FIRE INVESTIGATION REPORT

87-93 Wellesley Street West, Auckland Central, Auckland

Incident Information:

F2866954
High Value Loss
1:09 p.m. 22 October 2019

Report completed by:

Peter Wilding, Specialist Fire Investigator
Fire and Emergency New Zealand, Te Hiku (Region 1)

Table of contents

Authors briefs

The Fire and Emergency fire investigation team included:

- Peter Wilding - National Manager Fire Investigation and Arson Reduction
- Peter Hallett - Senior Specialist Fire Investigator with the Fire Research and Investigation Unit
- Rebecca (Bex) Baddeley - Specialist Fire Investigator with the Auckland City Fire Area

My full name is Peter John Wilding
I am the National Manager of Fire Investigation and Arson Reduction for Fire and Emergency New Zealand (Fire and Emergency),having been appointed to that role in 2008.

I have served with the New Zealand Fire Service, now Fire and Emergency, since 1987. I was an operational firefighter to the rank of Senior Station Officer for 16 years and have continued to respond to major incidents since promoted to an Executive Officer rank in 2004.

I have been responsible for determining the origin and cause of fires since 1996.

I have completed the following training courses:
Fire Investigation 1 NZ Fire Service
Fire Investigation - Kent Fire and Rescue Service (UK) 2008

I have attained the following tertiary level qualification
Advanced Diploma in Public Safety (Fire Investigation), Canberra Institute of Technology 2016

I have attained the following qualifications by examination:
Graduate and Member Examination, Institution of Fire Engineers (UK)
Graduate New Zealand Fire Brigades Institute

I have the following professional memberships:
Membership of Fire Investigators Association of New Zealand
Membership of the Institution of Fire Engineers

I was responsible for establishing the current Fire and Emergency Fire Investigation Training program and have frequently delivered training on many fire investigation and advanced fire investigation courses.

I am the Chair of the Australasian Fire Authorities Council Fire Investigation Network.

I was appointed as a Fire and Emergency Inspector under Section 166 of the Fire and Emergency New Zealand Act 2017 on 1 July 2017.

I am the manager of the Fire and Emergency Fire Research and Investigation Unit and have responded to many significant fires throughout New Zealand in the Pacific Islands in accordance with Fire and Emergency Operational Instructions with the principal objectives being to co-ordinate, supervise or undertake investigations into major and serious fires, including fatal fires, by determining the point of origin of a fire and from this establishing the cause of a fire.

I have previously given testimony in District Court, the High Court and Royal Commission of Inquiry.

I have read the Code of Conduct for expert witnesses, Schedule 4 of the High Court Rules 2016, and agree to abide with them.

My full name is Peter Leslie Hallett

My full name is Peter Leslie Hallett. I am a Senior Specialist Fire Investigator (SSFI) for Fire and Emergency New Zealand.

I have served with the New Zealand Fire Service, now Fire and Emergency, since 1978. I have been responsible for determining the origin and cause of fires since 2009 as an Operational Station Officer and 2012 as a Specialist Fire Investigator (SFI).

I have completed the following training courses:

Fire Investigation 1 - 2008
Fire Investigation 2 - 2012

I have attained the following tertiary level qualification:

Advanced Diploma in Public Safety (Fire Investigation), Canberra Institute of Technology 2014.

I have attained the following qualifications by examination:

National Diploma in Fire and Rescue Services (Urban Fire Rescue Operations) Level 5.

I have the following memberships:

International Association of Arson Investigators (IAAI)
Membership of Fire Investigators Association of New Zealand (FIANZ)
Graduate Membership of the Institution of Fire Engineers (GIFE)
Registered Fire Investigator – AFAC – Emergency Management Professionalisation Scheme (EMPS)

I have the following additional experience:

I was appointed as a Quality Assured Trainer for the New Zealand Fire Service, now Fire and Emergency in 2017.
I have been course manager/head trainer for Fire and Emergency Advanced Fire Investigation courses in 2018 and 2019.
I have assisted in a training role on the Fire Investigation 2 course for 5 years prior to 2018.

I have successfully undertaken tested continual professional development programs provided by the International Association of Arson Investigators. A transcript of these completed programs is available.

As a SSFI I have investigated in excess of 237 fires as of 23 November 2018. An ongoing updated transcript of these incidents are available.

As a SSFI, I along with 1 other SSFI are responsible for Peer Reviewing fire investigation reports from SFI's from around New Zealand.

I have completed Bomb Blast Examination Course to the Standard established by the Australia - New Zealand Counter Terrorism Committee.

I was appointed as a Fire and Emergency Inspector under Section 166 of the Fire and Emergency New Zealand Act 2017 on 1 July 2017.

As a SSFI for Fire and Emergency I am required to respond to significant fires in accordance with Operational Instructions with the principal objectives being to co-ordinate, supervise or undertake investigations into major and serious fires, including fatal fires, by determining the point of origin of a fire and from this establishing the cause of a fire.

I have previously given testimony in Coroners Inquests and the District Court.

I have read the Code of Conduct for Expert Witnesses, Schedule 4 of the High Court Rules 2016, and agree to abide with them

My full name is Rebecca (Bex) Baddeley

I am a Specialist Fire Investigator (SFI) for Fire and Emergency New Zealand (Fire and Emergency).

I have served with the New Zealand Fire Service, now Fire and Emergency, since 2004. I have been responsible for determining the origin and cause of fires since 2016.

I have completed the following training courses:

Fire Investigation 1 2018
Fire Investigation 2 2018

I am currently studying the following tertiary Level qualification:

Advanced Diploma in Public Safety (Fire Investigation), Canberra Institute of Technology

I have the following additional experience:
Chief Fire Officer – Kumeu Volunteer Fire Brigade

I was appointed as a Fire and Emergency Inspector under Section 166 of the Fire and Emergency New Zealand Act 2017 on 1 June 2018.

As a Specialist Fire Investigator for Fire and Emergency I am required to respond to significant fires in accordance with Operational Instructions with the principal objectives being to co-ordinate, supervise or undertake investigations into major and serious fires, including fatal fires, by determining the point of origin of a fire and from this establishing the cause of a fire.

I have read the Code of Conduct for expert witnesses, Schedule 4 of the High Court Rules 2016, and agree to abide with them.

Executive summary

At 1:03 p.m. on Tuesday 22 October 2019 a fire broke out on the roof of the New Zealand International Convention Centre (NZICC), 87 – 93 Wellesley Street, Auckland. This is a large building of 120 m by 80 m of 7 levels with a total floor area of 32,500 m^2. It was under construction at the time of fire and was due for completion in 2020.

The roof was covered with a water proofing membrane system consisting of 2 separate layers. The first layer had been completely laid and work was well underway to lay the second layer. Both layers were applied using a 'torch on' method to bond the membrane to the roof and create water tightness of the roof.

The fire started in the gutter area on the western side of the top level of the building and quickly involved the roofing membrane, being fanned by strong gusting winds. The wind played a key role in the development of the initial fire and its spread across the roof. Once established, the fire burned through the various layers of the roof and spread through the building. The mechanisms of travel included direct drop down of burning materials into cavities in walls and ceilings, on to construction equipment which included multiple gas cylinders, petrol fuelled lifts and other assorted equipment and via incomplete fire separations due to ongoing construction.

Level 5 had a concrete slab floor that was largely complete and prevented fire damage below that level. Firefighting water however reached all levels of the building.

Extinguishment was made difficult by many factors, including the structure of the roof and its water resistance, the height of the roof, strong winds and difficulty of direct access to the area on fire. The fire was declared to have been extinguished after 10 days of firefighting and overhaul[1].

Given the very high public profile and political nature of this fire and that it was anticipated to be 1 of the largest loss fires in New Zealand's history, a large number of parties wished to undertake investigations into its origin and cause. A cooperative fire investigation involving teams of investigators representing these parties was led by SFIs from Fire and Emergency. Each party conducted their own investigation but have worked cooperatively with the principal objective of establishing the facts about the origin and cause of the fire.

This fire has been classified as an accidental fire[2].

The probable cause[3] of this fire is believed to be an inadvertent ignition of the cardboard centre of a roll of waterproofing membrane. The cardboard centre of the roll smouldered for a period of up to 38 minutes

[1] **Overhaul.** A fire fighting term involving the process of final extinguishment after the main body of the fire has been knocked down. All traces of fire must be extinguished at this time. **NFPA 921:2017 3.3.126**

[2] **Accidental Fire Cause Classification**. Accidental fires involve all those for which the proven cause does not involve an intentional human act to ignite or spread fire into an area where a fire should not be. **NFPA921:2017 20.1.11**

[3] **Cause.** The circumstances, conditions or agencies that brought about or resulted in the fire or explosion incident, damage to property resulting from the fire or explosion incident, or bodily injury or loss of life resulting from the fire or explosion incident. **NFPA 921:2017 3.3.26**

before reaching flaming combustion[4] and providing sufficient heat to ignite to a self-sustaining fire involving the roll of membrane from which the building fire developed.

A separate report by Fire and Emergency Fire Engineering Unit will examine any active and passive fire protection systems of the building.

[4] **Combustion.** A chemical process of oxidation that occurs at a rate fast enough to produce heat and usually light in the form of either a glow or flame. **NFPA 921:2017 3.3.35**

Terms of reference

Sponsor

Richard Twomey – Area Manager, Auckland City.

Incident background

The circumstances of this incident met the criteria of Fire and Emergency operational instruction P3 requiring the attendance of Specialist Fire Investigators (SFIs). The National Fire Research and Investigation Unit was requested by regional management to lead this fire investigation.

The reason for the attendance of a SFI was: High Value Loss.

Objectives

Determine the origin and cause of the fire through best practice analysis and investigative processes.

Scope

- Focus on this incident specifically, but consider historical data and information from this site and other similar incidents, and other incident information that may have a bearing or contributed to the outcome.
- Analysis of the circumstances and factors, including the occupant(s) actions, building fire loading and design, fire protection/suppression systems performance, circumstances of the fire, and result of the fire.
- Where evidence or suspicion of a deliberate fire start is discovered, the matter is to be referred to the Police who will then have the responsibility for further investigation. The Police may request that the Fire and Emergency SFI assist with the origin and cause determination.
- Produce a completed report for the report sponsor outlining all relevant findings.

Description and use of building

The NZICC was a new building under construction. It was approximately 120 m by 80 m, had 7 levels and a total floor space of 32,500 m^2. It was due for completion in 2020. The core construction was largely concrete flooring and pillars with a waterproof membrane covered roof supported by steel trusses that covered Level 6 (lower roof) and Level 7 (upper roof), refer Image 3. The buildings' external walls were largely a mix of concrete slab construction and open area enclosed with glass facades.

The building was designed with comprehensive fire protection systems incorporating both active and passive systems, although the upper levels were not operational due to the ongoing construction.

Photo 1: NZICC building taken 2 days before the fire. Photo supplied by Fletcher Construction.

Pre-incident events

The weather on Tuesday 22 October 2019 was mainly fine although some brief showers had been reported earlier in the day. NIWA[5] reported south westerly winds of 46 km/h winds, gusting to 62 km/h, from their 10 m weather station at MOTAT[6] Museum at 1.00 p.m. Their instruments on the Sky Tower recorded gusts of 66 km/h. No lightning was recorded in the area.

The construction phase was well advanced and the building was almost entirely closed in. Work was underway to complete the final layer of waterproofing of the roof. A sublayer of plywood had been laid across the roof over supporting steel bearers, joists and a primer product applied to the top of the plywood. A Base Sheet membrane had been laid across the full surface of Level 6 and Level 7 earlier in the year.

On the day of the fire, workers were applying the top layer of waterproofing membrane known as the Cap Sheet on Level 6 and Level 7. These layers are a flexible waterproofing membrane improved with Atactic PolyPropylene. The application process required the product to be preheated which softens the underside causing it to adhere to the surface it is being applied to. When the Cap Sheet is laid both the Base Sheet and the Cap Sheet are heated which facilitates the bonding of the products together. Evidence was provided by the supplier that the Cap Sheet met the European Union Standard CEN/TS 1187:2012 Test Methods for External Fire Exposure to Roofs which includes resistance to fire brands and radiant heat. The Base Sheet is not fire resistant as in its finished state it would be covered by the Cap Sheet and would not be exposed to external heat. The Base Sheet was supplied in 2.5 mm thick 10 m rolls and the Cap Sheet in 4 mm thick 8 m rolls. The rolls are to be rolled out, aligned with an overlap to ensure water tightness, then rolled up from either end in the centre of the sheet. Workers then work outwards as they torch on the membrane. The Cap Sheet is typically laid in an offset brick pattern which provides an aesthetic finish.

