UNIT – 1 Vehicle air-conditioning fundamentals

Air conditioning system in a vehicle is a part of HVAC system which allows adjusting of air temperature, humidity, and direction. It also improves the air quality, which may benefit people with certain health problems, by dehumidifying and cleaning the air as it cools it.

To be effective, the automotive air-con system must control four (4) conditions within the vehicle interior:
- It must cool the air
- It must circulate the air
- It must purify the air
- It must dehumidify the air

Understanding Heat

For a simple definition we may say that **heat is energy**. Meshing of gears, or turning of wheels cause friction which results in heat. Combustion (fire) gives off heat. The burning of sun radiates heat to the earth's surface. Heat in the correct amount will provide life and comfort. Heat in either extreme - extreme too much or too little - will be uncomfortable. The control of temperature means the control of comfort. Air conditioning is a method of controlling heat.

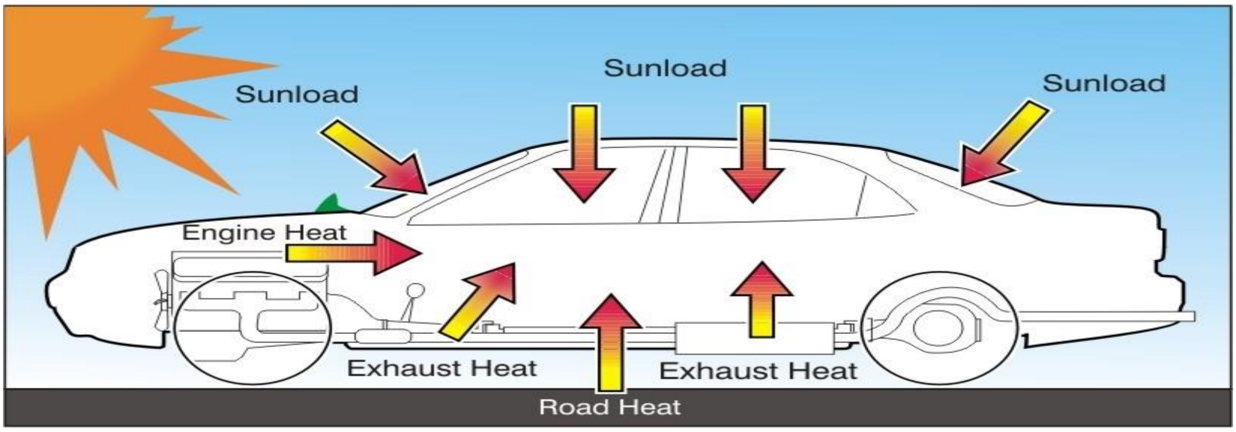
All substances contain heat. Science tells us that a measurement called "Absolute Zero" is the point at which all heat is removed from an object (approximately -273 C). Any substance above this absolute zero temperature retains some heat.

The average person requires a comfort zone of approximately 21ºC to 26 ºC, with a relative humidity of 45 to 50%. In this temperature and humidity range, we feel most comfortable. All objects within this same range are comfortable to touch. As the temperature of anything goes above or below this range, we think of it as HOT or COLD.

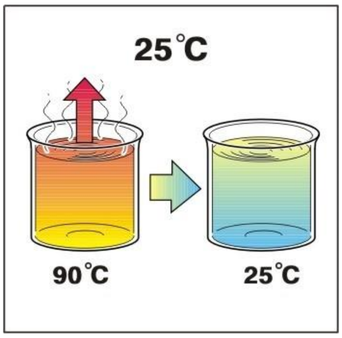
How does heat get inside a vehicle?

When a car is driven or parked in the sun, heat enters the vehicle from many sources: Ambient air, Sunlight, Engine heat, Road heat, Exhaust heat…

All of these and other miscellaneous heat sources increase the air temperature within the vehicle.
In a high ambient temperature situation (e.g. on a 37 ºC day), the interior of a vehicle left standing in the sun with windows closed could **reach 65-70 ºC .**



What causes heat to move?

