# Investigation into the Performance of an Automatic Fire Sprinkler System at a Medium Density Fibreboard Plant

by

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November 2006

# Introduction

1.0 Summary

1.1 An investigation was completed by VeriFire Limited into the performance of an automatic fire sprinkler system at a Medium Density Fibreboard (MDF) plant following a fire on the 11 September 2006. The investigation was undertaken in conjunction with the New Zealand Fire Service (NZFS) as part of their wider investigation into the fire.

1.2 The fire resulted from failure of a flexible hose connection to a swage fitting supplying hydraulic oil to a press ram. The hydraulic oil was probably ignited by a sodium lamp damaged by the flailing hose. The automatic fire sprinkler system operated but failed to control the fire. The inadequate control has been primarily attributed to incorrect identification of the flammable liquid process risk and inadequate sprinkler coverage.

1.3 A number of recommendations are made including a review of the automatic fire sprinkler protection design basis for similar special hazard process risks.

2.0 Purpose

2.1 The purpose of the investigation was to determine the probable sequence of events leading to the fire and its subsequent development, whether or not the automatic fire sprinkler system controlled the fire, and if not - why not.

2.2 Recommendations addressing any issues relevant to the operation and effectiveness of the automatic sprinkler protection were to be developed.

# Occupancy

3.0 Process Description

3.1 The fire occurred in a Medium Density Fibreboard (MDF) production facility. The manufacturing process consisted of refining sawdust or timber chip into wood fibres, mixing these with resins, forming the fibre into a mat, and using heat and pressure in a press to convert the mat into MDF. A summary of the process follows.

3.2 There are two similar refiner lines, one for wood chip and one for sawdust. The chip/sawdust is delivered to the refiner tower where it is converted to fibre by mechanical shear between rotating plates in two Sunds defibrators and one Hymac 63” refiner. The fibre is mixed with formaldehyde resin and wax and injected at high velocity into one of two blow lines located external to the press hall building. The fibre is dried by heated air in the blow lines, and separated from the (now moist) air stream by cyclone dryers. The dried fibre is transported to one of two pendisters at the western end of the press hall. Refer to the Press Hall Process Diagram in Figure 1. The pendisters lay down an even thickness fibre mat on a synthetic conveyor. The mat is pre-compressed, cut into sections and accelerated as it moves along the conveyor towards the press in-feed. The sections of mat are loaded onto the eight tier press loader from top to bottom by a mechanically operated incline conveyor.

3.3 The loader can be considered as a vertical array of eight steel shelves. When the press opens, the loader moves horizontally, driven by hydraulics, into the space between the press platens, delivering eight new mats. The loader simultaneously pushes the last batch of pressed MDF from the press onto the press unloader. The loader is then withdrawn from the press to be reloaded with the next batch of mat.

3.4 The press closes on the mats and follows a programmed pressure/time cycle depending on the thickness and properties of the board being produced. The press platens close upward driven by ten hydraulically operated rams located beneath the press. Each of the nine press platens is heated by heat transfer fluid supplied from the remote energy centre. The effects of temperature and pressure in the press convert the mat to MDF. The press opens at the end of the press cycle and the MDF is delivered to the unloader by a buffer on the leading edge of the loader.

3.5 The unloader can be considered as an eight-tier open-frame rack array. When it is loaded with MDF from the press it is at the top of its travel. It drops vertically on hydraulic rams to discharge each board to a discharge conveyor while the press commences the next compression cycle.

3.6 The discharge conveyor moves the MDF boards one at a time through a weigh station, thickness measuring station and marker, on to the cooling wheel. The cooling wheel stores the MDF radially, like spokes in a bicycle wheel. The rotation time allows each board to cool before being discharged for calibrated sanding, inspection and stacking.

## 3.7 The Press

3.7.1 The press was a Motala nine platen (eight board) hydraulically operated, heat transfer fluid (HTF) heated, MDF press. It was commissioned in 1984. The press was rated to produce up to 165,000 cu m of 2.440 m wide by 7.625 m long MDF, 9 mm to 36 mm thick, per year. At the time of the fire the press was reported to be manufacturing 18 mm thick board.

3.7.2 The press and the unloader were mounted in a reinforced concrete press pit 8.6 m wide x 19.3 m long x 5.5 m deep.

3.7.3 The press platens were heated by Mobiltherm 605 HTF at 260°C. The HTF was heated in the remote energy centre and supplied from a secondary, temperature regulating, control loop. The total capacity of the HTF system was reported as 120,000 litres. The HTF was supplied to the platens at a pressure of approximately 2 bar via steel reinforced rubber flexible hoses from a manifold at the southern side, in-feed end, of the press. The HTF return was via flexible hoses from each of the platens, on the southern side, out-feed end, of the press. The return HTF line expansion tank was understood to be vented to atmosphere. The HTF flexible hoses were surrounded by sheet steel clad vertical galleries to limit the extent of an HTF spray discharge in the event of a HTF leak. The HTF system was fitted with low level shut-off interlocks and an over temperature alarm. The HTF hoses were reportedly subject to replacement program with all hoses being replaced over two years.

3.7.4 The hydraulic fluid was Mobil DTE 25 with a maximum rated operating pressure of 16 MPa (158 bar). The capacity of the hydraulic system tank was documented as 27,000 litres with an estimated operating level of 21,000 litres at the time of the fire. The hydraulic fluid was transferred to the ten press rams via flexible steel reinforced rubber hoses from manifolds beneath the press. The flexible hoses were reportedly rated at 350 bar. The hydraulic oil system was provided with a low oil level interlock to shut down the pumps. There was no evidence of a replacement program for the hydraulic hoses.

3.8 The press pit was fitted with ballasted sodium high intensity discharge lamps in plastic cases on the walls of the press pit and on the inside of press foundation walls. The lamps were normally left on, and were on at the time of the fire.

## Construction

4.1 A plan and elevation of the MDF process buildings is attached at Figure 1. The MDF press hall was constructed of steel cladding on steel portal frames with a concrete floor. The walls had fiberglass reinforced plastic skylight bands at the eaves. The hall was 162 m long (from the pendister to the end of the sorting table) by 14.75 m wide. Roof heights varied over the process areas as follows: pendister: 13.1 m; mat forming line: 6.5 m; press: 9.6 m, cooling wheel: 6.5 m.

