Guidelines for the use of expanded foam polystyrene panel systems in industrial buildings so as to minimise the risk of fire

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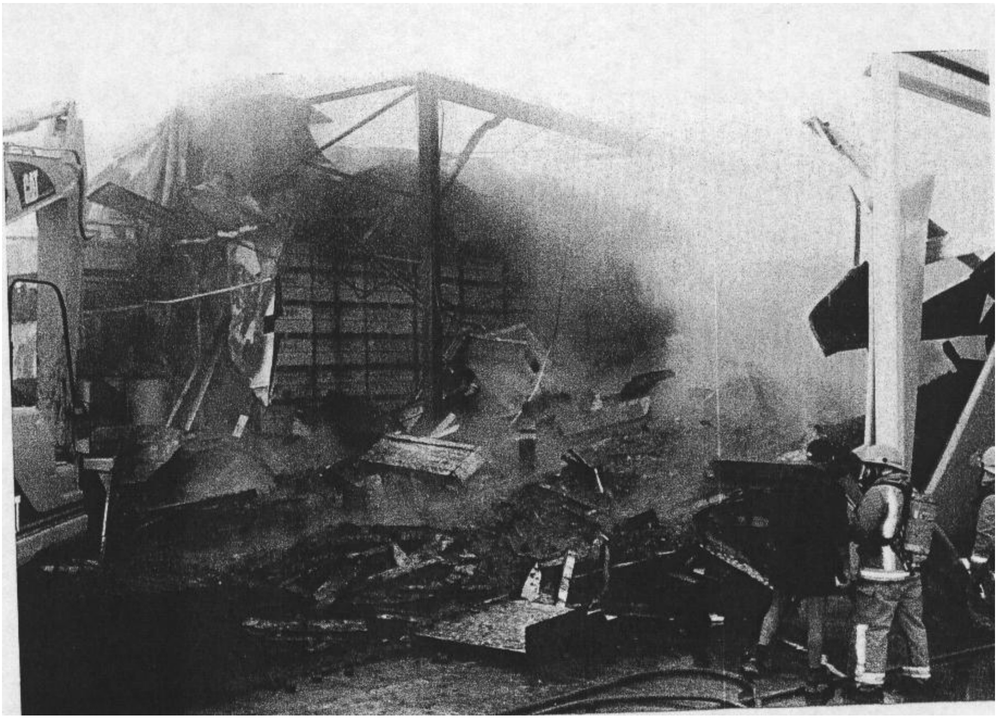

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Abstract

Many of New Zealand's primary food producers depend on buildings that are constructed using expanded foam polystyrene panel systems (EPS) for processing and controlled atmosphere storage.

It is now the most commonly used wall and ceiling lining building element in these industrial applications and has been in use for over 30 years. During this period the material has been exposed to and involved in many fires and this rate is now approaching one fire every month.

A review of New Zealand Fire Service data from the last four years shows that the major causes of fires in buildings containing EPS remain unchanged. They are: electrical faults, heating from solid fuel equipment, and hot work (welding gas cutting, braising). Electrical faults are twice as likely to start a fire than any other cause. Overseas experience is compared with some recent selected New Zealand case studies of fires to identify areas of potential concern.

The report concludes with a list of guidelines that encompass the lessons learnt from the case studies. These can be used to assist designers, constructors, renovators and maintainers of industrial buildings where EPS is present in significant quantities.

Cover Photograph. A kiwifruit coolstore and packing house built with expanded foam polystyrene panel is totally destroyed by a fire started by an electrical switchboard fault.

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1. INTRODUCTION

New Zealand's primary food producers and exporters have benefited enormously from the development of expanded foam polystyrene panel systems (EPS) as a building element. Its imperviousness combined with its insulating properties have enabled our manufacturers to renovate or build low cost, efficient food processing factories and cold stores that are as hygienic as anything around the world.

EPS can no longer be called a "new" building material as it has been in effective use in industry for over 30 years. It is well established as the first choice lining material in controlled atmosphere food processing and storage facilities. However inevitably in that time it has been involved in a number of building fires, and in many of these the material has directly contributed to losses of the building and its contents. There are also issues relating to the safety of fire fighters and rescuers in buildings when EPS is burning.

This report is intended to assist designers, builders and operators both of new facilities and those being renovated. The aim is to identify fire issues with EPS panels. The approach is to analyse NZFS data and compare the conclusions reached with reported overseas experience. A selection of local case studies is then considered to identify common trends and highlight particular problems. The author has had an involvement with each case study, hence their inclusion. Finally the guidelines focus on the building and maintenance details that experience has shown are critical for the prevention of the outbreak of fire, or once started, the containment of fire growth and spread.

2. HISTORY OF EPS IN THE NZ BUILDING INDUSTRY

For over 125 years the New Zealand economy has relied heavily on its export of primary produce, particularly meat and dairy products mostly in a refrigerated form.

As the export industry grew so too did the meat works and dairy factories that processed the products. While only a handful of these buildings are still in operation, from the beginning of 1900 to the 1980s they were some of the most substantial industrial multi-story complexes in New Zealand employing thousands of workers and shaped the industry of today.

Refrigerated spaces were mainly built from reinforced concrete or brick, with an internal insulating lining of cork or, in times of war shortages, from pumice. Interior wall linings were a variety of materials. Many older buildings were solid cement plastered or lined with timber panelling.

Processing areas were usually open via skylights to the outside air to marginally improve ghastly working conditions. As mechanisation of chains and plant occurred, steel structures evolved to support them. Despite the extensive use of galvanizing, aluminium and later stainless steel, and fibreglass, corrosion caused hygiene problems. Leaks through concrete floors caused drips and stains and allowed the growth of moulds and bacteria. As the world came to better understand how important it is to maintain food hygiene, slaughterhouses, dairy factories and fish processing plants received close attention from the NZ Ministry of Agriculture and Fisheries who imposed new work area standards.(1)

From about the 1970s non-tariff barriers were imposed by our overseas markets, and food processing firms were forced to again raise hygiene standards in manufacturing and storage. Upgrading included the removal of all wooden surfaces from the processing areas, and epoxy sealing of concrete surfaces. Buildings processing edible foods were sealed up to protect the work areas from airborne contamination, and filtered mechanical air ventilation was introduced.

Failure to do so meant that they risked losing their licence to export. This raising of standards flowed on to the domestic market so that for example, old high roofed bakeries that had baked the daily bread for decades were required to line roof trusses, and install false ceilings that could be more easily cleaned.

The introduction into the industry in the late 1970's of expanded foam polystyrene panel both as a washable hygienic wall and ceiling surface, and an insulating material was seen as a godsend for any industry demanding more hygienic workplaces. It was also a very cost effective way to build or renovate a cold storage facility. Apart from the obvious advantages of presenting a clean impervious surface, backed by a variety of thicknesses of insulation, the panel proved to be very quick to erect because of its lightness and the availability in any length. It also proved to be easy to cut through for services penetrations, doorways and windows. Lightweight doors could be made from the same material.

Older works simply poured a new concrete nib wall and erected panel in front of existing walls, and below existing ceilings or trusses to create the hygienic surfaces. However in doing so they often created concealed compartments or spaces containing combustible materials.

New cold stores chillers and freezers, were, and still are today built sometimes entirely out of polystyrene panel on a ventilated and insulated concrete pad, and under a corrugated iron roof supported outside the refrigerated envelope by steel portal frames or trusses.

Fig. 2.1 Purpose built EPS cold store for seafood storage

The actual number of individual buildings containing a significant quantity of EPS in New Zealand is not known but is estimated to be in the thousands. Baker G.(2) reports that over 750,000m^2 per annum of EPS is produced in New Zealand, and that a single large cold store can use up to 20,000m^2.

Fig. 2.2 Modern cold store built using EPS

During its introduction as a building element, the emphasis was almost entirely on EPS maintaining hygienic surfaces. Initially joins between panels were made dry using riveted aluminium extrusions but these were found to harbour contamination, so sealants were specified at the joins. Similarly coving at the base of walls has been found to need moisture proofing. The only obvious major disadvantage in the use of "polypanel" as it is commonly known in the industry, was the ease with which it can be damaged by wheeled traffic such as fork hoists or the careless set down of products close to walls and this risk of damage still exists and with it issues of maintaining the integrity of fire boundaries.

Less obvious was the increase in risk of the spread of fire when EPS was exposed to even modest heat fluxes.

In spaces requiring a vapour barrier, new construction techniques had to be developed to accommodate EPS. An example was in the use of non-ferrous bolts to support heavy plant items such as evaporators under a ceiling or even to support the ceiling in long span rooms. This reduced the heat gain by conduction into the space, and improved the loading capability of the ceiling. However under fire load conditions the stability was quickly lost.

Services penetrations initially were simply that, a hole drilled through the steel sheet, and fittings or brackets screwed or riveted to the surface. These practices have since been shown by Baker (2) to drastically reduce the integrity of the wall or ceiling when exposed to fire.

About this time the horticultural industry saw the opportunities to harvest produce such as kiwifruit, and environmentally control ripening in specially designed cool stores and packing sheds. Most of these buildings are constructed from EPS. There have been a series of spectacular fires in these buildings and in most cases the buildings and contents have been totally destroyed. Case Study No. 4 below is a typical example of this type of loss.

Another related use of polystyrene panel for food storage and hygiene has evolved in supermarkets, restaurants, liquor outlets and food malls. Many now have a walk-in cold store built within the tenancy and as part of a fit-out. In many instances it is not immediately obvious to a customer, or to a fire fighter, as the panel forms a seamless frontage. Case Study No.3 looks at a typical example of this type of fire.

The product has entered a further stage in its development as an architectural feature cladding combining the insulating qualities with clean washable surfaces. We can expect to see it appear more frequently in a wide range of commercial as well as industrial buildings. New Zealand’s largest panel manufacturer, Bondor has examples on its website.(3)

In another more recent development EPS is factory produced as modules that snap together on site to form hollow interlocking blocks. The blocks are built to form a wall that is filled with reinforced concrete forming a solid core. An exterior cladding or lining is then applied. Further information is available from the reference.(4)

A further development of the use of polystyrene is as a domestic building cladding known as External Insulated Finish System (EIFS). This comprises a 40mm or 60mm thick unlined block of polystyrene usually fixed to interior wall framing, and then coated with a thin plaster finish and painted to look like a solid plaster wall. Consideration of these domestic buildings has been excluded from this guideline document, however much of what is suggested is applicable to EIFS.

Other types of panel core systems such as polyurethane have been used in NZ however the volume is small in comparison to EPS. Fires in other panel systems are outside the scope of this report.