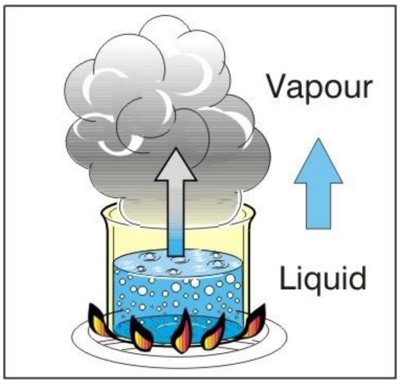


Heat always moves from the hotter objects to the colder one. Whenever there is a transfer difference between two objects, the heat energy will be transferred from the warmer object to the cooler one until both objects stabilize at the same temperature.

This is the basis of air conditioning operation. Automotive air conditioner is designed to move heat from one place (the inside of your car) to some other place (the outdoors).

When a hot cup of coffee is set aside for some time, it becomes cold.Heat moves out of the hot (90 ^oC) coffee into the cooler (25 ^oC) surrounding air. In time the coffee will reach the temperature of the surrounding air

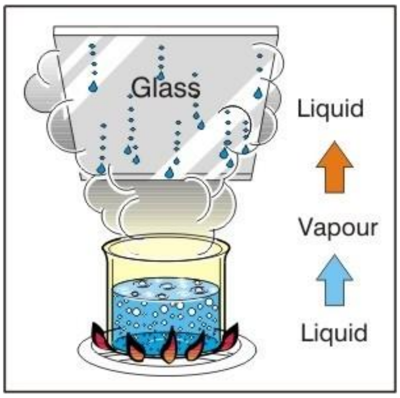
Basic physics of air conditioning



Evaporation

Is the term used when enough heat is added to a liquid substance to change it into a vapour (gas). For example, when water is boiled.

This condition occurs within the A/C system, only the refrigerant is evaporating.



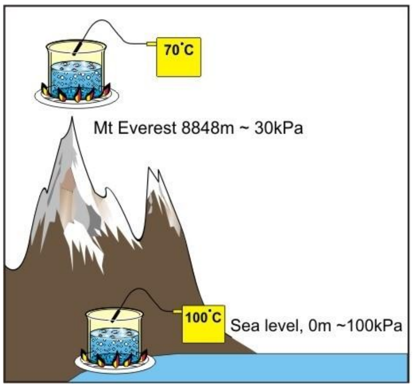
Condensation

Is the term used to describe the opposite of the evaporation process. If you take a vapour and remove enough heat from it, a change of state occurs. The vapour becomes a liquid.

The change of vapour to a liquid is called condensation.

This condition occurs within the A/C system, only the refrigerant is condensing.

Pressure & temperature relationship

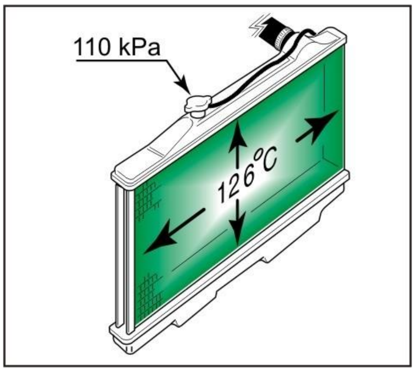


To increase or decrease the boiling point of a substance, we must alter the pressure on the substance.

Increasing the pressure increases the boiling point. To decrease the boiling point, decrease the pressure.

Example:
At sea level atmospheric pressure ~100 kPa boiling point of water is 100 ^oC. On Mt. Everest (~30 kPa) boiling point is 70 ^oC.

Water in a vacuum will boil at 19^{o}C.



If water is put under pressure, the boiling point will rise. Good example is the automotive cooling system. The pressure cap keeps the radiator from boiling over by increasing the pressure on the coolant.

Example: 110 kPa radiator cap allows the coolant temperature to reach 126 C before boiling.

The same holds true for the refrigerants used in an air conditioning system. Under pressure the boil point is raised, when pressure is lowered the boil point is lowered.

