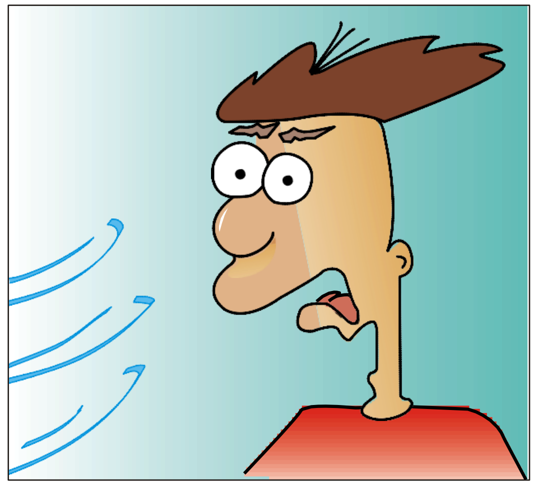
Air Conditioning Theory

The Four Major Functions Of An A/C system

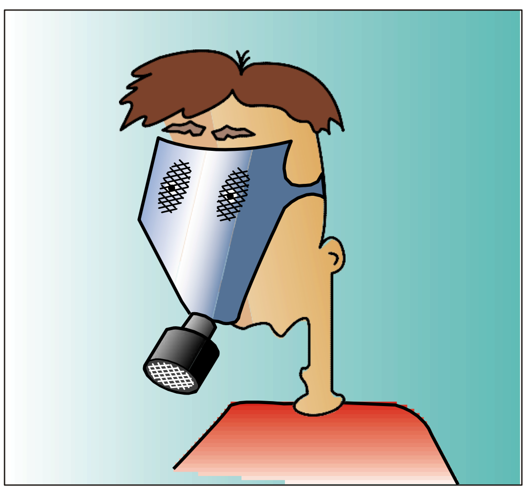
To be effective, the dash air conditioner must control four (4) conditions within the vehicle interior:

It must cool the air

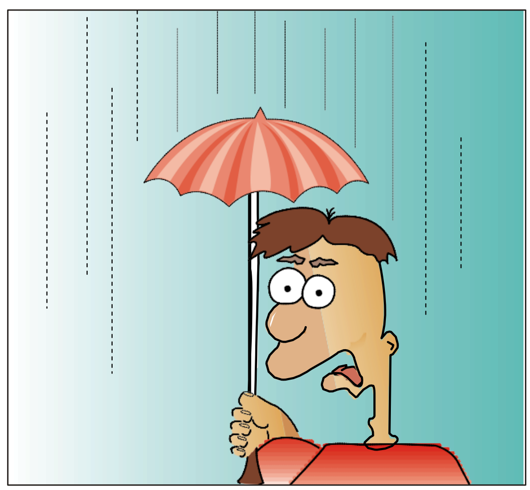
It must circulate the air



It must purify the air



It must dehumidify the air



These functions are essential if passenger comfort is to be maintained when the ambient temperature and humidity are high.

By performing these functions, the air conditioner maintains the body comfort of the driver and front passenger.

ASHRAE has developed a comfort range that is the standard in HVAC commercial, residential and automotive industries. In the summer, the comfort range is between 73ºF (22.5ºC) dry bulb (db) temperature and 79.5% relative humidity (rh) up to 81ºF (27ºC) db and 19.8% rh. In winter, it is between 67.1ºF (19.5ºC) db and 86.5% rh to 76ºF (24.5ºC) db and 23% rh.

Air Conditioning Theory

A/C System Basic Operation

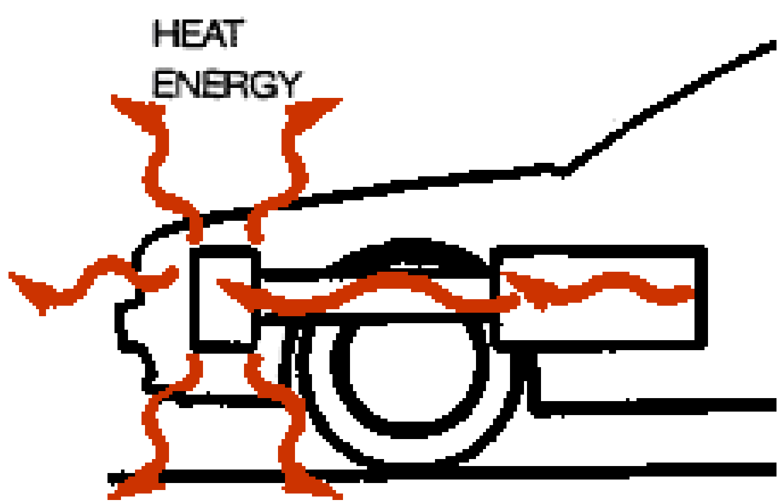
Air from either the interior of the vehicle (Recirculation Air Inlet Mode) or from the exterior of the vehicle (Fresh Air Inlet Mode) is sucked into the HVAC unit by an air flow moving device called a blower assembly.

The air flow passes through a heat absorbing coil called an evaporator located within the HVAC unit.

The evaporator then transfers the heat from the air to a cool fluid medium called R134a refrigerant which is encapsulated within a plumbing network.

