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BE(Hons)

Fire Engineering Investigation of a Cold Formed Steel Framed House Fire

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With correction to steel thickness on page 5 from 7.5mm to the correct thickness of 0.75mm made 08/04/2014

Executive Summary

This report presents New Zealand's first investigation of a fully developed fire in a light steel framed house. The outcomes of this investigation are to quantify the structural fire severity of the property at 9 Nuneaton Drive, Auckland and to use this information to better understand the performance of light steel frame houses in severe fires.

The HERA Report R4-127 and their FaST software were used as the principle tools in the analysis to simulate different fire conditions. The idea was to model the fire above and below the linings taking into account all the range of conditions that could have existed during the fire and to determine, through comparing the predicted failure times of the wall and ceiling linings with those observed, the likely fire load, boundary conditions and hence the likely structural fire severity and time temperature conditions.

It can be concluded that the house performed very well in the fire as the steel framing in the roof and walls did not collapse despite being exposed to the fully developed fire. A fire with a thermal inertia of 700 $J/m^2Ks^{0.5}$ and a fire load energy density of 300 MJ/m^2 best represented the chain of events from the Fire Report and hence was the most realistic model that was analysed. The steel framing could have been cleaned and reused but it was more practical to replace it.

Acknowledgements

I would like to thank Christopher Kay (Marketing Manager, NZ Steel) and Nikki Riddell (NZ Steel) for providing me with the site plans and Fire Service Report to proceed with my research.

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1. Introduction

This report presents the results of a fire engineering investigation on a fire in a modern, single storey light steel framed house in Botany South, Auckland. The fire occurred in 2011 and the report uses fire engineering methods in conjunction with the Fire Service response log and evidence from an on-site investigation to answer questions as to the likely fire load and fire time-temperature conditions in the enclosure of fire origin.

The purpose of this report is to quantify, as much as practicable, the structural fire severity within the building in order to better understand the performance of light steel frame houses in severe fires and to present key observations on this response.

The fire that occurred at this property commenced in the kitchen/lounge/dining room area and reached full development in this open plan area before the fire service arrived and extinguished the fire. From observations of the fire damaged house, this open plan area (approximately half the house floor area) was fully burnt out and the rest of the house was damaged by smoke and to a limited extent by flames.

The process involved modelling the fire above and below the linings as accurately as possible, taking into account all the range of conditions that could have existed during the fire and to determine, through comparing the predicted failure times of the wall and ceiling linings with those observed, the likely fire load, boundary conditions and hence the likely structural fire severity and time temperature conditions. The principal tool used in this was HERA Report R4-127 [1] and the associated computer software.

2. Details of the House

The property in Botany South was a single storey steel framed house on concrete slab with standard gypsum plasterboard linings to the walls and ceilings. The linings were GibBoard ® with 10mm thick Standard Gib® on the walls and 13mm thick Standard Gib® on the ceilings. The ceiling linings were fixed to steel ceiling battens and the wall linings fixed to the steel studs in accordance with 5113G GIB specification[2]. External cladding was brick veneer and the roof was interlocking pressed steel tiles on timber tile battens on steel roof trusses.

The house consisted of 4 bedrooms, 1 bathroom, 1 toilet, a garage and a family/kitchen/dining room where the fire occurred. Complete site plans can be found in the Appendix. Figure 1 and Figure 2 show pictures of the house after the fire occurred:

Figure 1: East Elevation of the house

Figure 2: Living room showing distortion of the steel roof trusses and ceiling battens

3. Method

To model the fire using FaST, information needs to be generated to input into the software in order to produce the time-temperature curves. These inputs include enclosure geometry, height, area of vertical and height of vertical openings, fire load, thermal inertia, insulation configuration and beam/column type. The process was split into two, where one curve was determined for the wall lining failing and another for ceiling failure. As there was a change in ventilation conditions due to the ceiling failing an overall curve combining both the wall and ceiling failure curves needed to be established. This was done using the methods described in the HERA Report R4-83. The steps in Clause 4.1.2.8 of the report were used. (Refer to Appendix)

The fire service log and eyewitness accounts described flames coming through the roof prior to the fire service arrival, indicating that the ceiling linings had failed prior to the fire service arrival. The physical damage to the steelwork in the roof space above the enclosure of origin was consistent with this. The internal wall linings on the fire exposed face of the enclosure of origin were missing in many places, however the wall framing behind these linings showed no sign of fire induced changes in most places. Some areas of wall framework did show the effects of high temperature exposure. These observations indicate that the linings were mostly intact until the temperatures in the enclosure of origin were below flashover level, brought down by fire service suppression of the fire, however some parts of these linings were just starting to fail.

The time to this state can be determined from the fire service log and comparing this actual time of failure with the predicted times to failure of the internal linings on the fire exposed face for different fire time-temperature scenarios allows the likely fire load, boundary conditions and ventilation conditions to be determined and hence the fire time-temperature conditions to be established with a reasonable degree of confidence. This allows the performance of the LSF house to be determined for a quantified level of structural fire severity.

The use of FaST requires an equivalent enclosure to be developed. This equivalent enclosure is shown in Figure 3.

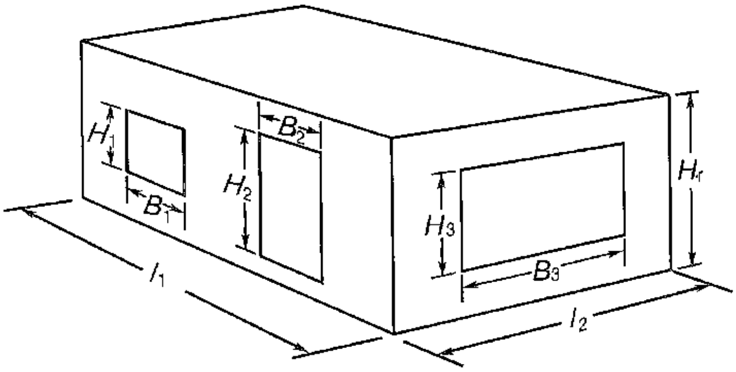


Figure 3: Equivalent Enclosure (A.H Buchanan, 2001)

The weighted average height of the openings, H_v, and the area of the internal surfaces of the enclosure, A_t, can be calculated using:

$H_v = (A_1H_1 + A_2H_2 + \ldots)/A_v$

$A_v = A_1 + A_2 + \ldots = B_1H_1 + B_2H_2 + \ldots$

$A_t = 2(l_1l_2 + l_1H_r + l_2H_r)$

Sections 3.1 to 3.7 describe how the input parameters for the enclosure of origin were determined for the analyses.

3.1 Enclosure Geometry

In order to get the enclosure geometry an averaged critical area that enclosed the kitchen, dining room and lounge was used. These are the open plan areas comprising the enclosure of origin. The plan view of this area consists of two different sized rectangles as shown in the Figure 4:

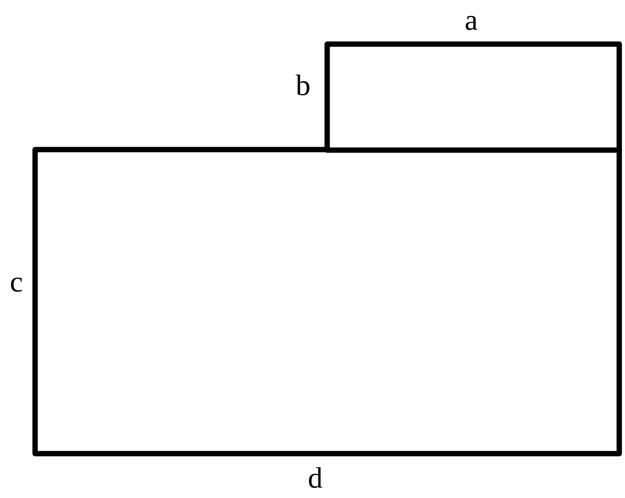


Figure 4: Plan View of the Critical Area of the Fire

The area of these two rectangles were calculated and added together. The length ‘d’ was used as input width l_1 into the FaST software and to get the second input width, the calculated total area was divided by length ‘d’ to give the dimension l_2. This gives an effective critical rectangular area on which the fire acts.

3.2 Height

The height was taken as the clear height between floor and ceiling and was determined from the plans.

3.3 Area and Height of Vertical Openings

The area of vertical openings was calculated by totalling the area of windows that were assumed to be broken using the following formula:

$A_v = A_1 + A_2 + \ldots = \textit{Length of Window 1*Width of Window 1 + Length of Window 2*Width of Window 2} + \ldots$

The height of the vertical openings was calculated using the second moment of area principle. It is important to note that the area is only calculated for the windows that are assumed to be broken. The height of vertical openings can therefore be calculated using the following formula:

$H_v = (A_1 {*} H_1 + A_2 {*} H_2 + \ldots) / A_v$

Note: A_v is the total area of vertical openings

3.4 Fire Load

Four fire loads were used in the analysis: 250, 300, 350 and 400 MJ/m^2 floor area. These values cover the range of fire load energy densities that would have existed in the house during the fire. The method described in section 5 was used to determine the most likely of these loads.

3.5 Thermal Inertia

The thermal inertia of the boundary elements is an important parameter determining the structural fire severity. It has units of $J/m^2Ks^{0.5}$ and is a measure of how slowly the heat from the fire is conducted away from the fire. An enclosure with low values will conduct heat away slowly, thereby making the fire hotter; conversely an enclosure with high thermal inertia will conduct heat more rapidly away from the fire, making the fire cooler. The house enclosure walls and ceiling boundary elements are plasterboard, as noted section 2, and the recommended value from C/VM2 [3] for such an enclosure is 700 $J/m^2Ks^{0.5}$. For these analyses, this value and the next highest value of 1160 $J/m^2Ks^{0.5}$ were used; the outcomes showed the lower value to be more accurate, as reported in section 5.

3.6 Beam/Column Type

The steel framing is made up of C-sections that are 'lipped'. Each section had a depth of 90mm, width of 40mm and thickness of 0.75mm.

3.7 Change in Ventilation (hole in roof)

To take into account the change in ventilation due to the hole in the roof the following formula was used:

$$(A_v\sqrt{H_v})_{crit} = A_v\sqrt{H_v} + 2.3A_h\sqrt{h}$$

The formula was then rearranged to make A_{vcrit} the subject. A_{vcrit} gives the combined ventilation taking into account the horizontal ventilation of the ceiling and the vertical ventilation of the walls.