4.2 The roof was lined with an aluminium foil clad vapour barrier with a bitumen layer. The foil was supported by wire mesh above the purlins.

4.3 A two level structure was located on the northern side of the press housing the control room, workshops and offices, the instrument room, the wax floor, hydraulic room, motor control rooms, and a compressor room. The wall separating the press hall from these areas was concrete block with areas of timber framed and clad infill. The wall was fitted with windows (double glazed in front of the control room) and non-fire rated single and double access doors. The ceiling of the control room was timber clad timber framing. The floor was timber clad timber joists.

4.4 A steel-mesh mezzanine floor extended from the second floor control and wax rooms to the northern side of the press.

4.5 The refiner building was of steel clad steel frame construction with four machine floors. Three were of concrete construction and the 4$^{th}$ was of steel grate on steel frames. The walls had sections of fiberglass reinforced plastic skylight bands at the eaves and immediately above the MDF press hall roof.

## Automatic Fire Sprinkler Protection

5.0 Compliance

5.1 The MDF Hall and Annexed Buildings were fitted with an automatic fire sprinkler protection system, designated Installation Number 3. The system was designed to the requirements of the Rules of the Fire Offices' Committee for Automatic Sprinkler Installations 29th Edition (FOC Rules). The design parameters were submitted to the Insurance Council of New Zealand (ICNZ) in April 1985 and were accepted. Application for approval of the installed system was lodged with the ICNZ in March 1986 and certificate number 10138 was issued in June 1986.

5.2 The most recent inspection of this system was completed in March 2005 by Fire Protection Inspection Services Limited (FPIS) against the requirements of the New Zealand Standard for Automatic Fire Sprinkler Systems, NZS 4541:2003. Their inspection report notes that the sprinkler system does not have an existing or current Certificate of Compliance. The report identifies ten items that required remedial action to reinstate the automatic sprinkler system to the Standard to which it was installed, and a further 20 items to bring the system into compliance with the current standard, NZS 4541:2003, under the legacy provisions of Clause 109. There were no remedial items identified that would have been expected to have any impact on the performance of the automatic sprinkler protection in this fire.

6.0 Sprinkler System Design Basis

6.1 The automatic sprinkler protection of the MDF Hall and annexed buildings was designed to Ordinary Hazard Group 3 (OH3) criteria for a wood processing occupancy. The required design density was 5 mm/min over an operating area of 216 sq m. This occupancy classification is typical of similar facilities in New Zealand. The sprinkler heads at the roof and ceilings were 15 mm glass bulb conventional pattern heads rated at 68°C. The system comprised 598 heads protecting a total floor area of 4,996 sq m. There were no hydrant or hose stream water supply allowances specified in FOC Rules.

6.2 There was no specific design or approval information pertaining to the protection of the press hood or the Aqueous Film Forming Foam (AFFF) press pit protection.

6.3 The water supply design basis was a Class A dual supply comprising a primary diesel pump and tanks and a secondary electric pump and tanks.

7.0 Post Incident Sprinkler System Inspection

7.1 Refer to Figure 2 for plans showing the extent of fire propagation and automatic sprinkler head activation. Automatic sprinkler heads had fused in the following areas: throughout the press hall extending from the pendister to the eastern end of the cooling wheel, around the perimeter of the press pit and beneath the press hood, on the southern face of the refiner tower at levels one and three, in the control room and the instrument room below. Approximately 300 sprinkler heads had activated.

7.2 The control room had collapsed and the area was not accessible during the evaluation limiting the opportunity for retrospective analysis. The automatic sprinkler heads were examined from the control and instrument rooms. The heads were Viking Model A, 15 mm orifice, 68°C glass bulb conventional pattern heads. The sprinklers had fused. The frames and deflectors of these heads were oxidized and scaled on the surface and the deflectors had deformed upward. There was no sign of mechanical damage to the deflectors. Scale inside the orifice and the deflection of the deflectors indicates that the heads had been exposed to a fire below without discharging water.

7.3 The Press

7.3.1 The press was shielded from the automatic sprinkler system at the roof by an aluminium clad hood. The press hood was fitted with a manually operated sprinkler system with four heads mounted beneath the hood on each side of the press. The sprinkler heads were Viking 15 mm glass bulb conventional pattern heads rated at 93°C. The system was activated by a manually operated ball valve located on the mezzanine outside the control room, or alternatively by a solenoid operated bypass understood to be activated by a switch in the control room. Water supply to this system was via an 80 mm diameter lead-in connected to the hydrant main located approximately 20 m to the north.

7.3.2 The out-feed end of the press pit was fitted with an automatic sprinkler system comprising of six Viking Model M 15 mm glass bulb conventional pattern heads rated at 93°C at the perimeter of the pit, and a further head located where the hydraulic fluid gallery opened into the press pit. There were no automatic sprinkler heads along the sides of the press, or in the concealed spaces beneath the in-feed end of the press, or below the press hydraulic rams. The water supply to the press pit protection was routed via a 50 mm diameter feed to the reticulation pipe-work associated with the control room. A sprinkler head from the perimeter of the press pit was examined. The brass deflector and pintel screw had partially melted. The frame and inside of the orifice were oxidized and coated in carbon. This indicates that this sprinkler was depleted of water during the fire.

## 7.4 AFFF System

7.4.1 The press pit was also fitted with a manually activated AFFF system. The system was activated by manually operated water supply ball valve at floor level outside the control room and a manually activated ball valve beside the AFFF tank in the instrument room. Both ball valves were fitted with solenoid operated bypass valves understood to be controlled by a switch in the control room. The water supply to the AFFF system was routed from the 80 mm diameter lead in to the press hood from the hydrant main.

7.4.2 The AFFF was Ansulite 6% AFC-3 proportioning concentrate. The volume of plastic AFFF container connected to the proportioner could not be determined as it was destroyed in the fire. However the plastic drum was estimated to have a capacity of less than 200 litres based on its diameter and the 200 litre drum of Ansulite used for refill.