The heated refrigerant is transferred by a pump or compressor into the engine compartment where it then rejects this heat to exterior air flow traveling through a heat rejection coil called a condenser.

This is a continuous process that occurs whenever the compressor is operating.



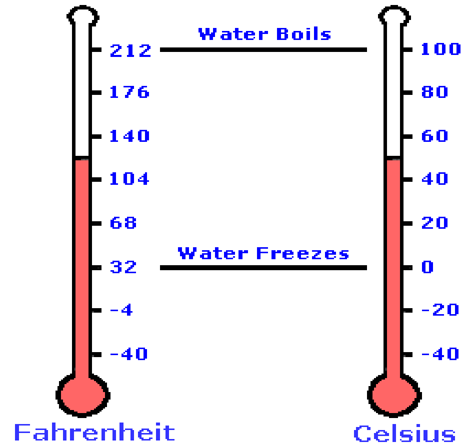
Air Conditioning Theory

Heat Measurement

First we need to understand the fundamentals of Heat.

The amount of heat energy present in the air and refrigerant is measured as the temperature.

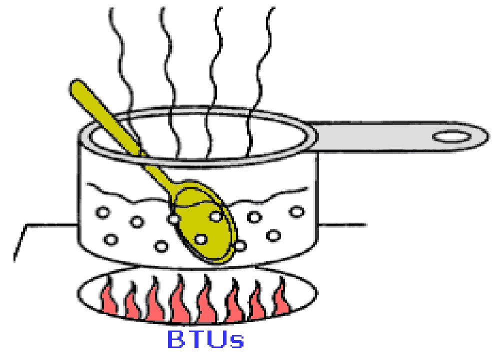
There are two different temperature scales most commonly used, Fahrenheit and Celsius.



Heat is measured in British Thermal Units (BTU's) 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.



Three Types Of Heat

Sensible Heat: When the heat that is applied to a substance merely raises its temperature, but does not change its physical state. It is the heat which, added to or subtracted from a substance, produces the **changes in temperature** indicated on a thermometer. (i.e. It is the heat that you feel or sense)

Latent Heat: The heat released or absorbed by a substance when it changes its physical state to another with **no change in temperature**. (i.e. ice to liquid and liquid to vapor)

There are two forms of latent heat:

latent heat of fusion in the conversion of a liquid to a solid, or vice versa (i.e. The Freezing Point – For water it is 32°F or 0°C).

latent heat of vaporization in the conversion of a liquid to a vapor, or vice versa. (i.e. The Boiling Point – For water it is 212°F or 100°C).

The latent heat of vaporization phenomenon is the founding principle in refrigeration and air conditioning. It is known as ***THE COOLING EFFECT!***

Air Conditioning Theory

Understanding Heat Transfer

How does heat get inside a vehicle?

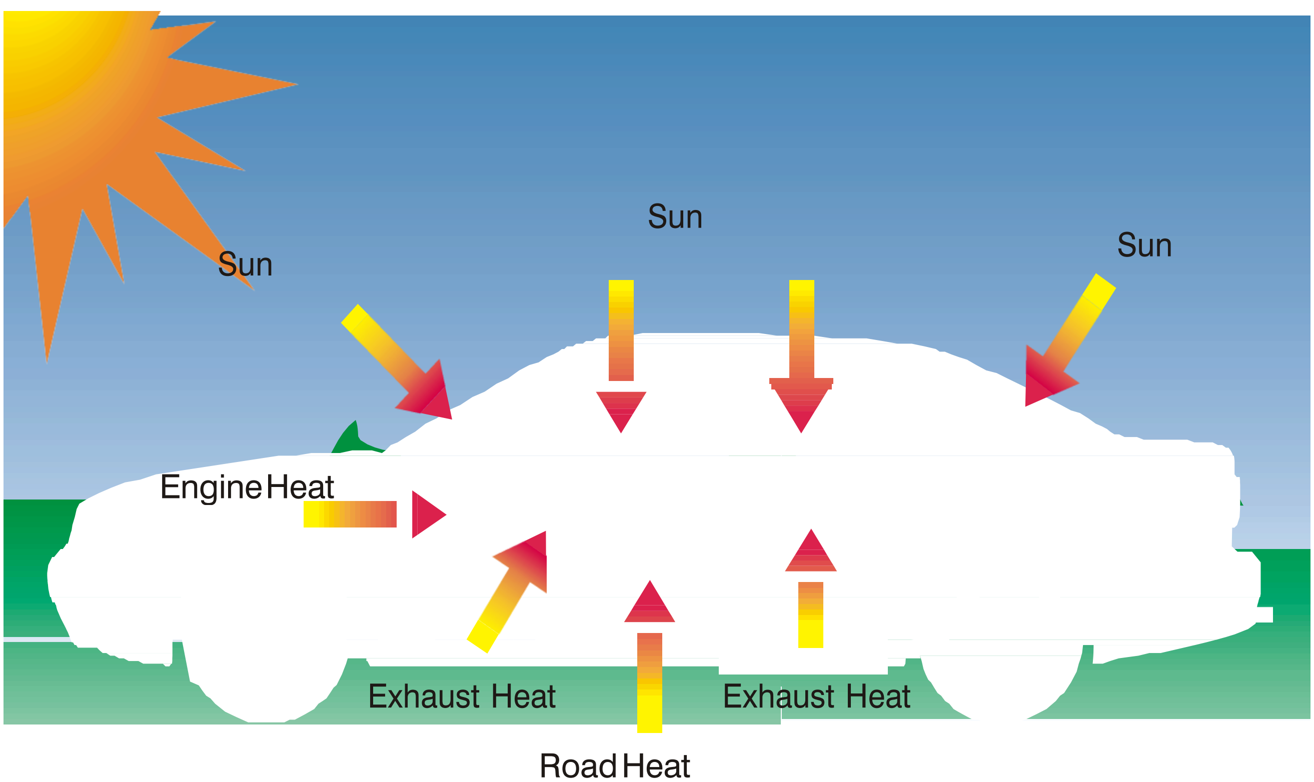
When a car is driven or parked in the sun, heat enters the vehicle from many sources.