The area of horizontal openings, $A_{h,}$ was calculated by estimating the shape of the roof from the pictures. Figure 5 below illustrates the assumed shaped of the hole in the roof.

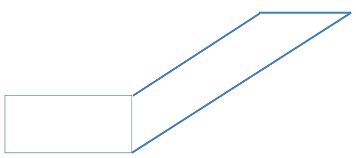


Figure 5: Approximated shape of the hole in the roof

A_h consists of a rectangle and trapezium so areas of these individual shapes were totalled to get the overall A_h. Figure 6 shows the actual picture of the hole in the roof.

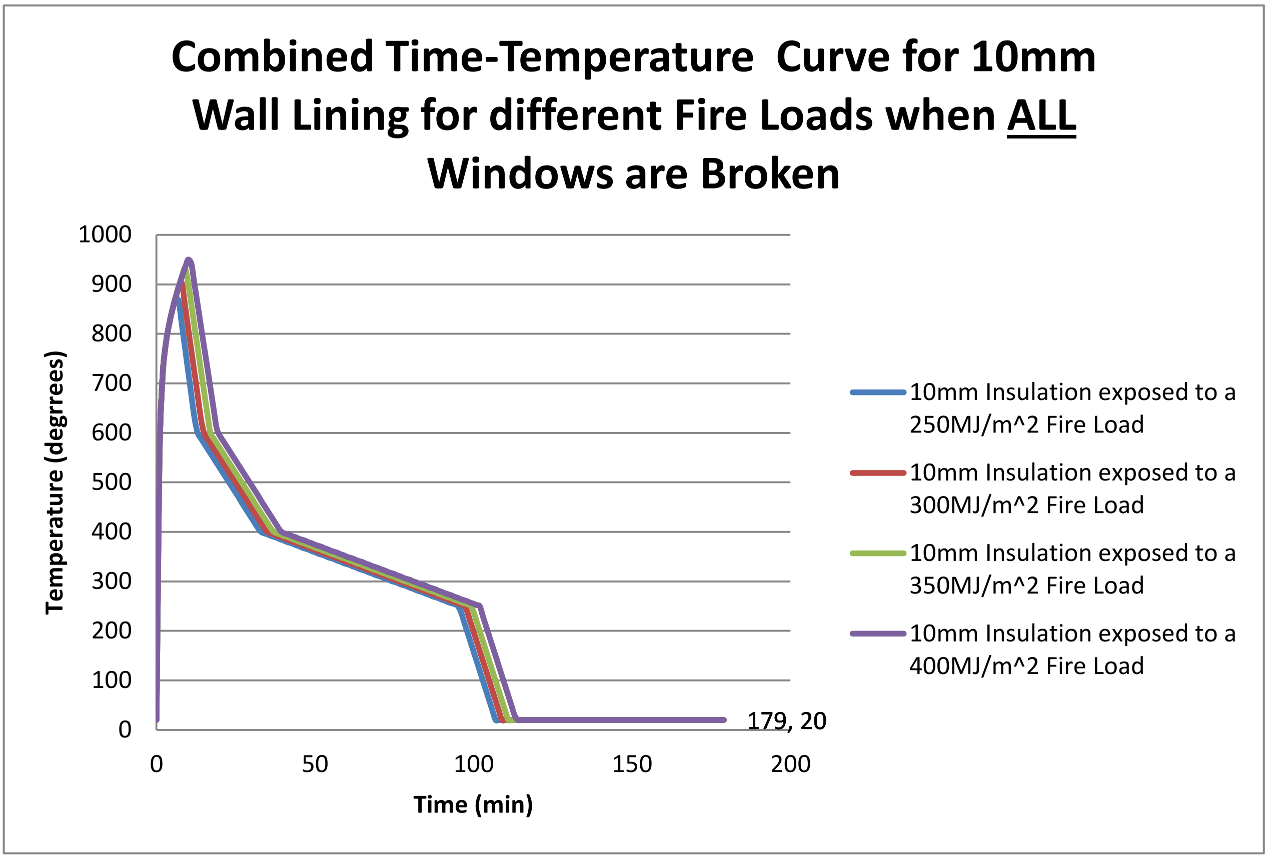
Figure 6: Hole in the roof from the East Elevation of the house

An important point to mention is that the some of the roof appears to have been pulled back by the firemen; this meant that the shape if the actual hole during would have to be smaller than what was seen in this picture. So, using the Floor Plan, an approximated shape as seen in Figure 5 was drawn and dimensions were measured to scale. This allowed the area to be calculated and used as A_h. Furthermore, the A_h was assumed to act at the ceiling height in the enclosure area shown in Figure 3.

4. Results

This section presents the analysis showing different time-temperature curves that were produced at different fire loads and ventilation conditions. The predicted times to failure of the ceiling and wall linings are then compared to the actual failure conditions and timeline from the fire service report in order to determine the likely fire load and ventilation conditions in the enclosure of origin. From this the performance of the house in this fire can be quantified.

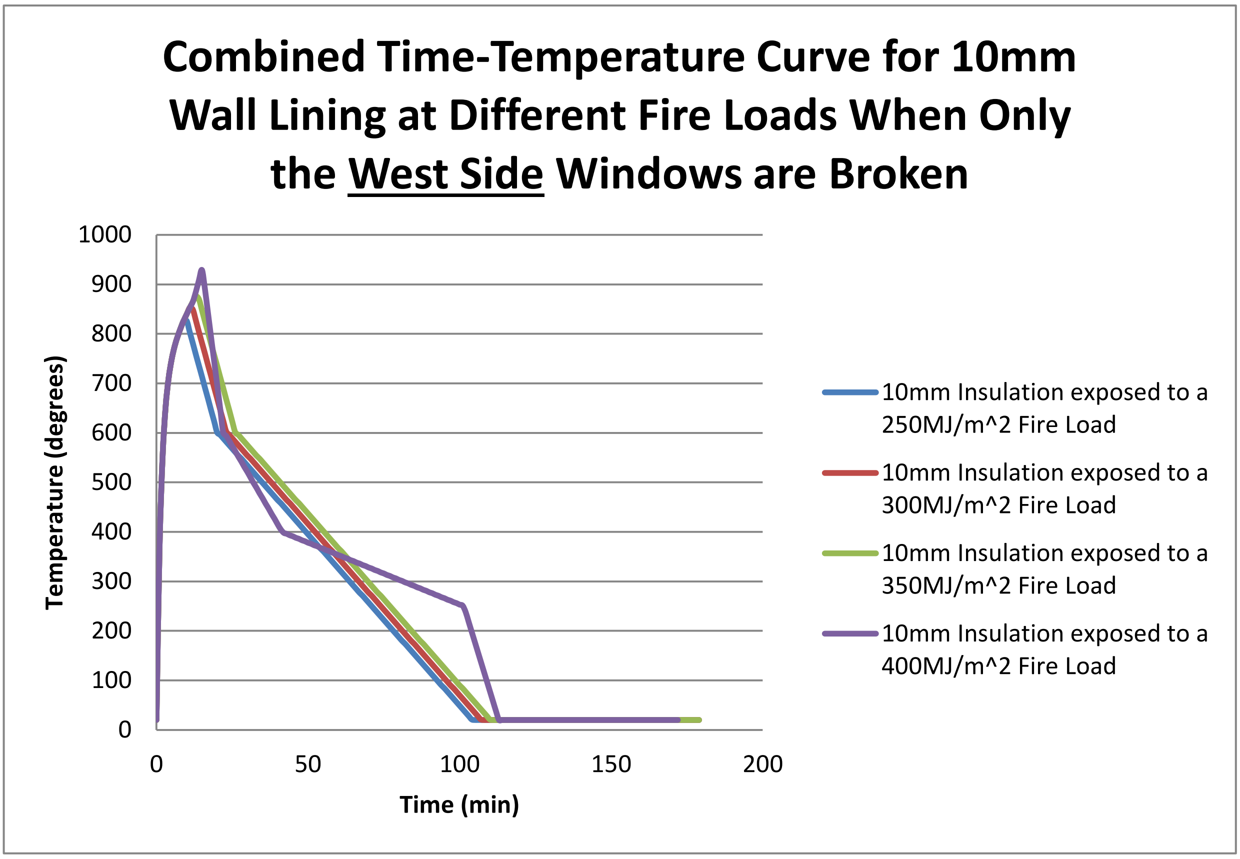
4.1 Fire Modelling Results



Wall Failure for a Fire Load 250MJ/m^2	Wall Failure for a Fire Load 300MJ/m^2	Wall Failure for a Fire Load 350MJ/m^2	Wall Failure for a Fire Load 400MJ/m^2
10mm Lining failed after 25 minutes	10mm Lining failed after 23 minutes	10mm Lining failedafter 21 minutes	10mm Lining failed after 19 minutes
20mm Lining did **not** fail	20mm Lining failed after 94 minutes	20mm Lining failed after 82 minutes	20mm Lining failed after 72 minutes

Figure 7: Time temperature curves and failure times for the Wall Lining when all windows are assumed broken

