Bord Iascaigh Mhara

Refrigeration Systems Management and Maintenance Guide for Seafood Processors

BIM Ireland's Seafood Development Agency

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Background

Bord Iascaigh Mhara (BIM) is the Irish State Agency responsible for supporting the development of the Irish seafood industry. BIM's mission is to support and enable an increase in value creation of a sustainable Irish seafood sector across the supply chain, from catch to consumer. We support the development of the Irish seafood industry by providing technical expertise, business support, funding, training and by promoting responsible environmental practices.

BIM sees an opportunity for the Irish seafood industry to enhance its sustainability credentials. Our Green Seafood Business Programme, launched in 2012, aims to assist Irish seafood processors to reduce their environmental impacts and their operational costs. Our objective is to deliver resource efficiency improvements across all aspects of processing operations.

Refrigeration is one of the most significant energy users for seafood processors. It is estimated to account for as much as 80% of all electricity costs. While these systems are complex to understand and manage, there are many opportunities to improve the efficiency of refrigeration systems. The aim of this guide is to provide a comprehensive overview of the range of best practice guidelines and available technologies to help you to reduce your energy consumption and ensure your refrigeration systems are operating optimally.

We hope you find this guide informative and that it helps to improve the overall sustainability of your business.

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Section 1
Guide Introduction

Refrigeration systems are one of the most significant energy consumers across all food production industries. These systems are an essential component of the seafood processing industry - storing, preserving, and maintaining the safety and quality of seafood products.

As the impacts of climate change unfold, Ireland is stepping up to the challenge of reducing our Green House Gas emissions by 50% within this decade. To play our part in becoming more sustainable there is a need to evaluate our energy use and management on site. The aim of this guide is to help reduce the energy consumed by the key components of refrigeration systems, while maintaining optimal performance, reliability, and the highest product quality standards.

The planning and design of refrigeration systems can have a significant impact on the system's energy consumption. Large savings can be made through the careful design and layout of these rooms. Additional savings can be made with strategic piping system design, alongside careful component selection and assembly.

Many seafood processors will be dealing with their existing refrigeration systems, some of which will have been in place for many years. This guide has been designed with them in mind. A range of measures can be considered to reduce energy consumption and ensure the reliability of existing refrigeration systems. These measures include proper control systems, efficient plant room operation and correct maintenance of various components.

What is the scope of this guide?

This guide covers the optimal operation and maintenance aspects of commercial refrigeration systems. The aim of the guide is to reduce energy consumption and optimise the performance and reliability of refrigeration systems. This guide does not cover the system design or any specific equipment installation.

Who is this guide for?

This guide has been written for the Irish seafood processing sector. In particular the owners or facilities managers of processing companies who have refrigeration systems operating on their site.

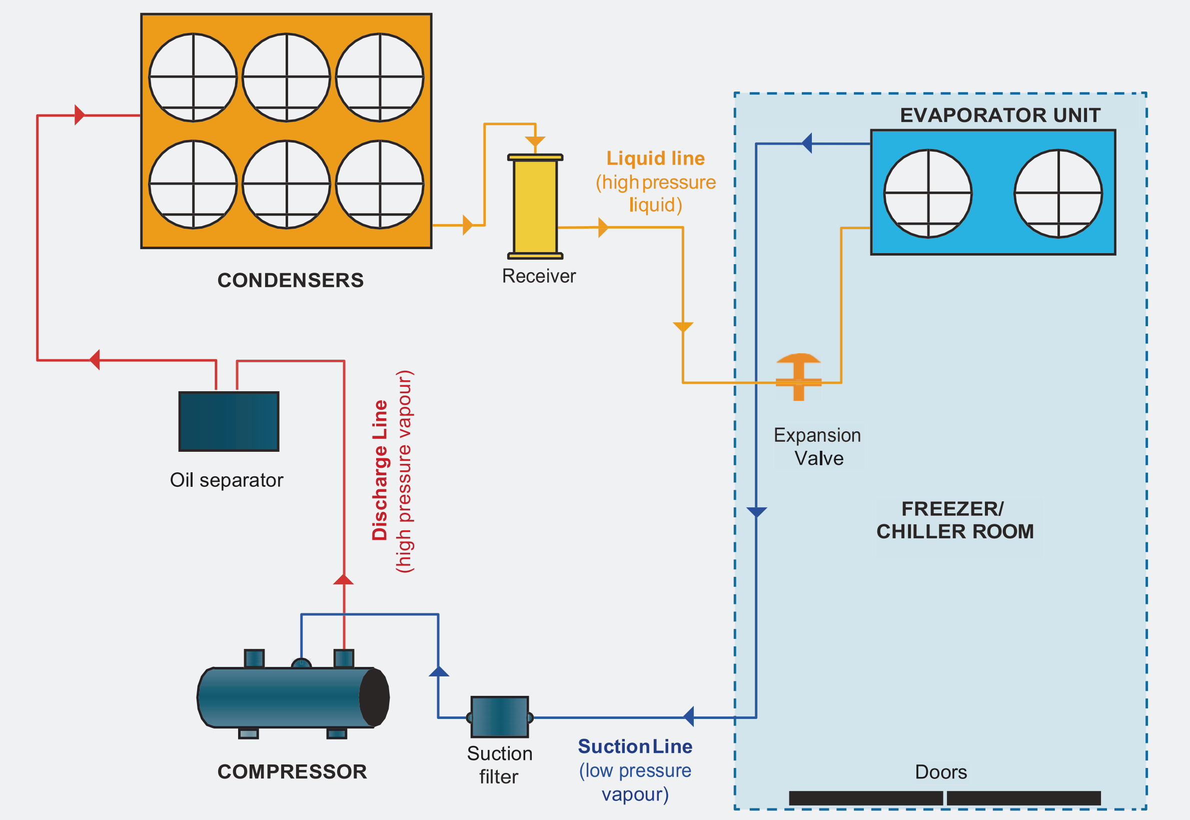


Figure 1: Schematic showing the main components of refrigeration systems.

How to use this guide?

In seafood processing, refrigeration systems are used across several different operations. The components of these systems are often situated in different areas of a site. While all these components work together to provide cooling, they each have their own set of requirements in terms of operation, management, and maintenance. Consequently, this guide is divided into six sections (see Table 1), which corresponds to each of the different components of refrigeration systems often used in seafood processing operations.

This guide follows the general structure of an on-site assessment carried out by an auditor or consultant. The guide should be read in sequence; however, each section can be read separately. The guide first outlines best practice for the highest energy consuming refrigerated systems (i.e., freezers) and concludes with checklists outlining the vital maintenance tasks that should be carried out within all businesses at a range of different time intervals.

Table 1: Breakdown of the guide

Section 1	Guide introduction
Section 2	Freezer and blast freezer areas
Section 3	Production areas and ice machines
Section 4	Plant room and piping system
Section 5	Preventative Maintenance Checklists

Section 2
Energy Efficiency Guidelines for Freezer and Blast Freezer Areas

Part 1

Freezing and Chilling Processes

Freezing and chilling are among the most energy-intensive processes for the seafood processing sector. These processes include freezers, air-blast freezers, chillers, and production areas, where specific low temperatures are required for food safety and quality purposes.

Chill rooms are used to cool products after production and operate at temperatures between 0°C to +2°C.

Air-blast freezers drive cold air at high velocity across seafood products, freezing products rapidly to maintain quality. These freezers operate at temperatures between -24°C and -28°C.

Freezer storage rooms store products at temperatures as low as -18 °C to -22 °C until they are ready to be shipped to the market. While freezers and chillers operate at different temperatures, the principles for ensuring that they are operating as efficiently as possible are effectively the same.

There are two mains aspects that affect energy consumption in these areas:

(i) The thermal envelope of the room

(ii) The operation of the system's components

The guidelines for managing and maintaining the thermal envelope of any temperature controlled freezing or chilling space follow the same key steps. However, the management and operation of the equipment and systems for these areas differ slightly (particularly for air blast freezing processes). In the following sections, details on maintaining the thermal envelope for all temperature-controlled spaces is outlined first. The operational factors for the freezer/chiller system and the air blast freezer systems are then discussed separately.

