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Functions and construction of refrigeration system

Introduction



- Cold storage facility for perishable products under controlled conditions
- A cold storage unit incorporates a refrigeration system to maintain the desired room environmental conditions

Classification

- Based on storage conditions
- Short term or temporary (7-10 days)
- Long term (6-8 months)
- Frozen storage (years)

Types of cold storage

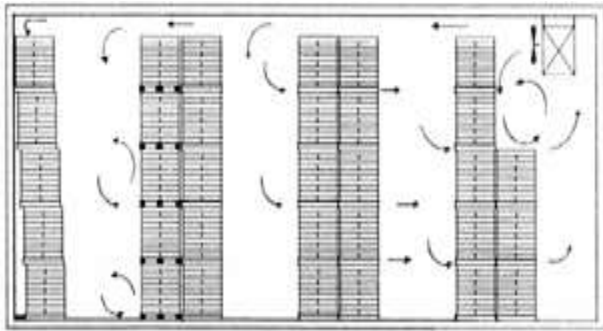


Figure 38 Uneven air distribution in a store with a unit-cooler with fan circulation

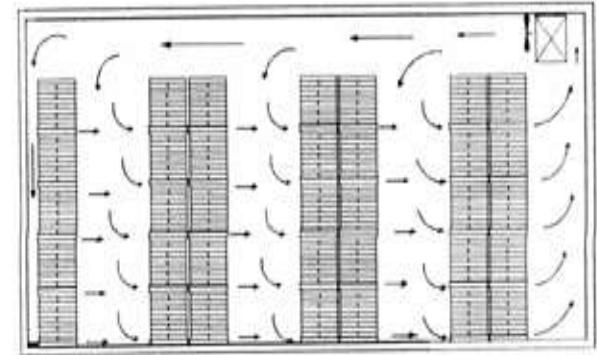


Figure 39 Cold store with suspended unit cooler and head space above pallet stacks

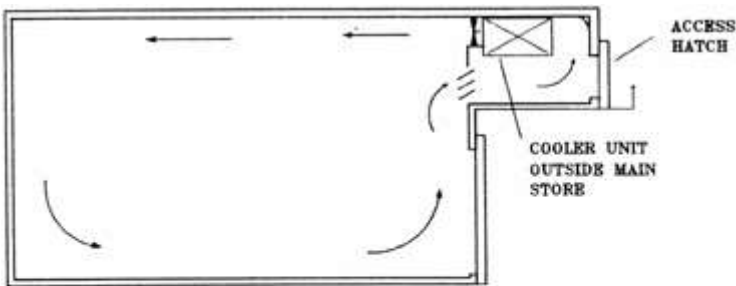


Figure 40 Cold store with cooler unit outside the main store.

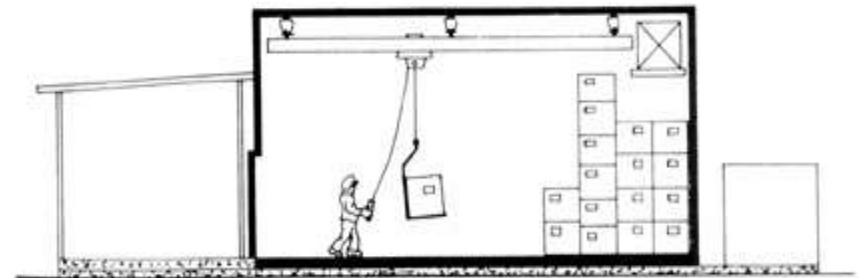


Figure 41 Cross-section of prefabricated cold store.

Specific considerations

- Uniform temperatures
- Length of air blow and impingement on stored products
- Effect of relative humidity
- Effect of air movement
- Controlling ventilation systems, if necessary.
- Product entering temperature
- Expected duration of storage
- Required product outdoor temperature
- Transportation in and storage area

Cold storage design

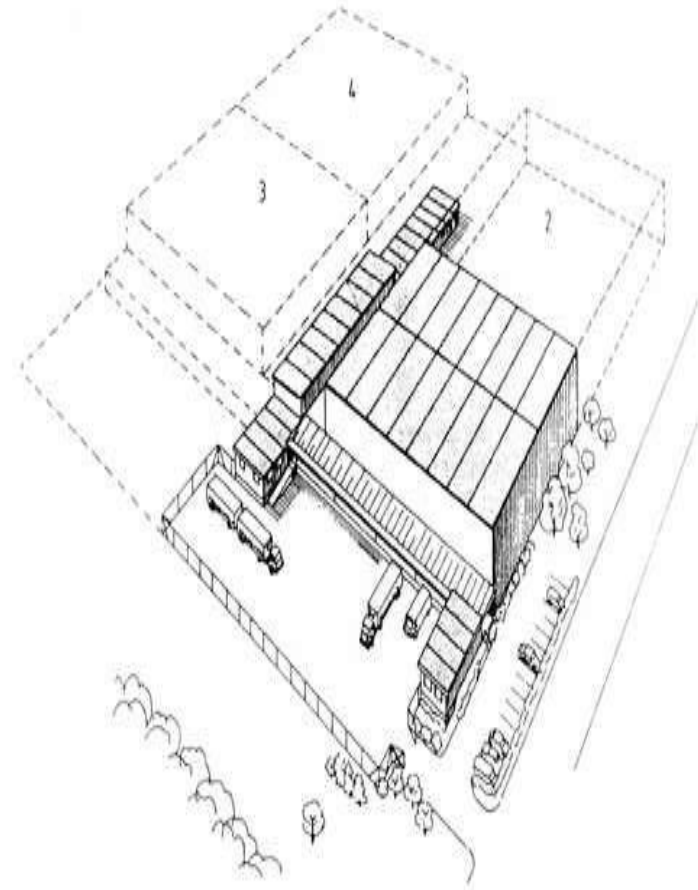
1. Selection of site
2. Orientation and building form
3. Size
4. Space requirement
5. Design of building
6. Thermal insulation
7. Refrigeration system for cold store
8. Heat Load calculation

Cold storage design (Contd..)

1. Selection of site

2. Orientation and building form

- ▣ N-S direction
- ▣ W-E walls should have good plantation
- ▣ Surface to volume ratio less



Cold storage design (Contd..)

3. Size

- Volume of product to store
- Product containers (boxes, hampers, buckets)
- Volume required per container
- Space for mechanical or manual operation
- Lateral and head space
- Available site space

Cold storage design (Contd..)

$$V = v(C+S)$$

Where,

- V is the total volume needs in cubic feet.
- v is the volume occupied by one product container in cubic feet.
- C is the maximum number of containers to be cooled at any one time.
- S is the maximum number of containers to be stored at any one time

Cold storage design (Contd..)