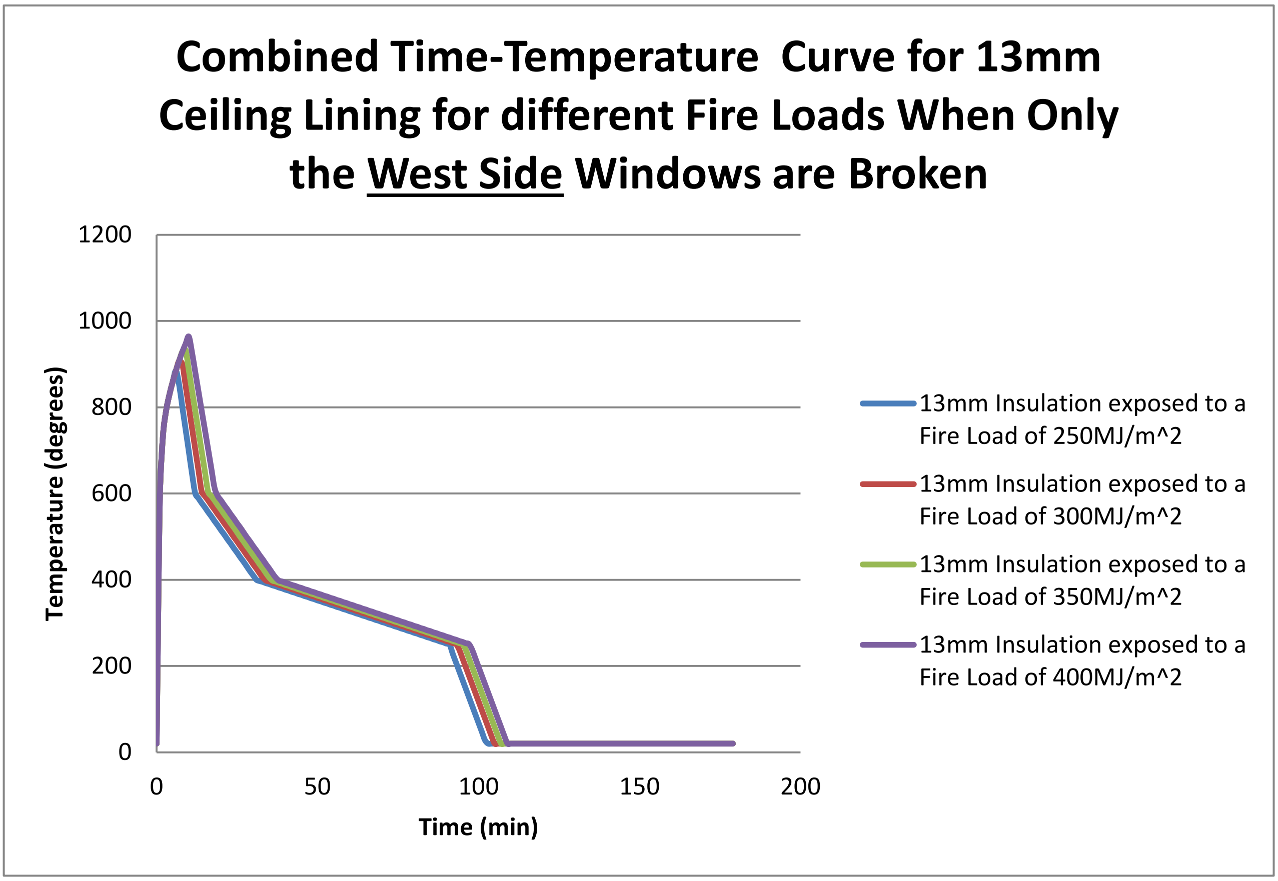
Figure 7 shows the time-temperature curves for the 10mm wall lining and failure times of both the 10mm and 20mm wall lining for different fire loads, when all the windows are assumed broken. It can be seen that as the fire load increases, the maximum temperature of the fire increases as well. The curves also have a similar shape. Full development of the fire is reached when temperatures exceed 500°C [3]. Failure times of the 10mm linings decrease as the fire load is increases, with a range difference of 6mins. The pictures of the house show that the wall lining that was facing the fire in the kitchen/lounge/dining room had failed i.e. was no longer in place, but the second wall lining behind the steel framing (10 + 10 = 20mm lining) was still intact. It is important to note that the 20mm failure times were not reached as the firemen had extinguished the fire well before these times could be reached. However it is not clear from this observation alone as to whether the fire exposed lining failed during the fire or as a result of fire service removal after the fire had been suppressed. To determine this, the condition of the visible steel framing has to be included in the considerations – similar appearance to the ceiling framing means the linings failed during flashover while a clean and shiny appearance means the linings remained intact during the fully developed period and were removed by the fire service once the fire had been suppressed.



Wall Failure for a Fire Load 250MJ/m^2	Wall Failure for a Fire Load 300MJ/m^2	Wall Failure for a Fire Load 350MJ/m^2	Wall Failure for a Fire Load 400MJ/m^2
10mm Lining failed after 23 minutes	10mm Lining failed after 21 minutes	10mm Lining failedafter 20 minutes	10mm Lining failed after 20 minutes
20mm Lining did **not** fail	20mm Lining failed after 66 minutes	20mm Lining failed after 57 minutes	20mm Lining failed after 52 minutes

Figure 8: Time temperature curves and failure times for the Wall Lining when windows on the West Elevation are assumed broken

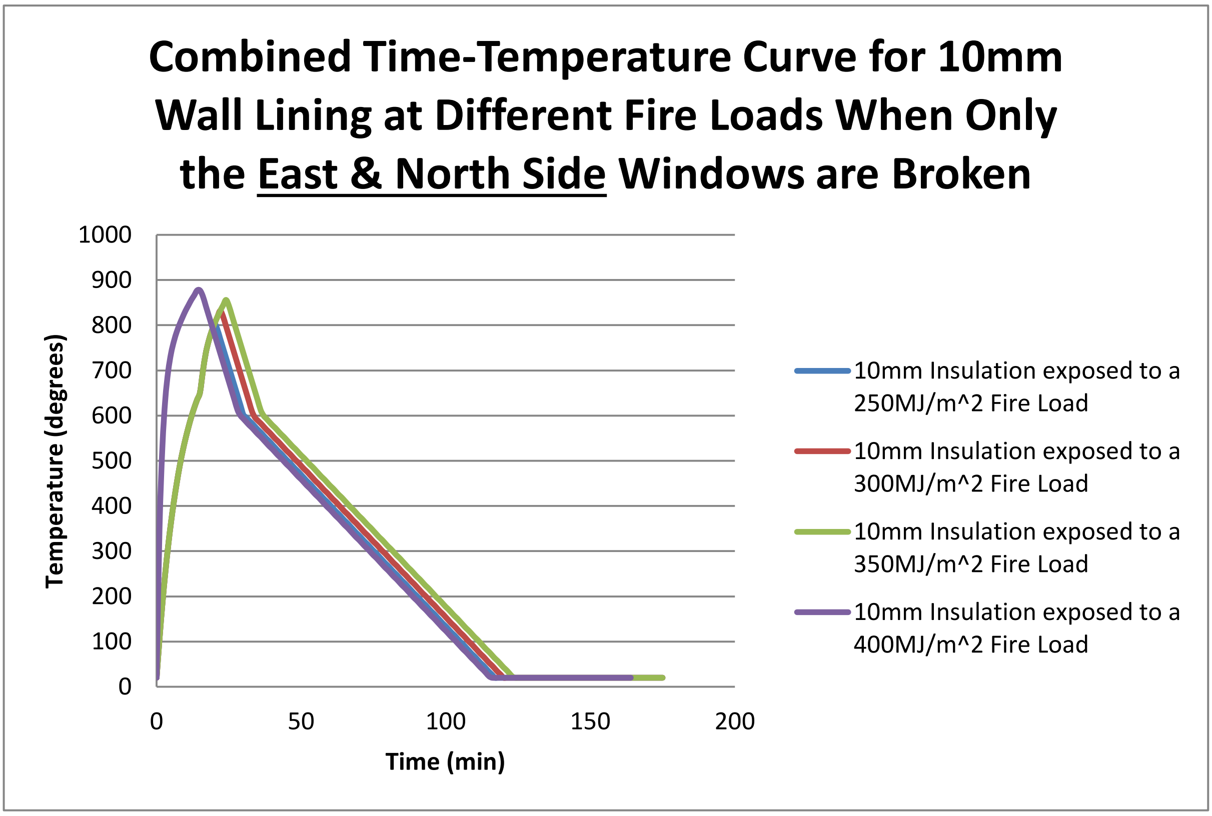
Figure 8 above shows the time-temperature curves for the 10mm wall lining and failure times for both the 10mm and 20mm wall linings at different fire loads when only the windows on the West Elevation of the house are assumed broken. Fire loads ranging from 250-350 MJ/m^2 have similar shape, however when analysing the fire load of 400 MJ/m^2, the change in ventilation due to the ceiling failing made the fire ventilation controlled as opposed to fuel-bed controlled which was seen in the other fire loads. This meant that in order to get the overall time-temperature curve, super positioning and shifting of the ceiling failure curve onto the wall failure curve was done hence the different shape. The time to failure for both the 10mm and 20mm wall linings decrease as the temperature increases. Peak temperatures ranged from 810^{o}C - 910^{o}C.



Ceiling Failure for a Fire Load 250MJ/m^2	Ceiling Failure for a Fire Load 300MJ/m^2	Ceiling Failure for a Fire Load 350MJ/m^2	Ceiling Failure for a Fire Load 400MJ/m^2
Failed after 16 minutes	Failed after 15 minutes	Failed after 14 minutes	Failed after 13 minutes

Figure 9: Time temperature curves and failure times for the linings in the ceiling when windows on the West Elevation are assumed broken

