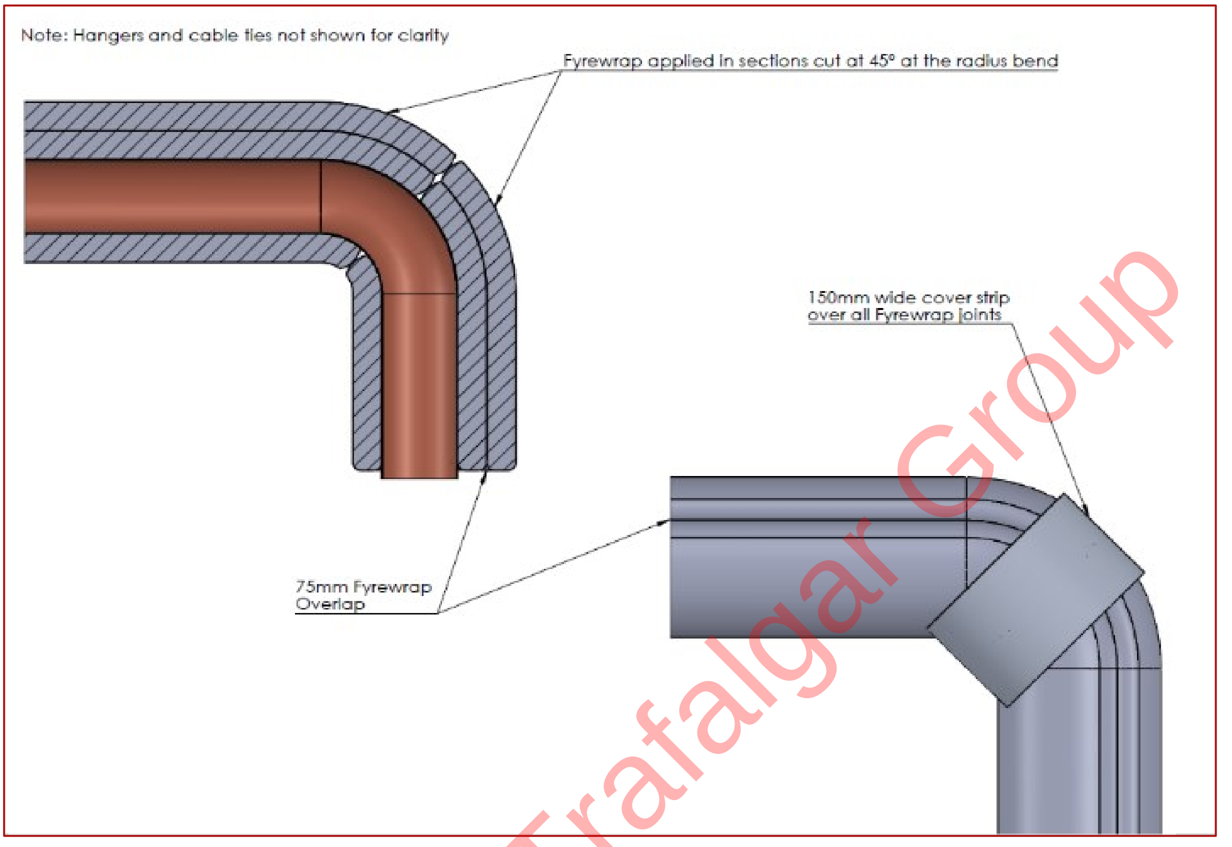

Figure 2: FyreWrap used in radius bend

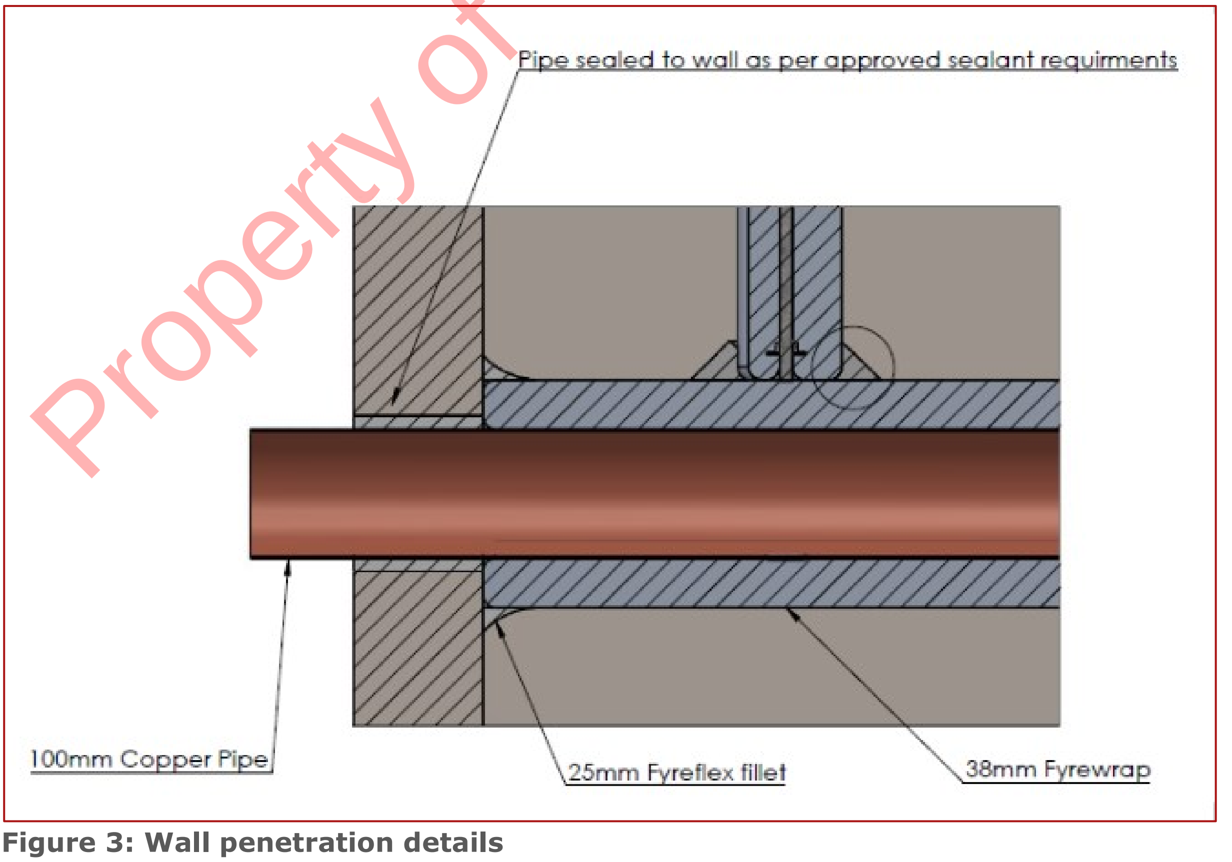

Figure 3: Wall penetration details

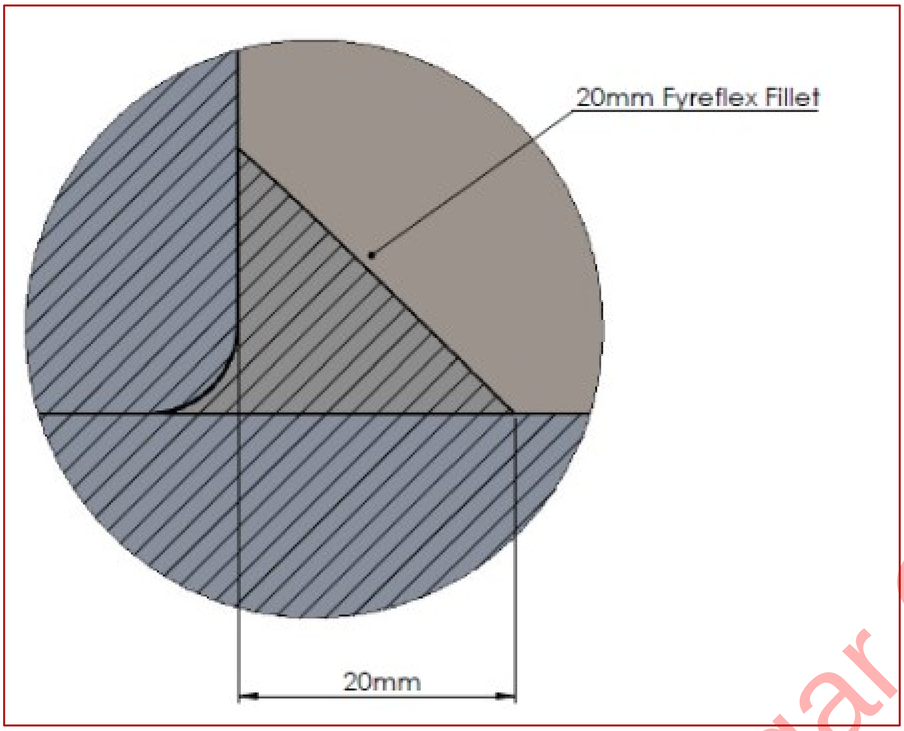

Figure 4: Sealant applied at the interface between hanger wrap and copper hydrant pipe wrap