□ 4. Space requirement

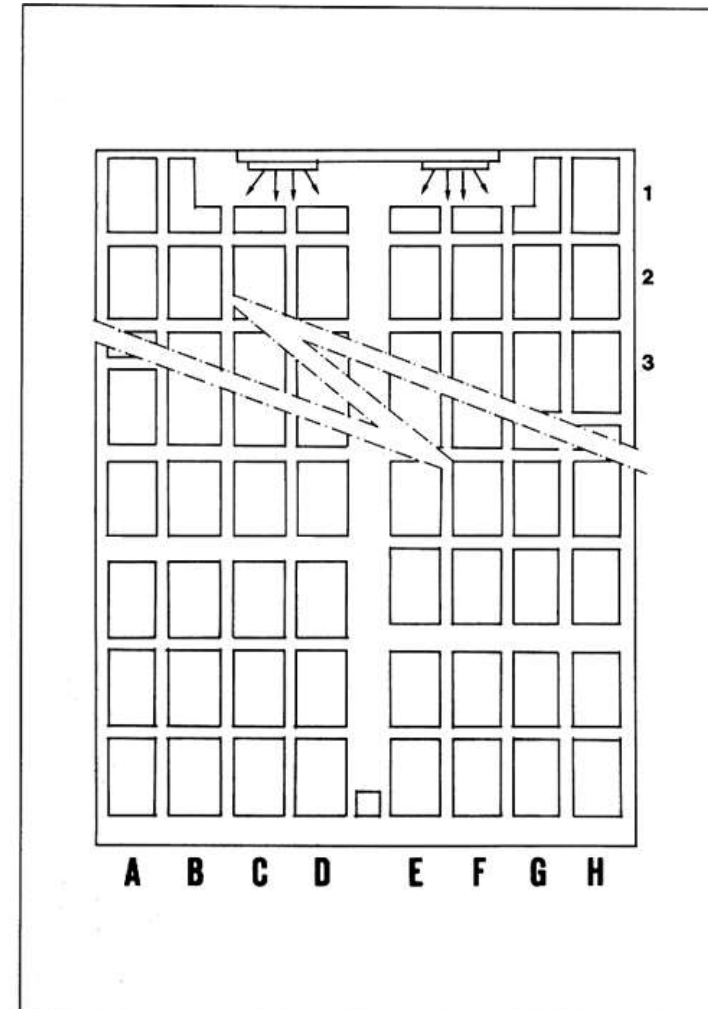
Storage space $3.4 \text{ m}^3/\text{ton}$ suitable for stacking and circulation of cold air (EIRI 2003)

Chamber height - 3 to 10 m

For loading and unloading distance between Rack & rack - should not $< 75\text{cm}$

Rack & wall - least 20-25 cm

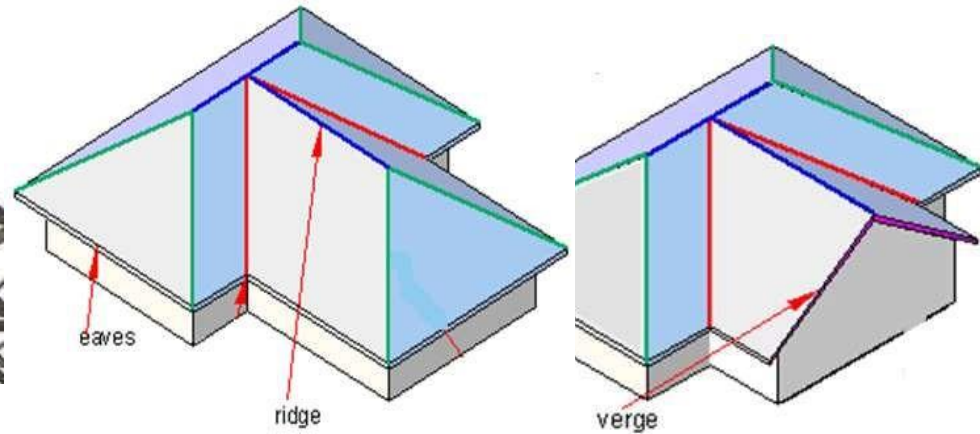
Ceiling & product shelf top - 30 cm



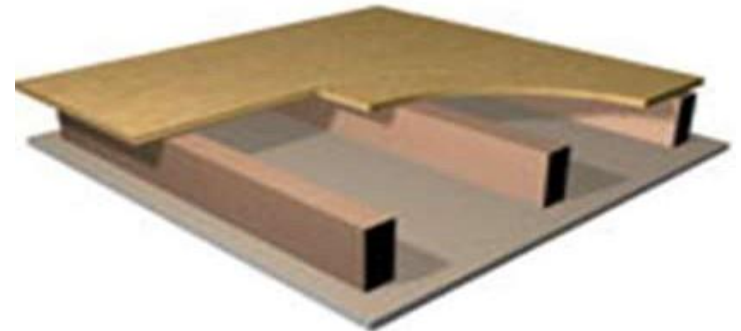
Cold storage design (Contd..)

□ 5. Design of building

□ Roof



□ Ceiling



Cold storage design (Contd..)

Floor
Ground load 5500-8000 kg/m
(FAO)

