Coldstore Engineering in New Zealand

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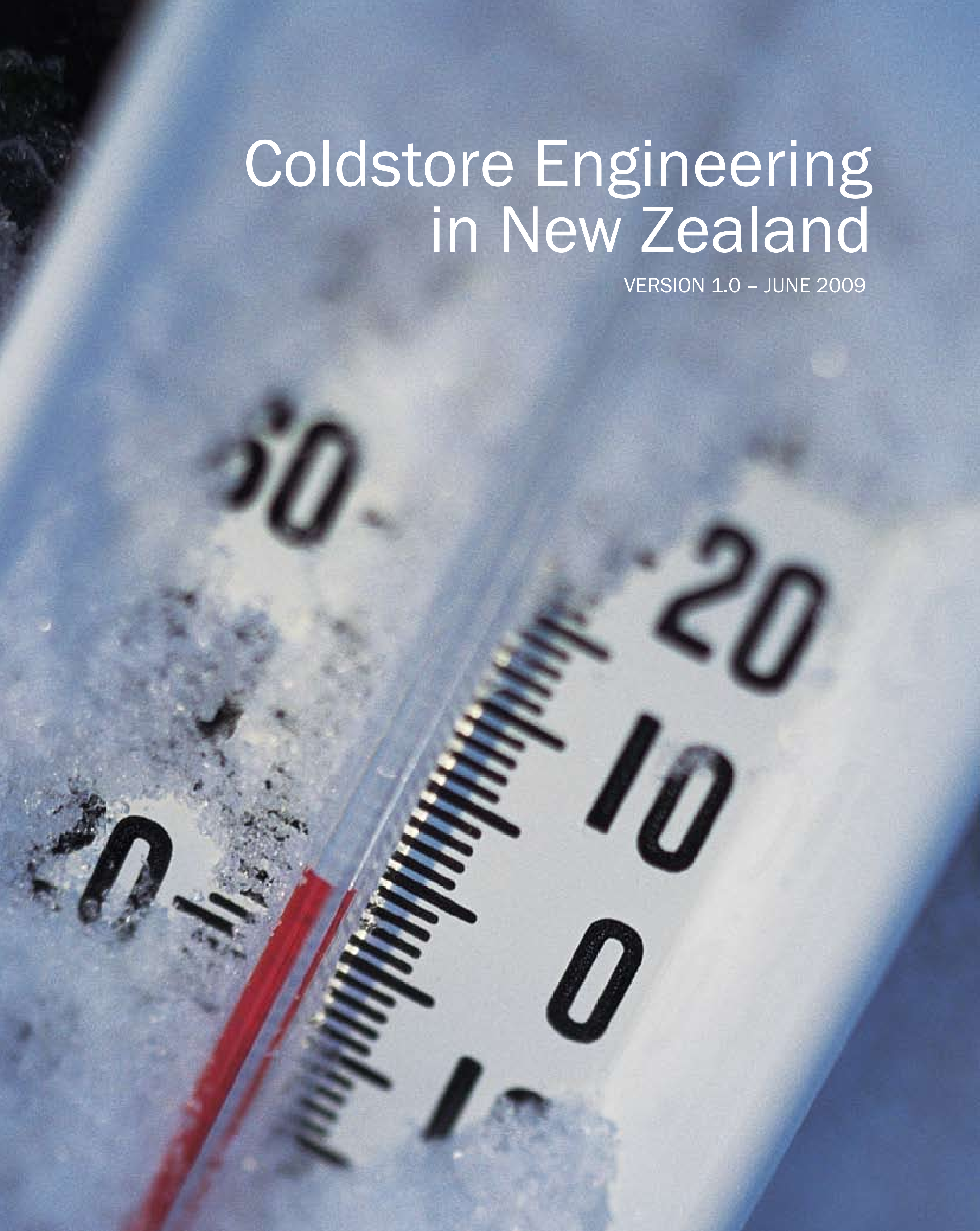

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CONTENTS

Introduction 3

1. Brief History of Coldstore Development in New Zealand 7

2. Design Considerations 11

3. Legislation, Regulations and Standards 17

4. Appropriate Structures 23

5. Insulation Techniques 29

6. Fire Engineering 33

7. Refrigeration 43

8. Electrical Services 51

9. Commissioning 59

10. Operations 60

Appendix A: Glossary 61

Appendix B: Example “Hot Work” Permit 62

Appendix C: Approved Handlers and Approved Fillers 64

References 65

The IPENZ Coldstore Working Party 68

INTRODUCTION

In 2006, Warrington Fire Research Australia provided a technical audit of the design review unit of the New Zealand Fire Service (NZFS). Warrington made many recommendations, including the development of notes to guide fire engineering practitioners undertaking performance-based fire engineering design. This recommendation led to IPENZ convening a Fire Engineering Taskforce with members drawn from the NZFS's Design Review Unit, the Department of Building and Housing (DBH), several local authorities, and practising engineers from the Society of Fire Protection Engineers.

In 2007, the Taskforce published *Hot Topics* (IPENZ), a document which advocated the International Fire Engineering Guidelines for design, the Construction Industry Council guidelines for documentation, and described the attributes of a fire engineer. However, *Hot Topics* contains no technical detail.

In April 2008, an explosion and fire destroyed a cold storage plant at Tamahere, near Hamilton. Firefighters responded to an alarm probably triggered by leaking refrigerant and were already on site when the explosion occurred. The explosion killed one firefighter and seriously injured seven others.

Aware of several serious fires in coldstores, IPENZ decided to convene a working party to study many aspects of coldstore engineering. The working party was a partnership of IPENZ Technical Interest Groups, design engineering companies, coldstore operators, and government regulators that work in the field of coldstores in New Zealand. Its aim was to write design guidelines in the form of a practice note, thus satisfying the Warrington recommendation on fire engineering, but with a scope wide enough to cover economics, insurance, structure, insulation, refrigeration, electrical, operations and maintenance of a coldstore.

REFRIGERATED BUILDINGS – DEFINITIONS

Coldstore, coolstore, chiller and freezer are all general descriptions of any refrigerated building constructed to cool product or keep it cool. These buildings are primarily used in New Zealand in the various food processing industries to retard bacterial degradation of food, that is, to preserve it. Pharmaceutical and photographic industries may also use coldstores.

Commonly accepted generic descriptions are as follows.

- Chillers operate from 0°C to 10°C and are used to lower product temperature (that is, remove heat from the product).
- Coolstores operate from 0°C to 10°C and are used to hold product temperature in this range.
- Freezers operate from -40°C to 0°C and are used to freeze product (that is, remove heat from the product to change the phase of the water contained in the product to ice). Blast freezers are specifically designed rooms which operate with high-volume/velocity airflow to freeze the product. Plate freezers, individual quick frozen (IQF) freezers, cryogenic freezers and other specific freezing systems are generally a specific plant item, contained inside an insulated room (coldstore).
- Coldstores operate from -30°C to 0°C and are used to keep product temperature in this range (frozen at appropriate temperature).

These terms and the temperature ranges vary between industries – horticulture, fish, dairy, meat, and vegetable processing – but the general terminology and principles are the same. For this practice note "coldstore" will be used as a generic term for all refrigerated buildings except where reference is made to a specific type of store.

The term "zero store" is frequently encountered being based on 0°F (-18°C).

Many parties are involved in the execution of a cold storage project and managing the associated risk, including:

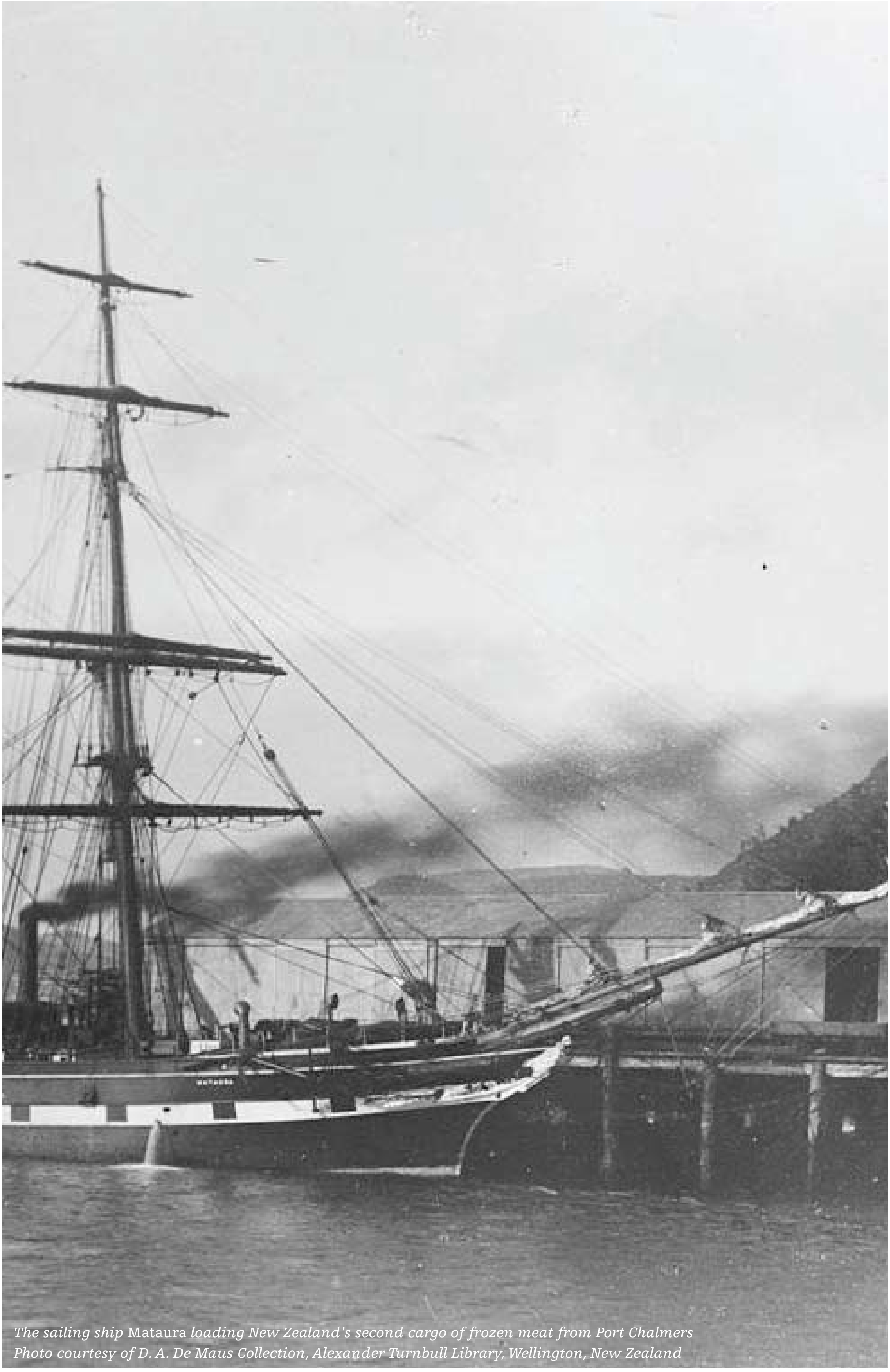
- owners and developers
- operators
- insurers
- design engineers from the various fields of practice required – there is an ethical self-regulating obligation not to misrepresent one's competence
- regulators, both locally and internationally
- end users – the consumers of products stored in the facility
- building and installation contractors
- maintenance and emergency workers.

PRACTICE NOTES – PURPOSE AND FORM

IPENZ practice notes are intended to provide detailed advice and guidance of a technical nature on an engineering topic. The intended audience is professional engineers already working in the specific field, and other associated practitioners in order to highlight areas where particular care is warranted. Practice notes are not intended to be comprehensive design guides. Rather, they are a review of current practices, describing issues that should be taken into account, and provide background information and references to standards and regulations that need to be heeded.

A practice note aims to:

- promote the efficient and effective provision of the specific service or structure covered
- ensure that there is an awareness of statutory responsibilities
- provide guidance on planning requirements
- provide consistencies of interpretation and approach
- update technical implementation approaches
- provide a source of reference for specific issues
- provide examples of good practice
- provide the historical relevance for current practices.



The sailing ship Mataura *loading New Zealand's second cargo of frozen meat from Port Chalmers*
Photo courtesy of D. A. De Maus Collection, Alexander Turnbull Library, Wellington, New Zealand

1 BRIEF HISTORY OF COLDSTORE DEVELOPMENT IN NEW ZEALAND

1.1 REFRIGERATION

Refrigeration machinery made New Zealand's frozen meat trade possible, which began in Otago in 1882. The very first shipment was killed near Oamaru, packed in ice, and railed to Port Chalmers where the sailing ship *Dunedin* was waiting. But its refrigeration plant failed, and the load had to be sold locally. Repairs were made, and the *Dunedin* sailed in February 1882.

Refrigeration machines became bigger and more complex, and were installed in steamships and land-based freezing works. The early ship-board machines drew air from above the frozen carcases, compressed it, cooled it with seawater, then made it do work in an expansion cylinder before releasing it at low temperature in the freezer hold.

Fluids that exhibited changes of phase promised savings in mechanical power. Ammonia and carbon dioxide systems were developed towards the end of the 19th century, and a carbon dioxide machine refrigerated the first shipment of chilled beef in 1895.

In the late 1930s, the first chlorofluorocarbon refrigerant, known as R12, was developed, giving economies in the form of smaller and lighter machines. However World War II delayed R12's general use until about 1950.

1.2 CONSTRUCTION

Coldstores were traditionally multi-storey when manual handling was normal and gravity was used to slide frozen product down chutes between levels, and into transport vehicles.

The holds of early ships were insulated with cork slab placed between timbers to take the weight of the cargo. Granulated cork insulated the sides and bulkheads. Fibreglass started to replace cork in about 1950.

Pumice insulation was used for coldstores (those below 0°C) prior to about 1935. It was cheap and readily available in the North Island, and was used as bulk fill in timber framed and lined walls, roofs and floors.

The construction was relatively robust, but was susceptible to tar emulsion vapour barrier failure with timber movement. When this occurred, the pumice would become saturated, which greatly reduced the insulation value and led to rotting of the timber. The timber framing and lining was also difficult to clean and harboured pathogens.

From the late 1930s through to the late 1960s, cork was the predominant insulation material. Massive structures were required to provide stable substrates for the vapour barrier and cork support. The inner coldstore cork surface was normally plastered, or provided with a concrete wear slab for floors.

In the late 1960s, with forklift operation of palletised product, large single-storey coldstores became common, using lighter insulation systems. Initially, fibreglass batt insulation using sheet membrane vapour barriers or multi-layered vapour barriers and air gap systems were used. Onazote – rigid bituminous foam – was occasionally used instead of cork. The major disadvantages of the fibreglass and multi-layered systems – particularly in below-0°C coldstores – was the susceptibility of the light membrane vapour barriers to puncture, with consequent saturation and slumping of the fibreglass and icing-up of air gaps. This saturation resulted from the high vapour permeability of the fibreglass and layered air gap system, which allowed convection currents within the insulation to convey water vapour from vapour barrier leaks through the insulation, and reduce insulation effectiveness.

From the mid 1960s to the present, bulk insulation – polystyrene and polyurethane – was used. These materials tended to be used in horticultural coldstores above 0°C, where hygiene is not a major consideration. Improved hygiene requirements have led to the phasing out of these materials, hastened by difficulty in insuring these stores because of unconfined insulation's higher perceived fire risk, even with fire-retardant foams.

Food storage coldstores and chillers require impermeable, cleanable internal surfaces. Plaster-style or sheet material facings – in steel or laminates – have traditionally been applied or fixed to the internal surfaces of the insulation material to provide this facility. The structural sandwich panel systems were first used in New Zealand in the late 1960s, and have been progressively developed since then to become the predominant coldstore construction method today.

1.3 ECONOMICS

During downturns in the business cycle, food products may be kept for prolonged periods in cold storage. During periods of peak demand there may be a need for rapid throughput with mechanised product handling.

Some coldstores are built for regulatory reasons, simply to replace an existing one that is non-compliant in some respect.

Some coldstore developments are speculative in that storage contracts are not in place.

In fast-moving consumer goods industries, business survival may demand absolute minimisation of cost. There is particular focus on cost reduction during design, construction and controlling the ongoing operating costs. These pressures to reduce cost may cause designers to be instructed to design for a minimum level of compliance and so can result in reduced useful asset life and increased through-life risks. Any such trade-off must be fully understood and explicitly taken.

1.4 HISTORICAL FIRES INFLUENCING COLDSTORE ENGINEERING

We list some significant fires which have impacted on the design of coldstores, but do not suggest that it is a comprehensive list of all significant coldstore losses.

1.4.1 Gear Meat fire, Petone – 1970

The fire occurred in a shade-roof, steel-framed, single-storey coldstore structure with aluminium-faced polystyrene core sandwich panel insulation. It was started by welding splatter igniting exposed polystyrene.

A feature of the fire was the rapid spread of the fire through the shade roof space resulting in rapid delamination and collapse of the sandwich panel ceiling suspended under the steel roof structure by nylon (acetal) bolts.

Specific lessons learnt from the fire and subsequent investigation were the need for:

- effective fire egress to be available from all areas of a building, including the roof space, and including during construction
- walkways need handrails to guide escapers through smoke
- self-extinguishing (SE) grade polystyrene to be used to reduce the threat of fire from hot work
- fire-resistant supports for ceiling panels.

1.4.2 Lion House fire, Wellington – 1987

Many small fires occurred before a big fire during construction in a brewery basement coolstore – three workers were overcome by fumes and died. This fire highlighted the risk from toxic fumes generated by burning polyurethane, and the need for effective egress and ventilation during construction. A record of problems during construction contracts is useful.

1.4.3 Eleos Coolstore fire, Te Puke – 1999

This fire in a kiwifruit coolstore and ethylene ripening facility was attributed to the main switchboard catching fire. It highlighted the need to ensure that switchrooms were fire-separated from the coolstore, and all penetrations sealed. It also emphasised the importance of adequate firefighting water supplies.

1.4.4 Westgate Coldstores fire, Melbourne, Australia – 2001

The fire originated in the meal milling section of a rendering plant attached to a meat slaughtering and processing plant, with attached carcass chillers and coldstore rooms. The fire initiated from a hot metal component passing through a hammer mill and lodging in and igniting meat meal dust that had accumulated over time. It spread through accumulated meat meal dust around an inadequately fire-separated penetration in polystyrene sandwich panel room linings. The polystyrene cores of sandwich panels contributed a significant part of the fire load and the panels collapsed quickly once they were affected by the fire.

Key lessons reinforced by the fire:

- the need for effective separation of fire compartments in a large building complex to limit the spread of fire and to provide manageable points within a building complex to fight and control a fire
- the effectiveness of good housekeeping in removing and reducing ignition and fuel sources.

1.4.5 Ernest Adams fire, Christchurch – 2002

The NZFS reported that the fire initiated at an exhaust flue from a hot fat cooker where it penetrated a polystyrene panel ceiling. The building was of traditional single-storey steel-framed structure with shade roof and enclosed roof services space above a suspended polystyrene sandwich panel ceiling over the food processing space. Once the fire became established in the roof space, ceiling panel collapse occurred rapidly, obstructing firefighting access to the building, with the polystyrene panel core material providing a large part of the fire load.

Major design issues clarified by the fire investigations were:

- nylon bolts supporting suspended sandwich panel ceilings failed early in the fire, with resultant ceiling collapse – New Zealand firefighters will enter burning sandwich panel buildings only to save lives, not to fight fires
- requirement for adequate separation of hot surfaces, exhausts and gas flues from combustible insulation.

1.4.6 Fonterra fire, Takaka – 2005

The NZFS reported that the fire started in this milk powder plant due to radiated heat from welding being carried out as part of off-season maintenance. Investigators found the fire spread quickly after starting in the ceiling because of extensive use of sandwich panel cladding and lining throughout the factory.

No fire separation was installed between the factory's sprinkler-protected areas and those areas without sprinklers or in the roof voids. This lack of fire separation allowed the fire to develop and spread uncontrolled throughout several parts of the factory.

The major cause of the fire was non-compliance with hot work conditions – that is, one person working with gas cutting equipment adjacent to timber framed wall cavities and polystyrene core sandwich panel construction. Hence, no fire watcher was with the worker, and falling sparks were able to ignite and establish a fire which developed unnoticed to the stage where handheld extinguishers were inadequate to stop it spreading.

Key lessons reinforced by the fire:

- special hot work procedures are needed during welding, cutting, and grinding
- ensure compliance with procedures including a dedicated trained fire watcher
- the need to ensure fire separation is installed between sprinkler-protected areas and those areas without sprinklers or in the roof voids.

1.4.7 Icepak Tamahere coolstore fire, Hamilton – 2008

A gas explosion and fire was apparently initiated by electric spark ignition of hydrocarbon refrigerant gas. One firefighter was killed and seven others were injured when they entered a refrigeration machinery room, unaware of the presence of explosive refrigerant gas. There was major explosion damage, which ignited stored butter and cheese and resulted in nearly complete fire destruction of the facility and store.

Key design lessons from the fire:

- hydrocarbon refrigerants need special treatment as hazardous potentially explosive gases, and not just refrigerants
- effective fire separation and compartmentalisation of fire hazard areas – switchrooms and machinery rooms – is needed.

1.4.8 Satara coldstore fire, Katikati – 2008

The fire was apparently caused by a switchgear fault in a switchroom with insulated sandwich panel walls. The fire caused the loss of the coldstore and a major loss of product.

Key lessons from the fire:

- effective fire-rated (one-hour fire resistance rating (FRR)) enclosures are necessary for electrical switchboards
- switchboards should not be bolted to sandwich panels (and nor should hydraulic oil reservoirs)
- regular infrared inspection of electrical switchgear can identify “hot spots” such as deteriorating cable terminations for repair.

1.4.9 Balanced Investments, Hastings – 2008

The fire was apparently caused by a dust explosion during removal of sprayed polyurethane foam from an old coldstore during conversion to another use. The fire was largely limited to the coldstore, as a fire-rated separation to the attached machinery room protected the refrigeration plant from damage.

Key lessons confirmed by the fire:

- special hot work procedures are needed during any activity that could cause fire
- a dedicated fire watcher needs to be present whenever hot work takes place
- an effective fire rating can protect buildings and plant adjacent to fires.

2 DESIGN CONSIDERATIONS

2.1 PURPOSE

The purpose of a coldstore is to store perishable products at low temperatures. There are two fundamental design issues:

- What product is to be stored?
- What handling system is to be used?

Different products – horticulture, fish, dairy, meat, and vegetable processing – have specific temperature ranges, handling, hygiene, and storage regulations, which often vary between clients for the same product. Product storage requirements can also dictate the interfacing transport vehicles and environmental loading requirements.

2.2 FORM

The storage regulations, handling, hygiene, and client requirements will determine the form of the coldstore. The predominant type of coldstore built in New Zealand since the late 1960s has been a single-storey, forklift-operated store, generally with a maximum storage height of approximately 7.6 metres. Few multi-storey coldstores have been built since then, but the gradual change to semi-automated rack systems and fully automated coldstores with remote-controlled stacker trucks means single-storey stores are now being built higher. Seismic design, fire protection and levelness of floors for stacker operation at height become major design considerations as height increases.

Typical storage regimes include the following.

- Stackable steel stillages (movable storage racks) in the meat and fish industries for frozen carcasses and cartons. Shelved stillages are also common in these industries for blast freezing, where the cartons are set on the shelves to provide good airflow across all surfaces to maximise freezing efficiency. These systems are specifically designed for forklift handling and it is not simple to mechanise their handling.
- Palletised stacking of cartoned product is common in most food industries, with the pallets generally being stored in racking systems generally up to six or seven pallets high. Timber and plastic pallets are an international product handling method so there are many handling systems available – conveyors, semi- and fully-automated systems – which can create high space-utilisation efficiency.
- Some palletised products are held in timber bins – such as fruit, vegetables and cheese – which can be bulk stacked. This is a flexible, low-cost method of storage and handling, but because of instability of high stacks, forgoes the space-utilisation efficiency of more sophisticated systems.
- Specialised product handling systems – plastic bins etc – specific to certain industries and products. These generally involve mechanised and automated racking systems for high-value products with high stock turnover.
- Individual product handling – this is prevalent in small-volume, high-value industries such as pharmaceuticals and generally involves manual selective racking systems, or simple shelves.