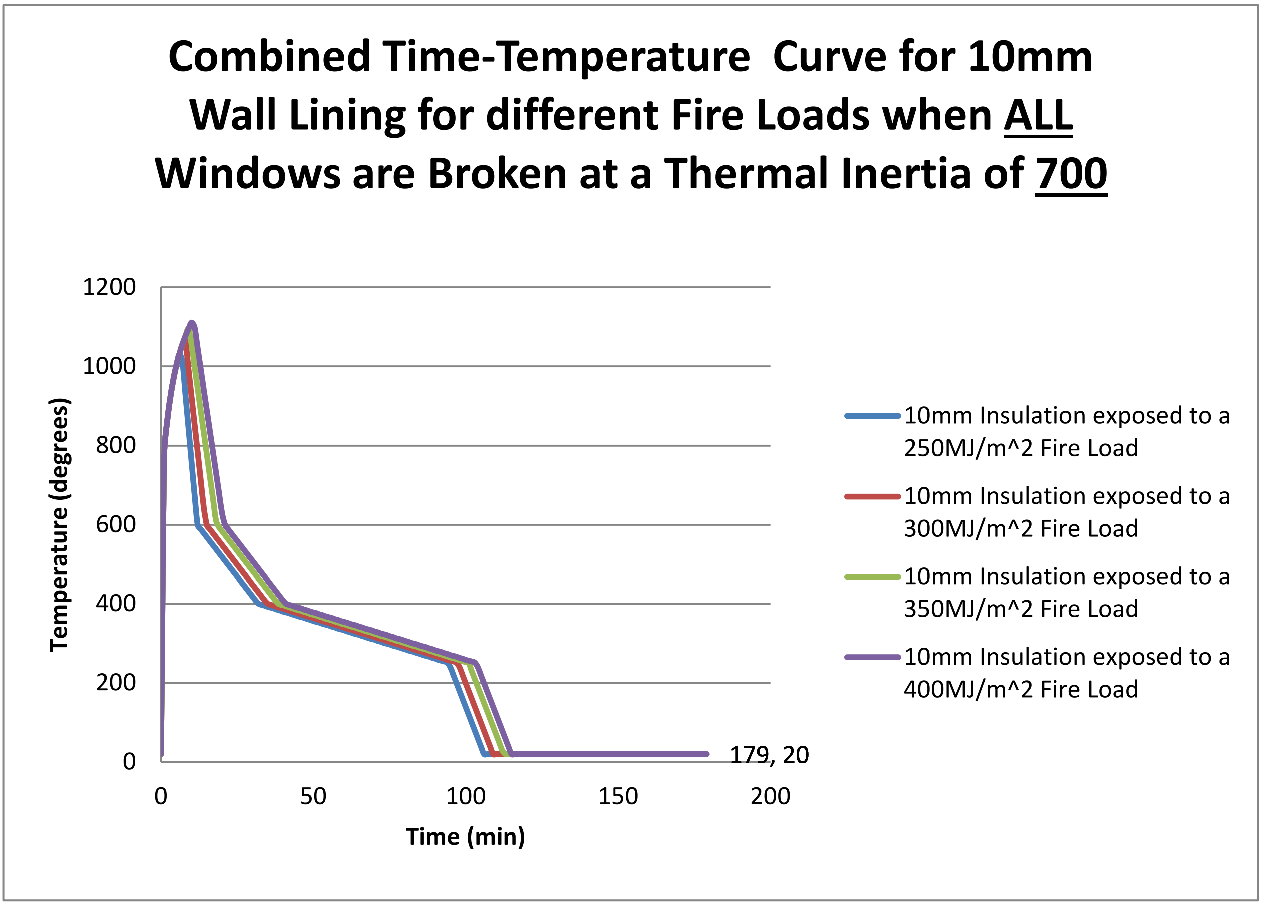
Figure 9 above illustrates the time-temperature curves and failure times for a 13mm ceiling lining at different fire loads respectively. The window on the west elevation was assumed to be broken. Observations from the graph indicate that an increase in fire load increases the peak temperature in the ceiling. Also, the ceiling failure times decreased as fire loads increased. All curves have similar shape with peak temperatures ranging from 860^{o}C - 950^{o}C.



Wall Failure for a Fire Load 250MJ/m^2	Wall Failure for a Fire Load 300MJ/m^2	Wall Failure for a Fire Load 350MJ/m^2	Wall Failure for a Fire Load 400MJ/m^2
10mm Lining failed after 29 minutes	10mm Lining failed after 28 minutes	10mm Lining failedafter 28 minutes	10mm Lining failed after 28 minutes
20mm Lining failed after 56 minutes	20mm Lining failed after 53 minutes	20mm Lining failed after 51 minutes	20mm Lining failed after 50 minutes

Figure 10: Time temperature and failure times when the windows on the East and North Elevations are assumed broken

Figure 10 shows the time-temperature curves for the 10mm walling and failure times for both the 10mm and 20mm wall lining when the windows of the living room at the east and north elevations are assumed to be broken. Peak temperatures at full development range between approximately 780^{0}C – 880^{0}C. The graphs for the fire loads of 250 – 350 MJ/m^2 have a similar shape as they are all fuel bed controlled. That is, the changes in ventilation conditions do not affect the curves. For the curve at 400 MJ/m^2, the shape is different. This is due to the fact that for this fire load, the change in ventilation conditions causes the fire to become ventilation controlled. Hence the curve shifting technique given in (Clifton, 1996) needed to be used to superimpose the ceiling failure curve and the wall failure curve.



Wall Failure for a Fire Load 250MJ/m^2	Wall Failure for a Fire Load 300MJ/m^2	Wall Failure for a Fire Load 350MJ/m^2	Wall Failure for a Fire Load 400MJ/m^2
10mm Lining failed after 22 minutes	10mm Lining failed after 19 minutes	10mm Lining failedafter 16 minutes	10mm Lining failed after 15 minutes
20mm Lining did **not** fail	20mm Lining failed after 80 minutes	20mm Lining failed after 66 minutes	20mm Lining failed after 57 minutes

Figure 11: Time Temperature and Failure times for the wall lining when all windows are assumed broken at a thermal inertia of 700 $J/m^2Ks^{0.5}$

Figure 11 shows the time-temperature curves of the 10mm wall lining and failure times of both the 10mm and 20mm wall lining assuming that all windows in the enclosure area are broken. This analysis was carried out with a thermal inertia of 700 $J/m^2Ks^{0.5}$ as opposed to 1160 $J/m^2Ks^{0.5}$ that was used on all other results. As before, the peaks of the time-temperature curves increase as the fire load increases and the failure times of the linings decrease as the fire load energy density increases. All graphs have the same shape indicating that that they are all fuel bed controlled and thus no shifting was required.

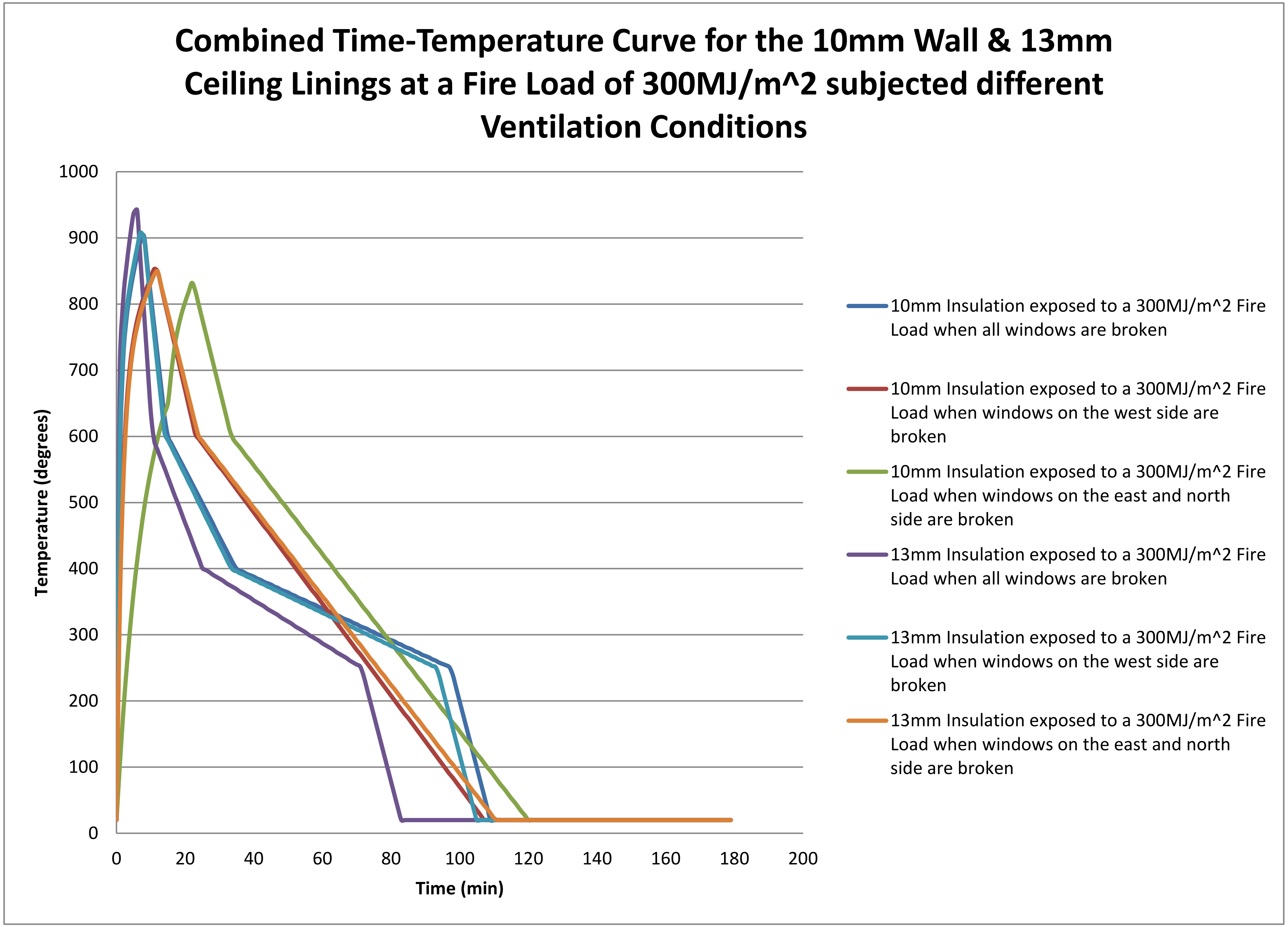


Figure 12: Time temperature curves for both the linings in the wall and ceiling at a fire load of 300 MJ/m^2

Figure 12 shows the time-temperature curves for the linings in the wall and ceiling at a fire load of 300 MJ/m^2 for different ventilation conditions. The curves with the highest temperature have the most ventilation. This is seen in the condition where all the windows are broken. Another point that can be deduced is that the curves for the ceiling lining are at higher temperatures than the curves for the wall linings indicating that the ceiling would have failed first. The peak temperatures at full development range from 820^oC - 940^oC.

4.2 Determination of Lining Failure Times from the Fire Service Timeline

Figure 13 overleaf describes the chain of events that occurred when the fire was reported and extinguished as per the Fire Report. The full Fire Report is in the Appendix. Important points to note from the timeline is that the fire fighters in the OTAR331 unit arrived at the site at 19:00:13, an ambulance was requested as it was found that there was someone in the house at the time of the fire and three fire fighting units helped put out the fire; OTAR331, PAPA347 and PAPA344. Furthermore, the fire was under control at 19:08:25. This was the time when the situation had been changed to '06C01 ABNML BRTH'.