3. A DESCRIPTION OF EPS

Polystyrene is a thermoplastic (meaning it can be heated and remoulded repeatedly) developed in Germany before WWII and made by the polymerisation of styrene, a chemical substance whose properties were first discovered in 1830.

The foam in Expanded polystyrene panel systems (EPS) is a lightweight cellular plastic consisting of small spherical shaped particles containing about 98% air. This micro cellular closed cell construction provides EPS with its excellent insulating and shock absorbing characteristics.

The manufacturing process involves the polymerisation of liquid styrene monomer which produces translucent spherical beads of polystyrene about the size of sugar granules. A low boiling point hydrocarbon such as pentane is added to assist the expansion process.

Manufacturing EPS is a three-stage process. First the beads are expanded to about 40-50 times their original volumes by heating to about 100°C with steam in a pre-expander vessel. The beads are then cooled, and stored for 24 hours to allow air to diffuse into the beads and fill the partial vacuums created in them. This is called maturing the beads. Finally the beads are conveyed into a mould where they are again heated with steam, causing them to soften, and further expand. The mould perimeter restricts expansion so that the beads fuse together. The mould is then cooled under vacuum to remove moisture, and the pentane gas is expended.

In general there are two commonly used grades of expanded foam polystyrene. Standard, and flame retardant. Standard grades are used widely in the packaging industry. Electronic equipment such as computers, telephones, and televisions are packaged for shipment and distribution using polystyrene. This product is easily ignited and burns readily although the heat release rate is low as there is a high ratio of air to polystyrene mass in the expanded form. This occurs at 285-440°C when the decomposed or depolymerized flammable materials including styrene ignite. The flash ignition temperature is given as 345-360°C and the self ignition temperature as 488-496°C. (5)

Flame retardant grades demonstrate different behaviour when exposed to temperatures above about 100°C. The EPS commences to soften and shrink, melting away from the heat source, until it is reduced to its original density prior to expansion. On further exposure to heat above about 200°C, gaseous combustible products are formed by decomposition of the melt. However at these temperatures if ignited with a flame, the EPS extinguishes itself as soon as the ignition flame is removed. This has been shown in a number of small-scale tests for ignitability and flammability. However Dougherty G.(6) warns that the term "self extinguishing" is a misrepresentation of the properties of the material. Flame retardancy is imparted to polymers by the incorporation of additive compounds to the formulation rather than by a spray on surface treatment. The first line of defence is the sheet metal panel construction. However once this is breached the product relies on halogenated compounds that have been added to the mix. They are thought to work in two ways or mechanisms: Firstly by inhibiting the free radical chain reactions involved in decomposing the polymer into combustible gases, and secondly by the evolution of heavy halogen containing gases that protect the condensed phase by inhibiting access of oxygen and transfer of heat. The most popular compounds are reported to be aromatic bromine in fairly small amounts (1-2%) and in bead foam, can be reduced to under 1% by the addition of radical initiators such as organic peroxides. Typical flame retardants include such complex compounds as hexabromobutene and hexabromophenylallyl ether. What should be noted, is that in such small proportions, these flame retardant compounds can easily be overwhelmed in a large fire to the extent that they will only slow down the fire growth until they are expended. It is also possible that after a prolonged period (years) of exposure to even modest heating, the flame retardant compounds lose their effectiveness. EPS will eventually burn provided it is in the presence of a large ignition source or a significant heat flux of at least 50 kW/m^2 (7). Pilot ignition temperature is 320-380°C. In the absence of a pilot flame the self ignition temperature is 450-510°C.

The imperviousness of the panel is provided by a thin layer of factory painted steel bonded to the surface of the polystyrene.

EPS has one other insulating property that is often overlooked. Just as it is used to keep heat out of a cold store, it is also equally capable of slowing the rate that any heat generated can escape by conductive or convective means from an enclosed cavity. Thus a heat source surrounded by insulating polystyrene, may increase the compartment temperature in comparison with a non-insulated scenario.

4. FIRE SAFETY ISSUES IN THE USE OF EPS

4.1 Construction requirements for flame retardants

From its early days, the use of EPS created a new and dangerous fire hazard. Once the expanded foam became exposed to even a moderate heat flux it ignited and burned with alarming results.

For over ten years it has been mandatory to use a flame retardant grade of EPS in the construction industry. The flame retardant conforms to AS1366 Part 3 – 1992(8) It reduces the flammability and spread of flame on the surface of EPS products to such an extent that it is classified as "flame retardant" according to the European DIN Standard 4102(9).

While the use of flame retardants has no doubt saved a number of small fires from becoming very large fires, it is dangerous to place too much reliance on these properties when EPS is exposed to a well developed fire with a large fuel load. Similarly, it is possible that the effectiveness of flame retardants becomes compromised after long term exposure to heat from such sources as lighting, door heaters and defrost systems. This hypothesis needs to be tested by subjecting EPS to long term exposures at above ambient temperatures and then testing for flammability.

4.2 Older buildings

There are two separate fire safety issues to consider. For the older buildings that have been "retrofitted" for want of a better term, by installing an inner lining of panel, the issue is one of predicting how the modified building will behave in a fire, and if the addition of panel adds further peril to those who work in, or enter the building during a fire.

4.3 New buildings

For the new buildings the issue is one of internal and external fire spread. These buildings present a whole new set of challenges for fire regulators. Whereas large cold store complexes were previously divided into multiple fire cells by the use of concrete or brick in the dividing walls between compartments, in the new stores these firewalls no longer exist. Similarly the proximity to boundaries or other buildings needs to be carefully considered to prevent the external spread of fire.

4.4 Issues common to all buildings

While in the last 25 years the method of construction of these types of buildings has changed, the ways that they catch fire has not substantially altered. As will be seen in the New Zealand Fire Service Data and in the selected case histories, electrical fires, fires caused by hot work (welding, braising, gas cutting, grinding etc) and fire spread from overheated machinery are the major contributors.

4.5 NZ Acceptable Solution

It is reasonable to ask why sprinkler protection has not been made mandatory in such high risk areas. The justification for not installing fire sprinklers has been the Building Industry Authority (now called the Department of Building and Housing) Approved Document for the New Zealand Building Code Fire Safety Clause C/AS1.(10) This document describes an acceptable solution for fire safety. A building that has as its purpose group WL (Working (light) business or storage activities with a low fire load) is given the lowest fire hazard category of 1. Generally sprinklers are not required. Examples given in the document include: cool stores, covered cattle yards, wineries, grading or storage or packing of horticultural products, wet meat processing. These are all buildings where the use of EPS is now widespread. In the writer's opinion the examples are too general to provide accurate guidance on the level of fire protection required.

4.6 The sprinkler protection debate

There is an on-going debate about the need for food processing and cold storage facilities in New Zealand to be sprinkler protected. The same debate is taking place overseas as reported by Rakic.(11) The argument goes something like this:

The insurance industry would make the installation of sprinklers in food processing and refrigerated storage facilities mandatory, and insurers usually do require sprinklers for new installations when the insured wants some form of business interruption cover. It has the support of the NZ Fire Service in this regard.

Matherson.(12) cites the record of significant losses when un-sprinklered facilities experience a major fire, both in NZ and overseas

Fig.4.1 Typical cold store with racking from floor to ceiling increasing the risk of fork hoist damage to electrical fittings and to sprinkler heads.

Many in the industry view the capital and on going monitoring, maintenance and false alarm costs of sprinklers as uneconomic, particularly in low risk wet processing areas with few combustible materials, and cold stores with steel racking and when protected with some form of smoke or heat detection system connected to a monitored alarm.

In particular racked storage systems are seen as difficult to sprinkler protect without installing extensive pipework and sprinkler heads which are vulnerable to damage particularly from fork hoists.

While it is generally correct to blame fork hoist operators for causing most of the damage, in many cases it is a harsh criticism. Even the most skilful of operators finds it difficult to control a loaded hoist on an iced up concrete floor while wearing multiple layers of clothing and gloves, and experiencing the effects of temperatures down to -40°C. Damage to sprinklers is only part of the problem. Of wider concern is the frequent and often not reported and repaired damage to panel systems exposing polystyrene. Damage to electrical equipment such as heated doorframes is also likely to lead to increased fire risk

Fig.4.2 Damaged freezer door heater switch that has caught fire.

In cold stores the maintenance cost of glycol systems is high, and even with routine checks there have been incidences where wet sprinkler pipes have frozen when the glycol/water mix gets diluted, causing joints to burst and flooding to result. Case study No. 7 describes an instance where even dry dropper sprinkler heads have caused extensive product damage.

Despite the urgings of insurers and the Fire Service, a large number of food factories, cool, and cold stores have been built in New Zealand in the last 20 years without sprinkler protection.

As we will see in case study No.4 (the kiwifruit packing shed) the usage for which a building is designed, approved by a local authority in its consent process, and built, can differ markedly in reality. Bulk storage of combustibles such as wooden pallets can increase the fire hazard category from 1 to 4. In the seasonal industries such as kiwifruit, packing houses are idle for long periods, and empty spaces are routinely used to store and secure packaging, pallets and racking. In these circumstances, unless it can be shown by specific fire engineering design that the fire load is kept below certain thresholds, these buildings would need to be sprinkler protected to satisfy the present requirements of the Building Code. Very few of them are.

Fig. 4.3 Wooden pallets stacked over 3m high and constituting a greater potential fire load than was envisaged by the designer.

The building industry needs to better recognise the actual end user requirements for such a building, including such factors as off-season storage of combustibles. This needs to be done at the concept design stage. Unfortunately the active fire protection component of a building budget is often a casualty of cost cutting or value engineering exercises.

There is also a case for considering each of the individual compartments in closer detail and applying differing FHC to say, refrigeration and air compressor plant rooms. The same applies to electrical meter boards switchboards or panels, some of which could warrant sprinkler protection in order to save or contain the fire to the compartment where it originated.

Case study No.4 is a good example of a fire that would probably have been contained if active and passive fire protection systems were installed around the plant room. By contrast, case study No.5 is an example where sprinklers would not have activated any earlier than the heat detectors, and water damage from sprinklers might have caused more product losses than directed hand held fire hoses.

Fig. 4.4 Typical modern kiwifruit cool store plant room showing refrigeration compressors and ethylene scrubbers.

4.7 Fire resistant panel materials

There are now available a small range of fire resistant panel materials available to the New Zealand construction industry. None are presently manufactured locally but some have BRANZ Appraisal Certificates for use as a non-loadbearing external façade system and can be used where fire rated walls are required under certain conditions. These include maximum heights and supports by building elements with the same fire resistance rating. Others have UK Loss Prevention Certification Board approval and Factory Mutual approval for a variety of internal and external uses.