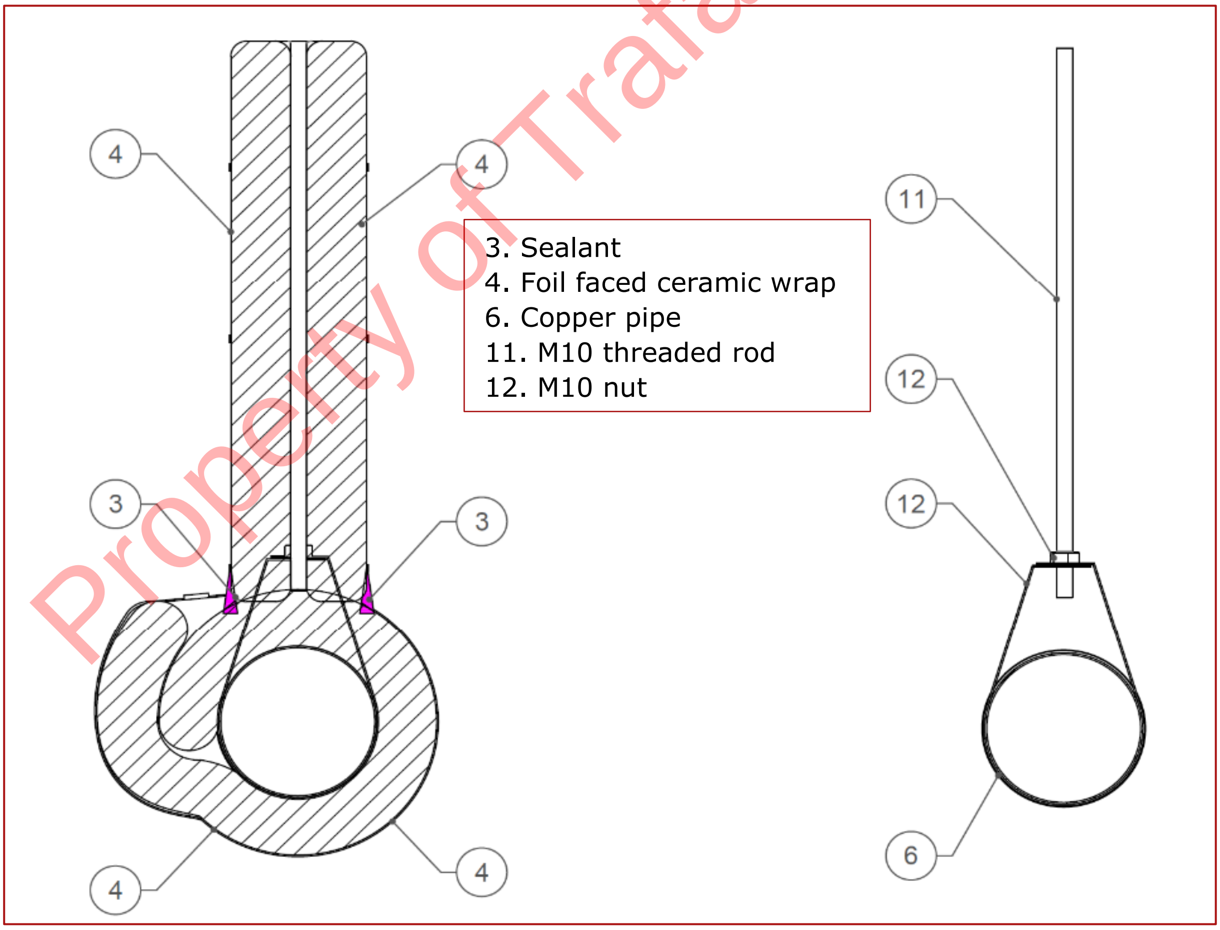

Figure 5: Cross-section of service tube with and without Fyrewrap

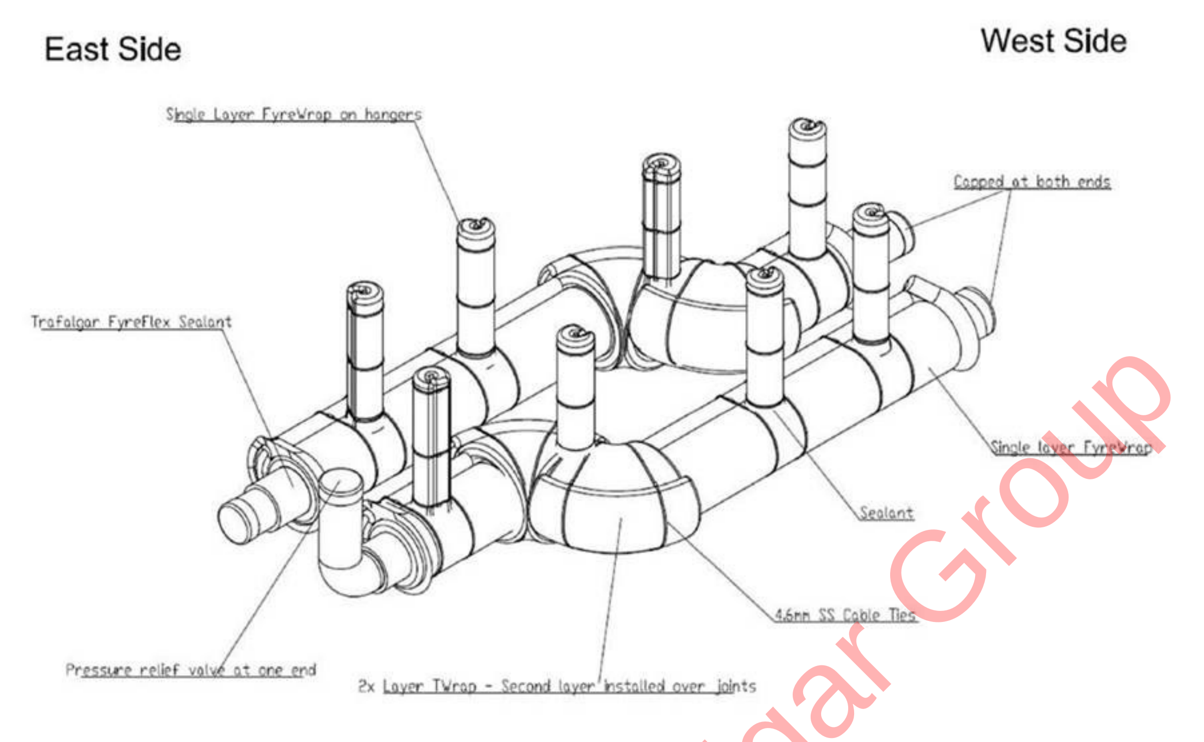

Figure 6: Schematic details of Fyrewrap test setup

2.2.14 Type K Thermocouples (TC) were used in the test to measure the temperatures of the copper pipe and the hanger system. The positions of TCs on test systems A and B are shown in Table 2, and Figures 7 and 8.

2.2.15 It should be noted that TCs were not attached to the concrete floor slab. Therefore, the concrete floor temperature is not discussed in this report.

Table 2: Thermocouple positions

Critical service system	T/C no.	Description
A	019	On the top side of the pipe at the elbow, between the pipe and insulation wrap
	020	On the bottom side of the pipe at the elbow, between the pipe and insulation wrap
	021	On the top side of the pipe at the mid-span, between the pipe and insulation wrap
	022	On the bottom side of the pipe at the mid-span, between the pipe and insulation wrap
	023	On the top side of the pipe at the quarter section, between the pipe and insulation wrap
	024	On the bottom side of the pipe at the quarter section, between the pipe and insulation wrap
	025	On the centre rod 25 mm from the pear band, between the pipe and insulation wrap
	026	At the underside of the centre pear band, between the pear band and insulation wrap
B	011	On the top side of the pipe at the elbow, between the pipe and insulation wrap
	012	On the bottom side of the pipe at the elbow, between the pipe and insulation wrap
	1013	On the top side of the pipe at the mid-span, between the pipe and insulation wrap
	014	On the bottom side of the pipe at the mid-span, between the pipe and insulation wrap
	015	On the top side of the pipe at the quarter section, between the pipe and insulation wrap
	016	On the bottom side of the pipe at the quarter section, between the pipe and insulation wrap
	017	On the centre rod 25 mm from the pear band, between the pipe and insulation wrap
	018	At the underside of the centre pear band, between the pear band and insulation wrap

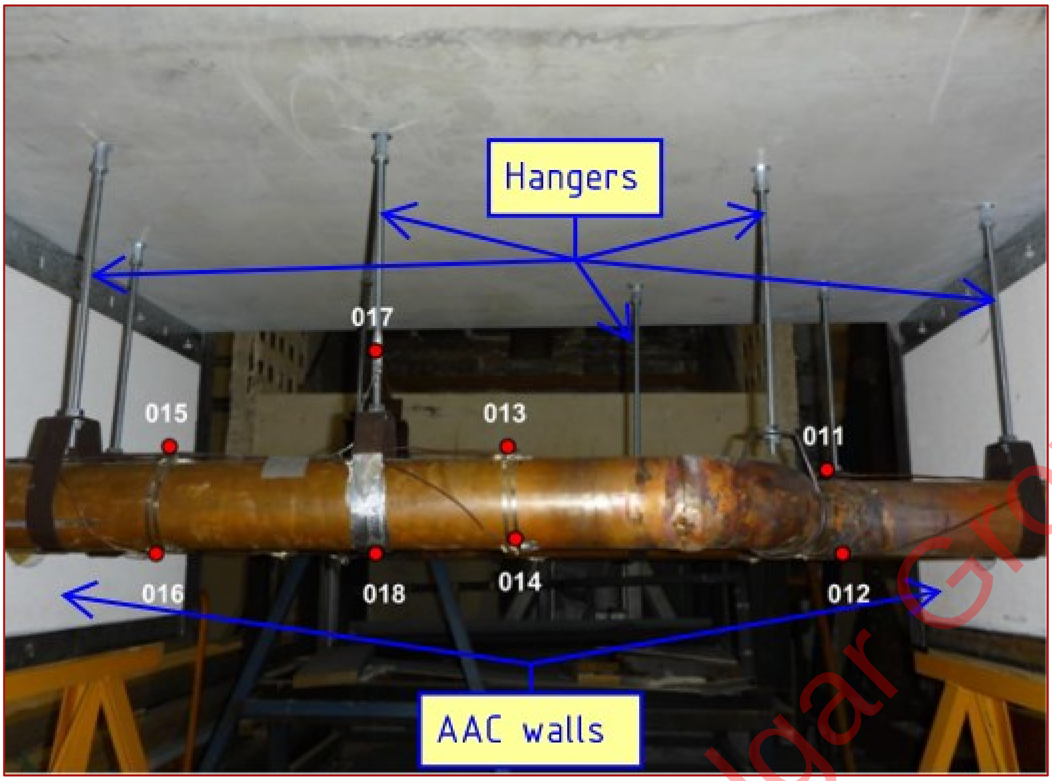

Figure 7: Thermocouple position in tested system A

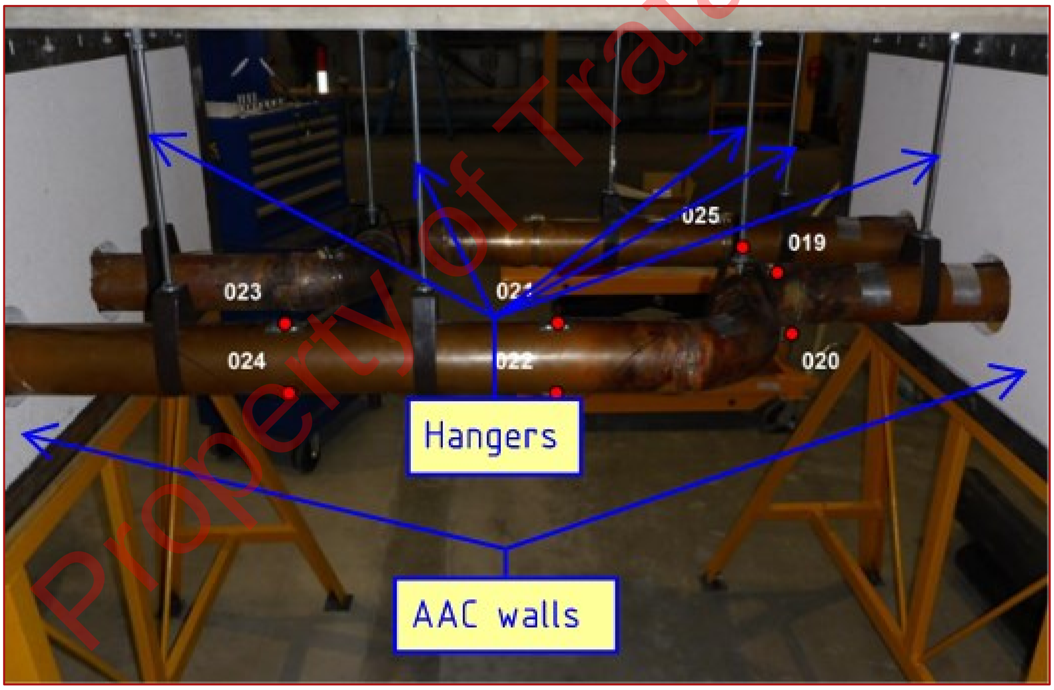

Figure 8: Thermocouple positions in tested system B

2.2.16 The test was performed in accordance with the requirements of Sections 2 and 12 of the Australian Standard AS 1530.4:2014 for the critical services. Thus, the standard time-temperature heating regime was applied in this test (Refer to Figure 9).