7.4.3 The AFFF concentrate supply was connected via a 17 m hydraulically equivalent length of 25 mm diameter pipe and fittings to the proportioner. The venturi proportioner had no approval marks or stamps. The proportioner was connected directly to a bank of nine 6.5 mm diameter orifice open spray nozzles (without approval marks or stamps) contained in a mesh-fronted 960 mm x 960 mm x 960 mm sheet metal box mounted on the northern wall of the out-feed end of the press pit.

## 7.5 The Cooling Wheel

7.5.1 The cooling wheel cowling was fitted with automatic sprinkler protection below. The sprinkler heads beneath the cowling had not activated. A sprinkler head from the roof beside the cooling wheel was a RASCO Model F1 15 mm orifice 68°C glass bulb conventional pattern head. The head had fused. The frame and deflector showed no sign of adverse heat exposure or carbon deposits. This head was likely to have discharged water from the time it activated until the automatic fire sprinkler system was isolated because it was located in a hydraulically favorable area by the sprinkler system lead-in.

## 7.6 The Refiner Building

7.6.1 The refiner building was provided with automatic sprinkler protection at the roof and on the first floor. The second level of the refiner tower was not fitted with automatic sprinkler protection. While this was compliant with the installation standard as the floor was open mesh, significant areas where shielded spaces were formed by equipment above were noted.

## 7.7 Water Supply

7.7.1 The water supply comprised a dedicated primary diesel engine driven fire pump and three coupled concrete tanks with a combined capacity of

1,415 cu m. The tanks were provided with up to 2,400 l/min town main infill. The tanks coupled to the fire pump via 200 mm mains. The pump set comprised a Hino EK 100 diesel engine with a continuous rating of 125 kW governed at 1745 RPM, directly coupled to a Thompson 200 x 200 x 500 pump with a 415 mm diameter impeller with a duty speed of 1660 RPM, rated at 6,960 l/min at 650 kPa.

7.7.2 The pump set was coupled to a 200 mm diameter automatic fire sprinkler main and a separate 200 mm diameter hydrant main connecting approximately 1 km to the site reticulation.

7.7.3 A secondary diesel driven pump and tank are reportedly connected to the automatic fire sprinkler reticulation main. The engine was a Detroit 6-71 246 kW at 2100 RPM connected to a pump rated to deliver 7,582 l/min at 825 kPa at 1850 RPM. This pump was not operated during the fire incident, and was not tested during the investigation.

7.7.4 The fire pumps are started by drop in pressure of either the sprinkler or hydrant main.

7.7.5 In the fire incident the Hino primary pump started at shortly after 19:00 on 11 September 2006. The pump continued to run until 05:30 the following morning when it was manually shut off. The total water consumption for sprinkler system demands and the NZFS has been estimated as 2,769 cu m for the duration of the incident.

## 7.8 Installation 3 Valve Set

7.8.1 The Installation 3 valve set and direct brigade alarm were inspected. The sprinkler system and alarm had been isolated following the fire to enable the unaffected sprinkler installations to be retained active.

7.8.2 The PFA Number for the system was 25017. Inspection records showed an installation pressure of 1,540 kPa with a defect switch pressure setting of 1,150 kPa and a fire call pressure switch setting of 1,000 kPa.

7.8.3 The direct fire alarm report records show that the Installation 3 direct brigade alarm simultaneously signaled defect and fire at 19:06:40 on 11 September 2006. The fire and defect alarms were reset and the panel isolated after 22:54 that evening.

7.8.4 The water supply from the primary diesel pump was flow tested from the fire service inlet at the Installation 3 valve set by Fire Protection Inspection Services Limited. The water supply was adequate for the sprinkler system design demand.

8.0 Hydraulic Analysis

8.1 An hydraulic analysis was completed of Installation 3 in the press hall. Refer to Figure 3 for the configuration of the sprinkler pipe work. The analysis was based on a water supply test completed on the diesel primary pump at the sprinkler system valve house. NZFS hydrant and hose stream demands were not taken into account.

8.2 The hydraulically remote design point of the automatic sprinkler system at the roof of the press hall was at the western end of the press hall above the pendister. Analysis of the remote area showed that the system was capable of achieving a minimum design density of 7.38 l/min over 216 sq m. The performance exceeded the minimum 5 mm/min over 216 sq m design requirement.

8.3 A further analysis was completed of the automatic sprinkler protection around the perimeter of the press pit. The seven sprinkler heads had a minimum design density of 5.82 mm/min based on maximum head coverage of 12 sq m per head. The automatic fire sprinkler protection in the area is considered to be localized, application specific, requiring concurrent operation of all seven heads. The available density exceeded the minimum design density of 5 mm/min over the out-feed end of the press pit.

8.4 A sequence of further analyses were performed to calculate the available design density from the automatic sprinkler protection based on the sequence of sprinkler head operation observed by witnesses.

8.4.1 The initial operating area was selected as the press pit protection and the automatic sprinkler heads beneath the control room mezzanine on the northern side of the press pit. This was the area where the initial fire ball was reported. With 12 sprinkler heads operating the minimum available sprinkler discharge density was 4.86 mm/min over the press pit. The available discharge density was below the design requirement of 5 mm/min over the protected area.

8.4.2 The second selected sprinkler operating area was the press pit, the area beneath the control room mezzanine, and the protection at the roof of the building (with coverage of 11.1 sq m per head) above the press. This area was defined by the raised section of press hall roof above the press between the mat-forming line and the cooling wheel. Hot gasses from a fire in the press pit would have accumulated beneath this section of roof before spilling down the mat forming line and over the cooling wheel. The selected analysis area exceeded the design requirements of the sprinkler system. With 60 sprinkler heads operating the minimum available sprinkler density was 2.34 mm/min in the press pit. The sprinkler discharge at the roof over the press ranged from 3.89 mm/min at the press in-feed to 9.17 mm/min at the out-feed end of the press pit (adjacent to the cooling wheel). The fire was largely shielded from these sprinkler heads by the press hood, the press, the loader and the unloader. The available discharge density at the ceiling is likely to have contributed to preventing fire spread from the press pit along the conveyor belts towards the pendisters and the cooling wheel.

