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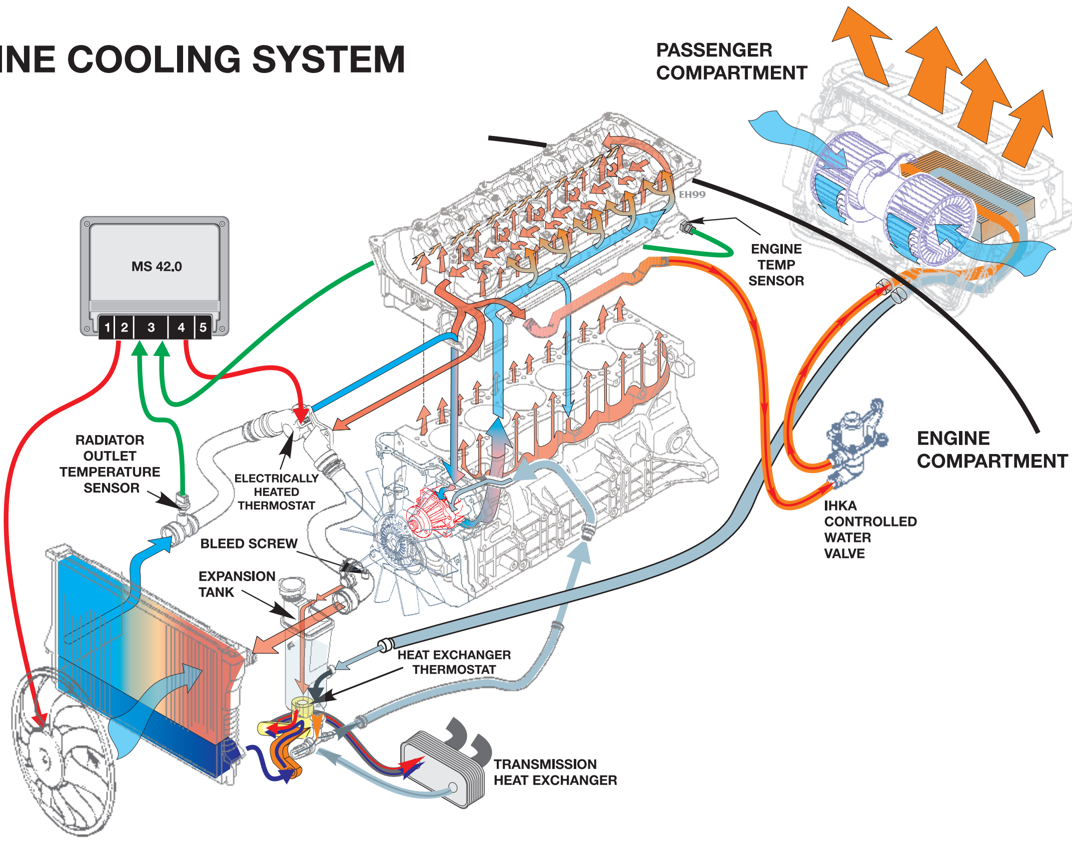
ENGINE COOLING/
PASSENGER COMPARTMENT HEATING SYSTEM

ENGINE COOLING SYSTEM

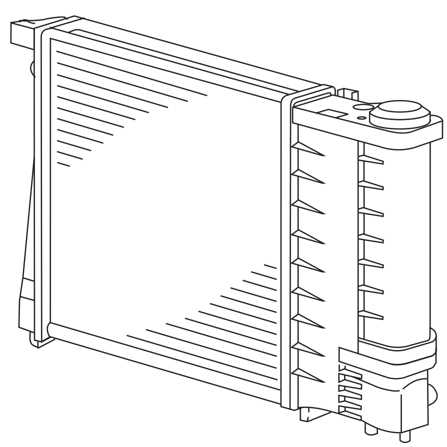


At operating temperature, an automotive engine produces excess heat. Heat is a by-product of all internal combustion engines. Modern engines operate at higher temperatures and therefore run more efficiently - less of the energy produced by burning fuel is turned into heat, and more of the energy is used to power the vehicle. However, they still produce excess heat.

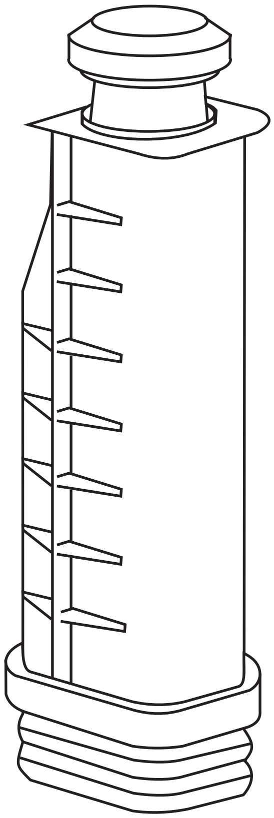
The engine is equipped with a cooling system designed to remove much of the excess heat. When functioning properly, the cooling system maintains an optimum temperature for the engine.

RADIATOR

The radiator is used to dissipate the excess heat from the hot coolant. At operating temperature, some of the engine coolant circulates through the radiator and gives up its heat to the outside air, as it passes across the radiator. So the radiator is a "heat exchanger."



COOLANT RECOVERY TANK



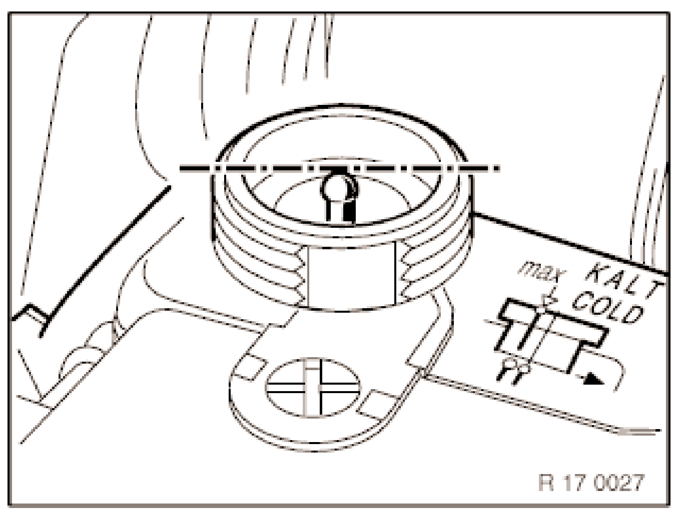
The engine cooling system is equipped with a reservoir to maintain a constant supply of coolant in the system. When the coolant is hot, it expands into the reservoir; when it cools, it contracts and flows from the reservoir into the radiator. The surge tank is transparent, so that the fluid level can be checked periodically, to ensure that the coolant level is adequate.

The level of coolant in the reservoir should be above the bottom line ("Kalt") when the engine is cool and below the top line ("Heisse") when the engine is at operating temperature.

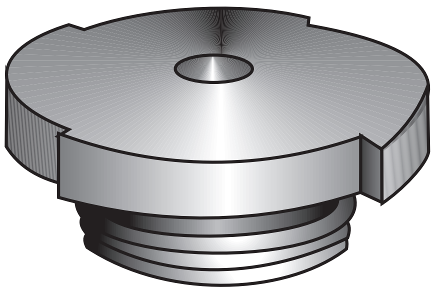
COOLANT LEVEL CHECK

To check coolant level, allow engine to cool down; coolant temperature may not exceed 30ºC. If ambient temperature is above 30ºC, then allow engine to cool down at least to ambient temperature.

Check coolant level, top up coolant if necessary until float is in line with top edge of expansion tank.