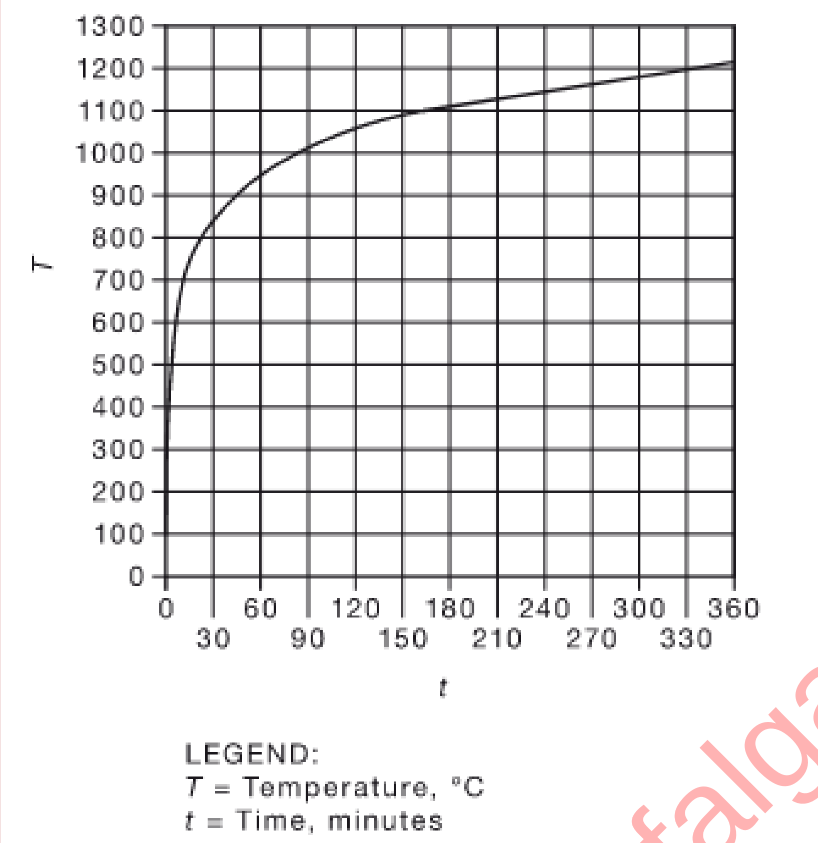

Figure 9: Standard time-temperature curve to AS 1530.4:2014

3 Loadbearing capacity of hanger at high temperature

3.1 Mechanical properties of materials used in tests

3.1.1 The mechanical properties of mild steel used in the test must be considered to evaluate the loadbearing capacity of hangers. Although mild steel has lower yield stress as compared with normal or high strength structural steel, its performance in a fire has been evaluated to be as good as those steels (Kirby, 1993). This approach has long been applied when analysing the performance of steel or reinforcement concrete structures at elevated temperatures (Hertz, K. D., 2004; Kirby, 1993; Bailey and Toh, 2007; Phan, L.T. et al., 2010).

3.1.2 The reduction factors of mechanical properties of mild steel at elevated temperatures are taken from EN 1994-1-2 (BS EN 1994-1-2, 2005). It should be noted that these factors from BS EN 1994-1-2 can be seen in NIST Technical Note 1681 (Refer to Table 3) (Phan, L.T. et al., 2010).

Table 3: Reduction factors of strength and elasticity of steel at elevated temperatures (BS EN 1994-1-2, 2005; Phan, L.T. et al., 2010)

Steel Temperature T (°C)	$k_{E,T} = E_T / E$	$k_{p,T} = f_p / F_y$	$k_{y,T} = f_y / F_y$	$k_{u,T} = f_u / F_y$
20	1.00	1.00	1.00	1.25
100	1.00	1.00	1.00	1.25
200	0.90	0.807	1.00	1.25
300	0.80	0.613	1.00	1.25
400	0.70	0.42	1.00	1.00
500	0.60	0.36	0.78	0.78
600	0.31	0.18	0.47	0.47
700	0.13	0.075	0.23	0.23
800	0.09	0.05	0.11	0.11
900	0.0675	0.0375	0.06	0.06
1000	0.045	0.025	0.04	0.04
1100	0.0225	0.0125	0.02	0.02
1200	0.00	0.00	0.00	0.00

3.1.3 The reduction factors of strength and elasticity of steel at elevated temperatures in Australian Standard AS 4100 have been compared with those in EN 1994-1-2.

3.1.4 Figure 10 shows the reduction factors used in EN 1994-1-2 and AS 4100. As can be seen from this figure, the reduction factors in EN 1994-1-2 are more conservative compared to those in AS 4100. The reduction factors in EN 1994-1-2 have been used for subsequent analysis.

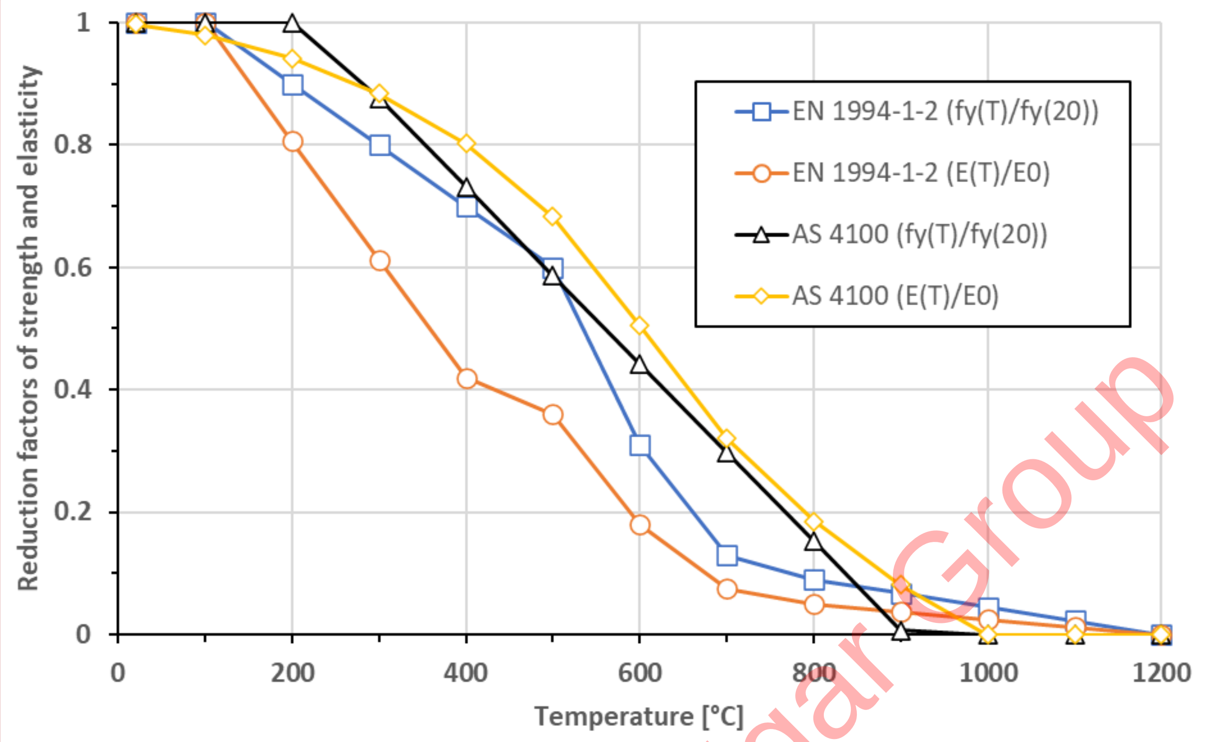

Figure 10: Reduction factors of steel strength and elasticity used in EN 1994-1-2:2005 and AS 4100

3.1.5 The yield strength of the threaded rod used in this test was not experimentally determined at ambient temperature. Therefore, we adopted the yield strength of mild steel found in the literature (Kirby, 1993), which is 235 MPa, and applied it for subsequent calculations in this report.

3.2 Distributed tension load on hangers

3.2.1 Based on the experimental setup, the copper pipes in critical systems A and B were hanged by four pipe-supports using M10 threaded rod. The load from the copper pipe is assumed to distribute evenly onto the four pipe-supports, regardless of the connection between the copper pipe and the AAC wall (See Section 2.2.4). A safety factor of 1.2 is used when considering the dead load on pipe support.

3.2.2 It should be noted that the copper pipe in the critical system A was filled with water. Therefore, the dead load in system A must take the weight of water into account.

Critical system A

Given:

The total length of the copper pipe (L):	2.6 m (approx.)
The copper pipe dimension:	101.6 mm (OD)
	98.4 mm (ID)
	1.6 mm (thickness)
Copper elbow:	104.6 mm (OD)
	101.6 mm (ID)
	1.5 mm (thickness)

Nominal weight (w):	4.6 kg/m
Copper pipe dead load (G_c):	2.6 × 4.6 = 12.0 kg
Water in pipe (G_w):	19.8 kg
Fyrewrap density:	96 kg/m^3
Area of Fyrewrap cross-section	0.0192 m^2 (as measured from Figure 5)
Nominal weight of Fyrewrap	1.85 kg/m
Fyrewrap dead load (G_f)	4.2 kg
Total dead load ($G_w + G_c + G_f$):	36.0 kg
Total design dead load (G_t):	1.2 × ($G_w + G_c + G_f$) = 43.2 kg

The dead load distributed on each pipe hanger is calculated using Equation 1:

$$P_h = \frac{G_t}{n} \qquad \textbf{Equation 1}$$

where:

G_t is the total design dead load (kg)
n is the number of pipe hanger
P_h is the distributed dead load on pipe hanger (kg)

The distributed dead load on each side of the pear band is calculated using Equation 2:

$$P_h = 2 \times P_b \times \cos\left(\frac{\alpha}{2}\right) \qquad \textbf{Equation 2}$$

Where:

P_h is the distributed load on pipe hanger (kg)
P_b is the distributed load on each side of the pear band (kg)
α is the angle between two sides of pear band

Distributed load in each hanger (P_h):	10.8 kg (approx.)
The angle between the pear band (α):	36° (measured)
Dead load on each side of pear band:	5.7 kg (approx.)

Critical system B (without water)

Given:

The total length of the copper pipe (L):	2.3 m (approx.)
The copper pipe dimension:	101.6 mm (OD)
	98.4 mm (ID)
	1.6 mm (thickness)
Copper elbow:	104.6 mm (OD)
	101.6 mm (ID)
	1.5 mm (thickness)
Nominal weight (w):	4.6 kg/m
Copper dead load (G_c):	2.6 × 4.6 = 11.96 kg
Fyrewrap density:	96 kg/m^3
Area of Fyrewrap cross-section	0.0192 m^2
Nominal weight of Fyrewrap	1.85 kg/m
Fyrewrap dead load (G_f)	4.2 kg
Total dead load ($G_w + G_c + G_f$):	14.9 kg
Total design load:	1.2×($G_c + G_f$) = 17.9 kg
Distributed load in each hanger:	4.5 kg (approx.)
The angle between the pear band:	36° (measured)
Dead load on each pear band:	2.4 kg (approx.)

