COLD STORAGE DESIGN

Dr. S. V. Kota Reddy
Academic President

Manipal Academy of Higher Education Dubai Campus
Dubai International Academic City, Dubai, UAE

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OUTLINE OF PRESENTATION

- *Introduction*
- *Factors Contributing to Food Spoilage*
- *Required Conditions in Cold Storage*
- *Design of Cold Storage*
- *Cold Chain Management*
- *Freezers*
- *Refrigerants and Equipment*
- *Conclusions*

INTRODUCTION

- ***In India around 40% of Fruits and Vegetables and 15% of Grains go as waste every year due to lack of Cold Storages – Post harvest loss - Rs 2 lakh Crores***

- ***India is the second largest Vegetable and third largest Fruit Producer***
  - ✓ Only 3 to 5% of produce is processed
  - ✓ Exports of fruits is limited

- ***India is the largest producer of Onions***
  - ✓ Available plenty during the season and very cheap
  - ✓ Almost every year there are fluctuations in the price
  - ✓ Proper storage facilities are required to meet the unseasonal demands

INTRODUCTION (continued)

Commodity	Percentage
Potato	*85.3*
Fruits and Vegetables	*1.1*
Meat and Marine Products	*1.7*
Milk and Dairy	*0.7*
Multi purpose and Others	*11.2*
Total	*100*
Source: Mr. Ramesh Paranjpey	

INTRODUCTION (continued)

All figures are in Million Indian Rupees

Source: Refrigeration Market Size in India (Krishna V. Jog)

INTRODUCTION (continued)

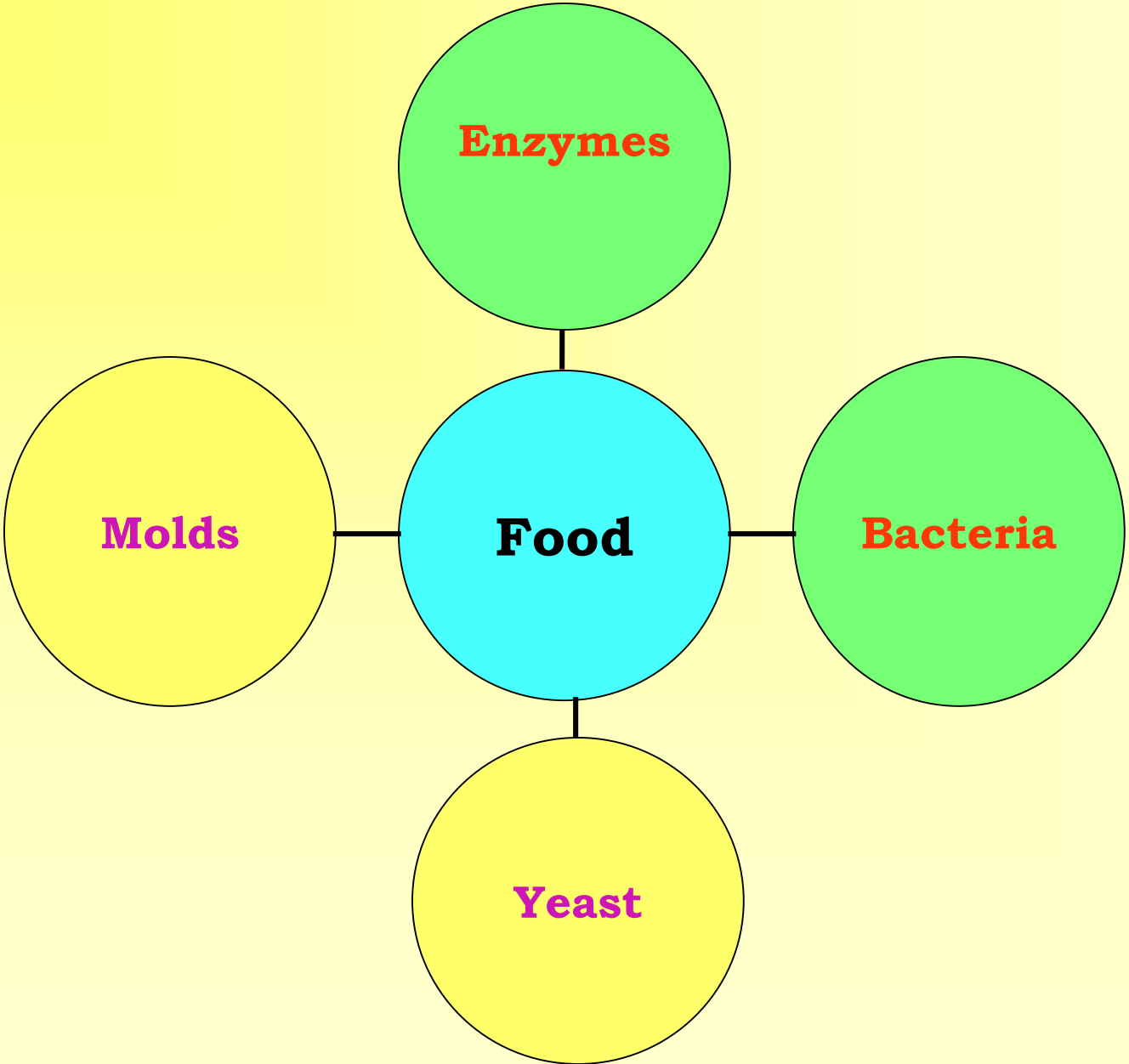
- **The total cold store capacity in the country was for about 30.11 million tons numbering 6300**

- **Market size of all cold storages is about Rs 952 Billion in 20172**
  - ✓ **Smaller capacity storages at Hotels, Restaurants, airports, etc. account for about 2/3rds and 1/3rd for large cold storages ranging from 1000 tons to 10,000 tons of product**

FOOD SPOILAGE

- ***Traditional methods like Salting, Pickling, etc. alter the natural properties of the food***
  - ✓ Taste, colour, appearance, flavour and nutritional values changes
- ***Destruction of Carbohydrates, Proteins, and Fats causes the food spoilage***
  - ✓ Bad odour, uncommon colour, bad taste, and physical appearance
- ***Loss of Moisture***
- ***Respiration changes***
  - ✓ Living cells takes oxygen and give up carbon dioxide
  - ✓ This action takes place along with enzyme action
- ***Spoilage agents of Food are Enzymes, Micro Organisms***
  - ✓ Bacteria, Yeast and Molds are Micro organisms

FOOD SPOILAGE (continued)



FOOD SPOILAGE (continued)

- ***Enzymes***
  - ✓ At room temperature they are active
  - ✓ These are destroyed by boiling food or freezing the food
- ***Bacteria***
  - ✓ Some help to preserve the food and their presence is necessary in food
  - ✓ Food subjected to 120 ^{0}C temperature or preserve in the temperature range of -17 to -24 ^{0}C
- ***Yeast***
  - ✓ Their action is more rapid in acidic condition
  - ✓ They spoil jam and syrups quickly
  - ✓ All types of yeast can be destroyed by heating to 100 ^{0}C or freezing
- ***Molds***
  - ✓ Larger in size than bacteria
  - ✓ More complex in the structure
  - ✓ Thread like structure
  - ✓ Different colours like green, yellow, brown, pink or black
  - ✓ Can be destroyed by heating to 60 ^{0}C or by deep freezing