The components of these fire proof panels are typically a zinc coated steel sheet, fixed by an adhesive covering the whole surface area, to a fire resistant core of structural stone wool lamella or polyisocyanurate (PIR). A fire safe joint at the edge makes the panel tight for hot gases and flames.

The U values (Thermal transmittance W/m^{2}K) are typically slightly higher for stone wool, but up to 50% lower for polyisocyanurate making it more attractive as the higher material costs can be set off against lower through life thermal losses especially in low temperature cold storage applications. Designers should carefully weigh up the benefits of using a rated fire resistant panel in future applications.

		Polystyrene		Stone Wool		Poly-isocyanurate	
Typical temperature range	Wall thickness	U values	FRR	U values	FRR	U values	FRR
+7˚C down to +3˚C	75mm	0.5	Zero	0.53	-/60/60	0.27	N/a
+3 -3	100	0.38	Zero	0.43	-/120/120	0.20	-/30/30
-3 -18	150	0.26	Zero	0.29	-/180/180	0.13	-/48/47
-18 -23	175	0.22	Zero	0.25	-/180/180	0.11	-/110/70
-23 -30	200	0.19	Zero	0.22	-/180/180	0.10	N/a

Fig 4.5 Comparison of typical internal wall U values (W/m^{2}K) and fire resistance ratings minutes(-/integrity/insulation)

5. NZ FIRE SERVICE DATA

5.1 The NZ Fire Service database

Whenever the Fire Service responds to an alarm an SMS Incident Report is prepared. SMS stands for Station Management System. This is an integrated software programme that pins all activities and incidents to a particular property by its street address. This enables the Fire Service to quickly obtain information about the status of an evacuation scheme, what fire safety facilities are present, and any special operational procedures that fire crews need to know about, as well as the incident history of the address. The NZFS database permits us to focus specifically on non-residential property structure fires (as compared with domestic houses, vehicles, equipment, scrub and bush, etc). Each report is summarised and identified by a CAD (computer aided dispatch) number, date and time, and contains the following data:

	Typical Examples
Specific property use	Cool store
Location of origin	Machinery room
Equipment involved	Arc welder
Object ignited 1	Thermal insulation
Object ignited 2	Framing timber
Material 1	Polystyrene
Material 2	Wood
Fire cause	Failure to clean
Heat source	Welder
Construction type	Timber frame unprotected
Lining internal	Polystyrene
Lining ceiling	Polystyrene
General property use	Industrial manufacturing
District/VRFF	Hastings Fire District

The reports were sorted by reference to polystyrene in two ways. One spreadsheet identified 49 non-residential property structure fires from January 1998 to December 2004 (an average of just over one fire every two months over a period of seven years) where the type of construction is plastic or polystyrene. A second spreadsheet identified 56 non-residential fires from October 2000 to December 2004 where the first or second material ignited was polystyrene. (an average of over one fire every month for four years). To put these numbers in perspective, there were 2,190 (an average of 183 per month) non-residential structure fires attended by the NZFS in 2003.

There was reasonable correlation between the two lists. However the second list contained a number of incidents involving portable polystyrene/plastic constructed public toilets that appear to attract arsonists but are not of interest to this report.

Note that prior to October 2000, there were no mandatory fields for fire data so many reports prior to this date may have overlooked the role of polystyrene in many structure fires.

A selection of 26 Incident Reports were requested from the database to identify the most common causes of industrial structure fires where polystyrene is involved. These were selected because the report summaries identified them as food processing or refrigerated storage facilities. The two case studies listed below that occurred since 1998 were identified from the incident reports.

Occasionally an incident will be of sufficient severity to deserve a Fire Investigation Report. This contains details of the cause and origin if known, the Fire Service response and any recommendations and conclusions that arise from the incident. These reports are available in the public domain.

It is interesting to compare the Fire Service conclusions as to the cause and fire growth with those made by other investigators working for insurance companies. As can be expected, Fire Service Fire Investigation reports provide detailed information on the way the fire was detected, the actions and response by the fire fighters, and the fire spread. However if the cause is not readily apparent, then the Investigation Report authors are naturally reluctant to speculate as to the supposed cause. For case studies 4, 5 and 6 where Fire Service Incident Reports were produced, their conclusions are noted. The reader can compare these conclusions with those reached by the insurance company sponsored cause and origin investigations.

These conclusions are of little help to someone wanting to learn and apply the lessons from the reports. There is a need for the Fire Service to follow up such generalities with a supplementary report once the findings of investigators are produced. Most investigators are engaged by insurance companies and so their findings are privileged.

However the public domain needs to have access to the findings and the best vehicle for this is through the Fire Service.

SMS Incident reports contain information that is subject to the provisions of the Official Information Act 1982 and the Privacy Act 1993. For this reason the summary of incidents involving polystyrene (Appendix A) does not contain company names or locations. Such information is available with the prior approval of NZ Fire Service or National Rural Fire Authority.

5.2 Summary of incidents from the sample

Suspicious/unlawful/careless	5
Welding	3
Electrical/lighting/trace heating	10
Heat from solid fuel equipment	5
Mechanical failure	1
Unknown/spontaneous	2

Total of sample	26

While this sample is too small to be statistically significant, it shows that the major causes of preventable fires in buildings where polystyrene is involved, are electrical faults, heat from solid fuel equipment, and welding. Of note is that instances of fires with an electrical cause are twice that of any other. These primary causes will be further considered in the guidelines section.

5.3 Specific events

5.3.1 Ernest Adams

An example of a fire caused by heating equipment started one of the most serious industrial fires in New Zealand involving EPS. In February 2000, the Ernest Adams Ltd bakery in Christchurch caught fire. Four fire fighters were hospitalised during fire fighting operations, and while none were seriously hurt, the Fire Service report (13) considered them to be very lucky. The major fire loss occurred within 30 minutes of ignition and the rapid growth of the fire caught everyone, fire fighters included by surprise. The heat source was a gas-fired fryer. Its flue became hot due to control problems with both the gas regulator and the fume extract fan. It should be noted that the fryer had been installed and operating since September 1998, and there had been several incidents that, in hindsight should have alerted staff to a potential fire hazard. They included electrical faults caused by overheating, reports of an excessively hot firebox, and an earlier fire incident at the penetration of the flue through the EPS panel that was not attended by the Fire Service.

5.3.2 Takaka

On 21 June 2005, a major fire was accidentally started by maintainers at Fonterra's Takaka milk factory.(14) According to the NZFS press release, the fire was started by radiant heat from welding being carried out as part of off-season maintenance. 60 fire fighters battled the fire for more than five hours. However the blaze was so intense that the damaged part of the factory is not worth repairing. The extent of the damage is blamed on the quick spread of fire in a ceiling because of the extensive use of EPS. No fire separation was installed between the factory's sprinkler protected areas and those areas without sprinklers or in the roof voids.

Fonterra have a company wide policy requiring hot work permits so what went wrong? While the details have not yet been made public, it is probable that one or more of the items on a typical hot work permit checklist were overlooked.

Guidelines for hot work permits are covered in Chapter 8.3.4 of this report.

6. OVERSEAS EXPERIENCE

A research study of UK cold stores by Loader(15) identified the risk of polystyrene producing copious amounts of toxic fumes when ignited. She noted that it is essential for polystyrene to be entirely protected by non-combustible linings and sealed with non-combustible material at all joins and edges. The linings should be protected regularly for damage especially from fork hoist trucks.

Loader also concluded:

- Glass fibre, phenolic foams and foamed glass are preferable from a fire protection point of view as the burn at a slower rate or not at all. False ceilings should be lined with at least Class 1 surface spread of flame materials.

- The most common sources of ignition were found to be electrical equipment, mechanical handling equipment and transport, and cutting and welding during repairs, alterations and maintenance. The use of general purpose PVC for electrical cable insulation in sub zero conditions was identified as being a risk because of its inflexibility at low temperatures. Door heater strips were also identified as a potential hazard especially where they are run through insulation.

- Means of escape from cold store rooms, especially those small enough to only require a single means of escape, need special attention perhaps with kick out panels (insulated plugs large enough to crawl through), emergency lighting and alarms.

- The plant rooms in cold stores require special consideration, particularly when ammonia refrigerant is used. Ammonia is flammable and can be explosive at 15-28% by volume, but is readily detected at very low concentrations of 0.01% by smell and 2% by detectors. Explosion venting of plant rooms should be considered.

The UK approach is to build the walls, floors and ceilings of plant rooms with a minimum of one hour fire resistance, and fitted with a one hour fire resisting door, but if the plant room adjoins storage compartments four hours fire resistance should be provided.

Where pipework and ducting penetrate fire resisting structures they are required to be tightly sealing to preserve the fire resistance, and prevent leakages of refrigerant, and a means of isolating the plant and ventilating the machinery room in case of an emergency. It is interesting to note that dampers are not mentioned in this report.

Carton stores are identified as a major risk with smoking the greatest potential source of ignition. Banning of smoking from occupied areas often results in smokers finding quiet un-manned areas to light up.
More recently in the UK the Association of British Insurers published a Technical Briefing Paper(16) in response to the staggering losses by fire in food factories in the UK of over £425M between 1991 and 2002. Nearly all of the stores contained a significant quantity of EPS, but as the report notes; sandwich panels do not start a fire on their own. Nor is the spread of fire via the external envelope considered a high risk.

The reasons given for fires starting are varied but include; debris in an oven, oil heated above its flash point, sparks from a smoke box, arson, oil deposits on filters ignited by sparks. The majority of cases related to cooking risks or malfunction of equipment – in other words, inadequate levels of safety management. Fire spread is generally attributed to poor prevention/containment measures. Poor joint detailing and inadequate support for the panels lead to rapid delamination of the facings, exposing any core directly to the fire is reported as a key contributor.

UK cold stores are reported to have suffered fire losses amounting to £12M between 1990 and 2000. The report notes that when cold stores are separated from hot food processing plant by walls with at least 90 minutes (integrity and insulation) the risk of a loss in the cold store substantially decreases.

The Paper(16) identifies the following fire safety management items as of particular importance:

- Locate processes which are a potential fire hazard well away from sandwich panels.
- Stack combustible materials such as pallets at least 10m from panels.
- Keep forklift battery charging away from panels unless the panel system has at least 60min fire resistance.
- Fit automatic fire suppression systems to heating and cooking equipment.
- Flues to extract hot gases should not pass through sandwich panels.
- As far as possible services penetrations through panels should be avoided. If necessary gaps should be fire stopped.
- Electrical cables passing through sandwich panels should always be enclosed in metal conduit.
- Test electrical equipment located near panels at least annually.
- Avoid attaching items to panels directly.
- Sub-divide buildings into a number of fire resisting compartments where practical.
- Encourage the use of sprinkler protection.
- Prevent unauthorised access to the external cladding to reduce the possibility of arson attack.