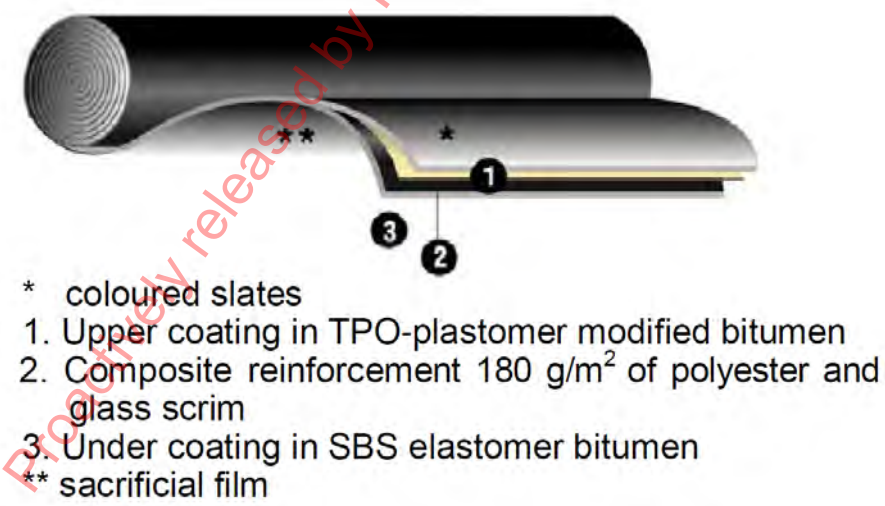


Image 1: Diagram of Cap Sheet (Duo Ht 4 Slates /F C180 FC)

Video footage of the roofing contractors throughout the morning shows them progressively rolling out and affixing rolls of the Cap Sheet on Level 6 and Level 7. At the western and eastern sides of Level 7

[5] National Institute of Weather and Atmospheric Research
[6] Museum of Technology and Transport, 805 Great North Road, Western Springs, Auckland 1022

the roof had gutters approximately 800 mm wide then a low parapet[7] that was the top of the wall on either side of Level 7, refer Image 3. At the time of the fire the gutters had been entirely covered in the Base Sheet membrane and the Cap Sheet was being torched on almost to the edge of the gutter with excess left for finishing and trimming at a later time. Where the roll of Cap Sheet finished short of the gutter, small sections would be added to finish the Cap Sheet to the gutter. The Cap Sheet had not yet been laid along the length of the gutter floor.

Two staff were seen on surveillance video laying Cap Sheet on Level 7 until 12:39 p.m. on 22 October 2019 when they exited Level 7. They then briefly joined the roofing staff working on the western end of Level 6 before going inside the main building for their lunch break at 12:46 p.m. on 22 October 2019.

The roof construction varied, however the large area at the centre of the building and adjacent to the area of origin of the fire consisted of a series of layers of building elements, refer Image 1, with a cavity running through the middle of the layers. The lower layer was Durasorb® insulation. Above the Durasorb® insulation were 2 layers of an insulation product known as Durra Panel®. Above the Durra Panel® was a 200 mm air gap then 100 mm of thermal insulation (Mammoth™ Polyester Insulation) inserted into timber boxing underneath the 20 mm plywood that was installed (Note: the drawing below specifies 17 mm plywood). A primer was painted to the topside of the plywood, wire mesh fixed to the topside of the plywood (used to detect water leaks) and 2 layers of a flexible waterproofing membrane consisting of a mixture of penetration bitumen, improved with APP (Atactic PolyPropylene), were applied using the "torch-on" process.

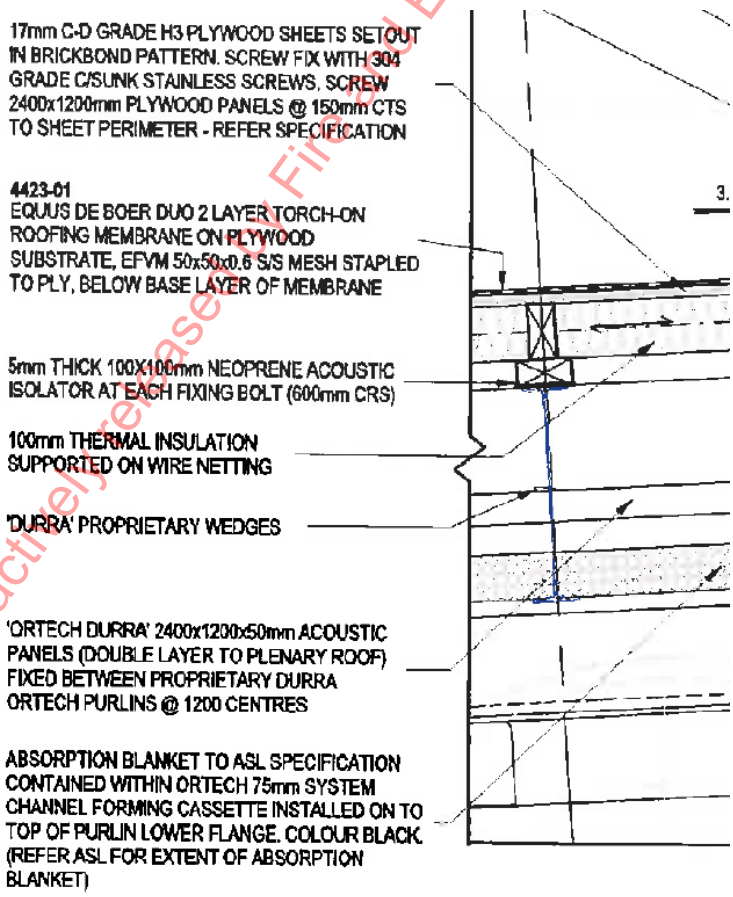


Image 2: Showing elements of Level 7 roof construction.

[7] A low protective wall along the edge of a roof, bridge, or balcony.

Discovery of fire

A tower crane, TC1, was situated inside the building site towards the eastern side near Hobson Street. The operator observed smoke from the northwest area of Level 7 and sounded his crane siren continuously to alert building occupants. At a similar time another tower crane operator working on the Sudima Hotel construction site, in Nelson Street across from the NZICC, observed an early developing fire and was able to briefly capture the incipient[8] fire development stages by video on his phone. Fire and Emergency advised they received 64 emergency 111 calls. The first 111 call was at 1.09 p.m. from a Fletcher Construction site manager working within the building, advising of a fire on the roof.

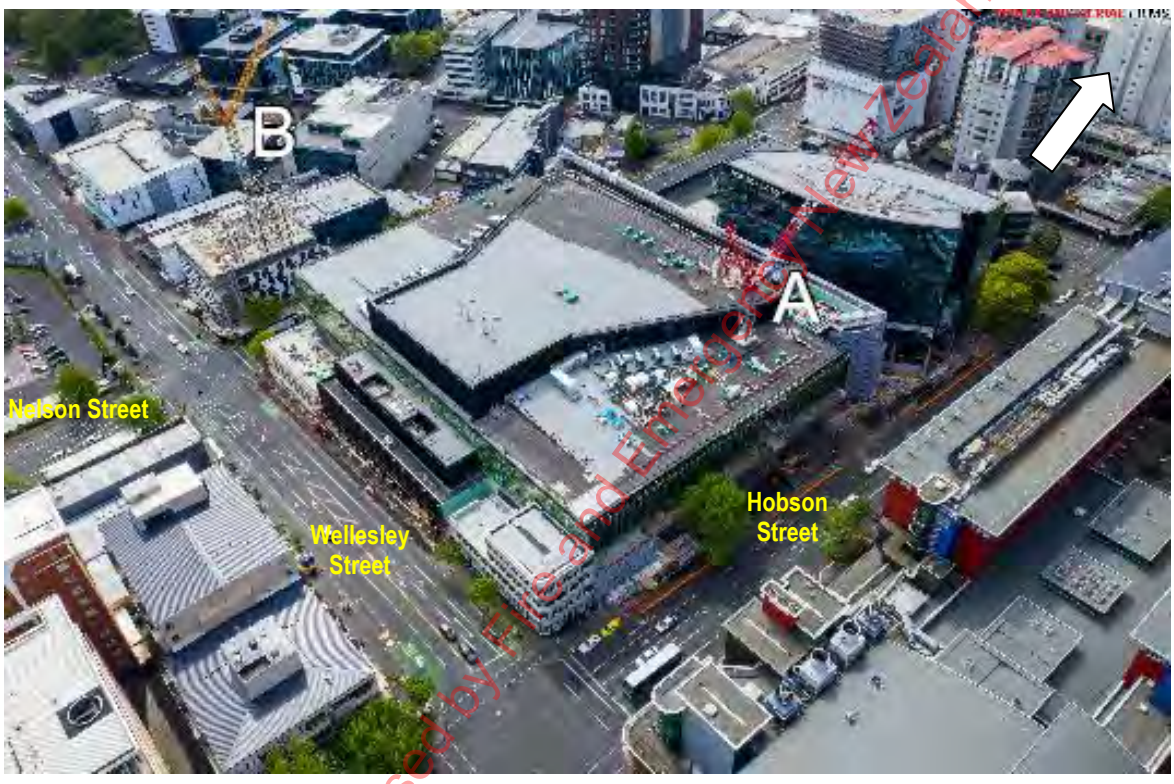


Photo 2: Tower Crane 1 (TC1) is marked "A", The Tower crane located in the Sudima Hotel Construction site is marked "B". North indicated by white arrow. Photo supplied by Fletcher Construction.

Just minutes before the fire was detected at the NZICC, 3 Fire and Emergency fire appliances responded to the activation of a Private Fire Alarm on College Hill Road, Freemans Bay, about 800 m from the NZICC. When crews arrived the building occupants drew their attention to a fire visible on the roof of the NZICC building. The Officer in Charge was able to quickly ascertain there was no fire risk at the College Hill Road location and redirected the 3 attending fire appliances to respond to the NZICC. They reported hearing a turnout to the NZICC from the Communications Centre just as they arrived at the NZICC although they were not able to transmit electronic arrival messages immediately due to radio traffic. This caused a slight disparity between their actual and recorded arrival times.

[8] A fire in its initial develop stage

Fire and Emergency New Zealand response

Information sourced from Fire and Emergency Computer Aided Despatch Incident Report.

Incident Number		F2866954
Call Type		Structure Fire
Method call received		111 Telephone
Incident date		22 Oct 2019
Incident time		1:09:37 p.m.
1st Arrival	AUCK201	1:14:03 p.m.
2nd Arrival	REGION1B	1:18:44 p.m.

The incident was escalated with a '6th Alarm' response being transmitted at its peak involving about 29 fire appliances and supporting vehicles to enable sufficient personnel and supporting resources to attend. An additional aerial fire appliance was requested at 1:27 p.m. on 22 October 2019 from Hamilton to support the aerial fire attack. Fire and Emergency drone operators were also responded to provide aerial observation. Fire and Emergency were present at the scene for 10 days.

A SFI responded to the location at 1:36 p.m. on 22 October 2019 and was able to access a nearby high rise building to observe and record early stages of the fire development.

At the request of the Fire and Emergency Management overseeing the incident management fire investigation support was requested from the Fire and Emergency Fire Research and Investigation Unit. An investigation team was established on Thursday 24 October 2019. The team consisted of the Manager Fire Investigation and Arson Reduction, a SSFI from the Fire Research and Investigation Unit and a SFI from the Auckland City Fire Area.

On Friday 25 October 2019, a collaborative investigation was established and led by Fire and Emergency which included representatives of 5 different insurers and parties, WorkSafe and Police. It was agreed the purpose of the investigation was to establish the facts about the cause of the fire and information gathered during this process would be shared with all parties involved.

Process of investigation

Interviews

Early in the investigation many witnesses were cautioned by their respective companies or legal advisors to refrain from comment. During interviews conducted by Police, interviewees were informed details of their discussion would be shared with Fire and Emergency and Worksafe.

Fletcher Construction Ltd. indicated their willingness to assist with the investigation and provided access to 2 senior project managers to coordinate access into the building, provision of documentation, structural assessment information and resources to assist with the investigation.

The following were interviewed:

Witness 1: Fletcher Construction Project Manager

Witness 2: Fletcher Construction Building Services Manager

Witnesses 3, 4 and 5: Officers of the first arriving fire appliances crews

Witnesses 6 and 7: MPM employees working on Level 6

Witness 8: Senior Technical Consultant for supplier of membrane – Equus Industries Ltd.