The incident started at 18:52:48 and was under control by 19:08:25. This means that it took the fire fighters a total of approximately 16 minutes to arrive at the house and put the fire below flashover levels. Having assumed that the fire reached full development at 18:52:48, the actual fire would have started 2-3 minutes before and would have gone through the ignition and smouldering phases before reaching flashover. As it is considered that the linings on the walls were failing just as the firemen were extinguishing the fire, that is, after a 16 minute period and a further 2-3 minutes to take into account the earlier phases of the fire, a fire load energy density and thermal inertia that matches the total 19 minute failure time scheme needed to be determined. From section 4 Figure 11, the case when there is a 300MJ/m2 fire load energy density with a thermal inertia of 700 $J/m^2Ks^{0.5}$ best matches this description as it has a failure time of 19 minutes as well. This is deduced as described in section 5.

18:52:48
Incident Started

18:55:08
OTAR331 Proceeding to Incident

18:55:34
PAPA347 Proceeding to Incident

18:56:00
Call from Prymian Power Calbes Adresses: 30 Binstead Rd New Lynn

18:56:32
Call from 021030000

18:56:39
Call from 13 Nuneaton Drive

19:00:13
OTAR331 in attendance at incident

19:00:32
PAPA344 recommended for PUMP

19:01:46
PAPA344 proceeding to incident

19:07:38
Ambulance requested

19:08:25
Problem Changed to 06C01 ABNML BRTH

19:12:49
Incident Ended

Figure 13: Timeline - Chain of events on 23/08/11

5. Determination of the Expected Fire Load and Ventilation Conditions

As the house was a standard built house, it was assumed that standard GIB was used in the ceiling and walls. The GIB in the ceiling and walls failed at temperatures of 120°C and 200°C respectively. From Figure 12 it can be seen that the ceiling would have failed before the wall. This is because the time-temperature curves for the ceiling were at higher temperatures that the ones for the wall lining.

The change in ventilation occurred when the ceiling had failed. That is, when the hole in the roof was formed. It is important to note that the hole in the ceiling occurred above Bedroom 4 as per the Floor Plan (refer to Appendix). It did not occur above the critical area consisting of the kitchen/dining/lounge. This was due to the fact that once the lining in the ceiling had failed, the fire moved to the roof cavities and generated high temperatures within the cavity above the opening. However, as the only combustible material in the ceiling cavity was the timber roof battens, the fire could not spread through the roof cavity and back down into adjacent rooms. Calculations were made to take into account this change in ventilation and the respective time-temperature curves were produced.

The analysis included different ventilation conditions to see how this would have affected the overall shape and temperature of the time-temperature curves. The curves in Figure 7 show higher temperatures than the time-temperature curves in both Figure 8 and Figure 10. This is due to the fact that there is more air available to fuel the fire and make it more intense. This model was considered as the critical one.

The alarm was raised when neighbours noted flames issuing from the windows and slightly later from the roof. This shows the fire had reached the ventilation controlled stage of full development [4, 5]. From the timeline in Figure 13, the fire was assumed to be under control at 19:08:25, when the situation had been changed to a '06C01 ABNML BRTH'. The firemen were on site approximately 8 minutes after the fire was reported and it took a further 8 minutes to put the fire under control. The time-temperature curves at a thermal inertia of 1160 $J/m^2Ks^{0.5}$ did not accurately match this time scheme because it over estimated the performance of the house in the fire. That meant that the time to failure of the wall linings were longer than what had been observed in the timeline. To match the events that actually had happened, a lower thermal inertia of 700 $J/m^2Ks^{0.5}$ was considered. This allowed the time to failure to decrease and accurately correspond to the chain of events on the timeline. The time-temperature graphs in Figure 11 that were produced with the lower thermal inertia had higher temperatures thus reinforcing the fact that the lining would have failed earlier.

The design fire load energy density for a house is taken to be 400 MJ/m^2 floor area [3]. This is the 80% value, meaning that the actual fire load will be lower than this in 80% of cases considered. In this house, the comparison of actual and predicted lining failure timelines gives an expected fire load energy density of 300 MJ/m^2 floor area for the enclosure of origin. As a thermal inertia of 700 $J/m^2Ks^{0.5}$ matched the timeline and a fire load of 300 MJ/m^2 was the most realistic, it can be said that the most accurate representation of the fire that occurred at this house was of a thermal inertia of 700 $J/m^2Ks^{0.5}$ and fire load of 300

MJ/m^2. Figure 12 shows comparisons of a 300MJ/m^2 fire for different ventilation conditions with the most critical case being when all the windows are broken.

The steel framing in the ceiling was visibly distorted but in the walls, the steel was shiny and had very little distortion over most of the visible framing, with localised regions of surface dulling and very small distortion. This implies that the firemen suppressed the fire just when the wall lining was about to fail. The 10mm wall lining was not there in the pictures and so it was assumed that either the firemen had pulled the damaged wall lining out once the fire had been extinguished or the hosing down of the fire had taken the lining off. The roof was supported by wooden battens and this was one of the only places in the house where timber was used as construction. From Figure 14 below, it can be seen that the battens were charred due to the high temperatures.

Figure 14: Image showing the charred battens

Also, the steel framing can be seen to be distorted heavily but still intact. It is, however, important to note that there was only distortion of the steel framing in the roof. The framing in the walls were well intact and had little to no signs of exposure to high temperatures and distortion. This observation can be seen in the picture below:

Figure 15: Undistorted steel framing in the walls

In Figure 15 it can be seen that the steel framing in the walls are ‘fresh’ and shiny. There are little patches of dark spots on the wall framing indicating that the wall lining had failed at these points but since the patches are relatively small there is little to no distortion.

6. Other Observations Indicating Temperatures Reached During the Fire

Through matching the predicted and actual timelines for lining failure, the most realistic fire load energy density and boundary elements thermal inertia has been determined, and from this the likely fire time-temperature conditions determined.

Other physical observations relating to the temperatures reached are now given and correlated back to the expected fire time-temperature conditions. These are:

1. The aluminium window frames tops and upper sides were melted, meaning temperatures had to have exceeded the melting point of aluminium, 660°C, by a considerable margin. This is consistent with the predicted temperatures in the enclosure of origin being over 900°C
2. Where the fire broke through the ceilings into the roof cavity above the enclosure of origin and then broke through the roof, the galvanizing is missing from some tiles indicating peak temperatures at the underside of the roof tiles of more than 420°C, the melting point of zinc. The severe charring of the timber roof tile battens supports this. Given the peak temperature below the ceiling in the enclosure of origin was over 900°C, temperatures of around 550 to 600°C in the roof space above the failed ceiling would have been expected with higher local temperatures of as much as 800°C.

7. Conclusions

This was the first example of a significant fully developed fire in a light steel framed house to be investigated in New Zealand. The conclusions from this investigation are:

- The time-temperature curve with a fire load of 300 MJ/m^2 and a thermal inertia of 700 $J/m^2Ks^{0.5}$ best represent the fire in terms of how the curve matched the chain of events in the timeline.
- The temperatures in the enclosure of origin exceeded 900°C, with over 600°C in the roof space.
- The highest temperatures on the time-temperature curves were achieved when all the windows in the critical region were assumed to be broken
- The lining in the ceiling had failed before the wall lining, causing a hole in the roof
- The hole in the roof did not occur directly above the point of ceiling failure due to the orientation of the roof above the enclosure of origin; rather it occurred at intersecting roof lines where restraint of thermal expansion caused openings to develop.
- The house performed very well in the fire. The steel framing in the roof space and walls were exposed to the fully developed fire distorted but did not collapse. This not only prevented the house from collapsing but meant that most of it remained weather tight and restricted the fully developed fire to the enclosure of origin. There was considerable smoke damage throughout the house but contents in the rooms away from the enclosure of origin were able to be salvaged.
- The external wall brickwork did not collapse and could be reused. In theory, much of the steel framing could have been cleaned and reused, however it was more economical to replace this framing

8. References

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9. Appendix

This section presents the House Plans, the steps from the HERA Report used to calculate the time-temperature curves and the Fire Service Report.

