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Clean Energy Cooperation with India (CECI): Legal and policy support to the development and implementation of energy efficiency legislation for the building sector in India (TA-ECBC)

Webinar

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The Role of HVAC in a new Energy-Efficient World

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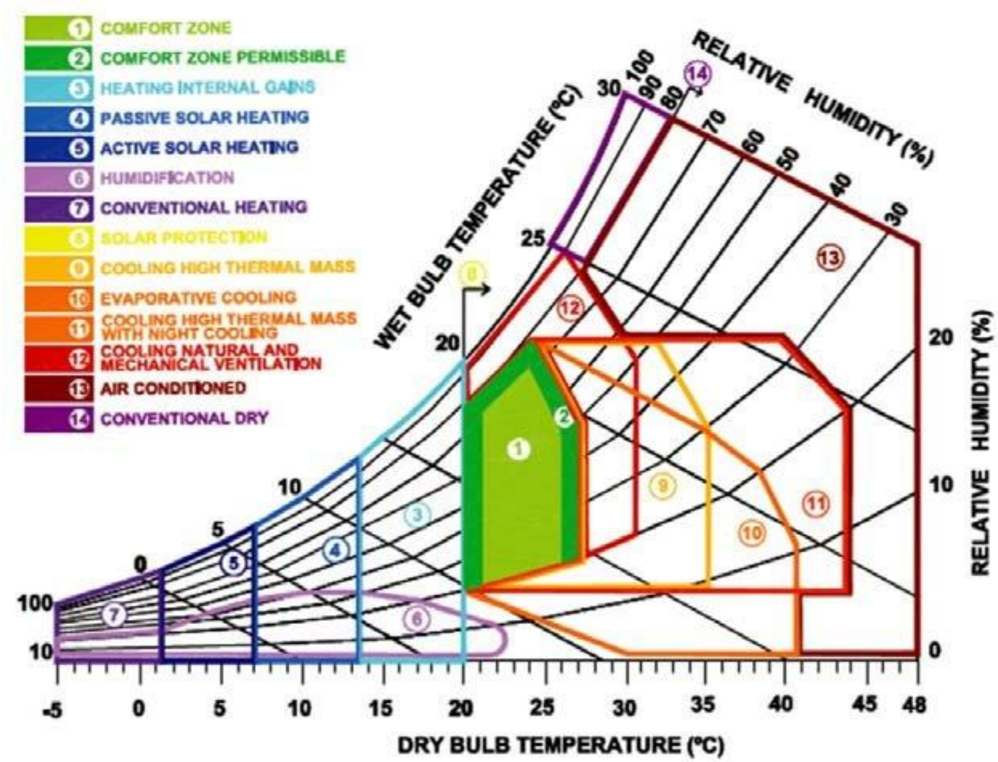
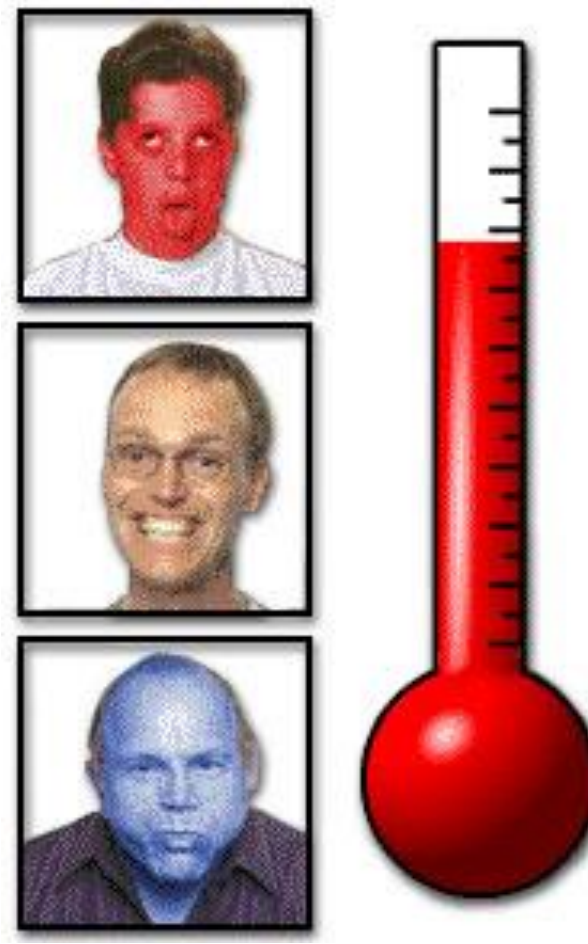
Thermal Comfort

The conditions of comfort (temperature and humidity) that must prevail in an interior space are determined by tables, charts and vary depending on the use of the space and the number of people in it.





Heating, Ventilation and Air Conditioning Systems

Heating, Ventilation and air-conditioning

Natural ventilation

- Air leak ventilation
- Open Window ventilation
- Shaft ventilation
- Roof-mounted opening ventilation

Air-conditioning systems

All-Air systems

- One-channel systems
  - Variable air volume systems (VAV)
  - Constant air volume systems (CAV)

Air-water systems

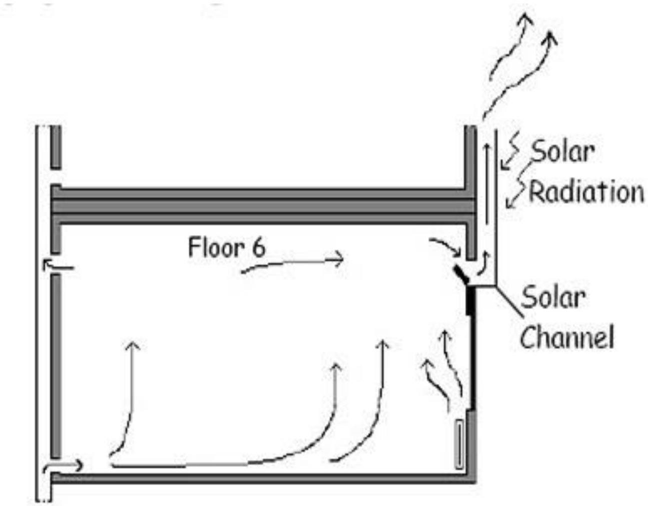
- CAV-systems combined with heating and cooling panel induction systems
- CAV-systems combined with fan-coils

