Advances in Refrigeration and Air Conditioning with Case Studies

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Refrigeration systems work by compressing a refrigerant, then allowing it to expand. The expansion of the gas absorbs energy, cooling the evaporator coils and, indirectly, the air passed over them. This delivery air must be colder than the room set point in order to cool the room and the products it contains.

All cool room refrigeration systems have five main components:

- The compressor, which compresses the refrigerant gas
- The condenser, in which the hot gas is cooled to a liquid
- An expansion valve, which controls flow of the liquefied gas and where liquid gas expands to vapour
- Evaporator coils, where the liquid gas expands and boils. This process absorbs energy, cooling the coils
- Fan or fans, to circulate air over the cold evaporator coils, thereby cooling the cool room. Air may also be circulated over pipes containing some type of liquid antifreeze, which have themselves been cooled using the evaporator. Fans also circulate air around the cool room to ensure even distribution of the cold air and reduce temperature variations within the room.

Compressor

A compressor is the most important and often the costliest component (typically 30 to 40 percent of total cost) of any vapour compression refrigeration system (VCRS). The function of a compressor in a VCRS is to continuously draw the refrigerant vapour from the evaporator, so that a low pressure and low temperature can be maintained in the evaporator at which the refrigerant can boil extracting heat from the refrigerated space. The compressor then has to raise the pressure of the refrigerant to a level at which it can condense by rejecting heat to the cooling medium in the condenser.

Condensers

Condenser coil of the refrigeration system removes heat from the system. It's not unusual to find condensers located in enclosed spaces or spaces with inadequate air flow to remove heat from the space. The temperature around the compressor rises resulting in higher head pressure for the compressor, which again increases compressor power.

To effectively remove heat, the condenser should be placed in a well-ventilated area where the temperature is controlled to allow heat to be removed easily. Enclosed spaces will require openings for cooling air intake and exhaust. In many cases, a fan will be required to move enough air through the space. If the condenser heat is never needed, it should be exhausted directly outside if possible. In cases where it may be used for space heating — such as for a nearby dry storage room — controls may be installed to direct the flow indoors for heating, and outdoors when heating is not required. Condenser coils should also be checked regularly for cleanliness. Dust and debris will act like ice buildup on an evaporator coil. This will insulate the heat transfer surface and reduce airflow, which will make the compressor run harder and longer. In extreme cases, compressors may fail.

Although the space itself doesn't have any mechanical parts or equipment, it shouldn't be ignored. The shell of the cooler or freezer should be inspected regularly for leaks and loose insulation or panels. Leaks and other voids in the shell can cause excess moisture to accumulate, potentially causing even bigger problems. The door is also a key component of the cooler. Doors must be sealed properly to eliminate air infiltration which increases the cooling load and may cause moisture buildup within the space and on the evaporator. Frost buildup on the door itself is a common occurrence when the door heater fails and has a tendency to either freeze the door shut or keep it from closing. Proper care should also be taken when placing items inside the space. If the space is overcrowded with items, or items are placed in front of the evaporator fans, the circulation of air is greatly reduced along with the performance of the refrigeration system.

