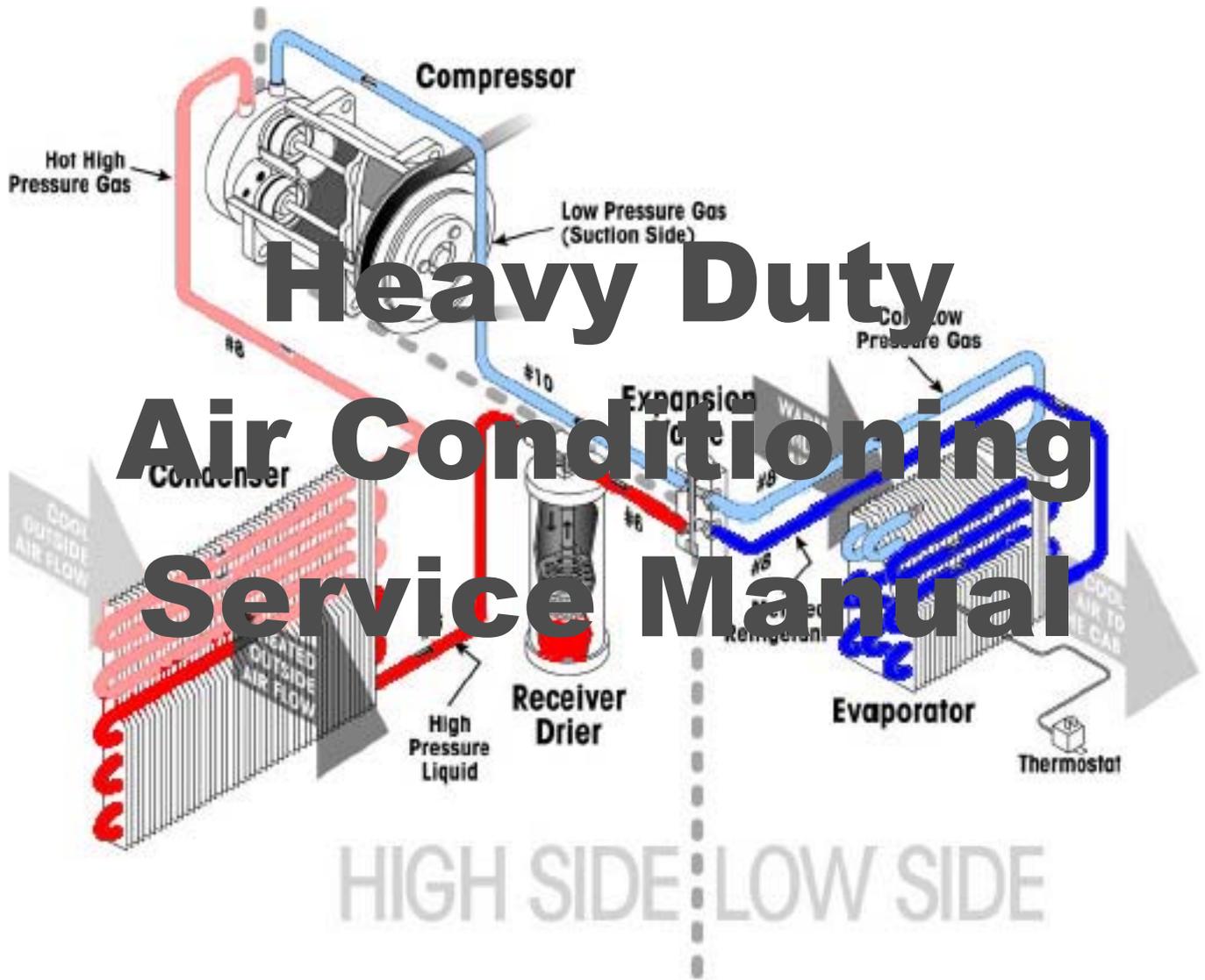


BADGER TRUCK REFRIGERATION INC.



**Heavy Duty
Air Conditioning
Service Manual**

Safety Precautions & Warnings

Servicing Refrigerant Systems

1. Always wear the proper protective eyewear and clothing before working on any refrigeration system. Remember, refrigerant in the air conditioning system can reach pressures of over 500 PSI – if one of those lines bursts while you're working on the system, it can cause serious injury. If refrigerant gets in your eye, it can freeze your eyeball, causing permanent damage or blindness.
2. Always wear work gloves whenever you're working with condensers or evaporators. The aluminum edges are sharp, and can cause serious cuts.
3. Always stay clear of the belts and fan blade, and be careful revving the engine on a car with a flex fan – damaged blades have been known to come flying off without a moment's warning.
4. Always use a DOT-approved tank for storing used and recycled refrigerants. Look for the Department of Transportation stamp: DOT 4BW or DOT 4BA.
5. Always provide plenty of ventilation when using any electrical testing, recycling or recovery equipment. Avoid breathing any refrigerant vapor, lubricant vapor or mist. Exposure to these (particularly PAG oil mist) may irritate your eyes, nose and throat.
6. Always follow the instructions for your recycling equipment; failure to follow those directions could end up causing personal injury or damaging your equipment. Never perform any maintenance or service on your recycling equipment while the unit is plugged in (unless directed to do so) or without first consulting with authorized service personnel. Removing internal fittings and filters can release pressurized refrigerant. Use care and always wear appropriate safety wear.
7. Never use compressed air to leak test or pressure test an R-134a system or R-134a service equipment. Under certain conditions, pressurized mixtures of R-134a and air can be combustible. Always follow the proper procedures to prevent any safety hazards. In addition, shop air injects moisture into the system, and a pressure surge could damage the evaporator.
8. Microprocessors and computers are susceptible to damage from electrostatic discharge. Always use a static strap when working with these components, and always take the necessary precautions to prevent damage to electronic components.
9. Most A/C service manuals indicate that R-12 turns into deadly phosgene gas when burned. Recent studies have shown that, while burning R-12 doesn't change it into phosgene gas, it does break down into carbonyl fluoride (COF₂), carbonyl chlorofluoride (COClF) with traces of free chlorine (Cl₂). And, while breathing these byproducts isn't as deadly as breathing phosgene gas, it still can be very harmful. In large enough concentrations, these byproducts can displace enough oxygen to cause asphyxiation.
10. To prevent cross contamination between refrigerants, verify that the A/C system has the correct label and unique service fittings designed for the refrigerant being used. If you're ever in doubt, check the system with a refrigerant identifier.

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Basic Air Conditioning System

Heat Transfer

How does an air conditioner make the air feel cooler?

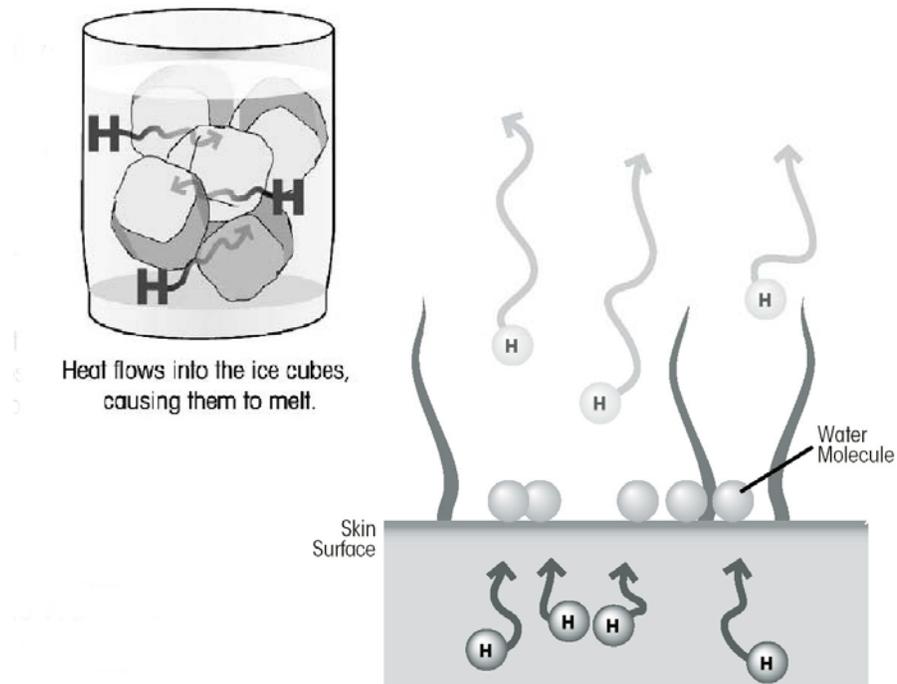
To understand how an air conditioner works, first we have to look at some of the physical principles involved. Let's begin with heat and heat transfer:

Everything you see, touch, taste, smell or hear has a certain amount of heat. Heat is energy, and everything you'll run into has some heat. The only exception is at absolute zero, or -460°F . Since you aren't likely to run into anything quite that cold, let's assume that every object has a certain amount of heat.

When talking about heat transfer, there really isn't any such thing as "cold" – sure, an ice cube may *feel* cold to the touch, but actually it just has *less* heat than your hand...that's why it feels cold. It's hard to think of an ice cube having heat, but that's actually the case.

Now, just for a minute or so, hold the ice cube in your hand. What happens? To begin with, the ice cube begins to melt. Another thing you'll notice is your hand gets colder. And wetter. What does all that tell us?

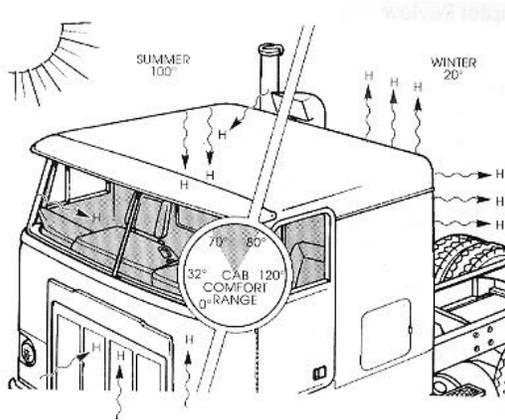
That tells us the heat is transferring from your hand to the ice cube. This example makes it obvious because the greater the difference in temperature, the faster the heat transfer.



THEORY OF OPERATION

Heat always flows to cold until the temperatures equal

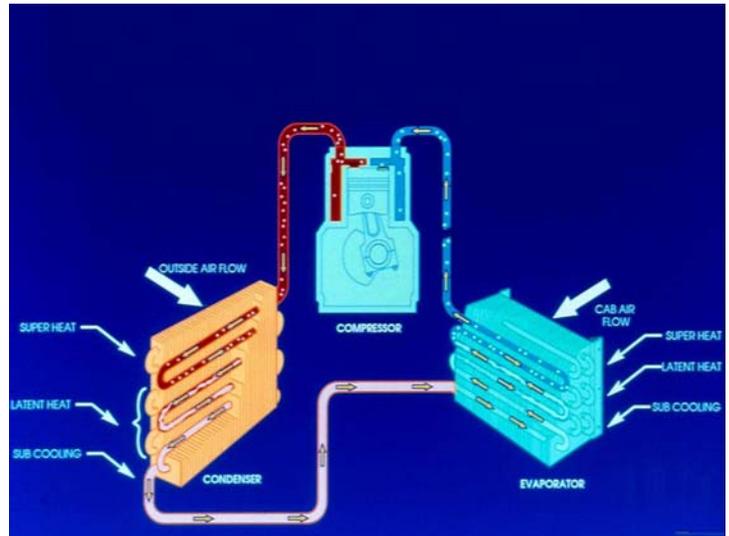
Basically, the *Second Law of Thermodynamics* says: Heat will always flow from a warmer object to a cooler one, until the temperatures become equal.



When you held the ice cube in your hand, the heat from your hand began to travel toward the ice cube. The ice cube absorbed heat, causing it to melt. As the heat traveled from your hand, your hand became colder; slowly, the temperature of the ice cube and your hand were trying to equalize. If the ice cube was large enough, and could absorb enough heat, eventually your hand and the ice cube would reach the same temperature.

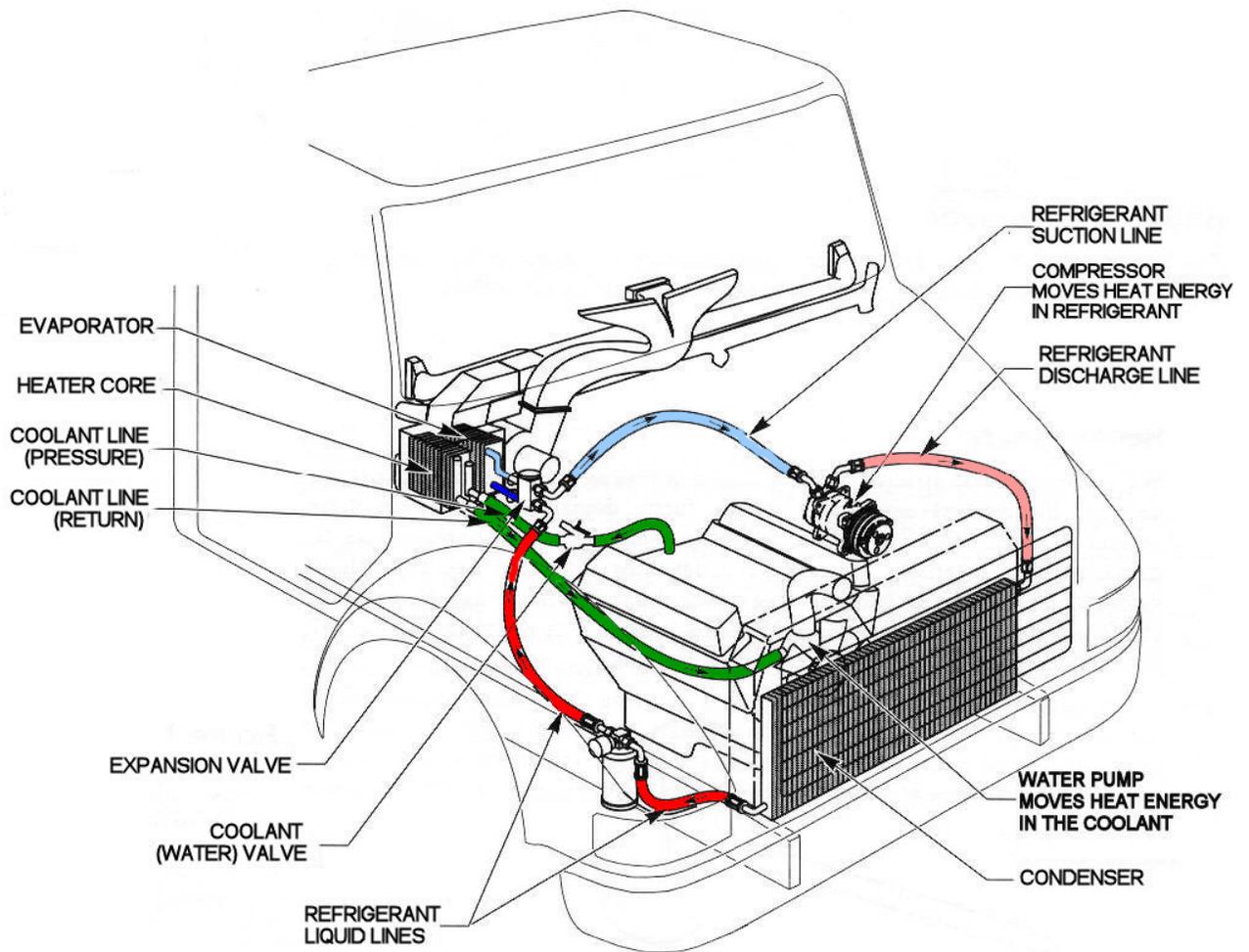
This drawing shows how heat moves; one of nature's laws. Heat always moves from a warm to a cool area – heat flows into the cab in hot weather and flows out in cold weather.