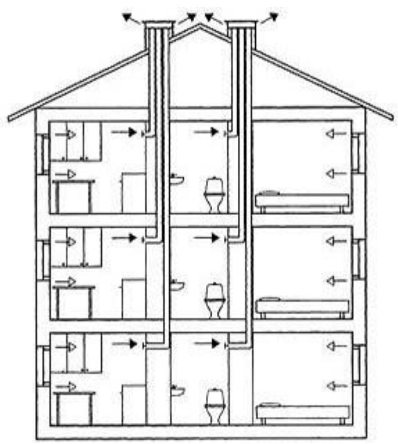
Air-refrigerant systems

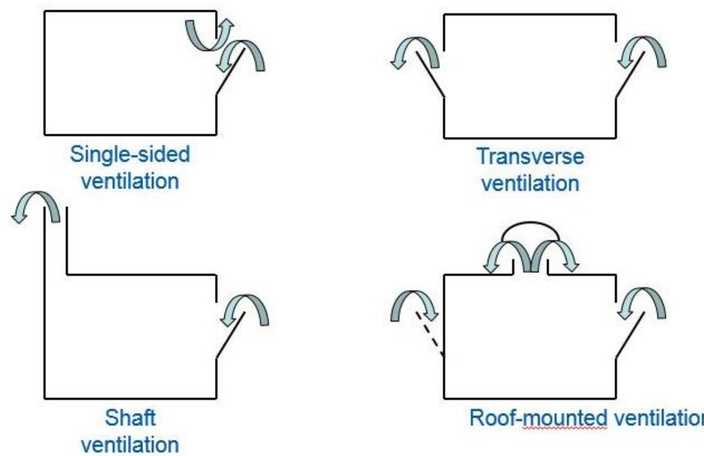
- CAV-systems combined with split system
- CAV-systems combined with multi-split or Variable Refrigerant Flow systems

1. Natural Ventilation

- Natural ventilation represents air exchange through joints in the building shell, open windows or special ventilation openings.
- It is caused by wind conditions that lead to pressure differentials and temperature differences between the interior and the exterior of a building.







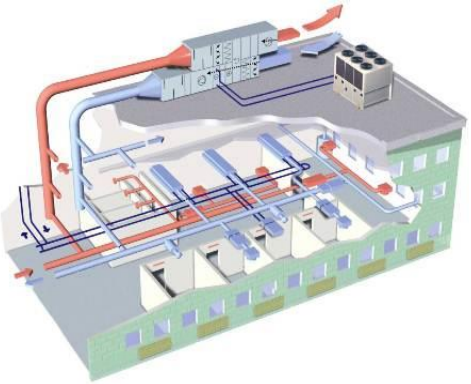
Source: Bretzke, A.: Lüftung und Luftdichtheit (HS Biberach) www.kth.se/en

Window Ventilation Performance

Window position	Air exchange rate n [1/h]
Tilted single sided windows	0,3 – 1,5
Tilted windows, transverse ventilation	0,8 – 2,5
Half-opened single sided windows	5,0 – 10,0
Completely opened single sided windows	9,0 – 15,0
Completely opened window, transverse ventilation	20,0 – 40,0

2. Mechanical Air Conditioning Systems

- If natural ventilation is not sufficient to cover the cooling loads, an air-conditioning system has to be installed. In the building sector air conditioning systems are used in:
  - Office buildings
  - Hospitals,
  - Shopping Centers
  - Theaters
  - Schools
  - Sports Halls



- Both in winter and summer they maintain a constant temperature between 20-27°C and a relative air humidity between 30 – 65 %. In office buildings and public buildings, the maintenance of a suitable comfort standard has a big influence on the performance and health of the employees and visitors.

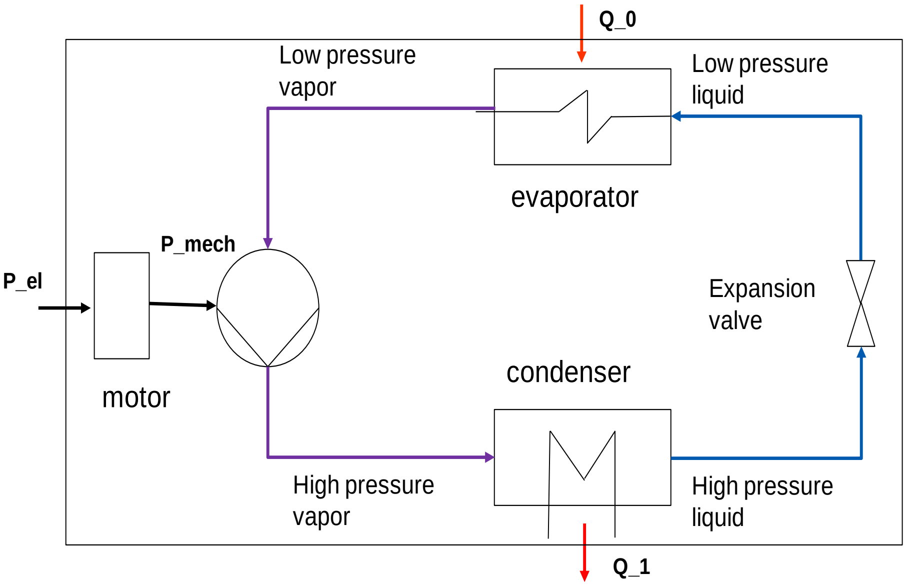
2.1 Cooling – Reference Model

Vapour Compression Refrigeration cycle

Operating power is used to transfer heat from one system with low temperature level to another system with higher temperature level.

The vapour compression cycle uses state changes (gas/liquid) of the coolant for heat transfer.