Part 2

Thermal Envelope

The best way to reduce energy consumption in any refrigeration system is through reducing the work that the system needs to do. In the case of refrigeration systems, 'the load' is the thermal energy, or heat, that needs to be removed from the product to reach the desired temperature.

Thermal energy (heat) will always flow from an area of high temperature to an area of low temperature. The temperature in freezer and chill rooms is relatively low in comparison to the external or 'ambient' air temperature. Therefore, if there are any gaps or openings in these rooms, warm moist air will enter and the freezer or chiller system will have to work harder to remove this 'heat load' and return to the system's setpoint temperature (i.e., the required cooling temperature).

Therefore, the thermal envelope of any temperature-controlled space, which includes all the elements of the room's exterior shell, should be airtight to reduce the flow of warm air into these chiller or freezer spaces.

The thermal envelope includes doors, ceilings, walls, anterooms and any vents or outlets made in the room's walls for pipes or electrical cables.

1. Doors

Freezer and chill room doors are among the most critical areas in any cold space and should be checked regularly. They are the main access point to the freezer or cold storage areas and, as a result, play an essential role in maintaining their thermal envelope. Malfunctioning or damaged doors can have a significant impact on energy consumption and costs.

Door seals

Door seals should be checked weekly. Faulty door seals can increase energy consumption by up to 10%. Door seals will generally wear over time and should be changed regularly (i.e., every 5 years depending on usage and the level of damage).

Using an infrared camera can help to determine if there are issues with seals or insulation (i.e. warm air entering or cold air escaping).

Ice

Ice forming on either side of a door indicates a door seal or closing issue. If the door seals are not working properly, there will be a constant flow of warm humid air into the room. This will lead to an increase in the running costs due to the added heat load and the requirements for additional defrosting of the cooling units.

> **TIP!** A quick way to check if there is an issue with a door seal is to enter the room and close the door (make sure there is a handle on the inside so you can get back out!). Once inside, turn off the lights - if you can see light coming through around the door seal, then either the door or its seal is faulty or damaged and this should be addressed immediately.

Wear and tear

Freezers and cold rooms are central to seafood processing operations. Consequently, access doors to these rooms are subjected to intensive use and are prone to damage through everyday wear and tear.

Protecting door openings from damage by passing pallet trucks, trollies, boxes, or forklifts can be achieved by fitting a metal sheet or barrier around the corners of door openings. This is an important intervention to protect the doors from damage, especially in high traffic areas.

> **TIP!** To check the functioning of the door mechanism, push the door while it is closed. If there is a noticeable shift in the door, this may be an indication of a fault in the door's mechanism. Where this occurs, the door's sliding rail, and the door guide should be checked. Faults in either can be adjusted or easily replaced.

An example of good protection for cold room door openings.

Ice build-up indicates issues with ceiling insulation or door seals.'

Humidity

Adding PVC strips at the entrance to different areas will reduce the amount of cold air escaping and humid air entering temperature-controlled areas during loading times.

Always check

Periodically check that all the door heaters are working correctly. Door heaters warm the area surrounding the door frame and prevent surfaces from sticking to each other. This will ensure that the door will open, close and seal correctly, as well as reduce ice build-up. These heaters will also make sure that the seals last for longer (less tear on rubber seals).

> **TIP!** If there is ice build-up around the door, you can simply clean it off. This should reduce the gap around the door and reduce humid high-temperature air from entering the freezer room. However, this is a short-term measure and ice will likely build up again quickly.

2. Room Integrity

The integrity of the thermal envelope of freezer and chill rooms is a critical aspect of any energy-efficient refrigeration system. Due consideration should be given to the insulation of freezer and chill rooms. While the integrity of the thermal envelope of these rooms should be evaluated at the design and build stage, improvements can be made retrospectively.

Good wall and roof insulation

Insufficient or poorly performing insulation in walls and roofs will lead to condensation and even frost formation due to moisture accumulation. This will lead to an increase in energy consumption as the system works to remove heat from these rooms. Freezer walls should be checked every three months for any leaks or loose insulation.

Cool down the lights

Minimising heat sources in freezers and cold rooms will improve efficiency. Improved lighting, (especially the use of LEDs over fluorescent bulbs) and using electrical forklifts (instead of petrol or diesel-powered engines) are two areas to consider. It is estimated that 5% of the refrigeration load in freezer/chill rooms is caused by the heat given off by traditional lighting systems.

Use LED lighting to lower the refrigeration cooling load.

3. Refrigeration Pipes and Electrical Cables

In addition to doors, there are other permanent openings in thermal envelopes to allow pipes and wires in and out of the cooling space. Good management and insulation of pipes and cables is often overlooked but should be part of any annual check.

Pipe and Cable Insulation

Refrigeration pipes and electrical cables that route through the thermal envelope of the room should be suitably insulated and sealed to maintain the thermal and vapour integrity of the room.

Drainpipes

The evaporator condensate drainpipes should be fitted with an externally located trap to prevent air from entering the room. The drainpipes should also be sealed well to prevent air from entering the room.

Good example of evaporator condensate stainless steel pipework with seal trap.

4. Antechamber/Dehumidifier

The use of an enclosed antechamber, known as a 'lobby', outside freezer rooms can have a significant impact in terms of the overall energy efficiency of the refrigeration system. The benefits of these include:

(i) They act as a large airlock between moisture-rich air outside the room and the low-temperature dry air in the freezer room.

(ii) By reducing the amount of warm air entering the room the antechamber will help to reduce the heat load. This will also reduce the frequency of defrosting cycles required for the evaporator units within the room.

(iii) By introducing a dehumidification system to the chamber, you can reduce the moisture ingress into the room by approximately 60%.

Part 3

Freezer and Chill Room Operation

Achieving and maintaining the optimum operational efficiency of refrigeration systems is key to reducing energy usage. Best practice and optimisation tips for the operational components of freezer and chill rooms are highlighted in this section of the guide.

1. Evaporator/Air Cooler Unit

Evaporator units (also known as cooler, coil and blower) are normally mounted on the ceiling of the freezer and chill rooms. The placement and maintenance of these units can have a significant impact on their operation.

Locating the evaporator should ensure that airflow is uninhibited by stored products or other equipment.

The following aspects should be considered when assessing the energy efficiency of evaporators:

Unit selection and heat balance

Evaporators are selected based on the room's heat load. The heat load is calculated based on the total amount of heat that enters the room through a range of different sources (e.g., via insulated walls, ceilings, lights, product load, people, forklifts etc.). If the evaporator is too small, the system will have to work harder, and for longer, to achieve the required temperature.

An example of a well maintained evaporator unit, free from ice or debris build-up.

As ice builds up on the evaporator, it will also need to run a defrost cycle more often – all of which will increase energy consumption. On the other hand, installing oversized evaporators will lead to greater and unnecessary energy consumption. Therefore, ensuring that evaporators are appropriately sized for the requirements and heat load of the room will reduce daily energy consumption and costs.

TIP! The evaporator should be located appropriately to maximise the airflow throughout the room. This helps to provide a uniform temperature throughout freezer and chill rooms.

Runtime and energy consumption

It is estimated that 15% of the heat load in freezer and cold rooms is caused by the operation of the evaporator itself (i.e., the heat emitted by the running of the fan's motor and the electric defrost heat). Reducing the runtime of both components will reduce energy costs.

Coil air circulation

It is important that there is sufficient space between the back of ceiling mounted evaporators (the coils) and the wall – approximately 1 meter is recommended. This helps to maintain good air circulation through the evaporator coils.

Ice beginning to build up on the evaporator coils, blocking air flow.

TIP! Make sure that the product is not stored directly in front of the evaporator fans. This is a common occurrence and will result in reduced air circulation and increased energy consumption.

Coil maintenance

Evaporator coils should be defrosted regularly to remove ice build-up. They should also be deep cleaned on a regular basis. Dirty or blocked coils are not efficient. When cleaning the coils, an environmentally friendly detergent should be used to help break down the build-up of dust and dirt on the coil surfaces. Deep cleaning of evaporator coils should be carried out at least once a year.