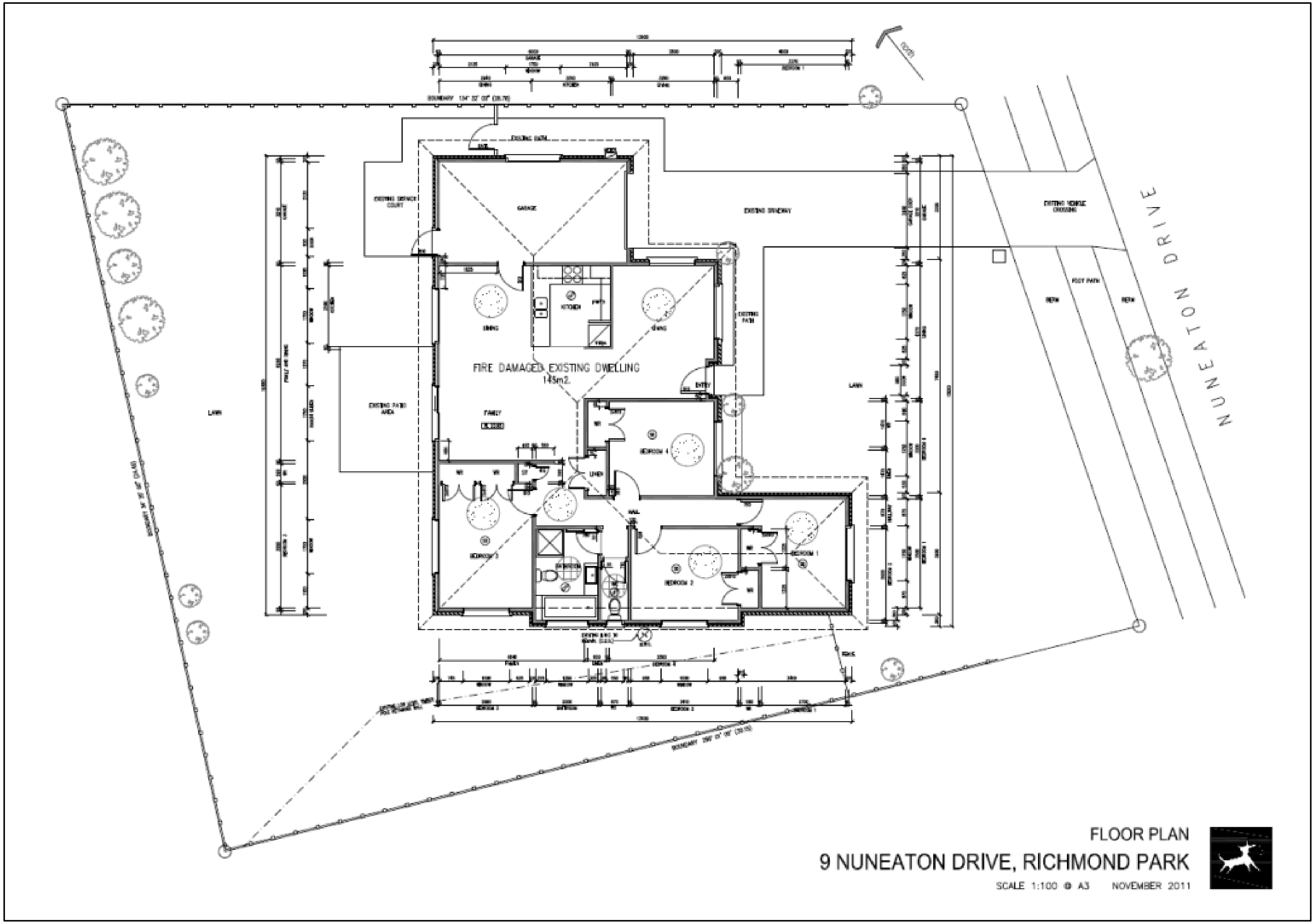

Figure 16: Floor Plan of 9 Nuneaton Drive

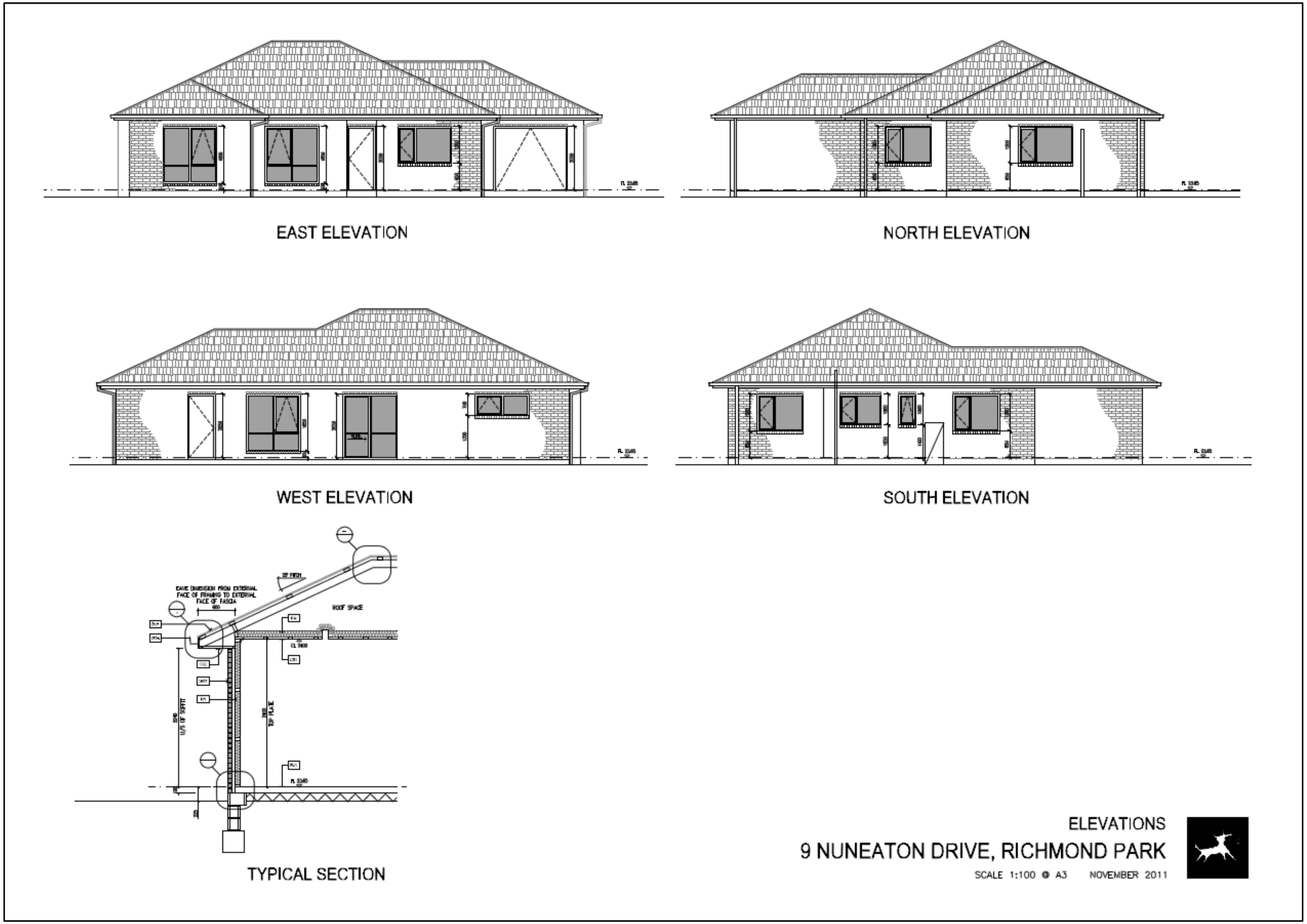

Figure 17: Elevation Plan of the house

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Secondly, comparing the time and extent of window breakage observed in the BHP large enclosure tests [4] with the gas temperature, at that time, measured at a point adjacent to the window, indicates that a figure of 350-400°C is appropriate to associate with significant window breakage.

For this model, the critical temperature assumed for window breakage is 350°C. This is just below the most widely used preheat temperature (θ_{ph} = 400°C) given in Table 2.

For the strip of firecell shown in Fig. 14, window breakage at the far end of the firecell will therefore occur during the preheating stage of $A_{fire,n,1}$. The design area of fire under consideration at that time is the previous cell, $A_{fire,n-1,1}$. For a strip of firecell comprising normal construction (see Table 2), θ_{ph} = 400°C occurs at $t_b = 0.5t_{\theta=400,n-1,1}$ and so window breakage will occur at $t_b = 0.44t_{\theta=400,n-1,1}$. At this point, the ventilation conditions in cell (n - 1) will change, mid-way through the period of full fire development in that design area of fire. This necessitates adjusting the calculated time-temperature curve in cell (n - 1) for the changed conditions. How to do this is covered in section 4.1.2.8.

4.1.2.8 Adjusting the time-temperature curve in a design area of fire for changing ventilation conditions

This adjustment is undertaken whenever the ventilation increases significantly during the period of fully developed fire consideration in a given design area of fire and the fire, prior to this increase in ventilation, is burning in a ventilation controlled regime. This change will be invoked at certain stages of the model, eg. during window breakage (as given in section 4.1.2.7) or through additional ventilation becoming available from adjacent strips of firecell (as given in section 4.2.3).

This alteration is undertaken in accordance with the following steps (to be read in conjunction with Figs. 19(a) and 19(b)).

Step 1: Determine the time at which the ventilation conditions change. This is time t^1 in Figs. 19(a) or 19(b)).

Step 2: Obtain the time-temperature curve $(t',\theta_g')_{ij}$ for the ventilation conditions applying to this design area of fire prior to time t^1. These are obtained by applying either the Natfire model (section 3.1.2) or the Modified Eurocode model (section 3.2.3) to the initial conditions relating to this design area of fire.

These conditions involve:

$A_{fire,i,i}$	(design area of fire i, in strip i of the firecell) (m^2)
$A_{t,i,i}$	(total surface area of this design area of fire) (m^2)
$e_{f,i,i}$	(design fire load over A_f) (MJ/m^2 floor area)

Definitions continued on the next page

Figure 18: Steps 1-2 to obtain the time-temperature curves for changes in ventilation conditions

$e_{t,i,i}$	(design fire load over A_t) (MJ/m^2 total surface area)
$A'_{v,i,i}$	(area of ventilation available at t' = 0) (m^2)
$h'_{i,i}$	(weighted mean height of openings at t' = 0) (m^2)

The curve so generated is the (t', θ_g') curve shown in Figs. 19(a) or 19(b).

Step 3: Determine whether the fire is burning in a ventilation controlled regime or in a fuel-bed controlled regime.

Step 3.1: Calculate the rate of burning associated with each regime.

$$\dot{m}_{pv} = 0.12 A'_{v,i,i} \sqrt{h'_{i,i}} \qquad (7.1)$$

where:
$\dot{m}_{pv}$ = rate of burning in a ventilation controlled regime (kg/s)

$$\dot{m}_{pf} = 6.7 \times 10^{-5}\, e_{f,i,i}\, A_{fire,i,i} \qquad (7.2)$$

where:
$\dot{m}_{pf}$ = rate of burning in a fuel-bed controlled regime (kg/s)

The derivation of equations (7.1 and 7.2) is presented in Appendix A.

Step 3.2 Determine which regime governs and what course of action to take

(1) If $\dot{m}_{pv} < \dot{m}_{pf}$, then the fire, prior to the increase in ventilation, is ventilation controlled. In this case, proceed to step 4.

(2) If $\dot{m}_{pv} > \dot{m}_{pf}$, then the fire, prior to the increase in ventilation, is fuel-bed controlled. In this instance, the increase in ventilation will not change the nature of the fire and no adjustment should be made to the time-temperature curve $(t', \theta_g')_{II}$ from step 2.

Step 4: Determine which side of the (t', θ_g') curve the time t^1 lies on (ie. the heating side or the decay side.

If t^1 lies on the heating side, go to step 5.

If t^1 lies on the decay side, go to step 6.

Step 5: Adjusting the calculated time-temperature curve for change of ventilation conditions applied while in the heating phase of the original curve.

Step 5.1: Determine the fuel loss, Δe_t, from equation (8).

Figure 19: Steps 2-5 to obtain the time-temperature curves for changes in ventilation conditions

$$\Delta e_{t,i,j} = \left(100.OF' t^{1}\right)_{i,j} \tag{8}$$

where:

$\Delta e_{t,i,j}$ = fuel loss over time t^1 (MJ/m^2 total surface area)

OF' = opening factor, calculated for the initial conditions

t^1 = time from $t' = 0$ to change of conditions, in minutes

The derivation of equation 8 is presented in Appendix A.