Note:
Tank mark indicates the fluid level at approx. 20ºC. Use only recommended coolant, refer to BMW Service Operating Fluid in Main Group



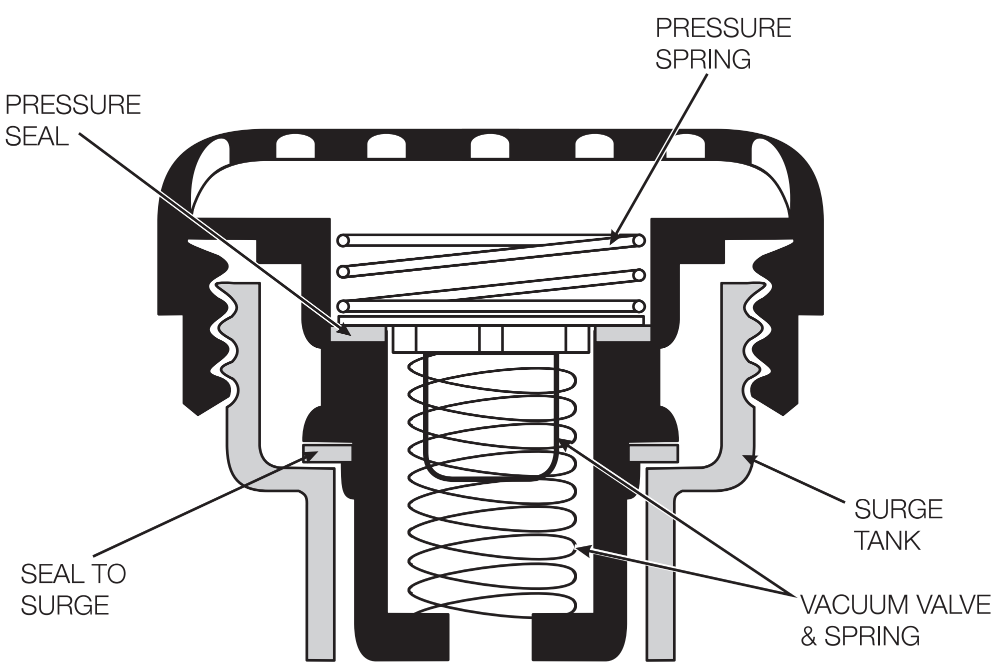
Radiator Cap

RADIATOR CAP

The reservoir has a pressure cap, which is designed to maintain pressure in the cooling system. As the engine warms up, coolant temperature increases and the coolant expands. The pressure cap prevents the expanding coolant from escaping and results in a pressure increase in the system. This raises the coolant's boiling point. This allows the cooling system to maintain the correct engine operating temperature without boiling over.

The radiator cap has both pressure and vacuum valves. At the rated pressure, the pressure valve opens, to allow vapor to escape into the atmosphere and coolant to flow into the reservoir due to expansion. This prevents excess pressure from building up in the system.

When the engine is stopped and allowed to cool off, the pressure in the cooling system drops from a pressure that is higher than the atmospheric pressure, to one that is lower. At this point, the vacuum valve opens to allow ambient air to enter the reservoir, and pressure in the system equals atmospheric pressure. If the coolant level in the radiator is low during this period, coolant will be drawn into the radiator.



NOTE: Please refer to repair manual group 17 for complete cooling system information and testing.

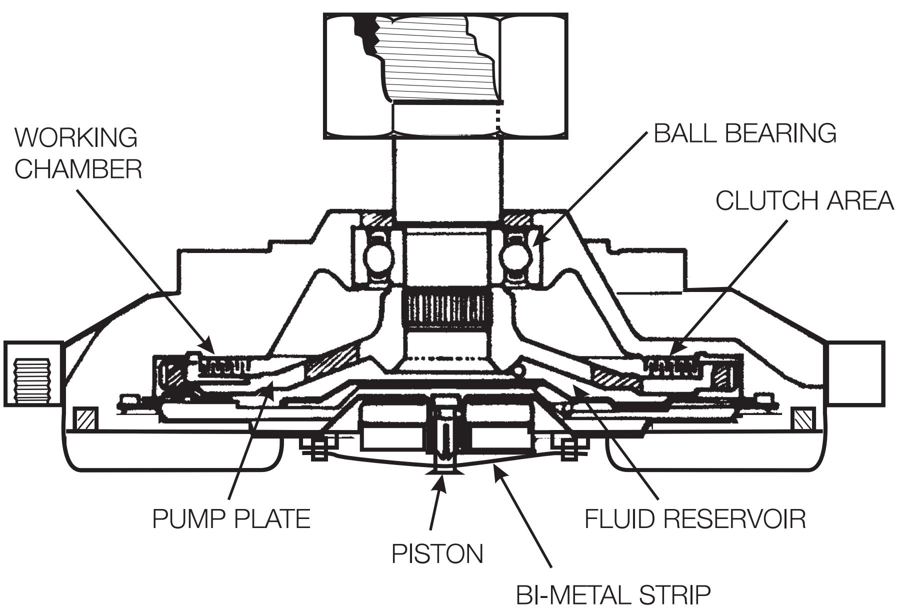
MAIN COOLING FAN

The radiator is equipped with a main cooling fan that is either electrically powered or engine driven via a belt, the water pump pulley, and a viscous clutch.

The viscous clutch reduces fan speed when cooling requirements are low. The clutch contains a small fluid coupling partially filled with a special silicone oil. When engine cooling requirements are high (during high-temperature operation), more oil is injected into the fluid coupling. This causes more power to pass through the coupling, so that fan speed increases. When cooling requirements are low (for example, during cool-weather operation), oil is withdrawn from the fluid coupling. Less power passes through and fan speed drops off.

Even when engine cooling requirements are high, there is still a small amount of slip (The coupling does not lock up). This allows the oil to continue to circulate through the fluid reservoir and the coupling.

The amount of oil in the fluid coupling, and the resulting fan speed, are controlled by a thermostatic strip. The strip bows outward with increasing under-the-hood temperature. This motion allows a control piston to move outward. As the piston moves outward, more oil is forced into the coupling, causing the fan speed to increase.



Viscous Clutch

ENGINE COOLANT

The cooling system contains a special liquid called coolant, or "antifreeze," which circulates through the engine and the radiator. The coolant picks up heat from the engine and transports it to the radiator, where it is dissipated to outside air. Some of the hot coolant can also be circulated through the heater core, where it can warm the air being blown into the passenger compartment.

The antifreeze concentration should be 50%, throughout the year. In addition, the coolant should be drained and refilled according to the recommendations in the BMW Operating Fluids Specifications, Group 17.

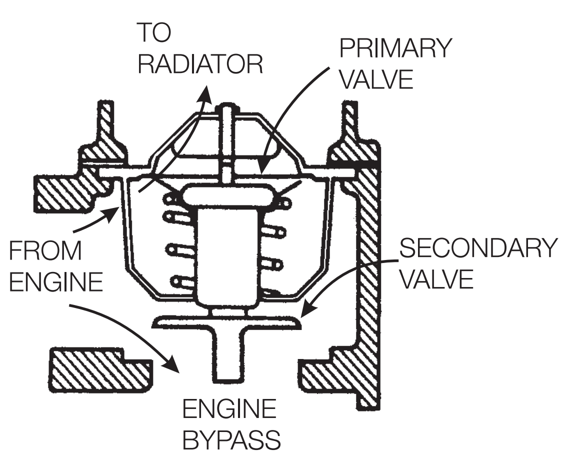
The cooling system does not need any additives besides a reputable brand of ethylene glycol antifreeze with corrosion inhibitors that are nitrite- and amino-acid free and compatible with aluminum radiators. Antifreeze other than the type specified by BMW for aluminum radiators may cause corrosion of the cooling system, which can lead to engine overheating and damage.

WATER PUMP

A water pump, driven by a belt from the crankshaft, is used to pump coolant through the cooling system.

Many BMW models have an auxiliary electric water pump to ensure adequate coolant flow to the heater core, especially at low engine RPM and very cold ambient temperatures. (Also models equipped with rest feature)

ENGINE THERMOSTAT



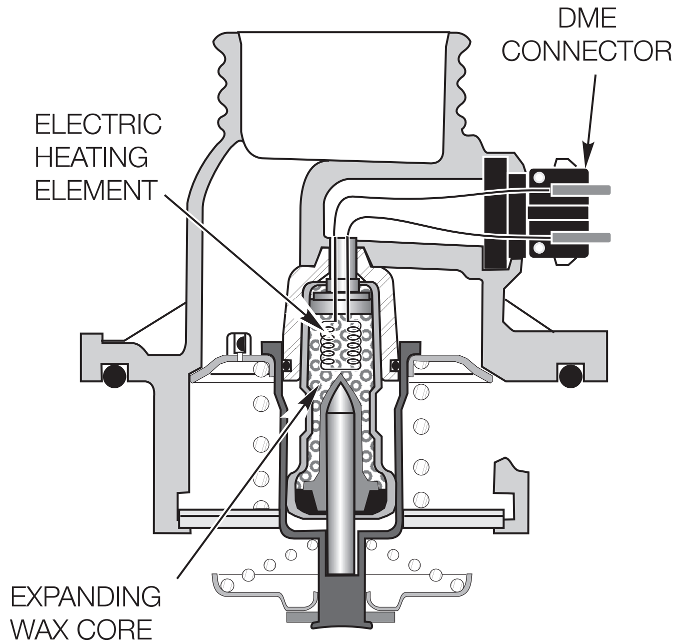
There are two types of thermostats in BMW cars, the mechanical type, and the type that is electrically heated. Both are designed to bring the temperature of the coolant up to operating temperature quickly.

When the engine is cold, the thermostat is closed; in the closed position, it sends coolant from the engine back to the engine, through a bypass; as a result, the coolant temperature rises quickly. As the coolant reaches the rated temperature, the thermostat gradually opens, to allow coolant to flow from the engine to the radiator.