Refrigerants in Automotive Air Conditioning Systems

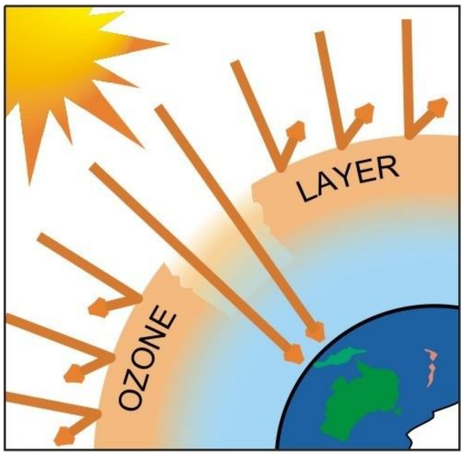
Refrigerant is a fluid capable of changes of its state at low temperatures. Released on atmospheric pressure refrigerants used in automotive industry will boil at ~ 26 ºC, changing its state from liquid to vapour (evaporate). In the process of evaporation they absorb large quantity of heat from surrounding (in our case the heat from inside the vehicle).

Automotive refrigerant has changed over the years from ammonia gas, to R12 (Freon), to R134a and now to 1234yf.

Since 1990's the Automotive industry has started to use a non-ozonex-depleting refrigerant **R134a (HFC)** which was selected as a replacement for old **R12 (CFC)** because is has a major effect to ozone layer depletion.

R134a lives for around 13 years in the atmosphere before breaking down. Its global warming potential (GWP) is ~1400.

HFO1234yf is a new refrigerant, developed for auto air conditioning as a replacement for R-134a. It was developed to meet EU directives, which demand a refrigerant with a GWP of less than 150. New refrigerant 1234yf breaks up in around 11 days, with GWP of 4.



Ozone layer acts as a shield that protects the earth's surface from harmful ultra violet radiation coming from the sun. Since R12 was phased out in the holes in the ozone layer have been healing themselves.

HFO-1234yf has a pressure-temperature curve and other key characteristics very close to R-134a. It is thermally stable and compatible with R-134a components, and would be a near drop-in replacement for R-134a. A drop-in test by Toyota showed HFO1234yf had slightly better cooling performance than R-134a.

R134a probably will not disappear till 2025 year. Vehicles produced from 1990 to 2015 will still need R134a. What is to expect that the R134a price will go up which will prevent frivolous use.

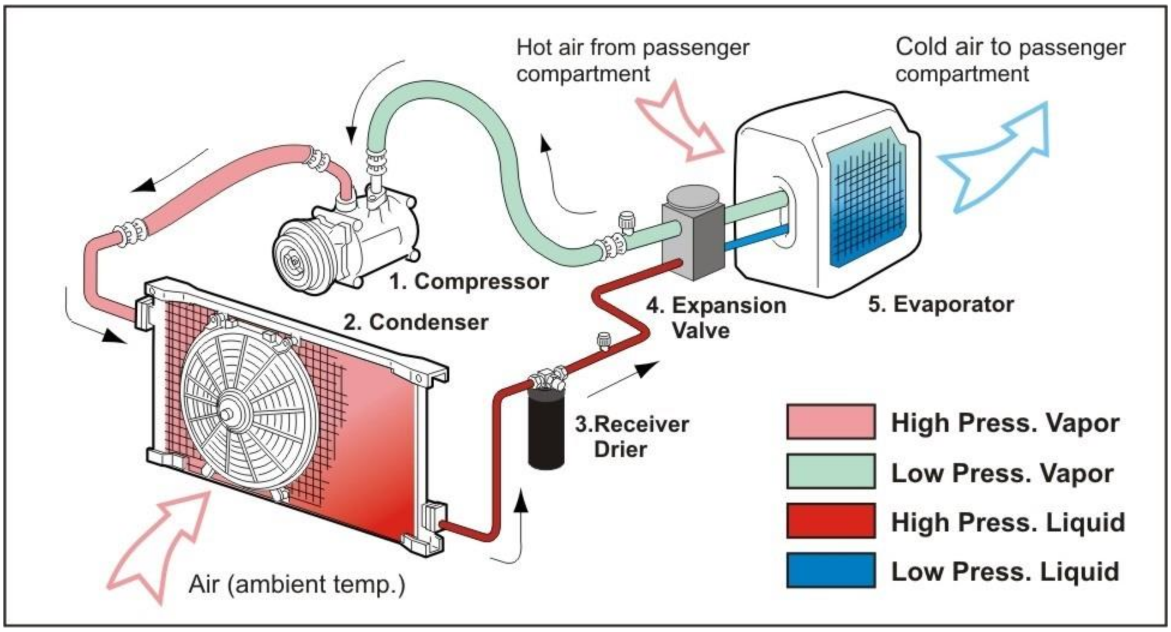
	R12 (in use till 1990)	**R134-a** (in use 1990-2016)	**1234yf** (in use from 2012)
Chemical name	**(CFC)** ChloroFluoroCarbon	**(HFC)** HydroFluoroCarbon	**HFO** HydroFluoroOlefin
Ozone depleting potential (1=max)	**1.0**	**0**	**0**
Global warming potential (GWP)	**2400**	**1400**	**4**
Boiling point on atmospheric pressure	**-29.6 ºC**	**-26.3 ºC**	**-29 ºC**
Flammability Risk	**No**	**No**	**Low-Mid**
Toxicity	**Low**	**Low**	**Low**

