

## E355 : Cold Chain Management

# Problem 09

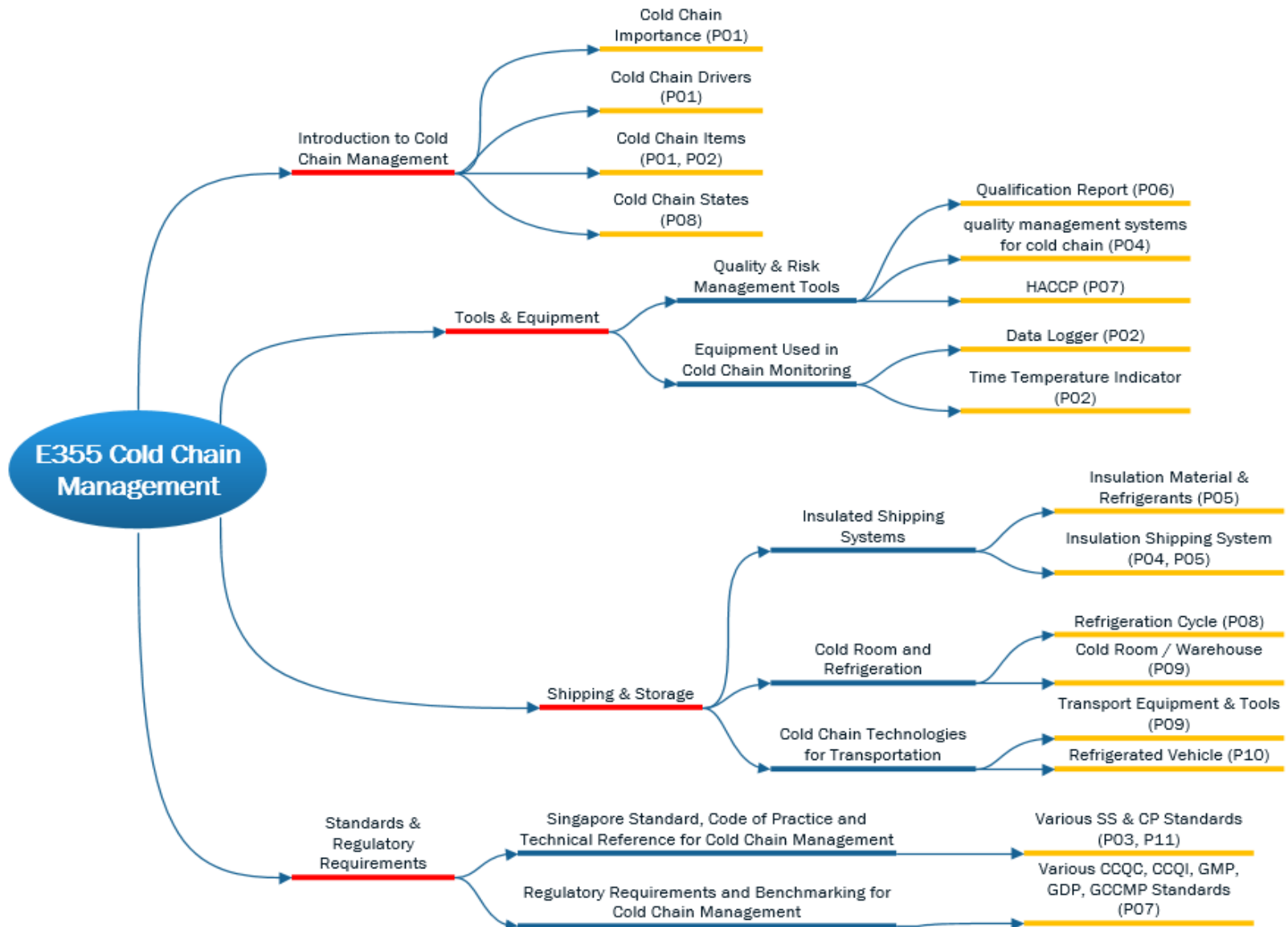
## New Cold Chain Facility

- Typical layout / operations in a cold warehouse
- Maintenance performed on industrial refrigeration system
- Types of storage and handling systems available for cold chain products in cold rooms