ELECTRONICALLY HEATED THERMOSTAT

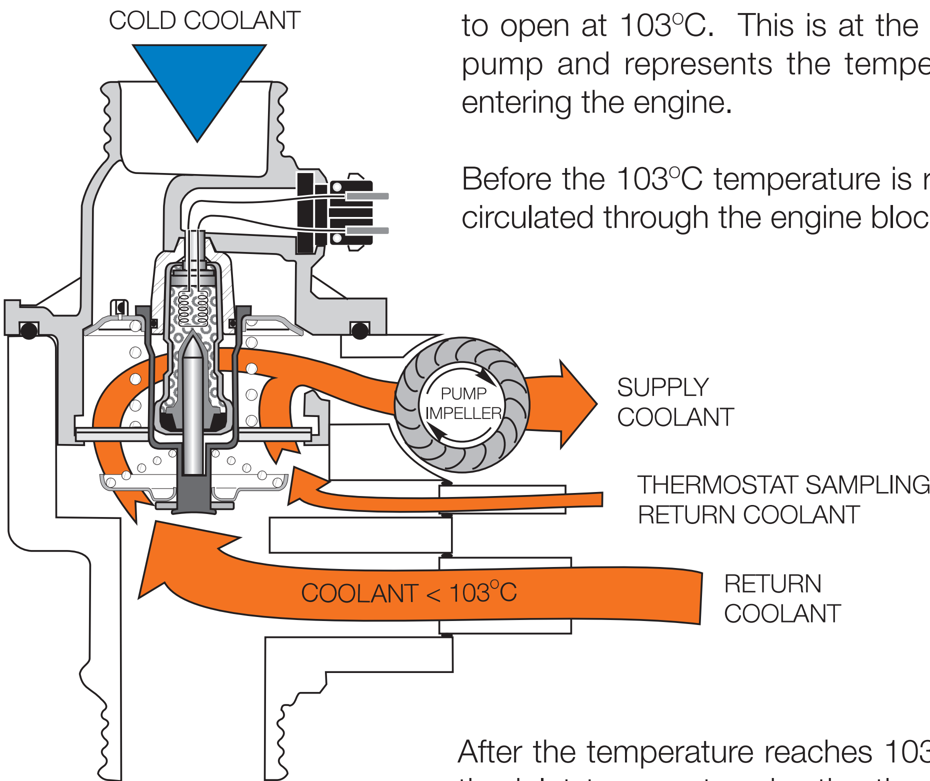
The heated thermostat is both a conventionally functioning and ECM controlled thermostat (two stage operation).

ECM control causes the thermostat to open sooner than the mechanical thermostat rating. This provides sufficient cooling for full load and high output conditions.



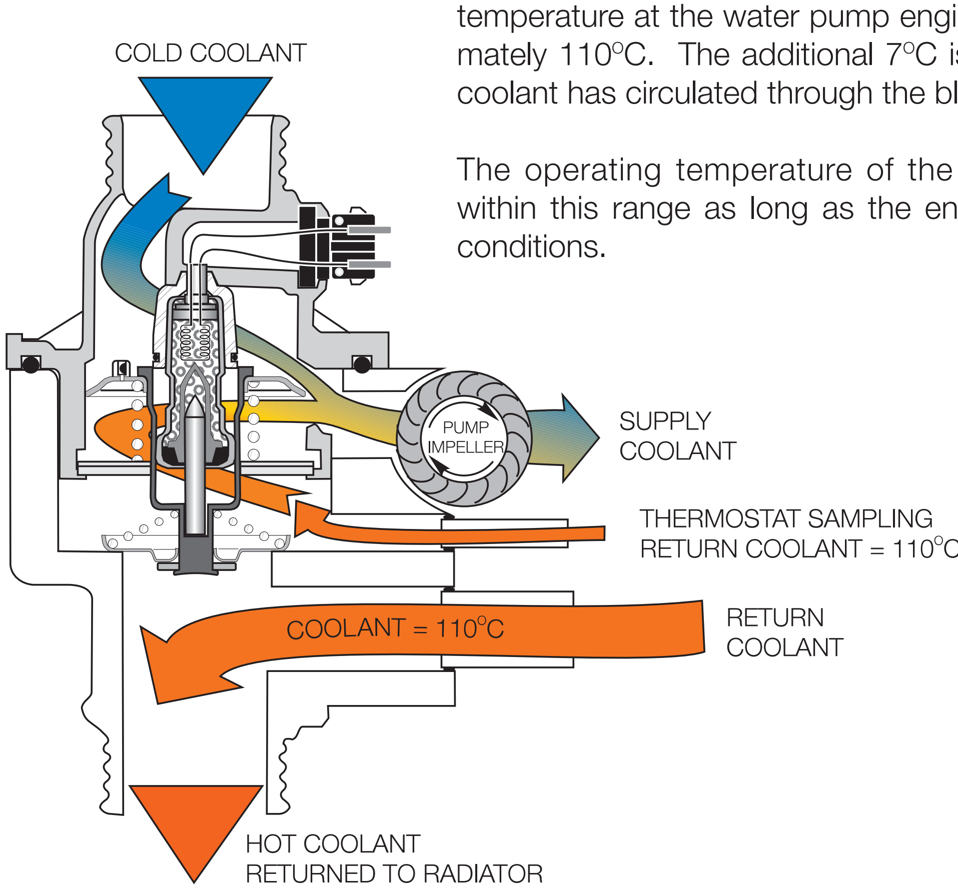
CONVENTIONAL FUNCTION: The thermostat begins to open at 103°C. This is at the inlet side of the water pump and represents the temperature of the coolant entering the engine.

Before the 103°C temperature is realized, the coolant is circulated through the engine block by the water pump.



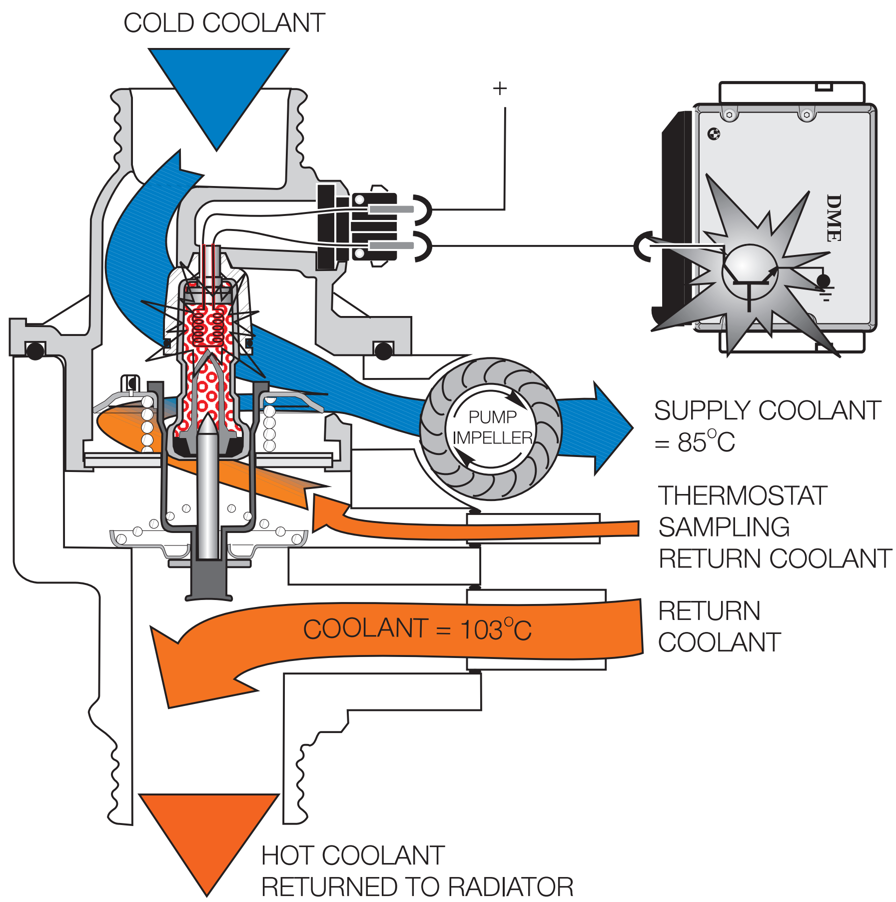
After the temperature reaches 103°C it is maintained as the inlet temperature by the thermostat. The coolant temperature at the water pump engine outlet is approximately 110°C. The additional 7°C is achieved after the coolant has circulated through the block.

The operating temperature of the engine will remain within this range as long as the engine is at part load conditions.