Always check

Check the 'air-on' and 'air-off' temperatures on each evaporator on a regular basis to determine if the evaporator is underperforming. This can be carried out using the room's digital control system or simply using a hand-held temperature probe on either side of the coil. If there is no difference between these temperature readings, there may be a problem within the coil during normal operation. This would normally indicate an air blockage or fan failure.

Ice build-up

In general, an excessive build-up of ice within the evaporator coil or its surroundings can indicate that something is not operating correctly. For example, excessive ice build-up on the evaporator fins might indicate a long period of time occurring between defrost cycles or incomplete defrosts. Ice build-up on the suction pipes might indicate a low refrigerant charge in the system. Both situations would require attention and correction.

An example of poor maintenance of the evaporator coil: ice builds up on the evaporator coil, which reduces air circulation. In this case, check the expansion valve and the defrost set up.

Thermostat set points

Make sure that the thermostat 'set points' are selected and set correctly according to requirements – they are almost always set too low. The best way to determine the optimal temperature is by using a temperature product probe to directly measure the core temperature of stored products. Details on how to use the temperature probe are on the next page (page 12).

Intelligent defrost system

When the refrigerant temperature within the evaporator is lower than -1°C, a frost line may occur on the fins and pipes. This is a common occurrence under normal system operation. This will vary depending on airflow and heat load variables. However, if the frost line increases in size, heat transfer through the fins and pipes will become progressively less efficient. This results in a reduction in the heat exchange capacity. Consequently, the evaporator will have to work harder and for longer. This will ultimately increase energy consumption and costs. Installing an intelligent defrost system will help to reduce energy consumption. These smart systems can detect when a defrost is required and operate on that basis rather than just responding to pre-determined time schedules. Examples such as 'defrosting on demand' or defrost optimisation should be investigated.

> **TIP!** A 2% reduction in energy consumption may be achieved for every 1°C increase in the temperature setting. However, an increase in set point must be determined by the product's temperature requirement.

2. Defrost Process in the Evaporator Unit

Evaporators in freezer and chill rooms or blast freezers must have a means of defrosting. There are three standard methods of defrosting:

(i) Off-Cycle Defrost Chill rooms: this involves turning off the refrigeration system and allowing the chill room temperature to increase (above +2°C) and melt the frost or ice build-up on the evaporator. This can be assisted by letting the evaporator fans operate for a time to accelerate the melting process.

(ii) Electric Defrost: this involves the use of bar heaters that pass through the evaporator coil and add heat to the evaporator during the defrost cycle. This also melts the frost or ice build-up in the evaporator.

(iii) Hot/cool gas defrost: this system uses discharge gas from the compressor. The discharge gas passes through the same tubes as that the liquid refrigerant moves through during the chilling or freezing cycle. As this gas condenses into liquid refrigerant during the defrosting cycle it gives up its heat to melt any frost or ice that has built-up in the evaporator coil.

A good example of a clean evaporator coil indicating good maintenance and an accurate defrost setting.

TIP! The removal of the melted frost or ice (i.e., condensate water) via a drainage system is an important aspect of the defrosting process. Drainage pipes allow condensate water, collected from the evaporator, to be channelled to a drainage upstand outside the room. These pipes can be copper or stainless steel. Following best practice drainage pipes should incorporate a good fall away from the evaporator and a 'P-Trap' to maintain the vapour seal integrity of the room. This also prevents odours from entering the room.

3. Temperature Control

Controlling room temperatures is typically achieved by monitoring the air temperature at several different points in the freezer or chill space. Freezer and cold store temperatures are often set lower than required (e.g. -22°C and -28°C) to ensure that the temperature of the product does not rise above -18°C. (in line with food safety temperature requirements). Installing temperature control systems that are linked directly to the product temperature in freezer or chill rooms is a much more cost-effective way of achieving the required room temperatures.

Temperature probes

Room temperature is commonly controlled by using air temperature probes located in the room generally or on the 'air-on' and 'air-off' airflows of the evaporator.

An example of temperature control system wiring to the freezer room. Installing temperature control systems that are linked to product temperature is a cost-effective way of controlling freezer/chill room temperature.

Product probe

A dedicated product probe can also be used to control room temperature. However, these may need to be changed on a regular basis depending on stock turnover and possible damage to the probe. A dedicated 'sacrificial' product sample can also be used to monitor and control room temperature.

Material pack probes

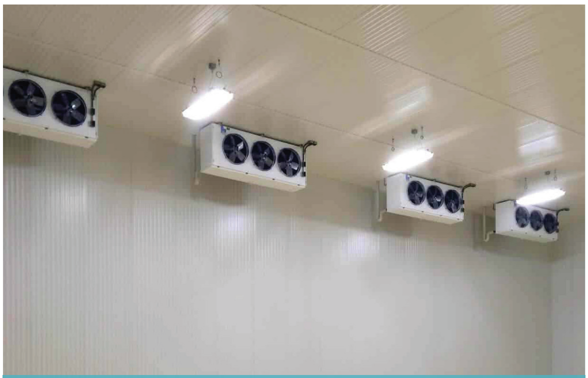
An alternative to the dedicated product probe is to use dedicated 'material packs' located within the room. These 'packs' or 'blocks' contain a gel and simulate the actual product. These packs can be used continuously as the temperature probe is located within the gel pack.

Programmable controls

Another control option is to use programmable digital controls and sensors which monitor the temperature and pressure within the freezer room for efficient refrigeration system cycling and to ensure that required conditions are maintained.

4. Underfloor Heating

Believe it or not, the floor in a freezer room should be heated. Low-grade heat is needed to protect the floor from 'frost-heave'. Depending on the soil and water table characteristics beneath a freezer room, the water may freeze and expand upwards. This can cause the freezer room floor above the water table to crack and lift (i.e., 'heave'). Insulation and integrated purpose-built underfloor heaters protect the floor and prevent it from freezing.



An example of an underfloor heating system in a commercial freezer room.

Types of underfloor heating

Underfloor heating is the most popular method used to prevent the freezer room floor from frost heaving and cracking. The most common types of underfloor heating include:

(i) Electrical underfloor heating: this involves laying an electric heating wire mesh within or under the concrete/insulation layer of the floor.

(ii) Forced or natural ventilation: this involves laying plastic pipes (air tubes) within the layer of concrete/under the insulation layer. Heat is then supplied to the tubes by forced or natural ventilation.

(iii) Pumped fluid-glycol: this involves pumping glycol through a tubing system that has been heated from a waste heat source (e.g., refrigeration). This is probably the most cost-effective floor heating method.

How to check underfloor heating

Installing a temperature sensor with an alarm is the best way to detect any fault in the underfloor heating. The sensor can be programmed to send an alert if the soil temperature falls below 0°C. Periodic inspection (every 2 months) should also be part of the refrigeration maintenance programme.

TIP! There are many signs that can indicate a faulty underfloor heating system. These include cracks in the floor, tilted or mis-aligned racking, uneven floor grade, or the forklift experiencing difficulty moving over certain parts of the freezer floor.

5. Pressure Relief Valve Maintenance

The pressure relief valve is a fundamental component of freezer rooms. It has two main functions: (i) ensuring pressure equalisation between the freezer room and the area outside the room (ii) helping to maintain the room's temperature.

Maintenance

Maintaining a pressure relief valve is relatively easy. The most important thing is to keep the valve clear with no obstructions that would impact the airflow to the valve.

Always check

These valves can get blocked and stop working overtime through the accumulation of dust or ice. The valves should be checked (every 2 months) as part of a refrigeration maintenance programme.

Ice build-up on the pressure relief valve limits the airflow to the valve.

6. Lighting System

An often-overlooked issue for freezers (and to a lesser extent, chillers) is the lighting system. If you are using older fittings (e.g., metal halides), the heat from these can add an extra load on to your refrigeration system. Some of these lights, are switched on continuously because it takes a long time for them to heat up. These can run at 90 °C – this is like running a kettle in your freezer! LED lights, which work more efficiently at lower temperatures, give off less heat. Because they come straight on (i.e., no warm-up time), they can also be controlled more effectively.