Step 5.2: Determine the amount of fuel remaining (for calculating the second curve) from equation (9)

$$e''_{t,i,j} = \left(e_t - \Delta e_t\right)_{i,j} \tag{9}$$

where:

$e''_{t,i,j}$ = amount of fuel remaining (MJ/m^2 total surface area)
e_t = design fire load over area A_t
Δe_t = fuel burned from equation (8)

Step 5.3: Obtain the time-temperature curve $\left(t'', \theta_g''\right)_{i,j}$ for the ventilation conditions applying to this design area of fire after time t^1, by applying either the Natfire model (section 3.1.2) or the Modified Eurocode Model (section 3.2.3).

These conditions involve:

$A_{fire,i,j}$; $A_{t,i,j}$
$e''_{t,i,j}$ from equation 9
$A''_{v,i,j}$ (area of ventilation for $t > t^1$)
$h''_{i,j}$ (weighted mean height of openings for $t > t^1$)

The curve so generated is the $\left(t'', \theta_g''\right)$ curve, shown in Fig. 19(a), with its origin at t^1.

Step 5.4: Translate the curve from step 5.3 to the left by Δt_h, where Δt_h is the interval corresponding to $\theta_g = \theta^1_{g,h}$ on both curves (see Fig. 19(a)).

Step 5.5: The design curve for $A_{fire,i,j}$ is the composite curve so determined from step 5.4; see Fig. 19(a) for details.

The adjustment process is now complete.

Figure 20: Continuation of Step 5

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Step 6: Adjusting the calculated time-temperature curve for change of ventilation conditions applied once the decay phase of the original curve has been reached.

Step 6.1: Obtain the time-temperature curve $\left(t'', \theta_g''\right)_{l,i}$ for the ventilation conditions applying to this design area of fire after time t^1.

These conditions involve:

$A_{fire,l,i}$; $A_{t,l,i}$

$e_{t,l,i}$ (design fire load over A_t)

$A''_{v,l,i}$ (area of ventilation for $t > t^1$)

$h''_{l,i}$ (weighted mean height of openings for $t > t^1$)

The curve so generated is the $\left(t'', \theta_g''\right)$ curve, shown in Fig. 19(b), with its origin at t^1.

Step 6.2: Translate the curve from step 6.1 to the left by Δt_d, where Δt_d is the interval corresponding to $\theta_g = \theta^1_{g,d}$ on both curves (see Fig. 19(b)).

Step 6.3: The design curve for $A_{fire,l,i}$ is the composite curve so obtained from step 6.2; see Fig. 19(b) for details.

The adjustment process is now complete.

When t^1 lies within the heating phase of the $\left(t', \theta_g'\right)$ curve, equation (8) is used to calculate the fuel loss from $t' = 0$ to $t' = t^1$.

When t^1 lies within the decay phase of the $\left(t', \theta_g'\right)$ curve, the majority of the fuel is burned and the more appropriate approach is to use the decay phase of the curve calculated for the (full) design fire load and enhanced ventilation conditions. This is the approach used in step 6.

Note that the design area of fire to which this adjustment is being made will not be the origin design area of fire (except if it involves application through section 5.3.2 herein). It is important, therefore, to keep account of the time elapsed from the time of fire start in the origin design area of fire (ie. the time $t = 0$ for the firecell as a whole). This is noted in Fig. 19 by the time, t_{lead}, shown dotted to the left of the origin, $t' = 0$.

Figure 21: Step 6

SMS Incident Report

10/12/2012 2:29:44 p.m.

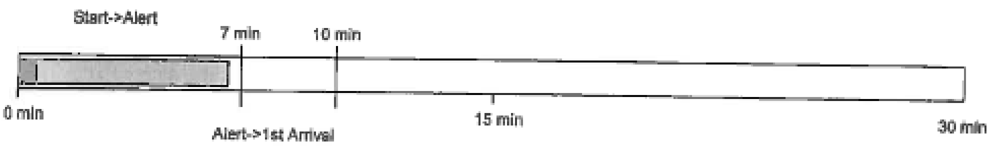
Summary

CAD Number	F1028939	**Status**	Industrial Action
Station	Papatoetoe Station		
Incident Started	23/08/2011 6:52:58 p.m.	**Incident Ended**	23/08/2011 7:12:49 p.m.
Incident Type	0:		
Common Name			
Address	/ 9 NUNEATON DRIVE FLAT BUSH		
Alarm Method	111 Telephone	**Alarm Level**	1
PFA Number			
Zone	143303	**Risk Classification**	N
Map Grid E	1769143	**Map Grid N**	5906079
First Caller		**First Caller Contact**	92723304
Incident Closed	23/08/2011 7:12:49 p.m.		
Report Completed	10:4, Wed 24 Aug 2011		

PRINCIPAL ADVISOR FIRE RISK MANAGEMENT
11 DEC 2012
Region 1 Auckland

Responses

Callsign	Type	Station Alert	Enroute Time	Arrival Time	Departed
PAPA347	PR	18:53:33 23 Aug 2011	18:55:34 23 Aug 2011	18:59:34 23 Aug 2011	22:10:43 23 Aug 2011
OTAR331	P1	18:53:31 23 Aug 2011	18:55:08 23 Aug 2011	19:00:13 23 Aug 2011	23:47:39 23 Aug 2011
PAPA344	PM	19:00:38 23 Aug 2011	19:01:46 23 Aug 2011	19:07:32 23 Aug 2011	19:58:38 23 Aug 2011
AUCKFPOL5	FPOL	19:04:53 23 Aug 2011	19:04:59 23 Aug 2011	19:17:52 23 Aug 2011	20:23:38 23 Aug 2011
AUCKFSO8	FSO	19:18:04 23 Aug 2011	19:31:02 23 Aug 2011	20:06:49 23 Aug 2011	21:35:58 23 Aug 2011
AUCKFSO3	FSO	19:13:04 23 Aug 2011			19:18:12 23 Aug 2011



Elapsed Times

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Some message timestamps may differ to actual times in multi-agency incidents. Communication centres can supply correct times if essential.

Figure 22: Fire Service Log showing the Responses of the Fire Fighting Units

SMS Incident Report F1028939 2 / 7 10/12/2012 2:29:44 p.m.

Callsign	Start To Alert	Alert To Arrival	Start To Arrival	Start To Depart
PAPA347	00:00:35	00:06:01	00:06:36	03:17:45
OTAR331	00:00:33	00:06:42	00:07:15	04:54:41
PAPA344	00:07:38	00:06:56	00:14:34	01:06:40
AUCKFPOL5	00:11:55	00:12:59	00:24:54	01:30:40
AUCKFSO8	00:25:06	00:48:45	01:13:51	02:43:00
AUCKFSO3	00:20:06			00:25:14

Notifications

Date	Time	Party Notified
23 Aug 2011	18:58:15	VECTOR
23 Aug 2011	18:58:25	AAM COUNTIES MANUKAU
23 Aug 2011	19:00:56	AAM5C RICHARD TWOMEY ACKS PAGE
23 Aug 2011	19:01:34	SM
23 Aug 2011	19:08:25	VECTOR
23 Aug 2011	19:08:25	AAM5C RICHARD TWOMEY ACKS PAGE
23 Aug 2011	19:08:25	SM
23 Aug 2011	19:08:25	AAM COUNTIES MANUKAU
23 Aug 2011	19:12:56	AAM COUNTIES/MANUKAU RE INFORMATIVE
23 Aug 2011	19:13:08	AAM COUNTIES/MANUKAU RE INFORMATIVE
23 Aug 2011	19:15:09	AAM 5B ACKS APGE
23 Aug 2011	19:18:10	HOUSING NZ
23 Aug 2011	19:38:20	AAM 5B ACKS APGE
23 Aug 2011	19:38:20	HOUSING NZ

Message Log

Time	Message
18:53:12	INC INFO: HOUSE FIRE
18:53:13	** LOI search completed at 23/08/11 18:53:13
18:53:22	** Recommended unit OTAR331 for requirement PUMP (>2.56 km)
18:53:22	** Recommended unit PAPA347 for requirement PUMP (>2.63 km)
18:55:08	Unit OTAR331 [K1 : PROCEEDING TO INCIDENT]
18:55:34	Unit PAPA347 [K1 : PROCEEDING TO INCIDENT]
18:56:00	Duplicate Event:Location = 9 NUNEATON DR,FLAT BUSH,AUCKLAND, Type = STRU -
18:56:00	INC INFO: HOUSE FIRE
18:56:00	STRUCTURE FIRE, Caller Name = PRYSMIAN POWER CABLES & SYST, Caller Ph Number
18:56:00	= 274716495, Caller Address = 30 BINSTED ROAD, NEW LYNN,WAITAKERE CITY, Call
18:56:00	Source = 111Inc InfoHOUSE FIRE
18:56:00	End of Duplicate Event data
18:56:32	Duplicate Event:Location = 9 NUNEATON DR,FLAT BUSH,AUCKLAND, Type = STRU -
18:56:32	STRUCTURE FIRE, Caller Ph Number = 021030000, Call Source = 111Inc InfoHOUSE
18:56:32	FLAT
18:56:33	INC INFO: HOUSE FLAT
18:56:33	End of Duplicate Event data
18:56:39	INC INFO: HOSUE FIRE
18:56:39	Duplicate Event:Location = 13 NUNEATON DR,FLAT BUSH,AUCKLAND, Caller Name =

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Some message timestamps may differ to actual times in multi-agency incidents. Communication centres can supply correct times if essential.

Figure 2315: Fire Service Log showing Notifications and Message Log

SMS Incident Report F1028939 3 / 7 10/12/2012 2:29:44 p.m.

