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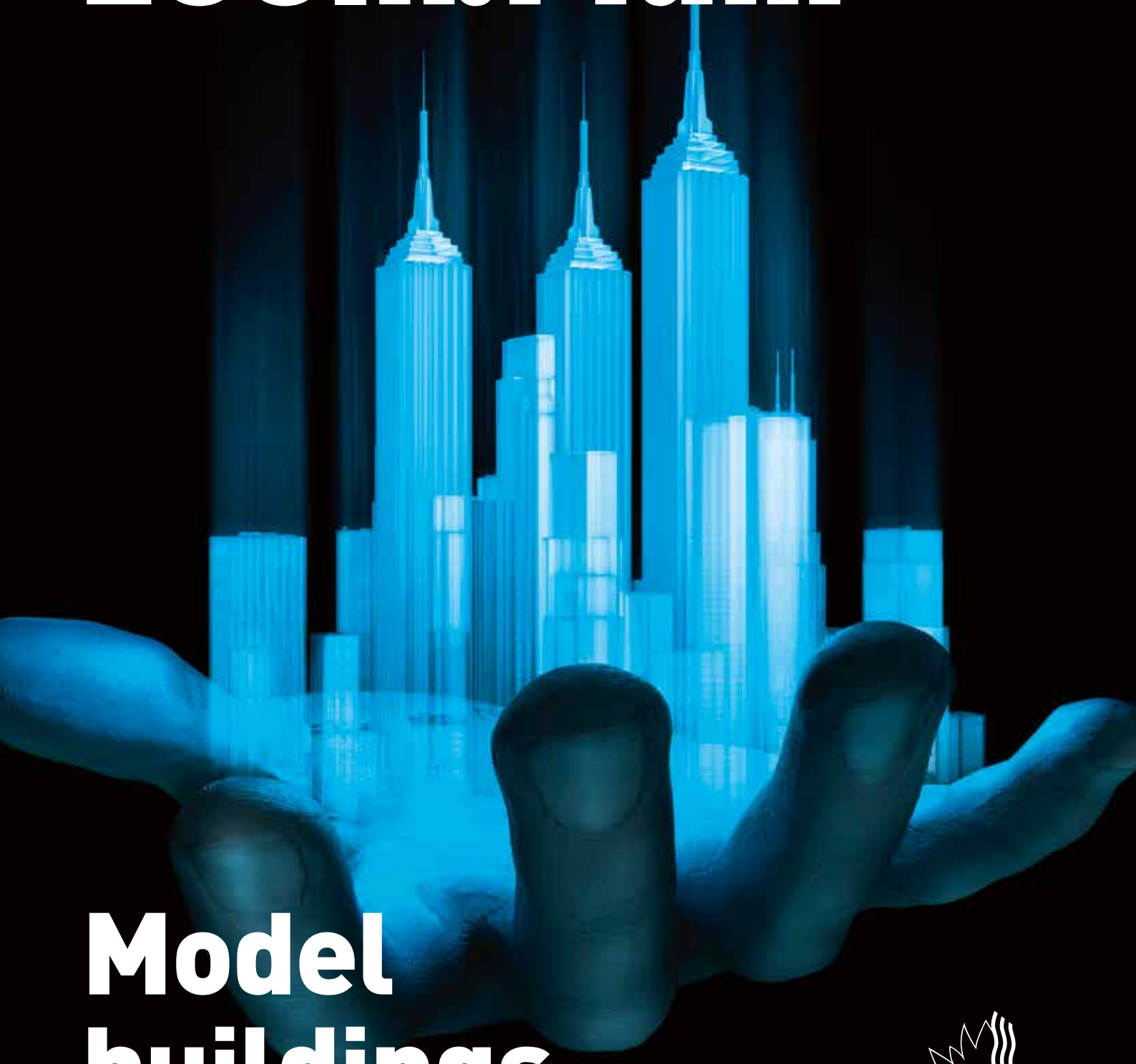

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Mitigating the risk of fire spread from pipe insulation

Dr Cameron Chick, M.AIRAH — Director – Acronem Consulting Australia
Dr Stephen Hodson, M.AIRAH — General manager marketing – Asia Pacific, Armacell Asia

ABSTRACT

The proliferation of different pipe insulation materials in buildings has highlighted shortcomings in the ability of existing test methods to adequately ensure the objectives of regulatory requirements with regard to fire performance behaviour.