In the USA a 1991 cold storage warehouse fire in Madison Wisconsin was considered to be of sufficient technical significance to be documented by the NFPA (17) as it contained elements of all of that is feared in a cold storage facility blaze. Two warehouses of a five building complex were destroyed together with their contents comprising 13 million pounds of butter, 15.5 million pounds of cheese and other foods. The loss was estimated at US$100M.

All of the stores were of polystyrene panel construction, with foam insulation on the roof covered in tar and gravel. A single ammonia system serviced all coolers. Product was stored on stretch wrap pallets and metal racking two deep and full height of 55ft.

[16.76m] A dry pipe sprinkler system was installed in the freezers and a wet pipe system protected the dock and a mezzanine area.

Despite arriving on the scene within two minutes of the alarm, and observing that sprinklers were activated, fire officers determined that it was too dangerous to enter the burning freezers due to a layer of heavy black smoke and the sound of creaking metal. Plastic strips over doorways could be seen being drawn into the freezers indicating a large inflow of air, suggesting that the fire had vented through the roof but this could not be confirmed because of the smoke. Despite mounting an external attack, fire fighters saw the fire spread to other freezers as the first fire-affected freezer walls collapsed and the ceiling fell. The fire continued to burn for over 24 hours and still contained deep-seated interior burning areas four days later. The fire was finally declared to be out eight days after it was first discovered.

While the damage was so extensive that a cause could not be established beyond doubt, an electric fork hoist was considered to be a primary suspect. The most likely reason for the sprinkler system failing to control the fire was attributed to the design of the sprinkler system which lacked longitudinal in rack “face” sprinklers so that there were large areas that were shielded by the product in the racks. Ceiling sprinklers were only effective for the top 15 ft [4.6m] of racking.

Once the fire overwhelmed the sprinkler system, wooden pallets and packaging materials together with butter created a significant fuel load. The foam insulation once it became exposed, significantly contributed to the fuel load. The decision to keep fire fighters out of the freezer was vindicated by the collapse of the structure within 45 minutes of the first arrival by fire fighters to the scene. Limited access for ladder trucks meant that an external aerial attack was not effective. Non fire-rated doors between freezers also allowed fire spread, and prevailing winds blew the fire plume into areas where fire fighters could not position themselves.

However the existence of masonry walls stopped the fire spread in several locations and allowed fire fighters to control the spread to other freezers.

An interesting approach proposed by a Swedish paper that was given at the XVth International Congress of Refrigeration back in 1979(18) has some points that still appear to be relevant today. The authors noted that the value of goods stored in a cold store are 5-10 times greater than the value of the building. It is therefore much more important to try to save some of the goods by isolating them, than to save the building at the time of a fire.

They suggested the following design guidelines for fire protection:

- Minimise the risk of collapse by making the structural members fire resistant.
- Make the roof of a material that, without contributing to the fire spread, is rapidly destroyed by the fire (or automatically vents over 25% of the floor area) to provide natural fire ventilation of heat and fumes.
- Provide many entrances to freezer spaces, or construct walls of materials that can be easily broken through.
- Limit the floor area of each freezer as far as is practical for materials handling, and separate each freezer with a fire resistant partition.
- Provide automatic alarms with direct connection to the Fire Service
- Install sprinklers to protect the surroundings of the cold store but do not sprinkler rooms that operate at below zero.

To this list we should add the need to isolate ventilation ducting so as to minimise the risk of tainting and smoke damage, or the carry-over of the products of combustion to unaffected areas.

Closer to home in Fairfield, NSW, Australia on 6 June 2002 a bakery caught fire. The cause was an accidental ignition of polenta flour by radiant heat in a muffin-proving room. The building with a floor area of 10,000 square metres was totally destroyed with a loss of approximately A$20M and the total loss was estimated at A$100M.

The single level factory had a concrete floor and iron roof but otherwise was predominantly constructed from EPS and this presented several major difficulties for fire fighting. An external only attack was used because of the loss of structural integrity, the fire load, heat, smoke and toxic products produced, the spread of fire hidden within panels, and the rapidity of the spread leading to flashover.

Despite the attendance of 17 appliances, 65 personnel, and 400 man hours of fire fighting the building and its contents were lost.

The NSW Fire Brigade concluded its summary report (19) with a recommendation that Standards Australia give consideration to the formation of an Australian Standards committee to formulate specific Standards for the use of insulated sandwich panels in construction, including:

- The provision of fire protection systems such as sprinkler protection, and perhaps plasterboard linings behind the metal skins and joins to prevent flame and heat penetration to the core.
- The incorporation of pre-finished and sealed areas for penetrations of services.

Two papers by Rakic (11) (20) are helpful in explaining the Australian (and New Zealand) fire requirements for wall and lining materials. Up until 2003 the Australian Building Code requirements for Spread of Flame, Smoke Developed, and Flammability Indices were determined by small scale testing in accordance with AS/NZS 1530.3(21) – "Simultaneous determination of ignitability, flame propagation, heat release and smoke release." Rakic suggests that although it is intended to change fire testing requirements to full scale testing such as ISO 9705(22), a more suitable ISO test method for sandwich panels may well be ISO 13784 Part 1(23) – Reaction-to-fire tests for sandwich panel systems. Test method for small rooms.

At this time BRANZ considers that the NZBC has shortcomings in its current requirements for EPS testing specifically in relation to flame barriers protecting the combustible EPS core. Baker (2) has identified that it is the gases evolved and escaping from the containment of the barriers that create the hazard because these gases burn and produce dense smoke.

What is clear is that as it presently used in New Zealand, EPS presents a far greater fire hazard than is generally appreciated by the engineers and architects who specify its use.

7. LESSONS FROM A SELECTION OF RECENT NZ INDUSTRIAL STRUCTURE FIRES

Case Studies

The first six of seven case studies that follow are selected to represent a cross section of recent actual industrial fires in New Zealand where EPS was involved. The final case study is included to provide an example of the type of argument used in the sprinklers-in-cold-store debate. It did not involve a fire but did result in a major product loss and there are some useful lessons to learn from it.

They are:

1. **Fire in cold store door caused by trace heating.**
2. **Fire in bakery during alterations.**
3. **Fire in supermarket cool room complex.**
4. **Loss of kiwifruit pack house caused by electrical switchboard fire.**
5. **Fire in evaporator space**
6. **Fire in meat works engine room**
7. **Loss of frozen fish due to sprinkler activation.**

The fires occurred over the period of the last 10 years in the upper North Island region. None of the fires involved loss of life or injury to occupants or fire fighters, but in each case there was building fire damage, extensive loss of stock or product, and major business interruption. For Case Studies 2, 3 and 4 the fire resulted in the buildings being subsequently demolished. As some of the information has been obtained during fire cause investigations or as evidence for use in recovery actions the names of the owners and locations of these fire incidents remains confidential.

7.1 Case Study No.1

Fire in a cold store door caused by trace heating

A large cold storage facility operates in South Auckland for the storage of packaged foods and acts as a distribution centre to supermarkets and outlets throughout New

Zealand. The facility comprises of a number of purpose built stores some parts of which are at sub-zero temperatures and others operate as chillers.

As is common in cold stores, insulated panels form both the lining of the stores and the doors. This particular area of the store contains a mixture of EPS and polyurethane panelling. Doors are protected from freezing to their surrounds by the use of what is referred to as "trace heating". This is an insulated electrical cable specifically selected to heat up when livened. The cable is housed in a slotted ABS (acrylonitile-butadiene-styrene) element and covered by an aluminium flashing that forms the sides and top of the door surround. ABS softens at around 85-87ºC. It is a thermoplastic with good resistance to impact and high tensile strength as well as resistance to chemicals. It should not however be exposed to long term temperatures of over 60ºC. The heat from the electrical cable is conducted through the aluminium and maintains the contact surface at above 0° C so water vapour that is drawn towards the cold store by the thermodynamic effect cannot condense and freeze the door to its frame or allow ice to build up around the opening.

On 6 September 1997 the Fire Service responded to an automatic alarm in the building activated by a combination of heat and smoke detectors. They found the building to be smoke logged, and that a fire had broken out in the EPS wall surround of two insulated doors separating chiller areas. (Fig.7.1). While the fire was quickly bought under control and the damage to the building contained to a small area, business interruption and product losses were large.

Fig. 7.1 Scene of fire in doorway between cold stores.

After an intensive investigation, the cause of the fire was attributed to an electrical fault in the trace heating around the insulated door. Several theories were postulated as to the actual ignition mechanism. The most popular one being that some form of arc tracking had occurred in the wiring to the trace heating element where the wires were pinched where they pass through the door frame by damage caused by fork hoist impact. (Fig.7.2). It was also suggested that damage may have caused a hot spot in the heating element.

Fig. 7.2 Corner of door frame with capping removed showing where wiring has been pinched.

A contributing cause was that the temperature of the store had been raised from -20°C to +4°C. At the higher temperature trace heating was not required, but due to an oversight it had been left on.

In a normal freezer duty it would be typical to select a heat trace element that maintained the surface of the door surround at about 30 to 40°C. This heat would normally be conducted away from the aluminium and radiated off the surface or convected by air movement. The aluminium in effect acts like a fin. If the surrounding air temperature is raised, then the amount of heat removed reduces until the aluminium finds a new hotter steady state temperature. This by itself is not sufficient to start a fire, but is a contributor to the environment for ignition to occur.

Lessons

- **Trace heat wiring that is not self limiting can cause fires if poorly installed or damaged**
- **Check suitability of, or requirement for, wiring when cold store duty changes.**
- **There is usually some other flammable material involved such as ABS element, timber packers, or masking tape.**
- **The combustible gases given off by the EPS during prolonged heating may contribute to the outbreak of fire if they are confined.**

7.2 Case Study No.2

Fire in a bakery during alterations.

There have been many reported fire incidents as a result of hot work such as welding, braising or gas cutting, so that most large firms now require maintenance workers to take out a hot work permit before carrying out such work. In fact it was insurers who first insisted on these measures following several large freezing works fires in the 1970s.

This case study does not involve hot work, but nevertheless highlights the heightened fire risk to a factory whenever alterations are undertaken.

On 28 May 1997 an operator in a large bakery in Kingsland, Auckland, noticed flames at the top of a polystyrene panel wall separating an oven from a load out area. The fire spread quickly engulfing the entire oven building and destroying it and adjacent buildings despite a concerted external attack by NZFS involving 19 pumping appliances, 10 specialist appliances, and over 100 Fire Service personnel.

