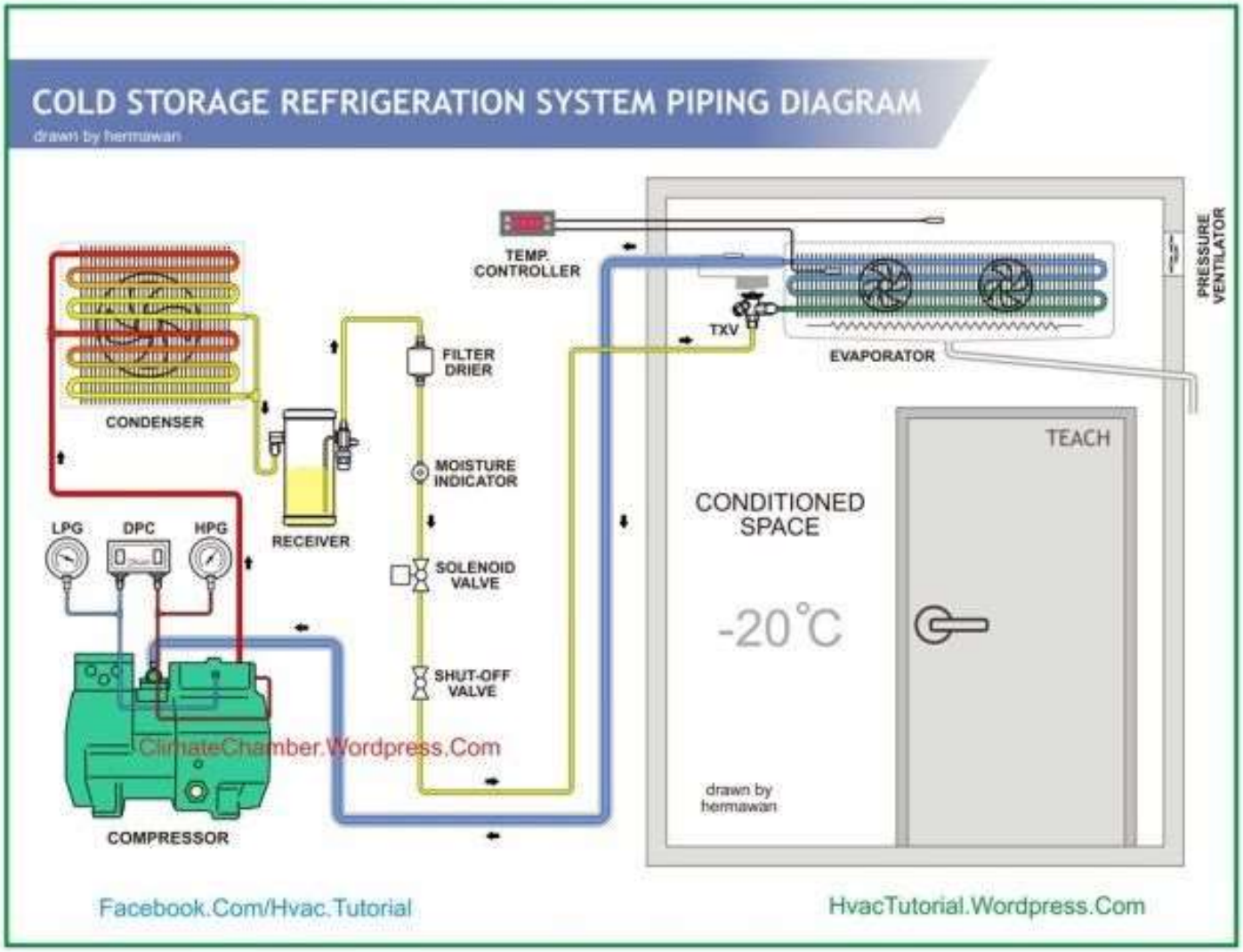
Refrigeration

Refrigeration – Mechanical Refrigeration

- Most storage facilities use mechanical refrigeration to control storage temperature.
- Liquid absorbs heat as it changes to a gas.
- Controlled release of liquid nitrogen or liquid carbon dioxide in the storage area is the simplest method.
- Common mechanical refrigeration systems ammonia or halide fluids as refrigerants.