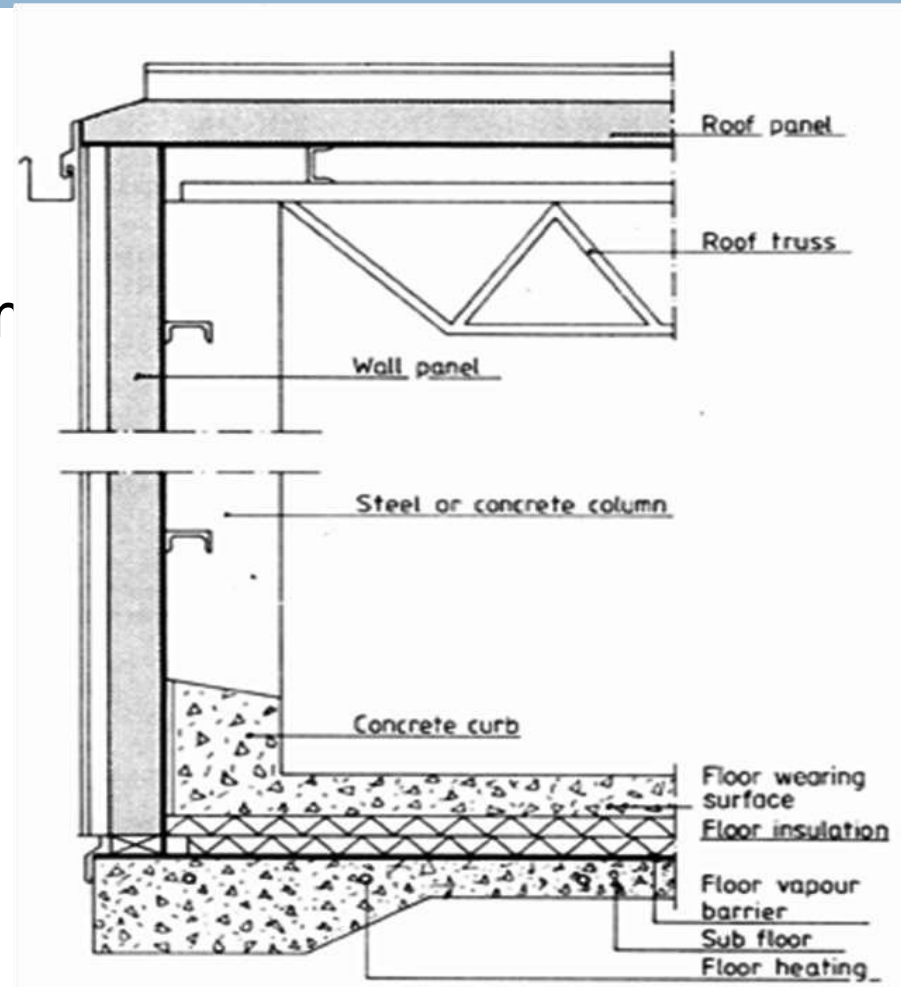
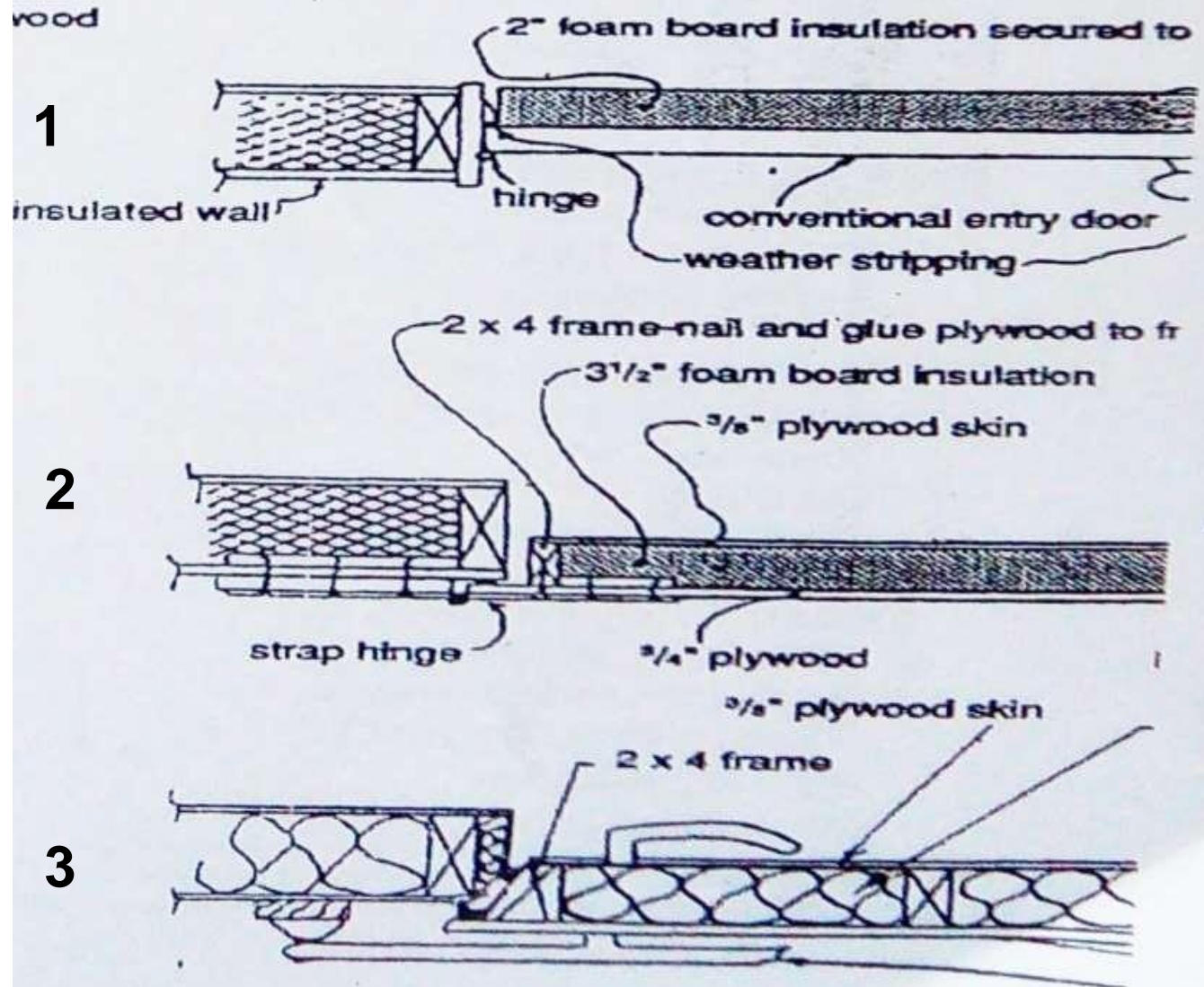


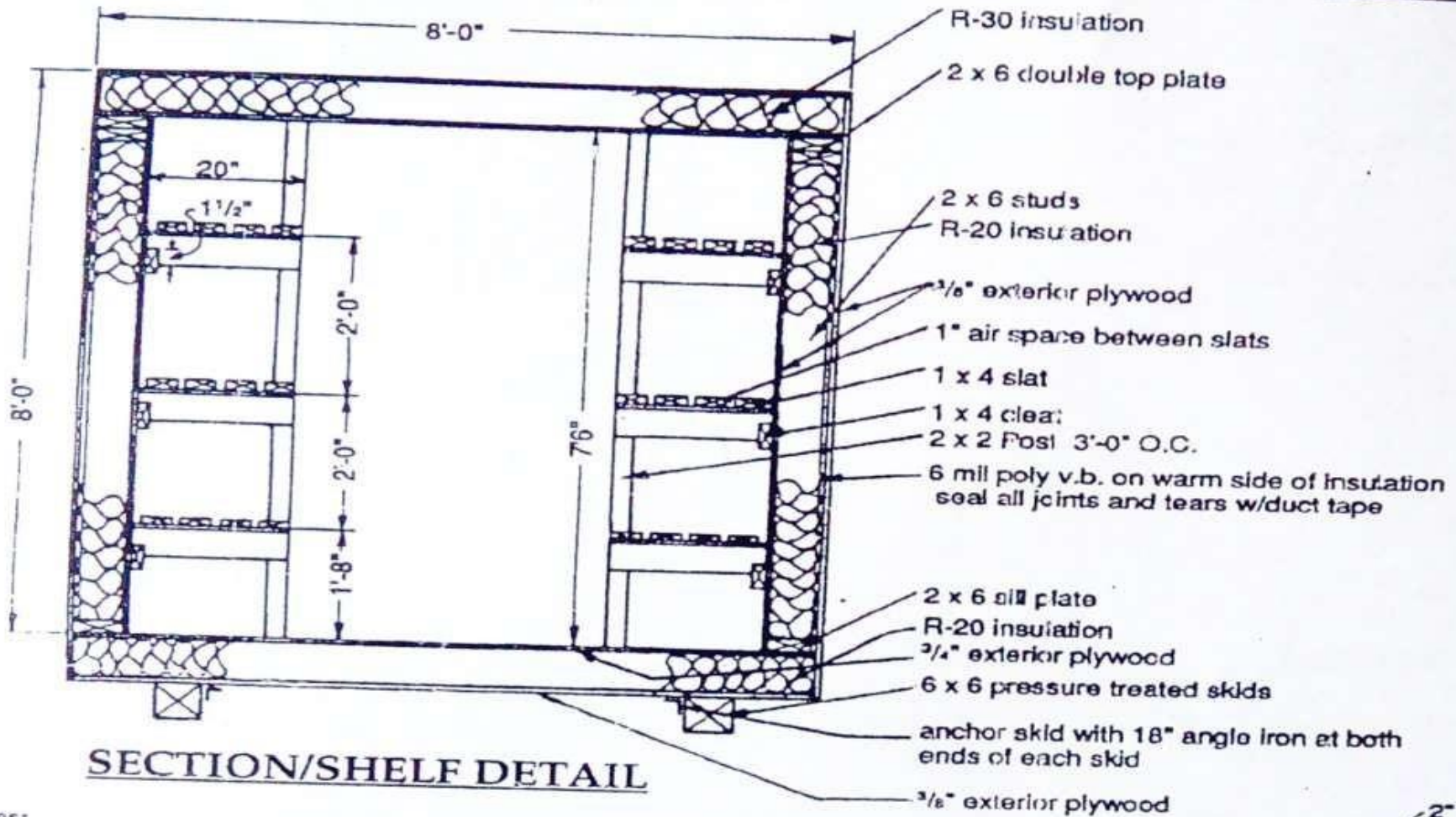
Figure 31 Panel-built cold store with internal structure

Cold storage design (Contd..)