TIP! Installing a control system for lights, such as motion sensors, ensures that the lighting systems are switched off when they are not in use.

Part 4

Air-Blast Freezer Operation

Air-blast freezing works by pushing very cold air across products at high velocities. This process freezes the product rapidly in order to maintain the quality of the product. There are two main techniques used in the blast freezing process (i) single load and (ii) continuous load blast freezing.

'Single load' blast freezing is the most commonly used blast freezing technique by the Irish seafood processing sector. In this guide, we will focus on this blast freezing technique.

In continuous blast freezers, such as tunnel freezers, the product freezes as it moves on a freezer belt through a freezing chamber. Refrigerated cold air or liquid nitrogen can be used as a freezing medium to freeze the product.

Room design, system operation and freezing time are key components in operating air blast freezers efficiently. Best practice guidance for the efficient operation of air blast freezers is outlined in this section.

1. Room Design

The interior design of a blast freezer room is essential to developing an energy efficient and optimally functioning freezer system. Through proper airflow design, the air can be directed through the product at the optimal velocity for cooling and freezing. Some of the key aspects to consider are:

Air flow and energy consumption

Studies have demonstrated that by using the appropriate room and airflow design for air blast freezer rooms, energy savings of up to 15% can be achieved on fan motor selection alone.

Air flow design

To achieve optimal airflow design in the room, a range of different design features should be considered. These include the use of roof and kerb baffles, turning vanes, block panels, traplines (to reduce air short circuiting) and product 'spacers' on the pallets (to maximise exposure of the product's total surface area to the cold air).

Product spacing in air blast freezers is crucial to ensuring optimal air flow through products and optimising freezing time.

TIP! Increasing the airflow, through increased fan speed, does not necessarily increase the airspeed through the blast freezer room. The air speed is determined by the airflow circulation and this is directly related to the interior design of the room.

2. System Operation

Air blast freezers operate by pushing cold air at a high velocity over product for a prescribed period of time. The operation of the blast room components has a fundamental impact on the systems energy consumption. Key aspects of the operation of air blast freezers are outlined in this section.

> **TIP!** Fans and air temperature are critical components of the operation of the blast freezer. Product freezing time is determined by the temperature and volume of air passing through the evaporator coil and over the product. The lower the temperature and the greater the volume of air, the shorter the freezing time will be.

Unit size and number

Selecting and installing the right size and number of evaporators is an important consideration for the design and operation of air blast freezers. Installing evaporators that fill the entire cross-sectional area of the room will ensure, uniform airflow through the room and over products.

Product packing

Often, seafood products are frozen in their transport packaging. The packaging process is a crucial stage in blast freezing operations as packaging helps to maintain the quality of the product. Packaging prevents the product from dehydrating in the blast freezer. However, it will also decrease the heat transfer properties of the product and thus increase the freezing time. This is due to the insulative characteristics of packaging materials and the presence of air within the packaging. Where cardboard packaging is used for products, it is advised that a single layer of cardboard is used. This helps to increase the heat transfer capacity through the packaging and reduces the freezing time of products.

Evaporator operation

Further details can be found on pages 9 - 10 of this guide.

Defrost process of the evaporator unit

Further details can be found on pages 11 - 12 of this guide.

3. Air-blast Freezing Time

Air blast freezers are considered one of the most energy intensive operations for seafood processors. Due to the nature of these high throughput freezers, they place a high energy demand on the refrigeration system for relatively long freezing cycles (e.g., 24 hours). One of the key ways to minimise energy consumption is by reducing the freezing time. Optimising the freezing time, while maintaining the required product temperature and quality, will depend on the (i) product type, (ii) product size and (iii) how the product is handled after freezing.

The temperature difference between the air and the product within the freezer needs to be recorded on a regular basis. Trials can be carried out to monitor the core temperature of products during the blast freezing process. This will allow operators to determine the precise time required for different products to reach their required freezing temperature and when the blast freezer can be turned off to reduce any excess energy consumption.

Accurately determining the optimal freezing time should consider that the product's core must reach the required temperature, after glazing, casing, and transporting to cold storage. This can reduce the energy used by the air blast freezer room. Determining the optimal freezing time could be achieved by following the steps outlined below:

(i) Select a random sample of products from different locations within the blast freezer.

(ii) To ensure that core temperature can be accurately taken a hole should be drilled into each of the centre of the randomly selected product samples.

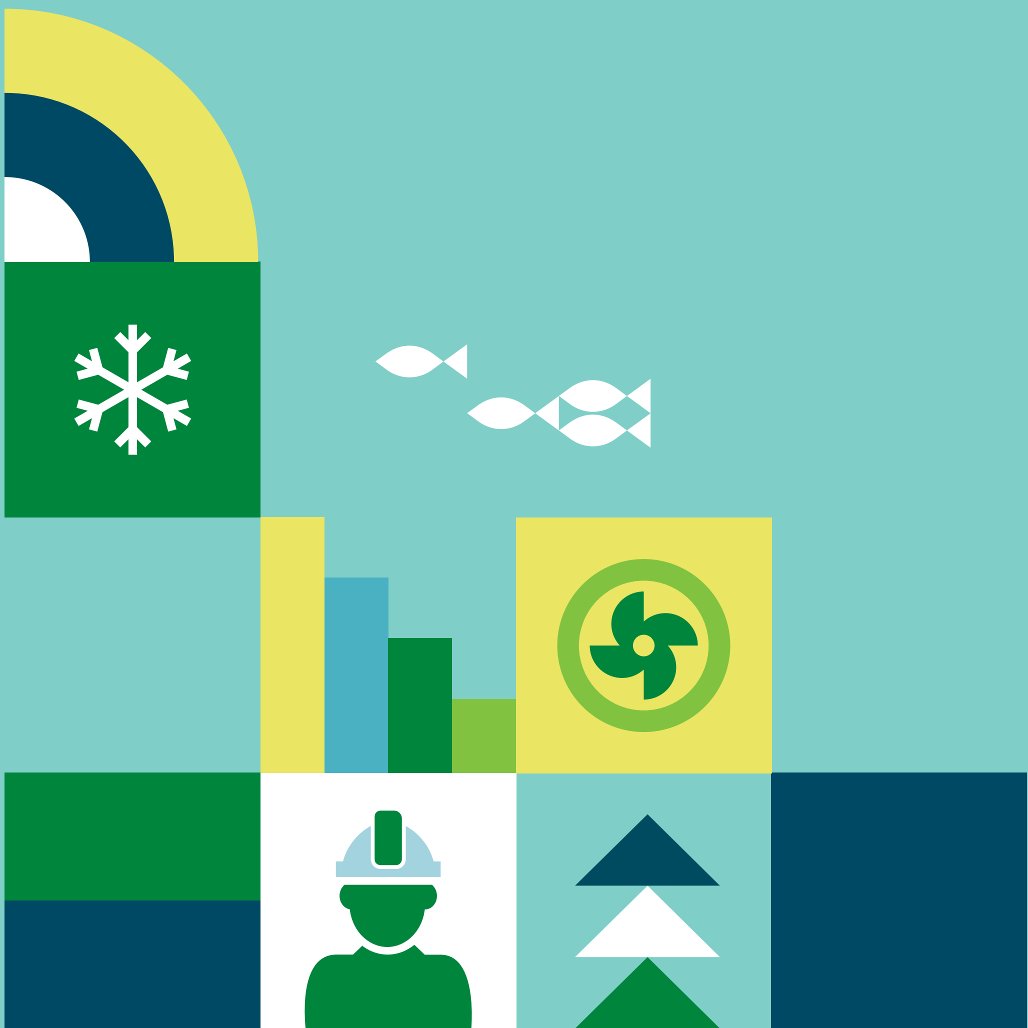
(iii) A temperature probe should then be inserted into the centre of the product, and a reading should be taken.

