

# Refrigerated Warehouses

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www.bahrns.com



# Agenda

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# Introduction

- The demand for food products drives the need to build logistical centres and warehouses for refrigerated or frozen products, necessary for distribution to various points of consumption.
- It is estimated that cold storage warehouses are used to store approximately 200 billion dollars of refrigerated or frozen food products each year. However, cold storage is also important to other industries, such as pharmaceuticals, petro-chemicals and high-tech electronics.
- These buildings are therefore strategic nodes in the logistic chain where high volume of capital is stored.



[www.123RF.com](http://www.123RF.com)

# The Building

- Cold storage buildings have been referred to as heated buildings turned inside out, where the cold side becomes the warm side and the warm side becomes the cold.
- Warmer air infiltration is one of the primary concerns in cold storage buildings.
- Although cold stores can be built using conventional building materials, such as bricks, cement or galvanized sheet metal, they require thermal insulation and a vapour barrier.



[www.pefipresa.com](http://www.pefipresa.com)



# Thermal Insulation

- Sandwich type insulated thermal panelling is used.
- The thickness of the insulation varies according to the desired working temperature in the cold store and the insulating capability of the material.
- It is estimated that 92% of the panels used in these systems are polyurethane or polystyrene insulated panels (an organic polymer with foam like consistency and thermal characteristics), which is manufactured as sandwich panels.
- As the material is combustible, there is a fire risk in the event of fire reaching the nucleus of the panel.



[www.pefipresa.com](http://www.pefipresa.com)

**intact**



# Use of glass wool or rock wool panelling

- The inorganic nature of glass wool and rock wool make these materials incombustible.
- However, they are not recommended for use with cold stores as pores within the panelling of these materials can allow for water to condense allowing for the formation of a thermal bridge leading to less thermal capability and loss of cold through the panel.
- Condensation within the pores of the panelling can allow for growth of bacteria or fungus that could contaminate food stored in the cold store.



[www.pefipresa.com](http://www.pefipresa.com)

## Vapour Barrier

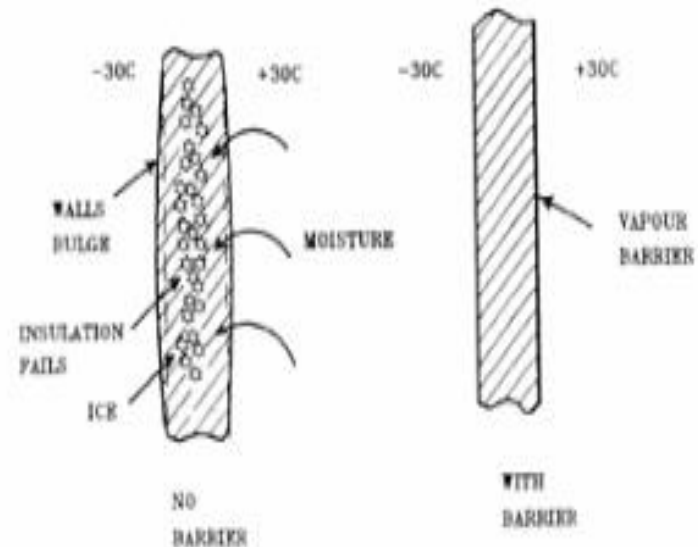
The air inside the cold store is denser and less humid than air from the outside.

The vapour barrier is tasked with preventing warmer air from outside, which carries more humidity from shedding its moisture as it meets the cold surface of the building.

It prevents or retards the process of moisture passing through the breathable building materials like drywall and insulation.

This moisture, which condenses as it cools down, will eventually freeze and turn into ice.

Long term accumulation of ice can affect the thermal effectiveness of the panelling as well as weaken the structure of the building.



32 Diagram illustrating the function of a cold store vapour barrier | [www.fao.org](http://www.fao.org)

# Vapour Compression System

- Although nearly 200 years old, the most commonly used method of cooling cold stores is through vapour-compression cycles.
- Any liquid in order to pass to a gaseous state, needs to absorb heat from the surrounding environment.
- A refrigerant is any liquid that acts as a cooling agent, thus removing heat from one area as it evaporates.
- For large cold storage facilities, ammonia remains the refrigerant of choice, as it is known to have the highest refrigerating capacity/effect per pound of any refrigerant, despite of being toxic, explosive and flammable within certain conditions.



- The temperature at which a liquid evaporates depends on the pressure exerted on the liquid.
- All vapour can again condense becoming liquid if properly compressed and cooled.
- The refrigerant operates under two separate pressures, the evaporation and the condensation pressure. There is a zone of high pressure and a zone of low pressure.
- Starting in liquid form, the expansion valve lowers the pressure as the liquid enters the evaporator. This drop in pressure in the evaporator causes the refrigerant to boil and evaporate and in doing so absorb and remove heat from the space to be cooled.
- The refrigerant in gas form is extracted from the evaporator through the compressor, which compresses it and in doing so increases its pressure.
- By the action of an external fluid (cooling water or cooling air flowing across the coil or tubes) the heat of the refrigerant gas is extracted, causing it to cool and condense and return to liquid state. Heat is carried away by either water or the air.