That's the principle behind how an air conditioner cools the air in your machine: by flowing warm air over a cold evaporator, the heat from the air flows to the cold evaporator, making the air less hot. The heat from the air flows into the evaporator fins, and from there into the cold refrigerant. The refrigerant carries the heat away from the evaporator, cooling the evaporator so it can cool more air.



The evaporator absorbs heat while the condenser releases heat.

THEORY OF OPERATION



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.

Change of State

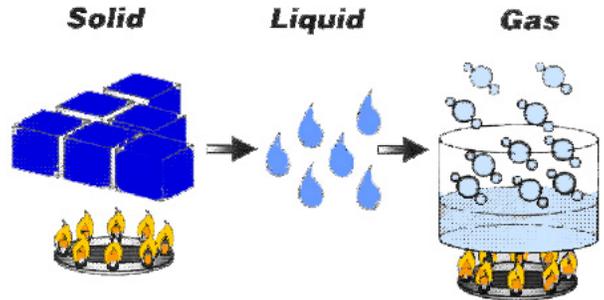
Heat transfer can force matter to change its state

All matter exists in three states: solid, liquid and gas. That's an important point to remember when looking at how an air conditioner works.

Remember what happened to your hand when you held onto the ice cube? Your hand became *colder*, but it also became *wetter* – the transfer of heat caused the ice cube to change its state from a solid to a liquid...that is, from ice to water.

That's one change that heat transfer can cause, but there's another change that we're going to be concerned with: the *change in state* when water goes from liquid to gas.

You're familiar with that change: if you continue to apply heat to water, eventually it begins to boil and turn to steam. But there's more going on than meets the eye.



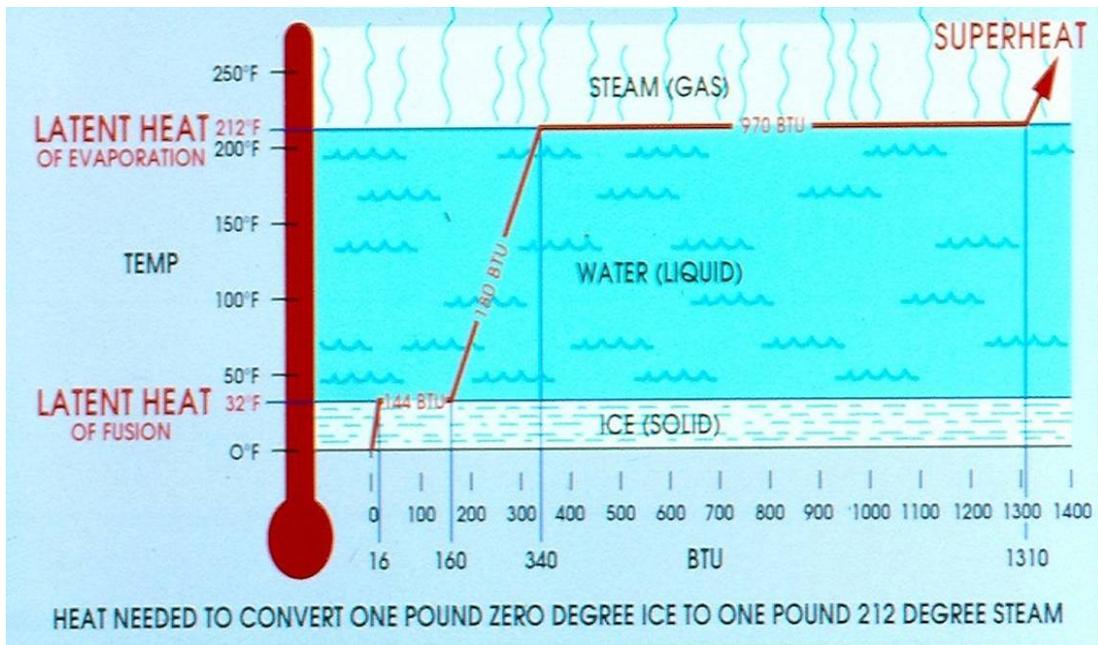
By applying enough heat, we can force an object to change its state, from a solid to a liquid...to a gas. The same is true in reverse: by removing enough heat, we can force an object to change states from a gas to a liquid...to a solid.

Latent Heat

It takes more heat to change water to steam than to boil water

To understand the heat necessary to force water to change states, we need to be able to measure the heat that water absorbs. Fortunately, someone already defined that for us. A *British Thermal Unit*, or *BTU*, is the amount of heat necessary to raise one pound of water one degree on the Fahrenheit scale at sea level. In other words, to increase the temperature of one pound of water from 100°F to 212°F (38°C to 100°C), you have to apply 112 BTUs of heat to the water. This is called "*Sensible Heat*" – as you apply heat, the temperature increases. But that still isn't enough heat to change that pound of water from a liquid to a gas. You'd have to apply an *additional 970 BTUs* of heat to change that pound of water into a pound of steam.

THEORY OF OPERATION



Heat needed to convert one pound zero degree ice to one pound 212° degree steam

The point to remember here is even though you added 970 BTUs to the water, the water temperature never went over 212°F (100°C). That 970 BTUs was the energy necessary to change the state of the water from a liquid to a gas (vapor). The extra heat being absorbed is known as “*The Latent Heat of Evaporation,*” or Latent Heat.

What about changing back from a vapor to a liquid? The principle’s the same, but the heat flows in the opposite direction. For steam to change states back to a liquid, it must release 970 BTUs of heat. At this point, as long as the liquid doesn’t release any more heat, the water will still be 212°F (100°C). The transfer of 970 BTUs simply allowed the water to condense back from a gas (vapor) to a liquid. This is “*The Latent Heat of Condensation.*”

The Merriam-Webster Dictionary defines *latent* as: “Present, but not visible or active.” The additional heat required for water to change states *is* present, but since the water temperature doesn’t change, we say the heat is latent.

What all that means is a substance can absorb or release a lot of heat, without actually changing temperature itself, while changing states from a liquid to a gas, or from a gas to a liquid. As you’ll soon see, these principles explain how the refrigerant in an air conditioning system can absorb and carry off heat.

But before we dive into the operation of a basic air conditioning system, there’s one more set of rules we need to examine: the rules that define the relationship between pressure and boiling temperature.

Boiling Temperature/Pressure Relationship

Boiling temperature directly affected by pressure changes

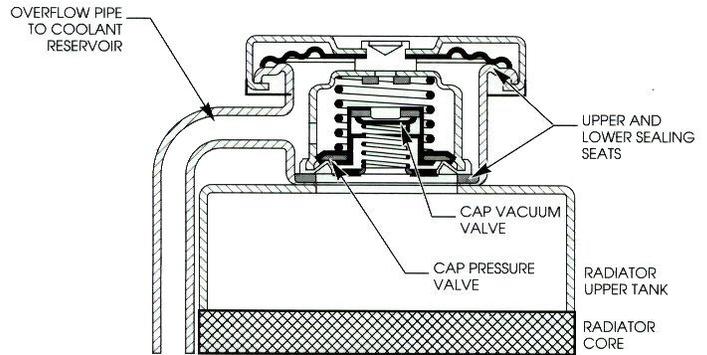
Until now we've made a lot of blanket statements about the boiling temperature of water. We said it boils at 212°F, or 100°C. That's true...but *only at sea level*. If you set up camp at the top of a mountain, say, 5000 feet elevations, you'd find that water boils at a lower temperature. That's because atmospheric pressure's lower at 5000 feet than it is at sea level.

The converse is also true: If you set up camp in Death Valley, you'd find water boils at a higher temperature than 212°F (100°C). Death Valley is below sea level, so atmospheric pressure's higher than at sea level.

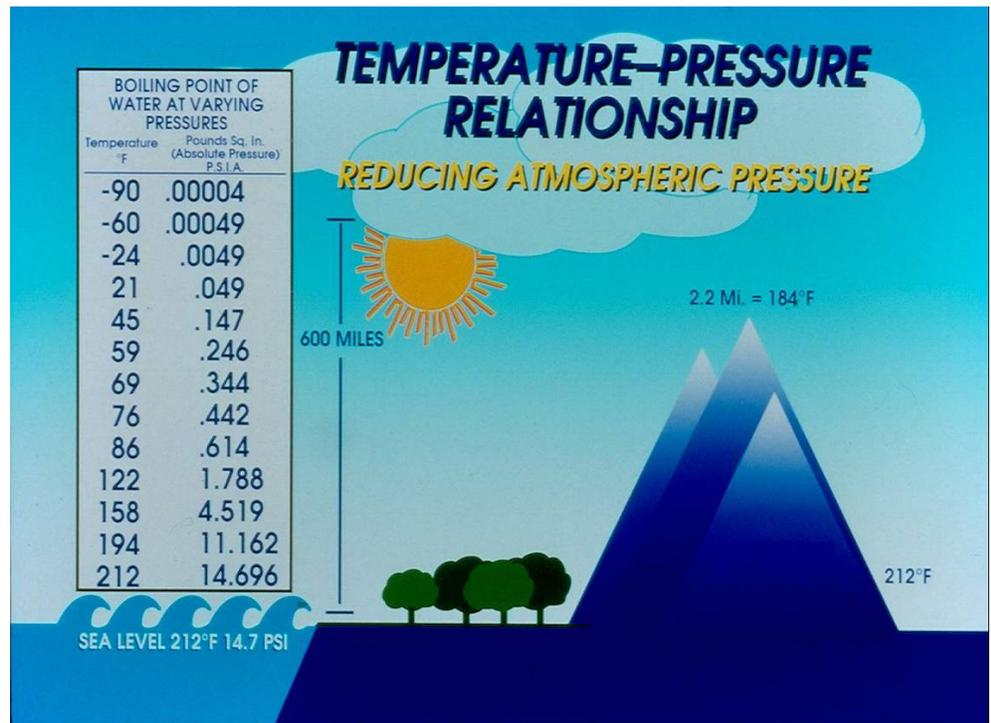
Now, granted, the temperature difference we're talking about isn't very much – maybe a couple degrees...no more. But the pressure differences aren't all that great either. You're only talking about a couple of pounds difference in atmospheric pressure between Death Valley and Mount St. Helens.

But inside an air conditioning system we'll be working with pressure differences ranging from a high of 350 PSI (2400 kPa), down to as little as 30" vacuum. At 30" vacuum, water boils at less than -10°F (-23°C)!

So far we've looked at the principles of heat transfer as they apply to water, but these principles remain the same for all condensable fluids. To work in an air conditioning system, we need a fluid with boiling temperatures and pressures that are more manageable than water's.



The pressure radiator cap seals the cooling system at the inlet on top of the radiator. Caps are pressure rated to match cooling system design. Each pound of pressure on the cooling system raises the boiling point of coolant three degrees Fahrenheit, so the pressure cap extends the cooling system operating range above the normal boiling point. The cap pressure valve opens when operating pressures are high. Coolant can flow through the heater core regardless of thermostat position.



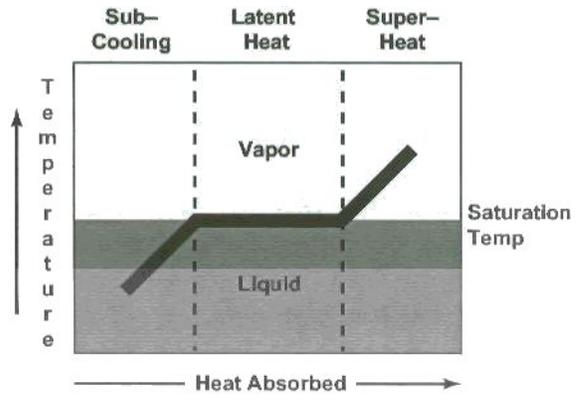
Water doesn't necessarily boil at 212°F, or 100° C - pressure affects boiling temperature. By increasing system pressure, boiling temperature increases.

Refrigerant Boiling Point/Pressure Relationship

Pressure changes affect the refrigerant temperature and boiling point...

That's how an air conditioning system works: The low side of the system maintains a fairly constant pressure designed to keep the evaporator temperature at about 32°F (0°C). Since the refrigerant is at its boiling temperature, it should take on heat and boil, changing state into a vapor.

On the system's high side, the process reverses – pressures rise well over 100 PSI (690 kPa), increasing the refrigerant's temperature and its boiling point. In fact, at these pressures, the refrigerant temperature would be higher than outside air – the refrigerant would like to change back into a liquid.



Latent heat is the heat required to make a liquid at a certain pressure turn into a vapor at that pressure. The saturation temperature changes with the pressure of the refrigerant.

But it can't. Not yet, anyway – not until it gets rid of the heat it absorbed earlier when it changed states to become a vapor. Until it gets rid of that additional heat, it will remain a vapor. The additional heat keeping the refrigerant from changing back into a liquid is called “*superheat*.” To condense back into a liquid, it has to release that superheat.

That's easy – remember, when the refrigerant pressure increased, so did its temperature – well above the ambient air temperature. The “superheated” refrigerant passes through the condenser and has no problem releasing its heat to the outside air, enabling it to condense back into a liquid.

These principles of temperature, pressure, boiling point and heat transfer are what allow an air conditioning system to work.

R-134a AUTOMOTIVE

R-134a TEMPERATURE PRESSURE CHART

TEMP F.	PSIG	TEMP F.	PSIG
16	15.69	93	110.20
18	17.04	94	112.10
20	18.43	95	114.10
22	19.87	100	124.30
24	21.35	102	128.50
26	22.88	104	132.90
28	24.47	106	137.30
30	26.10	108	141.90
32	27.79	110	146.50
34	29.52	112	151.30
36	31.32	114	156.10
38	33.17	116	161.10
40	35.07	118	166.10
42	37.03	120	171.30
44	39.05	122	176.60
45	40.09	124	182.00
50	45.48	126	187.50
55	51.27	128	193.10
60	57.47	130	198.90
65	64.10	135	213.70
70	71.19	140	229.40
75	78.75	145	245.80
80	86.80	150	263.00
85	95.40	155	281.10
90	104.40	160	300.10
91	106.30	165	320.00
92	108.20	170	340.80

All values rounded two places

The numbers above represent boiling points for R-134a

EVAPORATOR pressures represent gas temperatures inside the coil and not the coil surfaces. Add to temperature for coil air-off temperatures (8-10f.)

CONDENSER temperatures are not ambient temperatures. Add to ambient (35-40F) for proper heat transfer, then refer to pressure chart.

Example 90 F ambient temp
+40
 130 F condenser temp = 200 psig*
 *(Based on 30 MPH air flow)

Conditions will vary for different system configurations.
 Refer to manufacturers specifications.



HOW HVAC WORKS

Cab Environment

Understanding the three ways heat moves helps you consider all the heat sources that an air conditioner contends with.

- **Conduction** is when heat is transferred through a solid such as the metal fins of an evaporator.
- **Convection** is when a colder gas displaces a warmer gas causing them to move around and circulate.
- **Radiant** heat is when the sun's rays hit a solid surface causing it to heat up.

For example, understanding radiant heat will help you consider how the sun places an additional load on an air conditioner.

Truck cabs and off-road machinery cabs are hard to heat and cool. They have large glass areas and are not always well insulated. Hot and cold weather directly affect the temperature inside the cab. This means that any air conditioner system must have the capacity to do a lot of heating and cooling.