(iv) Samples should be treated in the same way as all other products including glazing, casing, putting on pallets and transferring to cold storage.

(v) Step 3 should be repeated at different time intervals (e.g., every 4 hours for 24 hours) to understand how long it takes for the product to freeze and how different processes influence the product's temperature.

(vi) Repeat the process for each product type as required until you determine the best combination of air blast freezing time and temperature to achieve the required core temperature for each of your products.

Section 3
Energy Efficiency Guidelines for Production Process Areas



Part 1

Production Process Areas

Some seafood processors use cooling systems to control temperatures in production and processing areas. This helps to maintain high food quality and safety standards by ensuring that the correct product temperature is maintained throughout the production process.

Air cooling and circulation are essential aspects to consider for controlling temperatures in production and process areas. Evaluating these key aspects can help to minimise energy consumption while providing comfortable working conditions for staff.

Reducing energy consumption in temperature-controlled production and process areas follow the same principles as reducing energy consumption in any other area. Guidance on how to maintain the room's thermal envelope and the optimal operation of the cooling system are outlined below.

1. Thermal Envelope

Like all other temperature-controlled areas, preventing cold air from escaping and limiting ambient moist air from entering is crucial to retaining the thermal integrity of production and processing areas. Ultimately this will reduce energy consumption and running costs.

The main source of ambient air entering the production area is generally through the loading doors. To minimise the movement of air into the production area operators should:

(i) Allocate a loading bay area with two doors, one at the production end and another on the loading (external) end. The area between the two doors operates like an air chamber to minimise moist air entering the production area.

(ii) Install an air curtain by the loading door to create an air barrier. This will keep the cold air in and the warm air out when the door is in use.

(iii) Install automatic doors that open and close in response to motion. This will ensure that the doors close rapidly when they are not in use. This will reduce opening time and the amount of ambient moist air entering the production area.

Having a dedicated entry or exit staff door, instead of large loading doors, will help to reduce the introduction of ambient air into the production area. For further information on the thermal integrity of chilled rooms see pages 7 - 9.

Loading area separated from processing area by vestibule. This acts like an air chamber, reducing the ingress of warm air to temperature controlled areas.

2. Components Operation

Evaporator units are often spread out in large production areas. This can present a challenge for the associated pipework and system maintenance. Measures that can be implemented to reduce energy consumed by these units are outlined in the section below. These measures cover the correct sizing and location of units and their control and maintenance (see pages 9 - 12 for further details).

Unlike other refrigerated areas, a full wash-down takes place in production areas at the end of the day or at the end of a shift. This will typically involve a hot wash cycle which often causes moist air to fill the production area. This fog will create condensation throughout the production area covering the walls, ceiling, equipment, and any other cold surface. This condensed air must be removed by the evaporator units causing the units to work harder and consequently consume more energy.

A simple two-step solution:

1. At the end of the processing shift, and 10-15 minutes before starting the cleaning process, switch off the cooling units. This helps minimise the fog that forms.

2. When finishing off the cleaning process and before turning on the evaporators, switch on the exhaust fans for ~ 15 to 20 minutes to discharge any excess moist air.

By carrying out these two steps, the production area will return to required chill temperatures faster and use less energy to do so.

Production area with over head dual discharge cooler note the build-up of ice in coil.

TIP! The temperature required in the production or processing area may vary between +8°C and +18°C. For staff comfort, the evaporator's airflow should be reduced. This can be achieved by installing low velocity evaporators and/or air socks (at the evaporators fans), thus providing uniform air delivery over the entire production or processing area.

Part 2

Ice Making

Ice machines or ice makers are designed to provide a reliable and consistent source of ice in a variety of grades for product cooling. There are three main factors that need to be considered to ensure ice making is energy efficient:

TIP! Ideally the ice room should be located close to the production area, where it is needed most. Production areas are usually temperature controlled and this will reduce work required by the ice machine to reach required temperatures and keep ice cool in storage bins.

1. Water quality

A clean, uncontaminated water supply is essential for making ice. Water contaminants such as dissolved air, organic matter, and minerals can significantly improve the freezing temperature of ice as well as its thickness. Water filtration and pre-treatment may have a significant impact on the quality of the ice produced and reduce the energy consumption of ice machines.

2. Ice making machine

For optimal operation, the following should be considered:

(i) The location of the machine can impact its operation, and energy consumption levels. There are two main components in the ice machine system, (a) the evaporator, (b) the condenser and compressor.

(ii) The evaporator is usually located inside the production area for easy access to ice.

(iii) The compressor and condenser section generally need to be located outdoors. If that is not possible, an air ventilation system should be installed, to provide a source of ambient air to the condenser. This will also allow warm air generated by the system's exhaust to be removed.

(iv) Regular cleaning and sanitising of the machine should be carried out to maintain the quality of ice produced. This should include cleaning the ice machine itself, the storage bins, dispensers and drain lines.

3. Ice storage

It is usually not feasible to produce enough ice 'on demand', so some sort of ice storage is typically required. In addition to production, the quality of ice depends significantly on the storage conditions. This in turn will affect how long the ice lasts and the cooling conditions that the ice provides. Several steps should be taken to ensure optimal storage conditions are maintained:

(i) The ice room door should always be closed when it is not in use.

(ii) Strip curtains should be installed around the ice storage silos if they are in an open area (this will prevent warm air from entering the area and melting the ice).

(iii) Ice production should be monitored and adjusted to determine the amount of ice required for different volumes of product. Minimising the volume kept in storage will reduce water build up and energy consumption.

(iv) The ice storage room should be strategically located on site. It should be close to where it is used/needed most, but away from sources of heat or ambient air.

Part 3

Display Cabinets

Where a seafood processor sells their products in their own retail outlet or shop, they will generally have refrigerated display cabinets. While these cabinets are not as energy intensive as other processes, their efficiency should be evaluated when reviewing and managing energy on site. To reduce the energy consumption of these display cabinets, the following list of actions should be considered:

(i) When purchasing cabinets check the energy efficiency rating. Generally, the initial cost of units, machines, and equipment account for only 10-15% of the total cost over their lifetime. Energy costs to operate equipment account for over 70%. Selecting equipment with higher energy efficiency ratings will ultimately reduce your operational costs and energy usage.

(ii) Overstocking cabinets can increase energy consumption by ~10 to 20%.

(iii) Cabinets located near natural lighting or the external environment (e.g., windows and doors) will be affected by higher temperatures, humidity, radiation, and wind. Locating the display cabinets in a cool area, and out of direct sunlight, will reduce energy consumption.

(iv) Installing LED lights in the cabinets will reduce the heat load and overall energy consumption of the unit. LED lights specifically designed for displaying fish can be installed (different coloured lights are generally used for displaying fish, meat, and vegetables).

(v) Open-front display cabinets consume more energy than closed-in display cabinets.

(vi) In the case of using an open-front display cabinet, installing night blinds can reduce the energy consumption by the cabinet when it is not in use. If the display cabinet has thermal doors make sure the cabinet door is well-sealed.

(vii) Periodic cleaning should be carried out to reduce the build-up of dirt, allowing the cabinets to operate more efficiently.

(viii) Installing variable speed drives (VSD) in the compressor and the evaporator.

(ix) When using an ice bedding cabinet, in many cases, the ice will be disposed of at the end of the day. This ice can be removed and stored in a chill room on site and reused (with due consideration for health and safety risks).

Section 4
Energy Efficiency Guidelines for System Operation and Piping

Part 1

Plant Area

The plant area is the central hub of a refrigeration system. The mechanical equipment and associated electrical equipment (including compressors, pipes, and refrigerant receiver) reside within the plant room. The condensers are generally located in an area with ambient air temperature close to or above the plant room.

In this section of the guide, these different types of equipment will be discussed and key actions to reduce their energy consumption will be outlined. The associated environmental and financial costs will also be evaluated.

Before discussing these, it is important to consider the layout and design features of the plant room. While it is best to consider these aspects at the design phase, there are some retrospective actions worth considering for existing rooms such as:

1. Ensure easy and safe access to the room for service and maintenance and the replacement of equipment.
2. Ensure the availability of adequate ventilation to prevent overheating. Mechanical ventilation could be installed to ensure adequate air circulation. Vents or windows should not be blocked.