Continuous cold chain handling requirements are increasing for all perishable products. This concept requires frozen and chilled produce to be held within a specified temperature range once frozen or chilled, which requires controlled temperature environments to be maintained from production through to the final market or customer.

The type of product, and whether it is sealed or exposed will largely determine the level of refrigeration and temperature control for stored and handled product. "Naked" processed products, such as chilled or frozen meat carcases, require full hygiene envelopes and tight temperature tolerances, but direct ex-orchard apples, whilst naked, require minimal hygiene protection but high refrigeration for heat removal. High-density frozen cartoned product such as frozen meat, butter or fish has high thermal mass and is relatively tolerant to short periods of quite wide temperature variation. The specific handling, hygiene and temperature regimes required for all products are generally clearly defined in New Zealand Food Safety Authority (NZFSA), European Union (EU), United States Department of Agriculture (USDA), client and other product specifications, and must be well understood before designing any coldstore.

The atmosphere inside a coldstore is sometimes controlled by introducing gases that improve the storage or ripening of products, or provide fumigation. Specialist expertise is required to achieve the required performance and to ensure the safety of people.

2.3 FUNCTION

The product flow – the volume and frequency of product movements, including the type of transport links to and from site, and within site – will dictate the pattern of operation of a coldstore. Similarly, there is a wide range of purposes for coldstores, as defined at the start of this practice note, which will determine whether there is any on-site packing, re-packing, containerisation, or order make-up and picking at the coldstore.

Layout design considerations include the type of storage system – bulk stow, racked (there are a wide range of racking systems), stillages – the extent of manual handling, mechanisation, semi-automation and full automation, and environment-controlled load-in and load-out systems for cold chain continuity.

As in most engineering, the degree of sophistication of the storage and handling systems will determine the capital cost, which must be assessed with the value and rate of turnover of product. Low capital cost may mean low efficiency, but also low maintenance cost – these need to be assessed and balanced as in any design assessment.

2.4 CONSENTING REQUIREMENTS

See *Practice Note 11 – Land development processes* (IPENZ, 2007).

Some issues that may need further consideration are:

- cold storage may be a permitted use under a territorial authority's district plan, so consent under the *Resource Management Act 1991* may not be required
- firefighting water supplies – some territorial authorities have included SNZ PAS 4509 *New Zealand Fire Service firefighting water supplies code of practice* (SNZ, 2008) in their district plans (see section 6.3.2 of this document)
- some territorial authorities or building consent authorities (BCAs) require bunds to contain firefighting water to prevent contamination from dirty water and melted product draining into local waterways
- some territorial authorities or BCAs require building consents for pallet racks.

2.5 DESIGN CRITERIA AND CO-ORDINATION

Co-ordination of the criteria for decision-making is essential when designing a coldstore as with any development involving many different design disciplines. In a coldstore, and blast freezers in particular, integration between the building, insulation and refrigeration designers, racking and materials handling designers, the owner and operator, and the relevant approval authorities at the appropriate stage is essential to ensure all understand how the coldstore or freezer is to be operated.

IPENZ and CPEng rules require sustainable management issues to be considered, such as energy use, refrigerant type, level of insulation, building materials, and design life.

The required storage temperature, changes required while the product is in storage, and what temperature variation tolerance limits are acceptable for the stored product must be assessed in the design process, both for the insulation envelope and for the refrigeration system. Factors include:

- the incoming product temperature
- the outgoing product temperature
- any requirements for product cooling on site, or simply holding and maintaining temperature
- the critical upper and lower temperature limits
- any humidity specifications
- the respiration characteristics of the product
- products prone to desiccation with fluctuations in temperature within the acceptable range
- the specification of any storage gases used to modify the atmosphere.

Other relevant design considerations include:

- hygiene cleaning requirements, for example, air ducts and plenums
- product handling cycles (tonnages/times)
- door opening frequencies and durations
- machinery heat loads
- lighting for inspection and processing activities.

Below-0°C storage and narrow temperature variation limits require much more rigorous attention to design of buildings and refrigeration systems.

Air volume changes on cooling and thawing need to be allowed for in design – pressure relief valves are essential to allow for contraction and expansion of air within the coldstore. In a blast freezer, which can operate at temperatures down to -35°C or lower, the air volume change can be 10 per cent on cooling depending on the temperature of adjoining rooms. This can occur over less than a minute in blast freezers loaded and unloaded during refrigeration cycles, which will require consideration of vacuum relief or slow fan start-up measures to provide adequate pressure relief.

IPENZ and the Society of Fire Protection Engineers have endorsed the mandatory requirement to discuss fire engineering design with the client as required by the *International Fire Engineering Guideline* (DBH, et al., 2005) (*IFEG*) system (IPENZ, 2007).

2.6 NEW BUILD V ALTERATION OR EXTENSION

As for any new development, a new coldstore development enables reassessment and, if necessary, redesign for all current site code and standard compliances. Designers undertaking refurbishment or redevelopment of existing coldstores must be aware of, and design for, the specific issues which arise with updating the construction, particularly at the early stage when deciding on the viability of refurbishment compared with a new build.

Particular issues when updating an existing coldstore include the following.

- For an alteration, section 112 of the *Building Act 2004* (*BA*) requires as near as reasonably practicable that the means of escape from fire and access and facilities for disabled persons must be upgraded to the current *New Zealand Building Code* (DBH, 2009) (*NZBC*).
- If the product being stored within a coldstore is changing, then the *BA*'s change of use provisions may need to be applied (see section 4.3 of this document).
- The *BA* requires all local authorities to have a timetable for assessing and seismically upgrading all existing buildings built before 1976. The local

policy should be checked for what, if any, seismic strengthening will be required for the structure and racking in an existing coldstore.

- Current food safety regulations should be checked for current requirements for the products to be stored. These regulations vary for different products (for example, meat, dairy, fish, horticulture, sealed or unsealed product). Depending on the age of a coldstore, there could be significant upgrade requirements, including the removal of timber from within the coldstore or cleanable surfaces.
- The *Health and Safety in Employment Act 1992* (*HSEA*) requirements will be important for product handling assessments, which could preclude old manual methods of handling heavy cartons, and require consideration of stair access, carbon monoxide and other fumes from forklifts, and battery charging facilities.
- Condition of existing insulation – in sub-freezing coldstores, older vapour barriers may be suspect or compromised leading to water saturation of insulation.
- A change of refrigerant may mean a change in the hazard level associated with the pressure equipment, subsequent conformity assessments, and piping requirements.
- A change to a hydrocarbon refrigerant will require electrical equipment to be checked for compliance with one or more hazardous area classifications.
- A change in refrigerant type or volume may require a redesign of the machinery room, piping and cold spaces to meet the requirements of the *Hazardous Substances and New Organisms Act 1996* (*HSNOA*) and AS/NZS 1677 *Refrigerating systems* (SNZ, 1998).
- Alterations may require attention to backflow prevention.
- The *HSNOA* hazardous goods storage regulations should be checked for changed requirements.

2.7 CAPITAL COST

Capital cost of a coldstore development will be determined by size, quality, and building life factors. Coldstores differ from other developments because of the controlled temperature environment, leading to:

- the required integration of the insulation envelope and refrigeration plant design and performance
- the size and volume of the coldstore spaces, how these are accessed, and how product is moved in and out of the space (that is, maintenance of the product "cold chain") – the cost of maintaining the low temperature is an operating cost, but is affected significantly by capital invested in smaller rooms with more walls, and effective airlocking control at doors
- insulation, with vapour barriers, conduction breaks, heated door frames, is much more expensive than standard construction, and coldstores require specialist construction.

The United Nations Food and Agriculture Organisation publish guidance on floor areas and refrigeration power required for "freezing works" of different killing rates (1991).

2.8 RISK, RISK MANAGEMENT, INSURABILITY

2.8.1 General

Risk can never be eliminated. Risk reduction comes at an increasing cost and there is an optimum level of investment in risk management beyond which the benefit gained is outweighed by the cost. The risk associated with a particular coldstore design needs to be considered in the context of the risk appetite of the client, the implications for insurability and the lifecycle costs for the building.

Advice on formal risk management processes can be found in a number of references including:

- *Engineering Risk* (IPENZ, 1983)
- AS/NZS 3931 *Risk analysis of technological systems* (SNZ, 1998)
- AS/NZS 4360 *Risk Management* (SNZ, 2004), to be replaced by ISO 31000 *Risk management – Principles and guidelines* (ISO, 2009)
- AS/NZS HB 436 *Risk Management Guidelines* (SNZ, 2004).

2.8.2 Nature of insurance

Insurance is a form of risk transfer and as such the premiums paid should reflect the assessed level of risk of the coldstore design and construction. Different policies may be needed to cover:

- construction works insurance including loss to the project and third party impacts
- liability insurances for professionals involved
- marine cargo insurance for plant and material being transported for the project
- post-construction insurances, including loss from material damage, business interruption, liability and bailees
- insurance costs reflect the experience of losses in this type of facility – the historical cost factor is modified to a degree by market cycles.

Insurance has a strong market cycle. In soft markets there is a glut of capacity, with multiple insurers interested in participating on a risk, and insurance prices are driven down, in a hard market this reverses and premiums increase. In a hard market it is also possible that the market for certain risks may disappear meaning that insurance is not available. This is unusual and normally a market can be found, for example by placing insurance in the international markets (such as London or Singapore) but this can come at a considerable price premium.

Insurers also depend on the reinsurance market and these re-insurers have specific requirements and ratings for sandwich panel construction. The reinsurance market can be strongly affected by global events such as hurricanes, terrorist acts, etc, and can cause a hardening of New Zealand insurance markets even when there have been no adverse events locally.

It would be prudent as part of the lifecycle costing to consider the impact of a hard market when making design decisions impacting on fire safety.

2.8.3 Factors influencing coldstore insurability

There are three main areas which impact on insurability:

- insurance market and insurance structure factors
- nature of stored product and risk associated with the design
- perception of the risk.

These are discussed below in general terms. For specific projects it is recommended that meetings be held with clients' insurance brokers or insurers (or if a design brief approach is being used, this stakeholder can be involved in the design brief along with the other parties).

2.8.4 Insurance market and insurance structure factors

The key factor influencing insurance premiums and insurability is the market cycle. Overlaid on this is the degree to which individual insurers are willing to insure certain types of risks. In the New Zealand market there is limited capacity and if one or two insurers take a position that they will not add any more unsprinklered sandwich panel properties to their books this can have a marked effect on premiums and insurability.

Insurers will also look at the whole portfolio and are much more likely to offer terms for a sandwich panel building where this is part of a wider portfolio.

Clients with large insured values, prestigious clients, and multinational clients are also likely to be in a better position in terms of premium and insurability, particularly where they demonstrate an acceptable track record in terms of both loss events and audit outcomes.

Insurance structure (loss limits and excess (deductible) values for example) can also impact on insurance.

2.8.5 Risk associated with the design

There are a number of factors which alter the level of risk.

- The type of panel being used. Insurance industry approved fire resistant panels may substantially improve insurability. At present the insurance industry recognises approvals from FM Global, but may not recognise approvals against BS EN 13501-1 *Fire classification of construction products and building elements. Classification using data from reaction to fire tests.* (BS, 2007).
- The extent of panel is a factor and where the quantity of panel is small (typically less than 10 per cent of the floor area) insurers are more willing to accept the risk.
- Exposures to the panel. For example, the presence of hot surfaces, open flame, or the handling of flammable liquids or gases.
- Evidence of effective fire prevention and panel protection activities. The detail of these (and how they are best communicated to the insurer) is outside of the scope of this document but guidance can be taken from the client's insurance broker or insurer.
- Fire separations within the building or between the building and neighbouring buildings will lower the risk. Note that insurers have particular requirements for fire separations which vary to some extent between insurers. Certainly a four-hour, parapeted masonry fire wall would be seen as the ideal by insurers but there may also be recognition of lesser levels of separation. Guidance on fire separations from an insurance perspective can be taken from FM Global's *Property Loss Prevention Data Sheets 1–19 Fire Walls, Subdivisions and Draft Curtains* (2000), *1–20 Protection Against Exterior Fire Exposure* (2007), *1–21 Fire Resistance of Building Assemblies* (2006), *1–22 Maximum Foreseeable Loss Limiting Factors* (2007), and *1–23 Protection of Openings in Fire Subdivisions* (2007).
- Fire alarm systems are seen as having limited benefit in sandwich panel constructed buildings given the rapid speed of fire development and uncertainty over fire service response.
- Fire sprinkler systems are accepted by insurers as being of significant benefit. The current sprinkler standard, NZS 4541 *Automatic fire sprinkler systems* (SNZ, 2007), specifies installation requirements for buildings with sandwich panel construction. The requirements of FM Global's *Property Loss Prevention Data Sheets 1–57 Rigid Plastic Building Materials* (2003) are slightly in excess of the requirements in NZS 4541 *Automatic fire sprinkler systems*. In principle, an alternative solution using National Fire Protection Association (NFPA) codes and standards, or earlier versions of NZS 4541 *Automatic fire sprinkler systems* could be acceptable to an insurer in which case the requirements would reduce. Views of individual insurers vary on whether they would accept (or equally rate) these alternatives.

2.8.6 Perception of the risk

Risk perception is influenced by the risk management measures in place and importantly, how these are documented and communicated. Two identical risks can be viewed by insurers quite differently depending on the effectiveness of risk communication.

2.8.7 Costs of insurance

Costs of insurance vary according to the factors expressed above. Some key parameters in determining insurance costs are:

- market conditions
- previous loss performance
- insurance audit reports
- type of insulating panel being used
- sprinkler protection.

For any market condition the latter two factors would be expected (but cannot be guaranteed) to significantly alter the insurance costs.

2.8.8 Risk management and loss scenarios

Credible loss scenarios depend on the type of insulating panel. For approved panels the loss scenarios are similar to those for any other construction type. For polystyrene core panel there is the potential for total loss scenarios where the panel becomes rapidly involved.

For older buildings where the polystyrene core material is not fire retarded there is the potential for fire starting from small ignition sources such as mechanical or electrical sparks.

For new buildings utilising fire retardant treated polystyrene core the risk of ignition is reduced where fire retardant (FR) grade expanded polystyrene (EPS) core has been used, but once a fire starts, a total loss situation is credible.

Fire probabilities in this construction type are not well documented and NZFS statistics are difficult to interpret. There is no evidence (for or against) the view that fire probabilities are higher in polystyrene core sandwich panel buildings compared to similar occupancies with differing construction. What is clear is that once a fire starts in these buildings, the fire develops into a major conflagration.

For base data on fire probabilities reference can be made to standard sources such as Barry (2002).

2.8.9 Business interruption issues

Factors impacting business interruption potential include:

- redundancy (available alternatives)
- seasonal variation in demand
- long lead time equipment and plant.

Mitigating factors include:

- agreements for mutual aid
- critical spares
- identified resources for clean up (for example, electrical equipment/plant recovery from smoke damage) and replacement equipment.

Recovery can be assisted by having established and tested recovery plans.

2.8.9.1 Insurance industry standards

Various insurance industry documents exist on the topic of sandwich panel construction (many of which are in the public domain) including the following:

- FM Global's *Property Loss Prevention Data Sheets*
- Association of British Insurers
- German reinsurer documents (Munich Re for example)
- other insurer datasheets (for example, ACE, New Zealand Insurance)
- insurance broker guidelines (Marsh, Aon).

2.8.9.2 Test standards and approvals

Various test standards exist for materials. These can be divided into those which measure the material's response to ignition sources, those that measure flame spread (heat release) and smoke development, and those that measure the ability of the material to withstand lengthy exposure to fire.

Small-scale tests which are typically used for measuring ignitability or flame/smoke development can be misleading for panel materials since they do not adequately represent the performance of the material when exposed to significant fires. This is partly due to the composite nature of the material and partly due to the physical and chemical properties of the plastics used.

The tests insurers recognise are large-scale tests, notably ISO 9705 *Fire tests – Full-scale room test for surface products* (ISO, 1993) and FM Global's test protocols.

3

LEGISLATION, REGULATIONS AND STANDARDS

3.1 FOOD SAFETY

3.1.1 Exported animal and dairy products

For stores that are used for holding animal and dairy products that are to be exported, there is specific legislation under the *Animal Products Act 1999* covering design and construction. Specific customers and markets may require separations beyond those specified in legislation, for example between dairy products and those which might taint them, organics and non-organics where insects might contaminate one or the other, EU and non-EU, halal and non-halal, and kosher and non-kosher.

All legislation is available via the New Zealand Food Safety Authority (NZFSA) web site. Note that there are different locations for animal products (meat, game, seafood, etc) and dairy products.

There are four levels of legislation:

1. *Animal Products Act 1999*
    - Design not specifically mentioned. Part 2, Risk Management Programmes, is the source of subsequent legislation on design and construction under clause 17: Contents of and requirements for risk management programmes.
2. *Animal Products Regulations* (NZFSA, 2000)
    - Part 1, Animal Product Standards, regulation 10: Requirements for premises, places, facilities, equipment and essential services.
3. Current versions of the following notices:
    - *Animal Products (Risk Management Programme Specifications) Notice* (NZFSA, 2008). No specific reference to design and construction but there are requirements for all hazards and other risk factors to be addressed (that is, design and construction must be addressed as part of good manufacturing practice).
    - *Animal Products (Specifications for Products Intended for Human Consumption) Notice* (NZFSA, 2004). Part 1, section 5 of this specification defines the requirements for design and construction. Key factors include cleanability of internal surfaces, food-safe materials and finishes, durability, and colours that leave contaminants visible. The facilities and equipment must be of "sanitary design" that is, they must be hygienic and easy to keep clean.
4. *Code of Practice for Cold and Dry Stores* (NZFSA, 2006)
    - approved in accordance with section 12 (3A) of the *Animal Products Act 1999*.
    - The code of practice includes the detailed requirements for all aspects of an export store where a risk management programme is required. It includes the following headings in relation to design and construction:
        - location (including access)
        - design and layout
        - facilities and internal structure (walls, floors, ceilings, lighting, etc)
        - refrigeration facilities and equipment (to ensure temperature maintenance and control)
        - loading facilities
        - detain facilities
        - amenities
        - repairs and maintenance
        - records.

The focus of the code of practice is to establish and maintain hygiene standards, prevent contamination, maintain appropriate temperature and produce records that demonstrate that the relevant requirements are met on a daily basis.

The NZFSA also publishes Overseas Market Access Requirements (OMAR) that set out the specific requirements for individual markets such as the EU that are not covered by New Zealand regulations. These can prescribe requirements relevant to cold storage operation, for example, the EU requirement for separation of EU/non-EU product and the Chinese requirement for provision of temperature gauges.

3.1.2 Horticultural exports

Both NZFSA and Ministry of Agriculture and Forestry (MAF) Biosecurity New Zealand oversee the requirements for exported horticultural products, but the level of specified standards is considerably less than for animal and dairy products. There is an expectation of "good manufacturing practice" which is often market driven.

3.1.3 Customer requirements

British Retail Consortium (BRC) Global Standards are used by some food industry sectors as the basis for their quality management system (QMS). They are based on the hazard analysis critical control point system (HACCP) combined with good manufacturing practice.

Supermarkets in the United Kingdom routinely carry out food safety audits, either directly or through audit agencies, using in-house or external standards (for example, the BRC). Attention is paid to food preservation methods, particularly for chilled product and cold chain compliance.

3.1.4 Food products for the local market

The *Food Act 1981* and associated *Food Hygiene Regulations* (DoH, 1974) contain no specific information about cold storage design requirements.

3.2 *HEALTH AND SAFETY IN EMPLOYMENT ACT*

The principal object of the *HSEA*[1] is to promote the prevention of harm to all persons at work and other persons in or in the vicinity of a place of work. To do this, it imposes duties on employers, employees, principals and others. It provides for the making of regulations and codes of practice. It requires workplace hazards to be identified and if significant to be, in order of precedence, eliminated, isolated, or minimised.

Employers have a general duty to take all practicable steps to ensure the safety of employees while at work. The phrase "all practicable steps" is defined in the *HSEA* and may be paraphrased to mean all steps that are reasonably practicable in the circumstances to achieve the result, having regard to:

a. the nature and severity of the harm that may be suffered if the result is not achieved
b. the current state of knowledge about the likelihood that harm of that nature and severity will be suffered if the result is not achieved
c. the current state of knowledge about harm of that nature
d. the current state of knowledge about the means available to achieve the result
e. the availability and cost of each of those means.

Section 18A of the *HSEA* imposes duties on persons supplying plant to take reasonable steps to design and make it so that it is safe for any known intended use or any use the supplier could reasonably be expected to have known.

Particularly relevant regulations are the *Health and Safety in Employment (Pressure Equipment, Cranes, and Passenger Ropeway) Regulations* (DoL, 1999) (*PECPR Regulations*). Designers, manufacturers and suppliers must take all practicable steps to comply with a duty relating to design, design verification, fabrication inspection, manufacture and supply which is placed on them by the *PECPR Regulations*.

The applicable code of practice is the *Approved Code of Practic*e (ACoP) *for Pressure Equipment (Excluding Boilers)* (DoL, 2001).

Clause 2.4.3 of this ACoP requires designers to ensure that all equipment, or any alteration to equipment, is designed in accordance with the appropriate standards specified in its Schedule C, or otherwise recognised by the Secretary for Labour. Schedule C lists AS/NZS 1677 *Refrigerating systems* (SNZ, 1998).

Clause 5.4.2(5) of this ACoP requires pressure vessels for refrigeration systems to be designed in accordance with AS/NZS 1677 *Refrigerating systems*, and clause 6.4.2 requires refrigeration piping systems to be designed in accordance with several standards including AS/NZS 1677 *Refrigerating systems*.

The parts of the ACoP applicable to refrigeration plant and equipment are detailed in section 7.5 of this document – System Code Compliance.

Compliance with this ACoP is not mandatory. However, its Ministerial foreword notes that compliance in all matters it covers may be used as evidence of compliance with the *HSEA* in court.

3.3 *BUILDING ACT*

The *BA* (provides the mandatory framework for the building control system to be followed when undertaking building work in New Zealand.

It applies to:

- all buildings including Crown buildings (except those that might be exempt for reasons of national security)
- all components of a building, including plumbing, electrical, and mechanical installations
- building construction, alteration, demolition or removal.

All building work must comply with the *NZBC* (DBH, 2009). The *NZBC* sets out performance criteria that building work must meet. It does not prescribe how work should be done, but states how completed buildings and their parts must perform.

The *BA* allows for the making of regulations. Other than the *Building Regulations 1992* (DBH, 2009) that include the *NZBC,* the most relevant regulation for coldstores is the *Building (Specified Systems, Change the Use and Earthquake Prone Building) Regulations* (DBH, 2005). This regulation has two parts that are particularly relevant.

1. The regulation defines what building features are "specified systems". In particular, smoke and gas detection, alarm systems and fire suppression systems are specified systems. A building that incorporates specified systems has to be issued with a compliance schedule that describes the inspection, maintenance and reporting regime required to keep each of the specified systems operating in order that the building continues to comply with the *NZBC*.
2. The regulations define what constitutes a change of use. Change of use may occur in a coldstore if the fire hazard of the contents changes – for example if:
    - storage of one type of product is replaced with another type, for example, butter and cheese instead of fruit
    - the height of storage is increased to over three metres.

1 The *Health and Safety in Employment Act 1992* has been amended several times.

If a change of use is intended the owner has to inform the territorial authority (TA) (local council) in writing that a change is intended. The TA may require work to upgrade some fire protection, structural and sanitary facilities.

The *BA* primarily concerns life safety and does not cover asset protection. It is necessary to discuss the requirements for the protection of the facility with the insurers to ensure that the complex will be insurable.

3.3.1 Compliance paths

Compliance with the *NZBC* can be demonstrated using various pathways. The two most common for a coldstore would be:

- Acceptable Solution – Compliance documents which include Verification Methods and Acceptable Solutions, provide details for construction that, if followed, result in compliance with the *NZBC*. An Acceptable Solution contains simple step-by-step instructions that show one way to comply with the *NZBC*.
- Alternative Solution (performance-based design) – An alternative solution is a building solution that differs, in part or wholly, from the solutions offered by the compliance document's Verification Method or Acceptable Solution but achieves compliance with the performance requirements of the *NZBC* to the satisfaction of the BCA. In coldstores, fire engineering and racking equipment normally requires performance-based design.