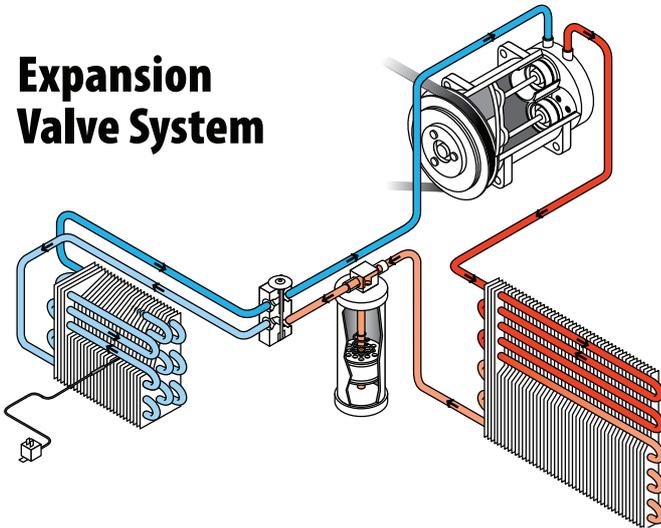
The purpose of an AC system is to keep the driver comfortable (which sometimes seems to be an impossibility). Most people feel comfortable in the 70°F to 80°F range. Because truck drivers and heavy duty vehicle operators are in their cabs for long periods of time, the cab temperature is very important for their comfort.

The ideal cab environment has a modest humidity level and should reach and remain at a temperature of 70°F to 80°F within several minutes of operation. Most air conditioners cycle on and off by the action of a thermostat or a low pressure switch. This switch cycles the compressor clutch and regulates the evaporator core temperature. This cycling action maintains a comfortable temperature range for the driver and any passengers.

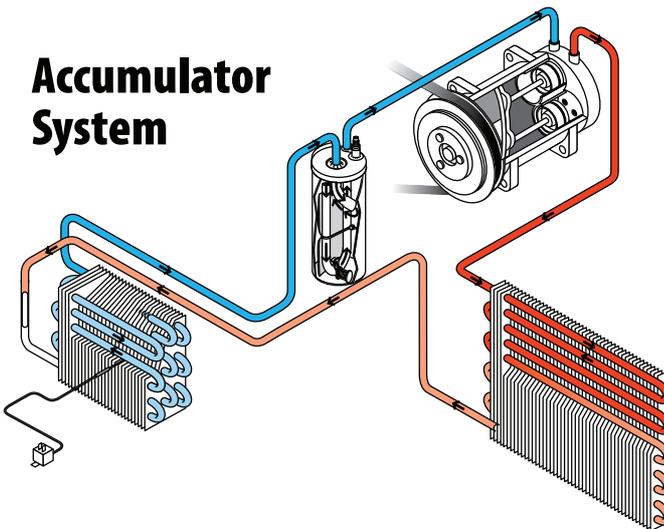


Introduction to A/C Operation

Expansion Valve System



Accumulator System



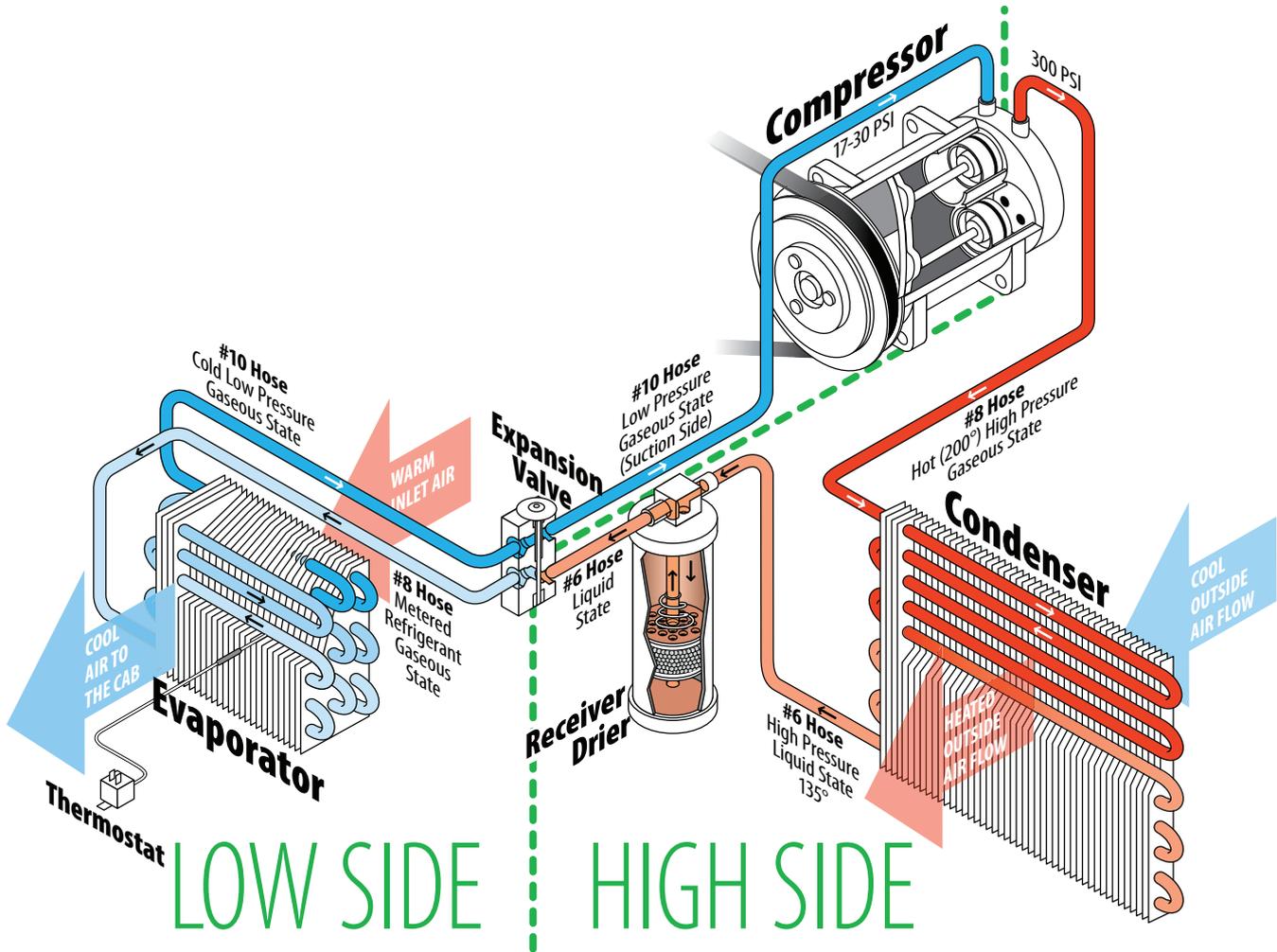
AC Systems are much like a mother, who uses a sponge to soak up milk from a spilled glass. She soaks it up and then wrings the milk out of the sponge and into the sink. Similarly, an AC system soaks up heat in the cab using evaporation and then squeezes the heat into the outside air using condensation. Let's take a closer look.

Air conditioners have two basic layouts: the **expansion valve system** and the **accumulator system**. Red Dot primarily uses the expansion valve system.

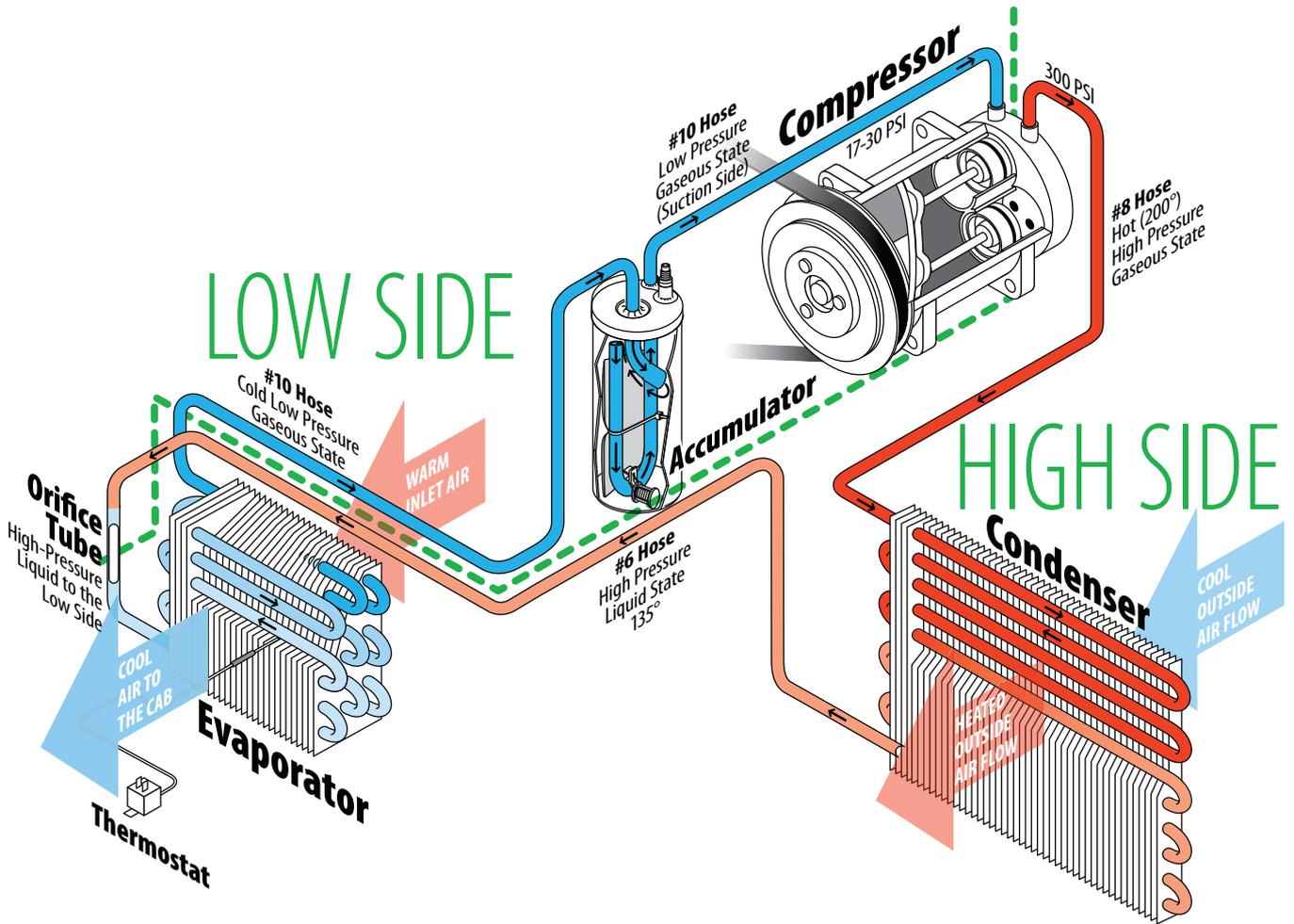
With five basic components

- 1. Expansion device:** A restriction in the liquid line of the system, purposely designed to cause a pressure drop.
- 2. Evaporator:** A device that removes heat from the cab air by exchanging it into boiling refrigerant.
- 3. Compressor:** Provides the mechanical energy to move refrigerant and manipulate pressures. This is the heart of the system.
- 4. Condenser:** Designed to exchange heat from the refrigerant to the outside air. Similar to the evaporator.
- 5. Drier Filter Device:** A storage container for extra refrigerant that usually contains a drying agent called desiccant and a filter to screen out contaminants.

Expansion Valve System



Accumulator System



Low-Side Operation

Since the low side has a very low pressure, the refrigerant can begin to boil off into a gas. When the refrigerant changes from liquid to gas it gathers heat from the cab air. The pressure difference is created by an expansion device.

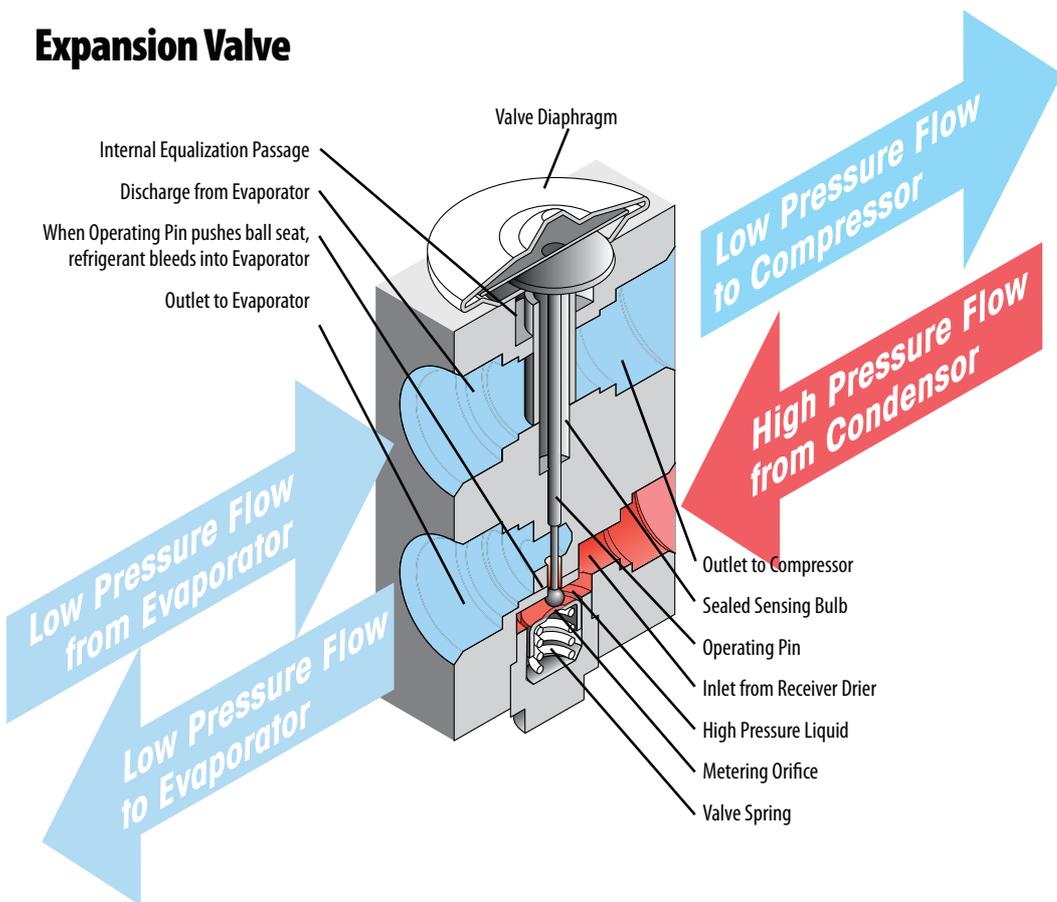
Pressure-Temperature Drop

There are two types of expansion device is the component that begins the evaporation process:

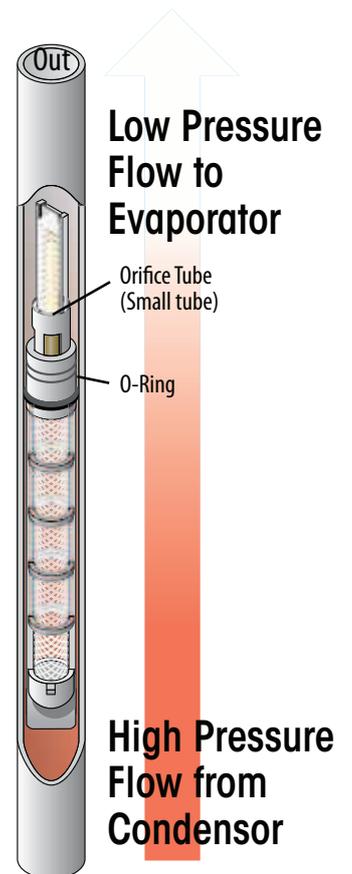
- 1. Thermostatic Expansion Valve (TXV) (left)
- 2. Orifice Tube (right)

The expansion device creates a pressure drop by restricting the flow of refrigerant around the system. Slowing down the flow of refrigerant causes the compressor to partially evacuate one side of the system. This low pressure void is called the "Suction side" or the "Low side" of the system.