TIP! Every component of a refrigeration system must match in terms of thermal cooling load and size. The condenser must be able to eject the heat collected and transferred by the evaporator. It must also be able to eject the heat generated by the process of compression from the compressor.

TIP! Correct design, layout and sizing of the piping system will minimise friction and refrigerant pressure drops, thereby reducing energy losses in the system.

1. Compressor

The compressor is one of the main elements of any refrigeration system, and it is usually the largest single energy consumer. Good management and control of the compressor operation will optimise the overall performance of the system and reduce energy consumption.

There are five main types of compressor. These are based on the specific mechanism used to compress refrigerant gases and include: rotary, piston, scroll, screw and centrifugal.

A well maintained ammonia compressor plant room.

Regardless of the type of compressor(s) used on-site, the basis behind reducing their energy consumption is mostly the same. By optimising the operation of the compressor, 20% to 30% savings in running costs can be achieved.

2. Compressor Operation

To optimise the operation of the compressor a number of key actions should be considered:

(i) At the outset the size of the compressor should be based on the requirements of the site. An oversized compressor will result in unnecessary electricity use.

(ii) Ensure the compressor area is well ventilated – this will prevent the compressor from operating at higher temperatures than necessary which can reduce the reliability and efficiency of the compressor.

(iii) Operating the compressors at higher loads is more efficient. Partial load operation (e.g., unloaded rotary screw compressors) still consume 15% to 35% of full load power while delivering no valuable output.

(iv) Allowing the system head pressure to float (up and down) during cooler ambient conditions will improve system efficiency and reduce energy usage by approx. 20%.

(v) Reducing the refrigerant temperature difference between the suction line and the discharge line can improve the efficiency of the compressor operation.

(vi) Installing variable speed drives (VSDs) on compressor motors, in conjunction with a control system, will help to better match compressor loads to system cooling demand. This can save up to 10% in energy costs (depending on the compressor type).

7. Rejected heat can be recovered from the compressor and used in other applications within the site (e.g., supplementing hot water systems or space heating). This can be done either directly or through a heat exchange system.

TIP! The difference between the refrigerant temperature in the suction line and the discharge line shows how much work the compressor has to do to get rid of heat and reduce the refrigerant to the desired temperature and pressure.

3. Control System

The main function of the control system in the compressor unit is to monitor and adjust the system's flow conditions (e.g., discharge and suction pressure). The control system can also schedule the simultaneous operation of multiple compressors (i.e., shutting off unused compressors and delaying the turning on of additional compressors units until they are needed).

(i) Floating head pressure controls are more efficient than fixed head pressure systems. These allow the compressor head pressure to regulate based on the variation in ambient wet-bulb temperature. This unit of measure is a function of relative humidity and ambient air temperature.

TIP! Typically, between 2% and 4%, energy savings can be achieved for every 1 °C reduction in condensing temperature.

(ii) In general, it is important to install an effective monitoring system that monitors pressure, temperature, flow rate, and dew point temperature. These systems can continuously optimise the operation of the compressor, which leads to energy and cost savings.

4. Condenser

The condenser is one of the main elements of a refrigeration system. It works to dissipate the heat removed by the evaporator/compressor by condensing the refrigerant vapours back into a liquid.

The energy efficiency of the condenser is dependent on its type and design. Energy efficiency is affected by the materials used, the contact area between the condenser surface and the condensing medium, flow rate and the ambient wet-bulb temperature and humidity.

There are three types of condensers:

1. Air-Cooled Condensers are mainly used in small to medium sized facilities.
2. Water-Cooled Condensers are usually used in large refrigeration plants, where a high cooling load and a large quantity of refrigerant passes through the condenser. The refrigerant flows through one side of the piping while water flows through the other to cool the refrigerant and condense it.
3. Evaporative condensers involve a combination of air-cooled and water-cooled condensers and are used in larger plants. Water is sprayed over the condenser coils (containing hot refrigerant gas) and a fan blows air through the coil to help maximise the heat transfer time. These are characterised by the plumes of 'steam' that billow out from the top of the units.

While each type of condenser has different management requirements, several actions can be taken to reduce their energy consumption:

(i) The size of the condenser should be relative to the requirements of the site and match the size of the evaporator and compressor units.

(ii) The condenser should have sufficient surface area for cooling to provide greater heat transfer from hot refrigerant gases to the ambient environment.

(iii) Control systems should be used to reduce the condensing temperature and pressure in line with the ambient wet-bulb temperature. This can reduce the energy required to compress refrigerant.

TIP! Where common drainage lines are utilised, the flow must always be from rooms maintained at a low temperature to those maintained at a higher temperature.

(iv) Hard water and bacterial build-up can raise the temperature of the condenser and reduce the heat transfer efficiency. Water-cooled and evaporative condensers should be cleaned to remove any build-up.

TIP! A 1°C increase in the condenser temperature will result in a 2%-4% increase in condenser energy consumption. Thus, regular coil cleaning is essential.

(v) Condensate drainage should be adequately sized to channel the anticipated volume of condensate water from the cold room evaporators.

(vi) In circumstances where condensate drains must be installed externally, adequate measures should be taken to prevent the possibility of freezing.

(vii) Variable speed drives (VSDs) should be installed on the fan motor to control the fan speed, improve condenser operation, and save energy.

TIP! VSD's control the speed of alternating and direct current motors by changing the input voltage. They are usually used in equipment driven by a motor, such as fans and pumps.

(viii) Variable speed drives (VSDs) should also be installed on condenser fans to control the fan's speed. This is particularly important where there is a large difference between installed and operating condensing capacity. The use of variable speed drives can bring about significant energy savings over fixed-speed condenser fans by up to 20%.

TIP! When non-condensable gases build up, they reduce the efficiency of the refrigeration system by increasing head pressure and impeding the condenser's heat transfer rate. These are often purged manually, but an automatic purging system can detect and remove these gases on a needs basis. For safety reasons, the purging valve should be installed in an open area outside the main plant room. This is particularly important for ammonia systems which carry a significant safety risk.

(ix) A special treatment should be applied to the condenser coil to prevent corrosion. This is particularly important for sites near the sea where the air is full of sea salt and humidity levels are high. These conditions can accelerate corrosion.

(x) Heat recovery systems can help to reduce energy use and costs on site. There are two main options. Heat can be recovered from the refrigeration system:

   a. where the gas is at its hottest (i.e., before it reaches the condenser). This reduces the energy (and water) used by the condenser by reducing the heat of the refrigerant that needs to be condensed, as well as providing 'free' heat for the site.

   b. at the condenser where the heat from the condenser vent can be captured for use on site.

5. Refrigerant Receiver

Depending on the type of refrigeration system installed, different refrigerant gases can be used. The purpose of the refrigerant is to transfer the heat in the system by phase- changing from liquid to gas and then back to liquid. In the Irish seafood industry, hydrofluorocarbons gases (HFCs) are the most commonly used refrigerant.

HFCs have a significant global warming impact. As part of EU policy to combat climate change, HFCs are being phased out and replaced by natural refrigerants. One of several measures includes cutting the EU's F-gas emissions by two-third by 2030 in comparison with 2009-2012 emission levels.

Regardless of the type of refrigerant used on site, there are some general operation and maintenance factors that should be considered:

(i) Refrigerant charge - maintaining the refrigerant charge level is a critical factor in optimising system performance and reliability.

> **TIP!** A low or high refrigerant charge can lead to significant deteriorations in the system's performance. This can increase the energy consumption of the direct expansion component of the refrigeration system.

(ii) Leak detection - check refrigerant system for leaks at least every three months.

> **TIP!** In smaller commercial refrigeration systems, (and when the system is operating at a steady state), check the liquid line sight glass for bubbles. If bubbles are present in the liquid line, it may indicate a leak.