ECM CONTROLLED FUNCTION

The map controlled heater in the thermostat will switch ON under the following conditions:



- Load signal "ti" > 5.8 ms
- Engine temperature "tm" > 113°C
- Intake air temp > 52°C
- Vehicle speed > 110 MPH

When the heating element is switched ON, the thermostat is heated higher than the temperature of the coolant.

The thermostat opens sooner causing additional coolant to circulate through the radiator which brings the temperature down.

The temperature of the coolant at the inlet side of the water pump will drop to approximately 85°C and the temperature at the outlet side of the water pump will drop to approximately 103°C.

NOTES:

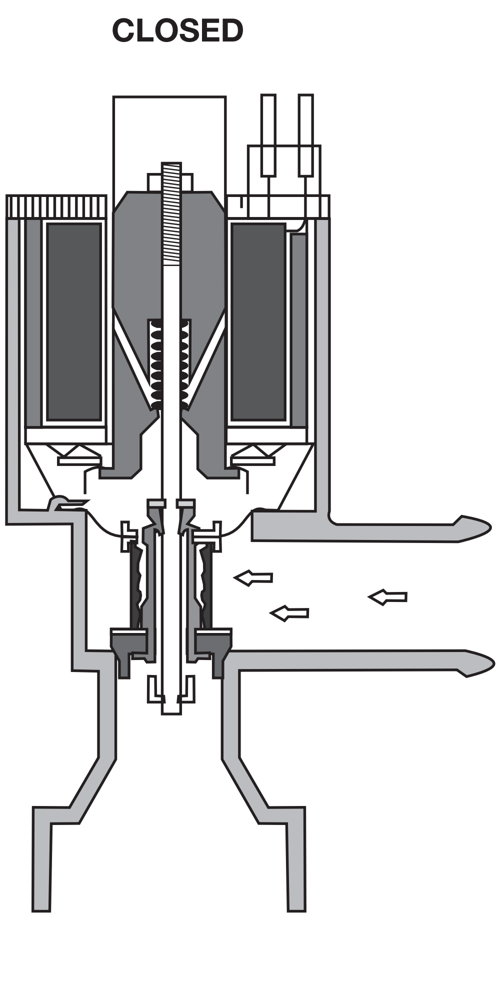
- If the coolant temperature is below 85°C, the heater will not switch on for any condition.
- The display characteristics of the temperature gauge in the instrument cluster have been calibrated to the higher engine temperatures.

WATER VALVE(S)

The heating system utilizes hot coolant from the engine cooling system to warm air for heating the passenger compartment. The amount of coolant that flows into the heating system is controlled by an electric water valve(s).

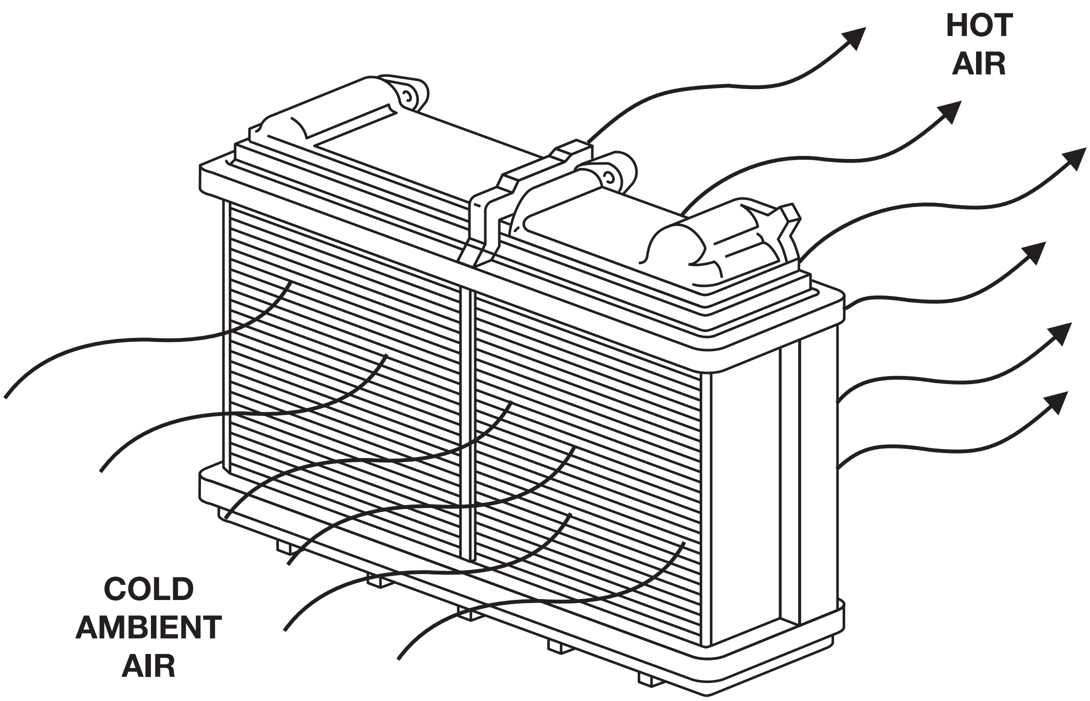
The water valve is electrically actuated. It is located beside the brake booster. It controls coolant flow through the heater core. The valve is powered closed by an electric switch; when not powered, it springs open. The valve, when powered closed, prevents hot coolant from entering the heater core, so the air entering the passenger compartment is not heated. When power is removed, the valve springs open, so that hot coolant flows through the heater core and can warm the air entering the passenger compartment.

The E31, E32, E34, E36 (IHKR and IHKA), E38, and E39 cars use pulsed water valves to control the heater core temperature.



HEATER CORE

When the water valve is open, hot engine coolant circulates through the heater core. The heater core heats the air that passes through it; the hot air can then be used to warm the passenger compartment. The heater core (like the radiator) is also a “heat exchanger.”



Warning!
Danger of scalding! Work on the cooling system should only be carried out when the engine is cooled down.

Caution!
Open cooling system only when it is cooled down. Opening the cooling system while hot can result in air entering the system.
This can cause overheating with permanent damage to the engine

Recycling!
Catch and dispose of drained coolant. Observe country-specific waste-disposal regulations.

Refer to repair procedures on:

- Pressure testing cooling system
- Flushing cooling system
- Bleeding cooling system

HEATING AND AIR CONDITIONING SYSTEM COMPARISONS

HEATING	AIR CONDIITIONING
Radiator	Condensor
Engine fan	Auxiliary fan
Expansion tank	Receiver/dryer
Thermostat	Expansion valve
Water valve(s)	Compressor clutch
Heater core	Evaporator
Blower motor	Blower motor
Waterpump	Compressor
Hoses (low pressure)	Hoses (high pressure)
Coolant	Refrigerant

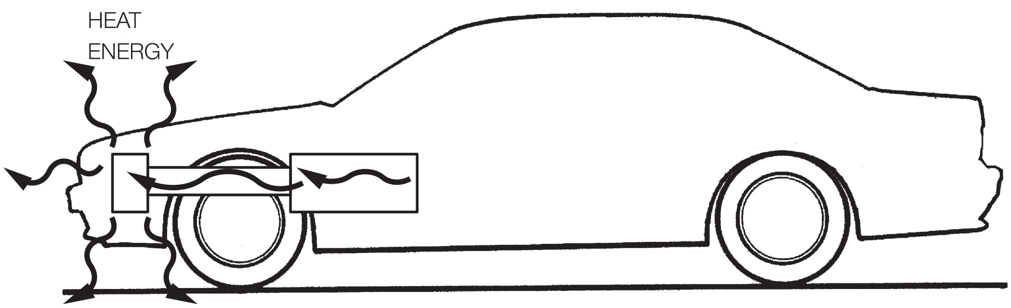
Many parallels can be drawn between the cooling system and the air-conditioning system. With a thorough understanding of the cooling system, air-conditioning becomes easier to comprehend.

The basic difference is that refrigerant has a much lower boiling point and goes through changes of state which produce much higher system pressures. This is why the components and servicing equipment are made to contain high pressures.

THEORY OF HEAT AND REFRIGERATION

BASIC PRINCIPLE OF AIR CONDITIONING

The basic principle at work in a climate control system is heat transfer. An automotive A/C system takes heat inside the passenger compartment and transfers it outside.