The use of pipe insulation has grown exponentially since the introduction of minimum mandatory energy-efficiency requirements. While the cost-benefit arguments for increased insulation are well documented, and payback periods are short, the resulting efforts to minimise any increase in construction costs has led to an influx of combustible thermoplastic insulation in this and many other building applications.

The risks associated with the increased use of combustible materials, particularly for pipe insulation, have gone un-checked. Consequently, the capability of existing test methods to adequately assess the fire hazard properties and preserve the intent of regulatory fire performance objectives has been depleted. The selection and installation of building products that are not only tested and approved, but also "fit for purpose", is key to ensuring the robustness of any fire safety design.

This report presents an overview of Australian and New Zealand regulatory requirements for the fire performance of pipe insulation. Key research findings with respect to the evaluation of surface fire spread in vertical pipe risers/chases are highlighted, resulting in the proposal to adopt the NFPA 274 standard test method as a replacement to AS/NZS 1530.3 for these applications.

In light of the findings presented, due consideration must be given to their impact on the basic premises of fire safety engineering. The course of action a prudent individual would follow to discharge a duty of care in providing a performance-based solution for fire safety in relation to choices of pipe insulation must also be considered.

1. INTRODUCTION

Insulated piping is typically required for the transportation of fluids between plant equipment, and is typically bundled in horizontal and vertical "chases" for simplicity of structural and mechanical design, construction, access for maintenance, and cost-effectiveness.

Increased usage of pipe insulation in these applications has resulted from improved best practice, more stringent energy-efficiency measures, and increased levels of regulatory compliance. The Australian National Construction Code (NCC) and the New Zealand Building Code (NZBC) regulate the fire hazard properties of materials through testing procedures. These provide an unrealistic assessment of the fire performance of common forms of pipe insulation.

The combination of the relatively recent proliferation of higher levels of pipe insulation and standard fire test methods that have not been designed to assess the fire hazard behaviour of insulated pipes in their most critical applications (which are commonplace in buildings) presents a potential fire risk that is discussed and addressed.

Insulation that does not promote the spread of fire in a pipe chase must be considered when assessing the fire safety performance of a building during a fire incident. Requirements for fire compartments with FRL-rated elements as-designed, are not always implemented in practice. Not all buildings perform "as expected" under fire conditions. Where materials contribute to a reasonable degree of fire safety they should be used, and where materials do not provide reasonable performance, the unreasonable risk attributed to their use should be eliminated.

Figure 1: NFPA 274 testing.

Test methods that enable a better understanding of the fire spread behaviour of the regulated practice of insulating pipework within the building envelope have grown in importance. They have been recognised as requiring re-assessment to more accurately represent the behaviour in these situations. The development of the NFPA 274 Vertical Pipe Chase standard test method developed in the US is addressed in an Australasian context.

2. BUILDING REGULATORY REQUIREMENTS FOR FIRE HAZARD PROPERTIES OF MATERIALS

The adoption of world's best practice through standards and regulatory processes is based on an ongoing review of national performance requirements and the implementation of relevant international research. A thorough knowledge of current developments is essential to support the informed decisions of building regulatory authorities. The development and dissemination of knowledge typically falls to industry through representations to those standards committees charged with the vetting and interpretation of the applicability of national and international efforts suitable for adoption as standards and regulations for Australia and New Zealand.

2.1 NCC 2015 and 2016

The National Construction Code (NCC 2015 and 2016) employs both small-scale and large-scale test methods to evaluate the early fire hazard properties of building materials. These range from the small-scale AS/NZS 3837-1998 Cone Calorimeter, and AS/NZS 1530.3 Early Fire Hazard Properties of Building Materials through to the full-scale AS/ISO 9705 Room Corner Burn. While the small-scale methods are designed to provide elements of a fire hazard assessment, their limitations are recognised as being not always suitable for describing the fire hazard properties of materials under actual fire conditions.