REQUIRED CONDITIONS IN COLD STORAGE

Commodity	Storage Temperature, ^{0}C	RH %	Product Life	Water Content %
Potato	*2 to 4*	*90-95*	*4 to 5 months*	*81*
Cauliflower	*0 to 1.5*	*95-98*	*3 to 4 weeks*	*92*
Cabbage	*0 to 1.5*	*98-100*	*5 to 6 months*	*92*
Mushroom	*0*	*95*	*3 to 4 days*	*91*
Orange	*7 to 8*	*85-90*	*5 to 8 weeks*	*86*
Mosambi	*6 to 8*	*85-90*	*6 to 8 weeks*	*86*
Apples	*0 to15*	*90-95*	*3 to 8 months*	*84*
Mango	*8 to 10*	*85-90*	*2 to 3 weeks*	*81*
Frozen Food	*-18 to -20*	*90-95*	*24 weeks or more*	

UNDERSTANDING OF THE PRODUCT

- ***Respiration***
  - ✓ Oxygen from air combines with carbohydrates in the plant tissue and results in the release of Carbon Dioxide and heat
  - ✓ Potatoes, Onions, Apples have low respiration and hence longer storage life
  - ✓ Fruits like Strawberry, Pear, Peach have moderate respiration
  - ✓ Vegetables like Spinach, Sprouts and Mushrooms have very high rate hence short storage life
  - ✓ Every 10^0C rise in temperature approximately doubles the respiration

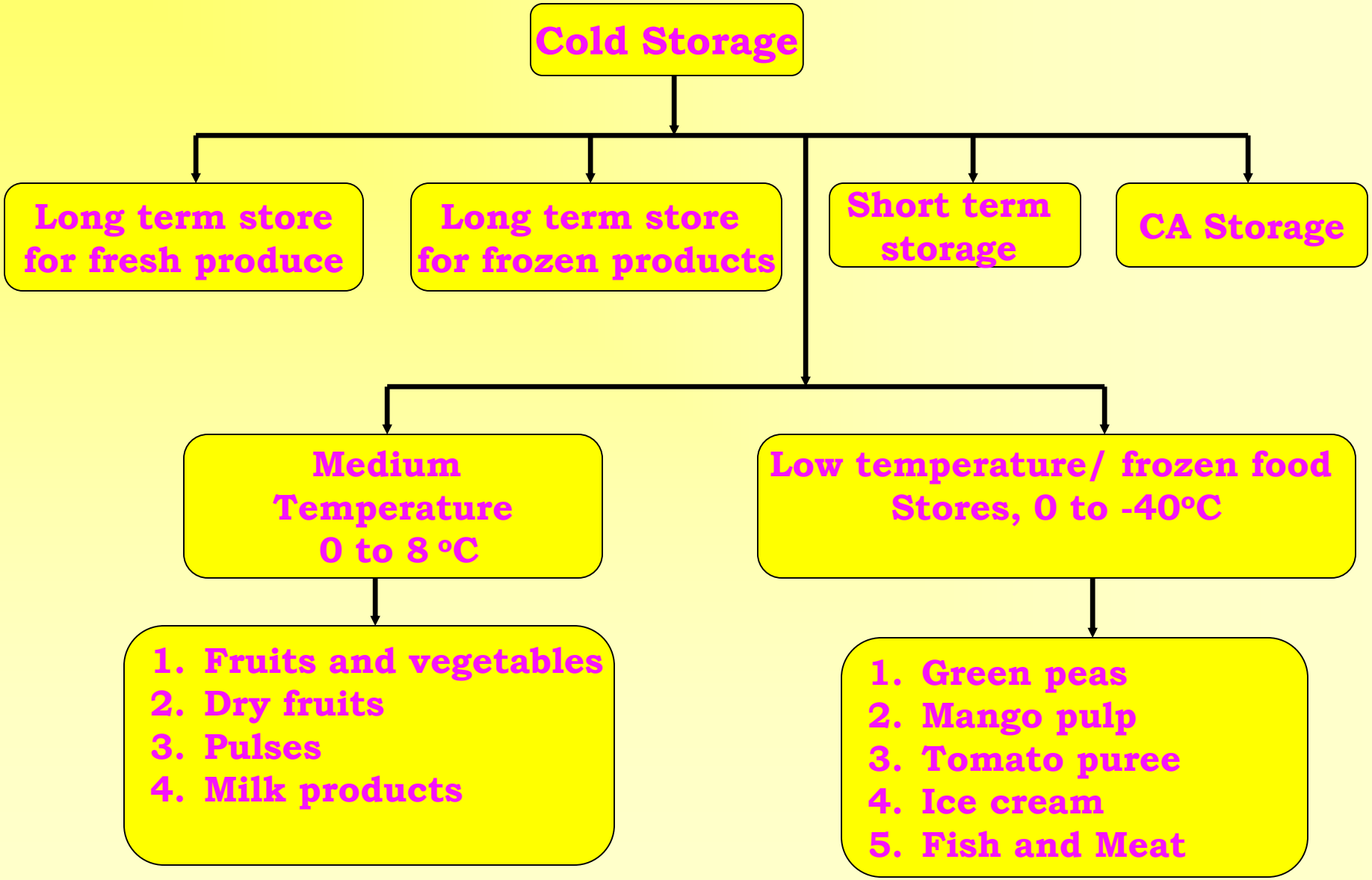
- ***Shelf Life***
  - ✓ Depending upon the chosen storage temperature and rate of respiration
  - ✓ For different temperature and humidity conditions the shelf life is also different

UNDERSTANDING OF THE PRODUCT (continued)

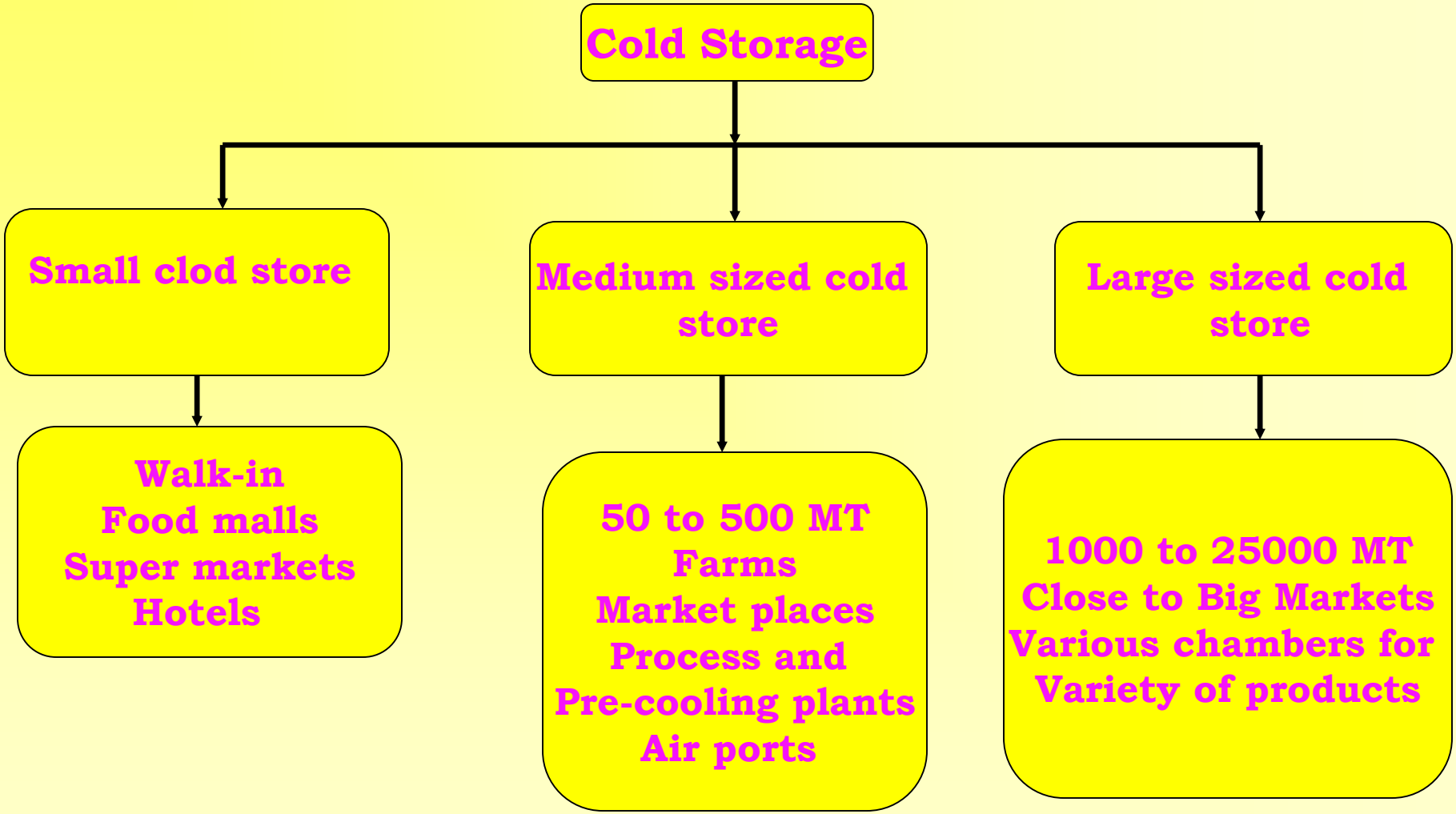
- ***Optimum Conditions***
  - ✓ Ideal temperature and RH ensures the optimum shelf life
  - ✓ Ideal temperature is the lowest temperature at which the product can be stored without causing chilling and freezing injury
  - ✓ Ideal RH which can be maintained without causing weight loss