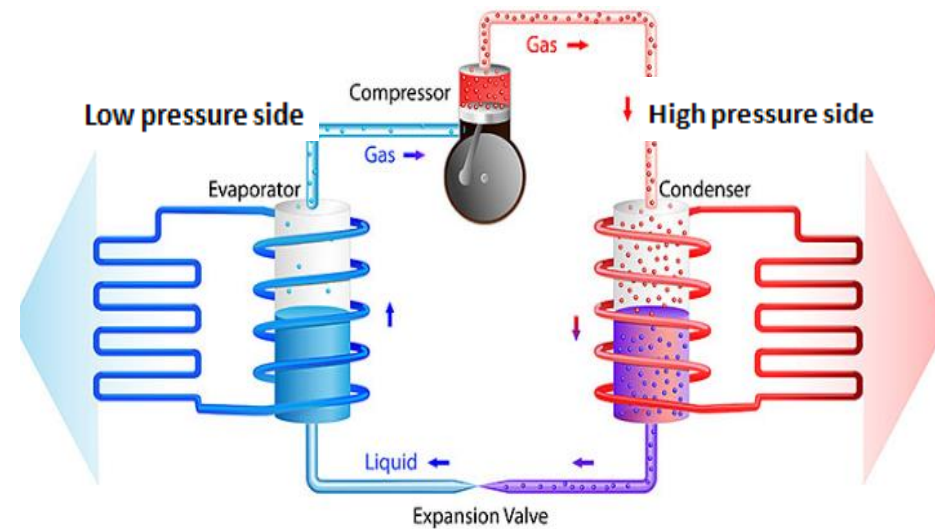
The system includes several pieces of hardware:

The evaporator

The compressor

The condenser

The expansion valve



# Ammonia

- Ammonia is toxic and can be explosive and flammable in large concentrations.
- Due to its irritating odour, it is easily detected in case of a leak or spill, giving staff early warning to evacuate.
- Gas detention systems for ammonia trigger an alarm in the event of a leak.
- Ammonia is toxic if breathed, causes burns and is irritating to the eyes, skin and respiratory system.
- Precautions must be taken, including use of breathing apparatus and skin and eye protection, if it is necessary to enter an atmosphere that contains ammonia.
- Any leak or spill can injure or kill employees and easily damage millions of dollars in product in storage.



Jerusalem Post



Accidental ammonia releases cause injuries and death to employees, emergency response personnel, and people in surrounding communities.

Here are some examples:

### **Two Workers Killed in Cold Storage Accident**

In May 2009, a leak of anhydrous ammonia killed 2 maintenance workers at a cold storage facility in Kentucky. Plant employees described the vapors as too thick to see through.

### **Thirty-Two Hospitalized after Rupture of Refrigeration Piping**

In August 2010, 32 offsite workers were hospitalized after a cold storage facility in Alabama released more than 32,000 pounds of anhydrous ammonia. The refrigeration system experienced a sudden, localized pressure surge called “hydraulic shock”, causing catastrophic failure of piping, valves, and other system components.

### **Seven in Intensive Care Following Ammonia Leak**

In March 2011, a poultry plant in Alabama accidentally released 32,000 pounds of anhydrous ammonia resulting in \$4 million in product losses. Approximately 150 people were taken to the hospital. The leak prompted road closures and the evacuation of workers and neighboring residents. Factors contributing to the accident include an early termination to the defrost cycle causing hydraulic thermal shock, too many evaporators going into defrost at the same time, and equipment and operator error.



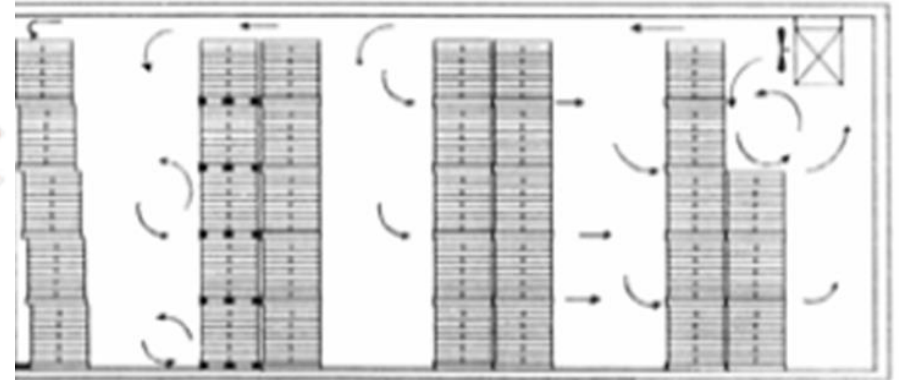
# Ammonia cont.