These sources include:

- Ambient air
- Sunlight
- Engine heat
- Road heat
- Transmission
- 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 99 ºF or 37ºC day), the interior of a vehicle left standing in the sun with windows closed could reach 150 - 158 ºF or 65-70ºC!



Air Conditioning Theory

Understanding Heat Transfer (Continued)

How does heat transfer work in an A/C system?

Three processes of heat transfer:

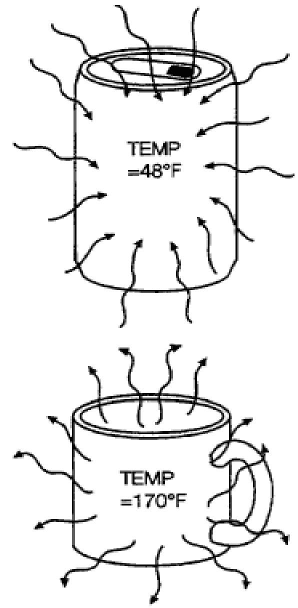
An air conditioning system's efficiency is based on how it moves heat.

Heat Transfer is the method by which heat flows.

Heat always travels from warm material 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.

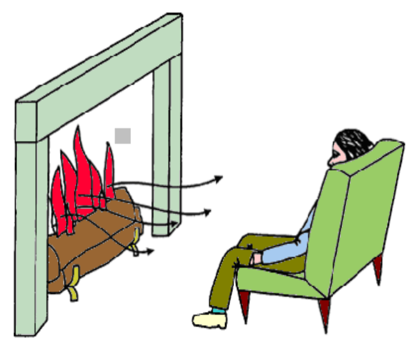
The heat from the warm coffee moves to the cooler surrounding air (i.e. condenser's heat rejection). The heat from the surrounding air moves to the cooler soda, until a balance is reached (i.e. evaporator's heat absorption).



Ambient Temperature = 70° F

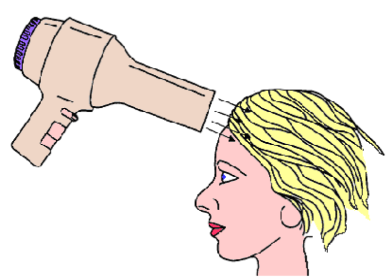
1. ***Radiation****:* Heat moves from a heat source to an object by means of heat rays.

   For example, you feel heat from a fireplace, even though air is traveling past you and going up the chimney. You are warmed by radiated heat. (i.e. Engine compartment heat, body of the vehicle exposed to the sun, etc.)

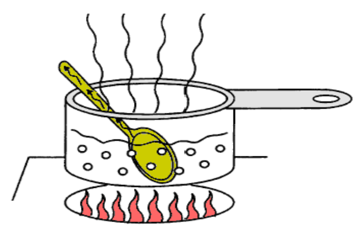


2. **Convection**: Heat flows in a stream of air or liquid that is hotter than what it flows over, around, or through.

   For example, a blow dryer generates a stream of heated air to dry hair. The hair is heated by convection. (i.e. The inlet air of the HVAC unit scrubbing the aluminum fins of the evaporator or vice versa with the condenser)

