Study Report SR410 [2018]

Assessing the risk of non-compliant firestopping and smokestopping in New Zealand residential buildings undergoing alterations

Kevin Frank, Greg Baker and Jonathon MacIntyre

1222 Moonshine Rd
RD1, Porirua 5381
Private Bag 50 908
Porirua 5240
New Zealand
branz.nz

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Preface

This is the second of a series of reports prepared during research into passive fire protection quality. This report is based on a 2-week visit to Auckland Council that included site visits to 11 buildings undergoing various stages of weathertightness remediation work, a series of fire resistance tests of service penetrations through passive fire protection systems as found in the site visits to Auckland Council and the development of a risk assessment process to provide consistency in determining ANARP compliance.

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Abstract

Passive fire protection (PFP) quality has been identified as an issue that must be addressed in buildings undergoing alterations in order to meet the New Zealand Building Code means of escape from fire requirements.

The objective of this project was to develop a process to provide consistency in the application of section 112 of the Building Act when PFP defects are found during building alteration work. To support that goal, a series of commonly found non-compliant residential firestopping configurations were fire tested to provide data on how actual construction may perform in a fire. The project outcome at this point is a proposed assessment process. Future fieldwork will investigate how it is applied in practice and identify if any adjustments are required.

This report describes the problem, development of the proposed process, one potential risk analysis tool that has been developed by industry and made available by BRANZ and the results of the testing programme.

Keywords

Passive fire protection, fire and smoke separations, firestopping, penetrations, defects, quality control, Code compliance, risk assessment, ANARP.

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Executive summary

Passive fire protection (PFP) quality has been identified as an issue that must be addressed in buildings undergoing alterations to meet the New Zealand Building Code means of escape from fire requirements as nearly as reasonably practicable (ANARP). Buildings undergoing weathertightness remediation have been found to have substantial PFP issues that have caused major cost and project delay implications before resolution of reasonably practicable compliance is reached among relevant stakeholders.

Defects can affect both structural adequacy and fire and smoke spread PFP objectives, but this project focuses on penetration firestopping and smokestopping performance as the most common and contentious problem. The objective of this project was to develop a process to provide consistency in the application of section 112 of the Building Act (i.e. ANARP compliance with the Building Code means of escape from fire provisions for building alteration consent) when firestopping and smokestopping issues are found during building alteration work.

To support that goal, a series of typical unproven residential penetration firestopping configurations, selected via site visits and consultations with stakeholders, were fire tested to 60 minutes using AS 1530.4-2005 *Methods for fire tests on building materials, components, and structures – Fire resistance tests for elements of construction* as a guide to provide data on how typical penetrations may perform. These configurations focused on plastic pipe and electrical service penetrations in five common residential building assemblies including a 60-minute plasterboard-lined timber-framed wall, 30-minute timber boundary joists, 30-minute fibre-cement board/plasterboard-lined timber-framed wall, 60-minute timber infill floor and 60-minute plasterboard ceiling/strand board/timber-framed floor – times represent nominal assembly fire resistance rating (FRR). A range of performance was observed, with the earliest insulation failure at 2 minutes and the earliest integrity failure at 19 minutes.

A process for systematically evaluating compliance of PFP defects has been developed based on the site and experimental observations, a review of related literature and discussions with the project stakeholders. The process includes a feedback loop that considers the risk over the lifetime of the PFP assembly. A risk analysis tool developed by industry that can be used as part of the process will be made available by BRANZ.

This report describes the problem, development of the proposed process, the risk analysis tool and the results of the testing programme.

1. Introduction

There has been a growing body of anecdotal evidence that PFP assembly construction in many existing New Zealand buildings is not fully compliant with appropriately tested and approved systems (Baker, Saunders & Kennedy, 2010). Recently, this issue has come to the fore, with Auckland Council (AC) being involved in inspection of many existing buildings that are being reclad due to weathertightness issues (i.e. leaky homes). The extent of this building alteration work requires a consent in accordance with section 112 of the Building Act (2004), which requires compliance "as near as reasonably practicable" (ANARP) with the Building Code means of escape provisions. As the fire and smoke separation PFP components are typically integral to the means of escape, they are inspected as part of the consent process. These inspections have led to the discovery of many issues with non-compliant PFP systems in the existing construction as well as issues around non-compliant systems being installed as a part of the reclad work (Taylor, 2015). The costs of these additional problems can be significant. The interpretation of the ANARP requirement is challenging for stakeholders to reach consensus as to what is reasonable and practicable. Also, the level of compliance of many actual PFP assemblies is questionable because there is no relevant test data.

The goal of this project was to develop a process to evaluate risk due to existing PFP defects and provide a technical basis for determining what solution is as near as reasonably practicable to compliance when remediating them. A stakeholder group, which drew upon a broad cross-section of parties involved in PFP in New Zealand, informed the results of this research.

A risk analysis tool has been developed by the consultancy firm Maynard Marks, which is presented in this report as one option for risk analysis and will be made available. The tool can be used to compare the relative risk versus cost of repair of the existing defect against that of a proposed ANARP solution or a fully compliant solution. As the tool also allows for the cost of each option to be assessed, it can determine if a solution is reasonably practicable. However, it needs to be used within an overall assessment process similar to what is proposed in this report because it is focused on individual non-compliant defects.

A major source of uncertainty in determining if a proposed solution is ANARP is a lack of information and understanding about how commonly constructed firestopping assemblies actually perform in a fire test. Five fire resistance tests following AS 1530.4-2005 with a range of previously untested construction details were completed as selected by discussion with building consent authority (BCA) inspectors and a number of site visits.

To help provide guidance to the project, a stakeholder group was assembled of interested parties from the passive fire industry. Much of this group was comprised of members of the Ministry of Business, Innovation and Employment (MBIE) PFP working group, with the addition of a member of the Auckland Council reclad building inspectors team and several other interested parties. While feedback on any aspect of the project was welcomed, the main purpose of the stakeholder group was to provide feedback for the fire testing plan and the ANARP decision process and risk analysis tool. An additional role was to assist in the delivery of the results of this project to the wider industry.

Section 2 is a summary of the site visits that were undertaken to weathertightness remediation building sites in Auckland to understand the scope and nature of the problem. Additional observations from Auckland Council regarding consent processing are also included.

Section 3 describes previous literature related to PFP deficiency performance. This includes previous work done by BRANZ to look at PFP deficiencies in New Zealand buildings and PFP post-earthquake performance. In particular, the reported performance of gaps and holes in timber-framed walls is useful for risk assessment of similar deficiencies in buildings undergoing alterations.

Section 4 discusses what the New Zealand building regulations require for buildings undergoing alterations. The terminology "as near as reasonably practicable" is particularly contentious, so this section delves into what this means based on precedent established in MBIE determinations and the High Court and also provides some international context from interim findings from the UK building regulation and fire safety independent review that was triggered by the Grenfell Tower fire. Finally, an extensive review of MBIE determination 2016/048 is included, which provides a typical case study of PFP deficiencies and was used as a partial basis for the experimental programme in this project.

An experimental programme was undertaken as part of this project to improve understanding of how non-compliant firestopping performs and is reported in section 5. The information from this experimental programme is useful to understand the potential risk of fire spread that may result from firestopping deficiencies.

The proposed risk management process and one risk analysis option are presented in section 6. The background for the process is provided based on the fundamental principles included in AS/NZS ISO 31000:2009 *Risk management – Principles and guidelines* and the Society of Fire Protection Engineers fire risk assessment guide (SFPE, 2006).

Finally, section 7 discusses future research opportunities, and section 8 provides overall conclusions and recommendations.

2. Auckland site visits

2.1 Visit summaries

Two trips were taken by BRANZ staff to Auckland to visit sites that exemplify the current problem for PFP in existing buildings undergoing alterations. The site visits were undertaken in conjunction with BCA staff. The first trip was a single day trip in September 2016 to get a broad understanding of the issues and was followed up by a more detailed 2-week visit to further investigate specific types of problems and the processes that are currently being used to address them.

The second visit to Auckland in November/December 2016 was undertaken with the purpose of accompanying the BCA inspectors and recording details of commonly occurring defects. These inspections occurred across 11 weathertightness remediation building sites and showed a variety of different stages in the remediation work. This allowed observations to be made of both original defects and defects that had already had some repair work undertaken. However, it became apparent that there were still compliance concerns with many of the repaired defects.

Over the course of the visits, a range of different PFP defects were observed and recorded on a simple detail sheet. Using these recorded defects along with guidance from the Auckland Council reclad inspectors, a list of penetrations to test was developed. This list included a series of primary substrates with multiple variations of construction.

In addition to the inspections, time was spent meeting with the Auckland Council consent processing teams. These meetings highlighted the difficulty facing the processing officers to obtain satisfactory supporting information about the PFP systems in the consent and the lack of oversight offered by the applicant to ensure that such PFP systems are installed appropriately.

2.2 Visit findings

2.2.1 Overview

Over the course of the November/December site visits, a wide range of defects were observed, many which were similar to those previously found in the September site visit. These included plasterboard pattresses covering concrete penetrations, bulkheads held together with combustible plastic strapping, unrated flush boxes, unsealed cable penetrations, penetrations sealed with smoke sealant, various non-combustible pipes and cables penetrating a fire wall without sealant (parts of the fire wall were also broken), non-rated access hatches into service shafts and multiple large cable bundles through a single fire seal without sealant between bundles. Photos of these defects can be found in Appendix A.

More detailed records were taken of a range of defects during the latter part of the site visit. These records include penetration type, penetration diameter, penetration seal type and information about the penetrated wall/floor. Of the 11 records taken, seven included plasterboard type systems that would seem to be part of a fire-rated system – one or two layers of fire-rated plasterboard, two layers of 13 mm standard plasterboard and a single layer of 13 mm standard plasterboard covered with a 13 mm fire-rated plasterboard pattress – with another being a concrete wall. However, no information is known about the concrete, so its fire resistance is completely unknown.

Approximately half of the records taken were of completely unsealed penetrations, with a few of the other records also being of uncertain quality. Of the unsealed penetrations, most could be easily rectified by the direct application of an intumescent sealant (notwithstanding manufacturer-specific requirements for backing insulation and so on). However, in some cases, the plasterboard would require repair and/or and additional plasterboard pattress. The full records collected can also be found in Appendix A.

A key observation from taking these detailed records was how it is difficult to tell if an installed penetration is compliant from a visual inspection only. Regardless of whether a penetration is properly labelled and seemingly installed correctly, without access to an installation datasheet for the penetration and information on the supporting construction system, it is not possible to determine if the system is fully compliant and able to provide the required FRR.

One of the original plans for these detailed records was to use them to assess the practicality of using the Maynard Marks risk analysis tool. However, it quickly became apparent that significant amounts of information are required in addition to basic penetration details. This information, such as the type of fire alarm/suppression systems in the building, purpose of location in the building and so on, is not necessarily determined by simple observation, although it is sometimes apparent with systems like sprinklers or in a kitchen. Because of this, it was difficult to use this data to determine the exact status of each defect per the existing Maynard Marks tool.

Several other defects were recorded without photographs. These included penetrations through rib and infill concrete floor systems, holes through fire doors that were not fully covered by the door handle, unsealed and undamped ducts penetrating fire walls and similarly firestopped undamped ducts penetrating fire walls.

2.2.2 Common issues and defects

Issues

During the site visits, it quickly became apparent that many of the contractors involved in the sites visited were not adequately identifying or were ignoring non-compliant PFP systems and/or were failing to correctly remedy them. While some of the contractors wanted to ensure that every part of the construction was Code-compliant, it was far more common for the contractors to simply not care about the PFP or not want to bring it up to compliance. Similarly, it was a common occurrence for PFP installers to fail to read the appropriate datasheets and specifications for the systems they were installing. Typically, they would just claim x years of experience in the trade and that “I’ve always done it this way” when required to supply datasheets or change their installation methodology.

Another issue that was observed was of issues with PFP systems that were outside the scope of the existing remediation work. Often once a building was stripped back, it would become apparent that a PFP defect was common and hence likely to exist throughout other parts of the building. This issue was recently brought to light in MBIE determination 2016/048 (MBIE, 2016a), which is discussed further in section 4.6. A further observation was that many of those involved in the PFP remediation work did not seem to understand the importance of PFP in a building and simply considered it to be an extra complication and cost in the construction process for no benefit. This highlights the fact that there is a need for education in the construction industry about the importance of fire safety systems. If there is not a clear understanding of the necessity of PFP systems within the construction industry, it is likely that insufficient care will be taken in ensuring their adequate provision and installation.

Defects

Depending on the stage of construction on site, it was possible to view a wide range of defects in varying states. The following defects most commonly found were:

- unsealed cable penetrations
- unsealed pipe penetrations
- unsealed/plastic/missing intumescent pad flush boxes
- non-rated walls/ceilings meeting rated walls/ceilings
- floor/ceiling penetrations sealed from the ceiling side but not the floor side
- non-smoke sealed penetrations protected by a collar/collars filled with sealant
- systems installed without sufficient depth of substrate to support them – firestopping sealants typically require 25 mm of plasterboard (i.e. 2 layers).

Other items of note included:

- non-rated fire hose reel boxes
- non-rated call points (with no flush box or non-rated flush box)
- gaps in concealed sides of fire-rated walls
- non-rated bulkheads covering pipes crossing between two fire-rated walls (around a corner column) without appropriate penetration seal/collar and so on
- lack of edge support for the substrate to be attached to/supported by.

2.2.3 Consent processing

During the site visits and at the BCA office, discussions were had about the process undertaken to achieve a building consent beyond the inspections themselves. This focused largely on the processing of consents and requests for information (RFIs) issued by the building inspectors.

A key issue was that fire reports supplied with the consent often only contained a performance specification stating the required level of fire resistance. Further details such as locations of PFP systems and typical construction, penetration and connection details were simply left to the designer or site manager to determine.

Subsequent design choices often resulted in products and systems being used for which there is no tested and approved PFP solution. Thus, it was not possible to provide the level of fire protection specified in the fire report. This would result in a situation where the building consent was approved based on a performance specification that could not actually be constructed.

Due to these issues, it has become apparent that, without more detailed information being supplied at the building consent stage, there is often insufficient design in place during the construction stage to construct the building to meet the specified level of fire resistance. This often results in the site manager or building contractor making an 'assessment' of the required PFP and how to provide it, or a fire engineer is brought in to determine the appropriate construction details to use. If the fire engineer is unable to identify an appropriate construction detail, they will often use 'engineering judgement' to specify an alternative solution to comply on an ANARP basis. These alternative solutions typically have no actual testing or appraisal by an approved testing laboratory and are often constructed without formal design plans.

Section 4 of AS 4072.1-2005 *Components for the protection of openings in fire-resistant separating elements – Part 1: Service penetrations and control joints* does allow variations subject to a formal opinion, but such an opinion is to be certified in writing by a registered testing authority. A full justification much be included with the statements from the testing authority, including details of test data and any limitations on the tested specimen (discussed further in section 5.3.3). Alternatively, the variation must be approved by the authority having jurisdiction and permitted in accordance with AS 1530.4-2005. In many cases, this process is completely circumvented with the fire engineers 'approving' the variation themselves.

BCA building inspectors have found that a lack of information regarding where the building design required PFP systems makes inspection very difficult. This lack of information includes a lack of a schedule of penetrations with typical details or product datasheets for all penetrations, unlabelled installation of PFP features (e.g. fire-rated service penetrations) and the fact that many PFP systems are hidden by subsequent construction. This has caused the BCA to rely on a producer statement (PS) from the fire engineer and/or construction contractors. Anecdotal evidence showed that spot checks of PFP systems covered by a PS can often be non-compliant, indicating that often a PS has been signed off without a thorough inspection by the PS author. Furthermore, recent legal action taken against a BCA regarding weathertightness issues[1] has deemed that the BCA was irresponsible to rely solely on a certificate from the installer as it did not comprise a PS4 (construction review producer statement). Due to this judgment and the fact that spot checks on site undertaken by the Auckland Council building inspectors have shown some PS3 and PS4 certificates to not be representative of what they say, it has resulted in Auckland Council being much more cautious about accepting producer statements simply on face value.

Presently, the performance specification approach is often successfully used at consent stage for active fire safety systems such as sprinkler and fire alarm systems. A performance specification will typically reference a standard such as NZS 4541:2013 *Automatic fire sprinkler systems* or NZS 4512:2010 *Fire detection and alarm systems in buildings*. These are system standards as opposed to the test standards (AS 1530-2005) and component standards (AS 4072.1-2005) referred to for PFP. Active system standards include design, installation, inspection and maintenance requirements and contractor qualifications to ensure initial compliance and long-term performance of each installed system, not just the performance of a representative sample in a standard fire test. Because PFP is generally not considered on a system level like active systems, there are many opportunities for gaps to be missed. For example, a wall system that has been tested to meet the FRR requirement for a specific fire separation in a building might be constructed, but if the services that are penetrating the wall do not have tested firestopping solutions, the fire separation becomes non-compliant.

International guidance documents address many of these problems. For example, the US-based Firestop Contractors International Association publishes a manual of practice (FCIA, 2014) that includes guidance on firestopping solution selection, quality management, project management and other aspects. Several ASTM standards are relevant for extending fire test results and firestopping inspection requirements and are discussed later. The Association for Specialist Fire Protection has guidance on many aspects including inspection, risk assessor competencies and firestopping installation.

[1] *Body Corporate 326421 v Auckland Council* [2015] NZHC 862.

3. Previous studies of PFP deficiencies

3.1 New Zealand

3.1.1 FPANZ

The Fire Protection Association of New Zealand (FPANZ) initiated a project in 2008 to look into PFP quality in New Zealand buildings (Baker et al., 2010; FPANZ, 2008). The project included three phases. The first was a pilot study of PFP quality where 11 new and existing buildings in metropolitan centres across New Zealand were inspected. The buildings included a range of occupancies including hospital, tertiary education accommodation, residential and office. Inspections were conducted by chartered professional engineers or New Zealand Fire Service staff with tertiary fire engineering qualifications. The findings of this stage of the study were that eight out of the 11 buildings inspected had PFP that would likely be ineffective if challenged by a fire, with the non-compliant service penetrations in fire separations noted as the most common deficiency. This was despite the fact that much of the PFP in the buildings could not be inspected due to access constraints. It was recognised that, while the small sample of buildings would not be representative of the overall New Zealand building stock, it was an indication of a wider systemic problem.

An additional report was provided to the researchers involved in this study for review on the condition of anonymity. The focus of this report was telecommunications penetrations in multi-storey buildings. A survey of 15 buildings found that, generally, most penetrations had no firestopping installed. Older buildings were found to have more problems due to multiple installations of cabling likely by sequential tenants of the building.

The next stage of the project involved interviewing a cross-section of relevant industry stakeholders including representatives from seven PFP suppliers, four BCAs, building officials responsible for processing independent qualified person (IQP) applications and two independent fire engineers. Again, the sample included a wide geographical representation. Concerns raised included a lack of end-to-end continuity in the PFP process, lack of coordination between trades, lack of product knowledge, competency issues and inclusion of PFP systems in the compliance schedule with identifying drawings provided for the IQP. Additionally, work done after building completion without a consent that affected PFP integrity was noted as an issue.

3.1.2 BRANZ research on post-earthquake PFP performance

BRANZ has conducted research to investigate the potential performance of fire separations in a damaged post-earthquake condition (Collier, 2005, 2013). The 2005 research simulated earthquake damage by racking test timber and steel-framed walls lined with single layers of 13 mm fire-rated plasterboard on both sides (nominally fire resistance rated for 60 minutes). The walls were racked up to 2.5% inter-storey drift and then subjected to a AS 1530.4-1997 fire test. A 30–70% reduction in fire resistance was observed, particularly for integrity.

The 2013 research included a survey of damaged fire separations following the Christchurch earthquakes in 2010 and 2011, with an estimate that 10% of PFP systems in moderately damaged buildings were sufficiently compromised to cause fire safety concerns.

Typical damage found in fire-rated walls included plasterboard lining cracking and detachment from frames, separation of plasterboard joints and lining cracking around service penetrations. A series of three AS 1530.4-2005 fire resistance tests was undertaken, which looked at the effects on fire resistance of defects including a range of circular holes from 3–24 mm diameter in 90 x 45 mm timber studs and a range of slots, detached and cracked plasterboard linings and doorset gaps. The circular hole specimen included a double layer of 16 mm thick fire-rated plasterboard on the exposed side and no lining on the unexposed side. The other defects were evaluated in timber-framed walls with 90 x 45 mm studs and nogs and a 13 mm fire-rated plasterboard lining on each side. Effects of differential pressure were also investigated.

Integrity failure was monitored using fitted mineral insulated metal sheath (MIMS) thermocouples, with the criteria being an exit temperature of 300°C. Insulation failure was evaluated using a temperature rise of 180 K or more as measured by thermocouples attached to the unexposed face of the specimen. Furnace gas concentrations were monitored, and flame spread characteristics were observed and compared to theory.

The integrity failures of the circular holes are summarised in Figure 1. Although the test was stopped at 118 minutes, the time to integrity failure was projected based on the flame progress through the timber studs. The quickest time to failure observed was 22 minutes for the 24 mm diameter hole at a pressure differential of 11.6 Pa. The 24 mm diameter holes did not fail before 60 minutes for negative pressure differentials. For the hole sizes below 24 mm, only the 12 mm diameter hole at 11.6 Pa pressure differential failed before 60 minutes (48 minutes).

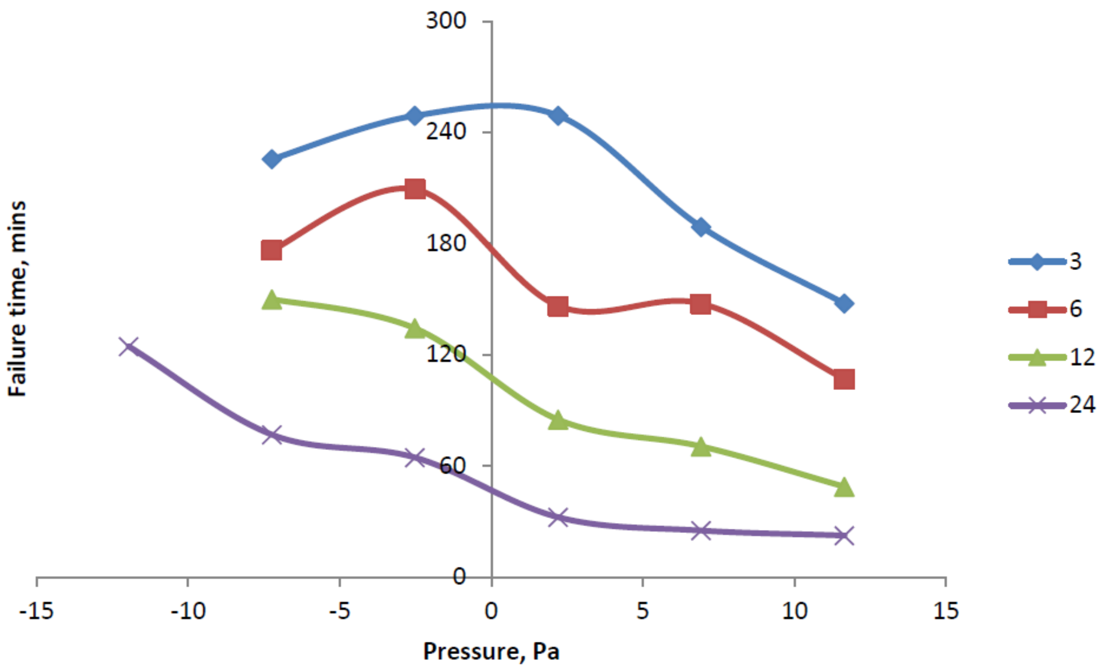


Figure 1. Time to integrity failure for 3–24 mm diameter holes in timber studs (Collier, 2013).

The trend in integrity failure for the vertical and horizontal gaps observed in the 2013 BRANZ research is shown in Figure 2. Integrity failures as soon as 10 minutes were noted at higher differential pressures, even for gaps as small as 2.6 mm. At differential pressures of zero or less, gaps of 3.2 mm up to the maximum tested 5.4 mm resulted in integrity failures at around 30 minutes.

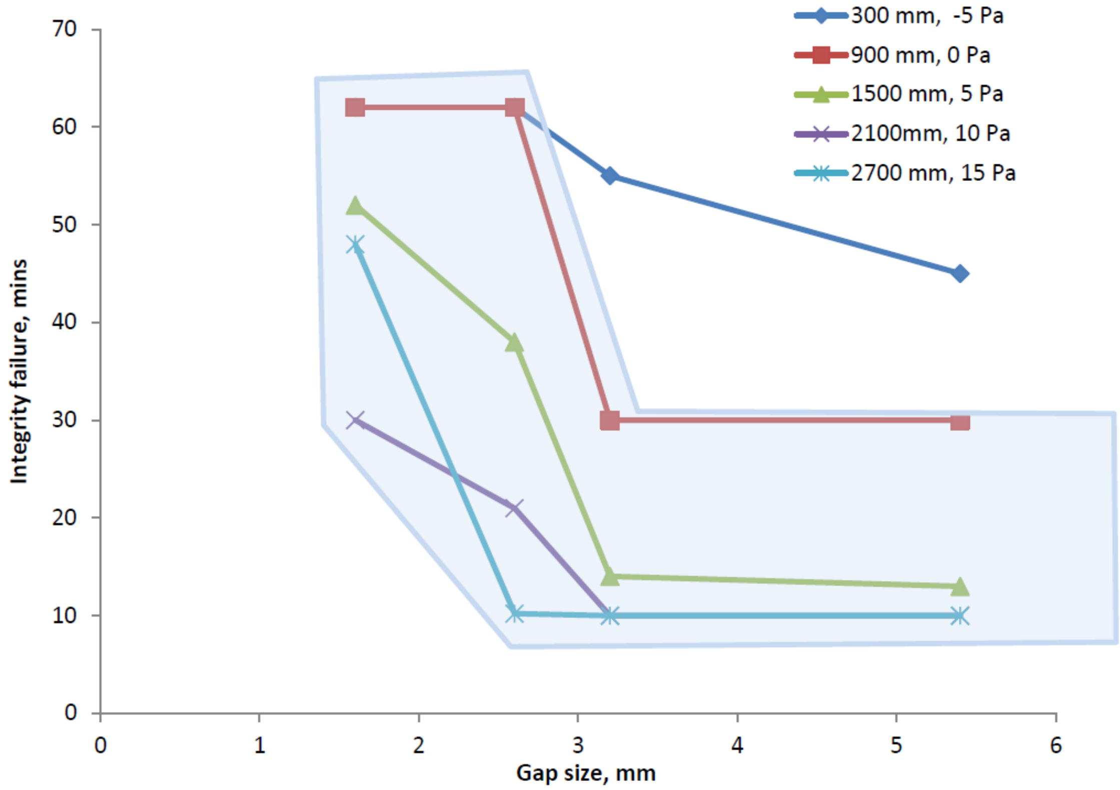


Figure 2. Integrity failures for gaps in timber-framed plasterboard walls (Collier, 2013).

For detached and cracked linings, the shortest time to integrity failure was noted to be 49 minutes for a loose 3 mm gap at the top of the specimen (fire exposed on both sides). The shortest time to insulation failure was noted to be 48 minutes for a loose 3 mm gap at the bottom of the specimen on the unexposed side.

General conclusions drawn in the 2013 BRANZ research included that, as gap size, pressure differential and elevation increase, fire resistance decreases. A decrease in oxygen concentration causes fire resistance to increase due to less combustion in and on the assembly itself. Pressure fluctuations tend to cause the fire resistance to go down due to a hypothesised 'whipsaw' effect where alternating hot combustion gases and cool high-oxygen content ambient air contributes to faster degradation of combustible elements of the assembly. The effect of temperature was described as ambiguous due to a reduction in heat-carrying capacity of hot gases beyond 200°C. The results of this research are useful for evaluating the potential integrity performance of fire separation penetrations.

3.2 United States

Valiulis and Phillips (2006) listed 12 common deficiencies found during firestopping inspections in the United States. The first deficiencies listed were categorised as general and included firestopping installations that did not reference either a tested system or engineering judgement (EJ) and an over-reliance on EJs. Through-penetration deficiencies listed next included annular space errors, insufficient depth of fill materials and cable penetrations exceeding their percent fill requirements. Construction joints and perimeter edge of slab joints rounded out the categories of deficiencies.

The National Bureau of Standards (NBS), now the National Institute of Standards and Technology (NIST) published a study that investigated construction deficiencies that led to fire spread in multi-family residential buildings (Vogel, 1977). Of the 84 fire incidents studied, 79 involved fire spread either vertically or horizontally to another apartment. A lack of proper firestopping between vertically connected firecells contributed to fire spread in 24 incidents. Pipe or duct penetrations through wood stud partitions were responsible for fire spread in 20 incidents. Beam and joist penetrations through firewalls were a factor in two incidents.

3.3 Australia

The Fire Code Reform Centre (FCRC) completed a series of furnace tests and room fire tests to investigate the influence of varying levels of workmanship (Blackmore et al., 1999). The first series of six tests investigated test walls in real rooms with representative fire loads. The second series consisted of furnace tests conducted to AS 1530.4-1990, and the third series consisted of furnace tests using the time-temperature curves from the first series of tests. Masonry and plasterboard/steel framing construction was investigated under non-loadbearing conditions.

The plasterboard construction nominally consisted of 16 mm fire-grade plasterboard on both sides of 64 mm steel studs. The 'bad' construction included gaps between sheets of plasterboard, larger screw spacing, broken edges and non-staggered plasterboard sheets. A 10 mm gap was present between two of the sheets and filled with plaster. One plasterboard sheet had every second fastener along the centreline driven so the screw head penetrated the paper. Every second screw on the gap side was to break the edge of the sheet. Fastener spacing was maintained at the standard spacing – 200 mm for screws on the perimeter and 300 mm spacing for screws along the centreline. The remaining two sheets had an increased fastener spacing of 375 mm. One of the sheets with increased fastener spacing also had every second screw adjacent to the gap break the edge of the plasterboard.

The performance of the standard and bad construction was not compared for the room fire tests. The room fire tests were found to be more severe than the standard furnace time-temperature curve up until 20 minutes and less severe afterwards. For the furnace tests, the bad construction plasterboard walls on average failed the insulation criteria 5 minutes earlier than the standard construction walls. Otherwise, there was no significant difference in the plasterboard wall performance, and all tests achieved greater than the 60 minutes fire resistance that they were designed for.

The masonry walls were constructed from 230 mm long x 110 mm thick x 75 mm ordinary dry pressed common bricks, using a mortar mix of one part type A Portland cement, one part lime and six parts bush sand. For standard workmanship, the walls were constructed using full beds and perpends. For the bad workmanship, mortar use was decreased. The incomplete application of mortar was estimated to affect 40–50% of the perimeter of the bricks to a depth of approximately 5–15 mm.

The masonry walls were tested to 240 minutes in the standard furnace. The three standard construction masonry walls failed due to insulation first at 105 ±2 minutes. One standard construction wall failed integrity at 220 minutes, while the other two did not fail integrity for the test duration. One of the bad workmanship walls failed integrity at 44 minutes and subsequently collapsed at 95 minutes. Another wall of similar construction collapsed at approximately 81 minutes but did not fail due to integrity or insulation prior. A third bad construction wall (that had slightly better construction reported) failed insulation at 98 minutes and collapsed at 147 minutes.

3.4 Canada

The National Research Council of Canada conducted a series of tests looking at the fire resistance of timber and steel-framed floor/wall junctions with a range of firestopping including no explicit firestop (Nightingale & Sultan, 1998). The performance of the firestopping approaches was evaluated on the basis of fire spread into the wall cavity after 15 minutes. This criterion was measured by either sighting of visible flames or temperatures in the wall cavity exceeding 550°C. An air gap was included in the wall cavity above the gap between the floor joist headers.

Air gap thicknesses of 13 mm, 25 mm and 38 mm were investigated. Firestops included a 13 mm OSB continuous subfloor under the wall, a 0.38 mm thick steel sheet installed under the bottom plate of the wall and two types of semi-rigid mineral fibre boards installed between the joist headers of the floor. The top of the wall cavity was covered with a top cap, which was opened to simulate a ventilated cavity at 15 minutes. All types of firestopping materials prevented flame spread into the wall cavity. The flames were contained within the subfloor assembly for the wood studs with a 13 mm air gap and no firestopping. Flames reached the wall cavity in 12 minutes and 4 minutes on the similar construction with 25 mm and 38 mm air gaps, respectively.

3.5 Japan

Mori et al. (2000) investigated the performance of plastic electrical flush boxes in timber and steel-framed plasterboard-lined walls using a small-scale furnace. Three treatments were considered, including no treatment, filling the void with 40 kg/m³ rock wool and sealing with a thermal intumescent. The use of plastic and aluminium covering plates was also investigated. Two layers of 12.5 mm plasterboard were used on each side, and two experimental series using test durations of 60 minutes and 75 minutes were run for the timber-framed experiments. Two layers of 21 mm plasterboard were used on both sides for the steel-framed tests, and the experiments were run for 120 minutes. The ISO 834-1:1999 *Fire-resistance tests – Elements of building construction – Part 1: General requirements* time-temperature curve was used for the experiments. Furnace pressure was measured to be 0.1–0.2 mmH_2O for the first 5 minutes of the test.

The unexposed side temperatures did not exceed 71°C for any of the experiments. This is not unexpected due to the thickness of plasterboard used in this research. Temperature measurement and observations of carbonisation (charring) within the cavity indicated that the treatments did limit temperatures and charring in the cavity space.

4. Building Act and Building Code requirements for building alteration consents

4.1 Building Act section 112

Section 112 of the Building Act provides the requirements for granting consent for existing buildings undergoing alterations.

112 Alterations to existing buildings

(1) A building consent authority must not grant a building consent for the alteration of an existing building, or part of an existing building, unless the building consent authority is satisfied that, after the alteration,—

(a) the building will comply, as nearly as is reasonably practicable, with the provisions of the building code that relate to—

(i) means of escape from fire; and

(ii) access and facilities for persons with disabilities (if this is a requirement in terms of section 118); and

(b) the building will,—

(i) if it complied with the other provisions of the building code immediately before the building work began, continue to comply with those provisions; or

(ii) if it did not comply with the other provisions of the building code immediately before the building work began, continue to comply at least to the same extent as it did then comply.

(2) Despite subsection (1), a territorial authority may, by written notice to the owner of a building, allow the alteration of an existing building, or part of an existing building, without the building complying with provisions of the building code specified by the territorial authority if the territorial authority is satisfied that,—

(a) if the building were required to comply with the relevant provisions of the building code, the alteration would not take place; and

(b) the alteration will result in improvements to attributes of the building that relate to—

(i) means of escape from fire; or

(ii) access and facilities for persons with disabilities; and

(c) the improvements referred to in paragraph (b) outweigh any detriment that is likely to arise as a result of the building not complying with the relevant provisions of the building code.

(3) This section is subject to section 133AT.

Section 133AT is specific to earthquake-prone buildings.

4.2 Means of escape review for works in existing buildings

The New Zealand Building Act 2004 section 7 defines means of escape from fire as follows:

> **means of escape from fire**, in relation to a building that has a floor area,—
>
> (a) means continuous unobstructed routes of travel from any part of the floor area of that building to a place of safety; and
>
> (b) includes all active and passive protection features required to warn people of fire and to assist in protecting people from the effects of fire in the course of their escape from the fire

The relevant Building Code clauses for means of escape are listed by MBIE (2013, 2014) as:

- C3.4 *Protection from fire* – Fire affecting areas beyond the fire source – Internal surface linings
- C4 *Protection from fire* – Movement to place of safety
- D1 Access routes
- F6 Visibility in escape routes
- F7 Warning systems
- F8 Signs

Clause C1(a) provides the overall objective that adequate provision for means of escape addresses being to safeguard people from an unacceptable risk of injury or illness caused by fire.

The functional requirements that will be affected by the performance of fire separations for means of escape include clauses:

- C4.1(b): Buildings must be provided with visibility in escape routes complying with clause F6
- C4.2: Buildings must be provided with means of escape to ensure that there is a low probability of occupants of those buildings being unreasonably delayed or impeded from moving to a place of safety and that those occupants will not suffer injury or illness as a result.

In relation to means of escape, fire and smoke separations keep fire and fire products out of the means of escape, allowing occupants the visibility to identify and traverse the escape route in a safe manner.

The performance clauses C4.3, C4.4 and C4.5 define the quantitative criteria that must be met to meet the above functional requirements:

- C4.3: The evacuation time must allow occupants of a building to move to a place of safety in the event of a fire so that occupants are not exposed to any of the following:
  (a) a fractional effective dose of carbon monoxide greater than 0.3
  (b) a fractional effective dose of thermal effects greater than 0.3

(c) conditions where, due to smoke obscuration, visibility is less than 10 m except in rooms of less than 100 m where visibility may fall to 5 m.

- C4.4: Clause C4.3(b) and (c) do not apply where it is not possible to expose more than 1,000 occupants in a firecell protected with an automatic fire sprinkler system.
- C4.5: Means of escape to a place of safety in buildings must be designed and constructed with regard to the likelihood and consequences of failure of any fire safety systems.

The means of escape is intended to provide occupants with a tenable environment for the time required to reach a place of safety. In the fire engineering profession, this is typically evaluated using an ASET-RSET (available safe egress time – required safe egress time) analysis. The ASET is the estimated time until untenable conditions in the means of escape are reached, and the RSET is the estimated time for occupants to reach a place of safety. If the ASET exceeds the RSET for a fire scenario, the means of escape provisions are sufficient.

However, the only way to predict the ASET and RSET times a priori requires many assumptions to be made regarding how a fire may develop in the scenario, how fire safety systems and the building will perform during the scenario and also the capabilities and actions of the occupants. Analytical and computational fire models are typically used, which will not perfectly represent any of these factors either. All of the uncertainties mean that some redundancy and conservatism is usually required, which is reflected in this statement from Determination 1993/004 (BIA, 1993):

> The Authority gave careful consideration to the consultant’s evidence but does not accept the consultant’s view that the provision of means of egress is simply a matter of exit times so that if the fire ratings are high enough there is no need for a second exit stair.

4.3 Building Code PFP requirements for full compliance

Demonstration of Building Code compliance for buildings can be established through meeting the criteria of Acceptable Solutions (C/ASx), a Verification Method (C/VM2) or by an alternative method. An alternative method allows the performance criteria of the Building Code to be met using engineering analysis, is specific for a given building design and can use any means that is shown through engineering analysis to meet the requirements of the Building Code. An alternative method becomes an Alternative Solution once it has been consented as being Code compliant by the BCA.

C/VM2 provides more prescriptive criteria for performing the engineering analysis. In C/VM2, fire resistance requirements are based on a full burnout fire, with a minimum FRR of 20 minutes. While the requirement of 20 minutes does not distinguish between the structural stability, integrity and insulation requirements. The test standard is not specified explicitly. C/VM2 does mention AS 1530.4-2005 in regard to the maximum FRR required for unsprinklered and sprinklered fire cells, but it is not otherwise mentioned as a requirement for compliance with the performance criteria in C/VM2.

For alternative method or Verification Method solutions, the basis for the PFP would have to be nominated and justified as meeting the performance requirements of the Building Code and/or the C/VM2 criteria. If the fire report that consent was originally based on is not available at the time alterations are taking place, the basis may need to be re-established when applying for a building alteration consent.

The requirement for PFP will typically depend on more factors than the means of escape. Property protection and firefighter access considerations are also normally required. The level of PFP required for occupant egress (perhaps based on an ASET-RSET analysis) and that required for property protection and/or firefighter access (perhaps based on full burnout of the fuel load in fire cells) may be different.

If the Acceptable Solutions are used as the means of establishing compliance with the Building Code, there are specific construction requirements for the fire separations to meet.

4.3.1 Acceptable Solutions

The C/ASx Acceptable Solutions provide prescriptive criteria for building design. For the purposes of this discussion, C/AS1 and C/AS2, which cover residential buildings, are discussed here, although the other protection from fire Acceptable Solutions have similarly structured requirements. C/AS1 is the Acceptable Solution for residential buildings that do not have shared means of escape and no more than one dwelling unit above another. Clause 2.3.1 FRR values states:

> Unless explicitly stated otherwise in this Acceptable Solution, the fire resistance ratings (FRRs) that shall apply for this risk group are as follows:
> Life rating = 30 minutes
> Property rating = 30 minutes.

Clause 4.1 Fire separation states:

> Each household unit, including any garage and escape routes in multi-unit dwellings, shall be fire separated from other household units and any escape routes with fire separations having an FRR of no less than 30/30/30.

In frequently asked questions on MBIE's website, it was noted that "any penetrations within internal fire separations should follow paragraph 4.4 C/AS2" in reference to C/AS1 buildings (MBIE, n.d.). While MBIE has removed this guidance it is assumed it is still accurate.

C/AS2 covers multi-unit non-institutional sleeping occupancies such as apartments, hotels and student accommodation. Relevant C/AS2 fire resistance and smokestopping requirements are included in Appendix C.

4.3.2 Compliant test methods

Appendix C of the C/ASx Acceptable Solutions lists:

> … test methods for confirming that specific building elements satisfy relevant provisions of the Acceptable Solutions for Protection from Fire. It includes both established standard tests and other test methods for building elements in situations where standard tests are unavailable.

Section C5.1 Fire resistance lists the allowable test methods to establish building assembly FRRs for acceptable solution compliance. It reads:

> C5.1.1 Primary and secondary elements, closures, and fire stops shall be assigned a fire resistance rating (FRR) when tested to:
>
> a) AS1530 Methods for fire tests on building materials and structures – Part 4: Fire resistance tests of elements of building construction, or

b) NZS/BS 476 Fire tests on building materials and structures – Parts 21 and 22.

C5.1.2 Fire stops shall be tested:

a) In circumstances representative of their use in service, paying due regard to the size of expected gaps to be fire stopped, and the nature of the fire separation within which they are to be used, and
b) In accordance with AS 4072: Components for the protection of openings in fire-resistant separating elements – Part 1: Service penetrations and control joints.

4.3.3 Formal opinions and engineering judgements

Engineering judgement is a term widely used in industry for untested PFP assemblies, but this term is not recognised in the New Zealand fire safety compliance documents. AS 4072.1-2005 does allow formal opinions, with the following description of what is required for a formal opinion from section 4 of this standard:

> The basis of this Standard is the interpretation of data taken from testing a specimen sealing system in accordance with AS1530.4 and the subsequent application of the test data to systems that incorporate minor variations from the tested specimens.
>
> Variations from the tested specimens shall be—
>
> (a) Approved by the regulatory authority or other authority having jurisdiction;
> (b) Permitted in accordance with AS1530.4; or
> (c) Certified in writing by a registered testing authority—
> (i) To be acceptable in terms of this standard
>
> (ii) To be capable of achieving a specified fire resistance level when subjected to the fire resistance test.
>
> A full justification shall be included with the statements set out in Item (c), giving details of the test data, and any limitations on the use of the tested specimen.

AS 4072.1-2005 section 4 further provides guidance regarding the preparation and presentation of formal opinions. This guidance states that formal opinions:

> … shall be derived directly from the full-scale fire resistance test results, by means of a technical analysis of the effects of the proposed variations in relation to the failure criteria of the fire resistance test … Formal opinions shall be prepared by competent persons experienced in both testing and writing laboratory reports on service penetrations and control joints of similar construction to those proposed.

Auckland Council firestopping position statement

Auckland Council has produced a position statement that clarifies their expectations for acceptable firestopping systems (Auckland Council, 2018). The terminology of Alternative Solutions is used to describe systems that do not meet the AS 1530.4-2005 or AS 4072.1-2005 compliance requirements and are not listed on the FPANZ register (FPANZ, 2018). The position statement indicates that these types of systems will only be accepted if it is demonstrated that there are no compliant available systems readily available on the market.

Alternative Solutions must be supported by the product manufacturer for the proposed usage circumstances including product durability and warranty requirements. Systems tested to overseas standards only are also defined as Alternative Solutions, and suitable evidence is required from someone suitably experienced and knowledgeable about the testing requirements. This party is expected to be the product manufacturer.

The second revision of this position statement also has specific consent documentation and approval requirements. Drawings showing all fire separations with required FRR and associated construction details (or reference to specifications) must be included. The plans showing the necessary fire separations are also to be included in the Compliance Schedule and updated when alterations occur.

International guidance on engineering judgements

There is international guidance on the use of EJs to evaluate firestop systems. The International Firestop Council based in the United States publishes guidance on the use of EJs (IFC, 2007):

> 1. Not to be used in lieu of tested systems when available;
>
> 2. Be issued only by a firestop manufacturer's qualified technical personnel or in concert with the manufacturer by a knowledgeable registered Professional Engineer, Fire Protection Engineer, or an independent testing agency that provides listing services for firestop systems;
>
> 3. Be based upon interpolation of previously tested firestop systems that are either sufficiently similar in nature or clearly bracket the conditions upon which the judgement is to be given…
>
> 4. Be based upon full knowledge of the elements of the construction to be protected, the understanding of the probable behaviour of that construction and the recommended firestop system protecting it were they to be subjected to the appropriate Firestop Standard Fire Test method for the rating indicated on the Engineering Judgement;
>
> 5. Be limited only to the specific conditions and configurations upon which the engineering judgement was rendered and should be based upon reasonable performance expectations for the recommended firestop system under those conditions;
>
> 6. Be accepted only for a single, specific job and project location and should not be transferred to any other job or project location without thorough and appropriate review of all aspects of the next job or location's circumstances.

The IFC also gives requirements for EJ presentation, which include complete descriptions of elements, proper justification including reference to tested systems that the EJ is based upon, clearly indicating the nature as an EJ, clear installation instructions and identification of the job and project information that the EJ is issued for.

The National Research Council of Canada also provides guidance for EJs in addition to the IFC guideline (Richardson, Quirt & Hlady, 2007). It is recommended that the EJ should be prepared by someone "independent of the manufacturer or others involved in the specific application". An explanation of "why the applicable code requirement (or listing requirement) cannot be met using a listed fire stop system" is suggested, along with "any special instructions related to long term performance".

ASTM E2750-17

ASTM E2750-17 *Standard guide for extension of data from penetration firestop system tests conducted in accordance with ASTM E814* provides guidance on when extending fire test results to untested penetration firestop systems might be acceptable. This includes some general principles for firestops in concrete or masonry assemblies and gypsum board wall assemblies. One of the key principles that applies in most cases is that "firestop systems cannot be used in assemblies of lower fire resistance without fire testing".

For concrete assemblies, this is modified to allow firestop installation in:

> … assemblies of equal or lower fire resistance as long as the firestop system tested design is not modified in relation to firestop thickness, bonding and support, and is not modified in relation to the assembly thickness.

There is also specific guidance for specific types of penetrations. For example, section 6.9 covers non-metallic pipe penetrations:

> 6.9.1 The fire resistance of a tested system is deemed applicable to a similar type of untested system when only one of the following changes is made:
>
> 6.9.1.1 The penetrant wall thickness is not changed.
>
> 6.9.1.2 Penetrations that are tested can be used for both vented and closed application without reducing the F-rating.
>
> 6.9.1.3 The pressure required for the installed firestop system must be within the tested range.
>
> 6.9.1.4 The penetrant diameter must be within the tested range.
>
> 6.9.1.5 The type of plastic (PVC, etc.) cannot be changed without fire testing.
>
> 6.9.1.6 The firestop material composition cannot be changed.
>
> 6.9.1.7 The ratio of penetrant cross-sectional area to firestop material cross-sectional area cannot be changed.
>
> 6.9.1.8 The number of penetrants in one opening must be within the tested range.
>
> 6.9.1.9 The separation between penetrants must be within the tested range.
>
> 6.9.1.10 The orientation of the firestop systems must not be changed.

4.3.4 What does ANARP mean?

As near as reasonably practicable (ANARP) has been interpreted slightly differently in different cases, but the existing precedent in New Zealand BIA, DBH, and MBIE determinations (including one that went to the High Court) provides clarity for the intended New Zealand Building Act purpose. The term "reasonably practicable" was established in English law in the 1949 case of *Edwards vs National Coal Board* in the UK.

MBIE has previously provided guidance on what the term ANARP means (MBIE, 2016b):

> This ratchet mechanism is a useful means by which the nation's building stock can be upgraded for safety, health, and access by people with disabilities, whenever the owner is doing other building work. It is therefore important that the evaluation to decide the extent of the upgrade is effective, whenever the conditions exist for section 112 … to be invoked.
>
> While the wording between the previous and current Act has changed slightly, the intent and detail remains, so the experience and knowledge gained under the 1991 Act can be applied.

A graphical explanation is provided as shown in Figure 3.

> The graph illustrates a number of points. Firstly it shows an increasing return (benefit) from an increasing level of sacrifice. Secondly, it shows that a point is reached where a significant increase in the sacrifice is made for a comparatively small gain in the resulting benefits. It can be argued that this defines the point "as near as reasonably practicable" (ANARP).

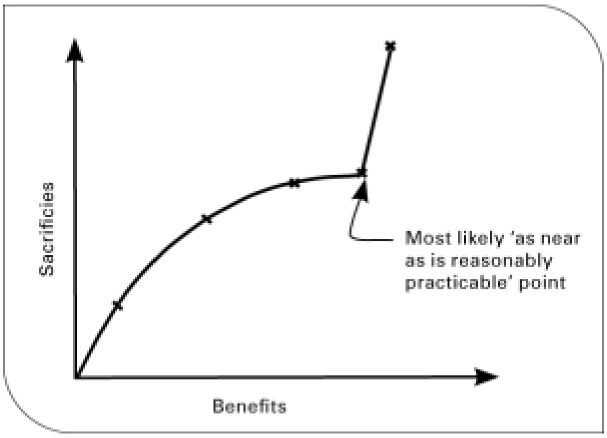


Figure 3. Sacrifices and benefits for ANARP analysis.

However, MBIE (2016b) also noted:

> Identifying and evaluating "as near as reasonably practicable" (ANARP) is not an easy task. That is why building consent applicants do not always provide a clear analysis on which a decision can be made. A proper analysis is based on an evaluation of the sacrifices and benefits.

Determination 1993/004 (BIA, 1993) provides an early example of the application in the New Zealand Building Act 1991. The applicant for this determination was the New Zealand Fire Service (NZFS) and the matter to be determined was the fire safety requirements for an office building conversion to residential apartments. The building had a single means of escape that was intended to serve apartments on 10 floors, was unsprinklered and had a Type 5 fire alarm system and an escape route pressurisation system. The Acceptable Solution at the time required two means of escape to serve more than four floor levels, unless a sprinkler system was installed, which increased the limit to six floor levels. The territorial authority (TA) had issued a building consent on the basis that a sprinkler system was not required and an additional means of escape was not required either.

The NZFS had submitted a letter to the TA concluding that:

> … if it is not reasonably practical to bring the building into compliance for the safety of the occupants of the building, the change of use should not be permitted.

The decision from the BIA in the determination was as follows:

> In accordance with section 20(a) of the Building Act the Authority hereby modifies the territorial authority's decision to issue a building consent for the building by requiring that a Type 7 sprinkler system shall be substituted for the Type 5 alarm system but with no other alteration to what is required by the current building consent.

The determination was then appealed and cross-appealed to the High Court by the territorial authority and the NZFS, respectively.[2]

The questions raised by the TA authority included the following:

> (e) Did the authority adopt an incorrect test for meeting the requirements of s 46 of the Act?
>
> (f) Was the authority correct in law in applying the standards set out in its approved documents as requirements for fire safety to the exclusion of other possible means of providing for fire safety, to the standard required by the building code?

The NZFS contended the following:

> (a) The assessment by the authority of the requirements of s 46 of the Building Act were wrong.
>
> (b) That its interpretation of the phrase "nearly as is reasonably practicable" where that appears in s 46 of the Building Act was wrong.
>
> (c) That the assessment by the authority of the time at which the reasonably practicable test fell to be determined, was wrong.
>
> (d) That the authority's assessment as to what measures were reasonably practicable in the particular circumstances, was wrong.
>
> (e) That the authority's conclusion that a second means of egress was not required, was wrong.

The Court decision provided discussion of the interpretation of the term "reasonably practicable". Judge Gallen made the following comments:

[2] *Auckland City Council v New Zealand Fire Service* [1996] NZHC.

> To equate "not reasonably practicable" with "virtually impossible" is I think to, at least in the circumstances of the Act, remove the significance of the word "reasonably".
>
> In the end, what the cases say is that the obligation is not absolute. It must be considered in relation to the purpose of the requirement and the problems involved in complying with it, sometimes referred to as "the sacrifice." A weighing exercise is involved. The weight of the considerations will vary according to the circumstances and it is generally accepted that where considerations of human safety are involved, factors which impinge upon those considerations must be given an appropriate weight.
>
> It seems to me that the use of the words "reasonably practicable" is designed to allow a commonsense, overall appraisal to take place.

In regard to the use of the Acceptable Solutions as a means to demonstrate compliance with the Building Code, Judge Gallen said:

> The acceptable solution is not an exclusive one. As the authority itself said, it is a guideline or a benchmark. To that extent, any deviation from it must achieve the same objectives, but whether it does or not is a question of fact.

The key outcomes of this High Court decision for this project is the interpretation of what "as near as reasonably practicable" means. Additionally, it provides clarification on how the Acceptable Solutions and alternatives are viewed by the High Court as means of satisfying the Building Code requirements.