Witness 9: Roofing contractor from another waterproofing company not engaged at the NZICC

Witness 10: Operations Manager SGS Laboratories New Zealand Ltd

Witness 11: Supervisor Salute Construction

Witness 12: Fletcher Construction Project Manager

Witness 13: Roofing contractor working on Level 7

Witness 14: Roofing contractor working on Level 7

As the NZICC is in the central city, several video cameras were directed towards the building either prior to, or soon after, ignition occurred providing a large amount of video footage. A large amount of other photographic evidence including pre-incident images were also collated. This information has assisted in the fire investigation and helped to corroborate the testimony of various witnesses.

Scene Examination

The collaborative investigation team was able to access the building on Friday 25 October 2019 with the assistance of Fletchers Construction staff to ensure safety while inside the building. The investigation team examined areas of Level 5 and Level 6 that were safe to access. Level 5 had a concrete floor that spanned that full width of the building. This included the floor of the main auditorium in the centre of the building and the atrium ceiling. Approximately 17 m above the auditorium area was the underside of Level 7. The ceiling showed significant structural damage and observations were initially limited to vantage points protected structurally by sound overhead construction.

Because the building was still in the construction phase, many of the surface finishes had not been applied and combustible fuels were often limited to building materials stored on that level.

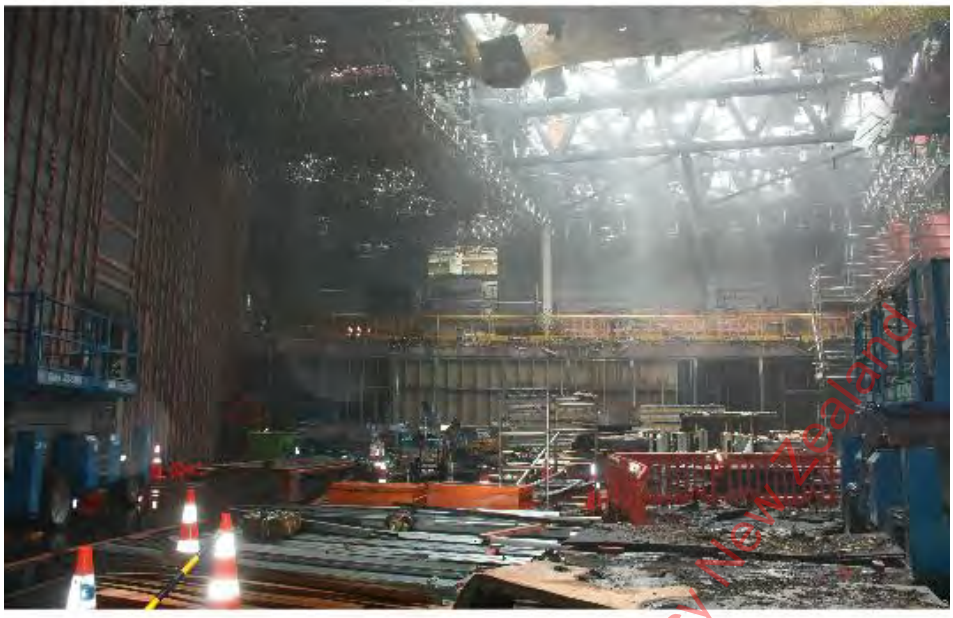


Photo 3: View of Level 5 atrium from the south side looking north.

Examination of western side of Level 5 showed considerable fire damage in the ceiling and some fire damage from drop down[9] burning as evidenced in Photo 4 below. The lack of combustible items in this area contributed to the limited fire development observed.

Photo 4: Western side of Level 5 showing limited fire damage at floor level other than from burning items dropping down. Largely unburnt remains of Durra Panels® can be seen amongst the floor debris. An electrical distribution box is visible to the left of the photo (red arrow).

[9] **Drop Down.** The spread of fire by the dropping or falling of burning materials. **NFPA 921:2017 3.3.48**

Electrical wiring was being installed throughout Level 5 but was not energised at the time of fire. A number of large commercial grade multi boxes were observed through the building, which were used to provide power for construction activities and temporary lighting.

Damage to the southern and eastern sides of Level 5 appeared largely confined to occasional burning debris dropping down from the ceiling and roof above as well as firefighting water.

Photo 5: Level 5 south side with no visible fire damage.

Level 4 and lower floors were examined to ascertain the extent of fire spread in the building. No thermal damage or fire products were observed to have penetrated the Level 5 floor and only firefighting water reached levels below Level 5.

Photo 6: Level 4 showing water damage.

There were some mezzanine floors above Level 5 which had sustained considerable fire damage. Examination of the damage showed it was largely attributable to drop down from above introducing burning within the rooms or from fire gases penetrating through incomplete fire separations[10] and igniting combustibles. A gas cylinder was located in 1 room with visible impact damage on the side of the gas cylinder. This cylinder appears to have vented directing an ignited gas jet against the adjacent wall.

Photo 7: A gas cylinder which has fallen in a mezzanine floor with visible denting on the top side. Venting gas has ignited creating a clearly visible burn pattern on the rear wall.

[10] A fire separation is defined in the Building Code as any building element which separates firecells, or firecells and safe paths, and provides a specific fire resistance rating.

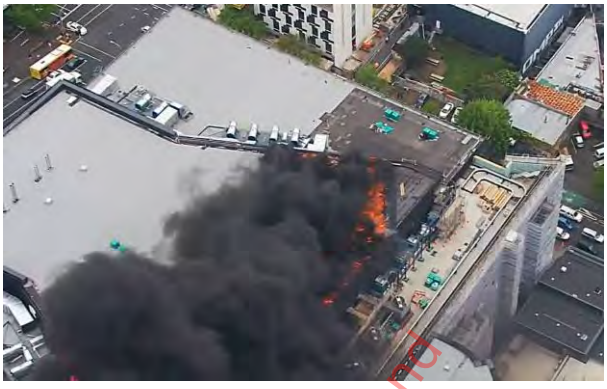
A plant room above Level 5 in the southwest area of the building sustained significant fire damage with intumescent paint[11] blistered on steel structures, large steel beams showed deformation from heat and indications of fire drop down were apparent.

Study of continuous video from the time of discovery of the fire showed gradual progression of the fire towards the south face along the western guttering of Level 7. By 9:26 p.m. on 22 October 2019 fire had reached the southern face closest to Wellesley Street. At 11:46 p.m. on 22 October 2019 the first signs of fire breaking out on the western side of the building on Level 6 were visible, most likely a result of burning materials dropping down from Level 7 and heat transferring through openings in the wall. This wall was constructed of Speed Wall, a non-combustible product with a metal exterior filled and a concrete like centre. Openings in the wall for doorways, air conditioning and other services permitted fire transfer to other parts of the building, notably the plant room.

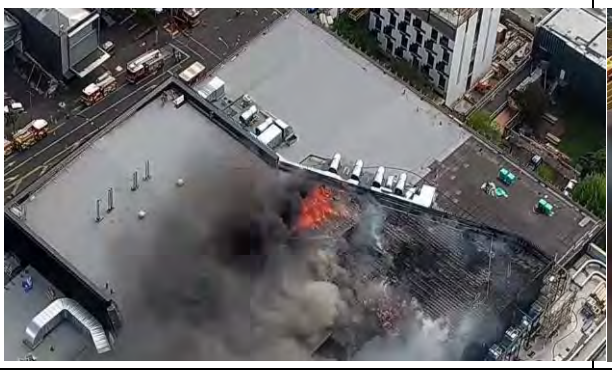
Photo 8: Example of a length of the non-combustible Speed Wall.

[11] Intumescent coatings, often referred to as intumescent paint, are used in buildings as a passive fire resistance measure. They can be applied to structural members as an aesthetically pleasing fireproofing product. The key feature of intumescents is that they expand significantly when exposed to high temperatures, such as those found in a fire. Some intumescent products can expand to more than 100-times the original thickness. As the product expands it becomes much less dense, which makes it act as in insulator that keeps the high temperatures away from structural members or protected openings.

1:07 p.m. 22 October 2019



1:18 p.m. 22 October 2019



3:47 p.m. 22 October 2019

9:26 p.m. 22 October 2019

11:46 p.m. 22 October 2019

2:34 a.m. 23 October 2019

2:54 a.m. 23 October 2019

6:00 a.m 23 October 2019

Photo 9: Progression of fire development. Images taken from video provided by Auckland Transport Operations Centre (ATOC).

Strong winds gusting to over 60 km/h drove the rapid fire progression across the top surface of Level 7 from the eastern side reaching half way along the northern face in about 10 minutes. As the firefighters entered Level 5 they reported seeing glimmers of flame beginning to protrude through the lower ceiling elements above them. Examination of the underside of the ceiling of the main atrium at about 1.20 p.m. on 22 October 2019 using Thermal Imaging Cameras showed elevated temperatures in the ceiling cavities. Witness 1 advised firefighters that at that stage he believed fire was inside the ceiling cavity and would be likely to be extending horizontally in these cavities.

At 4.00 p.m. on 22 October 2019 the fire was still largely confined to the Level 7 roof although some drop down burning was observed by the firefighters (Witness 3 and Witness 4).

Just before midnight fire was observed in the plant room on a mezzanine level above Level 5.

At 2:34 a.m. on 23 October 2019, the fire had burnt back along under the roof of Level 6 on the western side of the building and was first seen breaking out through the roof of Level 6. Twenty minutes later a 45 kg gas cylinder sitting adjacent to the large air conditioning ducting on Level 6 vented and an intense fire was visible for several minutes. This led to the ignition of the roofing membrane on Level 6 in this area and over the next four hours it gradually spread back to the south east corner of the building despite continuing gusting south westerly winds.

Through the examination of Level 5 and Level 6, the burn patterns and the video footage of fire development enabled the investigation team to conclusively ascertain that the fire originated above those levels. The fire travelled to those levels progressively spreading primarily through drop down in cavities and from ceilings, venting gas cylinders and flameover[12]. Witness information, photographs and video footage captured during the fire provided examples of each of these mechanisms of fire spread.

Photo 10: Shows ignition of smoke tracking across the ceiling within a period of 4 s and igniting combustibles several metres away adding to fire spread.

[12] **Flameover.** Where unburned fuel (pyrolysate) from the originating fire has accumulated in the ceiling layer to a sufficient concentration that it ignites and burns; can occur without ignition of, or prior to, the ignition of other fuels separate from the origin. **NFPA 921:2017 3.3.82**

Photo 11: Burning elements within the ceiling construction collapsing on Day 2 providing a mechanism of fire spread to combustibles below.

On Saturday 26 October 2019 information was received by Fire and Emergency SFIs from which they were not able to rule out a possible incendiary[13] cause of the fire. Police were requested to assist Fire and Emergency. At this point the collaborative investigation with private investigators was temporarily suspended. With the assistance of Police information gained through their enquiries, Fire and Emergency SFIs were later able to eliminate a possible incendiary cause of the fire. The collaborative investigation and scene examination recommenced with the private investigators on Thursday 31 October 2019.

[13] [13] **Incendiary Fire.** A fire that is deliberately set with the intent to cause the fire to occur in an area where the fire should not be. **NFPA 921:2017 3.3.108**

Area and point of origin

Area of Origin

Video footage of the NZICC viewed from the Sky Tower showed the first wafts of visible white smoke appearing near the western edge of Level 7 roof (Grid J- 5) at about 1:03.38 p.m. on 22 October 2019 with intermittent flame visible less than 1 minute later.

