The A/C System

The Refrigerant Circuit

The basic A/C system contains components to push refrigerant through a closed system in order to extract heat out of the vehicle interior and transfer that heat to the outside air. This cycle continues constantly until the vehicle's interior reaches a set temperature. Inside the A/C system, the refrigerant changes from a liquid to a gas and then back to a liquid. As we shall see, this "phase change" is what helps remove heat from the air circulating inside the vehicle.

Expansion and Evaporation

If a pressurized liquid is released into an area of lower pressure, it will evaporate into a gas and absorb heat from that area. This is the principle that causes the spray from an aerosol can to feel cold to your skin. Likewise, a liquid that changes from liquid to vapor at a low temperature (e.g. alcohol) will feel cool on the skin as it evaporates (phase change). This is the situation you feel when you get out of a swimming pool or shower. The evaporating water on your skin absorbs heat from your body even though the air temperature is quite high.

Vaporization

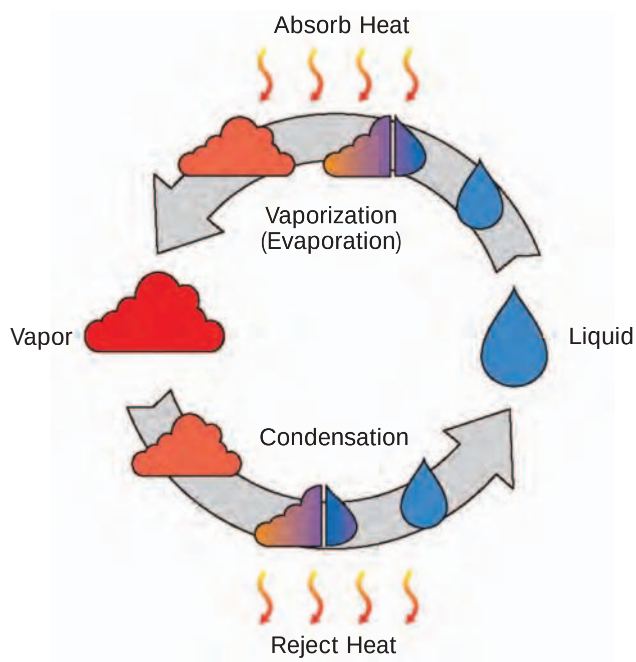

Fig. 2-1
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The device that regulates pressure in an A/C system is the **expansion valve.** The area where heat transfer takes place is the **evaporator** (heat exchanger).

Compression and Condensation

After the gaseous refrigerant absorbs heat, the system pressurizes it to change it back into a liquid. As this happens, the gas gives off much of the heat that was absorbed. This is what the **compressor** and **condenser** do in the A/C system. In order for the gas to actually give up heat while in the **condenser** (heat exchanger), it must be hotter than the air around it. The compressor makes this possible by increasing the line pressure, and therefore, the temperature of the refrigerant gas.

Refrigerant Properties

Automotive air conditioning has been widely available since the 1940s. The refrigerant CFC-12 or R-12 (also known as Freon®) was used for many years due to its relative safety in contact with humans and its low boiling point of –21° F. In other words, the CFC-12 refrigerant (HFC-134a –17°), and most liquids used as refrigerants, change from a liquid to a gas at a very low temperature.

For the last decade, another refrigerant, HFC-134a (R-134a), has been developed for use in automobiles due to its less negative impact on the environment. Most new vehicles manufactured today use HFC-134a. Federal laws regulate the use, recycling and recharging of CFC-12 and HFC-134a refrigerant.

Heat and Matter

Using water as an example, we can commonly find water in any of three states: Ice, water and steam. Its temperature is what determines the state of water (H20).