Determination 2006/77 (DBH, 2006) provides additional clarification relevant to this project. The first aspect is that the Building Code does not differentiate between new and existing buildings when it comes to compliance. This means that compliance of existing buildings is not grandfathered to the Building Code "of the day" when the building was constructed.

Secondly, Determination 2006/77 provides clarity for using the Acceptable Solutions as a basis of comparison for Alternative Solution compliance. The determination states:

> However, once any particular acceptable solution has been issued in a compliance document, then under section 19(1)(b) that acceptable solution must be accepted as establishing compliance with the Building Code unless and until the acceptable solution is amended or revised by the consultative procedures of section 29. To say that an acceptable solution is "not proven" is to misunderstand its legal status.

Determination 2006/77 also discusses the use of overseas documents to establish Building Code compliance for protection from fire:

> However, fire safety levels involve such complex interactions that the level achieved by an overseas document is not necessarily the same as, or higher than, that achieved by C/AS1.

Determination 2006/77 provides clarification on proposals to postpone or stage upgrades:

> As to postponing upgrading, or undertaking it in stages, as currently advised I take the view that proposals along these lines may be taken into account by a territorial

authority when it is considering what is "reasonably practicable". However, the territorial authority will also need to take into account that:

> (a) The test remains the balance between benefits and sacrifices
> (b) Postponing or staging any particular item of upgrading will frequently reduce the corresponding sacrifice by minimising disruption and reducing costs, or by at least improving cash-flow. However, the delay will always reduce the corresponding benefit.
> (c) There might be enforcement difficulties. If the upgrading is not in fact completed on time, the territorial authority could refuse to issue any outstanding code compliance certificates, but that could well be ineffective. Similarly, the territorial authority could threaten prosecution under the dangerous and insanitary buildings provision of the Act, but the fact that a building that does not comply as nearly as is reasonably practicable with certain provision of the Building Code does not necessarily mean that the building is dangerous or insanitary in terms of sections 121 and 123.

Finally, Determination 2006/77 discusses the level of rationalisation possible given the state-of-the-art fire engineering practices:

> I consider that, at least in respect of fire safety, it is not yet possible to express all of the relevant considerations in the same terms, so that one must inevitably compare apples with oranges, although I understand that there are some emerging tools and techniques that will improve the quality of decision-making. In other words, in the present state of knowledge there must be a subjective element in the decision as to what items of upgrading are reasonably practicable in any particular case. That being so, it seems appropriate that the decision must be made by a territorial authority or by the Chief Executive, being persons acting independently in the public interest.

4.4 Grenfell Tower fire interim report

The Grenfell Tower fire, which occurred on 14 June 2017, has brought worldwide attention to bear on fire safety in buildings. This fire involved a 24-storey residential building with public housing flats, causing 71 deaths. There were a multitude of factors that potentially contributed to the deaths, including combustible cladding, lack of sprinklers, a single means of escape, a defend-in-place evacuation strategy, lack of a building-wide interconnected alarm system and fire separation defects. At the time of writing this report, no definitive investigation report has been released that confirms the relative importance of these factors. However, an interim report on the state of building regulations and fire safety in the UK has been released (Haskitt, 2017), which has also investigated the state of building regulations and fire safety internationally. It provides some pertinent comments regarding the New Zealand building alteration requirements.

Section 5.16, which discusses requirements for existing buildings, states:

> Very few of the countries researched have a clear regulatory mechanism for ensuring that significant changes to existing buildings require fire safety measures to be brought in line with requirements for new buildings. It is more usual for those responsible to be required to ensure that any material modification or change in use results in "no worsening" of the fire safety system and its expected effectiveness in the building. There are exceptions, namely in the USA and Hong Kong, where there is clear guidance on the threshold at

> which any changes to existing buildings must meet new fire safety guidelines, and in New Zealand. But we have found only limited evidence of this taking place routinely or consistently, and a number of countries are looking actively at this particular fire safety issue.

A sidebar discusses New Zealand as a case study:

> In New Zealand, the Building Act 2004 requires that buildings must be brought to comply "as nearly as reasonably practicable" with the provisions of the Building Code where:
>
> - a change of use of a building is intended, which involves the incorporation in the building of one or more household units where household units did not exist before, then the building in its new use must comply in all respects; or
> - alterations to, or a change in use of, existing buildings are intended, then the means of escape from fire and access and facilities for people with disabilities must comply.
>
> This requirement demonstrates a move to improve fire safety cumulatively in existing stock, particularly in that considered to be high risk. This is not a new legal concept, with similar requirements seen in other legal mechanisms for evaluating safety systems in New Zealand. However, implementation is not always consistent.

In other words, New Zealand has been identified in this international building regulation review as one of a handful of countries that requires upgrades to be made to existing buildings. This does provide perspective on the ANARP principle in the Building Act. While full compliance is desirable, the key is that there is some improvement and the costs of that improvement need to be considered and balance with the benefits.

4.5 MBIE guidance on requesting information about means of escape from fire for existing buildings

MBIE (2013) has provided guidance intended to assist BCAs and TAs in determining how much information to request regarding the means of escape from fire in consent applications for alteration work on existing buildings. The guidance notes specifically that "it does not address the actual decision BCAs or TAs must make about any building consent application, including those required by the Building Act".

This document provides a scoring system to determine the level of recommended information to request regarding the means of escape. Examples of the aspects that may affect the means of escape are:

- fire-rated walls, doors, floors and ceilings anywhere on the escape route
- the internal surface finishes of walls, ceilings, and floors
- escape route lengths and their capacity
- fire detection and alarm systems that warn people of a fire and initiate their escape
- suppression systems that control fire and stop it spreading from its source
- visibility in escape routes
- wayfinding systems including signs.

There are three levels of information requirements based on the results of the scoring system, as listed in Table 1.

Table 1. MBIE-recommended means of escape from fire information.

Score	Description	Recommended information
0–11	List of fire safety features statement of changes	Can be a simple list of existing fire safety features and a statement of proposed changes or a comparison with the latest design documentation.
12–19	Gap assessment using appropriate Acceptable Solution	Highlight where existing building fully complies with the Acceptable Solution, where there are gaps. ANARP assessment should be made for each gap. Should cover the entire building.
20+	Full assessment using appropriate Acceptable Solution or relevant parts of Verification Method C/VM2 and other Acceptable Solutions	Full assessment of existing means of escape unless individual circumstances suggest otherwise. If building falls entirely within C/ASx Acceptable Solutions, this assessment can be used in a subsequent gap analysis for proposed changes. If the building falls outside the C/ASx Acceptable Solutions, either Verification Method C/VM2 or an Alternative Solution should be used with justification for how it meets the Building Code protection from fire clauses.

4.6 Determination 2016/048

MBIE determination 2016/048 (2016a) concerned non-compliant PFP that was exposed during weathertightness remediation work in an existing terraced housing development. The owners of the property (represented by a building consultant) had applied for a building consent to undertake the remedial work but disagreed with the building consent authority's requirements and filed an application for determination. The development consisted of 56 3-storey (basement at ground level, living spaces on the second level and bedrooms on the third level) terraced townhouses in four blocks, constructed in 2003/04. Each unit had an independent means of escape with a dead-end open path length less than 25 m (required in C/AS1 when combined with a Type 1 (domestic smoke alarm) system as was present in each bedroom and above the landing on level 3).

The non-compliant PFP involved the inter-tenancy walls (30/30/30 required FRR) between adjacent units, which were constructed of light timber framing lined with two layers of 10 mm plasterboard on acoustic battens on one side and one layer each of 10 mm and 13 mm plasterboard on the other side. At inter-storey floor levels, timber blocking consisting of two 250 x 50 mm boundary joists on a pair of 100 x 50 mm top plates was present. The determination implies that there was no plasterboard on this timber blocking, but a ceiling lining of 13 mm plasterboard was present. The timber blocking was located in the void above the ceiling lining.

The remedial weathertightness work included "removal and replacement of cladding and damaged timber framing, along with some internal plasterboard linings". As the boundary joists were exposed by removing the ceiling lining, observations were made of non-compliant electrical cable penetrations (typically one to three cables, but occasionally bundles up to 12). These penetrations had either no firestopping or intumescent sealant applied directly to the timber. There were also locations where a gap between the timber framing and the boundary joists existed. Instances were found of plastic electrical flush boxes with no intumescent pads installed in the inter-tenancy wall, plasterboard not fixed in accordance with the manufacturers' instructions and structural steel fire protection not applied. There had been a debate among the stakeholders regarding if all penetrations and gaps in the inter-tenancy walls should be remedied, including those not otherwise exposed for weathertightness work.

This determination decision only addressed the compliance of the cable penetrations and framing gaps associated with the boundary joists. The proposed solution (Figure 4) was deemed to comply for penetrations with up to three cables in a bundle. It was stated that there was insufficient evidence for larger cable bundles and framing gaps that had not been exposed. This decision was based on the expert opinions provided by several parties during the course of the determination. While the determination referenced the previously mentioned section 112 requirements, which only require ANARP compliance for means of escape from fire, the current Building Code functional requirement clause that was referenced was C3.3 which stated: "Buildings must be designed and constructed so there is a low probability of fire spread to other property vertically or horizontally across a relevant boundary." The determination decision also investigated the issue of whether PFP should be investigated and remediated beyond the areas exposed for the weathertightness remediation. If the exposed PFP is not compliant, the PFP in the rest of the building may also be assumed to be problematic. The determination concluded that this would be going beyond what would be considered reasonable and practicable.

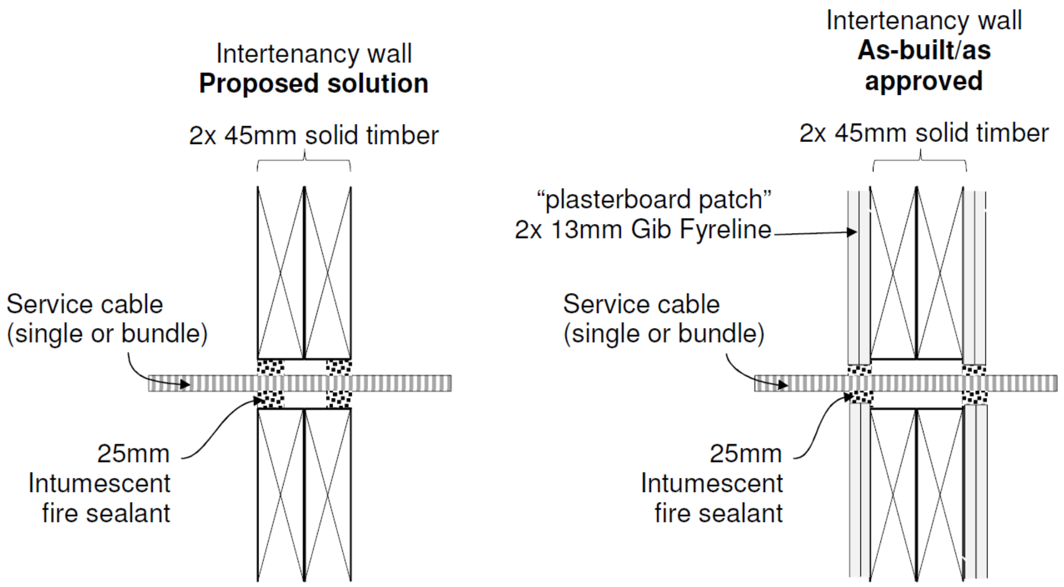


Figure 4. Proposed and approved timber boundary joists cable penetration solutions (MBIE, 2016a).

Determination 2016/048 (and other observed instances of non-compliance from other site visits) highlights a key aspect of the problem: as-built construction often does not match compliant construction details. The performance of the actual construction under standard fire resistance test conditions is not known. To investigate further, a test programme investigating the fire resistance test performance of typical non-compliant as-built penetrations in New Zealand residential construction was undertaken.

5. Penetration defect testing

Usually the only available fire test data is that provided by manufacturers for their recommended assemblies. More detailed information regarding how assemblies fail and also the test performance of assemblies that do fail is not made available due to commercial sensitivities. One of the major knowledge deficiencies that has been noted anecdotally among fire engineers is fire resistance testing, because only registered testing facilities or product manufacturers generally conduct fire resistance testing and, as previously stated, this information is not made public. Hence, the only exposure fire engineers might get to a fire resistance test would be possible if they were employed by a testing facility or product manufacturer at some point in their career.

This is a major limitation when fire engineers are asked to assess the risk of construction that varies from the recommended configuration. While fire engineers do not typically have competence in this area, many do provide engineering judgement as to the compliance of specific assemblies regardless.

The test data available from the manufacturer is typically only in terms of a three-number FRR representing structural stability/integrity/insulation (as an example, a 30/30/30 rating means 30 minutes structural stability/30 minutes integrity/30 minutes insulation). The fire resistance will only be reported in increments of 15 minutes, 30 minutes or 60 minutes. The amount that the tested specimen lasted beyond the reported number is unknown. A 60-minute rated assembly could have lasted 61 minutes or 89 minutes in the test. For example, a round-robin comparison between 32 European fire labs for a steel-framed plasterboard-lined wall showed integrity and insulation failure ranging from 36 minutes to 80 minutes and 36 minutes to 68 minutes, respectively (Dumont, 2010). A system may have been tested multiple times, including in multiple laboratories, until a pass result was obtained. There is no requirement for individually tested assemblies to have reliably repeatable performance.

In order to understand how typical non-compliant construction might perform in a standard fire test and to make some of the full test data available to fire engineers, a programme of testing was undertaken for this project. Some of the penetrations had firestopping installed and some did not. During the course of discussions with the stakeholder group, it was decided to not release specific test details for penetrations with firestopping products installed due to the aforementioned commercial sensitivities. Therefore, specific discussion in the following sections is limited to penetrations with no firestopping installed. However, aggregate statistics on the performance of all of the penetrations is presented. Anonymised test reports are included in Appendix B.

5.1 Planning

5.1.1 Penetration selection

Auckland Council building inspectors suggested a number of observed defects to test over the course of the Auckland site visits. This list along with the recorded defects and other observations made during the site visits were used to develop an initial test plan. This plan was shown to Auckland Council representatives for initial feedback and guidance as to typical materials of construction.

Penetration details were chosen based on four criteria: the number of penetrations that could be tested, the most commonly observed defects, defects for which the performance was questionable and a systematic approach to look at a range of construction from no firestopping to nearly compliant firestopping. The quantity of penetrations that could be tested was limited by the test furnace time available and the AS 1530.4-2005 standard requirements, which were followed for the tests.

As the most common PFP defects reported were related to service penetrations, it was decided to focus mainly on a range of typical cable and pipe penetrations found in New Zealand residential construction. Whole wall or ceiling defects such as insufficient lining material, supporting construction or fixings were not considered.

The services tested were as follows:

Cable – included in all test specimens

- 1 cable
    - 12 x 6 mm 3-wire main 2.5 mm²
- 3-cable bundle
    - 2 x 3-wire main as per 1 cable
    - 1 single wire earth 6.0 mm²
- 12-cable bundle – this case was also tested using a cable collar
    - 7 x 3-wire main as per 1 cable
    - 1 single wire earth as per 3-cable bundle
    - 2 x Cat. 6 network cable
    - 1 RG6 coaxial
    - 1 optical fibre patch lead

Pipe

- 20 mm Polybutylene
    - Timber boundary joist specimen only
- 40 mm uPVC
    - All specimens except timber boundary joist
- 65 mm uPVC
    - Horizontal test specimens only
- 100 mm uPVC
    - Plasterboard and fibre-cement board walls only

Penetration diameters were determined by using common tooling sizes. While there was some variation between construction types particularly at the larger hole sizes, this method was used to reflect what would most likely be observed in real buildings.

As per AS 1530.4-2005 requirements, all the plastic pipes were capped on the exposed side but not on the unexposed side. All pipes protruded a minimum of 500 mm into the furnace and at least 2,000 mm beyond the unexposed face. The pipes were supported at 500 mm and 1,500 mm on the unexposed side. No plastic pipe penetrations were tested with no firestopping, on the basis that they would fail integrity as soon as the plastic pipe melted. All cables protruded a minimum of 500 mm on both the exposed and unexposed sides. In most cases, spacing between the edges of the penetrations, adjacent penetrations and the edge of the specimen was maintained at a minimum of 200 mm. There were a few instances where the spacing decreased to a minimum of 170 mm, but this was not expected to influence the test results.

The stakeholder group was also given the opportunity to comment on the chosen penetration details prior to testing.

5.1.2 Test specimen selection and layout

Furnace time to complete five tests was available. These tests comprised three vertical (wall) and two horizontal (ceiling) tests. The vertical tests were conducted using the main furnace and included three main substrate types: a 60-minute plasterboard wall, a 30-minute cement board wall, and solid timber joists in a wall configuration similar to that described in Determination 2016/048. The horizontal tests were both undertaken using the pilot scale furnace and covered a plasterboard ceiling/strand board floor system and a concrete rib and timber infill system. Each test was given a two-letter code as described in Table 2. Due to the pressure gradient in the furnace when operating in a vertical orientation and the AS 1530.4-2005 standard requirements, it was necessary to keep all wall test penetrations within two horizontal rows across the width of the test frame. While it is physically possible to place penetrations outside this strip, it will result in pressures that are not representative of a real environment and may result in altered performance from some of the intumescent type seals.

Table 2. Test specimen letter codes.

Substrate	Test code
60-minute plasterboard wall	PV
30-minute solid timber joists	TV
30-minute cement board wall	CV
60-minute plasterboard ceiling/strand board floor	PH
60-minute timber infill floor	CH

Plasterboard wall construction (test PV)

The plasterboard wall supporting construction consisted of a 45 x 90 mm H1.2 timber frame of 3,000 x 3,000 mm nominal dimensions (Figure 5).

Figure 5. Plasterboard wall framing.

Studs were placed at nominal 600 mm centres and nogs were placed at 1,200 mm centres. Both the exposed and unexposed sides were sheathed with 13 mm fire-rated plasterboard and fixed as per the manufacturer's specifications, using 41 mm x 6g high thread drywall screws at 300 mm centres around the sheet perimeter and on intermediate studs, 12 mm from bound sheet edges and 18 mm from the sheet ends. All fastener heads were stopped and all sheet joints tape reinforced and stopped as per the manufacturer's specifications. No insulation was placed in the wall cavities.

Timber boundary joist construction (test TV)

The timber joist system was somewhat unique from the rest of the test cases as it is based on the findings of MBIE Determination 2016/048 instead of an existing tested substrate construction system (Figure 6). Plasterboard pattresses were designed per the information in the determination, which specifies two layers of 13 mm fire-rated plasterboard extending for a minimum of 75 mm beyond the edge of the penetration.

Figure 6. Boundary joist construction.

The supporting construction consisted of a 45 x 90 mm H1.2 timber frame of 3,000 x 3,000 mm nominal dimensions. Studs were placed at nominal 600 mm centres. Two layers of 10 mm thick fire-rated plasterboard were fixed to the exposed side. The unexposed side had one layer each of 10 mm and 13 mm thick fire-rated plasterboard fixed. The plasterboard was attached as per the manufacturer's specifications for an acoustic assembly with similar lining thicknesses. All fastener heads were stopped and all sheet joints tape reinforced and stopped as per the manufacturer's instructions. No insulation was placed in the wall cavities.

Fibre-cement board wall construction (test CV)

The fibre-cement board wall supporting construction consisted of a 45 x 90 mm H1.2 timber frame of 3,000 x 3,000 mm nominal dimensions (Figure 7). Studs were placed at nominal 300 mm centres and nogs were placed at 800 mm centres.

Figure 7. Fibre-cement board wall framing.

The exposed side was lined with 6 mm thick fibre-cement board, and the unexposed side was lined with 10 mm thick fire-rated plasterboard. The linings were fixed as per the manufacturer's instructions. The fibre-cement board was fixed using 40 x 2.8 mm stainless steel nails at 150 mm centres. The plasterboard was fixed at 300 mm centres around the sheet perimeter and on intermediate studs with 41 mm x 6 g high thread drywall screws. All vertical fibre-cement board joints were tape reinforced, the plasterboard fastener heads were stopped and the plasterboard joints were taped and stopped as per the manufacturer's instructions. Glass batt insulation was installed in the wall cavities as per the manufacturer's tested assembly.

Plasterboard ceiling/strand board floor construction (test PH)

The test specimen substrate was constructed in accordance with a tested floor-ceiling system, which is listed by the manufacturer as having a 60/60/60 FRR (Figure 8).

Figure 8. Plasterboard ceiling/strand board floor framing.

The timber frame was constructed of H1.2 treated SG8 240 x 45 mm *Pinus radiata* joists, with a maximum spacing of 475 mm. The flooring was 20 mm thick tongue and groove high-density reconstituted wood strand board, and the ceiling was 16 mm thick fire-rated plasterboard. The plasterboard was fastened as per the manufacturer's specification with 51 mm x 7g high thread drywall screws at 150 mm centres around the sheet perimeter and at 200 mm centres along each joist. The flooring was fastened with 45 mm x 8g chipboard screws at 150 mm centres around the sheet perimeter and 200 mm centres on the intermediate joists. No insulation was installed in the joist cavities.

Rib and timber infill floor construction (test CH)

To simplify the construction of the rib and infill system, the test case was undertaken using the pilot furnace as its reduced dimensions mean that the infill can be supported directly by the test frame. To ensure that the rest of the test is completely representative, the concrete slab was designed to include ductile mesh reinforcement capable of carrying a typical design live load ($Q = 3\ \mathrm{kPa}$).

The timber infill floor was constructed of H3 treated No. 1 framing grade 200 x 25 mm rough sawn *Pinus radiata*, spanning the 1,000 mm width of the pilot furnace (Figure 9). The timber was placed in a 1,200 x 2,500 mm frame made of structural steel channel that was larger than the pilot furnace test frames. An SE62 seismic mesh reinforcement was used with a minimum 25 mm cover from the top surface. A 75 mm thick concrete topping using a maximum aggregate size of 13 mm and minimum strength of 25 MPa was used. At the time of test, the concrete density was 2,400 kg/m³ and the moisture content was 12.7%.

Figure 9. Timber infill floor slab (75 mm concrete topping).

5.2 Test procedure

5.2.1 Test conditions

The AS 1530.4-2005 requirements were generally followed. All tests were conducted for 60 minutes regardless of whether the supporting construction was nominally fire rated for 30 or 60 minutes. The standard time-temperature curve with acceptable deviations was followed. An example from test PV is shown in Figure 10. Accuracy of the time-temperature curve was maintained within limits shown in Figure 11.

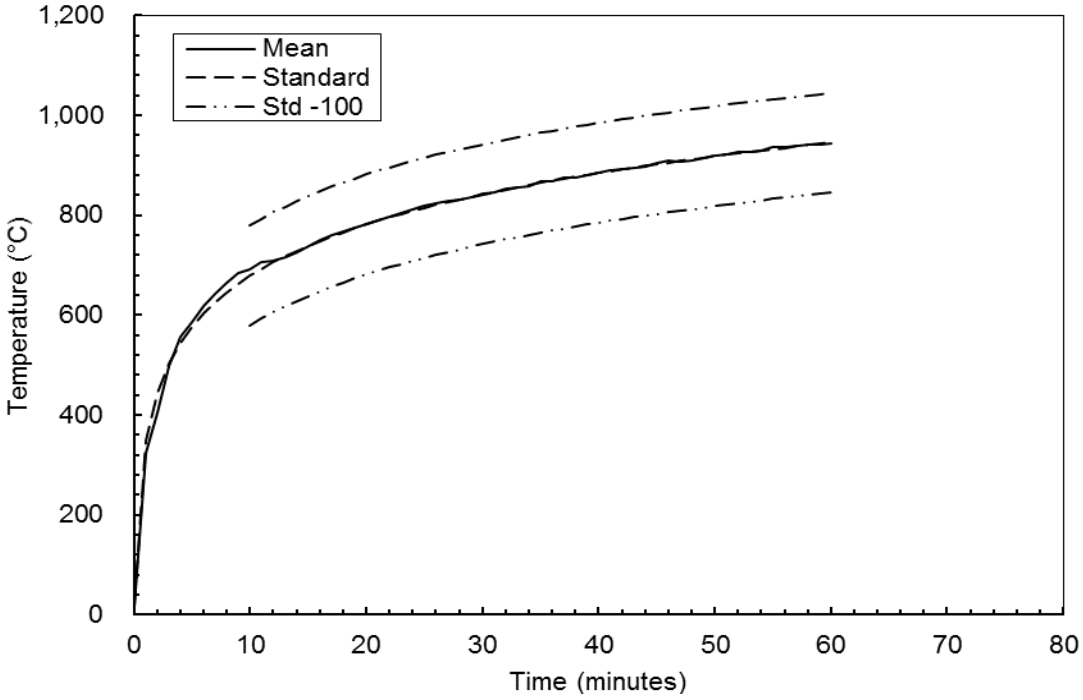


Figure 10. Test PV time-temperature curve.

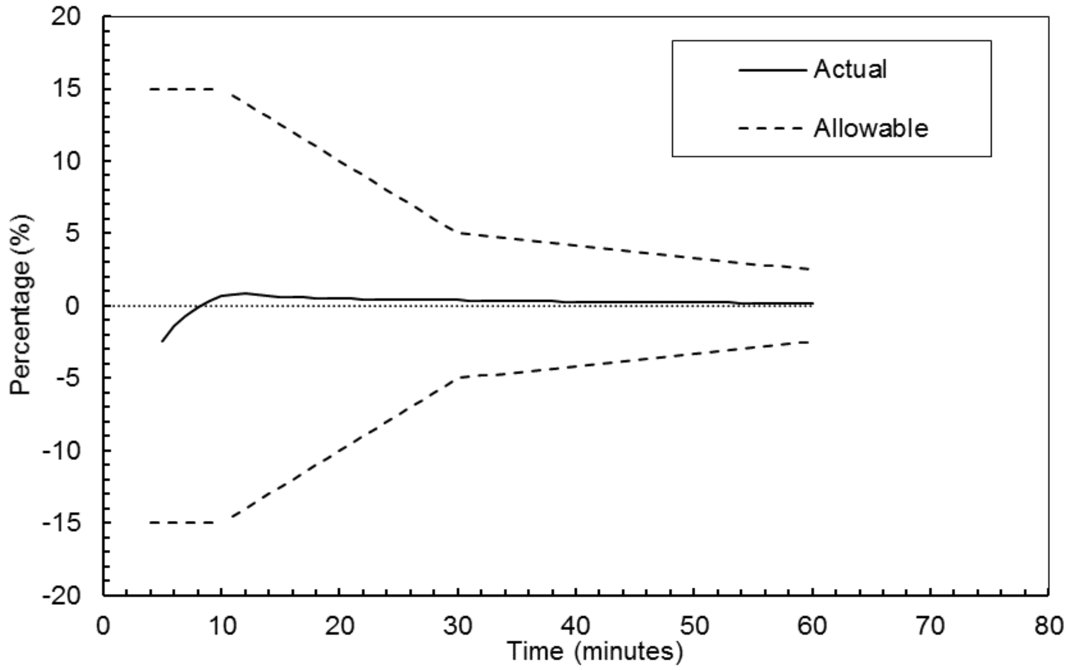


Figure 11. Test PV furnace control temperature accuracy.

The test pressure was controlled to be at least 15 Pa (gauge) at the lowest penetration as per the requirements of AS 1530.4-2005. The test pressure was maintained within the accuracy requirements required by AS 1530.4-2005, as shown in Figure 12. The test pressure was measured by a probe located 800 mm above the furnace sill. The target pressure was adjusted based on the AS 1530.4-2005 required pressure gradient of 8 Pa/m such that the minimum pressure requirements were maintained at the lowest penetration.

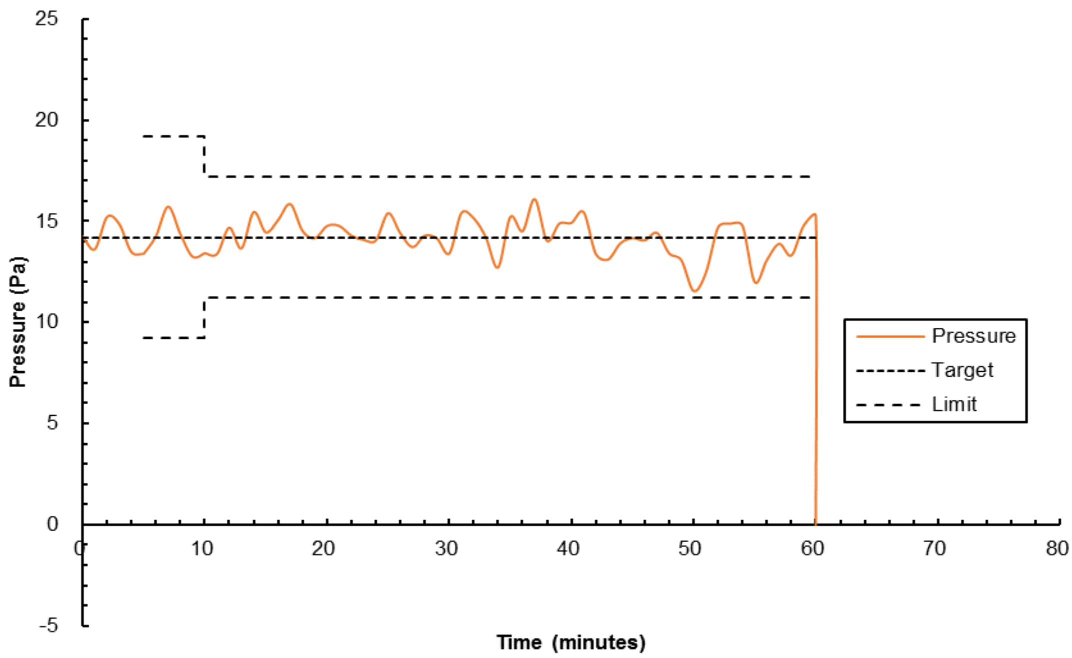


Figure 12. Test PV pressure control accuracy.

5.2.2 Failure criteria

The standard AS 1530.4-2005 integrity and insulation failure criteria for penetrations were followed.

As stated in the standard, integrity failure was:

> … deemed to occur when cracks, fissures or other openings develop through which flames or hot gases can pass. Failure occurs;
>
> a) If a gap, crack, or fissure develops, which exceeds 6 mm x 150 mm and, allows unobstructed vision into the interior of the furnace from any viewing angle, or a 25 mm gap gauge can be passed through the specimen so that the gauge projects into the furnace; or
>
> b) If flaming on the unexposed surface of the specimen is sustained for longer than 10 seconds; or
>
> c) When flames and/or hot gases cause flaming or glowing of a cotton fibre pad.

Examples of the cotton pad criteria are shown in Figure 13. As stated in the standard, insulation failure was:

> … deemed to occur when any of the relevant thermocouples attached to the unexposed face of the test specimen rises more than 180K above the initial temperature.

(a) Test application (b) Not failed (c) Failed

Figure 13. Cotton pad integrity test criteria.

As per the AS 1530.4-2005 standard, smoke leakage was not measured. Some observations could be made of the visible plume particularly at the start of the test. As the tests progressed, the visibility of the plumes reduced. The furnace combustion was quite clean with liquefied petroleum gas (LPG) as the fuel source burning in lean conditions. The majority of soot production observed at the beginning of the tests was likely to be from the burning specimen and services.

5.3 Test results

5.3.1 General

The timber boundary joists failed integrity at the top gap adjacent to the plasterboard at 29 minutes. Temperatures on the joists were not recorded other than at penetrations. The fibre-cement board wall failed insulation at 52 minutes, based on a temperature rise of more than 180 K at one of the key thermocouples. Otherwise, no substrate failures were noted within the 60-minute test duration.

Test results here are broken down into categories including all tests, vertical tests (tests PV, TV and CV), horizontal tests (tests PH and CH), 30-minute substrates (tests TV and CV) and 60-minute substrates (tests PV, PH, and CH). Note that these categories are not exclusive; i.e. there is overlap between the orientation categories and the substrate construction categories.

The time to failure for all of the penetrations tested is shown in Figure 14. Only one penetration failed on integrity but did not fail on insulation. This was likely due to the fact it was a plastic pipe penetration, and when the pipe melted on the unexposed side, the thermocouples mounted on the penetration were no longer attached to the furnace. Also, it failed at 53 minutes but was mounted on a 30-minute substrate assembly. Otherwise, all of the penetrations that failed integrity had failed insulation first.

All five of the penetrations that failed insulation by 8 minutes into the test were unsealed cable penetrations and are discussed in section 5.3.2. Of the seven penetrations that failed insulation by 15 minutes into the test, five were unsealed cable penetrations. Of the 14 penetrations that failed insulation by 30 minutes, eight were unsealed cable penetrations. Only two penetrations failed integrity before 15 minutes, and five failed integrity before 30 minutes. An additional three penetrations failed integrity between 30 and 60 minutes. Of the five penetrations that failed integrity before 30 minutes, three were unsealed cable penetrations discussed in section 5.3.2.

The vertical wall test times to failure are shown in Figure 15. Of the four penetrations that failed insulation before 15 minutes, two were unsealed cable penetrations. Five of 11 penetrations that failed insulation before 30 minutes were unsealed cable penetrations. Five of the remaining 20 penetrations that failed insulation between 30 minutes and 60 minutes were unsealed cable penetrations. Two vertical wall penetrations failed integrity before 15 minutes, and both used some form of firestopping. Five failed integrity before 30 minutes, including three unsealed cable penetrations. One penetration failed integrity between 30 and 60 minutes.

Horizontal floor/ceiling test times to failure are shown in Figure 16. Three penetrations failed insulation before 10 minutes and were all unsealed cable penetrations. Otherwise, no penetrations failed before 30 minutes. Two of the five penetrations that failed insulation between 30 minutes and 60 minutes were unsealed penetrations. Two of the unsealed cable penetrations failed integrity between 30 minutes and 60 minutes. There were no other integrity failures.

Test times to failure from the 30-minute substrates (test CV and TV) are shown in Figure 17. Two unsealed cable penetrations failed insulation before 15 minutes. Including these two, eight penetrations failed insulation before 30 minutes including a total of four unsealed cable penetrations. An additional 14 penetrations failed insulation before 60 minutes, including three unsealed penetrations. Three unsealed cable penetrations failed integrity between 15 and 30 minutes.

The 60-minute substrate (test PV, PH, and CH) penetration times to failure are shown in Figure 18. Five penetrations including three unsealed cable penetrations failed insulation before 15 minutes. A single unsealed cable penetration failed insulation between 15 minutes and 30 minutes, and 11 penetrations including four unsealed cable penetrations failed insulation between 30 minutes and 60 minutes. Two penetrations failed integrity prior to 15 minutes. Two unsealed cable penetrations failed between 30 minutes and 60 minutes, and there were no other integrity failures in the 60-minute substrates.

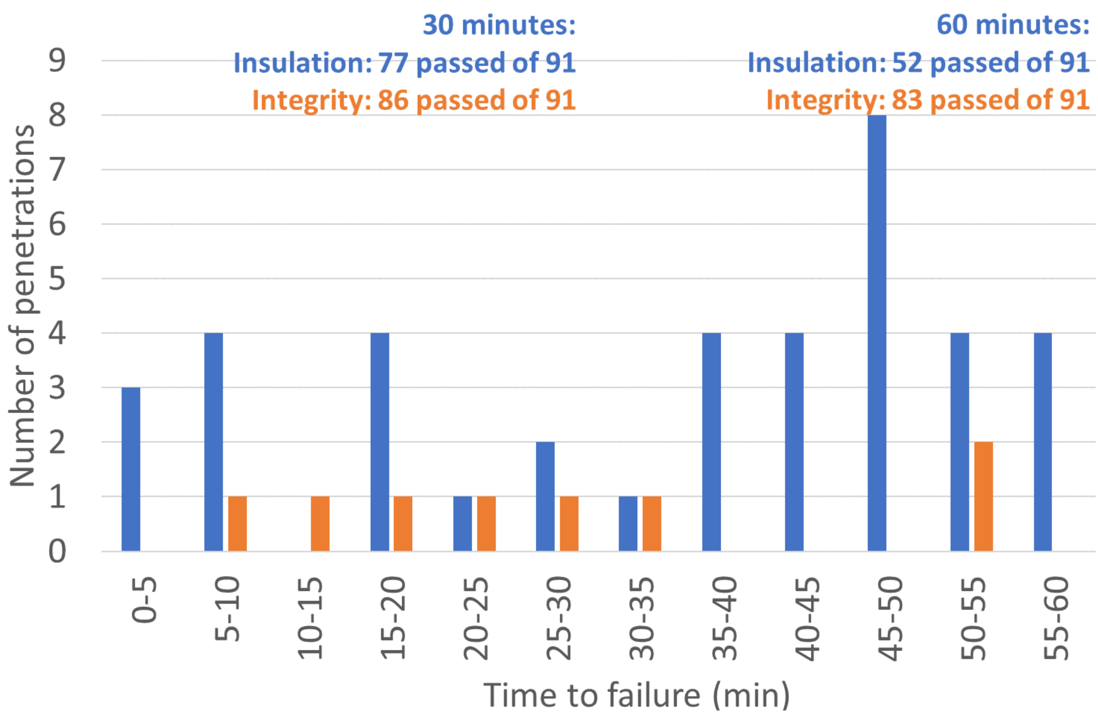


Figure 14. Overall test results.

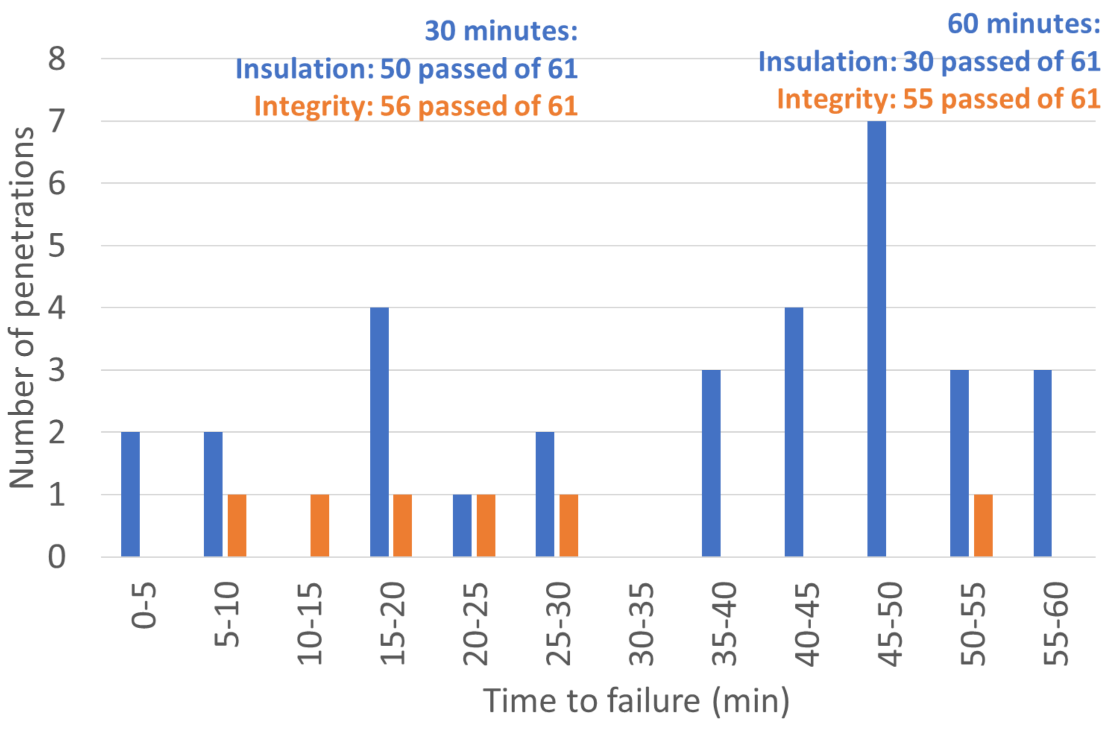


Figure 15. Vertical test results.

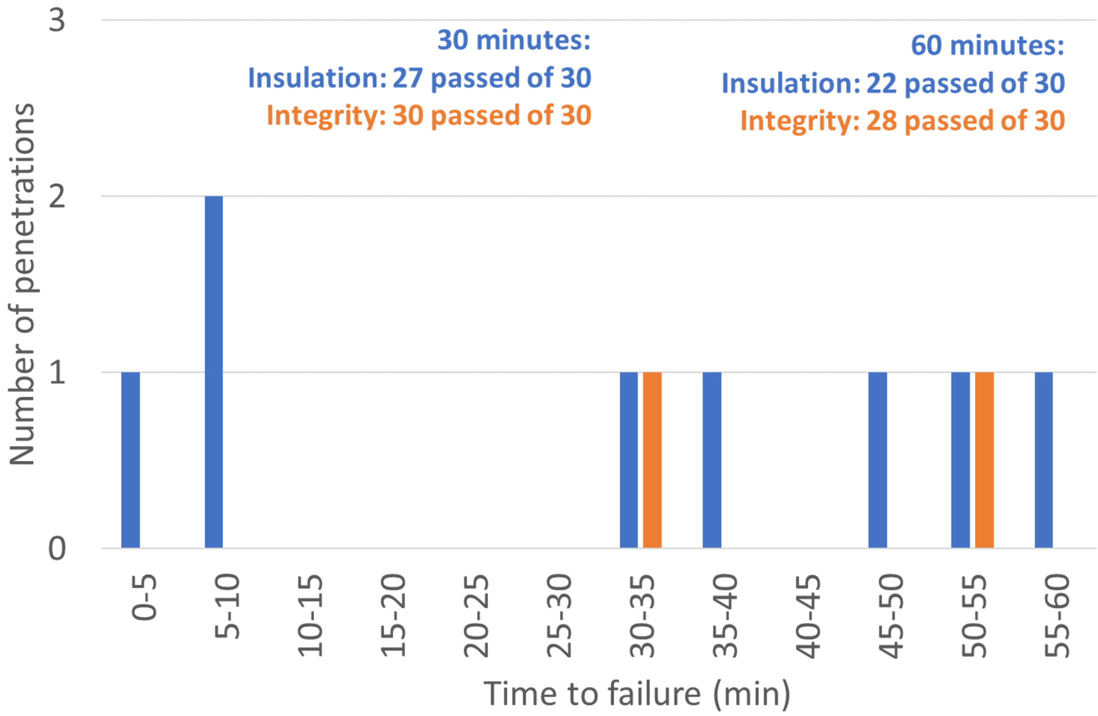


Figure 16. Horizontal test results.

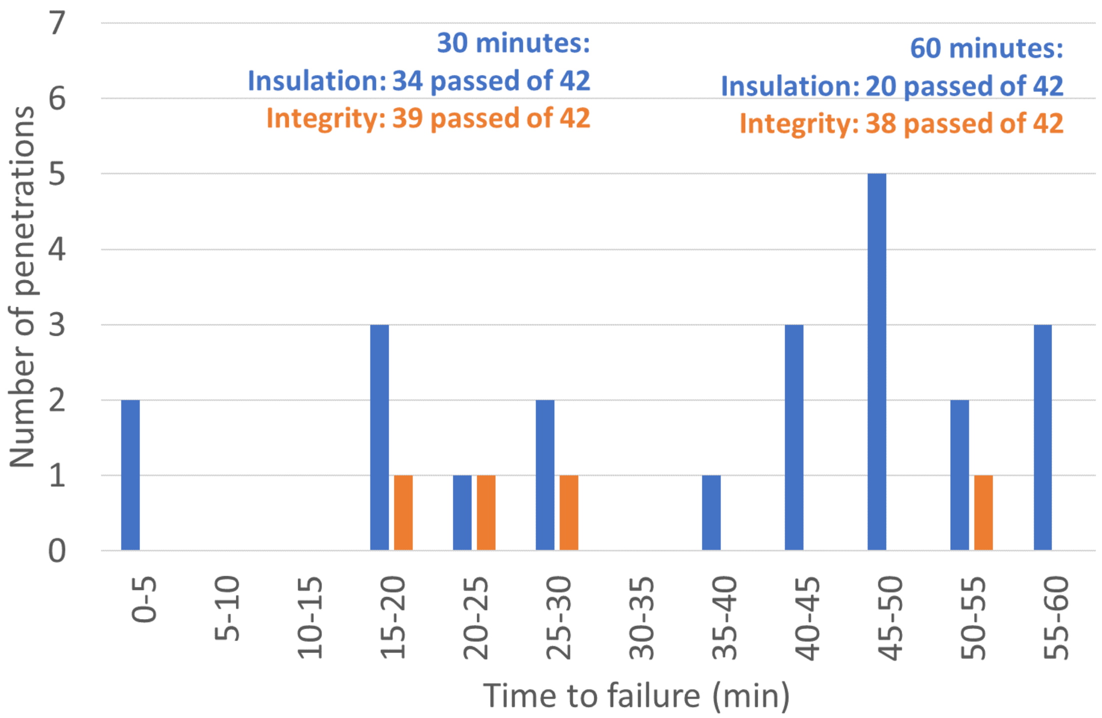


Figure 17. Penetration test results for 30-minute substrates.

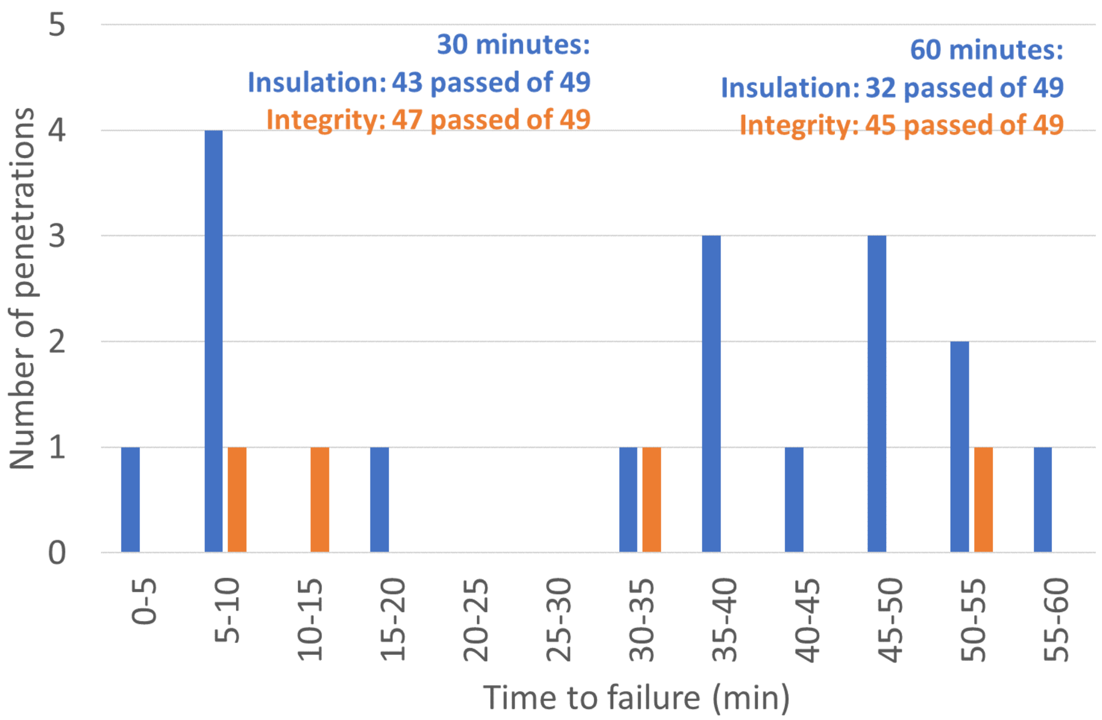


Figure 18. Penetration test results for 60-minute substrates.

5.3.2 Specific penetrations

Based on discussions with the stakeholders, it was decided to not release test results for specific penetrations where firestopping materials were used. The following section discusses the test results for penetrations where no firestopping was used. A summary of the results for these penetrations is shown in Table 3.

Table 3. Summary of unsealed cable penetration results.

	Plasterboard wall (60 min)			Timber joists (30 min)			Fibre cement wall (30 min)			Timber infill floor (60 min)			Plasterboard ceiling (60 min)		
Number of Cables	**Penetration Hole ø (mm)**	Insulation. (min)	Integrity. (min)	**Penetration Hole ø (mm)**	Insulation. (min)	Integrity. (min)	**Penetration Hole ø (mm)**	Insulation. (min)	Integrity. (min)	**Penetration Hole ø (mm)**	Insulation. (min)	Integrity. (min)	**Penetration Hole ø (mm)**	Insulation. (min)	Integrity. (min)
12	**44**	19	60NF	**52**	3	19	**48**	19	27	**47**	5	33	**44**	7	55
12				**52-PP**	5	21									
3	**25**	39	60NF				**25**	29	60NF	**24**	8	60NF	**25**	48	60NF
3	**18**	60NF	60NF				**18**	48	60NF	**18**	60NF	60NF	**18**	60NF	60NF
3	**16**	60NF	60NF	**16**	60NF	60NF	**16**	49	60NF	**16**	60NF	60NF	**16**	60NF	60NF
3				**16-PP**	60NF	60NF									
1	**13**	47	60NF	**13**	60NF	60NF	**13**	58	60NF	**16**	60NF	60NF	**16**	54	60NF
1				**13-PP**	60NF	60NF				**12**	60NF	60NF	**13**	60NF	60NF

60NF means no failure observed during the test duration.

Plasterboard wall

The plasterboard wall contained four unsealed cable penetrations. The largest was a 12-cable bundle in a 44 mm diameter penetration (Figure 19). This penetration failed insulation at 19 minutes and did not fail integrity for the duration of the test, despite several cotton pad tests. The maximum temperature rise was 349 K, measured at the top of the cable bundle. The cable insulation on the unexposed side of the penetration was substantially charred.

There were three 3-cable bundle unsealed penetrations in the plasterboard wall with 25 mm, 18 mm and 16 mm diameter penetrations (Figure 20–Figure 22). The 25 mm penetration failed insulation at 39 minutes and reached a peak temperature rise of 326 K. There was substantial charring observed on the cable insulation on the unexposed side.

The 1-cable unsealed penetration through a 13 mm diameter penetration (Figure 23) failed insulation at 47 minutes. The thermocouple attached to the top of the cable reached a maximum temperature of 243 K.

Timber boundary joists

Two 12-cable bundle penetrations were installed without firestopping, one without plasterboard pattresses (Figure 24) and one with (Figure 25). The 52 mm diameter hole size for these penetrations was almost large enough for the penetrations to fail based on the gap gauge before the test started. Both of these penetrations failed insulation quickly, at 3 and 5 minutes respectively. The penetration without a plasterboard pattress reached a peak temperature rise of 625 K on the unexposed side and the one with reached 603 K. Both penetrations also failed integrity before 30 minutes, at 19 and 21 minutes respectively. However, the plasterboard pattress kept the substrate temperature on the unexposed side well below 180 K temperature rise.

None of the 3-cable or 1-cable unsealed penetrations (Figure 26–Figure 29) failed insulation or integrity prior to 60 minutes in this substrate. Very little charring was observed on the unexposed side of these penetrations as well.

Fibre-cement board wall

One 12-cable bundle penetration was installed in the fibre-cement board wall without firestopping (Figure 30). It failed insulation at 19 minutes and integrity at 27 minutes, with one thermocouple recording a maximum temperature rise of 786 K. The substrate was severely damaged on both sides, and the cable insulation on the unexposed side was severely charred.

3-cable bundles were installed with penetration diameters of 25 mm, 18 mm and 16 mm (Figure 31–Figure 33). All failed insulation at 29, 48 and 49 minutes respectively. Maximum temperature rises of 348 K, 278 K and 373 K were recorded, respectively. None of these penetrations failed integrity, and the 25 mm and 18 mm penetrations were particularly charred.

One 1-cable penetration with a penetration diameter of 13 mm was installed in the fibre-cement board wall. It failed insulation at 58 minutes and did not fail integrity. Some charring was noted (Figure 34).

Plasterboard ceiling/strand board floor assembly

The single unsealed 12-cable bundle installed in a 44 mm diameter penetration (Figure 35) failed insulation at 7 minutes and integrity at 55 minutes. The peak temperature rise recorded was 676 K. The unexposed side was substantially charred.

Of the three 3-cable bundles installed in 25 mm, 18 mm and 16 mm diameter penetrations (Figure 36–Figure 38) only the 25 mm penetration failed insulation before the test completed, at 48 minutes. The peak temperature rise recorded for this penetration was 272 K. No integrity failures were observed for these penetrations. Substantial charring was observed near the 25 mm diameter penetration, light charring was noted near the 18 mm diameter penetration and nearly no charring was noted around the 16 mm penetration.

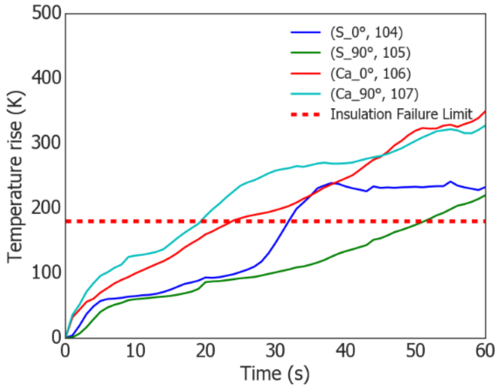
Single cables were installed in 16 mm and 13 mm diameter unsealed penetrations (Figure 39 and Figure 40). The 16 mm diameter penetration failed insulation at 54 minutes, with a peak temperature rise measured of 212 K. The 13 mm diameter penetration did not fail on insulation. Neither 1-cable penetration failed integrity prior to the end of the test. The cable insulation on the unexposed side of the 16 mm diameter penetration was substantially charred.

