Refrigerated Logistics Design Guide

A GUIDE TO HOW WE DO IT

GLP

V1.0 October 2020

Contents

SECTION 01

Foreword

Your trusted partner for innovative, sustainable, cost effective warehouse solutions across Europe – a focus on Chilled and Refrigerated Logistics

GLP is a global leader in logistics real estate with a long heritage and proven track record as an investor, operator and developer with one of the largest global logistics footprints in 16 countries across Brazil, China, Europe, India, Japan, the U.S. and Vietnam. Our experience and expertise as business builders and operators gives our team a distinct competitive advantage to build and scale smart logistics ecosystems for our customers and investors. We are a market and thought leader in logistics real estate with a focus on identifying and implementing technologies that will create more efficient and smarter logistics solutions that support our customers.

With the unprecedented growth in food and pharmaceutical distribution we anticipate a global increase in demand for Chilled and Refrigerated Logistics solutions. GLP have responded to that trend with the creation of a dedicated Chilled and Refrigeration team who aim to be the trusted partner of choice for our global customers. In this special report, we consider the options for Chilled and Refrigerated Logistics solutions, looking at how existing ambient facilities can be converted, and the principal factors that should be considered when constructing new facilities.

Anticipating and responding to our customers' needs is an important part of our global success. We're delighted to share this report with you and welcome the opportunity to discuss how we can support you with any Chilled and Refrigerated needs either now or in the future.

GRAEME MUNRO,
HEAD OF CONSTRUCTION EUROPE

NICK COOK,
PRESIDENT, GLP – EUROPE

SECTION 02

Introduction

This refrigeration fit-out specification is intended to provide general guidance as to how existing ambient temperature facilities can be ‘fitted-out’ into bespoke refrigerated facilities and the principal factors that should be considered when constructing a new refrigerated facility. In order to better visualise the principles of converting existing warehouses to refrigerated use, a series of drawings have been prepared which illustrate the typical conversion of three standard GLP warehouse configurations.

Drawings have been prepared which illustrate a typical conversion of three standard GLP warehouse configurations into refrigerated distribution centres as follows:

20,000m²

Freezer (-22°C)	Chill (+1°C)	Ambient
20%	55%	25%

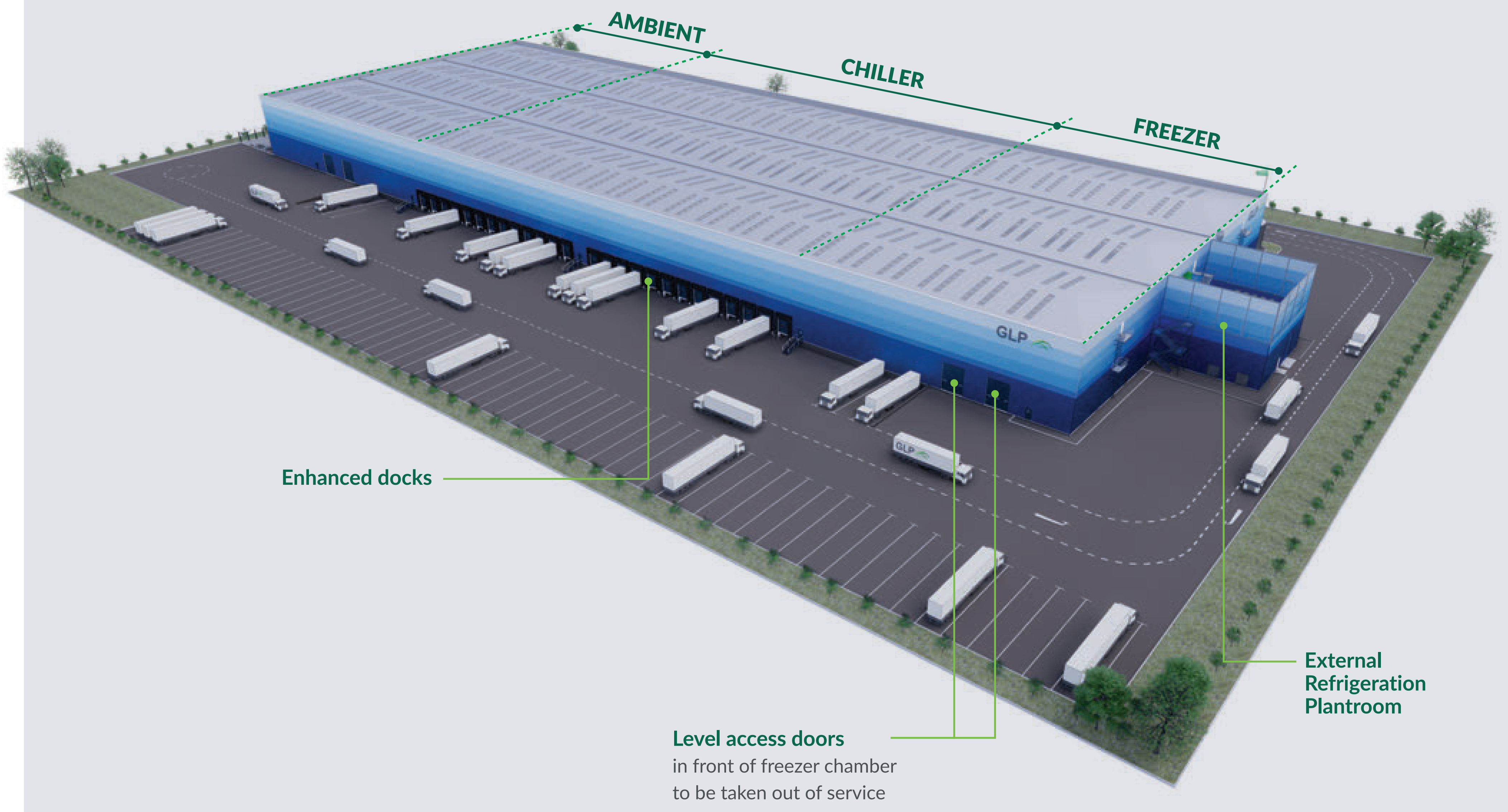
40,000m²

Freezer (-22°C)	Chill (+1°C)	Ambient
15%	35%	50%

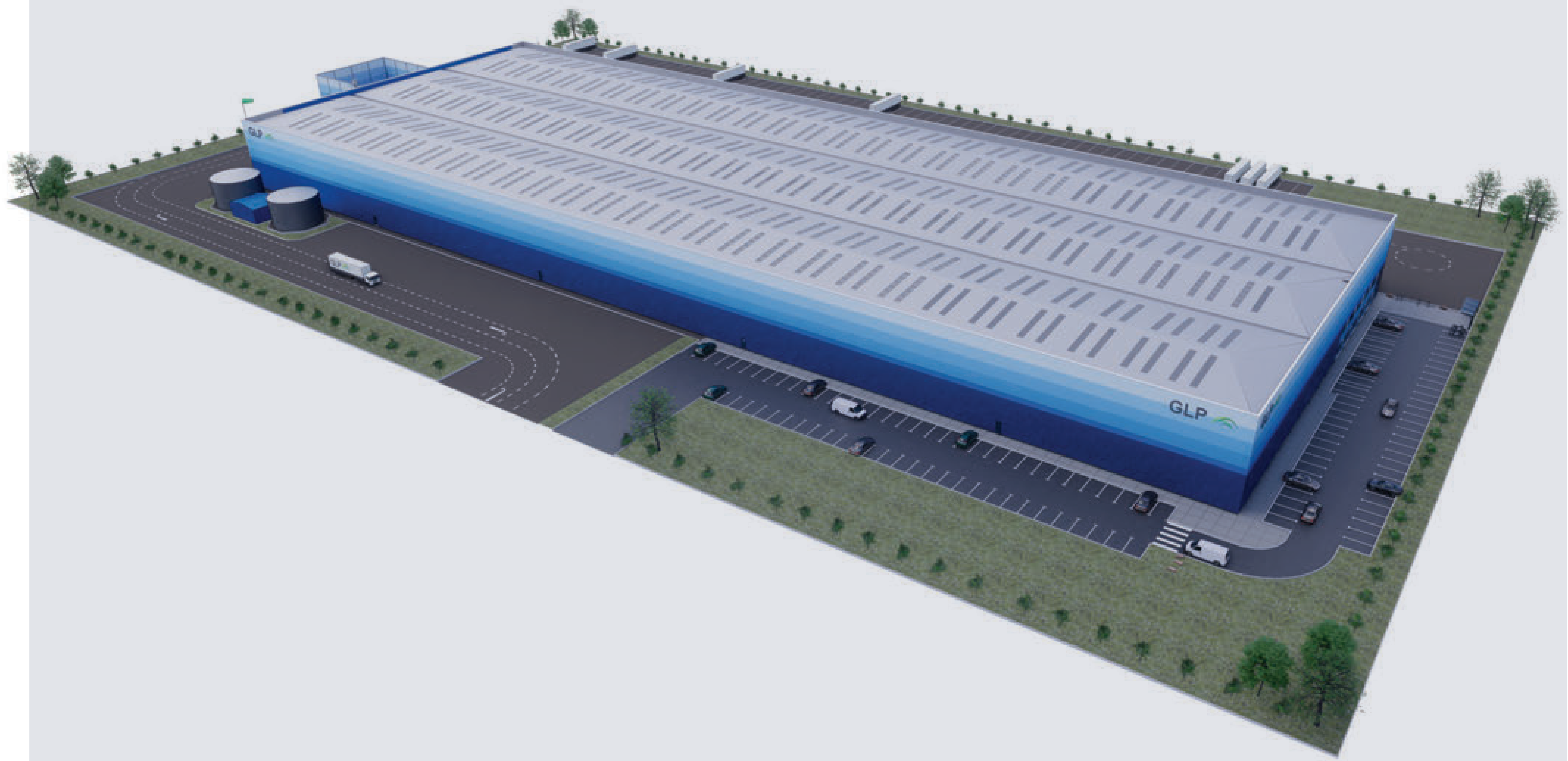
60,000m²

Chill (+1°C)	Ambient
95%	5%

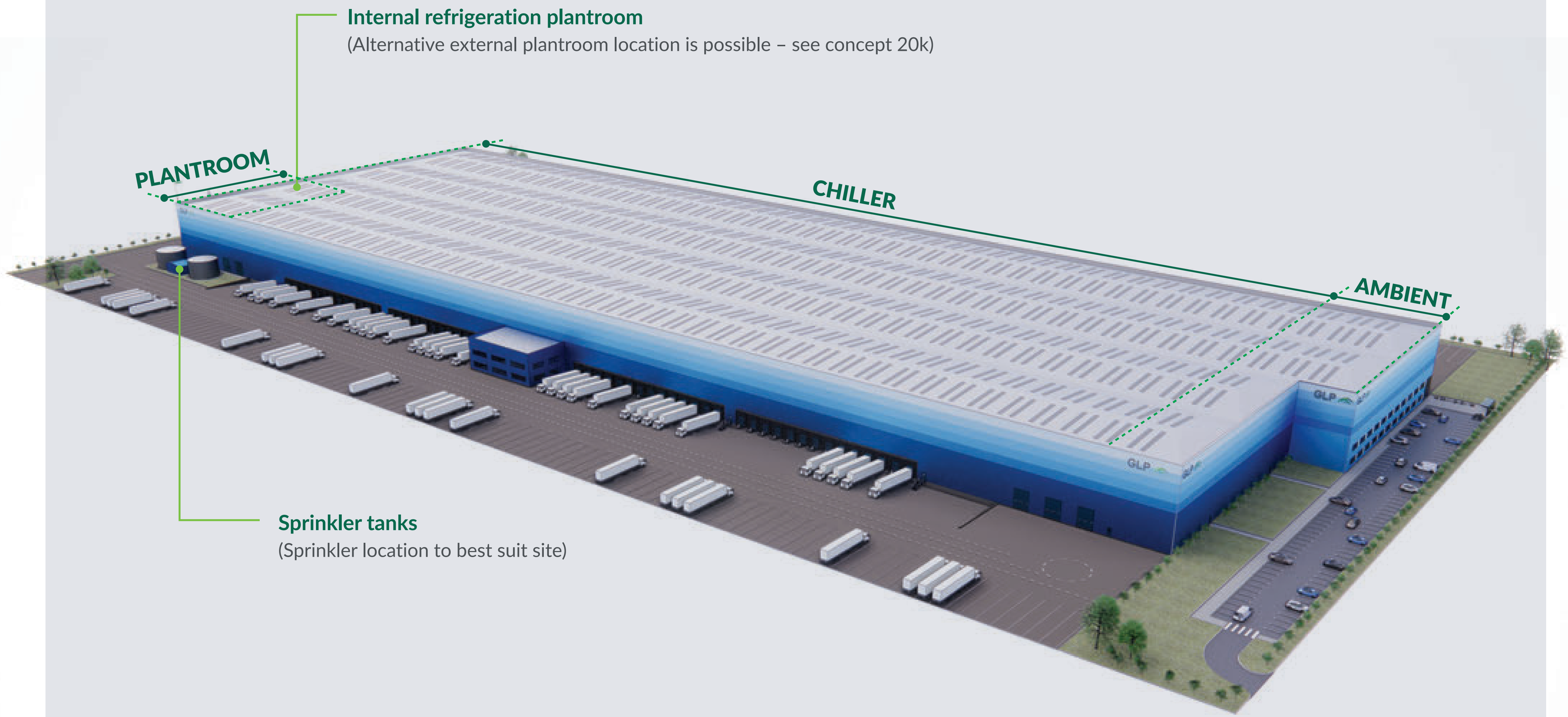
CONCEPT 20,000m² AMBIENT WAREHOUSE REFRIGERATED FIT-OUT



CONCEPT 40,000m² AMBIENT WAREHOUSE REFRIGERATED FIT-OUT



CONCEPT 60,000m² AMBIENT WAREHOUSE REFRIGERATED FIT-OUT



SECTION 03

Trusted Partners

All refrigerated facilities are unique and the design of each facility must be individually tailored to its specific intended use.

This use can vary from short- to long-term storage, low to high product throughputs, from storage to picking and distribution, the inclusion of specialist processes such as blast freezing and tempering and the large variance in product types, chamber configurations, etc.

It is therefore essential that experienced and specialist teams are used to carry out the feasibility review, conversion or construction of any refrigerated facility or fit-out. This includes determining the suitability of a warehouse for conversion, as well as ensuring compliance of the finished facility to the latest codes and regulations.

Whilst the general principles of construction will apply to most countries, there are numerous technical differences, regulatory and design preferences within Europe that will need to be considered.

This design document is not intended to replace or remove such design or feasibility work, but is instead intended to illustrate the principal considerations and decision-making processes involved, when planning a conversion or new facility.

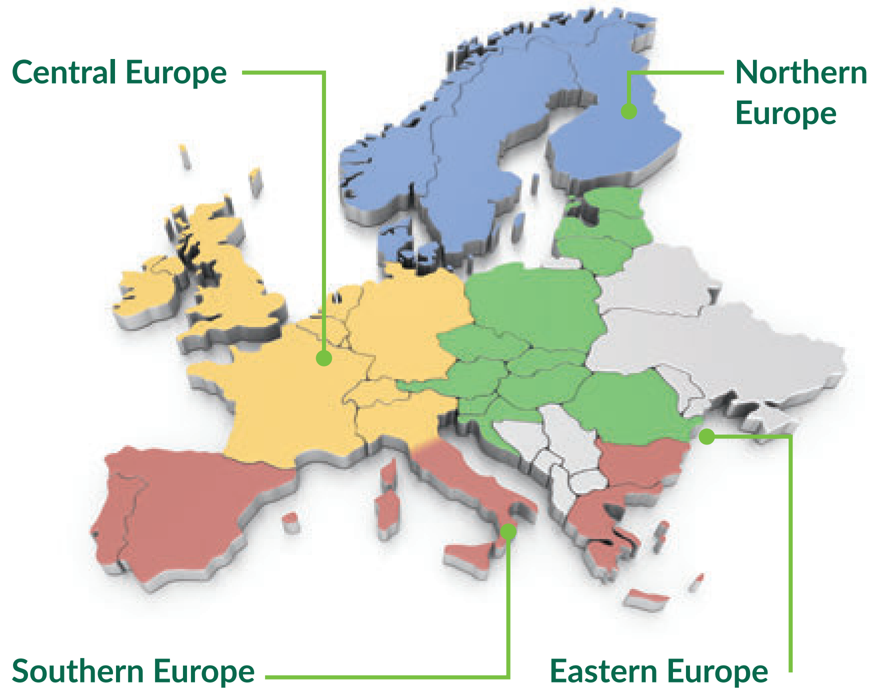
SECTION 04

Climate

A country's peak summer temperature and relative humidity will dictate both the size and type of refrigeration plant used. A refrigeration plant must maintain chamber design temperatures throughout the hottest days of the year, or product could spoil. The peak minimum winter temperatures are also of importance, as refrigerated chambers must not be permitted to fall below their design temperatures during the coldest days of the year.