Refrigeration – Mechanical Refrigeration



Refrigeration – Mechanical Refrigeration - Parts

Part	Features & Functions
Expansion valves	• Primary controlling unit of small mechanical refrigeration systems. • Regulates the pressure of the refrigerant in the evaporator. • Controls the flow of refrigerant. • Capillary tubes and thermostatic expansion valves are the common types. • Large mechanical refrigeration systems have expansion coils.

Refrigeration – Mechanical Refrigeration - Parts

Part	Features & Functions
Evaporators	• Used in modern cold storages. • Air from the storage is forced past the evaporator. • Transfer heat from the air to the refrigerant causing it to evaporate.
Compressors	• Recaptures the vaporized refrigerant. • Repressurize the vaporized refrigerant.

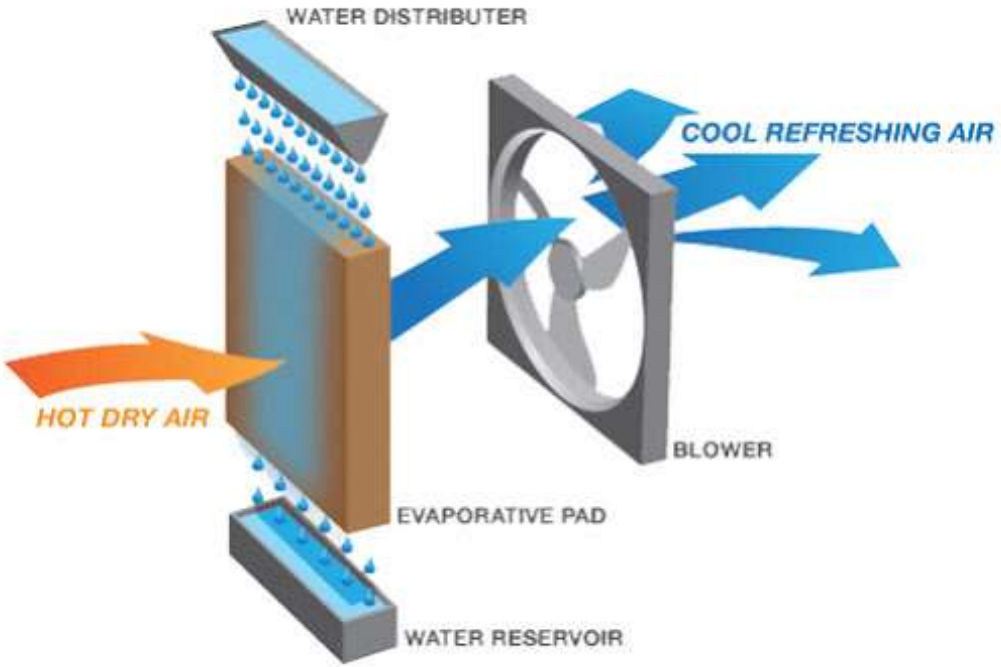
Refrigeration – Mechanical Refrigeration - Parts

Part	Features & Functions
Condensers	• Cools the vaporized refrigerant to a liquid. • Can be either air cooled or water cooled.
Refrigerants	• Cost of the refrigerant. • Compatibility. • Toxicity.
Control systems	• To facilitate manual operation of motors. • To display the operating status of compressors and the fluid levels.

Refrigeration – Alternative Refrigeration Sources

1. Evaporative cooling

- Energy efficient and economical.
- Produces air with RH greater than 90%.
- Water for the cooling system comes from domestic sources.



Refrigeration – Alternative Refrigeration Sources

2. Nighttime cooling

- Nighttime ventilation is used as a source of refrigeration.
- Commonly used for unrefrigerated storage of potato, sweet potato, onion and pumpkin.

Refrigeration – Alternative Refrigeration Sources

3. Well water

- Can be an effective source of refrigeration.
- The temperature of the ground water greater than 2m below the surface is equal to the average annual air temperature.

Refrigeration – Alternative Refrigeration Sources

4. Naturally formed ice

- Natural ice harvested during winter has been used as a source of refrigerant during spring and summer.