- Ammonia has a high affinity for moisture and is readily absorbed by many materials.
- The level of contamination depends on the level of ammonia concentration in gaseous state, the moisture level of the product, the length of time the product is exposed and the type of packaging. (e.g. plastic bags, cardboard boxes or no packaging).
- A study done by the University of Nebraska-Lincoln (Prajitna 2011) noted that frozen meat has a slower ammonia uptake rate which resulted in an ammonia concentration 6 times lower than the ammonia level in fresh meat samples after 12 hours exposure.
- Said study recorded that meat qualities affected by external ammonia contamination included colour, flavour, odour, water holding capacity and tenderness.
- In another study of ammonia absorption into frozen meat, ammonia could be detected in the meat by smell immediately after exposure. After a while, the ammonia could not be smelt but could be tasted (rancid flavour).

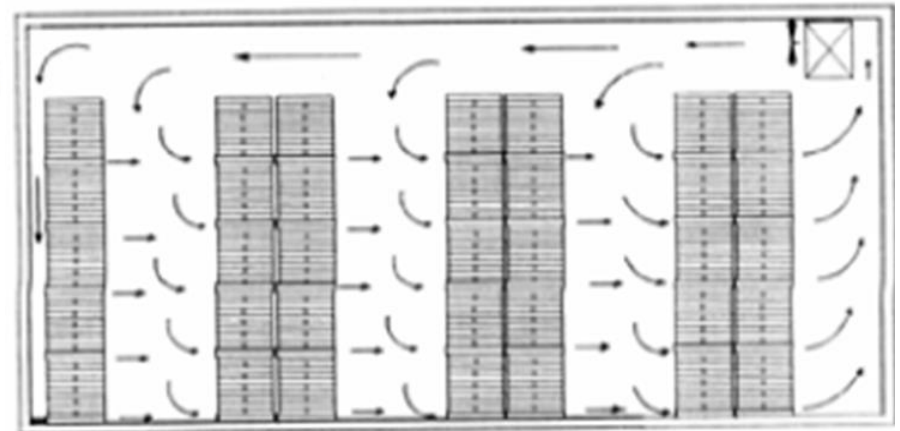


# Airflow and air distribution

- Despite having a properly sized refrigeration system, it becomes inefficient if it is unable to deliver air to areas that needed it.
- Air follows the path of least resistance, as in cases where there is too much free space.
- Loading patterns in particular, and fan capacity should be carefully calculated to ensure that there is uniform distribution throughout the cold chamber