3.4 *HAZARDOUS SUBSTANCES AND NEW ORGANISMS ACT*

The purpose of the *HSNOA* is to protect the environment, and the health of people and communities by preventing or managing the adverse effects of hazardous substances and new organisms. This section looks at how the *HSNOA* deals with hazardous substances.

The Ministry for the Environment administers the *HSNOA* by:

- developing and advising the Minister on policy for hazardous substances
- preparing and assisting Parliament with amendments to the *HSNOA*
- advising the Minister on regulations
- monitoring the activities of the Environmental Risk Management Authority (the Authority).

The Authority is an independent Crown entity accountable to the Minister for the Environment and to Parliament that makes decisions on applications for hazardous substances. The Environmental Risk Management Agency New Zealand (ERMA) is responsible for the efficient and effective administration of the affairs of the Authority.

A hazardous substance is any substance that has one or more of the following hazardous properties exceeding specified thresholds:

- explosive
- flammable
- ability to oxidise (accelerate a fire)
- poisonous to people
- corrosive to human tissue or metal
- poisonous to the environment
- able, on contact with air or water, to develop one or more of the above properties.

To manage the adverse effects of a hazardous substance on people and the environment the Authority will:

- classify and place controls on a hazardous substance
- set out in a group standard conditions for the management of hazardous substances of a similar nature or type having similar circumstances of use.

Under the *HSNOA*, any gas contained under pressure is considered hazardous, whether or not it has any of the hazardous properties described above.

The classification and the controls that apply to a hazardous substance can be found by:

- looking the substance up in the ERMA hazard register
- by assigning the substance to a group standard.

The controls or conditions are designed to manage the:

- hazardous properties, such as:
  - biological hazards, including toxic effects on humans or ecotoxic effects on other organisms
  - physical hazards, including flammability, explosiveness or oxidising capacity
- life cycle controls, such as:
  - packaging and containment – for example, strength, durability and resistance to contents for packages and bulk containers
  - identification – information on labels, signs, documentation, advertising and safety information for workers
  - competency of handlers – requiring appropriately skilled people to be in charge of hazardous substances (generally only required for more highly hazardous substances)
  - emergency preparedness – ensuring information or equipment is on hand to deal with emergencies
  - tracking – systems to locate highly hazardous substances
  - disposal – to be done in a way which does not create damage or harm

- controls on hazardous substances in containment, such as:
    - means to prevent the escape of the substance, or contamination of the containment facility
    - identification and security of the facility
    - most of these controls will apply to substances used as refrigerants, although controls may be varied by the Authority if the risk warrants it.

The most significant variations to the controls for refrigerants are the following.

- The vessels and pipework that comprise the refrigeration system must be designed, installed, and maintained in accordance with the *PECPR Regulations* (DoL, 1999). These regulations are under the jurisdiction of the Department of Labour (DoL).
- The controls for anhydrous ammonia, when used in a refrigeration system, have been varied to reflect the controls that were in place prior to the introduction of the hazardous substances legislation. There are, however, requirements for identification and emergency management. The controls for ammonia are available from ERMA (2004).

It must be noted that the variations to the controls apply only when the substance is contained within the refrigeration system. All hazardous substances and new organisms (HSNO) controls apply where the substance is imported, manufactured, stored or transported. See section 9 of this document for notes on hazard signage and see Appendix C for notes on approved handler test certificates.

3.5 OVERSEAS CODES AND STANDARDS

- FM Global's *Property Loss Prevention Data Sheets*
- NFPA guidelines
- International Association for Cold Storage Construction (IACSC) guidelines
- European EN standards

Overseas codes and standards may provide useful sources of information on alternative designs of coldstores and their services. For example, FM Global's *Property Loss Prevention Data Sheets* provide useful guidance on the construction of buildings against potential disasters such as flood, fire, and wind. They also provide useful guidance on the detailed design of fire protection systems, for example *Property Loss Prevention Data Sheet 7–29 Flammable Liquid Storage in Portable Containers* (2004) provides guidance on avoiding ice plugs in pipes located in sub-zero environments.

3.6 INDUSTRY STANDARDS

- Insurer requirements. See sections 2.8 *et seq*.
- Fire fighting. See sections 2.8.6, 4.3, 7.3.2.

3.7 CERTIFICATION

Steps needed for certification of a coldstore are as follows.

- Determine the need for resource consent, and if necessary apply to the TA.
- Apply for building consent from BCA. Documentation must include a compliance schedule listing specified systems. IPENZ recommends that it include a requirement for construction monitoring. The building consent may be conditional upon a resource consent being granted by a different department of the same TA or regional council.
- If the fire engineering design bypasses the Acceptable Solution provided in *Compliance Document for NZBC Clauses C1, C2, C3, C4 Fire Safety* (DBH, 2008), the BCA must provide a copy of the building consent application to the NZFS Commission, which may advise the BCA on means of escape from fire, and the needs of firefighters.
- An inspection body recognised by the DoL must obtain a certificate of design verification from a design verifier in respect of the pressure equipment. The inspection body must provide copies to the designer and to the owner.
- New electricity safety regulations are expected to require the designer to declare that the design was in conformance with the electrical safety regulations. The design may rely on the prescriptive Part 2 of AS/NZS 3000 *Electrical installations (known as the Australian/New Zealand Wiring Rules)* or with the performance-based Part 1 (SNZ, 2007).

The HSNO legislation requires a test certificate to be obtained in certain circumstances. Test certificates may include:

- for people:
    - approved handler test certificate (see Appendix C)
    - approved filler test certificate (see Appendix C)
- for the location and storage systems:
    - location test certificate
    - stationery container test certificate
- design, pre-commissioning, import clearance and periodic inspection of equipment:
    - compressed gas containers and fittings
    - road tank wagons.

When construction is complete:

- The building consent applicant must apply to the BCA for a building code compliance certificate.
- The electrical installer must sign a certificate of compliance stating that the installation is in accordance with the design, and must send copies of this and the design certificate to the owner and the Electrical Workers' Registration Board.
- Pressure vessel and piping equipment inspectors must report to their inspection body which then provides certificates of inspection to the controller (usually the owner) of the plant. If the equipment inspector has advised that the equipment is so unsafe that a certificate should not be issued, the inspection body must advise the Secretary of Labour through the nearest office of the DoL.
- The refrigeration equipment supplier must provide the information required by regulation 21 of the *PECPR Regulations* (DoL, 1999), such as manuals, piping schematics, and other safety-related documents required by the purchaser or inspection body. If any part of the system is AS 4343 *Pressure equipment – Hazard levels* (AS, 2005) hazard level D or higher, a certificate of design verification, must be obtained from a recognised inspection body and if hazard level C or higher a certificate of inspection. See section 7.5 of this document – System Code Compliance. Fabrication inspection in support of a certificate of inspection will normally need to be carried out by a recognised inspection body, and the details incorporated in the manufacturer's data report.
- Depending on classifications and quantities in storage and use, different *HSNOA* controls will apply, including specific requirements for signage and emergency plans.

4

APPROPRIATE STRUCTURES

4.1 CONSTRUCTION TRENDS

4.1.1 General

The service temperature of the structure is the principle factor in design of coldstores. The major issues which arise in coldstore design are listed below:

- thermal expansion and contraction effects – both on the structure and on air volumes and product inside the coldstore
- embrittlement of steel
- freeze-thaw breakdown of concrete
- frost heave of floors and foundations.

These become more important as the operating temperature lowers.

4.1.2 Steel structures

Steel is the predominant material for coldstore structures due to its economy and resilience in low-temperature environments, but in below-0°C applications, structural steel can become susceptible to brittle fracture under tensile or shock/impact loadings. This is avoidable if suitably ductile steels and thin walled sections are used, with appropriate joint and weld design. The general requirements for this are covered in NZS 3404 *Steel Structures Standard* (SNZ, 1997). Sourcing suitably specified ductile steel can be difficult, but testing of can frequently show available steel has adequate ductility, particularly for thin wall sections. Rectangular hollow sections (RHSs) generally have thinner walls than standard hot rolled sections and have proved suitable for coldstore environments. The Heavy Engineering Research Association (HERA) has published research on the low temperature ductility of RHS.

Structures in coldstores that support services need to be designed for similar loadings as in any other structure, but specific issues to be considered when designing for coldstores include the following.

- Allowance for expansion and contraction.
- Effective insulation and conduction breaks between support structures and services pipes – for example, refrigerant mains supported off ambient temperature structures.
- Requirements for anchorage, seismic restraint and movement allowance for pressure-rated refrigerant pipelines. These may require specific pipe stress analysis, which must include an allowance for/assessment of the deflection of supporting structures under various seismic, wind and snow loadings, and could require third party validation and checking. See section 8.5 of this document – System Code Compliance.
- Product racks may carry heavier loads and be subject to more impacts than the structure supporting the insulation. Proprietary systems exist where the insulation is mounted on and supported by the product racks.

4.1.3 Concrete floors

The main issues involved in floor design are:

- structural strength under stacked/racking loads and repeated forklift traffic, particularly for floors laid over insulation
- durability against mechanical breakdown of the surface under mechanical wear
- vapour barrier sealing for cold storage
- resistance to chemicals, both inside the coldstore and from the outside environment and ground
- resistance to freeze/thaw breakdown.

Similar design issues occur in non-forklift coldstores, but the structural loading will be different, and durability may not be so important.

4.1.3.1 Structural strength

For all above-0°C rooms (chillers) the floors would normally be concrete, generally laid on grade, but increasingly, on underfloor insulation for energy efficiency in chiller operation and to "smooth" temperature fluctuations by insulating the floor slab as a heat sink. The design of these floors should be based on standard structural design principles (for example, Westergaard modulus of subgrade reaction method) using assessed properties of the subgrade soils. Expansive additives or pre-stressing could be used to reduce or eliminate floor joints.

Floors in below-0°C rooms (freezers/coldstores) should also be concrete, but should be laid over insulation. The insulation should include a vapour barrier membrane and adequate thickness of insulation material (expected to be expanded or extruded polystyrene, or rigid polyurethane foam). The insulation must be laid on a stable surface – a non-structural concrete slab, or asphalt seal, to provide a smooth, even surface for the insulation. The concrete floor slab over-laying this insulation would be designed as structural slab-on-grade as above.

Assessment of the curing, drying, and in particular, thermal shrinkage effects on concrete floor slabs must be considered in design. Thermal shrinkage on cooling will create appreciable shrinkage in excess of normal concrete shrinkage and must be considered in the design of floor joints that normally undergo significant forklift wheel traffic, and sealing of gaps at wall/floor junctions. Post-tensioned floor slabs (which will create even more shrinkage at walls and door sills) and expansive additives in concrete have been used successfully on larger coldstore floors.

4.1.3.2 Durability

Repeated forklift traffic loadings, even assuming rubber tyres, create severe wear on the slab surface. As well as leading to uneven traffic surfaces, this creates dust which can contaminate stored product. The strength and surface finish of the concrete slab are critical to resisting this wear. Concrete strength should be appropriately high with aggregates of good abrasion resistance, and concrete placement, finishing and curing should be of a high standard to provide a suitably resistant surface. As with warehouse floor slabs, various modifying techniques can be used to enhance durability – steel or synthetic fibres, wear topping, or surface hardeners – but care should be taken to select a product, if any, which does not create early maintenance problems due to the hard wear environment.

4.1.3.3 Vapour barrier sealing

In coldstores, the underfloor damp-proof membrane should be specifically designed and installed to provide a barrier against the ingress of water vapour. The most impermeable underfloor vapour barriers are those with a metallic foil component – normally thin aluminium foils laminated with polythene or similar synthetic material. Although they are efficient vapour barriers, metallic foils can have suspect long-term life due to water passing through the slightly permeable laminating layers and corroding the aluminium foil. The best alternative is a rubberised bituminous vapour barrier which has significantly lower vapour permeability than polythene but can be expensive. Care should be taken in choosing a vapour barrier that is impermeable, mechanically tough to resist abrasion and resistant to corrosion. A laminated bituminous/foil/polythene vapour barrier membrane with synthetic fibre reinforcement combine all these properties but can be expensive.

4.1.3.4 Resistance to chemicals

Where wash-down may occur, adequate resistance of the floor to chemicals should be provided by a good concrete surface or topping as suggested above for mechanical durability. Resistance to external chemicals or corrosive salts in foundation soils is best dealt with by chemical resistant concretes, and by a corrosion-resistant damp-proof membrane/vapour barrier as described above. Local conditions will determine the necessity for any such special design.

4.1.3.5 Resistance to freeze/thaw breakdown

Freeze-thaw breakdown is the breakdown of concrete under the action of freezing and thawing. Floor slabs in coldstores, and particularly freezers where temperatures cycle above and well below 0°C, are potentially susceptible to this problem. The essential prerequisites for this breakdown to occur are:

- susceptible concrete
- freezing temperatures, at least below 0°C
- freeze-thaw cycling
- water.

The expansion of water on freezing, approximately nine per cent by volume, causes the breakdown, which characteristically appears as cracking and spalling of the concrete surface. The cement paste breaks down due to a chemical osmosis-like process of water accumulating within the cement paste binding the concrete. Aggregate breakdown can occur also, due to the physical forces of freezing expansion of water in the pores of the aggregate cracking the particles. In an advanced state the concrete may break down totally into a crumbly gravel of broken cement and aggregate.

The following range of measures should be considered in design of the concrete to reduce its susceptibility.

- Concrete should have a maximum practical content of entrained air – at least five to six per cent by volume.
- A low water-cement ratio should be used in the concrete mix – of the order of 0.4 to 0.45 maximum, and over-working of the concrete avoided during placing. This causes expulsion of air bubbles near the surface and can concentrate excess water at the worked surface as “bleed” water, leaving a weak, easily delaminated top surface layer on the slab.
- Care should be taken in selecting suitable aggregates with maximum resistance to freeze-thaw deterioration – low porosity and high specific gravity, low absorption values (below 0.5 per cent), and high sulphate soundness values (the sulphate soundness test simulates the growth of ice crystals in the aggregate pores and is accepted as giving a reasonable correlation with freeze-thaw resistance).
- Minimum practical sizes of aggregate should be chosen. Generally the required concrete strength will determine this selection, but 20 millimetres aggregate size is the normal minimum for this sort of wear slab.
- Concrete should be cured for the maximum time possible before freezing to allow maximum hydration and strength gain to take place, and also to allow as much free water as possible to evaporate from the concrete.
- If free water is likely to occur on the concrete in coldstores or freezers, provide good drainage.
- Other more “exotic” measures can be considered, such as polymer impregnation of concrete to prevent moisture permeability (epoxy and polyester resin toppings, for example), sealing of concrete surfaces with polymer concretes or paints (ensuring thorough prior drying of concrete to prevent entrapment of water), and the use of antifreeze agents in the mixing water (this is likely only to assist in the early stages of curing). Generally these measures involve higher costs and are only justified by special circumstances. A synthetic topping used for mechanical wear protection and/or sealing the slab surface as described above may be suitable, but its resistance to freeze/thaw cycling, particularly of cementitious toppings should be checked.

4.1.3.6 Loads from racking structures

The floor must be designed to accept the point loads, up and down, from the product racks. These are likely to have a shorter life than the floor, and so the anchors are likely to be replicated, perhaps several times, during the life of the concrete floor.

4.1.4 Frost heave

Frost heave, upwards heaving or buckling of ground caused by freezing of groundwater, is an all-too-common occurrence in coldstores. It is an indication of ineffective and/or poorly designed and constructed underfloor insulation systems. It is relatively simple to design underfloor insulation systems to prevent frost heave using known technology, but trying to repair frost heave after it has started is an uncertain art and potentially expensive.

The mechanism of frost heave is a complex process involving the interaction of soil, water, and freezing temperatures. As the temperature in soil under a coldstore lowers below 0°C, water in the soil will begin to freeze. This water comprises free water in the pores between soil particles, and adsorbed water existing as a thin film of water chemically bonded around soil particles. The free water, being purer, freezes first. The ice formation begins as a "bud" or minute crystal of ice which will grow as the free water within a pore freezes around it. As freezing progresses, these frozen buds grow and begin to encroach on the adsorbed water around soil particles. This sets up an osmosis-like suction drawing free water from adjacent soil pores into the bud. If a bud of ice grows sufficiently it forces the soil particles apart and forms an ice lens, lying normal to the direction of heat flow. The rate of water flow into the ice lens depends on the inter-relationship between the temperature and arriving water supply, with a frozen "fringe" occurring at the bottom of the ice lens. Depending on how cold the soil temperature becomes, and if soil and water conditions are suitable, these lenses in the soil can form as several layers spread throughout the soil matrix down to the frozen fringe.

Frost heave occurs in direct proportion to the amount of extra water drawn into the soil matrix, not just from the freezing of water in the soil. Water expands approximately nine per cent on freezing – that is, a one metre depth of water would only expand by 90 millimetres on freezing. In soil under a coldstore, water may only be 20 per cent or so of the volume of soil, so freezing of a one-metre depth of soil would cause only around 18 millimetres expansion, which would not cause significant floor movement. Frost heave occurs when additional water is drawn into the soil matrix, accumulates and freezes to cause expansion forces of such magnitude that they exceed the loadings from freezer floors above and create heaving.

4.1.4.1 Soils susceptible to frost heave

The soils most susceptible to frost heave are fine-grained permeable soils, particularly silts. In silts, being fine-grained, the amount of adsorbed water around soil particles is much greater than free water in the soil pores/voids between particles. Because silts are also relatively permeable, as the osmosis process is set up when adsorbed water freezes, additional water is able to flow through the silt to add to the frozen water, steadily accumulating to create frost heave. In sands and gravels, although water can readily flow through the soil matrix, the volume of free water is much greater than adsorbed water so exceptionally low temperatures are required to start osmotic "suction" and a frost heave process. In fine-grained clays, although the amount of adsorbed water greatly exceeds the free water in the soil pores, the attracted water is not able to readily flow through relatively impermeable clays to dilute the freezing and concentrating adsorbed water, so frost heave takes a long time to occur.

4.1.4.2 Freezing temperatures

To prevent freezing of the soil, the temperature needs to be kept above 0°C, but as indicated above, temperatures below freezing, normally well below freezing, are required to set up frost heave, although this can vary significantly depending on soil types and water proximity. Insulation under the coldstore floor will only slow the cooling of sub-soil under the coldstore, it will not prevent it.

4.1.4.3 Water

Water is the "fuel" for frost heave – for ice lenses to grow and create frost heave there must be a supply of water. Water can accumulate in soils that are severely frost heaved at up to four or five times the natural water content of the soil. Essentially, the height of frost heave is directly proportional to the amount of additional water drawn up into the soil matrix. The source of water is commonly natural groundwater, but any other water sources can provide the water for frost heave growth, including rainwater run-off, burst water pipes or blocked drains.

4.1.4.4 Prevention of frost heave

Prevention of frost heave is much cheaper than trying to repair it and the measures required are relatively simple. These involve removing one or more of the following prerequisites for frost heave:

- Treatment of susceptible soils
  Susceptible soil conditions under freezer floors should be avoided. For slabs-on-grade, normally the most cost-effective method of coldstore construction in New Zealand, this commonly involves removing any fine-grained silts, clays and fine sands to the maximum anticipated depth of frost penetration. The excavated susceptible soil should be replaced with compacted no-fines granular backfill. The granular backfill should exclude any silt or fine-sand fraction – particle sizes below 0.25 millimetres. No-fines backfill is the best form of fill to reduce the frost heave potential. As well as being resistant to frost heaving, that is, requiring much lower temperatures to frost heave, coarse no-fines gravel under a coldstore creates a drainage layer to prevent water rising near the underside of the coldstore. Elevating floors above the ground provides full separation from susceptible soils and provides excellent underfloor ventilation (and ambient heating), but is significantly more expensive.

- Insulation and heating
  It is normal to provide insulation and some form of heating below a freezer floor to reduce heat flow from the soil into the freezer. Underfloor insulation is required to provide steady temperatures inside freezers, and for energy efficiency of refrigeration, and is normally designed for this purpose. The underfloor insulation barrier and any necessary underfloor heating should also be designed to maintain the temperature at the underside of the insulation above 0°C to prevent freezing of the sub-soil.
  Frost heave may take many months or even years to commence as the ground freezes cold enough. Because frost heave occurs when additional water is drawn into the soil matrix and frozen, thawing this excess water can cause subsidence so heating should be introduced before frost heave occurs. There are three main methods to provide underfloor heating.

  - Ambient heating – provided by suspending floors above ground (can be expensive) or ventilation pipes under the floor to create air circulation.
  - Applied heating – this can readily be provided with electric cables, blown ambient air, warm water circulation etc, which can be retrofitted into underfloor ventilation pipes if and when required.
  - Waste heat recirculation from coldstore refrigeration system. This uses a heat exchanger to apply heat from refrigeration condensers to a thermal fluid such as glycol which is reticulated in a small diameter pipe network under the coldstore floor. It is a more expensive system to install than ambient heating pipes, but is operationally inexpensive as it uses waste heat from the coldstore refrigeration system.

4.1.5 In-ground temperature monitoring

In addition to providing some form of underfloor insulation and heating, it is prudent to install in-ground temperature monitoring in the ground under a coldstore so the initial pre-coldstore temperature, and the subsequent cooling of the ground after coldstore commissioning can be monitored. This is relatively simple to install with thermometer probes in a non-conducting pipe insert through the floor of the coldstore (with appropriate insulation and vapour barrier seals) and should extend 1.5 metres minimum below the underfloor insulation to detect changes beyond the floor of the coldstore. These probe read-outs are normally connected to data logging systems (SCADA) in the coldstore refrigeration system.

4.1.6 Steel racking structures

Racking structures should be specifically designed for the coldstore environment and should be treated as a building structure with a building consent, not as a mechanical plant item. The design basis and compliance will be determined by product loading and handling requirements, but seismic loadings must be considered. This is a specialist area as most racking structures use light cold-rolled steel sections which are unlikely to provide ductile response to seismic loadings. The Building Research Association of New Zealand (BRANZ) and HERA have provided some guidance notes on seismic design of racking structures, incorporating loading, design and material code requirements with a basis for assessing racking loads. This should be used as a minimum basis to consider racking design for coldstores, but racking manufacturers should also be closely integrated into the design process.

In buildings likely to be fitted with fire sprinkler systems, careful co-ordination is required with the fire protection engineer to ensure that adequate flue spaces are provided to minimise the need for in-rack sprinklers.

4.1.7 Timber structures for animal products

Food storage regulations for dairy, meat, and fish preclude the use of exposed timber inside coldstores unless it is clad with a washable impermeable surface (paint is unacceptable). It is not economic to clad an internal timber structure unless an old coldstore is to be kept in operation.

Supporting structures made from timber are unsuitable because of food hygiene requirements of markets overseas, particularly in the EU. Most coldstores holding export product want to provide the maximum flexibility in market destination and so must work to the most demanding standards, which currently are those of the EU.

4.1.8 Timber structures for horticultural products

Timber may be used for production-site coldstores where temperatures below 0°C are seldom required.

5 INSULATION TECHNIQUES

5.1 GENERAL

All coldstores are insulated. Insulation slows the heat gain into the coldstore, but does not stop it completely. Refrigeration is required to remove heat from the product and from gains through the insulation envelope, such as doors, forklift operations, plant, lighting, personnel and insulation losses. Building design and construction must be integrated with plant design and construction to create cost- and energy-efficient coldstores.

The most efficient shape for a coldstore is one that maximises the storage volume to surface area to optimise the heat gain. A cube is ideal, but generally operational requirements will dictate the coldstore shape – such as the product to be stored, handling methods, site/facility configuration, and fire egress distances. Most New Zealand coldstores are forklift operated, which has led to most coldstore designs being rectangular with a low height.

5.2 INSULATION DESIGN

Insulation is required in coldstores to slow heat gain from the outside and reduce refrigeration costs. Heat flows from hot to cold in three ways.

5.2.1 Conduction

Conduction occurs through heat paths such as structural supports, fixings, floors, non-insulating wall materials, etc. Insulation, including penetrations (for example, conduits and cabling) should have low-conduction properties, which will generally demand low thermal mass materials.