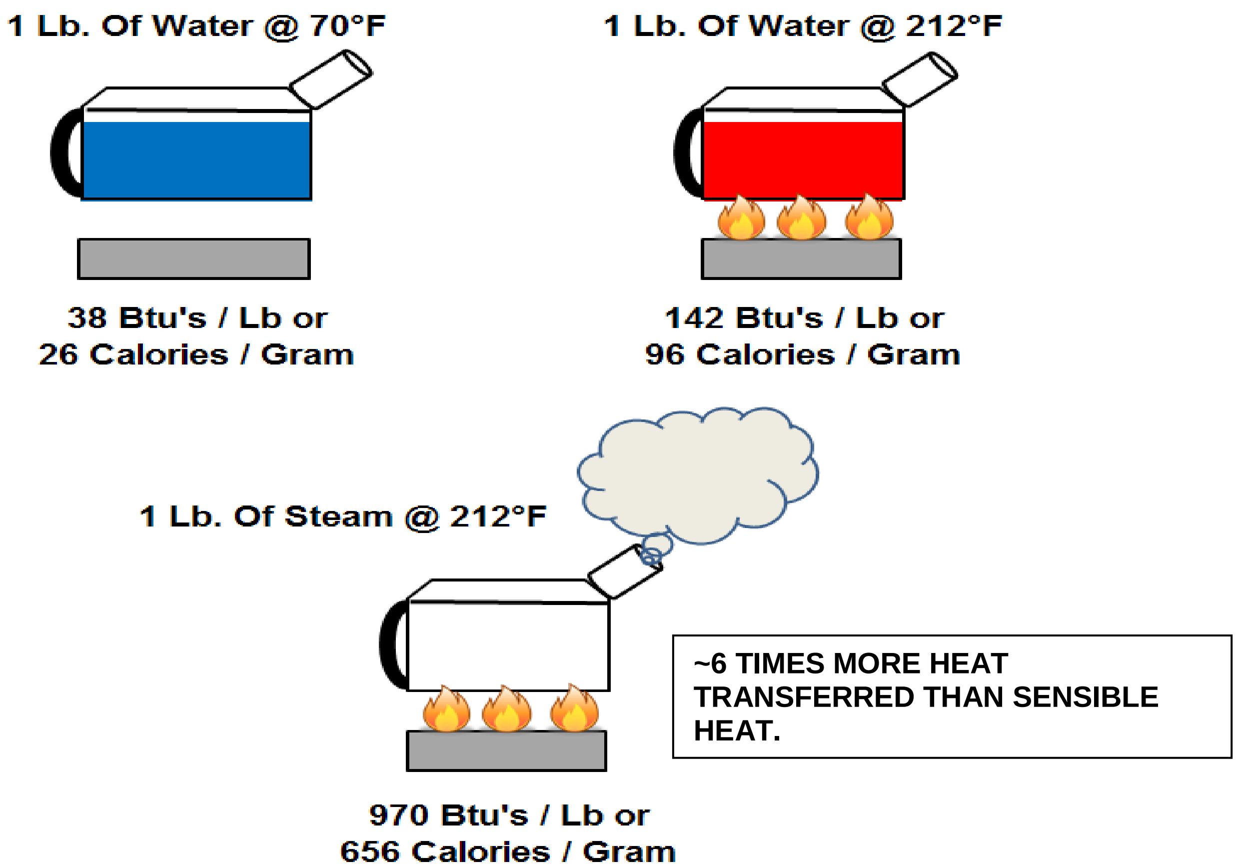


3. **Conduction**: Heat travels along a material.
   For example, if a spoon is left in a pot of boiling water, the spoon handle will get hot, even though the handle is outside the pot. Heat is conducted along the spoon handle. (i.e. The heat in the coil's fins passing to the refrigerant passages & into the refrigerant)



Air Conditioning Theory

The Added Value Of Latent Heat Transfer



A total of 1150 Btu's / Lb or 778 Calories / Gram

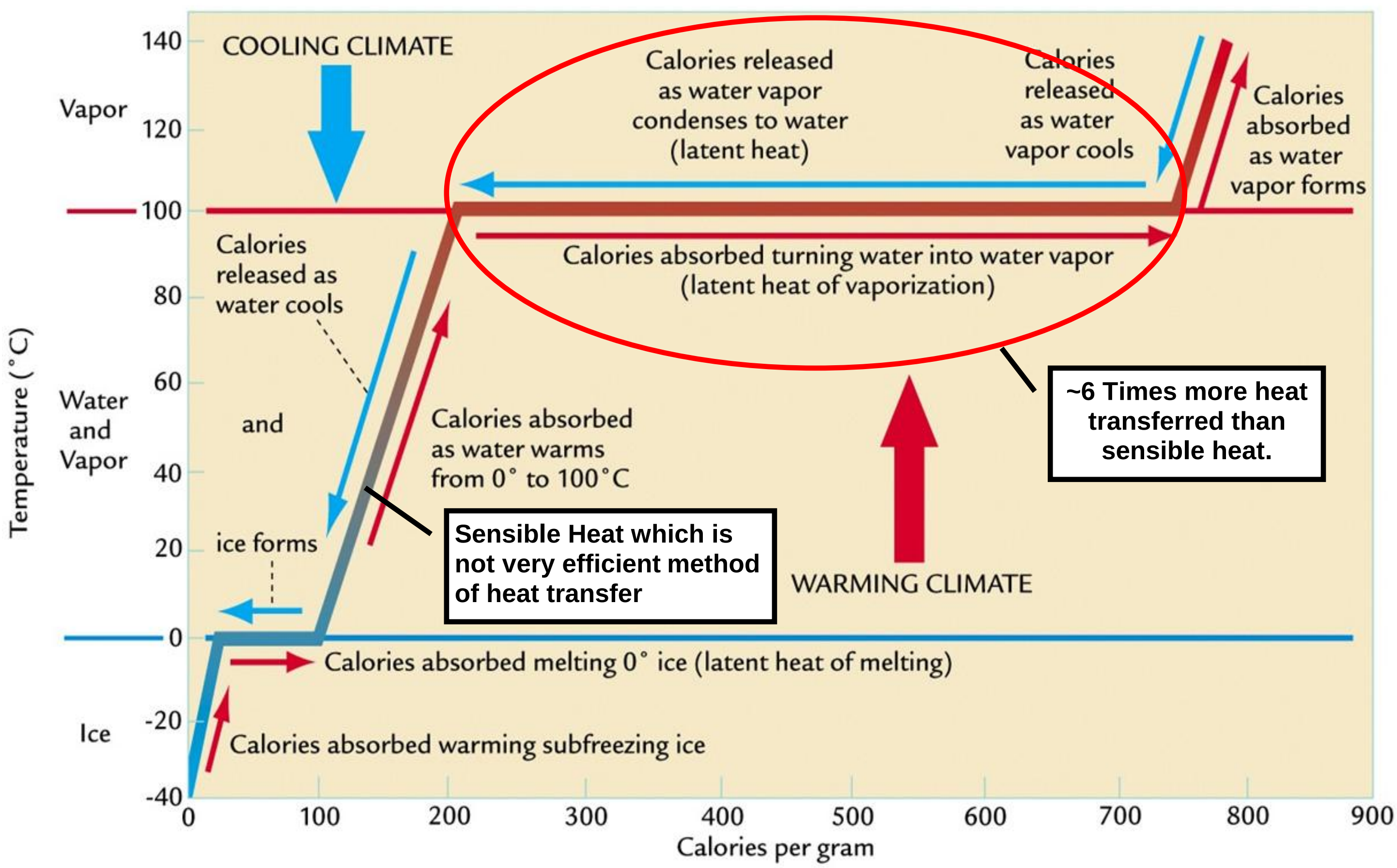
R134a refrigerant is about one tenth less in latent heat value but is used instead of water because it boils at temperatures below the freezing point of water and at a higher pressure than atmospheric pressure.