(iii) Contamination – contaminants in the refrigerant can reduce the systems efficiency. Check for any refrigerant contaminate on a regular basis. Build-up of contaminants over time will lead to operational problems or system failure. The three main types of refrigerant contamination include:

a. Water contamination- this is the most dangerous contaminant as it can reduce the system's efficiency and damage system components. Water contamination can combine with the compressor lubrication oil to form acids that can damage the motor and burn the compressor out.

A well maintained plant room showing compressors and refrigerant vessels.

b. Oil contamination- is the most common form of contamination. When present in the system it gives little indication of its presence but can reduce the system's efficiency significantly.

c. Air contamination - is one of the more difficult contaminants to remove and can cause excessive head pressure and increase the operational temperature. This causes an increase in electricity consumption and a reduction in the system's efficiency. Over time this will result in a decline in the performance of different system components.

(iv) System controls – control the refrigerant pump to provide enough refrigerant to the system components, ensuring optimal matching between the cooling demand and the systems energy load.

As part of the EU policy to phase out harmful refrigerant substances a number of less harmful alternatives have been identified. These include ammonia (R-717), propane (R-290) and carbon dioxide (R-744). Due to the advantageous properties of ammonia, it is the most-commonly used refrigerant. This substance has a high latent heat of evaporation. It is non- corrosive to iron and steel, and where leaks occur, it can be detected easily due its pungent smell.

> **TIP!** Always wear appropriate personal protective equipment, when working with any refrigerant substance for any purpose (e.g., manipulating refrigerant valve or refrigerant charge calibration).

TIP! The charging of the system with refrigerant must be recorded. The refrigerant charge should be weighed and accurately recorded and displayed on the assembly and on the rating plate.

Part 2

Pipe Work

One of the essential components in any refrigeration system is the piping network. The refrigeration process essentially entails moving heat from one location to another, through liquid and gas movement. Therefore, the performance and efficiency of a well-run refrigeration system will be highly dependent on good piping design. Good design requires proper sizing and routing of pipes to minimise the potential for friction and pressure drop.

Every refrigeration system, and every refrigerant type, will have specific piping requirements to achieve a reliable, efficient system performance. Pipe selection and sizing depends on many factors, including the cooling capacity, velocity requirements, the pressure drop, temperatures involved, pipe lengths and site layout.

For existing pipe work, there are several fundamental aspects which can be considered (i.e., the pipe size or diameter, pipe insulation, leaks and oil return).

1. Pipe Line

There are three main pipe lines in any refrigeration system:

1. The liquid line transfers warm liquid refrigerant from the condenser storage vessel to the evaporator. This then passes through the expansion valve, which causes the refrigerant pressure to drop.
2. The suction line is the outlet pipe from the evaporator that transfers cold, low-pressure refrigerant gas from the evaporator unit to the compressor where it is compressed into a high-pressure gas.
3. The discharge line takes hot compressed refrigerant gas from the compressor to the condenser where it is condensed back into its warm liquid state.

A good example of vertical pipes and cable support.

2. Pipe Insulation

All the pipe lines, including joints, seams and termination points, should be insulated and the insulation itself should be sealed well also. Good sealing is important to protect against air ingress, which can result in the formation of condensation between the insulation and cold pipes due to moisture present in the air. In addition to that, all insulation of pipework should be suitable for external ambient conditions and have the required protection against water ingress, UV and damage caused by wildlife (e.g., vermin and birds).

Issues associated with poor pipe insulation include a decrease in the system's thermal performance, higher energy consumption and operation cost, inadequate cooling capacity, mould and ice formation, condensation leading to corroded pipes and health and safety issues such as slippery floors.

> **TIP!** Insulation for commercial DX systems should be at least 19mm thick in chiller rooms and 25mm thick in freezer rooms.

For the three main pipes (liquid line, suction line, and discharge line) involved in a refrigeration system, the following should be considered with regard to insulation:

(i) The suction pipe is one of the most important pipelines. It transfers cold refrigerant vapour from the evaporator back to the compressor. These pipes should be insulated with vapour-proof insulation along the entire length of the pipe. This insulation will prevent the suction pipe from sweating and dripping inside temperature controlled cold/freezer rooms. This will protect the room from water damage and associated issues. Proper insulation will also protect the pipe on its way to the compressor and prevent it from being influenced by external conditions.

Recommended insulation thickness for suction pipes:

a. Blast freezer suction pipes should have a minimum wall thickness of 50mm.

b. Freezer room suction pipes should have a minimum wall thickness of 25mm.

c. Chill room suction pipes should have a minimum wall thickness of 19mm.

(ii) Discharge lines are generally not insulated. As these lines are normally very hot, (due to the hot compressed refrigerant gas passing between the compressor and the condenser unit), losing heat through these pipes is beneficial and part of the normal operation of the system. However, these pipes may require insulation for safety, or to prevent unused heat from being discharged if a heat exchange system is being used.

TIP! All insulation joints should be fully vapour sealed, using the correct grade of non-flammable adhesive. All excess glue should be removed.

TIP! Sizing of the suction and discharge lines must ensure that:

a. There is an adequate gas velocity to return oil to the compressor (for all load sizes)
b. System capacity and efficiency loss is minimised
c. Noise is reduced

3. Pipe Size

A properly sized pipe could have a significant impact on the operation of the systems components and the overall energy consumption. Undersized pipes will increase refrigerant velocities and improve oil return within the system, but they can also increase pressure drops, reduce the system capacity and overheat the compressor. On the other hand, oversized pipes will result in low refrigerant velocities, and poor oil return. But they can also reduce pressure drops.

Some key considerations regarding the different pipe systems include:

(i) Undersized suction line pipes can minimise suction pressure, which reduces the compressor capacity and efficiency. These undersized pipes will increase gas velocities (which is beneficial) but this may generate loud operational noises as a result. In contrast, oversized pipes will reduce the refrigerant gas velocity to such an extent that the gas can no longer carry the oil droplets back to the compressor.

(ii) Under-sizing the discharge line pipe can increase the discharge pressure in the compressor and cause the compressor to work harder for the same output. Like the suction line, if the discharge line pipe is oversized, the gas velocity will be insufficient and unable to transport the oil droplets back to the compressor.

(iii) Oversizing liquid lines will significantly increase the refrigerant charge within the system. This will decrease the reliability of the system and increase costs. Where the liquid line pipe is undersized, the increased pressure drop may cause 'flashing' (the spontaneous production of refrigerant gas) upstream of the expansion valve.

TIP! Sizing the liquid line must ensure that:

a. Only liquid refrigerant enters the expansion valve
b. Low refrigerant charge is maintained
c. Excessive noise and pipe erosion are avoided

Part 3

Refrigerant Leak

Leaks can occur throughout the refrigeration system at the compressor racks, evaporators, condensing units, and refrigerant pipes. Refrigerant leaks can occur for a variety of reasons including:

(i) Poor seals on the refrigerant pipes.

(ii) Uncapped valves which lead to refrigerant leaks though the valve stems.

(iii) Improperly tightened fittings – leaks often happen where fittings are not tightened sufficiently or where they have been over tightened and crack.

(iv) Sealant materials are incompatible with refrigerant – this can happen when replacing seals or changing the type of refrigerant used. New sealant material and or refrigerant substances can interact differently with each other.

(v) Vibration in the refrigeration system and poor pipe work can cause gas pulsation, especially near the compressor discharge line.

(vi) Changes in the temperature throughout the system can result in thermal expansion and contraction of the refrigeration piping and components.

(vii) Corrosion might occur in the system components or pipes for different reasons. For example, corrosion leaks can occur in the compressor rack as a result of condensation forming or dripping on steel racks.

1. Tracking Leaks

An insufficient refrigerant charge as a result of a leak will make the refrigeration system work harder and longer to reach the set cooling temperature.

There are two ways to track leaks:

1. Manual tracking involves periodic checking of all system components and pipes for leaks.
2. Tracking software automates leak checks by reporting any unexpected reduction in the amount of refrigerant. These can be set up to generate automatic alerts when a leak occurs in any part of the refrigeration system.