The Building Code of Australia was originally published in 1988. Prior to 1990 different technical provisions for fire hazard properties of materials were contained in the Building Regulations in each state. The 1990 edition of the BCA used AS/NZS 1530.3 as a requirement for fire hazard properties of materials including wall and ceiling linings, and was generally adopted throughout Australia. In 1996, the BCA mandated a performance-based design approach, making deemed-to-satisfy (DtS) provisions optional, for the reason that they may not satisfy the performance requirements. This provided for the approval of building solutions subject to the provision of evidence of suitability, typically via relevant test data adequately describing fire hazard properties. The use of AS 1530.3-1989 was curtailed following Fire Code Reform Centre (FCRC) 1998 review and recommendations to replace AS 1530.3 with ISO 9705 test for lining materials. Following review in 1999 AS/NZS 1530.3 was retained for miscellaneous systems such as pipe insulation and other materials. Small-scale test results can provide misleading results for combustible and composite materials or assemblies. These conclusions are supported by fire brigades and fire protection associations. The selection/installation of "fit for purpose" tested and approved building products and materials are of fundamental importance in ensuring the robustness of any fire safety design in building construction.

Fire performance criteria for commercial buildings are specified in NCC 2015, BCA Vol.1 Section C. BCA performance requirements to limit the generation and spread of heat and smoke, are typically satisfied by complying with deemed-to-satisfy provisions. BCA Deemed-to-Satisfy (DtS) requirements for fire hazard properties of pipe insulation involve AS/NZS 1530.3 testing for a spread of flame index (SFI) and smoke developed index (SDI). Limiting values of fire indices determined by this method, intended to control materials other than those used to line walls, ceilings and floors, are provided in NCC 2015, BCA Vol.1 Specification C1.10 Table 4, and are presented in Table 1.

Application	Spread of Flame Index (SFI)	Smoke Developed Index (SDI)
General	≤ 5	(no requirement)
(not ceiling, wall or floor linings, air-handling ductwork or lift cars)	5 < SFI ≤ 9	≤ 8
Fire-isolated exits	0	≤ 2
Class 9b (fixed seating, proscenium curtain, escalators, moving walkways...)	0 0 0	≤ 5 ≤ 3 ≤ 5

Table 1: NCC 2015 and 2016, BCA Vol.1 Limiting Values of AS/NZS 1530.3 Fire Indices (in-part).

2.2 NZBC

In May 2013, the New Zealand Building Code replaced fire hazard assessment through AS/NZS 1530.3 and AS/NZS 3837 in favour of ISO 5660. This effectively excluded the small-scale test assessment of fire-hazard assessment for any foil-faced materials and thermoplastic materials that shrink or melt. Materials that are unsuitable for small-scale test assessment must effectively be subjected to the "full-scale" ISO 9705 test method.

3. STANDARD FIRE TEST METHODS FOR PIPE INSULATION

The test methods used to satisfy regulatory requirements have been designed with the primary objective of providing guidance of the fire hazard assessment for wall and ceiling lining materials. This is evidenced by the background development of the standard test methods referenced e.g. AS/NZS 3837, ISO 5660, AS/NZS 1530.3, ISO 9705.

3.1 AS/NZS 1530.3

AS/NZS 1530.3 describes a test method for the determination of ignitability, flame propagation, heat release and smoke release by exposing a small-scale vertically oriented flat specimen to a radiant heat source where the test specimen is manipulated to lay flat, sandwiched between a solid substrate and a wire mesh. Originally developed to assess the potential hazard of wall linings, the NCC references AS/NZS 1530.3 results for pipe insulation and other materials. As such, a report of a test to this procedure is required to be submitted to the relevant regulatory

building permit authority (certifier) to demonstrate compliance with the BCA deemed-to-satisfy requirements unless an alternative solution and alternative test method or other evidence is being used to satisfy the BCA performance requirements.

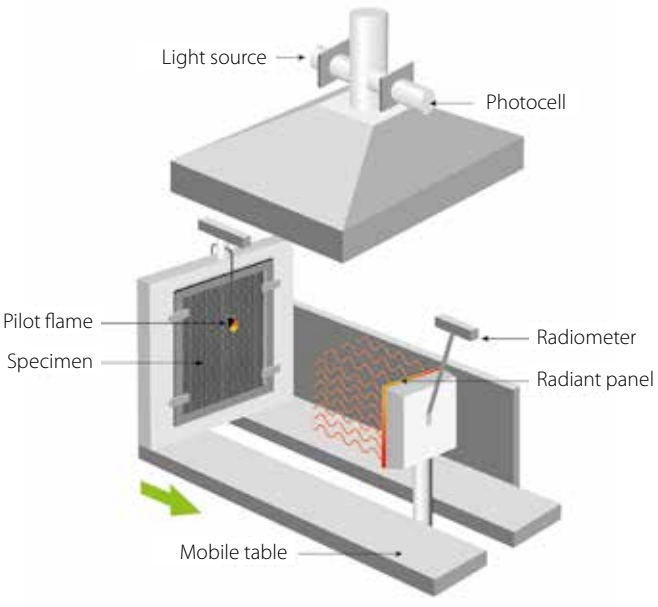

Figure 2: AS/NZS 1530.3 test set-up.