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# E355 Cold Chain Management - Topic Tree



# Considerations of a Cold Storage Facility

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- Layout and Compartmentalization
- Doorway
- Loading docks
- Auxiliary facilities
- Health of Personnel
- Air Circulation
- Storage & Material Handling Equipment
- Refrigeration & Defrosting
- Control & Backup
- Safety Measures
- Other Energy Saving Aspects



# Warehouse Grounds and Building



- Warehouse should be ideally located away from potential environmental hazards
- Roofs, walls, ceilings and floors should be smooth, clean and maintained in a good state of repair to prevent cross contamination.
- Windows and doors should seal tightly to prevent entry of pests
- No dead spaces around equipment or other structures that would provide harborage for pests and prevent efficient cleaning



# Compartmentalization and Food Storage

- Food items should be stored on pallets and at least 46 cm off ground and 46 cm off wall.
- Food items stored and rotated on a first-in-first-out basis.
- Food storage area should be clean and sanitary, and free from physical, chemical and microbiological hazards
- Storage area is divided into different compartments with different operating temperatures for different products
- Examples of the types of food stored at different temperatures include:

Storage Temperature	Products Stored
10 – 20 °C	Dry products, Transit area
1 – 4 °C	Fresh fruits, Dairy Products and Sauces, Vegetables
-18 °C	Frozen meat
-22 °C	Premium ice-cream

# Layout considerations

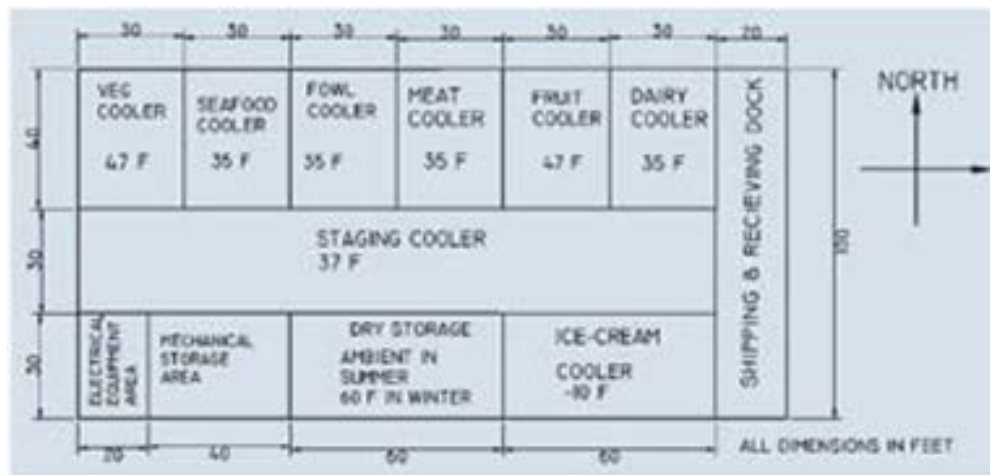


Figure 1 : Original layout block plan.