For simplification power for auxiliary equipment (lights,..) is included in the operating power P_el.



Q_0 [MW] heat flow from low temperature level
Q_1 [MW] heat flow to high temperature level
P_el [MW] operating power (electricity)
Energy balance: **Q_1 = Q_0 + P_el**

Coefficient of performance (COP)
COP [1] = Q_0 / P_el

Cooling – Basics, Power Input

Power Input :

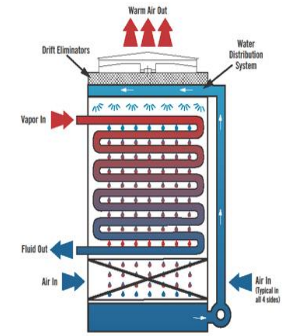
typically main contributors

- Compressor 65%
- Condenser pump 5%
- Condenser fan 10%
- Evaporator pump 15%
- Light 5%

Type of Refrigeration	COP Range
Mechanical compression refrigeration (air cooled units)	2.0-5.0 (max)*
Mechanical compression refrigeration (water cooled units)	4.0-7.0 (max)
Absorption refrigeration single stage :	0.40-0.75 (max)
Absorption refrigeration double stage :	0.8-1.0 (max)
NH_3/H_2O (Typical Absorption)	0.65 (max)

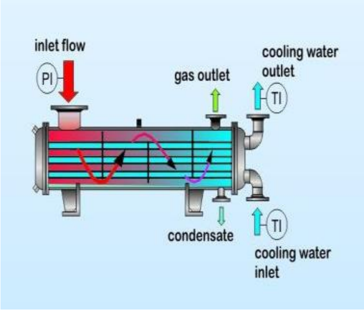
* For most industrial refrigeration installations based on mechanical vapour compression, the COP ranges between 2.0 for plants with T_e = -40°C and 5.0 for plants with T_e = 0°C.

Cooling – Condenser Classification



Evaporating condenser

- Condensation temperature depends on wet bulb temperature (usually 22 °C)
- Condensation temperature usually about 12 K high than wet bulb temperature



Horizontal multi-tube condenser with water running

- Condensation temperature depends on water input/output temperature
- Typical increase of water temperature in the condenser of about 8 K

Horizontal multi-tube with cooling tower

- Condensation temperature depends on wet bulb temperature (usually 22 °C)
- Air cooled condenser
- Condensation temperature be set at appr. 15 °C above most unfavourable temperature

Cooling – Condenser, Estimation of Savings

Energy Savings (Empirical estimation)

- Reduction of condensation temperature by 1 K - equal cooling capacity - **saves 1 - 2% energy** (operation power P_el)
- Increase of evaporation temperature by 1 K - equal cooling capacity - **saves 3 - 4% energy** (operation power P_el)

Cooling - Evaporator

Characteristics

Q [MW]	Heat_flow
T_C [°C]	Condensation Temperature
T_A [°C]	Ambient temperature
dT = T_A – T_C	Temperature difference
A [qm]	Evaporation surface
U [MW/(K*qm)]	Heat transfer coefficient

Characteristic Curve

$Q = U \cdot A \cdot dT$

Maximize Heat Exchange

- High temperature level in the evaporator
- Large evaporation surface
- Check (forced) convection

Temperature difference dT should be between 3 – 7 °C

Cooling – Control of Operations, Motivation

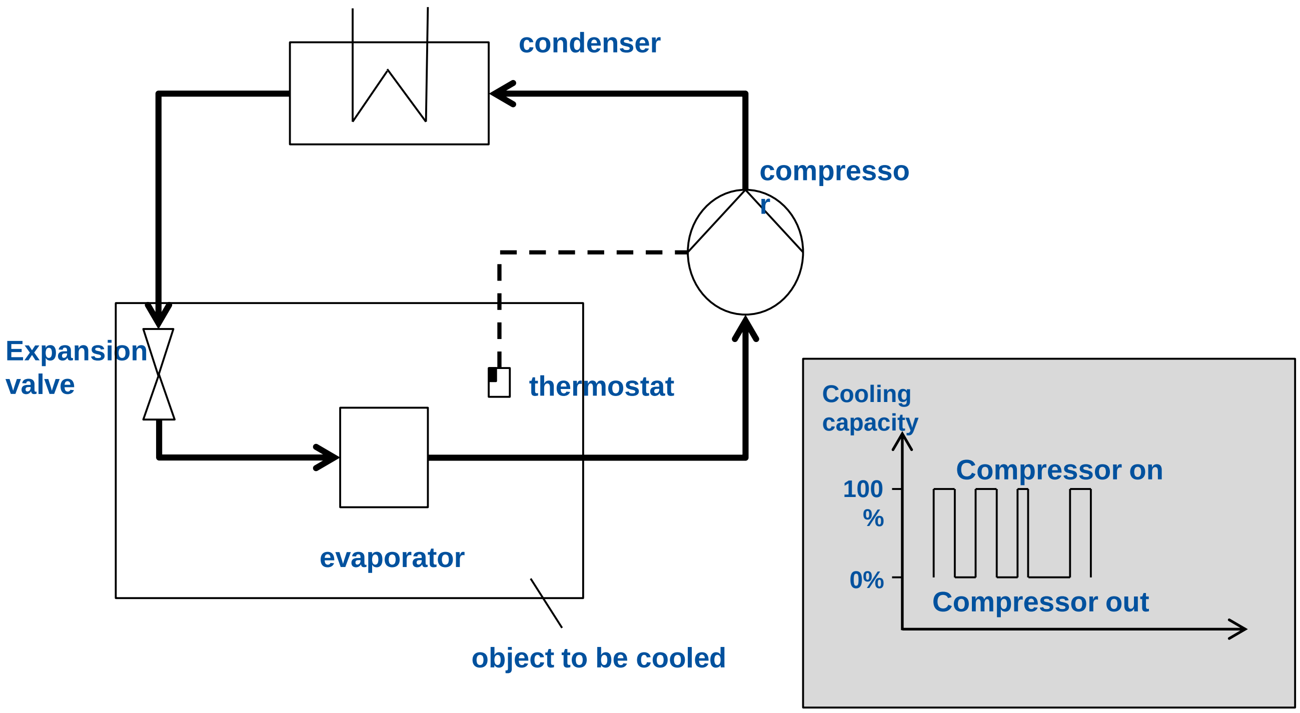
Objectives

- Maximize operating efficiency.
- Balance evaporator cooling capacity and average load
- Insure operational reliability