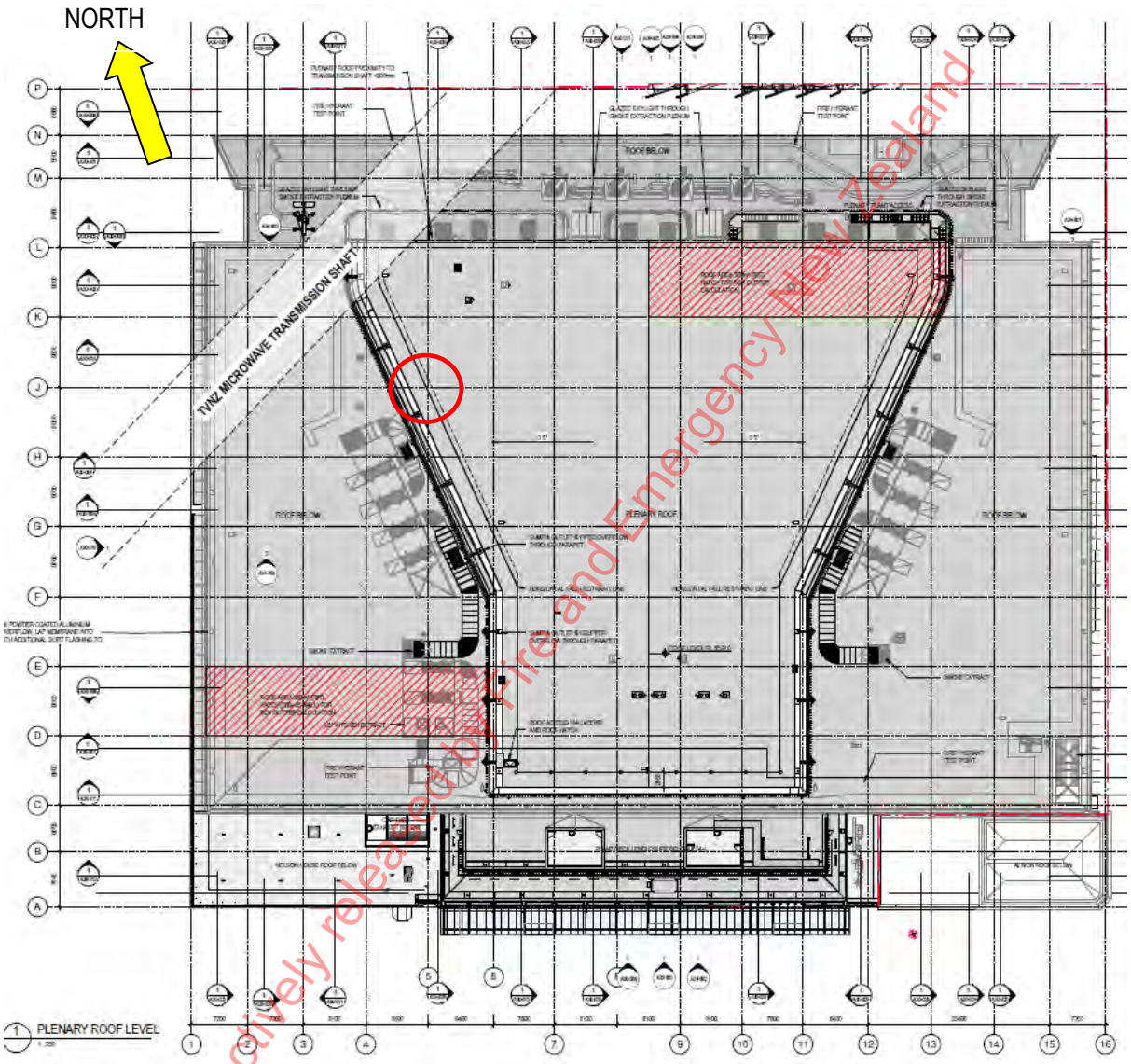


Image 3: Approximate location of first visible smoke and flame (red circle).

The puffing white smoke was consistent with the observations made by Fire and Emergency in live fire tests completed at the Fire Research and Investigation Unit test facility after this fire. Samples of the Base Sheet and Cap Sheet were exposed to a gas flame until ignition occurred. Prior to flame appearing the membrane produced occasional puffs of white smoke. When fire had penetrated the membrane and was impacting on the plywood base the production of white smoke increased considerably. Once sufficient heat developed the membrane began to produce black smoke.

Reviewing footage of the NZICC fire showed that within 2 minutes of the initial smoke being visible black smoke started to show and the flame grew in intensity and height. While the gusting wind was

buffeting the flame and smoke, momentary lapses in gusts showed the location of the source of flame to be in the area of the guttering approximately 1-2 m to the left of the large air ducting penetrating the Level 7 western wall.

Photo 12: During a lull in wind gusts (indicated by the vertical smoke position) the flame was clearly visible from the crane located to the west at the Sudima hotel construction site. Photo from witness.

Examination of the Level 6 roof area immediately below where the flame was first observed showed the absence of any fuel packages[14] that could have provided sufficient heat to transfer fire to the height of the Level 7 roof. A fire involving the membrane of Level 6 was ruled out as an initial fuel first ignited[15] due to the absence of smoke or flame that would have been produced from a fire with sufficient thermal energy to transfer fire to the Level 7 roof, some 6 m above it. Video of this area, Photo 13, at 2:23 p.m. on 22 October 2019, 1 hour and 20 minutes after the fire started showed no visible sign of fire at this level.

[14] A fuel item is any article that is capable of burning. A fuel package is a collection or array of fuel items in close proximity to one another such that flames can spread throughout the array. Single-item fuel packages are possible when the fuel item is located away from other fuel items. A chair that is located away from other fuels is an example of a single-item fuel package. Fuel packages are generally identifiable by the separation of the array of fuel items from other fuel items. **NFPA 921:2017 5.6.2.1**

[15] **First Fuel Ignited.** The first fuel ignited is that which first sustains combustion beyond the ignition source**. NFPA 921:2017 3.3.73**

Photo 13: Western side of Level 6 showing no signs of fire 1 hour and 20 minutes after the fire was first observed on Level 7.

The inside of the Level 7 western wall descended from the Level 7 roof to the atrium floor of Level 5. This area was examined from Level 5 for indications of fire damage and potential for a fire start. Apart from some remote damage caused by drop down, the wall and the immediate adjacent areas were largely free of fire damage.

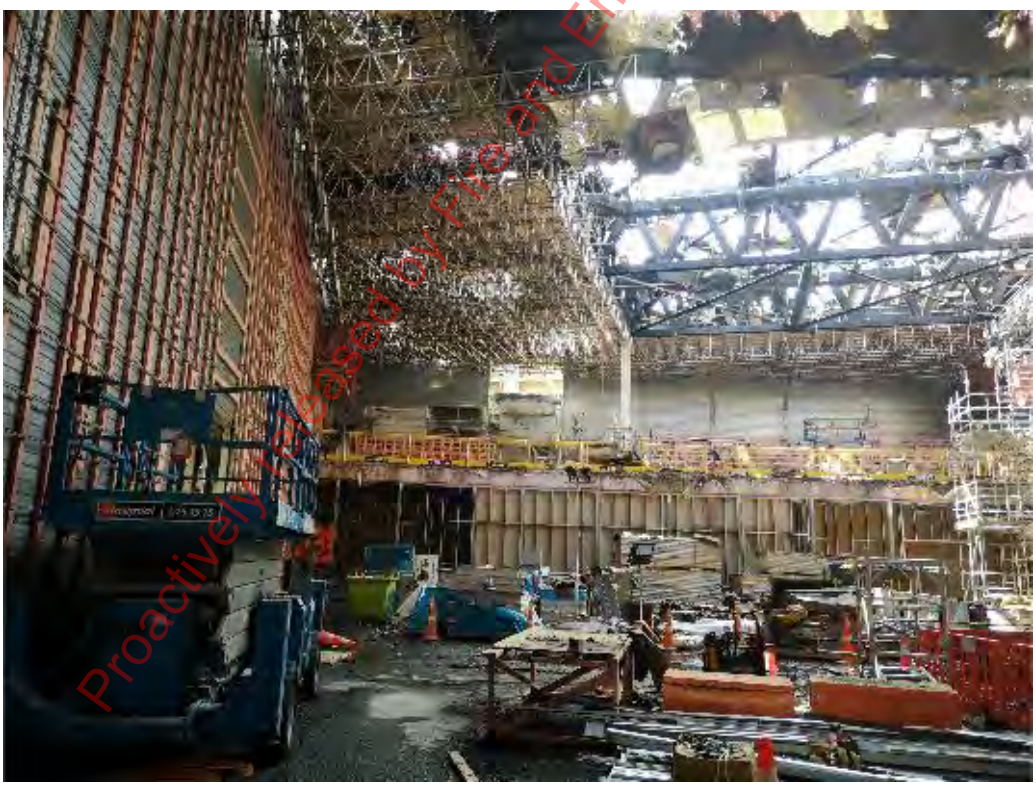


Photo 14: Level 5 western atrium wall (left) with minimal fire impact. The 'Birds Nest' scaffolding Is visible top left under the ceiling.

A scaffolding platform, referred to as the "Birds Nest", was suspended from the Level 7 roof structure. This was still largely intact and damage that was visible had occurred from burning debris dropping from above. A photo taken by Witness 1, who accompanied firefighters to this location, 30 minutes after

the fire started showed clear visibility in this location. The ceiling can be seen to be undamaged and the area free of fire and smoke at that time. Information received from Fletcher Construction advised that no work had been scheduled to be undertaken in the Birds Nest on the day of the fire. The wooden plank flooring of the Birds Nest was largely intact. Electric extension cords lying on the planks or suspended between temporary lighting lamps were fed from a commercial electrical distribution unit. The leads retained their colour with only small areas of damaged cable, the result of burning debris which was still visible resting on the cable. The light fittings were intact. The electrical distribution box was undamaged by fire and examination of its circuit breakers showed none had activated, refer Photo 18.

Photo 15: View across the Birds Nest taken approximately 30 minutes after the start of the fire. Visibility was clear and the only fire impact at this stage was from drop down from above. Photo provided by Fletcher Construction.

Photo 16: Burn damage to 'Birds Nest' floor caused from burning debris dropping from above the scaffolding floor.

A number of undamaged Durra Panels® were stacked vertically against the western wall of the Birds Nest with unburnt combustible material exposed on their ends, they were presumably left over from installation. They showed no sign of fire damage. The fire patterns and observable damage in this area indicated fire had come from above and not originated in this area. The large steel bearers and joists, approximately 2 m above the floor of the Birds Nest, exhibited deformity along their upper flanges indicating significant exposure to heat while the lower flanges showed very little heat damage. Sprinkler heads located above the Birds Nest and beneath the ceiling close to the area of origin of the fire had been fitted with quick response bulbs that activate at ±68°C. These were observed to still be intact after the fire suggesting air temperatures during the fire had remained well below ignition temperatures for combustibles in the Birds Nest area.

Photo 17: Example of a quick response sprinkler head under the ceiling in the area of origin with bulb still intact.

The western wall consisted of 2 walls of Speed Wall construction separated by a cavity that contained services including drainage pipework from the gutters. These pipes were lagged and mostly showed little impact from fire.

Electrical power sources

Witness 1 advised main electrical wiring within the building was in the process of being installed but had not been energised at the time of the fire. Electrical supplies were available for construction activities through commercial grade power plinths badged as "Lifeguard 17 Portable Distribution Assembly". These were typically successively joined (daisy chained) with heavy duty cable. The power plinth unit in the 'Birds Nest' area was at the end of a daisy chain. Firefighters who were operating in that area about 1 hour after the start of the fire noted visibility was still clear and the temporary lights powered from this unit were on. The circuit breakers had not tripped on any of its circuits. Witnesses reported no smoke or flame were visible in the area at that point.

Photo 18: Power box with circuit breakers showing none had tripped.

The area close to, and beneath, the area where the fire was first observed was examined. Remains of the Durra Panel® showed significant fire damage and had fallen onto unburnt insulation installed beneath it which indicated the direction of the heat came from above the insulation and Durra Panel®.

From the examination of lower levels, it was established that fire had originated above the underside of the ceiling of Level 7.

Examination of Level 7

Using an aerial photo of Level 7 taken 2 days before the fire and overlaying additional Cap Sheeting as observed from video taken on the day of the fire, it was possible to recreate the aerial view that replicated the progress of Cap Sheets application just before the fire.

Photo 19: Shows position of the last short length of Cap Sheet laid to the gutter ~12:20 p.m. on 22 October 2019 (red arrow). Location of the 2 gas cylinders marked with red and green circles. Photo supplied by Fletcher Construction – additions by Fire and Emergency.

A gutter ran the length of both east and west sides of the Level 7 roof.

Photo 20: Shows a comparable view of the gutter on the east side of the Level 7 roof after the fire showing the Base Sheet installed. The Cap Sheet had not been applied in this location.

The construction of the gutter consisted of the layers of membrane (Cap Sheet and Base Sheet) torched on and laid over a wire mesh stapled to a 20 mm (17 mm on drawings) plywood substrate. The

plywood was fixed on to timber framing secured to steel joists. Beneath the plywood was laid 100 mm of thermal insulation sitting on 2 layers of Durra Panel® with insulation beneath.