Doors

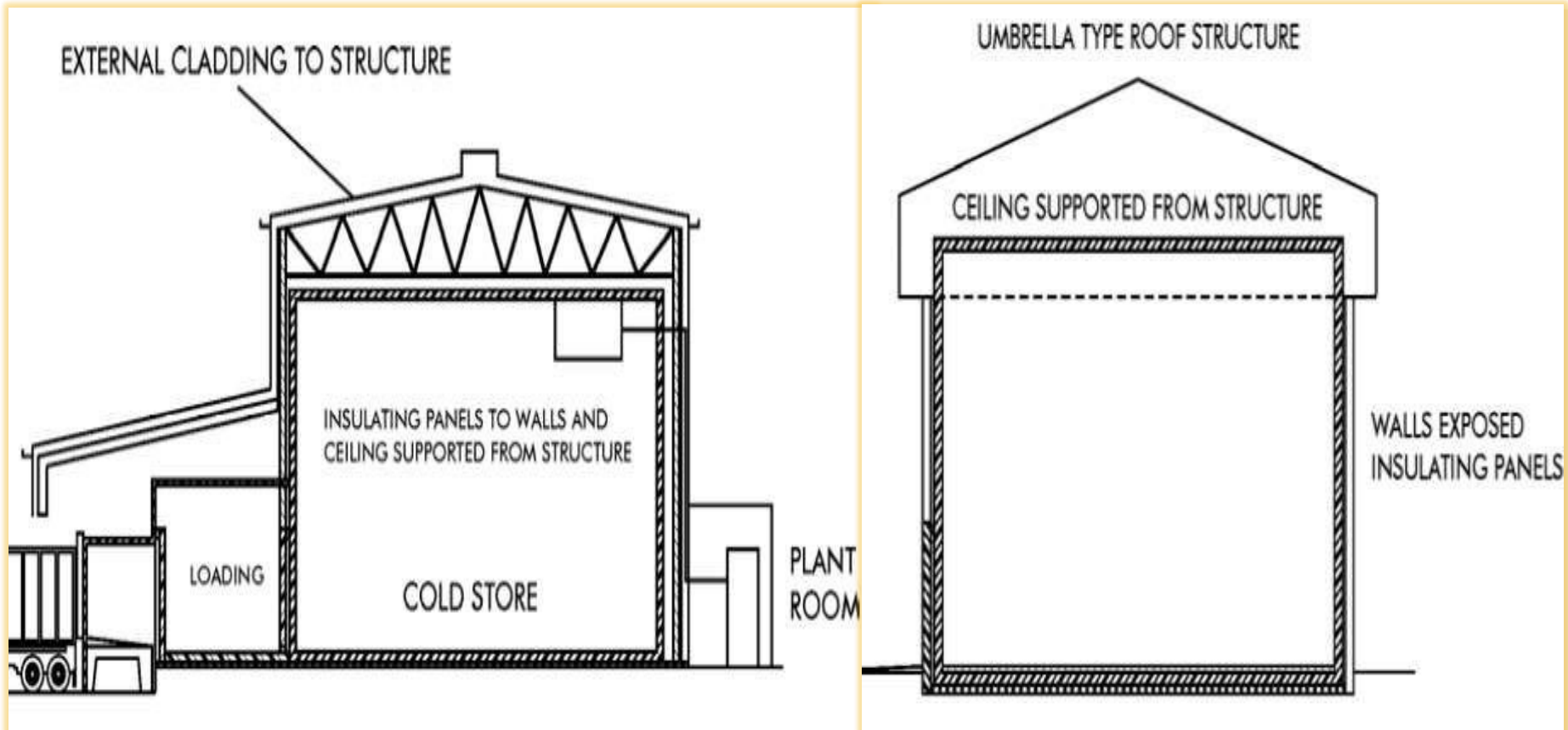


Shelf



Cold storage design (Contd..)

6. Insulation

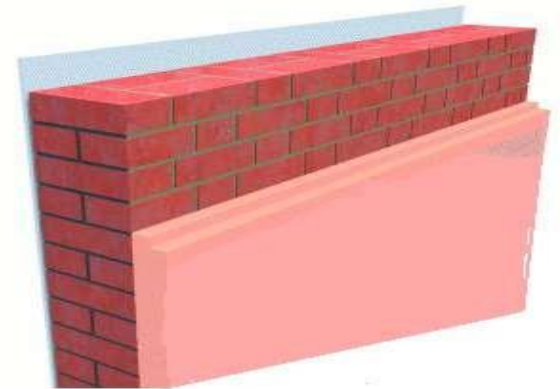


Cold storage design (Contd..)