Three States of Matter

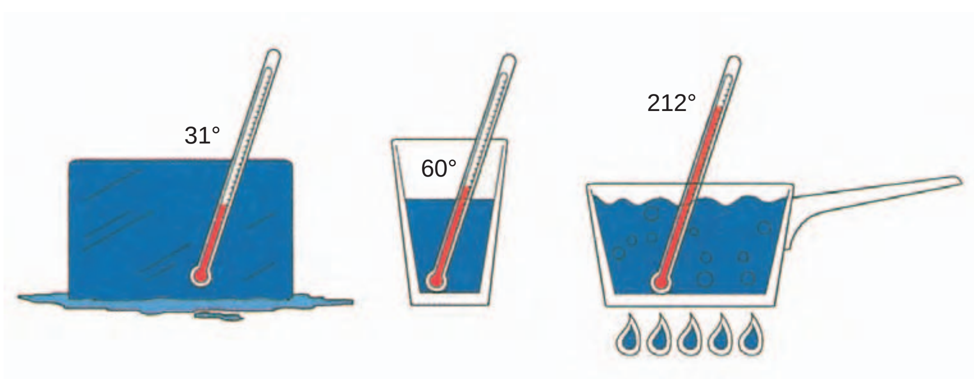

Fig. 2-2
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The concept of heat is directly related to the nature of all materials. Some materials are **solid,** some are liquid, and some are gaseous. In fact, all matter can exist in each of these three states depending on its temperature.

Matter has different characteristics as it exists in each different state. For example:

1. A solid has a defined shape and cannot flow to fill empty spaces in a container.
2. A liquid can flow to fill voids in a space, but it cannot be compressed or made more dense by pressure.
3. A gas (or vapor) also flows easily, and it can be compressed; that is, its density can be made greater or smaller by applying pressure to a closed vessel containing the gas.

As heat energy is applied to a solid, the solid absorbs the heat (we could say it “gets hotter”) up to a point. If the solid is heated past its freezing point, it will gradually become a liquid. The heat required for this to happen is called **sensible heat.** As heat energy is added to a solid, its observed temperature will increase. In fact, this relationship is consistent for each material. However, the process of changing its state requires the addition of an extra amount of heat.

Latent Heat is the additional energy necessary to cause refrigerant to change state from a gas to a liquid or from a liquid back into a gas. Water boils at 212° F and applying additional heat will not raise the water temperature but will increase vaporization or evaporation rate resulting in steam vapor. Humidity reduces the absorption of heat into the evaporator coils until the moisture is condensed on the coils and fins then drained from the case by the drain hose.

In fact, at the point at which a change of state is about to take place, a material will absorb a significant amount of heat **without getting noticeably warmer.** The additional heat is called **latent heat,** which means, unnoticed heat.

Sensible and Latent Heat

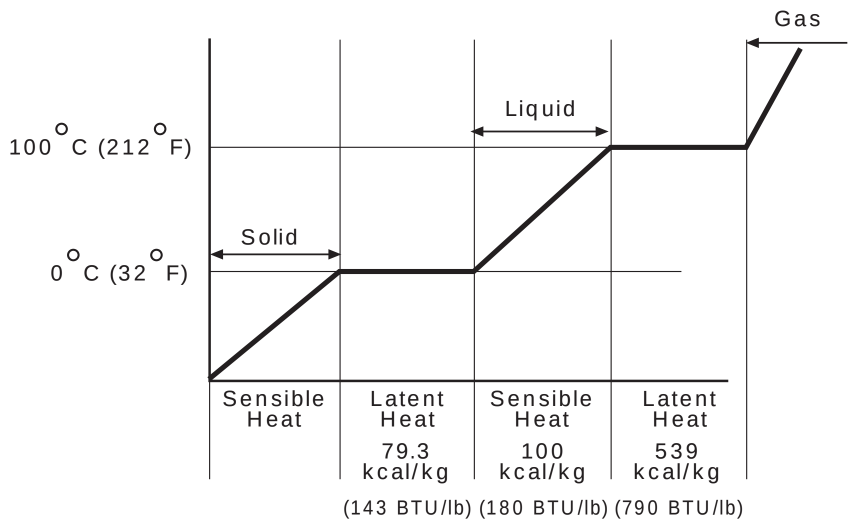

Fig. 2-3
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Pressure and Temperature

A physical relationship that affects heat transfer is the effect of pressure on the boiling point. When water freezes at 32° F (0° C) and boils at 212° F (100° C), these values only apply with an open container at sea level where the air pressure is 14.7 psi.