5.2.2 Convection

Convection occurs through movement of gases or liquids. In freezers this is generally by water vapour, which flows from high-temperature, high-vapour-pressure external air into the low-temperature, low-vapour-pressure chiller/freezer spaces. A vapour barrier is essential on the warm face of the insulation to prevent water vapour entering, including sealing gaskets, at all doors and openings.

Ideally, insulation should prevent air flow through it. Convection currents are set up in permeable insulation material such as fibreglass and expanded polystyrene with air circulating within the insulation due to cooling on the internal cold surface and heating on the external warm surface.

In coldstores, convection is mainly by air movement through doorways and other openings. Very high air flows will occur where large doors, doors at each end of a building, or at different levels, are left open for extended periods. This results in the ingress of warm air and water vapour. Water vapour freezing on cold surfaces can result in "snow" effects above doorways, on ceilings, and on product.

5.2.3 Radiation

Radiation warming occurs by absorption of heat through non-reflective surfaces into thermal mass. Insulation material should have a reflective surface on the warm face and have low thermal mass.

5.3 INSULATION PROPERTIES

Good insulation should retard heat flow from all these processes. The main requirements of good insulation for coldstores are:

- a vapour barrier is essential
- it must be a poor conductor of heat, and direct heat paths of conducting material should be interrupted
- it should retard internal convection currents
- it should be low cost as large volumes are required for large freezers
- it should have good mechanical strength, especially when used underfloor
- it should be resistant to vermin, moisture and rot
- it must be dimensionally stable so that major volume and shape changes do not occur
- it should be fire retardant.

5.4 INSULATION MATERIALS

There are a range of insulation materials available, including polystyrene (EPS) and polyurethane (PUR) core sandwich panel, polyisocyanurate (PIR) cored sandwich panel, phenol resin modified polystyrene panel, mineral and/or glass fibre insulation, sprayed polyurethane with a fire-retardant additive, concrete-insulation-concrete sandwich, bulk insulation products such as polystyrene and sprayed polyurethane, which have varying insulation and fire-resistance properties. The selection of the appropriate insulation material needs to be integrated with the fire safety design of the coldstore.

Materials imported from EU countries will be made to the specifications of EN 13501-1 *Fire classification of construction products and building elements. Classification using data from reaction to fire tests* (CEN, 2007), which has superseded the British, French, and Italian standards. Insurers may require these imported materials to have additional approvals against other standards, such as those published by FM Global and the United Kingdom Loss Prevention Council.

5.4.1 Structural insulated sandwich panels

Sandwich panels using a metallic sheet facing bonded to structurally strong, lightweight insulating material – such as polystyrene or rigid polyurethane and PIR – provide an ideal insulating material that has major advantages over traditional insulation systems. These provide lightweight structural panels capable of long spans, which allow for lighter support structures. The panels themselves provide all the required attributes of good insulation, namely:

- the metal surfaces are a perfect vapour barrier
- the polystyrene or polyurethane/PIR core is good, relatively cheap, insulation material

- the combination of the facings bonded to a stable core material is mechanically resilient and relatively stable under a wide range of temperatures
- although combustible, polystyrene and polyurethane can be made fire retardant, but are protected from direct ignition by the metal facings.

5.4.2 Typical New Zealand insulation construction systems

New Zealand coldstore construction experience since the 1970s indicates that use of structural sandwich panels is the most cost-efficient construction method for coldstores where hygienic food storage is required. Typically, a coldstore building has been constructed as a weather enclosure and the insulated coldstore created by lining the inside of the warehouse with sandwich panels to form an insulated “box”. These are known as shade roof structures, where the sheet metal cladding of the warehouse provides a shade and weather roof to the insulation. With the evolution of manufacturing techniques and improvement of sandwich panel quality, sandwich panels have been increasingly used, successfully, as unprotected cladding against external weather environments.

Significant cost savings are achievable through the reduction of support structure when insulated sandwich panels do triple duty as structure, weather cladding, and insulation. Sandwich panel spans of the order of nine metres are achievable on roof spans, even longer on walls, which leads to efficiencies in structural design.

Shade roof structures are generally more suitable for processing applications where process services are required to be run in the building. In a shade-roof coldstore, these services can be kept out of the insulated environment, and supported from the shade roof structure above the sandwich panel ceiling. Sandwich panels are used structurally in such applications, but sizing may often be rationalised to suit insulation rather than structural requirements. Where services requirements are less, as is typical in storage buildings such as coldstores, exposed sandwich panels are inevitably more economical in capital cost, and have been shown to be no more expensive to maintain than shade roof buildings over 10–15 years use to date. On large coldstores they have an additional advantage in avoiding the need for ventilation of the roof space to prevent condensation accumulation on top of the sandwich panel ceiling and consequent breakdown of vapour barrier sealants at panel joints.

Economical insulation thicknesses (that is, sandwich panel thicknesses) are in theory determined in conjunction with the design of the room shape and refrigeration plant to optimise capital, operating, maintenance, and depreciation costs. The room shape is generally dictated by storage considerations, and that provided the insulation is reasonably efficient, heat gains from general product handling operations and through door openings far exceed those through the insulation.

5.4.3 Sandwich panel construction

Depending on the size of coldstore rooms, the panel thicknesses designed for effective insulation may also be structurally the most efficient. With larger coldstore room sizes it is generally more economical to use thicker sandwich panels as structural elements to create cost savings in support structure, but care must be taken to fully integrate the building and insulation design, and construction. Critical items to be considered in structural sandwich panel design and construction are the following.

5.4.3.1 Manufacture

The strength and durability of the bond between the panel facings (steel or aluminium – pre-coated sheet steel is durable and structurally more efficient) is absolutely critical to panel performance. The adhesive must have appropriate elasticity to create a strong bond between the rigid facing and the flexible, relatively soft core material. It must not creep under shear loading, and the bond must not deteriorate under fluctuating temperatures and moisture. All constituent materials, and the manufacture of sandwich panels, must be of consistent high quality. This is only achievable by proven manufacturers using machine-run panels.

5.4.3.2 Jointing systems

The jointing system, for all joints in a coldstore insulation envelope, is the most critical item in the insulation system design as it provides vapour barrier continuity between the impermeable sandwich panel facings. If the vapour barrier seal fails, water vapour will enter the insulation system and progressively saturate all permeable insulation materials. This can lead to structural damage if the water content in insulation material becomes significant.

Jointing systems must be flexible to allow for the thermal movement and bowing of sandwich panels under fluctuating external temperatures. Sealants must be flexible, non-setting, effectively impermeable to water vapour, adhere thoroughly to panel facings to create a durable seal, and resistant to water deterioration.

Infra-red cameras are useful for checking the integrity of panel joints after construction.

5.4.3.3 Support systems

The temperature difference between the warm external face and cold internal faces of sandwich panels in coldstores can be up to 80°C. With such differences, the panels “bow” as the internal facing contracts and the external facing expands. Allowance for expansion and contraction must be made in design and construction to avoid buckling and rupture of panel facings, with consequent loss of the vapour barrier and weatherproofing. A range of types of panel connection to supporting structure may be used, such as stress relief cuts in panel facings, heat breaks, varying degrees of structural fixity, etc.

5.4.4 Fixings

Insulation fixings must be designed carefully for the specific coldstore environment. Issues to be considered in design should include the following.

5.5.4.1 Heat flow through the fixing

Either use a non-conducting material or provide non-conductive separation of a steel bolt with nylon bushes, or PVC sleeves so the bolt shank does not provide a direct conduction path between, for example, metal sandwich panel facings.

5.5.4.2 Vapour barrier seals

Bolts, rivets, screws etc, must effectively seal on the vapour barrier (that is, warm) face of the insulation. None of these fixings provide an effective vapour barrier seal on their own, they must be placed through sealants as a membrane, sealant layers at a washer etc, to ensure vapour barrier continuity.

5.5.4.3 Fire protection

Sandwich panels should not be suspended from combustible fixings. Either use sufficient non-combustible fixings to provide safe support to the panels, or provide bearing-type support to the panels so they are supported when combustible fixings fail. Sandwich panel edges must also be restrained against delamination of the facings during the initial stages of a fire.

5.5 COMBUSTIBLE INSULATION MATERIALS

Since 1973, following the lessons of the Gear Meat fire, all polystyrene used in insulation and building applications in New Zealand has been self-extinguishing (SE[2]) grade, sometimes known as EPS core FR. This polystyrene has an additive which prevents it from sustaining combustion on its own – it requires an external fire source. Welding slag or cutting sparks will self extinguish if dropped onto SE-grade polystyrene, but in a large fire there is sufficient heat to melt and vaporise the polystyrene (it starts to shrink at 70°C, then melt, drip, and potentially form a liquid pool at temperatures below 100°C) thus providing fuel to the fire. Worse, for polystyrene in sandwich panels, is that the metal panel facings prevent access to cool the polystyrene to stop melting and extinguish the burning.

Newer fire resistant insulation panel materials now in widespread use include polyisocyanurate (PIR) and phenol modified polystyrene, sometimes known as polyphenolic. These have a high degree of fire resistance and with effective fire-rated support can provide fire-rated construction. These materials char slowly during a fire so will be damaged and require repair, if not replacement, if exposed to fire that is hot enough for a long enough period. The main benefit of sandwich panels with these materials is they do not provide fuel to a fire and can prevent the spread of fire. In coldstore construction, the vapour barrier sealants in the panels will require replacement if they are affected by heat.

Mineral fibre (that is, ceramic fibre) and foamed glass insulation materials are truly non-combustible. Although very effective for fire-resistant construction, mineral fibre insulation, including when laminated into structural sandwich panels, is very porous so is readily saturated, particularly by condensing water vapour. This tends to rule it out for below-0°C coldstore insulation where even minor vapour barrier failure can lead to saturation of the panel cores. These are very effective fire-resistant construction materials, but will only be suitable for coldstore insulation in "special" situations where enhanced fire resistance is required.

Fire properties of concrete-insulation-concrete sandwich construction are very good with the concrete panels protecting the central insulation layer from fire on both faces. The internal insulation (generally extruded or expanded polystyrene) will still be damaged by heat if the concrete panels rise above 70°C at the polystyrene but this is only likely to occur in a significant fire, and where the concrete facing is thin. Care must be taken with this type of construction in below-0°C coldstores to ensure the vapour barrier to the insulation is complete. The vapour barrier is normally a membrane, laid on the "warm" face of the insulation, and has numerous punctures from the non-conducting ties through the insulation to hold the concrete facings together structurally, which need to be effectively sealed back to the parent membrane.

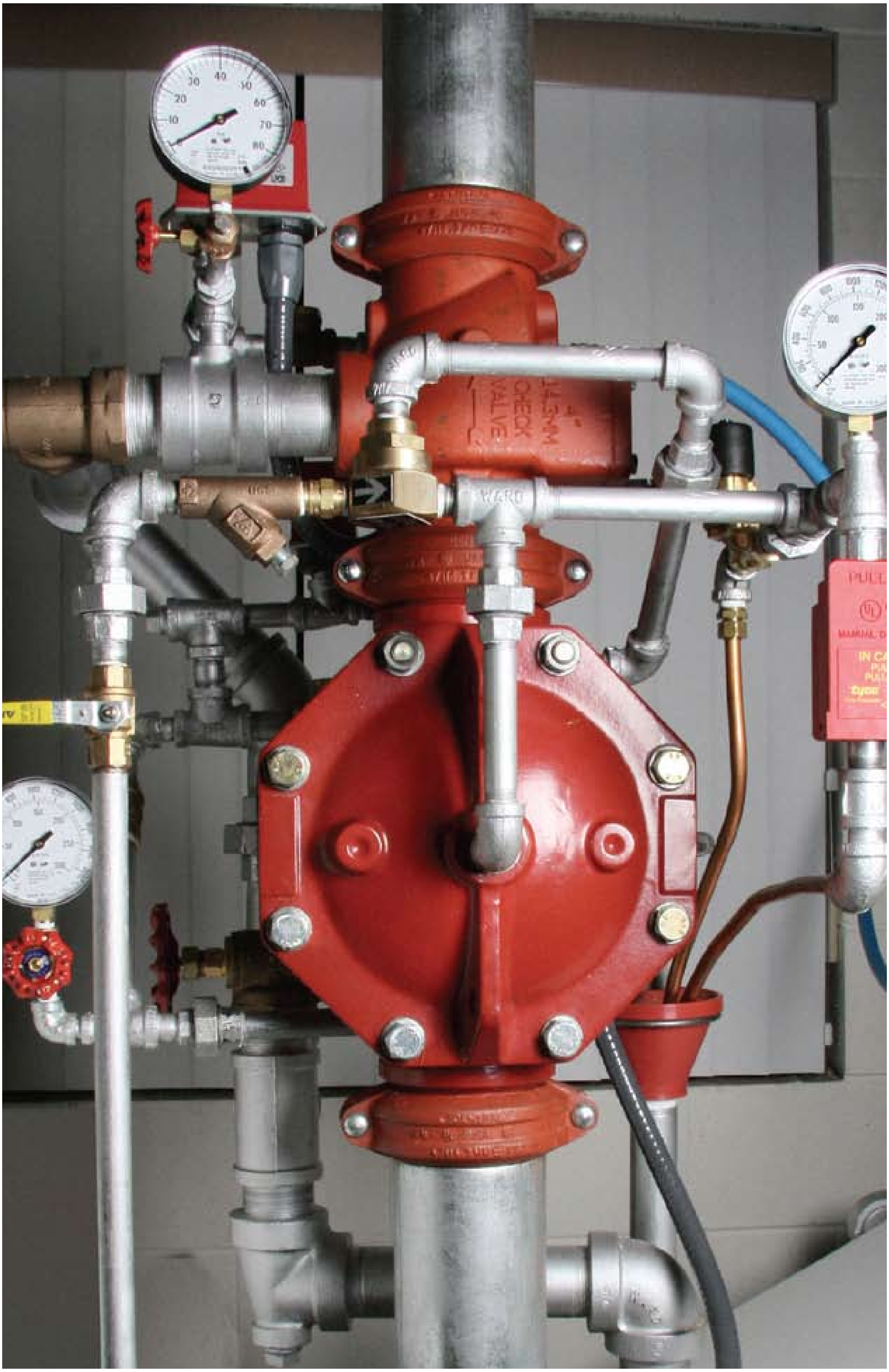
Still used occasionally in horticultural coldstores in New Zealand, for raw ex-field fruit and vegetables is bulk insulation, such as sprayed polyurethane or bulk slabs of extruded or expanded polystyrene treated with a fire retardant. This is a very cheap material for this type of coldstore where a washable hygienic finish is not required. It can be applied to the inside of standard warehouses and sheds, and is permitted under the *NZBC* if effective egress and boundary separation is provided. Insurers do not favour this form of insulation and such coldstores are unlikely to be insurable in the current market.

5.6 DOORS

Doors are one of the major sources of heat gain into a coldstore, and any improvements to door operation will reduce energy use. Doors for coldstores need to be designed and constructed with attention to vapour seals and avoidance of conduction paths. Effective seals – wiper type or compression type – are critical in all door installations, and particularly in applications below 0°C. In such applications door frame/mating faces must also be heated to prevent water vapour freezing around the frames and causing jamming of the doors. Significant reductions in heat gains, and improvements in refrigeration efficiency are achieved by the use of airlocks, rapid roll doors and strip curtains.

Electrical notes appear in section 8 later in this document.

2 Strictly speaking, SE does not stand for "self extinguishing", as the original German, Schwer zu Entzünden, means "difficult to ignite".


CHECK
VALVE

6 FIRE ENGINEERING

6.1 GENERAL

Fire-safe design of coldstore buildings has four principal aspects:

- design to prevent fires starting
- design to preserve life and protect adjacent properties
- design to suppress and extinguish a fire early before it grows and spreads
- design to contain a fire and protect adjacent buildings and property.

Design for each of these considerations inevitably overlaps, but all four aspects need to be specifically considered if a cost-effective design is to be achieved.

6.2 FIRE DESIGN TO MEET THE *BUILDING CODE*

All buildings shall be designed to meet the performance criteria of the *NZBC* (DBH, 2009). Therefore the design requirements for coldstores are no different to any other building – to provide safe and effective egress for people, to protect other property and to provide access and facilities for firefighting. The level of fire safety features installed in a building is related to the fire hazard contained in the building, its geometry and the number of occupants within the building space.

Table 2.1 of *Compliance Document for NZBC Clauses C1, C2, C3, C4 Fire Safety* (DBH, 2008) uses coldstores as an example of a type of building space that has a low fire hazard category. The use of an example is for guidance; however the classification of the purpose group can change dramatically in relation to the storage geometry, specifically where storage is over three metres high, within the building envelope. This change affects the fire engineering design of the building. Even if a coldstore is designed to fire hazard category (FHC) 1 and consent is granted a change of use occurs if the storage within the coldstore exceeds three-metre height. Under section 114 of the *BA* the owner must then apply for a building consent for the change of use and upgrade the fire safety systems accordingly. To obviate this problem, IPENZ recommends that coldstores be designed as fire hazard category 4.

IPENZ's Fire Engineering Advisory Taskforce recommended the *IFEG* (DBH, et al., 2005) as a design process and the New Zealand Construction Industry Council's *Design Documentation Guidelines – Fire Engineering* (2004) as a method for documenting the design (IPENZ, 2007).

6.3 FIRE DESIGN FOR PROTECTION OF ASSETS

Design for fire protection of a building and its contents beyond life safety and protection of other properties is not required by the *NZBC* (DBH, 2009) the extent of protection of assets is the commercial decision of the building owner. This is an important distinction when designing the building – personnel and adjoining property protection is relatively simple to achieve in the design of most coldstores, but fire protection design beyond this needs to be related to commercial considerations.

Performance-based design is widely used since it can provide evidence to justify divergence from prescriptive requirements, particularly in cases where there are practical limitations or a need for an improved level of fire protection.

There are some specific guidelines for the use of performance-based design and risk management concepts. The codes and standards referenced in this document are listed in the References section.

6.3.1 Coldstore and contents protection

Stored product in a coldstore is generally of much greater value than the coldstore itself, possibly up to eight times more than the building asset value. This is very important to remember when designing fire-protection systems for food coldstores as any fire in a coldstore, even if suppressed at an early stage, will still result in smoke and, if sprinklered, water contamination of the food product. Because of the difficulty of assessing the effects of product damage and guaranteeing food safety, it is likely any fire inside a coldstore will result in substantial, if not entire, loss of the coldstore contents. It appears that in many cases losses resulting from a non-fire-related accidental sprinkler discharge may not be covered by fire insurance.

Considering the possibility of product loss, fire safety design of coldstores should focus on reducing fire risk. Most coldstore fires occur as a result of an electrical failure or during hot work activities during construction or maintenance. NZS 4781 *Code of practice for safety in welding and cutting* (SNZ, 1973), although dated, gives some guidelines for the correct procedures and precautions involving hot work, but insurers regard its hot work permit certificate as inadequate.

Provision for repair or replacement of damaged product racking components without the need for hot work is likely to improve fire safety.

Studies have shown a consistent pattern in the causes of coldstore fires, as shown in Table 1.

FIRE CAUSE	FIRES (PER CENT)		
	New Zealand Freezing Companies Association Records 1952–72 (Hunt, 1982)	**International Records** (IIR, 1987)	**New Zealand Records** (Nelligan, 2006)
Hot work (welding, gas cutting etc.)	**56**	**34**	***31**
Electrical	**15**	**30**	**38**
Arson		**6**	*****(could include arson)
Solid fuel heating equipment		(not included)	**19** (for all panel buildings)
Chemical		**4**	
Ammonia		**2**	
Other causes	**15**	**9**	**4**
Unknown	**15**	**16**	**8**

Table 1: Causes of fires in coldstores.

Simple measures to prevent these fires include the following.

- Separate coldstores from adjacent buildings with physical separation, fire walls that provide compartmentalisation, non-combustible links and similar measures. Physical separation distances and "island" sites for coldstores will deter the spread of fire and enable firefighters to access buildings to fight and control fires.
- Enclose high-fire-risk rooms such as switchrooms and substations in fire-rated enclosures to confine any fire. Switchrooms rated 60/60/60 FRR[3] were a standard requirement of the NZS 4216 *Code of practice for design of meatworks complexes for fire safety* (SNZ, 1983) and IPENZ continues to recommend their use in new construction.
- Ensure that all electrical equipment is separated from combustible sandwich panels by a fire-rated material, for example, ceramic fibreboard.
- Seal all wall penetrations with fire-rated materials.
- Enforce simple and effective hot work conditions during all construction and maintenance. Hot work procedures are formalised and well established in most industries involved in coldstore construction and include the following.
    - Effective induction and training of workers in fire-safe hot work practices – that is, those involving gas cutting, grinding, welding, etc – using welding blankets, containment of falling sparks, and other measures.
    - Fire extinguishers and/or hoses are always at hand when hot work is taking place.
    - A separate fire watcher is present when all hot work is taking place – that is, two people should always be present when hot work is taking place, one doing the work and the other watching for any fire starting.
    - A formal notification of all hot work should be made before the works starts, ensuring the location, person doing the work, the fire watcher, fire-safe procedures, equipment to be used, and other details are recorded. This should be issued by a responsible manager on the site and returned to them at the end of the work.
    - Inspection of the site after the hot work has ceased to detect any incipient fires. This inspection is normally carried out two to four hours after the hot work has ceased to detect any fires resulting from sparks or embers which may lie dormant for a period and start fires well after the hot work has ended.
    - At least one coldstore operator insists that the hot work document be consulted every day.
- Separate heat generating equipment such as cables, door heaters and lights from combustible and heat-affected insulation material with non-combustible and non-conducting conduits and enclosures.
- Carry out good "housekeeping" during construction and operation – removal of sources of fire and fuel for fires. These measures are generally very simple to put in place.
    - Regularly remove rubbish from construction sites and near coldstores.
    - Ensure all exposed insulation material is covered with flashings to prevent sparks falling onto it.
    - Store timber pallets away from coldstore buildings.

3 Fire resistance rating in a standard test. The first number indicates the time in minutes the component will maintain its structural load capacity, the second number is the time to be penetrated by flame or hot gases, and the third is the time for an average temperature rise of 140°C or a local maximum of 180°C on the unexposed face.

- Don’t store combustible cleaning fluids and fuels near combustible insulation.
- Provide effective separation of forklift charging facilities from coldstores and insulated rooms.
- Prevent smoking in or near coldstores during operation and construction.
- Provide fireproof separation of drying and “warm-up” facilities.
- Ensure regular repair and maintenance of equipment, particularly fans and switches.
- Provide effective security containment and lighting around coldstore facilities to deter arsonists.

6.3.2 Firefighting water supplies

The prescriptive standard NZS 4404 *Land development and subdivision engineering* (SNZ, 2004) is widely used by building consent authorities. Its clause 6.3.8.1 requires many industrial and commercial developments to include special fire protection services. Whilst the site owner is responsible for providing these fire services, “the developer shall design the water infrastructure to meet the required demands, where these are known in advance”. Provide access for firefighting trucks, noting that there may be a need to relay significant quantities of water to the site during a major fire. Consult NZS PAS 4509 *New Zealand Fire Service firefighting water supplies code of practice* (SNZ, 2008). Reservoirs, tanks, and ponds can be cost-efficient means of providing firefighting and sprinkler water, and can also be used for cooling water for condensers or even defrosting.

The Centre for Advanced Engineering’s (CAE) *Fire Engineering Design Guide* (Buchanan, 2001) draws attention to section 6(2)(c) of the old *Building Act 1991* requirement that effects on the environment caused by fire in buildings containing hazardous substances be controlled. The CAE suggests that in practice this means that adequate water supplies must be available, either from the reticulated supply or from an onsite supply, to rapidly control fires. Provision may also need to be made to contain contaminated firefighting water runoff.

There is no similar containment requirement in the later *BA* or in the *HSNOA*, but individual territorial authorities may require containment, and some multinational companies have policies to do so. Some regional councils may require discharge consents.

Note that the term “hazardous substance” is defined in the *NZBC* to have the meaning ascribed to it in the *Fire Service Act 1975*, and that in turn leads to the *HSNOA*. This lists the properties of hazardous substances in a similar manner to those outlined in section 3.4 of this document.

6.4 DETECTION SYSTEMS

Detection systems would normally comply with NZS 4512 *Fire detection and alarm systems in buildings* (SNZ, 2003). In some cases, detection systems may comply with other recognised fire protection standards such as those published by SAI Global or the National Fire Protection Association.