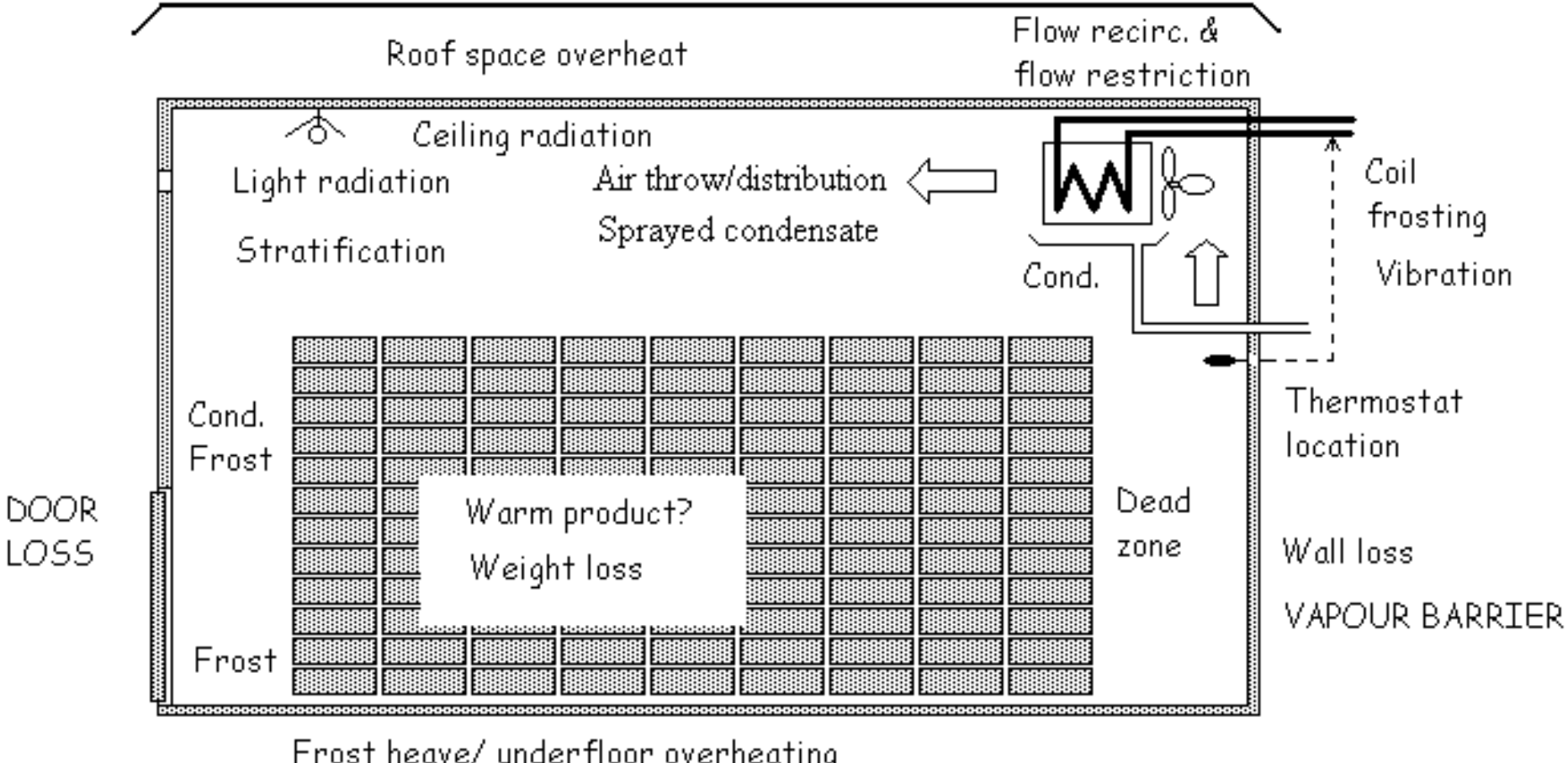
Insulating materials

Insulation	Calculated thermal conductivity (kcal/m h °C)	Thickness (mm)
Polystyrene	0.033	220
Styrofoam FR	0.030	200
Polyurethane	0.025	170

Polyisocyanurate Foam



Problems in cold store



Typical problems in cold store

Vapor Barrier

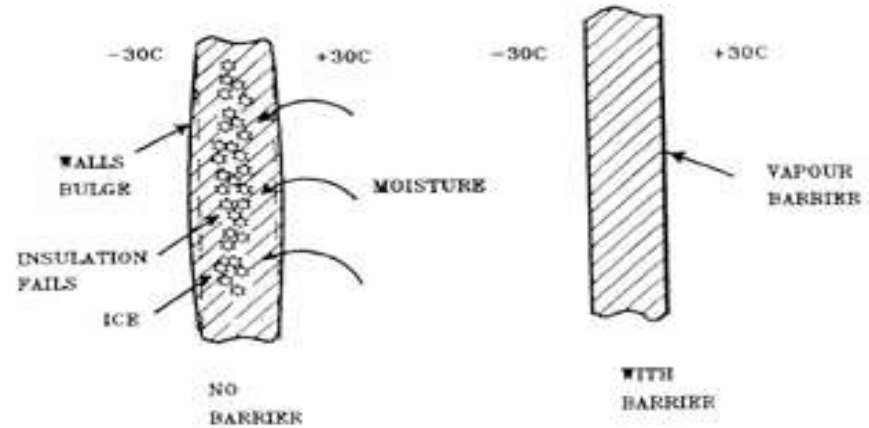


Figure 32 Diagram illustrating the function of a cold store vapour barrier.

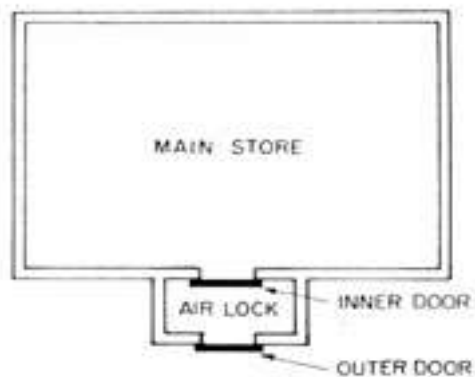


Figure 36 Illustration of a cold store air lock

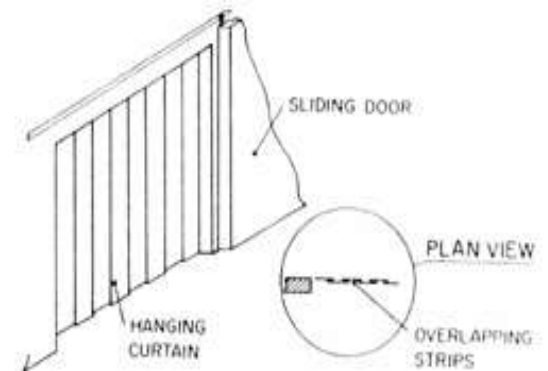
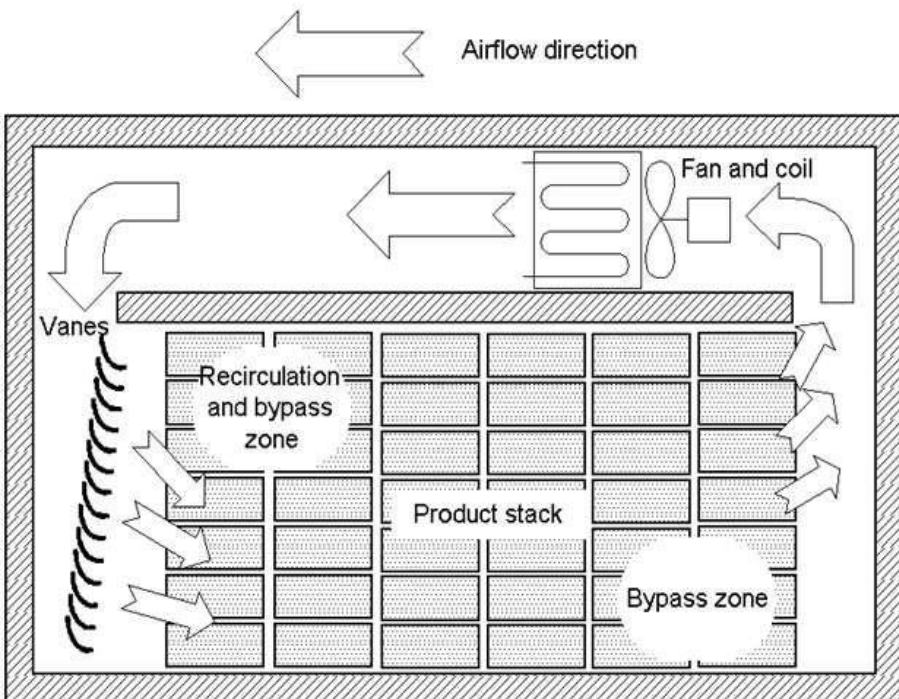
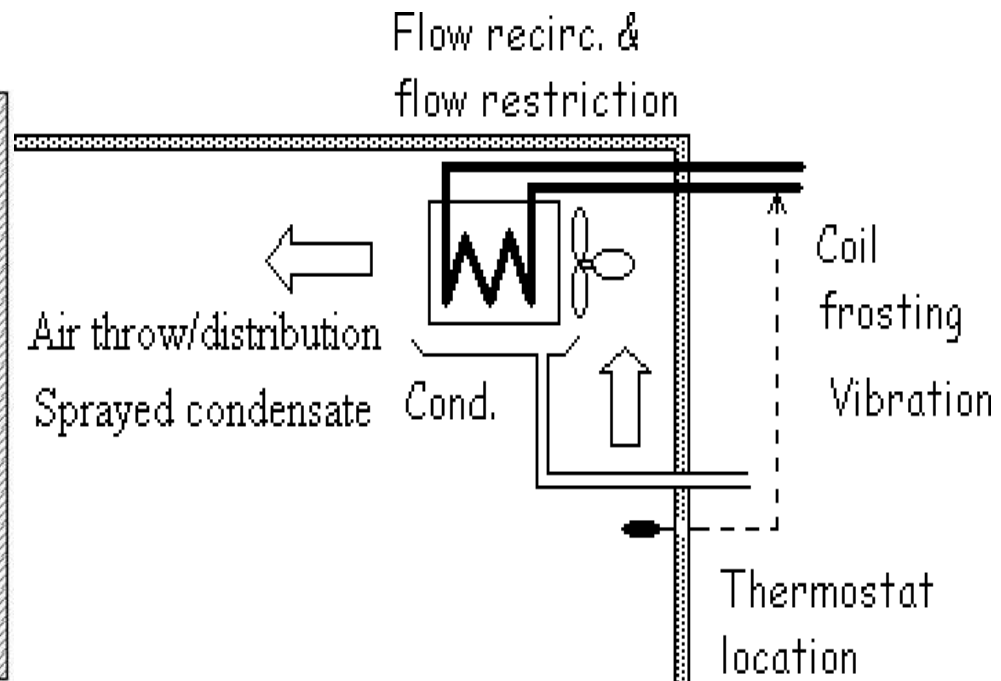