If, for example, the altitude is 5000' above sea level. The atmospheric pressure is only ≈12.5 psi and water in an open pot will boil at only 195° F (91° C). In addition, at this altitude, water will freeze at 35° F (2° C). In an extreme low pressure environment (sometimes called a **vacuum**), the boiling point can be further reduced and the freezing point increased until they meet. At this point, freeze-drying occurs and solid water (ice) changes state directly into gaseous water (steam).

Effect of Pressure on Boiling Point

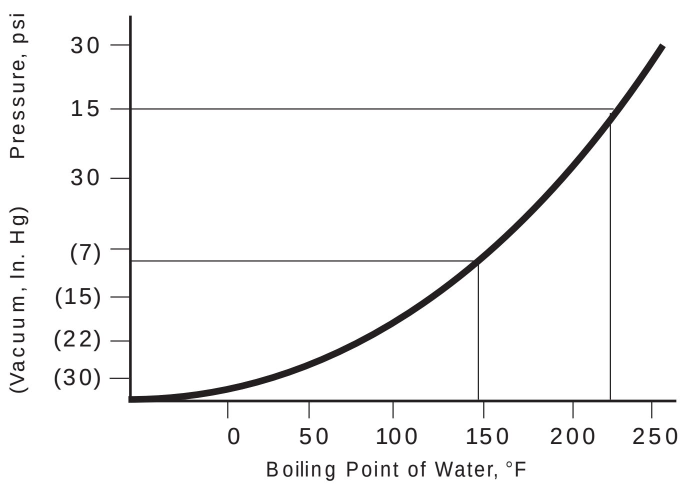

Fig. 2-4
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As pressure is increased the boiling point also increases as in a radiator with a pressure cap. The increase is approximately three degrees of boiling point for each one psi of pressure increase, meaning a 15 psi radiator cap will increase boiling point by 45 degrees F.

Humidity and A/C Performance

Relative humidity has a great influence on the apparent cooling effectiveness of an A/C system. The higher the humidity in the air, the less energy is available for cooling. A side benefit is that removing humidity from the interior air is in itself an improvement in comfort since humidity prevents the body from dissipating heat in its normal manner.

Humidty vs. Performance

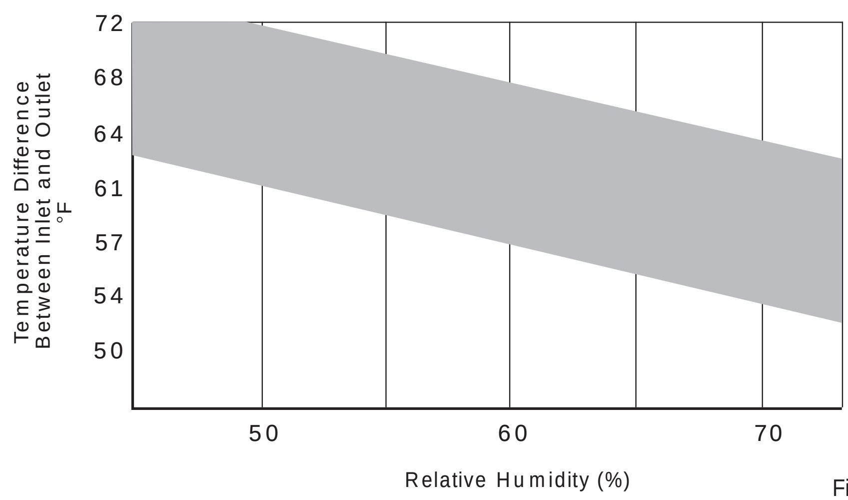

Fig. 2-5
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Humidity reduces evaporator heat absorption and efficiency due to humidity condensing on the coils and draining away out the drain tube.