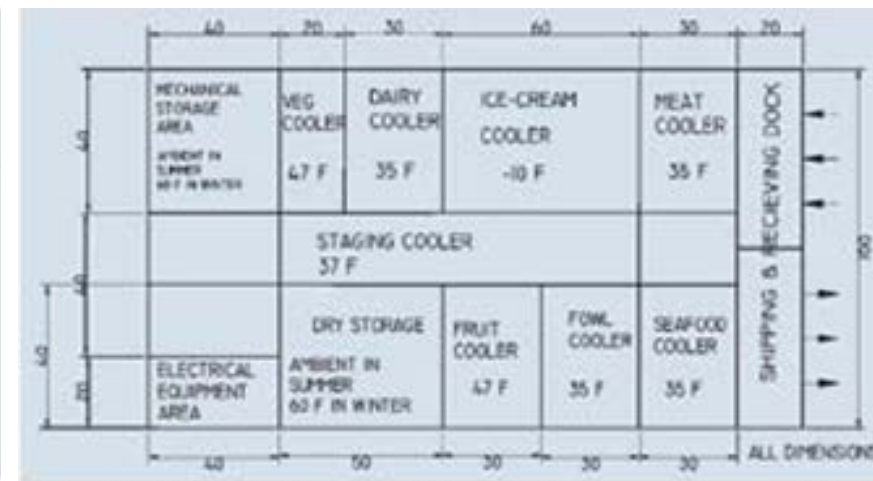


Figure 2 : Modified layout block plan.

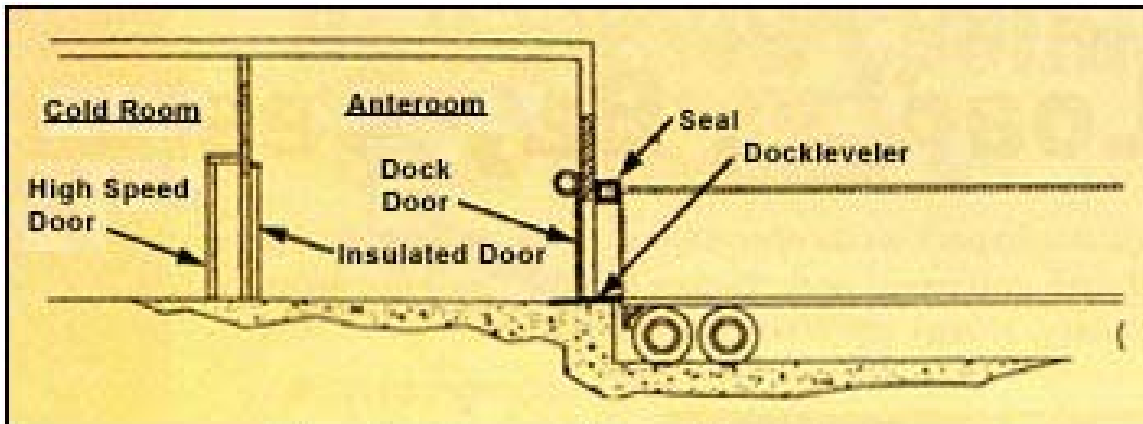
Source: [http://www.ishrae.in/journals\\_20042005/2005july/article06.html](http://www.ishrae.in/journals_20042005/2005july/article06.html)

- Machine and electric room were shifted to West end to help shield the cold rooms from direct exposure to the West side
- The low temperature ice cream room was shifted, so that it was sandwiched between two rooms.
- Cold rooms with large turnover were shifted near the loading area to reduce movement of goods.

# Ante-room



- The anteroom separates the cold room from the loading bay
- It is an intermediate area providing an airlock to prevent air infiltration and minimize the unnecessary load on the cooling units of the storage areas in terms of both heat and moisture
- Air-conditioning can be used as an inexpensive way to maintain its temperature at usually 20°C and 15% relative humidity
- Also serves as the shipping and receiving dock, and for staging purposes





# Doorway



- Door dimensions to the compartments must be in relation to transport, the type and size of MHE and the width of the traffic corridor, and the height of the pallet load
- Doors must be thermally insulated to the same extent as walls. Insulation is placed within a rigid frame which can withstand tough handling without distortion
- Doors must close tightly against the framework, exerting high-pressure on a dense elastic rubber-strip, which can be electrically heated to avoid ice accumulation
- With doors that are well-sealed, even in the event of power outages, quality of food that is stored inside the room can still be maintained for 6 hours





# Doorway



- Different ways of opening the doors (rotating on hinges, sliding horizontally or vertically); but it is important that the doors can close and open quickly
- Every time a door opens, an intense exchange of air takes place, leading to high heat and humidity loads in the compartment
- To reduce air exchange, flexible transparent plastic doors, transparent swinging doors or air curtains are used
- Number of doors should be kept to a minimum; should not be placed opposite each other, and face away from prevailing wind



# Doorway Effectiveness



- Air curtains and strip curtains are commonly used in cold rooms to improve its effectiveness as they help reduce air infiltration due to frequent door openings. This is a good energy-saving measure.
- Fan operated air curtains are expensive and work on electrical power whereas strip curtains are cheaper and need no energy for operation.