- ***Sensitivity***
  - ✓ Bananas, Mangoes, Cucumber are sensitive to storage at low temperature
  - ✓ Resulting damage is called Chilling Injury
  - ✓ Bananas it occurs at if they are stored below 12 ^{0}C
  - ✓ Surface pitting, tissue break down are the symptoms

CLASSIFICATION COLD STORAGES



CLASSIFICATION COLD STORAGES (Continued)



WALK-IN COOLER

LARGE COLD STORAGE PLANT

Large size cold storage made of PUF panels

DESIGN OF COLD STORAGE

- ***Building Location and its Orientation***
  - ✓ Longer walls should be in South/North direction if possible to reduce solar heat gain effect
  - ✓ Minimum surface to volume ratio
  - ✓ Cubical shape gives maximum storage space
- ***Layout***
  - ✓ Refrigeration plant, Cooling towers, Boilers etc. should be as close to as possible to reduce thermal losses
- ***Loading , Unloading and Stacking***
  - ✓ All operations should complete in minimum possible time
  - ✓ Shipping and receiving docks are recommended to be maintained at 5 to 10 ^{o}C

DESIGN OF COLD STORAGE (continued)

Cooling Load Calculations

- ***Wall Gain Load***
- ***Air Change Load***
  - ✓ Infiltration load
  - ✓ Ventilation load
- ***Product Load***
  - ✓ Above freezing, at freezing and below freezing
- ***Respiration Heat***
- ***Miscellaneous Load***
  - ✓ Lights, electric motors, people working etc.
- ***Use a Safety Factor of 5 to 10%***

DESIGN OF COLD STORAGE (continued)

Insulation

- ***Insulation***
  - ✓ Low thermal conductivity
  - ✓ Low moisture permeability and retention
  - ✓ Fire resistant
  - ✓ Light weight
  - ✓ Sufficient strength
  - ✓ Durability
  - ✓ Ease of applications
- ***In old units Rice Husk was used***
  - ✓ Very large thickness
- ***New materials are Expanded Polystyrene, Fiberglass or Polyurethane***

DESIGN OF COLD STORAGE (continued)

Insulation

- ***Insulation on walls and ceilings is finished with Cement Sand Plaster in conventional cold stores***
- ***Latest trend is to use Sheet Metal Cladding***
  - ✓ Aluminium sheet
  - ✓ Pre-coated galvanized steel sheet
- ***Prefab Insulated Panel Structure (Sandwich Panels)***
  - ✓ EPS panels with expanded polystyrene insulation bonded to sheet metal skins by using a special adhesive
  - ✓ PUF panels using polyurethane as insulation material foamed between two metal skins
  - ✓ PUF panels are structurally strong and have a better insulation value as compared to EPS panels for a given thickness

DESIGN OF COLD STORAGE (continued)

Insulation

Photo 1 : A large cold store with pre-fab insulated panels under installation for Snowman Frozen Food, Kochi. Room dimensions 50 × 20 × 9.5m high.
Photo courtesy of Beardsell Ltd.

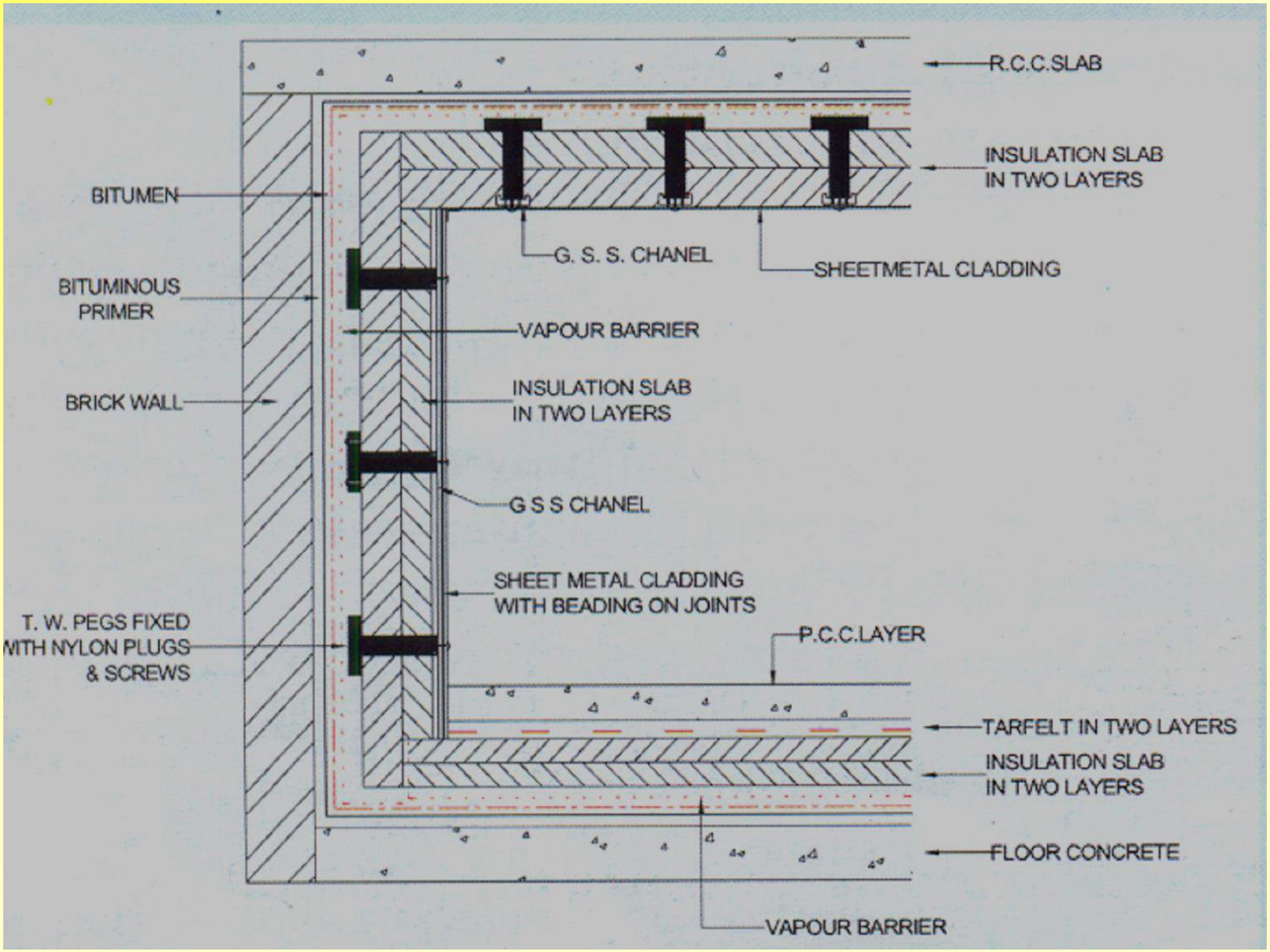
DESIGN OF COLD STORAGE (continued)