Different Temperature Scales

Centigrade and Fahrenheit Temperature Scales

°C	–30	–25	–20	–17.8	–15	–10	–5	0	5	10	15	20	25	30	35	40	50	60	70	80	90	100
°F	–22	–13	–4	–0	5	14	23	32	41	50	59	68	77	86	95	104	122	140	158	176	194	212

Fig. 2-6
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Basic A/C System

A basic A/C system has a **high-pressure side** and a **low-pressure side.** The high-pressure side (shown in red below) includes the **compressor, condenser** and the **receiver/drier.** The low-pressure side of the system (shown in blue below) includes the **expansion valve** and the **evaporator.**

Vehicle A/C System

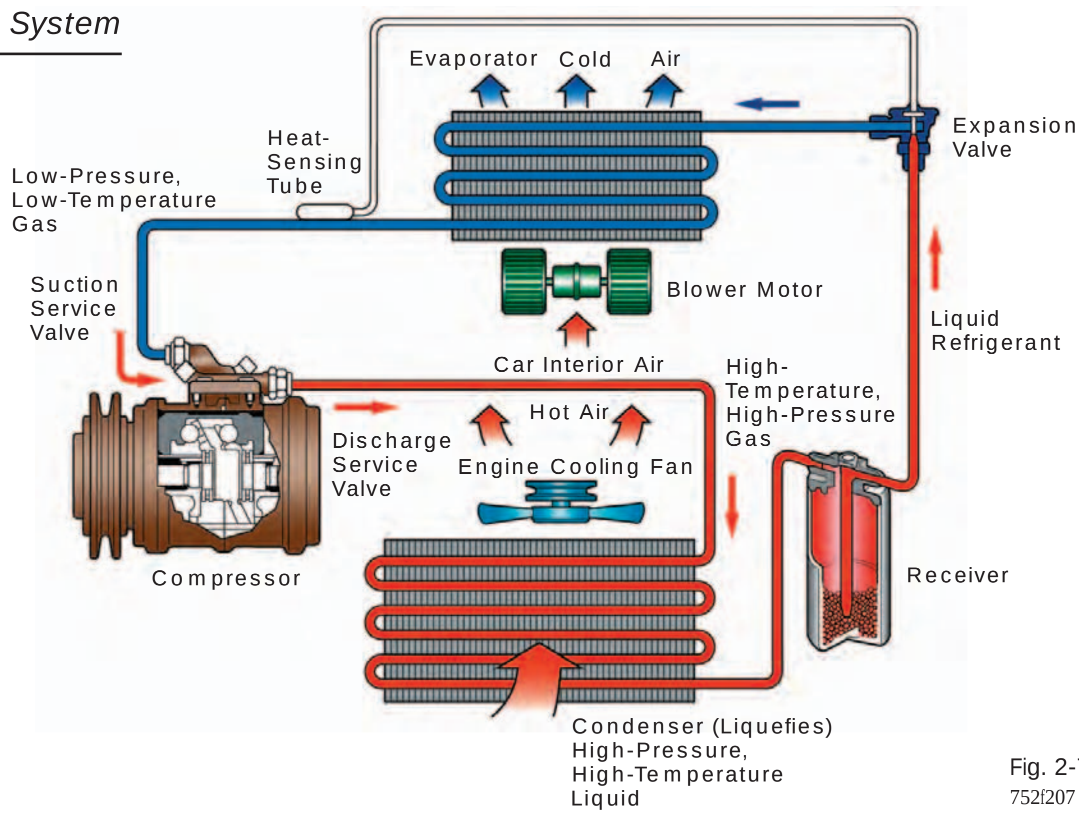

Fig. 2-7
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Here is the basic flow through the system. Beginning with the low side, the **expansion valve** controls the flow and pressure of liquid refrigerant into the **evaporator** (heat exchanger). As the lower pressure liquid refrigerant turns into a gas inside the evaporator, a tremendous amount of heat is absorbed from the warm passenger compartment air circulating over and around the evaporator. The A/C blower motor helps circulate air throughout the vehicle's interior. The still gaseous, but very hot refrigerant then flows into the **compressor.**

The **compressor** pressurizes the gaseous refrigerant. The high-pressure refrigerant then flows to the **condenser** (heat exchanger) where the absorbed heat in the refrigerant transfers to the air outside the vehicle. A "condenser" fan helps this heat transfer process. As heat is removed from the refrigerant, it changes from a gas back to a liquid. The liquid refrigerant is then ready for another cycle through the system. The **receiver-drier** acts as a filter and storage tank for refrigerant before entering the **expansion valve.**

System Pressure

All automotive A/C systems are now based on HFC-134a refrigerant. Because of this, all systems have similar characteristics.