The original bakery was built in 1929. On the day of the fire this building was undergoing renovations with machines breaking up the old concrete floor. The adjacent building containing the oven where the fire started had been added to the original structure in 1950 and shared a common line of columns. Further alterations to the 1950s roof to accommodate a large bread oven took place in 1983. This part of the building complex was a steel structure with steel roof trusses some of which had been changed to portal frames above the oven. Walls were brick and high glass windows and the roof was long run iron.

Fig. 7.3 Side of bread oven exposed by failure of EPS wall and ceiling panels.

A polystyrene panel wall and ceiling separated the oven from the working area and provided some protection to workers from the radiant heat of the oven which operated at 240°C. (Fig.7.3).

The principal reason for the wall and ceiling was to present a cleanable surface in the factory. Bread making involves large volumes of hot combustible crumbs and dust that can settle on ledges and sills presenting both a fire and a hygiene hazard.

The ceiling was installed by fixing it to wooden battens that were gun-nailed to the underside of the bottom chords of the steel roof trusses. One of these trusses also had the main power supply cabling to the oven tied to its bottom chord. It appears that shaking of the building from the earthworks, caused an exposed nail tip to penetrate the wiring insulation causing an earthy fault and starting a fire in the layer of combustible dust on the ceiling.

The buildings were not sprinklered and did not contain smoke or heat detectors. Neither were there any fire separations between the buildings. It is suspected that the fire started and developed in the ceiling space for some hours before it was noticed. Factory workers below the ceiling were in an extremely hot and noisy environment and knew nothing of the fire until it was well established.

Lessons

- **Buildings are most at risk from fire during periods of repairs, maintenance and upgrading.**
- **Even if no "hot work" is being undertaken, any non-routine event should be assessed for fire risk and its effect on operational machinery and if appropriate, appoint fire watchers to monitor the building before workers depart.**
- **Concealed ceiling spaces where combustible dust can gather must be included in routine cleaning procedures even when they are outside the hygienic area.**
- **EPS can conceal a developing fire from factory staff until well after it has taken hold of a roof space. Install detectors/sprinklers in confined areas that are seldom or never visited.**

7.3 Case Study No.3

Fire in a supermarket cool room complex

In December 1995, a supermarket in a suburb north of Whangarei suffered a fire thought to have started in refrigeration plant. The fire caused widespread losses to the building and its contents. Whilst the fire was generally contained to a group of insulated chillers and cool rooms at the supermarket level, and meat freezers/cold stores located at a basement level heat and smoke damage, together with the age and condition of the building resulted in it being assessed as uneconomic to repair and so it was demolished.

The chillers and freezers were built from two different types of materials, reflecting their different ages. The fire was external to them, but within the main building, The two types of enclosures within the main building behaved quite differently in the fire. The older type appeared to be constructed from a solid plaster, but in fact the walls were of a hollow construction. This part of the building was erected in the late 1960s before EPS was commercially available. Insulation was provided by multiple hollow reflective panels of aluminium foil separated by battens and protected on the outer surfaces by timber framing and a fibrous plaster painted finish. The inner surfaces were either plaster on cement or timber sarking. The most common brand name for this form of insulated wall at that time was “Sisilation.” These cool rooms were internally undamaged by the fire and did little to aid the fire spread although painted gypsum plaster board surfaces suffered heat damage from the fire. (Fig.7.4).

Fig. 7.4 Older type of cold room exterior with minimal damage

By contrast, a newer ham chiller and two meat freezers in the basement was constructed using 100mm thick EPS. The chiller suffered loss of structural stability of the ceiling although there was no noticeable load on it, and the freezers suffered from high heat flux in the upper areas of the walls so that paint burnt off both the inside and the outside surfaces, indicating a delamination and shrinkage of the polystyrene between the sheet metal outer layers. The meat freezers appeared to have retained their structural integrity only because they contained an internal steel strong-back for the rails that supported the meat carcasses. (Figs. 7.5, 7.6, 7.7)

Fig. 7.5 EPS Cold room exterior

Fig. 7.6 EPS Cold room interior showing ceiling has sagged due to load of evaporator.

Fig 7.7 EPS Cold room interior showing heat affected wall panel behind evaporators where cladding is compromised by services penetrations.

Electrical wiring and refrigerant pipework insulation mounted on the surface of the EPS was destroyed by heat in the upper hot layer, and penetrations were then open to the fire.

Lessons

- **Free standing EPS cool rooms will not protect their contents, produce or equipment, when the walls or ceiling is exposed to a high heat flux.**
- **Services penetrations through the panel will become exposed compromising the insulating property of the panel.**
- **Expect ceilings to sag dramatically even with a light load on them.**
- **Panel exposed to even moderate heat flux so that it is not discoloured can be not be expected to retain its insulating properties and will need to be replaced.**

7.4 Case Study No.4

Loss of kiwifruit pack house caused by electrical switchboard fire

Shortly after midnight on 1st June 1999, a kiwifruit packhouse and cool storage facility located in the Te Puke region, was discovered to be on fire by an employee who raised the alarm. Volunteer Fire Services from four regions were dispatched.(24) On arrival they found that the fire had spread through the packhouse and three cool stores and threatened a fourth via a canopy connecting it to those on fire. The site was not on a town water supply and so a water tanker was used. Eleven fire appliances and 58 fire fighters were involved.

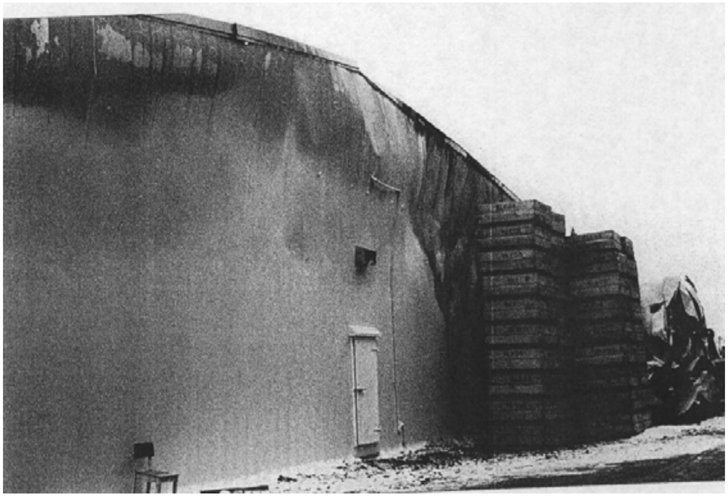

Fig. 7.8 Rear wall of cool store. Note increased fuel load from timber boxes.

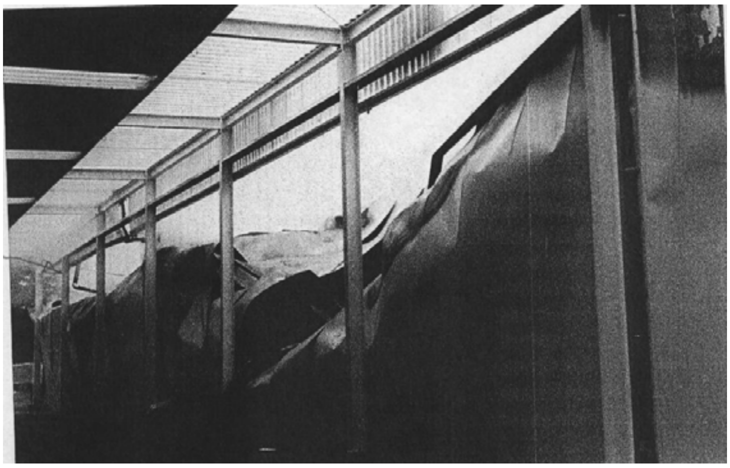

Fig 7.9 EPS Panel walls have collapsed inwards towards the fire.

The damage to the buildings and contents was so severe that demolition and debris removal commenced even as the fire was still being bought under control. (Report cover photograph, Figs.7.8, 7.9)

The original packhouse was about 20 years old and constructed with steel and timber framing and metal cladding. Three purpose built cool stores were added in 1996, 1997 and 1998. These buildings were constructed on a concrete pad with 150mm thick EPS walls and ceilings.

The fire was found to have started in the No.3 cool store plant room alongside the store. It moved quickly to the roof of the cool store where it spread to the packhouse and No's 1 and 2 stores aided by the substantial fire loading of timber bins, cardboard cartons, plastic liners, the kiwifruit, and other packaging material.

Heat and smoke damage was sustained by the canopy between 3 and 4 stores and smoke was able to enter No.4 store by various means including door openings, pressure relief flaps and services ducts.

Subsequent investigations into the cause and origin of the fire found that it had started in a switchboard within the plant room of No.3 cool store. The point of origin was generally agreed to be the electrical terminals of one of the power factor correction capacitors. The cause was thought to be a faulty connection allowing the component to overheat and ignite.

The Fire Service report(24) concluded that:
"Due to the severity of the fire in the plant room and to the electrical switchboards and wiring it was impossible to determine the cause.
However it is assumed that due to the smell of rubber burning and the explosion, that it may have been an electrical fault."

Lessons

- **Fires are most likely to start in plantrooms as these contain a large proportion of electrical switchgear, electric motors, and mechanical plant, and are the causes of most fires, so these should be built with fire separation from the storage areas.**

- **Some form of heat or smoke detector should be installed as a minimum and sprinklers in plant rooms are recommended.**
- **Ducting such as is used for ethylene scrubbing needs to have fire dampers between stores to protect products not involved in the fire.**
- **Canopies between stores will act as a bridge for fire to spread unless they contain some form of venting or firewall.**

7.5 Case Study No.5

Fire in evaporator space

In January 1999, a large cold storage facility in South Auckland caught fire. The building which was about two years old, had been purpose designed to hold frozen foods at -25°C. It comprised three separate stores, each with its own evaporator room above it, and these were refrigerated by a single ammonia system. The envelope of the stores and the evaporator rooms was built using 250mm EPS panel. Unusually for New Zealand cold stores, daily evaporator defrosts were carried out by isolating the evaporator rooms mounted on the roof from the cold store with large vertical sliding EPS doors, and reversing the fans so that warm air from the ceiling space above the cold rooms thawed the ice that formed on the evaporator coils before being blown out to atmosphere.

A problem with sealing around the EPS doors, had been solved by adding large hinged 150mm thick EPS flaps that opened up the evaporators to the outside of the building during the defrost cycle. These flaps had been in daily service for about five months before the fire. The flaps were actuated by an electrical window opener, and prevented from icing up by electrical trace heat wiring around the perimeter. (Fig.7.10). The trace heating was of a similar type and construction to that described in Case Study No.1.

Fig. 7.10 Evaporator room on roof with defrost flap in closed position

Fig. 7.11 Evaporator room showing effects of the fire.