Insulation

Source: Hiru M. Jhangiani, 2002

DESIGN OF COLD STORAGE (continued)

Insulation details for walls, ceiling and floor



DESIGN OF COLD STORAGE (continued)

Vapour Barrier

- ***To prevent vapour transmission through Insulation***
  - ✓ Cold storage operating at -10 to -20 ^{0}C and Blast Freezer operating at -30 to -40 ^{0}C with out side ambient temperature at 35 to 45 ^{0}C , there is big difference in vapour pressures
- ***The metal outer skin on pre-fabricated wall and ceiling panels of a cold store is an effective vapour barrier***
- ***All the Joints should be sealed properly***
  - ✓ Joints between panels, between wall and ceiling panels, between wall and floor panels
  - ✓ All the openings made in the panels for passage of pipes, conduits, and suspension rods, if not properly sealed permanently, will cause water and ice to form

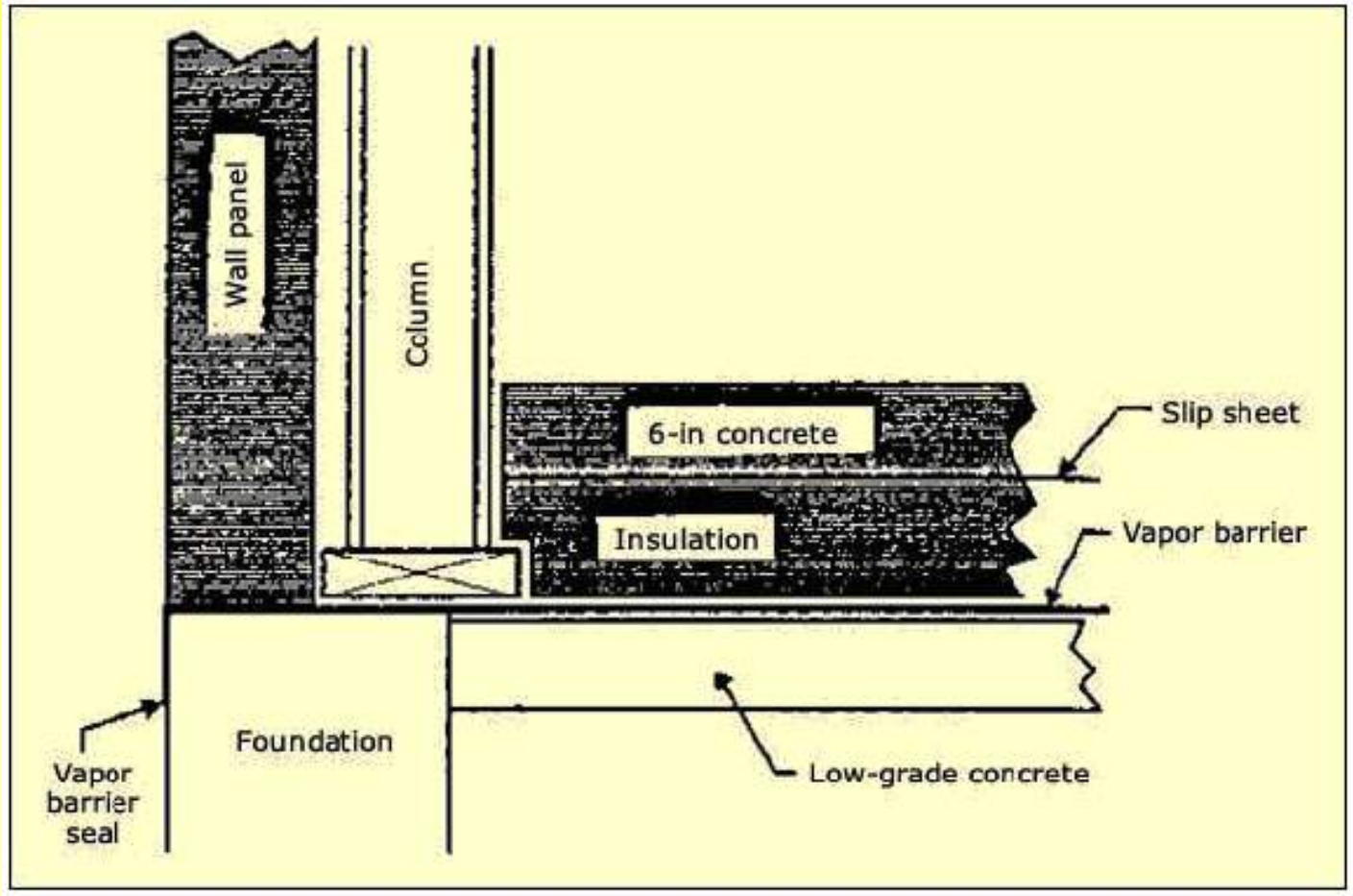
DESIGN OF COLD STORAGE (continued)

Vapour Barrier

- ***This reduces the insulation properties, increases operating cost, delaminates the panels and may even cause collapse of some panels***
- ***The vapour barrier commonly used is polyethylene sheet***
  - ✓ Adequate thickness to prevent tearing and puncturing during installation
  - ✓ The minimum thickness specified should be 0.3 mm
- ***Placing a 'slip sheet' of polyethylene between the finished concrete floor and insulation is advisable***
  - ✓ This 'slip sheet' (not a vapour barrier), which during construction is placed on the insulation before pouring the concrete
  - ✓ It permits differential expansion between the insulation and concrete, and it keeps the moisture of the concrete from contacting the insulation until the concrete dries