Expansion Valve



Orifice Tube

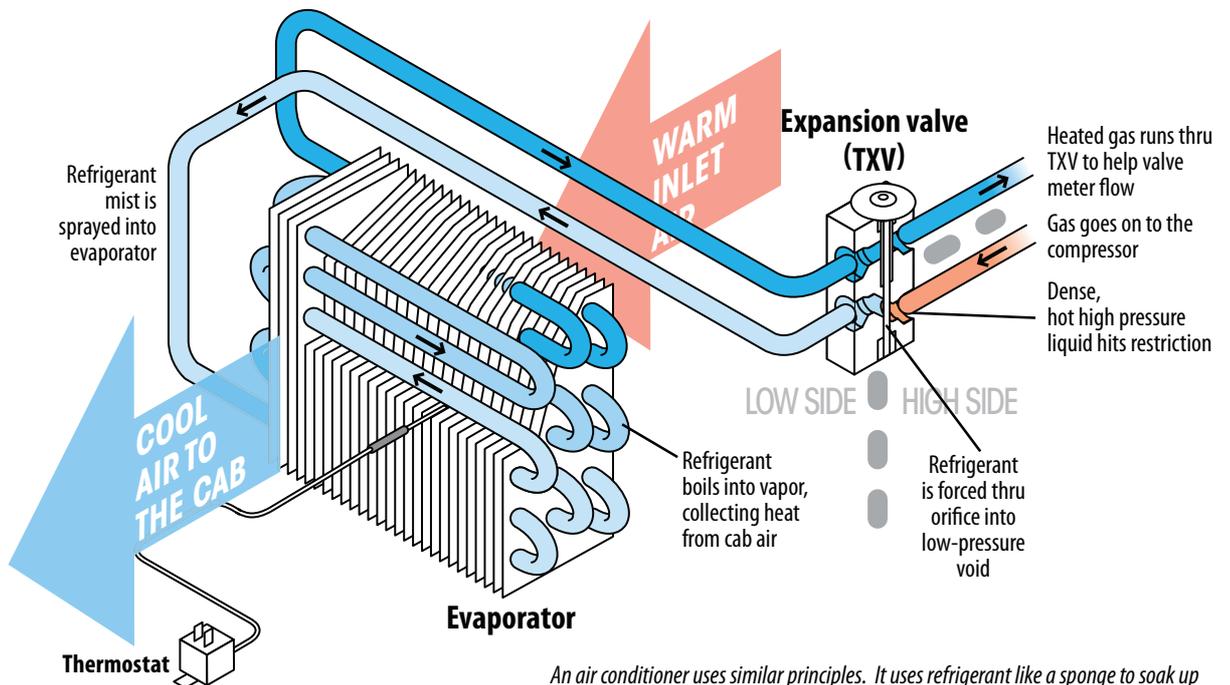


The refrigerant inside of an air-conditioner is essentially a "heat sponge." It very similar to taking a dry sponge and dunking it into a bucket of water. As the water fills the sponge, the sponge expands and becomes heavy with water. Then, when you want to remove the water, you simply squeeze the sponge with your hands and the water comes out.

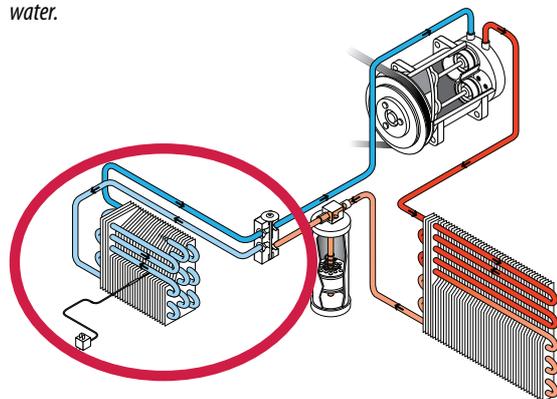
Expansion Cooling

Low-Side Operation

Cold refrigerant absorbs heat from the cab air while the refrigerant circulates inside the evaporator coil. Heat from the cab air passes through the metal of the evaporator and cause the refrigerant to expand by boiling off into a vapor. This boiling is possible because refrigerants used in AC systems have a boiling point of about one pound per square inch per 1°F. For example, the boiling point of refrigerant is approximately 20°F at 20 psi. As the refrigerant expands by boiling into a vapor, it takes massive amounts of heat with it.



An air conditioner uses similar principles. It uses refrigerant like a sponge to soak up heat (just like a sponge soaks up water). When the refrigerant enters into the thermal expansion valve (TXV) it is essentially a dry sponge. When it passes through the small orifice of the TXV it sprays into the evaporator. As the refrigerant heats up in the evaporator, it expands collecting large amounts of heat, like a sponge expands with water.

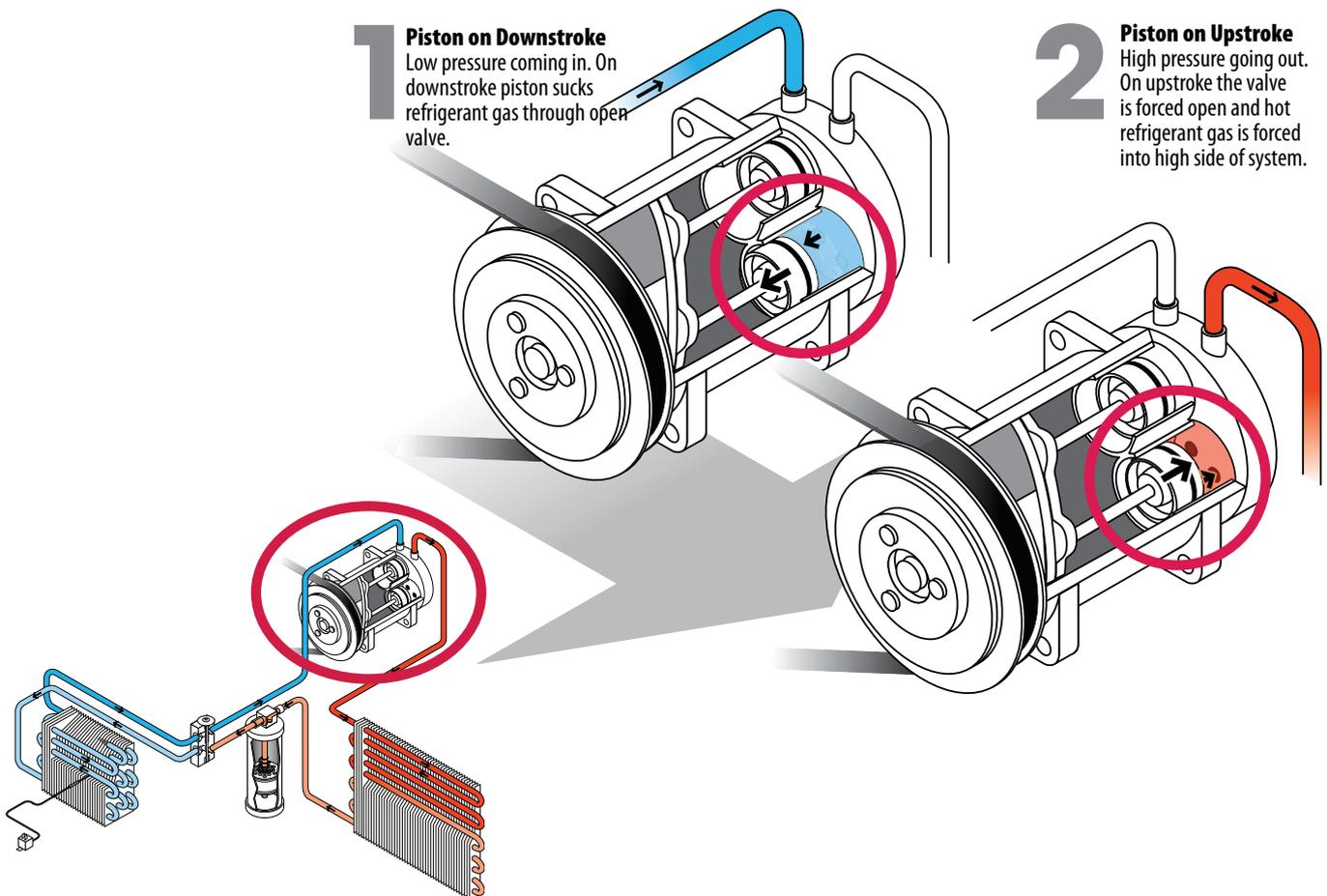


High-Side Operation

So far, we have learned that the low pressures attract heat into the system by expanding refrigerant. The part of the system that rejects heat into the outside air is known as the high side. It rejects heat by condensing hot vapor into warm liquid and through this process, squeezes heat out of the system. Heat rejection is accomplished using very high pressures (up to 350 psi) and large volumes of air.

COMPRESSION HEATING

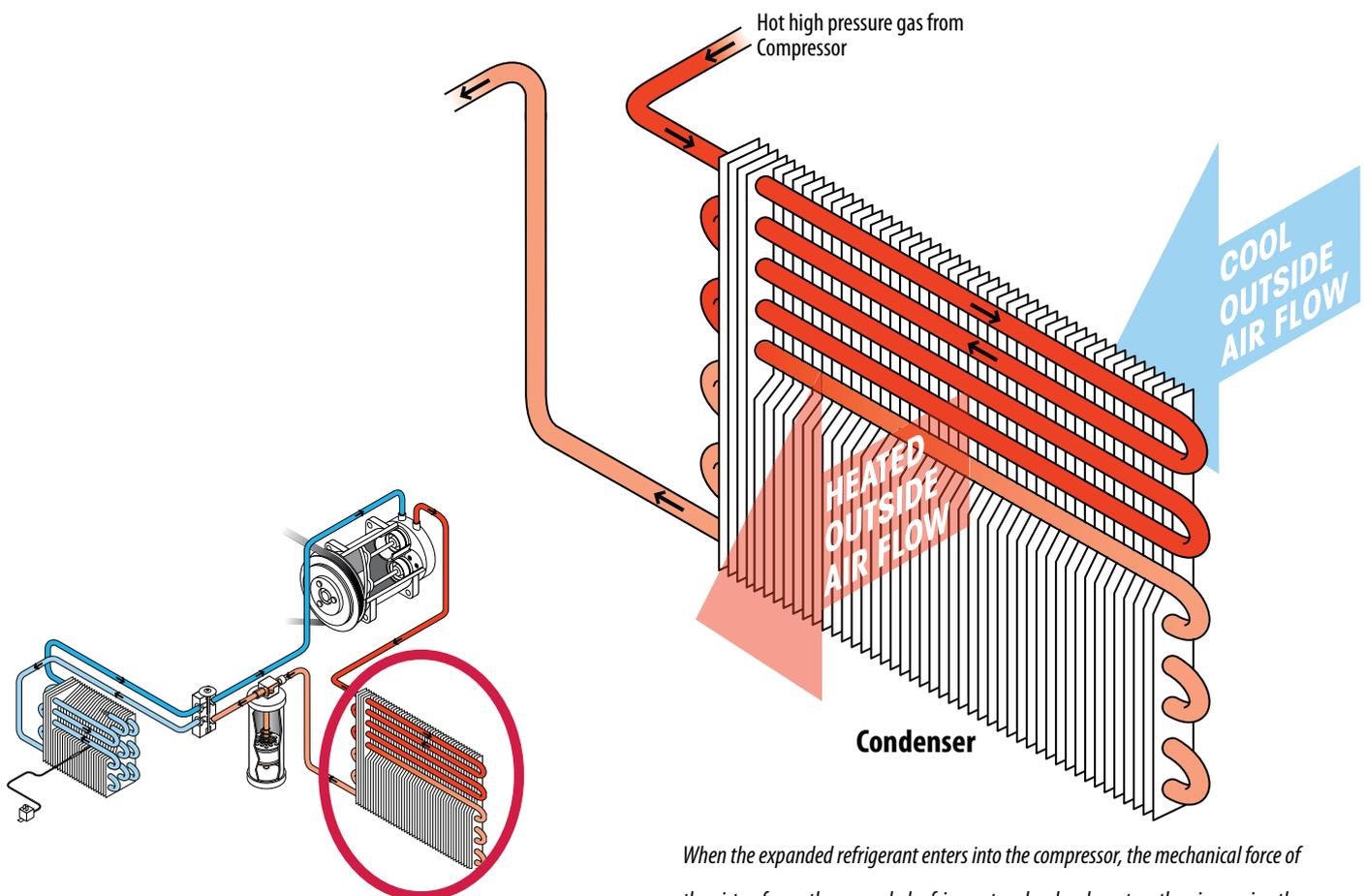
Remember that raising the refrigerant pressure is necessary to begin the process of rejecting heat into the outside air. On its downstroke (#1 at right), the compressor piston collects the expanded refrigerant inside the compressor. On its up-stroke (#2) the piston forces the refrigerant molecules closer together. The refrigerant vapor is raised in pressure, temperature and boiling point before being forced out of the valve plate assembly. The temperature of the vapor is normally two and a half times higher than the temperature of the outside air. Since heat always flows from hot to cold, the refrigerant must be much hotter than the outside air to be able to move heat out of the system.



High-Side Operation

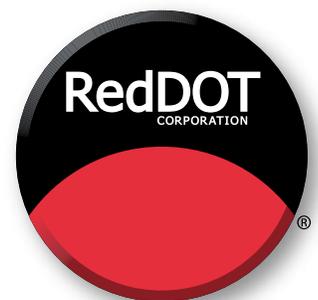
Subcooling

The hot, high pressure vapor makes its next stop at the condensing coil. The condenser is just like the evaporator – it is a heat exchanger. It looks a little different from the evaporator because it is more flat and a little larger (an evaporator must fit under the dash). Inside the condensing coil, the gas starts its way from the top to the bottom, cooling down a little with each pass. By the time the refrigerant reaches the lower third of the coil, it cools down enough to change back into a liquid. As a liquid, it continues to cool 15-30°F below its boiling point in a process called “subcooling.” Subcooling is an important concept to understand because it will tell what is wrong with the high side of the system. The next modules four, five and six will cover Troubleshooting, Inspection and AC Performance with more detail on subcooling and other topics.



When the expanded refrigerant enters into the compressor, the mechanical force of the piston forces the expanded refrigerant molecules closer together, increasing the pressure (just like when you squeeze a sponge full of water). When the high pressure refrigerant enters into the condenser, the heat is squeezed out into the outside air.

Refrigerants for Heavy-duty A/C Systems



Refrigerants for Heavy-duty A/C Systems

Why it's important to consider a global solution for all vehicles

Lean into the engine compartment of a commercial truck or piece of off-highway machinery and, as air-conditioning systems go, you'll see a familiar landscape.

Compressor? Check. Condenser? Check. Just about everything you'd find under the hood of a passenger car is in there, just built to handle a more demanding duty cycle.

How demanding?

The heavy-duty and severe-service mobile A/C market spans a mile-wide range of operating conditions, including heavy construction, mining, forestry, defense, farming, trucking, mass transit, and fire and rescue. Many of these vehicles operate 24 hours a day, seven days a week and shut down only for scheduled maintenance.

Even the average long-haul tractor-trailer will have its engine running for 21 hours a day, including six to seven hours at idle so the driver can heat or cool the cab during a rest period. With most heavy trucks logging between 100,000 and 125,000 miles a year, the warranty period on heavy-duty A/C components is longer than the life of most automobiles.