It has the needed characteristics to boil at a low temperature and is able to change its state readily from liquid to vapor, and vice versa.

The A/C system creates the situation were the refrigerant is either evaporating or condensing to provide the most efficient means of heat transfer.

Air Conditioning Theory

Heat Transfer Diagram

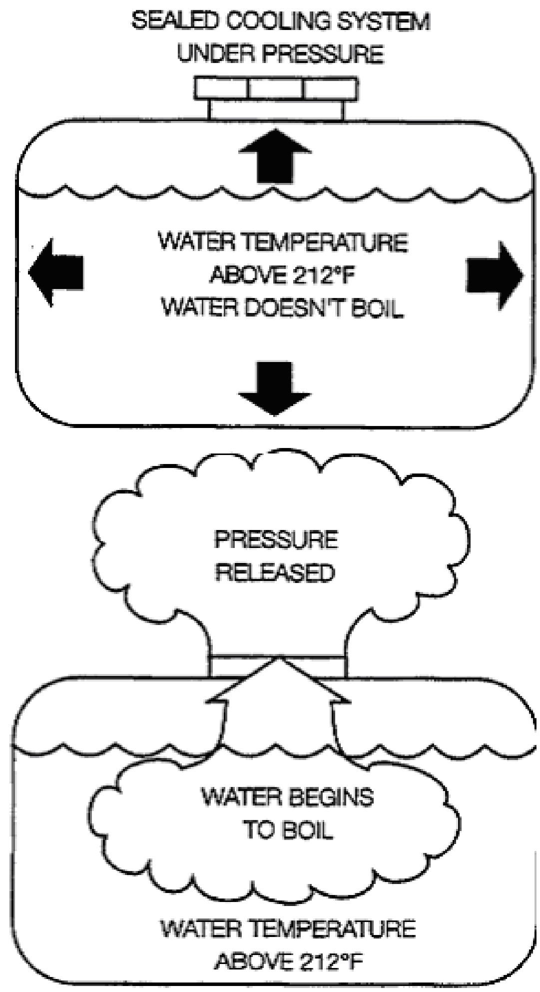


Air Conditioning Theory

Temperature/Pressure Relationship

How does the AC system create this phenomenon?

Pressure / temperature relationship: As the pressure on a liquid is increased, the boiling point rises. As the pressure on a liquid is decreased, the boiling point drops.



In an air conditioning system, the refrigerant is contained in a closed loop plumbing system that can be pressurized.

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

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 this air conditioning system, 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.

Air Conditioning Theory

Typical A/C Operating Conditions

A/C system typically operates in a 50°F to 110°F environmental range.

In those given conditions the A/C operating pressures range from 5 to 30 psig on the evaporator side and 75 to 325 psig on the condenser side.

This correlates in refrigerant temperature to -2°F to 35°F on the evaporator side and 73°F to 166°F on the condenser side.

In 110°F environment, the air flowing through the evaporator is ~75°F hotter than the refrigerant and it boils and becomes a vapor.

In 110°F environment, the air flowing through the condenser is ~56°F cooler than the refrigerant and it condenses and becomes a liquid.