Stress on hanger and pear band of system A

M10 cross-section area (A)[1]:	58 mm^2
Dead load on hanger (P_h):	10.8 kg = 106 N
Stress on each hanger (P_h/A):	1.82 MPa
Pear band cross-section area:	64 mm^2
Dead load on each side of pear band:	5.7 kg = 56 N
Stress on each side of pear band:	0.88 MPa
Yield strength of mild steel:	235 MPa

Stress on hanger and pear band of system B

M10 threaded rod cross-section area:	58 mm^2
Dead load on hanger:	4.5 kg = 44.2 N
Stress on each hanger:	0.8 MPa
Pear band cross-section area:	64 mm^2
Dead load on pear band:	2.4 kg = 23.5 N
Stress on each side of pear band:	0.4 MPa
Yield strength of mild steel:	235 MPa

3.3 The loadbearing capacity of each hanger at high temperature

3.3.1 The recorded temperatures on the rod and pear band of systems A and B (Refer to Figures 11 and 12) have been used to calculate the loadbearing capacity of the hanger at ambient and elevated temperatures.

3.3.2 Table 4 shows the temperature of the M10 rod and pear band of systems A and B at 30 min, 60 min, 90 min and 100 min into the fire resistance test.

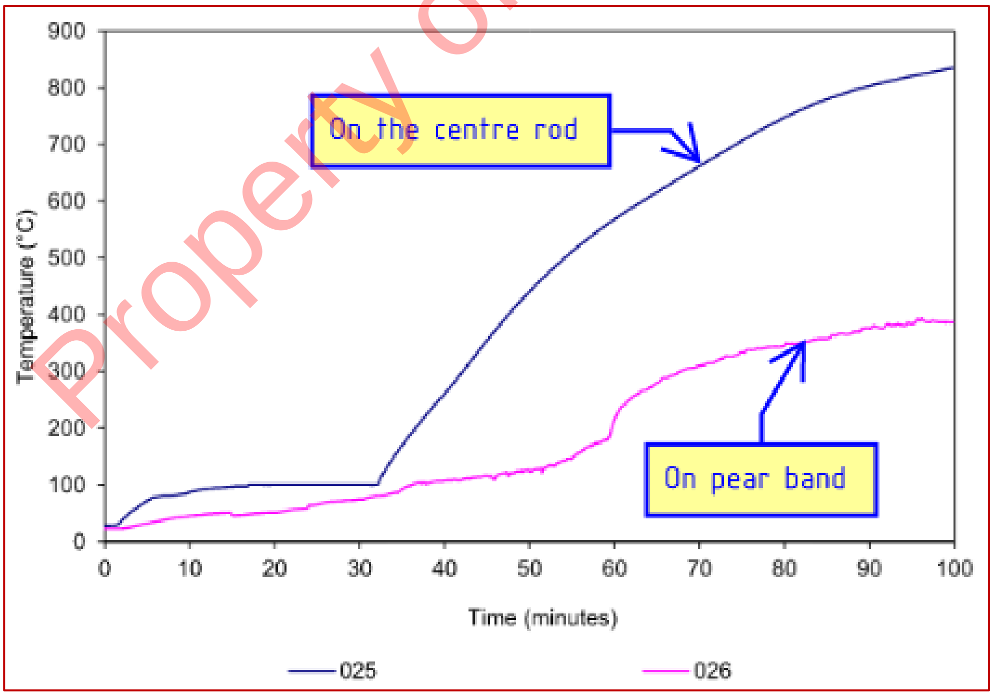

Figure 11: Temperature versus time of the rod and pear band for system A

1 https://www.engineeringtoolbox.com/steel-rod-hanger-capacity-d_643.html

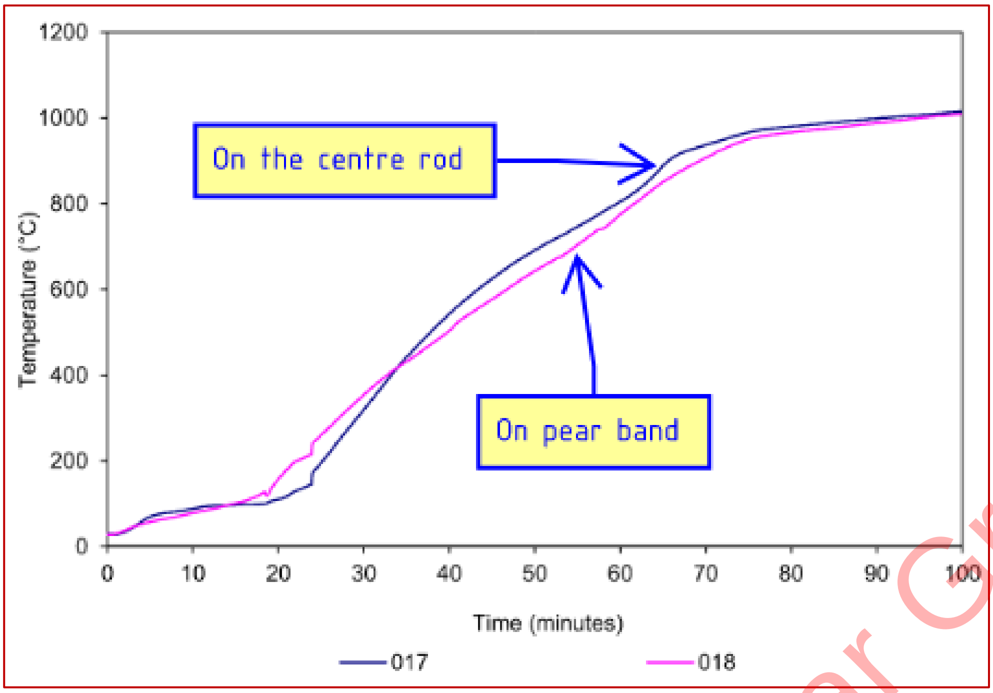

Figure 12: Temperature versus time of the rod and pear band for system B

Table 4: Recorded temperatures of threaded rod and pear band at different heating times

Heating time [min]	Temperature [°C]			
	Critical system A		Critical system B	
	M10 threaded rod	Pear band	M10 threaded rod	Pear band
0	28	23	28	28
30	101	75	321	355
60	569	218	805	776
90	803	375	998	989
100	835	386	1015	1009

3.3.3 Loadbearing capacities of hanger and pear band are calculated by using Equation 3:

$$N_t(T) = \sigma_t(T) \times A \qquad \textbf{Equation 3}$$

where:

N_t is the loadbearing capacity of an element

$\sigma_t(T)$ is the yield strength of mild steel (MPa) or (N/mm^2)

A is the cross-section of the element (mm^2)

The loadbearing capacity of system A's hanger and pear band

3.3.4 The yield strength of mild steel at 0, 30, 60, and 90 min into the fire resistance test can be calculated by using the reduction factor provided in Table 3 and temperature history provided in Table 4.

3.3.5 The loadbearing capacity of system A's hanger and pear band is calculated by using Equation 3, and the outcomes are summarised, as shown in Table 5. An example of the loadbearing capacity of M10 threaded rod at ambient temperature is as follows:

$$N_t = \sigma_t \times A = 235 \ \times 58 = 13630\ N = 1389\ kg$$

Table 5: Loadbearing capacity of threaded rod and pear band for System A at various times into the standard fire resistance test

AS 1530.4 heating time [min]	M10 threaded rod			Pear band		
	Yield strength of mild steel [N/mm^2] ($\sigma_t(T)$)	Cross-section [mm^2] (A)	Loadbearing capacity [kg][2] $N_t = \sigma_t(T)xA$	Yield strength of mild steel [N/mm^2] ($\sigma_t(T)$)	Cross-section [mm^2] (A)	Loadbearing capacity [kg] $N_t = \sigma_t(T)xA$
0	235	58	1389	235	64	1533
30	235	58	1389	235	64	1533
60	56.4	58	333	181	64	1181
90	11.75	58	69.5	110	64	718

The loadbearing capacity of a hanger:

At ambient temperature: 1389 kg > 10.8 kg
At 30 min heating time: 1389 kg > 10.8 kg
At 60 min heating time: 333 kg > 10.8 kg
At 90 min heating time: 69.5 kg > 10.8 kg

The loadbearing capacity of one side of pear band:

At ambient temperature: 1533 kg > 5.7 kg
At 30 min heating time: 1533 kg > 5.7 kg
At 60 min heating time: 1181 kg > 5.7 kg
At 90 min heating time: 718 kg > 5.7 kg

3.3.6 It can be seen that with four M10 threaded rod hangers established in the test, the loadbearing capacity of the hangers and pear bands are sufficient to carry the dead load of a 100 mm water-filled copper pipe.

The loadbearing capacity of system B's hanger and pear band

3.3.7 By using a similar calculation approach for system A, the loadbearing capacity of system B's hanger and pear band has been estimated and are shown in Table 6. It should be noted that the temperature of M10 threaded rod and pear band in system B is much higher than those are in system A, as shown in Table 4.

2 Assuming Earth gravitational constant at sea level is 9.81 m/s^2

Table 6: Loadbearing capacity of threaded rod and pear band for System B at various times into the fire resistance test

AS 1530.4 heating time [min]	M10 threaded rod			Pear band		
	Yield strength of mild steel [N/mm²] ($\sigma_t(T)$)	Cross-section [mm²] (A)	Loadbearing capacity [kg][2] $N_t = \sigma_t(T)xA$	Yield strength of mild steel [N/mm²] ($\sigma_t(T)$)	Cross-section [mm²] (A)	Loadbearing capacity [kg] $N_t = \sigma_t(T)xA$
0	235	58	1389	235	64	1533
30	135	58	798	119	64	776
60	11.75	58	69.5	13	64	85
90	6	58	35.0	6	64	39

The loadbearing capacity of a hanger:

At ambient temperature:	1389 kg > 4.5 kg
At 30 min heating time:	798 kg > 4.5 kg
At 60 min heating time:	69 kg > 4.5 kg
At 90 min heating time:	35 kg > 4.5 kg

The loadbearing capacity of one side of the pear band:

At ambient temperature:	1533 kg > 2.4 kg
At 30 min heating time:	776 kg > 2.4 kg
At 60 min heating time:	85 kg > 2.4 kg
At 90 min heating time:	39 kg > 2.4 kg

3.3.8 Although the temperature of threaded rod and pear band in critical system B are much higher than those in critical system A, the loadbearing capacity of the hangers and pear bands are sufficient to carry the dead load of a 100 mm non-water-filled copper pipe.

4 Calculation of minimum pipe hanger size and maximum pipe hanger spacing for water-filled hydrant pipes

4.1 Water-filled copper pipes

4.1.1 Two approaches are used in the hanger size and distance calculation, including:

(a) Choosing the number of hangers based on furnace geometry provided in the fire resistance test. The distance between hangers is calculated accordingly; and

(b) Choosing the size of hangers, then the number of hangers and the distance between hangers are calculated accordingly.