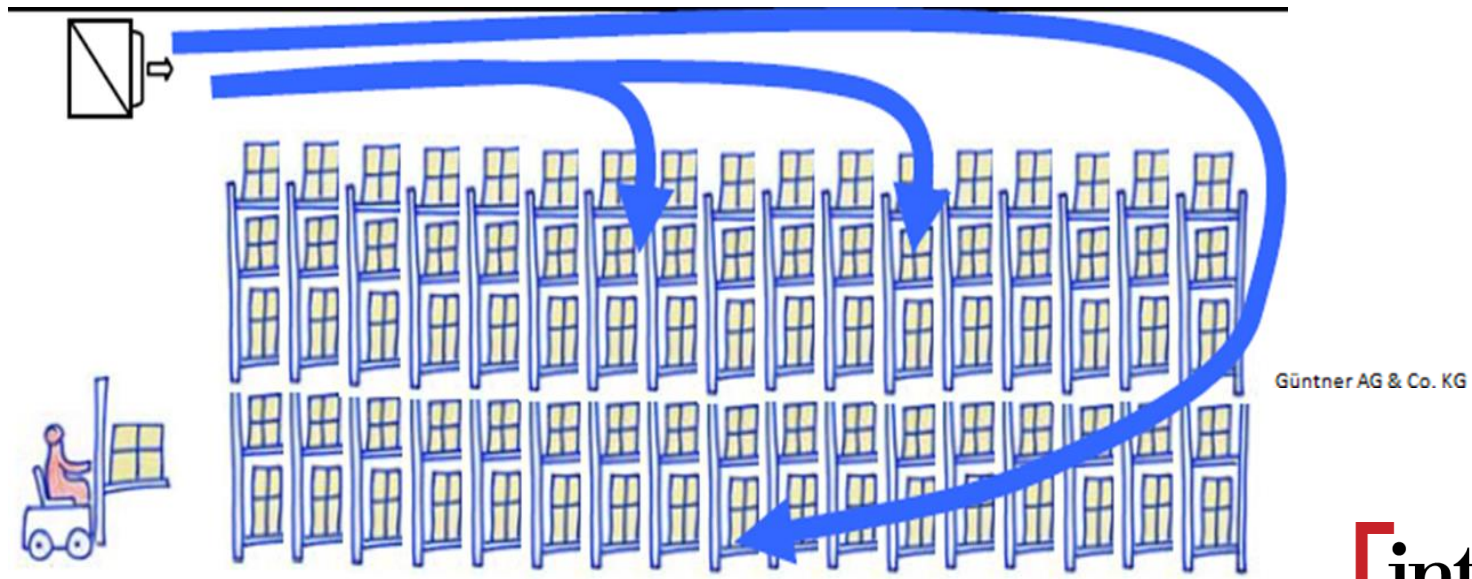
www.fao.org





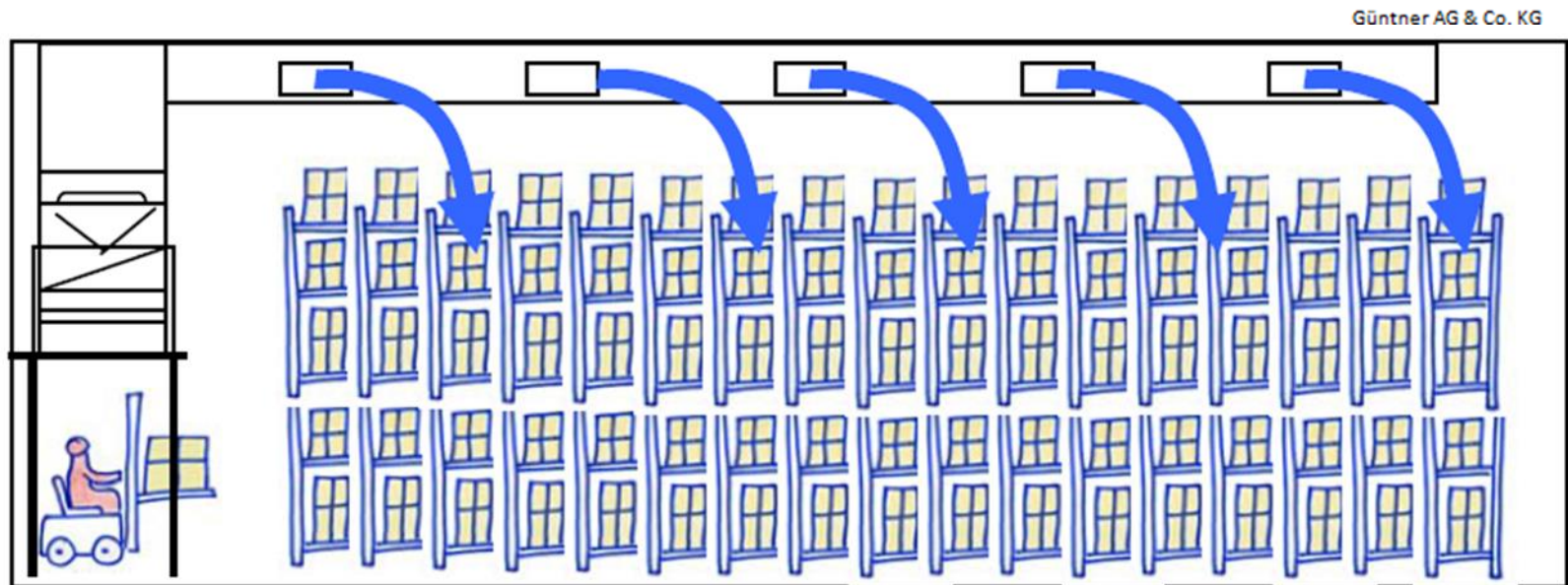
# Air Cooler Design: Air Cooler with Horizontal Airflow

- This is an economical design, popular in smaller warehouses.
- The design requires high-speed fans with high driving force.
- The airflow from the fans needs to be at least the length of the room to provide adequate coverage of product.
- For larger warehouses, it has obvious limitations. It does not allow for intrusive girders or lighting fixtures in the ceiling area.