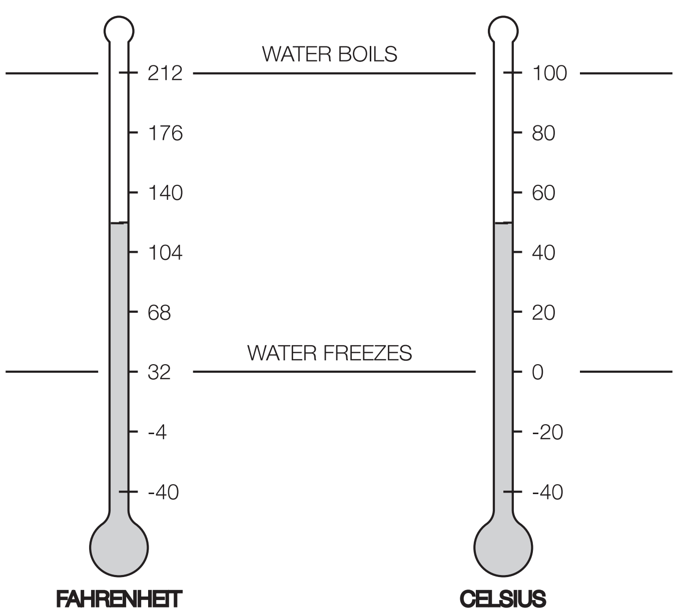


In an A/C system, heat is transferred using a refrigerant. The refrigerant absorbs heat from air entering the passenger compartment, carries the heat outside the compartment, releases the heat, and then re-enters the compartment to begin the cycle again.

An A/C system does not "add cold" to air - it removes some of the heat from it. Some heat is always present, but the less heat the air contains, the cooler it feels.

TEMPERATURE

The amount of heat energy present is measured as the temperature. There are two different temperature scales, Fahrenheit and Celsius.

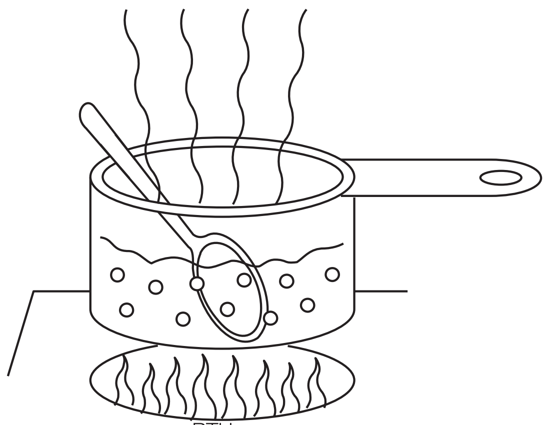


BTUs AND CALORIES

Heat is measured in British Thermal Units (BTUs) and calories.

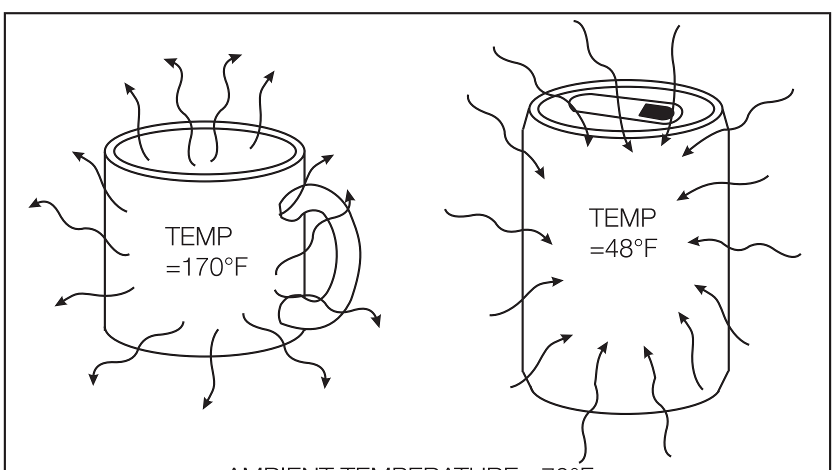
- BTU - amount of heat energy required to raise one pound of water one degree Fahrenheit.

- Calorie - amount of heat energy required to raise one gram of water one degree Celsius.



HEAT TRANSFER

An air conditioning system's efficiency is based on how well it moves heat. Heat always travels from warm to cold. The reverse is never true. For example, if a hot cup of coffee is left standing, it will cool off, while a cold soda will get warm. The heat from the warm coffee moves to the cooler surrounding air. The heat from the surrounding air moves to the cooler soda, until a balance is reached.

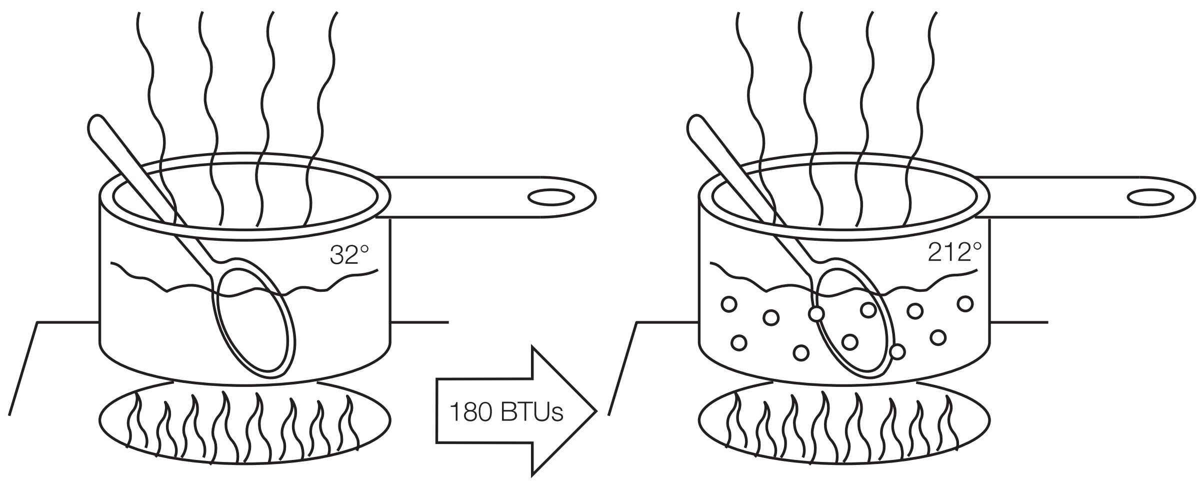


TEMPERATURE AND STATE CHANGES

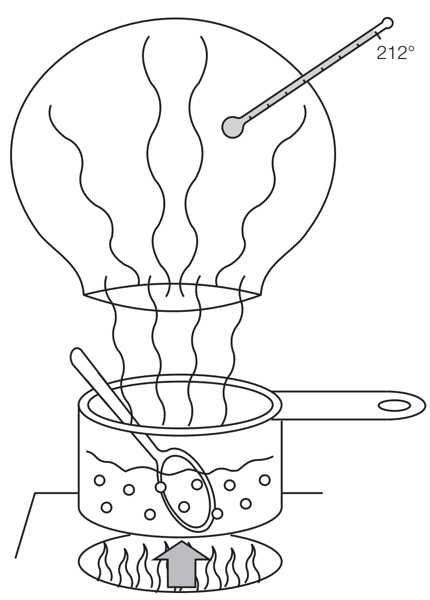
At sea level, water freezes at 32° F (0° C) and boils at 212° F (100° C). These are the temperatures at which water changes state.

When a liquid boils (changes to a gas), it absorbs heat. When a gas condenses (changes back to a liquid), it gives off heat.

Water requires one BTU of heat per pound to rise one degree Fahrenheit. If you place one pound of water at 32° F in a container over a flame, its temperature rises 1° F for each BTU of heat the water absorbs from the flame. Once the water has reached a temperature of 212° F, it has absorbed 180 BTUs of heat.

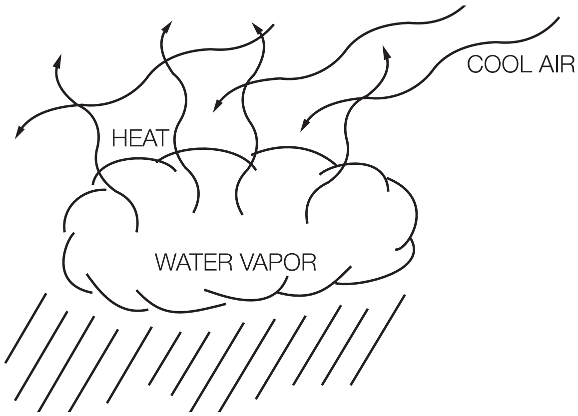


As the flame continues to heat the water, it boils, changing from a liquid to a gas, and it continues to boil until all of it has changed to a gas.