The climatic differences throughout Europe and its member countries are significant. These can be generalised into four separate regions:

Region	Summer Ambient Temperatures	Summer Relative Humidity	Winter Ambient Temperatures
Northern Europe	Low	Medium	Low
Eastern Europe	High	High	Low
Central Europe	Medium	Medium	Medium
Southern Europe	High	High	Above Zero



Where summer ambient temperatures and humidities are high, particular care is required in the design of the facility vehicle docking systems and warehouse layouts to minimise ambient air ingress and maintain the cold-chain. This is especially important as it allows the size of the refrigeration plant to be reduced, as well as resulting in reduced ongoing energy costs.

Where winter temperatures are low (Eastern & Northern Europe), specific measures may be required, such as chamber heating and specific refrigeration condensing solutions (remote sumps/air-cooled condensers).

SECTION 05

Permitting/Planning

Local requirements and processes for permitting and planning of refrigerated facilities; whether for new constructions or 'fit-outs', must be determined as they can vary significantly.

These requirements may preclude the use of certain refrigerants in particular applications (e.g., the use of ammonia in a facility close to residential areas), or they may dictate the equipment types that must be used in order to maintain required noise levels. Local requirements may also preclude the use of Single Envelope Construction systems due to their less aesthetic external appearance.

The local processes and procedures for permitting often have a significant impact on a project's timelines.

Understanding the local processes, requirements, procedures and timelines at the outset of a project is therefore fundamental.

SECTION 06

Selection of Chamber Temperatures

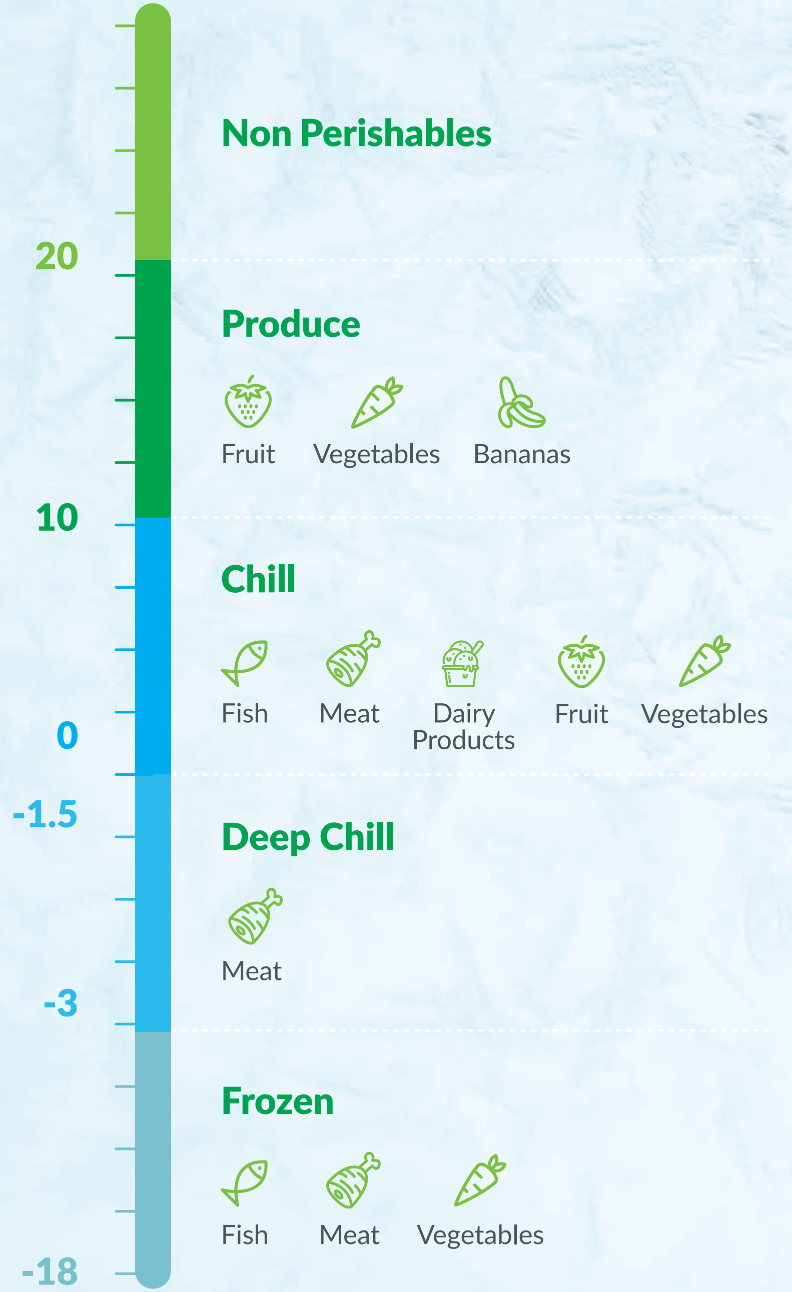
The selection of design temperatures for refrigerated chambers should aim to maximise the lifespan and quality of the stored product(s) and are generally dictated by food legislation, the age, type and duration of products to be stored, as well as the final retailer/customer's specific requirements.

Food product storage can generally be separated into:

Short-term storage – **less than a week**
Medium-term storage – **1 to 4 weeks**
Long-term storage – **4 weeks to 12 months**

The storage temperature, humidity and atmosphere control becomes more critical as storage duration increases.

Typical product storage temperature ranges can be seen in the following chart:



Some fruit and vegetables 'respire' and release ethylene and CO_2 gases, as part of their ripening process. These gases can result in accelerated ripening, as well as reducing product quality. The effects of ethylene and CO_2 on stored product exacerbate with longer storage periods. In some cases, fruit and vegetable storage facilities will require specialist ventilation and ethylene 'scrubbers', which remove these gases from the chambers.

Some fruits and vegetables are sensitive to low temperatures, which can cause 'chill injury', if they are stored below their critical temperature.

When different fruits and vegetables are stored together, one foodstuff may be tainted by odours given off by another. For example, carrots stored in the same chamber as onions, apples stored with potatoes etc.

Controlled atmosphere stores are hermetically sealed refrigerated chambers where the internal atmosphere (temperature, oxygen, carbon-dioxide and humidity levels) are specially adapted to extend a product's lifespan; the products (e.g., apples) are effectively placed into hibernation.

Due to the vast range of product types and categories available, each application must be carefully assessed and the optimum refrigerated chamber layout and temperature configuration selected to satisfy both product safety and logistical requirements. This is a highly specialist field.

SECTION 07

Refrigerated Building Types

There are three main types of refrigerated building:

1. Box-in-Box
2. Single Envelope
3. Clad Rack

Generally, the Box-in-Box design represents the traditional approach to forming refrigerated warehouses and is widely used world-wide. In particular, the Box-in-Box solution enables existing ambient warehouses to be 'fitted out' to the highest refrigerated standards both quickly and simply. In particular, the use of internal insulation envelopes that are inherent in the Box-in-Box design, has the benefit of providing smooth and washable internal surfaces, that are widely accepted for food storage and packing facilities.

The examples within this document detail the conversion of a GLP ambient warehouse, using the Box-in-Box approach. A technical description of the Single Envelope Design is provided within this document.

Single Envelope:

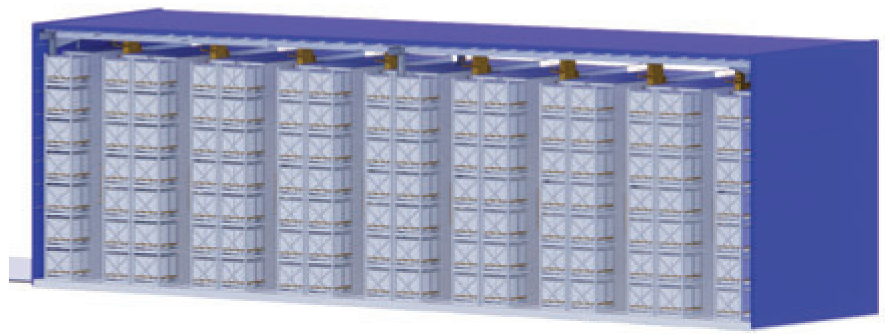
The Single Envelope design utilises an internal structure and specialist composite insulation sandwich panels installed exterior to the structure, to form a fully vapour sealed and insulated enclosure. The design requires a two pitched roof with external gutters in order to provide a fully insulated and vapour sealed enclosure:

Box-in-Box:

The Box-in-Box design utilises an internal structure which is externally clad using 'standard' ambient cladding panels (both roof and walls). A specialist internal insulation envelope is then installed within the structure to form the refrigerated enclosure:

Clad Rack:

Clad-rack systems are highly specialist buildings (usually these are high bay (typically 25m) with highly dense pallet storage), where the racking itself forms the building structure and specialist composite insulation panels are used externally to provide the insulation and vapour seal (in the same manner as the single envelope):



Construction System Comparison

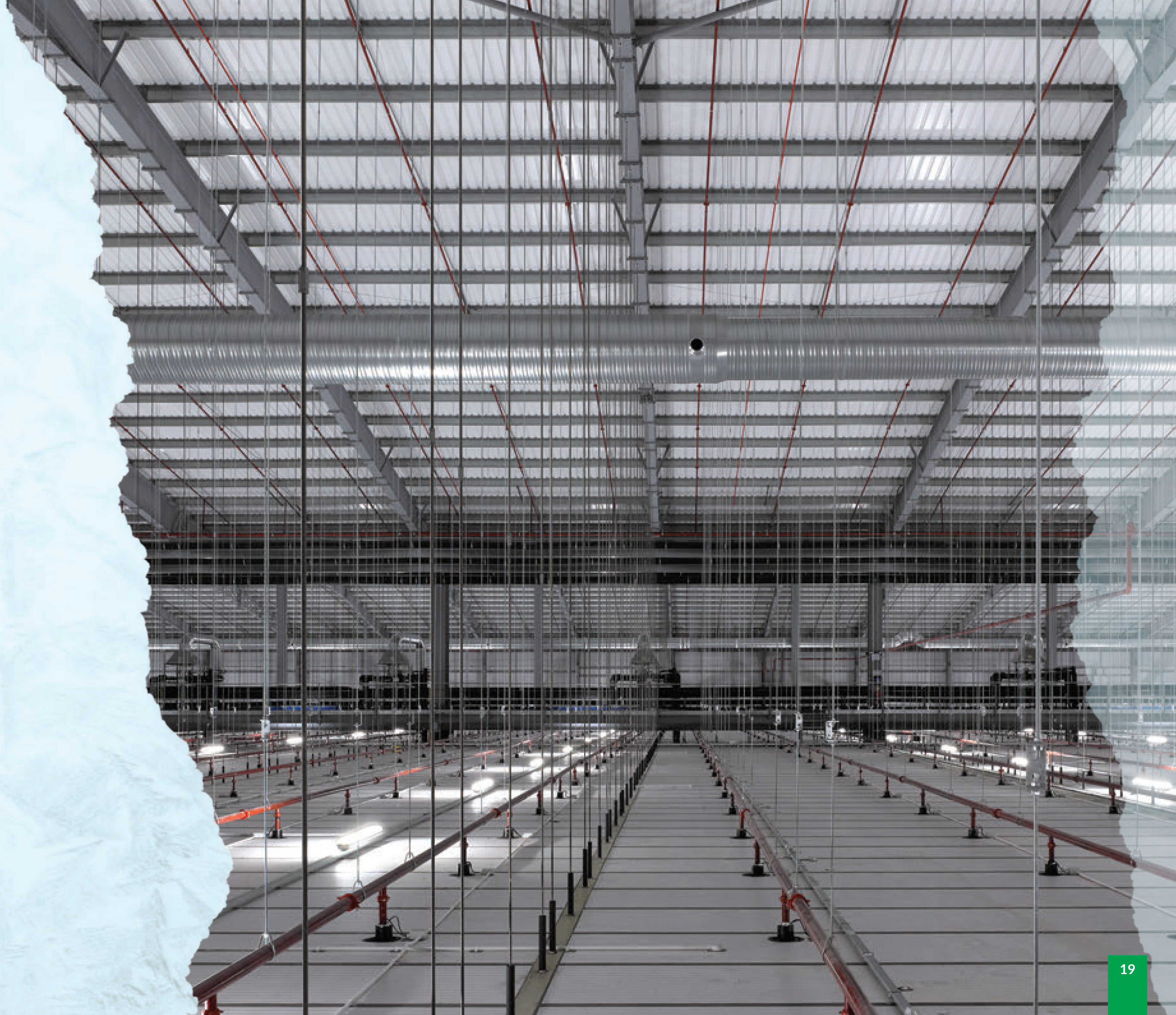
System	Cost	Suitability for Food Handling & Production	Build Time	Efficiency	Flexibility of Design	Ease of Refrigeration Installation	Ease of Planning/ Permitting	Resistance to Fire
Box-in-Box	↔	↑	↔	↑	↑	↑	↑	↓
Single Envelope	↑	↔	↑	↔	↓	↓	↓	↔
Clad Rack	↓	↓	↓	↑	↓	↓	↓	↓

SECTION 08

Design Process

Refrigerated Fit-Outs comprise of a number of specialist disciplines (insulation, refrigeration, sprinklers, electrics, structure, etc.). The correct selection of fit-out designer is an essential element in ensuring a fully integrated design. The selected designers should be highly experienced in refrigerated warehouse designs and fit-outs. Where possible, the use of multi-disciplinary designers should be considered, as this assists in achieving a more integrated design.

The use of ammonia and CO_2 refrigerants impose specialised risks on a building, its occupants and neighbours. These must be taken into full account during the initial facility designs and followed through to completion and occupation/use.