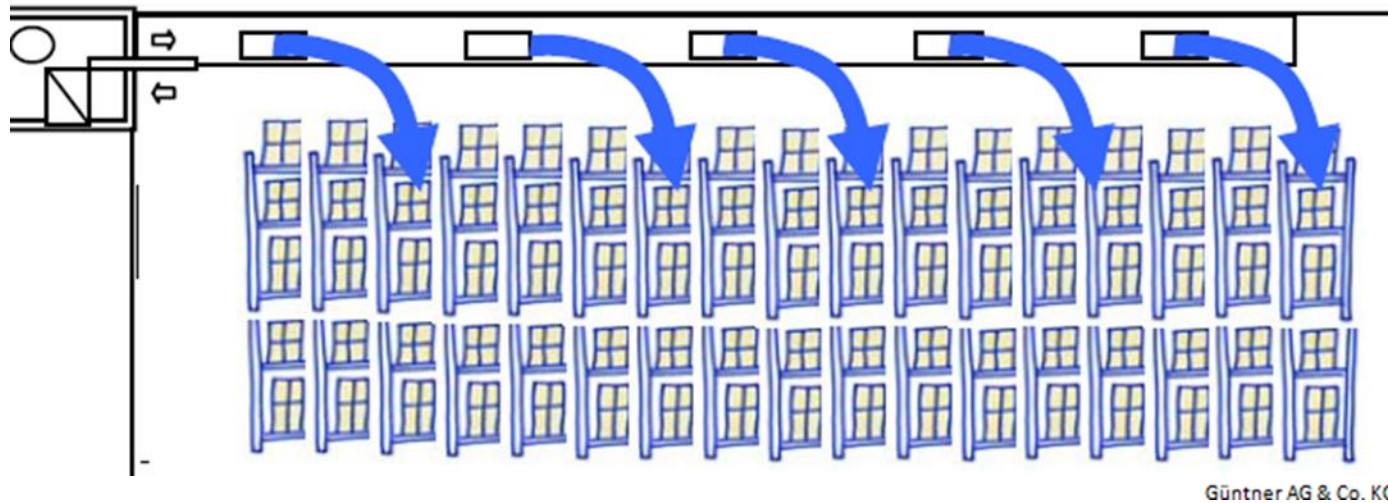
# Air cooler with ducts

- The benefit of this system is that it provides good air distribution because the ducts guide the air exactly where it is most needed.
- However, the distribution ducts occupy room within the refrigerated space, which could be used for pallets, as well as carry higher investment costs.



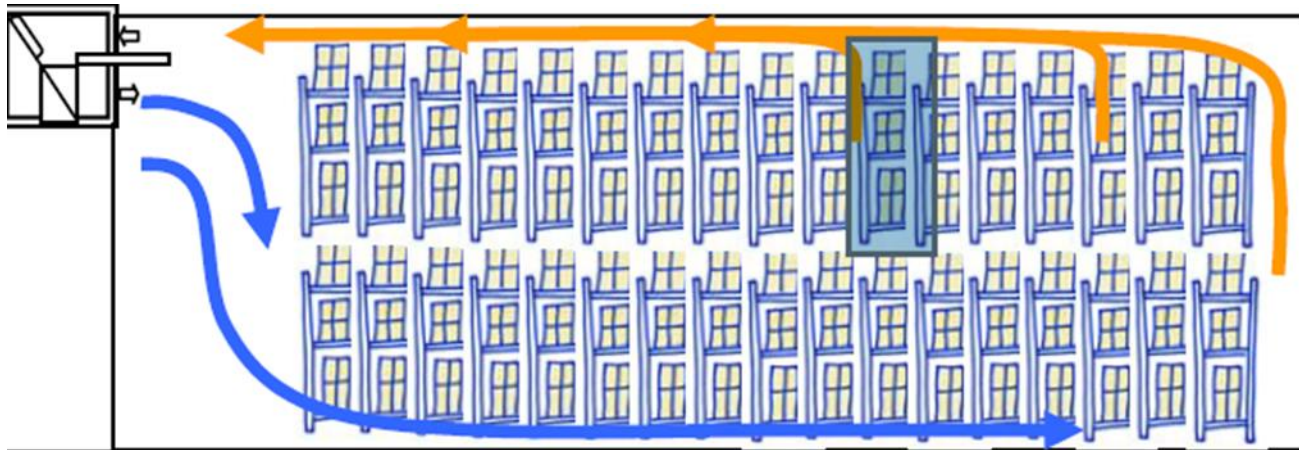
# Air Cooler with ducts

- When the air cooler is located in a insulated external storage area, it enables more pallets to be located within the refrigerated space and enables greater accessibility for servicing.



# Insulated unit air cooler without ducts

- This is an air cooler without air ducts, but one where air circulation is supported by thermal activity.
- In contrast with the other types, air enters from above and comes out below.
- The design distributes air via a *cold air lake* (via natural convection).
- As the walls and product heat up the cold air, the warmer air rises to the top of the room and flows in a small layer under the ceiling back to the cooler.