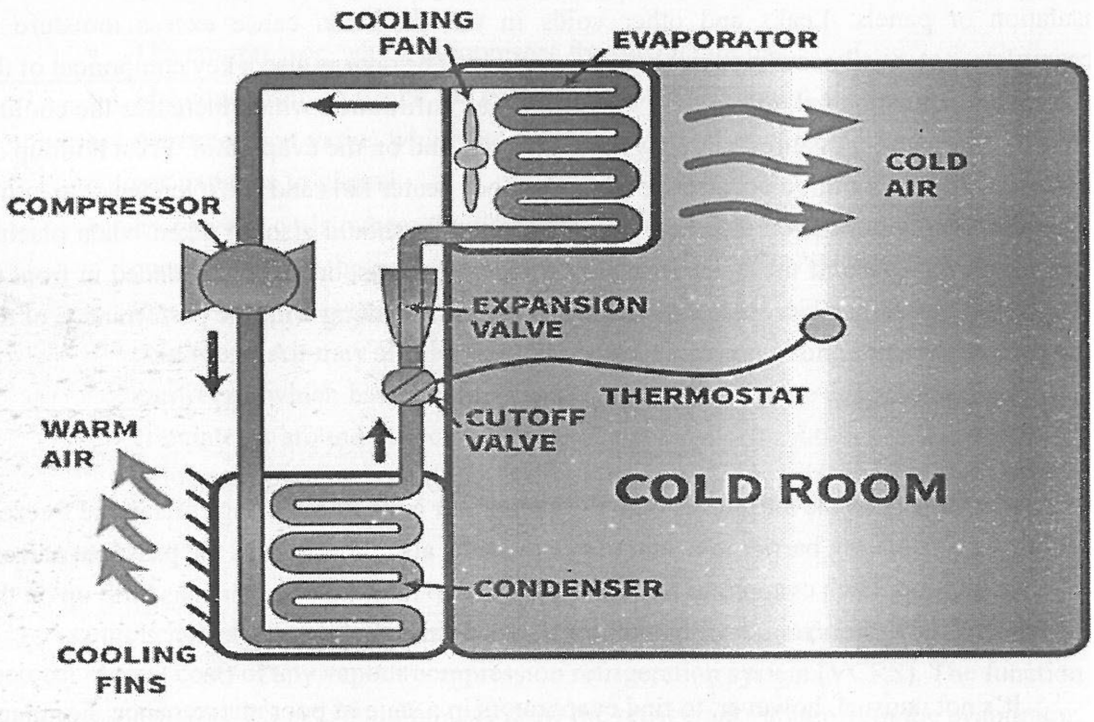
Evaporator

Moisture from the air freezes onto the evaporator coils (the cooling coils in the freezer) and forms an insulating barrier to heat transfer. Airflow also decreases as the passages narrow due to ice buildup. Each evaporator has a defrost cycle to melt frost/ice that has built up on the evaporator coils. Water from the melted ice is drained from the freezer ideally.

It's not unusual, however, to find evaporators in a state of poor maintenance. For many evaporator units, the ice isn't melted, or the water isn't properly drained, resulting in a block of ice taking over the evaporator. When the coil freezes, heat transfer is greatly reduced resulting in the compressor working harder and longer. It works harder because the suction pressure drops making the compressor work at a higher differential pressure, thus requiring more power. It works longer because heat transfer is reduced. When ice buildup is excessive, the compressor will run all the time and the freezer temperature set point will not be maintained. As the ice melts, the water has to drain out of the freezer. This doesn't always occur. Trapped water that freezes can do significant structural damage to a freezer; especially older ones where cracks allow water to seep in, then freeze and expand. Stalactites and stalagmites of ice appearing in your freezer are reason for swift action to avoid costly damage.

Expansion valve

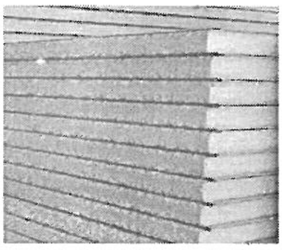
A thermal expansion valve or thermostatic expansion valve (often abbreviated as TEV, TXV, or TX valve) is a component in refrigeration and air conditioning systems that controls the amount of refrigerant released into the evaporator thereby keeping superheat, that is, the difference between the current refrigerant temperature at the evaporator outlet and its saturation temperature at the current pressure, at a stable value, ensuring that the only phase in which the refrigerant leaves the evaporator is vapor, and, at the same time, supplying the evaporator's coils with the optimal amount of liquid refrigerant to achieve the optimal heat exchange rate allowed by that evaporator. In addition, some thermal expansion valves are also specifically designed to ensure that a certain minimum flow of refrigerant can always flow through the system. Thermal expansion valves are often referred to generically as "metering devices".



Components of refrigeration system

Insulation

Insulation must be kept dry to be effective. Good insulation of floors, walls and ceiling improves temperature control and greatly reduces running costs.