How Automotive Air Conditioning Works

An air conditioning system was first used in automobiles as early as the 1940s. Over the years, car air conditioning systems have gone through much change, although the basic concept of vehicle air conditioning remains untouched.

The basic components found in a vehicle air conditioner are the **compressor, condenser, evaporator, receiver drier and expansion valve**. All these components have a specific task. Hard tubing and flexible hoses connect all the components of the air conditioning system. Pressurized refrigerant in both states (vapour or liquid) passes around the whole system.

To understand the operation of the five major components of an automotive A/C system remember that the air-conditioning unit is divided into two sides:
- The high side of the system refers to the parts that are under high pressure and high temperature. These components are identified by smaller diameter tubing and very hot to the touch components.
- The low side of the system referrers to low pressure components that are larger in diameter as far as the hoses and tubing and these components will be ice cold to the touch. This is very handy for diagnosis.



Compressor: The compressor is the work horse of the air conditioning system, powered by a drive belt connected to the crankshaft of the engine. When the air con system is turned on, the compressor pumps refrigerant vapor under high pressure to the condenser.

Condenser: The condenser is a device used to change the high-pressure refrigerant vapor to a liquid. It is mounted in front of the engine's radiator, and it looks very similar to a radiator. The vapor is condensed to a liquid because the heat is removed from the condenser by air flowing through the condenser on the outside.

Receiver-Drier: Now the liquid refrigerant moves to the receiver-dryer. This is a small reservoir vessel for the liquid refrigerant, and removes any moisture that may have leaked into the refrigerant.

Expansion Valve: The pressurized liquid refrigerant flows from the receiver-drier to the expansion valve. Expansion valve removes pressure from the liquid refrigerant.