ESTIMATED A/C PERFORMANCE GUIDELINES

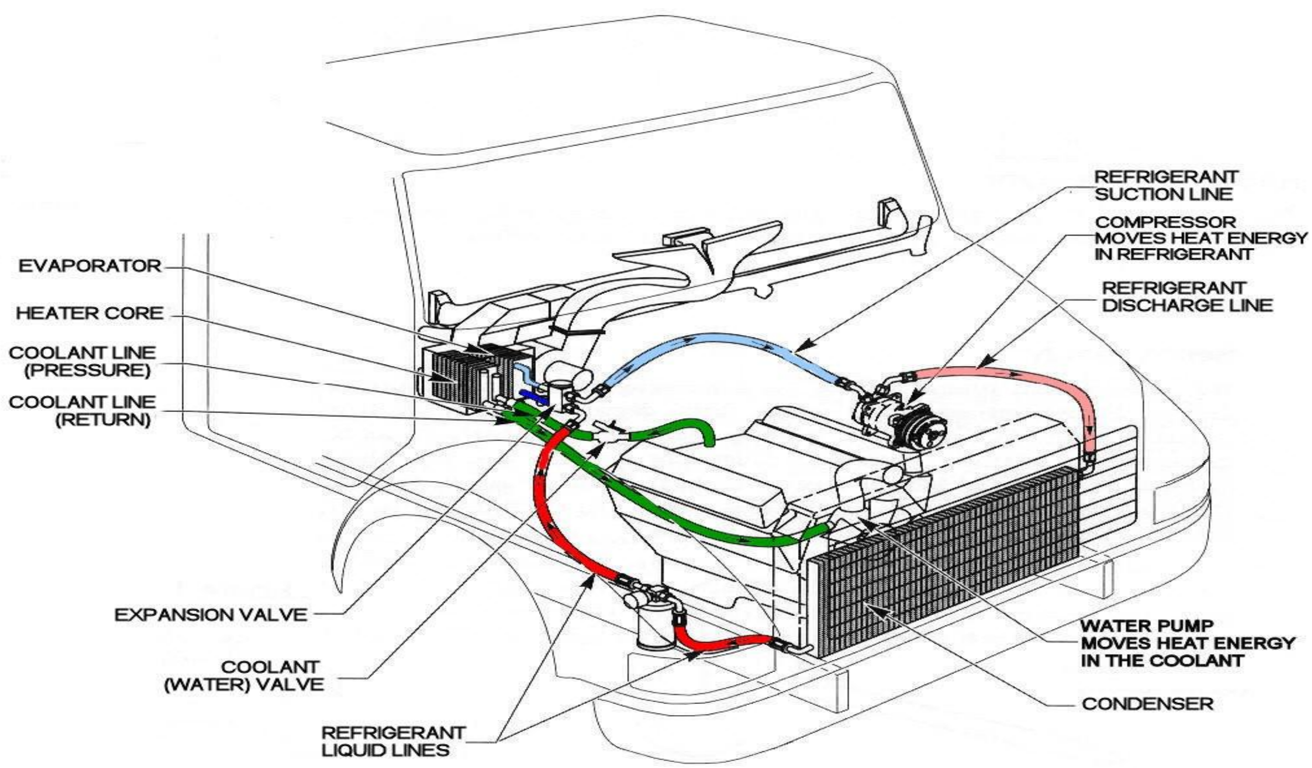
The following performance guidelines are based on test conditions outlined under [A/C System Operational Check](). Variables such as engine speed, condenser airflow, sun load, blower motor speed, and chassis voltage will all affect A/C system performance.

AIR TEMPERATURE (F) ENTERING A/C UNIT	INLET-OUTLET AIR TEMPERATURE DIFFERENTIAL**	
FRESH OR RECIRCULATED	LOW HUMIDITY	HIGH HUMIDITY
50	5 – 10	5 – 10
60	10 – 20	10 – 15
70	20 – 25	15 – 20
80	25 – 30	20 – 25
90	25 – 35	20 – 30
100	30 – 35	25 – 30
110	35 – 40	30 – 35

**The outlet louver closest to the A/C unit usually discharges the coldest air. The warmest inlet air temperature (fresh or recirculated) should also be used for the Differential calculation.

A/C SYSTEM OPERATING PRESSURES

AMBIENT AIR TEMPERATURE (F) ENTERING CONDENSER	SUCTION PRESSURE (PSIG @ EVAPORATOR OUTLET	DISCHARGE PRESSURE (PSIG) @ COMPRESSOR OUTLET
50	5 – 15	75 – 125
60	5 – 15	100 – 150
70	10 – 20	125 – 175
80	10 – 20	150 – 225
90	15 – 25	175 – 250
100	15 – 25	200 – 275
110	15 – 30	225 – 325



This picture shows the direction of refrigerant and engine coolant flow in the system. The air conditioner evaporator coil and condenser, and the heater core, are the main points of heat transfer.