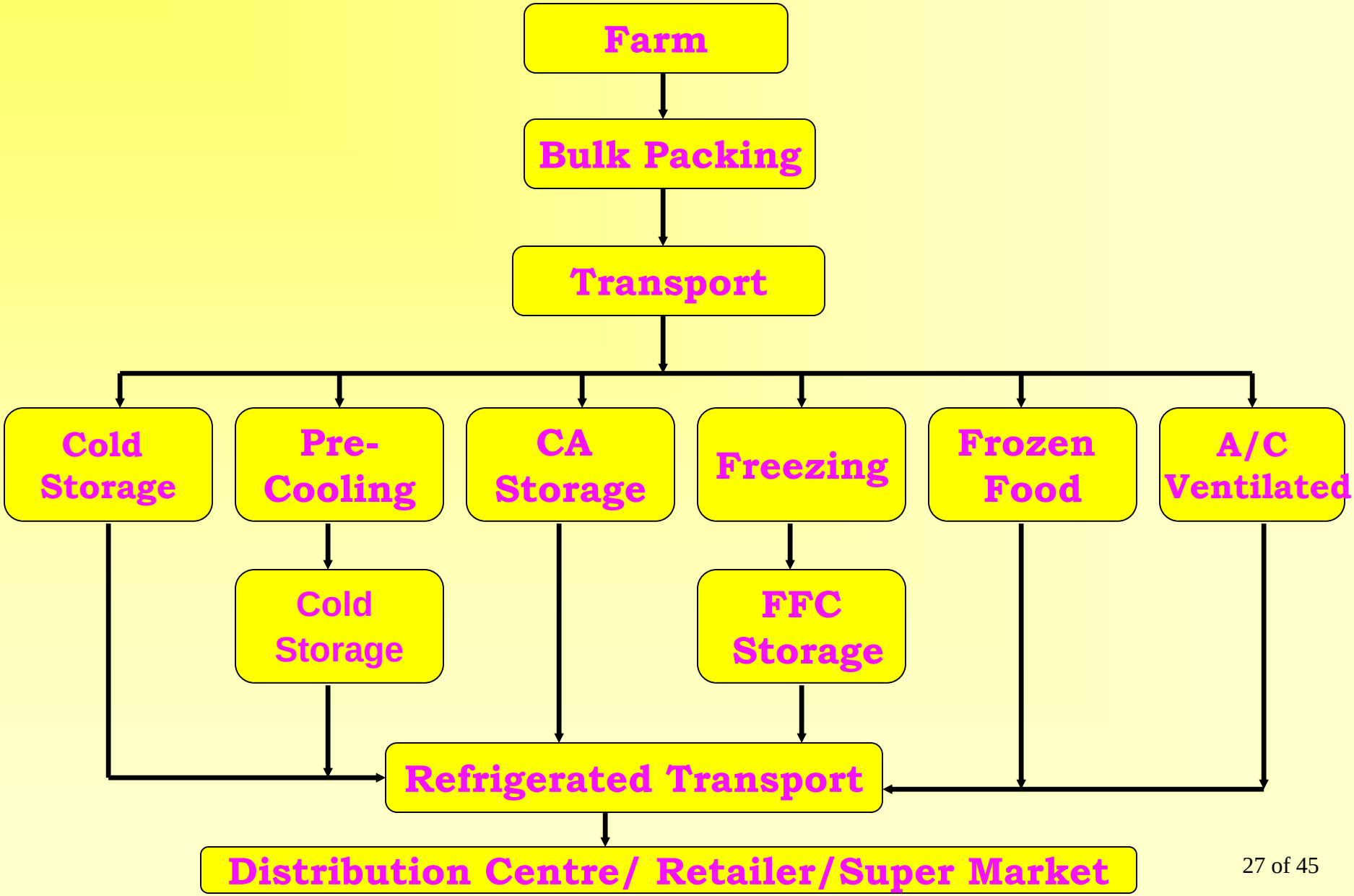
DESIGN OF COLD STORAGE (continued)

Vapour Barrier



Position of Vapour Barrier (Hiru M. Jhangiani, 2002)

COLD CHAIN MANAGEMENT



COLD CHAIN MANAGEMENT (continued)

- ***Conventional Cold Storage***
  - ✓ After initial sorting, grading and packing are transported to cold storage at the producing centre or consuming centre
  - ✓ Potatoes, Apples, Oranges, Tamarind, Red Chilies etc.

- ***Pre-Cooling and Cold Storage***
  - ✓ Many fruits are sensitive to heat susceptible to moisture loss after harvesting
  - ✓ Such fruits have to pre-cooled within a short time after harvesting
  - ✓ Grapes, Straw-berries and Flowers requires faster cooling within short time after harvesting
  - ✓ Mangoes, Pomegranates etc. can be pre cooled within 24 hours after harvesting

COLD CHAIN MANAGEMENT (continued)

- ***Controlled Atmosphere Storage***
  - ✓ Some fruits and vegetables can be stored for long periods by delaying the natural ripening process
  - ✓ Reducing the Oxygen level and by allowing higher percentage of CO_2
  - ✓ Temperature, Oxygen and CO_2 required varies from product to product
  - ✓ Apples, Pears and plums can be stored up to 10 months