The EU aims to reduce the impact of F-gases (fluorinated gases) on the environment through periodic leak detection and recording systems. This is required for all equipment containing F-gases in quantities that meet stipulated EU thresholds. These quantities are calculated based on CO_2 equivalents. EU guidance documents and conversion calculators are available online (see Regulation (EU) No 517/2014).

All refrigerant work and leak checks must be recorded. The frequency of mandatory leak checks under the European F-gases regulations is determined by the volume of refrigerant used:

- Systems with 5 - 50 tonnes of CO_2 equivalent refrigerant should be checked for leaks every 12 months as a minimum.
- Systems with 50 - 500 tonnes of CO_2 equivalent refrigerant should be checked for leaks at least every 6 months.
- Systems over 500 tonnes of CO_2 equivalent refrigerant should be checked for leaks at least every 3 months.

Part 4

Oil Return in Refrigeration Systems

All compressors must be lubricated well and should discharge oil into hot refrigerant gases undergoing compression. Refrigeration oil can be in two forms, liquid oil driven by the gas velocity or oil mist present in the discharge gas. The rate at which oil is discharged is measured by the mass of oil discharged per mass of refrigerant compressed. This can also be expressed as the mass percentage of oil in the discharged gas.

TIP! The rate of oil discharge depends on the compressor type and is much smaller in centrifugal compressors compared with screw compressors.

The oil is discharged from the compressor to the evaporator as outlined below:

(i) The dissolved oil in the discharged gas flows from the compressor to the condenser through the discharge line pipe.

(ii) At the condenser, where the hot gas condenses to its liquid state, the proportion of oil within liquid refrigerant is maintained (i.e., the same as it was at the compressor outlet).

(iii) This oil continues its route in the liquid refrigerant through the expansion valve to the evaporator unit, where the refrigerant boils off delivering its refrigerating effect.

(iv) When the oil reaches the evaporator, it will not evaporate due to temperatures in the evaporator and its high boiling point.

As the refrigeration cycle repeats, the oil will accumulate in the gas or liquid refrigerant. This leads to a gradual degradation of the heat transfer effect in the evaporator. As oil builds up in the refrigerant, it simultaneously decreases in the compressor. If this is left unchecked and is not corrected, it will also impact on the reliability and efficiency of the compressor.

> **TIP!** There are two indicators of high oil concentration in the evaporator (i) compressor failure and (ii) failure of the oil return system.

In the oil return system within the evaporator, the amount of oil removed by the return system depends on the removal rate and the oil's concentration in the liquid refrigerant. Oil return rates are often less than oil starting rates, indicating that oil is accumulating in the evaporator. If this is happing, there are two options to consider:

1. Reduce the compressor oil discharge rate, by implementing a system that decreases the oil concentration in the liquid before entering the evaporator.
2. Replace the oil return system with a more efficient one.

The design of the evaporator and the location of the oil pickup point within it can significantly influence the functionality of refrigeration systems. It is important to understand where oil accumulates within the evaporator and to connect the oil pick up point to that location. This point normally depends on the design of the evaporator and its internal liquid distribution system.

> **TIP!** The oil charge should be recorded. The type of the oil should be displayed on the assembly near the compressor.

Part 5

Low Power Factor

The power factor is the ratio between the real power used by an electrical component and the apparent power that is drawn from the power supply. Measuring the power factor is a way of measuring how efficiently a system uses the supplied power. Under ideal conditions, the power factor would be 100% or '1'. However, where there are 'inductive loads' in an electric circuit (e.g., any pump, motor or fan), a power factor of less than 100% will occur.

In refrigeration systems, low power factor issues can occur in the compressor motors or in the condenser fan motors, especially during partial loading. This can reduce the efficiency of the system's operation and, in certain cases, additional charges on your electricity bills. To solve this problem, a power factor correction device can be installed in the electrical circuit between the power supply and the inductive motor.

Many utility suppliers charge their customers an additional supply fee if their power factor is less than the predetermined value. A low power factor means that you are not fully using the power that you are paying for.

Section 5
Refrigeration System Preventative Maintenance Checklists

Part 1

System Maintenance

Planned Preventative Maintenance (PPM) is the systematic inspection and testing of refrigeration systems. Carrying out PPM will (i) optimise the performance, reliability, and efficiency of the system's operation and (ii) prevent the need for any emergency service call out events or system failures. Performing PPM will help reduce the energy consumed by the refrigeration system components and extend the lifetime of the system equipment. In particular, the longevity of components like the condenser, compressor, evaporator and fan motor will likely be extended. Overall, this will reduce the operational costs and environmental impact of refrigeration systems used on site.

Refrigeration system maintenance can be split into two main aspects: (1) maintaining the thermal envelope in temperature-controlled rooms such as freezer and chiller rooms, and (2) optimising the energy efficiency and operation of various components of the refrigeration system. This should be planned in advance and occur on a regular basis. Simple checklists and follow up action can be carried out by the facilities manager or maintenance team.

Part 2

Preventative Maintenance Checklists

The section below outlines a number of fundamental preventative maintenance steps that should be carried out on refrigeration systems on a daily, weekly, monthly and annual basis.

1. Daily Checklist		✔
1	Check for any unusual sounds or vibrations.	
2	Check the system's temperatures, pressures, and defrost frequency settings.	
3	Check room temperature logs.	
4	Ensure that there are no fluid leaks or excessive condensation in any part of the equipment or the system's piping.	
5	Organise, stock, and clear the freezer or chill room areas to maximise air flow (this includes clearing and organizing products, or any other items stored in these areas).	

2. Weekly Checklist		✔
1	Inspect all room door hinges, closers and gaskets. Ensure that all are functioning correctly.	
2	Look for an abnormal accumulation of ice patterns around the freezer or chill rooms doors (from both the inside and outside).	
3	Inspect the door and insulation seals and fix any obvious damage.	
4	Check the refrigerant levels.	
5	Check the oil levels.	
6	Check that all the evaporators are clear of ice.	
7	Clean the condensate drain pan and pipes. Ensure that there is no ice or water drips.	
8	Check that the evaporator defrost cycle and controls are operating correctly.	
9	Check the suction pressure and temperature in the suction line.	
10	Check that the condenser fans are operating correctly.	
11	Check that the condenser coil is clear of debris (e.g., rubbish, leaves etc.)	
12	Check the ice machine temperature controls and wiring.	
13	Check if the freezer door heaters are working correctly.	

3. Monthly Checklist		✔
1	Check the overall operation of the equipment.	
2	Inspect and clean the condensers and evaporators coils.	
3	Clean the fan blades.	
4	Check the suction line pipe insulation.	
5	Pressure wash the drain lines.	
6	Check for any refrigerant leaks.	
7	Check for any refrigerant contamination.	
8	Check the control wiring and electrical connections.	
9	Check if there are any obstructions or dirt around the pressure relief valve for the freezer room.	
10	Check the water filter in the ice machine for blockages and replace if necessary.	
11	Clean the ice machine evaporator from build-up of any materials (e.g., lime scale or dirt).	
12	Examine all the components for wear and tear and carry out maintenance where required.	
13	Check for any damage to insulated walls or ceilings.	

4. Six Monthly Checklist		✔
1	Test the thermometers and recalibrate if necessary.	
2	Lubricate the motors.	
3	Check that each fan rotates freely and quietly.	
4	Check the power factor value.	
5	Replace the water filter on the ice machines.	
6	Deep clean and sanitize all the ice machine parts.	
7	Check the electrical connections.	
8	Visually inspect all the wiring for wear or discolouration. Identify the cause and replace any damaged wiring.	

5. Annual Checklist		✔
1	Inspect the operation and control wiring of the condenser, compressor, and evaporators.	
2	Each system should be re-commissioned and settings recorded and compared with the previous year to understand the performance of the system over time.	
3	Recurring issues and changes should be checked, corrected, and recorded as required.	
4	Check the pressure and safety control settings and verify correct operation.	
5	Treat the condenser coils to prevent any corrosion.	
6	Check that the compressor area is well ventilated.	
7	Check the interior airflow in all chiller or freezer rooms.	

EUROPEAN UNION

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