Figure 37 Inner curtain of flexible strips used to reduce air exchange

□ Air diffusion



Air Chillers/freezers



Cooling coils

Defrosting

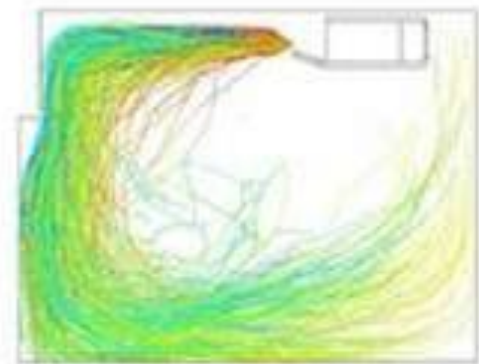
- Refrigerant below -3°C , deposition of frost



Fig 2. Frost on a duct of a refrigerating unit in a cold store

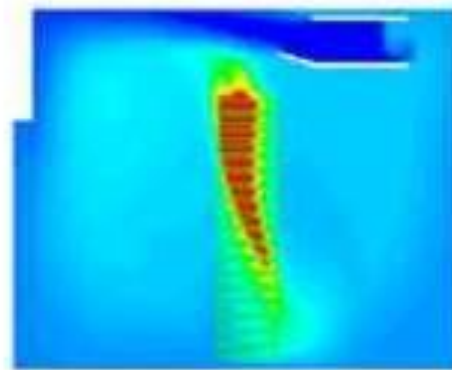
Monitoring

CFD of cool room including droplet tracks of humidification spray, temperature and humidity (taken with permission from Delele et al., 2008).



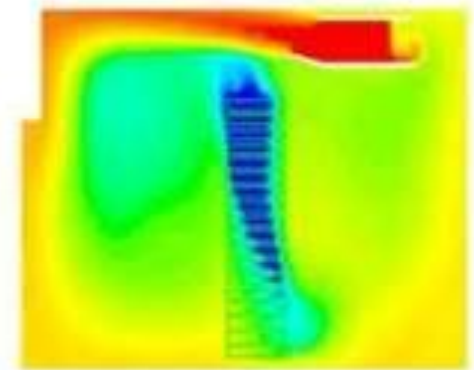
9 μm 70 μm

droplet size



-1°C 10°C

temperature



50% 95%

humidity

Refrigeration system

Vapor Absorption System

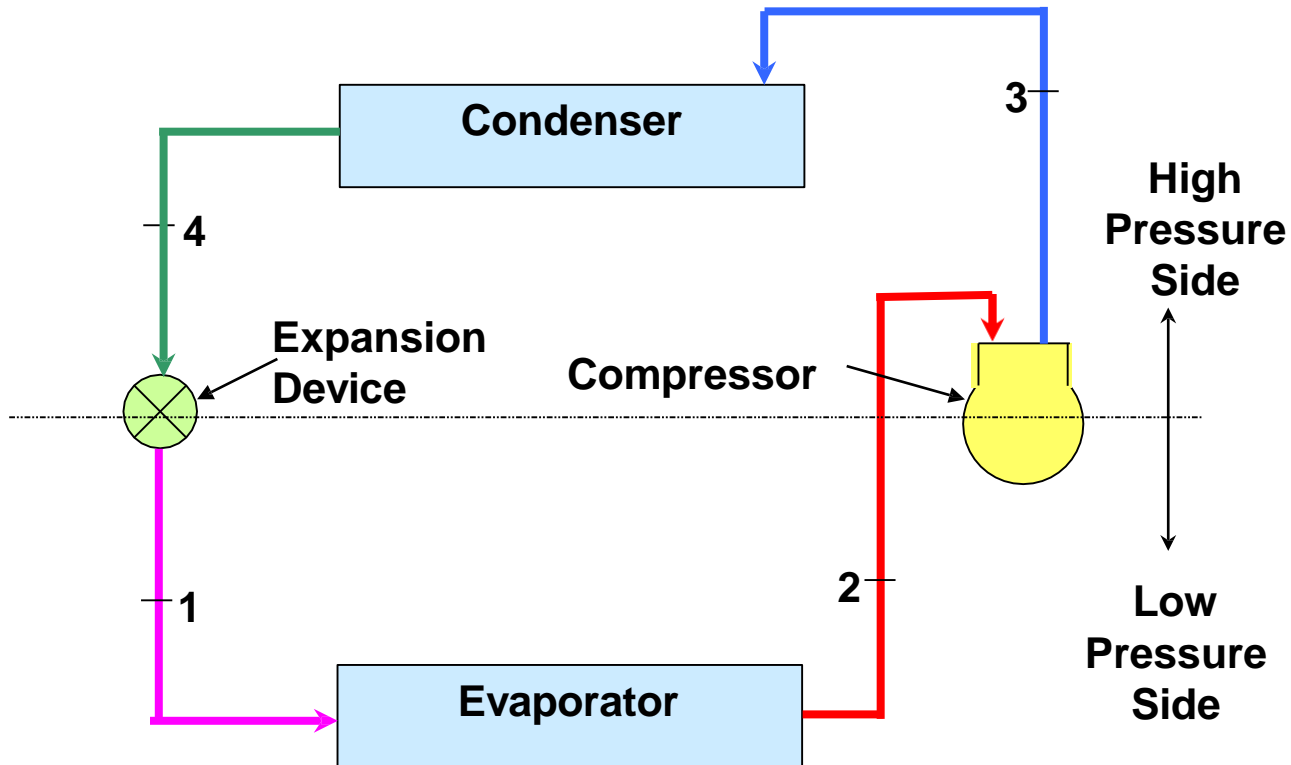
- Comparatively costlier but economical in operation
- Cannot be used for temperature below 10°C