  Ex. Apple

  Temperature : 0 to 1 ^{0}C

  RH : 85 to 95

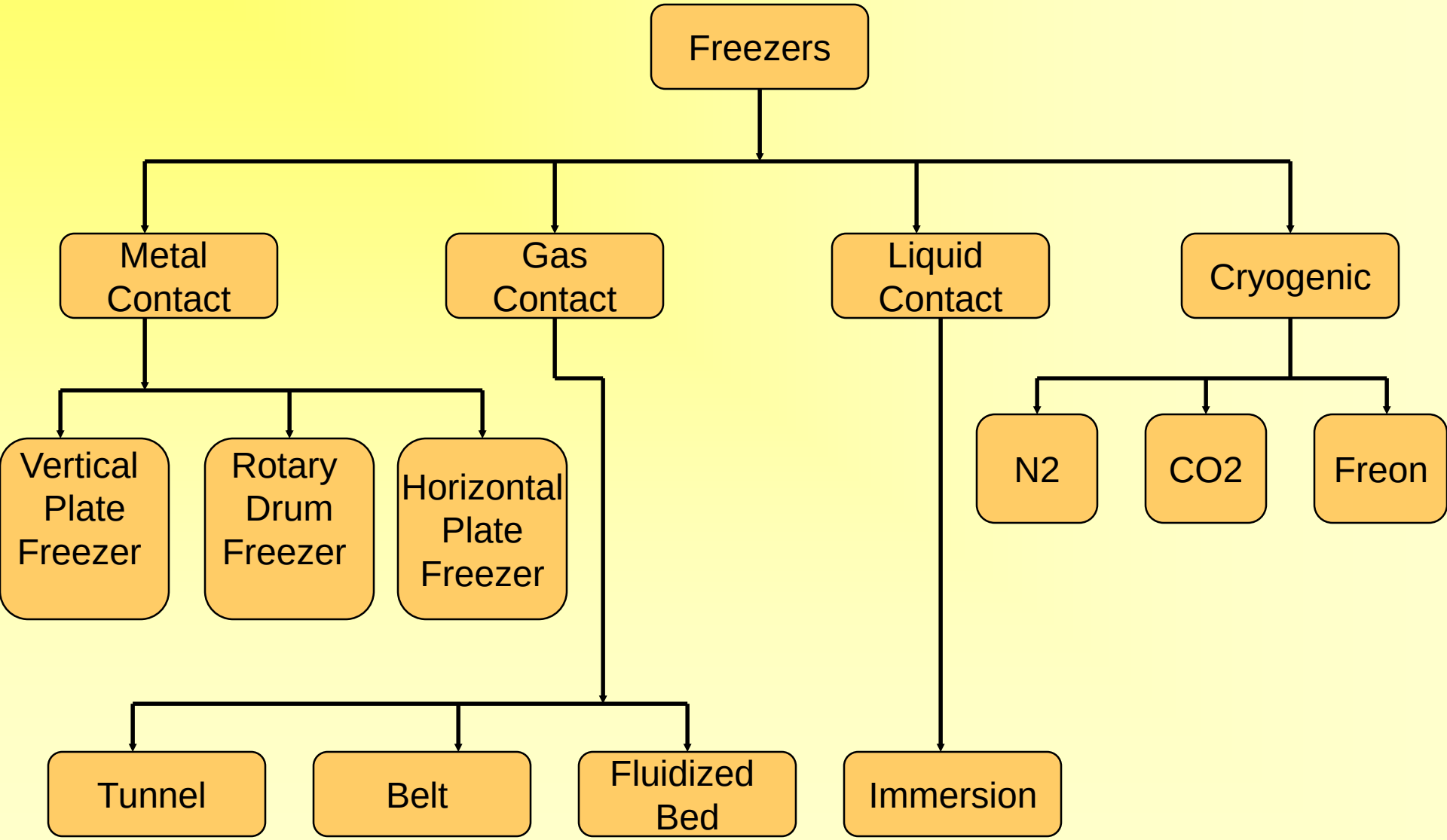
  O_2 : 1 to 2%

  CO_2 : 2 to 4%

COLD CHAIN MANAGEMENT (continued)

- ***Frozen Foods***
  - ✓ Frozen and stored for long time
  - ✓ Green peas, Corn, Okra, Mixed vegetables, Tomato Puree, Mango Pulp, Mango Slices and Dices, Pine Apple Slices etc.
  - ✓ Compact quick Freezers, Air Blast Freezers, Individual Quick Freezers (IQF) and Cryogenic Freezers
- ***Storage Pre-Frozen Foods***
  - ✓ Ice creams, Butter, Fisheries, Meat Products and Poultry undergo processing and freezing at the main production/processing plants
  - ✓ Transported through Reefer Vans
- ***A/C Ventilated Storage***
  - ✓ Chocolates, Confectionery Products, Tobacco need air conditioned stores
  - ✓ Onions need ventilated storage houses

FREEZERS


Freezers
Metal Contact
Gas Contact
Liquid Contact
Cryogenic
Vertical Plate Freezer
Rotary Drum Freezer
Horizontal Plate Freezer
N2
CO2
Freon
Tunnel
Belt
Fluidized Bed
Immersion

REFRIGERANTS

- ***Cold Storages attached to Five Star Hotels***
  - ✓ Old units R-12 and R-22
  - ✓ New units HFCs' R-134a, R-404A, R-407c

- ***Large Cold Storage Plants***
  - ✓ In India 95% are Ammonia based vapour compression systems
  - ✓ Advantages:
    - ➢ *0 ODP and 0 GWP*
    - ➢ *High latent heat of evaporation*
    - ➢ *Cheap*
    - ➢ *Lower power consumption (kW/TR)*

REFRIGERANTS (continued)

- ***Absorption refrigeration systems based on Aqua Ammonia offers an alternative to VCC***
  - ✓ Direct thermal heat from burring of fuel oil, Agricultural waste like rice husk, ground nut shell etc.
  - ✓ Heat from any waste heat source like engine exhaust, Generator exhaust etc.
  - ✓ M/S Transparent Energy Systems Pvt. Ltd., Pune built a cold storage
  - ✓ They imported machinery from Germany
  - ✓ Initial cost is high but the pay back period is in the rage of 3 to 4 years compared with conventional VCC cold storages
  - ✓ Absorption systems will play a vital role in near future as the electricity cost is increasing day by day

COMPRESSORS

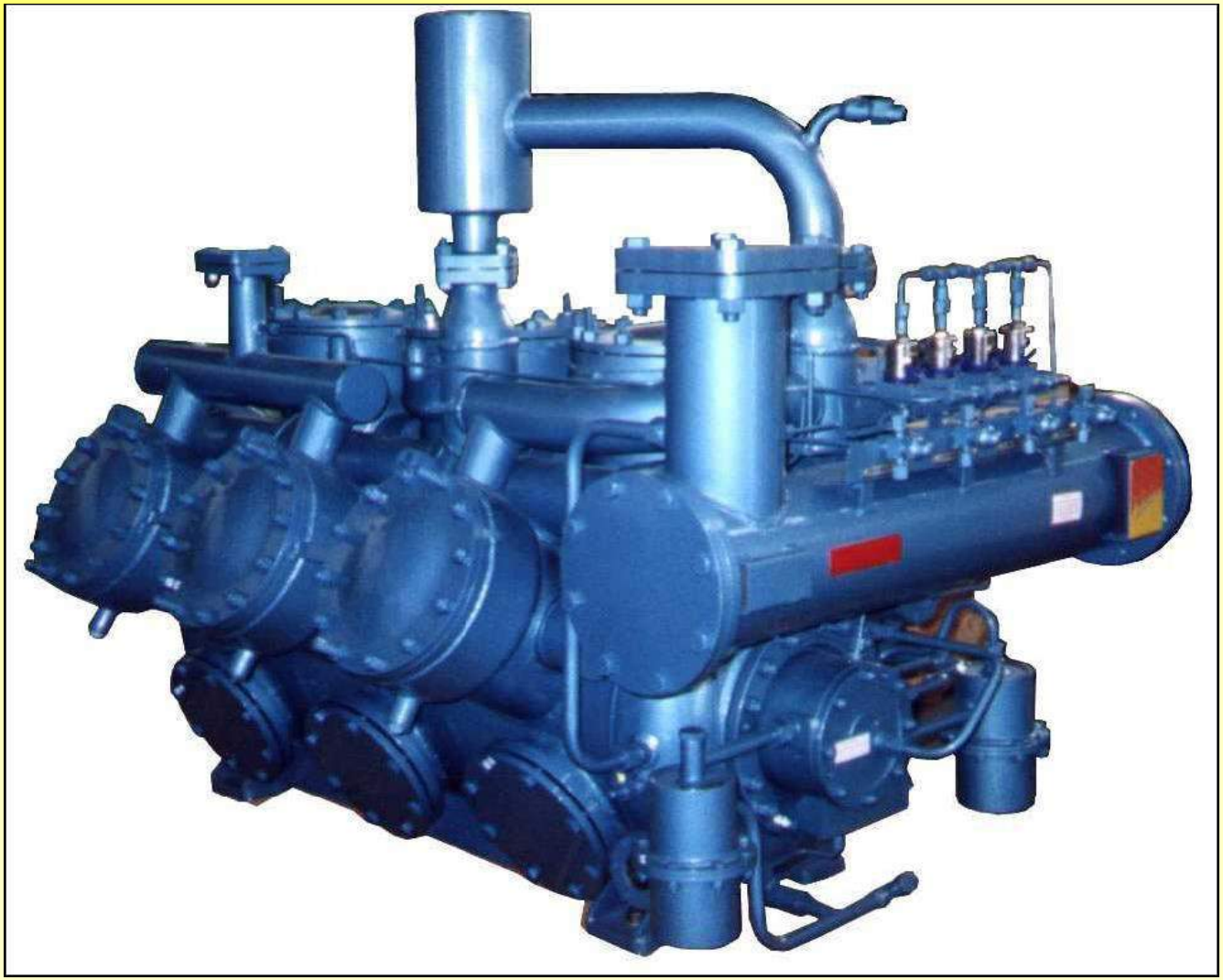
- ***Almost 90% of the Compressors are Reciprocating***
  - ✓ Kirloskar Pneumatics has been manufacturing KC open type reciprocating compressors since 40 years
  - ✓ Single stage and two stage versions and have minimum two cylinders to 12 cylinders