## Effectiveness in blocking the air exchange

Strip curtain	82-94%
Vertical air curtain	49-80%
Dual horizontal air curtain	65-78%
Fast sliding doors	78-93%

Values taken from:

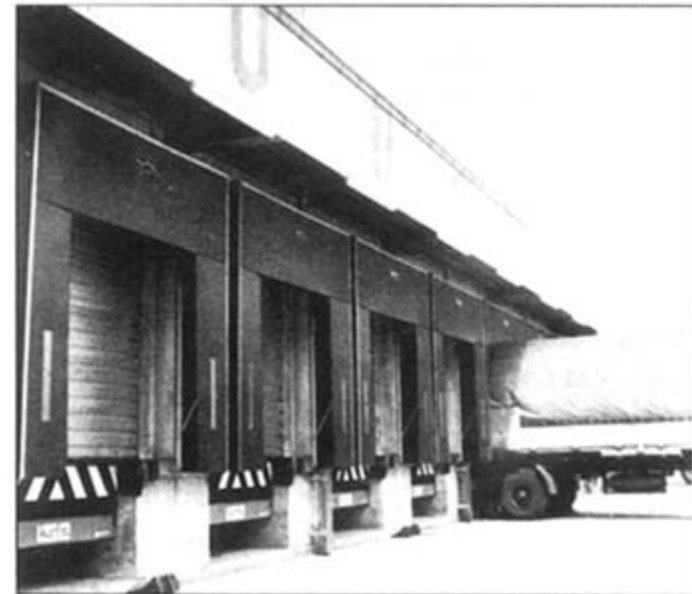
Downing, C.C., W.A. Meffert, 1993, "Effectiveness of cold-storage door infiltration protective devices," *ASHRAE Transactions*, vol. 99, part 2, pp. 356-366.



# Loading Docks



- Loading docks and dock levelers ease the handling of goods from the stores to the transport vehicles, and its height is determined by the vehicle that the operator utilizes
- To prevent cold air leakage, dock doors should be equipped with a perimeter cushion seal to adjust the rear of the truck to the loading door
- Some docks have power supply that are used to provide electricity for the reefers



# Auxiliary Facilities

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- Every space inside a cold store is expensive; hence auxiliary facilities such as offices, toilets, pantry, worker lockers, packaging store must not be located within the cold compartments
- Electric charging points and parking area for MHE are located outside of the cold compartments, as they are sources of heat generation

# Health & Safety of Personnel



- Working in cold rooms, particularly at temperatures below zero, demands a high physical and mental standard of personnel
- Protective clothing providing sufficient thermal resistance should be worn while working in cold environments; but it should not be so thick or heavy that it hinders work
- Heated & well-ventilated rest rooms for personnel to restore their physical and mental capacity should be provided with proper planning for their working hours
- A guide will be that a staff cannot work inside a  $-18^{\circ}\text{C}$  room for more than 30min consecutively
- Cold room staff must work in pairs to look out for each other



# Storage & MHE



- Pallet racks are the most common type of storage equipment in cold warehouses because of the ease in handling and increase in storage density
- Material of resistance to cold temperature and humidity must be chosen for these racks
- Despite a trend of total automation such as using ASRS for stock control, electric forklifts and reach trucks are still the most common MHE being utilized
- The trucks must be modeled for cold operations, e.g. the material must withstand coldness and wetness, the truck must be sealed such that the transmission fluid will not be affected by the coldness, and contain heating element within the machine