"The big difference between a car and a commercial vehicle is that the owner is counting on that truck or piece of equipment to help him earn a living," says Gary Hansen, vice-president and chief engineer at Red Dot Corp. in Seattle, which designs and manufactures heavy-duty mobile HVAC systems and components.

Downtime isn't an inconvenience, it's an expensive loss of productivity. When you're working in an open pit mine or have crops to harvest, you can't just pop into the local A/C shop for a repair. The idea of shutting down a multi-million-dollar piece of machinery to replace a blown compressor is pretty galling.

DRIVING TOWARD A COMMON ALTERNATIVE TO R-134a

Which is why suppliers to heavy-duty trucks and off-highway equipment have been vocal in the debate over what should replace R-134a even before regulations for commercial vehicles have been drafted.

The European Union's prohibition on fluorinated greenhouse gases with a global warming potential (GWP) greater than 150 applies only to cars and light commercial vehicles starting in 2011. Currently, there are no regulatory timetables in North America or abroad to require low-GWP refrigerants in on- or off-highway commercial vehicles.

"What works well in a car in Europe may not provide the best combination of performance, cost, and reliability for us."

"The auto market is where the production volumes are," Hansen says. "But what works well in a car in Europe may not provide the best combination of performance, cost, and reliability for our segment of the industry. Practically speaking there should be one low-GWP refrigerant that can be used all over the world in many different types of vehicles, including those in heavy-duty and severe-service environments."

In the United States, heavy trucks alone account for 21% of transportation-related greenhouse gas emissions, behind passenger cars (33%) and light-duty vehicles (28%). These figures include direct emissions from fossil fuel combustion as well as HFC emissions from mobile air conditioners.

Red Dot has been a leading voice on low-GWP alternative refrigerants for heavy-duty mobile HVAC systems. In 2007, the company received the prestigious Climate Protection Award from the U.S. Environmental Protection Agency for its research into the viability of HFC-152a.

“It makes sense for us to be proactive on the issue and have a voice in the process,” Hansen says. “Otherwise, we may face a mandate to use a refrigerant that doesn’t meet the specific needs of the heavy-duty market.”

CO₂: HEAVY-DUTY CONCERNS

An example of such a refrigerant is carbon dioxide (CO₂), or R-744, which has been promoted as a potential alternative to R-134a. While CO₂ refrigerant has the benefits of being non-flammable, non-toxic, and readily available, the drawbacks of CO₂ are amplified in heavy-duty vehicles.

A CO₂ system is transcritical: the refrigerant operates in one physical state instead of transitioning between a liquid to a gas. High operating pressures are necessary in order for CO₂ refrigerant to pick up and give off heat. Head pressures can exceed 2,000 psi compared to 275 or 300 psi on a typical R134a system. To handle the pressure and contain the relatively small CO₂ molecule within the system, metal hoses and seals would be required.

“Unlike rubber, metal seals don’t tolerate foreign material or slight imperfections. A spec of dirt, a human hair, a scratch—it doesn’t take much to compromise a metal seal,” Hansen says. Because CO₂ molecules are relatively small (less than half the molar mass of R134a), and in a highly pressurized system, leaking seals could be a problem.

Metal lines present another challenge. On a commercial truck, most cabs use a supplemental air suspension to cushion the ride. This isolates the cab from the vibrations and bumps endured by the rest of the truck. Metal lines are vulnerable to these differential movements between the engine and the cab.

Furthermore, the physical differences between a Mercedes-Benz and a BMW car—or a minivan and a sedan—aren’t particularly great, which makes it easier and more cost-effective for mobile A/C system suppliers to design their products.

PHYSICAL DIFFERENCES

Heavy-duty vehicles come in a wide range of configurations. In some cases, the cab and engine may not be in close proximity.

“Think about a big off-highway excavator, or a truck-mounted telescopic crane, where you have a separate cab that’s dozens of feet away from the main engine,” Hansen says. “You’d have to snake long runs of metal lines, which would make it difficult to keep up

the operating pressures in a CO₂ system, or complicate things with additional hydraulics or a second A/C system running off another engine that’s closer to the cab.”

Certainly, a CO₂ system would require longer operating periods in high ambient conditions. The higher the ambient, the less efficient a CO₂ system becomes compared to R-134a systems. For a heavy truck, the increased power demand would compromise fuel economy on the highway and require higher engine rpm at idle. That would be hard for truck owners—who consume more than 50 billion gallons of fuel a year and measure consumption in tenths of a mile per gallon—to accept.

“We may need to fine-tune the TXV, or use XH7 desiccant, but these are minor changes compared to what CO₂ or 152a would require.”

Finally, there’s an issue of engineering and development costs. Compressors, heat exchangers—virtually every component would have to be redesigned to handle the higher pressures.

“Today, the low-side pressure in our system is 50 psi in the evaporator. Well, you’re at 500 psi in the evaporator on a CO₂ system,” Hansen says. “If something lets go at 500 psi, that’s not a trivial problem.”

He says there’s a chasm between what is technically feasible versus what a factory can mass produce at a reasonable cost.

“We’ve developed components that we know will last a long time in hot, humid, and dusty environments. To go back to ground zero and engineer new components that would deliver the exact same results as what our customers expect now would be a monumental task,” Hansen says.

THE EMERGENCE OF HFO-1234yf

Ideally, a substitute for 134a would deliver similar performance without requiring a radical redesign of components. HFO-1234yf, developed jointly by Dupont and Honeywell, shows the most promise.

It enables vehicle manufacturers around the world to meet EU low-GWP mandates. While no requirements currently apply to heavy-duty and off-highway equipment, Hansen says HFO-1234yf would be a viable alternative to 134a in a wide range of vehicles.

“Tests show that 1234yf has 5% less cooling capacity than 134a in a drop-in state, but with some simple modifications we can optimize the A/C system,” says Hansen. “We may need to fine-tune the TXV, or use

XH7 desiccant instead of XH9, but these are minor changes compared to what CO₂ or 152a would require. A 1234yf system would look and perform very much like today's 134a systems."

Ultimately, Red Dot is not tied to any one refrigerant as much as they are the technology and performance.

"If you ask a customer what he wants from his A/C system, greenhouse gas reduction is probably not going to be on the list," Hansen says. "In fact, he wants it to be effective, reliable, easy to service, and not raise the cost to operate his vehicle. As we transition to a new refrigerant, the best change we can make to the A/C system is

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HFO-1234yf Refrigerant Charging

- **Systems will minimize refrigerant charge**
 - Knowing amount of system charge is critical
 - Overcharging may result in safety and performance concerns
- **Systems will have less refrigerant leakage**
 - Will require less service
- **No “Top off” refrigerant charging!!!!!!**
 - **Refrigerant removal and proper charge is required**



New standards for HFO-1234yf

- ★ **J2843 Recovery/recycle-Recharge required**
 - Flammability issues
 - System operation and performance
 - J2851 for recovery only
 - J2888 covers service hoses
- ★ **J2911 requires certification of equipment, components, and technician training**
- ★ **J2912 refrigerant identifiers**
- ★ **J2913 Leak Detector**
 - Some HFC-134a leak detectors may not Identify HFO-1234yf



R-1234yf

Fahrenheit

Pressure/ Temperature Chart

PSIG	°F	PSIG	°F	PSIG	°F
9	0	77	72	200	132
11	4	80	74	206	134
14	8	83	76	212	136
16	12	86	78	218	138
19	16	89	80	223	140
19	17	92	82	229	142
20	18	96	84	236	144
23	22	99	86	242	146
24	23	102	88	248	148
25	24	106	90	255	150
28	28	110	92	261	152
31	32	113	94	268	154
33	34	117	96	275	156
35	36	121	98	282	158
37	38	125	100	289	160
38	40	129	102	296	162
40	42	133	104	304	164
42	44	137	106	311	166
44	46	142	108	319	168
47	48	146	110	326	170
49	50	148	111	334	172
51	52	150	112	342	174
53	54	155	114	351	176
56	56	160	116	359	178
58	58	164	118	368	180
61	60	169	120	376	182
63	62	174	122	385	184
66	64	179	124	394	186
68	66	184	126	403	188
71	68	190	128	413	190
74	70	195	130		

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R-1234yf

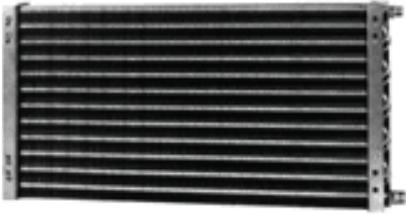
Celsius

Pressure/ Temperature Chart

kPa	°C	kPa	°C	kPa	°C
62	-18	544	23	1363	55
75	-16	562	24	1398	56
90	-14	581	25	1432	57
105	-12	601	26	1468	58
120	-10	620	27	1504	59
137	-8	641	28	1541	60
155	-6	661	29	1578	61
174	-4	682	30	1616	62
194	-2	704	31	1654	63
214	0	726	32	1694	64
225	1	748	33	1733	65
236	2	771	34	1774	66
248	3	794	35	1815	67
260	4	818	36	1857	68
272	5	842	37	1900	69
284	6	866	38	1943	70
297	7	891	39	1987	71
309	8	917	40	2032	72
323	9	943	41	2078	73
336	10	970	42	2124	74
350	11	997	43	2171	75
364	12	1024	44	2219	76
379	13	1052	45	2267	77
394	14	1081	46	2317	78
409	15	1110	47	2367	79
425	16	1140	48	2418	80
440	17	1170	49	2523	82
457	18	1201	50	2631	84
473	19	1232	51	2743	86
490	20	1264	52	2859	88
508	21	1297	53	2979	90
526	22	1330	54		

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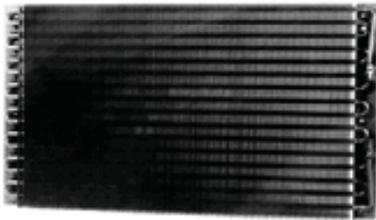
Condensers



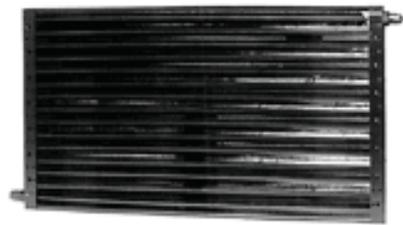
Tube & Fin (Radiator Mount)



Tube & Fin (Remote Mount)



Grilldenser



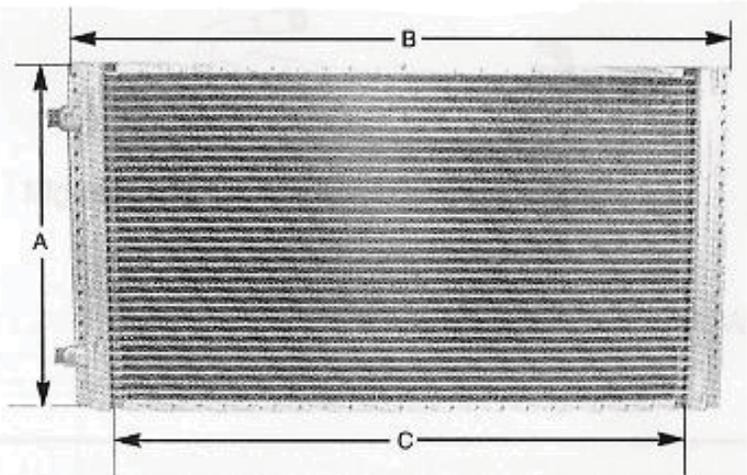
Serpentine Style



Frame is designed for numerous mounting locations



Multi-Flow Cross Section



4 Pass Coil
Male Insert O'ring Fittings
High density fin count produces exceptional heat transfer

Multi-Flow

Compressors and Clutches

Compressor

1. Tecumseh, York and CCI
2. Sanden & Zexel
3. Nippondenso
4. Harrison (GM)
5. Scroll



Two-Cylinder CCI or Tecumseh



Sanden



Seltec/Zexel/ICE



Nippondenso

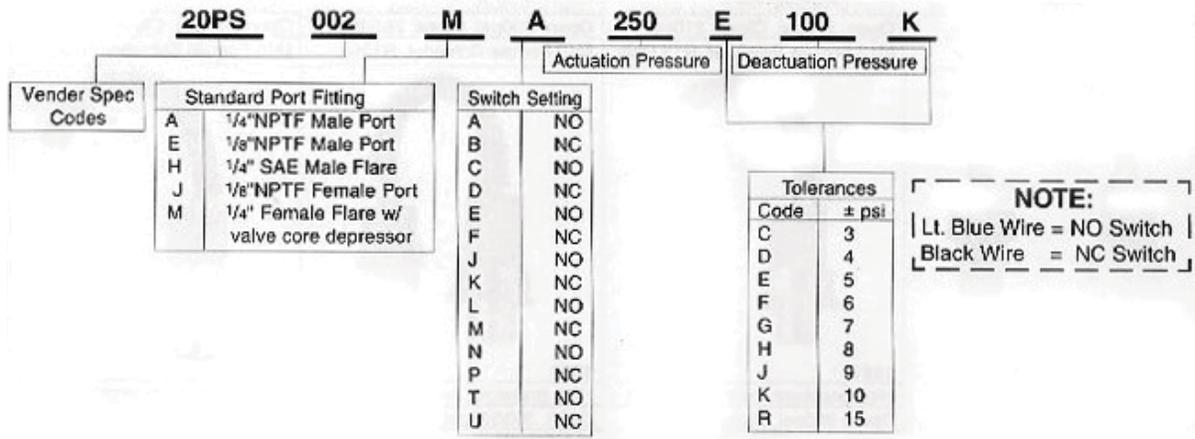


Harrison (GM)

AIR CONDITIONER COMPONENTS IDENTIFICATION

Switches

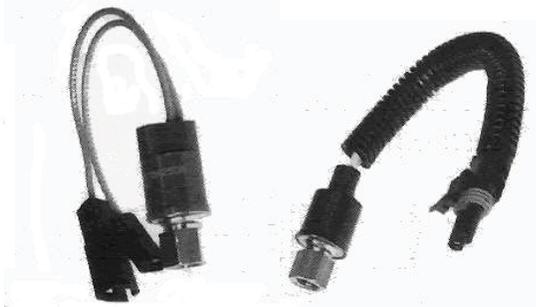
Pressure Switch Identification



Female Binary



Male Binary



Low Pressure Switch

High Pressure Switch



Male Trinary



Female Trinary

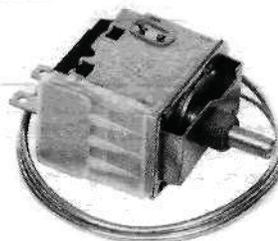
Thermostats



Cable Controlled Thermostat



Fixed (Pre-Set) Setting Thermostat



Rotary Thermostat



Electronic Thermostat

AIR CONDITIONER COMPONENTS IDENTIFICATION

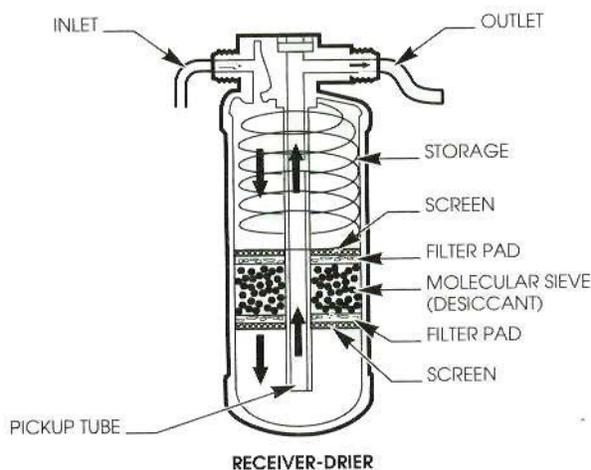
Receiver/Driers

Receiver/Driers, Accumulators and In-Line Filters are canisters used to filter debris and remove moisture to protect the A/C system. Various inlet and outlet fitting types and sizes are used. Many also have system protection devices, moisture indicators, charge ports, sight glass, fuse plugs, high pressure relief valves, and/or mounting brackets depending on the requirements from the original equipment manufacturer.