6.4.1 Detection v protection

Fire alarm systems only alert people to the presence of a fire. Such detection is usually linked into a monitoring station so that the fire service can be summoned to fight the fire. Active fire protection systems will not only alert people to the fire, they will also extinguish or control it until the fire service arrives.

When considering the installation of fire detection systems, consider what the systems need to achieve, such as life and/or property protection.

If combustible sandwich panel construction is exposed to a significant fire, the fire is likely to spread to the panel and result in a rapidly growing fire. In this situation, early detection with no automatic suppression system may provide limited value, as the fire could be too large for the fire service to control effectively once they arrive. This has been demonstrated over a large number of fires in these types of buildings worldwide.

One notable exception may be the use of high sensitivity smoke detection in areas where there is relatively low fire load – typically outside of storage areas – and the prime risk is from a fire of electrical origin, which can be effectively detected in sufficient time to prevent a major fire developing.

Detection systems may be installed in conjunction with fire suppression or control systems, such as providing the alarm signal to operate a pre-action valve set. In such cases, the fire detection/release system should be independent of the building or site fire alarm system, for purposes of reliability. However, the fire detection/release system can be linked into the main fire alarm system, for purposes of indication and integration with the evacuation system and other services’ control systems.

It is important to ensure that when detection systems are being specified for coldstores, their suitability for the environmental conditions needs to be reviewed. Most technologies are suited for temperatures above zero, but some components, cables and the like are not suited to freezing temperatures.

6.4.2 Heat detection systems

Simple spot heat detectors rated for the expected minimum temperatures will be suitable in coldstores. Generally, the detectors will need to be encapsulated, so that moisture does not condense, freeze and cause mechanical damage to these units. Consideration needs to be given to detector locations to ensure that ice does not build up on detectors near doorways and other openings where warm air may enter coldstores operating below zero degrees.

6.4.3 Smoke detection

Various forms of smoke detection are available as set out below.

6.4.3.1 General

Roof spaces should have the same level of smoke detection as the coldstore as they may have even higher fire risk due to the electrical cabling and refrigeration control equipment housed in the dry and dusty ceiling void.

6.4.3.2 Spot detection

Spot smoke detectors can be used in coldstores, but normally in conjunction with localised heaters to ensure that they are not subjected to temperatures below their minimum-rated operating temperature. Because of this, they are not commonly used.

AS/NZS 60079.29.2 *Electrical apparatus for explosive gas atmospheres - Gas detectors - Selection, installation, use and maintenance of detectors for flammable gases and oxygen* (SNZ, 2008) gives performance requirements for gas detectors.

6.4.3.3 Aspirating detection

- General

  Aspirating smoke detection (ASD) is perhaps the only really effective method of detecting fires in coldstores at the incipient stage and in low and sub-zero temperature environments. ASDs function in sub-zero temperatures without losing their very early-warning smoke detection capabilities.
  ASD systems provide for the detector to be installed outside the protected area with only the sampling pipe network exposed to sub-zero temperatures. Being on the ceiling and inside voids, it is unlikely that the ASD sampling pipes will be damaged. Alternatively the ASD pipe network can be installed in the ceiling space with penetrations through the sandwich panel. This method offers many advantages provided any penetrations are well sealed. The leading manufacturers of ASDs provide good design guidelines for the use of these detectors in coldstore environments.
  Aspirating smoke detection and their applications must be clearly understood since each is individual or unique. The assistance of the manufacturer or his agent must be sought during the specification stage where parameters for the specific application must be understood, defined and documented.

- Exhaust air treatment

  Air from the ASD system exhaust pipe should be returned to the area from which it is being sampled to prevent pressure differences – caused when the detector is powered down for any length of time – from introducing warm and humid air into the refrigerated storage area via the exhaust port.

6.4.4 Flame detection

Flame detectors are generally impractical in coldstores because of potential ice build up on the lens, and effect of racking and other obstacles for a line-of-sight device.

6.4.5 Gas detection

Gas detectors for flammable refrigerants including ammonia are discussed in AS/NZS 1677.2 *Refrigerating systems - Safety requirements for fixed applications,* Clauses 4.7.6 and 4.8 (SNZ, 1998). The same clauses specify the ways the detectors must be incorporated into the alarm and building management systems.

6.4.6 Acoustic detection

In hazardous areas, consideration should be given to the use of acoustic detectors. Such devices have the ability to detect small leaks and thus provide a valuable means of early “incident detection”. Acoustic detectors can be interfaced in a similar manner to gas detectors.

6.5 ACTIVE FIRE PROTECTION

6.5.1 History

Sprinkler systems have been installed in a significant number of coldstores in New Zealand in various industries including those processing dairy, meat, and fruit products.

Early coldstore owners disapproved of fire sprinklers because of the possibility that they would not work. Designers initially accepted this, but eventually moved to dry pipe sprinklers in the roof space. As these also tended to fail (see section 6.5.2.1 of this document), designers moved to glycol, which created its own problems when glycol dripped onto exposed meat. Glycol could also increase the fire growth rate, (see section 6.5.2.3 of this document) and its use is now restricted.

The New Zealand sprinkler standards have historically allowed a number of design options for protecting these systems including:

- dry pipe systems
- antifreeze filled systems
- dry drop sprinklers
- alternate wet and dry systems
- preaction systems.

Each type of system has its advantages and disadvantages.

In large coldstores, the predominant system type that has been installed is the antifreeze filled system. This was favoured over dry systems, as NZS 4541 *Automatic fire sprinkler systems* (SNZ, 2003) required that the design area of discharge for dry systems be increased by 30 per cent to cater for the delay between sprinklers operating, and water discharging over the fire. This same increase in design area was not required for antifreeze based systems, hence, given the lower cost of water supplies for antifreeze systems, they became the most common way to protect coldstores.

NZS 4541 *Automatic fire sprinkler systems* (SNZ, 2007) now effectively precludes the use of antifreeze filled systems in New Zealand due to the potential flammability of common antifreeze solutions that can be economically used in coldstore protection. This is because they can increase the rate of energy release in a fire before becoming empty and discharging water on a fire.

An exception exists for high-piled storage arrangements with "listed systems". Part of the listing process involves establishing the design requirements for antifreeze systems to recognise the initial impact that the discharge of the fluid has on the fire, before water can start to suppress or control the fire. The 2007 edition of the standard also places more emphasis on careful detailed design of dry pipe air supply systems, to ensure that these systems are reliable.

6.5.2 Design considerations

We discuss here concepts that apply to high-racked storage of products, predominantly in refrigerated environments in New Zealand and constructed of materials typically used in coldstores. Sprinkler standards classify various goods stored in buildings under commodity classifications of increasing fire loads. There are two common classifications of goods stored in coldstores.

- Items such as meat carcasses are usually a Class 2 commodity.
- Items such as butter and cheese are usually a Class 3 commodity.

A Class 2 commodity is equivalent to goods of limited combustibility with some combustible packaging, while Class 3 goods are equivalent to normal combustible goods. The commodity classification has a significant impact on the design requirements for a sprinkler system, and can place limitations on what protection options can be used in this environment. Specialist advice, or reference to NZS 4541 *Automatic fire sprinkler systems* (SNZ, 2007) will provide more information on this subject.

Specialist knowledge is essential when designing and specifying sprinkler systems in coldstores to ensure that the system minimises false discharges and is reliable in a fire.

Some of the following issues will need to be addressed at an early stage of the project.

- Water supplies, which may require large diesel driven pumps and water storage tanks.
- Specific structural considerations to support large pipes at roof level.
- Roof slope and geometry of the building, including purlin depths and spacings (NZS 4541 *Automatic fire sprinkler systems* (SNZ, 2003) forbids supporting large sprinkler pipes from insulation) as well as co-ordination with wind bracing.
- The nature of the goods being stored, including proposed packaging, pallet materials, and racking design.
- Idle pallets – stacks of idle pallets pose a significant risk, given the ventilated nature of the fire load, and multiple surfaces shielded from the water spray. If stored under shelter for hygiene purposes, they can result in design criteria more onerous than that of the goods being stored in the coldstore. If stored outside the building, they could necessitate wall wetting external drenchers.
- Plastic versus wooden pallets, in terms of fire load and commodity rating.

6.5.2.1 Dry pipe systems

Dry pipe systems are the most common form of sprinkler protection used in coldstores throughout the world. The sprinkler system is charged with air pressure. When a sprinkler operates, air pressure is lost and a valve opens, allowing water to enter the system, and discharge over the fire. There can be a significant time delay between a sprinkler opening, the valve opening and water discharging from the sprinkler heads. The time delay of a large and poorly designed system can be considerable (Golinveaux, 2002). For this reason, fire protection standards limit the volume of dry pipe systems, unless calculations are carried out. The calculations are complex, and at the time of writing, only one sprinkler component supplier could provide software for this purpose.

There are two common variants of dry pipe systems.

- A dry pipe system uses a differential valve where a lower air pressure keeps a valve shut with a higher water pressure. These systems are often fitted with "accelerators", which are mechanical devices which, on sensing pressure drop, will force the valve open and "accelerate" the process in getting water onto a fire. These devices have often provided unreliable service in the field. The most significant problem with dry systems is that if they trip accidently, either through damage to a sprinkler head, a pressure surge in the water supply, or other mechanical failure, the system will flood, and either cause water damage to the coldstore and its contents, or fill the system, leading to the need to defrost it, either by raising the temperature of the freezer, or by dismantling the system.
- A pre-action system is a closed dry pipe system installed with a parallel detection system. The detection system needs to operate, and a sprinkler head needs to fuse, before water will discharge. Coldstores require a special double interlock pre-action system. In this system, the valve will not open until both the detection system and a sprinkler head has operated. If only one event occurs, only an alarm signal will be generated. Hence, if the detection system malfunctions, the

system will not fill with water, which will avoid the need to defrost the pipe work.

Normally, cool room pre-action systems are controlled by electronic detection systems. The detection system should be more sensitive that the sprinkler head, and needs to stand alone from the building's main fire alarm systems.

All dry systems in coldstores must have completely dried air. A useful guide to designing sprinkler systems to achieve this is *Refrigerated Storage* (FM Global, 2000).

6.5.2.2 In-rack sprinklers

Often the most effective form of fire protection in high-piled racking systems uses a combination of roof level sprinklers and in-rack sprinklers. However, the use of in-rack sprinklers is not favoured by warehouse operators, as they are susceptible to mechanical damage, which not only leads to water damage to product, but in a coldstore environment, problems with freezing, which could require a partial strip out of the pipe work to allow the sprinkler system to be reinstated. In-rack sprinklers may require greater clearances between the product and the rack frame to reduce the risk of damage to the sprinklers.

For these reasons, it would be normally best practice to design a coldstore sprinkler system without in-rack sprinkler systems. In some cases, this is not possible, especially if the rack system is unusually high. In such cases, the following design considerations should be noted.

- The in-rack heads should be fed off a pneumatically charged preaction system, rather than a dry system. If a sprinkler head or pipe is damaged and air is lost from the system, a monitored alarm signal should be generated, so that remedial action is undertaken and the fault rectified, without water entering the system.
- The pre-action system should be operated by a linear wire heat detection system. The control panel should be independent of any building fire alarm system.
- The roof level heads should be fed off a different valve set. This may be a conventional dry pipe valve set or a pre-action valve set.
- The system pipe work should be fitted with "drum drips" so that condensation does not block low points of the system pipe work.
- The system can be defended against false alarms by use of a double interlock system. This needs to be balanced against the possible greater fire damage caused by delays in water discharge in a real fire situation.
- The system should be designed to allow the pipe work to be easily stripped out should an activation occur and the system freezes.

6.5.2.3 Antifreeze systems

The SP Technical Research Institute of Sweden has recently carried out research (2000) indicating that most antifreeze solutions used in fire protection systems will increase the rate of energy release. These tests indicate that solutions of calcium chloride and potassium lactate increase the effectiveness of the solution in controlling a fire, while solutions of common antifreeze agents such as propylene glycol and glycerine had the potential to increase the fire growth rate. This research has resulted in the 2007 edition of NZS 4541 *Automatic fire sprinkler systems* (SNZ) restricting the use of antifreeze solutions in high-piled storage applications to "listed" systems.

Calcium chloride has been used in fire protection systems in the past, but has been found to cause considerable problems with corrosion. One manufacturer experimented with a system based on solutions of potassium lactate, but had to withdraw the system from the market, reportedly due to difficulties with leakage.

Another manufacturer has commissioned extensive tests that have allowed the listing of their early suppression fast response (ESFR) antifreeze system based on the use of monopropylene glycol as an antifreeze agent. It is stressed that this is a system as a whole, and for the listing to be valid, the components, control system, sprinkler heads and antifreeze agent must be supplied by the manufacturer.

This system will allow a maximum storage of Class 2 commodities to a height of 10.7 metres in a building with a maximum ceiling height of 12.2 metres.

At the time of writing, IPENZ is unaware of any plans for alternative products or tests to extend the use of antifreeze systems to Class 3 commodities, or to greater heights.

Heat transfer through the pipe can result in significant lengths of pipe outside the freezer having a sub-zero surface temperature. Moisture in the air will condense a significant distance from the freezer boundary unless precautionary measures are taken.

6.5.2.4 Dry sprinklers

Dry sprinklers feature a fusible element and deflector located at one end of a short pipe, and a seal is located at the other end of the pipe. When the sprinkler operates, a rod releases the seal, allowing water to flow through the pipe.

Dry sprinklers can be used in coldstores within other structures. If the space above the coldstore is able to be maintained above 4°C, they can be used on a wet sprinkler system.

Recently, sprinkler manufacturers have added specialist seals to their product ranges, providing adequate vapour seals for most modern coldstore construction systems.

Dry sprinklers are available in various forms, including standard spray sprinklers, and even ESFR sprinklers. The only model of ESFR dry sprinkler currently available will allow rack storage of commodity Class 4 goods to a height of 10.7 metres in a building of up to 12.2 metres height.

Dry sprinklers have three main disadvantages.

- In most areas of New Zealand, they need to be installed inside a roof space where the winter ambient temperatures will not allow the pipe work to freeze. This precludes their use in buildings without a ceiling space, unless the additional complexity of a dry pipe sprinkler system is employed.
- They require multiple penetrations into the refrigerated space, leading to multiple points for heat transfer into the freezer.
- Due to the harsh environment they are installed in, they require either replacement or sample testing at 10-year intervals.

6.5.2.5 Alternate wet and dry systems

Alternate wet and dry systems are used in areas subject to seasonal freezing temperatures. They are no longer described within the New Zealand sprinkler standard, as they have not been installed for a number of years, and are generally considered to be of dubious reliability. They are still installed in the United Kingdom, and could be installed in specialised situations in New Zealand as an *NZBC* Alternative Solution.

6.5.2.6 Pipe work

Few sprinkler contractors have experience installing sprinkler systems in coldstores. A few key items that a specifying engineer should include in contract documents as a "reminder" include:

- the need to provide slope to drain points
- the need to allow flexibility and good seals at all insulation penetrations
- the need to use specialised grooved coupling gaskets and lubricants
- the unsuitability of hemp-based jointing seals, as commonly used in threaded pipe joints in the New Zealand sprinkler industry
- the need to ensure that any pipe penetrating the fabric of the freezer is adequately sealed and possibly insulated
- the need for insulation of the sprinkler pipe work immediately outside refrigerated spaces, to prevent "cold bridging" and subsequent condensation on the sprinkler pipe work
- the need to allow for product rack movement for in-rack sprinklers
- the need to avoid impairing the the structural and seismic performance of the product racks when fitting the sprinkler pipe work.

6.5.2.7 Reduced oxygen systems

Reduced oxygen "hypoxic" systems have been employed in some coldstores as a means of preventing a fire occurring, as against controlling a fire after it has started. Allianz Risk Consultants publish a loss control guideline entitled *Fire protection with low oxygen or Oxy-Reduct Principal Concept*s (2004), which provides useful background information on these systems. This document indicates some possible areas of detailed design requirements to ensure that lessons learnt from the first systems are incorporated into future designs.

The *HSEA*, and the *HSNOA* need to be taken into account when specifying hypoxic systems, and in addition, early consultation with the complex's insurers is essential.

6.5.2.8 Gas flood and other special hazard systems

Gas flood systems are not normally used in large coldstores as the cost would be prohibitive. They may be employed in small coldstores, (typically of supermarket cooler size) if the contents warrant special protection measures.

Similarly, in such special risks, other forms of special hazard system could be warranted. This could include dry powder flooding systems, or water-mist systems.

6.5.2.9 Smoke control

Consider active smoke control systems. The common arrangement of several coldstores connected to an environmental load-out area (ELA) means that individual smoke cells are formed. If ambient air is used as a defrost mechanism for the evaporators, then it is comparatively simple to reconfigure the defrost air flow to supply smoke extraction from the coldstores. Similarly, the ELA can have fans to allow either extraction when smoke is detected in the ELA, or pressurisation to stop smoke from entering the ELA.

6.6 MONITORING

Sprinkler and detection systems should be monitored by a NZFS Approved Monitoring Station.

Monitoring systems are designed to have two levels of alarms:

- defect – generally an indication of a fault, requiring a service technician to intervene
- fire – generally an indication of a real fire, or a serious system fault, however, with smoke detection systems, this can be a symptom of poor design or installation.

The level of monitoring of fire alarm systems needs to balance fire service intervention against false alarms. For that reason it is uncommon to have smoke detection systems signalling a fire, when installed in combination with an active system, such as a sprinkler system.

6.7 INTERFACES

Air handling systems may affect active fire systems. This is especially critical with new technology systems, which discharge a large volume of water from a relatively small number of heads. If the fire plume is distorted by air movement, or if heads operate away from the fire, heads remote from the fire could deplete the water supply and make the sprinkler system ineffective. IPENZ recommends that either air handling systems be configured to shut down in the event or fire or a specific fire engineered design be undertaken.

This is especially critical if ESFR technology is used in freezers. Early detection is required to ensure that the air movement generated by cooling fans does not distort the fire plume and cause sprinklers away from the seat of the fire to open, thereby overwhelming the sprinkler system.

6.8 PASSIVE FIRE PROTECTION

This section describes passive protection systems. Section 6.5 of this document describes active protection systems.

6.8.1 Background

Fire safety precautions are defined in the DBH's *Compliance Document for NZBC Clauses C1, C2, C3, C4 Fire Safety* as being "the combination of all methods used in a building to warn people of an emergency, provide for safe evacuation, and restrict the spread of fire, and includes both active and passive protection." (2008). Passive fire protection (PFP) features relate to elements of construction that are generally part of the fabric of the building as opposed to active features such as sprinklers, detectors, alarms, etc.

Passive and active fire protection systems combine to provide comprehensive fire safety in buildings.

From a *NZBC* perspective, the functionality of PFP in a building relates to Clause C2 – *Means of Escape*, Clause C3 – *Spread of Fire* and Clause C4 – *Structural Stability During Fire* (DBH, 2008).

With regard to demonstrating compliance with the *NZBC*, the designer may choose the option of following the compliance document, or use fire engineering principles to propose an Alternative Solution, or a mix of both, in which case it is an Alternative Solution[4].

If the designer chooses the Acceptable Solution, the compliance document provides recommendations on a 12-step design sequence in section 1.3 – Recommended Design Sequence.

4 *Hot Topics*, section 3.5 (IPENZ, 2007), identifies two types of mixed design: one falls within the Acceptable Solution, and one is an Alternative Solution.

6.8.2 Purpose group and fire hazard category

Generally, a coldstore will be classified as "working, business or storage activities" purpose group and will be classified WL to WF. Table 2.1 of *Compliance Document for NZBC Clauses C1, C2, C3, C4 Fire Safety* (DBH, 2008) notes coldstores under the purpose group WL, which has the lowest associated FHC (FHC 1), and hence the lowest fire load energy density (FLED). While this purpose group may apply in some situations, caution needs to be exercised in assuming that this applies to all situations. In some situations FHC 4 will be applicable, for example, high-rack storage. The FHC has a bearing on the requirements for PFP. See also section 6.2 of this document.

6.8.3 Means of escape

In some situations PFP will form part of the construction of escape routes for the coldstore. Protected paths and safe paths which form exit-ways (refer to *Compliance Document for NZBC Clauses C1, C2, C3, C4 Fire Safety* for definitions) require smoke and/or fire separation.

AS/NZS 1677.2 *Refrigerating systems - Safety requirements for fixed applications* (SNZ, 1998) specifies safety provisions for people in refrigerated spaces. The egress requirements are more onerous than those in the *NZBC*, but will be a means of satisfying the "all practicable steps" requirement of the *HSEA*, which leads successively to the *PECPR Regulations* (DoL, 1999), the *ACoP for Pressure Equipment (Excluding Boilers)* (DoL, 2001), and AS/NZS 1677 *Refrigerating systems*.

Escape routes need to be designed with the arrangement of the product racks in mind.

6.8.4 Firecells

The number of firecells needs to be determined for the coldstore. Where multiple firecells are required, then the common firecell elements will need to have fire separations with specific fire resistance ratings.

Fire separations are the building elements such as walls, ceilings, and floors which separate firecells, and firecells and safe paths. The FRR of fire separations comprises three numbers giving the time in minutes for each of the criteria stability, integrity and insulation. Product/system compliance is demonstrated in accordance with AS 1530.4 *Methods for fire tests on building materials, components and structures - Fire-resistance test of elements of construction* (AS, 2005), or the three NZS/BS 476.20 *Fire tests on building materials and structures - Method for determination of the fire resistance of elements of construction (general principles)*, NZS/BS 476.21 *Fire tests on building materials and structures - Methods for determination* *of the fire resistance of loadbearing elements of construction*, and NZS/BS 476.22 *Fire tests on building materials and structures - Methods for determination of the fire resistance of non-loadbearing elements of construction* (SNZ, 1987).

6.8.5 Structural stability

In some situations in coldstores, some structural elements may require FRRs. There may be requirements, for example, to provide intumescent coatings on structural steelwork to achieve a certain FRR where the steelwork supports a fire rated boundary wall. Product racks which support the insulated panels will require particular care.

6.8.6 Internal fire spread

Various requirements need to be checked for the coldstore. Closures in fire and smoke separations (fire and smoke control doors, dampers, etc) are required. Reaction-to-fire properties of internal surface finishes need to be confirmed. Fire stopping is a very important aspect – wherever services penetrate a fire separation element, the continuity and effectiveness of the fire separation needs to be maintained around penetrations and gaps between building elements by the use of products such as fire collars, fire rated sealants and mastics.

Foamed plastic materials (most coldstore insulated panels will be in this category) have special provisions in Acceptable Solution C/AS1 of *Compliance Document for NZBC Clauses C1, C2, C3, C4 Fire Safety* (DBH, 2008) to protect from ignition. The options to achieve compliance include flame barriers, fire-resistant surface finishes and restricting flame propagation properties. Appendix C of the compliance document lists various test methods that apply.

6.8.7 External fire spread

Depending on various project-specific factors such as boundary separation, external roofs and walls shall be constructed to avoid, amongst other things, horizontal fire spread by thermal radiation or structural collapse. Not all products used to construct coldstores will achieve this requirement.

7 REFRIGERATION

7.1 GENERAL

Refrigeration may be defined as the application of work to create a temperature difference between two spaces. It requires technology to pump heat from a low-temperature space to a higher-temperature space.

We discuss only mechanical refrigeration vapour compression systems as these are the typical application within the storage industry in New Zealand.

Other types of refrigeration systems, such as adsorption, thermoelectric and magnetic, and processes, such as immersion freezing and cryogenic freezing used in specific applications, are outside the scope of this practice note and are not covered.

7.1.1 Energy

Refrigeration technology is a large consumer of electricity within New Zealand across all scales of equipment size.

Generally, there is a relationship between capital cost and potential efficiency of any plant type. To realize the maximum potential efficiency of any plant requires excellence in plant design, installation, commissioning, operation and maintenance.

7.1.2 Refrigerant choices

At present the refrigerants most widely used are R134A for very small systems, R404A for larger commercial systems, and anhydrous ammonia for large industrial plants.

It is likely, if carbon trading or greenhouse taxes are applied, for the synthetic refrigerants (R134A and R404A) to become too expensive for larger direct systems and for them to be utilized together with secondary refrigerants to minimize system charges and likelihood of leaks.