# Refrigeration System



- The refrigeration system in a cold warehouse is usually a vapor compression system comprising the compressor, condenser, evaporator, air cooling units and associated piping and controls
- In smaller cold rooms and walk-ins the practice is to use air cooled condensing units with seal, semi-sealed or open type compressors
- Refrigeration systems have to be built as per proper specification to ensure that refrigerant leakage does not occur. It is essential to have proper emergency measures in case of any accidental leaks





# Maintenance of Industrial Refrigeration Unit

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- Periodic check-ups may cause disruption in the daily operations, but the costs of not doing maintenance far outweigh the costs of the disruption

## 2 types of check-ups –

1. **Preventive Maintenance:** the annual, pre-scheduled service, where all or part of the components of the refrigeration unit are tested, inspected or replaced by the service technician
2. **Predictive Maintenance:** the service technician walks around the refrigeration unit and look for anything unusual, such as condition of the insulation, vibration eliminators, worn couplings, equipment cleanliness, and may include analysis and testing

# Condenser & Evaporator Maintenance



- An inspection of the condenser coils and cleaning if necessary, as they are a key cause of pressure and temperature problems
- A dirty condenser is also very inefficient in transferring heat, which means equipment will have to work harder & longer to achieve the same cooling effect



- Evaporator coils in cold stores need to be kept clean and free of frost, as heat transfer is reduced when ice grows on pipes and air flow is obstructed

# Types of Defrosting Systems

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Frost formation on evaporator coils due to sub-zero evaporating temperature is inevitable, timely defrosting of coils is important as the frost build-up reduces heat transfer and affects the plant capacity

- **Water defrosting** – achieved by spraying water on the evaporator by means of tubes above it; simple but inefficient
- **Hot gas defrosting** – a more complicated process which re-circulates the hot refrigerant vapor discharged by the condenser; highly efficient and recommended for high-capacity installations
- **Electric defrosting** – involves provision of electric heating elements fixed in the evaporator coil section; although convenient, additional power consumption and maintenance problems are unfavorable factors

# Control & Backup



- Besides the refrigeration and defrosting cycle, other controls which are also incorporated include:
  - Dehumidifiers are required to maintain relative humidity and control fluctuations
  - Temperature loggers are mounted inside the cold compartments and will trigger an alarm once the temperature falls out of range
- Backup and alternative generators, compressors, and dehumidifiers should be available in case of power outages, equipment breakdown, defrosting cycles
- Reefers are sometimes utilized as backup storage compartments