SECTION 09

Description of Fit-Out Concept

The typical construction features of a GLP ambient warehouse are:

- Multi-pitch steel or concrete propped portal frame, externally clad with composite panels
- Insulation envelope air permeability of 2m³/hr/m² at 50Pa for buildings between 10,000m² and 50,000m² and less than 1m³/hr/m² at 50Pa for building footprints exceeding 50,000m²
- Insulated and lined gutter system with siphonic roof drainage
- Low level pre-cast concrete dock walls with tailgate slots, insulated sectional doors, telescopic dock levellers and collapsible dock shelters
- Reinforced concrete warehouse floor

The general principles of the Refrigerated Fit-Out concepts include:

- Installation of an internal specialist insulation envelope to form the refrigerated chambers, with associated lobbies, rapid action and insulated escape doors. The insulation envelope being supported from the main building structure
- Creation (where required) of a heated and insulated flooring system on top of the existing warehouse floor (for sub-zero chambers) including access ramps to accommodate the difference in floor levels
- Upgrading of insulated dock doors and shelters suited to the proposed refrigerated operation
- Construction of a bespoke 'Energy Centre' to house upgraded utilities and the refrigeration plant (this could be located either internal or external to the warehouse)
- Installation of a bespoke internal refrigeration cooler and pipework support maintenance gantry
- Installation of a bespoke refrigeration plant and associated equipment
- Installation of upgraded utilities to the Energy Centre including a new transformer, LV switchgear and water services
- Installation of foul drainage to service the new refrigeration plant and evaporators
- Structural strengthening of the warehouse flooring and steelwork systems; where necessary
- Installation of lighting, smoke detection and sprinkler systems into the refrigerated chambers
- Adaptation of the warehouse layout to create additional means of escape from within both the refrigerated chambers, the evaporator gantry and the roof void
- The creation of fire partitions and roof void smoke curtains, where required to comply with local Regulations

SECTION 10

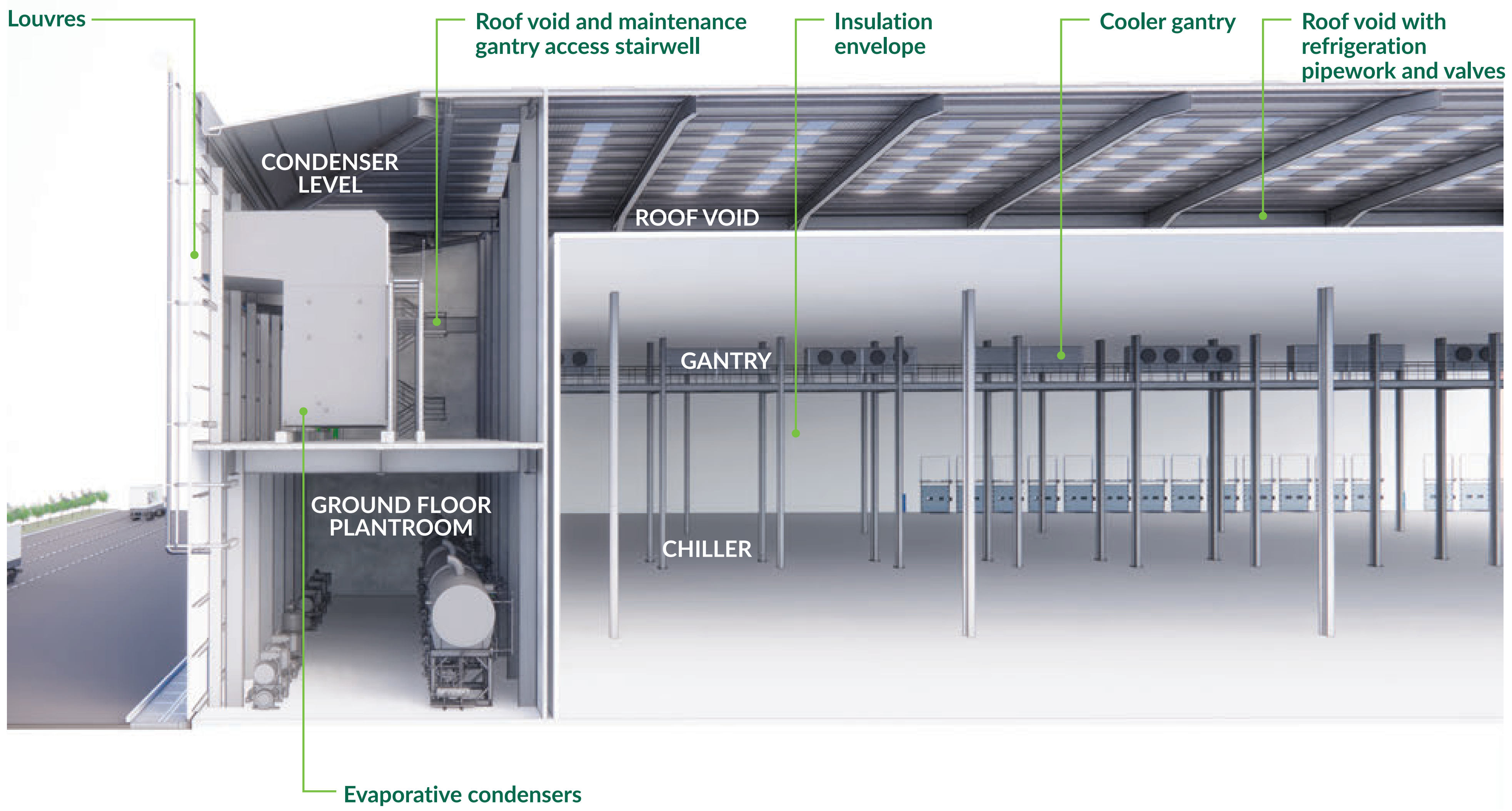
Structure

The use of pre-cast concrete structures is often preferred, as opposed to using steel. Whilst either form of construction is acceptable, the increased rigidity of concrete can often provide a significant benefit to Single Envelope Buildings. Concrete's improved fire resistance over steel is an additional advantage and is preferred in many countries for this reason.

Structures will need to be designed against the specific Codes and Regulations of the country of installation. Allowance for significant snow loads are of specific note within the Northern & Eastern European Areas. Allowance within the design to safeguard against the effects of earthquakes will be applicable within some Southern European countries.

SECTION 11

Insulation Envelope



The internal insulation envelopes forming the refrigerated chambers should be formed using high quality composite insulated panels, with a suitable fire-rating. Composite panel technology is under constant development and should be regularly reviewed for technical improvements. **Nevertheless, the following insulation type and characteristics represent the current 'best available technology' for low temperature refrigerated applications:**

- UltraTemp KS1100CS QuadCore, manufactured by Kingspan plc comprising of an internal IPN QuadCore hybrid insulation core, within 0.5mm thick galvanised steel outer sheets
- The panel core thickness will vary dependant on both the panel span, the required thermal value and the required fire rating (if applicable)
- The panel outer skins are to be coated with a Kingspan CLEANsafe finish. This is a chemically inert food-safe polymer film, laminated to the pre-treated outer metal skins and designed for use in food manufacturing applications and environments. Varying thickness's of the finish are available (25 microns to 125 microns) and should be selected according to the application
- The external and internal faces of the panels are classified as Class 0 Spread of Flame in accordance with the Building Regulations when tested to BS476:Part 6:2009 and Part 7:1997. The panels have passed the requirements of:
  - *FM 4882 for smoke sensitive occupancies: Class 1 for interior walls and ceiling (with no height restriction)*
  - *LPS 1181:2014:Part 1: Issue 1.2, series of fire growth tests for LPCB approval and is certified to LPS1181 Grade EXT-B (LPCB certification pending)*
  - *LPS1181:2005:Part 2:Issue 2.0, series of fire growth tests for LPCB approval and listing of construction product systems to LPS INT-3, INT-2 (LPCB certification pending)*
  - *LPS1208:2014:Issue 2.2, LPCB fire resistance requirements for elements of construction used to provide compartmentation providing: FR30 and FR60 – wall and ceiling*
  - *FM Approval to FMRC4880, 4881 Class 1 fire classification, unlimited height (FM Approval pending)*
  - *Reaction to fire classification according to BS EN 13501-1:2007+A1:2009:B-s1,d0*
- Biological - UltraTemp insulated panels are normally immune to attack from mould, fungi, mildew and vermin. No urea formaldehyde is used in the manufacture of the panels, and the panels are not considered deleterious
- Environmental - UltraTemp insulated panels with IPN-QuadCore formulation can achieve a Green Guide A+ rating as per the BRE Global Green Guide to Specification. End of Life: Fully recyclable

It is noted that the use of mineral-cored composite panels to form refrigerated insulated envelopes also remain a possibility for some specific refrigerated applications (especially where higher chamber temperatures are used – e.g., >+10°C). They are not suitable for sub-zero applications.

Mineral wool-cored panels can provide benefits where improved fire compartmentation is required. However, mineral wool panels have a significantly higher weight per square metre (than IPN-cored panels) and will result in higher imposed loads onto the building structure. Mineral wool-cored panels also have a greater propensity to delaminate when walked on (than IPN-cored panels) and require bespoke and structurally independent walkways. Their use is therefore subject to individual assessment on a case-by-case basis by suitable specialists. This document and associated drawings assumes the use of IPN-cored panels only.

SECTION 12

Design Principles and Considerations for Refrigerated Chambers

Vapour Barrier:

Refrigerated enclosures have a lower vapour pressure than adjacent higher temperature areas. Hence, insulation envelopes forming refrigerated chambers have natural forces within them which are continually attempting to 'draw' water vapour from the warmer outside and into the insulation panels.

In chill chambers, this can manifest itself as condensation forming within the insulation panels (causing thermal and structural degradation) as well as dripping within the refrigerated chambers (operational and hygiene concerns). In sub-zero chambers, the entrained water vapour freezes within the panels and degrades both the insulation panels' thermal efficiency and structural integrity. Over time, the increased resultant weight and general structural degradation can lead to panel collapse.

The lower the chamber temperature, the greater the forces imposed by vapour pressure.

Hence, in order to guarantee the long-term quality and durability of any insulation envelope, the construction and vapour sealing installed must be of the highest standard. A continuous vapour seal must be installed on the 'warm' side of an insulation envelope and this vapour seal must be well-maintained over time.

Thermal Bridging:

Where materials pass from a warm environment through an insulated envelope and into a cold environment, there may be a propensity for condensation to form on the external (warm) surfaces. This occurs when the surface temperature of the penetrating material falls below the dewpoint of the surrounding air.

Where the thermal conductivity of a material is high (e.g., steel), the propensity for condensation to form will be higher, as the temperature of the material on the warm side, will generally be colder.

Consideration in the design of any insulation envelope must therefore take this into account. The best form of mitigation is to avoid penetrations in their entirety. Where this cannot reasonably be avoided, the insulation and vapour seal should be extended around the material penetrating the envelope to a suitable distance (dependant on the temperature difference); thereby creating a thermal gradient and ensuring that the surface temperature of the material penetrating the extended insulation remains above the dewpoint of the surrounding air. An alternative mechanism is to trace heat a penetration, thereby raising the temperature of the material. Where trace heating is used, suitably selected and protected self-limiting tape is to be used, in order to limit the temperatures present; thereby mitigating against a fire risk. In all cases, the vapour seal must be continuous and durable on the warm side.

Condensation:

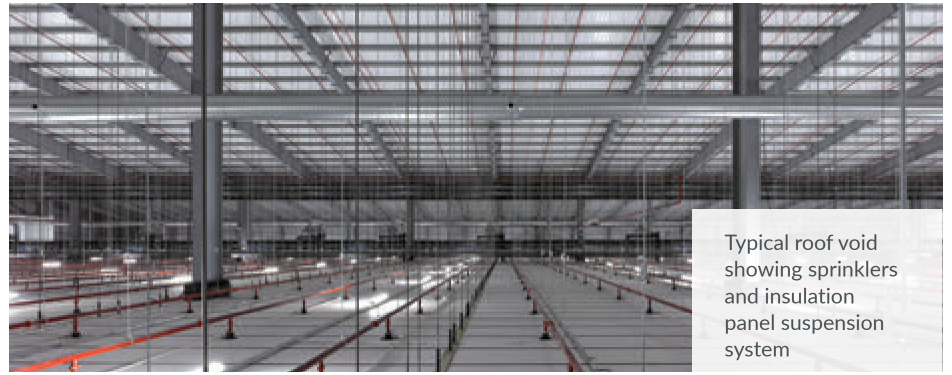
Condensation can be one of the most significant effects resulting from introducing refrigerated chambers into a building. Any fit-out design must therefore be suitably designed and planned to minimise this.

The following areas require particular attention:

Penetrations including Air Leakage through the Insulation Envelope

Air leakage from a warm environment into a cold environment can result in condensation when the warm air impacts a cold surface within the refrigerated environment and whose surface temperature is lower than the dewpoint of the incoming warm air.

The correct insulation and vapour sealing (on the warm side) of all penetrations/pathways between different temperature zones is essential to mitigate against this. The best form of mitigation is to avoid penetrations altogether.



Typical roof void showing sprinklers and insulation panel suspension system

Typical refrigerated chamber with central cooler gantry

Thermal Bridging

As detailed earlier.

Under Wall Condensation

Where a temperature difference exists across an insulated wall (e.g. between the internal insulated wall separating a refrigerated chamber from the external ambient cladding), there is a possibility of condensation forming at the base of the partition walls, as a result of thermal tracking and/or air leaking via the concrete floor at the base of the insulated wall. The higher the temperature difference across a partition, the greater the propensity for condensation. The effect of local air-flow is also a consideration; restricted voids with stagnant air provide a higher propensity for condensation.

Each scenario should be individually assessed and suitable provision should be made to counteract this effect. For chilled chambers, the correct installation and vapour sealing of the panel bases, as well as the installation of suitable concrete filled curbing along the internal perimeter of the insulated walls will assist in reducing thermal tracking and air leakage (the concrete fill acts to reduce leakage and increase the thermal insulation at the panel base). The curb also acts to protect the insulated wall, providing additional operational benefits.

Voids

Where a fit-out involves the installation of internal insulated envelope(s), there will be natural voids formed between the insulated envelope(s) and the building fabric. The same applies within the roof void above the insulated envelope. In certain circumstances, condensation can form within these voids; usually this is a result of insufficient ceiling or wall insulation (inadequate thickness), poorly installed or excessive penetrations or restricted voids/cavities (stagnant air).

Mitigation methods involve installing suitable or enhanced insulation panel thicknesses and, in some cases, the voids may require the introduction of heated ventilation systems (this decision will be based on thermal modelling of the voids and/or experience).

SECTION 13

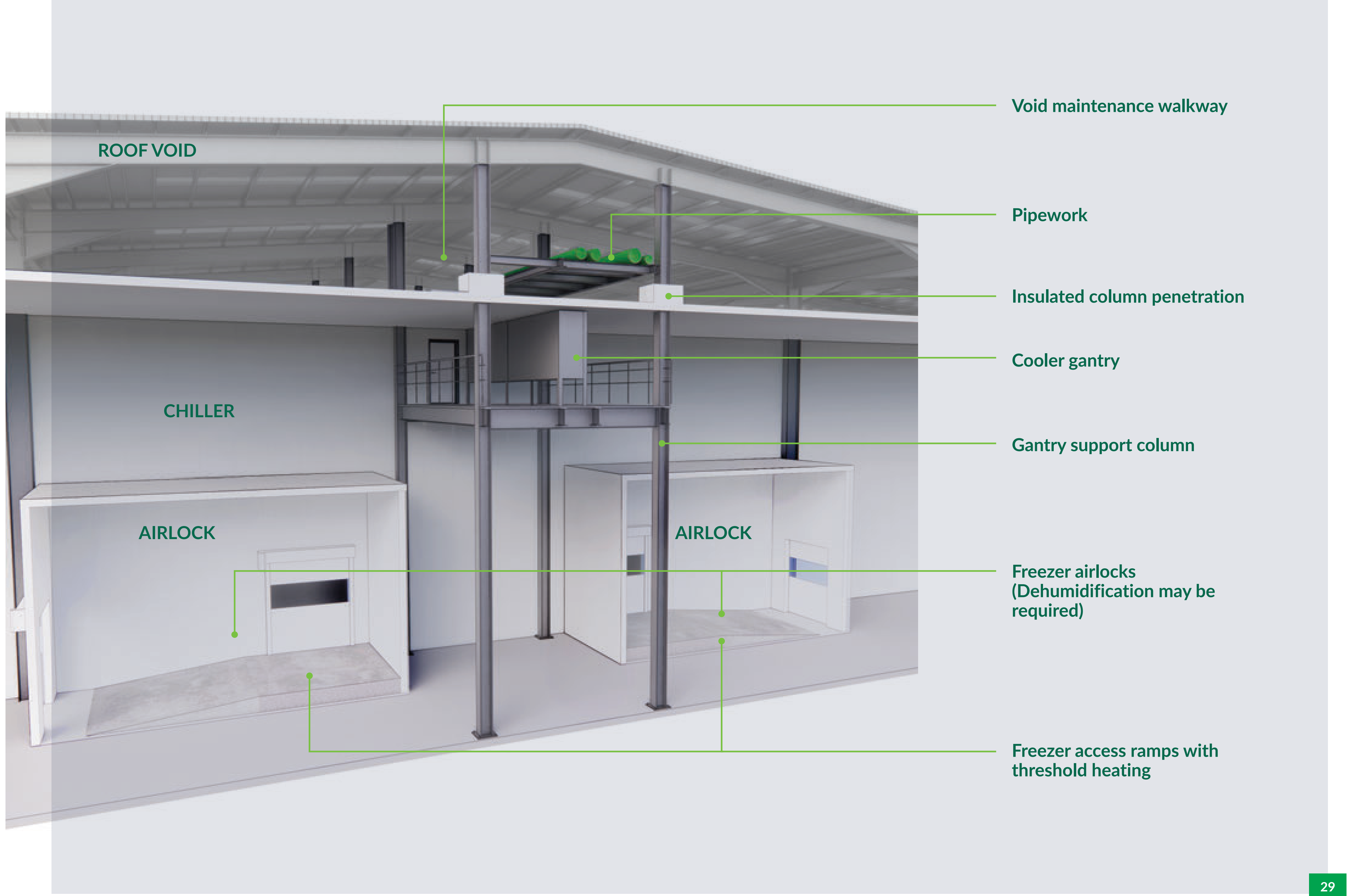
Facility Layout, Temperature and Gradients

The determination of the optimum layout of any refrigerated facility is fundamental to an efficient operation. Whilst the layout of refrigerated chambers is generally dictated by the logistical, storage and process flow requirements, consideration must also be given to the general arrangement of refrigerated chambers so as to minimise the chances of condensation forming.