Even though current vehicles use less refrigerant or a smaller volume of refrigerant, **system pressure** will be about the same under similar conditions. Therefore, the pressures within a working system will provide- the technician with an accurate measure of the following:

- Amount of refrigerant in the system
- Operation of the compressor
- Degree of pressure regulation provided by the expansion valve
- Efficiency of the condenser to dissipate heat (dirt or bugs reduce efficiency)

For these reasons, the system pressures (high and low) will provide useful diagnostic information.

Sources of heat in a Passenger Car

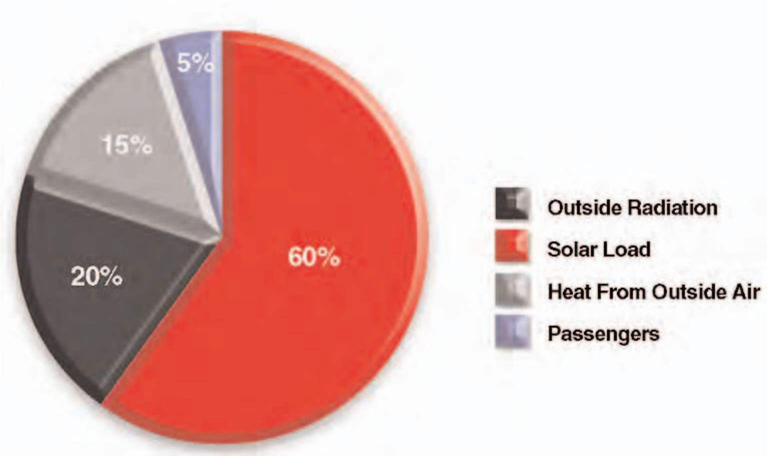

Fig. 2-8
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2 Way Airflow

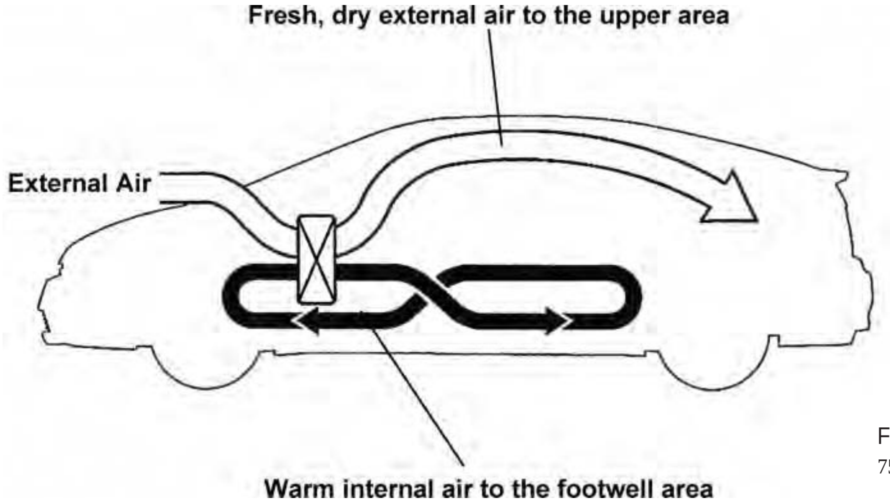

Fig. 2-9
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The A/C system uses the properties of refrigerant to remove heat from the passenger interior.

The A/C system contains two pressure zones: **low** and **high** pressure.

The low pressure portion of the system contains the **expansion valve** and the **evaporator**.

The **high pressure** portion of the system contains a **compressor, condenser and a receiver-drier.**

There are two heat exchangers in the system: A **condenser** (gets rid of heat) and an **evaporator** (absorbs heat).

Electric fans assist heat transfer: An A/C blower fan for the **evaporator** and a fan for the **condenser**.

The entire system is connected by high and low pressure hoses (hard and flexible lines).