The result is that many building materials, which exhibit behaviour that cannot be measured by this method, hold AS/NZS 1530.3 certificates that incorrectly indicate their fire hazard properties, solely to demonstrate compliance with an inappropriate regulatory requirement.

The types of behaviour that are not captured for thermoplastic materials includes the shrinking and melting of the sample from the test heat/ignition source, continuing to combust outside of the metered area, and still producing regulatory compliant SFI and SDI results.

In recognition of this and in addition to the required indices, Accredited Testing Laboratories typically include the following statements on their Test Certificates:

- Non-homogeneous materials, eg. Protected by reflective facings or non-combustible layers (steel sheet) are unsuitable for test by this method.
- The specimens melted and flowed away from the area of maximum heat during the test. Due to this phenomenon, it should be recognised that this test result may not be a true indication of the product's fire hazard properties.
- Since the heat source for this test is a radiator, a reduction in the reflective properties of certain materials by the deposition of dust and soot, by surface damage and by the formation of surface corrosion products, may produce a significant change in the index numbers from those obtained when the materials were tested in a new and clean condition.

- The specimens were mounted to simulate use in an unsupported or free hanging mode. The results may be significantly different when mounted to simulate a wall cladding or upholstery application.
- Each test specimen was sandwiched between two layers of galvanised welded square mesh made from wire of nominal diameter 0.8mm and nominal spacing 12mm in both directions and the assembly clamped in four places.
- The AS/NZS 1530.3 results only apply to the specimen mounted, as described. The results of this fire test may be used to directly assess fire hazard, but it should be recognised that a single test method will not provide a full assessment of fire hazard under all fire conditions.

3.2 ISO 5660

ISO 5660 specifies a test method for the determination of the heat release rate, smoke production rate and mass loss of a sample by exposing a small-scale horizontally oriented flat test specimen to controlled levels of irradiance with an external ignition source. Established to assist technical fire modelling and to predict the fire performance characteristics of products under development, ISO 5660 is a small-scale test method referenced by the NZBC. AS/NZS 3837 is based on ISO 5660 but with different end-of-test criteria which, for some materials, may affect the assessment of a Group Number.

Where foamed plastics or combustible insulating materials form part of an element requiring a Group Number in accordance with NZBC Clause C3.4(a), the completed assembly shall achieve a Group Number determined in accordance with C/VM2 Appendix A, which allows testing to either ISO 5660, or ISO 9705.

3.3 Pipe-chase test methods

During a fire incident, pipe chases provide a means of transportation/carriage assisting the spread of a fire typically via the combustion of materials located in these elements. Pipe- chase test methods have been developed and are maintained by a number of key testing bodies including:

- Underwriters Laboratories (UL), a global independent safety science company providing performance and compliance services for developing superior products.
- ASTM International, a non-profit organisation that develops and publishes procedures for testing of materials of every sort.
- FM Global, a commercial insurance company supporting risk management objectives through developing loss prevention engineering solutions.
- National Fire Protection Association (NFPA), an international non-profit organisation that develops, publishes and disseminates fire risk consensus codes and standards.

	NFPA 274 –						AS/NZS 1530.3 (SFI, SDI)			
Material/ criteria	Peak heat release rate (kW)	Total heat released (THR600) (MJ)	Total smoke released (m^2)	Extent of flames (m)	Maximum temperature above pipe chase (°C)	Result (Pass/ fail)	Ignitability index (0–20)	Spread of flame index (0–10)	Heat evolved index (0–10)	Smoke developed index (0–10)
NCC Criteria							– –	≤5 5<SFI≤ 9	– –	(no req) ≤ 8
ANSI UMC Criteria	**< 300**	**< 50**	**< 500**	**< 0.305**	**< 538**					
Armaflex FRV pipe 25x60 (2/4/14)	127	49.6	295.9	< 0.300 Nil above pipe chase	223	Pass	0	0	0	5
Armaflex FRV pipe 25x60 (20/5/14)	139	28.2	269.3	< 0.300 Nil above pipe chase	220	Pass	0	0	0	5
Armaflex FRV 25mm (2/4/14)	105	42.5	281.5	< 0.300 Nil above pipe chase	227	Pass	0	0	0	5
Non cross-linked PE(2/4/14)	2156	127.7	345.4	> 0.305	568	Fail	8	0	1	3
Non cross-linked PE foil faced (2/4/14)	795	62.3	493.2	> 0.305	567	Fail	0	0	0	2
Non cross-linked PE (20/5/14)	801	21.1	709.7	> 0.305	568	Fail	8	0	1	3

Table 2: Comparison of NFPA 274 Limiting Values &Test Results with AS/NZS 1530.3 indices.