8.4.3 The hydraulic analysis of the area described in paragraph 8.4.2 was repeated with the water supply at the Installation 3 fire service inlet (FSI) increased to 1,050 kPa at the demand flow to model the effect of boosting the water supply. With 60 sprinkler heads operating the minimum delivered density at the roof over the press increased from 3.89 mm/min to 5.20 mm/min. The minimum delivered density at the perimeter of the out-feed end of the press pit increased from 2.34 mm/min to 2.8 mm/min. Whether or not the increased density that would have been provided by boosting the sprinkler system water supply would have prevented fire propagation beyond the press pit can not be determined with any certainty. However the increased design density over the control room and ancillary rooms (with the exception of the hydraulic room and the HTF pump room which were not involved in the fire) would have exceeded the minimum requirements of the current edition of the New Zealand Automatic Fire Sprinkler Standard, NZS 4541:2003.

8.4.4 A final hydraulic analysis was completed with sprinkler heads activated in the press pit, below the control room mezzanine, at the roof of the press hall above the press, and at the roof of the press hall above the cooling wheel. The selected analysis area exceeded the design requirements of the sprinkler system. With 102 sprinkler heads operating the minimum delivered design density was 1.84 mm/min in the press pit. The protection over the cooling wheel ranged between 3.9 l/min and 7.89 l/min. The design density available over the hydraulically favorable cooling wheel is considered to have been effective in preventing fire spreading from the press pit into this area.

8.5 Further hydraulic analysis was not considered necessary as the progressive operation of additional sprinkler heads observed by witnesses over the mat-forming line towards the pendister would have only further depleted an already over-taxed water supply.

## 9.0 Probable Sequence of Sprinkler Operation

9.1 The initial fire-ball is likely to have activated the automatic sprinklers at the perimeter of the press pit, beneath the control room mezzanine, and some of the heads at the roof above the press. The hydraulic analysis shows that the water supply to the press pit sprinklers would have been immediately over-taxed against the FOC design requirements. The remaining sprinklers at the roof above the press pit would have operated but the sprinkler discharge was shielded from the fire by the press hood and the press. Additional sprinkler heads operated at the roof over the cooling wheel. The delivered sprinkler discharge density in this hydraulically favorable area, combined with a lack of combustible material, was likely to have been sufficient to prevent fire spread into the adjoining MDF warehouse. As hot gases accumulated at the roof of the press hall the sprinkler heads were progressively fused towards the western (pendister) end of the building.

9.2 At about this time NZFS demands from the hydrant ring main, fed from the common water supply, would have further degraded the water supply pressure.

The maximum NZFS demand was estimated to have been 13,000 l/min for manual fire fighting. The sprinkler system water supply was not boosted through the Installation 3 Fire Service Inlet (FSI).

9.3 Sprinkler protection in the control room and refiner building would have been ineffective due to their elevation, their hydraulic remoteness from the point of supply, the operation of approximately 250 sprinkler heads in the press hall, and NZFS demands.

10.0 Discussion of Sprinkler System Performance

10.1 The FOC Rules design requirements for Extra High Hazard – Process Risks involving oil and flammable liquids was 7.5 mm/min over an operating area of 260 sq m. This is comparable to the requirements of current international standards for process risk protection of mineral based hydraulic oils and heat transfer fluid. FM Global[1] recommends a design density of 8 mm/min over 280 sq m with 141°C sprinkler heads for hydraulic oil equipment, and 10 mm/min over 280 sq m with 141°C sprinkler heads for thermal oil equipment. NFPA 13[2] defines the occupancy as Extra Hazard (Group 2) due to the presents of flammable liquids. The recommended design density and operating area ranges from 12.2 mm/min over 465 sq m to 16.3 mm/min over 232 sq m. NFPA 850[3] provides specific design criteria for hydraulic equipment used in power generation plant as 10.2 mm/min extending 6.1 m beyond the process risk.

10.2 The OH3 design density and area (5 mm/min over an operating area of 216 sq m) is not considered to be adequate for process risk associated with a flammable liquid (heat transfer fluid and/or hydraulic oil) fire against the design criteria of the FOC Rules or the current protection criteria for flammable liquid process risks.

10.3 It appears that this occupancy classification and design basis has been applied to similar facilities in the past by the relevant Authorities Having Jurisdiction.

10.4 The use of low temperature sprinkler heads has been the subject of significant debate. It has been argued that that low temperature sprinkler heads will activate earlier in a fire than high temperature heads, achieving more rapid control. The counter-argument is that high temperature heads are less susceptible to operation away from the fire, restricting sprinkler operation to the fire area. In this particular fire event it is likely that the initial fire ball would have activated all heads in the immediate vicinity of the press no matter what their temperature rating. However the use of high temperature heads may have reduced the number of heads that operated over the mat-forming line, pendister and cooling wheel. This proposition is supported by the limited

[1] FM Global Property Loss Prevention Data Sheet 7-98 May 2003 Revision

[2] National Fire Protection Association, NFPA 13, Standard for the Installation of Sprinkler Systems, 2007 Edition.

[3] National Fire Protection Association, NFPA 850, Recommended Practise for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations, 2005 Edition.

extent of fire damage to the vapour barrier on the underside of the press hall roof and to plastic cable insulation remote from the press pit.

10.5 AFFF is recognized as a useful supplement to automatic fire sprinkler protection of flammable liquid fires. In this event the AFFF protection was not activated so further analysis of the AFFF system was not conducted.

## Observations and Analysis

11.0 The roof was lined with aluminium foil clad vapour barrier with a bitumen layer. The vapour barrier was burned and charred over the press, the loader and the unloader. The bitumen was smoke stained above the cooling wheel and the mat-forming line.

11.1 The steel I-beam portal frames over the press and the unloader had sagged. The inner surface of the aluminium vent ducts above the unloader and the cladding on the press hood had melted indicating a temperature of at least 660°C at the roof above the out-feed end of the press.

11.2 The control room had been gutted. The ceiling and floor had collapsed into the rooms below. The grated steel mesh decking around the perimeter of the press at floor level had buckled.