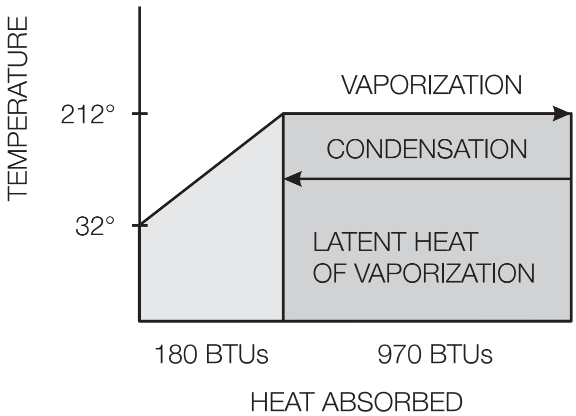


If this gas is collected in a container and checked with a thermometer, it would also have a temperature of 212° F. The temperature has not risen further, but the flame has applied an additional 970 BTUs of heat. The heat is absorbed by the liquid as it boils. It is “hidden” in the water vapor.

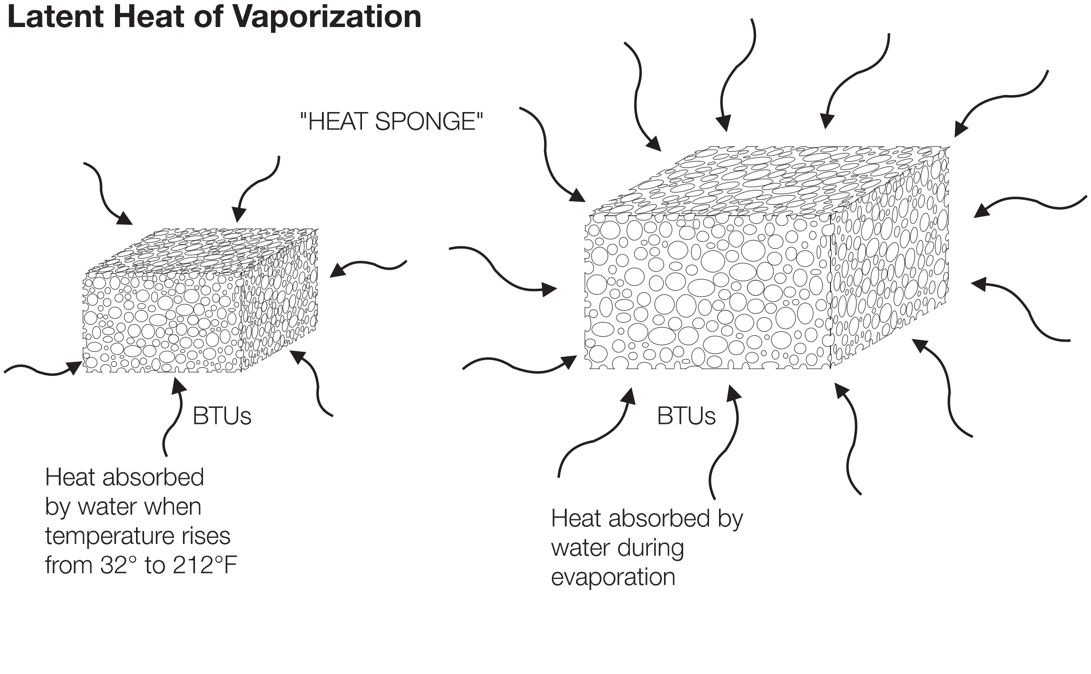
If the vapor contacted cool air, the heat would flow into the cooler air as the vapor condensed back into water. This hidden heat is called the "latent (hidden) heat of vaporization."



Water has a latent heat of vaporization of 970 BTUs. This means one pound of water at 212° F will absorb 970 BTUs of heat when it boils and becomes a vapor. In the same way, the vapor will give off 970 BTUs of heat when it condenses back to water.

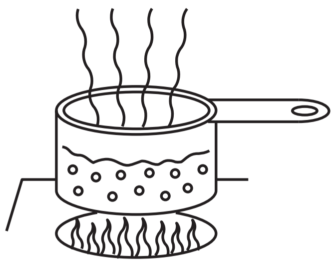


Latent Heat of Vaporization



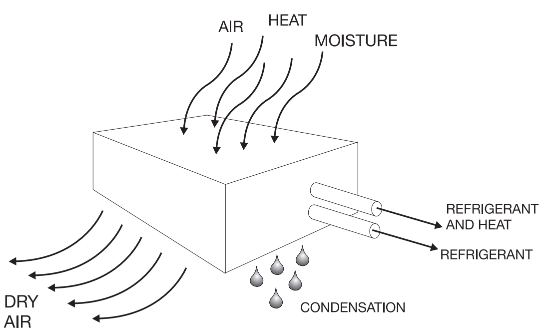
In other words, water acts like a "heat sponge": it soaks up a small amount of heat (180 BTUs per pound) when its temperature rises from 32° F to 212° F; and it soaks up a large amount of heat (970 BTUs per pound) when it changes from a liquid to a gas.

EVAPORATION



Evaporation is one of the basic principles by which a refrigeration system works. In evaporation, liquid changes to a vapor. Adding heat causes a liquid to evaporate.

CONDENSATION

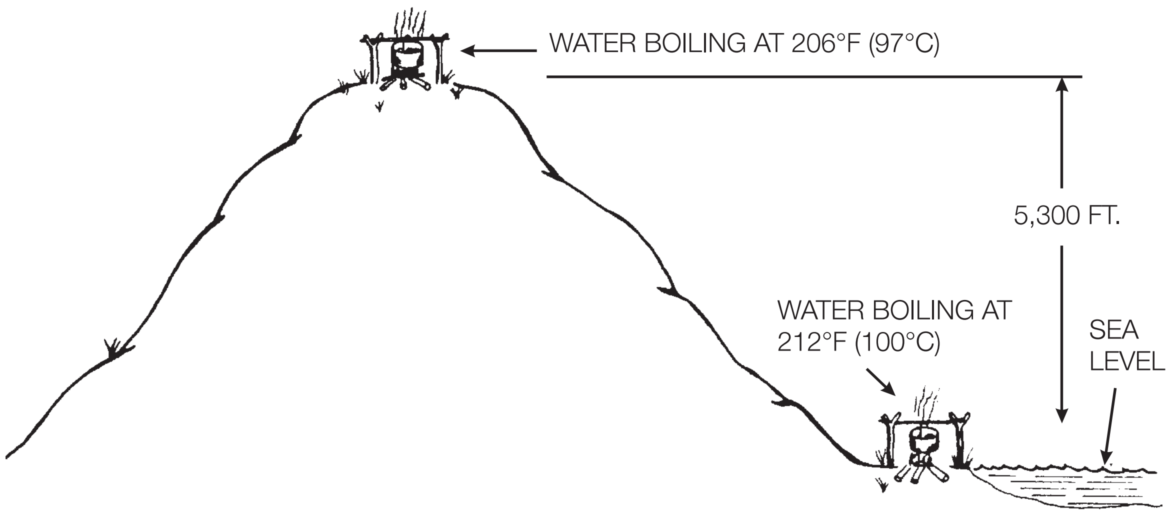


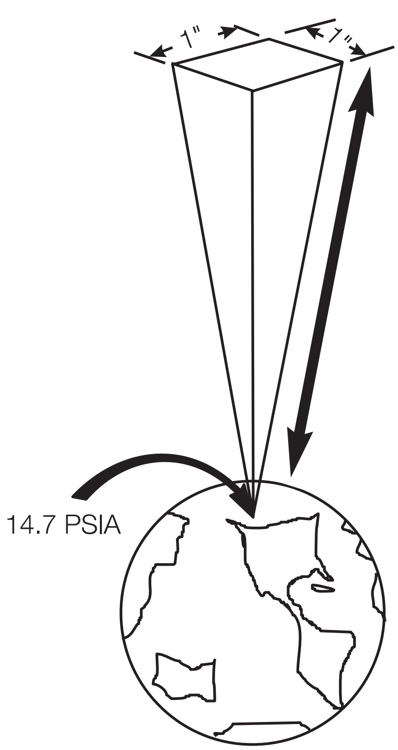
Condensation is the reverse of evaporation. In condensation, a vapor changes to a liquid. Removing heat causes a vapor to condense to a liquid.

The task of an air conditioning system is to absorb a large amount of heat, move it away from the passenger compartment, and exhaust it. When the refrigerant in the A/C system evaporates, it absorbs a large amount of heat from the air entering the passenger compartment. As the refrigerant vapor is pumped outside the passenger compartment, it transports this heat with it. When the refrigerant condenses back into a liquid, this heat is released.

THE EFFECTS OF PRESSURE ON BOILING POINTS

- As the pressure on a liquid is increased, the boiling point rises.
- As the pressure on a liquid is decreased, the boiling point drops.