"Tunnel-type" materials testing standards maintained by these bodies include:

- U.L. 723, Test for Surface Burning Characteristics of Building Materials.
- ASTM E84, Test Method for Surface Burning Characteristics of Building Materials.
- FM 4924, Approval Standard for Pipe and Duct Insulation.
- NFPA 274, Standard test method to evaluate fire-performance characteristics of pipe insulation.

UL recognises that it is incorrect to assume that flame spread and smoke-developed values resulting from materials tested in a flat orientation will be compliant with electrical, building or mechanical code surface burning requirements. The above methods are maintained in codes to quantify the fire performance of materials intended for installation in plenums.

FM Approvals developed a tunnel test method to evaluate the potential for a horizontal spreading fire in parallel runs of insulated pipes within a pipe chase or plenum. FM Approvals Standard 4924 for Pipe Insulation incorporates vertical and horizontal legs to address the "greatest risk in a commercial building" of fire spread by combustion of pipe insulation. Consisting of a full-scale horizontal pipe chase with a small vertical run and longer horizontal run, this test method represents a horizontal pipe chase enclosed at the top and sides, and does not represent a ceiling or wall cavity. While the FM 4924 test is globally recognised, it is a horizontal test, and does not represent the more severe circumstance of a vertical fire.

NFPA published a vertical pipe chase test method to fill the need for a standard method of determining the fire performance of pipe insulation materials, NFPA 274.

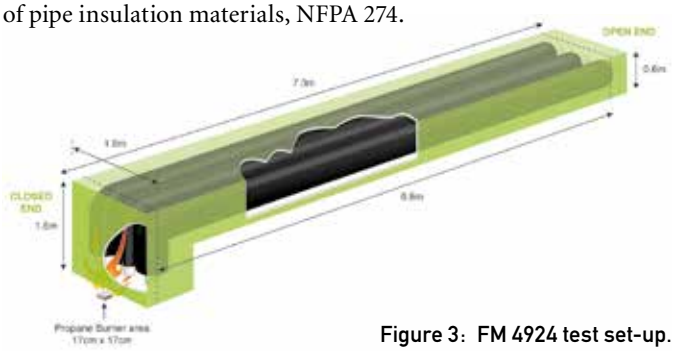

Figure 3: FM 4924 test set-up.

4. NFPA 274 STANDARD TEST METHOD

The National Fire Protection Association NFPA 274 - Standard test method to evaluate fire performance characteristics of pipe insulation is a full-scale test method designed to represent the as-installed behaviour of insulated piping in vertical pipe chases.

Published in 2003, and adopted by the Uniform Mechanical Code in the first revision cycle in 2006, the test method consists of a short horizontal section and a longer vertical section designed for determining the fire spread (loss of fire separation/containment) by pipe insulation in a common vertical configuration. The behaviour of different insulation materials has been defined by comparative testing over a period of 13 years.

The Uniform Mechanical Code (UMC), American National Standards Institute (ANSI), Chapter12, Hydronics, 1201.2.1.8 Insulation, specifies limiting values for the key test measurable identified in NFPA 274 as:

- Maximum heat release rate (HRR max.) shall not exceed 300kW
- Total heat release (THR) at 10 minutes does not exceed 50MJ
- Total smoke release (TSR) does not exceed 500m^2
- Flames shall not extend more than 0.305m past the top end of the test apparatus.

The results of recent testing performed at Exova Warringtonfire Melbourne Laboratories, in accordance with the requirements of *NFPA 274 and Uniform Mechanical Code (UMC), American National Standards Institute (ANSI), Ch.12 Hydronics,* 1201.2.1.8 Insulation identify stark differences in the fire hazard properties of materials that are otherwise indistinguishable by AS/NZS 1530.3 indices. These differences are common to building insulation materials and assemblies containing thermoplastic components. While they are examined in the context of pipe insulation, they are regrettably common throughout the Australian building industry in other insulation and lining applications.