Warm external ambient air which enters a refrigerated chamber can give rise to condensation, when it mixes/impacts onto colder air/surfaces. This phenomenon is particularly prevalent when internal chamber temperatures reduce below +12°C (although condensation can still also occur at +12°C and above).

The following general design measures should be adopted, where possible, in order to mitigate against this issue:

- Where multiple temperature chambers are incorporated within a fit out, they should be arranged to provide a temperature gradient; so that the higher temperature chambers are located adjacent to ambient areas, with the lower temperature chambers located furthest away. This approach reduces the temperature difference between adjacent chambers
- Airlocks with interlocked doorways should generally be installed between the external ambient areas and lower temperature chilled chambers, so as to minimise warm air ingress to the refrigerated chambers. The use of airlocks between chilled and sub-zero chambers is also recommended and where a sub-zero heated and insulated floor is installed on top of the existing warehouse floor, the airlock can be formed around the resultant ramps. This approach will not only mitigate against condensation/snow, but will also reduce the energy consumption of the refrigeration plant(s), by reducing warm air ingress
- The use of specialised dehumidified high velocity air-curtains can sometimes provide a compromise in reducing air ingress, whilst avoiding the onerous spatial requirements of an airlock
- Care should be taken with the design of airlocks to minimise condensation (as the junction between warm and cold environments, the airlock can often act to trap condensation). Dehumidification can assist in reducing this
- Door sizes should be kept as small as practically possible, high quality rapid action doors should be used with the two airlock doors being interlocked. This approach will minimise both warm air ingress



SECTION 14

External Alterations

A Refrigerated Fit-Out will typically require a number of changes to the external appearance of the warehouse. These typically include:

- Addition of an Energy Centre (an alternative internal Option is shown for the 60k Concept)
- External ammonia extraction ductwork and pressure relief lines
- Additional external doorways
- Sprinkler tanks and pump housing
- External stairwells/cat-ladders
- Additional noise (from external or internal plant)
- Additional lighting
- Possible external dock alterations
- Ventilation louvres

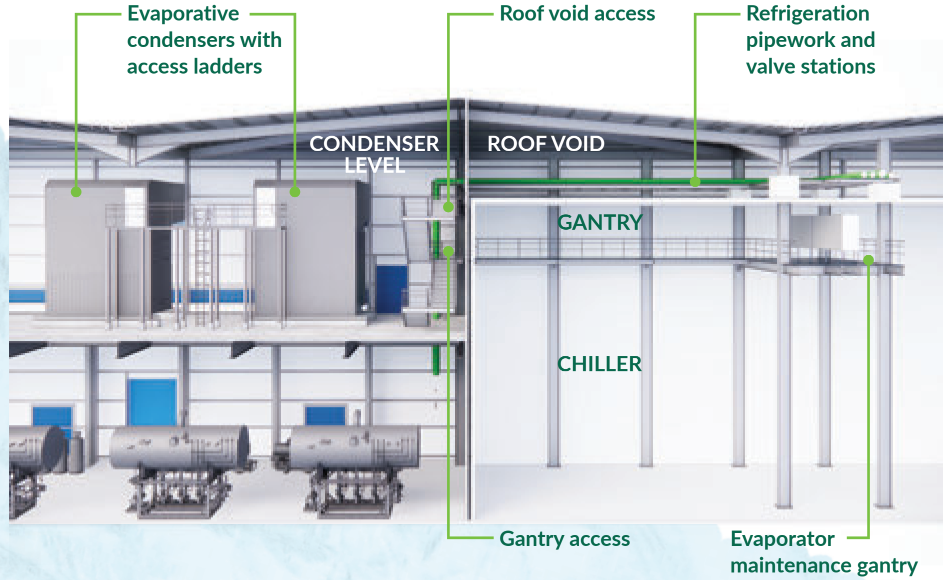
Liaison with the relevant authority and reference to the existing planning/permitting permissions will be required in order to determine whether additional permits/permissions are required for the proposed changes or whether they can be accommodated as part of an existing permission.

SECTION 15

Formation of the Internal Refrigerated Chambers (Insulation Envelopes)

In order to form refrigerated chambers as part of a fit-out, a bespoke insulation envelope, suitable for the anticipated design temperatures and panel spans will need to be installed within the ambient warehouse.

Insulated ceiling panels will be suspended from the main overhead steel portal frames. The insulated wall panels will be seated onto warehouse finished floor and will span vertically and connect onto the ceiling panels to form the insulated envelope.



The following is noted:

- The insulation wall and ceiling panel thicknesses are to be determined based on the selected panel manufacturer's structural capabilities, the proposed use, the refrigeration requirements, the deflection criteria required and the design loads anticipated. Each application is unique and will require individual assessment and determination

  As a general guide, typical insulation ceiling panel systems should be designed to accommodate a concentrated load of 1.2kN and a uniformly distributed load of 0.25kN/m^2 in accordance with EC1:1991-11. Consideration must also be given to the natural degradation of ceiling panels over time and a suitable safety factor introduced (to be determined by the Insulation Designer)

  Insulated wall panel thicknesses are to be designed based on the anticipated imposed loads, panel spans, deflection criteria and thermal requirements. Where the insulated wall panel spans are significant, it may be necessary to introduce additional perimeter steelwork connected onto the steel frame in order to provide horizontal support. In some instances, it might be possible to increase the insulation panel thickness and avoid perimeter support. Particular consideration is required during the construction phase to ensure that suitable temporary support is used

  Extreme care is required in selecting and designing the insulation envelope thicknesses and spans

- It is stressed that insulated panels are fragile and are not designed to accommodate static loads. It should therefore not be permitted for any items to be secured to the insulated panels (especially the ceiling panels), unless agreed by the Insulation Designer. Generally, all items (cable trays, etc.) are to be supported from the overhead steelwork or purlins or from the building columns. Some items (e.g., light fittings) must be secured to the ceiling panels and the insulation ceiling panel design, penetrations and luminaire support systems must be designed to accommodate this

- Insulated ceiling panels must in all cases be supported by the overhead steelwork concrete beams. They are not permitted to be supported by wall panels. Dependant on the chamber configuration, additional overhead steelwork may be required in order to accommodate this

- Insulation panels can delaminate over time from foot traffic. Consideration should therefore be given to introducing suitable specialist walkways within the roof void in order to provide additional strength in frequently trafficked areas.

  Due to these limitations and the associated risks associated with accessing roof voids, services within the roof void should be limited and should be designed to be located external to the roof voids, where reasonably practicable. Where services are installed within the roof void, they should be located along the main roof void walkways, with easy access.

  Installing control panels on the internal refrigerated gantry is a consideration (chill chambers only)

- Penetrations into the insulation panels are to be avoided, unless they cannot be avoided. Penetrations must be individually assessed for structural integrity; where penetrations are large, additional support steelwork may be necessary

- Insulation envelope joints. The insulation envelope jointing details must be designed to provide a long-term fully insulated and vapour sealed solution, with consideration to the anticipated insulation envelope deflections (see structural considerations)

- Edge protection will be required around the perimeter of the roof voids. Self-supporting systems, which do not require fixing into the insulation envelopes are preferred

- The finished insulation envelope systems should achieve an air leakage of less than 0.25m^3/hr/m^2 @ 50Pa

- The internal insulation envelope chamber heights will be determined by the following:
  - Storage heights
  - Air-flow for refrigeration systems and height of evaporators
  - Sprinkler requirements (distance from the top of the uppermost pallet stored to the underside of the insulation envelope, as well as dependant on the selection of sprinkler system and heads)
  - Roof void access/egress
  - Internal chamber air-flow requirements; too low an insulated ceiling can result in high drafts on personnel
  - The roof void height required in order to slope the refrigeration pipework back to the Energy Centre (site dependent)
  - Sub-zero chambers will require additional considerations (see later)

SECTION 16

Sprinkler Systems

The use and **selection of sprinklers within the refrigerated chambers is a decision based on a number of factors including:**

- Landlord requirements
- Insurers' requirements
- Local Building Code and regulatory requirements including purpose group, travel distances, occupancy, etc.
- Customer's requirements
- Product types, packaging type, storage densities and racking type/heights
- Fire Risk Assessment

Commonly used Sprinkler Standards/Codes are:

- FM Global
- EN 12845
- National Fire Protection Association (NFPA)
- CEA 4001
- Loss Prevention Council (LPC)

The selection of sprinkler system can greatly influence the maximum storage height of products, the type of products stored as well as the maximum chamber heights. Close liaison with all parties is essential at the start of the construction or fit-out to ensure compliance.

A typical installation may include:

- Roof level sprinklers
- Intermediate level sprinklers (most commonly In-Rack sprinklers)
- In-chamber (ceiling level) sprinklers.
- Refrigeration Plantroom/Energy Centre (in association with alternative provisions)

The sprinkler tank size, number and location will be dependent on the site layout, the water supply to site and the hazard classification. The Concept Drawings show this illustratively adjacent to the warehouse, but it is likely that the tanks will be located remote from the warehouse.

The exact selection of sprinkler system installed will be determined by the User in conjunction with their Sprinkler Specialist and the parties detailed above. For refrigerated enclosures, the installed sprinkler systems will also be dependant on the minimum temperature of the refrigerated chambers, with the following options:

1. Refrigerated Chambers above +4°C - Conventional wet system with wet heads.
2. Refrigerated Chambers below +4°C - there are three main alternatives:
    - Wet installation with wet heads with trace heating
    - Wet installation with dry pendant heads
    - Pre-action (double knock) dry installation

The finished design must make allowance for fully vapour sealing and insulating of the sprinkler heads where they pass through the insulated envelope. The penetrations including the insulation must take into account the requirements of both the sprinkler head type used and the requirements of both the Insulation Envelope Designer and Sprinkler Specialist to ensure a long lasting, well sealed and insulated solution that minimises condensation within the roof void.

The design is to be fully co-ordinated with the other services and the requirements of Building Control and the Principal Designer, in order to provide unencumbered access and egress routes.

Energy Centre:

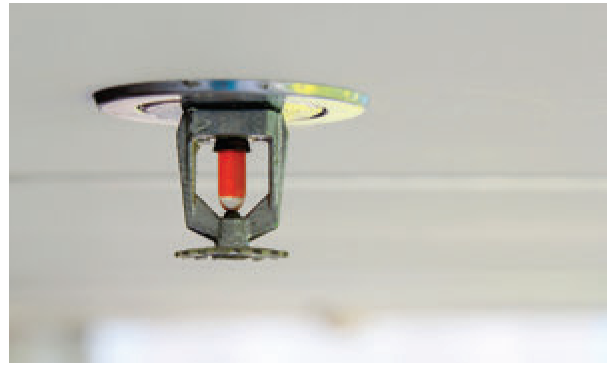
The Concept Energy Centre comprises of a ground floor refrigeration plantroom (or a 2-storey refrigeration plantroom for the internal option), an LV Switchroom and a transformer room.

EN378-3:2016 permits the use of sprinklers within a refrigeration plantroom incorporating ammonia, but cautions about the high release of energy should water impinge on a pool of ammonia. EN378 also recommends that if sprinklers are installed within ammonia plantrooms that:

- The individual sprinkler heads are individually activated at +141°C or higher (high temperature according to EN12845)
- There is no manual override of the activation of the sprinklers
- The sprinkler installation conforms to the requirements of EN12845
- A pre-action system where an actuated water valve in the sprinkler supply is controlled by a fire detection system can be used to reduce the probability of accidental discharge of any of the sprinkler heads
- The provision of a remote sump in the drainage system from the ammonia plantroom will reduce the risk of environmental pollution from the run-off water

Special consideration should also be given to both the LV switchroom and transformer rooms. The use of both detection and fire suppression systems (e.g., CO_2) can provide enhanced security, without the resultant risk of water damage that would occur with sprinklers.

The selection of sprinklers and fire suppression systems within the Energy Centre should therefore be risk assessed on an individual basis and discussed and agreed with the various parties.



SECTION 17

Smoke Detection and Fire Alarm Systems

The fit-out will involve the installation of specialised smoke detection and extension/renewal of the fire alarm system within the warehouse and associated areas.

Conventional smoke detectors are liable to fail within refrigerated environments, due to the varying temperatures and the frequent presence of condensation, high humidities and mist. Aspirator detection systems are therefore the preferred solution for use within refrigerated chambers.

The principle criteria for the selection of aspirators within refrigerated chambers are detailed below:

- Aspirator systems, designed for use within the proposed refrigerated environments and compliant with the agreed fire standards selected for the project

- Aspirators should ideally be located within the refrigerated environments; locating aspirators external to the refrigerated envelope creates additional penetrations (which should be avoided), as well as substantial additional technical requirements to avoid condensation forming both within the aspirator unit and local to the aspirator pipework

- High capacity air filters. Distribution centres and refrigerated stores in general are subject to substantial Mechanical Handling Equipment (MHE) tyre dust and cardboard dust. Conventional filters can be prone to frequent blockage

- Within sub-zero chambers, there can be a propensity for 'snow' and ice to form on the insulated ceilings and aspirator pipework (especially when the pipework is located close to evaporators or above doorways). Whilst good design can act to minimise this, any aspirator design must nevertheless make allowance for this reality. Aspirators that incorporate heated sample points can act to significantly reduce these problems

- Due to the onerous environments within refrigerated chambers, aspirator manufacturers will have additional guidelines that must be followed for refrigerated chamber installations

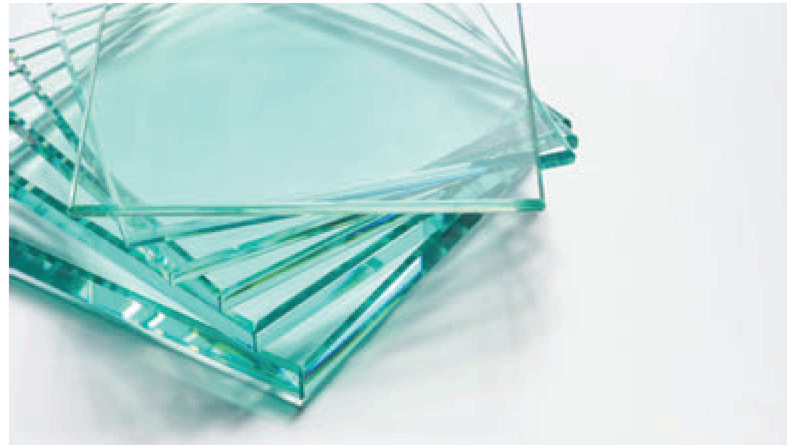
- For the Concept Layouts, a fire alarm system including smoke detection will also be required within the various refrigerated airlocks, the roof voids, the plantroom, switchroom and transformer room

- The Concept Fit-Out uses ammonia refrigerant within the ground floor refrigeration plantroom. Ammonia is classified as a B2L refrigerant with high toxicity and lower flammability. The ammonia plantroom should be designed to a Zone 2NE classification and the fire alarm equipment (call-points, sounders, beacons, detectors etc.) installed within it and their associated installation should comply to a minimum of Zone 2-T3 classification

- The total facility fire alarm system classification and system, including smoke detection and suppression systems must be agreed between the End-User, Building Control, Landlord and Insurers

SECTION 18

Glass



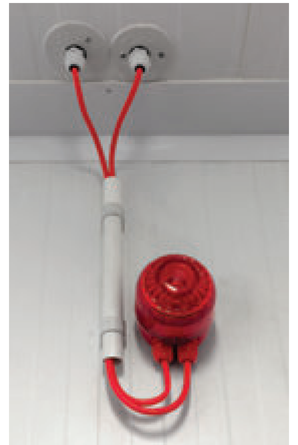
Most refrigerated facilities will store or handle food products. Glass will therefore be prohibited within both the warehouse and employee amenities. All fittings and equipment (e.g., lighting) must therefore be glass-free.

Where windows are used within the insulated envelope, polycarbonate systems can be used. However, due to their propensity to scratch, installing kite-marked laminated safety glass with a secondary safety film is often undertaken instead used. This approach should be considered, as it results in a longer lasting solution; however, approval will normally be based on either internal Quality Assurance approval or Customer Approval.

If used within refrigerated environments, all windows must be suitably double or triple glazed and internal heating may be required to prevent condensation (application specific).