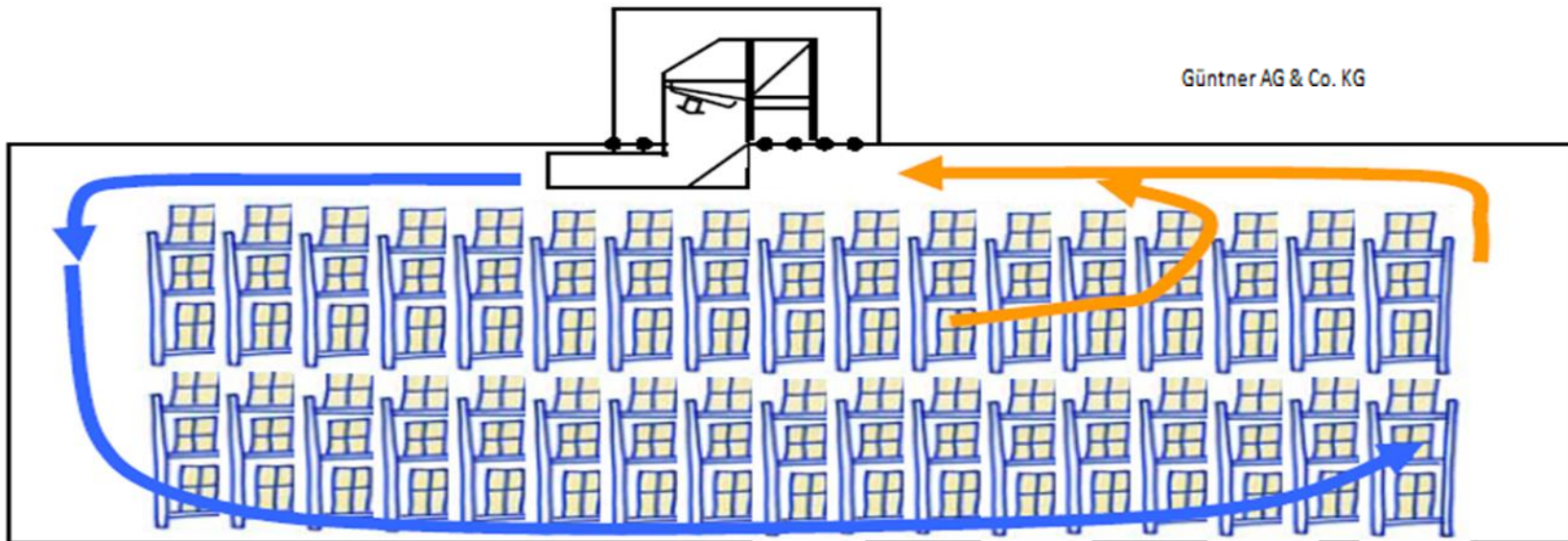


Güntner AG & Co. KG



# Penthouse cooler

- The air cooler is located outside the storage area on the roof, permitting high space utilization.
- This design provides good accessibility for service; no service personnel need enter the refrigerated warehouse.





# Modular Curtains

- In a cold storage environment, reconfiguring space is not as simple as in a conventional warehouse, as temperature is a factor that must be taken into account. Different products require different temperatures (e.g. vegetables 10C, dairy products 1C , fresh meat -2C, ice cream -23C) or the mix of product may vary according to the season.
- Use of modular curtains (flexible fabric curtains) that can be easily installed, dismantled and reinstalled provide more flexibility and adaptability than permanent solid walls.



[www.randallmfg.com](http://www.randallmfg.com)

# Air curtains

- It is critical to conserve cold air.
- Every time a door is opened, and interchange with warmer air takes place, which increases the temperature of the cold zone.
- By forcing a continuous stream of air over the entrance, an air curtain creates a barrier across the doorway, creating a seal between two temperature zones, thus keeping the chilled air inside the cold store and the warm air out, effectively reducing the load on the refrigeration equipment and energy consumption,
- The air current moves at such speed and angle that is able to push back the warmer air that tries to penetrate the space

www.airinmotion.nl



- Curtain efficiency in preventing air infiltration oscillates between 60% and 80%

# Rapid Closing Doors

- Slow doors allow warm air spikes to enter the cold storage facility.
- Many cold storage facilities use rapid closing doors.
- With speeds upto 120” per second, another way to enhance temperature control and minimize temperature variations, is through use of high-speed/rapid roller doors.



[www.americandoorworks.com](http://www.americandoorworks.com)

# Automated Storage and Retrieval Systems

- The use of automated storage and retrieval systems is an effective way to control warm air from entering the cold zone or expensive cooled air from escaping.
- This type of automation allow for the pallets to pass in and out through a small opening, which is then sealed once the products have passed through, effectively minimizing the amount of warmer air that enters the temperature controlled area.



[www.westfalia.usa.com](http://www.westfalia.usa.com)

# Small rooms

- Small rooms a good option for storage of fruits and vegetables.
- Vegetable and fruit storage rooms require periodic cleaning and small rooms offer more flexibility.
- Once harvested, fruits and vegetables continue to generate chemical reactions that consume oxygen, generate heat, release carbon dioxide, water and ethylene.
- Certain fruits are not compatible. One must take into account optimum temperature, relative humidity ethylene production levels and tolerance, as well as odour.



Global Cold Chain Alliance



# Examples of non compatibility

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- Ethylene-sensitive vegetables (such as arugula, lettuce, cauliflower, celery) should not be mixed with ethylene-producing fruits and vegetables (such as apple, kiwi fruit, peaches, avocados, tomatoes), as this can lead to ripening and decay, resulting in changes in colour, flavour and texture.
- Odour transfers:
  - Avocado odour is absorbed by pineapple.
  - Green onion odour is absorbed by figs, grapes, mushroom, rhubarb and corn.
  - Odours from apples and pears are absorbed by cabbage, carrots, celery, figs, onions and potatoes.



External browning on lettuce caused by carbon dioxide levels above 5%.