The NFPA 274 test specimen provides a method for an examination of the complete insulation assembly, including elbows, in an actual configuration that is found in the end-use application. Test specimens include any jackets, elbows, tapes, sealants, coatings, adhesives, or other accessories used with the insulation in practice. These provisions highlight why NFPA 274 is able to identify differences in key performance criteria of thermoplastic materials relates to its ability to provide a realistic measure based on actual installation practice. Where AS/NZS 1530.3 allows thermoplastic test specimens to melt and escape from the heat affected area prior to ignition, no such behaviour is afforded in practice, nor in the NFPA 274 standard test method. NFPA 274 and AS/NZS 1530.3 test results and regulatory criteria are presented in Table 2 for elastomeric and polyethylene materials.

Figure 4: NFPA 274 test apparatus.

While the vertical orientation of test specimens is identified as providing the most severe conditions for measuring fire performance, it remains highly relevant to typical applications for pipe insulation in commercial buildings.

The NFPA 274 standard test method requires pipe insulation material to be tested as installed, around a pipe, in the critical vertical orientation commonly found in buildings. An important feature involves the location of the fire source below the test specimen so that any weaknesses in more highly flammable materials are exposed (the ability to shrink or melt away from a small heat source is effectively removed as a means of achieving regulatory compliance). This method is recognised as being more appropriate than the standard test methods currently employed to determine regulatory fire indices that have not designed to assess materials that behave in this manner.

Different insulation materials have been shown to fall onto a performance continuum from which important fire performance characteristics can be compared. This is an improvement on the current situation where even though the behaviour of different materials varies greatly, all continue to achieve identical fire performance indices.

Testing performed to the vertical pipe chase standard test method has exposed the inability of current small-scale test methods to accurately determine the fire performance of combustible thermoplastic materials installed as pipe insulation, and clearly demonstrate the need for the adoption of a well-established and accepted standard test method to assess the fire performance in this application.

5. DISCUSSION

A review of the tests methods employed to assess regulatory requirements has been performed in recognition of the highly variable fire performance behaviour of different "compliant" pipe insulation materials to the NFPA 274 test. The results of a series of experiments using a well-established standard test method has provided specific information, in an Australian context, for applications not already well defined by existing test methods.

Figure 5: NFPA 274 testing.

The proposal is made to limit the applicability of existing test methods to pipe insulation applications where they are not capable of measuring fire performance behaviour to ensure the intent of building regulations.

A recent example of a similar assessment has been reflected in the June 2012 amendment to AS/NZS 3837 in recognition the limitations of applicability of this fire test method to thermoplastic and non-homogeneous (faced/layered) materials, and the subsequent adoption of this amendment by the NCC 2015. As a consequence, AS/NZS 3837 testing may now only be used to derive NCC Group Numbers for materials that are essentially homogeneous, that do not shrink or melt away from a flame, and discrepancies in NCC Group Numbers derived from AS/NZS 3837 results versus AS/ISO 9705 room corner burn testing have been eradicated. AS/NZS 3837 may no longer be used for materials that do not have validated correlations including:

- All assemblies, including those with profiled facings
- Materials or assemblies that contain materials that melt or shrink away from a flame
- Assemblies with joints and openings
- Products with a reflective surface.

A similar review of AS/NZS 1530.3 computation of indices and classification for regulatory purposes in the NCC must be conducted. The current overgeneralised use of AS/NZS 1530.3 in an Australian regulatory context, especially in the case of pipe insulation materials, results in the publication of fire hazard indices, which while conforming to regulatory requirements, provide potentially misleading information as to the true behaviour of thermoplastic materials.

The NFPA 274 - Standard test method to evaluate fire performance characteristics of pipe insulation is proposed for the specific case of determining the fire performance of pipe insulation material. For the reasons identified, it provides a more realistic indication of the fire hazard performance 'as-installed' through measures that better account for the melting and combustion of these materials. The capability to distinguish between important behavioural characteristics of different pipe insulation materials in the as-installed condition will assist in the ongoing effective management of fire risk of modern insulation materials.