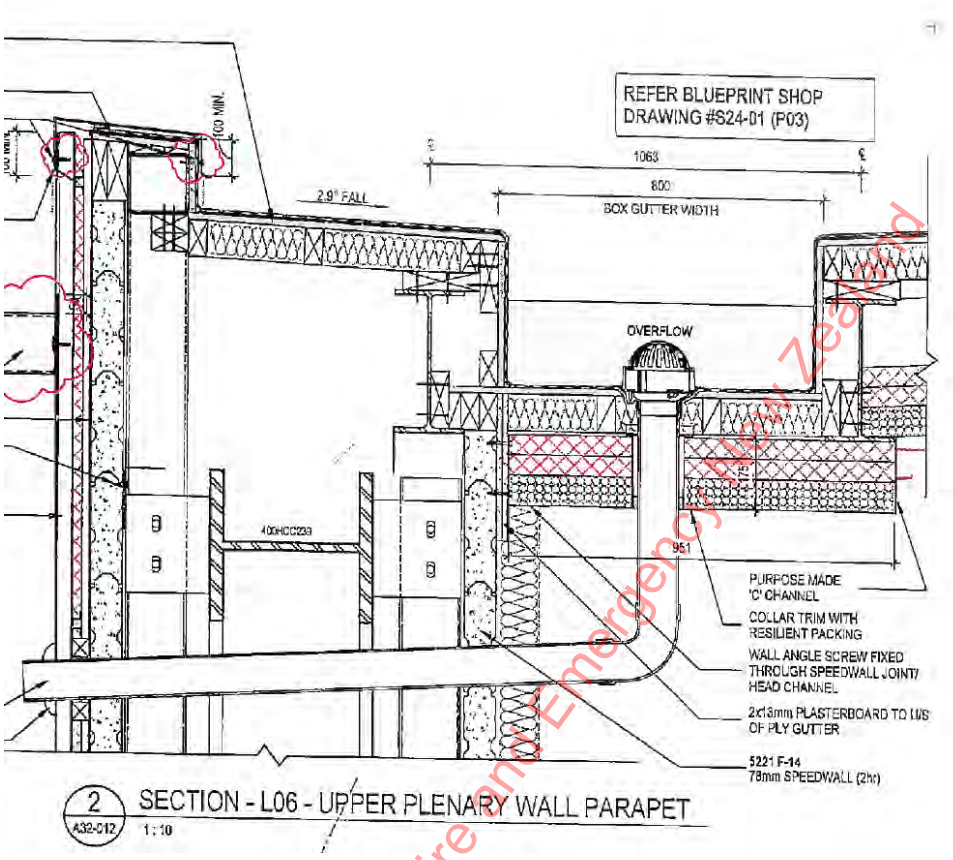


Image 4: Shows sample cross section of guttering.

During the morning both workers on Level 7 were laying full lengths of Cap Sheet across the roof and spent various times in the gutter area where the fire was later first observed. As the line of the gutter on Level 7 was on a rake[16] of approximately 30°, each run of Cap Sheet was progressively longer. Full rolls of Cap Sheet would therefore finish short of the gutter and required additional short sections to be installed. The workers could be seen interacting with the gas cylinders and retrieving rolls lying further along in the gutter, presumably the leftover of membrane rolls from earlier runs.

Witness 9 explained the process of finishing the Cap Sheet into the gutter. The short length of Cap Sheet was positioned and then torched on to just before the bevelled edge of the gutter. The remainder of the Cap Sheet was left unattached and lying over the bevelled edge of the gutter and into the gutter.

A photo of the gutter further south of this area, taken 2 days earlier, show the Cap Sheet had been laid to the gutter edge with residue rolls lying in the gutter, refer Photo 21. There was no reason to believe the practice had changed on the day of the fire. The deliberate application of heat to this area would therefore have been limited to the final length of Cap Sheet and Base Sheet beneath it on the eastern side of the gutter as the Cap Sheet was laid.

[16] Rake: The angle between the front of the work face and a line perpendicular to the work piece.

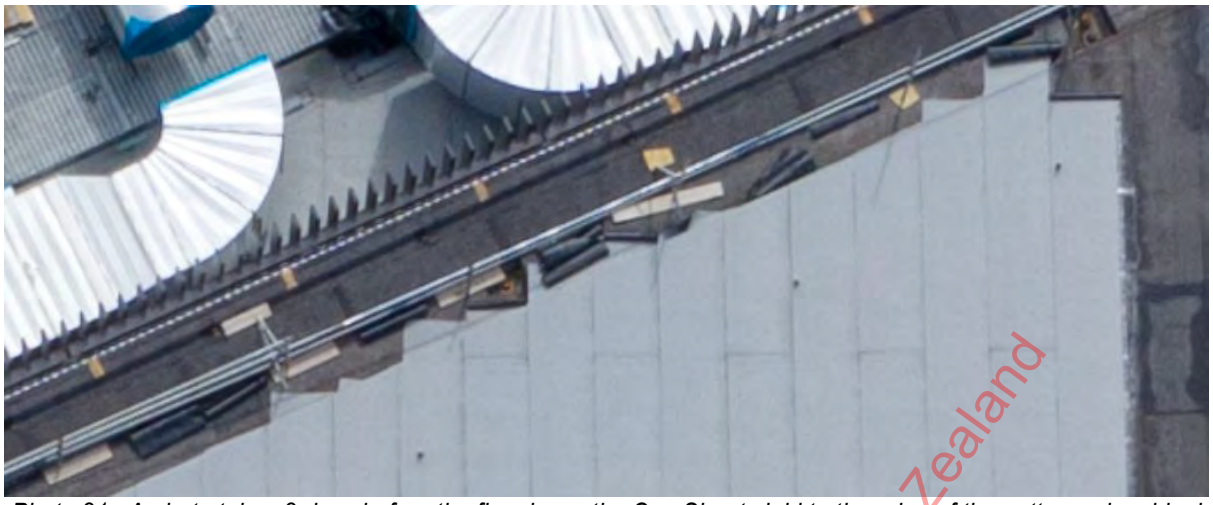


Photo 21: A photo taken 2 days before the fire shows the Cap Sheets laid to the edge of the gutter and residual rolls left lying in the gutter area. Photo supplied by Fletcher Construction.

Photo 22: Left top and bottom images show early signs of the fire with a distinct gap between the flame and smoke and the parapet. The shadow of the parapet is visible behind the flame. This suggests the area of origin was in the gutter rather than the parapet area. Video images from ATOC.

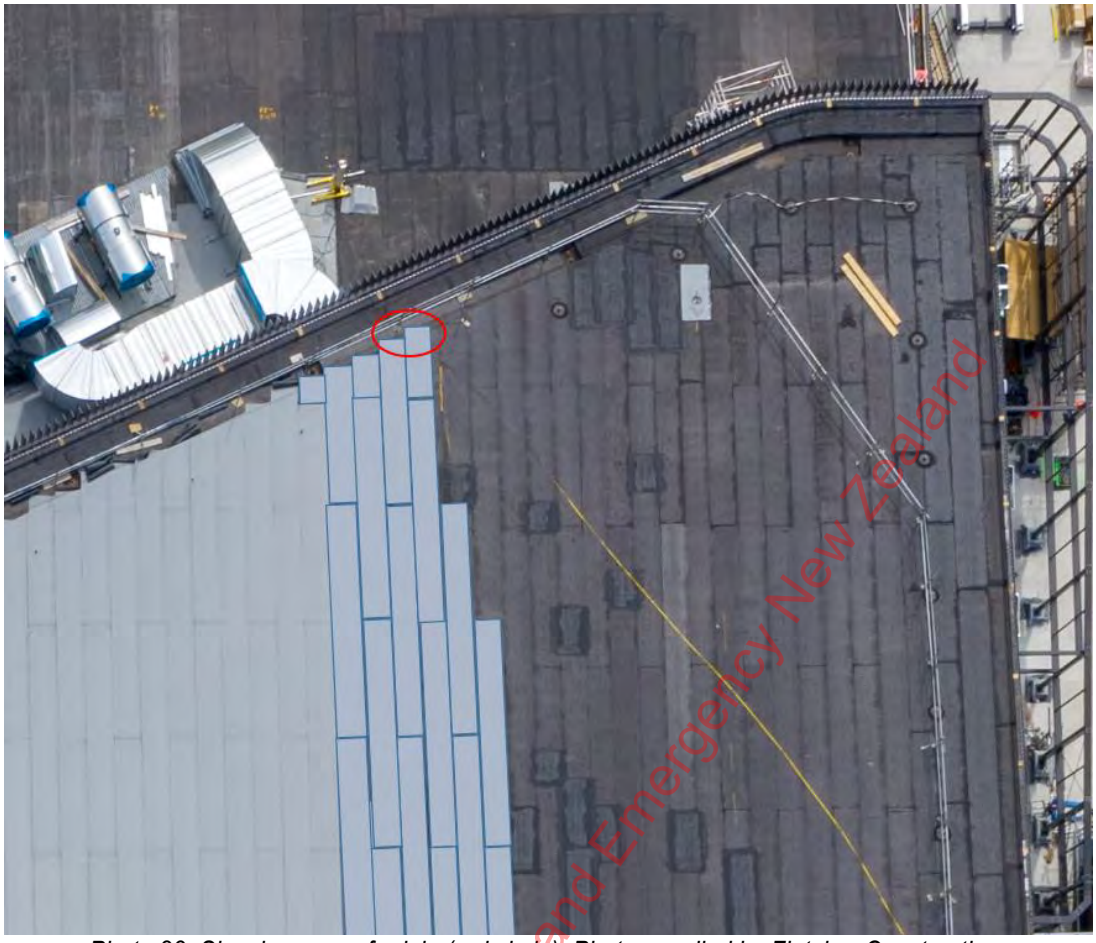


Photo 23: Showing area of origin (red circle). Photo supplied by Fletcher Construction. Addition by Fire and Emergency.

The area of origin[17] was determined to be in the gutter of the western side of Level 7 as indicated in Photo 23.

No substances that were likely to lead to spontaneous ignition[18] were identified in the area of origin. Witness statements also supported this observation.

[17] **Area of Origin.** A structure, part of a structure, or general geographic location within a fire scene, in which the "*point of origin*" of a fire or explosion is reasonably believed to be located. **NFPA921:2017 3.3.11**

[18] **Spontaneous Ignition.** Initiation of combustion of a material by an internal chemical or biological reaction that has produced sufficient heat to ignite the material. **NFPA 921:2017 3.3.180**

Point of Origin

The area of origin was examined from immediately beneath using existing scaffolding in the Birds Nest and above using a crane basket suspended immediately above the area of origin and direct walking access on the area using scaffolding installed after the fire.

Within the area of origin, examination of the video footage of the fire in its incipient stage, the fire patterns[19] and thermal impact on the structure reveal the point of origin[20] as being in the gutter, about 1.8 m north of the large air conditioning ducting visible in Photo 23.

The point of origin is indicated by the red circle in Photo 24.

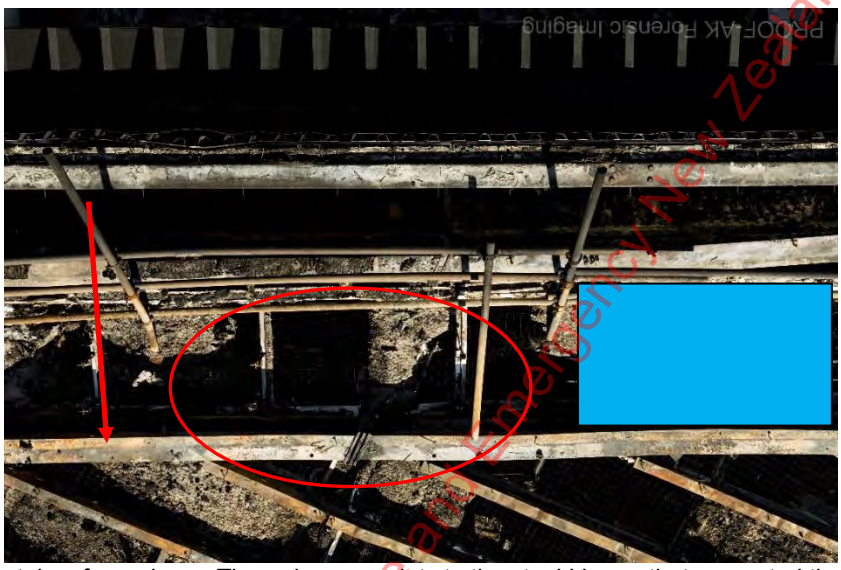


Photo 24: Photo taken from above. The red arrow points to the steel I beam that supported the eastern side of the guttering at the point of origin (red circle). The approximate position of guttering floor is indicated by blue rectangle.