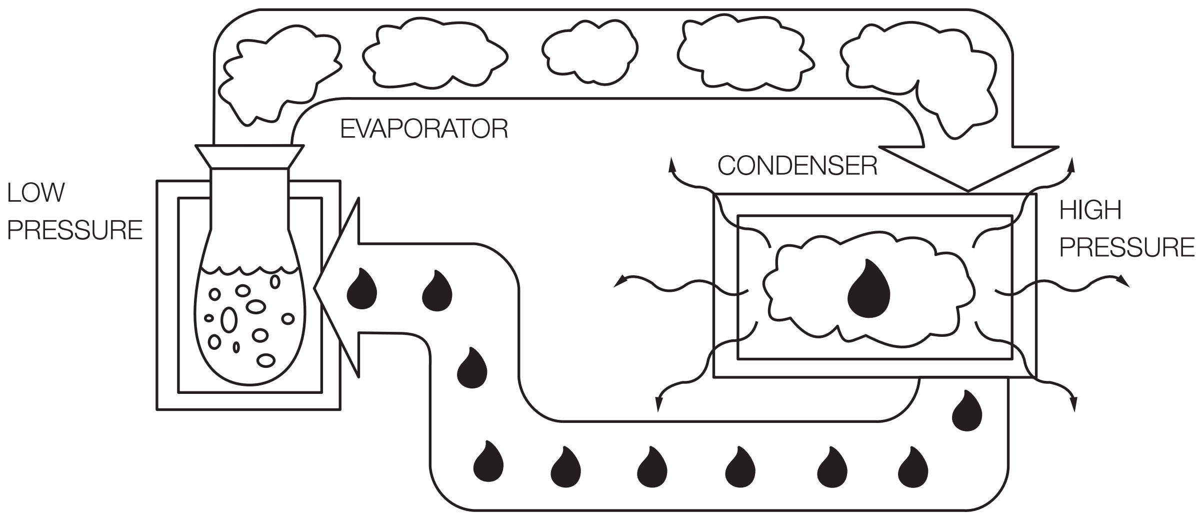




At sea level, where the atmospheric pressure is 14.7 psi, the boiling point of water is 212° F (100° C). At any point higher than sea level, the atmospheric pressure is lower and so is the boiling point. In Denver, Colorado (elevation 5,300 feet), water boils at only 206° F (97° C).

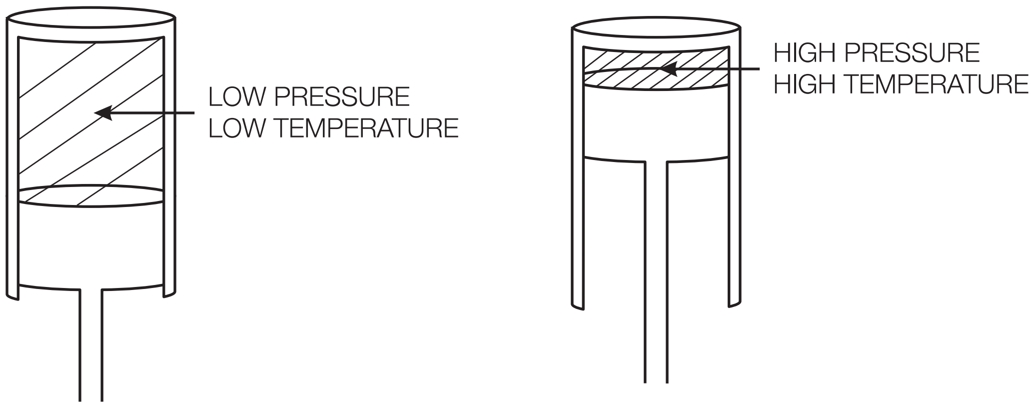
Atmospheric pressure is approximately 14.7 psi (absolute) at sea level, and somewhat lower at higher elevations. At sea level, the entire weight of a "column" of air approximately 600 miles high, presses down on everything. At higher elevations, the column of air is shorter and the air is thinner, so the pressure is lower.

Of course, you don't notice the 14.7 psi pressing in on everything, and air pressure gages are calibrated to read 0 psi at atmospheric pressure. But this atmospheric pressure exists, and you can feel its effects, particularly at higher elevations; for example, if you exercise vigorously, at a high elevation, you become winded more quickly.

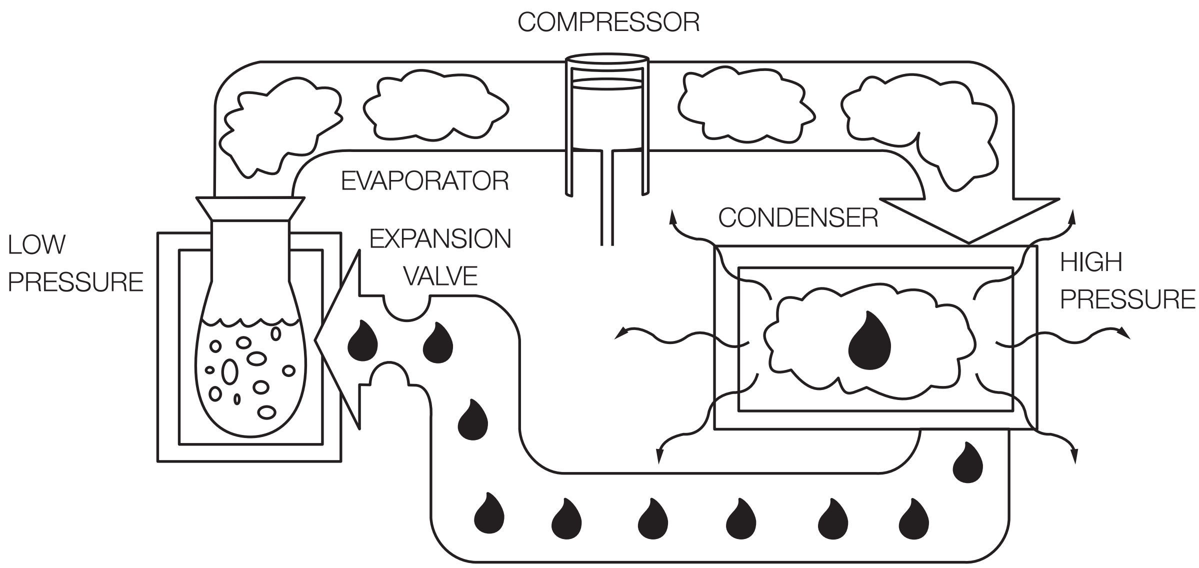


In an air conditioning system, the pressure in the evaporator is low, so that all the refrigerant vaporizes. The pressure in the condenser is high, so that all the refrigerant readily changes state to a liquid.

PRESSURE/TEMPERATURE RELATIONSHIP



Raising the pressure of a vapor raises its temperature; lowering the pressure decreases its temperature.



In an air conditioning system, a compressor is used to increase the pressure of the refrigerant; this raises its temperature. The refrigerant vapor entering the condenser is hot.

In BMW air conditioning systems, an expansion valve is used to lower the pressure of the refrigerant; the refrigerant in the evaporator is cold.

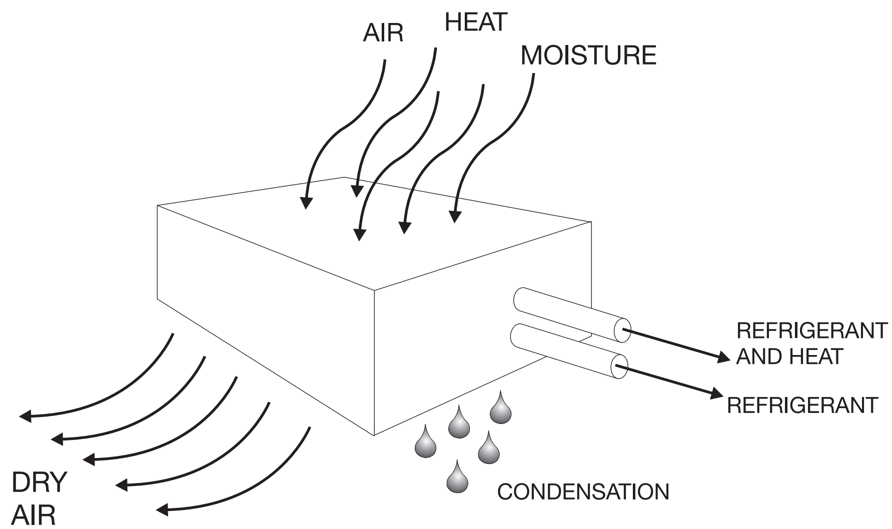
Automotive A/C systems are designed to operate at pressures that keep the refrigerant at the optimum temperature for taking heat out of the passenger compartment.

THE "COMFORT ZONE"

- Temperature / 70° to 80° F (21° to 27° C).
- Humidity / 45% to 50% (at 70° to 80° F).
- Movement of air around the body (the more air, the cooler the body feels).