With the development of newer equipment and the necessary associated skills, hydrocarbons and carbon dioxide will be used on small systems, and anhydrous ammonia on larger systems. Carbon dioxide will also find application on large low-temperature freezing applications. Volume production of the newer types of equipment will be required before these systems become cost effective.

7.2 SYSTEM OPTIONS

The refrigeration solution chosen will depend on the following factors:

- type of product to be cooled, for example, fresh, chilled, high-humidity or frozen
- temperature required for stored product, typically ranging from -30 to 5°C
- shape and volume of refrigerated space
- size of heat load – small facilities can have very high heat loads if latent heat of freezing is involved
- water vapour loads from product
- energy costs
- opportunities for using heat rejected from condensers
- number of separately refrigerated spaces
- number of different temperatures required to be controlled within refrigerated spaces
- availability of service support personnel
- availability of services – electricity, water, sewage and stormwater
- proximity of residential properties and schools
- property zoning and noise requirements.

7.2.1 Direct refrigerant

Refrigerant is evaporated within the air cooling coils (evaporator).

7.2.2 Direct expansion

High-pressure refrigerant liquid is metered into evaporator coils by a diaphragm- or bellows-operated needle valve known as the thermostatic expansion valve (TX). This system has high power consumption due to its requirement to maintain constant high discharge pressures to ensure reliable liquid supply to the TX valves and maintain cooling capacity and performance. This is the most widely used small refrigeration system.

7.2.3 Surge drum

The evaporator coil is gravity flooded from a storage vessel above the evaporator. More effective wetting of the evaporator coil's internal piping provides higher effective evaporator capacities than TX operation and the system is used for large cool rooms or cooling processes. It is cost-effective for up to three rooms, although it requires makeup controls on each room vessel.

7.2.4 Pump recirculation

A single storage vessel distributes liquid to multiple evaporators through liquid pumps and distribution metering valves. Evaporators are partially flooded giving simple reliable high performance cooling, although a relatively large refrigerant charge is required. This is the most commonly applied system for large refrigeration loads with multiple rooms (greater than 500 kWr chilled, 100 kWr freeze).

7.2.5 Secondary

A fluid is cooled by the primary refrigerant then pumped through the air cooling room coils. Secondary refrigeration fluids can allow more accurate temperature control, avoiding the complications of phase change with primary refrigerants. Secondary systems are used where the primary refrigerant is toxic or flammable or the refrigerant is liable to cause asphyxiation if it all leaked into the cool space. IPENZ expects the widespread use of propane as the primary refrigerant in secondary refrigeration systems to occur in the future. Secondary refrigerants are typically water with a freezing point depressant additive (for example, monoethylene glycol) but others such as boiling carbon dioxide are increasing in application.

7.3 REFRIGERANT FLUIDS (DIRECT)

IPENZ recommends that almost all refrigeration systems comply with AS/NZS 1677 *Refrigerating systems* (SNZ, 1998), as this is adequate for all except low temperature cascade systems.

7.3.1 Nomenclature

Refrigerants are internationally identified in technical publications and on equipment nameplates by an alphanumeric string starting with R. The strings following the R enable the chemical structures of hydrocarbon and halocarbon refrigerants to be deduced without ambiguity. The strings following the R for other refrigerants, for example, carbon dioxide and ammonia, are a 7 followed by the substance's molecular weight.

In non-technical, public, and regulatory communications on ozone-depleting compounds, it may be more appropriate to use the chemical name.

In New Zealand and Australia AS/NZS 1677.1 *Refrigerating systems - Refrigerant classification* (SNZ, 1998) describes the system. This also lists physical properties such as critical temperature and molar mass, and "safety" properties such as toxicity, flammability limits, global warming potential (GWP), and ozone depletion potential. These safety properties are condensed by assigning each refrigerant to one of the safety groups A1, A2, A3, B1 and B2, where A1 is the most benign. Note that AS/NZS 1677.1 *Refrigerating systems - Refrigerant classification* does not use the terms "hazard" or "hazardous".

Trade names can add confusion. For example, the refrigerant now known as Hychill – 50 was at one time known as HR22/502, but is mostly propane (R290) and contains neither R22 nor R502.

7.3.2 Common refrigerants

7.3.2.1 R134A (hydrofluorocarbon HFC)

Typically used on small direct expansion systems or where a high degree of reliability is required, this refrigerant requires larger compressors and pipe sizes than alternative refrigerants, has GWP problems. It is classified under the HSNO legislation as a non-hazardous gas 1,1,1,2-tetrafluoroethane, Cas No 811-97-2, UN No 3159.

7.3.2.2 R404A (HFC)

Presently, this is the most commonly used direct expansion refrigerant for coldstore applications, but has GWP problems. It is classified under the HSNO legislation as a non-hazardous gas UN No 3337.

7.3.2.3 R410A (HFC)

Widely used in split system domestic heat pumps and air conditioners, but it has GWP issues. It has no HSNO classification, but could be assigned to an appropriate group standard.

7.3.2.4 R717 (anhydrous ammonia)

This is the most widely used refrigerant for large industrial applications. It has a flammable vapour, a strong smell, is toxic, is strongly ecotoxic to fish, and is incompatible with copper components. Other than in very small systems, it requires regulatory compliance with *PECPR Regulations* (DoL, 1999), and elements of the HSNO legislation.

The HSNO legislation has varied the controls for anhydrous ammonia but only when it is contained in equipment that forms part of any other equipment in which anhydrous ammonia is used as a refrigerant. If it is not in a refrigeration system, it is subject to all the controls. If in a refrigeration system there are aspects of the *Hazardous Substances (Identification) Regulations* (ERMA, 2001) and *Hazardous Substances (Emergency Management) Regulations* (ERMA, 2001) which apply – emergency management levels 1 and 2 apply for any quantity of anhydrous ammonia, and level 3 applies to five kg or more. Industrial refrigeration systems are likely to have hundreds of kilograms.

The DoL's ChemSafe software will list all the relevant regulatory controls when the names and quantities of a hazardous substance are entered into the system.

7.3.2.5 R744 (carbon dioxide)

Carbon dioxide is increasingly being used for low temperature applications (down to –50 °C) as the lower of two cascade refrigerants, where it is used as the low boiling temperature secondary refrigerant, and is being used transcritical for heat pump and air conditioning applications. It provides high performance in high heat-load applications such as product freezing in plate carton freezers. Other than in very small systems, carbon dioxide requires compliance with a wider range of statutory regulations, notably the HSEA and the *PECPR Regulations* (DoL, 1999).

Carbon dioxide is a non-hazardous gas in both the HSNO legislation and AS 4343 *Pressure equipment – Hazard levels* (AS, 2005). However, when it is in the form of a refrigerated liquid, or as a solid (dry ice), AS 4343 *Pressure equipment – Hazard levels* classifies it as a hazardous gas and it is subject to the *Hazardous Substances (Compressed Gases) Regulations* (ERMA, 2004).

7.3.2.6 R290 (propane)

This option is limited due to flammability. Other than in very small systems, R290 requires compliance with a wider range of statutory regulations, notably with the *PECPR Regulations* (DoL, 1999), the *HSNOA*, and the *Electricity Regulations* (MED, 1997). If a location holds more than 100 kg it will also be subject to the HSNO test certification requirements (ERMA, 2004).

Detailed adherence to AS/NZS 1677 *Refrigerating systems* (SNZ, 1998) allows practical utilisation in storage applications, as adherence ensures that in the event of a leak, explosive concentrations are unlikely to form, and if they do form are unable to ignite.

AS/NZS 1677 *Refrigerating systems* Appendix D, gives a flowchart that shows how electrical apparatus for hazardous (potentially explosive) areas may be selected, and leads designers to the standards AS/NZS 2430 *Classification of hazardous areas* (SNZ, 2004) and AS/NZS 2381 *Electrical equipment for explosive gas atmospheres* (SNZ, 2005).

There are plans to supersede these during 2009 with AS/NZS 60079.10 *Electrical apparatus for explosive gas atmospheres - Classification of hazardous areas* (SNZ, 2004) and IEC 60079-14 *Explosive Atmospheres – Part 14: Electrical Installations Design, Selection and Erection* (IEC, 2007) respectively.

7.3.3 Odorising

AS/NZS 1677.1 *Refrigerating systems - Refrigerant classification* (SNZ, 1998) requires group A3 refrigerants to be odorised in a manner functionally equivalent to that required for liquefied petroleum gas. A3 refrigerants include ethane, propane, butane and propylene.

Filters and driers commonly used in the refrigeration industry will remove the ethyl mercaptan odorant used for liquefied petroleum gas. The NZFS has suggested that odorants be checked and refreshed if necessary (NZFS, 2008, p14). AS/NZS 1677 *Refrigerating systems* (SNZ, 1998) recognises “alternative safety provisions” so we note that R1270 propylene, with refrigerant properties very similar to propane, has a natural strong odour of its own. Signage may also be an “acceptable alternative” safety provision.

7.3.4 Changes of refrigerant (drop-ins)

A change of refrigerant may change the hazard level of the installation given by AS 4343 *Pressure equipment – Hazard levels* (SA, 2005). IPENZ recommends that designers follow the procedure given in section 7.5a–c of this document for existing and the new refrigerants, and if the hazard level increases a full plant design review is needed as described in section 7.5 of this document.

7.4 SYSTEM EQUIPMENT

7.4.1 Compressors

7.4.1.1 Hermetic (cans)

These are used on small systems, and feature a reciprocating or scroll compressor and motor housed within a sealed metal can. They are compatible with most refrigerants except ammonia, are available for all applications and are reliable if correctly applied, although they have a high power consumption.

7.4.1.2 Semi-hermetic

Semi-hermetic compressors have the motor driving to a reciprocating or screw compressor, with the motor cooled by refrigerant gases. They are available for all applications, are used on medium-sized systems, and are compatible with most refrigerants except ammonia. They are reliable if correctly applied, although they are limited by pressure range, have a high power consumption and high electrical draw requirements.

7.4.1.3 Open drive reciprocating compressors

These are used on medium to large systems and are compatible with all refrigerants, but are limited by pressure range. They are efficient, but require high levels of maintenance.

7.4.1.4 Screw compressors

These are used on medium to large systems, are compatible with all refrigerants, are able to operate over most typical pressure ranges, but have poor efficiency under partial load unless operated on variable speed drive (VSD). They are reliable and have low maintenance requirements.

7.4.1.5 Compressor oil

The compressor oil must be compatible with the refrigerant and the refrigeration system design. Different oils have variable solubilities in different refrigerants at different temperatures. Some oils are highly hygroscopic and care is required when handling them.

7.4.2 Evaporators

The success of a particular facility operation is critically dependent on correct design and installation of the evaporator and fan combination within the refrigerated space. Most other components within the refrigeration system can be expanded or upgraded as required, but this is generally not the case with equipment within the coolspace.

Coldstores generally are of forced draft cooler (FDC) or ducted types.

7.4.2.1 Forced draft coolers

FDCs provide even airflow within the cooled space but incur significantly higher operating and maintenance costs with multiple fans, valves, and refrigerant leak points within the cool space. FDCs come in two forms

– forced draft (fan blowing through the evaporator) and induced draft (fan pulling through the evaporator). Induced draft FDC is the standard type, and while forced draft provides significantly higher air humidity in chilled produce storage environments, they are “specials” of higher cost and longer delivery.

7.4.2.2 Ducted systems

Ducted systems require care with air distribution design and will generally have areas of poor air distribution. Ducted systems will handle high localised heat loads within the cool space that FDC systems will not due to the “averaging” of the load throughout the coldstore. Ducted systems allow minimum numbers of fans and refrigerant control valves thus minimising maintenance requirements. Ducted systems allow all refrigerant controls to be mounted outside the coolspace reducing risk of product damage due to refrigerant leaks and further assisting maintenance. Ducted systems allow the use of “air defrost” systems, maximising potential energy efficiency. Duct air velocities should be in the range of six to eight m/s to optimise the required fan power. Fan noise transmission to neighbouring properties can be an issue.

7.4.2.3 Evaporator design

Evaporators must be of sufficient size to handle the storage heat load.

Chilled heat loads are generally, in order of significance: product temperature reduction requirement, door air infiltration, fan heat, building fabric transmission, product respiration, lighting, miscellaneous forktrucks and people.

Freezer heat loads are generally, in order of significance: product temperature reduction requirement, fan heat, building fabric transmission and lighting.

Frozen heat loads are generally, in order of significance: building fabric transmission, fans, lighting, door air infiltration, forktrucks and people. Note that due to joint losses, building fabric transmission is 1.5–3 times the published theoretical values depending on the quality of the vapour barrier installation and the age of the facility. The above assumes that doors are optimally managed with environmental areas, rapid or automatic doors and air locks. Without these measures, door heat loads will dominate.

Air circulation through the storage space must be maintained at a level consistent with the product storage specification temperature fluctuation range. For frozen storage, typical airflow volumes range from 10 to 20 room changes per hour. For chilled produce, storage typical airflow volumes range from 40 to 80 room changes per hour, depending on the heat removal requirement of the produce.

Evaporators must have sufficiently wide fin spacing and sufficient fin area to allow room cooling to be maintained without constant interruption for evaporator defrosting. If not catered for, loss of room temperature control will result. Typically, wide fin spacing for frozen storage is required, although the most difficult is holding of product accurately at 0 °C. Conservative fin spacing will range from six to 12 mm.

Defrost system options in preference by energy efficiency are air, hot gas, water, and electric. Water defrosters in freezer environments are difficult to automate successfully. Hot gas defrosters require heated drain trays and defrost drains.

7.4.3 Condensers

The condensing plant enables the heat drawn from the refrigerated space to be exhausted to the environment and is second in significance to the evaporator equipment. The condensing plant must be sized for the expected maximum heat removal rate from the cool space, plus the heat applied by the compressing equipment in transferring heat from the cool space, which is generally the maximum compressor drawn power. The design conditions to which the heat is to be wasted is based on the ambient conditions. Note that designing to one per cent ambient weather will mean that, on average, 3.65 days per year the plant will not perform to design, or in an exceptionally hot year, it may not perform for several weeks on end. Specifically, beware of fresh produce heat loads, as there is a multiplier effect as the heat load increases and the capacity of the plant decreases.

Refrigeration system efficiency is proportional to the temperature difference up which heat must be pumped. Small condensers operating at high pressures increase power consumption and wear and tear on the compressor.

7.4.3.1 Air-cooled condensers

Air-cooled condensers are simple, reliable and cheap, and facilitate maintenance of the high discharge pressures required for the TX valve’s direct expansion operation. Condensing temperature is determined by air dry bulb temperature. No water supply is required. These are the standard condensers used in small facilities.

7.4.3.2 Evaporative condensers

Evaporative condensers allow maximum efficiency operation. The condensing temperature is determined by air wet bulb temperature (lower than dry bulb), but they require water treatment for corrosion and *Legionella*. These condeners are the standard for medium- and large-size facilities.

7.4.3.3 Shell and tube condensers

The characteristics of shell and tube condensers are similar to evaporative condensers, but they feature a compact transport package, require cooling towers, and allow heat discharge to atmosphere to be remote from the compressors with minimal refrigerant piping (pumped water to cooling towers). They are common on medium-sized facilities but PHE condensers are cheaper on large facilities.

7.4.3.4 Plate heat exchanger condenser

Plate heat exchanger (PHE) condenser characteristics similar to shell and tube condensers, but they allow operation with the minimum refrigerant charge.

Noise generated by fans on condensers and cooling towers must be considered. It may be necessary to fit variable speed drives to fans to allow operation at lower speeds to achieve acceptable noise levels and make energy savings during low load periods. This will reduce the capacity of the condensing system.

7.4.4 Groundwater

Some coldstores rely on heat exchangers that reject heat to water supplied from groundwater bores through the municipal supply system. If that water is then run to waste, either through stormwater and a water course, or through the sewer system, an unnecessary load is placed on those systems. If that water is re-injected into the source aquifer, that aquifer is maintained, and no load is placed on either of the municipal disposal systems. The water must be re-injected at a point where it will not recirculate to the intake point.

Where the cooling water is drawn from a river and returned downstream the designer must ensure that temperature increases are not detrimental to fish life and controls are in place to minimise contamination through leaks in the condensing system.

Extracting or re-injecting groundwater or river water may require RMA consent.

7.4.5 Refrigerant piping

Piping must be suitably sized. Insufficiently sized piping will create pressure drops that will reduce the effective capacity of the plant and increase the power consumption per unit of heat removed. Oversized piping and/or lack of or incorrectly designed traps will cause oil logging in direct expansion systems with the risk of compressor hydraulic failure and liquid logging with the risk of compressor protection vessel high levels on flood back with liquid recirculation systems. Separator vessels and liquid pumps close to the heat load can improve efficiency by reducing suction line pressure drops.

Piping must be designed and supported to allow sufficient flexibility to cater for thermal expansion and mechanical vibration, yet be sufficiently restrained to cope with gravity, wind and design earthquake loads.

Piping design must comply with the requirements of the *PECPR Regulations* (DoL, 1999), and IPENZ recommends the *ACoP for Pressure Equipment (Excluding Boilers)* (DoL, 2001) and AS/NZS 1677 *Refrigerating Systems* (SNZ, 1998). There is no requirement to consult the DoL during design, but in practice many designers seek advice from the DoL or from the relevant standards body.

Refrigeration pipe work near the compressors will be subject to vibration, and has to be sufficiently flexible to avoid cracking and consequently leaking refrigerant. Similarly, ice that forms on fan blades will cause imbalance and vibration.

Most pressure piping uses standard ASME flanges with hard-faced gaskets. To avoid leaks, most ammonia refrigeration pipe joints and valve connections are welded. Use connections with bolted flanges sparingly. Very small steel pipes usually feature screwed joints. Many proprietary types exist and they must be chosen to suit the application. To avoid leaks, the sealing surfaces must be clean and without damage, and the screws must be properly tightened. Small copper pipes may use screwed or brazed joints. Copper is not suitable for ammonia refrigerants.

Steel pipes can corrode under the insulation, as discussed by Dettmers and Reindl (2007).

7.4.6 Refrigeration service valves

Valves must be installed to allow all service work to be performed within the constraints of the operating environment. Valve location and orientation should allow acceptable service access, and ideally, valves should be located outside the cold space. Care is required to avoid the very high pressures generated by trapped cold liquid between closed valves.

7.4.7 Non-condensables

Air must be absent from the refrigeration piping system at startup and removed after all maintenance procedures. Plant that operates in vacuum must have a means of removing air and moisture that enters through piping leaks.

7.4.8 Oil management

If oil must be regularly added to the refrigeration compressors then system practices will be required to remove an equal quantity of oil at specific drain points or through an oil rectification system.

This will generally be the case for ammonia (R717) plant using mineral oil.

7.4.9 Refrigeration plant planning

A cost-benefit analysis is required on the level of plant availability, reliability, cost of down time, degree of plant duplication/standby, operation in high ambient temperatures, and the operation of critical plant components at loadings higher than their design loading rates.

The selection of refrigerant will depend on plant scale, complexity and availability of adequate service support personnel.

7.4.10 Refrigeration machinery room

The refrigeration machinery room should be in a fire-rated enclosure as close as possible to the cold room evaporators and fans, as close as possible to the electrical supply, and as far as possible from residential neighbours. Ideally, the electrical equipment should be in a separate fire-rated room adjacent to the refrigeration plant room. AS/NZS 1677.2 *Refrigerating systems - Safety requirements for fixed applications*, clause 4.7.2 (SNZ, 1998) specifies ventilation rates.

If a hydrocarbon refrigerant is used, the refrigeration machinery room needs to be completely open or in the form of a cage.

7.5 SYSTEM CODE COMPLIANCE

The following is the general design procedure to ensure pressure piping compliance.

a. From AS/NZS 1677.1 *Refrigerating systems - Refrigerant classification* (SNZ, 1998), determine refrigerant classification. A is non-toxic, B is toxic; 1 is non-flammable, 3 is highly flammable. For example, HFCs and carbon dioxide (R744) are classified A1, hydrocarbons are classified A3, and ammonia (R717) is classified B2.

b. From AS/NZS 1677.2 *Refrigerating systems - Safety requirements for fixed applications*, clause 2.2 (SNZ, 1998), determine the storage facility's category of occupancy and from clause 2.3 select the permitted refrigerant and cooling system. High-occupancy public areas or places where people have limited movement limit the type of refrigerant and cooling system that may be used.

c. From AS 4343 *Pressure equipment – Hazard levels* (AS, 2005) determine the hazard levels for pressure vessels and piping. These are determined by the type of refrigerant, and by the product of size (the volume of pressure vessels and diameter of the piping) and pressure of the equipment.
Gas or liquid contents are classified as lethal, very harmful, harmful, non-harmful. Table 1 combines the nature of the contents with the product of size and pressure to provide a measure of hazard ranging from A high, B average, C low, D extra low, E negligible.

d. From the DoL's *ACoP for Pressure Equipment (Excluding Boilers)* (2001), Appendix A and the hazard level, determine the required level of system-independent design verification and plant installation inspections for the pressure vessels and piping.
Equipment with hazard level D and above requires piping system design verification by a recognised inspection body. Hazard level C and above requires certificate(s) of inspection from a recognised inspection body[5].
Only relatively small ammonia and hydrocarbon refrigeration systems do not require independent verification, but even for these systems, the fullly documented design and peer review processes should be followed during the manufacturing and fabrication stages of the project.

e. AS/NZS 3788 *Pressure equipment – In-service inspection* (SNZ, 2006) requires in-service inspections by an independent inspection body for all equipment with hazard level C and greater. The owner is responsible for inspections of equipment with hazard levels D and E.

7.6 CONTROL SYSTEMS

7.6.1 System control overview

A properly designed and implemented control system is critical to the safe and efficient operation of refrigeration plant, and design and implementation should be performed only by experienced and competent personnel.

Small- to medium-size refrigeration plants may have proprietary control systems provided by the manufacturer. Medium- to large-size systems will use programmable logic controller (PLC) industrial computer control systems.

It is now standard practice to have supervisory control and data acquisition (SCADA) systems to perform as the "operator interface" to allow the plant operator to monitor equipment functions and parameters, and to control the plant, through a desktop computer.

All critical room temperatures, plant temperatures and pressures, will be observable through the SCADA system. It will record and file all relevant data allowing subsequent viewing and reporting of all previous temperatures and plant operational parameters. Historical data should be backed up to provide a permanent record of product storage history.

The SCADA computer and operating system software should be upgraded at least every five years to ensure the system remains currency with IT industry personnel skills.

5 Recognised inspection bodies, which are organisations recognised by the Secretary of Labour, employ or engage design verifiers and/or equipment inspectors. Design verifiers are engineers registered by IPENZ under a scheme functionally equivalent to that for chartered professional engineers.

7.6.2 Temperature sensors

A sufficient number of temperature sensors should be located throughout the refrigerated space to measure product temperatures.

Air on and air off evaporator temperature sensors should be provided for each separately controlled refrigerated zone.

7.6.3 Temperature sensor installation

Temperature and other critical sensor cabling must be run with a physical separation from power cabling to reduce signal interference and noise. Electrical earth loops can cause problems.