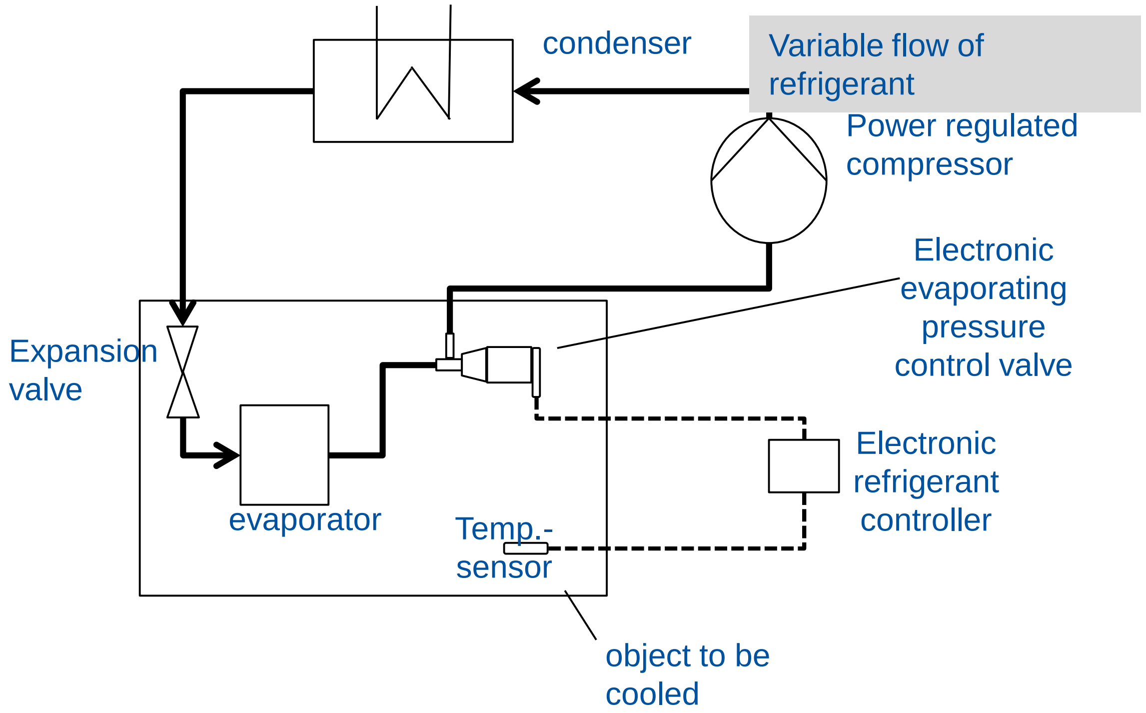
Options

- Discontinuous Control
  - (thermostatic)
- Continuous Control
  - (electronic)

Cooling – Control of Operations, Discontinuous Control



Cooling – Control of Operations, Continuous Control



Cooling – Control of Operations, Comparison

Expansion valves

- Pressure reduction by expansion
- Active control of refrigerant flow and the cooling capacity
- Control of superheat

Thermostatic control

- Constant load
- Storage or low tolerances for set points e.g. cold water storage or ice storage

Electronic control

✓ **Variable load**

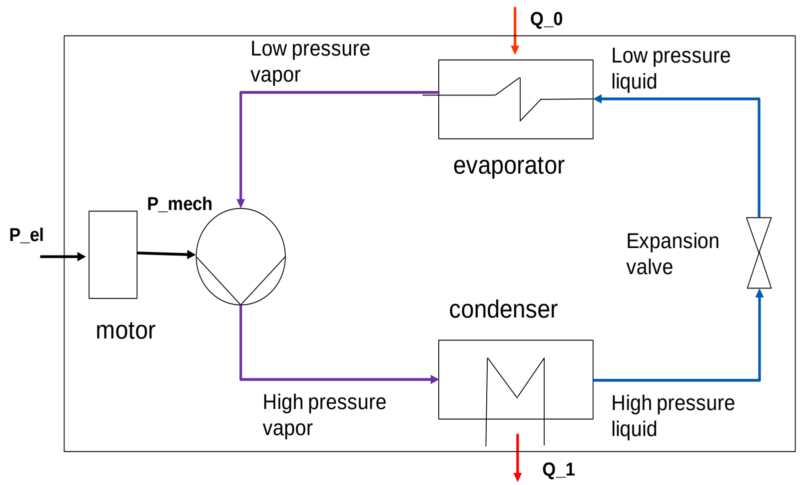
✓ **Requirements for set points**

– **Higher costs**

Cooling – Measures

Overview

- Load analysis
- Multi-stage systems
- Integrated plant layout
- Heat recovery
- Control of operations and instrumentation
- Insulation



Efficient design

- Condensers
- Evaporators
- Compressors
- Insulation
- Ice storage

Control of Operations

- Continuous/ discontinuous
- Expansions valve
- Pressure switch
- Defrosting

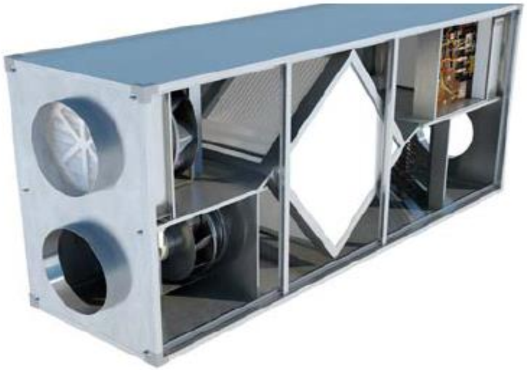
Good Housekeeping

- Maintenance (mechanical parts maint., cleaning of evap/cond, repair of insulation etc.)