Time	Message
18:56:39	KHAN, MOHAMMED SABIR, Caller Ph Number = 92784933, Caller Address = 13 NUNEATON
18:56:39	DRIVE, EAST TAMAKI,AUCKLAND, Call Source = 111Inc InfoHOSUE FIRE
18:56:39	End of Duplicate Event data
18:57:05	INC INFO: HOUSE FIRE
18:57:05	Duplicate Event:Location = NUNEATON DR,/SAMBROOKE CR,FLAT BUSH,AUCKLAND, Type =
18:57:05	STRU - STRUCTURE FIRE, Call Source = 111Inc InfoHOUSE FIRE
18:57:05	End of Duplicate Event data
18:57:39	Unit OTAR331 [COMCEN COM : MESSAGE] HAVE RECIEVED MULTIPLE CALLS TO THIS
18:57:39	INCIDENT
18:57:59	Unit OTAR331 [SITREP :] K99 PROCEEDING
18:59:34	Unit PAPA347 [K99 : PROPERTY FIRE WELL INV]
19:00:07	FP AUCKLAND
19:00:10	Unit PAPA347 [SITREP :] MAKE PUMPS3
19:00:13	Unit OTAR331 [K2 : IN ATTENDANCE AT INCIDENT]
19:00:32	** Recommended unit PAPA344 for requirement PUMP (>2.84 km)
19:01:46	Unit PAPA344 [K1 : PROCEEDING TO INCIDENT]
19:03:30	Unit PAPA347 [KC : UNIT CALLING]
19:03:33	INC INFO:
19:03:33	Duplicate Event:Location = NUNEATON DR,FLAT BUSH,AUCKLAND, Call Source = 111
19:03:34	End of Duplicate Event data
19:04:32	Unit PAPA347 [SITREP :] SSO BLYDE - 9 NUNEATON - SINGLE STOREYED PRIVATED
19:04:32	DWELLING WELL INVOLVED IN FIRE1HPOD 1 LPD ALL PERSONS ACCOUNTED FOR K11E
19:05:00	Unit AUCKFPOL5 [K1 : PROCEEDING TO INCIDENT]
19:05:05	Unit AUCKFPOL5 [K38 : ASSOCIATE THIS UNIT TO EVENT - EVENT ADDRESS]
19:05:14	Unit AUCKFPOL5 [K39 : RE-TRANSMIT YOUR CURRENT STATUS]
19:06:32	Unit PAPA347 [KC : UNIT CALLING]
19:07:02	Unit PAPA347 [K11A : AMBULANCE REQUIRED] K11A - 1 RESIDENT SUFFERING FROM SHOCK
19:07:32	Unit PAPA344 [K2 : IN ATTENDANCE AT INCIDENT]
19:07:38	AMB - YOU HAVE BEEN REQUESTED TO ATTEND HOUSE FIRE - 1 RESIDENT SUFFERING FROM
19:07:38	SHOCK
19:07:47	AMBO EVENT 1453-1-2011/08/23-FIR LINKED AT 23/08/2011 19:07:47
19:08:24	Caller Name = Caller Address = 9 NUNEATON DRIVE, EAST
19:08:24	Location = 9 NUNEATON DR,FLAT BUSH,AUCKLAND
19:08:24	Duplicate Event:Location = 9 NUNEATON DR,FLAT BUSH,AUCKLAND, Type = STRU -
19:08:24	INC INFO: HOUSE FIRE
19:08:24	DRIVE, EAST TAMAKI,AUCKLAND, Call Source = 111Inc InfoHOSUE FIRE
19:08:24	= 274716495, Caller Address = 30 BINSTED ROAD, NEW LYNN,WAITAKERE CITY, Call
19:08:24	End of Duplicate Event data
19:08:24	AMBO update to 1453-1-2011/08/23-FIR:
19:08:24	STRUCTURE FIRE, Caller Name = PRYSMIAN POWER CABLES & SYST, Caller Ph Number
19:08:24	Source = 111Inc InfoHOUSE FIRE
19:08:24	STRUCTURE FIRE, Caller Ph Number = 021030000, Call Source = 111Inc InfoHOUSE
19:08:24	FLAT
19:08:24	Duplicate Event:Location = 13 NUNEATON DR,FLAT BUSH,AUCKLAND, Caller Name =
19:08:24	INC INFO: HOSUE FIRE
19:08:24	KHAN, MOHAMMED SABIR, Caller Ph Number = 92784933, Caller Address = 13 NUNEATON
19:08:24	INC INFO: HOUSE FLAT

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Some message timestamps may differ to actual times in multi-agency incidents. Communication centres can supply correct times if essential.

Figure 24: Continuation of Message Log showing calls from neighbours and request for ambulance assistance

SMS Incident Report F1028939 4 / 7 10/12/2012 2:29:44 p.m.

Time	Message
19:08:24	TAMAKI,AUCKLAND, Caller Phone = 92723304, Headline = HOUSE FIRE
19:08:25	INC INFO:
19:08:25	Duplicate Event:Location = NUNEATON DR,FLAT BUSH,AUCKLAND, Call Source = 111
19:08:25	SHOCK
19:08:25	AMB - YOU HAVE BEEN REQUESTED TO ATTEND HOUSE FIRE - 1 RESIDENT SUFFERING FROM
19:08:25	INC INFO: HOUSE FIRE
19:08:25	STRU - STRUCTURE FIRE, Call Source = 111Inc InfoHOUSE FIRE
19:08:25	Problem changed to: 06C01 ABNML BRTH
19:08:25	End of Duplicate Event data
19:08:25	Duplicate Event:Location = NUNEATON DR./SAMBROOKE CR,FLAT BUSH,AUCKLAND, Type =
19:08:25	FP AUCKLAND
19:11:14	Unit PAPA347 [KC : UNIT CALLING]
19:11:32	Unit PAPA347 [K11F : FIRE SAFETY REQUIRED]
19:12:49	INC INFO: HOUSE FIRE TOC 1853............TOA 1859
19:13:07	INC INFO: HOUSE FIRE TOC 1853...........TOA 1859
19:13:08	[FIR] RESPONDING
19:13:32	AMB - COPY THANKS
19:16:12	Unit PAPA347 [KC : UNIT CALLING]
19:16:13	Unit PAPA347 [SITREP :] K11 POLICE VICITM SUPPORT OFFICER AND A SUDANESE
19:16:13	INTERPRETER
19:16:36	Unit PAPA347 [SITREP :] HOUSING NZ REP REQUIRED
19:16:41	POL: CAN WE HAVE VICTIM SUPPORT OFFICER ATTEND PLS AND A SUDANESE INTERPRETER
19:17:03	RRRR
19:17:52	Unit AUCKFPOL5 [K2 : IN ATTENDANCE AT INCIDENT]
19:18:12	Unit AUCKFSO3 [K6 : ON TELEPAGER]
19:18:54	** Event Type changed from FIR2POL to 1F(4) at: 23/08/11 19:18:54
19:19:09	CEV WILL ORGANISE - VICTIM SUPPORT AND TRY FOR INTERPRETER
19:23:08	AUCKFSO08 WILL BE RESPONDING IN 10 MINS
19:28:05	*
19:28:19	CEV@1928HRS - VICTIM SUPPORT ADVISED
19:28:42	MANUKAU STATION ADVISE NIL SUDANESE INTERPRETERS KNOWN TO THEM
19:28:48	*
19:31:02	Unit AUCKFSO8 [K1 : PROCEEDING TO INCIDENT]
19:38:20	AMB - COPY THANKS
19:38:20	POL: CAN WE HAVE VICTIM SUPPORT OFFICER ATTEND PLS AND A SUDANESE INTERPRETER
19:38:20	RRRR
19:38:20	CEV WILL ORGANISE - VICTIM SUPPORT AND TRY FOR INTERPRETER
19:38:21	MANUKAU STATION ADVISE NIL SUDANESE INTERPRETERS KNOWN TO THEM
19:38:21	AUCKFSO08 WILL BE RESPONDING IN 10 MINS
19:38:21	*
19:38:21	CEV@1928HRS - VICTIM SUPPORT ADVISED
19:38:21	** Cancel Event:Event Canceled by InterCAD
19:38:21	Incident Closed. Reason: Complete - Accident - Other
19:52:52	Unit PAPA347 [KC : UNIT CALLING]
19:54:06	Unit PAPA347 [SITREP :] CONFIRM FSO HAS BEEN NOTIFIED AND WHAT IS THERE ETA
19:54:15	Unit AUCKFSO8 [COMCEN COM : MESSAGE] WHAT IS YOUR ETA
19:55:08	Unit AUCKFSO8 [SITREP :] UNKNOWN ETA - JUST COMING UP TO THE MT WELLINGTON

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Some message timestamps may differ to actual times in multi-agency incidents. Communication centres can supply correct times if essential.

Figure 2516: Message Log showing fire is under control

Time	Message
19:55:08	Unit OTAR331 [K4 : ON RT INSIDE NORMAL TURNOUT AREA]
19:55:08	HIGHWAY GOING SOUTH
19:55:23	Unit PAPA347 [COMCEN COM : MESSAGE] DID YOU COPY
19:55:33	Unit PAPA347 [SITREP :] AFFIRM
19:58:38	Unit PAPA344 [K4 : ON RT INSIDE NORMAL TURNOUT AREA]
20:06:49	Unit AUCKFSO8 [K2 : IN ATTENDANCE AT INCIDENT]
20:21:11	Unit PAPA347 [KC : UNIT CALLING]
20:21:29	Unit PAPA347 [K26 : UNIT WILL BE ENGAGED AT INCIDENT - STATE TIME] 1
20:23:38	Unit AUCKFPOL5 [K4 : ON RT INSIDE NORMAL TURNOUT AREA]
20:29:23	Unit PAPA347 [SITREP :] ETA HOUSING NZ REP
20:35:42	PUT HOUSING NZ THROUGH TO PAPA347 - LANCE BLYDE
21:35:58	Unit AUCKFSO8 [K4 : ON RT INSIDE NORMAL TURNOUT AREA]
21:48:40	Unit OTAR331 [K39 : RE-TRANSMIT YOUR CURRENT STATUS]
21:49:19	Unit OTAR331 [K1 : PROCEEDING TO INCIDENT]
21:55:33	Unit OTAR331 [K2 : IN ATTENDANCE AT INCIDENT]
22:09:39	Unit PAPA347 [KC : UNIT CALLING]
22:10:01	Unit PAPA347 [K45 : COMMAND RESPONSIBILITY CHANGED TO - NAME] SO FOWLER 331
22:10:44	Unit PAPA347 [K4 : ON RT INSIDE NORMAL TURNOUT AREA]
23:47:16	Unit OTAR331 [KC : UNIT CALLING]
23:47:39	Unit OTAR331 [K4 : ON RT INSIDE NORMAL TURNOUT AREA]
23:47:42	Unit OTAR331 [STOP : MESSAGE] NO FURTHER STAND BY REQUIRED

Figure 2617: Final chain of events as per the Message Log