Cool room panelling relies on trapping air, usually in a foam or polystyrene matrix, to prevent transfer of heat from the outside environment into the cool room inside. However, it is vitally important to keep this material dry. If the inside of the panelling becomes wet due to condensation and/or entry of humid air from the room then it will become ineffective. Seals around all cool room panels must be intact and waterproof enough to repel water used for cleaning (e.g. jet washing).

Concrete floors should include layers of insulating materials, and be thoroughly sealed against water from floor puddles or washing. Many commercial cool rooms do not have well insulated floors, even though good floor insulation can greatly reduce temperature leakage.

Cool room design and construction

There are many factors to consider in cool room design. It is important to have a clear plan of how the room will be used to ensure it has sufficient cooling capacity, appropriate temperature range and accurate enough control of temperature, humidity and air circulation to operate effectively.

A cool store is essentially a large, insulated box with a refrigeration system and a door. Temperature will vary in different areas inside the room depending on airflow, the way produce has been loaded inside, and the amount of heat contained within that produce.

The design of cool rooms needs to take into account a number of criteria:

Temperature range

- Systems which need to achieve temperatures below zero are usually more expensive than those which have a minimum temperature of 2°C or greater.

Accuracy of control.

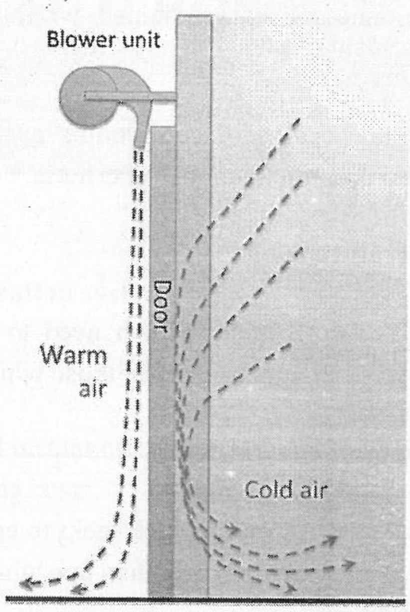
- A room which seeks to control temperature within ±0.2°C, for example, will be more costly than one which allows larger fluctuations.

Degree of spatial variation within the room.

- All rooms have warmer areas, often by the door, or in the back corners. The coldest zone is almost always in front of the delivery air.
- Minimizing spatial variation requires increased air circulation and volume, adding cost to equipment and materials.

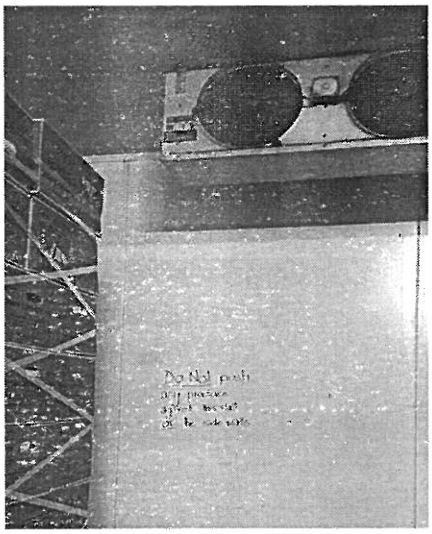
Cooling capacity.

- For example, a room might need to have sufficient cooling capacity to reduce the temperature of 20 harvested bins of broccoli (equivalent to 20% of the total room capacity) from 25°C (harvest temperature) to 5°C within 12 hours.
- This will affect the thickness and quality of insulation materials chosen for the walls and floor.
- Using heat reflective paints and materials as well as roof shading can significantly reduce heat load on the room.
- Air circulation should ideally be consistent with the normal orientation of pallet skids.
- Frequent door opening, particularly if ambient temperatures are high, greatly increases the load on the refrigeration system.
- Having a small door for foot access, in addition to a roller door for forklifts, can reduce loss of cold air.
- These can be further enhanced with flexible curtaining materials, fast automatic roller doors, or double door systems.
- An air curtain (as shown at right) can also be used to reduce entry of warm air into the cold room.
- Electricity is a major cost for packing and storage facilities. Spending more on better insulation and door seals may be highly cost effective if it reduces power costs.
- If temperature control is not critical and rooms are left closed during the day, it can be possible to use mainly off peak electricity. Product is cooled overnight and allowed to slowly increase during the day.