Timber infill floor

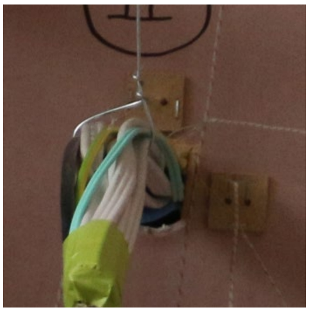
A 12-cable bundle in a 47 mm diameter unsealed penetration (Figure 41) failed on insulation at 5 minutes, with a peak temperature rise of 702 K. It failed on integrity at 33 minutes, and the unexposed side cable insulation was substantially charred.

3-cable bundles were installed in 24, 18 and 16 mm diameter penetrations (Figure 42–Figure 44). The 24 mm diameter penetration was the only one that failed on insulation, at 8 minutes. The maximum temperature rise recorded on this penetration was 294 K. None of the 3-cable bundle penetrations in this substrate failed integrity before the end of the test. The cable insulation was substantially charred on the unexposed side of the 24 mm diameter penetration, while charring was minimal on the unexposed side of the 18 mm and 16 mm diameter penetrations.

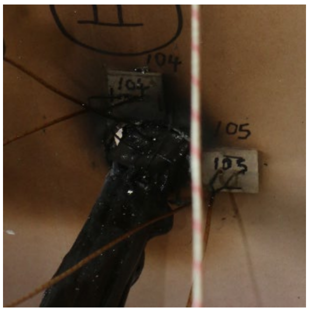
Neither the 16 mm or 12 mm diameter 1-cable penetrations failed either insulation or integrity in the timber infill floor substrate (Figure 45 and Figure 46). The cable insulation was charred on the unexposed side of the 16 mm diameter penetration.



(a) Penetration thermocouple temperature history



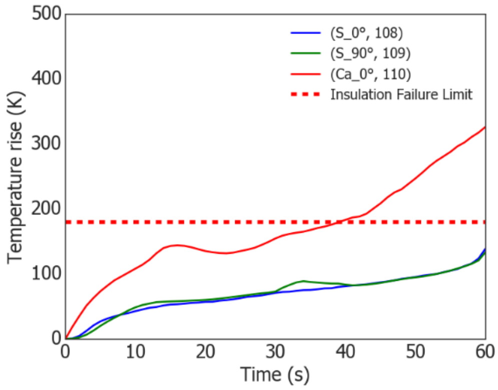
(b) Unexposed pre-test



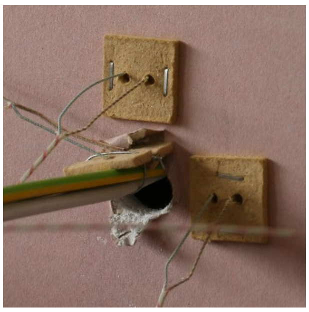
(c) Unexposed post-test

(d) Exposed post-test

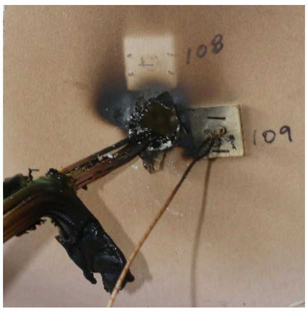
Figure 19. Test PV: 12-cable bundle, 44 mm diameter penetration.



(a) Penetration thermocouple temperature history



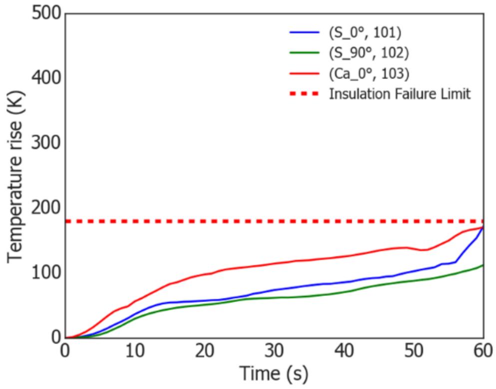
(b) Unexposed pre-test



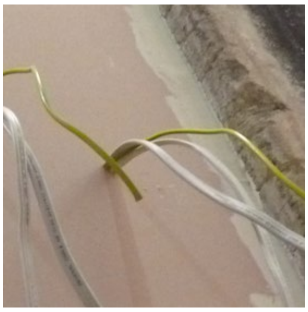
(c) Unexposed post-test

(d) Exposed post-test

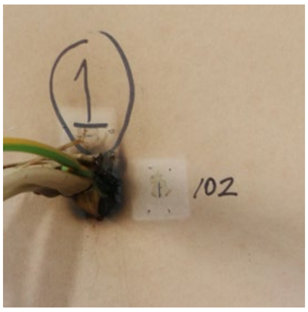
Figure 20. Test PV: 3-cable bundle, 25 mm diameter penetration.



(a) Penetration thermocouple temperature history



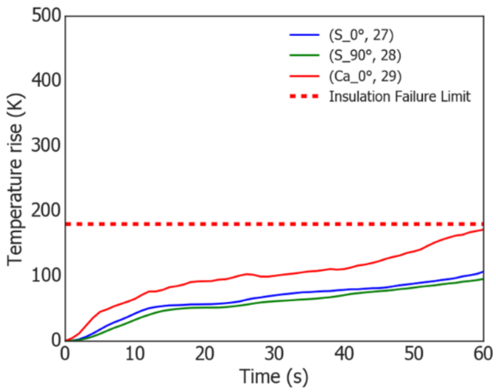
(b) Unexposed pre-test



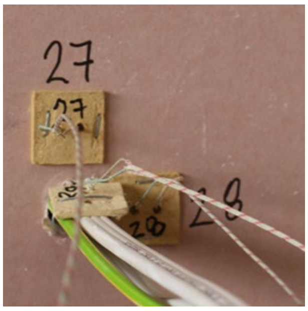
(c) Unexposed post-test

(d) Exposed post-test

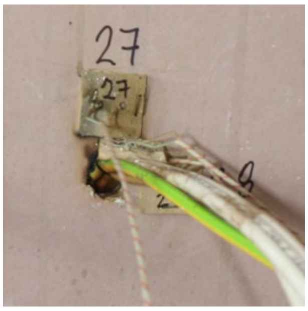
Figure 21. Test PV: 3-cable bundle, 18 mm diameter penetration.



(a) Penetration thermocouple temperature history



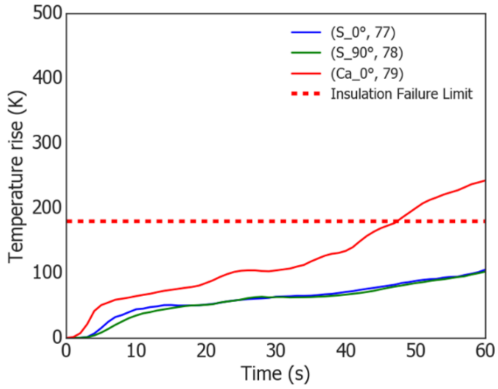
(b) Unexposed pre-test



(c) Unexposed post-test

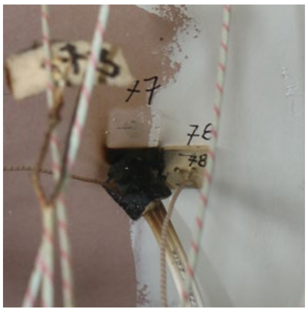
(d) Exposed post-test

Figure 22. Test PV: 3-cable bundle, 16 mm diameter penetration.



(a) Penetration thermocouple temperature history

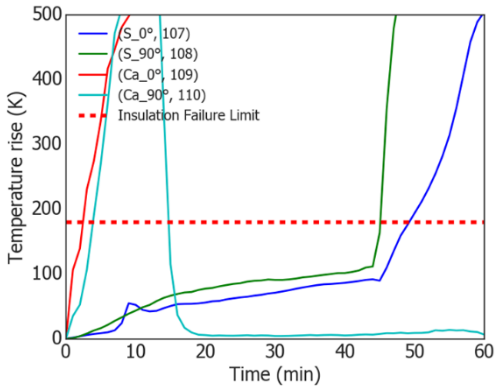
(b) Unexposed pre-test



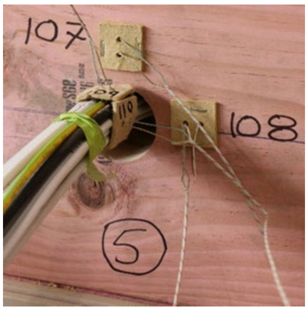
(c) Unexposed post-test

(d) Exposed post-test

Figure 23. Test PV: 1-cable, 13 mm diameter penetration.



(a) Penetration thermocouple temperature history

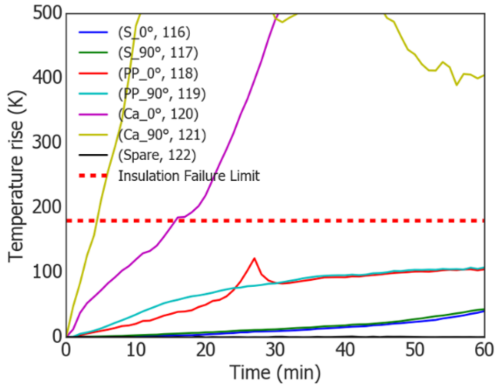


(b) Unexposed pre-test

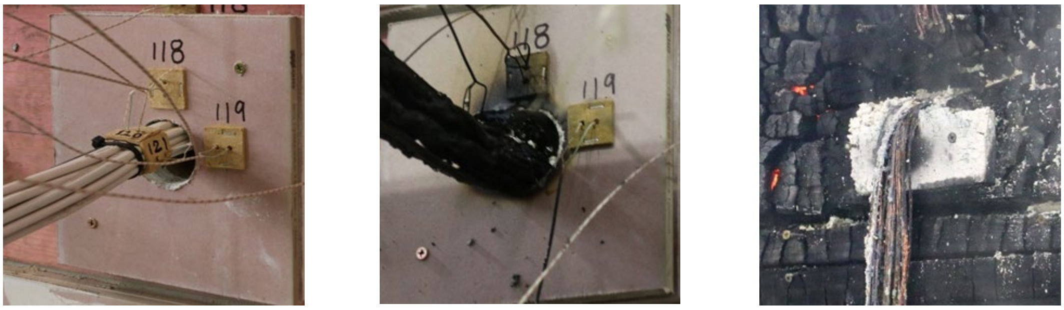
(c) Unexposed post-test

(d) Exposed post-test

Figure 24. Test TV: 12-cable bundle, 52 mm diameter penetration.

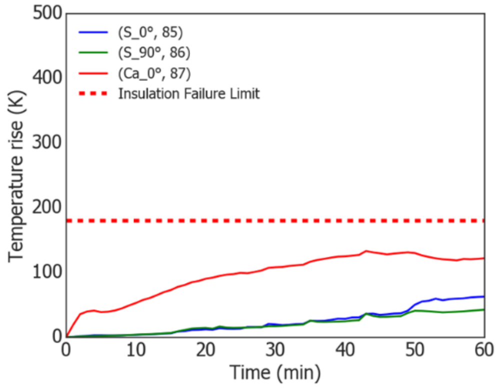


(a) Penetration thermocouple temperature history

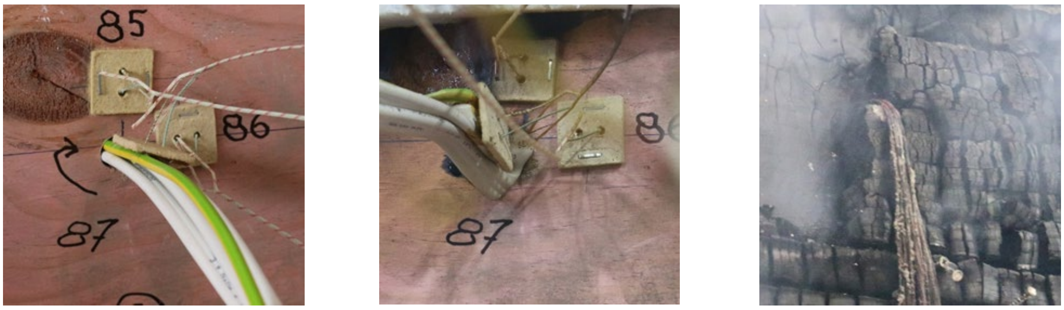


(b) Unexposed pre-test **(c) Unexposed post-test** **(d) Exposed post-test**

Figure 25. Test TV: 12-cable bundle, 52 mm diameter penetration, pattress.

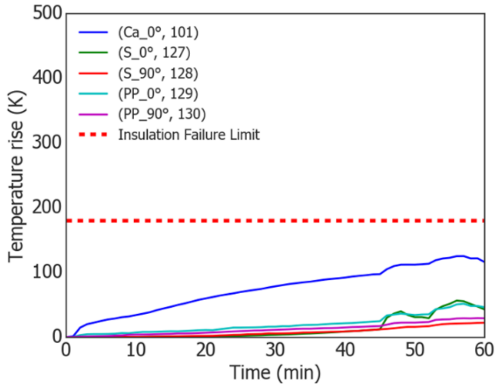


(a) Penetration thermocouple temperature history



(b) Unexposed pre-test **(c) Unexposed post-test** **(d) Exposed post-test**

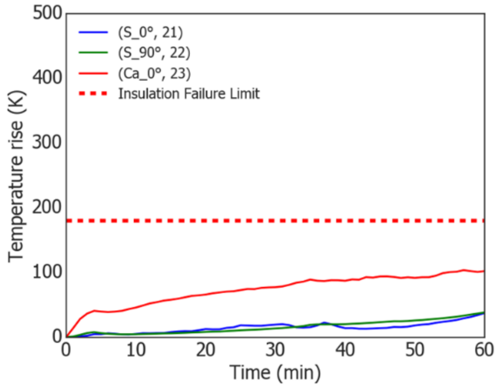
Figure 26. Test TV: 3-cable bundle, 16 mm diameter penetration.



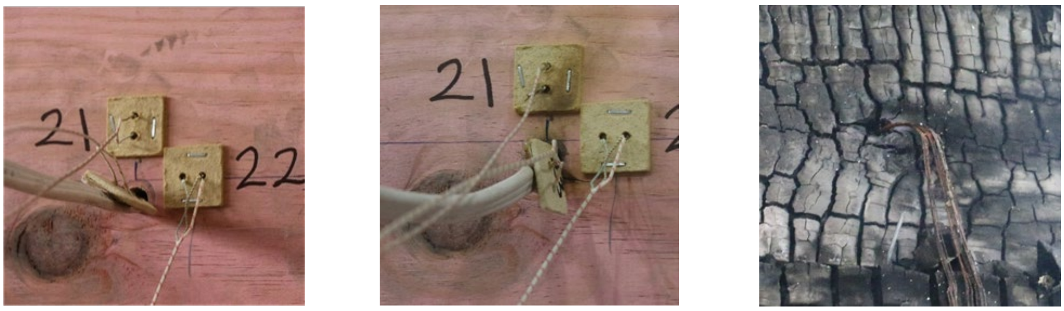
(a) Penetration thermocouple temperature history

(b) Unexposed pre-test **(c) Unexposed post-test** **(d) Exposed post-test**

Figure 27. Test TV: 3-cable bundle, 16 mm diameter penetration, pattress.

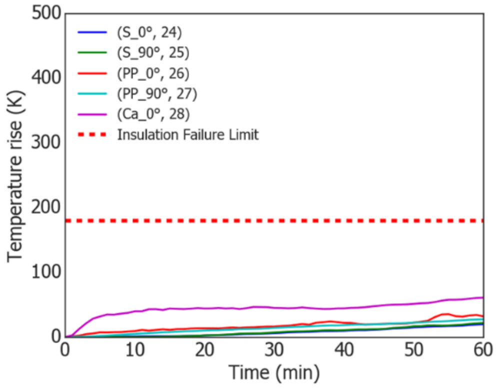


(a) Penetration thermocouple temperature history

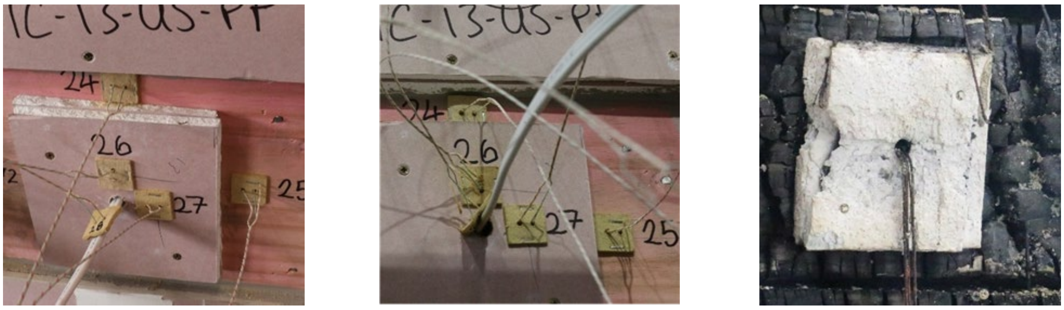


(b) Unexposed pre-test **(c) Unexposed post-test** **(d) Exposed post-test**

Figure 28. Test TV: 1-cable, 13 mm diameter penetration.

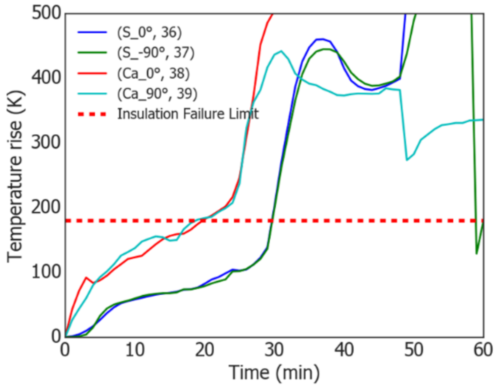


(a) Penetration thermocouple temperature history



(b) Unexposed pre-test (c) Unexposed post-test (d) Exposed post-test

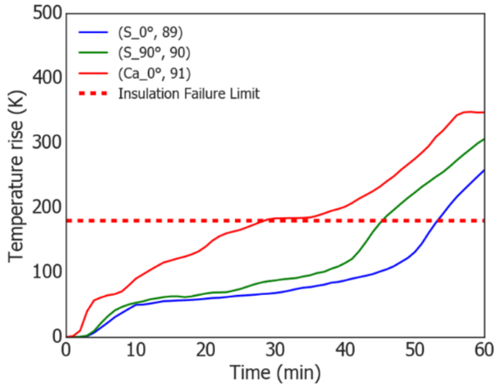
Figure 29. Test TV: 1-cable, 13 mm diameter penetration, pattress.



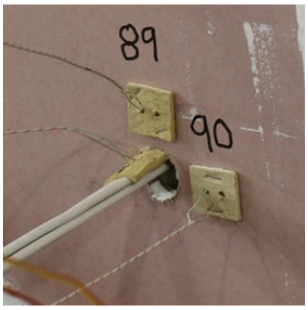
(a) Penetration thermocouple temperature history

(b) Unexposed pre-test (c) Unexposed post-test (d) Exposed post-test

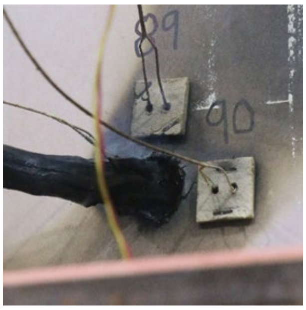
Figure 30. Test CV: 12-cable bundle, 48 mm diameter penetration.



(a) Penetration thermocouple temperature history



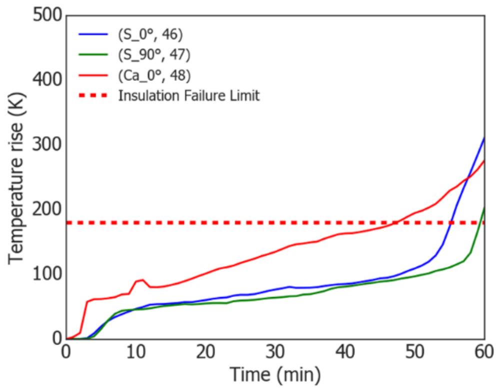
(b) Unexposed pre-test



(c) Unexposed post-test

(d) Exposed post-test

Figure 31. Test CV: 3-cable bundle, 25 mm diameter penetration.



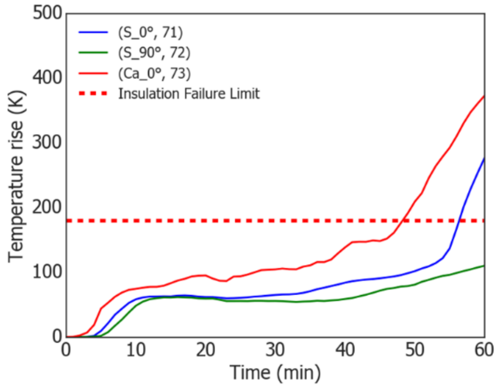
(a) Penetration thermocouple temperature history

(b) Unexposed pre-test

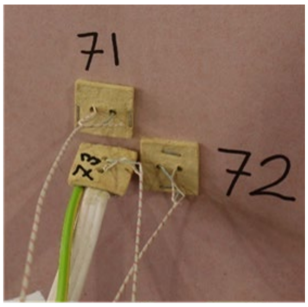
(c) Unexposed post-test

(d) Exposed post-test

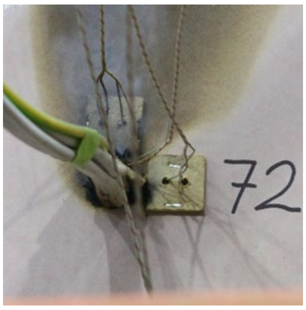
Figure 32. Test CV: 3-cable bundle, 18 mm diameter penetration.



(a) Penetration thermocouple temperature history



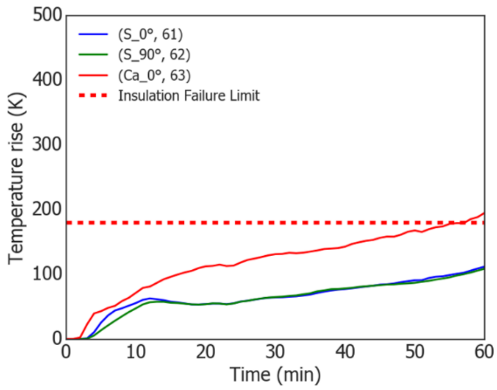
(b) Unexposed pre-test



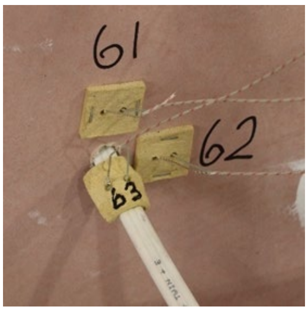
(c) Unexposed post-test

(d) Exposed post-test

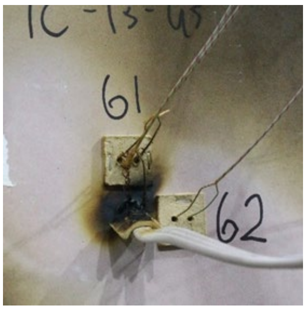
Figure 33. Test CV: 3-cable bundle, 16 mm diameter penetration.



(a) Penetration thermocouple temperature history



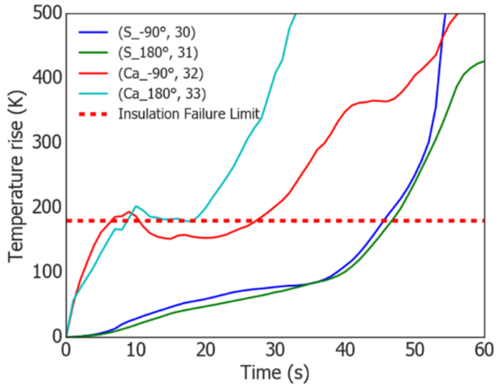
(b) Unexposed pre-test



(c) Unexposed post-test

(d) Exposed post-test

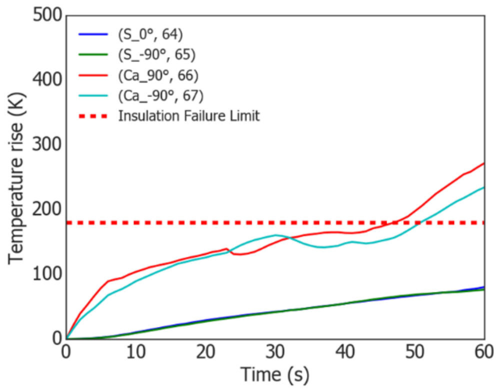
Figure 34. Test CV: 1-cable, 13 mm diameter penetration.



(a) Penetration thermocouple temperature history

(b) Unexposed pre-test **(c) Unexposed post-test** **(d) Exposed post-test**

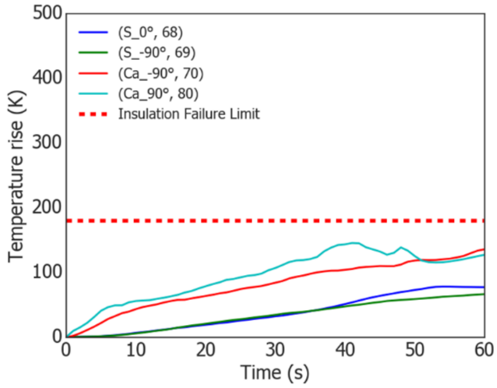
Figure 35. Test PH: 12-cable bundle, 44 mm diameter penetration.



(a) Penetration thermocouple temperature history

(b) Unexposed pre-test **(c) Unexposed post-test** **(d) Exposed post-test**

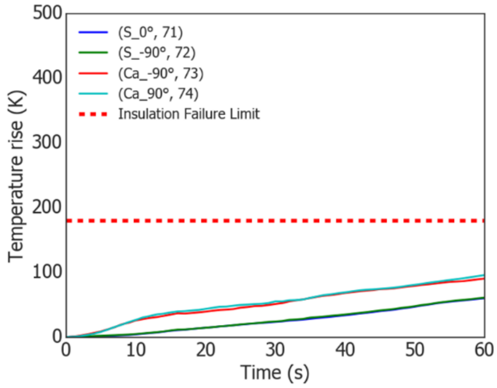
Figure 36. Test PH: 3-cable bundle, 25 mm diameter penetration.



(a) Penetration thermocouple temperature history

(b) Unexposed pre-test (c) Unexposed post-test (d) Exposed post-test

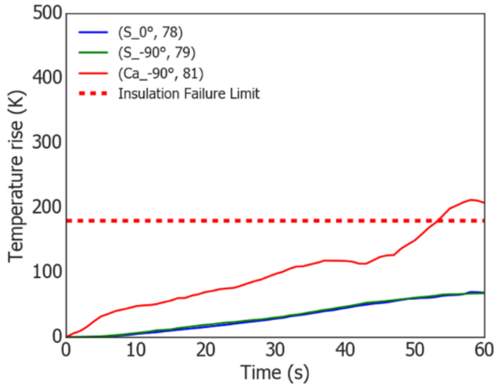
Figure 37. Test PH: 3-cable bundle, 18 mm diameter penetration.



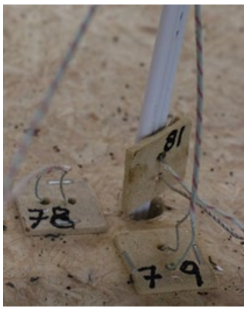
(a) Penetration thermocouple temperature history

(b) Unexposed pre-test (c) Unexposed post-test (d) Exposed post-test

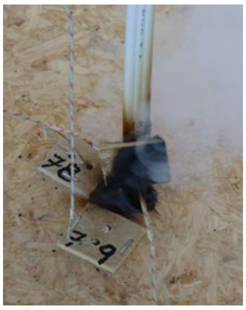
Figure 38. Test PH: 3-cable bundle, 16 mm diameter penetration.



(a) Penetration thermocouple temperature history



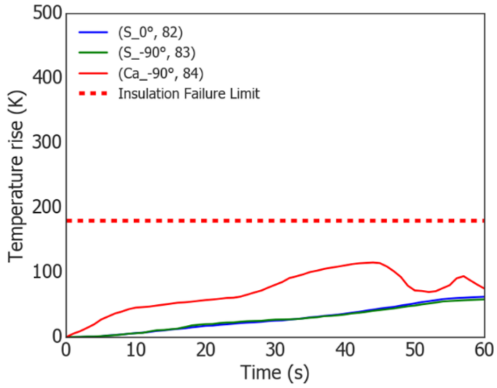
(b) Unexposed pre-test



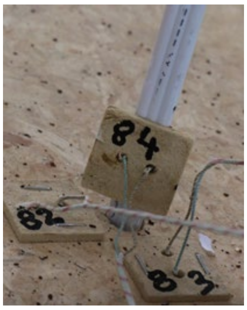
(c) Unexposed post-test

(d) Exposed post-test

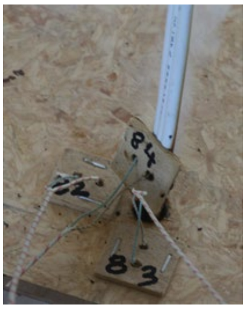
Figure 39. Test PH: 1-cable, 16 mm diameter penetration.



(a) Penetration thermocouple temperature history



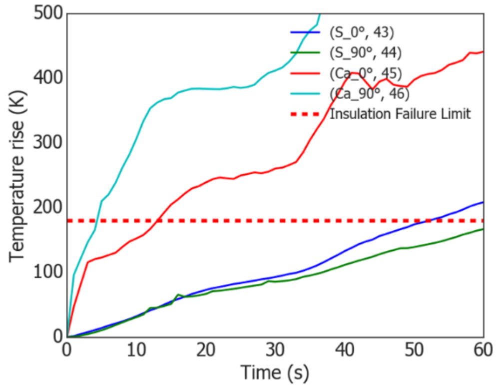
(b) Unexposed pre-test



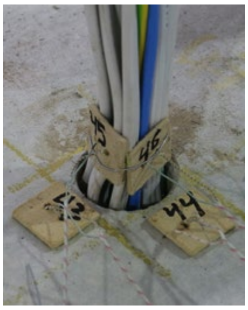
(c) Unexposed post-test

(d) Exposed post-test

Figure 40. Test PH: 1-cable, 13 mm diameter penetration.



(a) Penetration thermocouple temperature history

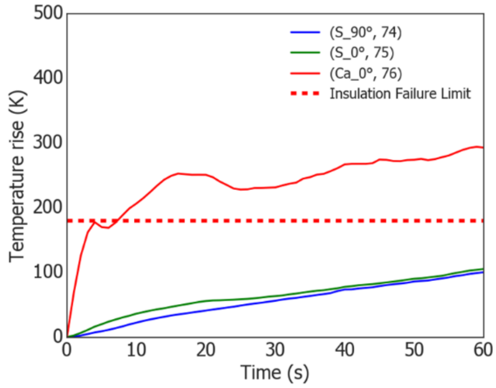


(b) Unexposed pre-test

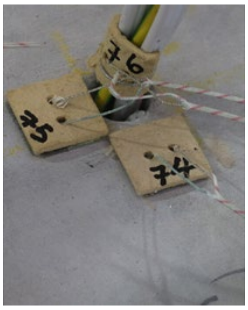
(c) Unexposed post-test

(d) Exposed post-test

Figure 41. Test CH: 12-cable bundle, 47 mm diameter penetration.



(a) Penetration thermocouple temperature history

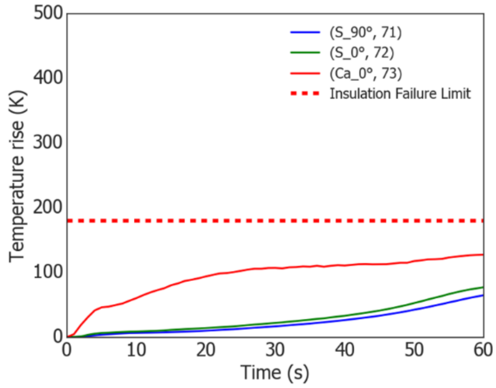


(b) Unexposed pre-test

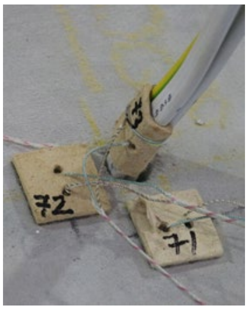
(c) Unexposed post-test

(d) Exposed post-test

Figure 42. Test CH: 3-cable bundle, 24 mm diameter penetration.



(a) Penetration thermocouple temperature history

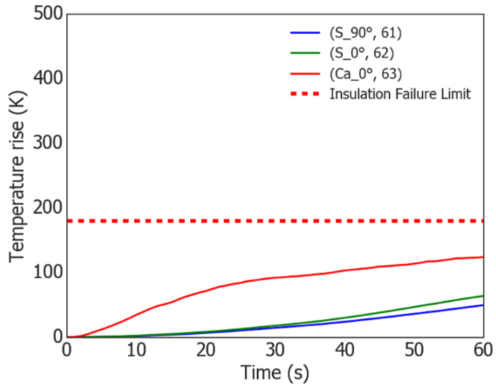


(b) Unexposed pre-test

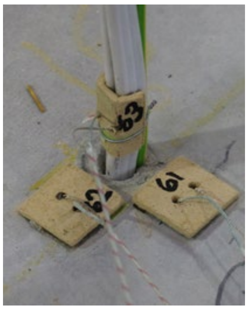
(c) Unexposed post-test

(d) Exposed post-test

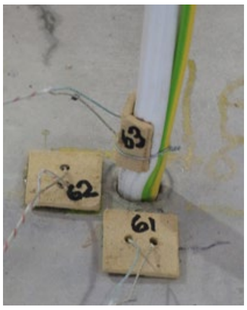
Figure 43. Test CH: 3-cable bundle, 18 mm diameter penetration.



(a) Penetration thermocouple temperature history



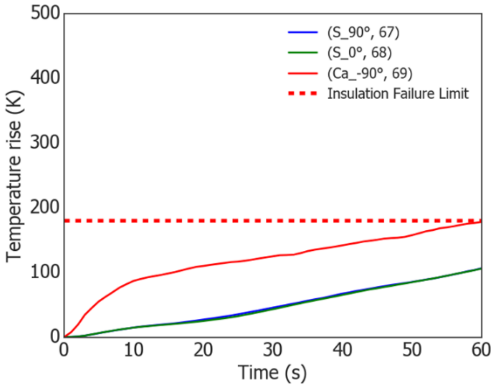
(b) Unexposed pre-test



(c) Unexposed post-test

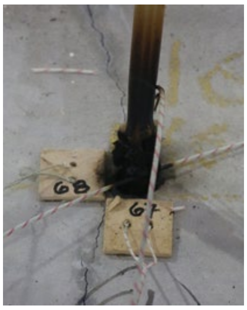
(d) Exposed post-test

Figure 44. Test CH: 3-cable bundle, 16 mm diameter penetration.



(a) Penetration thermocouple temperature history

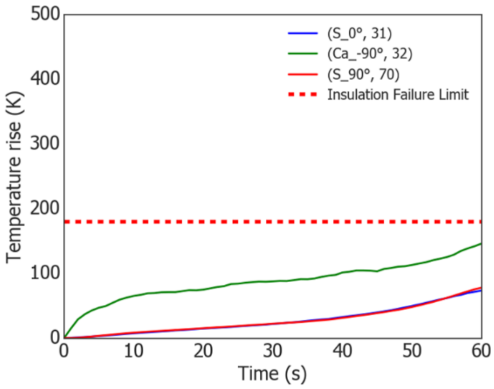
(b) Unexposed pre-test



(c) Unexposed post-test

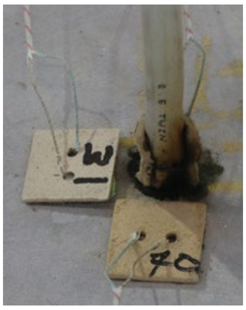
(d) Exposed post-test

Figure 45. Test CH: 1-cable, 16 mm diameter penetration.



(a) Penetration thermocouple temperature history

(b) Unexposed pre-test



(c) Unexposed post-test

(d) Exposed post-test

Figure 46. Test CH: 1-cable, 12 mm diameter penetration.

Unsealed cable fire test discussion

The general behaviour of the unsealed cable penetrations followed the behaviour of the other unreported penetrations, i.e. in the majority of the cases, insulation failure preceded integrity failure. As expected, the larger-diameter penetrations failed before smaller penetrations most of the time. With the exception of the fibre-cement board, the substrate remained intact around the penetration until the end of the test, although it should be remembered that the fibre-cement board construction was only rated for 30 minutes. There were no integrity failures prior to 15 minutes and two between 15 minutes and 30 minutes. None of the 3-cable bundle or 1-cable penetrations failed integrity by the end of the tests, which was quite remarkable for the 30- minute fibre-cement board construction.

One aspect that the tests do not address is the long-term durability of holes cut directly in unsupported linings. The argument could be made that the size of the penetration should be set based on the nearest support – for example, an unsupported penetration through plasterboard on a timber wall with studs spaced at 600 mm centres and with nogs at 1,200 mm could be considered as a 600 x 1200 mm penetration, regardless of the actual hole in the plasterboard. The durability concern can be partially addressed by periodic inspection but does represent an increased level of risk that is hard to quantify.

Another observation that was made particularly for the timber boundary joist penetrations without plasterboard pattresses (with timber exposed) was that there was minimal flaming on the unexposed side until the furnace was shut down. This is likely a result of the positive furnace pressure pushing the low oxygen concentration combustion products out through the openings, preventing flaming from occurring. Once the furnace was shut down and the pressure returned to ambient, fresh air from both sides could approach the hot timber, mix with the pyrolysis products from the hot timber and burn.

6. Risk assessment for non-compliant PFP

A risk assessment methodology has been developed for stakeholders to determine the technical basis for decisions to resolve non-compliant PFP with a consistent and systematic process. This methodology uses a modified version of a flow chart currently being developed for a new revision of the SFPE fire risk assessment guide (SFPE, 2006).

The use of this process is expected to be successful if relevant stakeholders also adhere to the risk management principles, framework and process described in AS/NZS ISO 31000:2009, which provides a general process for risk management.

The modified flow chart for the process is shown in Figure 47.

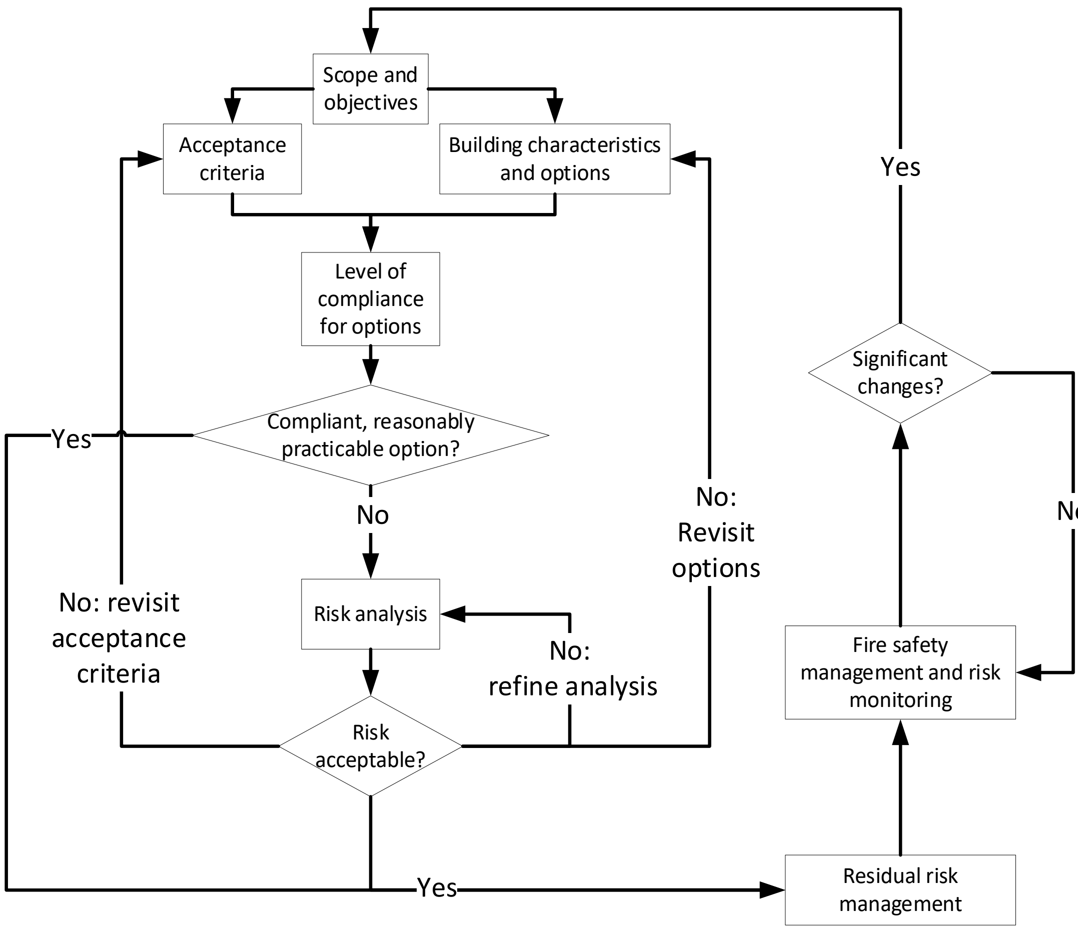


Figure 47. Modified risk assessment flow chart.

6.1 Risk assessment process description

The main steps of the flow chart are as follows.

6.1.1 Scope and objectives

The top step is to define the scope and objectives of the risk assessment. This requires consensus from the stakeholders as to what part of the building is included under the alteration building consent and how impact on the rest of the building will be considered.

The objectives should be determined and documented at this stage, including if the section 112 requirements for means of escape from fire compliance ANARP are only being considered or if other aspects will be addressed as well. The MBIE building score criteria discussed in section 4.5 can be used to assist in developing the scope of information required to make an assessment of the means of escape compliance.

The context of the risk assessment should be defined at this stage, as per 5.3 on Figure 48. This should include a discussion of the perspective of the risk assessment, and whether the criteria for the required cost/benefit analysis that forms the decision basis as to what is reasonable and practicable is established upon the private interest (building owner) or public interest.

6.1.2 Acceptance criteria

The acceptance criteria should then be determined along with investigation of the building characteristics and options. The acceptance criteria would likely be a comparison to the Acceptable Solutions or a Verification Method-based design, although other measures could be considered. The original design criteria of the building would inform this decision. If the original design criteria for the building is not known and an Acceptable Solution is not applicable, the design criteria may need to be re-established through fire engineering analysis.

6.1.3 Building characteristics and options

Investigation of the building characteristics is expected to be a time-intensive step. Thorough documentation of the occupancy, escape routes and other systems is required. An analysis of the actual requirements for compliance is required. This should look at aspects such as concessions for suppression systems and external unprotected area allowances. For example, the New Zealand Acceptable Solution for multi-unit residential buildings C/AS2 does not require an insulation FRR if the building is sprinklered throughout.

All of the building characteristics information should be verified by site inspection. The level of required destructive inspection should be discussed and agreed upon by the stakeholders. ASTM E2174-14b *Standard practice for on-site inspection of installed firestops* provides a guideline of 10% inspection during installation and destructive verification of 2% or not less than one example of each type of system per floor area up to 10,000 ft^2. If non-compliance is found, further destructive verification up to 10% of each type of system is also recommended. If the 10% is reached, then all firestops of that type could be assumed to be non-compliant. At this stage, the estimated amount of non-compliant construction in areas that will not be exposed for alterations can be made.

Once the building characteristics are known, a list of potential options is compiled. Types of options include do nothing, non-compliant repairs and fully compliant repairs. Costs of each type of option including the costs of determining the level of compliance for do nothing and non-compliant repair options are to be provided. The costs should include aspects like increased ongoing inspection and maintenance requirements to monitor the long-term durability of non-compliant assemblies.

6.1.4 Level of compliance

Once the building configuration and option information is complete, the level of compliance of the do nothing and non-compliant options (if they are considered viable) will then be determined.

This is preferably done through fire testing, including the worst-case scenarios expected for each type of system. Formal opinions may be accepted as allowed by the test standard. Engineering judgements outside of the parameters set by standards are discouraged, and all stakeholders need to be consulted before proceeding on such a basis. Additional compliance requirements not measured in the standard fire resistance test (such as smoke leakage) should also be considered.

6.1.5 Risk analysis

If a compliant, reasonably practicable solution has been found at this point, further risk analysis is not required. Otherwise, the risks associated with the non-compliant solution must be investigated. A risk analysis option that has been developed by industry is discussed in section 6.3. Other forms of acceptance criteria (Verification Method or Alternative Solutions) require more in-depth fire engineering analysis.

6.1.6 Implementation, residual risk management and ongoing monitoring

Once a solution with an acceptable level of risk has been determined based on agreement among the stakeholders, implementation can commence. Ongoing residual risk management and elevated fire safety management and risk monitoring are required. This includes quality assurance to ensure that the chosen solution is implemented properly and documentation of the remaining risks (unexposed construction that was not remedied and outstanding non-compliance). Quality assurance will involve such aspects as installer qualifications and credentials, construction monitoring and inspection. Since quality assurance is likely a cause of the deficiencies in the first place, particular care needs to be taken here.

Documentation should include a thorough description and indication on drawings of the building elements that are intended to be fire or smoke rated. The ANARP criteria only applies at the time of consent, so it is important to communicate any non-compliance at the time of consent to those involved in future activities with the building. For example, if a future IQP is not aware that certain non-compliant aspects were agreed to be ANARP at the time of consent, they may rightfully require full compliance. A risk register of outstanding non-compliant issues attached to the compliance schedule is necessary to communicate this information. This documentation will also be available when future work is done in the building, which may provide the opportunity to remedy outstanding issues if reasonable and practicable at that time.

A plan for monitoring the long-term durability of not fully compliant assemblies is to be provided. This may include potential material compatibility issues and degradation due to inadequate support or fixing.

6.2 AS/NZS ISO 31000:2009 principles and process

The AS/NZS ISO 31000:2009 principles, framework and process are shown in Figure 48. Some of the principles are organisational and are not specifically relevant at the project level considered for this process.

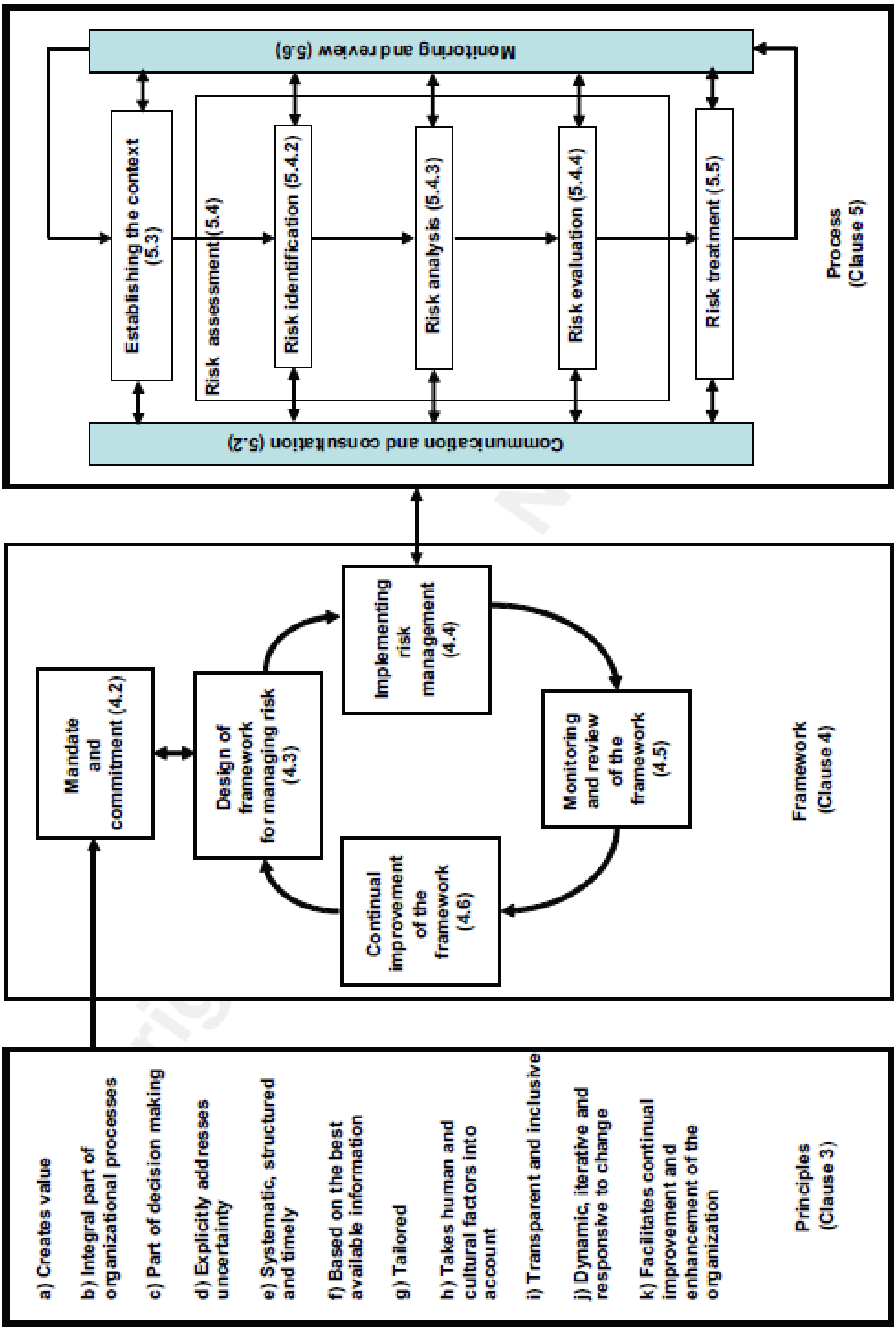


Figure 48. Risk management conceptual diagram from AS/NZS ISO 31000:2009.

The principles that need to be considered in the overall risk assessment process described in section 6.1 are as follows:

- **Risk assessment creates and protects value:** This is the key principle driving the need for this research. The unfortunate circumstances of existing buildings with pervasive non-compliant PFP creates a potential fire safety risk to life safety and property. However, the significant costs associated with bringing non-compliant PFP into full compliance will also have an adverse effect on building owner and occupier property and potentially quality of life. Because the upfront risk management of determining compliance requirements and assurance that the actual construction meets the compliance criteria, this risk management needs to be readdressed when buildings undergo alterations. The increased costs of repairing existing construction need to be balanced with the potential increased risk of less than fully compliant PFP.
- **Risk management explicitly addresses uncertainty:** Uncertainty needs to be considered when evaluating PFP compliance on an ANARP basis. In particular, uncertainty in the actual performance of PFP assemblies in a fire needs to be addressed if the proposed solutions are not tested or subject to a formal opinion. Other aspects of uncertainty that need to be considered include but are not limited to fire brigade response, durability of PFP solutions and potentially unexposed and unremedied PFP defects.
- **Risk management is systematic, structured and timely:** This process needs to be initiated as early in a building alteration project as possible. Options that are potentially reasonable and practicable such as commissioning fire tests to reduce uncertainty in the performance of proposed solutions may become unreasonable if excessive project delays are required due to fire lab availability. The risk management process needs to be followed in the manner as agreed by the stakeholders to ensure it is systematic and structured.
- **Risk management is based on the best available information:** Information-gathering steps in the process are critical to understand the complete picture.
- **Risk management is a part of decision making:** The proposed process is intended to provide a more consistent, risk-based approach to making PFP ANARP decisions, but the process does not make that decision. That is up to the BCA.
- **Risk management is tailored:** While the risk management process needs to be systematic and structured, there will likely be situations where the full process is not required or additional steps are needed. Communication among stakeholders is key to setting and agreeing upon the process to be used for a specific application.
- **Risk management takes human and cultural factors into account:** There are many human factors that are critical to the success of this risk management process. The ability of the occupants to egress the building must be taken into account – if it is likely that occupants will have limited mobility or difficulty sensing and responding to fire alarm signals, the level of risk will be elevated. The quality assurance steps and ongoing risk monitoring are also critical to manage the human factors that resulted in the non-compliant construction in the first instance.
- **Risk management is transparent and inclusive:** Clear and regular communication with all relevant stakeholders is critical to the success of this process. Thorough documentation that describes the building characteristics and options, acceptance criteria, risk analysis, quality assurance plan and documentation and residual non-compliant issues for ongoing monitoring and potential future remedy is critical to ensure success of the process.
- **Risk management is dynamic, iterative and responsive to change:** The life-cycle approach to risk management reflected in the ongoing risk monitoring in the

process adheres to this principle. The process is also meant to be flexible (based on clear communication and acceptance by stakeholders) to be adaptable for different situations.

The risk assessment process in Figure 47 also follows the AS/NZS ISO 31000:2009 process.

The top step of scope and objectives is all about establishing the context. Next, the acceptance criteria, building characteristics and options and level of compliance identify the risk. Risk analysis is self-explanatory. Risk evaluation is covered by the acceptable risk decision point. Once a proposed solution has been deemed to result in acceptable risk, implementation of the chosen solution and residual risk management cover the risk treatment.

While not shown in the diagram, communication and consultation is expected at each step. Monitoring and review also continue throughout but are particularly important for residual risk management, quality assurance and ongoing risk monitoring.