[19] **Fire Patterns.** The visible or measurable physical changes, or identifiable shapes, formed by a fire effect or group of fire effects. **NFPA 921:2017 3.3.68**

[20] **Point of Origin.** The exact physical location within the area of origin where a heat source and the fuel interact, resulting in a fire or explosion. **NFPA 921:2017 3.3.132**

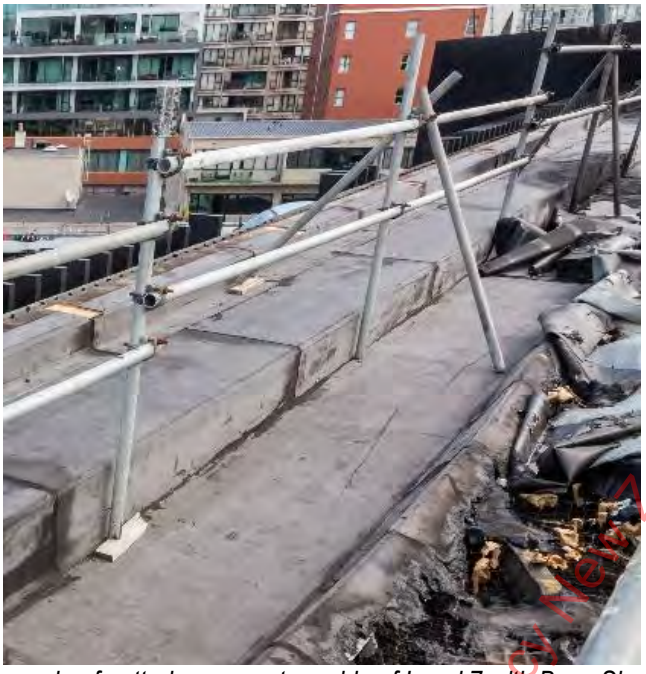


Photo 25: Example of guttering on eastern side of Level 7 with Base Sheet complete.

Determination of fire cause - Sequence of ignition – construction elements ignitability tests.
The determination of a cause of a fire requires the identification of the circumstances, conditions, or agencies that brought about or resulted in the fire incident, damage to property resulting from the fire.[21]

With the assistance of Fletcher Construction, Fire and Emergency acquired samples of the Base Sheet and Cap Sheet, adhesive capping sheet for the parapet and insulation used in the roof space. These were tested at the Fire and Emergency fire research site under fire conditions using a gas torch of the type identified as used at the NZICC. The purpose of the tests was to observe the ignitability of the different elements. The conclusion from these tests was that neither the Base Sheet or Cap Sheet of the membrane would readily ignite or achieve self-sustaining combustion until a significant application of the heat energy is applied. When sufficient heat energy was applied to initiate visible flame, if that heat source was then removed the fire self-extinguished. The investigation team considered the membrane was highly unlikely as a first source of fuel ignited. The insulation was found to shrink away from exposure to heat but would not ignite.

Since the Base Sheet extended fully across the roof and gutter to the parapet, a readily combustible fuel source was required to be identified that would produce sufficient heat to ignite the membrane to a point of self-sustaining combustion.

Ignition of cardboard centre of the roll of Cap Sheet roll.
Each roll of membrane has a cardboard centre around which the membrane is rolled. The supplier of the membrane product provided advice that the membrane roll should be unrolled to relax the roll and if necessary, cut to the required length before torching on. This process would normally occur when full lengths are laid. It appears that when only a short length is needed to finish a run, instead of cutting off the required length, a person just rolls out sufficient membrane required for the short length leaving the rest on the roll with the cardboard centre still inserted. This would enable the cardboard centre of the roll to be exposed to the flame of the gas torch.

The investigation identified an incidence of a similar fire involving waterproofing membrane in the gutter of a roof of another building that occurred on 15 November 2019. A worker on that roof smelt smoke and saw a very small fire in a membrane roll. Action was immediately taken to extinguish the fire. An investigation into that fire identified that the cardboard centre of a roll of membrane had started to smoulder before eventually igniting producing flames. That fire was discovered approximately 20 – 23 minutes after the roofing contractor had left the roof for lunch.

[21] **Cause**. The circumstances, conditions, or agencies that brought about or resulted in the fire or explosion incident, damage to property resulting from the fire or explosion incident, or bodily injury or loss of life resulting from the fire or explosion incident. **NFPA 921: 2017 3.3.26**

Photo 26: Shows cardboard Centre inside Cap Sheet membrane roll.

Photo 27: Shows cardboard Centre of roll of membrane from 15 November 2019 fire reported to investigation team. Photo supplied by [redacted].

With the assistance of Witness 9, an experienced waterproofing roofing contractor, Fire and Emergency carried out 3 tests to assess this as a hypothesis for the cause of the fire at the NZICC. A replica of the roof structure was constructed which included insulation, primed plywood and base layer laid to replicate construction details as close as possible to the pre-fire condition of the NZICC roof and gutter area. As it is impossible to recreate exact conditions, reconstructions can only indicate likelihood of any theory. However, in the 3 reconstructions, ignition occurred with flame appearing 17, 23 and 40 minutes after the Cap Sheet was torched on and the residue roll rolled into the gutter.

Photo 28: Cap Sheet torched on with residue roll left in gutter initially presenting little evidence of smouldering.

Photo 29: Gradual smouldering tracked inside the roll with occasional flickering flame returning to smouldering.

Variables in the tests included the extent of exposure to the gas flame of the torch while the membrane was being laid, moisture content and tightness of the cardboard roll, the rolls' orientation and the strength of the wind. It was noted during tests that the first emissions of smoke were not easily detectable to witnesses standing approximately 10 m away when viewed against the light grey background of the Cap Sheet and with a swirling wind the smoke quickly dissipated.

Once a flame was sufficiently kindled within the roll, flame was observed to penetrate through the layers of the membrane and contribute to the membrane's ignition, refer Photo 30. The membrane ignition continued to be supported by the cardboard centre until sufficient heat was being generated from the burning membrane to become a self-supporting fire. The vertical surface of the gutter provided additional surface area that was preheated and then ignited by the roll on fire.

Photo 30: Flame penetrating through membrane on the roll. Notable is the white puffing smoke similar to that observed at the NZICC.

Photo 31: Fire developing beyond the roll to the vertical gutter surface and beginning to extend to the horizontally laid Cap Sheet representing the main roof surface. Smoke is becoming black.

During these tests a local weather station indicated wind speed was around 16 km/h with occasional stronger gusts. A battery powered portable fan was introduced to simulate stronger wind gusts and set on approximately 1/3 of its full power (a maximum capacity of ~4.5 m^3/s). The growth of the fire responded immediately and in less than 6 minutes had spread from only impacting the roll to across the full width of the simulated roof area.

Photo 32: Fire development at 5 minutes 30 s from when only the roll was burning.

The hypothesis that a full or partial roll was used to finish the short length of Cap Sheet was consistent with what is visible on video showing the worker working in this area.

Prior to the fire 2 workers had been installing the Cap Sheets on Level 7. Video shows them laying full lengths of Cap Sheet during the morning. Below is a timeline of their activities. Notably 1 worker spent a number of minutes in the gutter area close to the area where the fire was first observed and can be seen finishing a short run of Cap Sheet to the gutter.

Approximate Times 22 October 2019	**Activity of workers on Level 7**
11:46 a.m.	One worker moves a gas cylinder towards the western wall where the fire is later first observed.
11:51 a.m.	Worker appears to interact with the gas cylinder closest to western wall.
11:55 a.m.	Worker returns to gutter in area of origin, followed by 2nd worker and appears to be working in gutter.
11:56 a.m.	Both workers depart gutter.
11:57 a.m.	One worker briefly returns to gutter location then departs again (17 s).
11:58 a.m.	Worker rolls out last full Cap Sheet towards gutter (short of gutter by ~3 m).
11:59 a.m.	Worker rolls half of full length up again in preparation for torching. Travels to gas cylinder (5 s) then back to rolled Cap Sheet.
12:02 p.m.	Second worker rolls up other half of Cap Sheet.
12:03 p.m.	Second worker travels to other gas cylinder further east, returns to roll. Both workers then unroll the Cap Sheet in opposite directions, presumably torching the Cap Sheet down.
12:06 p.m.	Worker returns to gutter area where a short length (~3 m) is required, for about 25 s; then departs and walks south along the gutter passing several rolls of membrane lying in the gutter (Photos 35 - 36). Stoops and retrieves an object and returns to area of work.
12:07 p.m.	Worker deposits object and rolls out Cap Sheet (Photos 37 - 38).
12:13 p.m.	Departs gutter area, visits gas cylinder briefly twice.
12:14 p.m.	Returns to gutter area.
12:17 p.m.	Cap Sheet visible not completely finished to gutter (Photos 19 and 21, 33 and 34).
12:20 p.m.	Cap Sheet laid to gutter. Worker leaves the gutter area for the final time and visits gas cylinder for ~30 s.
12:25 p.m.	Worker relocates gas cylinder away from gutter area. Note: this is the last time a gas torch could provide ignition to the gutter area. Together workers prepare to lay another full length of Cap Sheet ~ 10 m away from gutter.
12:36 p.m.	Final Cap Sheet laid and 1 worker walks to within 5 m of gutter, stoops for 9 s and departs.
12:39 p.m.	Both Level 7 workers depart roof.
1:03 p.m.	First signs of smoke and flame from gutter area.

Photo 33: Shows Cap Sheet at 12:17 p.m. incomplete to gutter edge.

Photo 34: Shows Cap Sheet complete to gutter edge at 12:20 p.m.

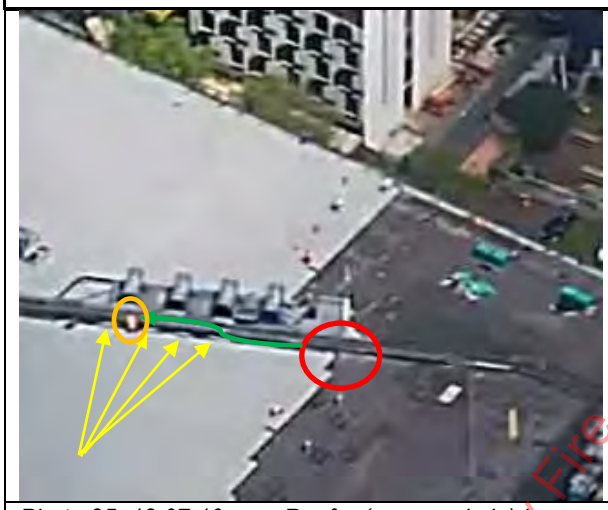


Photo 35: 12:07.10 p.m. Roofer (orange circle) leaves area where a short length is required (red circle) and walks along gutter passing several rolls of membrane (yellow arrows).

Photo 36: 12:07.14 p.m. Roofer stoops in gutter, presumably to uplift a roll and returns to the area of work.

Photo 37: Roofer deposits horizontal object (red arrow), believed to be a roll of Cap Sheet.

Photo 38: Roofer extends Cap Sheet to gutter while walking behind it. This would exclude the Cap Sheet being an unrolled section which could not be positioned if the worker was standing on it.

Evidence of a Cap Sheet roll being transported to and used in the immediate vicinity of the area of fire origin places a cardboard centre in this location.

The roofer moved to and from the closest gas cylinder to this area of gutter indicating the gas torch was being used.

At 12:20 p.m. on 22 October 2019 the roofer left the gutter area for the final time and at 12:25 p.m. on 22 October 2019 moved the gas cylinder away from reasonable reach to the area suggesting no further opportunity for a heat source from the roofer's gas torch would be practical in the gutter area.

The first indication of fire was observed at 1:03 p.m. on 22 October 2019, 38 minutes later, consistent with times established through the scenarios tested by Fire and Emergency.

Interviews with Level 7 roofing contractors

Interviews with the roofing contractors from Level 7 (Witness 13 and Witness 14) were conducted on 13 March 2020 at the offices of Duncan Cotterill Law, Auckland.

Both witnesses confirmed they were the only workers on the Level 7 roof on 22 October 2020, prior to the fire. They stated they observed no other ignition sources[22] on the roof besides the 2 gas torches being used to lay the Cap Sheet membrane.