- With water-cooled systems, off-peak electricity can be used to cool a chilled water tank ('heat sink'), which can then be used during the day.
- Rooms need to be kept clean, so using materials that are easily washed and including provision for drains will make this easier.
- Produce must be loaded into cool rooms with consideration of airflow. Blocking airflow will prevent the room operating effectively and can lead to warm areas developing in packed pallets.

For the cool room to operate correctly, air must be able to circulate around the produce inside, whether it is already cool or not. Produce should therefore never be stacked against the cool room wall. It is recommended to leave a gap of at least 10cm for air to circulate. A larger gap (10–15cm) should be left if the wall is exposed to the sun. These gaps will allow any heat transferring from the outside environment to be carried away in the room air before it can warm the product. Likewise, a clear air space of 25cm or more should be left between the fan unit and the top of stacked pallets or bins. This will allow the cold air to move over the top of the store contents, rather than being blocked by products nearest to the refrigeration unit. Stacking products on pallets allows air circulation between the floor and the packed products. Aligning the pallet skids to run parallel to the direction of the cooling air (i.e. towards the refrigeration system) will create a more efficient air circulation.



Diagnose Walk-in Cooler & Freezer Refrigeration Problems

The ubiquitous walk-in cooler or freezer is an essential part of many cafeterias, restaurants and convenience stores. It is also a large energy user in these facilities but is rarely considered until problems emerge. Problems include failure to maintain pressure and compressor failure, both of which can result in expensive losses to the products stored in the cooler. These problems, as well as unnecessarily high energy use, can be avoided by observing equipment and taking corrective action.

Walk-in Cooler/Freezer Diagnostic Protocol		
MALFUNCTION	POSSIBLE CAUSE	SOLUTION
Power is on, but control board does not display	Phase loss or fuse blown Power phase open or transformer shorted Control board failure	Check wiring for breaks and replace fuse Check Transformer output voltage (12V) Replace cold storage room control board
Control board displays, but compressor does not run	Compressor relay tripped. Hi-Lo pressure safety switch shut down. Defective contactor or coil Cold room temperature is lower than operation setpoint Internal thermal overload tripped. Compressor malfunction	Determine reason and take correct action Determine type and cause of shutdown and correct it before resetting safety switch. Repair or replace Reset operation temperature setpoint Wait until compressor cools down for reset Check compressor motor winding
High discharge pressure	Dirty condenser coil Fan not running System overcharged with refrigerant	Clean walk-in cooler and walk-in freezer condenser coil Check fan motor and its electrical circuit Reclaim excess refrigerant
Low discharge pressure	Insufficient refrigerant in system. Low suction pressure	Check for leaks; repair and add charge. See corrective steps for low suction pressure
High suction pressure	Excessive load. Expansion valve overfeeding	Reduce load Regulate superheat
Low suction pressure	Lack of refrigerant Plugged suction filter Evaporator dirty or iced. Fan not operate Expansion valve underfeeding	Check for leaks. Repair and add charge Replace suction filter Clean and defrost Check fan motor and circuit control Regulate superheat
Large difference between actual cold storage room temperature and set point on control panel	Incorrect room temperature Sensor placement, wire too long, Sensor contactor open	Re-position sensing point of temperature sensor Enlarge wire section Reconnect sensor
Heavy frost builds up on evaporator fins	Too much time between defrost cycles or incomplete defrosts	Manual defrost and adjust defrost cycle
High temperature alarm	Overload and door open door excessively Bad refrigeration performance Heavy frost build-up on evaporator	Reduce load and door opening See corrective steps for discharge and suction pressure malfunctions Manual defrost and adjust defrost cycle
Coil not clearing of frost during defrost cycle.	Heater malfunction Not enough defrost cycles per day	Check heater operation. Adjust defrost control
Ice accumulating in drain pan	Defective heater. Drain line plugged.	Check heater; replace if necessary Clean drain line
Display screen flashes, unit emits humming noise	Observe alarm indicator	See alarm indicator for remedy