Approach (a): choosing the number of hangers

4.1.2 After 60 min into the fire resistance test, the test data collected from System A and B shows that the maximum temperature recorded in pipe hanger and pear band were up to 805 °C. At this temperature, the yield strength of mild steel is reduced by 95% of its strength at ambient temperature. This critical temperature is used for the following calculation of minimum pipe hanger size and maximum pipe hanger spacing.

4.1.3 To simplify the calculation, within 2.6 m length of the copper pipe provided in the fire resistance test, the number of hangers is chosen prior to a calculation by taking into account the test geometry. The minimum pipe hanger size is calculated accordingly.

4.1.4 Based on the geometry of the test setup with 2.6 m of 100 mm water-filled copper pipe, the number of pipe hangers could be two, three or four.

4.1.5 Depending on the number of pipe hangers (n), the dead load distributed on each pipe hanger is calculated using Equation 1.

4.1.6 To maintain the structural adequacy of pipe hanger, the following condition must be met at 60 min of heating time:

$$N_t(T) = \sigma_t(T) \times A > P_h \qquad \textbf{Equation 4}$$

4.1.7 The cross-section of pipe hanger must satisfy the following condition:

$$A > \frac{P_h}{\sigma_t(T)} = A_{min} \qquad \textbf{Equation 5}$$

4.1.8 At 60 min into the fire resistance test, the temperature of mild steel hanger was recorded to be 805°C, the yield strength is thus 11.75 MPa as shown in Table 6. The minimum cross-section area and the nominal size of the hanger are calculated and shown Table 7.

Table 7: Minimum hanger size versus spacing between hangers

Number of hangers	P_t (kg)	A_{min} (mm²)	Minimum nominal size of the hanger	The maximum distance between hangers (mm)
Two hangers	23.2	19.0	M6	1
Three hangers	15.5	12.7	M5	860
Four hangers	11.6	9.5	M5	650

Approach (b): choosing the size of hangers

4.1.9 The size of hangers can be chosen from M5, M6, M8, M10, M12, which are common to be used for hanging purpose.

4.1.10 The loadbearing capacity of hangers after 60 min heating in the furnace can be calculated using Equation 3 and the temperature data provided in Table 4.

4.1.11 It is assumed that the designed dead load of copper pipe distributes evenly on hangers. Thus, the dead load on hangers (P_h) can be calculated using Equation 1.

4.1.12 It is required that the distributed dead load on each hanger must be smaller than the loadbearing capacity of the threaded rod at 60 min of heating time, as described in Equation 6:

Equation 6

$$P_h < N_t$$

$$\frac{G_t}{n} < N_t = \sigma_t(T) \times A$$

4.1.13 The number of hangers (n) must, therefore, satisfy Equation 7:

Equation 7

$$n > \frac{G_t}{\sigma_t(T) \times A}$$

4.1.14 Also, the number of hangers should not be less than 2 to simplify the assembling procedure.

4.1.15 By choosing the threaded rod of M5, M6, M8, M10 or M12, the number of hangers is calculated and summarised in Table 8.

4.1.16 Based on the number of hangers, the total dead load and the total length of copper pipe, the maximum distance between hangers can be calculated to ensure the even distribution of dead load on hangers. It should be noted that the maximum distance between hangers can be increased if the size of threaded rod increases.

4.1.17 The total dead load of the water-filled copper pipe is 43.2 kg. The total length of the copper pipe is 2.6 m. The nominal distributed dead load of the copper pipe system A (w_p) is 43.2/2.6 = 16.6 kg/m.

4.1.18 Based on the distributed dead load of the copper pipe system A and the load-bearing capacity of the threaded rod at 800 °C, the maximum length of water-filled copper pipe that each hanger can carry is calculated in Table 8 using the following Equation:

$$L_p = N_t / w_p \quad \textbf{Equation 8}$$

Where:

L_p is the maximum length of the water-filled copper pipe (m)
N_t is the load-bearing capacity of the threaded rod at 800 °C (kg)
w_p is nominal weight or distributed dead load of the water-filled water pipe (kg/m)

4.1.19 It should be noted that Clause 8.7.7 of the AS 2419.1-2005 (Amendment 1) requires that the maximum distance between supports for horizontal copper pipework shall not exceed 4 m (AS 2419.1:2005 (Amendment 1), 2005). AS 2419.1:2017 contains the same requirement. Therefore, although the size of threaded rod could be increased to M12, the maximum distance between hangers would still be 4 m. The maximum distance between other types of threaded rods is chosen and detailed in the final column of Table 8.

4.1.20 Other requirements for the location of pipe hangers should comply with Clause 8.7.8 of the AS 2419.1-2005 (Amendment 1) or Clause 10.7 of AS 2419.1:2017.

Table 8: Minimum number of hanger and maximum distance between hangers

Type of threaded rod	Cross-section (mm²)	Minimum number of hangers	Load-bearing capacity of threaded rod at 800 °C (kg)	Maximum length of water-filled copper pipe each hanger can carry (m)	The maximum distance between hangers (m)
M5	14.2	2	17.0	1.02	1.0
M6	20.1	2	24.1	1.45	1.4
M8	36.6	2	43.8	2.64	2.6
M10	58.0	2	69.5	4.18	4.0
M12	84.3	2	101.0	6.08	4.0

4.1.21 The data from Tables 7 and 8 show that M5 threaded rod should be the smallest hanger chosen to hang the water-filled copper pipe with the maximum distance between two hangers being 1.0 m. When the size of the threaded rod is increased, the maximum distance between hangers can be increased as detailed in Table 8, up to 4.0 m.

4.2 Water-filled steel pipes

4.2.1 This section provides the data on the size of the threaded rod and distance between two hangers for water-filled steel hydrant pipes. Four types of steel pipe are considered in the subsequent calculations, including:

- NB 100 medium steel pipe
- NB 100 heavy steel pipe
- NB 150 medium steel pipe
- NB 150 medium steel pipe.

4.2.2 The galvanized steel pipe is chosen for subsequent calculations [3]. The details of the service pipe are summarised in Table 9.

Table 9: Properties of service pipes

Service pipe type	Length (m)	Density (kg/m3)	OD (mm)	Wall thickness (mm)	ID (mm)	Nominal weight (kg/m)
Steel NB 100 medium	2.6	8050	114.3	4.5	105.3	12.4
Steel NB 100 heavy	2.6	8050	114.3	5.4	103.5	14.8
Steel NB 150 medium	2.6	8050	165.1	5.0	155.1	20.1
Steel NB 150 heavy	2.6	8050	165.1	5.4	154.3	21.7

4.2.3 An approach similar to copper service pipe in section 4.1 has been used to calculate the minimum size and maximum distance of hangers used to hang the various types of steel pipes in Table 9 to the concrete floor slab. It should be noted that no protection to steel hydrant pipes is required under AS 2419.1-2005 (Amendment 1). The designed dead load and a nominal distributed load of pipe can then be calculated without considering the dead load of the Fyrewrap self-weight. The nominal design loads of pipe are summarised in Table 10.

Table 10: The total design dead load from different types of pipe

Service pipe type	Self-weight of pipe (kg)	Self-weight of water in pipe (kg)	Fyrewrap self-weight (kg)	Total Deadload (kg)	Design Dead load (kg)	Nominal design load of pipe (kg/m)
NB 100 medium steel pipe	32.2	22.6	0	54.9	65.9	25.3
NB 100 heavy steel pipe	38.5	21.9	0	60.4	72.4	27.9
NB 150 medium steel pipe	52.3	49.1	0	101.4	121.7	46.8
NB 150 heavy steel pipe	56.4	48.6	0	105.0	126.0	48.5

4.2.4 The temperature profiles of hangers measured in critical system B of the test are used for subsequent calculation.

4.2.5 The steel pipe is water-filled. Thus, the total design dead load must take into account this component. The nominal designed dead load is then calculated.

4.2.6 The load-bearing capacity of the hanger at 800 °C could be referred to as column 4 of Table 8.

[3] http://www.hvsteel.com.au/SiteFiles/hvsteelcomau/pipe.pdf

4.2.7 By using the same approach detailed in Sections 4.1.9 to 4.1.20, the maximum distance between the different size of hangers can be calculated and summarised for different types of service pipe, as shown in Table 11.

Table 11: Calculated maximum distance between hangers

Hanger size	Calculated maximum distance between the different size of hangers (m)			
	NB 100 medium steel pipe	NB 100 heavy steel pipe	NB 150 medium steel pipe	NB 150 heavy steel pipe
M5	0.67	0.61	0.36	0.35
M6	0.95	0.86	0.51	0.50
M8	1.73	1.57	0.94	0.90
M10	2.74	2.49	1.48	1.43
M12	3.99	3.62	2.16	2.08

4.2.8 Based on the calculated results from Table 11 and the requirements according to Clause 8.7.7 of the AS 2419.1-2005 (Amendment 1) or Clause 10.6 of AS 2419.1:2017, the recommended maximum distance between hangers for different types of service pipes are summarised in Table 12.

Table 12: The recommended maximum distance between hangers for different service pipes

Hanger size	The recommended maximum distance between the different size of hangers (m)			
	NB 100 medium steel pipe	NB 100 heavy steel pipe	NB 150 medium steel pipe	NB 150 heavy steel pipe
M5	0.6	0.6	0.3	0.3
M6	0.9	0.8	0.5	0.5
M8	1.7	1.5	0.9	0.9
M10	2.7	2.4	1.4	1.4
M12	3.9	3.6	2.1	2.0

5 Hanger-concrete interface at high temperature

5.1.1 We understand that in the aforementioned fire resistance test, hangers were restrained in a concrete floor slab by penetration. The concrete floor slab is likely subjected to spalling, which leads to the breaking of concrete layers when a concrete floor slab is exposed to fire (Kodur and Harmathy, 2016). If spalling occurs at the position of a hanger, the penetration depth of such hanger is reduced, leading to the loss of load-carrying capacity of the associated hanger.

5.1.2 Additional causes of hanger failure could be the reduction of concrete strength and Young's modulus at high temperature. As presented in Eurocode 2 (EC2), the strength of concrete reduces by 40% (siliceous aggregates) and 26% (calcareous aggregates) at a temperature of 500 °C (EN 1992-1-2, 2004). The reduction of both strength and Young's modulus of concrete could reduce the bond between hangers and concrete floor slab, thus reducing the load-carrying capacity of hangers.

5.1.3 Although this restrained condition was not mentioned in the fire resistance test, it is worth evaluating the effects of the failure of the restrained condition of the hanger into the analytical study. For instance, the failure restrained condition between a hanger and concrete floor slab due to spalling can lead to the redistribution of tension load on hangers when subjecting to high temperature.

5.1.4 As established in the test setup, the junction between hangers and concrete floor slab was covered by Fyrewrap blanket. The Fyrewrap blanket is expected to reduce the heat transfer from furnace to the concrete area at the hanger-concrete junction. Therefore, the likelihood of concrete spalling at the hanger-concrete junction is likely reduced.

6 Conclusions and recommendations

6.1.1 Based on the information presented in the previous sections of this report, the following conclusions and recommendations are made:

- Based on the performance of the Fyrewrap system to protect the pipe support system for 100 mm copper hydrant pipes in a fire resistance test described in the Warringtonfire test report Ref. FRT190004 R4.0 dated 13/10/2020 and the installation requirements in the FyreWrap critical services datasheet 16072019 (Refer to Appendix A), early collapse of the service pipe and supports (hangers) when exposed to fire was demonstrated to have been prevented.