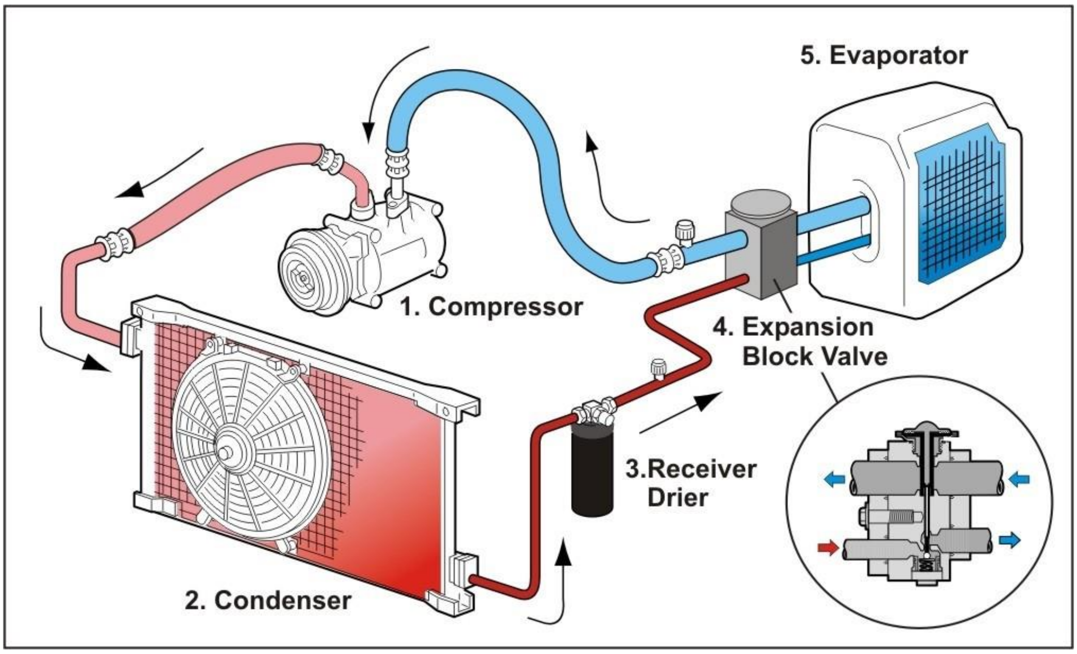
Evaporator: The evaporator is another device that looks similar to a car radiator. It has tubes and fins and is usually mounted inside the passenger compartment. As the cold low-pressure refrigerant is passedinto the evaporator, it vaporizes and absorbs heat from the air which comes from the passenger compartment. The blower fan inside the passenger compartment pushes air over the outside of the evaporator, so cold air is circulated inside the car.

Back to Compressor: The compressor then draws in the low-pressure refrigerant vapor to start another refrigeration cycle.

There are three types of automotive air conditioning systems: orifice tube, expansion valve or a combination of this two which is found in rear air conditioning systems.

Expansion Valve System

This system uses an expansion valve to meter the flow of refrigerant to the evaporator core. The expansion valve uses a temperature sensor at the evaporator core to determine the amount of refrigerantthat it will allow to pass through its variable orifice.
An expansion valve system uses a receiver drier (3) which acts as a particle filter, refrigerant storage container and most importantly moisture absorber.



What is a Refrigerant

- Working substances
- **Primary** and **Secondary** refrigerants.
- **Primary refrigerants** are those fluids, which are used directly as working fluids.

Ex.-refrigerant used in VCC and VAR systems.

These fluids provide refrigeration by undergoing a phase change process in the evaporator.

- **Secondary refrigerants** are those liquids, which are used for **transporting thermal energy from one location to other.**
- Secondary refrigerants are also known under the name **brines or antifreezes.**

Desirable Properties of Secondary Refrigerant

- **Low** freezing point.
- **High** heat transfer coefficients.
- **High** specific heat.
- **Low** vapour pressure.
- **Good** stability.
- **Non**-flammable and **non**-toxic.
- **CFC's**
  - First developed by **General Motor's researchers in the 1920's** and commercialized as **Freon's.**
  - **Most stable** – remain in atmosphere for many years, allowing them to diffuse to high altitudes
  - Contains Chlorine, Fluorine, Carbon.
  - CFC's break down, and Cl combines with and consumes some ozone

HCFC's

- **Hydrogenated**
- **Not as stable** – most of it breaks down before reaching high altitudes
- Contains Hydrogen, Chlorine, Fluorine, Carbon.
- Less damaging to ozone

HFC's

- Contains Hydrogen, Fluorine, Carbon.
- **Contains no Cl (Chlorine)**
- **Causes no depletion of ozone**

Examples :