2.2 The important role of Heat Recovery: Exhaust air heat recovery

- When recovering heat from exhaust air, both sensible heat and condensed heat from the water vapour in the air (i.e. latent heat) can be exploited, provided that the exhaust air is cooled below the dew point.
- The amount of heat recovered will depend on **initial moisture content** of the exhaust air, the **initial temperature** of the supply air effectiveness of the heat recovery system.
- Air-to-air heat exchangers can reduce energy consumed in exchanging the air by **up to 50%**. This can reduce a building's total energy consumption by **2%-9% (*)**

(*) Source: Economizers in Air Handling Systems, CED Engineering



Source: Carbon Trust -CTG057

Exhaust air heat recovery-heat wheel

Heat Wheel or Rotary Regenerator

Gas to gas -Rotating wheel from metallic or ceramic mesh, warmed by hot air stream. Heat is transferred from the mesh to incoming fresh air as the wheel rotates.

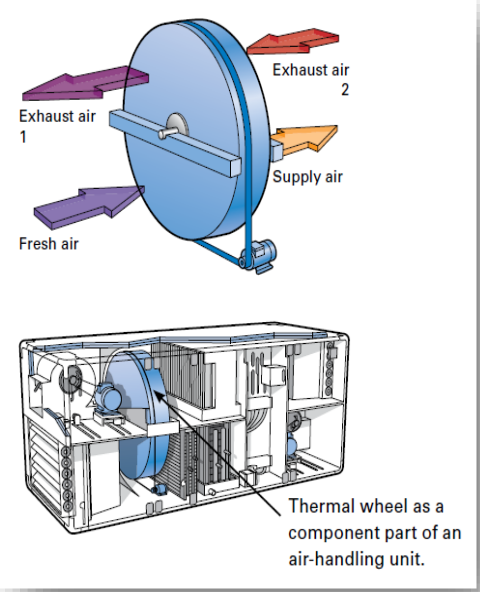
Small size and low P drop compared with other gas to gas heat exchangers

Efficiency: up to 80 %.

Some mixing of the two gas streams

Diameters up to 4 m and maximum gas flow of 70,000 m^3/h

Applications: HVAC, HR from dryers

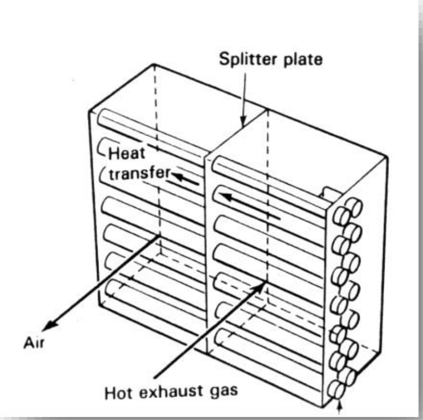


Source: Carbon Trust ECA771

Exhaust air heat recovery-heat pipes-run-around coils

Heat Pipes

- Closed evaporation-condensation loop
- Sealed tube with a porous wick attached to the inner surface, containing a working fluid.
- Operates by continuously evaporating and condensing the working fluid,
- Large quantities of heat transported with small temperature

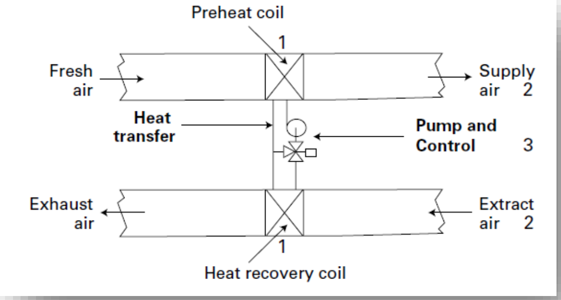


Run-around coils

Two physically separated heat exchangers (coils) in the air supply and exhaust ducts recover and transfer heat between them- intermediate fluid e.g. water

Flexibility: supply and extract ducts can be physically separated, even in different parts of the building

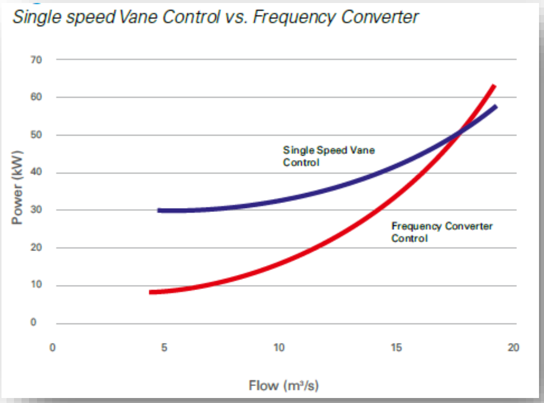
Reduced efficiency due to intermediate fluid; electricity is required for pumping fluid



Source: Carbon Trust ECA771

2.3 Energy Efficient Design

- Selection of High Efficiency (HE) Motors and Variable Speed Drives (VSD)
- Selection of a high efficiency fan (which will be determined by blade geometry and casing shape);
- Design the ventilation system so that losses are minimised at its expected load. This will influence the length and position of ducts, the type of regulation devices and the shape of its cross-section;
- Selection of the best fan for the application;
- Selection of the best type of control to regulate the fan's speed and cross-section.



Power of a Fan Drive

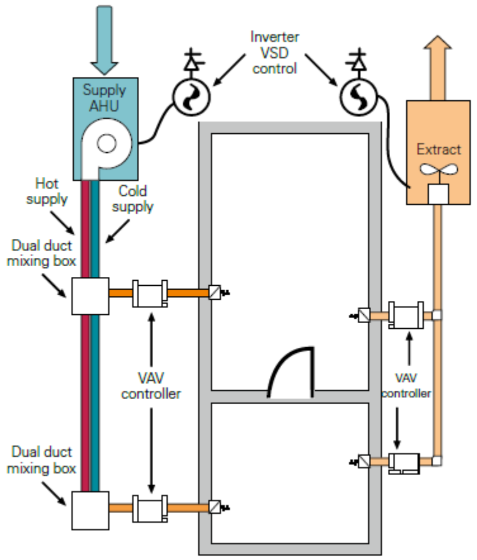
Source: Carbon Trust ECA773

Reduction of fan motor speed-VAV

- Normal practices:
  - Dual duct systems: supply heated and cooled air to each zone -then mixes the air locally
  - supply and extract a constant volume of air, but at a variable temperature

Energy wastage!!!