- The calculations presented in this report based on the temperature data from the fire resistance test demonstrate that the load-bearing capacity of Fyrewrap protected M10 mild steel threaded rod hangers and 32 mm wide × 2.0 mm thick mild steel pear bands with a maximum distance of 4 m between two hangers is sufficient to carry the 100 mm water-filled copper pipe for at least 60 min in a standard fire resistance test when the temperature of the hangers reaches up to 800 °C.

- If a larger threaded rod is selected to hang the copper service pipe, then the maximum distance between hangers can be increased, but this maximum distance between hangers must not exceed 4.0 m if Clause 8.7.7 of AS 2419.1-2005 (Amendment 1) or Clause 10.6 of AS 2419.1:2017 is to be complied with.

- The maximum distance between two hangers using different sizes of threaded rod to support NB 100 mm copper pipe as well as NB 100 & NB 150 medium and heavy grade steel pipes has been calculated and recommended in Table 8 and Table 12.

- Evaluation of the structural stability and integrity of the hanger-concrete slab interface and the hanger-pear band interface is outside the scope of this report; it is assumed that the FRLs of these interfaces are at least equivalent to the FRL of hangers.

6.1.2 A sealant similar to that for the interface between hanger's wrap and copper pipe wrap (Figure 4) in the aforementioned fire resistance test is recommended to be applied to the interface between hangers' wrap and concrete floor slab. The installation must conform to the fire test details and the FyreWrap critical services datasheet 16072019 (Refer to Appendices A and C). An example of sealant applied to the interface between the hanger's wrap and concrete floor slab is shown in Appendix C.

6.1.3 It should be noted that internal above ground pipework requires protection from fire under AS 2419.1-2005 (Amendment 1), so installing FyreWrap as per Appendix C of this report to protect the pipe supports and brackets only will meet the requirements of the AS 2419.1-2005 (Amendment 1) Clause 8.4.7 and therefore comply with Clause 8.5.3(b).

6.1.4 The aim of this report as stated in Section 1.2.1 has been achieved. This report could be used as an evidence of suitability as defined in Clause A2.2(a)(iii) of the NCC2016 Volume 1 BCA, Clause A2.2(a)(v) of the NCC2016 Volume 1 Amendment 1 BCA, and Clause A5.2(1)(e) of the NCC2019 Volume 1 BCA.

6.1.5 Any departure of the setup of hangers' support and wrap as assessed in this report may render this report invalid, and RED fire Engineers Pty Ltd should be contacted to assess the potential impact of the proposed substitution.

7 References

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Appendix A. Fyrewrap installation

TRAFALGAR

FYREWRAP®

Fire Protection for Copper Hydrant Pipe

AUSTRALIAN OWNED 70 Years and Still Innovating

The Trafalgar fire stopping range includes:

Sealant | Pillows | Mortar | FR Batts

FR Collars | FR Access Panels | Pipe Wraps

FyreWrap Duct Wrap | FR Downlight Covers

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FYREWRAP

Insulation for Copper Hydrant Pipe

Product Overview

During fire conditions where copper hydrant pipe has been used in un-sprinklered compartments, the heat within the fire compartment can potentially weaken copper pipes making the hydrant system ineffective which compromises the entire fire suppression capacity of the building. To address this, fire hydrant pipes made from copper require fire isolation or critical service protection under AS2419.1 using materials that provide an FRL of no less than -/60/60.

FyreWrap Critical Services Protection
Wrapped around the copper pipe and steel hangers to protect the hydrant system

Constructing fire resistant bulkheads to enclose the pipes can be impractical and expensive so **Trafalgar now has a tested system** that meets the AS1530.4 section 12 requirements for critical services with copper hydrant pipes. The solution is FyreWrap!

FyreWrap, wrapped and fastened with stainless steel cable ties can be applied directly to copper hydrant pipes up to DN100 to allow safe operating conditions for up to a 90-minute period, well in excess of the requirements of AS2419.1.

Fast | Clean | Easy

FYREWRAP

Insulation for Copper Hydrant Pipe

Installation Details

PRODUCT DESCRIPTION

Fire Rating	Up to 90-minute operational protection
Colour	Silver foil finish with distinctive red FyreWrap® logos printed on outer surface for ease of identification.
Testing	In accordance with AS1530.4-2014 (section 12) charged hydrant pipes at 1000KPa.
Storage	Store in dry areas on site.
Microbial Resistance	GREENGUARD listed for microbial resistance.
Safety	Total bio-soluble insulation material - refer to MSDS available on request or online at www.fyrewrap.com.au
Installation	Apply a single layer of FyreWrap Elite 38mm along the straight sections of the pipe held in place with 4.6mm stainless steel cable ties at 200mm centres. Hangers also require wrapping, see installation details over page.
Also Available	Trafalgar also supply a full range of fire stopping products to achieve integrity ratings.

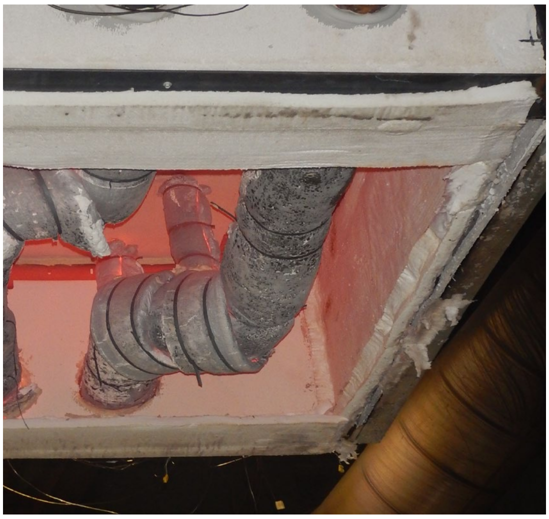
Unwrapped hydrant pipes

Hydrant pipes wrapped with **FyreWrap** within the fire compartment

FYREWRAP

Insulation for Copper Hydrant Pipe

Technical Specifications



TESTING:

AS1530.4 section 12 provides a test method for assessing the ability of systems to protect critical services under fire conditions. FyreWrap Elite 1.5 has been tested to this onerous method, wrapped around a copper hydrant pipe and has met the operational test requirements in excess of 90 minutes.

Heating Regime	Design Capacity	Time to Operational failure (min)	Average temperature at failure (°C)	Max. temperature at failure	Mode of failure
AS 1530.4	1000 kPa and charged with water	98 minutes	259 °C	346 °C	Service

SUITABLE FOR:

- Vertical or horizontal hydrant pipe systems designed and installed as per AS2419.1 requirements, for up to DN100 copper pipes.

SPECIFICATION:

Where a Copper hydrant pipe is required to have an FRL of-/60/60, it should be appropriately wrapped for the full length of the fire compartment, and the full height of the hanger with 38mm, fully encapsulated Trafalgar FyreWrap 1.5, sealed/wrapped and installed to meet manufacturers guidelines to meet the fire rating.

FYREWRAP

Insulation for Copper Hydrant Pipe

Ordering Information

Trafalgar FyreWrap

Product	Specifications	Dimensions
FyreWrap Elite 1.5	1x layer of 38mm foil faced wrap	FyreWrap is available in 7.62m long rolls at the following widths: - 450mm - 610mm - 1220mm
Cable Ties	Stainless steel	12mm wide, available in 520mm and 910mm lengths
FyreWrap Accessories Kit	Steel Banding Roll	12.7mm wide x 250m long
	Snap on Seals	13mm (box of 1000)
	FyreWrap Tensioner	1x
	FyreWrap Crimper	1x
	Steel Strap Cutter	1x
	Premium Reinforced Tape	96mm wide x 50m long

Other Applications

FyreWrap is approved for use for a range of applications, including the wrapping of ductwork to provide 2-3 hour fire protection, and increasing insulation performance with service penetrations. Refer to www.fyrewrap.com.au or call Trafalgar for more information.

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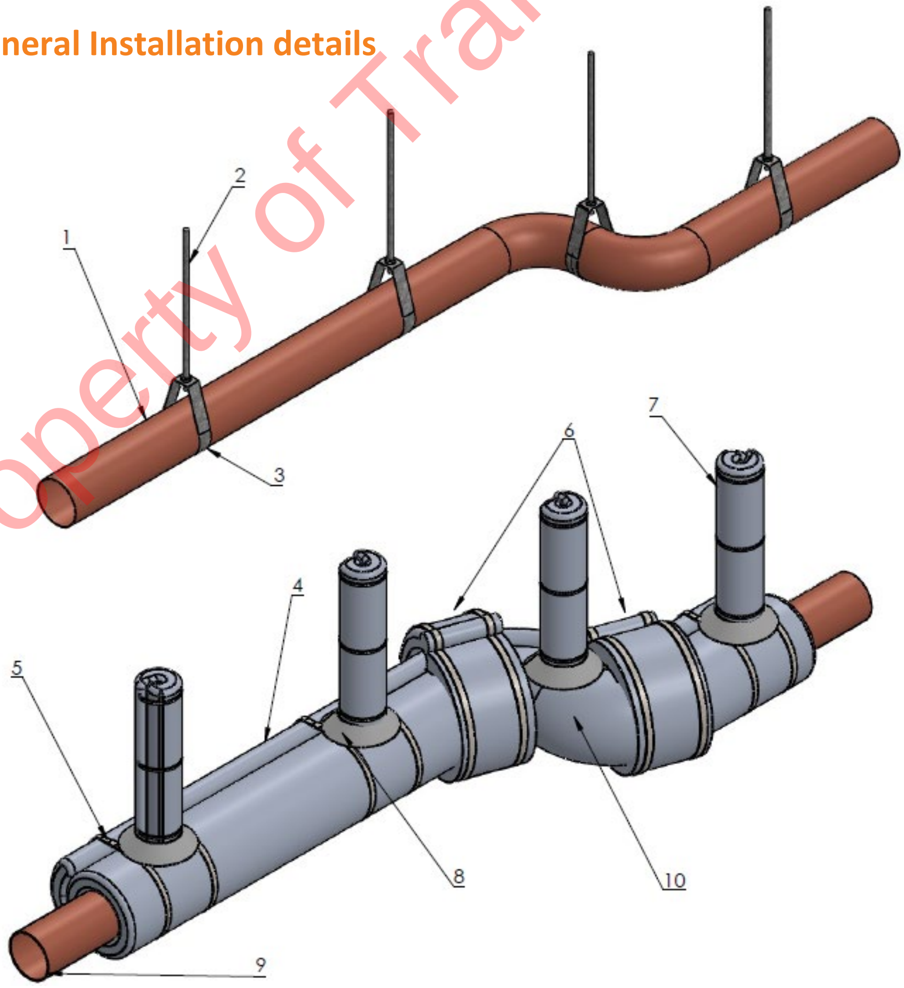
Trafalgar has developed a range of **installation videos** to assist our customers. To view these step by step install videos please go to Trafalgar TV our YouTube Channel.

Subscribe and you will be notified when new videos are uploaded.