11.3 The fiberglass skylight bands on the southern side of the press hall had been burned adjacent to the press unloader. The steel cladding was intact. There was no indication of over-pressure on the cladding. This indicated that the incident involved fire rather than an explosion.

11.4 The insulation on grouped cables from the press pit extending through to the top floor of the refiner building had been burnt. The fiberglass skylight bands on the southern side of the refiner building above the control room had burnt. Vertical fire propagation from the control room to the upper levels of the refiner building was likely to have been via grouped cables and skylight bands as there was otherwise limited combustible loading in this area.

11.5 The top section of the chip conveyor belt from the chip yard to the refiner building had been burnt.

11.6 There was no appreciable fire damage to the mat-forming line or the cooling wheel. Rubber and plastic components not melted or charred. The leading edge of the incline conveyor's synthetic belt had been burned. This indicates that the fire in the press hall was largely confined to the press pit. The limited fire spread is attributed to a lack of continuity of combustible material and pre-wetting by automatic sprinklers at the roof of the press hall.

11.7 The last board to enter the cooling wheel had charred on the underside. The char was not apparent on the leading half of the board but became progressively more pronounced towards the trailing edge. Batch marking (painted blue strip) has reportedly identified that the last board on the cooling wheel was the fifth board of the batch of eight. This is supported by evidence of charred remnants of MDF on the top of the unloader. It is probable that boards 6, 7 and 8 were consumed by the fire in the unloader. There was no evidence of char on the other boards in the cooling wheel. This indicates that the fifth board from the previous press cycle was being ejected from the unloader to the weigh station when ignition occurred. The restriction of char to the underside indicates that the fire started below the board.

11.8 The material between the press platens was uncompressed mat. The press had not subjected the mat to compression and heating. It can be concluded from this, and the observations in paragraph 11.6, that the press had commenced a compression cycle when the fire occurred. The failure of a flexible hydraulic hose is likely to have prevented the press from closing on the mat between the platens. Without hydraulic pressure the press would have opened downward under its own weight.

11.9 Paintwork on the railings and the weigh conveyor indicate that flames from the press pit were confined to the press area on the out-feed end of the pit.

11.10 Plastic on a fluorescent light fitting and a switch on the block concrete wall on the lower level on the control room side of the press pit indicated that this area was not subject to direct flame impingement or significant radiant heat. Smoke staining on the inside of the doors to the instrumentation room and hydraulic room indicates that fire exposure was from the inside of these rooms, probably following collapse of the control room floor.

11.11 Concrete spalling was noted on the control room side of the press pit wall. There was no spalling apparent on the southern press pit wall. The spalling indicates that the control room wall of the press pit was subjected to greater heat exposure than the other walls of the pit.

11.12 A fire hose reel and sign on the southern press pit wall were partially melted but had not been consumed by the fire. A hose reel in a similar position on the opposite wall of the press had been largely consumed by the fire. This was further evidence that the fire intensity was greater on the northern (control room side) of the press pit.

11.13 The in-feed end of the press had cracked the top of the concrete foundation blocks and moved approximately 50 mm away from the control room. The foundations at the out-feed end of the press appeared to be intact. The displacement is attributed to thermal expansion of the press and indicates that the northern, control room, side of the press had attained a higher temperature than the southern side. This further supports the contention that the fire intensity was greatest on the control room side of the press.

11.14 The floor of the pit was coated in a layer of wet fibre approximately 30 mm deep. The top surface of the fibre was charred but the lower levels were unburnt. This, and the presence of unburnt paint on the base of steel columns and other equipment mounted on the press pit floor, indicates that there was up to 100 mm of fibre in the bottom of the pit at the time the fire occurred.

11.15 The hydraulic flexible lines to the press rams were visually examined. Four hoses had become disconnected. The swage fittings to the rams and manifold piping did not appear to be distorted or otherwise damaged. Three of the hoses had disconnected at the ram swage fittings. The sheathing and lining on these hoses had been burnt leaving the steel braid. The braid on the disconnected ends of the hoses was not significantly splayed. One hose had disconnected at both the ram and the manifold swage fittings and had fallen to the press pit floor at the out-feed end of the press. The hose braid had splayed and spread at both ends, one markedly more so than the other. The sheathing and rubber lining of this hose was largely unburnt. It is reasonable to conclude that this hose had detached from the swage fittings early in the incident, and that the significantly splayed end of the hose had flailed against other objects.

11.16 On removal of the detached hydraulic hose from the press pit a sodium lamp was found entangled in the hose braid at the splayed end. The lamp quartz tube, brass bayonet fitting and support wire appeared to be intact. Sodium lamps were fitted in the press pit on the sides of the foundation wall and were normally turned on. The length of the detached hydraulic hose was sufficient to extend to the lamp fitting immediately adjacent on the press side of the northern foundation wall. The flailing hydraulic hose could have hit the sodium lamp case. An alternative hypothesis would be that when the section of hose eventually detached from both swages it may have hit the lamp housing. It is improbable that the lamp was damaged by direct impingement of a hydraulic oil stream given that at least one end of the hydraulic hose had detached from a swage fitting. The operating temperature of quartz inner envelopes in sodium lamps is in the order of 1,100°C which could readily ignite hydraulic fluid.

11.17 The hydraulic oil in the reservoir was reported to be at the three-quarter sight glass level prior to the fire. The sight glass oil level had reduced to one-sixth by the end of the fire, below the reported one-third low oil level pump shut-down. Once the hydraulic pumps had shut down hydraulic fluid would have been expected to continue to flow into the press under gravity feed. With a system capacity of 27,000 litres it is estimated that up to 16,500 litres of hydraulic oil was released into the press pit during the fire.

11.18 The heat transfer fluid flexible hoses connecting the platens to the welded reticulation pipe work were examined. The hoses were intact. The thermal oil bleed valves were opened at the in-feed and out-feed end of the press. Air was drawn into the bleed valves indicating that the heat transfer fluid system was intact and had not been involved in the fire.

11.19 The heat transfer fluid pressure and temperature were reported as being less than 2 bar and 230°C in the secondary loop. The return path is vented to atmosphere so the maximum pressure of the HTF loop should be expected to be less than 200 kPa. A study[4] into the effects of temperature and pressure on the formation on HTF aerosols was reviewed. This indicated that the formation of an HTF aerosol spray at the return path of the press is improbable at the reported pressures and temperature.