AIR CONDITIONING AND COMFORT

The purpose of an A/C system is to make the driver and passengers comfortable. An A/C system achieves this by cooling the air temperature inside the passenger compartment and removing moisture (humidity), dust, and pollen particles.



By removing moisture and lowering the humidity, an A/C system can achieve passenger comfort at higher temperatures. The reason for this is that the human body cools itself by allowing moisture on the skin to evaporate.

The relative humidity governs how quickly evaporation occurs:

- High relative humidity = low evaporation rate.
- Low relative humidity = high evaporation rate.

When the A/C system removes moisture from the air, the relative humidity in the passenger compartment decreases. By reducing the relative humidity, the A/C system increases the rate at which the moisture on passengers' skin will evaporate.

AIR CONDITIONING (A/C) SYSTEM

The air conditioning system is a self-contained system, completely sealed off from the atmosphere. While operating, it recycles refrigerant through the system.

The major components of the A/C system include:

- The compressor
- The condenser
- The receiver/dryer
- The expansion valve
- The evaporator

When the A/C compressor clutch is engaged, the compressor draws in low-pressure refrigerant gas. It compresses the gas and moves it to the condenser. Compressing the gas raises its temperature above that of the outside air. As the hot, high-pressure gas flows into the condenser, cooler air flowing across the condenser absorbs heat from the gas. As the refrigerant gives up heat to the air, it condenses and changes to a liquid.

The high-pressure liquid refrigerant flows from the condenser to the receiver/dryer. The dryer contains a filter screen, to remove small impurities, and a drying agent to absorb and hold any moisture. The dryer is also a storage tank; a steady supply of liquid refrigerant is drawn out of the bottom of it, to the expansion valve. The expansion valve meters the refrigerant, so that its pressure drops, causing it to boil as it enters the evaporator.

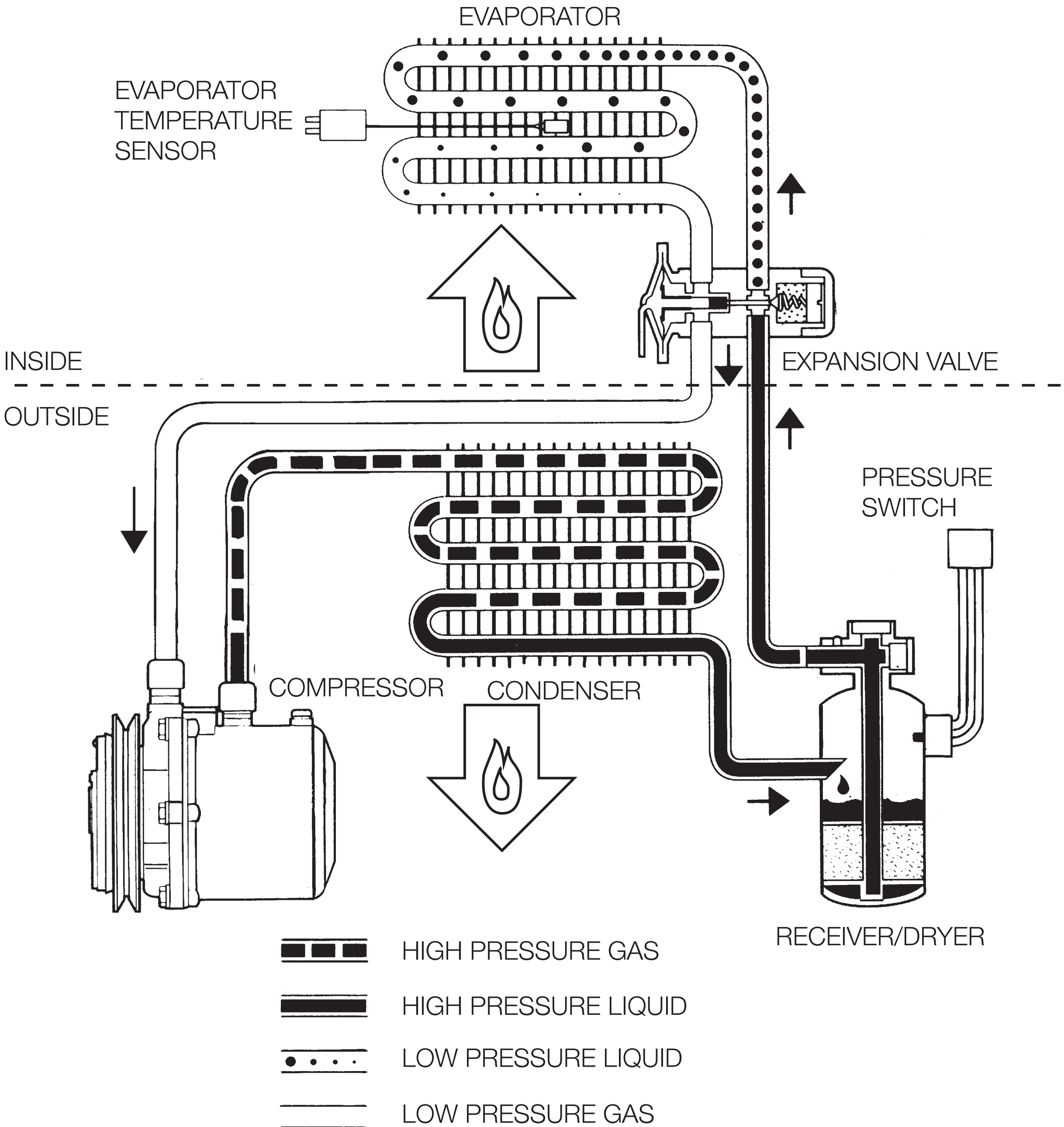
Hot air is blown across the evaporator as the refrigerant boils. Heat from the air is transferred to the refrigerant, causing the air to be cooled. The hot, low-pressure refrigerant is then drawn back into the compressor to complete the loop.

In addition to cooling the air, the A/C system also dehumidifies it.

Additional components of the A/C system include:

- The compressor clutch
- The pressure switches
- The evaporator temperature sensor

The compressor clutch allows the compressor to be disengaged when the A/C system is not used. The pressure switches cause the compressor clutch to disengage when the pressure in the system is too low or high, to prevent damage. The evaporator temperature sensor also causes the compressor clutch to disengage when the evaporator temperature drops close to freezing. This prevents ice or frost from forming on the evaporator fins.


EVAPORATOR
EVAPORATOR TEMPERATURE SENSOR
INSIDE
OUTSIDE
EXPANSION VALVE
PRESSURE SWITCH
COMPRESSOR
CONDENSER
RECEIVER/DRYER
HIGH PRESSURE GAS
HIGH PRESSURE LIQUID
LOW PRESSURE LIQUID
LOW PRESSURE GAS

REFRIGERANT

An air conditioning system uses refrigerant to absorb heat from the air that passes through the evaporator. Refrigerants are special materials that are vapors at room temperature and liquids at much lower temperatures. Automotive refrigerants, for example, boil at -16° F to -22° F (-27° C to -30° C). Refrigerants are also able to contain and transport a large amount of heat, efficiently; and they can be evaporated and condensed over and over without being damaged.

In the air conditioning system, liquid refrigerant under high pressure flows through a small hole into the evaporator, where the pressure is then greatly reduced. When the pressure drops, the refrigerant boils and changes from a liquid to a vapor. As it changes its state, it absorbs a large amount of heat.

As the air passing through the evaporator gives up some of its heat, it becomes colder; it can then be blown into the passenger compartment, to cool it.

Once the refrigerant has absorbed heat from the air, it is returned to the compressor. The A/C system removes the excess heat from the refrigerant as the refrigerant passes through the condenser.

There are two types of refrigerant used in BMW vehicles; these will be discussed later in

ADDING OIL TO THE SYSTEM

- The oil should be replaced whenever a ruptured component is replaced, because the quick discharge causes some of the oil to be released along with the refigerant

- Use only PAG oil in an R-134a system (not mineral oil)

- Use only mineral oil in an R-12 system (not PAG oil).

- Add the right amount of oil into the system when replacing a major component such as the compressor, condenser, or evaporator.

  - When replacing the compressor, drain the oil from the old compressor and measure the amount. Turning the clutch plate by hand helps “pump” out any remaining oil. Inject an equal amount of fresh oil. Note: service compressors are shipped full of oil; this oil must be drained before the new compressor is installed.

  - When replacing the condenser or evaporator, add 2 oz. of oil to the system.

  - When replacing a receiver/dryer, add 1 oz. of oil to the system.

  - You do not need to add any oil when replacing a hose, since hoses do not collect much oil.

- Oil can be added to a charged system using the Robinair 18065 oil injector and a manifold gauge set, or the injector bottle on the ACR[4] unit.