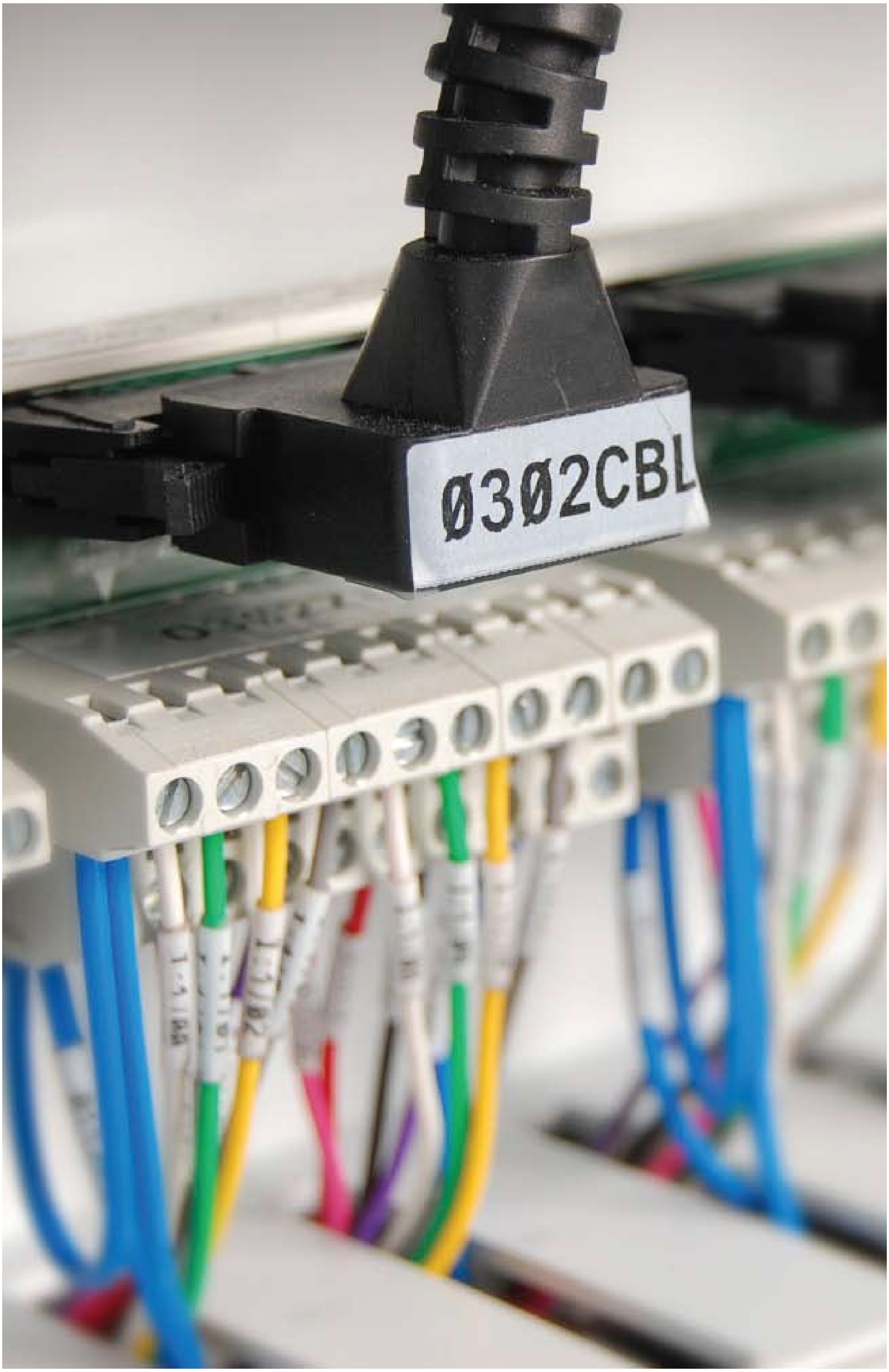
7.6.4 Plant controls

Sufficient control hardware and software should be in place to allow the plant to operate in a safe, effective and efficient manner.

Hardware and software must be planned and installed to allow as simple and practical operation and maintenance as possible.

7.6.5 Documentation

Documentation of the control system logic is important, both in PLC/SCADA terminology and in lay language. If a clear explanation of the logic is not available, it is difficult to assess the design principles and failsafe applications at a later date when the designer is no longer available.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8 ELECTRICAL SERVICES

8.1 GENERAL

Section 3(d) of the *BA* requires buildings to be designed, constructed, and able to be used in ways that promote sustainable development. This suggests energy efficient design, which may be promoted by electrical load shedding, timed shutdown with the doors closed, power factor correction, and variable speed fans.

Historically, electrical faults are reported to account for 30 per cent of fires in coldstores and are the biggest single cause of all fires (Nelligan, 2006).

The *Electricity Regulations* (MED, 1997) provide the legal environment for electrical designers. These regulations refer to AS/NZS 3000 *Electrical installations (known as the Australian/New Zealand Wiring Rules)* (SNZ, 2000). All installations must comply with this standard, which has useful sections for both hazardous areas (clause 7.7) and refrigeration rooms (clause 6.6).

The additional costs for a reliable installation can be particularly justified in a coldstore since the full electrical load can run 24 hours per day often with no staff present, relying on automatic systems to shut down in the event of a problem.

Electrical devices and circuits should be kept to a minimum within cold storage areas and also in areas classified as hazardous, where all equipment must be certified in accordance with AS/NZS 2381.1 *Electrical equipment for explosive atmospheres - Selection, installation and maintenance - General requirements*, Appendix G for the correct zone classification (SNZ, 2005).

The following provides a checklist for minimal equipment needs.

1. Normal working lights
   - luminaires must be enclosed to retain the hot elements of lamps when they fail
   - the maximum rating of lamps must be indicated on each luminaire
   - discharge lamps should be "instant start" types.
2. Egress lights
   - see AS/NZS 1677.2 *Refrigerating systems - Safety requirements for fixed applications*, clause 4.2 (SNZ, 1998)
   - some designers arrange that the egress lights are always on, as stored product can be a significant barrier to reaching a door in the dark. See section 8.11.3 of this document.
3. Power outlets
   - only essential power outlets should be within coldstores – all maintenance outlets should be placed outside the doors
   - battery-powered robotic material handling devices will need special provision for safe battery charging – see section 8.10 of this document
   - power outlets should not be installed in hazardous areas. Even if they are rated for the hazardous area, they may only be used for equipment that is also rated for the hazardous area. Experience suggests that rated outlets are sometimes connected to a lead fitted with a normal cord socket, which is then connected to normal electrical equipment, defeating the whole principle.
4. Push-button alarm systems for use other than in a fire (for example, egress).
5. Temperature and humidity sensors
   - All sensor circuits in classified areas (zones 1 and 2) must comply with either the intrinsic safety requirements in AS/NZS 60079.11 *Electrical apparatus for explosive gas atmospheres - Equipment protection by intrinsic safety 'i'* (SNZ, 2006) or another suitable method of explosion protection meeting the requirements of AS/NZS 2381 *Electrical equipment for explosive atmospheres* (SNZ, 2005).
6. Defrost and trace heaters (for example, doors)
   - All heating devices in areas classified hazardous (zones 1 and 2) (see section 8.2 of this document) must comply with flameproof or increased safety requirements.
7. Primary plant (for example, fans and air-handling units, compressors)
   - All primary plant in areas classified hazardous (zones 1 and 2) (see section 8.2 of this document) must be suitable for the hazardous area.
8. Fire detection and alarm devices
   - All detection and alarm devices in areas classified hazardous (zones 1 and 2) (see section 8.2 of this document) must be suitable for the hazardous area.

8.2 HAZARDOUS AREAS

8.2.1 Flammable gases, mists, vapour or dust

The first step in determining the risks from fire or explosion of flammable materials is to carry out an assessment of the process materials, chemicals, equipment and coldstore operations. The output from this assessment provides documented evidence of the types of process plant and flammable materials used in a particular area and a provides a set of schedules and drawings that define the "hazardous areas". Once this assessment has been reviewed and agreed with the site management, a suitable protection system can be designed and installed to minimise the risk of ignition.

Hazardous areas are those in which risks of ignition of flammable gases, mists, vapours or dust may exist.

Electrical equipment and instrumentation for those areas must have appropriate explosion-protection. This type of electrical equipment is generally significantly more expensive than otherwise similar equipment.

Note that the standards listed in this section relate only to ignition protection from electric power sources. Other techniques of explosion protection are also relevant to prevent ignition from other sources, such as from self heating, spontaneous combustion, mechanical friction, impact or static electricity.

AS/NZS 3000 *Electrical installations (known as the Australian/New Zealand Wiring Rules)* (SNZ, 2000), AS/NZS 2430.3.1 *Classification of hazardous areas - Examples of area classification - General* (SNZ, 2004), and AS/NZS 60079.10 *Electrical apparatus for explosive gas atmospheres - Classification of hazardous areas* (SNZ, 2004) all use very similar wording to define hazardous areas as those in which an explosive atmosphere is present, or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of potential ignition sources.

AS/NZS 3000 *Electrical installations (known as the Australian/New Zealand Wiring Rules),* clause 7.7.2.1, places the responsibility for classification of a hazardous area onto the persons or parties in control of the installation. AS/NZS 60079.10 *Electrical apparatus for explosive gas atmospheres - Classification of hazardous areas*, clause 4.1, requires the area classification to be carried out by those who have knowledge of the properties of flammable materials, the process and the equipment, in consultation, as appropriate, with safety, electrical, mechanical and other engineers.

IPENZ recommends that this responsibility be discharged within the framework required by the *IFEG* (DBH, et al., 2005) collaboration described in section 6.2 of this document.

The NZFS's Design Review Unit has stated that it is more than happy to discuss particular projects with designers in the *IFEG* process, before a building consent is lodged.

Other parties include:

- the designer or contractor responsible for selecting the hazardous materials, for example, the refrigeration designer or contractor
- the refrigerant fluid supplier
- the electrical services designer or specifier
- the owner of the coldstore (for hazardous areas classification, not for engineering).

Overall requirements are set by the identification of hazardous areas, as described in the AS/NZS 2430.3 *Classification of hazardous areas - Examples of area classification* series of standards (SNZ, 2004). AS/NZS 60079.10 *Electrical apparatus for explosive gas atmospheres - Classification of hazardous areas*, clause 4, now specifies the procedure for classifying the areas, which became known as either zone 0, 1 or 2. A section of the plant where the hazard is highest is known as zone 0 or zone 1, and where it is lower is known as zone 2. Non-hazardous areas are zoned NH.

The standard defines the hazardous areas zones by the likelihood of the presence of flammable mists, vapour or gas.

8.2.1.1 Zone 0

Zone 0 is a place in which an explosive atmosphere consisting of a mixture in air of flammable substances in the form of a gas, vapour or mist is present continuously, for long periods or frequently.

8.2.1.2 Zone 1

Zone 1 is a place in which an explosive atmosphere consisting of a mixture in air of flammable substances in the form of a gas, vapour or mist is likely to occur occasionally in normal operation.

8.2.1.3 Zone 2

Zone 2 is place in which an explosive atmosphere consisting of a mixture in air of flammable substances in the form of a gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only. "Persist" is defined in AS/NZS 60079.10 *Electrical apparatus for explosive gas atmospheres - Classification of hazardous areas*.

If flammable refrigerant fluids are to be used then any enclosed refrigeration machinery rooms must be classified as zone 1. They must also be suitably ventilated and should be separated from the coldstore structures by a fire-rated barrier.

AS/NZS 2381.1 *Electrical equipment for explosive atmospheres - Selection, installation and maintenance - General requirements* (SNZ, 2005) prohibits the following equipment from being installed in a hazardous area:

- battery chargers with their control equipment and batteries being charged, unless such equipment is suitable for the hazardous area
- low-pressure sodium-vapour discharge lamps.

The standard requires electrical equipment selected for use in hazardous areas to be protected by one or a combination of specified explosion-protection techniques.

8.2.2 Refrigerant fluid characteristics

The definition of hazardous areas depends on the particular refrigerant used in the plant. A plant designed for one refrigerant cannot be assumed to be suitable for a different type of refrigerant.

The following section describes some of the differences between anhydrous ammonia, a traditional refrigerant, and propane, a typical hydrocarbon refrigerant.

Anhydrous ammonia has very different physiological effects, flammability limits and other characteristics to propane refrigerant as shown in Table 2 below.

	Vapour density at 15 °C (Air = 1)	**Toxicity** (ppm)	**Auto-ignition temperature** (°C)	**Lower explosive limit** (v/v %)	**Upper explosive limit** (v/v %)	**Upper minimum ignition energy** (mJ)
Anhydrous ammonia	**0.89**	**25**	**630**	**15.0**	**28.0**	**680**
Propane	**~ 1.8**	**1,000**	**450**	**2.1**	**9.6**	**0.26**

Table 2: Characteristics of refrigerants.

Ammonia is lighter than air and so dissipates and disperses readily. Propane is heavier than air and consequently will accumulate at floor level and will not be dispersed by natural ventilation in the same way ammonia will do.

Ammonia leaks are evident to humans at extremely low concentrations, which can provide an early warning of an ammonia leak. Ammonia toxicity to humans occurs at 25 ppm while propane becomes toxic at 1,000 ppm.

AS/NZS 1677 *Refrigerating systems* (SNZ, 1998) states in clause 2.7, that "group A3 refrigerants shall be odorised in a manner functionally equivalent to that required for LPG. Alternative safety provisions may be approved". Group A3 refrigerants include ethane, propane, butane and the higher order hydrocarbons.

Ammonia is difficult to ignite, as it has a high auto-ignition temperature and high minimum ignition energy of 680 millijoules (mJ). Propane has a lower auto-ignition temperature and much lower minimum ignition energy in air of only 0.26 mJ. (Kuchta, 1985).

The lower explosive limit (concentration of refrigerant vapour in air) of ammonia is very high at 15 per cent, whereas propane is low at 2.1 per cent mixture. This means that a relatively dilute mixture of propane and air will be capable of being ignited.

8.2.3 Combustible dusts

Some food processing operations generate finely-divided particles that can form combustible dusts. The AS/NZS 61241 *Electrical apparatus for use in the presence of combustible dust* (SNZ, 2005) series of standards provides guidance.

8.2.4 Ventilation systems

An alternative to installing explosion-protected electrical equipment in hazardous areas is to install a ventilation system that dilutes any gas or vapour leaks and thus prevents an explosive or flammable mixture from forming. The ventilation systems must be engineered specifically for the plant and the controls for the ventilation system must comply with recognised standards such as AS 1482 *Electrical equipment for explosive atmospheres - Protection by ventilation – Type of protection v* (AS, 1985). This standard stipulates the features and operational requirements for these ventilation systems. The design, installation, operation and maintenance of such a system is complex and expensive, however this type of system will prevent gas or vapour fires and explosions.

8.3 POWER TRANSFORMERS

Transformers should be installed with fire-rated blast walls separated from the adjacent buildings and from adjacent transformers. Assuming that the transformers are external to the building, then at least the top and one side should be open to atmosphere for cooling and pressure relief.

For oil-filled transformers, each transformer should be bunded to contain oil leakage. Bund drains should incorporate oil-stop valves or an interceptor to prevent oil entering the stormwater system.

8.4 SWITCHROOMS

Main switchboards and motor control centres should be located in purpose-built one-hour-fire-rated electrical switchrooms. The rooms must not be in any low-temperature area or in any classified hazardous area, and should be located well clear of any water risks, such as drainpipes, refrigeration pipes or overhead gutters (especially internal roof gutters) that have a high probability of leaking at some time in their design life.

The only water pipes that should be located in electrical rooms are fire sprinkler pipes. The probability of a sprinkler accidentally activating is extremely low. If a fire occurs within a switchroom, the sprinkler will limit the damage, and allow earlier re-commissioning when compared with a room not protected by sprinklers. If a risk assessment dictates the need to minimise the possibility of accidental water damage in a switchroom, some design approaches could include the specification of welded pipe work, as against screwed or mechanically jointed pipe work, protected sprinkler heads, and possibly the installation of a pre-action system.

Because gnawing damage from rats or mice can occur to plastic components and cable sheaths, rodents must be deterred from entering switchrooms and rodent bait stations should be maintained.

8.5 SWITCHBOARDS

The total electrical load for large coldstores can be in the 200–1,500 kVA range. A short circuit fault in an electrical switchboard can release a very high level of energy. If an electrical fault occurs, some or all of that energy can be released within the switchboard or at the short circuit location. The short circuit current available from transformers can be of the order of 20 times the full load current. If the transformers are connected in parallel then these figures can almost double.

For this reason switchboards must be type-tested and segregated to form 3 or form 4 in AS/NZS 3439.1 *Low-voltage switchgear and control gear assemblies - Type-tested and partially type-tested assemblies* (SNZ, 2002). This provides greater safety and protection and will assist in protecting operators against some internal arcing faults.

Apart from the dramatic explosive effects of a short circuit, there are also other long-term electrical problems that can occur.

- Low current leakage – especially related to moisture and contamination of insulation – can develop over a period of time. Whilst this may dissipate only a few joules of energy, it can cause tracking over insulation and eventually an arcing fault and possible fire.
- Poor electrical connections, as cable or conductor terminations can also degrade over time and cause fires due to heat conducted from the source.
- Ground or earth faults.

Mitigation measures to monitor and protect against many of these risks include:

- ground fault protection elements on all incoming circuit breakers and on major feeder circuit breakers, set to no more than 10 per cent of the rated current
- 300-mA residual current detectors (RCD) and shunt trip units on all moulded case circuit breakers
- all circuit breakers that are fitted with ground fault or RCD protection should be fitted with auxiliary contacts connected to an automated alarm monitoring system.

Power and control circuits should be segregated wherever possible in separate compartments of the switchboards.

The switchboard enclosure should be adequately rated for the environment where it will be installed. In switchrooms, IP42 should be the minimum rating, however IP54 would be more suitable for sites where dust is present.

Switchboards require routine inspection, testing and preventive maintenance to protect against deterioration. This can include annual physical checking of all equipment, contact terminations, and regular infra-red (thermographic) monitoring using hand-held infrared detectors or cameras to identify and quantify hot spots in switchboards.

8.6 ELECTRIC MOTORS

Large coldstores can have refrigeration compressors driven by electric motors with powers in excess of 300 kW. All refrigeration compressor motors require adequate fast-acting protection to sense all the potential faults from overload, stator winding faults, loss of one or more phases, over temperature, and in the case of large motors, bearing temperatures.

Motors in hazardous areas must meet explosion protection requirements specified generally in AS/NZS 2381.1 *Electrical equipment for explosive atmospheres - Selection, installation and maintenance - General requirements* (SNZ, 2005).

Motors connected to VSDs often require special features, such as non-drive-end bearing insulation and increased stator winding dV/dt rating. Consult motor manufactures for recommendations and follow their installation guidelines. Particular care is required during installation of motor cables to provide adequate high-frequency earthing. Alternatively, output filters can be specified for the VSDs to minimise the requirement for high-frequency mitigation.

8.7 CABLES

PVC and some other plastic insulated cables become brittle at low temperatures, and should not be installed in low-temperature situations. Cables with insulation suitable for use below 0ºC (and down to -40°C, or lower) are:

- silicone rubber (EPR)
- cross-linked polyethylene (XLPE)
- mineral-insulated metal sheathed (MIMS)

The use of PVC cables in conjunction with expanded polystyrene insulation has been identified as causing problems due to the migration properties of the plasticisers used in PVC sheath. Cables passing through sandwich insulation panels must therefore be enclosed in suitable mechanical protection or conduits (Nelligan, 2006).

Applications involving electric trace heating cables (doors and defrost trays, for example) must not be fitted in contact with timber, plastic or other combustible insulation materials, and must be temperature self-limiting type. It is also advisable to provide RCD protection with a sensitivity not exceeding 30 mA to each trace heater circuit.

Power cables used with most electronic VSDs must be screened, multi-core cables to reduce interference with adjacent circuits.

8.8 ELECTRICAL EQUIPMENT AND CABLE INSTALLATION

All equipment in hazardous areas must comply with AS/NZS 2381 *Electrical equipment for explosive gas atmospheres* (SNZ, 2005). This standard is expected to be superseded by IEC 60079-14 *Explosive Atmospheres - Part 14: Electrical Installations Design, Selection and Erection* (IEC, 2007). Where possible, electrical and instrumentation equipment should be installed away from the hazardous areas. In such cases, explosion-protected construction will not be required, reducing the installation's cost and simplifying maintenance.

All electrical service equipment, including transformers, switchboards, cabinets, machinery, recessed light fittings, and racks must be seismically restrained in accordance with NZS 4219 *Seismic performance of engineering systems in buildings* (SNZ, 2009). With respect to structures and cabinets, AS/NZS 2381.1 *Electrical equipment for explosive atmospheres - Selection, installation and maintenance - General requirements* (SNZ, 2005), clause 3.4, requires equipotential electrical bonding of metal parts in hazardous zones 0 and 1 and for exposed conductive parts of electrical enclosures in zone 2.

Power cables are usually run underground from the transformer into a cable trench or in PVC ducts to the switchroom and then, with a sufficient bending radius, to a gland plate in the underside of the switchboard. Where the trench passes under the wall, the fire rating must be maintained and water must be kept out, so a fireproof and waterproof plug must be provided.

Some switchrooms house oil-filled transformers or oil-filled switchgear. Cable trenches in these rooms may be filled with sand after commissioning, as the sand inhibits oil combustion.

Cable trenches may extend into the refrigeration machinery room, with power cables clipped to one side and control cables to the other. Fireproof plugs must be provided where the trenches pass under fire-rated partitions or walls.

AS/NZS 1677 *Refrigerating systems* (SNZ, 1998) imposes restrictions on flammable and potentially explosive A3 refrigerants and, except for extremely small systems, requires installation at ground level or above, hence refrigeration pipe work must not be located in the cable trenches. The practice of making vertical holes for cables in coldstore sandwich panels by using hot tools[6] is to be discouraged. Apart from the fire risk, the melting is uncontrollable and could create large voids in the foamed plastic insulation. Plasticisers in the foam also react with plasticisers in the cable sheath to degrade the foam.

Sub-circuit cables are usually run in conduit fixed to the surface of the sandwich panels and/or may be covered with "top hat" flashings to facilitate hygiene. Cables penetrating sandwich panels must be enclosed in UPVC conduit with seals at the panel surfaces to prevent migration of plasticiser from the PVC cable sheath to the polystyrene.

Ensure that all electrical equipment is separated from combustible sandwich panels by a fire-rated material, for example, ceramic fibreboard.

Avoid using plastic enclosures for housing electrical and control equipment as these enclosures contribute to fire development. Use only suitably ingress-protected (IP) painted steel or stainless steel enclosures. The minimum IP rating for enclosures installed outside of switchrooms should be IP54. For items installed in areas subject to the weather or wash down, IP56 or better ingress protection should be adopted.

Items which generate heat during normal or abnormal operation, such as luminaires, should be mounted to leave an air gap between the fitting and the structure to which they are mounted. Note that limits on the maximum surface temperatures for electrical equipment are specified in AS/NZS 2381.1 *Electrical equipment for explosive atmospheres - Selection, installation and maintenance - General requirements*. These limits should also apply to any other heating equipment or devices.

8.9 COLDSTORE CONTROL AND ALARM MONITORING

Because coldstores and plant rooms are rarely staffed fulltime, a comprehensive control and alarm monitoring system for equipment control, status, faults and temperature monitoring is necessary. Operator interface is usually by way of a desktop computer operating a SCADA system. Refer section 7.6 of this document for more information.

Usually control and monitoring of coldstores is incorporated into a PLC for the plant, often conveniently located in the switchroom. Remote input and output racks may be installed in control panels at several locations in larger plants to reduce the requirement for long cable runs to the central PLC monitoring system.

6 Related manufacturing practices to conceal the cables occur offsite where insulated panels are being prepared for other types of buildings. The fire-retardant chemicals in the foam are designed to deter ignition from small heat sources.

An uninterruptible power supply (UPS) should be provided to ensure that the control and alarm facilities continue to operate should the main electricity supply be lost. The UPS is intended to maintain operation of the control system, including all critical alarms, and it must be sized in accordance with the process load and the time required to either restore emergency power (for example using a standby generator) or the time required to fully and safely shut down the plant.

UPS equipment should also be selected appropriately and with due regard to redundancy and failure modes for the intended duty. Industrially-rated UPS equipment should be specified; "data centre" types should be avoided. UPS batteries should be installed either in separate fire-rated cabinets or in separate fire-rated battery rooms to ensure that UPS availability is not compromised by battery failure resulting in a battery fire.

UPS equipment must be installed outside any classified hazardous area unless designed and rated for operation in the intended zone.

8.10 ELECTRIC FORKLIFT TRUCKS

If it is necessary for vehicles to operate in classified hazardous areas, vehicles are available with explosion-protected specifications.

Battery chargers for these vehicles must be installed outside any classified hazardous area and preferably outside any cold storage area. A mechanical ventilation system shall be provided to charging areas to dissipate any flammable gasses generated during battery charging.

8.11 ANCILLARY ELECTRICAL SERVICES

While other services such as fire and gas detection are covered in other sections there can be considerable overlap with electrical services and there must be close co-operation during the design phase.