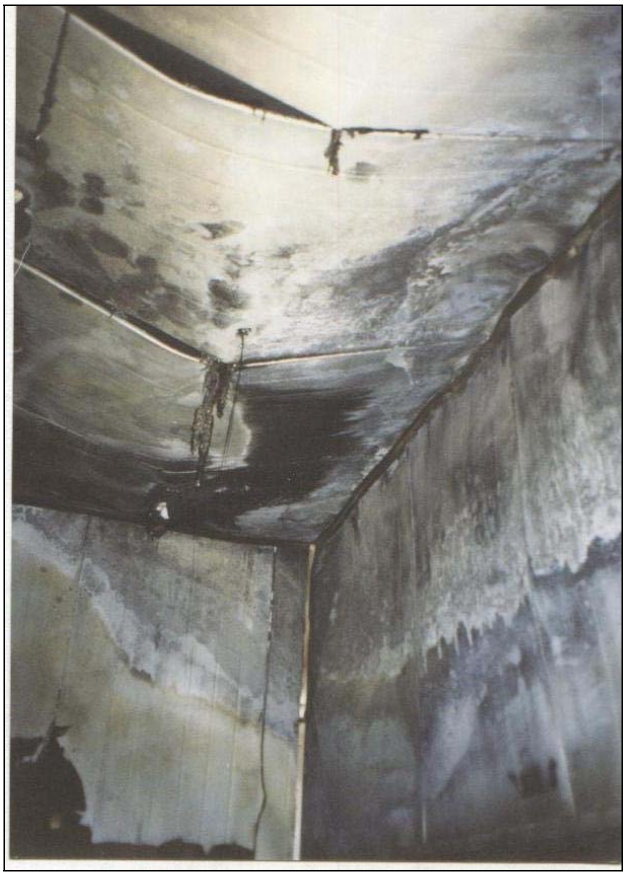

Fig. 7.12 Evaporator room inlet plenum showing failure of 250mm EPS panel caused by fire.

One evening while the store was manned and operating, a heat detector in the ceiling triggered an automatic alarm. The Fire Service contained the fire to the No.3 evaporator room within 30 minutes of arrival, however smoke and products of combustion had circulated through the cold store tainting its contents all of which had to be destroyed.

Investigators determined that the fire started in the wall surrounding the No.3 hinged flap however the fire damage was too severe to isolate the source of ignition. (Fig.7.11). Subsequent inspections of the other two undamaged flaps revealed that the trace heating wiring was very hot and had installation deficiencies. These included using masking tape (combustible) at 400mm spacing to hold the trace heat wiring in place, and pinching of the element at the corners of the frame. A large glulam timber packer had been inserted in the panel below the flap frame to give the polystyrene wall some strength. The fire growth appeared to be from the inside of the wall both outwards, and into the evaporator room. (Fig.7.12). While the electrical flap actuator was considered as a possible ignition source, the overheating discovered in the other two rooms pointed to the trace heat wiring as the most likely cause of the fire.

It appears (to the writer) that long term excessive heat from the wiring caused deformation of the breaker strip, charred masking tape strips, and reduced polystyrene so that some of the beads turned black (as evidenced by an inspection of the other two flaps) but most of it shrank back creating an insulated cavity above a finger jointed glulam beam. Whether the timber charred or the ABS breaker strip with a softening temperature of 70-80°C allowed wiring to arc track could not be determined. However there were sufficient combustible materials present to enable a fire to ignite and develop.

The trace heating was live continuously for five months. It is suspected that the wiring installation defects caused overheating of the element shortly after it was livened. It is possible that as temperatures in the cavity increased, the daily defrost helped to cool the space down as for some 30 minutes, cold air was blown across the face of the flap surround. However an unusual event occurred in the period immediately preceding the fire. An electrical surge tripped the evaporator fan motors shutting down the refrigeration over a period of about 15 hours and included a scheduled defrost which did not occur. It is possible that this extended period allowed temperatures in the wall cavity to increase to an ignition temperature.

The Fire Service SMS Incident Report(25) concluded that the source of the fire was:
"Arcing or overloaded electrical equipment."

Lessons

- **Check trace heat wiring annually, by a visual, thermal and electrical test**
- **Where possible replace with self limiting trace heat wiring**
- **Install electrical wiring strictly in accordance with the manufacturers instructions**

7.6 Case Study No.6

Fire in meat works engine room

In February 2002, a fire started in the engine room of a meat works in a central North Island town. The room contained the refrigeration compressors that maintained blast freezers and cold rooms and chillers containing beef carcasses and boned beef boxes. The building was seven years old and not sprinklered. (Fig.7.13)

Fig. 7.13 Engine room where the fire started. Note increased fuel load from refrigerant oil.

The engine room was unmanned and work had been completed for the day so that the only people on site were security guards.

One twin screw compressor set running on Freon R22, and direct driven at 1800rpm by a large electric motor, fractured its cast iron casing. The fractured part was forced against the rotating coupling between the motor and the compressor creating a shower of sparks and heat. (Fig.7.14). Freon gas carrying lubricating oil escaped from the compressor under pressure. The gas was forced through the sparks igniting the oil before spraying it onto EPS panels that formed some of the walls of the engine room.

Fig. 7.14 Damaged compressor component "machined" by coupling causing sparks and heat.

The only fuel available to burn was some small items of wooden furniture and surface mounted plastic electrical conduit and the wiring that it contained. By the time that the volunteer Fire Brigade responded to the alarm raised by security, the fire had all but self extinguished. It appears that the EPS was sufficiently well sealed at penetrations, joins and edges for it to be protected from the fire.

The PVC that was consumed in the fire generated sufficient volumes of acidic fumes to cause significant damage to other plant and fittings resulting in consequential losses.

However the room walls and ceiling were sufficiently sound for the remaining refrigeration plant in it to be run while repairs to the fire damage took place.

The Fire Service SMS Incident Report$_{(26)}$ concluded that the heat source was: *"Friction heat, overheated tyres"* and the indicated cause was reported as: *"part failure, leak or break."*

Lessons

- **Properly sealed panel systems provide a first line of defence against small fires.**

- **The panel remains functional despite acidic attack from chlorides generated by plastic fires.**

7.7 Case Study No.7

<u>Loss of frozen fish due to sprinkler activation.</u>

Although not a fire loss, this case study highlights a reason why many operators are reluctant to install sprinklers in cold storage areas where there is a low fire risk and load.

A new 860 square metre seafood processing plant, freezers and cold storage facility was built as an extension to an existing factory in South Auckland in 2003. All walls and ceilings are of EPS construction. The entire complex including cold stores is sprinkler protected as a condition of insurance cover. Sprinklers used are a standard response dry pendant type in the sub-zero rooms. Installation of the sprinklers was generally in accordance with the standard and the manufacturers recommendations.

The pallet-racked cold store operating at minus 24°C was put into service in August 2003 **before** sprinkler pipe work was fully commissioned and charged with water. Dry pendant sprinklers, as their name implies, do not contain fluid in the last 500mm or so of pipe and no water is in proximity with the cold temperature of the refrigerated space. The dry section contains a Belleville spring seal at the water end, and is held in place by an inner tube under compression from the glass bulb at the sprinkler head.(Fig.7.15).Fork hoist masts caused unnoticed damage to at least two sprinkler heads. The moisture naturally present in the installed but uncharged sprinkler pipes was drawn thermodynamically towards the open heads in the room allowing condensation and freezing to form an ice-plug in the sprinkler droppers where they penetrated through the EPS ceiling.

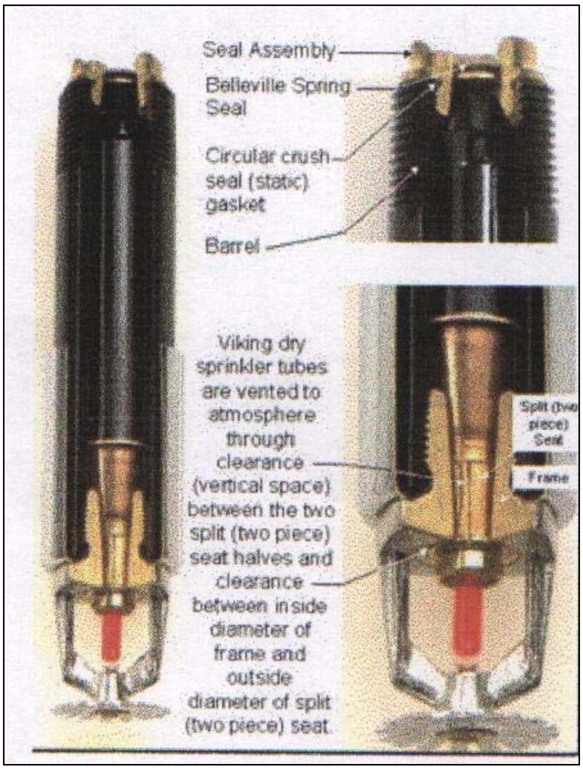

Fig. 7.15 Viking dry pendant sprinkler used in cold stores.

The store sprinkler system was subsequently charged with water in December 2003 with the ice plugs which by now were about 100mm in length, maintaining the pressure despite the damaged heads. Inspectors missed the damage because the heads were obscured by pallets of frozen product immediately below them. As is standard practice, dropper penetrations are cut oversized and the annulus around the dropper foamed in place once the escutcheon is fitted. Thus when a head is knocked, there is no noticeable damage visible from the outside of the store. Outstanding maintenance items meant that the connection to AFA (Automatic Fire Alarm) monitoring had not been made at the time of the incident.

On a Sunday in February 2004 as ambient temperatures rose, the ice plugs thawed sufficiently to allow water to flow as if there had been a sprinkler activation but no monitored alarm was raised and no one was present to respond to the gong at the valve house. The cold store had a high temperature alarm but a series of previous false alarms meant that the response by the people called out was slow. For several hours water poured down onto frozen product stacked under the sprinkler heads. Initially water froze on contact with the floor forming a thick ice layer over the surface and in behind covings at the floor wall intersection. This placed the integrity of the insulation under the wear slab at risk. Water vapour caused extensive icing of the evaporators, and water poured out under the insulated door transferring heat into, and cold out, of the compartment. Temperatures in the cold store rose such that all of the frozen product (some 400 tonnes) was declared inedible. It is feasible that only a fraction of the product loss would have occurred if a faster response had been made.

Lessons

- **Ensure that any protrusion into a cold store such as light fittings, sensors, refrigerant pipe work, and in particular sprinkler heads are physically protected from fork hoist impact.**
- **Commission sprinklers before stores are put into service, and sight all heads.**
- **Do not delay connection to alarm monitoring services once sprinklers are commissioned as timely response to alarms could significantly reduce the loses even if as in this case, the alarm is found to be false.**

8. GUIDELINES

Introduction

The purpose of this section is to provide designers, specifiers, building constructors, and maintainers with a summary of the key lessons that have been learnt from recent fires both in NZ and overseas where EPS has been involved.