11.20 A gravimetric analysis was completed on samples of the HTF, hydraulic oil and the liquid that had accumulated in the press pit to determine the composition of the flammable liquid in the press pit. The sample collected from the press pit was at least 99.8% water by weight. The composition of the oil fraction was inconclusive. The lack of oil in the sample indicates that the oil in the press pit had been consumed by the fire, as opposed to being extinguished.

## 12.0 Ignition Source

12.1 The ignition source could not be conclusively determined. The presence of the sodium lamp entangled in the braid at one end of the detached flexible hydraulic hose suggests that this was the probable source of ignition. Electrical arcing, which may have occurred if the hose had hit the lamp housing and wiring, may have also been causal. There was no evidence of open flames or mechanical friction in the vicinity of the press pit. A review of ignition sources for similar fires would suggest that a probable cause of ignition would be electrical equipment.

## 13.0 Probable Scenario

13.1 The flexible hydraulic hose on the control room side of the press out-feed disconnected from a swage fitting during the pressure cycle of the press. Hydraulic oil released under pressure created an oil mist in the press pit. The flailing hydraulic hose damaged a sodium lamp fitting. The hot quartz inner element of the lamp ignited the oil. The resulting fireball extended from the out-feed side of the press and down the control room side of the press pit. The fire flashed back to the hydraulic hose and the bulk of the discharged oil in the press pit. The fire flared up as the hydraulic oil and fibre in the press pit ignited.

13.2 The control room operator proceeded to initiate a controlled press shut-down. This was overridden by isolation of the control electrical circuitry as personnel evacuated the building.

13.3 Heat from the initial fire ball activated the automatic sprinkler heads around the perimeter of the out-feed end of the press pit, and under the mezzanine below the control room, followed rapidly by activation of the sprinkler heads at the roof over the press area. At this time the water supply to the sprinkler system was unable to meet the demand as approximately 60 sprinkler heads

[4] Effects of Operating Conditions on Heat Transfer Fluid Aerosols, Masters Thesis by P. Sukmarg. Texas A&M University. August 2000.

had fused, exceeding the 216 sq m (18 head) design basis. The sprinkler system had been overcome.

13.4 The fire in the press pit was shielded from the sprinkler protection by the press hood and the press. The manually operated press pit AFFF and press hood sprinkler systems were not activated. The shielded fire beneath the press continued to burn resulting in failure of additional hydraulic lines at the in-feed end of the press due to thermal expansion of the swage fittings and burning of the rubber lining.

13.5 Heat from the burning hydraulic oil resulted in hot gases at the roof which activated the automatic sprinkler heads above the cooling wheel and progressively down the mat-forming line towards the pendister. The fire did not spread from the press pit to these areas due to lack of combustible material and the operation of the sprinkler system above the cooling wheel.

13.6 Air may have been drawn into the press pit via the thermal oil galleries on the southern side of the press pit. This kept the thermal oil flexible hoses relatively cool and prevented the involvement of HFT in the fire.

13.7 With the sprinkler system overcome, the intense heat of the press pit fire caused ignition of the combustible construction of the control room. The fire spread through the control room and via the insulation in grouped cables to the refiner building. The control room collapsed and fire spread to the instrumentation and storage rooms below.

13.8 Intervention by NZFS prevented the fire from propagating to other buildings and equipment. The fire in the press pit burned until the hydraulic oil had been consumed.

## Recommendations

14.0 The fire hazard associated with process use of flammable liquids such as HTF and hydraulic oils should be identified and protected accordingly. This facility was protected as a wood processing plant. The occupancy did not identify the hazardous processes inherent in hot press manufacture of MDF resulting in the specification of an inadequate design density and sprinkler operating area. Existing automatic sprinkler installations protecting similar extra hazard process risks should be reviewed.

14.1 Automatic fire sprinkler protection should be provided throughout machinery pits (including coverage of concealed spaces) where significant quantities of flammable liquids are used and/or where combustible material can accumulate.

14.2 Press pits should be kept clear of accumulations of fugitive fibre. Clean-up procedures should prevent creating airborne fibre as this could create the potential for an explosion.

14.3 Automatic fire sprinkler protection should be installed to ensure full coverage of shielded areas below equipment and machinery.

14.4 Fire protection systems should be automatically actuated. The manually activated press hood sprinklers and AFFF press pit systems were not actuated in this fire event.

14.6 Automatic sprinkler heads installed over combustible materials with the potential for a sustained high-heat release fire should have a high temperature rating.

14.7 Interlocks should be provided to automatically shut down HTF and hydraulic pumps in the event of automatic fire sprinkler operation. Process interlocks and alarms should be provided to detect and control abnormal operating conditions such as loss of pressure and leakage of HTF and hydraulic fluid.

14.8 Construction between process areas and control and ancillary rooms should be fire and explosion rated to ensure the safety of operators and prevent potential fire spread. The rating should extend to glazing, grouped cables, services and process liquids.

14.9 Operators should be fully conversant with emergency shutdown procedures. They should have sufficient training to recognize the circumstances under which emergency shutdown is warranted and be fully authorized to initiate these procedures.

14.10 Pressurized flexible hose couplings transporting flammable liquids should be subjected to inspection and service life replacement. One international standard[5] recommends that the rating of flexible steel reinforced rubber hose should be rated at four times the anticipated maximum working pressure.

14.11 The New Zealand Fire Service operational review should consider whether boosting of automatic fire sprinkler water supplies to sprinkler protection through the Fire Service Inlet (FSI) would have been beneficial in their response to this fire incident.