- Large energy savings if the volume of fresh air is varied to meet actual needs , from reducing fan motor speeds using VSDs
- By fitting control dampers constant volume systems can be converted to Variable Air Volume (VAV)
- Sensors detect whether rooms are in use and adjust ventilation
- Alternatively CO_2 sensors at air extraction ductwork regulate air e.g. constant level of 800 ppm.

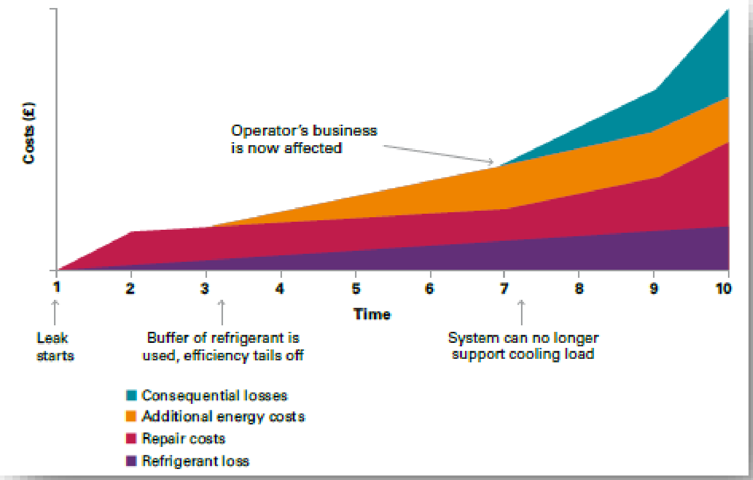


Proposed alteration of a dual duct air conditioning system to variable air volume (VAV).

Modifying dual duct to VAV system
Source: Carbon Trust CTG028

Leak reduction

- HFC refrigerants: high environmental impact (GHG potential 3000 of CO_2)
- Refrigerant leak detection system
- Reduces costs for leak repairs



Source: Carbon Trust

Insulation

Thermal losses depend on effective heat transfer area, heat transfer coefficient and temperature difference.

<u>Additional aspects for freezing rooms</u>

- Energy exchange caused by material transfers
- Energy exchange caused by air convection (open door)
- Initial freezing of products

Bad practice

Source: Carbon Trust

Good practice

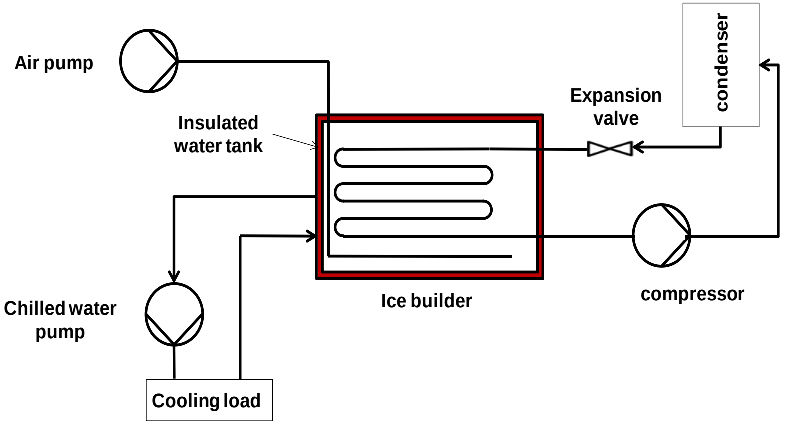
Ice Storage

Ice bank cooling

- Takes advantage of low price night electricity rates
- Water is circulated around ice bank's coil where it is cooled by surrounding ice layer
- Ice melts and is built up next night

Base Conditions

➢ Minimum temperature of 2 °C



Ice Storage

Benefits of Ice storage

- ✓ Reduced chiller size
- ✓ Variable capacity, quick pulldown, reduced compressor wear
- ✓ Constant low temperature supply
- ✓ Reduced electrical capacity and equipment
- ✓ **Reduced energy costs**
- ✓ **Improved quality**