FyreWrap Installation Details

#	Item	Specification	Installation
1	Pipe	DN100 type B copper hydrant pipe	In accordance with AS4809 requirements
2	Pipe supports	Minimum M10 steel rod	In accordance with AS2419.1 requirements
3	Pipe hangers	Selected in accordance with AS2419.1 requirements	Installed as per manufactures and AS2419.1 requirements
4	FyreWrap	38mm thick blanket	Wrapped around the pipe with 75mm overlaps, through the entire length of fire compartment
5	Cable ties (min.)	4.6mm stainless steel cable ties	Installed at max. 200mm centres along the pipe
6	Cover-strips	150mm wide, FyreWrap blanket	Wrapped over any joins between two sections of FyreWrap, tied in place with steel ties on either side of the join.
7	Hanger protection	FyreWrap 38mm blanket	Wrapped around the steel hangers with 100mm overlaps, secured in place with steel ties at 120mm centres
8	Sealant	Fyreflex acrylic sealant	20mm fillet applied between FyreWrap/hanger junction
9	Wall penetration	Copper pipe sealed through wall using an approved method as per NCC C3.15 requirements	Refer to drawing 3
10	Bend radius	FyreWrap 38mm blanket with joint/coverstrip detail	Refer to drawing 4

Drawing 1 – General Installation details



FYREWRAP

Insulation for Copper Hydrant Pipe

Installation Requirements

Installation steps

1. Cut down the FyreWrap to size, ensuring that any cut edges of FyreWrap are sealed with reinforced aluminium tape. Allow for an overlap of 75mm once installed around the pipe.

2. Slit and tape the FyreWrap as required to fit around the existing steel support hangers, ensuring that when installed the overlap section will cover any open slits in the FyreWrap.

3. Install the FyreWrap around the pipe using steel cable ties at 200mm centres, and either side of a support hangers. Cable ties should be tightened appropriately to hold FyreWrap firm to the pipe, however over tightening will damage the FyreWrap. Aim for approximately 10mm compression.

4. Butt joints between two FyreWrap sections require a cover-strip of 150mm FyreWrap (refer to drawing 4).

5. Steel hanger supports also need to be wrapped with FyreWrap, allowing for a 100mm overlap. Once wrapped, apply a 20x20mm fillet of Fyreflex sealant to the base of the wrapped hangers, where the two sections of FyreWrap meet (refer to drawing 2).

6. Where the hydrant pipe exits the fire compartment, the pipe should be sealed in accordance with NCC section C3.15 requirements using Fyreflex sealant – refer to the Fyreflex Sealant technical manual for wall-specific installation requirements.

Frequency Asked Questions:

Do I need to apply Fyrewrap to the hangers?
Yes, this prevents the pipework and supports from early collapse when exposed to fire.

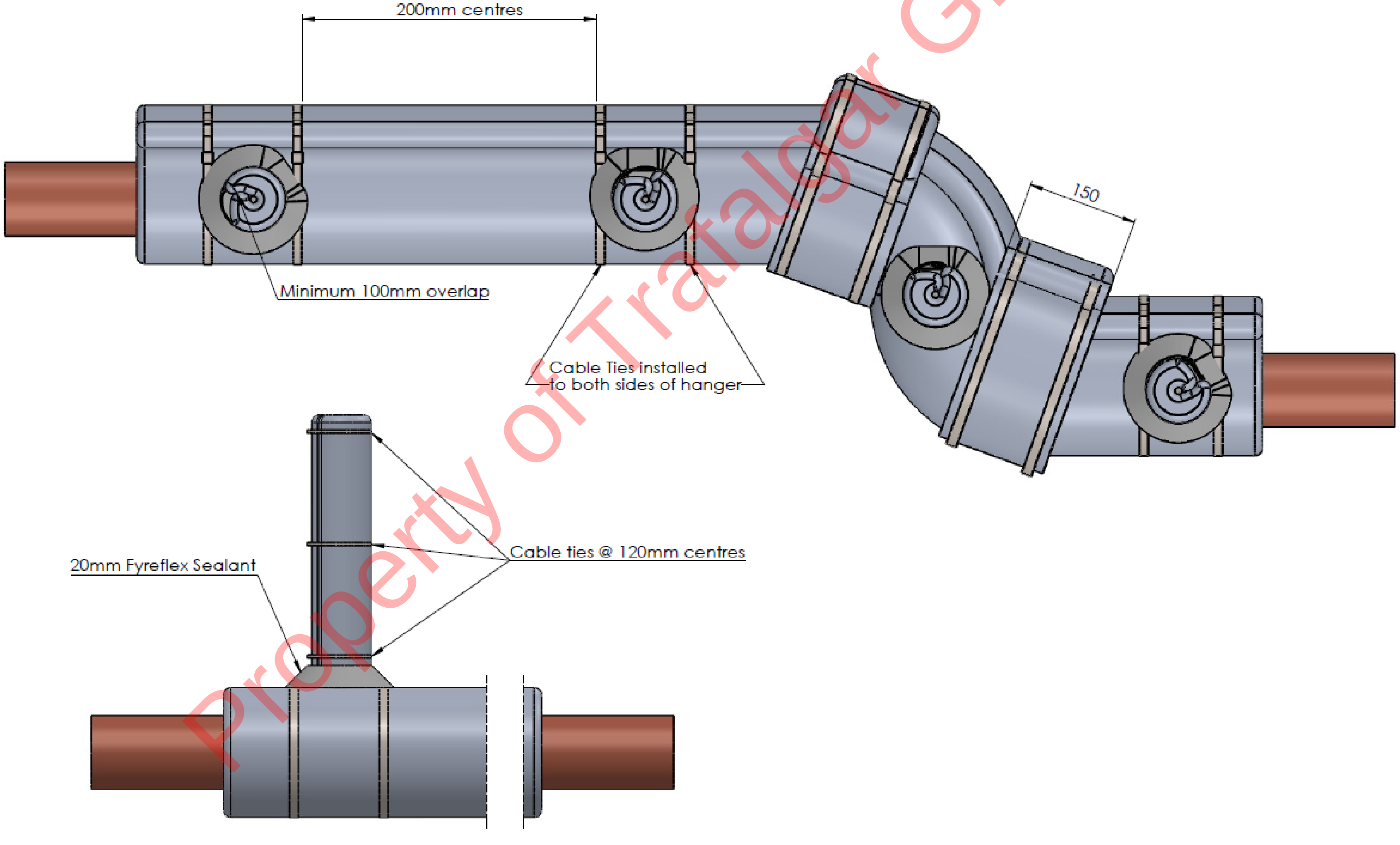
Can I treat pipes larger or smaller than 100mm?
Copper pipes up to DN100 can be treated with FyreWrap.

Do I need to use sealant?
Fyreflex sealant forms an integral part of the fire stopping system. It must be used to ensure performance.

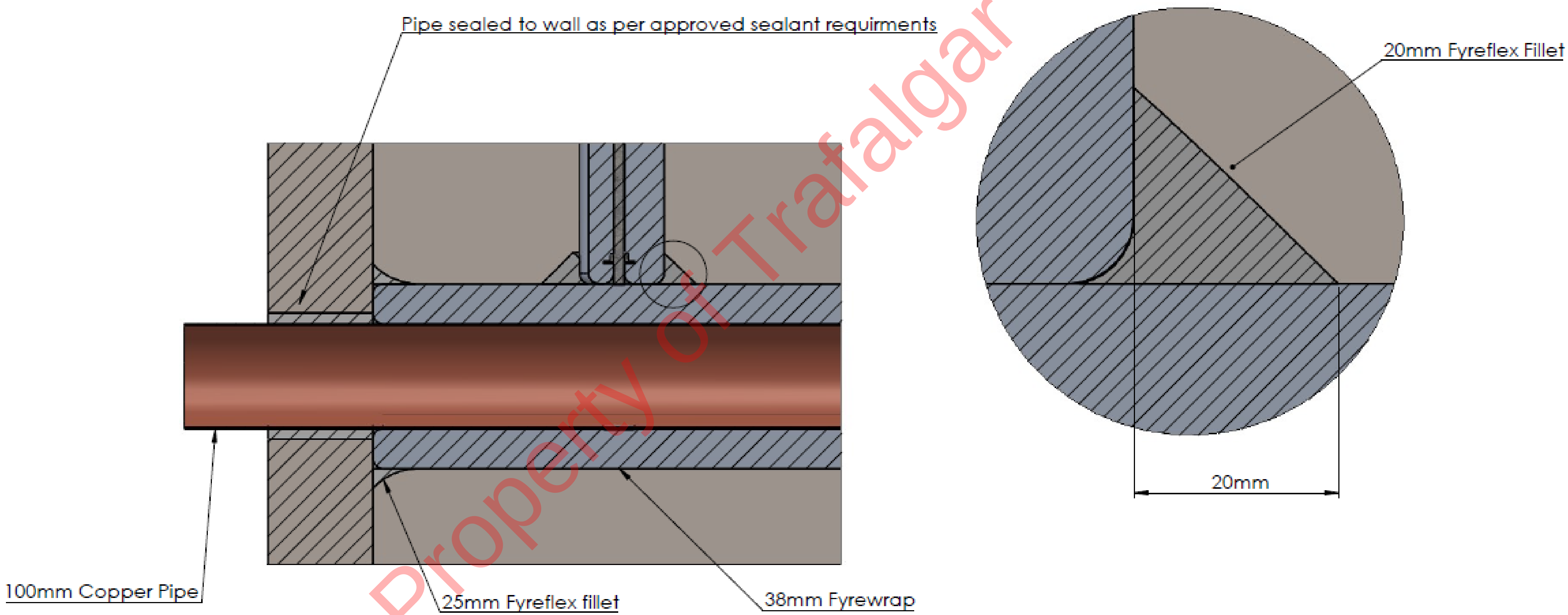
Does the system achieve -/60/60?
The wrapped pipe achieved 60 minutes of insulation, and over 90 mins operational performance.

Can this system be used if the hydrant is not charged?
No, Fyrewrap is only suitable for charged hydrant pipes.