Ethylene yellowing of broccoli



Surface darkening of peaches caused by ammonia from a refrigerant leak.



Shriveling caused by excessive water loss



Skin cracking of apples kept near 100% relative humidity.



# Loading docks

- Product enters and leaves the facility through this area (the beginning or end of the supply chain).
- One of the most neglected areas in cold storage facilities.
- For good quality control, loading docks should be refrigerated.



# Use of vertical storing door levelers

- Designed to store in a vertical position completely inside the facility.
- The overhead doors open, followed by the inflatable dock shelter which automatically inflates.
- The platform descends onto the trailer bed, the aim being to eliminate air gaps, as the door can close completely to the floor.



[kelleyentrematic.co](http://kelleyentrematic.co)

[www.northerndocksystems.com](http://www.northerndocksystems.com)

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[www.mcdoorgroup.com](http://www.mcdoorgroup.com)



# Effects of the cold environment on equipment

- Constant exposure to the cold environment has a negative effect on batteries:
- The average life cycle of a battery on a fork lift truck can decline by 20% to 50%.
- An 8-hour cycle battery used in a conventional warehouse will only last 4 to 6 hours in the cold environment.
- Cold storage facilities tend to use longer lasting batteries such as 12-hour cycle ones, which taking into account the 25% reduction, the battery will last for a full 8 hour shift.



[www.bahrns.com](http://www.bahrns.com)



- Special consideration on product labels, such as barcode labels and rack labels.
- In the cold environment, conventional adhesives harden and labels will detach, leading to unidentified product placed in the racks or actual location being misidentified, which can affect the traceability system.
- Handheld devices used built with seals designed to withstand temperature changes from the freezer to the ambient conditions than can lead to condensation.



[www.scoop.it](http://www.scoop.it)



- Personnel working in the cold chamber are dressed for extreme cold.
- Use of gloves makes it more difficult to operate electronic equipment.
- The buttons on scanning devices designed for cold storage warehouses need to be big enough to be felt through gloves with touch screens being sensitive to respond to the gloved touch.



[www.kenoshanenews.com](http://www.kenoshanenews.com)

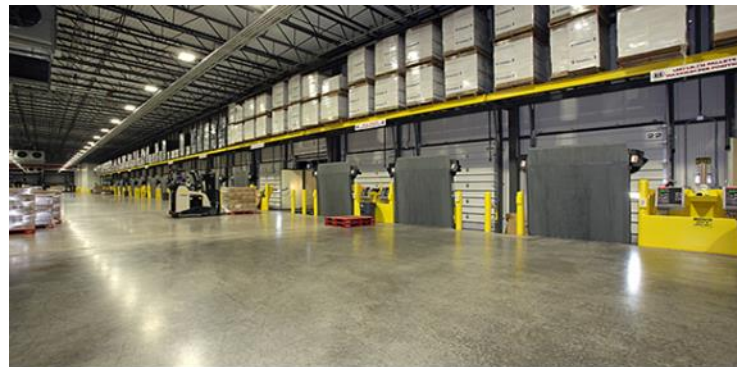


# Flooring

- The flooring in cold chambers should be the type able to withstand prolonged periods of low temperature without embrittlement.
- Cold environments pose challenges, whereby most repair materials become unworkable, there being a need to repair concrete in temperature above zero.
- This can lead to additional expenses when product has to be relocated and stored elsewhere to allow for repair work.



[www.concretemender.com](http://www.concretemender.com)



[www.concreteonly.com](http://www.concreteonly.com)



# Ice and Condensation



Merchandise



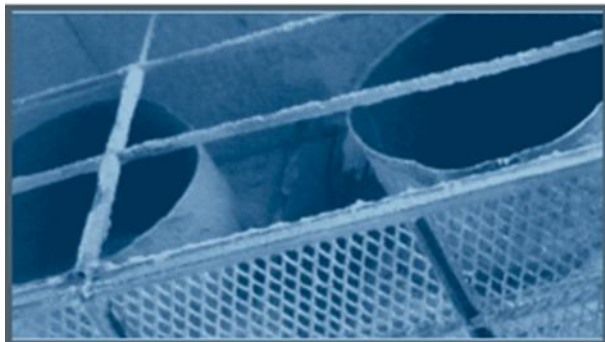
Roof



Walls



Floors



Evaporators



# Ice and Condensation

## Sources of humidity

- Points of entry into the cold chamber where doors or barriers are opened for too long or close too slowly.
- Inappropriately sealed doors or openings in the outer structure.
- Merchandise stored within the facility, particularly when packed with hydroscopic material (paper, cartons and wooden pallets., capable of absorbing or releasing moisture from the surrounding air.
- Personnel and equipment working within the facility .
- The level of humidity in loading areas where goods are in transition.