Source: Hafner Muschler

Applications

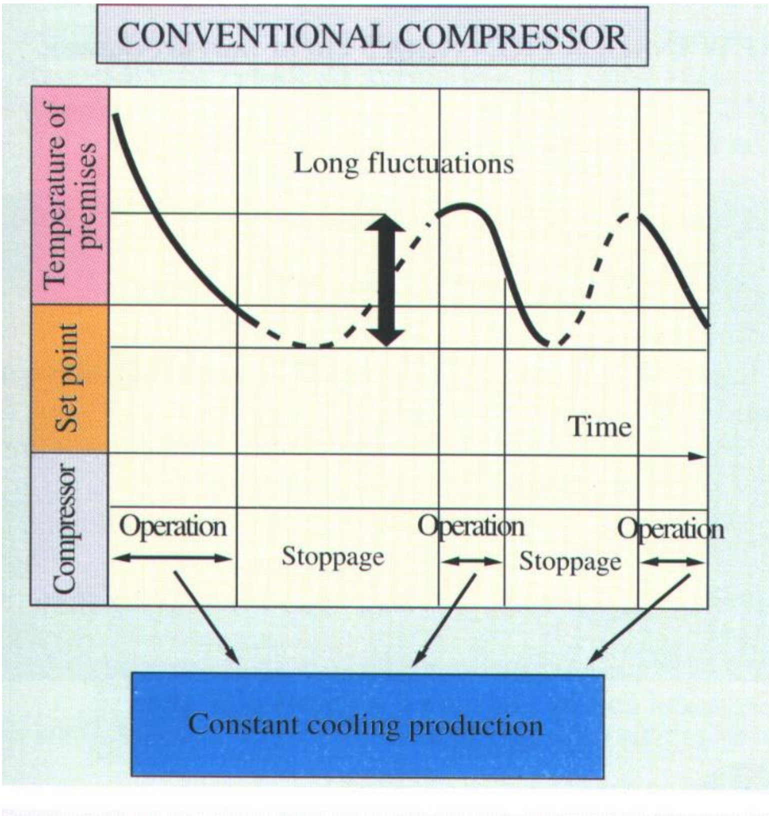
Dairy, food industry

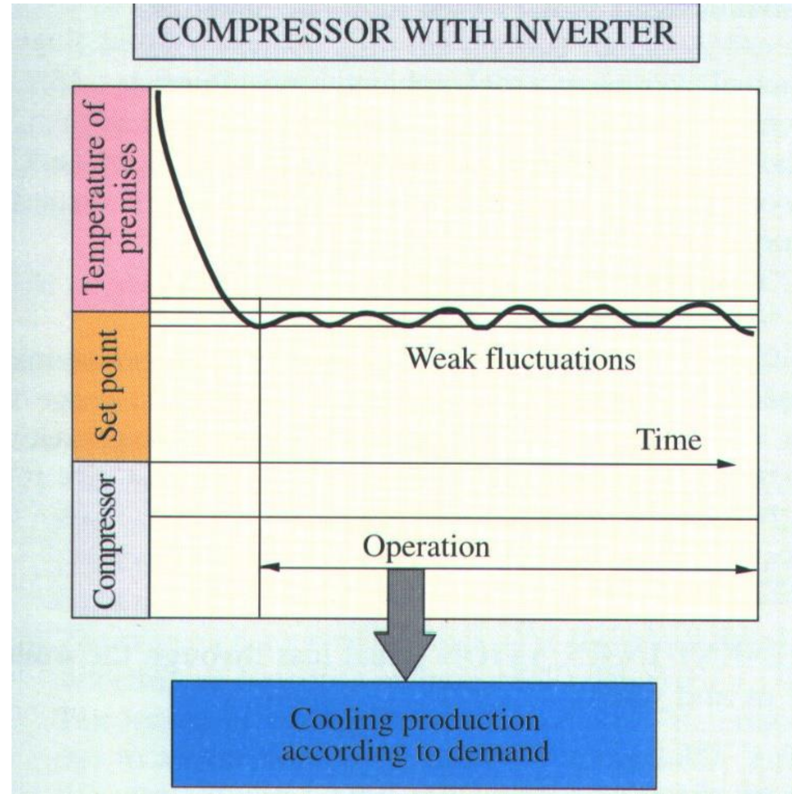
Pharmaceutical

Plastics

Particularly where there are high cooling loads for short periods

VSD


CONVENTIONAL COMPRESSOR
Temperature of premises
Set point
Compressor
Long fluctuations
Time
Operation
Stoppage
Operation
Stoppage
Operation
Constant cooling production


COMPRESSOR WITH INVERTER
Temperature of premises
Set point
Compressor
Weak fluctuations
Time
Operation
Cooling production according to demand

Absorption Process

Absorption processes use thermal instead of mechanical operation energy

Refrigerants (solvent mixtures)

- Water/ lithium bromide
- Ammonia - water

Usage of thermal energy from

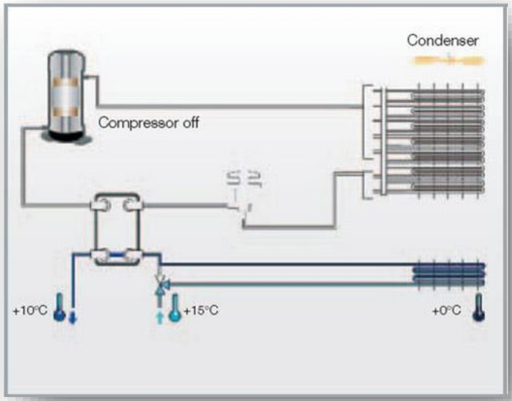
- **CHP**
- **Gas turbines**
- **District heat**
- **Waste heat**
- **Solar heat**

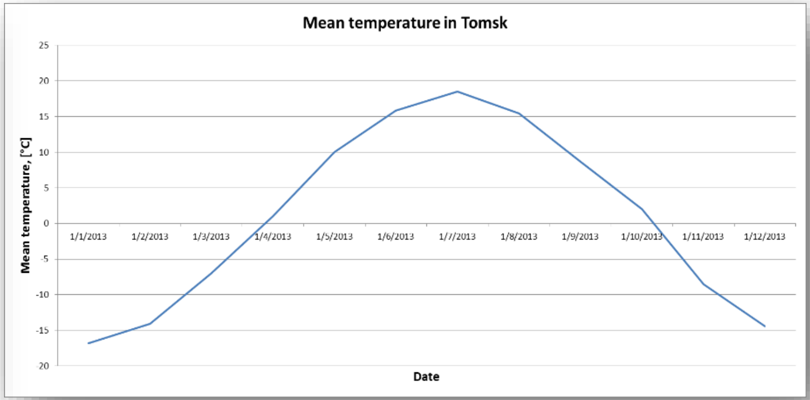
Dependent from base conditions:

Up to 30 % savings of primary energy in comparison to compression based cooling

Free cooling

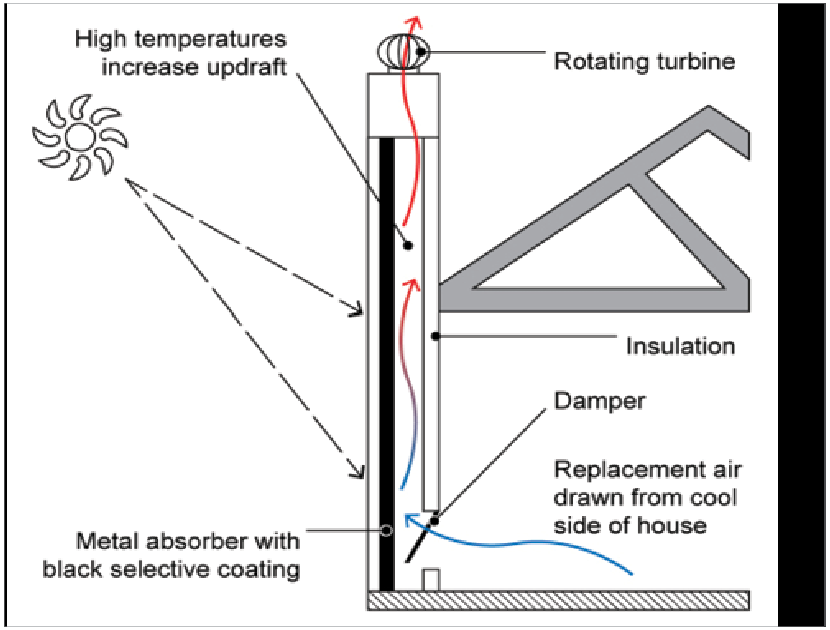
- Many AC system and refrigeration processes need chilled water at relatively high temperatures (often 10-15 °C)
- When air temperatures colder than water needed, then free cooling is an option
- Also if constant energy requirement all year round





Passive cooling - Solar Chimney

- Solar chimneys enhance stack ventilation by providing additional height and well-designed air passages that increase the air pressure differential.



Source Australian government, Yourhome guide
http://www.yourhome.gov.au/passive-design/passive-cooling

Cooling – General Energy Savings Measures

- Ensure proper air flow at heat exchangers, e.g. periodic checks
- Ensure periodic maintenance intervals
- Periodic check of insulation
- Minimize idle times
- Minimize overall load
- Minimize part-load conditions
- Check usage of improved control systems
- Utilise waste heat where possible
- Check replacement of inefficient components

2.4 Good housekeeping measures in HVAC systems

- Pressure losses: Air friction loss in ducts can be reduced by 75% if their internal diameter is increased by 50%. In addition, velocities of above 10 m/s should be avoided.
- If capacity currently controlled by the throttling of a damper - more efficient to install several small fans in parallel (which would be switched on or off as required);
- Changing the rotational speed of fans improves the efficiency of the control, especially when a ventilation system is working at a low load. If capacity is constantly too high, it may be possible to modify the belt drive ratio. However, some key rules should be remembered:
  - *Doubling the speed will double capacity;*
  - *Doubling the speed will quadruple the pressure; and*
  - *Doubling the speed will increase power input eight times.*
- Employee training
  - *Natural ventilation -service staff should close* windows *when AC is working and switch AC off when windows are open*

Importance of Installation Practice to System Performance

- **Do**

✓ Ensure ducts take the path of least resistance to maintain system efficiency. Reducing amount of bends and flexible duct in the duct routes will help maintain performance. Flat ducts of an appropriate size for the system can be used instead of rigid round duct

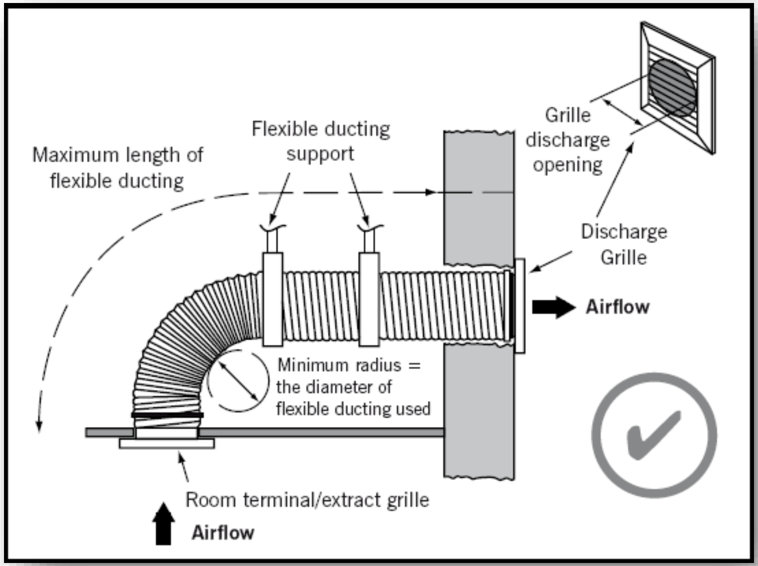
- **Don't**

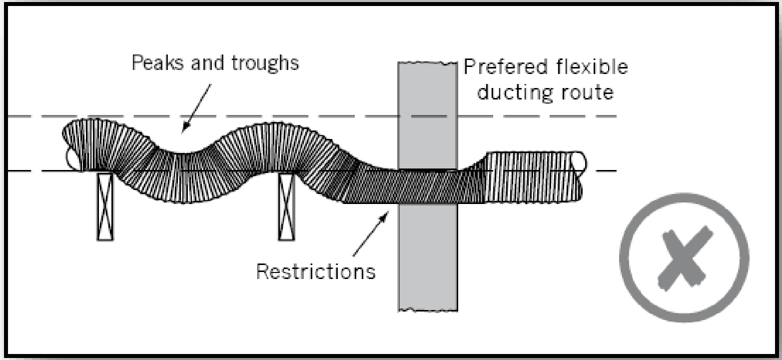
X Allow ducts to be unsupported

X Introduce more bends than necessary

Here, the system is using too much flexible duct and has sharp bends in close proximity, which will greatly affect performance

Importance of Installation Practice to System Performance





Do

- ✓ Ensure duct takes the most economical route out of the building
- ✓ Ensure that duct is adequately supported
- ✓ Ensure that bends are swept to offer the least amount of resistance

Don't

- x Allow duct to sag, causing peaks and troughs
- x Pass duct through an opening that allows a restriction to form causing resistance

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