Originally published by the NFPA in 2003 and incorporated in the 2006 Uniform Mechanical Code (UMC), the NFPA 274 standard test method has had rigorous review, over a period of 15 years. Prior to 2013 insulation materials under the UMC were able to be qualified on the basis of a surface spread of flame determination, current UMC pipe insulation regulations require either combustibility requirements, or protection by metal sheathing, or NFPZ 274 testing to demonstrate fire hazard compliance.

NFPA 59A standard for the production, storage and handling of liquefied natural gas has adopted NFPA 274 conditions of acceptance for pipe insulation assemblies in areas where the mitigation of fire exposure is necessary. The NFPA 274 requirement is in addition to the requirement of a maximum flame spread index determined in accordance with ASTM E84 – Standard test method for surface burning characteristics of building materials in recognition that the qualification of insulation materials on the basis of surface spread of flame is no longer a valid means of demonstrating compliance in these critical applications. This further supports a growing realisation that similar requirements are also reasonable for more common building applications.

While being a full-scale test, NFPA 274 standard test method is relatively cheap to perform and is available in Australia in an accredited public testing laboratory.

It is proposed that the NFPA 274 test be adopted as a standard inclusion into mechanical services specifications for the insulation of services, in addition to the minimum mandatory fire-hazard properties of materials required of the NCC.

6. CONSIDERATIONS FOR DESIGNERS

To achieve the basic premises of safeguarding people from the effects of fire in a building, and adequate performance with regard to occupant evacuation, fire brigade intervention, property protection and business continuity, it seems fitting to highlight appropriate information to assist fire safety engineers develop performance-based solutions for buildings.

The relevance and accuracy of the current test methods to accurately represent the early fire hazard behaviour of pipe insulation is brought into question through the alarming results of this more representative method of assessment.

In the execution of specialised technical duties, professionals involved in the design of mechanical services within a building have a responsibility to alert their clients to the limitations of a particular design.

For the particular case of pipe insulation, professionals must be aware of the potential risks and consequences of adopting the AS/NZS 1530.3 deemed-to-satisfy requirements for materials in these applications without due consideration of the likely impact of their real fire performance behaviour.

While the limitations of the AS/NZS 1530.3 test methods are noted at the foot of every test report, the requirement for a material to demonstrate fitness for purpose in its intended application is essential.

In assessing the potential impact of even a nominally minor fire event, fire safety engineers should provide due consideration of:

- Life safety
- Fire brigade access
- Fire spread to other buildings,

as well as

- Fire spread within a building
- The ability to withstanding an event without being damaged to disproportionate extent
- Reduction of loss
- Maintaining business continuity.

Alternative solutions should be supported, wherever possible, with appropriate test data.

Should a material become involved in a fire incident, a test report to any standardised method will not absolve a manufacturer from a legal requirement comply with a fitness-for-purpose definition. In such cases, settlements resulting from these types

of incidents are usually confidential and building industry professionals are unable to benefit from this knowledge.

While standard test methods are typically not legislated in Australian states and territories until first included in the NCC, fire authorities and major corporations may expect fire performance that is fit-for-purpose regardless of any minimum mandatory regulatory requirement.

NFPA 274 – Standard test method to evaluate fire performance characteristics of pipe insulation reflects the current state of knowledge in this area. Whilst not currently enacted through Australian building law, it represents a standard of care that a prudent person would follow to assess the fire performance of pipe insulation in Australian buildings.

The small-scale test method of AS/NZS 1530.3 provides inadequate definitions of the fire hazard properties of thermoplastic pipe insulation materials. NFPA 274 represents a full-scale standard test method capable of more accurately describing the fire hazard properties of pipe insulation materials.

While it is recognised that these proposed changes to NCC fire performance criteria for pipe insulation may be years away, the NFPA 274 Vertical Pipe Chase standard test results provide fire safety engineers the opportunity for a more realistic assessment of fire hazard properties that manufacturers, specifiers and fire authorities can employ at their discretion today.

7. ACKNOWLEDGEMENTS

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ABOUT THE AUTHORS

With 25 years of structural engineering and corporate marketing experience, Cameron Chick, M.AIRAH, runs Acronem Consulting Australia. A multidisciplinary engineering practice with expertise in Australian standards, codes and regulatory development, Acronem provides appraisal and compliance solutions to the building industry.
Email: cameron@acronem.com.au

Having held management positions in general management, sales, marketing and R&D, across the Asia-Pacific region, Stephen Hodson, M.AIRAH, is the general manager marketing – Asia Pacific for Armacell.
Email: stephen.hodson@armacell.com