SECTION 19

Low Temperatures

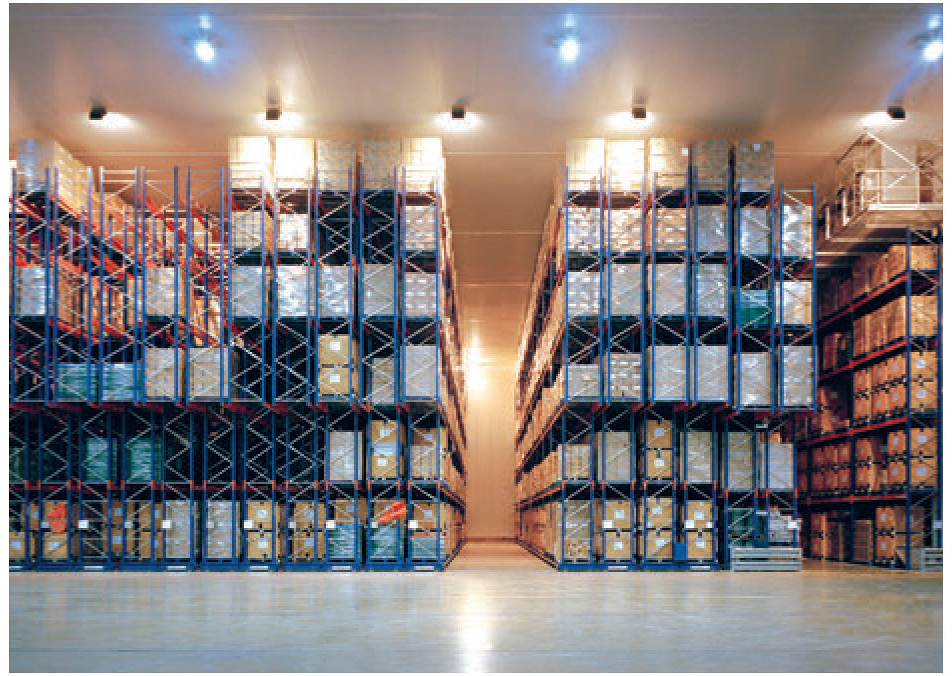


All equipment, fittings and materials used within the refrigerated chambers must be designed for use within their proposed environment, taking into account both temperature and humidity.

Care is also required within the design to accommodate the variances in temperatures between chambers and in particular penetrations between areas of varying temperature. This includes the correct design of penetrations through the insulation envelopes, as well as the use of designs to prevent condensation and moisture ingress.

SECTION 20

Lighting



Refrigerated Chambers:

Lighting and emergency lighting internal to the refrigerated chambers should generally be:

- LED type with colour rendition to suit the end-user's requirements
- Lux levels to suit the end-user's requirements and both industry and local codes/recommendations
- Minimum IP65 rated
- Supported and cabling should be designed to accommodate the specialist requirements of refrigerated chambers
- Control to suit the end-user's requirements
- Consideration should be given to installing centralised battery systems for the emergency lighting systems, as this eliminates the problems associated with batteries being located in either the roof void and/or refrigerated chambers

Refrigeration Plantroom:

The Concept Fit-Out uses ammonia refrigerant within the ground floor refrigeration plantroom. Ammonia is classified as a B2L refrigerant with high toxicity and lower flammability. The ammonia plantroom should be designed to a Zone 2NE classification and the lighting and emergency lighting systems and their associated installation should comply to a minimum of Zone 2-T3 classification.

Emergency lighting within the ammonia plantroom should be of a sufficient level to enable the refrigeration plant to be operated in the event of a lighting failure. A minimum of 100lux at floor level is considered adequate. LED luminaires serviced by a centralised UPS system located within the LV Switchroom is recommended.

All lighting, emergency lighting and refrigeration pipework/equipment within the refrigeration plantroom should be fully co-ordinated.

SECTION 21

Underfloor Heating

Underfloor heating is required within refrigerated chambers held at sub-zero temperatures, to prevent freezing of the ground beneath the building. Heating is installed in conjunction with an insulated sub-floor system. Three types of underfloor heating systems are used:

- Electric heater wire/mat system
- Warm glycol pipework system
- Warm air system

Electric Heater Mat systems are typically more economical to use in smaller freezer chamber, but incur an ongoing energy penalty. Standby electric heater mats are often used, to safeguard against a failure.

Warm Glycol Systems are most commonly used in large freezer chambers. The glycol is typically heated using waste heat from the refrigeration plant, resulting in low energy use. Extreme care is required in the design and installation of these systems. The use of 'straight-through' pipework systems can often provide insurance against a later pipework leak.

Warm Air Systems are often used in regions where ambient temperatures are always above +15°C. This can present a very cost-effective solution, with extremely low running costs. Designs should use 'straight-through' ducts, with large pipe diameters and suitably spaced to ensure sufficient heat transfer. In the case of large coldstores, it may be necessary to introduce forced ventilation fans and header pipework in order to guarantee even and sufficient air-flow. Where fans are used, suitable alarms must be used to alert local personnel of a fan failure.

Each system must be individually assessed and a solution designed and calculated on a case by case basis.

As a heater mat system is essential to the proper operation of a sub-zero chamber, the correct selection of heater system (and associated control and alarming systems) and their installation methods are of critical importance.

Failure of a freezer underfloor heating system can result in frostheave (the freezing of the sub-ground, resulting in the finished concrete floor being lifted), which can render a coldstore inoperable. Consideration should always be given to either installing a back-up heating system or designing the underfloor systems so as to enable any failures to be repaired/supplemented without the requirement to dig up the floor.

SECTION 22

Sub-Zero Chambers

Sub-zero chambers will require a number of additional requirements due to their low internal temperatures. These will include:

- A heated and insulated flooring system. For a fit-out, the floor will be constructed on top of the existing warehouse floor, with suitable ramps
- A typical insulated and heated flooring system will include:
  - Heater mat – see detailed earlier. Electric and warm glycol systems will be installed within a concrete screed (typically 50-75mm thick)
  - Vapour barrier
  - Specialist high density insulation boards (minimum 2 No. layers) – specification of boards to be determined to match the proposed imposed loads (e.g., Dow Floormate 300-700-A) and thickness to suit the refrigeration load calculations and heater mat selection. Typically 200-240mm thickness
  - Slip membrane
  - Finished concrete floor. Thickness to be designed based on anticipated floor loadings
- Electric threshold heaters cast within the upper floor slab below the rapid action and personnel doors (to prevent freezing of the concrete upper surface). Electric threshold heaters should also be installed within the airlocks to sub-zero areas
- Heated and insulated columns
- Pressure relief valves
- Finished floor slab design. Finished floor slabs within sub-zero refrigerated chambers are to be designed to accommodate both the anticipated structural loadings, as well as the significant thermal contraction that is anticipated. Specialised sinusoidal expansion joints within the finished floor slabs and around doorways should be considered, as these reduce the impact from MHE wheels crossing, when contraction has occurred

SECTION 23

Fire Partitions

The requirement for fire partitions within the insulated envelope will be subject to local Building Codes and Regulations and Client and Insurance Requirements, which should all be determined at Concept/Feasibility Stage.

Kingspan IPN-cored insulation panels have been certified to achieve specific fire ratings dependant on their thickness. However, their fire rating certification is also dependant on the installation systems employed, including the use of suitably fire protected steelwork and approved panel fixings, sealants and connections. A simply supported insulated envelope will not attract a fire rating; regardless of the insulation panel certification or thickness.

The use of composite panels as fire walls is under constant review and updates, and so the latest guidance, advice and Codes must be checked when considering these.

Where composite insulation panels are used as fire walls, the exact certification required must be determined and the installation should be designed and installed by a suitably certified specialist insulation contractor and a final certificate confirming the fire rating of the finished partition wall system is to be provided. A common standard for fire partition certification is LPS1208, with the Insulation Contractor being certified to LSP1500. Independent certification of the installed systems may also be considered.

The use of composite panels as a fire rated structure/compartment is not permitted in some Countries and pre-cast concrete panel structures are instead used. The use of concrete compartments within refrigerated environments requires careful design in order to minimise the risk of condensation forming in cavities, as well as to prevent thermal bridging.

Similarly, the use of smoke hatches within insulated chambers (which some countries require) requires careful design to prevent condensation and to ensure a long-lasting and effective seal.

Refrigeration Plantroom:

The refrigeration plantroom could either be installed external or internal to the warehouse; dependant on both Client preference and a structural assessment.

Where ammonia refrigerant is used, EN378 requires that the ammonia plantroom has a minimum of 60-minute fire rating. Nevertheless, it is usual for Insurers, Landlord, End-User and local Building Codes to require a higher fire rating, which can range between two and four hours.

SECTION 24

Impact Protection

Insulation envelopes and associated equipment (e.g., doors etc.) can be subject to impact damage; especially from MHE. Similarly, consideration should be given to the protection of personnel.

Suitable systems are to be installed to provide protection to any areas at risk (to be assessed dependent on location, type of use, MHE employed and other relevant factors).

Typically protection will include a combination of:

- Steel concrete-filled angles at the insulation wall panel bases and column bases
- Protection barriers (suitable for MHE and personnel)
- Goalpost protection barriers for doorways
- Bollard protection for docks

The use of polymer style barriers, which have the ability to accommodate a degree of impact can provide significant benefits in reduced maintenance and damage to MHE during the lifetime of a refrigerated facility.

SECTION 25

Insulated Personnel Doors

There are a variety of alternative insulated personnel doors within the marketplace, of varying qualities and cost. The following criteria should generally be used when considering their selection:

- The proposed application and environmental conditions
- Durability/robustness for the intended application (including the furniture, hinges, etc.)
- Suitable insulation value; for chilled chambers, a minimum of 80mm PIR-cored insulation is generally suitable. For freezer chambers, a minimum of 120mm PIR-cored insulation is generally suitable. Each application must be assessed individually. Certain applications will benefit from a lighter door with a reduced insulation value
- Fire rating to suit the application
- The selection of 3-sided or 4-sided frames; dependant on the application
- Rising hinges and heavy-duty self-closers
- Suitable frames
- Thermal breaks to be integrated into the door and frame design
- Where vision panels are installed, suitable insulation is required to mitigate against condensation. In some instances, heating may also be required. See also section on 'Glass'
- In sub-zero applications, the door frames are to be heated, as well as the thresholds, to ensure that the gaskets do not adhere to the frames/floor

SECTION 26

Rapid Action Doors

High quality, well-sealed, automatic closing rapid acting doors dedicated for forklift trucks/MHE are recommended to be used between refrigerated areas in order to keep warm air ingress to a minimum. Warm air ingress generally represents the largest proportion of load on a refrigeration plant, and a well-designed refrigerated facility which minimises warm air ingress has the additional benefit of allowing smaller, more efficient and lower cost refrigeration plant(s) to be installed.

As with insulated personnel doors, there is a large variance in both quality and cost in the marketplace. **The following criteria should generally be used when considering their selection:**

- The proposed application and environmental conditions
- Durability/robustness – including the ability to 'self-repair' following MHE impact (this is to be expected). The robustness of rapid doors is fundamental
- Sized to the absolute minimum to reduce air ingress
- Suitably protected from impact
- Suitably insulation curtains to best match the intended environment. Where a large temperature differential applies across the door, the selection of a suitably insulated door curtain will minimise condensation. This particularly applies between ambient and +1°C and also into freezer chambers.
- Rapid opening and closing to minimise time open
- Separately protected by suitably fire-rated shutter doors (where relevant); fire rated rapid action doors suitable for refrigerated use are not available within the marketplace
- Suitable frames to support the door weight and prevent load transfer onto the insulation wall panel system
- Thermal breaks to be integrated into the door and frame design
- Vision panels to be installed, where required. Generally, vision panels in rapid action doors can be prone to premature failure
- Suitable alarm and notification systems (both sides) to alert personnel and other MHE drivers that the door is in-use and that MHE may be passing
- Suitably safety features, including pedestrian protection and pedestrian warnings
- Suitable alarm and notification system to alarm when broken/stuck open (to enable its rapid repair)
- In sub-zero applications, the door frames and blades are to be suitably heated, as well as the door thresholds, to ensure that the doors do not adhere to the frames/floor. Any electric heating systems must be suitably safeguarded against fire

SECTION 27

Fixings through Insulation Panels

It will be necessary to fix various items onto the insulation panels (lights, conduit, door frames, etc.). Whilst fixings onto insulation should be avoided, wherever practicable, any fixings should always be undertaken according to the insulation panel manufacturer's recommendations.

Nylon fixings are routinely used within the refrigerated chamber industry, due to their low thermal conductivity and theoretical strength. Nylon fixings have shown a history of failure, over time, (for various reasons) and as such they are only to be used in conjunction with other more substantial fixings (e.g., stainless steel). Suitable measures should be employed at any fixing to minimise both thermal transfer and condensation, whilst maintaining a full vapour seal.

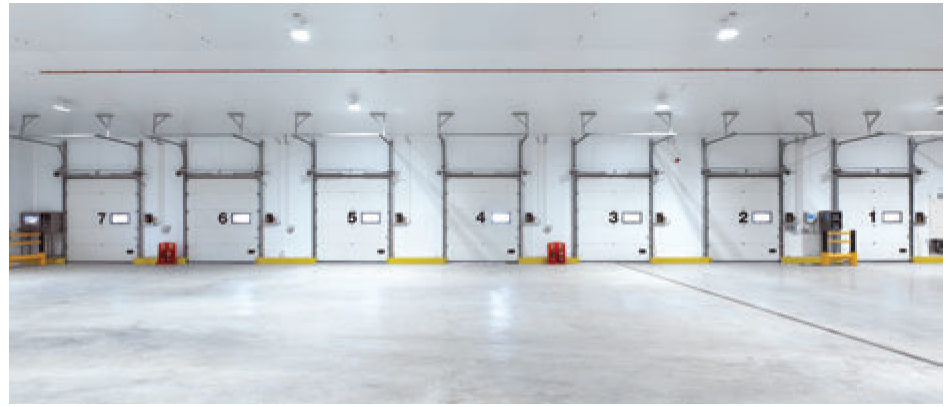
SECTION 28

Dock Doors and Shelters

The loading docks represent one of the most significant areas of air ingress within a refrigerated chamber and the correct selection of dock shelters is critical to reducing refrigeration plant loads and running costs.

The selection of door, shelter, bumper and leveller must be determined by undertaking an assessment of the anticipated refrigerated vehicle fleet that will use the facility and their associated dimensions. Where a variety of different vehicles are anticipated, the selection of dock seal system becomes more complex and a good seal becomes harder to achieve. It may become necessary to allocate certain specific docks to certain vehicles.

It is always recommended that the final selection of dock seals is undertaken in conjunction with the refrigeration plant designer, so that the resultant air ingress can be accommodated within the refrigeration plant design.



For a basic chill conversion, the following will generally need to be undertaken:

- Insulated overhead dock doors. Motorised 40mm PIR-cored sectional insulated vertical acting doors are to be mounted on an aluminium frame system internal to the insulation envelope, with suitable insulated reveals installed between the insulation envelope and the external door opening. Where reduced external condensation is required, the sectional door insulation core thickness can be increased to 80mm. The dock doors are to include perimeter and panel joint seals and double-glazed vision panel
- Dock sealing system upgrade (as detailed earlier). Three main types are available:
  - Cushion seals
  - Shelters
  - Inflatable shelters
- The optimum solution will depend on the vehicle fleet anticipated. Care and attention in the selection should be given to ensuring an effective seal when docked, as an effective seal will reduce the refrigeration plant duty, size and ongoing running costs, as well as keeping moisture out of the refrigerated chambers
- Dock levellers. The length and reach of dock leveller may require adapting, based on the vehicle fleet proposed. Where chill operation is anticipated, insulating under the dock levellers and introducing seals between the leveller and the leveller pit will assist in reducing air ingress and condensation

In warmer and more humid climates (e.g., Southern & Eastern Europe), the correct selection of loading docks and sealing onto vehicles is of increased importance.

Where docks do not seal correctly, ingressing warm and humid air can result in condensation within the facility, when the warm air contacts the colder internal building elements.

Condensation can cause product quality concerns (dripping), personnel safety concerns (slip hazards) and corrosion (particularly of the dock door mechanisms).