Receiver/Driers are usually located on the high side of the A/C system before the expansion valve. The receiver/drier “receives” liquid refrigerant from the condenser, stores it, filters out contaminants from the A/C system, and removes moisture. A/C systems using a receiver/drier use an expansion valve to control the refrigerant flow.

Accumulators are similar to that of a receiver/drier. It is usually mounted on the low side, at the outlet of the evaporator. The accumulator “accumulates” or stores excess refrigerant, filters and dries the refrigerant. Accumulators are CCO (Cycling Clutch Orifice Tube) or FFOT (Ford Fixed Orifice Tube) systems. These systems use an orifice tube instead of an expansion valve to control the refrigerant flow.

In-Line Filters are designed to be used in the liquid line in A/C systems with the orifice tube located in the evaporator. Placing the in-line filter “up stream” of the orifice tube eliminates the need to flush most systems, because the impurities are trapped before they reach the orifice tube. These filters are designed to hold up to 90 grams of debris, without a substantial penalty to the system’s flow. The screens and filter pads inside the canister, catch particles and filters the refrigerant oil.



74R0460



Service Tools and Their Use

The basic air conditioner and heater service tools include some special tools and test equipment as well as normal tool chest items.

Safety is important to you as well as to others in your working environment. The air conditioner and heater system are as safe or safer to work on as other vehicle systems, engines, etc. – but they are a little different.

Safety & Safety Equipment

- In servicing HVAC systems you will be exposed to high pressures, temperatures and several chemical hazards. Moving belts and pulleys are normal shop hazards.
- In addition to exercising caution in your work, **ALWAYS WEAR SAFETY GOGGLES OR A FACE SHIELD** when you are using refrigerant or a leak detector, adjusting service valves or the manifold gauge set connectors. Safety goggles or a transparent face shield are practical safety items. **ONE OR THE OTHER IS ABSOLUTELY REQUIRED.**
- Refrigerant inside a container and in parts of the A/C system is a liquid under pressures. When refrigerant escapes or is released to the air, **ITS TEMPERATURE DROPS INSTANTLY (R-134a is -16°F)**. If it spills on your skin or in your eyes, flood the area with cool water and **SEEK MEDICAL ATTENTION IMMEDIATELY.**
- The compressor creates pressure when it runs. If pressures get too high in the system, the weakest point may separate or blow out. A system restriction, too much refrigerant, or improper charging procedures are all potentially dangerous.
- Keep in mind the fact that R12 refrigerant becomes a poison gas when it burns. **DO NOT SMOKE AROUND REFRIGERANT.**
- Do not grab hold of a clutching fan to stop it when it is disengaged but turning at low RPM. **THE FAN CAN SERIOUSLY INJURE YOUR HAND.**
- Be sure the area you are working in has plenty of ventilation and that no gas or other fumes are present. **DO NOT USE A LEAK DETECTOR OR REFRIGERANT WITHOUT ADEQUATE VENTILATION. DO NOT RUN THE VEHICLE ENGINE DURING A PERFORMANCE INSPECTION OR WHEN CHARGING THE SYSTEM WITHOUT ADEQUATE VENTILATION.**

WARNING: Fire or explosion hazards exist under certain conditions with R134a. A combustible mixture can form when air pressures are above atmospheric pressure, and a mixture of air and R134a exist. For this reason do not pressure test air conditioning systems with compressed air.

A/C SERVICE EQUIPMENT & SYSTEM SERVICING

6. If the refrigerant pressure is above the limit shown for its present temperature, the refrigerant's contaminated; check the refrigerant with your refrigerant identifier.

If the contamination is only air, follow the procedure that comes with your recycling equipment to purge the air from the tank. Continue until the pressure falls below the limit shown in the charts; the tank may require several purge cycles, depending on how much air is in the tank.

If the contamination is something other than air, label the tank as contaminated, and turn it over to a reclaiming facility to be reclaimed or destroyed.

Non-Condensables Pressure Chart

Maximum Allowable Refrigerant Container Pressures

°F	PSIG		°F	PSIG		°F	PSIG		°F	PSIG		°F	PSIG	
	R12	R134a		R12	R134a		R12	R134a		R12	R134a		R12	R134a
65	74	69	75	87	85	85	102	100	95	118	118	105	136	139
66	75	71	76	88	86	86	103	102	96	120	120	106	138	142
67	76	73	77	90	87	87	105	103	97	122	122	107	140	144
68	78	74	78	92	88	88	107	105	98	124	125	108	142	146
69	79	75	79	94	90	89	108	107	99	125	127	109	144	149
70	80	76	80	96	91	90	110	109	100	127	129	110	146	151
71	82	77	81	98	93	91	111	111	101	129	131	111	148	153
72	83	79	82	99	95	92	113	113	102	130	133	112	150	156
73	84	80	83	100	96	93	115	115	103	132	135	113	152	158
74	86	83	84	101	98	94	116	116	104	134	137	114	154	160

If tank pressures are higher than shown, chances are you have excess air trapped in the top of the tank. Bleed the air off and recheck the pressure. If pressures are still too high, check the refrigerant with a refrigerant identifier.

Evacuating the System

One procedure you can perform to make sure an A/C system will work well for a long time is to evacuate it. Evacuating means pumping the system down into a vacuum of nearly 30” Hg for at least 30 minutes, to remove any air and a small amount of moisture in the system.

It’s important to keep the system as moisture –free as possible, because, as the refrigerant pushes through the expansion valve, it becomes very cold. Any moisture in the system will freeze when it gets to the expansion valve. “The system works fine for about 10 minutes. Then it starts blowing warm air. If I shut it off for about 10 minutes and turn it back on, it blows cold again...for about 10 minutes.” This is a classic symptom of moisture in the air conditioning system.

The easiest way to prevent moisture in a system is to keep all refrigerant lines sealed when you open the system. Another recommendation is to replace the receiver/drier or accumulator on any system that’s been open for a long time, or is getting major repairs, such as a new compressor. That’s because evacuating won’t remove moisture trapped in the desiccant. Remember, the desiccant is your best protection against moisture. When in doubt, replace the receiver/drier as it is less costly than a compressor.



To keep your equipment working properly, always follow the manufacturer’s service recommendations.

Water Boils under a Vacuum	
System Vacuum Inches Hg	Boiling Point Degrees F
24.04	140
25.39	130
26.45	120
27.32	110
27.99	100
28.50	90
28.89	80
29.18	70
29.40	60
29.66	50
29.71	40
29.76	30
29.82	20
29.86	10
29.87	5
29.88	0
29.90	-10
29.91	-20

Whether you’re replacing the receiver/drier or not, always evacuate the system whenever you open it to the atmosphere. Here’s how:

Step 1: Connect your vacuum pump to the service ports.

Step 2: Open both valves all the way – remember, by this time the system should be empty. Never evacuate a system until all the refrigerant’s been recovered.

Step 3: Let the system evacuate for at least 30 minutes, then hold vacuum for five minutes.

Step 4: After the system’s evacuated for 30 minutes, close the valves. If the system loses more than two inches of vacuum in five minutes, there’s probably a leak in the system or your servicing equipment.

A/C SERVICE EQUIPMENT & SYSTEM SERVICING

To pull a good vacuum, you need a good pump...

Not all pumps are created equal – pumps have ratings, in cubic feet per minute (CFM). CFM indicates the capacity of the pump and microns tells you its ability to create a deep vacuum.

Some evacuation pumps don't have the power to pull the vacuum low enough to evacuate the system properly. That's why it's important for you to check the specification on any evacuation pump you're using, to make sure it'll provide enough vacuum to prepare the system you're working on properly.

In addition, many pumps suffer from lack of maintenance; most evacuation pumps have a crankcase, just like your car's engine. This crankcase has to be drained regularly, and the oil replaced, to keep the pump working up to specifications. In a busy shop, you may have to change the evacuation pump's oil as often as once a month!

Failure to change the oil can allow the oil to become thin, and reduces the pump's ability to pull a good vacuum. Very often, just changing the oil in the pump is all that's necessary to get the pump working like new again. Always follow the manufacturer's recommendations for any maintenance on your evacuation pump and always use approved vacuum pump oil.



Evacuation pressure depends on altitude...

So far we've been looking at how lowering pressure lowers water's boiling point. But the numbers we've been looking at depend on a specific altitude; in this case, sea level.

If you're working at a higher altitude, your evacuation pump won't be able to pull as much vacuum as it could at sea level.



LCD Vacuum Gauge



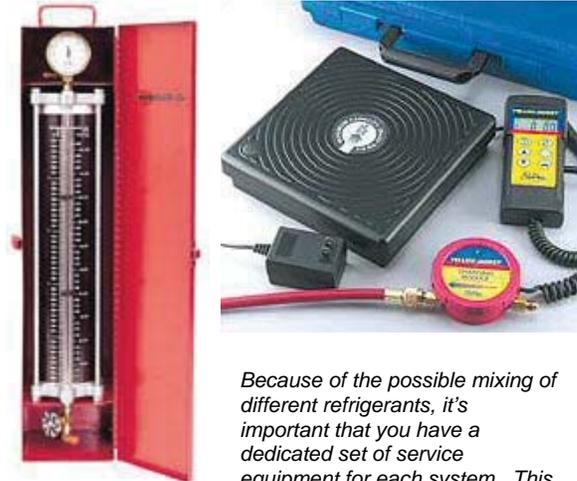
Just changing the oil in the pump is often all that's necessary to get a pump working like new again. Always follow the manufacturer's recommendations for any maintenance on your evacuation pump.

Charging the System

There are several systems you can use to charge the A/C system:

- Temperature compensated charging cylinders
- Electronic weight scales
- Charging station

CAUTION: *Before charging any recycled refrigerant, make sure there's no air in the tank. You must purge the air to keep from charging too much noncondensable gas into the vehicle A/C system.*



Because of the possible mixing of different refrigerants, it's important that you have a dedicated set of service equipment for each system. This prevents the possibility of system contamination.

Regardless of which charging system you're using, there is one rule that remains constant about A/C system charging: Never open the high side with the system running! The pressures on the high side can become high enough to blow the refrigerant container apart. To prevent system damage or bodily harm, always charge a running A/C system through the low side.

There are two main ways to charge any system:

- Through the high side, as a liquid, with the system off
- Through the low side, as a gas, with the system running.

No matter which type of system you're using to charge the vehicle, it charges the A/C system one of these two ways.

Charging stations with some type of heater, such as the temperature compensated cylinders or the units with a heater blanket, will usually provide a means of measuring out the proper charge, and charging the entire system through the high side, with the system off. Heating the refrigerant provides the pressures necessary to force the entire charge into the vehicle as a liquid, through the high side, without starting the engine.

Systems without any type of heater won't be able to push all of the refrigerant necessary into the system themselves. With these systems only some of the refrigerant will get into the A/C system through the high side. To get the rest of the charge into the system, you'll have to start the engine, and allow it to pull the refrigerant in, as a low pressure gas, through the low side.

How much refrigerant does the system require?

In the old days of A/C service, most systems were easy to fill: You just added R12 to the system until the sight glass was clear. Those early systems had a large capacity and extra storage, so accuracy wasn't as critical as it is today.

Today's systems are smaller and hold less refrigerant than early A/C systems. Most systems hold about two pounds (or less), as opposed to three or four pounds of early systems. But this new found accuracy comes at a price: Charge levels are more critical than ever before. A few ounces too little or too much can have an enormous effect on the system performance.

The best way to be sure that the system you're working on has an accurate charge is to drain the system completely, and then measure out the exact amount of refrigerant the system requires.

Charging Procedures

Important: *Every charging station has its own particular procedures. Always read the directions that came with your charging station, and follow them precisely.*

With many charging stations, the station controls whether the refrigerant enters the system as a gas or a liquid. But on other systems, such as the units that provide a weight scale for measuring how much refrigerant goes into the system, you have to decide how to deliver the refrigerant.

If you set the R134a cylinder so the valve faces up, the refrigerant will leave the cylinder as a gas. If you turn the refrigerant cylinder over, so the valve is at the bottom, the refrigerant will leave the cylinder as a liquid.

In general, the only time you should charge the refrigerant in liquid form is with the system off. Usually the only time you'll do this is when the system is completely empty, and evacuated properly.

During this situation, you can set the can upside-down, and allow pure liquid refrigerant to enter the system through the high side port. *This is the only time you should ever try to charge the system through the high side!*

Once the refrigerant level stabilizes, you'll probably have to add a bit more to finish filling the system. *Shut the high side valve off before going any further.*

Then turn the refrigerant cylinder over, run the A/C system, and finish filling the system through the low side port as a gas.



Recharge the system with the exact amount of refrigerant specified on the decal. Recharge either with a recovery unit, an A/C charging station or an electronic weight scale.

A/C SERVICE EQUIPMENT & SYSTEM SERVICING

Never add more refrigerant than is listed on the system capacity tag. Refrigerant levels are very critical in today's systems; overfilling the system – even slightly – can have a dramatic effect on system operation.

Improper Charging Procedures

Charging the system through the low side as a liquid allows the system to charge much faster, but can damage the compressor if that liquid makes it into the compressor. This is called *liquid slugging*.

If the low side port is fairly far away from the compressor, you may get away with charging the system this way, because the refrigerant has time to expand before reaching the compressor. But if the low side port is near the compressor, charging the system with liquid refrigerant could destroy the compressor.

Another way to damage the compressor is to charge liquid refrigerant through the low side with the engine off. You might think this would be okay, but this procedure has the unexpected side effect of washing all of the lubricant from the compressor. Then, when you start the system, the compressor runs without any lubrication. Though in many cases, it won't run that way for long!

To prevent damaging the system, always follow the procedures for charging the A/C system.

Proper evacuation prior to charging a mobile air conditioning system is very important. Unless the system is totally dry, devoid of any moisture, the system can self-destruct. Moisture in the system can cause acid to develop and if the dryer is overloaded with moisture it will freeze at the expansion valve, block the refrigerant flow and cause the compressor to go into a vacuum. If the compressor operates in a vacuum for very long the compressor oil will be pumped out to the condenser and the compressor will likely fail.

To properly evacuate a system you need a good quality vacuum pump capable of pulling a deep vacuum, at least 29.9 inches of vacuum at sea level. To ensure the system is dry a nitrogen sweep is essential. You will need a cylinder of nitrogen, a very dry inert gas and a regulator to reduce the pressure in the nitrogen cylinder. A newly refilled nitrogen cylinder often has as high as 2, 200 psi (15,168.5 kPa) of pressure. Care must be taken when handling the cylinder to be sure the tank valve is never damaged. If the valve were to be knocked off, the cylinder will immediately take flight like a rocket.



Vacuum pump, nitrogen cylinder, pressure regulator, micron gauge, manifold, dryer made into a bypass

After the air conditioning system has been repaired or serviced the next important step is to evacuate the system so it is free of all moisture. If a new dryer is to be installed it is wise to bypass the dryer and pull the deep vacuum through a filter bypass fitting first. You can bypass the dryer by making up a set of fittings or take an old dryer, cut the bottom off, drill a hole straight through and then weld up or plug the holes under the top. You can make up various bypass adaptors to fit the various types of dryers you encounter. The reason for this bypass: why pull moisture that could be in a severely contaminated system through a brand new dryer?