- ***Screw Compressors are used only for very large cold storages and frozen foods***
  - ✓ Very few moving parts compared with reciprocating compressors
  - ✓ Hindustan Lever Limited (HLL), Nashik used Howden (UK) Screws on Ammonia for Ice cream hardening, Frozen storage etc.
  - ✓ Walls Ice cream, Pune

COMPRESSORS (continued)

Single Stage Kirloskar Compressor (Courtesy of Kirloskar Pneumatics)

COMPRESSORS (continued)



Two Stage Kirloskar Compressor (Courtesy of Kirloskar Pneumatics)

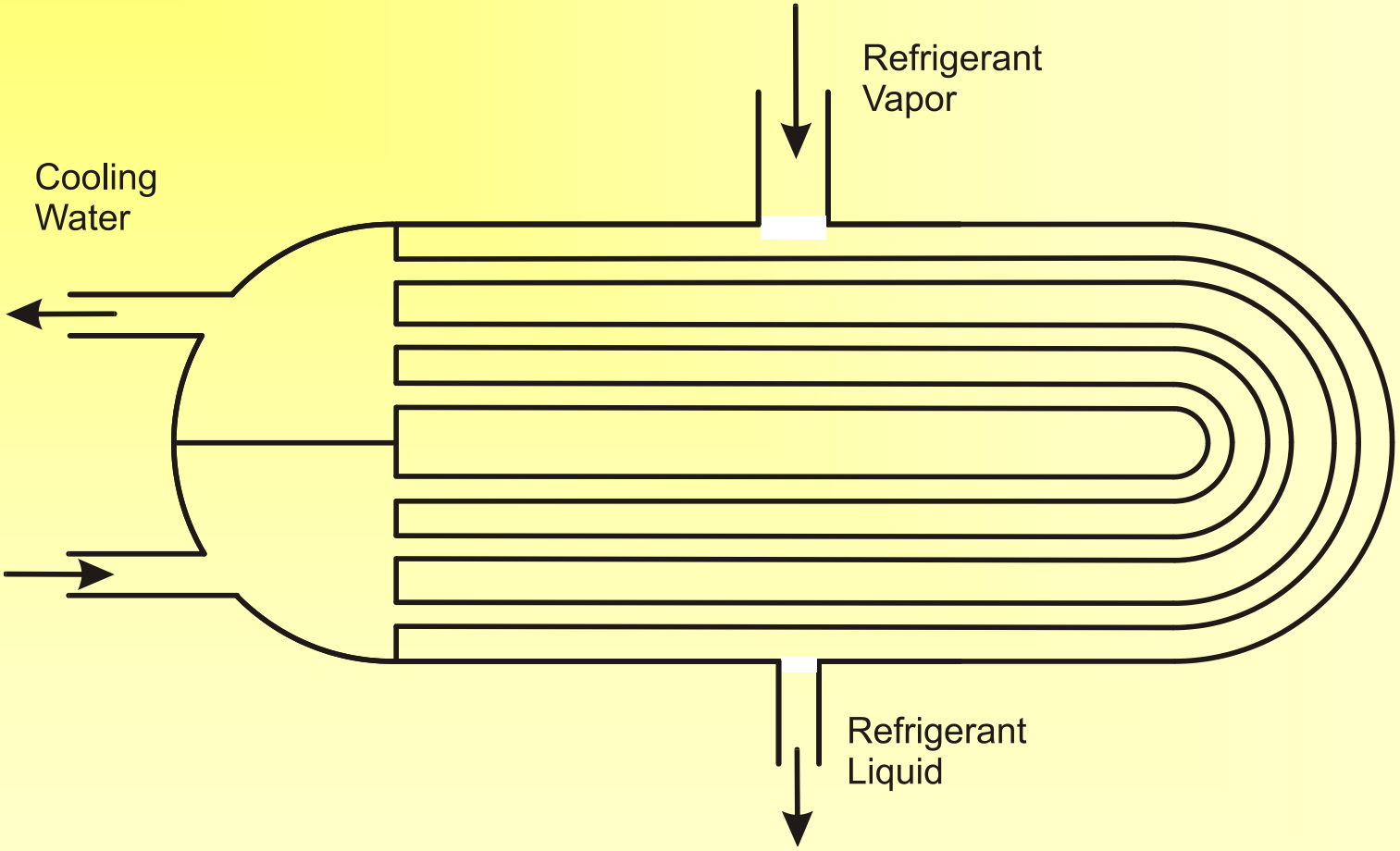
CONDENSERS

- ***Selection of Condenser depends on DBT/WBT of ambient conditions, availability of Water and location***

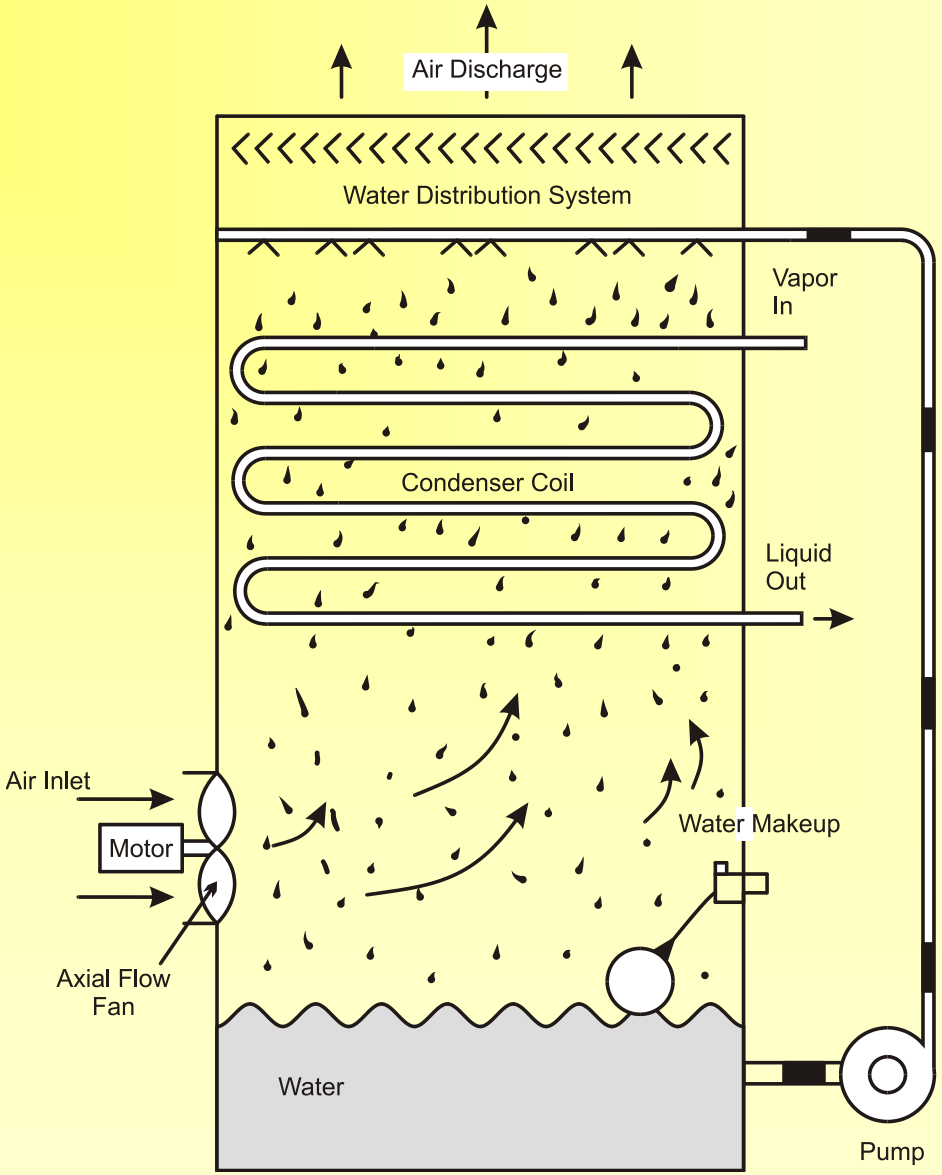
- ***Small Cold Rooms which use HFC/HCFC uses Air Cooled Type and for large Shell and Tube type***