Where vehicle fleets are uniform, the correct docking system and seal selection can ensure excellent results. Where vehicle fleets are varied, alternative systems should be considered. Where small vehicles are used (commonly at Goods-In from small suppliers) a ‘double dock door’ arrangement with an increased holding area could be considered. These incorporate both an internal and an external insulated dock door, enabling suppliers to discharge their products onto the docks. The outer doors can then be closed, and the inner door opened; thereby minimising air ingress. Air curtains (see later), can sometimes further assist.

The use of external dock pods can often provide significant benefits. These docks, including the dock levellers, are installed external to the main building shell, which permits dock levellers and docking systems to be more easily changed, as a vehicle fleet (or operation type) changes.

The use of alarming systems or key interlocks to alert personnel or prevent doors from being opened without a vehicle present are recommended.

SECTION 29

Air Curtains and Dehumidifiers

Preventing warm air ingress into refrigerated chambers is essential in order to reduce energy costs, maintain temperatures and to prevent condensation and/or snow/ice formation.

The correct selection of vehicle docks as well as rapid action doors on refrigerated chambers can reduce ingress to acceptable levels. Where additional measures are required (for example where throughputs are high and door openings are frequent), additional measures can be taken; such as installing air-locks with interlocked doorways and/or air curtains.

There are numerous air curtains within the marketplace and their efficacy varies significantly between make and application. Nevertheless, significant benefits have been noted in using dehumidified air curtains. These act as conventional air curtains over doorways, but utilise a rotary wheel desiccant dehumidifier to dry the air to extremely low levels of humidity, prior to discharge. This solution is often used between chill and freezer chambers where high activity is anticipated and the use of an airlock is not considered viable.

SECTION 30

Evaporator Gantry

The Concept Fit-Out designs introduce a galvanised steel evaporator gantry internal to the warehouse in order to support the refrigeration evaporators (within the chambers) as well as the refrigeration pipework and valves (within the roof void).

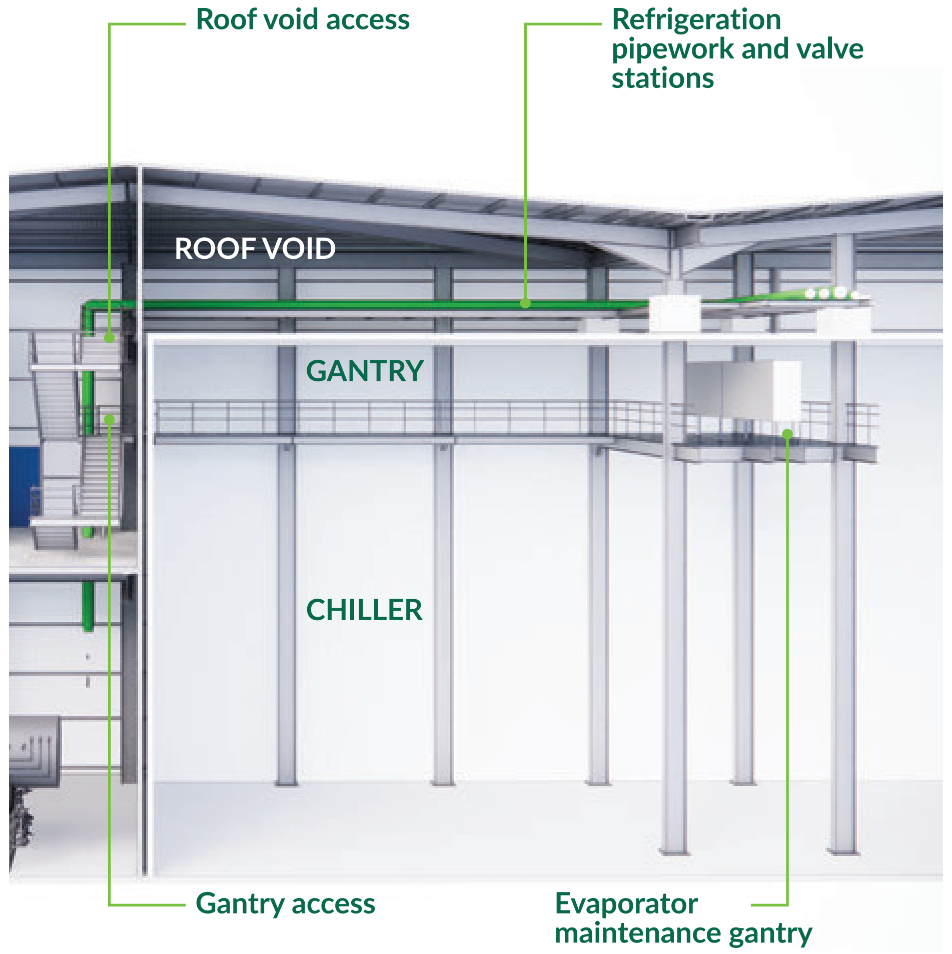
The design concept is to accommodate the substantial structural loadings of the refrigeration system by using a floor mounted support system; as opposed to supporting them from the overhead steelwork.

The evaporator gantry system provides additional benefits, such as ease of access to the evaporators for both maintenance and cleaning.

The evaporator gantry system is to be designed in conjunction with the refrigeration designer and structural engineer to ensure that the loadings can be accommodated on the existing flooring system and to ensure compatibility with the proposed refrigeration equipment (weights, sizes and access requirements). Additional means of evaporator gantry access and egress may be required to suit Building Codes.

Penetrations of the gantry steelwork into the roof void will need to be suitably insulated to minimise condensation.

Where installed within a sub-zero chamber, specialised low temperature steelwork may be required.



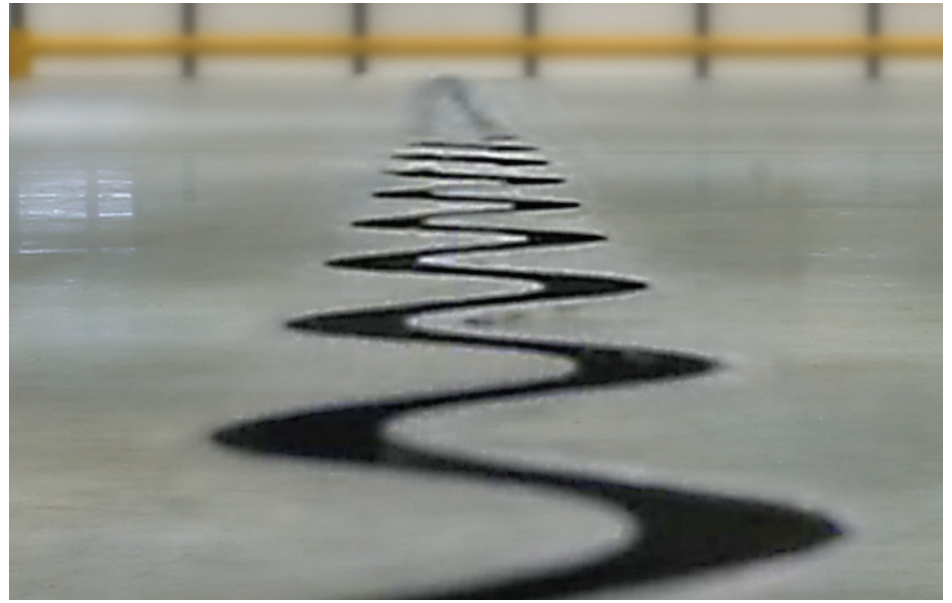
SECTION 31

Floor Loadings

The warehouse floor loading capability must be checked against the proposed imposed loads, as part of the fit-out, to ensure compatibility/suitability.

This includes the imposed loads from the evaporator gantry (and associated pipework, valves and evaporators), from the refrigeration plantroom (if located internal to the warehouse) and from the proposed racking systems.

Specialised sinusoidal expansion joints within the finished floor slabs and around doorways should be considered, as these reduce the impact from MHE wheels crossing, when contraction has occurred.



SECTION 32

Pressure Relief Valves

Correctly designed and installed refrigerated chambers will be well sealed, with a low air leakage. During the normal course of a refrigerated chamber's operation, the pressure within the chambers will reduce and this can impose structural forces onto the insulation envelope. These forces can be substantial during periods of rapid pressure changes (e.g., during defrost), when doors are closed.

The refrigeration designer is to calculate and select suitable pressure relief valves (heated, where required) in order to mitigate against this. These are to be installed within the relevant insulated chambers.

SECTION 33

Chamber Heating

Where winter temperatures are low (particularly in Eastern & Northern Europe), refrigerated chambers may require heating in order to maintain the chamber set-point temperatures. Where low temperature freezer chambers are installed, the waste heat from the refrigeration process can be used to provide the necessary heat.

SECTION 34

Refrigeration Plant

The layout and use of a refrigerated Fit-Out can vary significantly due to product throughputs, incoming product types, temperature layout, processes (e.g., blast freezing) etc. As a result, the refrigeration plant for each Fit-Out will be unique and their selection and design must be individually tailored to the intended use and energy efficiency requirements.

Due to the current phase-out of HFCs (Kigali Amendment to the Montreal Protocol), the use of 'natural' refrigerants is considered most suitable for the Concept Fit-Outs. These include ammonia and carbon-dioxide (CO_2) refrigerants. Whilst hydro-carbon refrigerants are also natural, due to their high flammability, they are not considered suitable for this application.

Throughout Europe, there are significant differences in the refrigeration technologies that are both used and available, with each country having specific preferences and experiences. Furthermore, these have to be co-ordinated with the End-User's requirements. Often these can be highly specific and based on a customer's agreed central standards.

Nevertheless, certain trends are prevailing throughout Europe. The use of high charge direct ammonia refrigeration systems is becoming less common; primarily due to ammonia's high toxicity, increased legislation and the associated risks to personnel and neighbours. It is considered that this trend will continue.

Conversely, the use of carbon-dioxide (CO_2) as a refrigerant has increased dramatically over the past five years and is becoming more commonplace for industrial solutions.

Whilst the actual selection of refrigerant and system must be individually assessed and determined by the Fit-Out Designers, the use of a low-charge ammonia refrigerant plant (with ammonia confined to the Energy Centre) and used to refrigerate a secondary sub-critical pumped CO_2 plant is considered better suited to this application and has been assumed in the three Concept Fit-Outs. The use of both ammonia refrigerant must nevertheless be first validated via risk assessment, including its impact on both the warehouse and adjacent properties. Dispersion modelling is an essential tool in this process.

The use of pumped CO_2 can result in reduced pipework sizes within the roof voids, thereby reducing structural loadings, as well as removing ammonia from within the production, warehouse and roof void areas.

CO_2 refrigerant is an asphyxiant. Suitable care in the refrigeration plant design and associated safety systems should be incorporated. This will include (amongst other items) suitable detection and alarming systems. A risk assessment to validate the use of carbon-dioxide within a specific application is therefore also required.

All refrigeration plant should be sized to suit the application's requirements, the peak ambient design temperature, the anticipated refrigeration loads and should be designed according to local Codes and Regulations. Specific risk assessments should be undertaken as part of the design process and the design adapted accordingly including the installation of all necessary safety equipment.

SECTION 35

Utilities

A refrigerated facility will have a significantly increased utility requirement relative to an ambient warehouse.

The additional utility requirements are principally derived from:

- Refrigeration Plant (electricity and water requirement)
- Electric heater mats, column and threshold heaters (where sub-zero chambers are installed)
- Increased lighting (resulting from the internal insulated envelope)
- Rapid action doors
- Dehumidifiers
- Roof void ventilation (if required)
- Additional internal processes (e.g., mobile racking, tempering, etc.)

The exact utility requirements will need to be individually assessed according to the proposed facility layout and refrigeration plant size, system and type. However, the assessment of an existing or proposed site's utility suitability for conversion or construction to refrigerated use is an important first step.

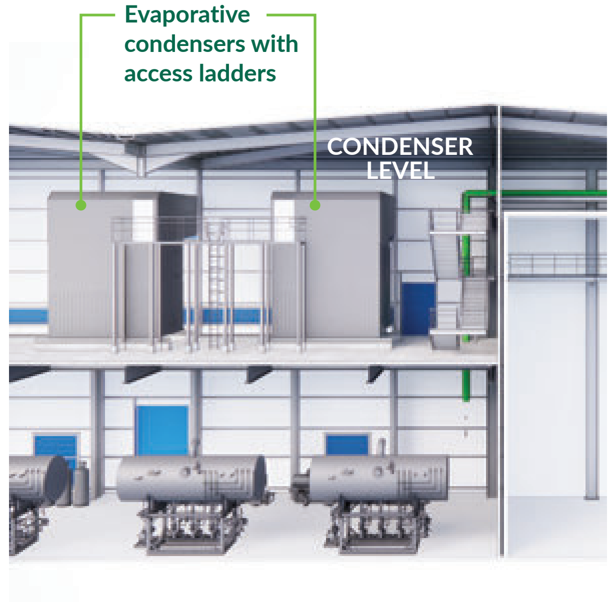
The Concept Fit-Out assumes a distribution centre with moderate product throughputs, efficient door control and a low charge ammonia refrigeration plant with pumped secondary CO_2 refrigerant.

The refrigeration plant represents the largest utility user on site requiring electricity, as well as water for the evaporative condensers. The use of evaporative condensers enable a smaller sized refrigeration plant to be installed, with a lower peak electrical demand.

Evaporative condensers require a substantial water supply to be provided at the Energy Centre, with the water being of a suitably high quality. Evaporative condensers also require ongoing water treatment to satisfy local Codes and Regulations regarding the control of legionella bacteria in water systems, as well as disposal of the treated water to foul.

Where a suitable water supply or foul discharge is not readily available, or there is a preference to avoid water treatment systems, the use of air-cooled condensers can instead be used, although the refrigeration plant peak electrical demand will increase. In the case of the 60k Fit-Out Concept, due to the extensive size of the refrigerated facility, air-cooled condensers (and their associated high peak electrical demands and extensive footprint requirements) have not been considered.

The required water quality for evaporative condensers will depend on the equipment selected and water treatment systems proposed. Each application is unique and the selection and suitability of any water treatment system and condensers must be individually assessed on a case by case basis. This includes the economics of the selection of air-cooled condensers versus evaporative condensers. Nevertheless, the following table summarises typical water quality requirements for evaporative condensers and should be used as an initial selection step:



Typical INDICATIVE Water Quality Requirements for Evaporative Condensers*

Recirculating Water Quality Measure	Galvanised Steel	316 Stainless Steel Throughout
pH	7.0 – 9.0	6.5 – 9.5
Total Hardness as CACO3	70 – 600mg/l	750mg/l max.
Total Alkalinity as CACO3	500mg/l max.	600mg/l max.
Total Dissolved Solids	1250mg/l max.	2500mg/l max.
Conductivity	2000 microS/cm	4000 microS/cm
Chlorides	200mg/l max.	750mg/l max.
Sulphates	200mg/l max.	750mg/l max.
Total suspended solids	25mg/l max.	25mg/l max.

*Note: It is stressed that the above guidelines will not themselves guarantee the protection of a cooling system, but instead provides initial selection criteria at the start of a decision-making process. The economics of a water treatment programme and condensers must also be considered.

The Concept Fit-Outs provide an alternative option for an internal plantroom/Energy Centre with evaporative condensers located within the main warehouse. It is noted that this solution requires particular care in its design in order to ensure that the evaporative condenser air flows do not recirculate and that the discharge air is suitably directed away from the intake air. It is not considered that air-cooled condensers will function correctly when the internal plantroom solution is selected and for this reason only suitably adapted evaporative condensers should be considered for this Option.

Indicative utility requirements for the refrigeration plants servicing the three Concept Fit Out solutions have been calculated, as follows:

Typical INDICATIVE Water Quality Requirements for Evaporative Condensers*

	20k		40k		60k	
	Refrigeration Plant Water/[litres/s]	Refrigeration Plant Power/[kVA]	Refrigeration Plant Water/[litres/s]	Refrigeration Plant Power/[kVA]	Refrigeration Plant Water/[litres/s]	Refrigeration Plant Power/[kVA]
Evaporative Condenser Solution	2.5	770	3.0	1,000	7.0	2,350
Air-Cooled Condenser Solution	n/a	950	n/a	1,200	n/a	n/a

*Note: The above figures are based on the Concept Schemes only. Each facility must be assessed on an individual case by case basis and may change dramatically based on product throughputs, refrigeration plant selection and water quality. It is noted that the above figures are estimates for the refrigeration plant only and do not include any other utility requirements, such as offices, warehouse, roof void, lighting, rapid doors, heater mats, water for ammonia emergency drench showers etc.