Refrigeration – Alternative Refrigeration Sources

5. High altitude cooling

- Air temperature decreases by 1 ^{0}C with every 100m increase in altitude.
- This cool air cannot be taken to ground level as it gets heated due to compression.
- Store commodities at high altitudes in mountainous areas.

Refrigeration – Alternative Refrigeration Sources

6. Underground storage

- Cellars, abandoned mines and other underground spaces can be used to store fruits and vegetables.
- Good for storing already cooled commodities.
- Soil has a poor ability to transfer heat.

Storage Building

Storage Building

- Must be sized to handle peak amounts of products.
- Should have adequate room for aisle ways for easier forklift handling.

Storage Building

- Maximum storage can be increased by using shelves or racks.
- Multistory structures are not used.
- The floor perimeter should have a square shape.
- Entrances, storage area and exits should be in a way that moves products in one direction.
- Availability of good utility services.
- Good drainage and room for future expansion.
- Enough space for smooth movement of large trucks.

Storage Building

- Vapour barriers are installed in floor and foundation.
- Walls and ceiling are insulated using rigid foam boards.

Controlled Atmosphere Storage

Controlled Atmosphere Storage - CAS

- Utilizes O_2 and CO_2 concentrations of about 1-5% for each gas.
- This causes;

✓Reduction in senescence and other related biochemical and physiological changes.

✓Reduction of commodity sensitivity to ethylene.

✓Alleviation of certain physiological disorders.

✓Affects post-harvest pathogens, decay incidence and severity (Botrytis rot on strawberry).

✓Useful tool to control insects in some commodities.

Controlled Atmosphere Storage - CAS

- Potential harmful effects include;

✓Initiation / aggravation of certain physiological disorders.

✓Irregular ripening of fruits.

✓Off-flavour and off odour development due to anaerobic respiration.

✓Susceptibility to decay may increase.

Fruits and vegetables are classified according to their tolerance to low O_2 concentrations

Minimum O_2 concentration tolerated (%)	Commodities
0.5	Nuts, dried fruits and vegetables
1.0	Minimally processed fruits and vegetables, onion, garlic
2.0	Strawberry, papaya, pineapple, lettuce, cabbage
3.0	Avocado, tomato, pepper, cucumber
5.0	Citrus fruits, potato, sweet potato

Fruits and vegetables are classified according to their tolerance to elevated CO_2 concentrations

Maximum CO_2 concentration tolerated (%)	Commodities
2	Apple, tomato, lettuce, grape
5	Orange, avocado, banana, mango, eggplant, cabbage
10	Pineapple, cucumber, okra, garlic, potato
15	Strawberry, blackberry, blueberry, spinach

CA recommendations for some vegetables

Commodity	Temperature ^0C	O_2 %	CO_2 %	Time
Cabbage	0	2-3	5-10	10 days
Cucumber	12	1-4	0	20 days
Garlic	-1	3	5	07 months
Leeks	0	2-4	5-10	05 months
Onion	0	1-2	0-1	09 months
Tomato	2	3-4	2-3	30-40 days

CAS – Atmospheric Modification

- The slowest method is by natural respiration of product.
- If O_2 drops too low, outside air is added to restore it.
- Respiration increases CO_2 levels above the requirement.
- Bags of hydrated lime are used to absorb excess CO_2.
- CO_2 can also be controlled by activated carbon absorption systems, molecular sieves, or brine pumped over evaporator coils.
- Scrubbers using activated charcoal are currently the most popular.

CAS – Atmospheric Modification

- Some operations purge the CA room with nitrogen.
- Some operations use either molecular sieve process or semipermeable membrane to remove oxygen.
- Some use machines to remove oxygen by combustion of natural gas or propane.

Examples of CA injury

Commodity	CO_2 injury level	CO_2 injury symptoms	O_2 injury level	O_2 injury symptoms
Apple	>3%	Internal browning	<1%	Alcoholic taste
Banana	>7%	Green fruit softening	<1%	Browning
Cabbage	>10%	Discolouration of inner leaves	<25%	Off flavour
Mango	>10%	softening	<2%	Skin discolouration