Drawing 2 – General Installation details



Drawing 3 – Wall Penetration Details

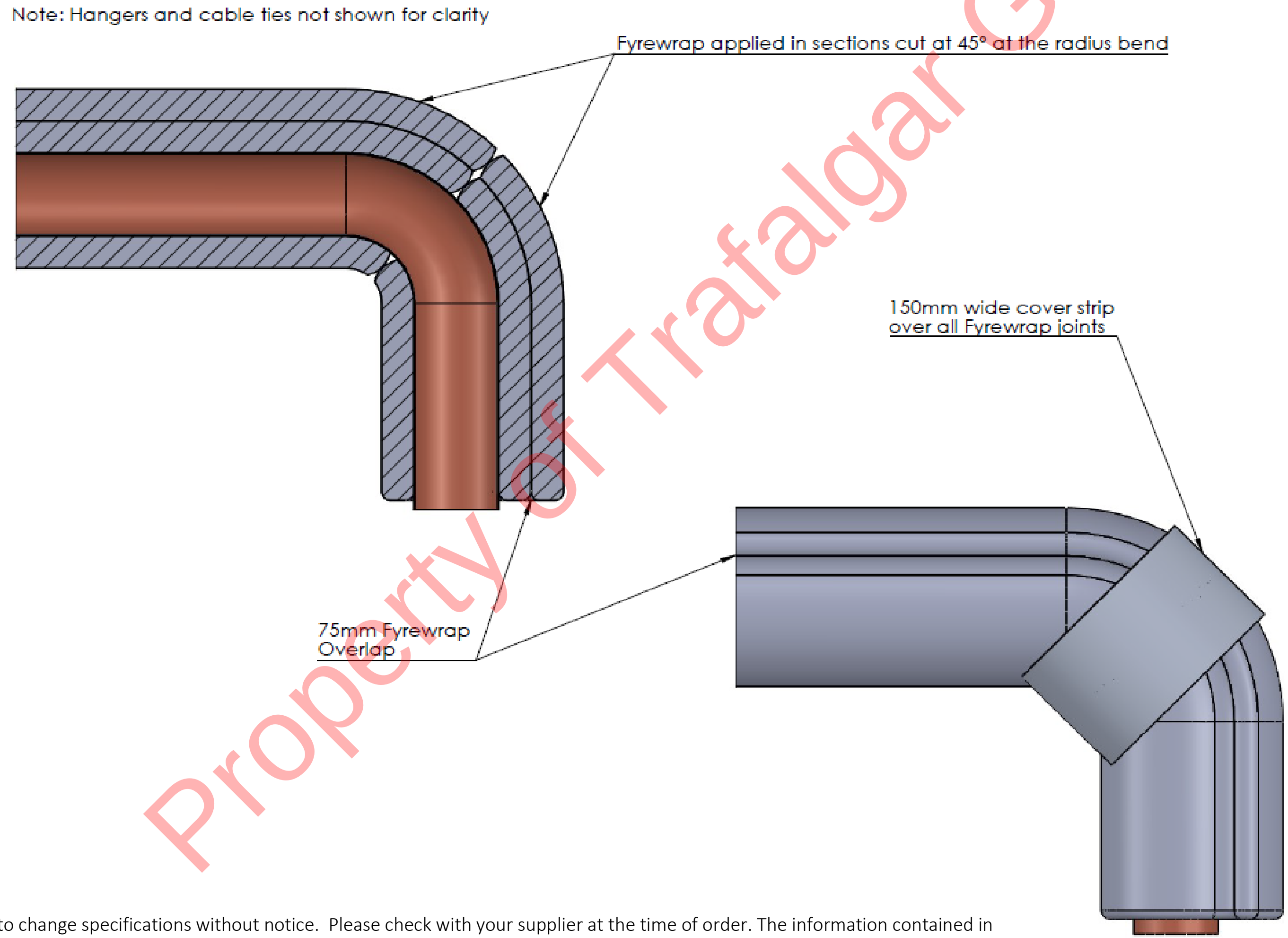


FYREWRAP

Insulation for Copper Hydrant Pipe

Installation Requirements

Drawing 4 – Recommended Radius Bend



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Appendix B. Details analysis of maximum spacing

B.1 Assumptions

B.1.1 In practice, the diameter of the threaded rod is normally selected before the commencement of the installation. In the following calculations, the minimum threaded rod is M5, while the maximum threaded rod is M12.

B.1.2 The number of threaded rods used to hang the copper pipe should not less than 2 to simplify the assembling procedure.

B.1.3 The deadload of water-filled copper pipe distributes evenly on the hangers. The positions of threaded rods are chosen to ensure this condition is satisfied.

B.1.4 The deadload used in this calculation is based on the experimental data of critical system A presented in the Warringtonfire test report, as shown in Table 1.

B.2 Details of calculation procedures

B.2.1 The total deadload of critical system A (G_t) is 43.2 kg. The total length of the copper pipe is 2.6 m.

B.2.2 The aim of this calculation is to determine the number of threaded rods (n) used to hang the copper pipe system at 60 minutes into the standard fire resistance test. It should be noted that the minimum number of hangers is two.

B.2.3 The distributed deadload on each hanger (P_h) can be calculated by using Equation 1.

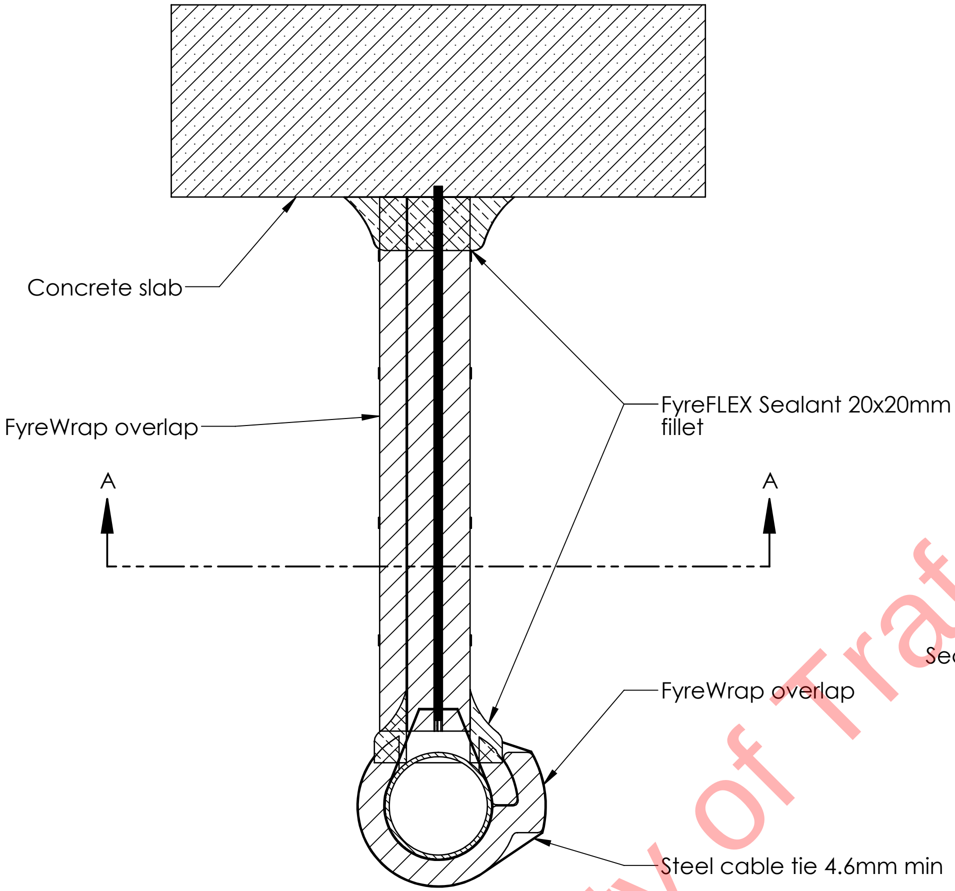
B.2.4 In order meet the requirement of structural adequacy for the threaded rod, the load-bearing capacity of each threaded rod (N_t) at 60 min into the fire resistance test must be sufficient to carry the distributed deadload from the water-filled copper pipe, as shown in Equation 6.

B.2.5 As observed in the test, although critical system A and B were protected using the same approach, the temperature of threaded rods and pear band in critical system B was much higher than those are in critical system A. Thus, the temperature of the threaded rod and pear band in critical system B at 60 min into the fire resistance test has been used for subsequent calculations.

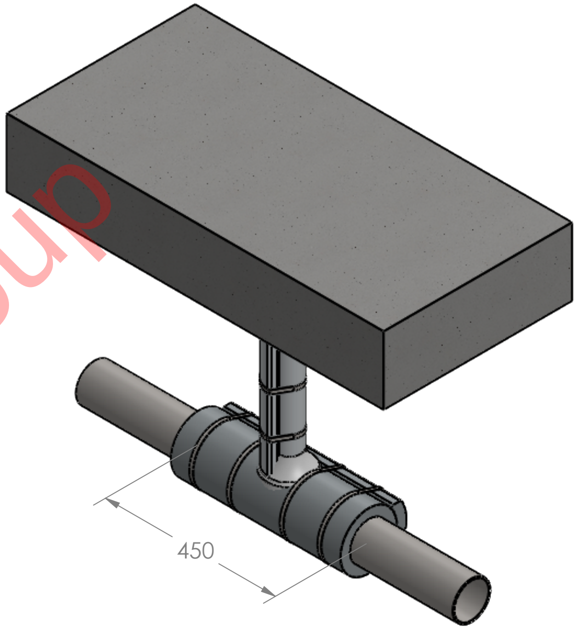
B.2.6 As shown in Table 4, the temperature of the threaded rod and pear band are 805°C and 776°C at 60 min into the standard fire resistance test, respectively. According to Table 3, the yield strength of mild steel at 800°C reduces by 95% of its original strength at ambient temperature.

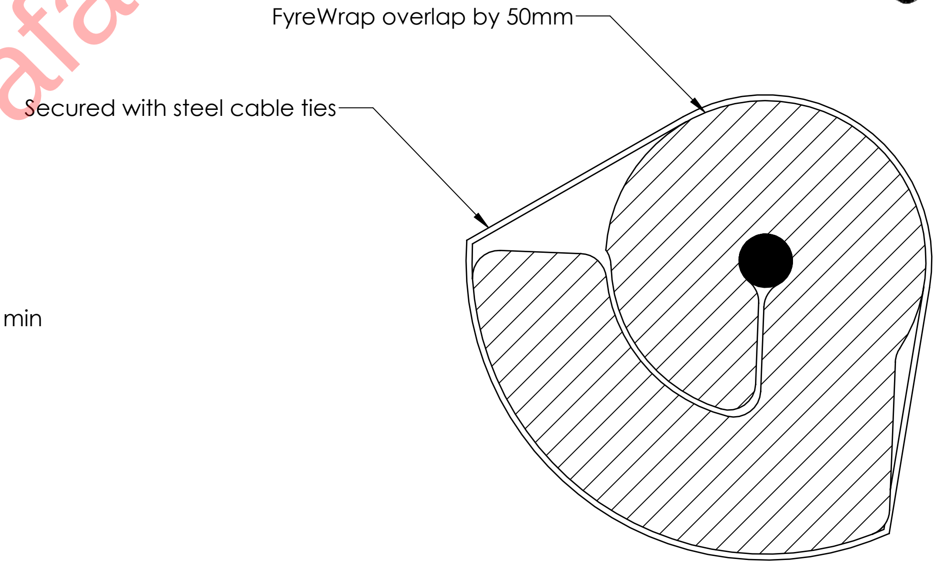
Appendix C. Protection of steel pipework supports

Figure 13: Sealant applied at the interface between hanger's wrap and concrete floor slab.



SECTION B-B





SECTION A-A

Note:

- Steel cable ties used to secure wrap 50mm from each end and at 200mm centres up the hanger.
- A single 450mm width of FyreWrap is used around the pipe, with a 50mm overlap on itself, cut a slit in the middle for the hanger to go through, seal open edges with aluminium tape. Secured with steel cable ties as depicted, 50mm from each end and either side of hanger.

Drawing Name: Overview

Project Title: FyreWrap Hanger Protection

Drawing No. :	**Sheet:**	**Date:**	**Scale:**
1	1 of 1	14/12/2020	NTS

Test Standard: AS1530.4

Codes:

Fire resistance level:

Drawn By: SM

Based on Report No.:

Checked By: JH

Revision:	**Date:**	**No.:**

NOTICE:

NOTE: ALL DIMENSIONS ARE IN MILLIMETRES (mm)

STANDARD DRAWING

PROJECT DRAWING

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