6.3 Maynard Marks risk analysis model

One risk analysis option for PFP defects has been developed in the industry for use in multi-unit residential buildings. It has been reviewed by the stakeholder group involved with this project and is available from BRANZ. This tool is a semi-quantitative risk-cost model that creates a numerical score based on factors for the risk and cost for individual defects.

This tool on its own does not provide a basis for Building Code compliance but can be used in conjunction with the risk assessment process to systematically evaluate individual defects. The use of this tool can only be undertaken with agreement among the stakeholders for the project at hand. It is not designed for use with new construction.

6.3.1 Risk score

The overall calculation for the risk score is shown in Figure 49. A building risk score and defect risk score are calculated and multiplied by a factor based on the estimated percent PFP compliance.

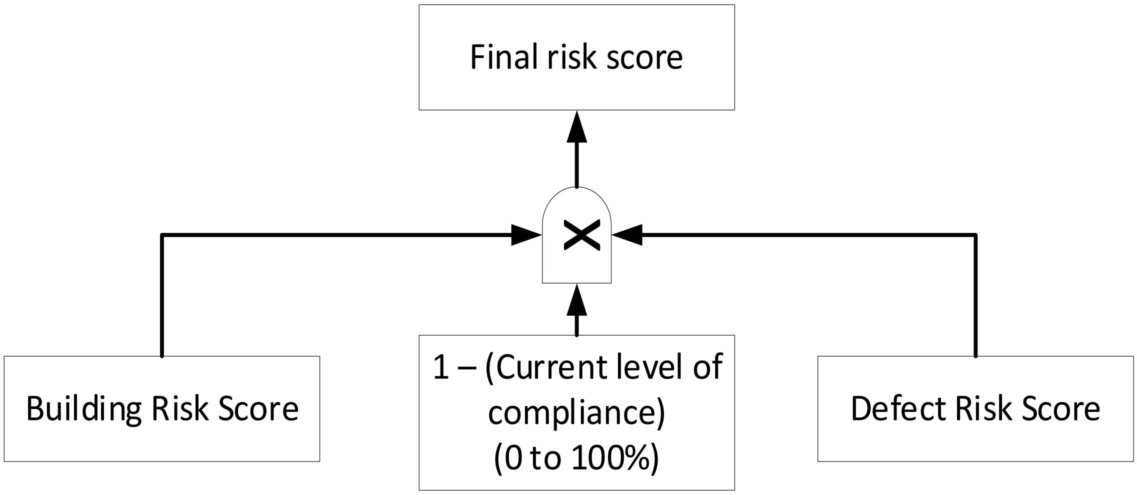


Figure 49. Simple PFP defect risk analysis tool: risk score.

The building risk score is comprised of four factors as shown in Figure 50.

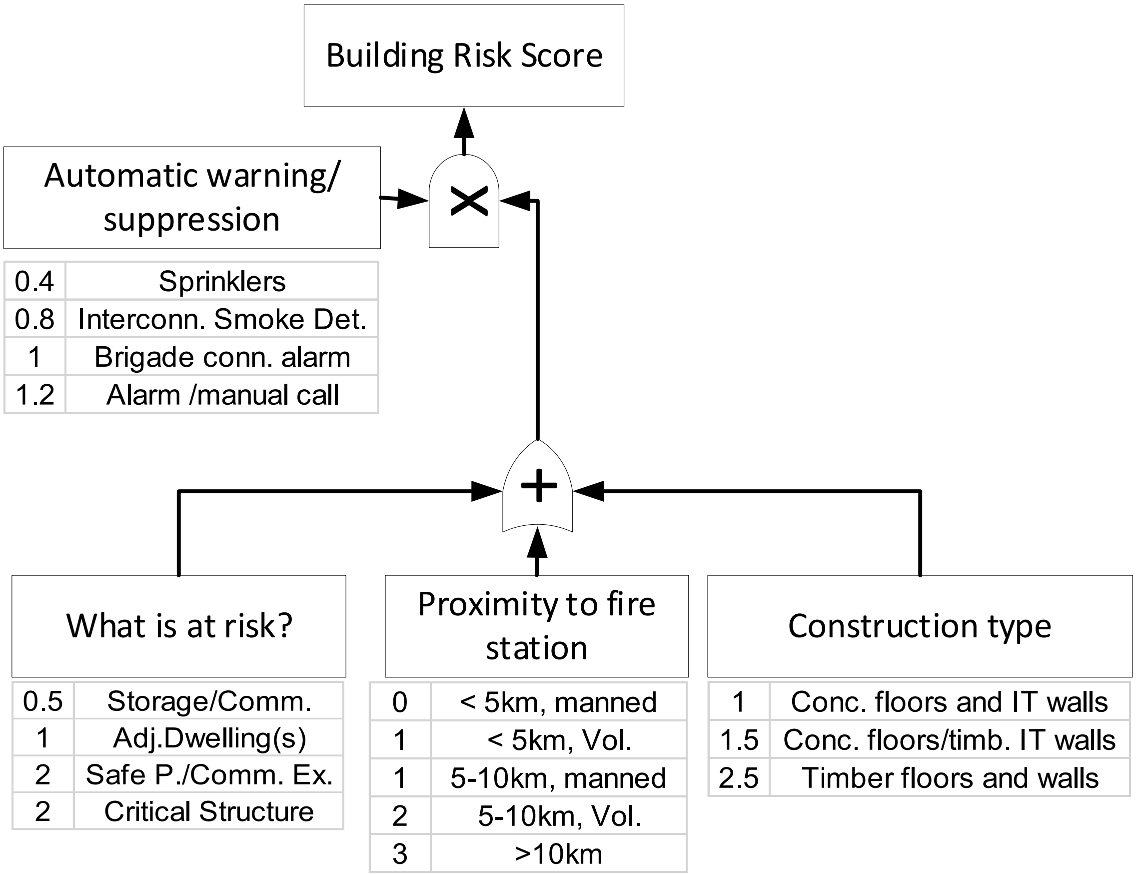


Figure 50. Building risk score factors.

Automatic warning/suppression

The building risk score is multiplied by a factor that represents the effect that automatic warning or suppression systems will have on the fire risk to occupants. The premise is that warning systems provide occupants with more time to escape before the fire develops to the point where the PFP systems are challenged. Also, the fire brigade is notified earlier, allowing intervention earlier in the fire development. The factor for sprinklers also includes the fire suppression or control aspect. A 20% penalty is applied to the building risk score if the alarm is not brigade connected. Interconnected alarms provide early warning to occupants not in the compartment of fire origin. These occupants are mostly likely to be affected by compromised PFP, so the early notification provides some compensation.

The factor of 0.4 for sprinklers is consistent with the concession that the FRR can be reduced by a factor of 2 when a sprinkler system compliant with NZS 4541:2013 or NZS 4515:2009 *Fire sprinkler systems for life safety in sleeping occupancies (up to 2000 square metres)* is installed, which is included in most of the Acceptable Solutions. The additional relaxation of insulation requirements for sprinklers in the Acceptable Solution likely makes up for the difference since, as noted from the test results, typically insulation failures precede integrity failures.

One potential concern with the use of the Maynard Marks model is that credit for sprinklers should not be applied twice. The required FRR specified in the model should not already include the Acceptable Solution sprinkler concessions. Installed systems also need to be compliant with an acceptable standard, such as NZS 4541:2013 or NZS 4515:2009 for sprinklers or NZS 4512:2010 for smoke detection systems.

What is at risk?

The level of risk depends on the compartment that is compromised. Critical structure and shared escape routes are given the highest rating of 2. Adjacent dwellings are rated next highest because of the sleeping risk, which increases pre-movement time. Storage or commercial occupancies are rated lowest because the number of occupants is likely to be less and they are likely to be alert.

Proximity to fire station

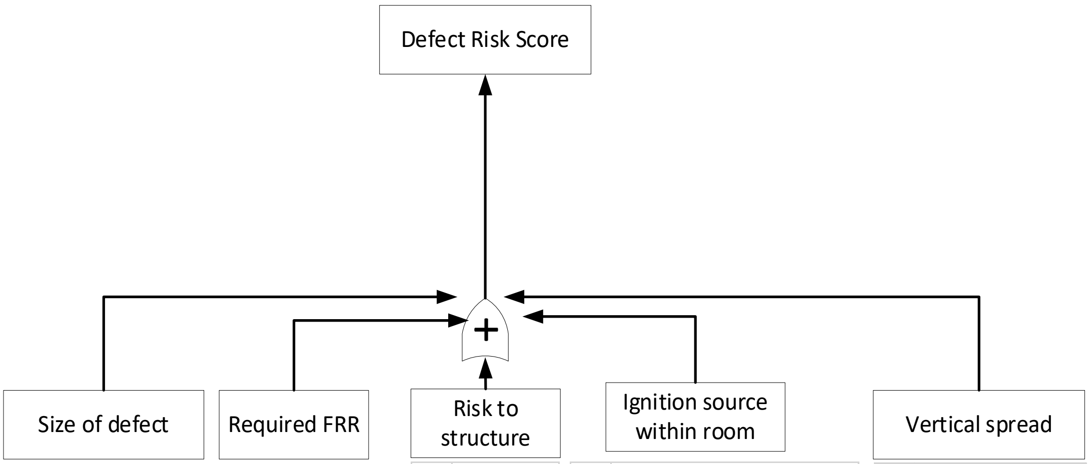
Fire brigade response times are considered in the building risk in the proximity to fire station factor. Discussion with Fire and Emergency New Zealand (FENZ) has indicated that the second-closest fire station should be used because fire stations can move. Other factors that may influence fire brigade response such as hose run distances, appliance staging areas and hydrant location may also affect the time before effective fire service intervention can occur. Specific discussions with FENZ should be undertaken on a project-specific basis to evaluate expected response times for the individual building.

Construction type

The final building risk score factor is construction type. Timber-framed construction is considered highest risk in the model. Linings are vulnerable to damage, particularly if not supported near penetrations, and combustion can spread in the concealed spaces in the walls and floor. Fire spread through walls is considered to be lower risk than fire spread through timber floors because vertical fire spread is aided by the buoyancy of the hot combustion products.

6.3.2 Defect risk score

The defect risk score is comprised of five factors as shown in Figure 51.



1	Small
2	Medium
3	Large
5	Whole Wall/Ceiling

1	Smoke Seal Only
1	15 min.
2	30 min.
3	60 min.
4	90 min.
6	120 min.
8	240 min.

0	Low
1	Medium
2	High

0	None
1	Balcony/Deck
2	Electrical Cupboard
2	Car Park/Other
3	Comm. Kitchen/Fuel Appl.
4	Domestic Kitchen

0	None
2	Pipe/Cable
5	Ceiling
10	Stairs/Duct/Shaft

Figure 51. Defect risk score factors.

Size of defect

Size of defect is the first defect risk factor. There are four options: small, medium, large and whole wall/ceiling. There is some subjectivity involved in determining the difference between small, medium and large. However, there are criteria that can be used to support this decision. The likely mechanism of failure and fire and/or smoke transmission through the building element can be considered in determining the size of a defect. The three types of fire and/or smoke transmission are direct flame and hot gas ignition (integrity), excessive temperature on the unexposed side (insulation), and smoke leakage.

Smoke leakage

The key factor here in most cases will be the imperforate barrier requirement. While 'imperforate' is not a defined term, the alternative smoke permeation requirement in BS EN 12101-1:2005 *Smoke and heat control systems – Specification for smoke barriers* of 25 m³/hr per m² of barrier area at a 25 Pa pressure difference, measured at ambient temperature and 200°C, can be used as a comparison. Other example requirements are as follows:

- AS/NZS 1530.7:1998 *Methods for fire tests on building materials, components and structures – Smoke control door and shutter assemblies – Ambient and medium temperature leakage test procedure* notes that "in a number of countries a leakage rate of between 20 m³/hr and 25 m³/hr is used where life safety is the main consideration". This standard measures the leakage rate at pressure differentials of up to 50 Pa and at ambient temperature and 200°C.
- NFPA 101 *Life safety code*, 2015 edition, clause N8.5.6.5 notes:

  … in new construction, through-penetrations shall be protected by an approved through-penetration firestop system installed and tested in accordance with the requirements of ANSI/UL 1479, for air leakage and shall comply with one of the following:

  - A maximum 5 ft³/min per ft² (0.025 m³/s per m² or 90 m³/hr per m²) of penetration opening for each through-penetration fire-stop system
  - A maximum total cumulative leakage of 50 ft³/min (0.024 m³/s or 86 m³/hr) for any 100 ft² (9.3 m²) of wall area or floor area.

Using orifice flow equations, an estimate of an equivalent circular leakage area can be obtained.

$$\dot{V} = C_D A \sqrt{\frac{2\Delta P}{\rho_g}} \qquad \textbf{Eq. 1}$$

Where:

$\dot{V}$ is the volume flow rate (m³/s)

C_D is the flow coefficient (typically 0.67)

A is the leakage area (m²)

ΔP is the pressure difference across the leaking element (Pa)

ρ_g is the density of the gas upstream of the leak (kg/m³).

The gas density ρ_g can be determined using the ideal gas law. At a nominal pressure of 101.325 kPa, the ideal gas law equation simplifies to the following for air or air-like (nominally equivalent molecular weight, such as smoke) gas density:

$$\rho_g = \frac{353}{T_g} \qquad \textbf{Eq. 2}$$

Where T_g is the temperature of the gas (K). An equivalent circular leak diameter can be calculated using the equation for the area of a circle:

$$A = \frac{\pi}{4} D^2 \qquad \textbf{Eq. 3}$$

Where D is the equivalent circular leak diameter in m.

From these equations, the equivalent diameters can be calculated for the smoke leakage criteria listed above as shown in Table 4.

Table 4. Equivalent hole diameters calculated using the orifice equation and leakage guidance from three sources.

Leak flow rate (m^3/hr)	dP (Pa)	Gas temperature (°C)	Equivalent diameter (mm)	Referenced Standard
20	50	200	30.2	AS 1530.7 (2007)
25	50	200	33.8	AS 1530.7 (2007)
25	25	200	40.2	AS 1530.7 (2007)
25	25	25	45.1	BS EN 12101 Part 1 (2005)
90	75	200	57.9	NFPA 101 (2015), UL 1479 (2003)

The leakage values would be quite conservative because fully involved fire maximum pressure differences are typically approximately 16 Pa (Fang, 1980), although temperatures could be higher as well.

The height of a leak may also be a factor, as the expected pressure difference will decrease the closer the leak is to the neutral plane. Leaks at the floor-ceiling interface will have the greatest pressure difference, with decreased pressure difference as the height approaches the typical fully involved neutral plane height of approximately 40% of the room height (or major ventilation opening height – i.e. windows or doors).

The intention of smoke separations is to keep occupants from exposure to conditions that are toxic or where visibility is impaired. The ability of a separation to achieve this will depend on how fast smoke fills a compartment and how much dilution is available. Therefore, the smoke-filling time of the compromised compartment should be considered based on the compartment volume and configuration. Fire modelling by a competent fire engineer can be done to investigate the potential for smoke filling in compartments through smoke leaks from an adjacent fire compartment. For example, several 25 mm diameter holes connecting a compartment to a large atrium may not be a concern in terms of smoke filling but may be for a short and narrow corridor.

Insulation

Insulation is the PFP criteria that firestopping assemblies are most likely to fail first, as was discovered in the experimental programme for this project. An integrity failure implies insulation failure at the same time. An insulation failure will only result in fire spread if a combustible material is present and ignited on the unexposed side of the assembly. This is reflected in the C/AS2 concession for firestop insulation requirements:

> 4.4.5 A fire stop for a penetration is not required to have an insulation rating if means are provided to keep combustible materials at a distance of 300 mm away from the penetration and the fire stop to prevent ignition.

Additionally, insulation ratings are not required in C/AS2 for glazing in fire separations, or anywhere in a building that is fully sprinklered to NZS 4541:2013 or NZS 4515:2009. It should be noted that these standards include the requirement for insulation ratings in many circumstances, and the justification for removing the insulation requirement in the protection from fire Acceptable Solutions is not clear.

The probability of combustible materials being located adjacent to an assembly that has failed on insulation will likely increase with the size of the assembly. The location should be considered in the probability of having combustible materials in close proximity. If the assembly is easily and regularly accessible to occupants and on the floor, for example, there is a high likelihood of combustible material contact. Areas high on walls and in ceiling concealed spaces may be less likely to have combustible material contact.

Integrity

An integrity failure, characterised by openings in the PFP assembly or direct ignition of combustible materials by hot fire products escaping during a standard fire test, is expected to have a higher risk of fire spread than an insulation failure. An easy 'first pass' screen for integrity failures is to apply the AS 1530.4-2005 gap gauge requirements to the assembly. Further determination of the integrity rating of a building element requires an AS 1530.4-2005 fire test or AS 4072.1-2005 formal opinion.

Structural stability

If a PFP element will not meet the structural stability requirements to maintain a means of escape, it is recommended that either it is brought to full compliance or a detailed risk analysis be conducted by a fire engineer, structural engineer or structural fire engineer, depending on how it will affect the means of escape. This tool is not further applicable for evaluating cases of existing PFP that will not meet the structural fire resistance requirements. The only application to structural stability is where a structural element is protected by a fire separation that is intended to maintain its integrity and insulation to protect the conditions that the structural element is exposed to.

Required FRR

The required FRR is another parameter that has some degree of subjectivity depending on what is used for the acceptance criteria. If the Acceptable Solutions are used, the life safety requirements are explicit, but credit for sprinklers should not be applied additionally here. The Maynard Marks model only includes one value for FRR even though FRR is evaluated on three criteria of structural stability, integrity and insulation, as previously mentioned. The required FRR may take into consideration factors such as escape route geometry and the number of alternative escape routes available. Burnout times for expected fuel loads should be considered as well.

Risk to structure

As previously mentioned, this model is not designed to address structural strength of building elements during fire specifically but can only be used if fire-separating elements are installed to protect structural elements. A factor of low, medium or high is applied in this instance. Low would be expected to be applied for non-loadbearing assemblies that are not protecting structural elements.

Ignition source within room

The Maynard Marks model acknowledges that, in some fire compartments, the probability of fires occurring may be lower because there is a lower probability of ignition sources present in the room. Domestic kitchens are considered most prone to ignition sources, followed by commercial kitchens, car parks, electrical services, balconies/decks and compartments where no ignition sources are likely to be present. Care should be taken here that ignition sources in all fire compartments served by the building assembly are evaluated.

Vertical spread

This factor in the Maynard Marks model acknowledges that, if the potential for vertical fire spread exists, the risk increases because fire spreads faster vertically due to buoyancy. Defects associated with vertical compartments like stairs or shafts (along with ducts) are assigned a factor of 10. Defects associated with large areas of ceiling are assigned a factor of 5. Pipes and cable penetrations through floors are assigned a factor of 2.

6.3.3 Level of compliance

The level of compliance is likely the most difficult measure to determine accurately and to the satisfaction of all stakeholders. Ideally, this will be based on an AS 1530.4-2005 fire test of a worst-case specimen representing the actual construction or an AS 4072.1-2005 formal opinion based on related fire tests. One scenario where this will be straightforward will be when a lower-rated assembly that has relevant test data (for example, a 30-minute FRR assembly) has been installed where a higher-rated assembly is required.

Without this level of evidence, the default level of compliance should be zero. As previously stated, the cost portion of the ANARP decision where the performance of the existing construction or proposed solution is unknown based on fire test results should include the cost of conducting fire tests as required to determine the level of compliance. Engineering judgements of the level of compliance of untested assemblies should be discouraged and as a minimum follow the guidelines described in section 4.3.3.

6.3.4 Cost factors

The Maynard Marks model includes cost factors as shown in Table 5. The factors include the amount of builder's work required to access the defect, the cost of repairing the defect and additional time involved in repairing the defect.

The cost of a representative fire test can be spread across the number of relevant defects in the building.

Table 5. Maynard Marks risk analysis tool cost factors.

Time Factors			
Q: Builder's Work Required	None (defect is completely acce		0
R: Total Cost of Work (per defect)	$4001-$6000	Source: Guess	4
S: Additional Time Involved	2-3 weeks	Source: Estimate	3
Total Score: Sum of cost and time factors			7
Final Cost/Time Score:			**4**
Score Boundaries: 1: 0 - 2, 2: 2 - 4, 3: 4 - 6, 4: 6 - 8, 5: 8 +			

6.3.5 Model outcomes

Based on the model inputs, risk scores of 1 to 5 and cost scores of 1 to 5 are plotted on the risk matrix shown in Figure 52. There are three regions on the matrix that result in different outcomes.

		High		**Risk**		Low
		5	4	3	2	1
Low	1	V. Hi	V. Hi	High	High	Med
Cost/ Time	2	V. Hi	High	High	Med	Med
	3	High	High	Med	Med	Low
	4	High	Med	Med	Low	Low
High	5	Med	Med	Low	Low	Low

Figure 52. Maynard Marks model risk/cost matrix.

Region 1 is shown in Figure 53. Any model outputs in this region result in the outcome of repair defect.

		High		**Risk**		Low
		5	4	3	2	1
Low	1	V. Hi	V. Hi	High		
Cost/ Time	2	V. Hi	High			
	3	High				
	4					
High	5					

Figure 53. Maynard Marks model risk/cost matrix – region 1.

Region 2 is shown in Figure 54. The outcome for model output in this area depends on whether sprinklers are installed or not. If sprinklers are installed, the model output is smoke seal only. If sprinklers are not installed, the model output is repair defect.

		High		**Risk**		Low
		5	4	3	2	1
Low	1				High	Med
Cost/ Time	2			High	Med	
	3		High	Med		
	4	High	Med			
High	5	Med				

Figure 54. Maynard Marks model risk/cost matrix – region 2.

Region 3 is shown in Figure 55. Model outputs in this region result in the outcome of not reasonable and practicable to repair.

		High		Risk		Low
		5	4	3	2	1
Cost/ Time: Low	1					
	2					Med
	3				Med	Low
	4			Med	Low	Low
High	5		Med	Low	Low	Low

Figure 55. Maynard Marks model risk/cost matrix – region 3.

6.3.6 Limitations of the Maynard Marks risk analysis tool

As a simplified tool, the Maynard Marks risk analysis tool can only be applied to a limited scope and must be considered within the wider building context. The tool only looks at the cost and potential risks for individual defects. Individual defects need to be considered within the context of the entire fire or smoke separation that the defects are part of.

The Maynard Marks risk analysis tool does not consider escape route geometry, including path lengths and heights. The project stakeholders should review the specific building characteristics and make sure that they are comfortable with applying this tool for the specific application. This may mean running some representative examples through the tool at the start of the project, sharing the tool outcomes and making sure that all the stakeholders agree with the outcomes. Weighting factors in the tool could be adjusted at this time as necessary. The tool may not be suitable for tall buildings or buildings with a single means of escape.

Non-compliance of other aspects is not considered within the Maynard Marks tool. The interactions of other potentially non-compliant aspects such as detection or suppression systems, lighting systems, escape route geometry and internal and external surface linings needs to be addressed if they are present.

The overall project cost and the relation of the cost of fixing the defects to the building value and project cost is not considered by the Maynard Marks model. This should be addressed in the overall risk assessment process.

Staging of repairs or upgrades is not considered by the Maynard Marks model or future opportunities to improve towards fully compliant. As noted in section 4.3.4, any staging needs to consider the reduction in the benefit and potential future enforcement difficulties.

6.3.7 Examples of the use of the Maynard Marks model

The following are some examples of how the Maynard Marks model has been applied to a real project.

Penetration example

In this case, a cable bundle was installed in a timber/infill floor/ceiling assembly above a car park and below an apartment, as shown in Figure 56. The model inputs are shown in Figure 57.

Figure 56. Cable bundle through timber infill floor.

Risk Factors (select from drop-down lists)				
A:	**What is at Risk?**	Adjacent Dwelling(s)		1
B:	**Proximity to Fire Station**	Within 5km, manned		0
C:	**Construction Type**	Concrete floors/timber IT walls		1.5
D:	**Automatic Warning/Suppression**	Brigade connected alarm		1
		Building Risk Score (A+B+C)xD		**2.5**
E:	**Size of Defect**	Medium		2
F:	**Required FRR**	60 Minutes		3
H:	**Risk to Structure**	Low		0
J:	**Ignition Source Within Room**	Car Park/Other		2
K:	**Vertical Spread**	Pipe/Cable		2
		Defect Risk Score		**9**
G:	**Current Level of Compliance**	(Certified by Passive Fire Consultant)		**0%**
	Total Score: Building Risk x Defect Risk x (100-Current Level of Compliance)			**22.5**
	Final Risk Score:			**4**
	Score Boundaries: 1: 0 - 6, 2: 6 - 12, 3: 12 - 19, 4: 19 - 25, 5: 25 +			
Cost and Time Factors				
M:	**Builder's Work Required**	Minor (e.g. remove linings only)		1
N:	**Total Cost of Work (per defect)**	$2001-$4000	Source: Guess	3
O:	**Additional Time Involved**	Less than 1 w	Source: Estimate	1
	Total Score: Sum of cost and time factors			**5**
	Final Cost/Time Score:			**3**

Figure 57. Maynard Marks model inputs – cable bundle example.

In this case, an adjacent dwelling was at risk. The building happened to be within 5 km of a manned fire station. The building had timber inter-tenancy walls, and the main construction of the floor assembly was concrete (timber infill floor). A brigade connected alarm was present.

The size of defect was considered to be medium. Based on the C/AS2 acceptable solution, the required FRR was 60 minutes. The risk to structure was low because the concrete floor would not be expected to fail structurally even if fire penetrated the defect. The ignition source input was based on the fact that the lower compartment was a car park. Vertical spread was given the pipe/cable classification.

This resulted in a building risk score of 2.5 and a defect risk score of 9. The current level of compliance was assigned a value of 0%. This resulted in a total score of 22.5, which corresponds to a final risk score of 4.

For cost, the work required to access the defect was minor. The total cost of work to repair the defect was guessed (a guess has less certainty than an estimate) to be between $2,000 and $4,000. The additional project time required to complete the repair was estimated to require less than 1 week. The combination of these inputs resulted in a total cost score of 5 and a final cost/time score of 3.

The combination of the final risk score of 4 and cost/time score of 3 resulted in an outcome of repair defect. If interconnected smoke detection was to be installed, the final risk score would reduce to 3, but the outcome would still be to repair the defect. If sprinklers were to be installed, the final risk score drops to 2 and the outcome becomes not reasonable and practicable to repair.

Wall example

In this example, a kitchen wall is protecting a structural steel element of an apartment building. The wall is the compartment boundary between two household units. The Maynard Marks risk analysis model inputs are shown in Figure 58.

Again, a manned fire station is located within 5 km of the building, and it has timber infill floors with timber-framed plasterboard walls. However, the kitchen wall construction is similar to a tested 30-minute system, while the requirement has been determined to be 60 minutes, again based on the C/AS2 requirements.

In this case, the final risk score and final cost/time score end up at 3, which results in a repair defect outcome. Adding an interconnected smoke detection system still requires repairs, but sprinklers result in an outcome of not reasonable and practicable to repair. In fact, this would be a compliant solution (if C/AS2 is used as the acceptance criteria) because 30 minutes FRR is all that is required in C/AS2 buildings if an NZS 4541:2013 or NZS 4515:2009-compliant sprinkler system is installed.

Risk Factors (select from drop-down lists)			
A:	What is at Risk?	Adjacent Dwelling(s)	1
B:	Proximity to Fire Station	Within 5km, manned	0
C:	Construction Type	Concrete floors/timber IT walls	1.5
D:	Automatic Warning/Suppression	Brigade connected alarm	1
		Building Risk Score (A+B+C)xD	**2.5**
E:	Size of Defect	Whole Wall/Ceiling	5
F:	Required FRR	60 Minutes	3
H:	Risk to Structure	High	2
J:	Ignition Source Within Room	Domestic Kitchen	4
K:	Vertical Spread	None	0
		Defect Risk Score	**14**
G:	Current Level of Compliance	(Certified by Passive Fire Consultant)	**50%**
	Total Score: Building Risk x Defect Risk x (100-Current Level of Compliance)		**17.5**
	Final Risk Score:		**3**
	Score Boundaries: 1: 0 - 6, 2: 6 - 12, 3: 12 - 19, 4: 19 - 25, 5: 25 +		

Cost and Time Factors					
M:	Builder's Work Required	Minor (e.g. remove linings only)			1
N:	Total Cost of Work (per defect)	$2001-$4000	Source	Guess	3
O:	Additional Time Involved	1-2 weeks	Source	Estimate	2
	Total Score: Sum of cost and time factors				**6**
	Final Cost/Time Score:				**3**
	Score Boundaries: 1: 0 - 2, 2: 2 - 4, 3: 4 - 6, 4: 6 - 8, 5: 8 +				

Figure 58. Maynard Marks model inputs – whole wall example.

7. Future research

A variety of issues have arisen as a part of this research that could warrant further investigation either as an extension to this research project or as their own stand-alone project:

- Fire resistance performance of fire-rated bulkheads – this includes the use of plasterboard bulkhead boxes covering oversized/awkward penetrations (typically combined with a pipe collar).
- Quantitative measurement of smoke/gas release from penetrations and risk analysis.
- Quantitative heat flux measurements of each penetration, especially large penetrations.
- Fire resistance performance of non-rated lift door systems.
- Pipe collars attached to plasterboard by screws, not expansion anchors – this could also be expanded to look at the performance of various types of screws (wood, laminating and so on).
- Fire performance of penetrations in a 125 mm concrete rib-and-infill floor (to give a compliant floor slab thickness).
- Fire resistance performance of different depths of sealant on various substrates and ways of accurately but easily measuring the depth.
- Comparative fire resistance performance of different sealant brands and types especially between intumescents that have substantially different expansion rates. This could be extended to collars, wraps and sleeves as well and a test of non-fitting pipes through sleeves and collars (sleeves with extra wraps in place and so on).
- Further development of risk analysis processes (holistic approaches).

The next stage in this project includes fieldwork to investigate how the recommended process is used in actual projects. Feedback from this exercise will be used to identify any areas of improvement.

8. Conclusions and recommendations

Non-compliant firestopping and smokestopping has been identified as a major problem in New Zealand buildings undergoing alterations. The problem is caused by the following factors:

- Quality assurance during construction
- Design communication and specification (performance specification rather than detailed design at consent)
- Documentation of fire and smoke separations
- Knowledge and uncertainty of PFP assembly performance and compliance requirements
- Cost and time required to repair PFP issues.

The standard for consent for building alterations is ANARP compliance with the Building Code means of escape from fire and disability access provisions. The process and outcomes of applying the ANARP standard have not been consistent.

This project has developed a risk assessment process for non-compliant PFP that is intended to improve ANARP application consistency. It remains to be seen if this goal will be successful or not as it requires buy-in from project stakeholders. The outcome will be determined by the understanding and utilisation of the principles of risk management in the application of the process. Early communication with all stakeholders, thorough inspection and documentation and quality assurance are all crucial for success. An extension to this project will investigate how the process is implemented on selected projects.

An example of a risk analysis tool developed by industry has been demonstrated but this tool is not without limitations, as discussed in this study report. Observations of how the tool is applied in actual applications and how it is perceived by relevant stakeholders is critical to understanding its success.

There are a wide range of PFP problems that have been identified, and the need to repair is more obvious in some cases than others. Non-metallic pipe and electrical cable service penetrations through fire and smoke penetrations were found to be among the most contentious and also most commonly occurring. Fire resistance tested solutions are not available for these types of penetrations in many commonly used 30-minute and 60-minute residential building fire separations.

A testing programme was undertaken as part of this project, based on feedback from the project stakeholder group and site visits, to understand how these types of PFP defects would actually perform in fire tests. The results indicate that, in many cases, they may actually perform well enough to be compliant. However, no simple means of ascertaining assembly performance without a fire test has been identified, due to the complexity of factors influencing performance and the large variability in assemblies in actual construction. The cost of a fire test or formal opinion should be factored in for untested proposed solutions when doing an ANARP assessment.

If an engineering judgement approach is taken, extra documentation is required to justify the basis for the judgement. The competence of the person making the judgement needs to be considered, and a conservative approach to account for uncertainty in actual performance is necessary.

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Appendix A: Site visit photos and details

Figure 59. Plasterboard pattress covering a penetration through a concrete ceiling.

Figure 60. Plasterboard bulkhead held together with combustible plastic strapping.

Figure 61. Unrated flush boxes in fire-rated walls.

Figure 62. Penetrations through fire walls sealed with smoke seal only.

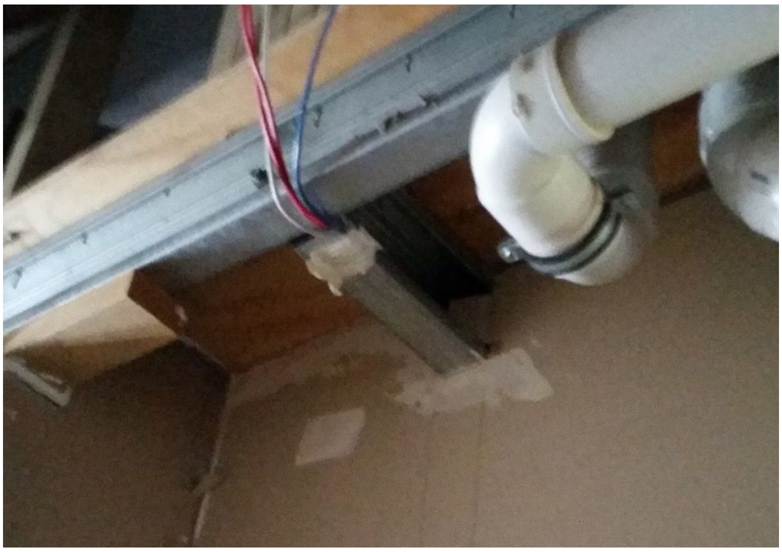


Figure 63. Non-sealed structural steel penetration of a fire-rated wall.

Figure 64. Non-rated access hatch into a full-height service shaft.

Figure 65. Multiple large cable bundles without stopping between bundles.

Sketch Number: 01

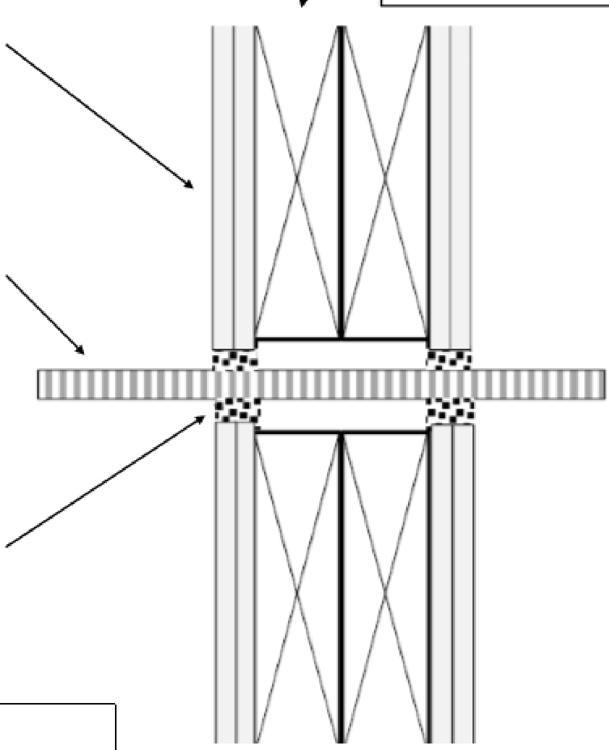
Location: Internal Corridor (Means of Escape)

Cavity Details:

One sided wall lining

Wall Lining Type: Gypsum Plasterboard (appears to be standard type)

Thickness: 2 x 13 mm



Penetration Type: Non-Combustible Pipe

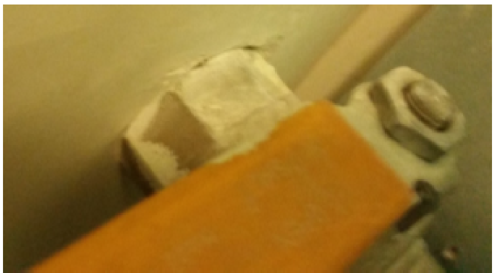
Penetration Diameter: 100 mm

Hole Details: Snug fit—Square on internal layer

PFP System: None

Sealant Details: None

Comments:



Sketch Number: 02

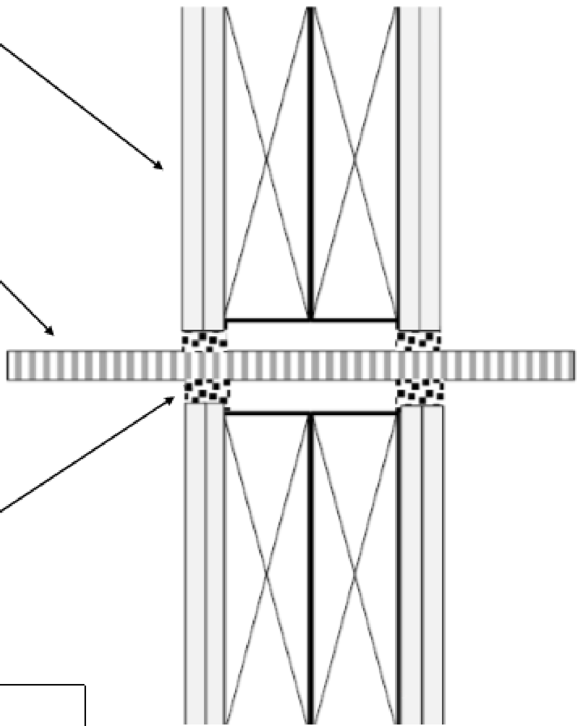
Location: Service Shaft

Cavity Details:

90 mm cavity with 13mm internal pattress on one side.
Two sided wall lining

Wall Lining Type: Gypsum Plasterboard - Braceline

Thickness: 2 x 13 mm
One side internal pattress



Penetration Type: 50mm Plastic Conduit + 12x6mm 3 wire

Penetration Diameter: 55 mm

Hole Details:

PFP System: None

Sealant Details: None

Comments:

Site manager said that penetration was simply yet to be sealed. Conduit will be trimmed back and then the cables sealed appropriately

Sketch Number: 03

Location: Kitchen - in apartment

Cavity Details:

N/a

Wall Lining Type: Concrete

Thickness: Unknown

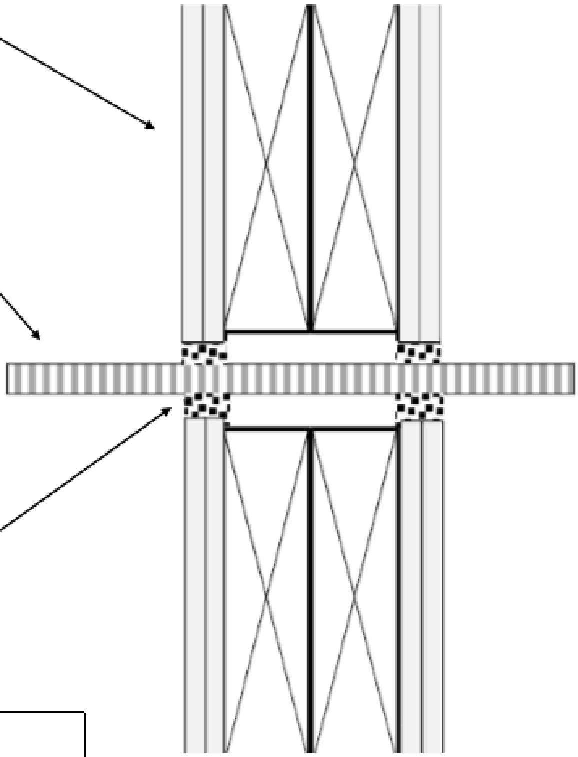
Penetration Type: uPVC Pipe

Penetration Diameter: 80mm

Hole Details: Not visible

PFP System: 90mm Fire Collar

Sealant Details: None

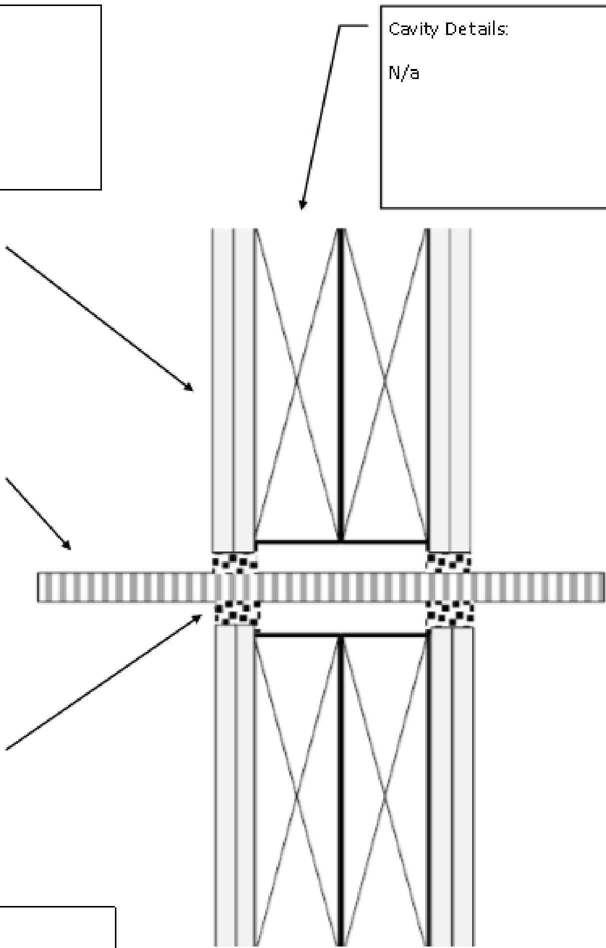


Comments:

Sketch Number:	04
Location:	Kitchen—in apartment

Cavity Details:

N/a



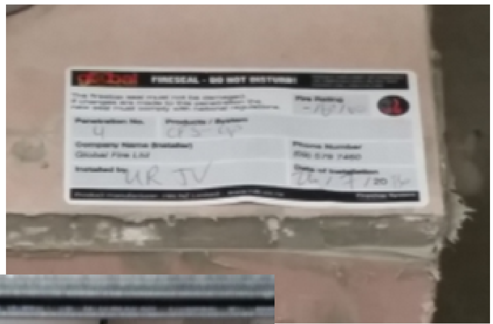
Wall Lining Type:	Gypsum Plasterboard - Fyreline
Thickness:	19mm

Penetration Type:	uPVC Pipe
Penetration Diameter:	100 mm
Hole Details:	Not visible

PFP System:	110mm Fire Collar
Sealant Details:	None

Comments:

Plasterboard bulkhead box attached to concrete wall



Sketch Number: 05

Location: Lvl 7 Corridor (Means of Escape)

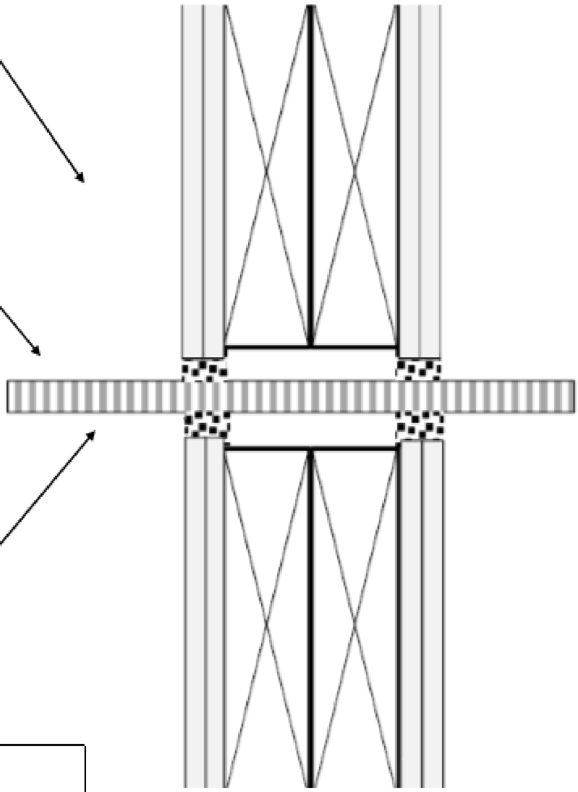
Cavity Details:

None Recorded/apparent

Penetration in IT wall above ceiling height

Wall Lining Type: Gypsum Plasterboard - Standard (appears)

Thickness: 13mm



Penetration Type: Cable

Penetration Diameter: 5-7 mm x 7-9

Hole Details: 60 mm
Rough hole (made with hammer blow)

PFP System: None

Sealant Details: None

Comments:

Corridor wall into apartment

Sketch Number: 06

Location: Lvl 7 Corridor (Means of Escape)

Cavity Details:

None Recorded/apparent

Penetration in IT wall above ceiling height

Wall Lining Type: Gypsum Plasterboard - fire-rated

Thickness: 2 x 13mm

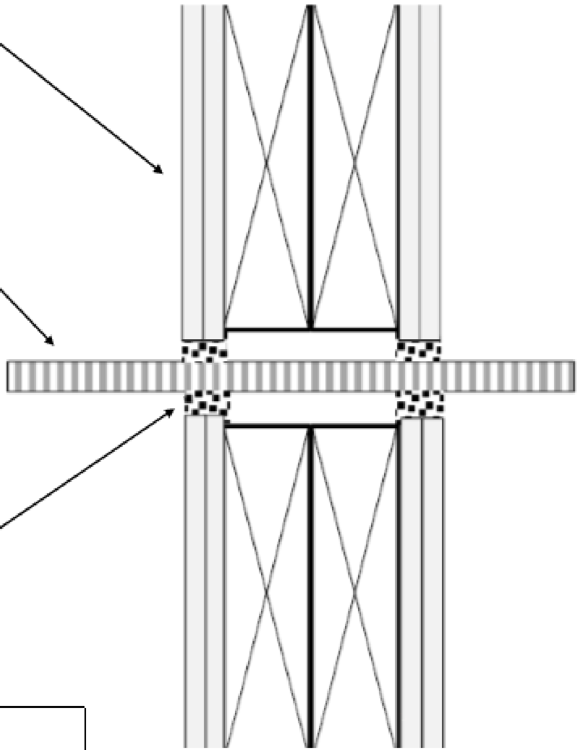
Penetration Type: Copper Pipe

Penetration Diameter: 20 mm

Hole Details: 30 mm

PFP System: None

Sealant Details: None



Comments:

Corridor wall into apartment

Plasterboard not fully stopped in surrounding area

Sketch Number: 07

Location: Lvl 7 Corridor (Means of Escape)

Cavity Details:

None Recorded/apparent

Penetration in IT wall above ceiling height

Wall Lining Type: Gypsum Plasterboard - Standard + fire-rated Pattress

Thickness: 2 x 13mm

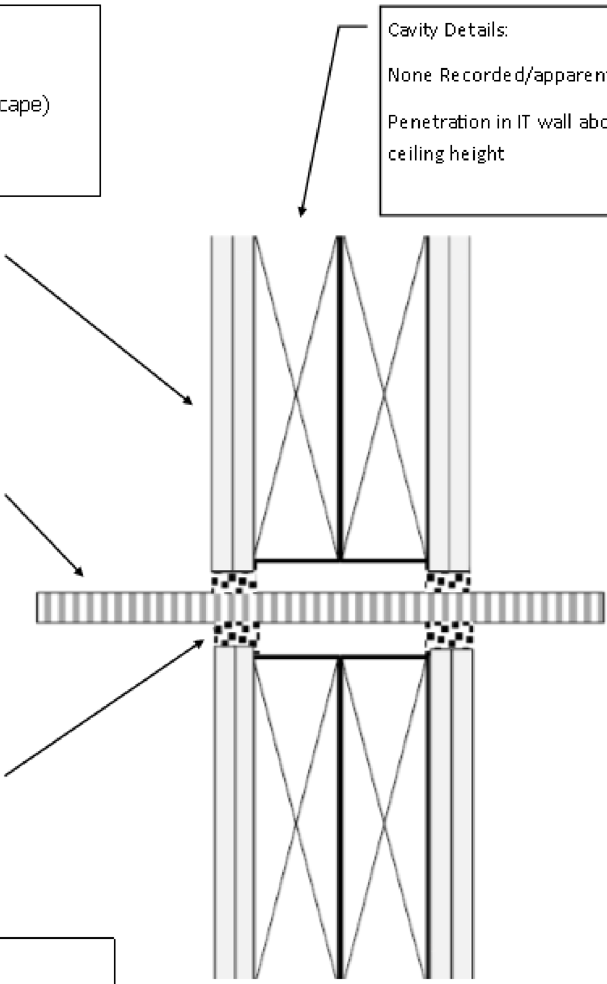
Penetration Type: Sprinkler Pipe

Penetration Diameter: 35 mm

Hole Details: 40 mm

PFP System: None

Sealant Details: None



Comments:

Corridor wall into apartment

Pattress appears to end within 10-20 mm of top of penetration. Penetration on edge of sheet, join is not stopped

,

Sketch Number: 07a

Location: Corridor (Means of Escape)

Cavity Details:

None Recorded/apparent

Penetration in IT wall above ceiling height

Wall Lining Type: Gypsum Plasterboard - Standard (appears)

Thickness: 1 x 13mm

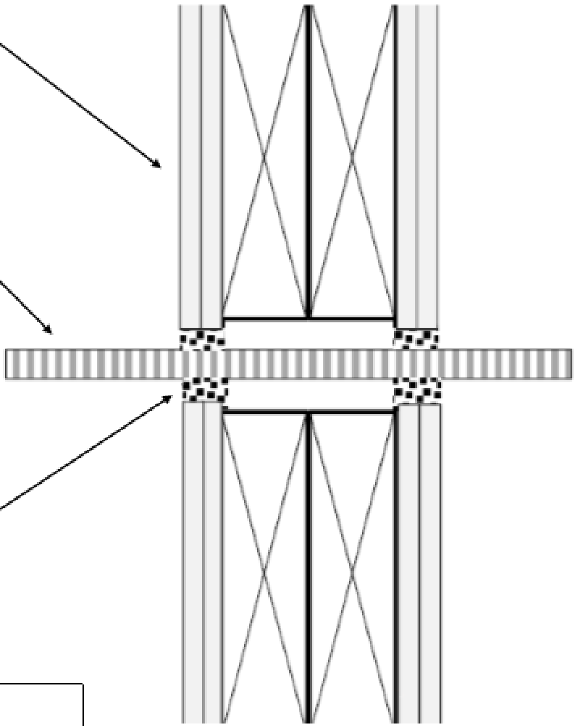
Penetration Type: Cables

Penetration Diameter: Unrecorded

Hole Details: Cables penetrating through broken section of plasterboard

PFP System: None

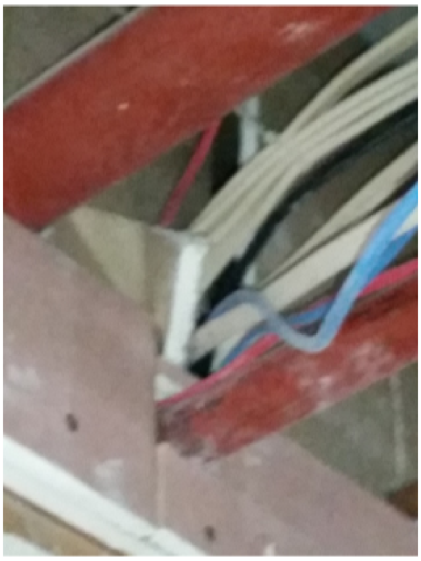
Sealant Details: None



Comments:

Corridor wall into apartment

Plasterboard is broken and unstopped in surrounding area



Sketch Number: 08

Location: Corridor (Means of Escape)

Cavity Details:

None Recorded/apparent

Wall Lining Type: Gypsum Plasterboard - Standard (appears)

Thickness: 1 x 13mm

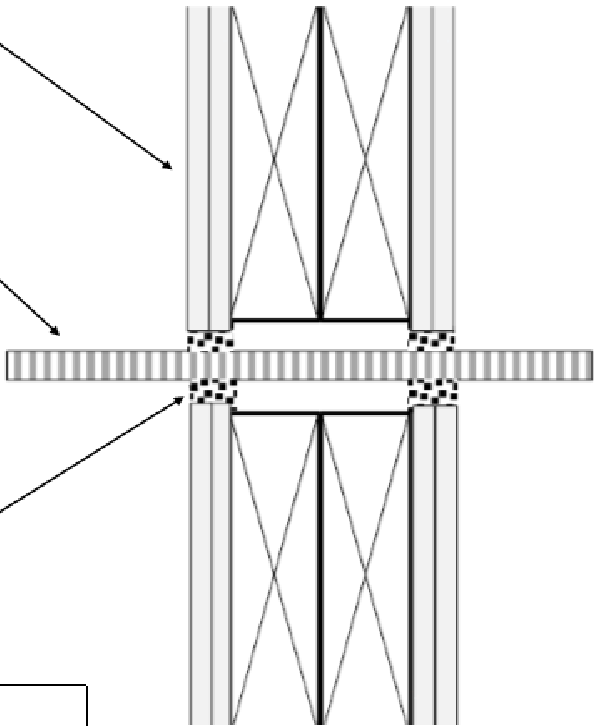
Penetration Type: uPVC Pipe

Penetration Diameter: 110 mm Pipe in 120mm Sleeve

Hole Details: 140mm

PFP System: Wrap

Sealant Details: None



Comments:

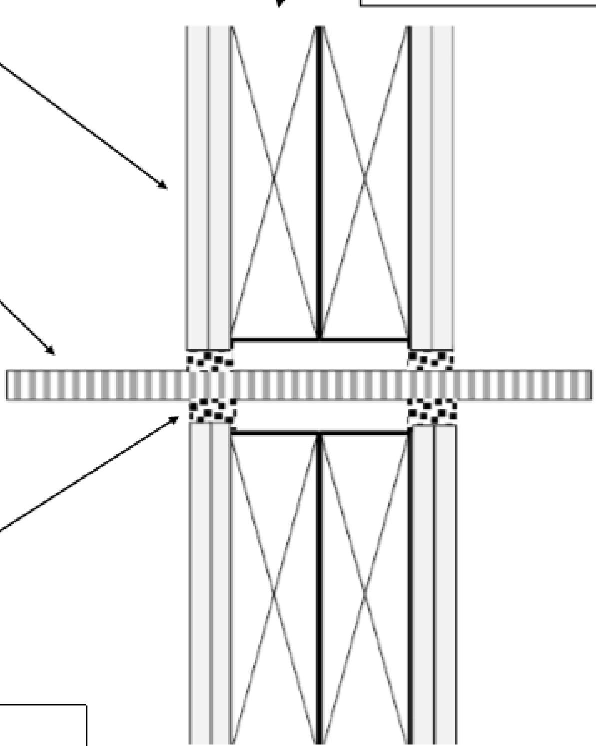
Corridor wall into apartment

Sketch Number: 09

Location: Corridor (Means of Escape)

Cavity Details:

None Recorded/apparent



Wall Lining Type: Gypsum Plasterboard - Standard (appears)

Thickness: 2 x 13mm

Penetration Type: Non-combustible duct

Penetration Diameter: 150 mm

Hole Details: 160mm

PFP System: See Comments

Sealant Details: None

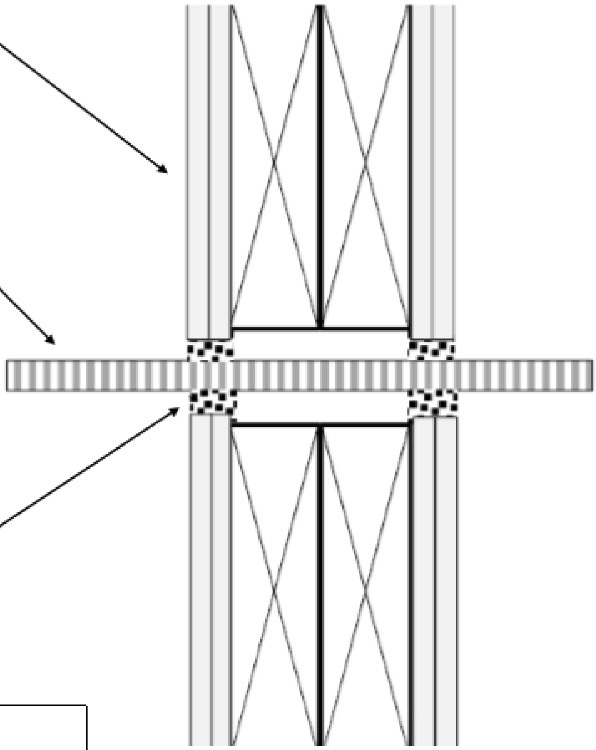
Comments:

Corridor wall into apartment. Two ducts observed. The first was unsealed and the second has stopping around the penetration (no label to identify if the stopping material is fire rated).