SECTION 36

Energy Centre

The Concept Fit Out schemes will require a new Energy Centre to be constructed sized to suit the proposed refrigeration plant and associated plant/equipment.

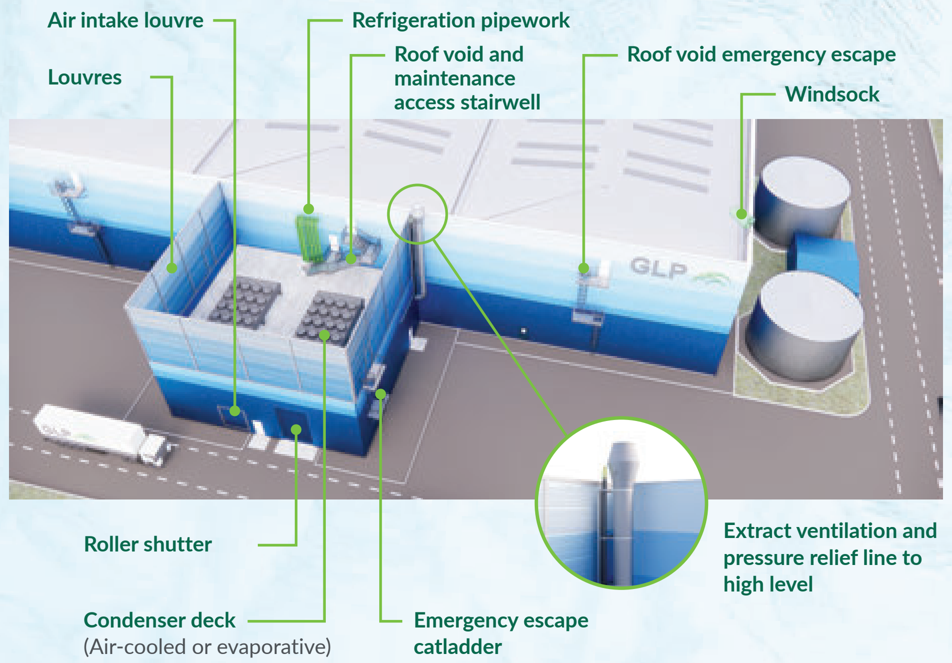
Two alternative options are considered:

- An external 2-storey Energy Centre
- An internal 2-storey Energy Centre

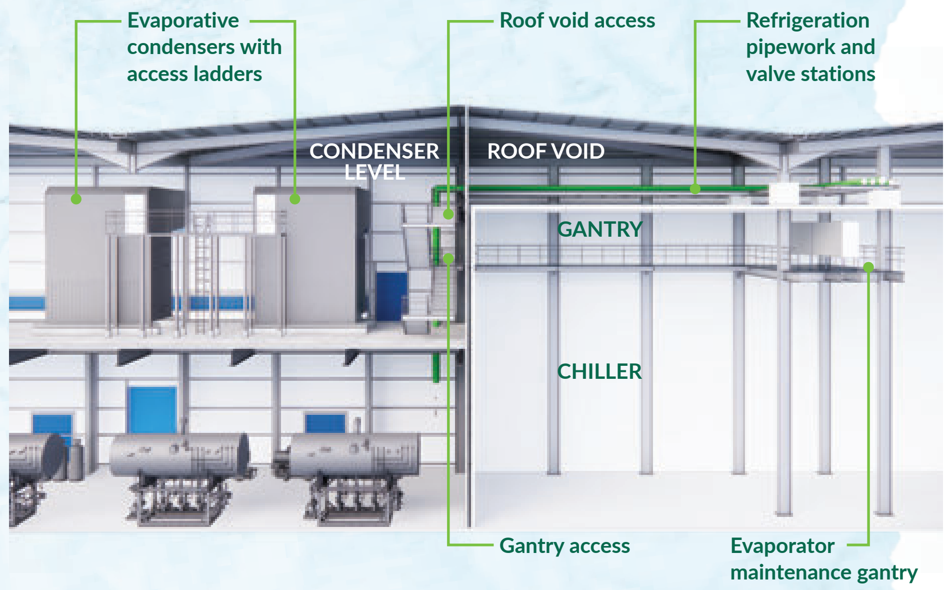
The Concept Layouts show indicative Energy Centre Layouts and sizes. The Concept assumes that a new transformer will be installed within the Energy Centre to service the Refrigeration Plant and all other associated requirements of the refrigerated warehouse (e.g., heater mats, lighting etc.).

The exact Energy Centre sizing will be dependent on the final refrigeration and condenser scheme selected, the transformer, HV and LV switchgear selections and the method of fire suppression.

External 2-storey Energy Centre



Internal 2-storey Energy Centre



The following considerations and features also apply to the Energy Centre:

- Noise constraints (from both the plantroom and the condensers); this may affect both the selection of plant and louvres/noise suppression equipment
- Transformer size; housed in the ground floor of the Energy Centre
- LV switchroom size (combined with Refrigeration Plant Switchgear)
- Fire suppressions systems (e.g., in switchgear room) and sprinklers (plantroom)
- Refrigeration plantroom ventilation system (discharging to highest point of warehouse to improve dispersion)
- Ammonia pressure relief pipework (discharging to highest point of warehouse to improve dispersion)
- Bunding to prevent leakage of ammonia from the plantroom
- Fire rating of separate sections to satisfy Insurance, Building Regulations, Landlord and End-User
- Structural considerations; refrigeration plant can be of a substantial weight. Once a refrigeration plant design has been determined, the principal equipment weights can be determined and an assessment made as to whether an internal plantroom solution is possible (given the constraints of the particular site), or whether an external plant solution is more practical
- Windsock – where ammonia refrigerant is used, windsock(s) should be installed on site to advise first responders of wind direction
- Location. Where ammonia refrigerant is used, the Energy Centre should be sited as far away as possible from offices and occupied areas
- The design should ensure that there is sufficient access for maintenance.
- Foul drains and utilities to suit the selected refrigeration plant
- Designed according to all CO_2 and Ammonia Codes, Guidance and Regulations

SECTION 37

Structural Considerations

The conversion of an ambient warehouse to refrigerated use will impose additional loads onto the existing structural frame. The Energy Centre (internal or external) will have its own specific structural requirements.

Where a fit-out is proposed, the existing structural frame will need to be assessed for suitability against the additional structural loadings imposed. In some cases, additional strengthening works may be required in order to accommodate the additional loads or to prevent excessive deflections.

The Concept Fit-Out incorporates a central evaporator gantry in order to support the additional loadings from the refrigeration plant. The principle is for the gantry to transfer these significant loads onto the floor slab, as opposed to onto the steel frame (the floor slab will require structural assessment to ensure suitability).

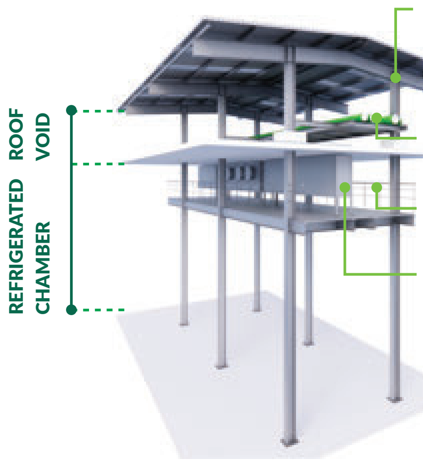
The following details the typical additional loadings that the Concept Fit-Outs will impose.

These are in addition to all statutory loadings, self-weight and existing equipment and building loads (please note that each actual site will require assessment on a case-by-case basis):

Evaporator Gantry:

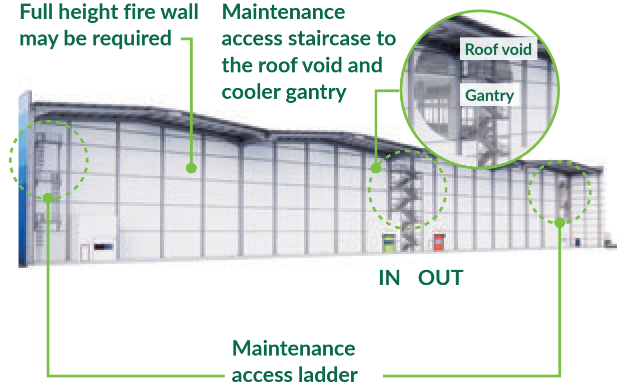
- Point loads representing the refrigeration evaporators supported from the evaporator gantry
- Linear loads representing the refrigeration pipework supported at high level (above the insulated ceiling) from the evaporator gantry

The Concept Drawings show typical equipment weights. These loadings must be assessed on a site and project specific basis, based on the actual installed equipment and design solution.



Warehouse Steel Frame:

- A suspended insulation ceiling system (IPN-cored composite panel) representing a universally distributed load of 0.2kN/m² supported from the main building portal frames
- A general services allowance (universally distributed load) of 0.25kN/m² representing lighting, cabling, refrigeration pipework and sprinklers. The services are to be supported from the overhead purlins or steel frame (dependant on their structural capability)
- A general access load onto the insulation panel ceilings (and transferred onto the main structural frame) to represent an occasional access load of 0.19kN/m²



These loadings must be assessed on a site and project specific basis, based on the actual installed equipment and design solution.

The structural steelwork will be supporting the insulation envelope and it is therefore essential that the building deflections are limited so as not to impose undue loads on the insulation panel systems and joints.

Whilst each case must be individually assessed according to the insulation envelope and equipment installed, the steelframe deflection should generally be no worse than the following criteria, when all loads (including statutory loads – e.g., wind, snow, etc.) are imposed:

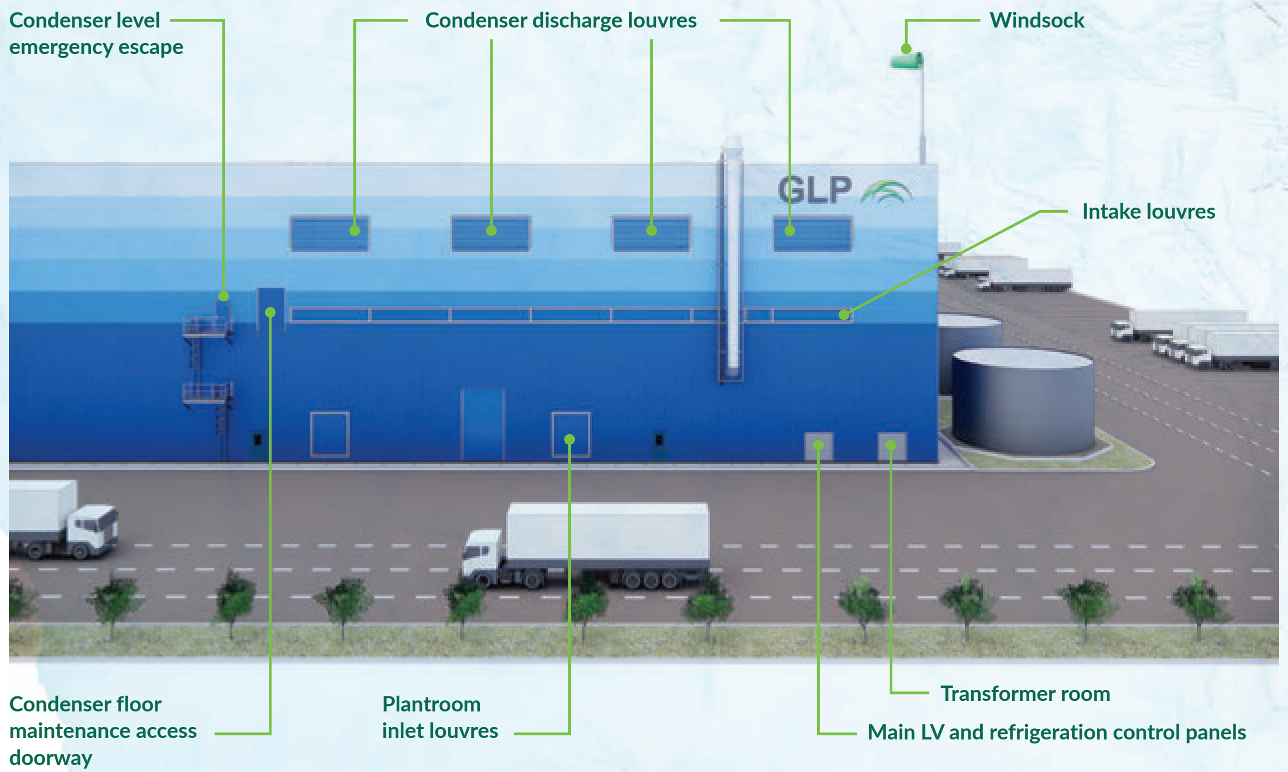
- Vertical deflection caused by live load for frame rafters shall be limited to H/180
- Deflection of portals at eaves H/150 total under wind load or imposed load or 80% combined wind and imposed load
- Deflection of cold rolled cladding rails L/200

Energy Centre:

- Point loads from refrigeration equipment including compressors, inertia bases, vessels, pumps, condensers, pipework, water treatment equipment, etc.
- Transformer and HV switchgear loads
- LV Switchgear

Where the external Energy Centre solution is selected, the new structures, foundations and flooring systems will need to be designed to accommodate these imposed loads.

Where the internal Energy Solution is selected, the existing warehouse flooring systems will need to be assessed against the final loads to determine suitability. Strengthening works may be required.



SECTION 38

Foul Drainage

Foul drainage is generally required in both the refrigeration plantroom and within the refrigerated chambers as follows:

1. Within the ground floor refrigeration plantroom (suitably bunded) to accommodate water treatment blowdown (e.g., softeners) and evaporative condenser drains (from above). Where ammonia refrigerant is used, extreme care is to be taken in the drainage design to take into account the highly toxic nature of ammonia and also the effects of a total ammonia spillage and/or in conjunction with a sprinkler activation.

2. On the 1st floor plantroom condenser deck (when evaporative condensers are installed) to accommodate blowdown.

3. LV switchroom – for air-conditioning condensate.

4. Within the refrigerated chambers (and external to the refrigerated chambers for sub-zero chambers) to take condensate waste from the gantry mounted evaporators. It is noted that refrigeration evaporators will be cleaned regularly and therefore their waste must be discharged to foul.

An assessment as to the feasibility of installing foul drains within and external to the warehouse is to be undertaken, to suit the refrigeration design. Where this is not considered feasible, it may be possible to pump the evaporator condensate to the building foul drain, using suitable pumping systems. In the case of the plantroom, the selection of air-cooled condensers will negate the requirement for foul drains.

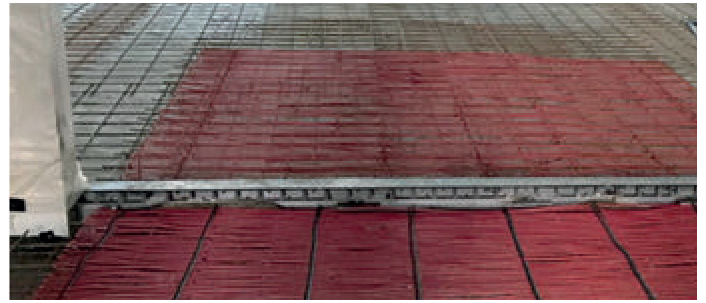
SECTION 39

Temperature Pull-Down

Refrigerated chambers should be slowly reduced in temperature in order to minimise thermal stresses within both the floor and the envelope fabric. Cracking within floor slabs and joint failures within the insulation envelope can occur, if the temperature is pulled down too quickly. Whilst some guidance is available within industry codes, a bespoke temperature pull-down schedule should be agreed by all of the specialist designers and contractors suited to the individual project.

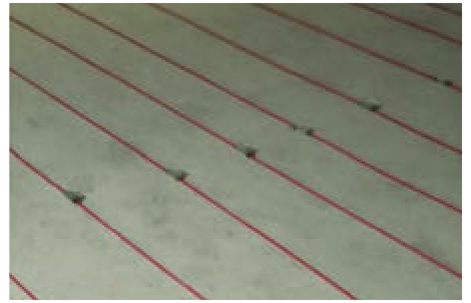
Generally, the slower the temperature pull-down, the lower the risk.

The introduction of temperature probes at top and bottom slab level can provide accurate indication as to the floor slab condition and provide guidance on the rate of temperature pull-down.