Witness 14 confirmed they were the person working in the gutter area finishing off a short length, approximately 2.6 m, to the gutter. They stated they retrieved a partially used roll from along the gutter and used it to "complete the line" of Cap Sheet to the gutter. They stated that it was usual practice to fully roll out membrane rolls to allow the membrane to relax before affixing it to the roof and that they followed this practice at the NZICC site. Fully unrolling a roll would allow the cardboard inner tube, refer photo 26, to be removed. Later tests by Fire and Emergency demonstrated the cardboard inner could not be removed without unrolling the full roll.

Witness 14 stated the partially used roll they acquired from along the gutter already had the cardboard inner tube removed. The investigation team examined an image of the gutter area taken 2 days prior to the fire and noted up to 7 partial rolls appearing to be still adjoined to the Cap Sheet fixed to the roof as shown in the 2 photos below. Refer to photos 39 and 40.

[22] **Competent Ignition Source.** An ignition source that has sufficient energy and is capable of transferring that energy to the fuel long enough to raise the fuel to its ignition temperature. **NFPA 921:2017 3.3.36**

Photo 39: Three examples of residual rolls appearing to be still joined to laid Cap Sheet.

Photo 40: Four examples of residual rolls appearing to be still joined to laid Cap Sheet.

For the cardboard inner to be have been removed from the roll, prior to being used by Witness 14, would have required the roll to have been completely rolled out previously in another location due to the space available, a piece removed from it, and then the remaining roll neatly rerolled before placing into the gutter. The rolls still fixed to the runs of Cap Sheet (circled red) suggest this practice had not necessarily occurred in all cases.

The investigation team believes it would also be very difficult to fully roll out residual rolls when laid in their final positions, being close to the edge of Level 7 with the tall decorative aluminium fins preventing extension of the rolls over the side of the wall. We believe both these propositions are unlikely.

Conclusions

Supposed Cause

Based on the evidence available at the time of this investigation, the classification of this incident has been recorded as accidental.

The probable cause of this fire is believed to be an inadvertent ignition of the cardboard centre of a roll of Cap Sheet torch-on waterproofing membrane. The cardboard centre of a roll smouldered for a period of up to 38 minutes before reaching flaming combustion and providing sufficient heat to ignite the roll of Cap Sheet membrane to a point of self-sustaining fire. This time delay is consistent with tests conducted by Fire and Emergency. Strong gusting winds then contributed to a rapid and significant spread of fire across the roof.

Elimination of Other Possible Causes

Natural causes were eliminated as there were no identified substances or scenarios that could have contributed to spontaneous combustion, sunlight induced ignition or reported lightning events near the time of fire.

Incendiary causes were eliminated due the location of the point of origin, the length of delay between human interaction in the point of origin and ignition and there was no evidence of delayed ignition devices. The speed and nature of the development of this fire was consistent with the testing completed by Fire and Emergency. CCTV footage supports this conclusion

Other accidental causes

Ignition of fine fuels under the membrane was considered. Examination of an unburned section of roofing on the eastern side of Level 7 showed the edges of the plywood generally butted together tightly however there were instances observed of 2–4 mm gaps between sections of plywood. Small amounts of sawdust were observed trapped in these gaps. It was noted the configuration of plywood construction differed to the area of origin. Near the area of origin on the western side of Level 7 the top horizontal sheets of plywood overlapped the vertical plywood which made up the walls of the gutter, refer Photo 41. On the eastern side of Level 7 the vertical gutter walls reached the top of the horizontal plywood sheets making collection of sawdust more likely, refer Photo 42.

Consideration was given that the sawdust may have been exposed to flame or heat sufficient to cause smouldering leading to ignition. For this to occur the ignition source must have penetrated the Base Sheet membrane. This would have required either the membrane to have been previously compromised at some stage prior to the laying of the Cap Sheet, it being damaged during the laying of the Cap Sheet or heat being transmitted by conduction through the membrane.

Photo 41: Example of roof on western side of Level 7 near the area of origin with top plywood sheets overlapping vertical plywood.

Photo 42: Example of roof on eastern side of Level 7, with residue sawdust in space between joints of plywood sheets (yellow arrow) extracted by investigators.

Penetration of membrane prior to fire

Information provided by Fletcher Construction noted that the Base Sheet had been laid over a period starting from February 2019. UV or impact damage was considered as possible causes of membrane penetration. However previous damage would have caused a failure in weather tightness and been visible to the person laying the membrane. Witness 8 (technical consultant for the supplier of the membrane) stated that "long term UV-exposure of the sand-finished Base Sheet could lead to what we call in the industry 'crocodile skin', refer Photo 43. This would be easy to detect and only occurs after very long exposure certainly in case of plastomer". The base Sheet was reinforced with a composite fleece of 175 g/m^2 polyester and glass[23]. Witness 8 stated that "UV can't penetrate right through the membrane due to the reinforcement layer within each membrane sheet", refer Image 5.

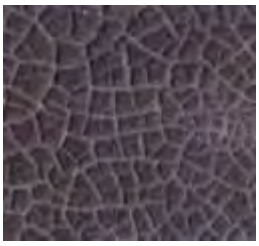
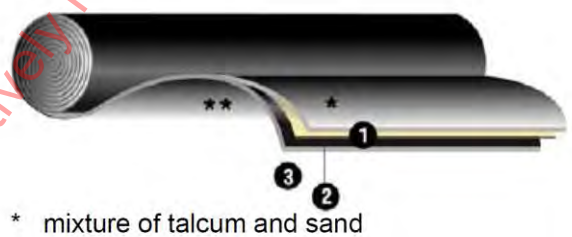


Photo 43: Example of crocodiling visible on base sheet after long term exposure to UV.

Photo supplied by Equus Industries Ltd.

Considering information provided by witnesses about the attention to weather tightness, a break in the membrane occuring prior to the fire, being unnoticed by the contractor, on the vertical wall of the gutter, in line with a gap between plywood sheets and where sawdust collected, was deemed unlikely. Recent weather tightness checks had also been completed in September 2019 according to Witness 1. This hypothesis was considered highly unlikely.



* mixture of talcum and sand
1. Upper coating: APP-plastomer modified bitumen
2. Composite reinforcement of 175 g/m^2 of polyester and glass
3. Under coating: APP-plastomer modified bitumen
** sacrificial film

Image 5: Diagram of DeboPlast 2.5 T/F C175

[23] Technical Data sheet DeboPlast 2.5 T/F C175

Membrane penetrated during laying of Cap Sheet

Tests conducted by Fire and Emergency demonstrated that both the Base Sheet and Cap Sheet membranes withstood considerable heat before penetration was achieved. Cues of pending penetration included discolouration, significant melting of membrane which was easily visible and emission of smoke. The area of origin was clear of waste traps or other objects which would have required detail work that needed additional application of heat. As the Cap Sheet was not yet laid in the gutter Witness 9 stated that the Cap Sheet on the main roof would have likely been torched down close to the top edge but not into the gutter. This would allow the gutter Cap Sheet to be laid with a ~100 mm turn up on either side. The roof Cap Sheet would then later be torched down over the edges of the gutter and the gutter Cap Sheet to maximise water tightness. This practice would minimise exposure of heat to the area of membrane above the plywood joins where residue sawdust may have been located in either configuration. This hypothesis was considered highly unlikely.

Ignition by conduction through the membrane

Tests conducted by Fire and Emergency showed the brief application of a gas torch sufficient to soften the Base Sheet ready for laying the Cap Sheet had little impact on the underside temperature of the Base Sheet. An unprotected hand could be temporarily held against the membrane demonstrating poor initial conduction of heat through the membrane and below sufficient energy to initiate ignition of light combustibles under its surface. A steel flange, used to join 2 lengths of a main steel bearer (RSJ) was at the point of origin and its role in conduction was considered. However, examination of the area of origin and a similar and less damaged area on the eastern side of Level 7; and with information received from Witness 11 concluded this flange had been covered by plywood and was not in contact with the membrane. In addition, the width of the steel plates of the flange were ~20 mm. This width steel would be unlikely to conduct ignition temperatures from brief exposure to a gas flame. This hypothesis was considered unlikely.

Ignition of waste in area of origin

Witness 12 stated that regular rubbish collection occurred throughout the working day. This was to minimise likelihood of light items becoming airborne from wind gusts across the roof. Photographic evidence shows gutters free of rubbish with the exception of partially used rolls of membrane which would not present an airborne hazard. This hypothesis was considered unlikely.

Ignition of membrane or waste by discarded cigarette

The construction site had a no smoking policy. Three discarded butts were observed around the Level 6 roof area however there was no evidence that this was common practice. The investigation team concluded a smouldering cigarette would have insufficient heat emission to ignite the Base Sheet membrane which covered the roof, or the Cap Sheet. There was no evidence of smoking on Level 7 in video surveillance from 11:21 a.m. on 22 October 2019 until the time of fire at 1.03 p.m. on 22 October 2019. This hypothesis was considered and dismissed. Witness 13 and Witness 14 stated there had been no smoking on level 7 on the 22 October 2019.

Gas torch left burning during a lunch break.

There had been considerable speculation in some news media attributing the cause of the fire to a gas torch left on while workers took a lunch break.

On the morning of the fire roofing contractors were observed using 2 45 kg gas cylinders on Level 7 to apply the membrane. A worker finishing Cap Sheet runs in the gutter area visited the nearest gas cylinder, presumably to collect the gas torch and returned to the gutter to continue his work.

At 12:20 p.m. on 22 October 2019 the worker left the gutter area and travelled to the nearest cylinder. At 12:25 p.m. on 22 October 2019 the worker moved the gas cylinder to a more central location on the roof to enable work in that area. The gas cylinders' final locations prior to the fire were 11.6 m and 16.9 m respectively from the western gutter. Video show both workers laying another full length of Cap Sheet. No further work was done in the gutter area and workers left Level 7 at 12:39 p.m. on 22 October 2019. Once the fire reached the locations of the gas cylinders on Level 7 they fell horizontally landing on the burned debris and wiring netting on the roof. The final location of the gas cylinders prior to the fire was identified by examining key markers on the roof such as membrane patches clearly visible in a range of pre-fire photographs and comparing these to the video that captured the first sighting of the fire.

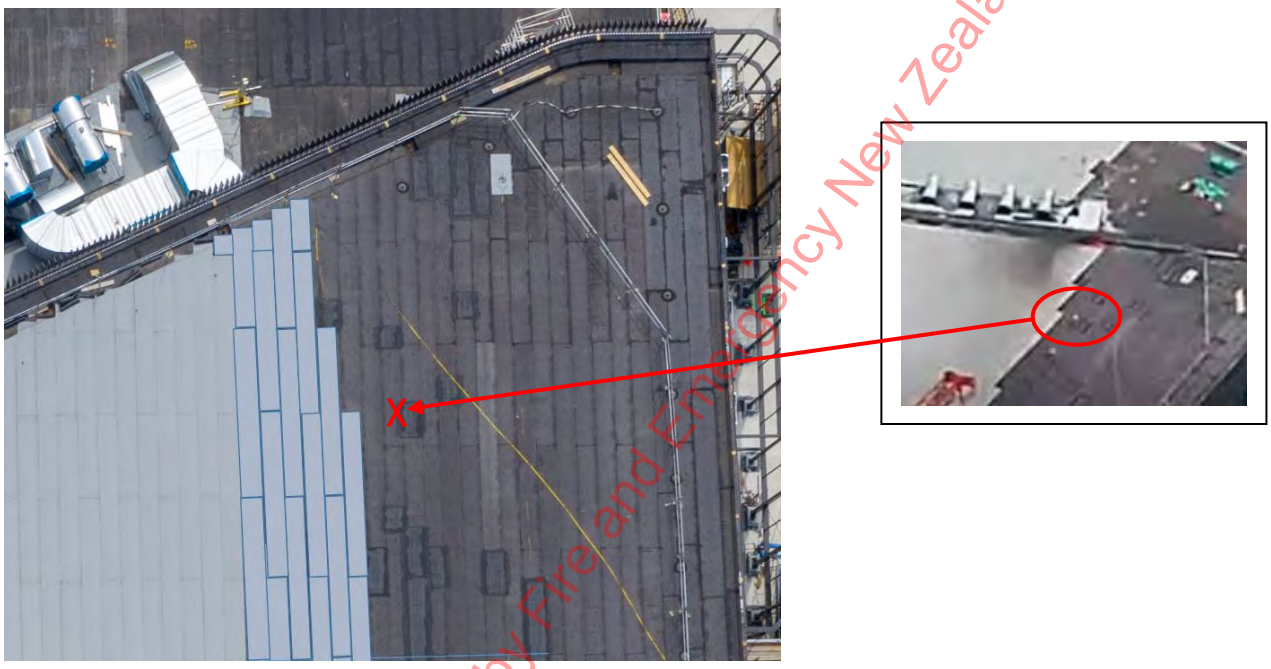


Photo 44: Showing last location of gas cylinder (marked 'X') nearest point of origin while in the vertical position prior to the fire. Photo supplied by Fletcher Construction and modified by Fire and Emergency.
Inset image shows gas cylinder at time of fire. Video image from ATOC.