Sketch Number:	10
Location:	Corridor (Means of Escape)

Cavity Details:	
None Recorded	
One sided wall lining	

Wall Lining Type:	Gypsum Plasterboard - Standard (appears)
Thickness:	2 x 13mm



Penetration Type:	Electrical Cables
Penetration Diameter:	2 x 12x6mm 3 wire main + 5mm earth
Hole Details:	40 x 120 mm Hole

PFP System:	Smoke Seal
Sealant Details:	None

Comments:

Corridor wall into apartment

Flush box type hole - penetration filed with smoke seal, no flush box in place.

Appendix B: Fire test reports

This appendix contains five fire test reports with the test details and anonymised test results.

BRANZ
1222 Moonshine Road
Judgeford RD1
Porirua 5381
New Zealand
T +64 4 237 1170
F +64 4 237 1171
branz@branz.co.nz
www.branz.co.nz

INTERNAL REPORT

QR 1615 - PV

RELATIVE FIRE PERFORMANCE OF NON-STANDARD PENETRATION SEALS IN A PLASTERBOARD WALL

CLIENT
BRANZ Inc.

PROJECT NUMBER:	ISSUE DATE:	PAGE:
QR1615-PV	19-APR-2017	1 of 18

TEST SUMMARY

Objective

The objective of this research was to investigate the relative performance of non-standard penetration sealing systems that represent real-world construction in a typical plasterboard wall using an indicative fire resistance test. The results of the test will be used in the development of a process and risk analysis tool to inform ANARP decisions when evaluating the means of escape from fire as required by Section 112 of the New Zealand Building Act 2004.

The relative fire resistance performance of these cable and plastic pipe penetration sealing systems was determined by testing in a similar fashion to AS 1530.4-2014 *Fire Resistance tests of elements of building construction: Section 10 Service Penetrations and Control Joints,* with reference to AS 4072.1-2005.

Test sponsor

This fire test was part of a Building Research Levy funded project, QR1615.

Description of test specimen

The test specimen consisted of a nominal 3,000 mm x 3,000 mm timber-framed plasterboard wall assembly (45 mm x 90 mm timber framing with 13 mm thick fire-rated plasterboard on both the exposed and unexposed sides) that has a -/60/60 fire resistance rating as listed by the plasterboard manufacturer as the supporting construction. A range of electrical and communications cable (from one cable to twelve cables) and polyvinylchloride (PVC) pipe penetrations (40 mm to 100 mm OD) were tested with penetration systems that deviated from manufacturers' previously tested and approved specifications, but were representative of observed construction practices from real buildings in Auckland where penetrations have been exposed due to undergoing weathertightness remediation.

Date of test

13 February 2017

Test results

The comparative performance of 19 cable and PVC pipe penetrations and their sealing systems in a plasterboard wall substrate when tested under similar conditions to those required by AS 1530.4-2014, ranged from cotton pad ignition in 10 minutes to no ignition in 60 minutes. The maximum temperature measured on the unexposed side of the test specimen and the penetration services for each specimen ranged from 82 K to 413 K. The earliest time at which a temperature rise of 150 K was exceeded was 9 minutes.

The AS 1530.4-2014 test standard requires the following statements to be included in a report to demonstrate compliance with the standard. While this experiment was similar and not deemed to be compliant, these statements are relevant here as well:

"The results of these fire tests may be used to directly assess fire hazard, but it should be recognized that a single test method will not provide a full assessment of fire hazard under all fire conditions."

"This report details methods of construction, the test conditions and results obtained when the specific element of construction described herein was tested following the procedure outlined in this standard. Any significant variations with respect to size, constructional details, loads, stresses, edge or end conditions, other than those allowed under the field of direct application in the relevant test method, is not covered by this report.

Because of the nature of fire resistance testing and the consequent difficulty in quantifying the uncertainty of measurement of fire resistance, it is not possible to provide a stated degree of accuracy of the result."

Since methods of construction are not provided and there is no link provided between test results and construction details for specific penetration assemblies, this report does not prove or disprove compliance with the test standard for any tested assemblies. It only provides the range of performance that was experienced by the assemblies.

LIMITATION

For BRANZ project QR1615 stakeholder circulation only. The results reported here are not specific for a particular system and have been anonymised. This report shall not be used to endorse any particular product or system. The information contained within is for research purposes only and cannot be used as a basis to determine building code compliance.

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FIGURES

DOCUMENT REVISION STATUS

ISSUE NO.	DATE ISSUED	DESCRIPTION
1	29-March-2017	Initial Issue
2	19-April-2017	Prepared for Stakeholder Review

1. TEST PROCEDURE

The test was conducted in a similar manner to the requirements of AS 1530.4-2014 *"Methods for fire tests on building materials, components and structures, Part 4 Fire-resistance tests of elements of construction", Section 10 Service penetrations and control joints*, with reference to AS 4072.1-2005, Service penetrations and control joints, Section 3.1 Fire Resistance Testing.

2. DESCRIPTION OF TEST SPECIMEN

2.1 General

The supporting construction consisted of a 45 mm x 90 mm H1.2 timber frame of 3,000 mm x 3,000 mm nominal dimensions. Studs were placed at nominal 600 mm centres and nogs were placed at 1,200 mm centres. Both the exposed and unexposed sides were sheathed with 13 mm fire-rated plasterboard and fixed as per the manufacturers' specifications. All fastener heads were stopped and all sheet joints tape reinforced and stopped as per the manufacturer's specifications.

All pipes protruded a minimum of 500 mm into the furnace and at least 2,000 mm beyond the unexposed face. All pipes were capped with PVC caps on the exposed face and were open on the unexposed face. The pipes were supported at 500 mm and 1,500 mm on the unexposed side. Nominal PVC pipe sizes of 40 mm and 100 mm were used.

All cables protruded a minimum of 500 mm on both the exposed and unexposed sides. Cable bundles consisted of single cable (12 mm x 6 mm three wire main – 2.5 mm² 2C+E TPS 15150199/100 General Cable), three cable (2 x three wire main, 1 x single wire earth 6.0 mm² conduit wire GN/YL BAAP11A1001AAHN 6112 Olex), and twelve cable (7 x three wire main, 1 x earth, 2 x network Cat 6 UTP 0.53 3pr CMR BU 24154021 p/m Hubbell, 1 x RG6 coax 75 ohm SKY BK 152, and 1 x optical fibre OM3 Fibre patch lead 30 mt Fib-mm 1043).

Spacing between the edges of the penetrations and the edge of the specimen was maintained at a minimum of 200 mm, with one exception where the spacing between the edges of two penetrations was reduced to 170 mm.

2.2 Penetration details

2.2.1 Pipe support spacing

All pipes were supported at nominal distances of 500 and 1,500 mm from the unexposed face with pipe clamps which were in turn attached to a wood frame.

2.2.2 Penetration 1

Penetration 1 was a three cable bundle through an 18 mm diameter hole drilled through both the exposed and unexposed linings. No additional fire stopping was provided.

2.2.3 Penetration 2

Penetration 2 was a three cable bundle through an 18 mm diameter hole drilled through both the exposed and unexposed linings. Intumescent sealant was used on both the exposed and unexposed side. Sufficient sealant for the thickness of the plasterboard lining was used, and the exposed excess was smoothed with a putty knife. No backing element (rod or cavity insulation) was used to ensure the thickness of the sealant.

2.2.4 Penetration 3

Penetration 3 was a 40 mm nominal diameter PVC pipe through a 50 mm diameter hole drilled through both the exposed and unexposed linings. Fire collars were used on both sides, and attached to the plasterboard and supporting timber with two anchors. The plasterboard was not otherwise fixed to the additional timber framing for the collar. The gap between the pipe and the hole was sealed with approximately 10 mm of non-intumescent firestop sealant. No backing element was used due to the thickness of the plasterboard.

2.2.5 Penetration 4

Penetration 4 used the same construction as Penetration 3 but a single collar was used on the unexposed side. No collar was fixed to the exposed side.

2.2.6 Penetration 5

Penetration 5 was of similar construction to Penetration 3, with the exception that no timber was provided behind the collar fixings for support.

2.2.7 Penetration 6

Penetration 6 was of similar construction to Penetration 4, with the exception that no timber was provided behind the collar fixings for support.

2.2.8 Penetration 7

Penetration 7 was a three cable bundle through a 25 mm diameter hole drilled through both the exposed and unexposed linings. No additional fire stopping was provided.

2.2.9 Penetration 8

Penetration 8 was of similar construction to Penetration 2, except that the hole diameter was 25 mm instead of 18 mm. Similar intumescent sealant was applied.

2.2.10 Penetration 9

Penetration 9 was of similar construction to Penetration 2, except that a single cable was used and the hole diameter was 15 mm. Similar intumescent sealant was applied.

2.2.11 Penetration 10

Penetration 10 was of similar construction to Penetration 1, except the hole diameter of 16 mm was specified which was as tight as possible while still allowing the three cables to pass through. No additional fire stopping was provided.

2.2.12 Penetration 11

The construction of Penetration 11 was similar to Penetration 1, but used a twelve cable bundle through a 44 mm diameter hole. No additional fire stopping was provided.

2.2.13 Penetration 12

The construction of Penetration 12 was similar to Penetration 11 with a cable collar installed on the exposed side. The collar was fastened to the plasterboard and supporting timber framing (the plasterboard was not otherwise fixed to the framing) with two screw anchors. Intumescent sealant was used in the collar at a depth of 20 mm and an intumescent wrap was installed on the cables adjacent to the collar, as per the manufacturer's requirements.

2.2.14 Penetration 13

Penetration 13 construction was similar to Penetration 12 with the collar and associated fire stopping materials (sealant and intumescent wrap) installed on the unexposed side rather than the exposed side.

2.2.15 Penetration 14

Penetration 14 construction consisted of a single cable through a 13 mm diameter hole through the linings on both sides. The 13 mm diameter hole was sized to provide a tight fit. No additional fire stopping was provided.

2.2.16 Penetration 15

Penetration 15 consisted of a twelve cable bundle through a 44 mm diameter hole. Intumescent sealant was used on both the exposed and unexposed side. Sufficient sealant for the thickness of the plasterboard lining was used, and the exposed excess was smoothed with a putty knife. No backing element (rod or cavity insulation) was used to ensure the thickness of the sealant.

2.2.17 Penetration 16

Penetration 16 consisted of a 100 mm nominal diameter PVC pipe through a 110 mm diameter hole in both linings. A single fire collar was installed on the unexposed side, and attached with four M8 threaded 316 stainless steel rods, galvanised steel nuts and 19 mm galvanised steel washers. Three of the four rods were placed through the supporting timber. The plasterboard was not otherwise fixed to the additional timber framing for the collar. The gap between the pipe and the hole was sealed with approximately 10 mm of non-intumescent firestop sealant, as well as the holes drilled for the M8 threaded rods. No backing element was used due to the thickness of the plasterboard. The unexposed side was chosen for the collar as this was expected to be the weakest configuration.

2.2.18 Penetration 17

Penetration 17 was similar in construction to Penetration 16, but with collars on both the exposed and unexposed faces.

2.2.19 Penetration 18

Penetration 18 was similar in construction to Penetration 16, but without supporting timber framing.

2.2.20 Penetration 19

Penetration 19 was similar in construction to Penetration 17, but without supporting timber framing.

3. TEST CONDITIONS AND RESULTS

3.1 General

The specimen was tested on 13 February 2017, at the BRANZ laboratories at Judgeford, New Zealand. The test was closed due to the potential commercial implications of testing non-compliant assemblies which were expected to fail. The ambient temperature at the beginning of the test was 18°C.

The frame containing the test specimen was sealed to the 3,000 mm wide x 4,000 mm high furnace, and the temperature and pressure conditions were controlled to the limits defined in AS1530.4-2014.

The test was terminated after the specimen had been exposed to the standard fire resistance conditions for 60 minutes. The test was stopped to observe the condition of the exposed face at this time.

3.2 Specimen temperature measurement

To monitor heat conduction through the sealing systems, 89 chromel-alumel thermocouples were attached to the specimens. The arrangement consisted of thermocouples placed as specified in clause 10.5 of the test standard AS 1530.4-2014.

Thermocouples were placed on the unexposed surface of the plasterboard wall at 25 mm from the penetrations, on the collars (where used), and on the services (pipes and cables) at 25 mm from either the plasterboard or collars (where used). For single or three cable penetrations, a single thermocouple was placed on the cables. Maximum substrate and service (collars, pipes, or cables) temperatures for a selection of penetrations that demonstrate the range of performance are shown in

Figure 1 to Figure 13. The penetration letter designations are based on descending maximum measured temperature.

All of the thermocouples described above were connected to a computer controlled data acquisition system which recorded the temperature at 15 second intervals.

Figure 1: Penetration A thermocouple temperatures

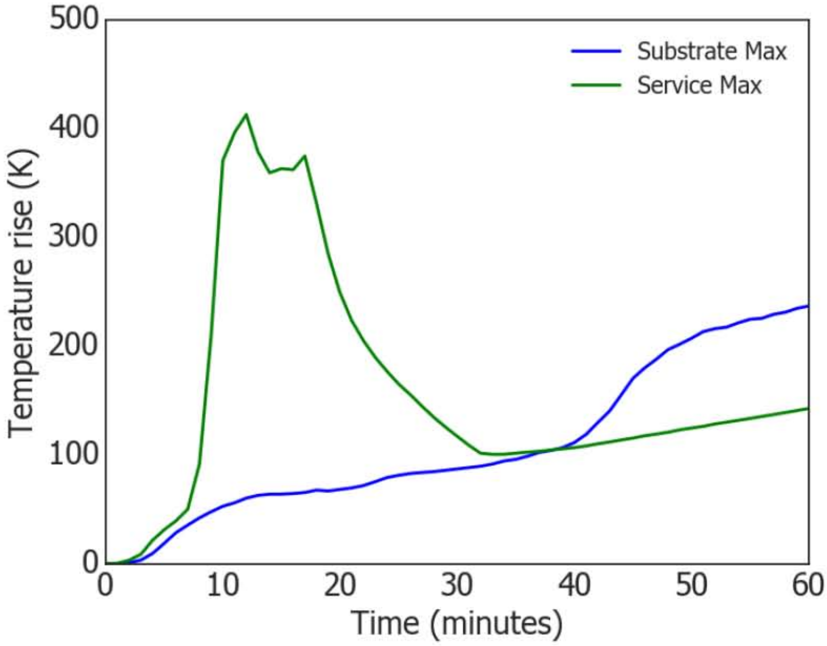


Figure 2: Penetration B thermocouple temperatures

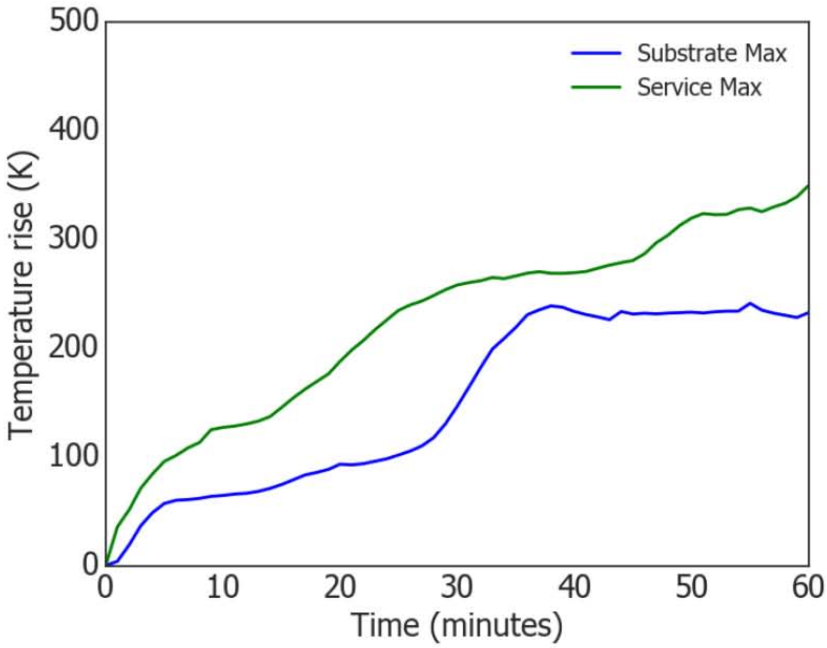


Figure 3: Penetration C thermocouple temperatures

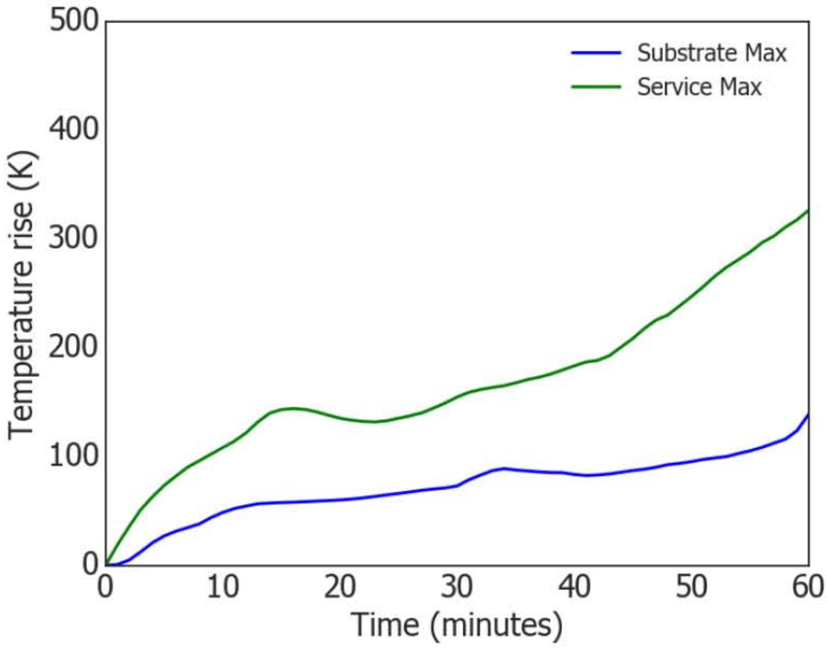


Figure 4: Penetration E thermocouple temperatures

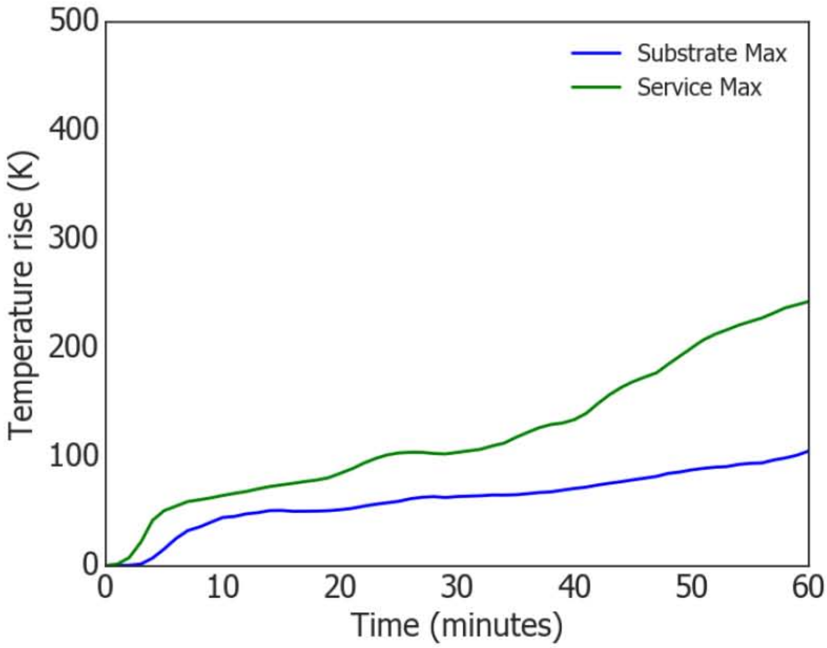


Figure 5: Penetration G thermocouple temperatures

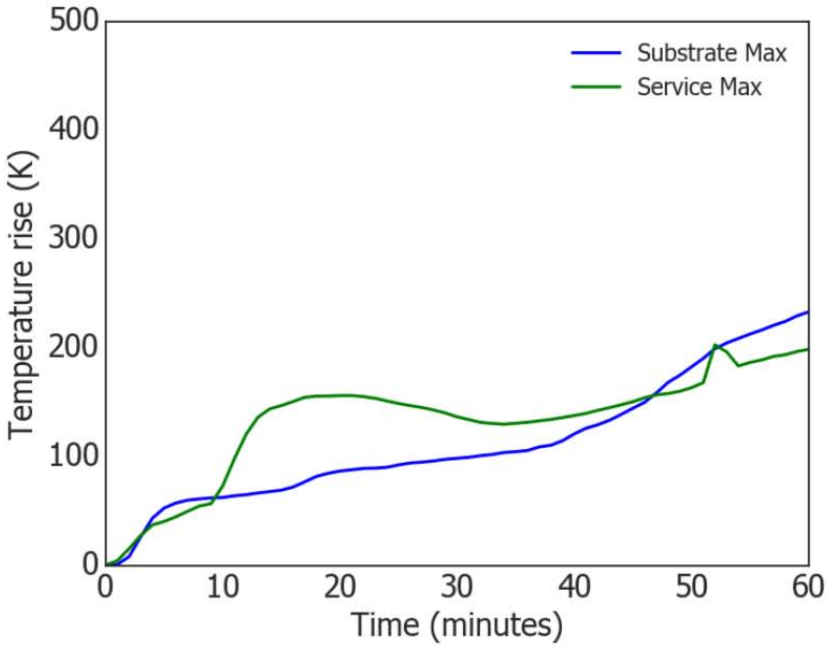


Figure 6: Penetration H thermocouple temperatures

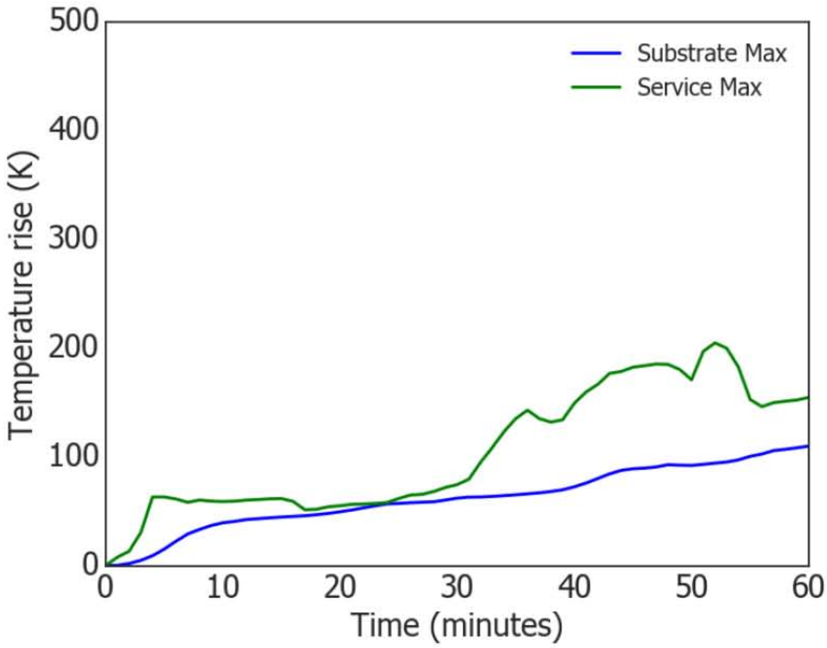


Figure 7: Penetration I thermocouple temperatures

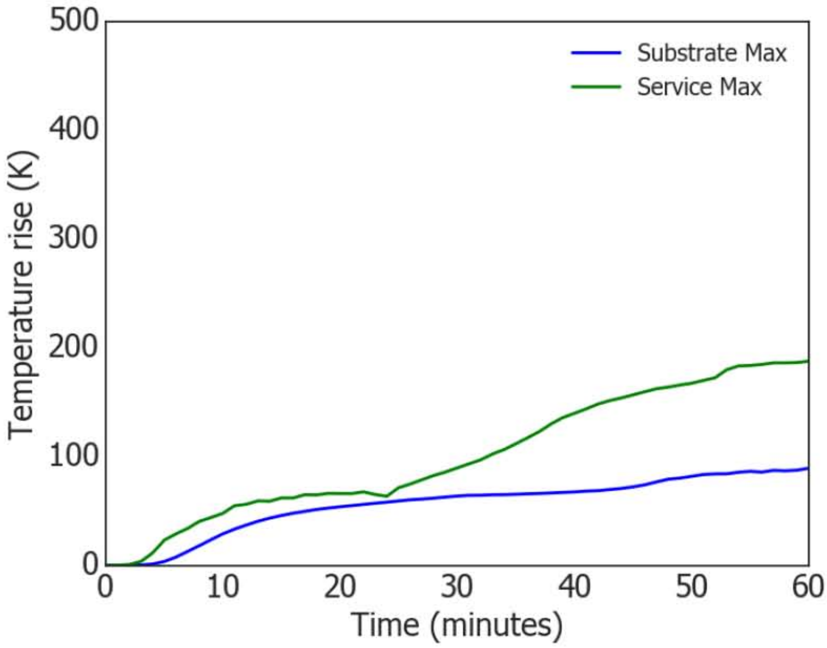


Figure 8: Penetration J thermocouple temperatures

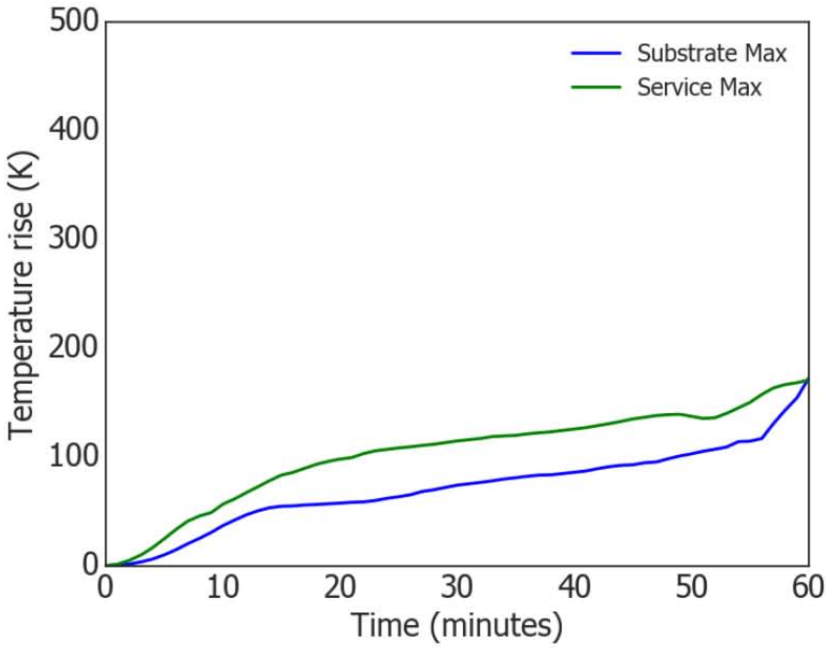


Figure 9: Penetration L thermocouple temperatures

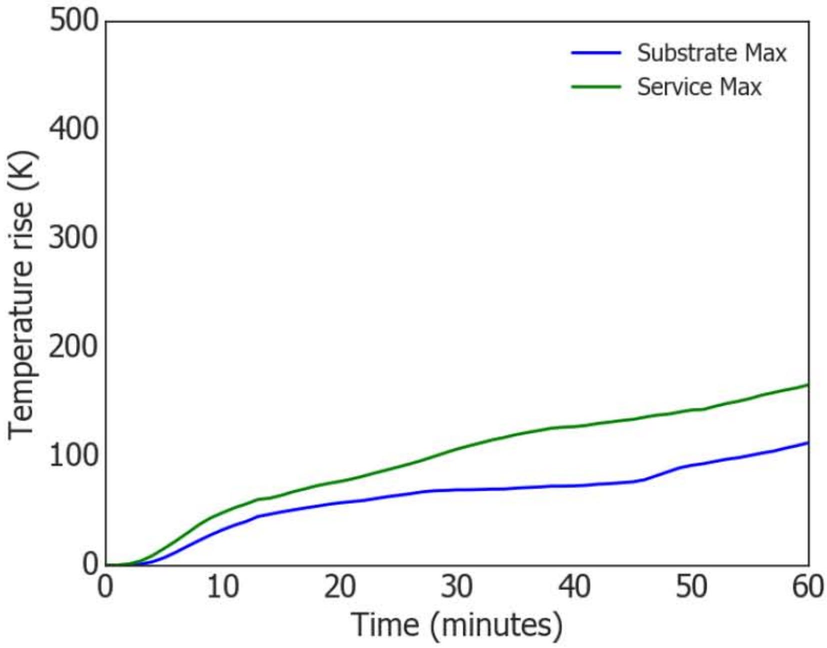


Figure 10: Penetration N thermocouple temperatures

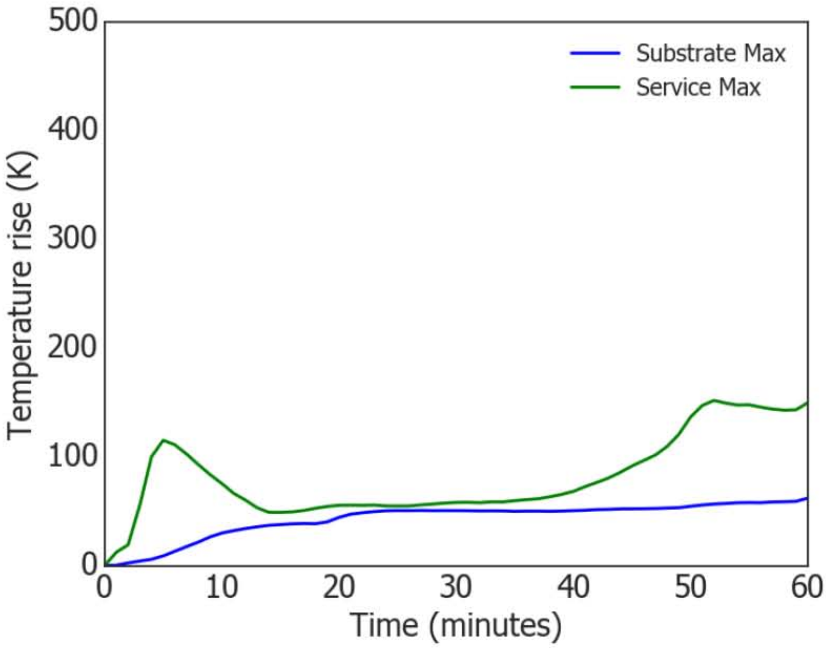


Figure 11: Penetration P thermocouple temperatures

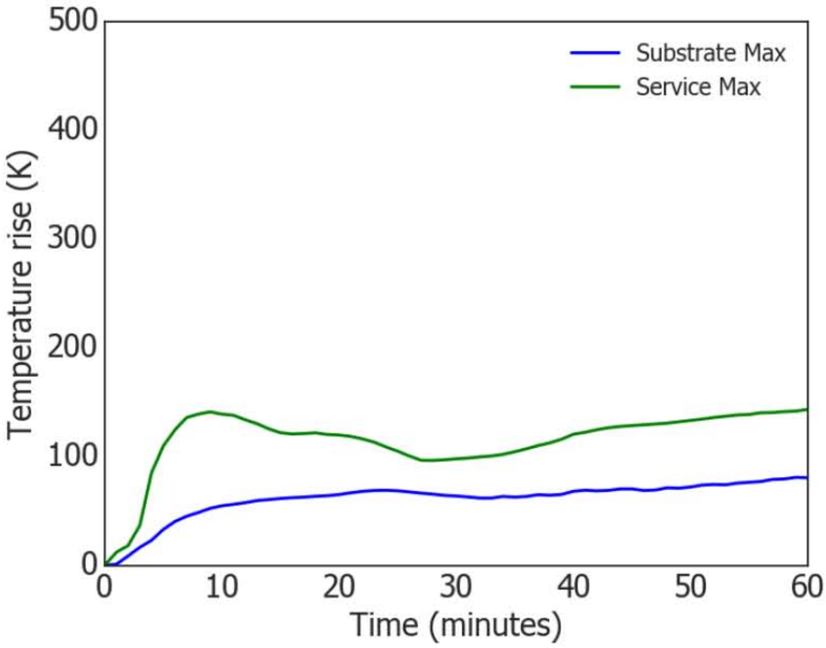


Figure 12: Penetration R thermocouple temperatures

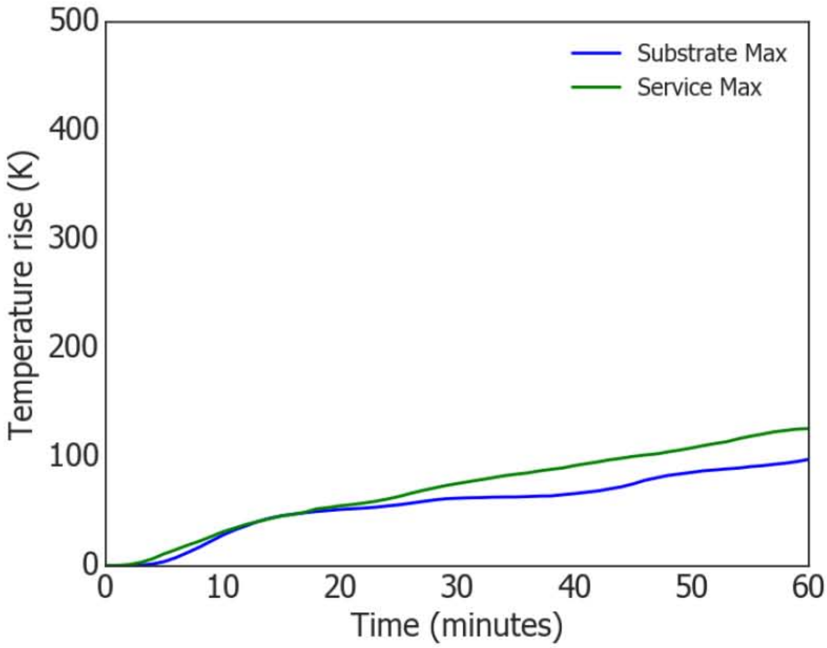
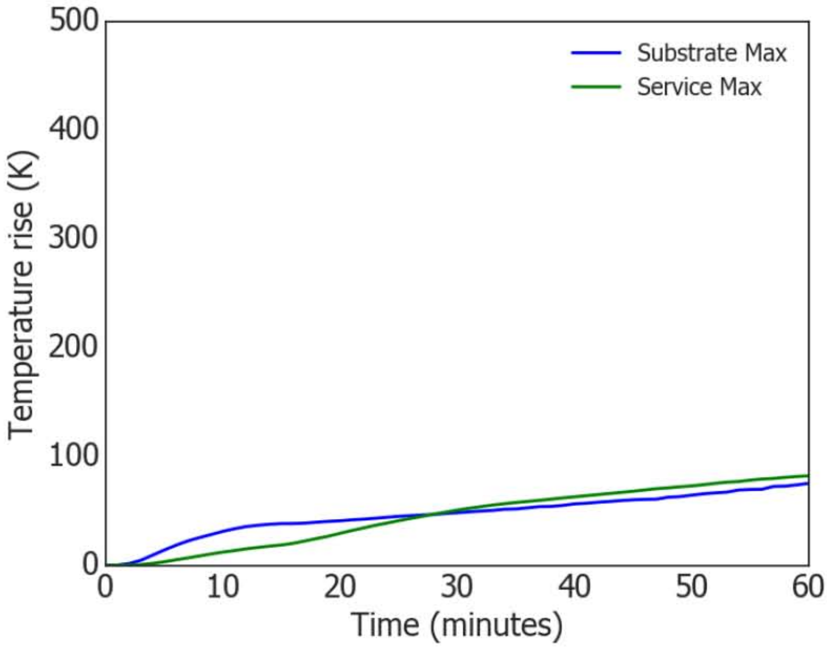


Figure 13: Penetration S thermocouple temperatures



3.3 Integrity Observations

Observations related to the integrity performance of the specimens were made during the test. A 25 mm gap gauge could be projected into the furnace through Penetration A at 14 minutes and a cotton pad was ignited at Penetration F at 10 minutes. No significant integrity observations were made during the test duration for the other penetrations.

3.4 Conclusion

The objective of this test was to investigate the relative performance of non-standard penetration sealing systems that represent real-world construction in a typical plasterboard wall. The results of the test will be used in the development of a process and risk analysis tool to inform ANARP decisions when evaluating the means of escape from fire as required by Section 112 of the New Zealand Building Act 2004.

The comparative performance of 19 cable and PVC pipe penetrations and their sealing systems in a plasterboard wall substrate when tested under similar conditions to those required by AS 1530.4-2014, ranged from cotton pad ignition in 10 minutes to no ignition in 60 minutes. The maximum temperature measured on the unexposed side of the test specimen and the penetration services ranged from 82 K to 413 K. The earliest time at which a temperature rise of 150 K was exceeded was 9 minutes.

BRANZ
1222 Moonshine Road
Judgeford RD1
Porirua 5381
New Zealand
T +64 4 237 1170
F +64 4 237 1171
branz@branz.co.nz
www.branz.co.nz



FIRE TEST REPORT

QR 1615 - TV

FIRE RESISTANCE OF REPRESENTATIVE REAL-WORLD PENETRATIONS IN A PLASTERBOARD WALL

CLIENT
BRANZ Inc.

PROJECT NUMBER:	ISSUE DATE:	PAGE:
QR1615-TV	**1-MAY-2018**	**1 of 22**

TEST SUMMARY

Objective

To determine the fire resistance of representative real-world construction cable and plastic pipe penetration sealing systems in accordance with AS 1530.4-2005 *Fire Resistance tests of elements of building construction: Section 10 Service Penetrations and Control Joints,* with reference to AS 4072.1-2005.

Test sponsor

This fire test was part of a Building Research Levy funded project, QR1615.

Description of test specimen

The test specimen consisted of a nominal 3,000 mm x 3,000 mm timber-framed plasterboard wall assembly (45 mm x 90 mm timber framing with two 10 mm thick fire-rated plasterboard layers on the exposed and one layer each of 10 mm and 13 mm thick fire-rated plasterboard on the unexposed side) as the supporting construction. A range of electrical and communications cable (from one cable to twelve cables) and polyvinylchloride (PVC) pipe penetrations (40 mm) were tested with penetration systems that deviated from manufacturers' specifications.

Date of test

7 September 2017

Test results

The comparative performance of 22 cable and PVC pipe penetrations and their sealing systems in a plasterboard wall substrate when tested under similar conditions to those required by AS 1530.4-2014, ranged from cotton pad ignition in 19 minutes to no ignition in 60 minutes. The maximum temperature measured on the unexposed side of the test specimen and the penetration services for each specimen ranged from 43 K to 786 K. The earliest time at which a temperature rise of 150 K was exceeded was 4 minutes.

The AS 1530.4-2014 test standard requires the following statements to be included in a report to demonstrate compliance with the standard. While this experiment was similar and not deemed to be compliant, these statements are relevant here as well:

"The results of these fire tests may be used to directly assess fire hazard, but it should be recognized that a single test method will not provide a full assessment of fire hazard under all fire conditions."

"This report details methods of construction, the test conditions and results obtained when the specific element of construction described herein was tested following the procedure outlined in this standard. Any significant variations with respect to size,

constructional details, loads, stresses, edge or end conditions, other than those allowed under the field of direct application in the relevant test method, is not covered by this report.

Because of the nature of fire resistance testing and the consequent difficulty in quantifying the uncertainty of measurement of fire resistance, it is not possible to provide a stated degree of accuracy of the result."

Since methods of construction are not provided and there is no link provided between test results and construction details for specific penetration assemblies, this report does not prove or disprove compliance with the test standard for any tested assemblies. It only provides the range of performance that was experienced by the assemblies.

LIMITATION

The results reported here are not specific for a particular system and have been anonymised. This report shall not be used to endorse any particular product or system. The information contained within is for research purposes only and cannot be used as a basis to determine building code compliance.

CONTENTS

FIGURES

DOCUMENT REVISION STATUS

ISSUE NO.	DATE ISSUED	DESCRIPTION
1	17-March-2017	Initial Issue
2		Prepared for Stakeholder Review

1. TEST PROCEDURE

The test was conducted in accordance with AS 1530.4-2014 *"Methods for fire tests on building materials, components and structures, Part 4 Fire-resistance tests of elements of construction", Section 10 Service penetrations and control joints*, with reference to AS 4072.1-2005, Service penetrations and control joints, Section 3.1 Fire Resistance Testing.

2. DESCRIPTION OF TEST SPECIMEN

2.1 General

The supporting construction consisted of a 45 mm x 90 mm H1.2 timber frame of 3,000 m x 3,000 m nominal dimensions. Studs were placed at nominal 600 mm centres. Two layers of 10 mm fire-rated plasterboard pattresses were fixed to the exposed side. One 10mm fire-rated plasterboard pattress and one 13mm fire-rated plasterboard pattress on the unexposed side and fixed as per the manufactures' specifications. All fastener heads were stopped and all sheet joints tape reinforced and stopped as per the manufactures' specifications.

All pipes protruded a minimum of 500 mm into the furnace and at least 2,000 mm beyond the unexposed face. All pipes were capped with PVC caps on the exposed face and were open on the unexposed face. The pipes were supported at 500 mm and 1,500 mm on the unexposed side. The nominal Polybutylene pipe size of 20 mm was used.

All cables protruded a minimum of 500 mm on both the exposed and unexposed sides. Cable bundles consisted of single cable (12 x 6 mm 3 wire main – 2.5 mm^2 2C+E TPS 15150199/100 General Cable), three cable (2 x 3 wire main, 1 x single wire earth 6.0 mm^2 conduit wire GN/YL BAAP11A1001AAHN 6112 Olex), and twelve cable (7 x 3 wire main, 1 x earth, 2 x network Cat 6 UTP 0.53 3pr CMR BU 24154021 p/m Hubbell, 1 x RG6 coax 75 ohm SKY BK 152, and 1 x optical fibre OM3 Fibre patch lead 30 mt Fib-mm1043).

Spacing between the edges of the penetrations and the edge of the specimen was maintained at 200 mm.

Penetration details

2.1.1 Pipe support spacing

All pipes were supported at nominal distances of 500 and 1,500 mm from the unexposed face with pipe clamps which were in turn attached to a wood frame.

2.1.2 Penetration 1

Penetration 1 was a 20mm polybutylene pipe through a 25 mm diameter hole drilled through both the exposed and unexposed linings. A fire-rated collar was fitted on both the exposed and unexposed side.

2.1.3 Penetration 2

Penetration 2 was a 12 cable bundle through a 52 mm diameter hole drilled through both the exposed and unexposed linings. A fire-rated cable collar was installed on both the exposed and unexposed side. This was then sealed with 20mm of intumescent sealant in the collar and 2 layers of 100mm wide fire-rated putty bandage was installed on each side (around the bundle of cables).

2.1.4 Penetration 3

Penetration 3 was a 12 cable bundle through a 52mm diameter hole drilled through both the exposed and unexposed linings. Intumescent sealant was used on the penetration at a depth of 30-40mm without a pattress on both the exposed and unexposed side.

2.1.5 Penetration 4

Penetration 4 used the similar construction to penetration 3 but only 20-25mm of intumescent sealant was used to seal the hole.

2.1.6 Penetration 5

Penetration 5 was of similar construction to penetration 3, with the exception that nothing was used to seal it.

2.1.7 Penetration 6

Penetration 6 was a 3 cable bundle, through a 25mm diameter hole drilled through both the exposed and unexposed linings. Intumescent sealant was installed at a depth of 30-40mm to seal the holes diameter.

2.1.8 Penetration 7

Penetration 7 was of similar construction to penetration 6, with the exception that the Intumescent sealant was only installed at a depth of 5-10mm on both the unexposed and exposed sides.

2.1.9 Penetration 8

Penetration 8 was a 3 cable bundle through a 16mm diameter hole through both the exposed and unexposed side. There was not any sealant used on this penetration.

2.1.10 Penetration 9

Penetration 9 was a single cable through a 16mm hole through both the unexposed and the exposed sides. Intumescent sealant was installed at a depth of 5-10mm to seal the hole from both sides.

2.1.11 Penetration 10

Penetration 10 was of similar construction to penetration 9, except that it was sealed with 30-40mm of intumescent sealant instead of 5-10mm.

2.1.12 Penetration 11

Penetration 11 was a single cable through a 13mm diameter hole which is the smallest that a single cable can fit through. There was no sealant used.

2.1.13 Penetration 12

The construction of Penetration 12 was similar to penetration 1 except only one fire-rated fire collar was installed on the unexposed side with a plasterboard pattress installed on both the exposed side and unexposed side.

2.1.14 Penetration 13

Penetration 13 construction was similar to penetration 10 except only 5-10mm of intumescent sealant was installed as well as plasterboard pattresses being installed on both the exposed and unexposed sides.

2.1.15 Penetration 14

Penetration 14 was of similar construction to penetration 7, except that it had plasterboard pattresses installed on both sides.

2.1.16 Penetration 15

Penetration 15 was of similar construction to penetration 14, except the diameter of the hole was 16 instead of 25 and no sealant had been installed on either side.

2.1.17 Penetration 16

Penetration 16 was similar in construction to penetration 14, except 20-25mm of intumescent sealant had been installed.

2.1.18 Penetration 17

Penetration 17 was similar in construction to penetration 16, but with no plasterboard pattress installed.

2.1.19 Penetration 18

Penetration 18 was a 12 cable bundle through a 47mm diameter hole. No sealant was installed as this is the smallest diameter that a 12 cable bundle will fit in. plasterboard pattresses were installed on both sides.

2.1.20 Penetration 19

Penetration 19 was similar in construction to penetration 4, but also had plasterboard pattresses installed on both sides.

2.1.21 Penetration 20

Penetration 20 was of similar construction to penetration 9, except the intumescent sealant was installed at a depth of 20-25mm.

2.1.22 Penetration 21

Penetration 21 was of similar construction to penetration 19, except a fire-rated cable collar was installed on the unexposed side.

2.1.23 Penetration 22

Penetration 22 was of similar construction to penetration 11, but it also had a plasterboard pattress installed on both sides.

3. TEST CONDITIONS AND RESULTS

3.1 General

The specimen was tested on 7 September 2017, at the BRANZ laboratories at Judgeford, New Zealand. The test was closed due to the potential commercial implications of testing non-compliant assemblies which were expected to fail. The ambient temperature at the beginning of the test was 18°C.

The frame containing the test specimen was sealed to the 3,000mm wide x 4,000mm high furnace, and the temperature and pressure conditions were controlled to the limits defined in AS1530.4-2014.

The test was terminated after the specimen had been exposed to the standard fire resistance conditions for 60 minutes. While some of the penetrations had not failed at this time, the test was stopped to observe the condition of the exposed face at this time.

3.2 Specimen temperature measurement

To monitor heat conduction through the sealing systems, 89 chromel-alumel thermocouples were attached to the specimens. The arrangement consisted of thermocouples placed as specified in clause 10.5 of the test standard AS 1530.4-2014.

Thermocouples were placed on the unexposed surface of the plasterboard wall at 25 mm from the penetrations, on the collars (where used), and on the services (pipes and cables) at 25 mm from either the plasterboard or collars (where used). For single or three cable penetrations, a single thermocouple was placed on the cables. Temperatures for each of the penetrations are shown in Figure 1 to Figure 22.

All of the thermocouples described above were connected to a computer controlled data acquisition system which recorded the temperature at 15 second intervals.