First, install the air conditioning manifold, connect the vacuum pump or recovery unit and begin to pull a deep vacuum. As we increase in elevation, we are not able to pull a deep vacuum as indicated on our manifold low side compound gauge. For each 1,000 ft. (304m) of elevation gain we lose ½ inch of vacuum. In Calgary at an elevation of approximately 3,500 ft. the manifold gauge would show about 27.9 inches of vacuum at the deepest vacuum.

If a system contains any moisture at all you will not be able to pull a deep vacuum. Most times even at sea level you will pull down to approximately 26 inches of vacuum and the needle will sit there. Often times my students

ask how long should I operate the vacuum pump and my answer is **always long enough to get a deep vacuum.** To remove all traces of moisture from the system, here is where the nitrogen is very helpful. With the manifold connected to the air conditioning system and the vacuum pump operating, set up the nitrogen bottle/container with the regulator. Close the manifold service valve at the high side access port leaving the low side of the system as it was. Close the high side manifold valve, then connect the high side hose to the regulator and then open the high side service valve. With the vacuum pump running admit very small puffs of nitrogen into the system. Here is where the regulator is so important. This will take some practice as you do not want to put any pressure in the system or you will blow the oil out of the vacuum pump. After 4 to 5 puffs you will see that the vacuum gauge will continue to drop to the lowest point and you can now shut off the vacuum pump. Using the nitrogen raises the pressure in the system until it is slightly positive, above zero. Now replace the dryer bypass with the new dryer and evacuate the dry nitrogen from the system and you are now ready to recharge the very dry system. By using the nitrogen sweep we can be sure the system is as dry as possible, which lengthens the life of the air conditioning system. The electronic vacuum gauge does away with the need to consider what your elevation is in relation to the vacuum. This will indicate what the vacuum really is in the system. If you achieve 1,270 microns water boils at 6°F (-14.4°C).

THE MICRON CHART

The MICRON is a unit used to measure the pressure remaining in an air-conditioning system.

1.000 inch = 25,400 microns = 2.540 cm = 25.4 mm

.100 inch = 2,540 microns = .245 cm = 2.54 mm

.039 inch = 1,000 microns = .100 cm = 1.00mm

Temperature In Deg. F.	Temperature In Deg. C.	Inches of Vacuum	Microns	Pounds/sq. in. Pressure
212	100	0.00	759,968	14.696
205	96.1	4.92	535,000	12.279
194	90.0	9.23	525,526	10.162
176	80.0	15.94	355,092	6.866
158	70.0	20.72	233,092	4.519
140	60.0	24.04	149,352	2.888
122	50.0	26.28	92,456	1.788
104	40.0	27.75	55,118	1.066
86	30.0	28.67	31,750	.614
80	26.7	28.92	25,400	.491
76	24.4	29.02	22,860	.442
72	22.2	29.12	20,320	.393
69	20.0	29.22	17,780	.344
64	17.8	29.32	15,250	.295
59	15.0	29.42	12,700	.196
53	11.7	29.52	10,160	.196
45	7.2	29.62	7,620	.147
32	0	29.74	4,472	.088
21	-6.1	29.82	2,540	.049
6	-14.4	29.87	1,270	.0245
-24	-31.11	29.91	25.4	.0049
-35	-37.22	29.915	12.7	.00245
-60	-51.11	29.919	25.4	.00049
-70	-56.67	29.9195	12.7	.00024
-90	-67.78	29.9199	2.54	.000049

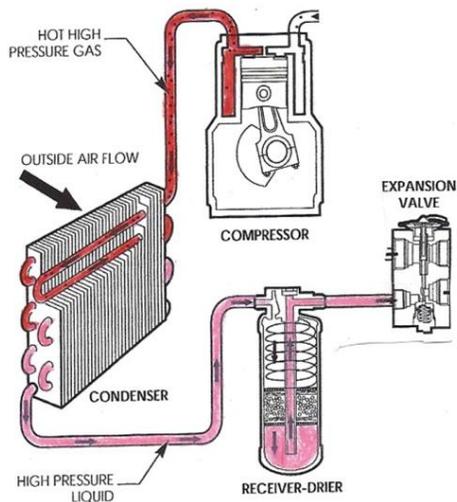
How to determine the correct refrigerant charge amount when there is no label.

Many of the air conditioning systems that are factory installed are equipped with a label describing the volume of refrigerant required for a proper charge. With these systems if a hose length or size is changed, a replacement condenser, a different dryer, the label will no longer reflect the correct charge. Unfortunately many pieces of off highway equipment such as agricultural equipment and construction equipment do not come with a capacity label. Often times the AC technician will call a local dealer attempting to determine how much refrigerant they should put into the system.

The best method to deal with the issue of no label is to charge the system using the sub cool method. I find it best to check all systems after you have charged them regardless if you charge to what the label states because over charging that often happens. In previous articles I shared the compressor discharge pressure should be about 2 to 2 ½ time the ambient air temperature. An example would be 70°F (21.1° C) 140 to 175 PSI (965.2 to 1,206.6 kPa). If the compressor discharge pressure is higher than this then we can expect shortened compressor life. The discharge pressure should never exceed 10 times the compressor suction pressure, eg. 30 psi (206.8 kPa) suction pressure = maximum 300 psi (2,068.4 kPa) compressor discharge pressure. Higher than normal discharge pressures can be caused by a refrigerant overcharge, air in the system, dirty or damaged condenser fins, lack of adequate air flow through the condenser, or tubing or restricted hoses. Contaminated refrigerant can also cause very high compressor discharge pressures. **Always test a new container of refrigerant prior to ever charging a system to ensure it is pure R-134a.**

TEMPERATURE PRESSURE CHART for R-12 and R-134a

Degrees F	R-12	R-134a
102	120.9	128.5
104	124.7	132.9
106	128.5	137.3
108	132.4	142.8
110	136.4	146.5
112	140.5	151.3
114	144.7	155.1
116	148.9	161.1
118	153.2	166.1
120	157.7	171.3
122	162.2	176.6
124	166.7	182
126	171.4	187.5
128	176.2	193.1
130	181	198.9
132	185.9	204.7
134	181	210.7
136	196.1	216.8
138	201.3	223
140	206.6	229.4
145	220	246
150	234	263



All the system in red is considered to be the high pressure side of the system

To determine the refrigerant sub-cooling, first measure the compressor discharge pressure. If the access port is between the compressor and the condenser you will always have high pressure vapor. If the high side access port is between the condenser and the dryer then there will always be high pressure liquid at that port. Be careful even though this is warm to hot liquid if it escapes it immediately becomes very cold and can freeze any exposed skin. Using a refrigerant pressure temperature chart determine the saturation point (change of state) of the refrigerant. An example would be at 151.3 psi (1,043.17 kPa) the refrigerant changes state at 112°F (44.4°C). Next measure with an accurate contact thermometer the temperature of the refrigerant at the outlet of the condenser coil. Subtract this temperature from the refrigerant saturation temperature and you have the sub-cooling point of the refrigerant. Typically most systems operate well on 15 to 25 degrees Fahrenheit of sub-cooling. With the micro tube or micro channel condensers we are experiencing a pressure drop across the condenser which can be quite significant and as a result we have to operate on the high end of the sub-cooling. Any sub cooling above 25°F will cause high compressor discharge pressures.

It is wise to check the sub-cooling on any system that you charge to ensure you have the correct charge for that particular mobile air conditioning system. Remember that with R-134a even the refrigerant that remains in the charging hose if it is added to the system can be enough to cause an overcharge on smaller air conditioning systems.

After completing the charging be sure to replace the access port protective caps. The caps not only help to prevent leaks but they also prevent air from entering the system. In ambient temperature conditions below -15°F (-26.1°C) the air conditioning system begins to go into a vacuum or absence of pressure. At -40°F (-40°C) there is 14.5 inches of vacuum in the system. At this point air containing moisture can be drawn into the system. Air is a non-condensable in the system so when it warms up again you can expect to have higher than normal compressor discharge pressures.



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General Air Conditioning Charging Guide Refrigerant R-134a

Safety Precautions & Warnings:

- 1) Charging of an air conditioning system should be conducted by a qualified a/c technician.
- 2) Always wear the proper protective eyewear and clothing before working on any air conditioning system.
- 3) Always wear work gloves when working with condensers or evaporators. The aluminum edges can be sharp, and cause serious cuts.
- 4) Always use DOT-approved tanks for storing refrigerants.
- 5) Always provide plenty of ventilation when working with refrigerants. Avoid breathing refrigerant vapor, or lubricant mist.
- 6) Never use compressed air to leak test or pressure test an R134a system. Under certain conditions, pressurized mixtures of R134a and air can be combustible. In addition, shop air injects moisture into the system.
- 7) Always use mineral oil to lubricate O-rings, even on R134a systems.

Recommended Tools:

- 1) Safety glasses and work gloves.
- 2) Thermometer
- 3) R134a Refrigerant
- 4) Compressor oil (if needed)
- 5) Mineral oil to lubricate o-rings
- 6) Manifold Gauge Set – similar to RD-5-11104-0P
- 7) Vacuum Pump – similar to RD-5-11118-0P
- 8) Charging Scale – similar to RD-5-11153-0P
- 9) Alternately a Recovery/Charging Station similar to RD-5-11087-0P can be used instead of items 6, 7 and 8 above.
- 10) Thermistor Vacuum Gauge Sensor – similar to RD-5-11115-0P
- 11) Alternate charging technique- infrared temperature sensor



Field Charging Procedure:

- 1) Insure all fittings are tight and components installed correctly.
- 2) Attach manifold gauge set to high and low side service ports. The blue coupler attaches to low pressure charge port and red coupler attaches to high pressure charge port.
- 3) Attach yellow (center) hose from manifold gauge set to vacuum pump.
- 4) Attach Thermistor Vacuum Gauge to a/c system not at the vacuum pump. The reading at the vacuum pump may not give an accurate indication of the true vacuum in the a/c system.
- 5) Start vacuum pump.
- 6) Open both red and blue (high and low side) valves on manifold gauge set.
- 7) Let vacuum pump run until thermistor vacuum gauge reads 1000 microns. Then run an additional 15 minutes.
- 8) Close red and blue valves on manifold gauge set.
- 9) Monitor pressure reading on thermistor vacuum gauge for 10 minutes with vacuum pump off and manifold gauge valves closed. Reading should be between 1000 and 400 microns and should not climb above 1000 microns.
- 10) If pressure in a/c system rises above 1000 microns the system has a leak and needs to be repaired prior to charging system.
- 11) **After verifying the system has no leaks, remove thermistor vacuum gauge.** Vacuum gage may be damage if pressurized above atmospheric pressure.
- 12) Attach yellow hose from manifold gauge set to refrigerant.
- 13) Place refrigerant tank upside down on charging scale. (Yellow hose should be attached and tank valve open.)
- 14) Zero charging scale measurement.
- 15) Open red (high side) valve on manifold gauge set and add the factory recommended charge amount. **Close red valve on manifold gage set.** Charging is complete. Verify proper a/c operation. Document total refrigerant added to system and apply appropriate label near compressor stating refrigerant charge amount.
- 16) If the proper refrigerant charge amount is not known, add one to two pounds of liquid refrigerant to the system through the high side port (red). The amount of refrigerant added depends on the estimated full charge amount. It is typically $\frac{1}{2}$ to $\frac{3}{4}$ of the estimated full charge. **Close red valve on manifold gauge set.** This type of refrigerant charging should be done at an ambient temperature of 32°C (90°F) or greater with machine doors open to provide a load on the evaporator.
- 17) Turn refrigerant tank right side up on charging scale (vapor charge position).
- 18) Start machine engine and turn on a/c system.



- 19) Record ambient temperature, evaporator inlet temperature, evaporator air outlet temperature, suction pressure and discharge pressure.
- 20) If suction pressure is 5 psig or less, keep engine speed at idle until additional refrigerant has been added and suction pressure exceeds 5 psig.
- 21) Slowly open blue valve on manifold gauge set and bleed vapor refrigerant into low side of system in small increments (0.1 to 0.2 lbs at a time). Suction pressure should not exceed 50 psig while charging vapor into the low side of the system or the compressor can be damaged.
- 22) Continue to add refrigerant in this manner in small increments until optimum a/c performance is achieved.
- 23) Document total amount of refrigerant added to system and apply appropriate label near compressor stating refrigerant charge amount.

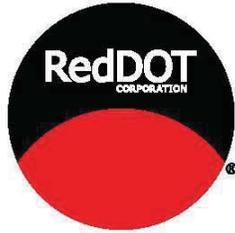
Alternate Charging Technique:

- 1) Perform steps 1- 20 above.
- 2) With an infrared thermometer measure condenser tube temperatures from refrigerant inlet to refrigerant outlet (typically from top to bottom).
- 3) The temperature will be highest at the refrigerant inlet (superheated region). Then the temperature will decrease to the saturation temperature of the refrigerant at the operating discharge pressure (saturation or condensing temperature). Near the outlet of the condenser the temperature should once again decrease by roughly (10° to 14° F) (6 to 8°C) below the saturation temperature (sub-cooled region).
- 4) If the refrigerant at the outlet of the condenser is not sub-cooled by (10° to 14° F) (6 to 8°C) below the saturation temperature, continue to add vapor refrigerant in small increments through the blue (low side) charge port.
- 5) When (10° to 14° F) (6 to 8°C) of condenser outlet sub-cooling is reached, verify proper a/c operation.
- 6) Document total refrigerant amount added to system and apply appropriate label near compressor stating refrigerant charge amount.

Typical Manifold Gauge Set



°F	°C	HFC 134a	CFC-12	°F	°C	HFC 134a	CFC-12
-60	-51.1	21.8	19.0	55	12.8	51.1	52.0
-55	-48.3	20.4	17.3	60	15.6	57.3	57.7
-50	-45.6	18.7	15.4	65	18.3	63.9	63.8
-45	-42.8	16.9	13.3	70	21.1	70.9	70.2
-40	-40.0	14.8	11.0	75	23.9	78.4	77.0
-35	-37.2	12.5	8.4	80	26.7	86.4	84.2
-30	-34.4	9.8	5.5	85	29.4	94.9	91.8
-25	-31.7	6.9	2.3	90	32.2	103.9	99.8
-20	-28.9	3.7	0.6	95	35.0	113.5	108.3
-15	-26.1	0.0	2.4	100	37.8	123.6	117.2
-10	-23.3	1.9	4.5	105	40.6	134.3	126.6
-5	-20.6	4.1	6.7	110	43.3	145.6	136.4
0	-17.8	6.5	9.2	115	46.1	157.6	146.8
5	-15.0	9.1	11.8	120	48.9	170.3	157.7
10	-12.2	12.0	14.6	125	51.7	183.6	169.1
15	-9.4	15.0	17.7	130	54.4	197.6	181.0
20	-6.7	18.4	21.0	135	57.2	212.4	193.5
25	-3.9	22.1	24.6	140	60.0	227.9	206.6
30	-1.1	26.1	28.5	145	62.8	244.3	220.3
35	1.7	30.4	32.6	150	65.6	261.4	234.6
40	4.4	35.0	37.0	155	68.3	279.5	249.5
45	7.2	40.0	41.7	160	71.1	298.4	265.1
50	10.0	45.3	46.7	165	73.9	318.3	281.4



Refrigerant Guide

Refrigerant Oil Retained in System Components

The amount of oil typically retained in system components is shown here. The amount will vary with component size and design.