Air Conditioning Theory

Air Conditioning System

1. The compressor sucks in & compresses the cool R134a refrigerant gas, causing it to become hot, high pressure gas.

2. This hot gas runs through the condenser & dissipates its heat into its cooling air flow and condenses into a liquid.

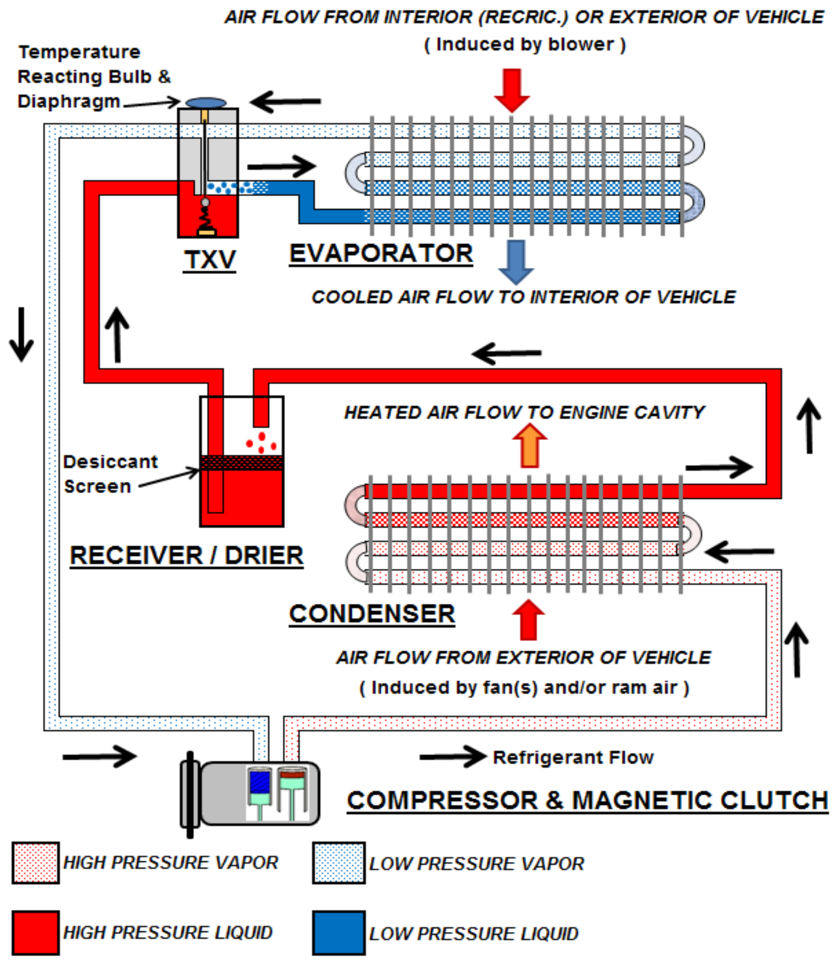
3. The high pressure liquid enters the receiver/drier for storage and moisture removal.

4. The liquid is drawn off the bottom of the receiver/drier and runs through a pressure dividing, fixed size orifice hole in the thermostatic expansion valve.

5. A bulb containing R134a liquid refrigerant controls the flow of refrigerant by using a diaphragm to push down or retract a pin. The pin pushes downward onto small, metal ball plugging the orifice allowing liquid refrigerant to enter the evaporator. The ball is cradled by an upward spring force to counter the pin's downward force. Together, these forces will modulate the refrigerant flow through the TXV.

6. The low pressure liquid refrigerant travels through the coil and evaporates thus becoming cold, low pressure gas which absorbs heat from the hot air flowing through the coil.

7. A small amount of lightweight oil is mixed in with the refrigerant to lubricate the compressor.



Air Conditioning Theory

Super Heat

At a certain point in the evaporator the R134a refrigerant is completely vaporized, after that point any additional heat absorbed by the R134a vapor is described as SUPER HEAT.

The value of this SUPER HEAT is the temperature difference above the point at which R134a liquid changes to a vapor. A proper Super Heat value is the insurance that vaporized refrigerant will enter the vapor compressor instead of liquid (i.e. Slugging).

The thermal expansion valve (TXV) super heat setting is established at the factory for particular applications. Ensure when a valve is replaced that it is of the type suited to the R134a A/C system.