- ***For Ammonia Cold Storage Plants Evaporative Condensers are used***
  - ✓ Consumes less quantity of water
  - ✓ Preferred for large cold storages

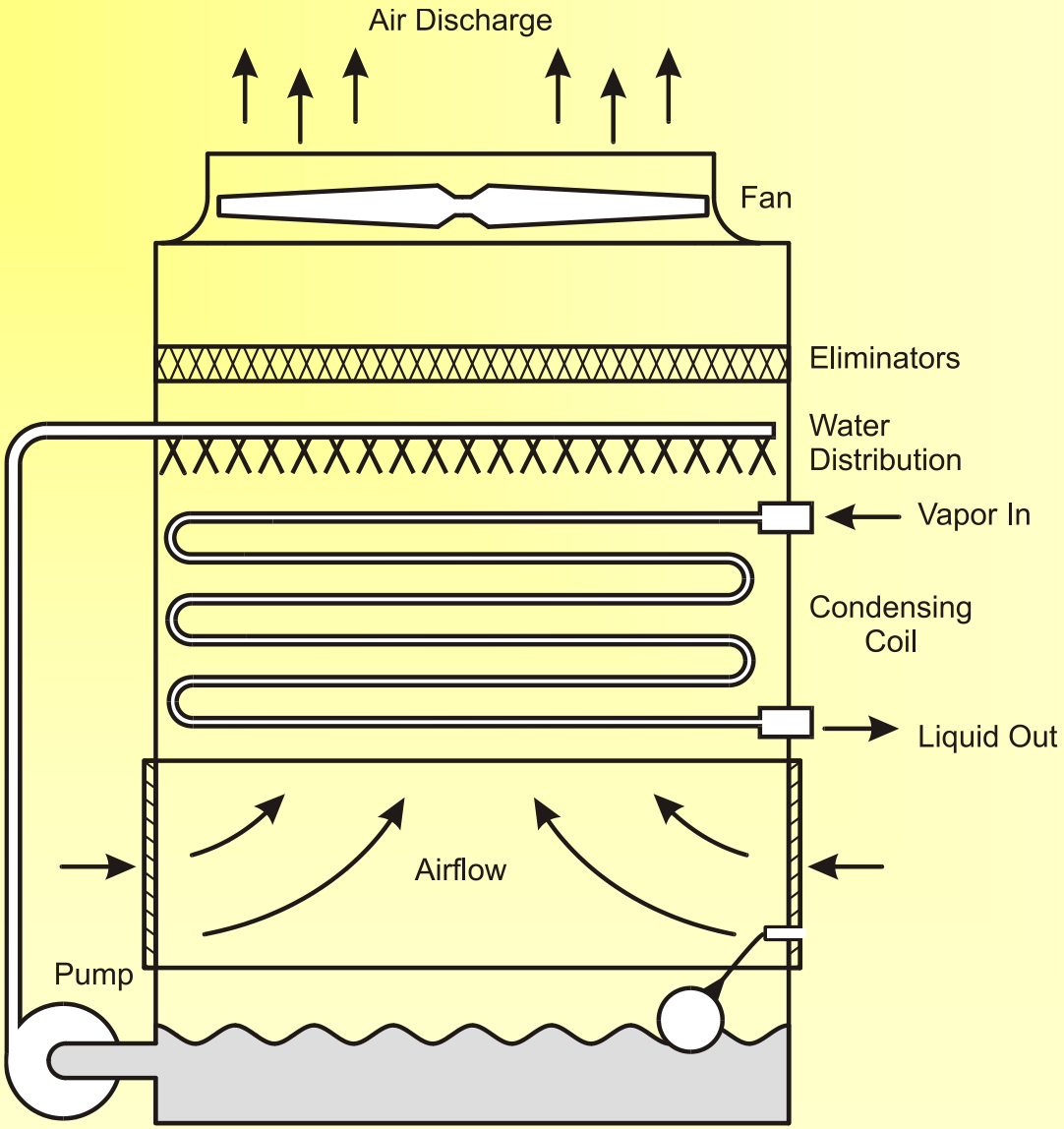
WATER-COOLED CONDENSER



BLOW-THROUGH EVAPORATIVE CONDENSER



DRAW-THROUGH EVAPORATIVE CONDENSER



EVAPORATORS

- ***Old plants uses Bunker type Coils installed on the top floor with conventional ceiling fans***
  - ✓ Occupies large volume
  - ✓ Carrying large quantity of Ammonia
  - ✓ Poor cooling performance
- ***Later floor mounted air circulating units with air distribution ducting have come into picture***
- ***Recent trend is to use ceiling mounted units with finned coils and axial flow fans with Aluminum or Stainless Steel Impellers***
- ***NH_3 systems mostly uses Gravity fed systems with Flooded Coil Evaporators***
- ***Large cold storage units use Liquid Circulation Pumps for circulating low temperature and low pressure refrigerant***
  - ✓ Effective performance of Evaporator Coils

SAVLA FOOD AND COLD STORAGE

- ***Savla Food and Cold Storage , Navi Mumbai***
  - ✓ **Cold storage facility** - for storing **22,000 Metric Tons** of goods at temperatures between 0 ^{o}C and 5 ^{o}C
  - ✓ Ideal for storage of pulses, dry fruits, spices, horticultural products, fresh fruits, confectioneries and all other vegetarian products
  - ✓ **Deep freeze facility-** for storing **1,500 Metric Tons of goods** between 0 ^{o}C and - 30 ^{o}C ideal for storage of frozen foods, milk products, ice-creams, pulps and other vegetarian products
  - ✓ **Warehousing facilities** admeasuring **more than 20,000 sq. ft**. within R.C.C. constructed building ideal for dry storage, sorting, repacking, etc.
- ***Ammonia gas-based plant operating on Kirloskar make KC-3, KC-4 and KC-6 reciprocating compressors and motors with adequate stand-by arrangements***
- ***Evaporative condensing systems using imported air coil condensers***

SAVLA FOOD AND COLD STORAGE

- ***Refrigerant pump recirculation system (overfeed system) for Multipurpose Cold Storage Project designed for multi-level temperature operation. This is India's largest cold store project with 56 cold chambers***

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CONCLUSIONS

- *In the Design of Cold Storage clear understanding of the Product behavior is essential*
- *Transportation plays a vital role in product preservation*
- *Quick and efficient transportation from farm to sorting, grading, pre-cooling and cold stores increases the shelf life*
- *Proper sealing of vapour barriers is essential*
- *Ammonia based vapour absorption systems should be developed such that the Agricultural waste, and any waste heat sources can be used to operate the system instead of depending on the Electric Power*
- *The non conventional source of energy should be used for cold storage applications*
- *Proper waste heat management should be adopted for existing and new cold storage plants*

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