# Problems in the cold store facility caused by unwanted ice and condensation

- Melting ice or pooled condensation can damage the packaging of goods stored in the storage facility and may lead to growth of mould and bacteria.
- Humidity can condense on the strip curtains through which people/vehicles move product, which can lead to contamination of product entering and exiting the cold storage.
- Ice formation can lead to slippery floors , resulting in accidents.
- Ice can form on the barcodes of products, packaging and pallets, which can lead to falling labels or difficulties in scanning product.
- Ice prevents doors from closing properly.
- When levels of humidity are high in the cold working environment, personnel experience a colder and more uncomfortable than being in an environment with the same temperature but low humidity.
- Once ice has formed, it needs to be removed. Non-productive use of manpower, as well as additional energy consumption for defrosting of fixtures, fittings and refrigeration equipment. Evaporators will work inefficiently when they are iced up, leading to additional energy consumption.



# Mitigate

- Two fundamental approaches:
- 1. Once it has formed, deal with the problem by de-icing and defrosting.
- 2. Prevent ice and condensation from actually forming through humidity management.
- A) Prevent the actual entry of moisture into the refrigerated/frozen area.
- B) Use of dehumidifiers, aiming to bring humidity under control in order to prevent the formation of ice and condensation.



[www.drycogroup.com](http://www.drycogroup.com)

# Automation

- Use of automated and retrieval systems (AS/RS) is an effective way to reduce amount of warm air that enters the temperature controlled area.
- Despite a higher investment cost, the additional advantage of automated storage and retrieval systems is that they allow for use of high-rise facilities, (deep and tall designs) permitting storage of high volumes, maximizing the cube of the facility.



mmh.com

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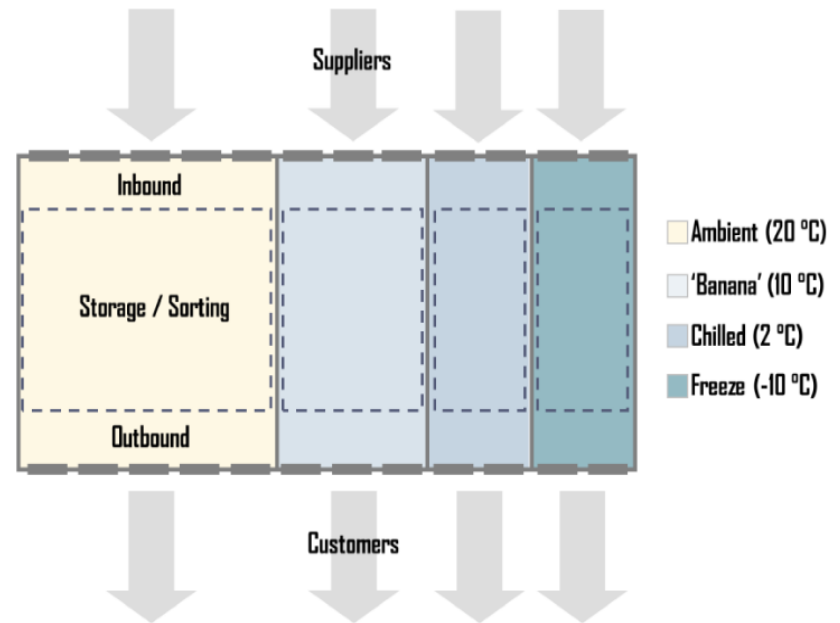


# Basic Necessities

- A cold storage facility must have continuous and reliable electric power supply, allowing the generator to maintain critical temperatures within the facility.
- There must be a continuous monitoring of temperature and humidity levels through use of automated alarm systems capable of detecting if the temperature or humidity falls outside the acceptable parameters.
- There must be gas detection alarms that will be activated if there is an ammonia leak, as well as fire sprinkler systems specifically designed for cold storage facilities.
- The emergency plan should address items such as an alternative source of power supply, repair facilities, independent contractors, availability of temporary cold storage sites, which can include staging empty reefer containers and/or trailers to move product to other facilities.
- With respect to ammonia leaks, evacuation routes must be planned and designated employees tasked with assuring proper evacuation and contacting emergency response personnel.

# Large Scale Grocery Cold Chain Distribution Centre

- A cold storage facility provides a buffer along the supply chain
- Within the warehouse, there must be several compartments of different temperatures to support specific cold chain requirements.
- **Cross docking facility:**
- Inbound loads, originating from local, national and international suppliers in many cases done by third party logistics operators.
- Outbound loads: Customized shipments bound to specific grocery stores in most cases by a fleet of reefer vehicles owned by the retailer.



Large Scale Grocery Cold Chain Distribution Center

Jean-Paul Rodrigue, PhD  
Van Horne Institute

Ambient: (20C) Non- perishable grocery products (pasta, bread, canned goods).

Banana: (10C) Applies to whole range of products: bananas, fruits, potatoes, onions.

Chilled: (2C) dairy products, meat.

Frozen: (-10C) ice cream, prepared meals (e.g. pizza), frozen vegetables, meat and seafood

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