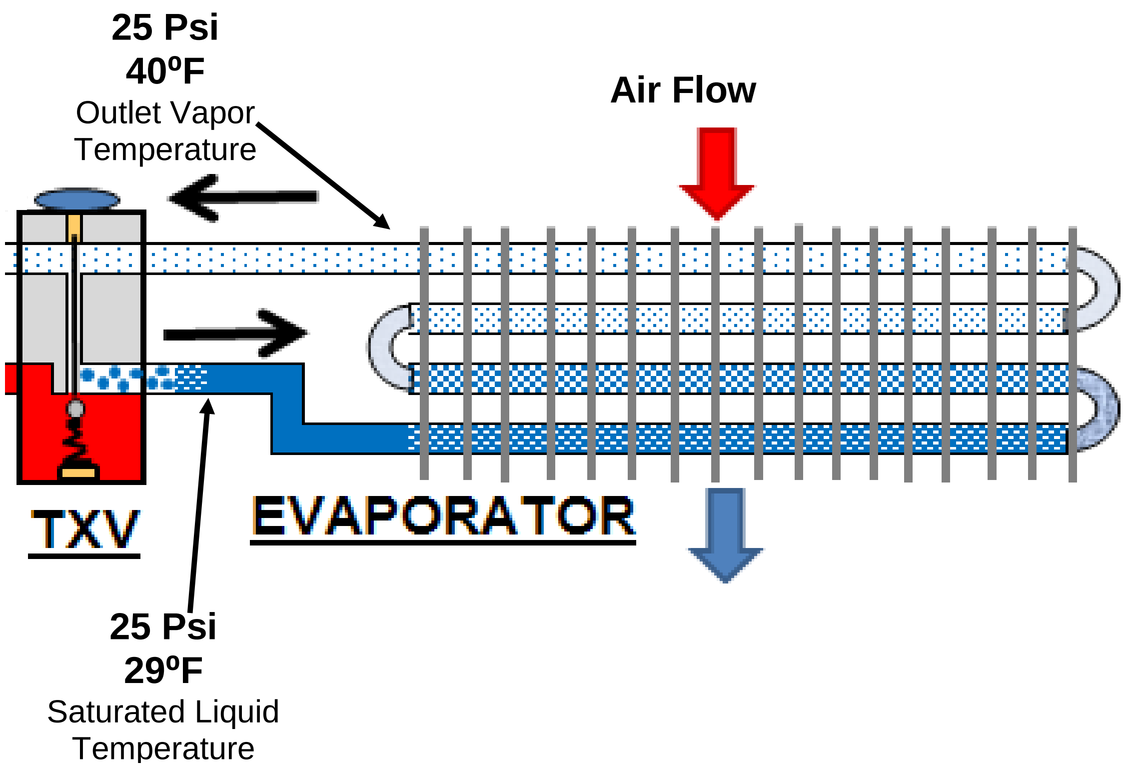
Saturation temperature = The temperature at which refrigerant in liquid form changes to a vapor at a given pressure. Saturation temperatures values can be derived from a R134a Temperature/Pressure Chart.

Actual temperature = The temperature of refrigerant at the evaporator outlet.

Example - Calculation for Super Heat

Actual Refrigerant Temperature = 40ºF
minus
Saturated Refrigerant Temperature = 29ºF

Super Heat = 11ºF



Air Conditioning Theory

R134a Temperature / Pressure Chart

Pressure	Temp	Pressure	Temp	Pressure	Temp	Pressure	Temp	Pressure	Temp	Pressure	Temp
psig/Hg"	Deg F	psig	Deg F	psig	Deg F	psig	Deg F	psig	Deg F	psig	Deg F
22	-62.38	13	11.77	37	42	61	62.75	145	109.4	265	150.6
20	-55.02	14	13.38	38	43	62	63.5	150	111.5	270	152
18	-48.85	15	14.94	39	43.98	63	64.24	155	113.6	275	153.4
16	-43.5	16	16.46	40	44.95	64	64.98	160	115.6	280	154.7
14	-38.76	17	17.95	41	45.91	65	65.71	165	117.6	285	156.1
12	-34.49	18	19.4	42	46.85	66	66.43	170	119.6	290	157.4
10	-30.6	19	20.81	43	47.78	67	67.14	175	121.5	295	158.7
8	-27.02	20	22.19	44	48.7	68	67.85	180	123.3	300	160
6	-23.7	21	23.55	45	49.61	69	68.55	185	125.2	305	161.3
4	-20.59	22	24.87	46	50.51	70	69.24	190	126.9	310	162.5
2	-17.67	23	26.16	47	51.39	75	72.62	195	128.7	315	163.8
0	-14.92	24	27.43	48	52.26	80	75.86	200	130.4	320	165
1	-12.31	25	28.68	49	53.13	85	78.98	205	132.1	325	166.2
2	-9.84	26	29.9	50	53.98	90	81.97	210	133.8	330	167.4
3	-7.47	27	31.1	51	54.82	95	84.87	215	135.5	335	168.6
4	-5.21	28	32.27	52	55.65	100	86.66	220	137.1	340	169.8
5	-3.04	29	33.43	53	56.48	105	90.37	225	138.7	345	171
6	-0.95	30	34.56	54	57.29	110	92.99	230	140.2	350	172.1
7	1.05	31	35.68	55	58.1	115	95.53	235	141.8	355	173.3
8	2.99	32	36.77	56	58.89	120	98	240	143.3	360	174.4
9	4.86	33	37.85	57	59.68	125	100.4	245	144.8	365	175.4
10	6.67	34	38.91	58	60.46	130	102.7	250	146.3	370	176.3
11	8.42	35	39.96	59	61.23	135	105	255	147.7	375	177.3
12	10.12	36	40.99	60	62	140	107.2	260	149.2	380	178.2

The numbers above represent the boiling points for R134a

Air Conditioning Theory

Sub Cooling

At a certain point in the condenser the R134a refrigerant is completely condensed, after that point any additional heat released by the R134a liquid is described as SUB COOLING.

The value of this SUB COOLING is the temperature difference below the point at which R134a vapor changes to a liquid. A proper Sub Cooling value is the insurance that liquid refrigerant will enter the thermostatic expansion valve instead of vapor.

Saturation temperature = The temperature at which refrigerant in vapor form changes to a liquid at a given pressure. Saturation temperatures values can be derived from a R134a Temperature/Pressure Chart.

Actual temperature = The temperature of refrigerant at the condenser outlet.

Example - Calculation for Sub Cooling

Saturated Refrigerant Temperature = 138ºF

minus

Outlet Refrigerant Temperature = 125ºF

Sub Cooling = 13ºF