8.11.1 Door seal heating

To prevent door seals, especially personnel and safety doors, from freezing, door heating circuits are provided in the fixed portion of the door sills and jambs. These systems must use self-limiting trace heating cables and be supplied from a 30-mA RCD circuit breaker to ensure safety. Such systems need to be remotely monitored to ensure that they operate continuously.

Electrical resistance trace heating equipment in explosive gas atmospheres should comply with AS/NZS 60079.30 *Electrical apparatus for explosive gas atmospheres - Electrical resistance trace heating* (SNZ, 2007).

8.11.2 Air curtains

Air curtains are "obsolete" technology and have been replaced by rapid roll doors, air locks and strip curtains. Air curtains have been found to be ineffective and in some cases counterproductive.

8.11.3 Emergency power and lighting

Full emergency power, that is, 100 per cent of connected load would obviate the need for separate emergency power circuits. However this is rarely economic to provide.

The usual solution to loss of mains power for a sustained period is to close up the cold storage areas for the duration of the loss and provide the following emergency power.

1. Escape route lighting in the cold storage area, ELAs and plant room areas in compliance with *Compliance Document for NZBC Clause F6 Lighting for Emergency* (DBH, 2000). Escape route lighting is required whenever the length of the escape route exceeds 20 m or a change of level occurs. The compliance document specifies the rate at which the lamps must illuminate, the illuminance, and the period the lamps must remain on. AS/NZS 1677.2 *Refrigerating systems - Safety requirements for fixed applications* (SNZ, 1998), clause 4.2, also specifies requirements for emergency lighting. LED egress lights are available for hazardous areas classified zone 2 and draw lower currents than conventional units on a centrally reticulated system.
2. Working or spot-level emergency powered lighting in plant rooms.
3. No-break or UPS for all alarms and communications systems.
4. Portable handheld lanterns placed at strategic points on standby charge and activated on loss of mains power (not to be installed in hazardous areas).

Central batteries are best located in separate, centrally-located rooms with easy access for servicing. Sealed batteries do not require ventilation, whereas standard lead-acid types do. Battery maintenance is important in any event, and batteries have a limited life (five to 10 years maximum) before replacement.

Self-contained emergency lights for example, with their own integral batteries, are difficult to monitor and service, and generally have a relatively short life. However monitored systems are available.

8.11.4 Ventilation systems and electrical shutdown

Plant equipment and refrigeration equipment rooms will generally require ventilation. Where flammable refrigerants are used, additional precautions must be taken to monitor and provide for the possibility that flammable vapour concentrations could reach hazardous levels. This situation can arise due to failure of compressors, valves, instruments or pipe work.

The flammable gas or vapour monitoring system and the mechanical ventilation system must be installed and maintained to an appropriate explosion-protection class.

For flammable refrigerants, an automatic electrical shutdown system should be provided for refrigeration plant rooms and any other areas where natural ventilation is restricted. Detection of the flammable vapour is used to isolate all electrical supplies to the protected area.

The control requirements for electrical isolation systems associated with ventilation are described in AS 1482 *Electrical equipment for explosive atmospheres - Protection by ventilation – Type of protection v* (AS, 1985). These requirements must be strictly applied, tested and maintained throughout the life of the plant.

9 COMMISSIONING

See *Practice Note 09 – Commissioning Capital Plant* on this subject (IPENZ, 2007). Only aspects specific to coldstores have been included in this section.

Commissioning plant is a specialized part of a contract, carried out by experienced personnel distinct from the construction and installation staff.

To prevent damage to concrete floors and other building fabric during commissioning of a coldstore, an appropriate slow-temperature reduction regime should be used.

The following items are invaluable for long-term quality assurance but care must be taken to ensure that they are not "glossed over" on completion of the work.

1. As-built drawings based on and including fully up-to-date construction drawings. The detail should be greater than the original drawings, as much will have been developed during construction.
2. Full service manuals for all installed equipment including product racks and materials handling equipment – sales brochures alone are insufficient.
3. Schematic diagrams and troubleshooting guides for quick servicing – especially with emergencies in mind. Forklift trucks can cause severe damage to product racks, so guidance on assessing and repairing damage is necessary.
4. Operating circuit diagrams – also oriented to emergency conditions.
5. A fully indexed catalogue of all drawings, manuals and any other recorded information.
6. Maintenance analysis documentation, setting out the criticality analysis and philosophy (for example, run-to-failure, replacement schedules, monitoring methods).
7. Task instructions and job procedures for operators that cover normal operations, planned maintenance and emergency procedures.
8. A specifically designed paper or electronic service logbook for the whole plant for ongoing use. This provides a legal document for historical service and modification records at any time in the future.
9. Safety data sheets (SDS) for refrigerants and other chemicals.
10. Hazard signage to ensure compliance with all applicable legislation, including:
    - *NZBC Clause F8 Signs* (DBH, 1992), which has the "objective of safeguarding people from injury…resulting from…hazards within or about the building". Clause F8.3.1 requires signs to be clearly visible and readily understandable under all conditions of foreseeable use. The Acceptable Solution shows sizes and colours of signs.
    - ERMA's code of practice, *Signage for Premises Storing Hazardous Substances and Dangerous Goods* (2004), which explains and provides a means of compliance with the *HSNOA* for the signage required for sites containing hazardous substances (see section 3.4 of this document). These HSNOA signs must be located where they will be noticed by persons entering the site.
    - AS/NZS 1677.2 *Refrigerating systems - Safety requirements for fixed applications* (SNZ, 1998), clause 5.4, which requires a permanent, durable, legible and clearly visible plate to be prominently displayed in machinery rooms, and lists the information the plate should display.
    - The DoL's *ACoP Pressure Equipment (Excluding Boilers)* (2001), clause 2.4.6(2), which requires manufacturers to label equipment with key data relevant to safe operation, and clause 3.6.2, which requires nameplates on lagged vessels in a position visible to the operator.
11. Training for operator staff.
12. Official handover procedure with a full demonstration of all operations and formal handover of documentation. This procedure must include a full test of all alarm circuits in full failure mode of the circuits being monitored by the alarms.
13. Full documentation to emergency services such as the NZFS. AS/NZS 2381.1 *Electrical equipment for explosive atmospheres - Selection, installation and maintenance - General requirements* (SNZ, 2005) requires a verification dossier to be prepared and either kept onsite or stored in another location. If the latter, a document shall be kept on site indicating who the owners are and the location of the verification dossier. The electrical inspector must see the verification dossier.

9.1 ROUTINE TESTING AND INSPECTION

Fire protection systems in coldstores must operate in a harsh environment. Technicians who test and service these systems may be working outside their comfort zone, as they may have little exposure to similar systems on other sites.

For these reasons, it is imperative that a comprehensive maintenance manual be prepared outlining specific maintenance requirements for the systems. These should detail specific compliance schedule requirements, preferably in the form of a checklist or service logbook.

For electrical equipment in hazardous areas AS/NZS 2381.1 *Electrical equipment for explosive atmospheres - Selection, installation and maintenance - General requirements* (SNZ, 2005) requires regular periodic inspections, gives a method for determining the inspection interval, and gives a form for recording the inspections.

NZS 4541 *Automatic fire sprinkler systems* (SNZ, 2007) requires that such information be submitted to a sprinkler system certifier, who in turn, must make the information available to approved sprinkler contractors if instructed by the owner of the building.

10 OPERATIONS

10.1 STAFFING AND ALARMS

In the past, large food storage operations may have been staffed 24 hours a day seven days a week, but in recent years, the advent of PLC and SCADA systems (see section 8.9 of this document) with monitoring and alarming features have provided a more economical alternative. For example, the SCADA system can send error messages on the status of the refrigeration system to the plant operator's pager.

Emergency alarm signals (indicating a fire or refrigerant leak, for example) can be onsite with audible sounders and suitably placed annunciator panels, with additional links to operations staff pagers and mobile phones.

When the site is unattended, alarm signals, especially fire alarms, must be connected by radio telephone or public telephone networks to an externally monitored system. If the site has an emergency response team, the alarms must also be sent to that team so that at least one member responds to the hierarchy of levels of signal.

All staff in the above operations must be kept up to date with procedures, modifications to plant, and any other issue that has a bearing on their ability to carry out their job. Their point of reference, as a minimum requirement, would be the service logbook referred to in section 9 of this document.

10.2 REGULAR COMPLIANCE INSPECTIONS

The *BA* requires regular, periodic inspections be carried out by qualified personnel (for example, an Independent Qualified Person) for buildings which include the "specified systems" listed on the "compliance schedule". Specified systems include automatic systems for fire suppression.

AS/NZS 2381.1 *Electrical equipment for explosive atmospheres - Selection, installation and maintenance - General requirements* (SNZ, 2005), clause 4.1, requires the person having legal ownership to nominate a competent person to carry out or supervise regular inspection and testing procedures of explosion-protected electrical equipment acting as a source of ignition. Section 4 of the standard goes on to describe suitable methods of inspection and test. The *Electricity Regulations* (MED, 1997) requires re-inspection every four years for electrical equipment installed within a hazardous area.

10.3 TRAFFIC AND PRODUCT MOVEMENT

The purpose of a coldstore is to preserve the product. The purpose of a warehouse is to provide suppliers and customers with an effective and efficient operation.

The requirements for traffic and product movement will depend on factors such as the products being stored, the speed of inventory turnover, whether orders are for cartons or pallets, the amount and type of mechanisation and automation, and capital constraints.

The coldstore needs to be designed to minimise unintentional damage caused by machinery, for example, having aisles of sufficient width and installing protective bollards. The design also needs to minimise conflicts of machinery and people.

The throughput of the product relative to the thermal mass will affect the refrigeration requirements. The designer should bear in mind operational practicality and controllability when providing facilities to retain the cooled air. With rapid-opening doors, for example, consider the operationally practical door opening time.

Trucks that load or unload under an enclosed canopy introduce noxious fumes and diesel soot that contaminate the product and building. It may be necessary to monitor the air quality and provide passive or active methods of air exchange.

10.4 MAINTENANCE ISSUES

The design of a cold storage complex can have a marked effect on future maintenance expenditure. The choice of equipment, materials and construction methods has to be balanced between the initial cost and ongoing costs. Usually, when the developer is also the owner, this trade off between capital and operating expenditure can be made in a sensible way.

Maintenance of a cold storage complex must cover both the plant and buildings, which each have different timing requirements. For example, the equipment in refrigeration mechanical systems requires regular on-demand servicing by skilled technicians from a limited pool of skilled labour. On the other hand, building maintenance is not usually time-critical and requires a different and often more universally available level of skill.

Nowadays there are good arguments for outsourcing most if not all maintenance requirements. However sufficient capacity should exist in-house to let and supervise maintenance contracts, and to ensure that work is not only done as required, but achieves value for money. The speed of response and technical capacity are major factors in assessing bids from contractors.

APPENDIX A: GLOSSARY

ACoP	Approved Code of Practice
ASD	Aspirating Smoke Detection
ASME	American Society of Mechanical Engineers
AS/NZS	Australian Standard / New Zealand Standard
BA	Building Act
BCA	Building Consent Authority
BMS	Building Management System
BRANZ	Building Research Association of New Zealand
C/AS1	Clause C/Acceptable Solution 1
CEN	European Committee for Standardization
DBH	Department of Building and Housing
DoL	Department of Labour
DX	Direct expansion
ELA	Environmental load-out area
EPS	Expanded polystyrene
ERMA	Environmental Risk Management Agency
ESFR	Early Suppression Fast Response
EU	European Union
FDC	Forced Draft Cooler
FHC	Fire Hazard Category (in *NZBC*)
FLED	Fire Load Energy Density (in *NZBC*)
FM	Factory Mutual Global
FPA	Fire Protection Association
FR	Fire Resistant
FRR	Fire Resistance Rating
GWP	Global Warming Potential
HERA	Heavy Engineering Research Association
HSEA	Health and Safety in Employment Act
HFC	Hydrofluorocarbon
HSNO	Hazardous Substances and New Organisms
HSNOA	Hazardous Substances and New Organisms Act
IACSC	International Association of Cold Storage Companies
IFEG	International Fire Engineering Guidelines
IHRACE	Institute of Heating, Refrigerating, and Air Conditioning Engineers
IIR	International Institute of Refrigeration
IP	Ingress Protection
IPENZ	Institution of Professional Engineers New Zealand
IQF	Individual quick frozen
IQP	Independent Qualified Person
LED	Light Emitting Diode
LPC	Loss Prevention Council (of the UK)
LPG	Liquefied Petroleum Gas
MAF	Ministry of Agriculture and Forests
MED	Ministry of Economic Development
NFPA	National Fire Protection Association (of America)
NZBC	New Zealand Building Code
NZFS	New Zealand Fire Service
NZFSA	New Zealand Food Safety Authority
OMAR	Overseas Market Access Requirements
PECPR	Pressure Equipment, Cranes and Passenger Ropeways Regulations
PFC	Power Factor Correction
PFP	Passive Fire Protection
PIR	Polyisocyanurate
PLC	Programmable Logic Controller
PUR	Polyurethane
RCD	Residual current device
RMA	Resource Management Act
SCADA	Supervisory, control, and data acquisition
SE	Schwer zu Entzünden (German for “difficult to ignite”)
SFPE	Society of Fire Protection Engineers
SKM	Sinclair Knight Merz
SNZ	Standards New Zealand
TX	Thermostatic expansion valve
UK	United Kingdom of Great Britain and Northern Ireland
UPS	Uninterruptible Power Supply
VSD	Variable Speed Drive

APPENDIX B: APPROVED HANDLERS AND APPROVED FILLERS

APPROVED HANDLERS

In some circumstances a hazardous substance has to be under the personal control of an approved handler. The need depends on the hazardous nature of the substance and the quantity involved. An approved handler may be required where a refrigerant has a flammable property but as a general rule, refrigerants do not have toxic, corrosive or ecotoxic properties that require an approved handler. Always check that this is the case. The approved filler requirement is separate to and different from the approved handler and is dealt with separately. An approved handler is not an approved filler and vice versa.

Where anhydrous ammonia is used, the HSNO controls have been varied and an approved handler is not required when the anhydrous ammonia is contained in equipment that is an integral part of the refrigeration system. Any anhydrous ammonia stored, for example, for future use will be subject to the legislative controls.

An approved handler is a person who is certified as competent to deal with the substance in the specified stages of its lifecycle. The lifecycle will include import, extraction, manufacture, storage, transport, use and disposal. The qualifications for an approved handler are found in the *HSNO (Personnel Qualifications) Regulations* (ERMA, 2001). An applicant will need to demonstrate they are competent to handle the substance, the operating equipment, and know about the protective clothing and safety equipment required. The qualifications require some basic knowledge of the hazardous substances legislation, mainly information relating to what the law is trying to achieve, enforcement issues, the hazard classifications, and relevant regulations and approved codes of practice.

The application process is straightforward, particularly if the applicant has been trained and knows about the substance, the equipment used, and the legislation. A test certifier will issue a test certificate to the approved handler if satisfied they have the necessary knowledge and experience. The certificate is valid for five years from the date of issue. After five years, the approved handler must re-apply and demonstrate his or her knowledge is up to date.

The test certifier will need evidence of the applicant's qualifications, experience and competence in the following way:

- training providers – if the applicant has completed a training course that covers all or part of these requirements he or she can provide the qualification from the course
- work supervisors – if the applicant has been trained at work or "on the job" a supervisor or manager from the organisation can provide evidence.

Whichever way or combination of ways chosen, the evidence provided must describe how the applicant's knowledge and skills were assessed and the results of that assessment.

A test certifier may not need to see the approved handler applicant. In most cases the application can be handled satisfactorily by mail provided all the necessary evidence is provided. These requirements can be discussed with the chosen test certifier. There is a list of test certifiers on the ERMA New Zealand web site at www.ermanz.govt.nz/search/tc.html

The certificate will specify the classes of substances, the lifecycle phases, and any limitations on the approval. Keep the certificate safe as it may need to be produced for an enforcement officer if requested.

The approved handler must make sure the hazardous substances are handled safely, and that they do not cause harm to people, or damage to the environment. The nature of the substance and the manner in which it is used will determine whether an approved handler is needed all of the time or just to be available.

Where an approved handler is required, not everyone handling the substance needs to be an approved handler. Another person may handle the substance if an approved handler has provided guidance to the person actually handling the substance but the approved handler must be "available" to provide assistance at all times while the substance is being handled. Available in some instances may mean present at the location, in others it may be acceptable for the approved handler to be contacted quickly and if not onsite, be available, for example, on a telephone. For toxic, corrosive or ecotoxic substances, "available" requires the approved handler to be present at the place in person.

An approved handler does not need to be present if the substance is secured so that a person cannot gain access to the substance without a key or similar device. A substance contained within a closed system would normally be considered secured. However, the legislation also requires an emergency management plan subject to the hazardous nature of the substance and the quantity involved. The emergency plan needs to consider all likely emergencies, which means even though the substance is secure, should an emergency such as a leak arise, there must be effective plans in place to deal with the emergency.

Refrigerant gases fall within several hazardous substance classifications, some are flammable gases or flammable liquids, others are oxidising or toxic gases and some are non-hazardous. The classifications and threshold quantities depend on the classification. For example:

Nature of Substance	Classification	Examples	Threshold quantity above which an approved handler is required
Flammable gas	2.1.1A	methane ethane, propane, butane, isobutene, ethylene, propylene, LPG, di-methyl ether.	100 kg
Flammable liquid	3.1A	Methyl formate (R-611)	Any amount

The transportation of packaged hazardous substances by road does not require an approved handler, provided the *Land Transport Rules* (NZTA, 2005) are followed.

APPROVED FILLERS

A person must not charge a compressed gas container with a compressed gas unless the person is an approved filler. This applies to both hazardous gases, such as LPG, and non-hazardous gases, including air, irrespective of the quantity and classification. The approved filler requirement is separate to and different from the approved handler and is dealt with separately. An approved handler is not an approved filler and vice versa.

The *Hazardous Substances (Compressed Gasses) Regulations* (ERMA, 2004), deal with the filling of compressed gas cylinders. Everyone who fills a compressed gas cylinder is covered, including those working with refrigerant gases and transferring the gas from the system into a cylinder.

A person may fill a cylinder with gas only if satisfied that the cylinder is marked correctly, is within its inspection date and there is no evidence of damage or corrosion to the cylinder, valve or over-pressure protection device that suggests the cylinder is unsuitable.

Approved fillers must, for the gases they deal with, be able to demonstrate the procedure for safe filling, including visual inspection and safe charging of compressed gas into a container. They must understand and be able to describe the different forms of compressed gases, notably, low-pressure liquefiable gas, high-pressure liquefiable gas, permanent gas, and gas that may be held at cryogenic temperatures. They must know about factors that can cause failure of a compressed gas container and the consequences of a failure of a container associated with the different forms of compressed gas, including asphyxiation.

The application process is straightforward particularly if the applicant has been trained and knows about the substance and the equipment used. Unlike the approved handler they need not know the details of the legislation. A test certifier will issue a test certificate to the approved handler if satisfied they have the necessary knowledge and experience. The certificate is valid for five years from the date of issue. After five years the approved handler must re-apply and demonstrate that his or her knowledge is up to date.

The test certifier will need evidence of the applicant's qualifications, experience and competence in the following way:

- training providers – if the applicant has completed a training course that covers all or part of these requirements he or she can provide the qualification from the course
- work supervisors – if the applicant has been trained at work or "on the job" a supervisor or manager from the organisation can provide the evidence.

Whichever way or combination of ways chosen, the evidence provided must describe how the applicant's knowledge and skills were assessed and the results of that assessment.

A test certifier may not need to see the approved handler applicant. In most cases the application can be handled satisfactorily by mail provided all the necessary evidence is provided. These requirements can be discussed with the chosen test certifier. There is a list of test certifiers on the ERMA New Zealand web site at www.ermanz.govt.nz/search/tc.html

The certificate will specify the forms and classes of gases and types of containers that the approved handler may work with. Keep the certificate safe as it may need to be produced for an enforcement officer if requested.

If the applicant has already attended a training course or has received instruction and has experience filling cylinders, this should be sufficient. The applicant will, however, need to confirm their level of training and experience, and a supervisor and/or trainer should sign the certificate.

Clearly, there is a need to train people in the filling operation. Any trainee must gain both the theoretical and practical experience. The trainee must be directly supervised, that is, the approved filler must be in attendance during filling, until the trainee is judged to have the necessary skills. Unsupervised filling of cylinders can only be done by a certified approved filler.

C

APPENDIX C: EXAMPLE "HOT WORK" PERMIT

The following is a generalised version of a hot work permit used by one company and is not a required format. It is applicable to all operations involving welding and cutting equipment. Attach the permit to equipment while in use.

Site Name and Location:

Date:

Name of person carrying out work:

Company:

Name of fire watch person:

Type of equipment used:

Exact location of work:

Start Time:

Finish Time (including 30 minute fire watch):

This work permit is issued subject to the following items being identified and risk of fire hazard reduced to a minimum.

- Check fire protection system is in service.
- Cutting and welding equipment is in good repair.
- If location of works identifies that smoke detectors, heat detectors are within working area, ensure that they are isolated.
- No combustible liquids, vapours, gasses or dust are present.
- All combustible material has either been removed or suitably protected against heat and sparks.
- All wall and floor openings are covered.
- Extinguisher / hose reel to be provided.

Work on enclosed equipment (for example, tanks, containers, ducts and dust collectors) require the following additional checks.

- Equipment cleaned of all combustibles.
- Containers purged of flammable vapours.

Fire Safety Equipment:

Fire Blanket: Yes

Water Hose: Yes

First Aid Kit: Yes

Other: ___________________________________

Number of Extinguishers:

Type: ____________________________________

Work area and all adjacent areas to which sparks and heat might have spread were thoroughly inspected on completion of the works and 30 minutes later no smouldering fires were discovered.

Authorised By:

Name and Signature of Site Manager : **Date:**

Name and Signature of person carrying out works: **Date:**

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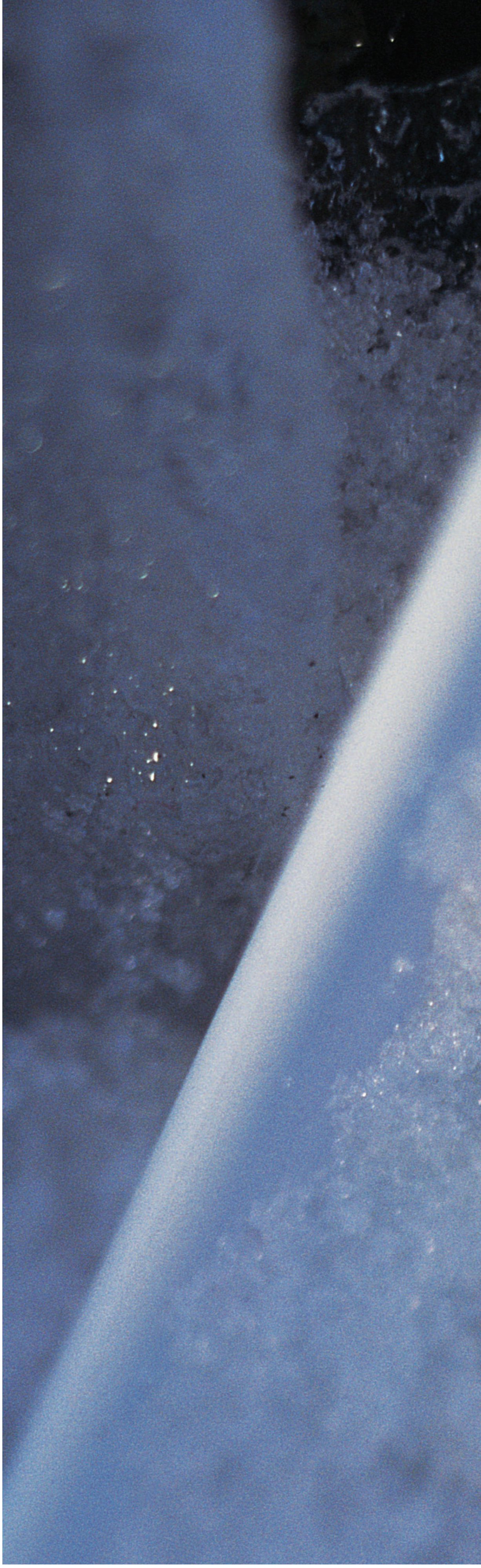

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