[5] FM Global Property Loss Prevention Data Sheet 7-98 May 2003 Revision

## 15.0 Acknowledgements

15.1 Assistance from the following people in completing this investigation is gratefully acknowledged.

Mr M. Kelly, NZFS Engineering Unit
Mr S. Cradock, NZFS Fire Safety Officer Taupo and South Waikato
Mr B. Houston, Fire Protection Inspection Services Limited
Mr R. Nelligan, R. J. Nelligan & Associates Ltd, Consulting Engineers
Mr D. Mitchell, Mitchell Engineering Associates Pty Ltd
The Management and Staff of Fletchers Laminex MDF plant, Taupo

T. G. O'Brien
Manager, VeriFire Limited

9 November 2006

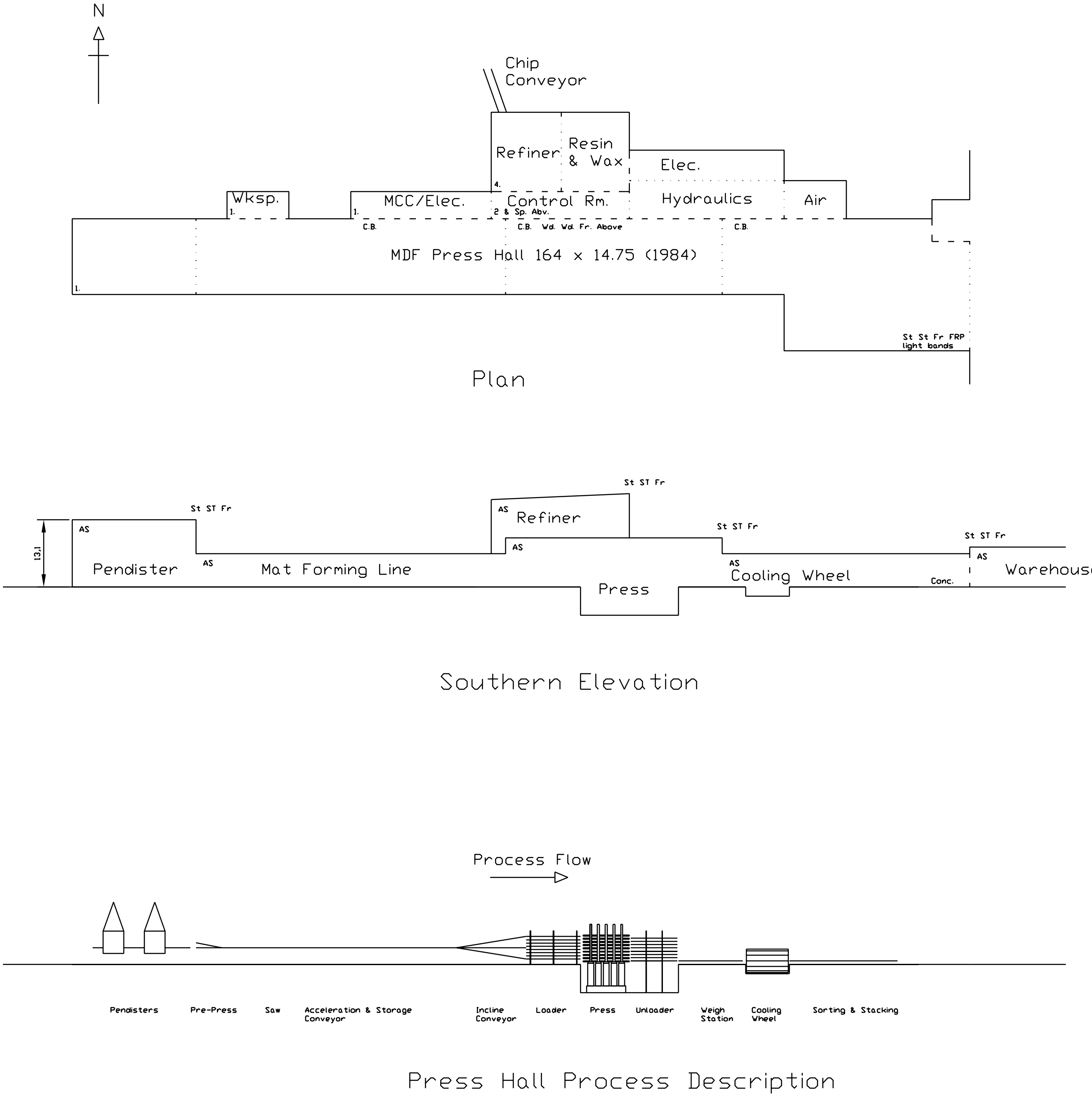
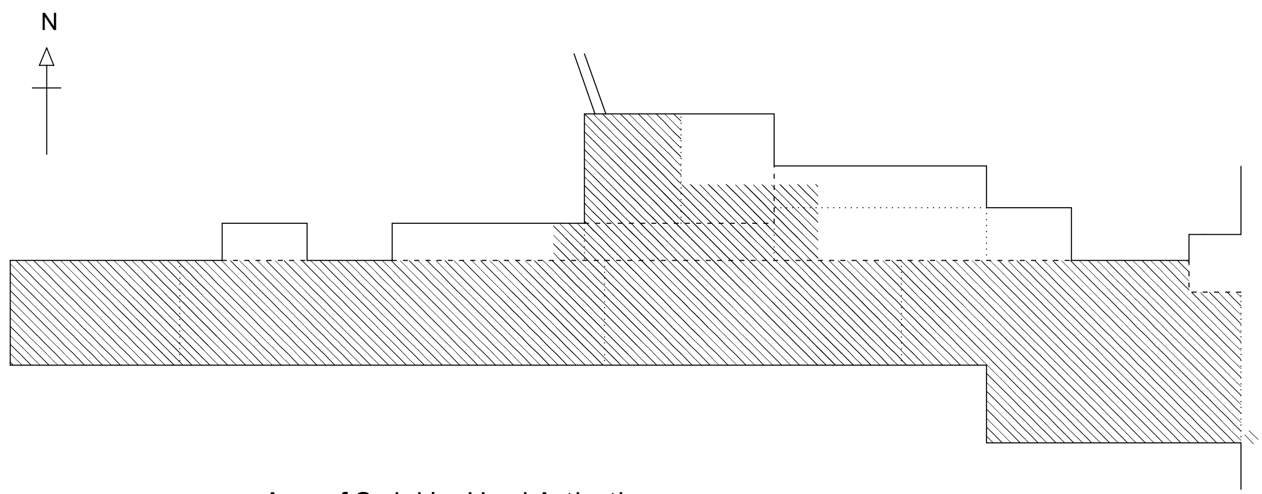
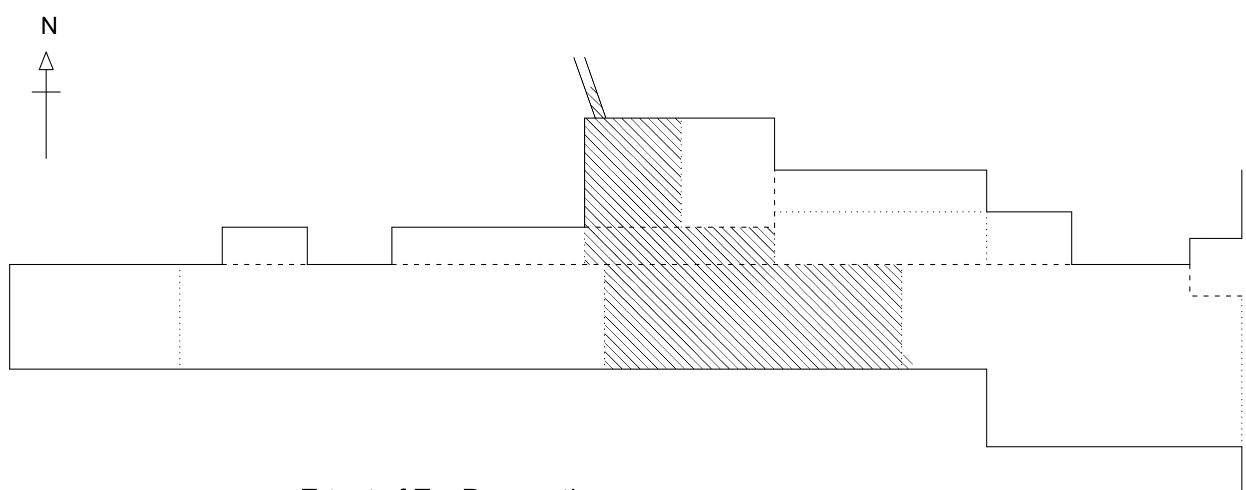