Typical freezer door threshold heater being installed

Typical glycol heater mat



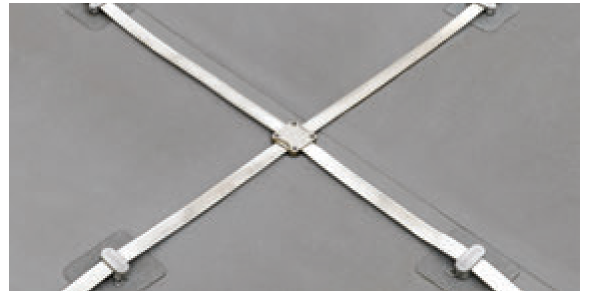
Typical electric heater mat

SECTION 40

Single Envelope Refrigerated Buildings

The Single Envelope form of construction is commonly used within Europe for warehousing. However, as a Single Envelope system incorporates exposed internal steelwork, this type of construction would typically not be acceptable for facilities where food is processed or packed. Where used, the Single Envelope construction system requires particular attention to detail to ensure a long-lasting and effective design. Key features of a well-designed Single Envelope building are:

- A structural frame (concrete or steel), suitably designed so that the external insulation envelope is not required to provide bracing or act as a stressed liner (skin)
- The use of bespoke insulation panels for both the walls and roof, designed specifically for refrigerated environments and incorporating a proprietary jointing system (e.g., Kingspan KS1100CS), with an external vapour seal
- Vertical spanning single length insulated wall panels – no joints
- Insulated roof panels to be designed as long as possible, to minimise joints
- Thicker insulated roof panels to compensate for the increased solar gain
- All fixings throughout the installation should be 316 grade stainless steel
- Both the wall and roof panel support system must be calculated to provide sufficient support to accommodate all statutory loads, internal support loads (e.g., sprinklers and services), as well as thermal stresses
- Roof panel supports should typically be provided at maximum 2.1m centres; this spacing also permits support for services (lights, sprinklers and other services), as well as ensuring minimum roof deflections
- Where refrigeration pipework and valves are run on the roof of the building, suitable supports must be installed below the insulation panels and the load suitable spread across the panels, to ensure that the insulation panels can sustain the loads over the long-term. Typically, the imposed load should not exceed 20% of the minimum panel design compressive strength
- The Single Envelope building should incorporate a two-pitched roof with external gutters, in order to provide a fully insulated and vapour sealed enclosure. No internal gutters or rainwater pipes are permitted
- The roof panels should be carefully vapour sealed and plated, prior to the application of a suitable single ply membrane system to provide a final weatherproofed finish. The single ply membrane must be adhered to the insulation panel system; mechanical fixings are not permitted. The membrane and adhesive selected must be fully compatible and tested with the proposed insulation roof panel to ensure long lasting adhesion. A minimum 25-year warranty for the membrane system including the rainwater disposal, lighting protection and man-safe systems is required
- The design should prevent penetrations through the insulation envelope. These cause thermal bridges and a weakness in the external envelope vapour seal
- Where lightning protection systems and/or man-safe edge protection systems are installed, these must use a suitable adhesion system to avoid penetrating the membrane



SECTION 41

Food Storage, Processing and Packing

In some instances, a refrigerated warehouse will also incorporate specific internal areas dedicated to either food processing or food packing/re-packing. Often, these facilities will be subject to more stringent local regulation, inspection and construction standards. This may include licensing of the facility for food handling. Where incorporated, the layout and construction of the facility may also require:

- Additional and separate amenities to service the food processing areas
- Increased lighting requirements
- Floor drainage with suitable finish
- Washdown facilities
- Smooth, white and fully sealed internal surfaces – walls and ceilings (including the insulation panel joints)
- Angled/sloped protection curbs

SECTION 42

Regulatory Considerations

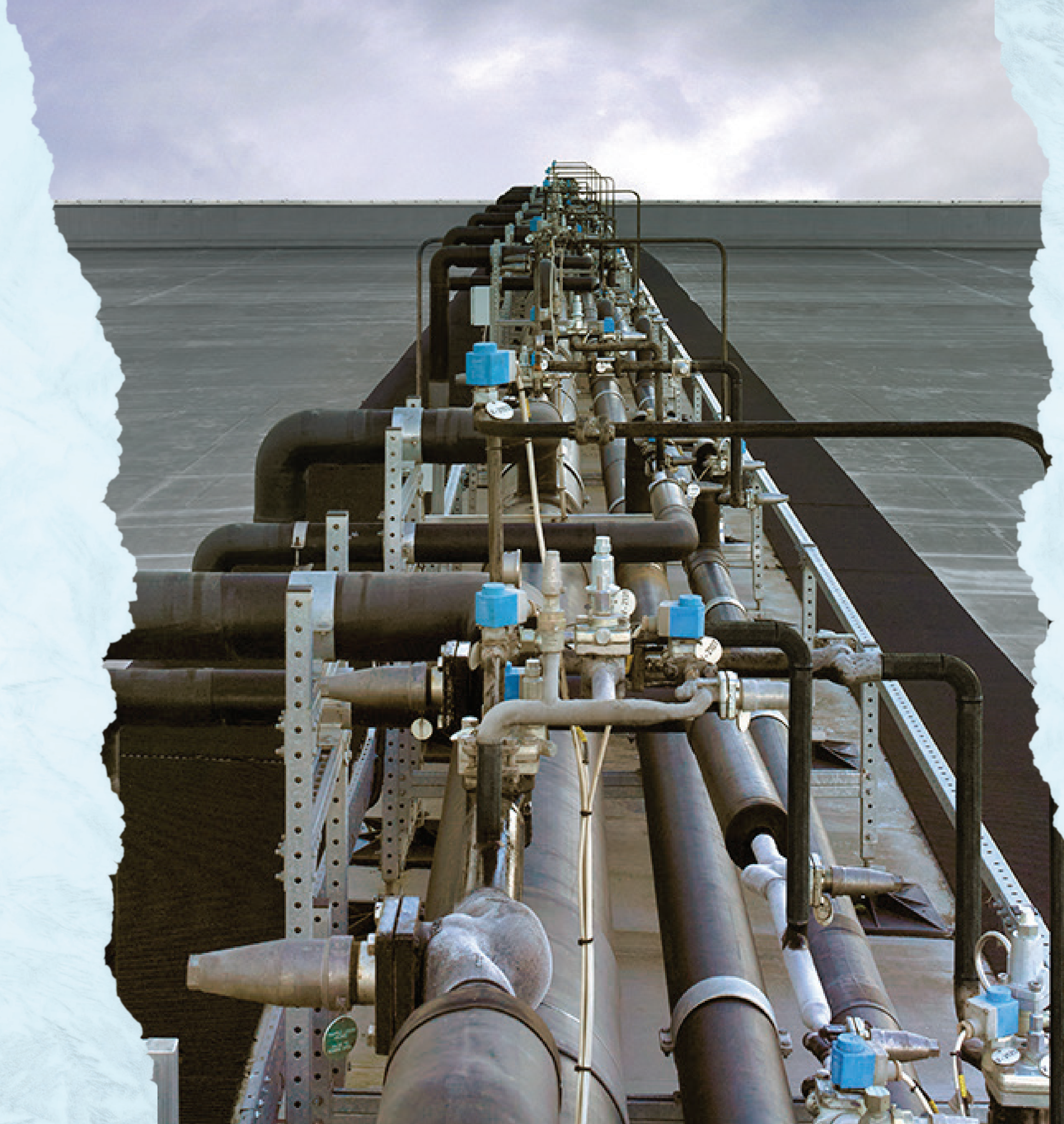
Where insulation envelopes and refrigeration plant are installed as part of a fit-out, this must be undertaken in full compliance with local Building Codes and Regulations (and issuing of formal approvals). A Refrigerated fit-out will change the warehouse layout, occupancy, escape distances, means of escape and risk categories, as well as introducing additional risk areas (for example roof voids and refrigeration plant).

Particular attention should also be given to the use of composite insulation panels within the fit-out and any internal fit-out will therefore need to be individually assessed for Building Codes and Regulations compliance, adapted to suit, and a full application made.

A building specific Fire Risk Assessment will also need to be undertaken and the overall building Fire Risk Assessment updated accordingly.

Within the 20k, 40k and 60k Concept Fit-Outs, the following items are noted:

- Due to the size and complexity of the Concept Fit-Outs, a Fire Engineered Solution should be considered; where permitted. The use of Fire Engineered Solutions, with minimal warehouse compartmentation is not an accepted solution in some Countries. Compartmentation of a warehouse can reduce logistical efficiency and therefore early liaison and discussion with the local authorities is recommended
- Additional external doorways may need to be formed in order to satisfy the requirements for means of escape
- The installation of the insulation envelope creates a roof void area, which will require means of both access and egress for maintenance workers, via either stairways or cat-ladders. The concept layout shows cat ladders installed at the central (highest) point of each portal frame both within the building and external to it. The internal height of the insulation envelope has been lowered to permit the installation of a full height central maintenance walkway within each building portal (the gable roof ends are pitched). Due to the travel distances being significant, additional means of escape from the roof void will be necessary
- The Concept refrigeration gantry includes access and egress at either end. Additional access/egress points may also be required along its length in order to comply with local requirements
- Dependent on the final fire solution adopted, the height of the insulation envelope may need to be further lowered in order to enable egress at the eaves.
- The roof void may require smoke/fire curtains to be installed in order to provide compartmentalisation
- Roof voids will require bespoke and unencumbered maintenance and access/egress walkways, as agreed with Building Control. Services will need to be reticulated to ensure full unencumbered access. This will include 'looping' of sprinkler and other services. A fully integrated services design is therefore essential
- Stairwell access to the roof void and gantry will provide improved maintenance access and is the preferred solution over cat-ladders
- The facility should be assessed at the design stage in conjunction with the refrigerant risk assessments and proposed design (for ammonia and CO_2 refrigerants) and the design should be adapted accordingly



SECTION 43

Energy Reduction Considerations

The refrigeration plant represents the largest single energy user within a refrigerated warehouse and any energy reduction strategies should therefore be focused on the refrigeration plant.

The following details a list of energy initiatives that should be considered when designing a refrigeration plant (subject to detailed assessment):

- The use of ammonia refrigerant (ODP and GWP of zero) and CO_2 refrigerants (ODP if zero and GWP of one)
- Specification and selection of efficient refrigeration system, components and control; the selection of efficient refrigerants alone does not guarantee an efficient plant or plant operation
- The use of hybrid condensers; minimising water and water treatment usage and optimising winter performance
- The use of low energy over-sized condensers
- Chemical-free water treatment systems where evaporative condensers are used
- Glycol underfloor heating, using refrigeration plant waste heat (in lieu of electric heater mat)
- Warm glycol evaporator defrost (using recovered waste heat from the refrigeration plant)
- Pre-insulated refrigeration pipework; minimising heat loss and preventing degradation of the vapour seal
- High efficiency evaporators (high surface area) with EC Fans. Discharge socks and suction dampers to be used within freezer chambers
- Combined Heat and Power (CHP) plant generating electricity for the site and whose heat is used in conjunction with an absorption plant to supplement the refrigeration plant
- Dehumidified air curtains between refrigerated chambers; preventing air and moisture ingress
- High quality rapid action doors to refrigerated chambers
- Thermal storage systems; installing eutectics in order to store refrigerated energy during cooler night periods.
- Enhanced insulation envelope thickness

Each initiative should be individually assessed to determine its associated return on investment and carbon saving.

GLP UK - Typical refrigeration sustainability considerations

- Zero ODP and GWP 1 Refrigerants
- Efficient refrigeration plant
- Hybrid condensers
- Glycol underfloor heating
- Chemical-free water treatment
- Pre-insulated pipework
- High efficiency evaporators with EC fans and defrost dampers
- CHP and absorption plant
- Dehumidified air curtains
- Rapid action doors
- Thermal storage systems
- Enhanced insulation thickness

SECTION 44

Glossary of Terms

Absorption Plant – a refrigeration plant that uses a heat source to provide cooling.

Air Curtain – a forced fan system located above a door, creates a fast moving air stream to separate two different temperature zones.

Air Permeability – the resistance of a building/structure to air infiltration.

Airlock – a small room between different temperature zones that creates a buffer, thereby reducing air infiltration and heat loss.

Ammonia – also known as NH_3. Highly efficient refrigerant with 0 OPD and 0 GWP, but toxic.

Aspirator Smoke Detector (ASD) – a system used in active fire protection which draws air through a network of pipes to detect smoke.

Blast Freezing – a rapid freezing system to bring down the temperature of foodstuffs or fresh produce, freezing them very quickly.

Box-in-Box – refers to a refrigerated storage system where an insulated enclosure is installed within an ambient building.

Carbon Dioxide – also known as CO_2. Highly efficient refrigerant with 0 OPD and 1 GWP, but ashphxiates.

Chill Chamber – a refrigerated chamber operating at a temperature >0°C.

Clad Rack – a construction system where the racking forms the structure of the building.

Condensation – the change from water vapour into liquid water.

Condenser – a device used to condense refrigerant into a liquid state, releasing heat into the surrounding environment.

CHP – Combined Heat and Power. A highly efficient process that captures and utilises the heat that is the by-product of electricity generation.

Composite Insulation Panel – an insulation core sandwiched by steel skins forming a strong and thermally efficient building product.

Deep Chill – storage at a temperature of between freezing and -12°C. Often used to extend the lifespan of meat products.

Defrost – a process to free a refrigeration evaporator of accumulated ice.

Dehumidification – removal of moisture from the air.

Dock Leveller – a variable height hinged platform forming a bridge between a warehouse and a docked vehicle.

Dock Shelter – a system installed around an external door opening designed to seal around a docked vehicle, thereby preventing air ingress.

EC Fan – a fan using a high efficiency DC motor .

Energy Centre – a plantroom housing a building's main services and utilities, including refrigeration plant and transformers.

Evaporator – a finned coil with fans that forms part of a refrigeration system and removes heat from a refrigerated chamber.

Fire Risk Assessment – a formal assessment of how a building is protected against fire.

Fit-Out – the conversion of an existing premises into a different function; for example converting an ambient warehouse into refrigerated use.

Frozen Storage – refers to sub-zero refrigerated chambers. Usually <-18°C.

Glycol – a type of anti-freeze with a low freezing point.

GWP – Global Warming Potential is the heat absorbed by any greenhouse gas in the atmosphere as a multiple of the heat that would be absorbed by the same mass of carbon-dioxide.

HV – High Voltage.

Hybrid Condenser – a condenser that is designed for both dry and wet operation.

Humidity – is the concentration of water vapour present in the air.

Insulation envelope – the extent of the specialist insulation envelope forming a refrigerated chamber.

IPN – an insulated core material developed by Kingspan plc with enhanced fire resistance properties.

Long-term storage – storage of refrigerated products for a period of time longer than approximately 4 weeks.

LV – Low Voltage

Means of Escape – the methods used to facilitate escape from a building.

MHE – Mechanical Handling Equipment for example forklift trucks.

ODP – Ozone Depletion Potential of a chemical is the relative amount of degradation to the ozone layer that it can cause.

Picking – a warehouse process where articles are collected in a specified quantity against a customer's order.

PIR – Polyisocyanurate. A form of polyurethane that is often used as an insulation core material in composite panels.

Pressure Relief Valve – a valve that is installed within an insulated envelope to relieve differential pressures that form due to the internal refrigeration plant.

Rapid Action Door – a door that opens and closes quickly (thereby reducing energy loss from a refrigerated chamber).

Refrigeration – cooling of a space by removing heat and rejecting it elsewhere at a higher temperature.

Roof Void – the area formed above a refrigerated chamber in a 'box-in-box' design.

Short-term storage – storage of refrigerated products for a period of time less than approximately 1 week.

Single Envelope Coldstore – a refrigerated building where the specialist insulation also forms the external surface of the building.

Sub-Zero – temperatures below 0°C

Tempering – to increase the heat of a product. Usually warming a frozen product to just below or just above its freezing point.

Thermal Bridge – an area which has a higher thermal conductivity than the surrounding materials, creating a path of least resistance for heat transfer.

Thermal Storage – storing thermal energy so that it can be used at a later time. Typically eutectic plates.

Underfloor Heating System – a system to introduce heat under a coldstore floor to prevent freezing of the ground below the coldstore.

Valve Station – part of the refrigeration piping system that controls the flow of refrigerant to the evaporators.

Vapour Barrier – a product used to seal insulation envelopes to prevent water vapour transfer

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