- **CFC's (CHLOROFLUROCARBONS):**
  R11 (CCl_3F) Trichloromonofluromethane

R12 (CCl_2F_2) Dichlorodifluoromethane

R40 (CH_3Cl) Methyl Chloride

R13, R21, R22,R113, R114, R115

- **HCFC's(HYDROCHLOROFLUROCARBONS):**

R22 ($(CHClF)_2$) Monochlorodifluromethane

R123 ($C_2HCl_2F_3$) Dichlorotrifluoroethane

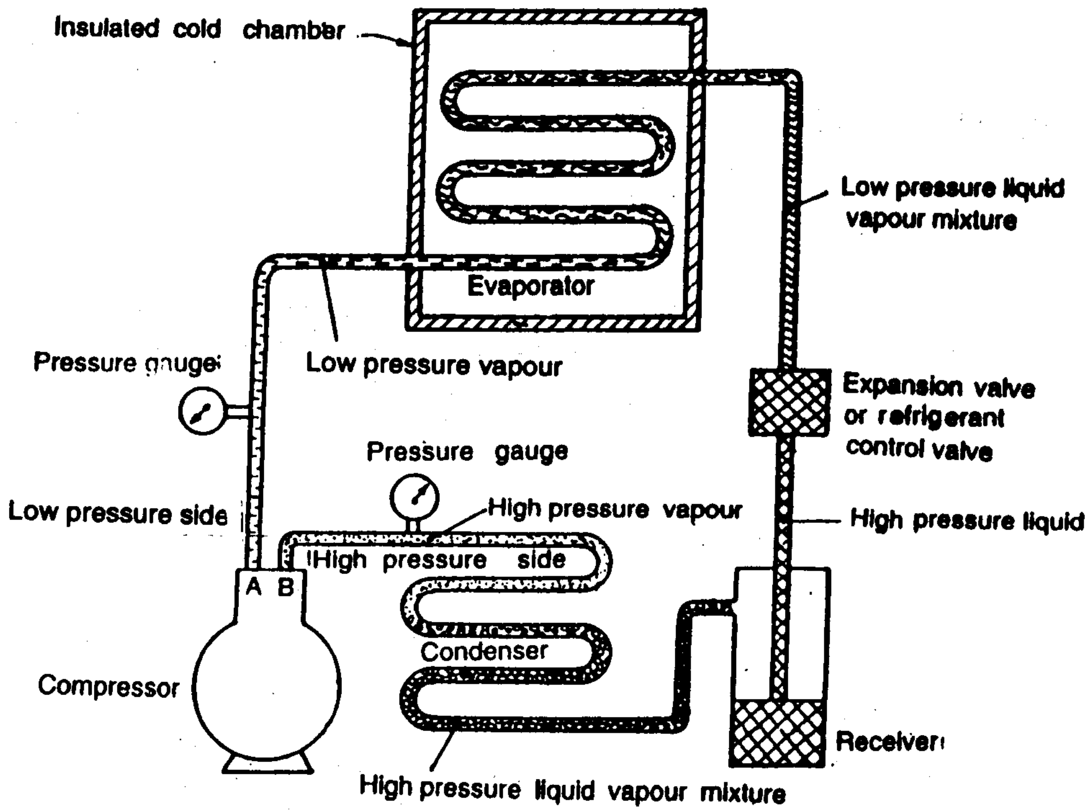
- **HFC's (HYDROFLUROCARBONS):**
  - R134a (CH_2FCF_3)Tetrafluoroethane
  - R404a, R407C,
  - R410a mixture of Difluromethane (CH_2F_2, called R-32) and Pentafluroethane (CHF_2CF_3, called R-125)

R-134a

- ODP-0, GWP-1300
- Used as a substitute for R12 and to a limited range for R22
- Good performance in medium and high temp application
- Toxicity is very low
- Not miscible with mineral oil

Components of Vapour Compression Refrigeration System:

- Compressor
- Condenser
- Receiver
- Expansion Valve
- Evaporator



1. Compressor: To remove the vapour from the evaporator & to raise the pressure and temperature to a point such that vapour can be condensed in condenser.

2. Condenser : To provide a heat transfer surface through which heat passes from hot refrigerant vapour

3. Receiver : to provide storage for condensed liquid so that constant supply of liquid is available to evaporator.

4**. Expansion valve** : To meter the proper amount of refrigerant (Flow control) to the evaporator & to reduce the pressure of liquid entering the evaporator.

5. Evaporator: To provide a heat transfer surface through heat can pass from the refrigerated space into the refrigerating vapour.