Vapor Compression System

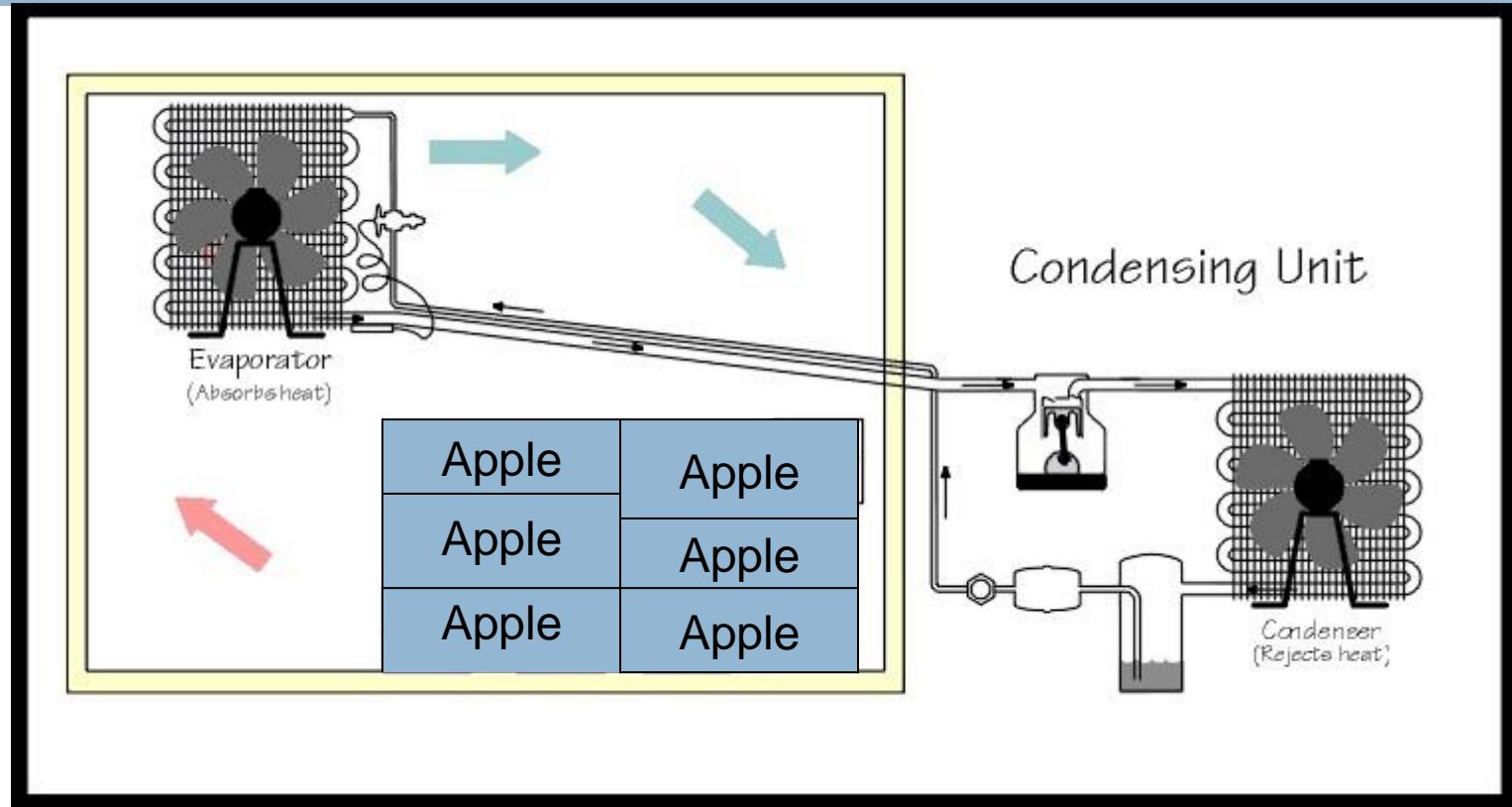
Comparative chapter than VAS

Characteristics	Diffusive VCS	Fin coil VCS	Bunker VCS
Height of storage room	Low	5.4	11.5
Economic status	costliest	5% costlier than Bunker	Cheapest Energy efficient