Figure 1: Penetration A thermocouple temperatures

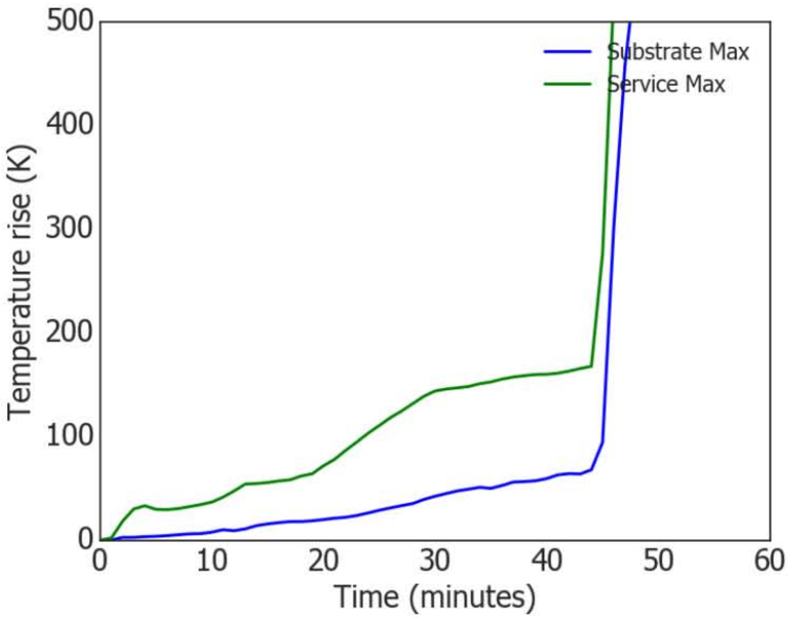


Figure 2: Penetration B thermocouple temperatures

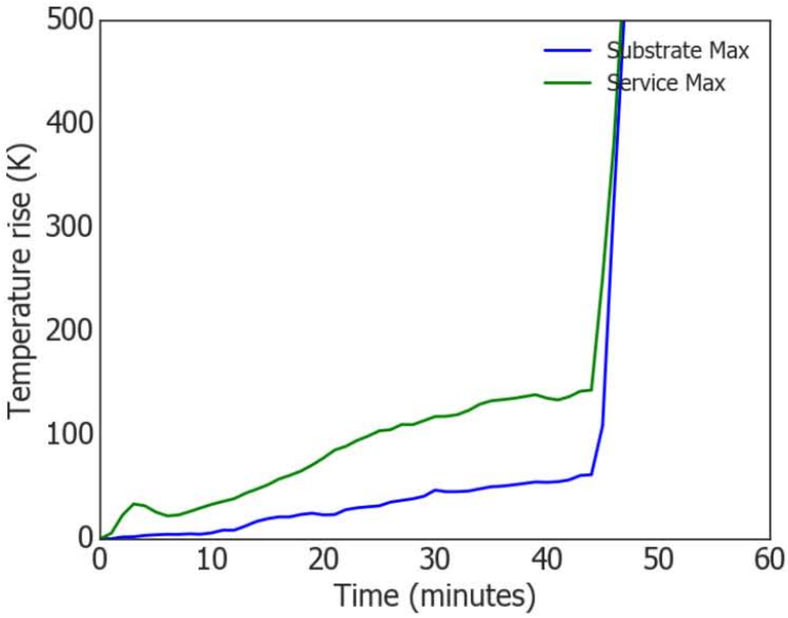


Figure 3: Penetration C thermocouple temperatures

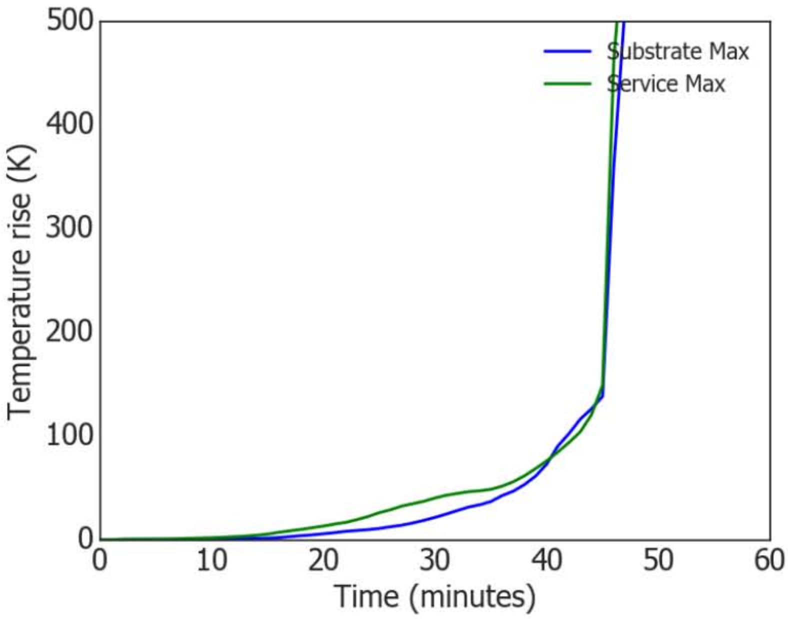


Figure 4: Penetration D thermocouple temperatures

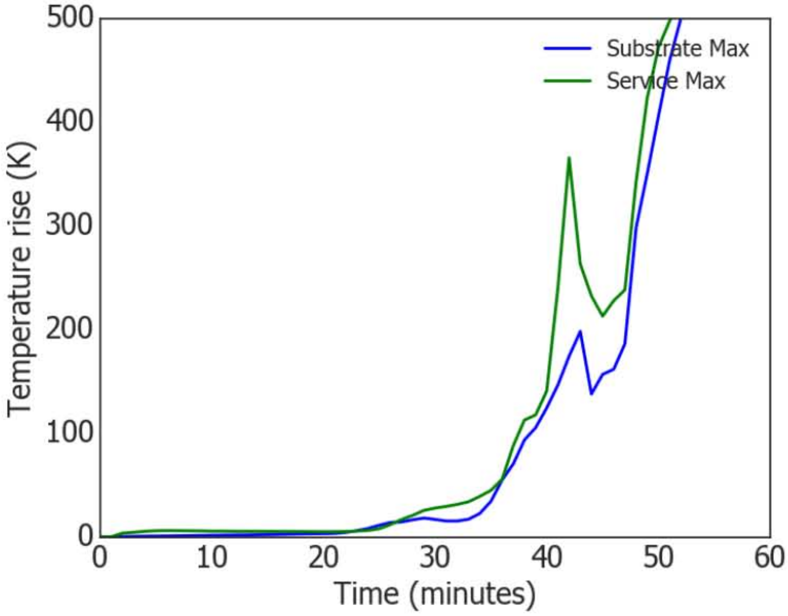


Figure 5: Penetration E thermocouple temperatures

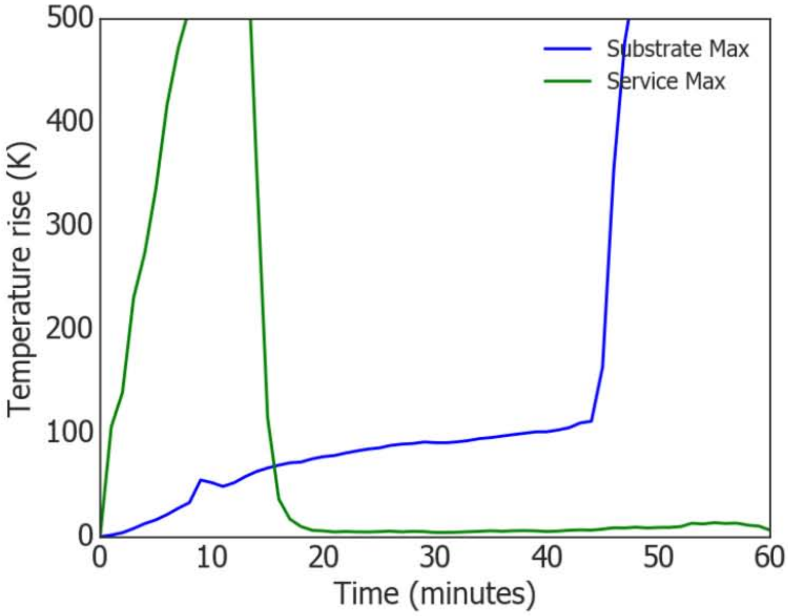


Figure 6: Penetration F thermocouple temperatures

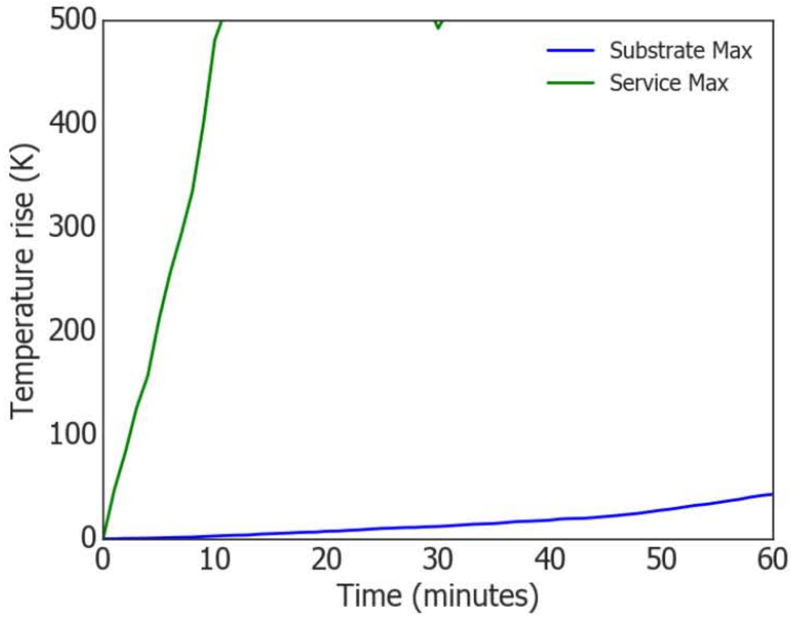


Figure 7: Penetration G thermocouple temperatures

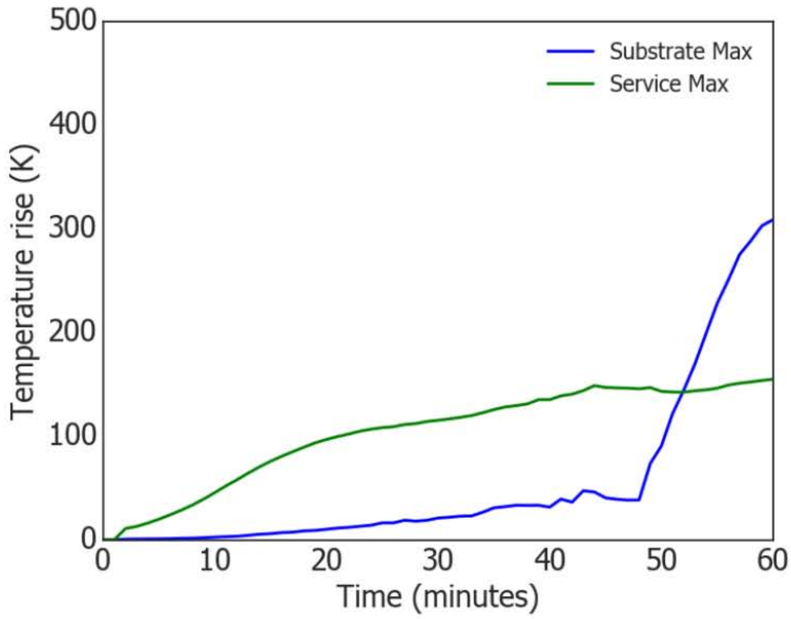


Figure 8: Penetration H thermocouple temperatures

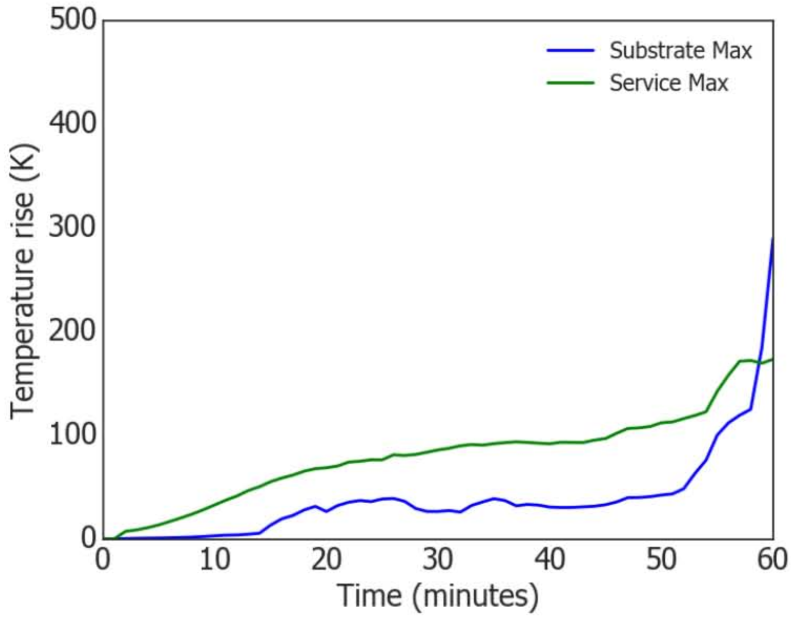


Figure 9: Penetration I thermocouple temperatures

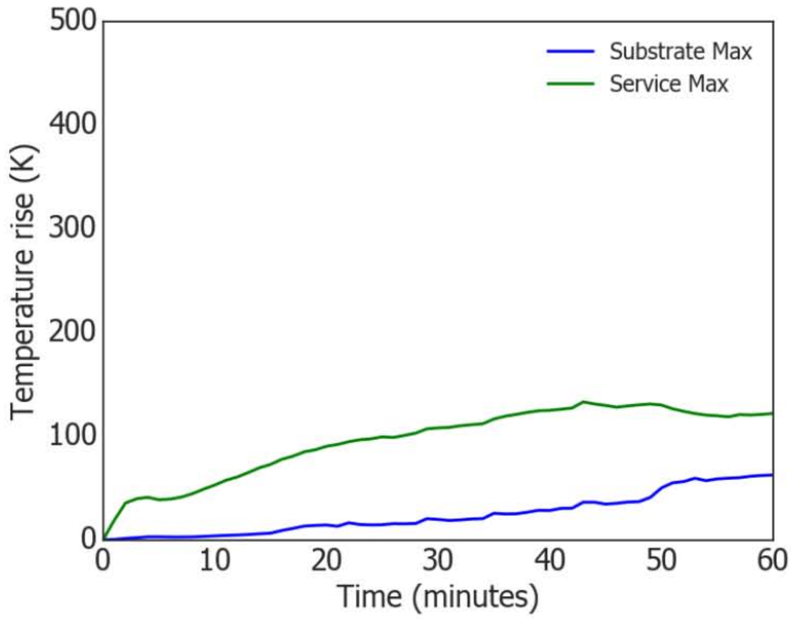


Figure 10: Penetration J thermocouple temperatures

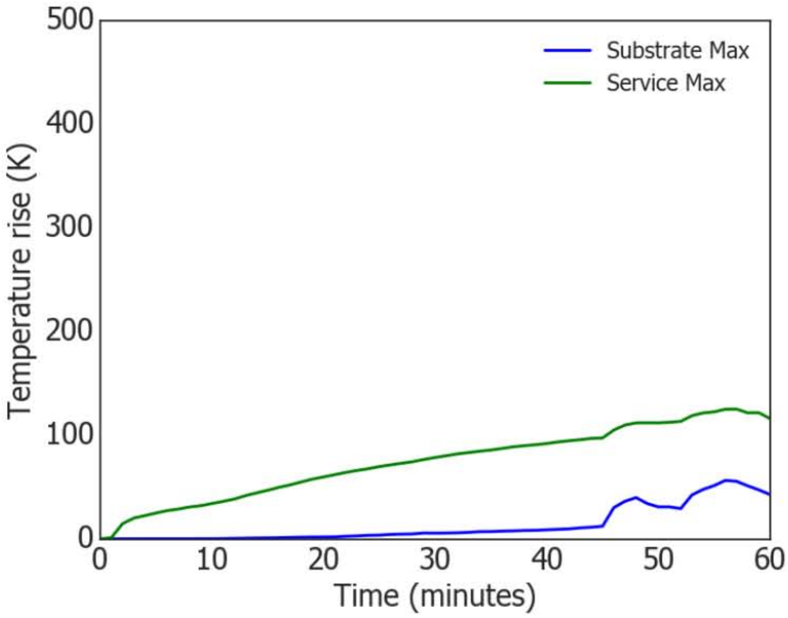


Figure 11: Penetration K thermocouple temperatures

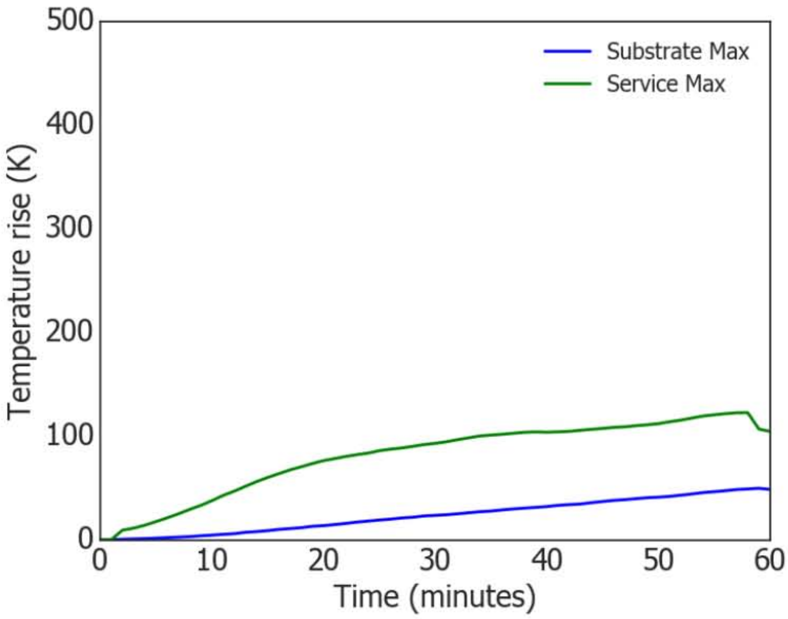


Figure 12: Penetration L thermocouple temperatures

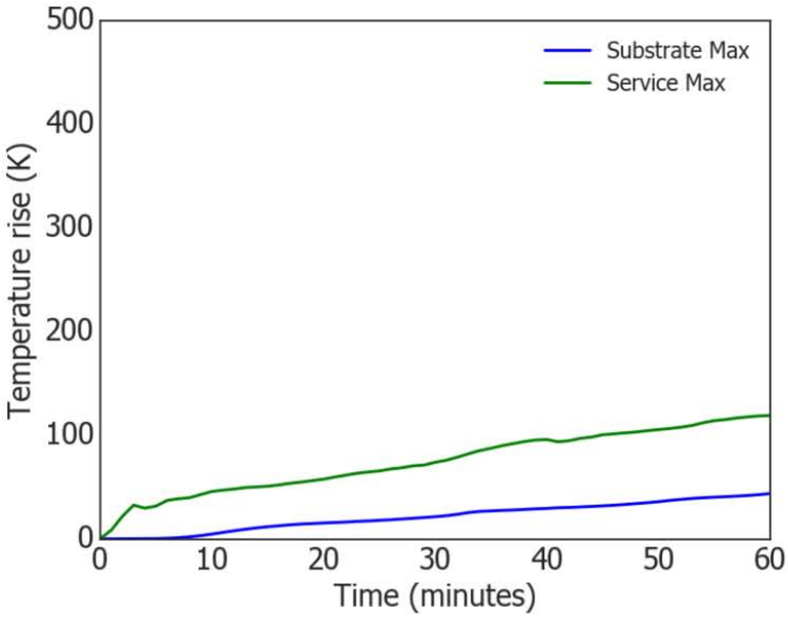


Figure 13: Penetration M thermocouple temperatures

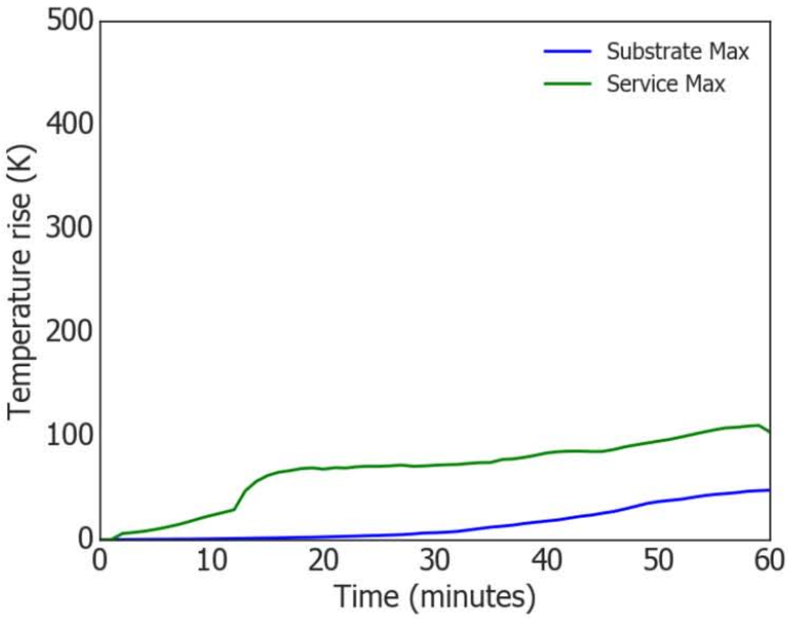


Figure 14: Penetration N thermocouple temperatures

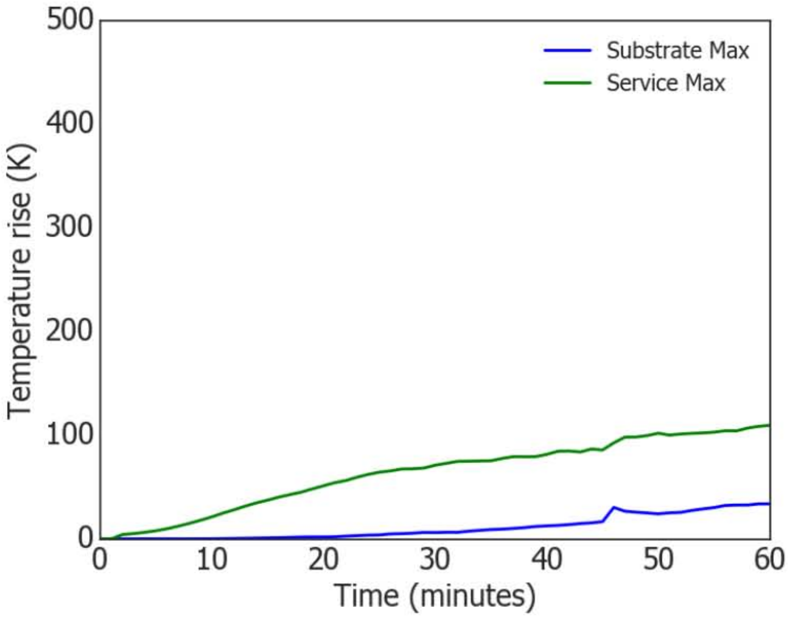


Figure 15: Penetration O thermocouple temperatures

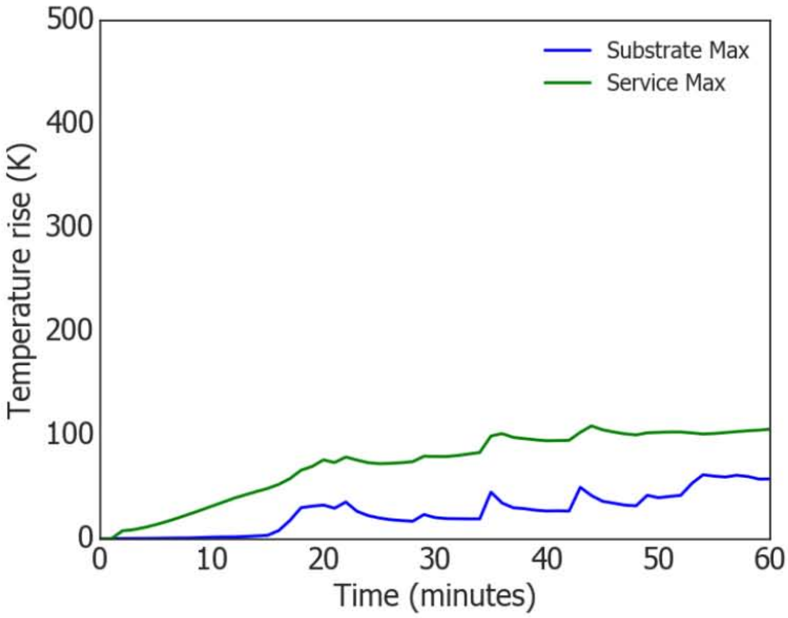


Figure 16: Penetration P thermocouple temperatures

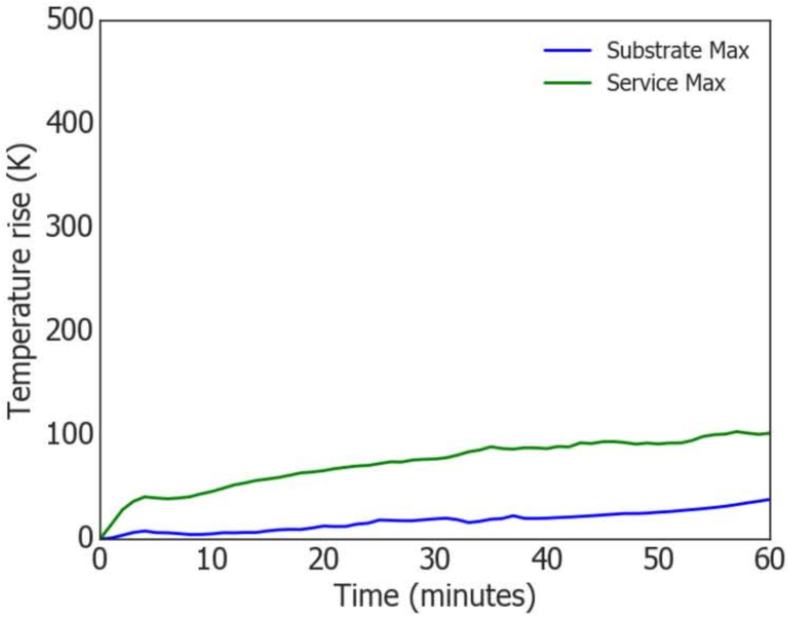


Figure 17: Penetration Q thermocouple temperatures

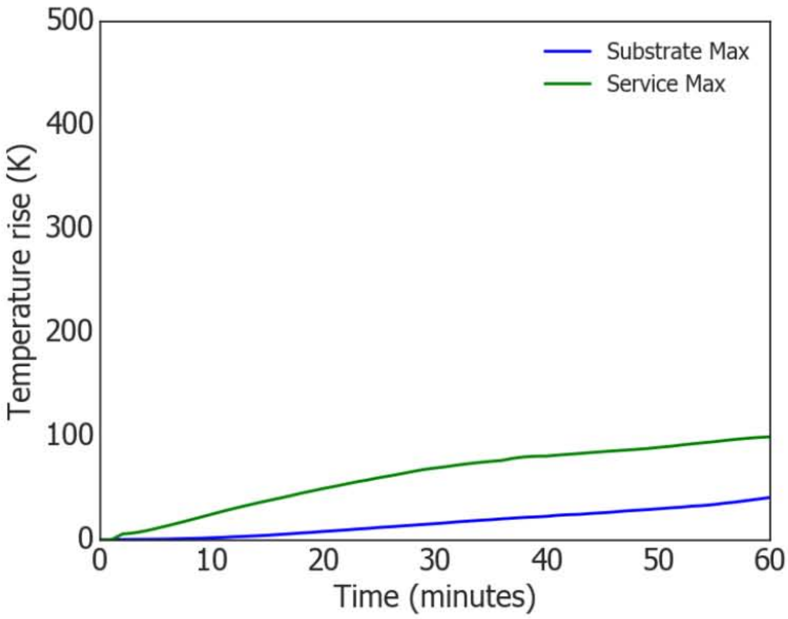


Figure 18: Penetration R thermocouple temperatures

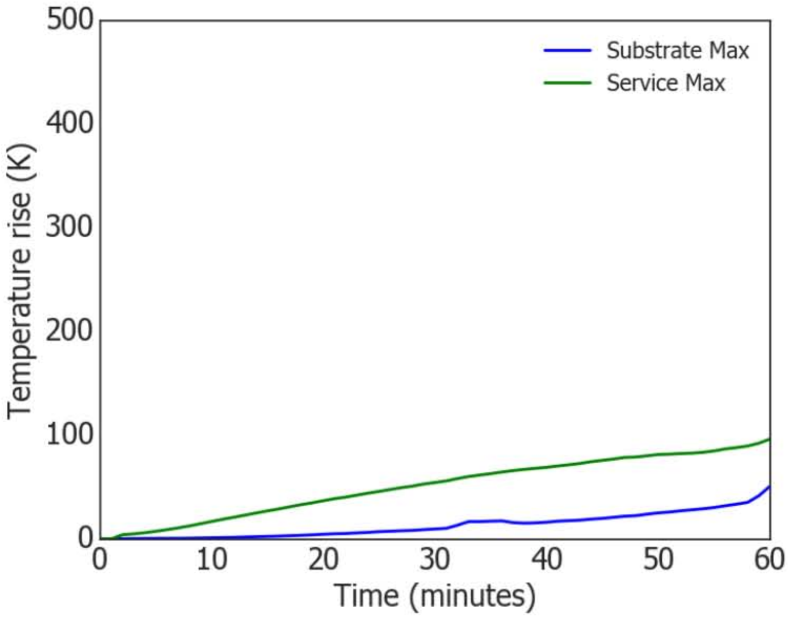


Figure 19: Penetration S thermocouple temperatures

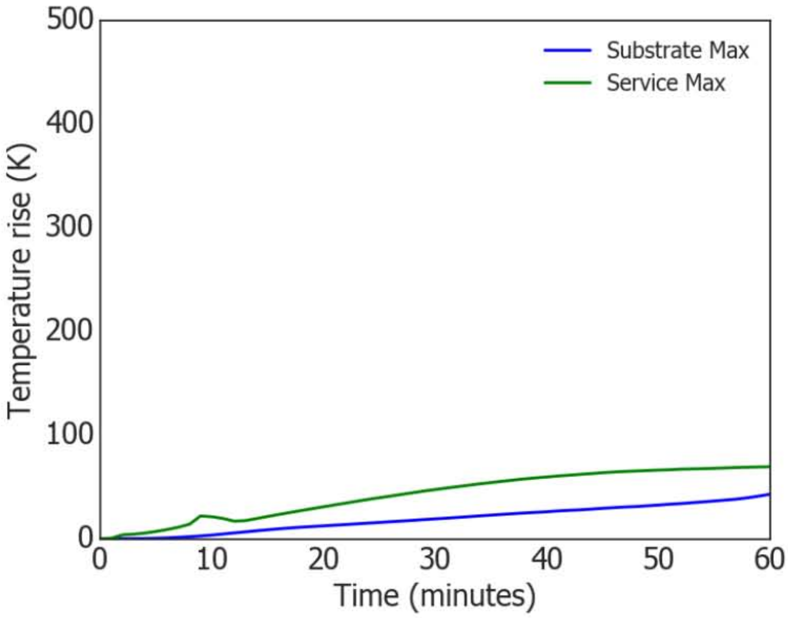


Figure 20: Penetration T thermocouple temperatures

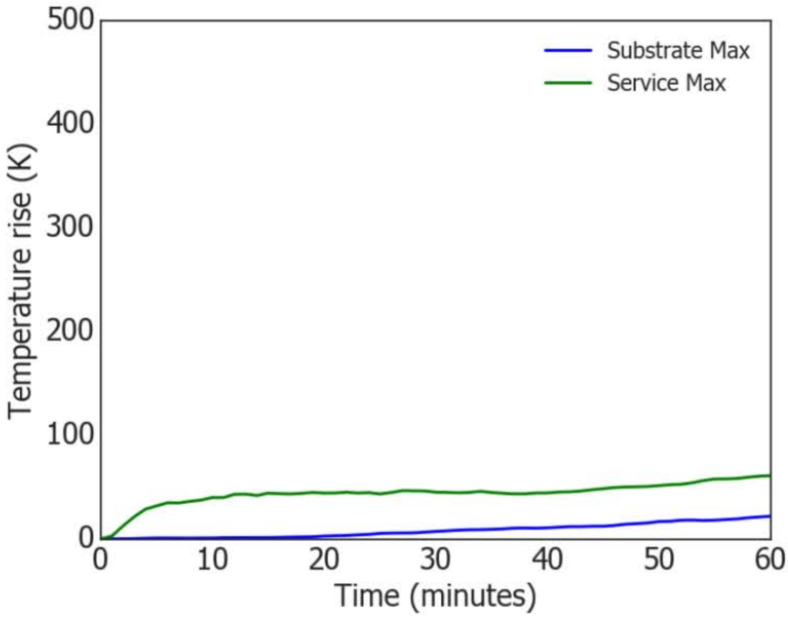


Figure 21: Penetration U thermocouple temperatures

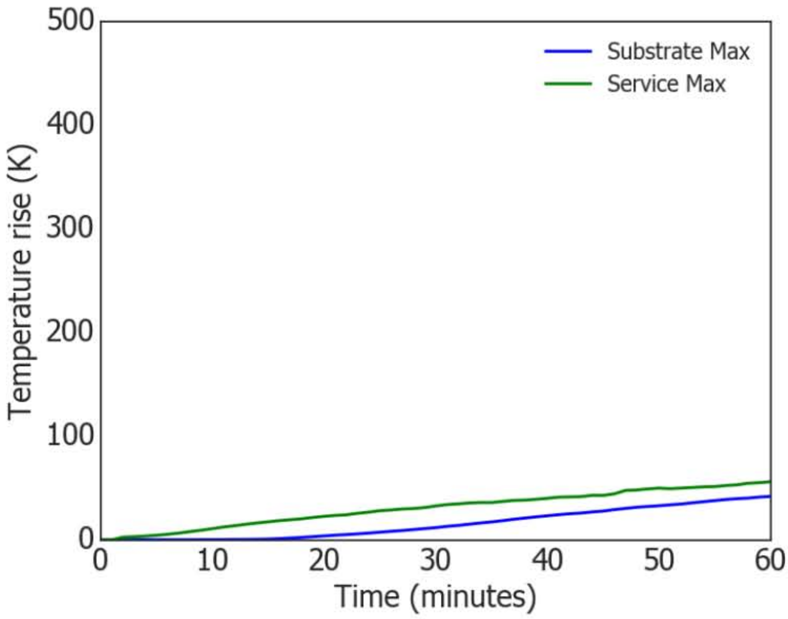
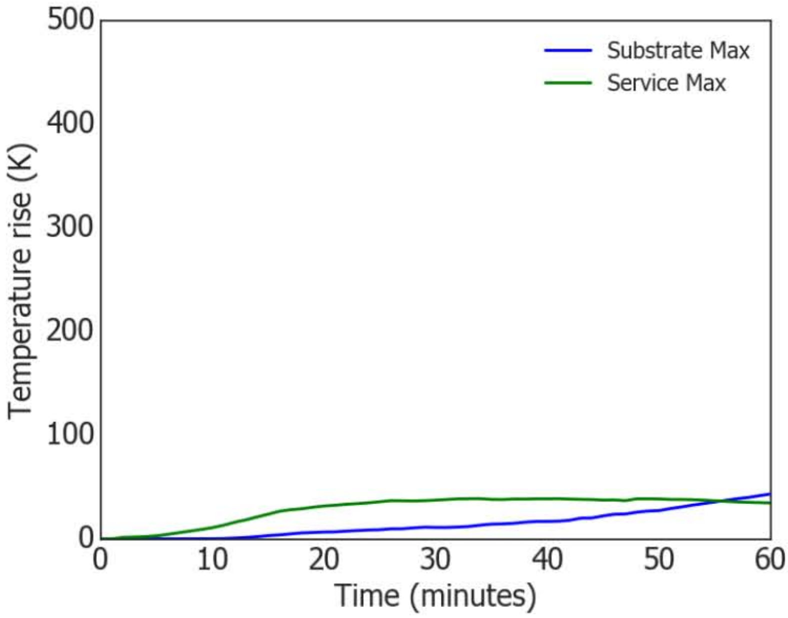


Figure 22: Penetration V thermocouple temperatures



3.3 Integrity Observations

Observations related to the integrity performance of the specimens were made during the test. A 25 mm gap gauge could not be projected into the furnace through Penetration F at 13 minutes and a cotton pad was ignited at Penetration E at 19:30 minutes and one at Penetration F at 21 minutes. No significant integrity observations were made during the test duration for the other penetrations.

3.4 Conclusion

The objective of this test was to investigate the relative performance of non-standard penetration sealing systems that represent real-world construction in a typical plasterboard wall. The results of the test will be used in the development of a process and risk analysis tool to inform ANARP decisions when evaluating the means of escape from fire as required by Section 112 of the New Zealand Building Act 2004.

The comparative performance of 22 cable and PVC pipe penetrations and their sealing systems in a plasterboard wall substrate when tested under similar conditions to those required by AS 1530.4-2014, ranged from cotton pad ignition in 19 minutes to no ignition in 60 minutes. The maximum temperature measured on the unexposed side of the test specimen and the penetration services ranged from 43 K to 786 K. The earliest time at which a temperature rise of 150 K was exceeded was 2 minutes.

BRANZ
1222 Moonshine Road
Judgeford RD1
Porirua 5381
New Zealand
T +64 4 237 1170
F +64 4 237 1171
branz@branz.co.nz
www.branz.co.nz

FIRE TEST REPORT

QR 1615 - CV

FIRE RESISTANCE OF REPRESENTATIVE REAL-WORLD PENETRATIONS IN A PLASTERBOARD AND FIBRE CEMENT CLAD WALL

CLIENT
BRANZ Inc.

PROJECT NUMBER:	ISSUE DATE:	PAGE:
QR1615-CV	1-MAY-2018	1 of 22

TEST SUMMARY

Objective

The objective of this research was to investigate the relative performance of non-standard penetration sealing systems that represent real-world construction in a typical plasterboard wall using an indicative fire resistance test. The results of the test will be used in the development of a process and risk analysis tool to inform ANARP decisions when evaluating the means of escape from fire as required by Section 112 of the New Zealand Building Act 2004.

The relative fire resistance performance of these cable and plastic pipe penetration sealing systems was determined by testing in a similar fashion to AS 1530.4-2014 *Fire Resistance tests of elements of building construction: Section 10 Service Penetrations and Control Joints*, with reference to AS 4072.1-2005

Test sponsor

This fire test was part of a Building Research Levy funded project, QR1615.

Description of test specimen

The test specimen consisted of a nominal 3,000 mm x 3,000 mm timber-framed wall assembly (45 mm x 90 mm timber framing with 6 mm fibre cement board on the exposed side and 10 mm thick fire-rated plasterboard on the unexposed side) as the supporting construction. A range of electrical and communications cable (from one cable to twelve cables) and polyvinylchloride (PVC) pipe penetrations (40 mm to 100 mm) were tested with penetration systems that deviated from manufacturers' specifications.

Date of test

5 September 2017

Test results

The comparative performance of 20 cable, PVC pipe, and flush box penetrations and their sealing systems in a fibre cement board wall substrate when tested under similar conditions to those required by AS 1530.4-2014, ranged from cotton pad ignition in 27 minutes to no ignition in 60 minutes. The maximum temperature measured on the unexposed side of the test specimen and the penetration services for each specimen ranged from 85 K to 786 K. The earliest time at which a temperature rise of 150 K was exceeded was 16 minutes.

The AS 1530.4-2014 test standard requires the following statements to be included in a report to demonstrate compliance with the standard. While this experiment was similar and not deemed to be compliant, these statements are relevant here as well:

"The results of these fire tests may be used to directly assess fire hazard, but it should be recognized that a single test method will not provide a full assessment of fire hazard under all fire conditions."

"This report details methods of construction, the test conditions and results obtained when the specific element of construction described herein was tested following the procedure outlined in this standard. Any significant variations with respect to size, constructional details, loads, stresses, edge or end conditions, other than those allowed under the field of direct application in the relevant test method, is not covered by this report.

Because of the nature of fire resistance testing and the consequent difficulty in quantifying the uncertainty of measurement of fire resistance, it is not possible to provide a stated degree of accuracy of the result."

Since methods of construction are not provided and there is no link provided between test results and construction details for specific penetration assemblies, this report does not prove or disprove compliance with the test standard for any tested assemblies. It only provides the range of performance that was experienced by the assemblies.

LIMITATION

The results reported here are not specific for a particular system and have been anonymised. This report shall not be used to endorse any particular product or system. The information contained within is for research purposes only and cannot be used as a basis to determine building code compliance.

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DOCUMENT REVISION STATUS

ISSUE NO.	DATE ISSUED	DESCRIPTION
1	1-May-2018	Initial Issue

1. TEST PROCEDURE

The test was conducted in a similar manner to the requirements of AS 1530.4-2014 *"Methods for fire tests on building materials, components and structures, Part 4 Fire-resistance tests of elements of construction", Section 10 Service penetrations and control joints*, with reference to AS 4072.1-2005, Service penetrations and control joints, Section 3.1 Fire Resistance Testing.

2. DESCRIPTION OF TEST SPECIMEN

2.1 General

The supporting construction consisted of a 45 mm x 90 mm H1.2 timber frame of 3,000 m x 3,000 m nominal dimensions. Studs were placed at nominal 300 mm centres and nogs were placed at 800 mm centers. The exposed side was lined with fire-rated RAB board and the unexposed side was lined with 10 mm fire-rated plasterboard and fixed as per the manufacturers' specifications. All fastener heads were stopped and all sheet joints tape reinforced and stopped as per the manufactures' specifications. All pipes protruded a minimum of 500 mm into the furnace and at least 2,000 mm beyond the unexposed face. All pipes were capped with PVC caps on the exposed face and were open on the unexposed face. The pipes were supported at 500 mm and 1,500 mm on the unexposed side. Nominal PVC pipe sizes of 40 mm and 100mm were used.

All cables protruded a minimum of 500 mm on both the exposed and unexposed sides. Cable bundles consisted of single cable (12 x 6 mm 3 wire main – 2.5 mm² 2C+E TPS 15150199/100 General Cable), three cable (2 x 3 wire main, 1 x single wire earth 6.0 mm² conduit wire GN/YL BAAP11A1001AAHN 6112 Olex), and twelve cable (7 x 3 wire main, 1 x earth, 2 x network Cat 6 UTP 0.53 3pr CMR BU 24154021 p/m Hubbell, 1 x RG6 coax 75 ohm SKY BK 152, and 1 x optical fibre OM3 Fibre patch lead 30 mt Fib-mm1043).

Spacing between the edges of the penetrations and the edge of the specimen was maintained at 200 mm.

2.2 Penetration details

2.2.1 Pipe support spacing

All pipes were supported at nominal distances of 500 and 1,500 mm from the unexposed face with pipe clamps which were in turn attached to a wood frame.

2.2.2 Penetration 1

Penetration 1 was a three-cable bundle through a 18mm diameter hole drilled through both exposed and unexposed linings. No sealant was used to seal the penetration.

2.2.3 Penetration 2

Penetration 2 was of similar construction to penetration 1 but intumescent sealant was used to seal the penetration on both sides.

2.2.4 Penetration 3

Penetration 3 was a 40mm uPVC pipe with a fire-rated Intumescent sleeve 50 mm x 300 mm attached to the unexposed side. Intumescent sealant was used in the sleeve at a depth of 20 mm.

2.2.5 Penetration 4

Penetration 4 was a 40mm uPVC pipe fitted with a fire-rated collar on the unexposed side. A 10mm layer of intumescent sealant was installed between the pipe and the wall board.

2.2.6 Penetration 5

Penetration 5 was a non-rated flush box attached to the unexposed side. No additional sealant was used.

2.2.7 Penetration 6

Penetration 6 was of similar construction to penetration 4, but the collar was not supported.

2.2.8 Penetration 7

Penetration 7 was of similar construction to penetration 1, except that the hole was 25 mm instead of 18 mm.

2.2.9 Penetration 8

Penetration 8 was of similar construction to penetration 2, except that the hole diameter was 25 mm instead of 18 mm.

2.2.10 Penetration 9

Penetration 9 was a non-rated flush box with an intumescent pad attached to the exposed side. Intumescent sealant was used to hold the pad in place.

2.2.11 Penetration 10

Penetration 10 was of similar construction to penetration 1, except the hole diameter of 16 mm was specified which was as tight as possible while still allowing the three cables to pass through.

2.2.12 Penetration 11

The construction of penetration 11 was similar to penetration 1, but used a twelve cable bundle through a 48 mm diameter hole.

2.2.13 Penetration 12

The construction of penetration 12 was similar to penetration 11 with a fire-rated cable collar installed on the exposed side. The collar was fastened to the RAB and supporting timber framing (the plasterboard was not otherwise fixed to the framing) with two 10g x 40mm timber screws and washers. Intumescent sealant was used in the collar at a depth of 20 mm and 2 layers of 100 mm wide fire-rated putty bandage were installed on the cables adjacent to the collar, as per the manufactures' specifications. Variations from the approved assembly included a collar installed on only one side, no cavity insulation, and no beading.

2.2.14 Penetration 13

Penetration 13 construction was similar to penetration 12 with the collar and associated fire stopping materials (sealant and putty bandage) installed on the unexposed side rather than the exposed side.

2.2.15 Penetration 14

Penetration 14 construction consisted of a single cable through a 13 mm diameter hole through the linings on both sides. The 13 mm diameter hole was sized to provide a tight fit.

2.2.16 Penetration 15

Penetration 15 consisted of a twelve-cable bundle through a 48 mm diameter hole. Intumescent sealant was used on both the exposed and unexposed side. Sufficient sealant for the thickness of the plasterboard and RAB lining was used, and the exposed excess was smoothed with a putty knife. This was a variation from the manufacturers' specification, which require beading (a frame of additional layers of plasterboard) around the penetration to achieve 25 mm sealant thickness. No backing element (rod or cavity insulation) was used to ensure the thickness of the sealant.

2.2.17 Penetration 16

Penetration 16 consisted of a 100 mm nominal diameter PVC pipe through a 110 mm diameter hole in both linings. A single fire-rated collar was installed on the unexposed side and attached to the manufactures' specifications. The plasterboard was not otherwise fixed to the additional timber framing for the collar. The gap between the pipe and the hole was sealed with approximately 10 mm of intumescent. No backing element was used due to the thickness of the plasterboard. This system was a variation from the requirements in the manufacturers' specifications. The variation was that the wall was not steel framed, did not have two layers of fire grade plasterboard lining on each side, and only had a collar on the unexposed side. The unexposed side was chosen for the collar as this was expected to be the weakest configuration.

2.2.18 Penetration 17

Penetration 17 was similar in construction to penetration 16, with a fire-rated intumescent sleeve 50 mm x 300 mm attached to the unexposed side. Intumescent sealant was used in the sleeve at a depth of 20 mm.

2.2.19 Penetration 18

Penetration 18 was similar in construction to penetration 16, but without supporting timber framing.

2.2.20 Penetration 19

Penetration 19 was a single cable through a 16mm diameter hole through the linings on both sides. Intumescent sealant was used to seal the remainder of the hole.

2.2.21 Penetration 20

Penetration 20 is a horizontal joint with fire-rated RAB Board PVC Horizontal Flashing. There was no additional sealant.

3. TEST CONDITIONS AND RESULTS

3.1 General

The specimen was tested on 5th September 2017, at the BRANZ laboratories at Judgeford, New Zealand. The test was closed due to the potential commercial implications of testing non-compliant assemblies which were expected to fail. The ambient temperature at the beginning of the test was 18°C.

The frame containing the test specimen was sealed to the 3,000mm wide x 4,000mm high furnace, and the temperature and pressure conditions were controlled to the limits defined in AS1530.4-2014.

The test was terminated after the specimen had been exposed to the standard fire resistance conditions for 60 minutes. While some of the penetrations had not failed at this time, the test was stopped to observe the condition of the exposed face at this time.

3.2 Specimen temperature measurement

To monitor heat conduction through the sealing systems, 89 chromel-alumel thermocouples were attached to the specimens. The arrangement consisted of thermocouples placed as specified in clause 10.5 of the test standard AS 1530.4-2014.

Thermocouples were placed on the unexposed surface of the plasterboard wall at 25 mm from the penetrations, on the collars (where used), and on the services (pipes and cables) at 25 mm from either the plasterboard or collars (where used). For single or three cable penetrations, a single thermocouple was placed on the cables. Temperatures for each of the penetrations are shown in Figure 1 to Figure 20.

All of the thermocouples described above were connected to a computer controlled data acquisition system which recorded the temperature at 15 second intervals.