The recommendations are the author's and at this time are not to be taken as building code requirements or acceptable solutions.

8.1 During new building design and construction.

Review the active and passive fire protection systems specified by the designer against the full range of usage scenarios. Determine the worst-case fire load and check that the fire hazard category (As described in the Acceptable Solution, or as determined by specific fire engineering design) is appropriate. In particular, consider off-season storage of combustible materials such as packaging and wooden pallets.

Compare the anticipated replacement cost of the contents (stock, work in progress, plant and equipment) with the replacement cost of the building. Assuming that a fire can be contained to a single compartment, determine the practical size of individual storage compartments that will contain the loss of product (plant and stock), and still enable the operation to continue at a reduced level or capacity.

Separate this optimum compartment size from other compartments with one hour fire rated walls and doors. Install dampers in ducts that are common to or connect more than one compartment.

Provide each compartment with a means of venting through the roof under fire conditions.

Consider separately attached plant rooms containing refrigeration compressors, electrical switchboards, and other ancillary plant. If the building as a whole is not sprinkler protected, consider a dedicated sprinkler system for the plant room with sufficient water supply (if town mains are not available) for the period of time that is realistically required before a fire fighting response team arrives. For example this might require two heads to be operating for up to one hour as a means of suppression or containment.

Pay particular attention to the detail and method of sealing and fire rating all penetrations through EPS regardless of their physical size and number. Bunch services to minimise penetrations and provide plugs for future changes particularly in electrical conduit or trunking.

Fig. 8.1 Modern switchboard with wiring surface mounted on ladder rack.

Cold stores fitted with pressure/vacuum breakers need to have them located where the store is least likely to be contaminated with smoke from a fire in an adjacent compartment.

Use only self limiting electrical trace heating cables.

Require and check that the builder precisely follows the panel manufacturer’s recommendations on joining, corners and flashings.

Factory Mutual Insurance Company $_{(27)}$ publish property loss prevention data sheets that give guidance in the use of EPS. These are far more stringent than the present requirements of the NZ Building Code. For example, non-approved EPS core minimum 26ga (0.5mm) steel-faced sandwich panels can only be used on the walls and roof/ceiling of existing sprinklered locations provided, in addition to a list of other restraints, they:

- Are less than 9.1m high, and are through bolted with a minimum of two bolts per panel (one near the top and one near the bottom) or alternatively are fixed by self-drilling screws on both sides to steel channels or angles at the top and bottom of the panels. Screws to be at a maximum spacing of 0.4m with a minimum of two fasteners per panel section.
- Where peripheral sprinklers are required, install a line of wet, quick response (74°C) sprinklers spaced at a minimum of 3m.
- Provide perimeter sprinklers at ceiling level.
- Protect areas above suspended ceilings with a wet pipe sprinkler system.
- Provide a minimum 950 l/min hose stream allowance.

This example shows the emphasis placed by insurers on sprinkler protection and highlights the need for the designer to consult with the owner's insurers so as not to void cover.

8.2 During renovations and upgrading.

When EPS is used to create a new lining inside an existing compartment, check that no fire hazard exists in the cavity behind the new wall or ceiling. If a hazard is to be concealed, place a detector (heat or smoke) or sprinkler in the cavity with a means of access to it for servicing.

Fig. 8.2 Cold store being built on existing warehouse floor using electrical heating cables

Alternatively, remove the hazard or fire load, or apply a form of passive protection if it is necessary to retain it. (An example is timber structural roof trusses in the ceiling space of a production area requiring a cleanable surface.) Line trusses with gypsum plaster board.

Take particular care when modifying or replacing heating plant such as boilers, hot oil generators, ovens, cookers etc. Where pipes ducts or stacks penetrate EPS ensure that adequate clearance is maintained, that exposed polystyrene is capped, and that heat cannot be radiated or conducted so as to directly impinge on EPS.

Note that a fire hazard caused by a defective installation may take months or years to eventuate, long after installers have handed over the plant to operators and maintainers.

Fig. 8.3 Food processing area being built inside existing building.

Consider the behaviour of panel used to support plant items such as evaporators under fire conditions as being at best a secondary element with no F rating. (F rating is a Building Code Fire Safety measure usually in minutes, of the time that an element is expected to withstand a fire on one or both sides, and considers structural adequacy, integrity and insulation.) Consider the option of supporting plant items from the floor. Require installers of replacement equipment to cap and seal **both sides** of old, redundant penetrations through EPS as part of their scope of work.

Treat as suspect and non-conforming, any panel that has been exposed to a significant heat flux either in a short term incident of overheating, or during long-term exposure to elevated temperatures.

Fig. 8.4 Row of evaporators suspended from EPS panel ceiling.

Fig. 8.5 Roof space above cold store

Keep roof spaces clear of unnecessary combustible material such as spare filters.

Ensure new doorways are protected from fork hoist damage by a combination of posts, nibs and crossbars. Fit rails to protect walls in high traffic areas.

Photograph 8.6 Typical cold store door showing (yellow) protective bollards.

8.3 Maintenance and servicing.

<u>8.3.1 Electrical floor, door and opening heating.</u>

Switch off heating when not required.

Establish a routine (weekly) visual inspection, and insist on prompt reporting of accidents or electrical damage to fittings and doorways.

Fig.8.7 Ice-cream manufacturing room. Note surface mounted lights and pipework.

Always have doors containing trace heating inspected by an electrician after impact damage, or annually as a preventative maintenance routine.

8.3.2 Rotating machinery especially refrigeration compressors and motors in cold stores.
Mobile plant such as fork hoists, pallet lifters, stackers.

Consider such plant as potential fire hazards and keep fuel loads in the area to a minimum.

Consider battery chargers and fork hoist batteries under charge as a potential fire risk and isolate accordingly.

Instigate a policy switching off and isolating plant when not in use or unattended.

For un-manned engine rooms and refrigeration plant rooms, install an early warning (local alarm only) heat or smoke detector to warn of impending hazardous conditions.

8.3.3 Damage to walls doors and ceiling panels.

Instigate a routine (weekly) inspection of panels that are exposed to potential impact damage. Take particular notice of passages and doorways, and set down areas in cold stores. Note that fork lift operators may cause damage without being aware of it, so that it is not sufficient to rely on them to report incidents.

Repair promptly, even if by temporary patching using sheet steel and pop rivets. This is preferable to waiting for an opportunity to carry out a more permanent repair. It is more important from a fire safety perspective, to cap and seal the exposed polystyrene, than to make it look hygienic or by hiding the damage from view.

Fig. 8.8 Freezer wall showing fork hoist damage and exposed polystyrene.

Consider the surface sheet metal and capping as the first line of defence in a fire scenario. This defence is only effective while the panel retains its shape and strength. Well-jointed panels can remain uninvolved in a fire as sufficient air is unable to allow flaming combustion. However Firestone J.(28) reports that once the panel integrity is compromised fires in polystyrene can propagate at rates of 1.5 cm/sec in the vertical direction.

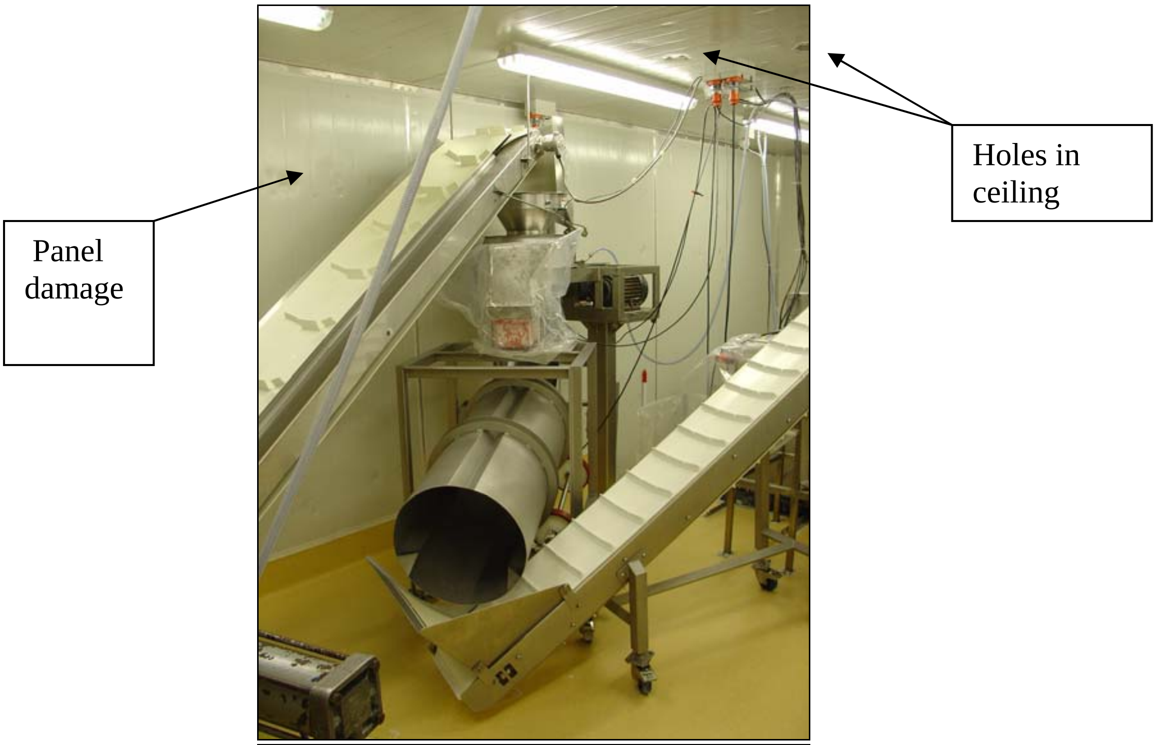

Fig. 8.9 Cheese grating room showing panel damage and old holes not sealed up.

Fig. 8.10 Typical EPS freezer door showing damage to bottom edge

8.3.4 Hot work

Hot work is one of the primary causes of fires involving EPS and yet it is the one that can most easily be prevented by a strict adherence to what is now a commonly accepted workplace procedure.

Hot work includes welding, braising, gas cutting, air arcing, grinding, drilling and any other metal work where heat, sparks or molten metal is produced. It also includes use of LPG burners to soften and apply linings and insulated lagging, or to prepare plastic pipe for joining.

For those issuing hot work permits

1. Issue hot work permits specifically for a task and to an individual tradesman rather than as a blanket cover for a compartment or region. The issue by individual, prevents another tradesman or worker carrying on with a task without personally checking for fire hazards, but rather assuming that they have been checked by the permit holder.
2. Do not issue permits for more than 24 hours.
3. The issuer should be a supervisor with sufficient experience and authority to access compartments adjoining or behind the wall of the room where the hot work is to be performed. This access may then be required by the fire-watcher during and after the work.
4. The issuer must inspect the site.
5. Designate fire watchers as a primary responsibility.