An analysis of the original pre-fire location of the gas cylinder nearest to where the fire started shows it to be beyond 10 m. Witness information suggested the length of hoses to be between 5 and 8 m. An undamaged gas hose located on Level 6 was found to be 8.3 m when placed under tension. The length of a gas torch was a further ~600 mm. A new length of hose purchased from an Auckland supplier of gas torches and equipment was 10 m long. However, when in a resting position the hose naturally fell down the side of the gas cylinder which is approximately 1.250 m high, as seen in Photo 45.

Photo 45: Shows an un-tensioned gas hose falling slack beside
A gas cylinder and slack in the hose on the ground. Photo provided by Worksafe.

Flex in the hose also reduces the un-tensioned length of the hose 0.3 m - 0.5 m. In an un-tensioned state, a 10 m hose can be expected to reach less than 9 m.

The 2 gas cylinders were recovered from the Level 7 roof. They were sent to SGS New Zealand Ltd, an industrial certification and verification laboratory to be forensically examined to assess the position of the gas cylinder valves at the time of fire, refer Appendix 2 for test results. The laboratory concluded that the valve of the gas cylinder (location marked with red X in Photo 46) closest to point of origin was in the closed position. Due to the effects of heat from the fire on any rubber or Teflon sealing components it was unclear if it remained sealed during the fire. The other gas cylinder further away from the point of origin also appeared to be in the closed position. Witnesses stated they checked these valves were off twice before leaving the roof. Video footage of the workers just prior to them departing Level 7 appears to support their statements.

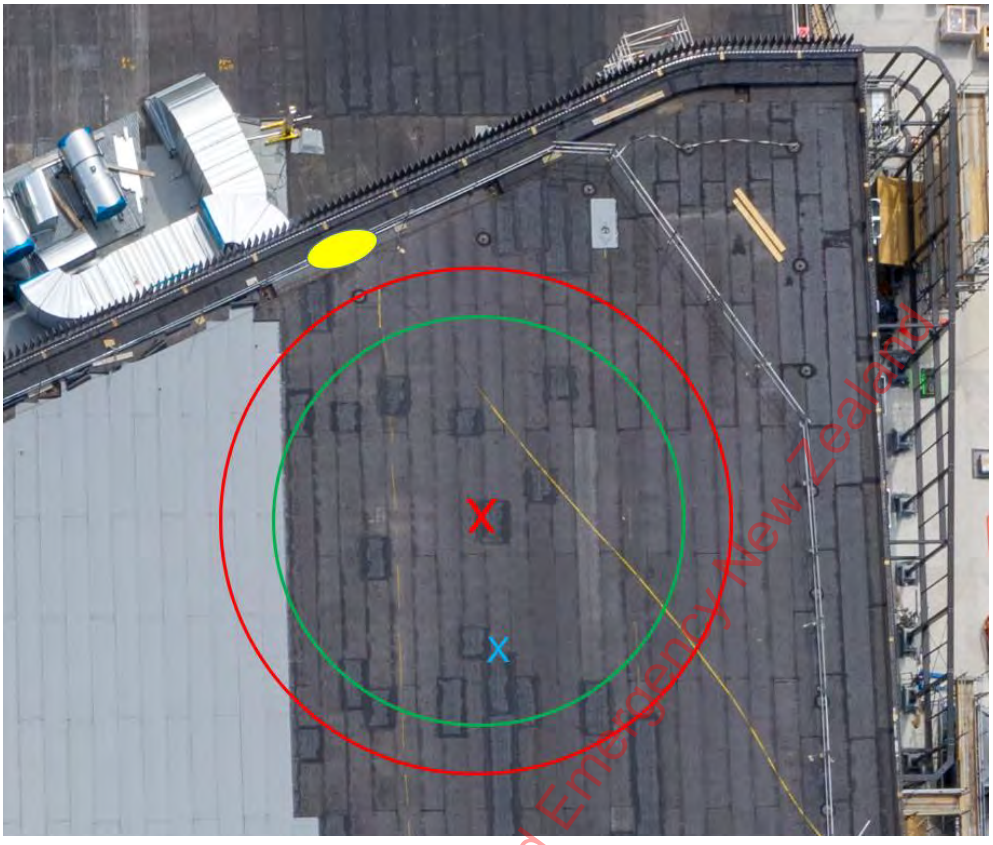


Photo 46: Indicates a 10 m radius (red) and 8 m radius (green) indicating the maximum reach of a gas hose line from the gas cylinder (red 'X') closest to the area where the fire started (yellow ellipse). The adjacent gas cylinder location is marked with blue 'X'

Photo supplied by Fletcher Construction. Illustrations by Fire and Emergency.

Based on the evidence available the hypothesis of a gas torch left running in the area of origin was eliminated.

When a gas torch is in use it has a 'pilot' flame. To generate the larger flame for torching membrane a valve is manually operated. On releasing the valve, the torch reverts to the 'pilot' flame only, this is effectively a 'dead man' operation.

The investigation team were aware of common media speculation about a gas torch left running however the evidence does not support this speculation.

Report approvals

Investigation and report completed by:

Investigator

Name: Peter Wilding
Job Title: Specialist Fire Investigator
Date: 21 November 2019 02:18p.m.

I confirm the truth and accuracy of this statement. I make the statement with the knowledge that it is to be used in court proceedings. I am aware that it is an offence to make a statement that is known by me to be false or intended by me to mislead.

A technical review of this report has been completed by:

Name: Colin Clemens
Job Title: Senior Specialist Fire Investigator
Date: 03 April 2020 08:51a.m.

This report has been approved by:

Name: Richard Twomey
Job Title: Area Manager, Auckland City
Date: 07 April 2020 10:43a.m.

Appendix 1: Witness Details

Removed in compliance with the Privacy Act 1993 and the Official Information Act 1982

Appendix 2: SGS Live Fire Tests

SGS Industrial

Print

IANZ

SGS New Zealand Ltd, NDT & Materials Services
22 Vestey Drive, Mt Wellington, PO Box 12-356, Penrose, Auckland
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Email: NZ.NDT.Enquiries@sgs.com Web: www.sgs.com

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Auckland

Radiographic Inspection Report

Draft Final Endorsed

Client:	Worksafe NZ	**Location:**	SGS Mt Wellington NDT Workshop
Project:	LPG Cylinders	**Order No:**	TBA
Plant Name:	n/a	**Activity No:**	N/A
Equipment Name:	Valves	**Item Tested:**	Valves
Job Description:	Radiographic inspection of valves to check valve's status (Open or close)		
Inspection Spec:	AS 2177:2006	**Acceptance Criteria:**	Report Findings
SGS Procedure:	ITP254	**Welding Process:**	N/A
Surface Condition:	As Found	**Heat Treatment:**	N/A
Material Type:	Copper Alloy	**Equipment:**	X-Ray - Site X D3006
Film Type:	Agfa D7 Vacpac	**Technique:**	SW SI - General
Intensifying Screens:	Pb 0.027mm Front & Back	**Radiation Source:**	Xray @220KVP
IQI:	n/a	**F Spot Size:**	F Spot - 2.5 x 2.5
Development:	Automatic @ 28°C	**FFD (mm):**	700mm
Exposure:	5-6 mA min	**Date of Test:**	19th and 27th Nov 2019

2 x LPG cylinders were submitted for inspection following an incident involving an uncontrolled fire. The examination was to try and determine the status of the valve, open or closed.

The 2 cylinders were tagged by client; ID: 105484 and 105485, photos of the cylinder identification can be found in figure 2 and 3.

One of the cylinders (105484) had the manufacturer ID of 'Galpro' stamped into the cylinder. The manufacturer was located and contacted, and new replacement valve purchased for comparison in the open and closed position. (Figure 6 and 7). No manufacturer was able to be located for the other cylinder (105485) for a comparison valve.

Based on the comparison valve of 105484 it would appear that the valve is in the closed position but if it was sealed is unclear. Cylinder 105485 would also appear to be in the closed position based on the limited information.

Recommendations:

The regulators could be removed from the main valves, and a visual examination carried out on the internals of the valve to obtain more information. It is however likely that any sealing parts, rubber, Teflon etc would have been damaged by the heat compromising any sealing effect.

LEGEND											
EXP	EXCESS PENETRATION	DNC	DOES NOT COMPLY	C	COMPLIES	A	ABSENCE OF DISCONTINUITIES	PD	PROCESSING DEFECT		
EXP	HEAD	SRC	ROOT CAVITY	SGI	INCOMPLETELY FILLED GROOVE	SGS	SHRINKAGE GROOVE	SUC	UNDERCUT		
SSP	SPATTER	SED	EXCESSIVE DRESSING	SMG	GRINDING MARK	SMT	TOOL MARK	SMH	HAMMER MARK		
SPT	SURFACE PITTING	STS	TORN SURFACE	MLo	LINEAR MISALIGNMENT	DM	DIFFRACTION MOTTLING	CP	CRATER PIPE		
BT	BURN-THROUGH	KL	LONGITUDINAL CRACK	KT	TRANSVERSE CRACK	KE	EDGE CRACK	KC	CRATER CRACK		
LS	LACK OF SIDE FUSION	LR	LACK OF ROOT FUSION	LI	LACK OF INTERRUN FUSION	LP	INCOMPLETE ROOT PENETRATION	IN	INCLUSION		
IL	LINEAR INCLUSION	IO	OXIDE INCLUSION	IT	TUNGSTEN INCLUSION	IC	COPPER INCLUSION	GP	GAS PORE		
PU	UNIFORM POROSITY	PG	LOCALISED POROSITY	PL	LINEAR POROSITY	EC	ELONGATED CAVITIES	WH	WORM-HOLE		

Technician: [redacted] AINDT RT

Film viewed:

Reviewed By [redacted] 29-Nov-19

Authorised By [redacted] 29-Nov-19

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Test Results (continued) **Radiographic Inspection Report**

Figure 1: Cylinders as supplied

Figure 2: Cylinder 105484

Figure 3: Cylinder 105485

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Test Results (continued) **Radiographic Inspection Report**

Figure 4: Valves of both cylinders in as found condition

Figure 5: Images obtained by radiograph

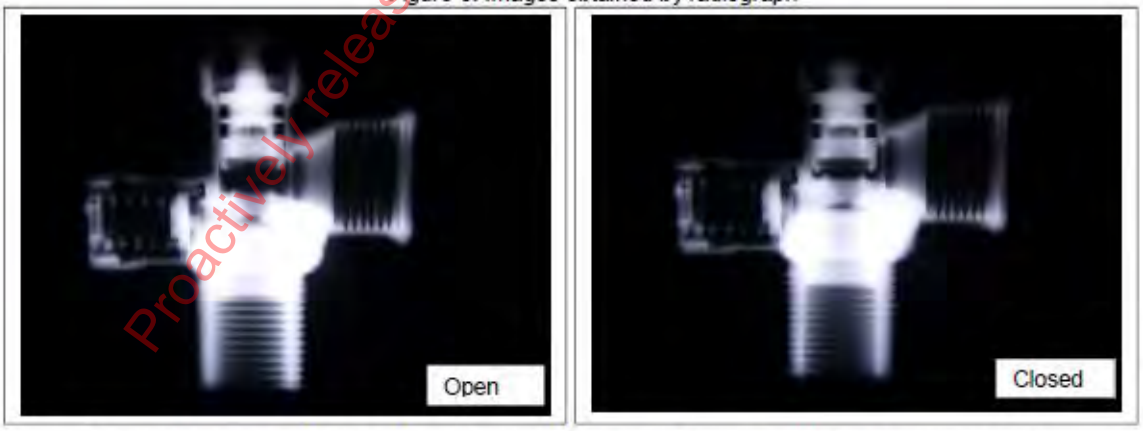

Figure 6: Images of the new valve obtained from the manufacturer in open and closed positions

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Test Results (continued)

Radiographic Inspection Report

Figure 7: New valve obtained from Galpro