Figure 1: Penetration A thermocouple temperatures

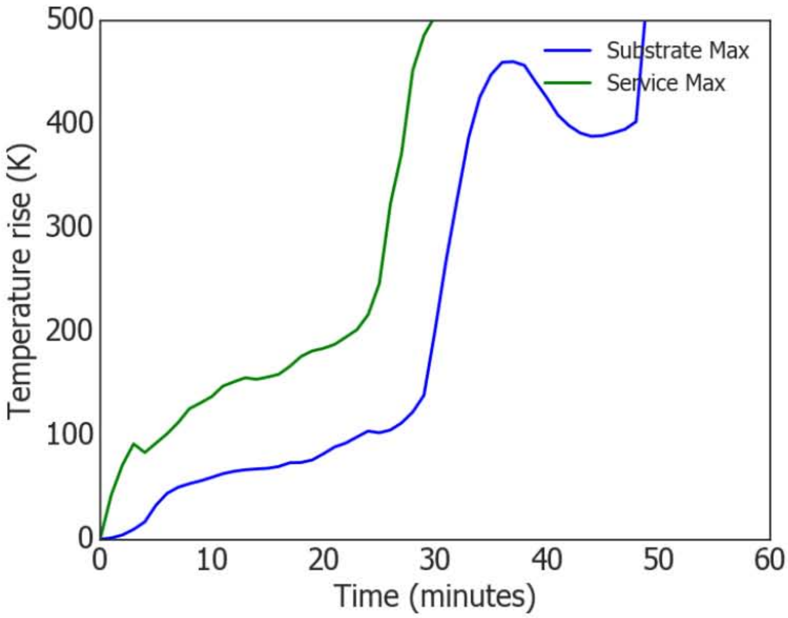


Figure 2: Penetration B thermocouple temperatures

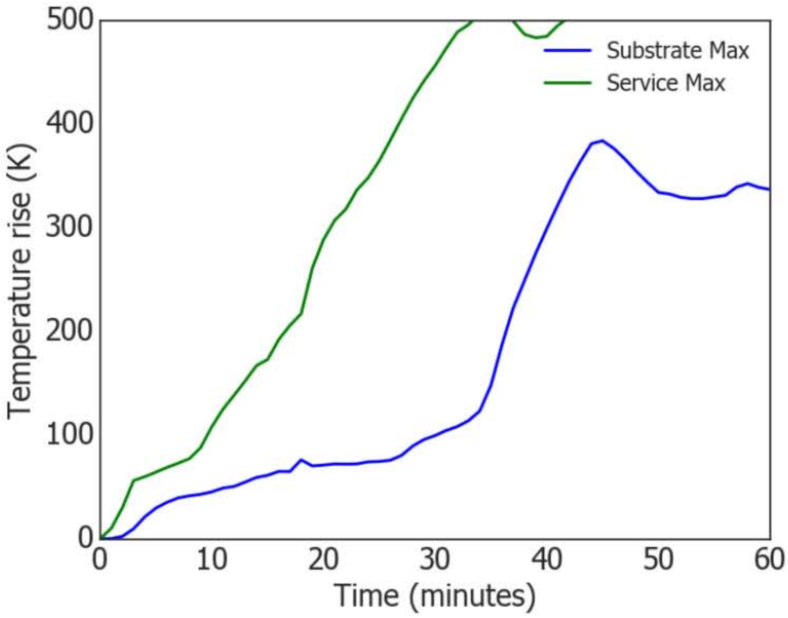


Figure 3: Penetration C thermocouple temperatures

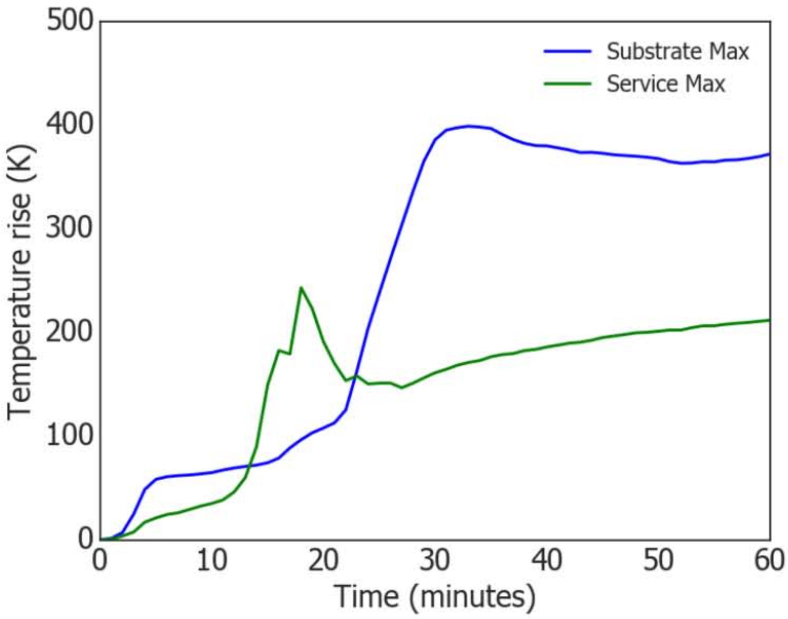


Figure 4: Penetration D thermocouple temperatures

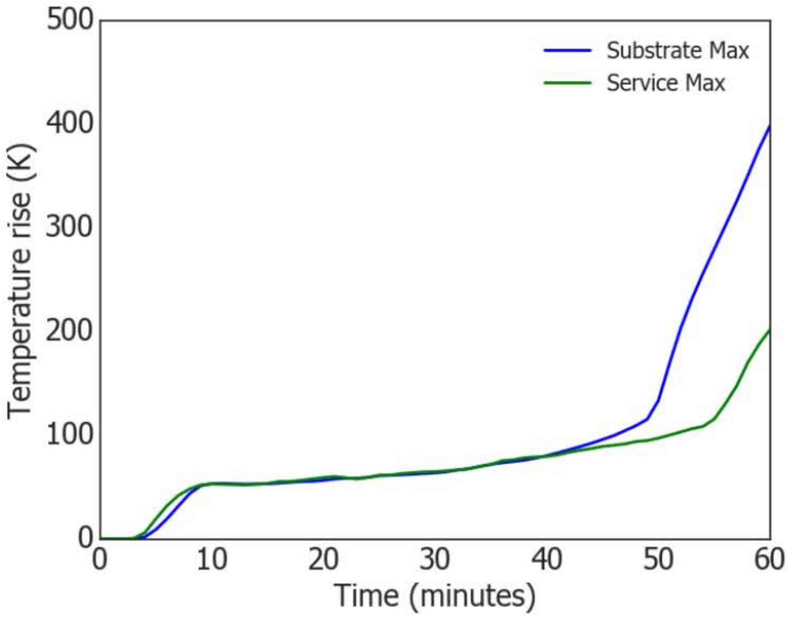


Figure 5: Penetration E thermocouple temperatures

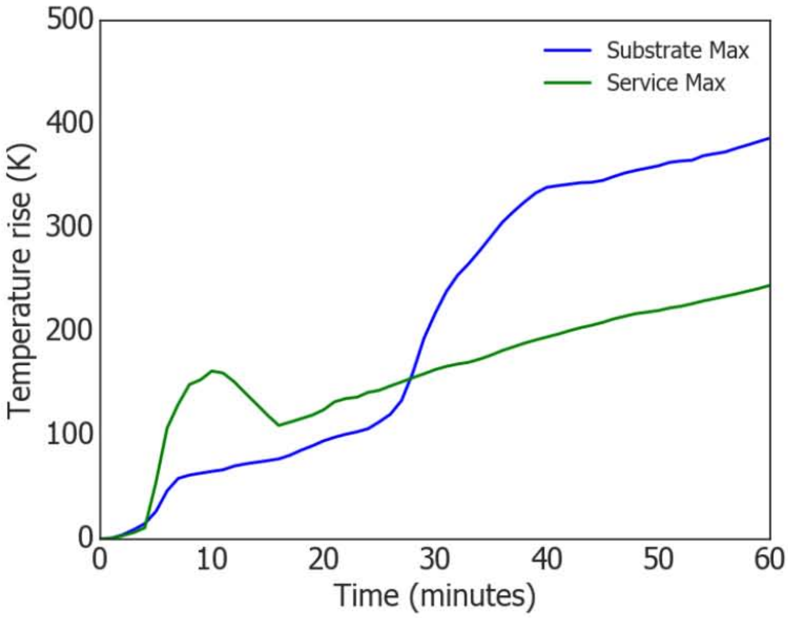


Figure 6: Penetration F thermocouple temperatures

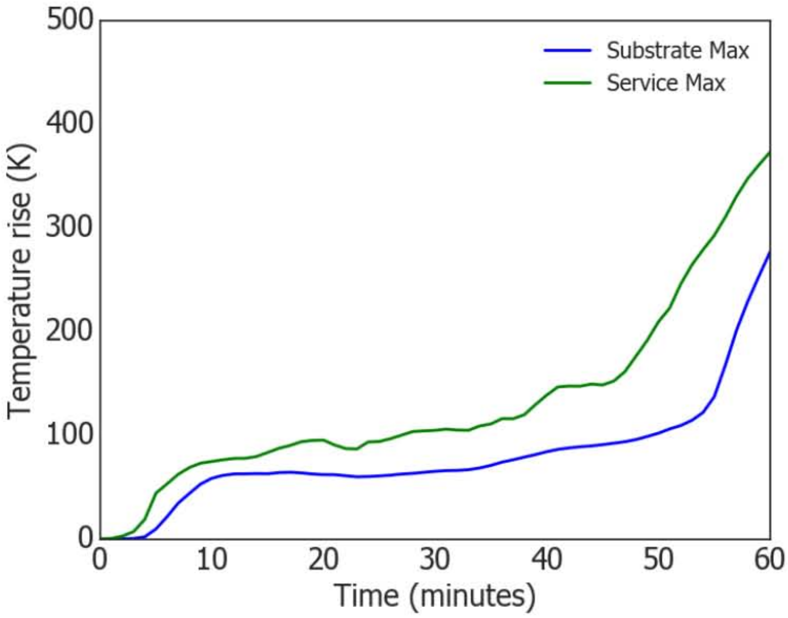


Figure 7: Penetration G thermocouple temperatures

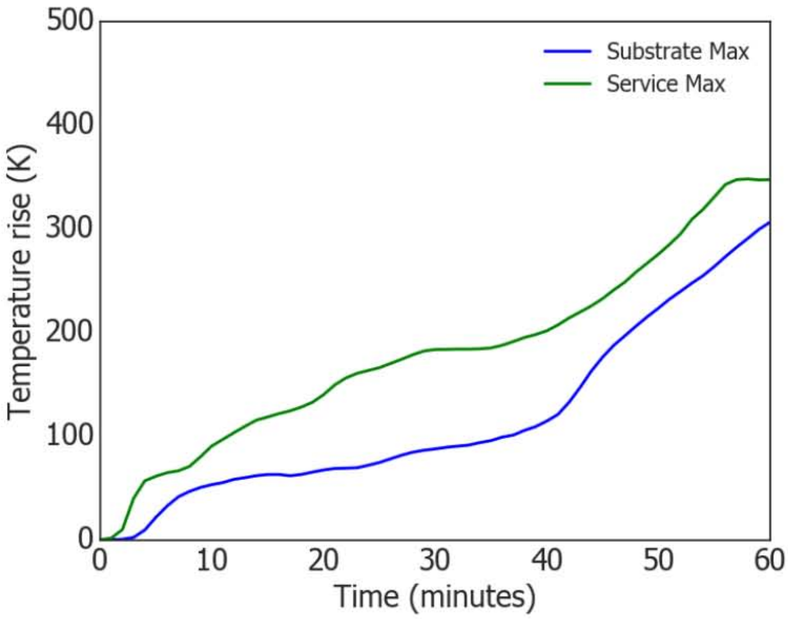


Figure 8: Penetration H thermocouple temperatures

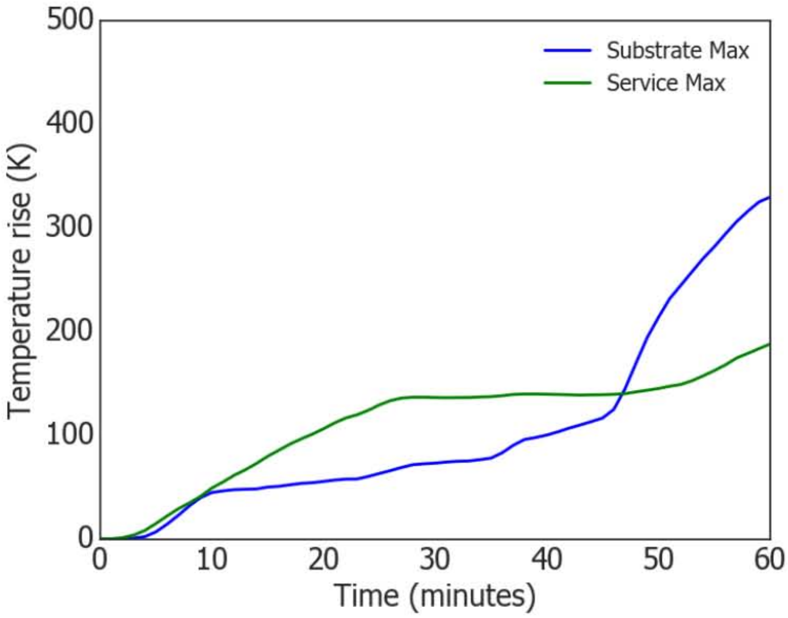


Figure 9: Penetration I thermocouple temperatures

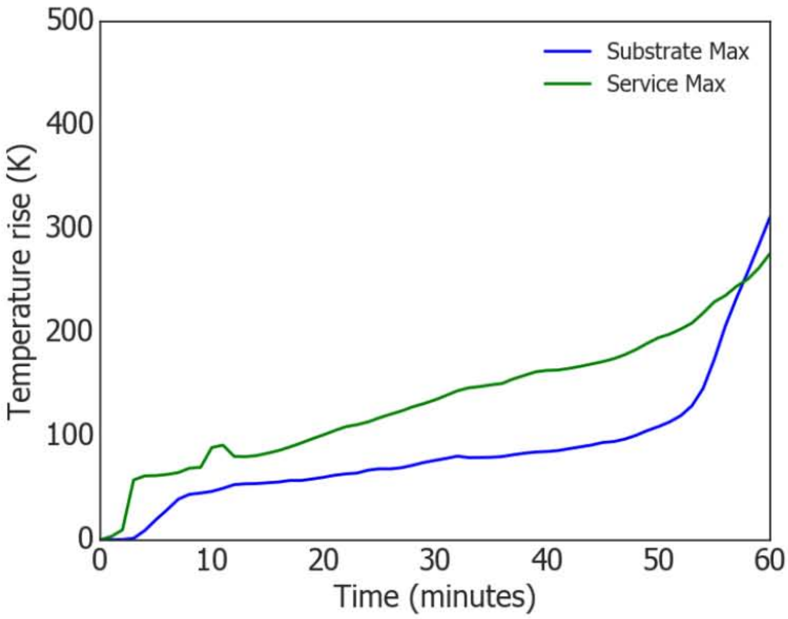


Figure 10: Penetration J thermocouple temperatures

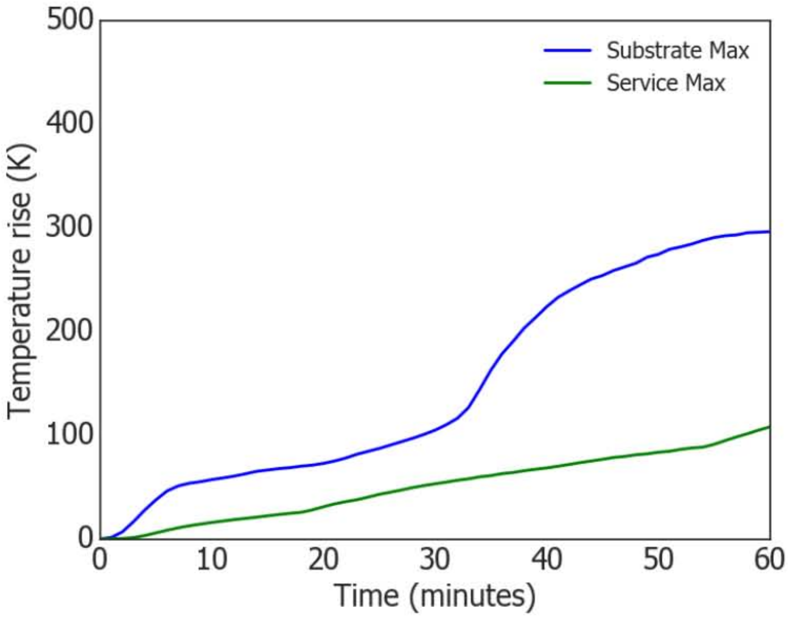


Figure 11: Penetration K thermocouple temperatures

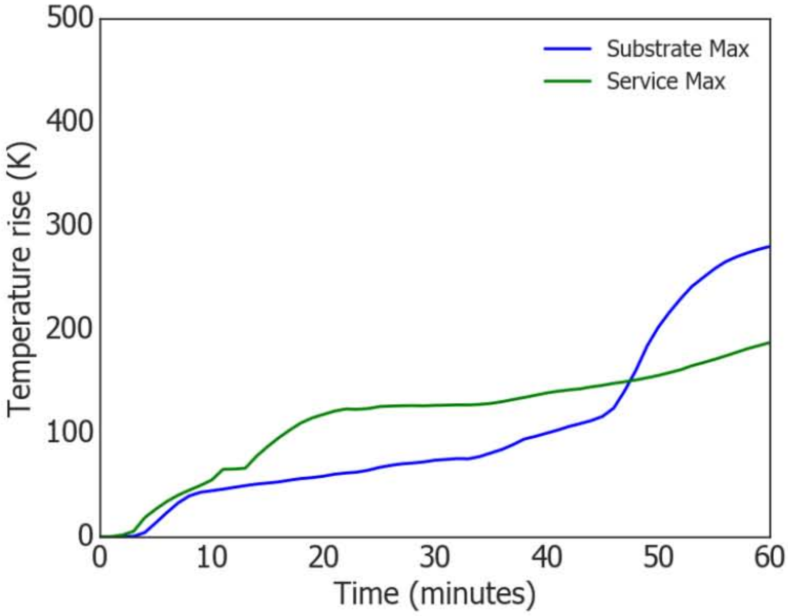


Figure 12: Penetration L thermocouple temperatures

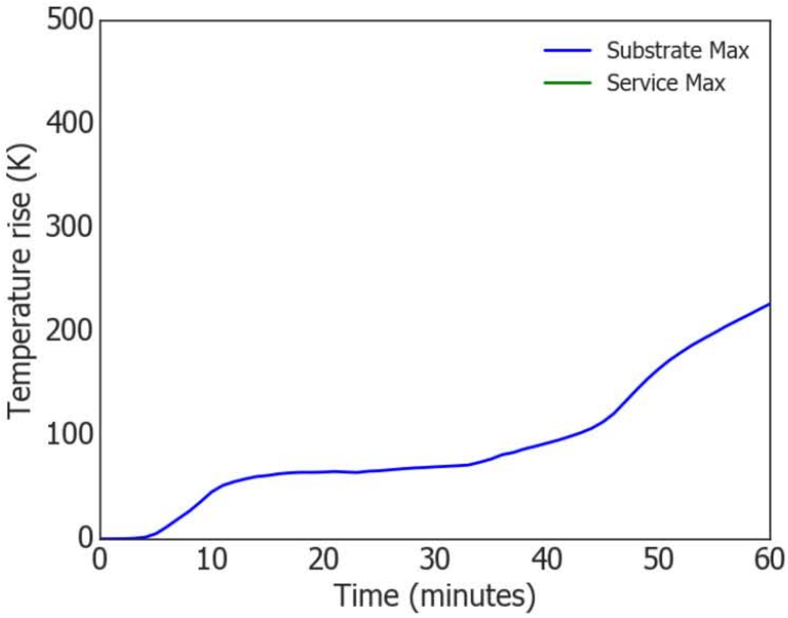


Figure 13: Penetration M thermocouple temperatures

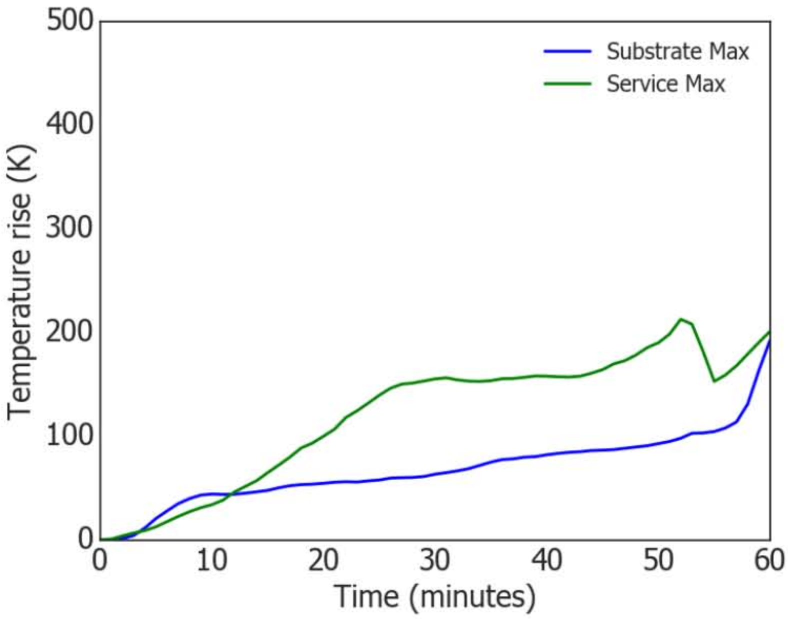


Figure 14: Penetration N thermocouple temperatures

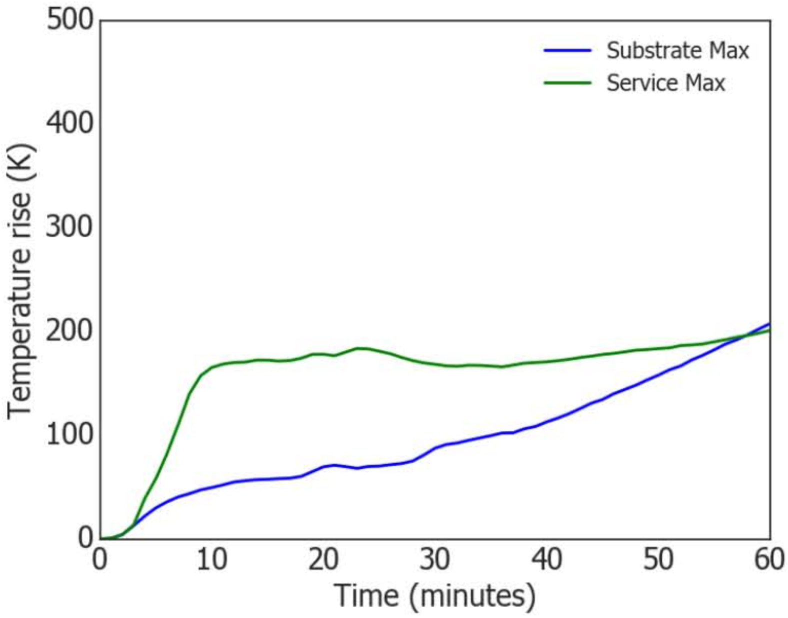


Figure 15: Penetration O thermocouple temperatures

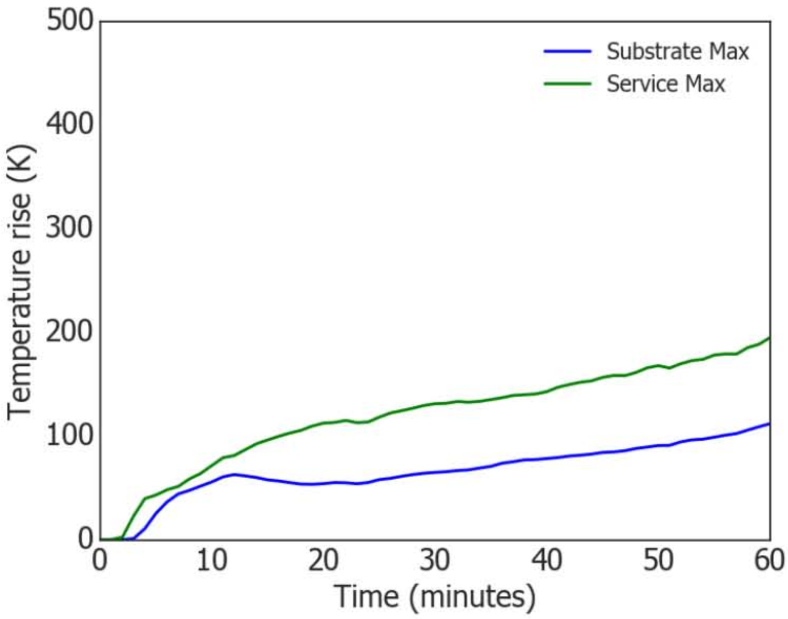


Figure 16: Penetration P thermocouple temperatures

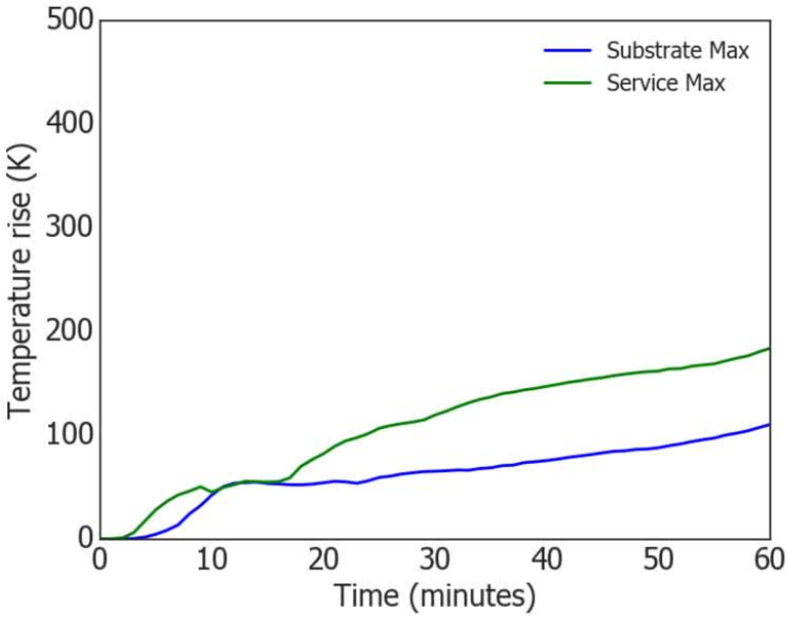


Figure 17: Penetration Q thermocouple temperatures

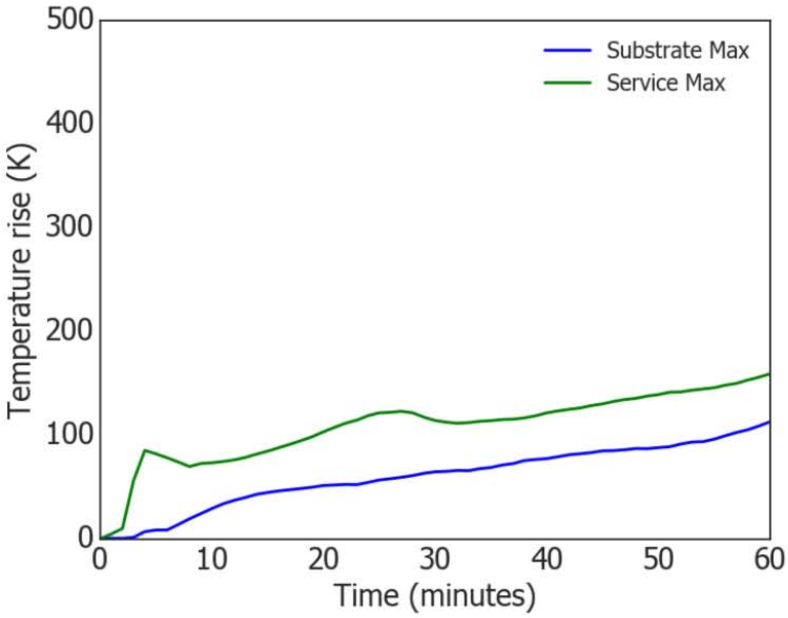


Figure 18: Penetration R thermocouple temperatures

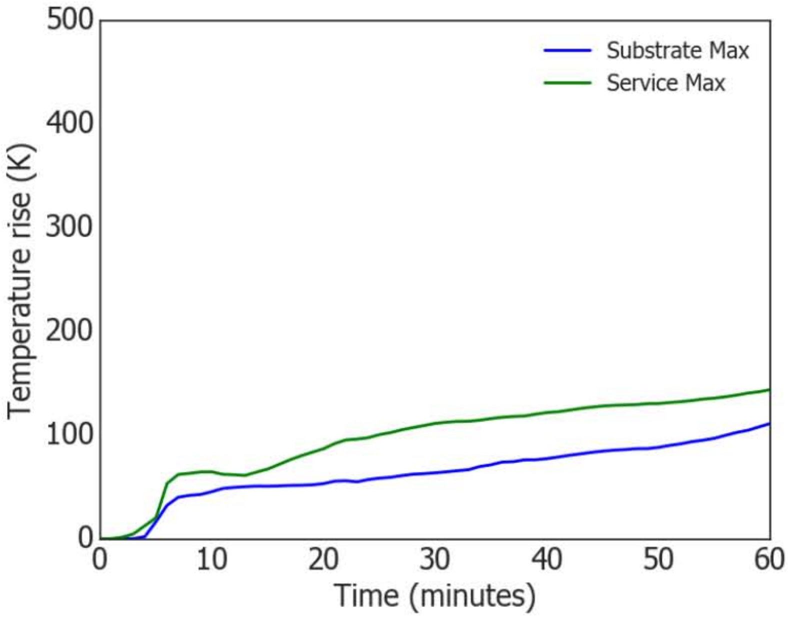


Figure 19: Penetration S thermocouple temperatures

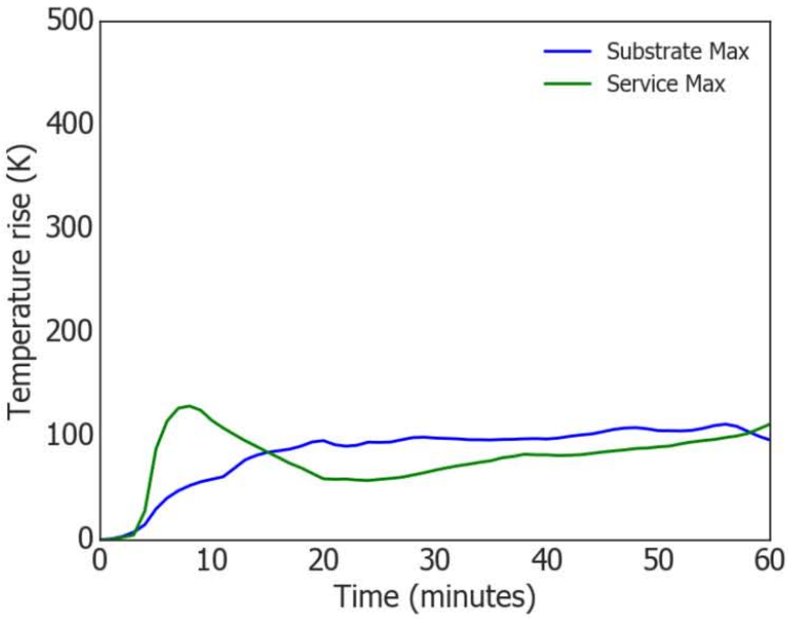
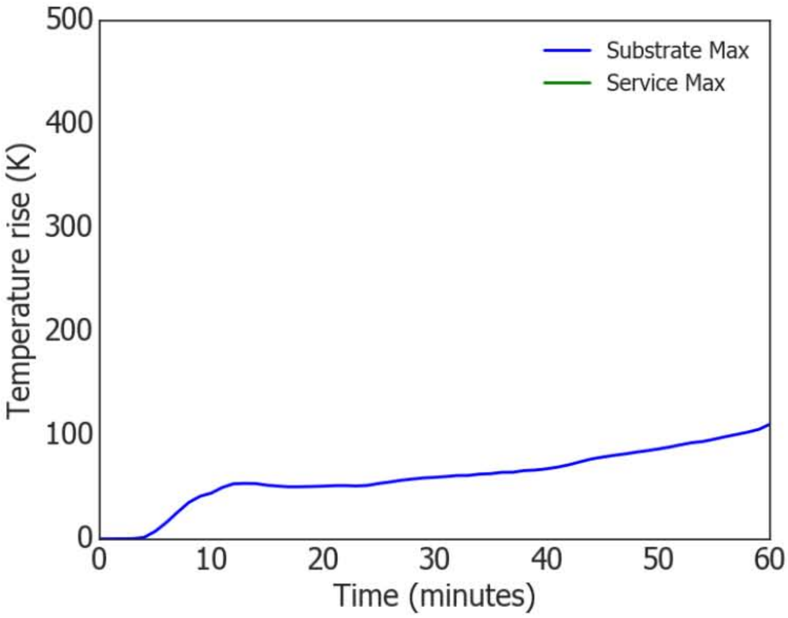


Figure 20: Penetration T thermocouple temperatures



3.3 Integrity Observations

Observations related to the integrity performance of the specimens were made during the test. A cotton pad was ignited at Penetration A at 27 minutes. No significant integrity observations were made during the test duration for the other penetrations.

3.4 Conclusion

The objective of this test was to investigate the relative performance of non-standard penetration sealing systems that represent real-world construction in a typical plasterboard wall. The results of the test will be used in the development of a process and risk analysis tool to inform ANARP decisions when evaluating the means of escape from fire as required by Section 112 of New Zealand Building Act 2004.

The comparative performance of 20 cable and PVC pipe penetrations and their sealing systems in a plasterboard wall substrate when tested under similar conditions to those required by AS 1530.4-2014, ranged from cotton pad ignition in 27 minutes to ignition at 52 minutes. The maximum temperature measured on the unexposed side of the test specimen and the penetration services ranged from 85 K to 786 K. The earliest time at which a temperature rise of 150 K was exceeded was 16 minutes.

BRANZ
1222 Moonshine Road
Judgeford RD1
Porirua 5381
New Zealand
T +64 4 237 1170
F +64 4 237 1171
branz@branz.co.nz
www.branz.co.nz



INTERNAL REPORT

QR 1615 - PH

RELATIVE FIRE PERFORMANCE OF NON-STANDARD PENETRATION SEALS IN A TIMBER-FRAME FLOOR AND PLASTERBOARD CEILING ASSEMBLY

CLIENT
BRANZ Inc.

PROJECT NUMBER:	ISSUE DATE:	PAGE:
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TEST SUMMARY

Objective

The objective of this research was to investigate the relative performance of non-standard penetration sealing systems that represent observed construction in a typical timber-frame floor and plasterboard ceiling assembly using an indicative fire resistance test. The results of the test will be used in the development of a process and risk analysis tool to inform ANARP decisions when evaluating the means of escape from fire as required by Section 112 of the New Zealand Building Act 2004.

The relative fire resistance performance of these cable and plastic pipe penetration sealing systems was determined by testing in a similar fashion to AS 1530.4-2014 *Fire Resistance tests of elements of building construction: Section 10 Service Penetrations and Control Joints,* with reference to AS 4072.1-2005.

Test sponsor

This fire test was part of a Building Research Levy funded project, QR1615.

Description of test specimen

The test specimen consisted of a nominal 2,000 mm x 1,000 m timber frame with a plasterboard ceiling and a particle board floor. A range of electrical and communications cable (from one cable to twelve cables) and polyvinylchloride (PVC) pipe penetrations (40 mm to 65 mm OD) were tested with penetration seal systems that deviated from manufacturers' approved specifications, but were representative of observed construction practices from buildings in Auckland where penetrations have been exposed due to undergoing weathertightness remediation.

Date of test

28 March 2017

Test results

The comparative performance of 15 cable and PVC pipe penetrations and their sealing systems in a timber-framed plasterboard ceiling substrate when tested under similar conditions to those required by AS 1530.4-2014, ranged from cotton pad ignition in 55 minutes to no ignition in 60 minutes. The maximum temperature rise measured on the unexposed side of the test specimen and the penetration services for each penetration ranged from 58 K to 676 K. The earliest time at which a temperature rise of 150 K was exceeded was 5 minutes.

The AS 1530.4-2014 test standard requires the following statements to be included in a report to demonstrate compliance with the standard. While this experiment was similar and not deemed to be compliant, these statements are relevant here as well:

"The results of these fire tests may be used to directly assess fire hazard, but it should be recognized that a single test method will not provide a full assessment of fire hazard under all fire conditions."

"This report details methods of construction, the test conditions and results obtained when the specific element of construction described herein was tested following the procedure outlined in this standard. Any significant variations with respect to size, constructional details, loads, stresses, edge or end conditions, other than those allowed under the field of direct application in the relevant test method, is not covered by this report.

Because of the nature of fire resistance testing and the consequent difficulty in quantifying the uncertainty of measurement of fire resistance, it is not possible to provide a stated degree of accuracy of the result."

Since methods of construction are not provided and there is no link provided between test results and construction details for specific penetration assemblies, this report does not prove or disprove compliance with the test standard for any tested assemblies. It only provides the range of performance that was experienced by the assemblies.

LIMITATION

The results reported here are not specific for a particular system and have been anonymised. This report shall not be used to endorse any particular product or system. The information contained within is for research purposes only and cannot be used as a basis to determine building code compliance.

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1. TEST PROCEDURE

The test was conducted in a similar manner to the requirements of AS 1530.4-2014 *"Methods for fire tests on building materials, components and structures, Part 4 Fire-resistance tests of elements of construction", Section 10 Service penetrations and control joints*, with reference to AS 4072.1-2005, Service penetrations and control joints, Section 3.1 Fire Resistance Testing.

2. DESCRIPTION OF TEST SPECIMEN

2.1 General

The test specimen substrate was constructed in accordance with a tested floor-ceiling system, which is listed by the manufacturer as having a 60/60/60 FRR. The timber frame was constructed of H1.2 treated SG8 240 mm x 45 mm pinus radiata joists, with a maximum spacing of 475 mm. The flooring was 20 mm thick tongue and groove high density reconstituted wood panel and the ceiling was 16 mm thick fire-rated plasterboard. The plasterboard was fastened as per the manufacturer's specification with 51 mm x 7g high thread drywall screws, at 150 mm centres around the sheet perimeter and at 200 mm centres along each joist. The flooring was fastened with 45 mm x 8g chipboard screws.

All pipes protruded a minimum of 500 mm into the furnace and at least 2,000 mm beyond the unexposed face. All pipes were capped with PVC caps on the exposed face and were open on the unexposed face. The pipes were supported at 500 mm and 1,500 mm on the unexposed side. Nominal PVC pipe sizes of 40 mm and 65 mm were used.

All cables except for Penetration 1 protruded a minimum of 500 mm on both the exposed and unexposed sides. The cables in Penetration 1 protruded 450 mm and 470 mm on the unexposed and exposed sides, respectively. Cable bundles consisted of single cable (12 mm x 6 mm three wire main – 2.5 mm^2 2C+E TPS 15150199/100 General Cable), three cable (2 x three wire main, 1 x single wire earth 6.0 mm^2 conduit wire GN/YL BAAP11A1001AAHN 6112 Olex), and twelve cable (7 x three wire main, 1 x earth, 2 x network Cat 6 UTP 0.53 3pr CMR BU 24154021 p/m Hubbell, 1 x RG6 coax 75 ohm SKY BK 152, and 1 x optical fibre OM3 Fibre patch lead 30 mt Fib-mm1043).

2.2 Penetration details

2.2.1 Pipe support spacing

All pipes were supported at nominal heights of 500 and 1,500 mm with pipe clamps which were in turn attached to a steel frame.

2.2.2 Penetration 1

The construction of Penetration 1 was a twelve cable bundle through a 44 mm diameter hole with a cable collar installed on the exposed side. The collar was fastened to the plasterboard and supporting timber framing with two 8 x 65-75 screw anchors. Intumescent sealant was used in the collar at a depth of 20 mm and two layers of 100 mm wide putty bandage were installed on the cables adjacent to the collar, as per the test report which is listed on the manufacturer's website as the approval document for the cable collar. Variations from the approved assembly included a collar installed on only one side and a flexible floor substrate.

2.2.3 Penetration 2

Penetration 2 had a similar configuration to Penetration 1 (twelve cable bundle, 44 mm diameter hole) but used intumescent sealant only on the exposed side of the penetration. The depth of sealant was approximately the thickness of the 16 mm plasterboard. No backing element was used. This varied from approved assemblies described in the manufacturer's test report because a flexible floor substrate was used, no backfilling material was used, sealant was applied to the exposed side, and the sealant thickness was less than 25 mm.

2.2.4 Penetration 3

Penetration 3 was a twelve cable bundle through a 44 mm diameter hole with no other sealing.

2.2.5 Penetration 4

Penetration 4 was a 65 mm nominal diameter PVC pipe in a 110 mm diameter hole. An 80 mm diameter 300 mm long metal sleeve with an internal intumescent material was used with two extra layers of intumescent wrap inside the sleeve. The inside and outside of the sleeve was sealed with fire-stopping sealant at both ends.

2.2.6 Penetration 5

Penetration 5 was a 65 mm nominal diameter PVC pipe in a 73 mm diameter hole. A fire collar was installed on the exposed side and held in place with three 8 x 65-75 screw anchors. The gap between the pipe and the hole was sealed with approximately 10 mm of acrylic fire-rated sealant. No backing element was used for the sealant application.

2.2.7 Penetration 6

Penetration 6 was a 40 mm nominal diameter PVC pipe in a 50 mm diameter hole. A fire collar was installed on the exposed side and held in place with two 8x 65-75 screw anchors. The gap between the pipe and the hole was sealed with approximately 10 mm of acrylic fire-rated sealant. No backing element was used for the sealant application.

2.2.8 Penetration 7

Penetration 7 was a 40 mm nominal diameter PVC pipe in a 73 mm diameter hole. A 50 mm diameter 300 mm long metal sleeve with an internal intumescent material was used with an extra layer of intumescent wrap inside the sleeve. The outside and inside of the sleeve was sealed with firestopping sealant on both the exposed and unexposed sides.

2.2.9 Penetration 8

Penetration 8 construction consisted of a single cable through a 13 mm diameter hole through the linings on both sides. The 13 mm diameter hole was sized to provide a tight fit. No additional fire stopping was provided.

2.2.10 Penetration 9

Penetration 9 construction was similar to Penetration 8, but utilizing a 16 mm diameter hole. No additional fire stopping was provided.

2.2.11 Penetration 10

Penetration 10 was a single cable through a 16 mm diameter hole drilled through both the exposed and unexposed linings. Intumescent sealant was used on the exposed side. This was a variation from the requirements in the manufacturer's test report because a flexible floor substrate was used, no backfilling material was used, sealant was applied to the exposed side, and the sealant thickness was less than 25 mm.

2.2.12 Penetration 11

Penetration 11 construction consisted of a three cable bundle through a 16 mm diameter hole, with no additional fire stopping provided.

2.2.13 Penetration 12

Penetration 12 construction was similar to Penetration 11, but with an 18 mm diameter hole. No additional fire stopping was provided.

2.2.14 Penetration 13

Penetration 13 construction was similar to Penetration 11, but with a 25 mm diameter hole. No additional fire stopping was provided.

2.2.15 Penetration 14

Penetration 14 construction was similar to Penetration 12, but intumescent sealant was applied to the gap around the cables on the exposed side. This was a variation from the manufacturer's test report requirements because a flexible floor substrate was used, no backfilling material was used, sealant was applied to the exposed side, and the sealant thickness was less than 25 mm.

2.2.16 Penetration 15

Penetration 15 construction was similar to Penetration 14 but with a 25 mm diameter hole.

3. TEST CONDITIONS AND RESULTS

3.1 General

The specimen was tested on 28 March 2017, at the BRANZ laboratories at Judgeford, New Zealand. The test was closed due to the potential commercial implications of testing non-compliant assemblies which were expected to fail. The ambient temperature at the beginning of the test was 19°C.

The test specimen was placed on top of and sealed to a pilot furnace test frame with a 2,200 mm long x 1,000 mm wide opening and then sealed to the furnace. The temperature and pressure conditions were controlled to the limits defined in AS1530.4-2014.

The test was terminated after the specimen had been exposed to the standard fire resistance conditions for 60 minutes. The test was stopped to observe the condition of the exposed face and framed cavities at that time.

3.2 Specimen temperature measurement

To monitor heat conduction through the sealing systems, 61 chromel-alumel thermocouples were attached to the specimens, and two thermocouples were attached to the substrate. The arrangement consisted of thermocouples placed as specified in clause 10.5 of the test standard AS 1530.4-2014.

Thermocouples were placed on the unexposed surface of the substrate at 25 mm from the penetrations, on the sleeves (where used), and on the services (pipes and cables) at 25 mm from either the substrate or sleeves (where used). For single cable penetrations, a single thermocouple was placed on the cables. Maximum substrate and service (collars, sleeves, pipes, or cables) temperatures for a sample of the penetrations are shown in Figure 1 to Figure 11.

All of the thermocouples described above were connected to a computer controlled data acquisition system which recorded the temperature at 15 second intervals.

Figure 1: Penetration A thermocouple temperatures

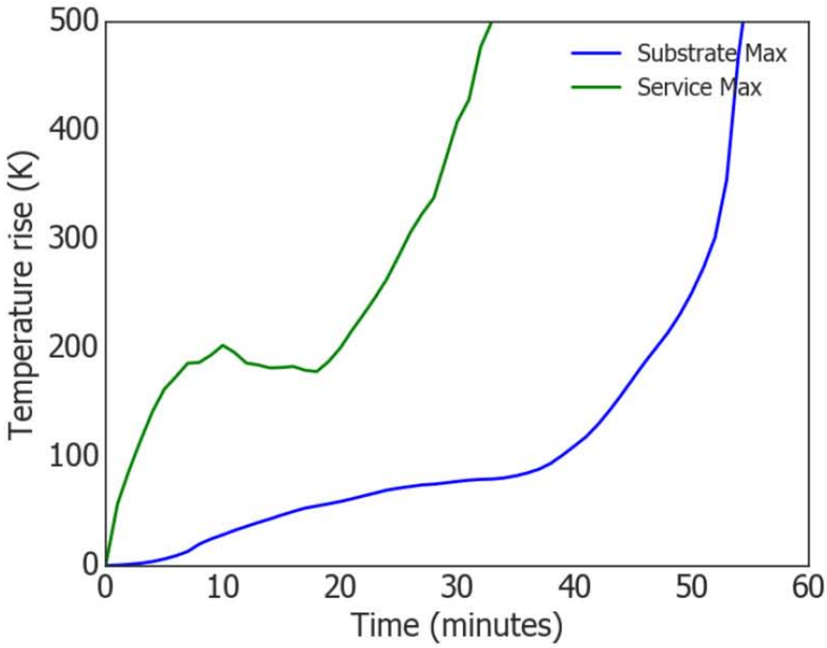


Figure 2: Penetration B thermocouple temperatures

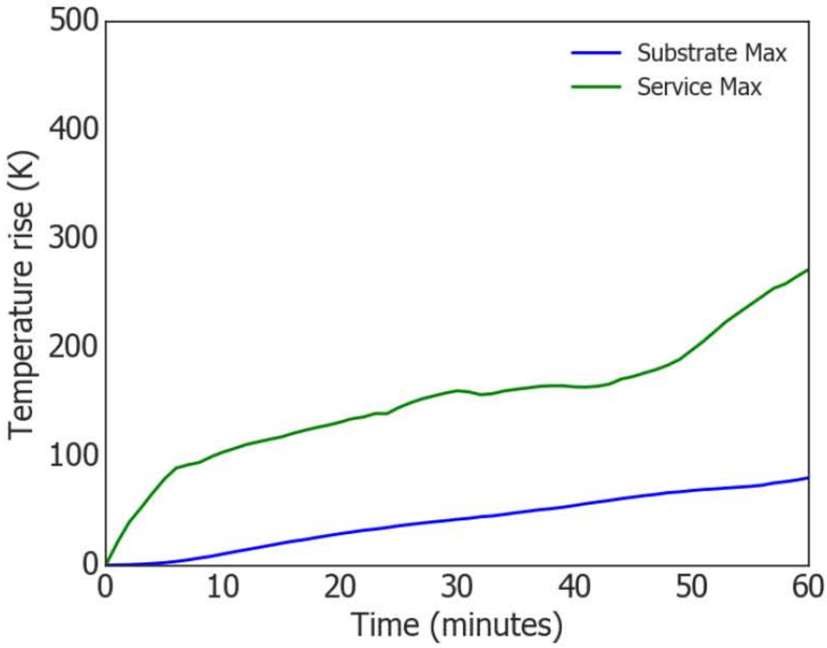


Figure 3: Penetration C thermocouple temperatures

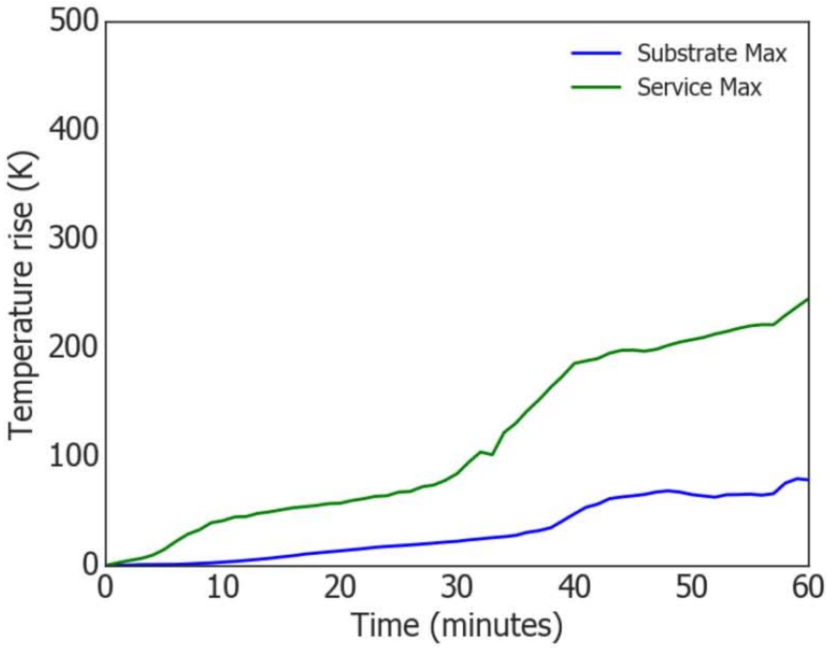


Figure 4: Penetration E thermocouple temperatures

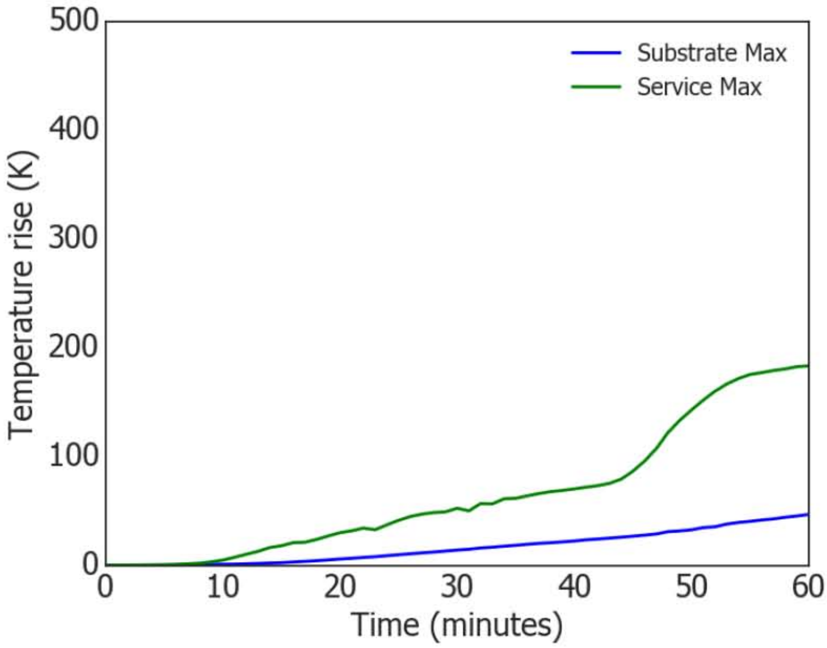


Figure 5: Penetration F thermocouple temperatures

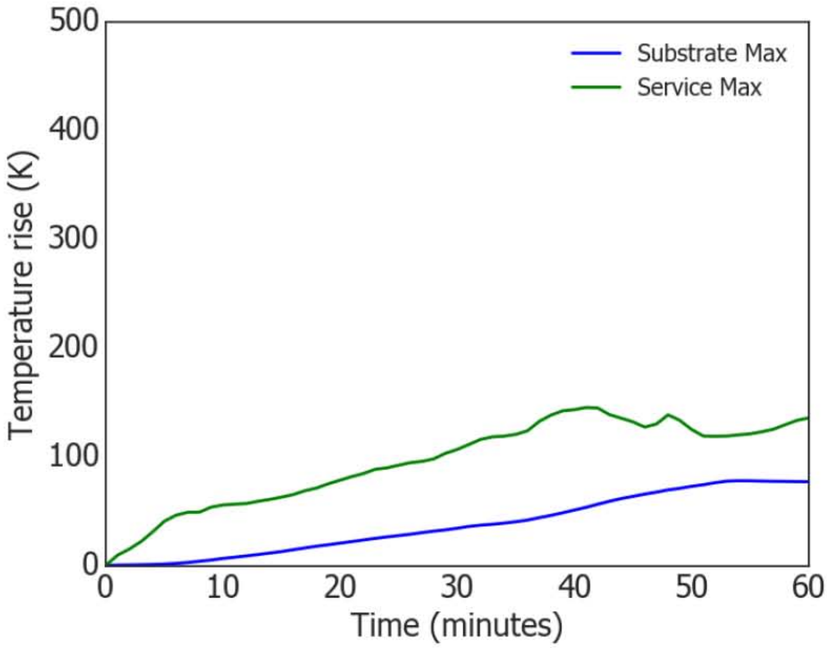


Figure 6: Penetration G thermocouple temperatures

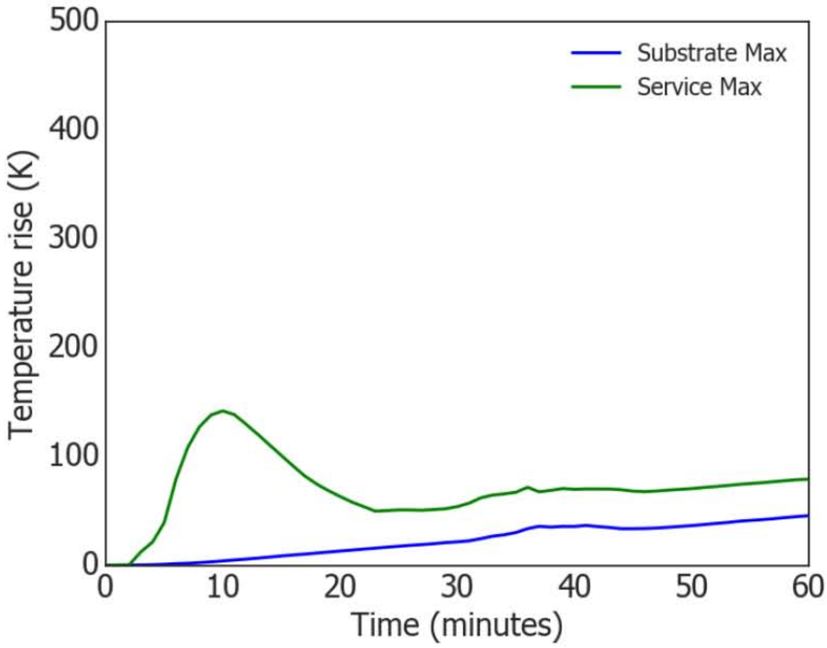


Figure 7: Penetration H thermocouple temperatures

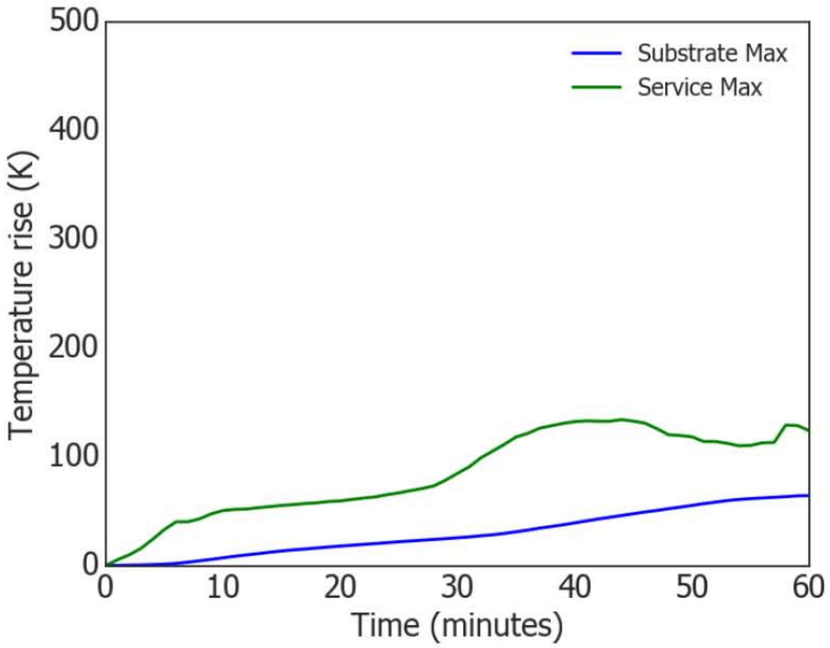


Figure 8: Penetration I thermocouple temperatures

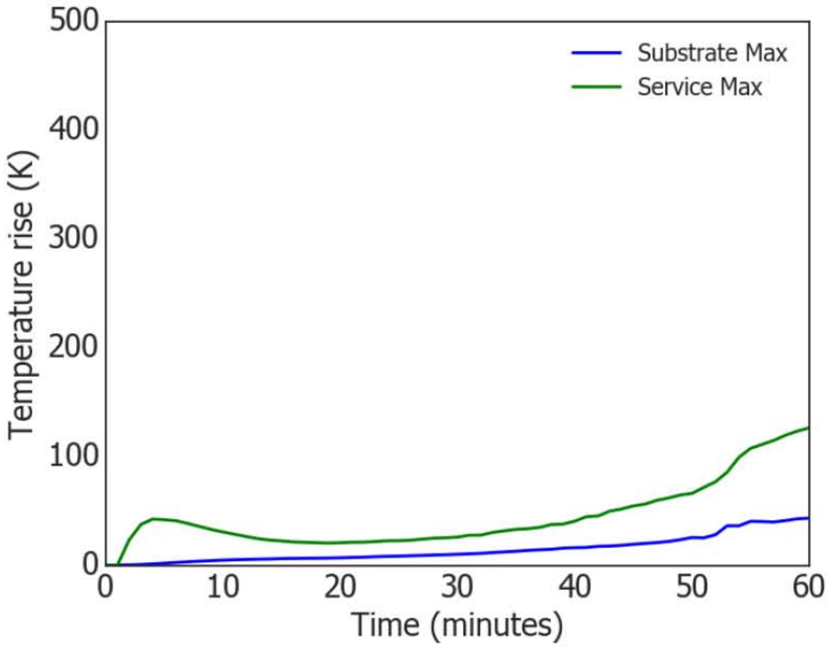


Figure 9: Penetration K thermocouple temperatures

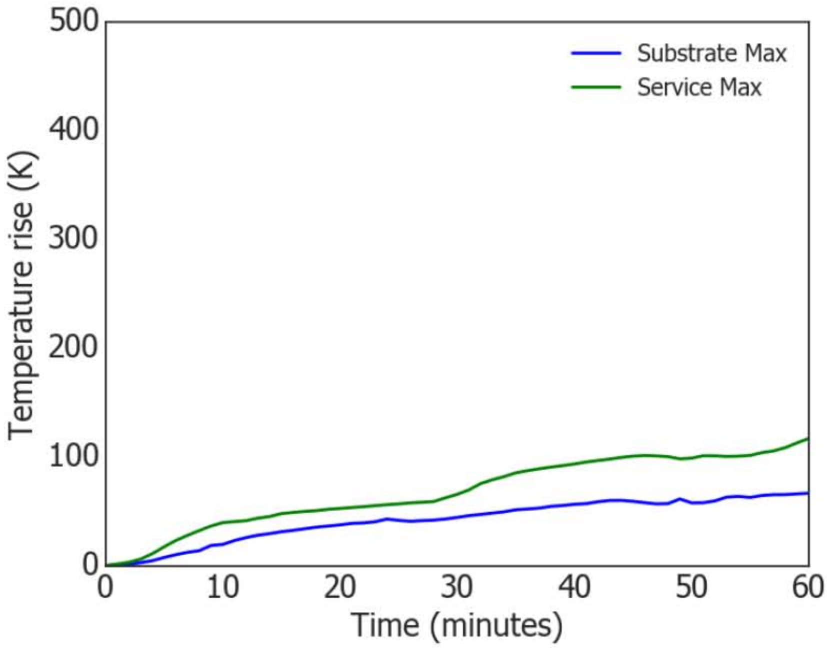


Figure 10: Penetration L thermocouple temperatures

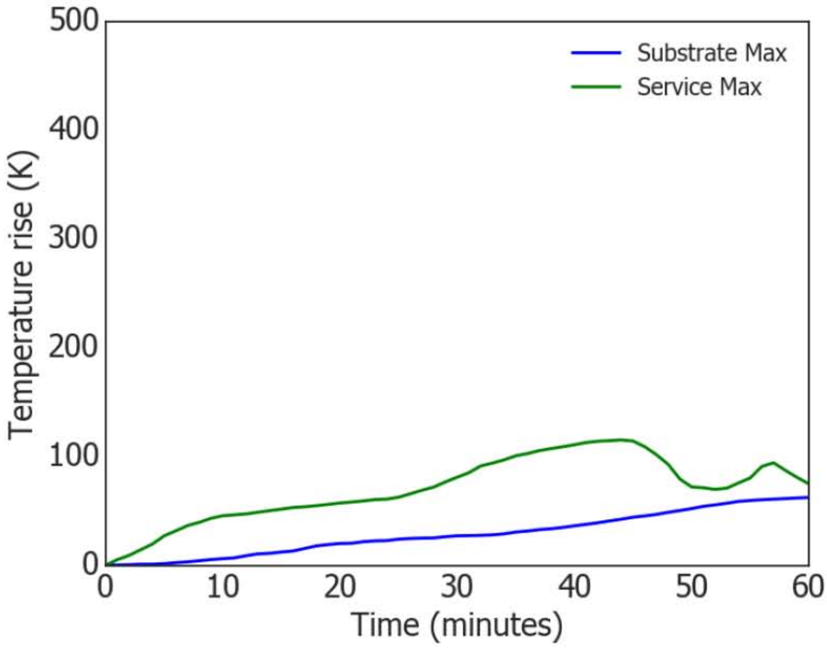
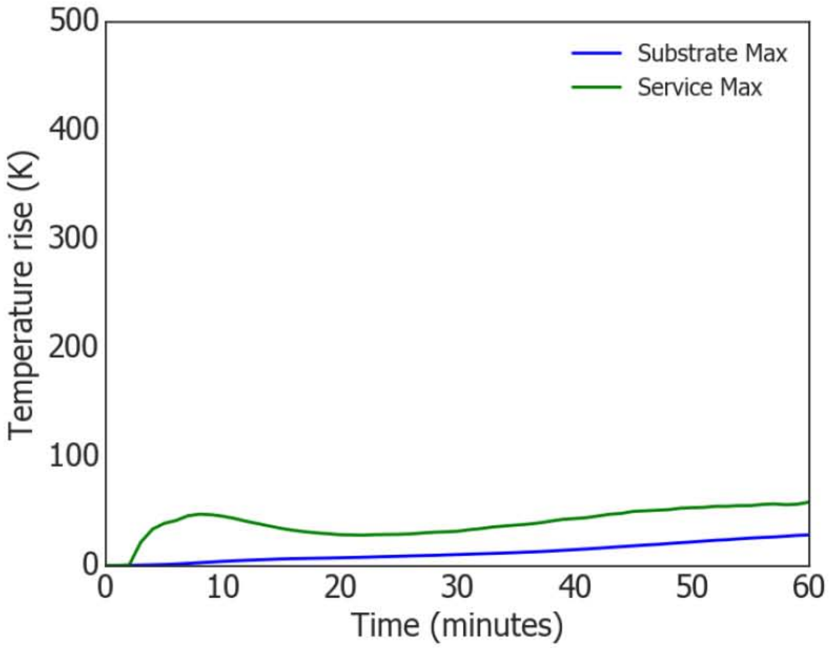


Figure 11: Penetration O thermocouple temperatures



3.3 Integrity Observations

A cotton pad was ignited at Penetration A 55 minutes into the test. No other significant observations relevant to the test integrity criteria were made during the test duration.