For those carrying out the hot work

6. Locate the nearest fire alarm
7. Have cutting and welding equipment in good working order
8. Sweep the floor clear of all combustible materials
9. Remove all flammable liquids (gas free tanks)
10. Rope off the affected area to prevent inadvertent access

11. Wet down combustible floor and wall linings
12. Use fire blankets to cover walls etc.
13. **Identify any EPS panel and recognise that radiant heat may ignite the polystyrene behind the sheet metal cladding without the fire being visible from the front surface. – take particular care when hot work is close to penetrations in the panel.**
14. Do not use sheet metal screens to protect flammable materials as they are capable of transmitting heat while screening the fire from the fire watcher.
15. Where possible limit welding to site-tacks and remove for full welding.
16. If it is impossible to carry out the task without heating the EPS consider alternative ways to do it. Can the job be done another way without risking a fire?

For those designated as fire watchers

17. Fire watchers to have a portable extinguisher/charge fire hose and know how to operate it.
18. Be aware that gas cutting or air arcing can throw molten metal several metres across a compartment.
19. To regularly check the rear wall/ceiling/floor on the opposite side to the hot work.
20. To attend during and for at least 30 minutes after hot work is completed as authorised by the permit.
21. To be aware of the location of the nearest alarm.
22. To re-inspect the area 30 minutes after the completion of all work on that day.
23. Fire watcher to then return the permit to the supervisor.

8.3.5 Cold work

When cutting holes through panels for pipe or cable penetrations, use liquid cooled cutting or drilling equipment to prevent overheating.

After making a penetration cover the exposed plastic foam with a close fitting metal collar or bush. Do not rely on plastic conduit to separate electrical cables from foam.

Do not mount electrical switches on EPS panels so that the body of the switch penetrates the metal skin of the panel.

Electrical panels, switchboards, and gas fired or electrically operated heaters should not be positioned directly against an EPS wall. An air gap should be maintained, or a sheet of fire resistive material placed between the equipment and the wall. Consider radiation effects particularly for long term exposure.

When working on EPS panels, always replace the joint cover strips and refit any seals that have been removed during the work.

In factories where EPS is the predominant wall and ceiling material, consider a Permit to Cold Work procedure similar to the hot work permit described above. A sample permit is given in Zurich Risk Engineering. (29)

9. CONCLUSIONS

In the future New Zealand food processors and cold store operators can expect to be placed under increasing pressure to better protect their building assets, the foodstuffs they produce or process and the staff they employ. This pressure will be applied respectively by insurers, customers, The Department of Labour (Occupational Safety and Health) and the Fire Service.

By heeding the lessons that have been learnt from previous fires where polystyrene panels has been a factor, both here in New Zealand and overseas, the stake holders will be better placed to avoid a fire loss, or to survive the potentially devastating effects of a fire incident if it develops.

While preventing fires should always be the first priority of food processing and cold store management teams, our recent history shows that we can expect them to continue to break out at the rate of about one incident/ month requiring a Fire Service intervention.

If the guidelines outlined in Section 8 of this report are followed, the risk of fire in industrial buildings where expanded foam polystyrene panel systems are used, can be minimised.

A summary of these guidelines:

During new building design and construction:

- **Review fire protection against the worst-case fire load scenario.**
- **Compare the cost of the contents with the building replacement cost and separate accordingly.**
- **If possible provide roof ventilation.**
- **Separate plant rooms and sprinkler protect them.**
- **Locate pressure/vacuum breakers away from exposure to other compartment fires.**
- **Use only self-limiting trace heating.**

- **Require and check that builders follow the manufacturer's joining, corner and flashing details for EPS.**

During renovations and upgrading

- **When lining an existing compartment with EPS, fire protect cavities created.**
- **Maintain separation/shielding of EPS from hot services.**
- **Cap all exposed EPS on both sides.**
- **Recognise that EPS will not support weight during a fire.**
- **Replace panel that has been exposed to heat.**
- **Keep roof spaces clear of combustibles.**
- **Protect doorways from impact damage.**

During maintenance and servicing

- **Switch off electrical heating when not required**
- **Routinely inspect and test trace heated doorways and after impact damage**
- **Repair all damaged and exposed polystyrene even if with a temporary patch.**
- **Minimise fuel loads in EPS buildings**
- **Isolate batteries under charge**
- **Install heat or smoke detectors in un-manned engine rooms**
- **Instigate and rigidly enforce a hot work permit.**
- **Consider a cold work permit system in EPS buildings.**

10. REFERENCES

1. **MAF Qual Manual MQD1: Code of Practice Part A – *Sanitary Design of Dairy Food Factories.* Issued Dec 1988**
2. **BRANZ Report No FCR9 – *Improving the fire performance of polystyrene insulated panel in New Zealand* – April 2004. Authors Collier P.C.R and Baker G.B.**
3. **Bondor New Zealand website www.bondor.co.nz posted May 2005**
4. **Superform Building Systems Polyblock website brochure posted September 2004. www.superform.co.nz**
5. **APME "*Fire Behaviour of Expanded Polystyrene (EPS) Foam*". Rev. 1 18/12/1992.**
6. **Dougherty G., South Australian Fire Service – Email to NZFS dated 16 Feb 2000 appended to Fire Service Investigation Report for Ernest Adams Ltd Christchurch, fire on 4 Feb. 2000, reported by Joe Hefford.**
7. ***Flammability Handbook for Plastics*. Technomic Publishing Company Westport Connecticut 3rd edition 1982.**
8. **AS 1366 Part 3:1992 *Rigid cellular plastics sheets for thermal insulation. – Rigid cellular polystyrene – Moulded. (RC/PS-M)***
9. **European DIN Standard 4102-1 *Fire behaviour of building materials and elements. – Classification of Building Materials. – Requirements and testing.***
10. ***Approved Document for New Zealand Building Code Fire Safety Clauses C1, C2, C3, C4 first published December 2000 effective from*1 June 2001.**
11. **Rakic J. *Fire rated insulated (sandwich) panels* – p33 Fire Australia May 2003.**
12. **Matherson P. Manager Risk Management Services ACE Insurance Ltd article in FPANZ issue 94 July 2004.**
13. **Fire Investigation Report for *Ernest Adams Ltd*. Incident Number M074901 Date of incident 4 February 2000.**
14. ***Fire Service's Takaka dairy factory fire findings*. NZFS Press Release 13 July 2005.**
15. **Loader K. *Fire Protection of Cold Storage Warehouses*. Fire Protection No.140**

16. **ABI Technical Briefing: *Fire performance of sandwich panel systems*. May 2003**
17. **NFPA Summary Fire Investigation Report. *Cold Storage Warehouse Fire* Madison, Wisconsin May 3, 1991. Author Isner Michael S.**
18. **XVth International Congress of Refrigeration (Venice – 1979) Proceedings Vol.IV.**
19. **Tip Top Bakery Fire, Fairfield PIA No.011/02 Post Incident Summary Report. NSW Fire Brigades August 2002.**
20. **Rakic J. *Plastics burn, don't they?* Fire Australia 2004.**
21. **AS/NZS 1530.3 1989 *Simultaneous determination of ignitability, flame propagation.heat release and smoke release.***
22. **ISO 9705: *Fire Tests – Full-scale room test for surface products*. (ISO, 1993)**
23. **ISO 13784 Part 1 – *Reaction-to-fire tests for sandwich panel systems. Test method for small rooms.***
24. **Fire Investigation Report Event No. AO49345 Eleos Trust 242 Rangiuru Road Te Puke 1 June 1999.**
25. **NZ Fire Service SMS Incident Report CAD Number AO26771 Date of Incident 25 Jan. 1999.**
26. **NZ Fire Service SMS Incident Report CAD Number A275747 Date of Incident 3 Feb. 2002.**
27. **M Global Property Loss Prevention Data Sheets 1-57 *Rigid plastic building materials*. Sept. 2003.**
28. ***Effectiveness of sprinklers in cold-room storage warehouse fire.* Correspondence from Firestone J. Fire Engineer NZFS. 10 May 2001.**
29. **Gravestock N. *Polystyrene Insulated Panel.* Presentation Marsh & McLennan Companies. 30 April 2003.**
30. ***Risk Topics*. Zurich Risk Engineering Issue No.2 August 2002.**

11. Appendix

APPENDIX A

List of structure fires involving polystyrene

CAD No.	Date	Industry	Ignition	Size	Cause
623	26.1.98	Coolstore	polystyrene	small	short circuit arc
M003594	10.8.98	Meat works	Fire in meat meal hopper	large	Heat from electrical equipment
A002999	21.8.98	Shopping mall	Rubbish bin fire	small	unlawful
A026771	25.1.99	Coolstore	polystyrene evap room	large	trace heat wiring
W074468	23.12.99	Coolstore	machine room	total	welding torch
M072186	21.1.00	Fish factory	ash and embers	large	Heat from solid fuel equipment
M074901	4.2.00	Bakery	polystyrene	total	hot flue gas
M078830	22.2.00	Pet food	polystyrene	large	suspicious
M079750	26.2.00	Fish factory	cardboard	large	heat from smoking material
W083407	5.2.00	Meat works	polystyrene	large	unknown
M090105	17.4.00	Coolstore	Electrical wiring	small	Heat from overloaded equipment
W154586	4.11.00	Dairy powder	food	smoke	Heat from gas fuelled equip.
A250322	20.10.01	Rendering	polystyrene	total	unknown/electrical
A275747	3.2.02	Meat works	electrical equipment	small	compressor failure
M274077	23.6.02	Dairy coolstore	polystyrene	small	welding/cutting
M290349	10.9.02	Dairy whey	electrical equipment	smoke	short circuit arc
W351475	25.11.02	Coolstore	polystyrene	small	trace heat wiring
M340587	29.4.03	Meat works	polystyrene	small	welding
A374312	11.5.03	Bakery	polystyrene	small	unlawful
M376690	10.10.03	Bakery	rubbish fire	small	unlawful
A404971	19.10.03	Milk powder	wax	small	heat from electrical equipment
W442708	13.12.03	Meat works	hot damp overalls	large	spontaneous combustion
M393938	17.12.03	Shopping mall	smouldering from hot object	small	careless with heat source
M432361	25.5.04	Coolstore	polystyrene	small	short circuit
A461576	5.7.04	Meat works	polystyrene	small	heat from electrical equipment
W507847	31.8.04	Dairy cheese	cardboard	small	light ballast/elctrical insulation