Figure 1. Press Hall Plan, Elevation and Process Description

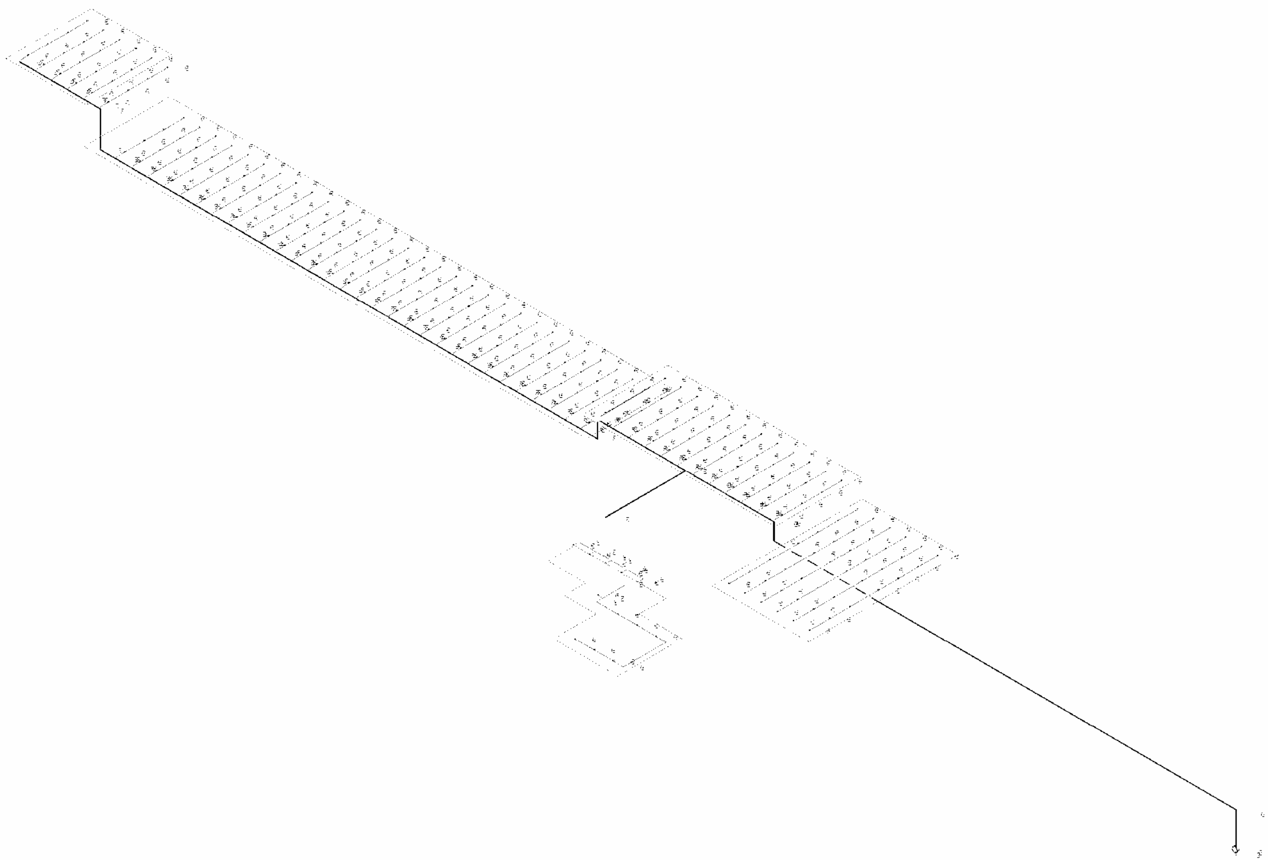



Area of Sprinkler Head Activation




Extent of Fire Propagation

Figure 2. Plans Showing Areas of Sprinkler Head Activation
and Fire Propagation



Note: The press pit and control room mezzanine automatic sprinkler protection has been offset for drawing clarity.

Figure 3. Automatic Fire Sprinkler System Hydraulic Analysis Node Diagram