Refrigeration system VCS



Working



Source: <http://www.google.ca/search?hl=en&q=refrigeration+effect&meta>

Refrigeration cycle

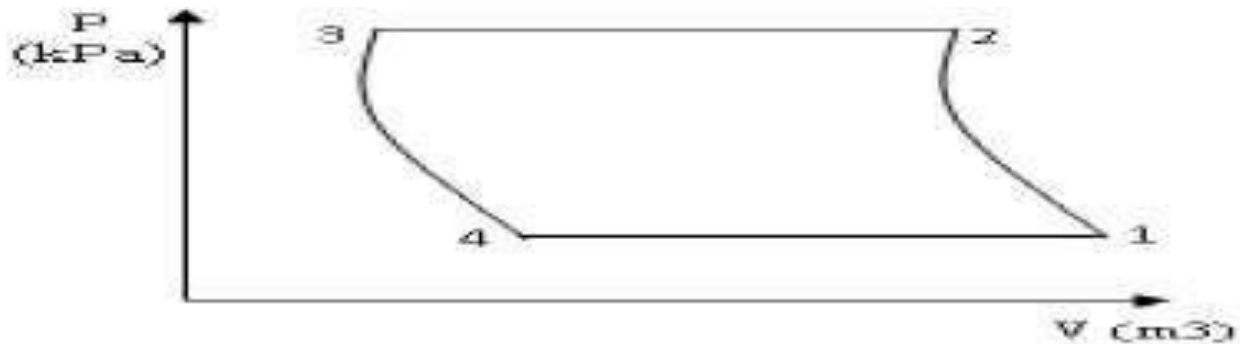


Fig.3 (a): Pressure-volume (P-v) diagram of the process

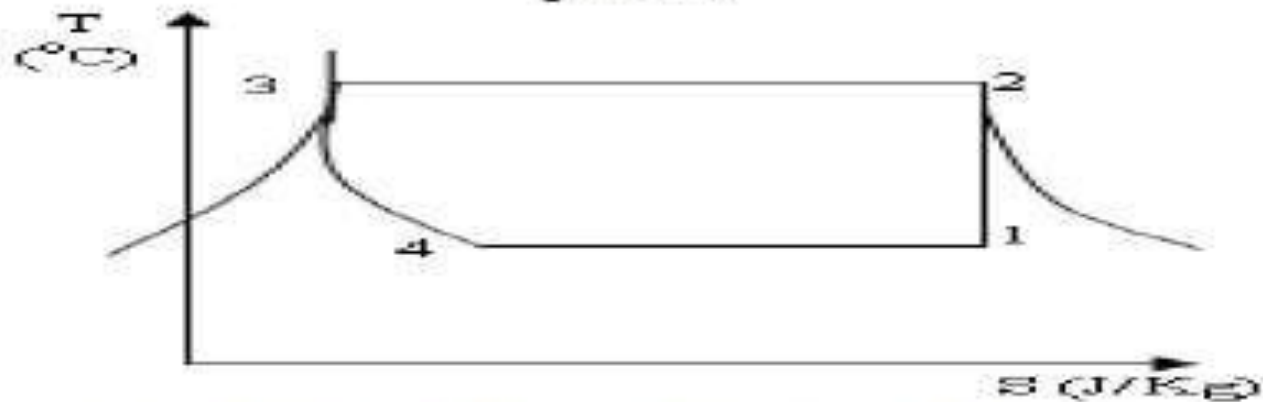


Fig.3 (b): Temperature-entropy (T-s) diagram of the process

Refrigerants

PRIMARY

- **Group I** -nontoxic and nonflammable
CFC
- **Group II** -slightly toxic and flammable
Inorganic R-717(NH₃), CO₂, Azeotropes
- **Group III** - highly toxic and flammable
Hydrocarbons

SECONDARY

Brine solutions, alkylene glycols

Selection of refrigerant

- Thermodynamic & thermophysical

- ▮ Suction pressure

- ▮ Discharge pressure

- ▮ Pressure ratio $\ln(P_{\text{sat}}) = -\frac{h_{\text{fg}}}{RT} + \frac{s_{\text{fg}}}{R}$ Clausius Clapeyron Eq.

$$\frac{P_c}{P_e} = \exp\left[\frac{h_{\text{fg}}}{R}\left(\frac{1}{T_e} - \frac{1}{T_c}\right)\right]$$

- ▮ Latent heat of vaporization

- Environmental & safety properties

- Economics

Refrigeration equipment

National codes of practice, insurance companies, as well as international recommendations

- (ISO R1662)
- (BS4434 1989/).

Flooded type evaporator

$$x_4 \cdot \dot{m} + x \cdot f \cdot \dot{m} = \dot{m}$$

$$\therefore f = \frac{(1 - x_4)}{x}$$

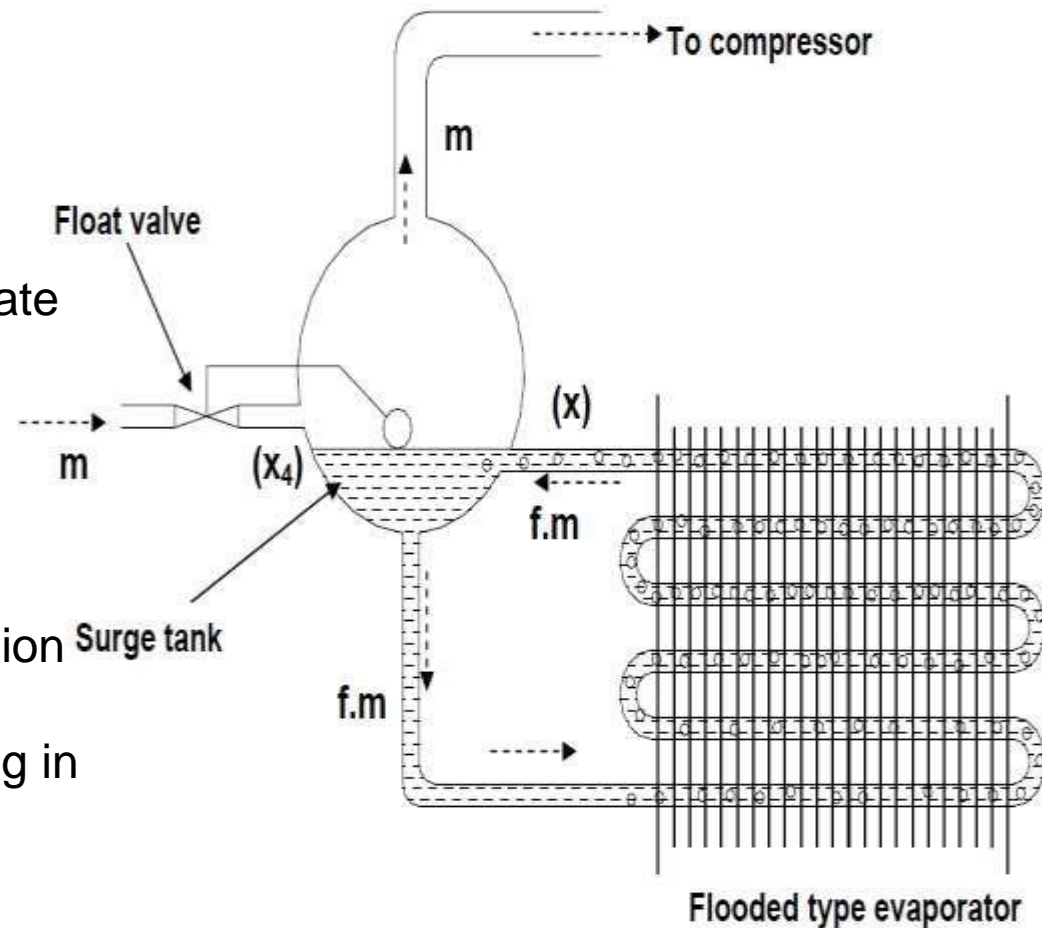
Where,

f.m = recirculation factor & mass flow rate in the evaporator tubes

m = mass flow rate through the expansion valve and to the compressor.

X_4 = quality of mixture after the expansion valve

x = be the quality of mixture after boiling in the tubes



Heat load calculation

- **Field heat:** heat required to reduce the product temperature at harvest down to the safe storage level.
- **Heat of respiration :** energy released by the product during the respiration process.
- **Conductive heat gain :** is heat gained/lost through the building floor, walls and ceiling by conduction.
- **Convective heat gain :** is heat that is transferred by convection, the mixing of outside air with the cold inside air.
- **Equipment heat load :** is the energy gained from equipment operating in the room.
- **Human energy load**

Heat load calculation

- Visual basic 6.0
- Heat transfer through wall ceiling & floor

$$Q = U A (T_o - T_i) \quad \text{kJ/s}$$

- Field heat $Q = \frac{m C_p (T_j - T_z)}{t}$

- Heat produced from lightning

$$Q = \text{Number of bulbs} * W * (UF) * (AF) \text{ kJ/s}$$

Heat load calculation

- Heat produced due to human occupancy

$$Q = n \cdot \text{Sensible heat gain}$$

- Heat given by power equipment

$$Q = \frac{\text{Power range of motor in hp} \times 746 \times 3.41}{\text{Motor efficiency}} \text{ kJ/s}$$

- Total refrigeration required

$$\frac{\text{Total heat removed}}{3.5}$$

3.5

1 Ton of refrigeration = 3.5 kJ /s