3.4 Conclusion

The objective of this test was to investigate the relative performance of non-standard penetration sealing systems that represent observed construction in a typical timber-frame floor and plasterboard ceiling assembly. The results of the test will be used in the development of a process and risk analysis tool to inform ANARP decisions when evaluating the means of escape from fire as required by Section 112 of the New Zealand Building Act 2004.

The comparative performance of 15 cable and PVC pipe penetrations and their sealing systems in a timber-framed plasterboard ceiling substrate when tested under similar conditions to those required by AS 1530.4-2014, ranged from cotton pad ignition in 55 minutes to no ignition in 60 minutes. The maximum temperature rise measured on the unexposed side of the test specimen and the penetration services for each penetration ranged from 58 K to 676 K. The earliest time at which a temperature rise of 150 K was exceeded was 5 minutes.

BRANZ
1222 Moonshine Road
Judgeford RD1
Porirua 5381
New Zealand
T +64 4 237 1170
F +64 4 237 1171
branz@branz.co.nz
www.branz.co.nz



INTERNAL REPORT

QR 1615 - CH

RELATIVE FIRE PERFORMANCE OF NON-STANDARD PENETRATION SEALS IN A TIMBER INFILL FLOOR

CLIENT
BRANZ Inc.

PROJECT NUMBER:	ISSUE DATE:	PAGE:
QR1615-CH	17-MAY-2017	1 of 15

TEST SUMMARY

Objective

The objective of this research was to investigate the relative performance of non-standard penetration sealing systems that represent real-world construction in a typical timber infill floor using an indicative fire resistance test. The results of the test will be used in the development of a process and risk analysis tool to inform ANARP decisions when evaluating the means of escape from fire as required by Section 112 of the New Zealand Building Act 2004.

The relative fire resistance performance of these cable and plastic pipe penetration sealing systems was determined by testing in a similar fashion to AS 1530.4-2014 *Fire Resistance tests of elements of building construction: Section 10 Service Penetrations and Control Joints,* with reference to AS 4072.1-2005.

Test sponsor

This fire test was part of a Building Research Levy funded project, QR1615.

Description of test specimen

The test specimen consisted of a nominal 2,000 mm x 1,000 m timber infill floor with a 75 mm thick reinforced concrete slab. A range of electrical and communications cable (from one cable to twelve cables) and polyvinylchloride (PVC) pipe penetrations (40 mm to 65 mm OD) were tested with penetration systems that deviated from manufacturers' approved specifications, but were representative of observed construction practices from real buildings in Auckland where penetrations have been exposed due to undergoing weathertightness remediation.

Date of test

17 February 2017

Test results

The comparative performance of 15 cable and PVC pipe penetrations and their sealing systems in a timber infill floor substrate when tested under similar conditions to those required by AS 1530.4-2014, ranged from cotton pad ignition in 33 minutes to no ignition in 60 minutes. The maximum temperature rise measured on the unexposed side of the test specimen and the penetration services for each penetration ranged from 81 K to 702 K. The earliest time at which a temperature rise of 150 K was exceeded was 3 minutes.

The AS 1530.4-2014 test standard requires the following statements to be included in a report to demonstrate compliance with the standard. While this experiment was similar and not deemed to be compliant, these statements are relevant here as well:

"The results of these fire tests may be used to directly assess fire hazard, but it should be recognized that a single test method will not provide a full assessment of fire hazard under all fire conditions."

"This report details methods of construction, the test conditions and results obtained when the specific element of construction described herein was tested following the procedure outlined in this standard. Any significant variations with respect to size, constructional details, loads, stresses, edge or end conditions, other than those allowed under the field of direct application in the relevant test method, is not covered by this report.

Because of the nature of fire resistance testing and the consequent difficulty in quantifying the uncertainty of measurement of fire resistance, it is not possible to provide a stated degree of accuracy of the result."

Since methods of construction are not provided and there is no link provided between test results and construction details for specific penetration assemblies, this report does not prove or disprove compliance with the test standard for any tested assemblies. It only provides the range of performance that was experienced by the assemblies.

LIMITATION

The results reported here are not specific for a particular system and have been anonymised. This report shall not be used to endorse any particular product or system. The information contained within is for research purposes only and cannot be used as a basis to determine building code compliance.

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FIGURES

DOCUMENT REVISION STATUS

ISSUE NO.	DATE ISSUED	DESCRIPTION
1	17 MAR 2017	Initial Issue
2	17 MAY 2017	Issued for Stakeholder Review

1. TEST PROCEDURE

The test was conducted in a similar manner to the requirements of AS 1530.4-2014 *"Methods for fire tests on building materials, components and structures, Part 4 Fire-resistance tests of elements of construction", Section 10 Service penetrations and control joints*, with reference to AS 4072.1-2005, Service penetrations and control joints, Section 3.1 Fire Resistance Testing.

2. DESCRIPTION OF TEST SPECIMEN

2.1 General

The timber infill floor was constructed of H3 treated No. 1 framing grade 200 x 25 mm rough sawn pinus radiata, spanning the 1,000 mm width of the pilot furnace. The timber was placed in a 1,200 mm x 2,500 mm frame made of structural steel channel that was larger than the pilot furnace test frames. A SE62 seismic mesh reinforcement was used with a minimum 25 mm cover from the top surface. A 75 mm thick concrete topping using a maximum aggregate size of 13 mm and minimum strength of 25 MPa was used. At the time of test, the concrete density was 2,400 kg/m³ and the moisture content was 12.7%.

All pipes protruded a minimum of 500 mm into the furnace and at least 2,000 mm beyond the unexposed face. All pipes were capped with PVC caps on the exposed face and were open on the unexposed face. The pipes were supported at 500 mm and 1,500 mm on the unexposed side. Nominal PVC pipe sizes of 40 mm and 65 mm were used.

All cables protruded a minimum of 500 mm on both the exposed and unexposed sides. Cable bundles consisted of single cable (12 x 6 mm 3 wire main – 2.5 mm² 2C+E TPS 15150199/100 General Cable), three cable (2 x 3 wire main, 1 x single wire earth 6.0 mm² conduit wire GN/YL BAAP11A1001AAHN 6112 Olex), and twelve cable (7 x 3 wire main, 1 x earth, 2 x network Cat 6 UTP 0.53 3pr CMR BU 24154021 p/m Hubbell, 1 x RG6 coax 75 ohm SKY BK 152, and 1 x optical fibre OM3 Fibre patch lead 30 mt Fib-mm1043).

2.2 Penetration details

2.2.1 Pipe support spacing

All pipes were supported at nominal heights of 500 and 1,400 mm with pipe clamps which were in turn attached to a steel frame.

2.2.2 Penetration 1

The construction of Penetration 1 was a 12 cable bundle through a 47 mm diameter hole with a cable collar installed on the exposed side. The collar was fastened to the timber infill and concrete with two screw anchors. Intumescent sealant was used in the collar at a depth of 20 mm and 2 layers of 100 mm wide intumescent wrap were installed on the cables adjacent to the collar.

2.2.3 Penetration 2

Penetration 2 had a similar configuration to Penetration 1 (12 cable bundle, 47 mm diameter hole) but used intumescent sealant only on the exposed side of the penetration. The depth of sealant was unknown.

2.2.4 Penetration 3

Penetration 3 was a 12 cable bundle through a 47 mm diameter hole with no other sealing.

2.2.5 Penetration 4

Penetration 4 was a 65 mm nominal diameter PVC pipe in a 107 mm diameter hole. A 300 mm long metal sleeve with an internal intumescent material was used. The outside of the sleeve was sealed with a non-intumescent firestop sealant and the gap between the inside of the sleeve and the pipe was sealed with additional intumescent sealant.

2.2.6 Penetration 5

Penetration 5 was a 65 mm nominal diameter PVC pipe in a 77 mm diameter hole. A collar was installed on the exposed side and held in place with three screw anchors. The gap between the pipe and the hole was sealed with approximately 10 mm of non-intumescent firestop sealant. No backing element was used for the sealant application.

2.2.7 Penetration 6

Penetration 6 was a 40 mm nominal diameter PVC pipe in a 47 mm diameter hole. A collar was installed on the exposed side and held in place to the timber and concrete with two screw anchors. The gap between the pipe and the hole was sealed with approximately 10 mm of non-intumescent firestop sealant. No backing element was used for the sealant application.

2.2.8 Penetration 7

Penetration 7 was a 40 mm nominal diameter PVC pipe in a 77 mm diameter hole. A 300 mm long metal sleeve with an internal intumescent material was used. The outside of the sleeve was sealed with a non-intumescent firestop sealant and the gap between the inside of the sleeve and the pipe was sealed with additional intumescent sealant.

2.2.9 Penetration 8

Penetration 8 construction consisted of a single cable through a 12 mm diameter hole through the specimen. The 12 mm diameter hole was sized to provide a tight fit. No additional fire stopping was provided.

2.2.10 Penetration 9

Penetration 9 construction was similar to Penetration 8, but utilizing a 16 mm diameter hole. No additional fire stopping was provided.

2.2.11 Penetration 10

Penetration 10 was a single cable through a 16 mm diameter hole drilled through the specimen. Intumescent sealant was used on the exposed side. No backing element (eg. rod) was used to ensure the thickness of the sealant due to the difficulty of access.

2.2.12 Penetration 11

Penetration 11 construction consisted of a three cable bundle through a 16 mm diameter hole, with no additional fire stopping provided.

2.2.13 Penetration 12

Penetration 12 construction was similar to Penetration 11, but with an 18 mm diameter hole. No additional fire stopping was provided.

2.2.14 Penetration 13

Penetration 13 construction was similar to Penetration 11, but with a 24 mm diameter hole. No additional fire stopping was provided.

2.2.15 Penetration 14

Penetration 14 construction was similar to Penetration 12, but intumescent sealant was applied to the gap around the cables on the exposed side. No backing element (eg. rod) was used to ensure the thickness of the sealant due to the difficulty of access.

2.2.16 Penetration 15

Penetration 15 construction was similar to Penetration 14 but with a 24 mm diameter hole.

3. TEST CONDITIONS AND RESULTS

3.1 General

The specimen was tested on 17 February 2017, at the BRANZ laboratories at Judgeford, New Zealand. The test was closed due to the potential commercial implications of testing non-compliant assemblies which were expected to fail. The ambient temperature at the beginning of the test was 19°C.

The test specimen was placed on top of and sealed to a pilot furnace test frame with a 2,200 mm long x 1,000 mm wide opening and then sealed to the furnace. The temperature and pressure conditions were controlled to the limits defined in AS1530.4-2014.

The test was terminated after the specimen had been exposed to the standard fire resistance conditions for 60 minutes. The test was stopped to observe the condition of the exposed face at this time.

3.2 Specimen temperature measurement

To monitor heat conduction through the sealing systems, 59 chromel-alumel thermocouples were attached to the specimens. The arrangement consisted of thermocouples placed as specified in clause 10.5 of the test standard AS 1530.4-2014.

Thermocouples were placed on the unexposed surface of the concrete floor slab at 25 mm from the penetrations, on the sleeves (where used), and on the services (pipes and cables) at 25 mm from either the concrete or sleeves (where used). For single or three cable penetrations, a single thermocouple was placed on the cables. Maximum substrate and service (collars, sleeves, pipes, or cables) temperatures for a sample of the penetrations are shown in Figure 1 to Figure 9.

All of the thermocouples described above were connected to a computer controlled data acquisition system which recorded the temperature at 15 second intervals.

Figure 1: Penetration A thermocouple temperatures

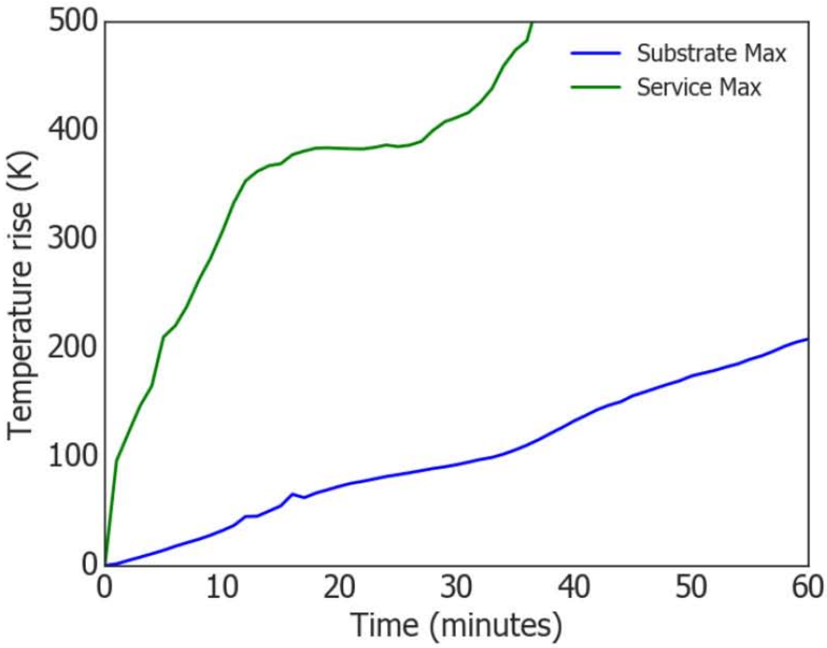


Figure 2: Penetration B thermocouple temperatures

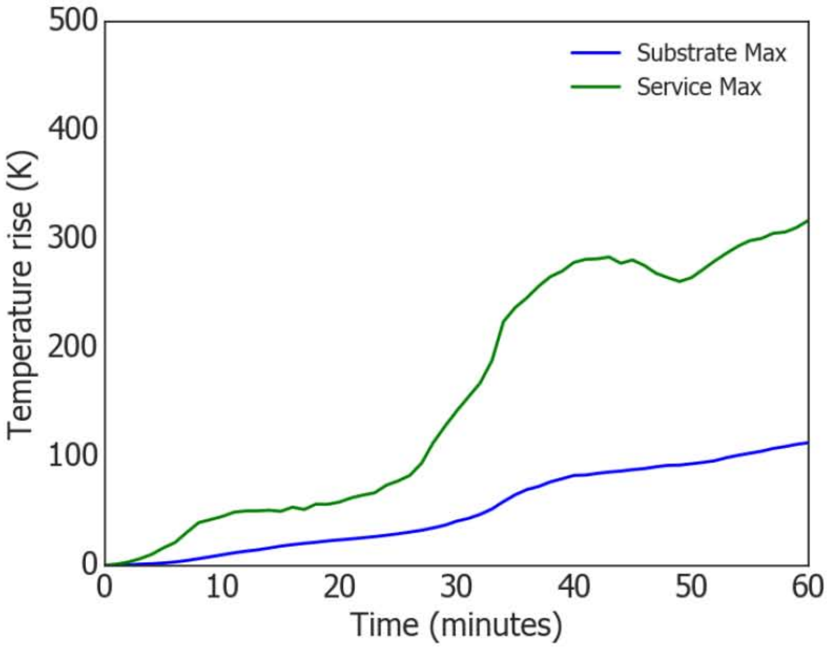


Figure 3: Penetration C thermocouple temperatures

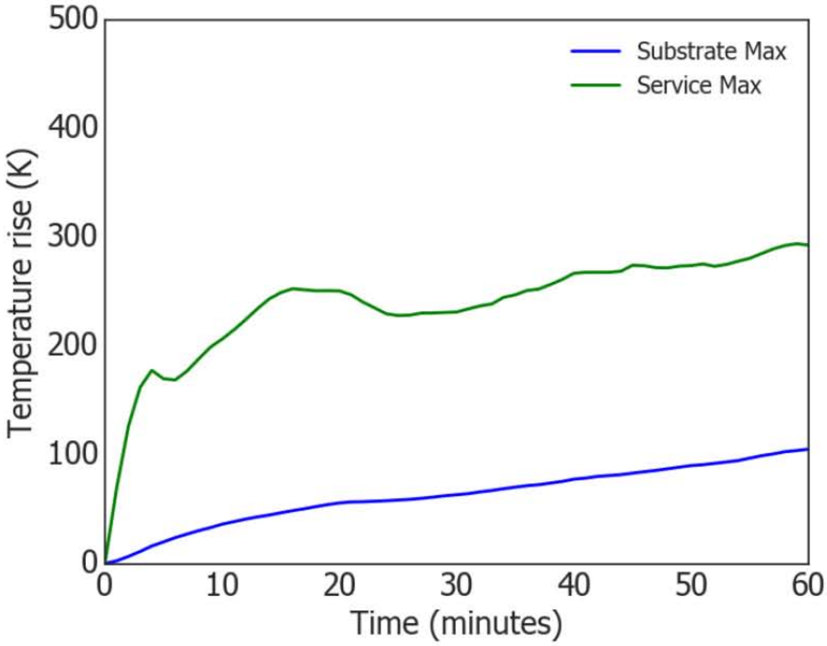


Figure 4: Penetration D thermocouple temperatures

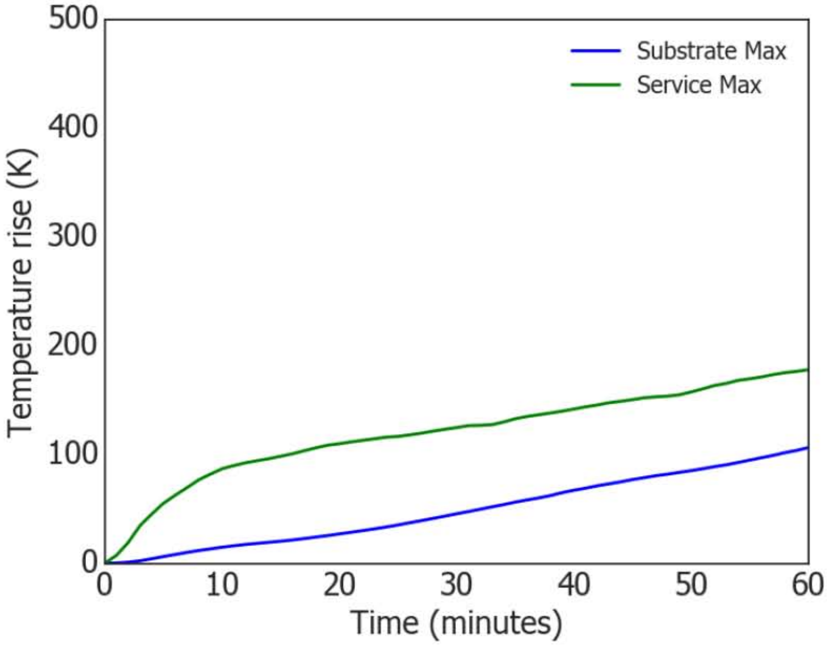


Figure 5: Penetration G thermocouple temperatures

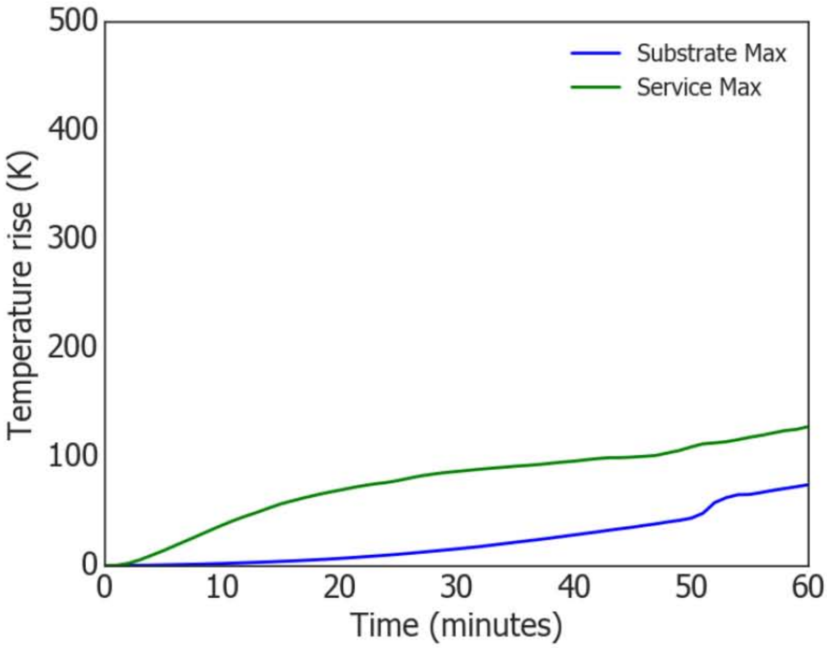


Figure 6: Penetration J thermocouple temperatures

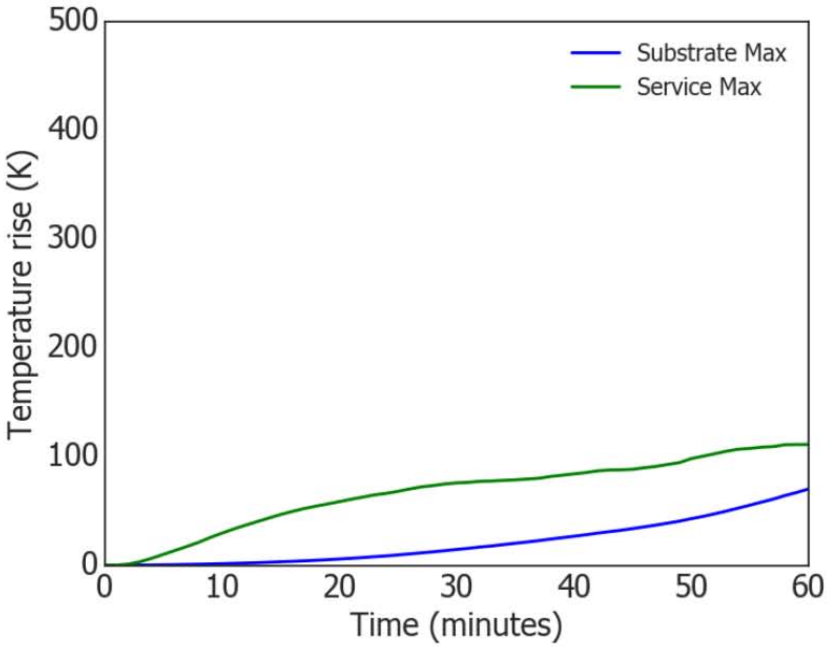


Figure 7: Penetration K thermocouple temperatures

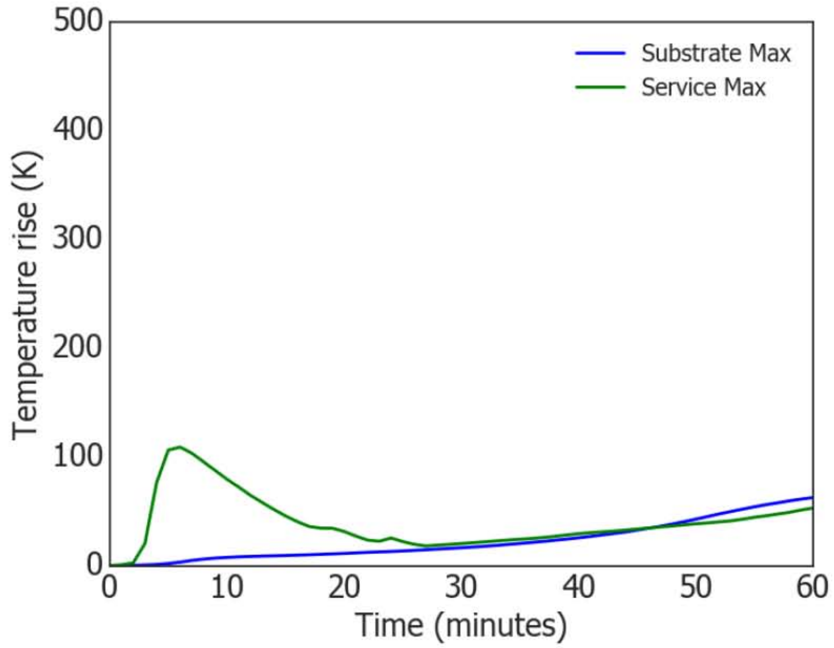


Figure 8: Penetration N thermocouple temperatures

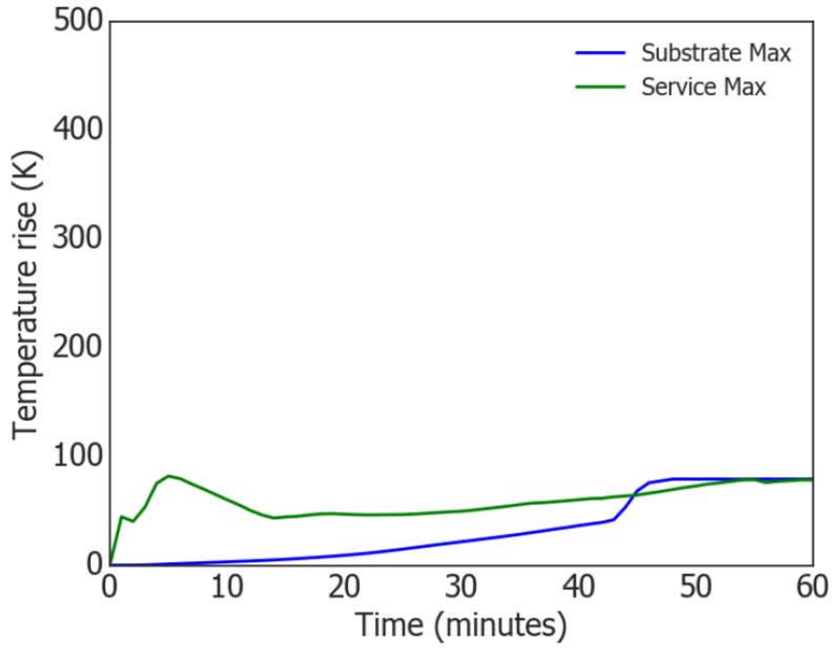
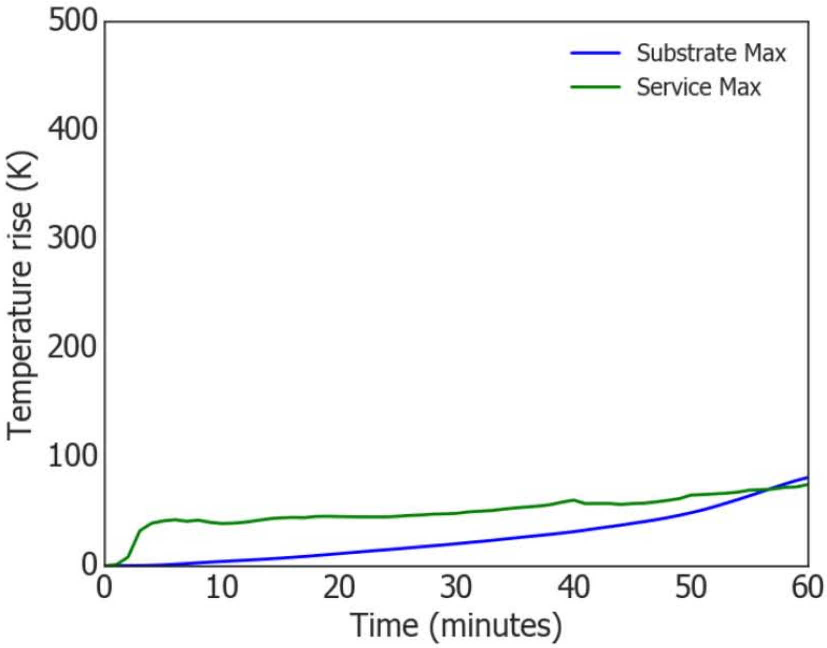


Figure 9: Penetration O thermocouple temperatures



3.3 Integrity Observations

Observations related to the integrity performance of the specimens were at the times stated in minutes and seconds. A cotton pad was ignited at Penetration A 33 minutes into the test. No other significant observations relevant to the test integrity criteria were made during the test duration.

3.4 Conclusion

The objective of this test was to investigate the relative performance of non-standard penetration sealing systems that represent real-world construction in a typical timber infill floor. The results of the test will be used in the development of a process and risk analysis tool to inform ANARP decisions when evaluating the means of escape from fire as required by Section 112 of the New Zealand Building Act 2004.

The comparative performance of 15 cable and PVC pipe penetrations and their sealing systems in a timber infill floor substrate when tested under similar conditions to those required by AS 1530.4-2014, ranged from cotton pad ignition in 33 minutes to no ignition in 60 minutes. The maximum temperature rise measured on the unexposed side of the test specimen and the penetration services for each penetration ranged from 81 K to 702 K. The earliest time at which a temperature rise of 150 K was exceeded was 3 minutes.

Appendix C: Relevant C/AS2 fire and smoke separation requirements

Taken from C/AS2 Amendment 4, dated 1 January 2017. © Ministry of Business, Innovation and Employment.

Safe place A place, outside of and in the vicinity of a single *building* unit, from which people may safely disperse after escaping the effects of a *fire*. It may be a place such as a street, *open space*, public space or an *adjacent building* unit.

Comment:
The Fire Safety and Evacuation of Buildings Regulations 2006 use the term *place of safety* and allow the *place of safety* to be within the *building* provided that it is protected with a sprinkler system. In this Acceptable Solution a *place of safety* can only be within a *building* in *Risk Group* SI.

Secondary element A *building element* not providing load bearing capacity to the structure and if affected by *fire*, instability or collapse of the *building* structure will not occur.

Smokecell A space within a *building* which is enclosed by an envelope of *smoke separations*, or *external walls*, roofs, and floors.

Smoke control door A *doorset* that complies with Appendix C, C6.1.2 of this acceptable solution.

Smoke lobby That portion of an *escape route* within a *firecell* that precedes a *safe path* or an *escape route* through an adjoining *building* which is protected from the effects of smoke by *smoke separations*.

Smoke separation Any *building element* able to prevent the passage of smoke between two spaces. *Smoke separations* shall:

a) Be a smoke barrier complying with BS EN 12101 Part 1, or

b) Consist of rigid *building elements* capable of resisting without collapse:

   i) a pressure of 0.1 kPa applied from either side, and

   ii) self weight plus the intended vertically applied live loads, and

c) Form an imperforate barrier to the spread of smoke, and

d) Be of *non-combustible construction*, or achieve a *FRR* of 10/10/-, except that non-*fire resisting glazing* may be used if it is toughened or laminated *safety glass*.

Comment:
The pressure requirement is to ensure rigidity and is not a smoke leakage requirement.

Walls and floors, whether *constructed* of sheet linings fixed to studs or joists, or of concrete, glazing, metal or fired clay, need only be inspected by someone experienced in *building construction* to judge whether the *construction* is tight enough to inhibit the passage of smoke.

Item d) is intended to ensure that the *smoke separation* will continue to perform as an effective barrier when exposed to *fire* or smoke for a short period during *fire* development.

There is no requirement for *smoke control doors* or other closures in *smoke separations* to meet the provisions of item d).

Stability In the context of *fire* protection is the support provided to a *building element* having a *FRR*, intended to avoid premature failure due to structural collapse as a result of applied load, dead and live loads or as a result of any additional loads caused by *fire*.

Stairway A series of steps or stairs with or without landings, including all necessary *handrails* and giving access between two different levels.

Standard test A test method which is recognised as being appropriate for the *fire* protection properties being assessed.

Comment:
A list of *standard test* methods is given in Appendix C.

Structural adequacy In the context of the standard test for *fire* resistance, is the time in minutes for which a prototype specimen has continued to carry its applied load within defined deflection limits.

Comment:
The *fire* design load should be as specified in B1/VM1.

DEPARTMENT OF BUILDING AND HOUSING – 10 APRIL 2012 I 17

2.3 Fire resistance ratings

FRR values

2.3.1 Unless explicitly stated otherwise in this Acceptable Solution, the *fire resistance ratings (FRRs)* that apply for this *risk group* shall be as follows:

Life rating = 60 minutes

Property rating = 60 minutes.

Amend 4 Jan 2017

Comment:
Throughout this Acceptable Solution, minimum *FRRs* are specified for particular situations. It is therefore essential to check for specific requirements.

Amend 2 Dec 2013 Structural elements in a single storey *building* need not be *fire* rated if *FRRs* are not required for any other reason.

2.3.2 If a Type 7 system is provided, the *fire* ratings for *risk group* SM shall be:

Life rating = 30 minutes, and

Property rating = 30 minutes.

2.3.3 If there is more than one *risk group* on one floor in the *building*, the highest required *FRR* shall be applied to common spaces and shared *escape routes* for that floor level.

General requirements for FRRs

2.3.4 *FRRs* shall apply to the sides of *primary* and *secondary elements* which are exposed to *fire*.

2.3.5 When different *FRRs* apply on each side of a *fire separation*, being a wall, the higher rating shall apply to both sides.

2.3.6 Floors shall have an *FRR* for exposure from the underside.

2.3.7 The *FRR* of a *primary element* integral with a *fire separation* shall be no less than that of the *fire separation*.

Errata 1 Feb 2013 **2.3.8** Except as required by Paragraph 2.3.9, areas of *external wall* not permitted to be *unprotected areas* shall be rated for *fire* exposure from within a *firecell*.

2.3.9 Areas of *external wall* not permitted to be *unprotected areas* shall be rated for *fire* exposure from both sides equally where:

a) Walls are within 1.0 m of the *relevant boundary*, or

b) The *building height* is more than 10 m, or

c) The *final exit* is two or more floor levels below any *risk group* SM occupancy.

2.3.10 *Building elements* shall have an *FRR* no less than that of any *building element* to which they provide support within the *firecell* or in any adjacent *firecell*.

2.3.11 Structural framing members connected to *building elements* with an *FRR* shall be rated at no less than the elements to which they are connected, or alternatively their connections and supports shall be designed so that their collapse during *fire* will not cause collapse of the *fire* rated elements.

Applying insulation component in FRR

2.3.12 *Insulation* ratings shall apply to:

a) All *fire separations*, except as noted in Paragraph 2.3.13, and

b) Parts of *external walls* that are not permitted to be *unprotected areas*, and

c) Parts of *external walls* which are within 2.0 m of an external *exitway* where it is a single *means of escape from fire* (see Paragraph 3.11.2).

2.3.13 *Insulation* ratings are not required to apply to:

a) Glazing installed in accordance with Paragraph 4.2, or

b) All elements where sprinklers are installed throughout the *building*, in accordance with either NZS 4541 or NZS 4515 as appropriate, or Amend 3 Jul 2014

c) *Fire stops* in accordance with Paragraph 4.4.5, or

d) *Fire dampers* and *damper blades* in accordance with Paragraph 4.16.12, or

e) *Fire resisting glazing* in accordance with Paragraph 5.4.3. Amend 2 Dec 2013

Part 4: Control of internal fire and smoke spread

CONTENTS

4.1 Firecells

4.1.1 *Firecells* shall be *fire separated* from each other by the *life rating* specified in Paragraph 2.3 of this Acceptable Solution if the *firecell* is categorised in *risk group* SM, or by the higher of the two *life ratings* if it is categorised in another *risk group* (see Paragraph 2.3 of the relevant Acceptable Solution to determine that *life rating*).

Comment:
All *firecells* must be *fire separated* from one another. Also, within sleeping *risk groups*, Paragraph 4.6 contains requirements for certain activities to be *fire separated* and for *fire separations* to limit the number of occupants in a *firecell*.

4.2 Glazing in fire and smoke separations

4.2.1 Glazing in *fire separations* shall be fixed *fire resisting glazing* having the same *FRR* values for *integrity* as the *fire separation*. Amend 3 Jul 2014

4.2.2 Uninsulated *fire resisting glazing* having the same *integrity* value as the *fire separation* is permitted in *external walls* in accordance with Paragraph 5.4. Amend 3 Jul 2014

4.2.3 There is no restriction on the area of glazing in *smoke separations* (including *smoke lobbies*). Non-*fire resisting glazing* may be used if it is toughened or laminated *safety glass*. Glazing shall have at least the same smoke-stopping ability as the *smoke separation*.

Fire doors and smoke control doors

4.2.4 Glazing in *fire doors* shall be *fire resisting glazing* having the same *integrity* value as the door. If the door requires an *insulation* value, an uninsulated vision panel may be used without downgrading the *insulation* value of the door. Vision panels shall comply with NZS 4520.

4.2.5 Glazing in *smoke control doors* shall meet the requirements for *smoke separations*.

4.4 Fire stopping

Introduction

4.4.1 The continuity and effectiveness of *fire separations* shall be maintained around *penetrations*, and in gaps between or within *building elements*, by the use of *fire stops*.

Fire stops

4.4.2 *Fire stops* shall have an *FRR* of no less than that required for the *fire separation* within which they are installed, and shall be tested in accordance with Appendix C C5.1.

4.4.3 *Fire stops* and methods of installation shall be identical to those of the prototype used in tests to establish their *FRR*.

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4.4.4 The material selected for use as *fire stops* shall have been tested for the type and size of the gap or *penetration*, and for the type of material and *construction* used in the *fire separation*.

Comment:
There are many types of *fire stops* (eg, mastics, collars, pillows), each designed to suit specific situations. A *fire stop* is appropriate for a particular application if it passes the test criteria when installed as proposed.

4.4.5 A *fire stop* for a *penetration* is not required to have an *insulation* rating if means are provided to keep *combustible* materials at a distance of 300 mm away from the *penetration* and the *fire stop* to prevent ignition.

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4.5 Firecell construction

4.5.1 Each of the *building elements* enclosing a *firecell* is permitted to have a different *FRR*, as this rating will depend on the characteristics of the *firecell*, the reason for the *FRR*, and the *risk groups* contained on either side of any *fire separation*.

Comment:
An *FRR* of zero may apply to some walls and most roofs.

4.5.2 Except where *intermediate floors* are permitted, each floor in a multi-storey *building* shall be a *fire separation*.

4.5.3 *Fire* and *smoke separations* shall have no openings other than:

a) For closures such as *doorsets*, and

b) *Penetrations* complying with Paragraph 4.4, and

c) For glazing permitted by Paragraph 4.2.

4.5.4 *Firecell* and *smokecell* effectiveness shall be maintained by ensuring continuity of *fire* and *smoke separations* at separation junctions, and around joints where closures, *protected shafts* and *penetrations* occur.

Junctions of fire separations

4.5.5 Where *fire separations* meet other *fire separations* or *fire* rated parts of *external walls*, they shall either be bonded together or have the junction *fire stopped* over its full length (see Figures 4.2 and 4.3).

4.5.6 Where one *fire separation* is a wall and the other a floor, the wall/floor junction shall be *constructed* with the *FRR* required for the higher rated element.

Junctions with roof

4.5.7 Vertical *fire separations* and *external walls* shall either:

a) Terminate as close as possible to the external roof cladding and *primary elements* providing roof support, with any gaps fully *fire stopped* (see Figures 4.2 and 4.3), or

b) Extend not less than 450 mm above the roof to form a parapet.

Figure 4.2 **Junctions of fire separations – 1**
Paragraphs 4.5.5 and 4.5.7

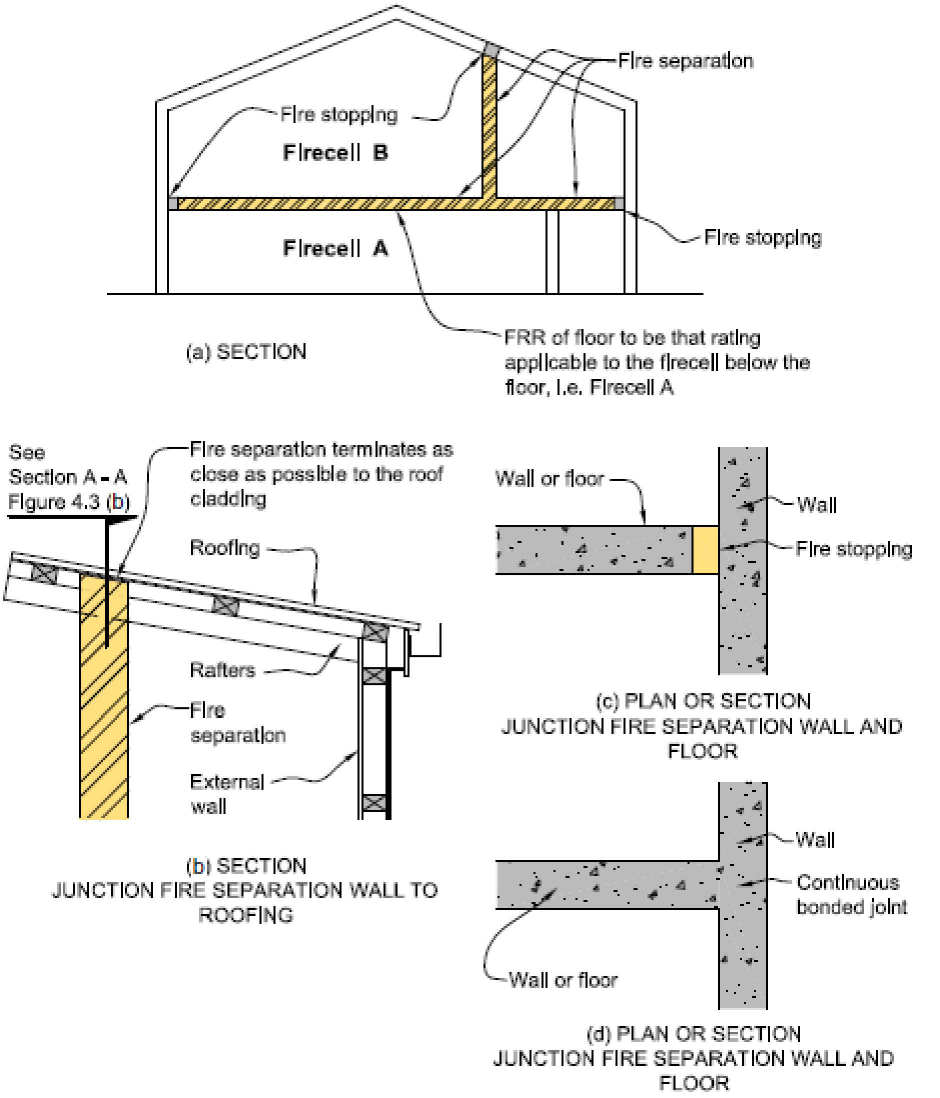
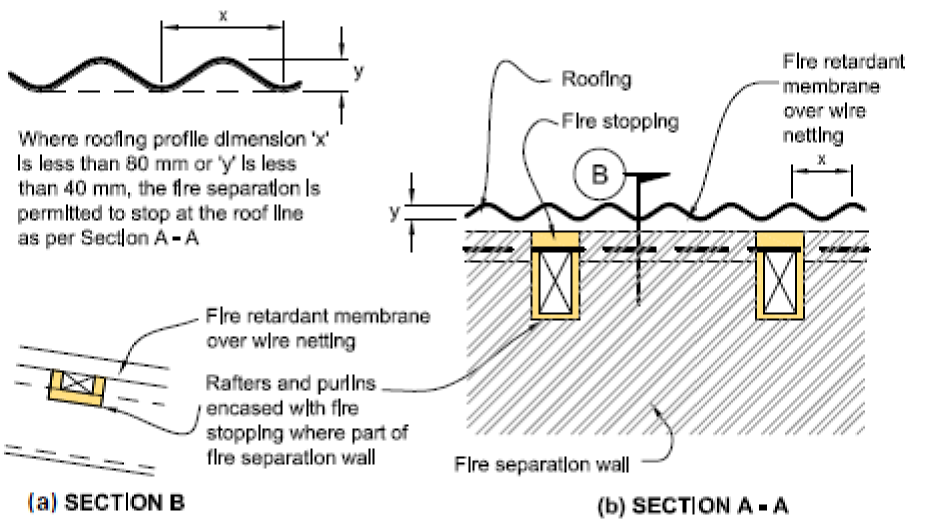


Figure 4.3 Junctions of fire separations – 2
Paragraphs 4.5.5 and 4.5.7



Ceiling space firecells

4.5.8 Large roof or ceiling spaces may be *constructed* as separate *firecells* above more than one occupied *firecell* provided that the ceiling is a *fire separation* rated from below. In this situation, vertical *fire separations* in the *firecell* below need terminate only at the ceiling.

Sealing of gaps

4.5.9 To avoid the passage of smoke through *fire* and *smoke separations*, gaps shall be sealed with *fire* resistant materials complying with AS 1530.4 in their intended application if they are located:

a) In *smoke separations*, and between *smoke* and *fire separations*

b) Around glazing in *smoke separations*

c) Between *fire* or *smoke separations* and unrated parts of *external walls*.

4.5.10 Gaps around *penetrations* shall be *fire stopped* (see Paragraph 4.4).

4.6 Specific requirements for sleeping areas

Group sleeping areas

4.6.1 *Group sleeping areas* shall be *fire separated* from each other and from non-sleeping areas. *Fire separations* between *group sleeping areas* and non-sleeping areas, and between adjacent *group sleeping areas*, shall have an *FRR* in accordance with Paragraph 2.3. Each *group sleeping area firecell* shall contain no more than 40 beds if unsprinklered, or 160 beds in *firecells* which are sprinklered.

Comment:
In this Acceptable Solution, the term 'beds' is used to denote the number of people expected to be sleeping in the *firecell*. Therefore, a double bed counts as two beds and a tier of three separate bunks (one above another) counts as three beds.

Group sleeping areas of up to 40 beds might include accommodation such as ski lodges or school dormitories. Larger bed numbers, up to the 160 maximum, would apply to group gatherings in a *wharenui* or a sleep-over for students in a school hall.

C5.1 Fire resistance

C5.1.1 *Primary* and *secondary elements*, closures and *fire stops* shall be assigned a *fire resistance rating (FRR)* when tested to:

a) AS 1530 Methods for fire tests on building materials and structures – Part 4: Fire resistance tests of elements of building construction, or

b) NZS/BS 476 Fire tests on building materials and structures – Parts 21 and 22.

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C5.1.2 *Fire stops* shall be tested:

a) In circumstances representative of their use in service, paying due regard to the size of expected gaps to be *fire stopped*, and the nature of the *fire separation* within which they are to be used, and

b) In accordance with AS 4072: Components for the protection of openings in fire-resistent separating elements – Part 1: Service penetrations and control joints.

C6.1 Fire doors and smoke control doors

C6.1.1 *Fire doors* shall be evaluated in circumstances representative of their use in service, and shall comply with NZS 4520 Fire-resistant doorsets.

Smoke control doors

C6.1.2 A door shall be deemed to be a *smoke control door* if, in addition to the requirements in this Acceptable Solution for *smoke control doors* if:

a) The door is a *fire door* that is fitted with appropriate smoke seals, or if:

b) It is *constructed* with solid core leaves. Solid timber core leaves, when used, shall have a leaf thickness of no less than 35 mm, and

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c) It is provided with smoke seals as required by this Acceptable Solution. Smoke seals shall be in continuous contact with the mating element, and located so as to minimise interruption by hardware, and

d) The frames are constructed of timber, and the jambs are no less than 30 mm thick, and

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e) Any vision panel cut-outs are no less than 150 mm from the leaf edges, and

f) The maximum average clearances (excluding pre-easing) are:

i) Leaf to frame 3 mm

ii) Leaf to leaf 5 mm

iii) Leaf to top of any floor covering 10 mm, and

g) Any additional facings shall be adhesive fixed, and

h) It is provided with signage identifying it as a *smoke control door* in accordance with Acceptable Solution F8/AS1.

Frictional forces

C6.1.3 The forces required to open any *fire door* or *smoke control door*, on an *escape route* shall not exceed 67 N to release the latch, 133 N to set the door in motion, and 67 N to open the door to the minimum required width. These forces shall be applied at the latch stile. These requirements do not apply to horizontal sliding doors in *risk group* SI or to power-operated doors.

Self-closing provision

C6.1.4 All *fire* and *smoke control door* leaves shall be self-closing, and provision shall be made for the self-closing device to be adjustable during commissioning to satisfy the requirements of Paragraph C6.1.3 after installation.

C6.1.5 Where it is desirable in normal circumstances for a *fire door* or *smoke control door* to operate freely, it is acceptable to use a self-closer mechanism which activates in the event of *fire* but does not operate at other times.

Comment:

1. These circumstances can occur where people are under care. Leaving the door to the occupant's room (or *suite*) open reduces that occupant's feeling of isolation and permits ready observation by staff.
2. Self-closers can be an obstruction to the elderly and *people with disabilities*, who may have difficulty in opening the door against the pressure applied by the self-closer. Acceptable Solution C/AS3 Paragraph 4.6 describes situations where smoke control doors do not have to be self closing where they are used within a *group sleeping area* or *suite*.

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