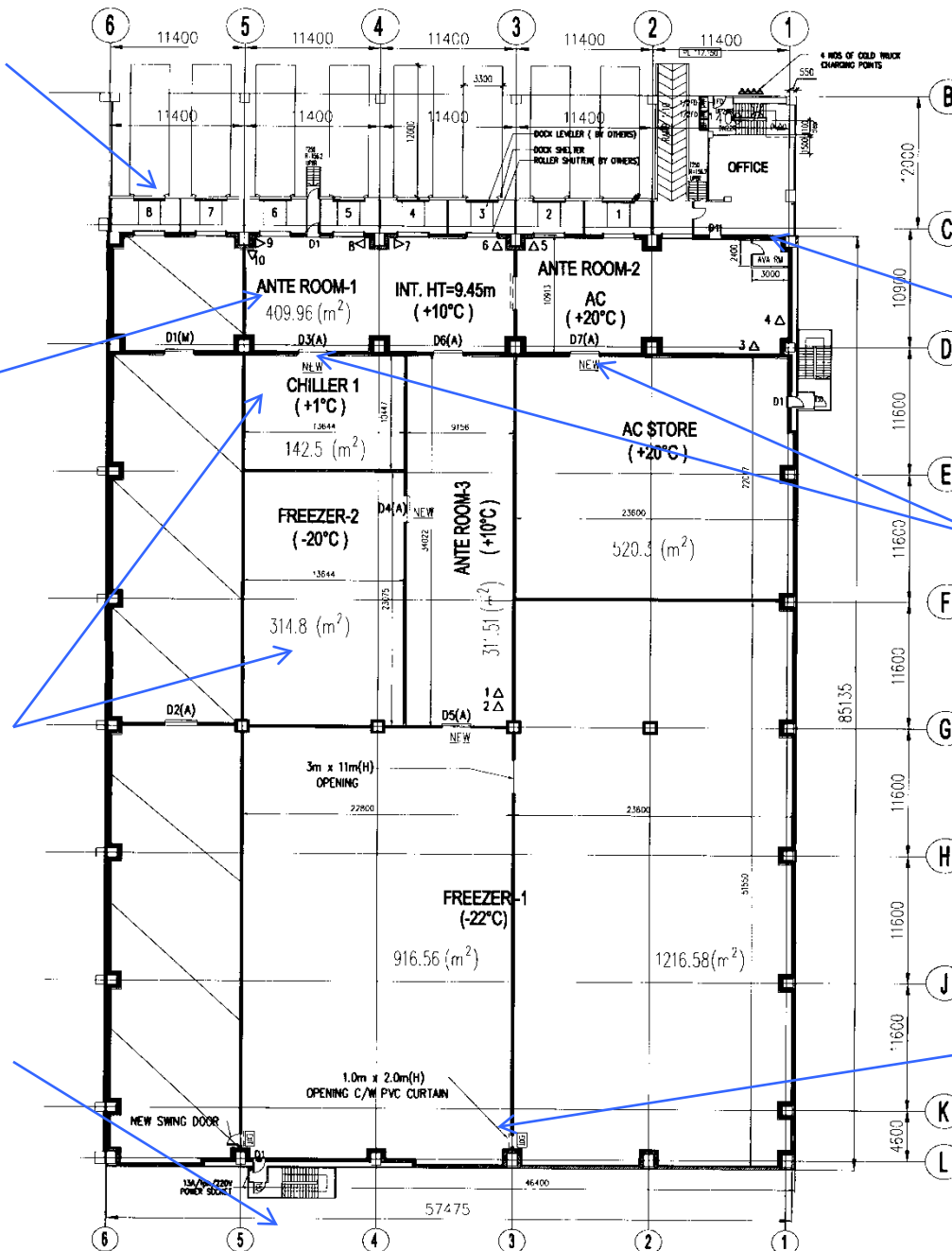


**Loading docks**

**Ante room**

**Different compartments with different temperatures**

**Possible location of backup compressors and generators**



**Auxiliary facilities – e.g. Office, MHE charging areas; can also be personnel rest area**

**Doorways**

**PVC Curtain**

**Suggested Warehouse Design**



# Doorway Effectiveness



Air curtains or plastic strip curtains are often used to minimize air exchange. Newer technology such as Air door is also available.



Strip Curtains/plastics strips



Newer technology: Air door

# Conclusion

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- The operations in a cold warehouse is similar to other warehouses except for the difference in temperature conditions.
- However, careful planning of layout of a cold storage facility is important to ensure energy efficiency and to avoid exposing to products to high ambient temperature.
- It is necessary to include an anteroom which will also serves as an enclosed loading / unloading area. The office must be outside the cold room.
- Doorway effectiveness using strip curtains reduces air exchange.
- Although MHE used at ambient temperature can be used, the battery life will be reduced at temperature.



# Conclusion

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- The main components used for big cold storage facilities (industrial refrigeration systems) are the same as that of a fridge (i.e. Compressor, Condenser, Evaporator, and Expansion Valves). The difference is in the types and scale of compressor, evaporator.
- Ammonia (R717) is widely used in industrial cold storage as it is energy efficient, cost effective and it has zero ozone depletion potential and very low global warming potential.
- Predictive and preventive maintenance are important for maintaining the industrial refrigeration unit.

# Learning Objectives

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- Explain how maintenance can be performed on industrial refrigeration system
- Identify the types of storage and handling systems available for cold chain products in cold rooms
- Explain the typical layout / operations in a cold warehouse and differentiate it from a general goods warehouse
- Explain the function of the ante room in a cold room
- Recognize that doorway to the cold room is the main cause of temperature rise and discuss the methods available to prevent this from happening