Component	Typical Amount of Oil	
Evaporator	2.0 fl.oz.	60 cc
Condenser	1.0 fl.oz.	30 cc
Receiver Drier	0.5 fl.oz.	15 cc
Accumulator	2.0 fl.oz.	60 cc

Refrigerant Oil Amount Based on Charge Quantity (TXV System)

AC System with *less than* 3.5 pounds of R134a

Five cylinders or less: $[R134a (lbs) \times 2] + 1.35 = \text{Total Oil Charge (oz)}$

Seven cylinders or more: $[R134a (lbs) \times 1.07] + 2.4 = \text{Total Oil Charge (oz)}$

AC System with *more than* 3.5 pounds of R134a

On Vehicle Testing Recommended

Conversion Factors

Pounds to ounces: $(lb) \times 16 = (oz)$

Ounces to cubic centimetres: $(oz) \times 29.6 = (cc)$

RD-5-12561-0 Rev-

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Refrigerant charge amount per foot of hose length change for TXV system (pounds)

Hose size and Location	Charge Factor	Refrigerant Hose Length in feet (results in decimal pounds rounded to the nearest hundredth)										
		1'	2'	3'	4'	5'	6'	7'	8'	9'	10'	
High Pressure Vapor												R134a amount in pounds
#8 (1 ³ / ₂ " ID)	0.0043	0.00	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.04	
#10 (1 ¹ / ₂ " ID)	0.0065	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.07	
High Pressure Liquid												
#6 (3/ ₁₆ " ID)	0.0346	0.03	0.07	0.10	0.14	0.17	0.21	0.24	0.28	0.31	0.35	
#8 (1 ³ / ₂ " ID)	0.0584	0.06	0.12	0.18	0.23	0.29	0.35	0.41	0.47	0.53	0.58	
Low Pressure Vapor												
#10 (1 ¹ / ₂ " ID)	0.0011	0.001	0.002	0.003	0.004	0.005	0.007	0.008	0.009	0.010	0.011	
#12 (5/ ₈ " ID)	0.0017	0.002	0.003	0.005	0.007	0.009	0.010	0.012	0.014	0.015	0.017	
#14 (3/ ₄ " ID)	0.0025	0.002	0.005	0.007	0.010	0.012	0.015	0.017	0.020	0.022	0.025	
#16 (7/ ₈ " ID)	0.0034	0.003	0.007	0.010	0.013	0.017	0.020	0.024	0.027	0.030	0.034	

Formula for R134a per Hose Length: Hose length (ft) * Charge Factor = R134a (lb)

Vapor line changes have minimal impact on refrigerant charge

Liquid line changes have greater impact on charge (rule of thumb: 1/2 oz per foot of #6 liquid line)

Condenser changes can have a significant impact on system charge



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System Flushing

Most A/C system manufacturers don't recommend A/C system flushing. Instead, they recommend replacing components and installing in-line filters.

However, there are two flushing methods in use today that may remove contaminants, debris and old oils out of the system:

- Closed loop flushing with liquid refrigerant
- Solvent-based flushing

Some shops will perform a closed loop liquid refrigerant flush when they feel it's necessary. This method uses the same refrigerant for the system, and the same charging and recovery equipment. This method circulates liquid refrigerant through the lines and heat exchangers. You should connect an external filter, to catch any debris before it reaches your recycling equipment.



Aftermarket Flush Kit

Flushing tube-and-fin evaporators and condensers may successfully get rid of some debris. But evaporators with multifold circuits, such as plate-fin evaporators and serpentine evaporators and condensers, present another problem. On these components, the flush will take the path of least resistance, and may not clean the component thoroughly.

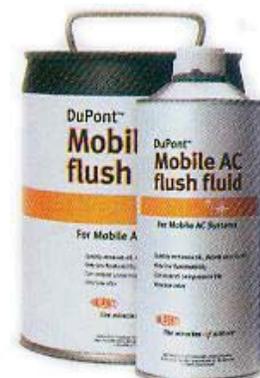
An important point to remember is that flushing an A/C component with air, nitrogen or some other vapor is never satisfactory. Flushing solutions must be liquid, and must get to all parts of the component, to be effective. A good analogy to think of is how much more difficult it might be to stand in a 5 MPH river current than a 30 MPH wind.

It's imperative that no flushing liquid remains in the system after you're done. Flushing liquid can have a chemical effect on O-rings and seals, and hurt the long-term chemical stability of the A/C system.

Solvent-Based Flushing

Once you have the system flushed, purge it with clean, dry air, and let it dry out for at least a half hour before closing the system. That gives any leftover solvent a chance to evaporate, and leaves the system clean and dry, and ready to go back to work.

Always check the local, state and federal ordinances for disposing of used flushing solvent. While the new solvent may be environmentally safe and biodegradable, the used solvent contains all of the old oil and contaminants that were in the system. That could turn the solvent into a hazardous waste, and may require special procedures for disposing of it.



A/C Flush Fluid

And always replace the oil in the system after flushing. The flushing procedure removes all of the oil that was in the evaporator and condenser. If you're replacing the

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accumulator and the compressor, chances are there's no oil left anywhere in the system. Check your shop manual for how much oil the system contains, and replace the oil before you run the system.

System flushing is somewhat restrictive; you can't flush every part of the A/C system. And there's no reason to: In most cases, you'll only flush a system while replacing certain components. You wouldn't want to flush contaminated fluids through a brand new part.

In general, the only parts you can flush are the heat exchangers: the evaporator and the condenser. Never run a flushing solvent through the accumulator or receiver/drier, the compressor, the expansion valve or orifice tube.

So flushing should be restricted to the evaporator, condenser, and any metal lines. In addition, when the system's been contaminated, replacing the accumulator or receiver/drier is always recommended.

With an expansion valve, you'll have to use your own judgment. If the valve looks okay, and seems to work okay, you may want to leave it alone. But if there's any question about the expansion valve's condition, you should replace it while replacing the compressor and the receiver/drier.

While flushing is a great way to clean out old oil and debris in the air conditioning system, it doesn't necessarily remove all of the debris in the system. Very often, some of that debris gets trapped in the small, winding passages in the condenser or the evaporator. Then, after you charge the system and let it run, that debris can break free, and work its way back to the compressor, where it can do the most damage.

The best way to prevent that debris from getting back to the compressor is to install an in-line filter in the liquid line, between the condenser and the expansion valve or orifice tube.

Never use these chemicals to flush...

R11 (CFC11) – It causes corrosion problems after retrofitting to R134a, even in trace amounts. Venting R11 is illegal since it contains chlorine. R11 has been phased out, so it isn't readily available. And, if you were to have R11 available, you'd have to recover it, just like any other CFC. Depending on the system, R12 or R134a works just as well, and you can recycle that through your dedicated recycler.

Denatured alcohol and trichloroethane – Its residue will ruin a retrofit job and legally you must recycle it. Your existing R12 and R134a machine won't handle denatured alcohol or trichloroethane.

Methyl chloroform (1,1,1, trichloroethane) – Readily absorbed by the hoses, methyl chloroform causes rapid lubricant decomposition with either PAG or ester lubricants. Methyl chloroform chemically attacks the copper surfaces, which guarantees compressor failure. In testing, researchers were unable to get most of the methyl chloroform out, even with extended deep vacuum pumping.. Use methyl chloroform for its intended purpose – cleaning brake and electrical contacts.

Leak Testing

Probably the most common problem you'll run into on air conditioning systems is low refrigerant level.

One of the rules of air conditioning is that refrigerant doesn't just disappear – if the system's low, it must have a leak.

There are several ways to run a leak check:

- Look for oil stains, bubbles or listen for a hissing sound
- Use an electronic leak detector
- Use a blacklight sensitive dye

Look for a leak in the system. Large leaks will probably be obvious; to start with, the system will probably be completely empty. You'll have to add about a pound of refrigerant to find a leak on a totally empty system. To perform an accurate leak test, you need about 7 to 15% of the total system charge. This gives the system a saturated pressure above 50 PSI.

After you have an adequate charge, then look for the leak: You may hear it hissing, or see it bubbling. A little soapy water will help you pinpoint those large leaks – this is a great way to check for fitting leaks. Don't forget to recover the refrigerant after you find the leak.

And don't forget the service fittings; your gauge set will mask this type of leak. Always check the fittings for leaks after removing your gauges, and don't forget to install the threaded caps – the caps, not the valves, are the primary seal for the service fittings.

Oily stains or caked-on dirt in a specific location are good indicators of refrigerant leaks.

Always check the bottom of the evaporator housing for oil. When the evaporator leaks, oil runs to the same opening as condensation. The oil soaks the bottom of the evaporator housing. But not every leaking evaporator will be oil-soaked. If the system's been running a little low on oil, there might not be enough oil to wet the case.

Notice: *On R134a systems, you may not find any evidence of oil, even with a leak, because the lubricant is water soluble, and could wash away.*

Warning: *Never use compressed air to leak test or pressure test an R134a system or R134a service equipment. Under certain conditions, pressurized mixtures of R134a and air can be combustible. Always follow the proper procedures to prevent the potentially dangerous mix of air and R134a. In addition, shop air injects moisture into the system, and a pressure surge could damage the evaporator.*



Two excellent ways to locate refrigerant leaks are with an electronic leak detector or a black light system. Remember, leak detectors for R12 may not detect leaks in an R134a system. If the label says it meets the SAE J1627 standard, you can use it for both refrigerants.

A/C SYSTEM DIAGNOSIS

Hose leaks won't always be accompanied by obvious damage. If the hose appears oily, wipe it dry and watch it for a few seconds. If you see an oily stain begin spreading on the hose, there's a good chance it's become porous – replace it.

Using a Leak Detector

Warning: Always check the refrigerant in the system before using a leak detector; some leak detectors use a technology that could ignite flammable hydrocarbon refrigerants.

Not every leak is going to jump out at you; to find smaller leaks you'll need to use a leak detector.

The most accurate method to check for leaks is an electronic leak detector. In some cases these units use a small vacuum pump to draw air samplings past the sensor, enabling you to find leaks as small as a couple ounces a year. When the sensor detects refrigerant, it beeps to let you know it found a leak.



Electronic leak detectors enable you to find leaks as small as a couple of ounces of refrigerant per year. Early R12 detectors can't detect R134a...make sure you're using the right type of leak detector for the system you're working on.

Here's how to use a leak detector to find leaks:

Make sure you have enough refrigerant in the system to show the leak. A few ounces – enough to bring the system to around 7% to 15% of its normal charge – should usually be enough. Once some of the refrigerant in the system remains a liquid, the pressure won't increase by adding more refrigerant; this is called the "saturated pressure."

Turn the leak detector on, and slowly run the detector wand along the system, paying particular attention to the fittings, seals and hose joints. Run the detector all the way around the lines – remember, the leak could be anywhere, even though refrigerants are heavier than air.

Make sure you have the charging hoses disconnected while running a leak check – that way you can check the Schrader valves for leaks, too. Remember to install the threaded caps when you're done.

And don't forget the evaporator. Place the detector by the drain hole – leaking refrigerant will head right for that opening in the bottom of the case.

Think you may have a small evaporator leak? There are a couple ways to check: You can remove the blower resistor to get access to the evaporator with your probe.

Or let the system sit with the blower on high for about 15 seconds to clear out any refrigerant built up in the ducts. Then turn the blower off and wait a few minutes; the directions with your leak detector should specify how long to let the system sit. This allows any leaking refrigerant to build up in the evaporator housing, and set off your leak detector.

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Another common place to look for leaks is at the pressure switches – refrigerant often leaks past the plastic, along the electrical connectors or adjustment screws. Unplug the electrical connectors, and give the switch a careful going-over.

Once you find the leak, make the necessary repairs, recheck, evacuate and recharge the system.

Remember, low side system pressures are higher when the system's off. Finding a small leak on the low side is often easier when the compressor isn't running.

Types of Leak Detectors

There are two main styles of electronic leak detectors available today:

- Corona Discharge
- Heated Diode

Heated diode units only respond to halogens, so they tend to be less likely to false trigger than the corona discharge unit. But heated diode units require more power than the corona discharge leak detector; the battery-powered heated diode units will usually operate for about two hours before requiring recharging.

On the other hand, corona discharge units tend to be less costly, and will operate for a long time on flashlight batteries; heated diode units require much more power to operate than corona discharge units. A corona discharge unit can work fine – and they're easy to use, especially when it has an adjustment to control its sensitivity.



Most leak detectors require periodic maintenance procedures to keep them operating properly. Always read and follow the recommendations in your instruction manual.

Black Light Leak Detectors

Another way to look for leaks is to inject a dye in the system, and shine a black light along the lines, fittings and seals.

Warning: *Always wear the protective goggles that come with your black light leak detector. These goggles protect your eyes from damage caused by ultraviolet light from the black light. In addition, the goggles enhance the luminescence from the dye, to make leaks easier to spot.*



One way to make your leak-finding chores easier is with a black light. You inject a small amount of dye into the air conditioning system, and run the black light along the system lines and fittings. Any leaks in the system will show up a luminous green.

Leaks will show up as luminous green or yellow under the black light. This is a good way to find extremely slow leaks, or leaks that only occur during special circumstances, such as driving vibrations or road shock. These leaks won't appear during normal leak

A/C SYSTEM DIAGNOSIS

checks; in many cases, the only way you'll be able to find them is by adding a dye to the system.

Remember, the oil used in R134a systems is water soluble. So in some cases, leaks that would have been obvious on R12 systems, due to an oil stain on the components, could easily wash away before you have a chance to find it.

Always use the correct dye for the system you're working on – R12 uses a completely different type of dye than R134a systems. Both dyes work the same way for indicating leaks, but the two dyes aren't compatible.

Never add more than one bottle of dye to a system. One bottle is enough to highlight a leak; two won't make the leak any more visible, and could thin out the oil in the system enough to damage the compressor.

Once you find the leak, repair it – then evacuate and recharge the system. Then clean off any residual dye from the components: Otherwise, you're likely to find that dye later, and be fooled into thinking you found a leak, where no leak exists.

Look for additional information regarding procedures for using refrigerant leak detection dyes in SAE J2298 procedures.

Diagnostic Procedure Worksheet

Complaint:

- No A/C Insufficient A/C Odors/Leaks
 Noise Other _____

- When does the complaint occur?
 Always Other _____
- Temperature/conditions when complaint occurs:
 Always 70° – 90° 90° High temperature/High humidity
- Equipment condition/maneuver when complaint occurs:
 Always Engine idling Under load Other _____

System Function Test

- Blower Fan Operation:
 OK No high blower Missing speeds Other _____
- Air Distribution:
 OK No defrost No panel No floor
 No recirculation Other _____
- Temperature Controls:
 OK No temp change Control level problem
 Other _____
- A/C Function:
 OK No clutch operation Clutch operates; no temp change
 Clutch operates; some temp change Other _____

Supporting Systems

- Electric Cooling Fan (Condenser):
 OK (Fan comes on with A/C) Fan operates continuously with no A/C clutch operation
 Fail (Fan doesn't come on with A/C) Other _____
- Cooling System:
 OK Signs of overheating Other _____
- Heater Control Valve (if applicable):
 OK Stuck open Not being controlled Other _____

Repair Service Recommendations

- Electrical diagnosis of: Fan Blower Motor A/C Clutch Electric Cooling Fan
 Other _____
- Diagnose ventilation system: Air Distribution Temperature Controls
 Other _____
- A/C refrigerant system: Performance Test Leak Test
 Other _____

All diagnosis, service or repairs to the refrigeration system of automotive air conditioning systems should only be performed by a Certified Refrigeration Technician, and should follow all procedures for refrigerant recovery and recycling, using only certified repair equipment, as provided in local, state and federal laws, requirements and provisions. No part of this program should be construed to recommend any service procedure contrary to those laws or provisions.

System Function Tests

Begin by asking for a complete description of the complaint

One of the most important things to remember when attempting to diagnose any problem is always make sure you understand the operators' complaint thoroughly. It doesn't matter how good a job you do or how many problems you take care of...if you didn't address the operators' original complaint, you didn't do the job correctly.

If it's possible, have the operator accompany you during the initial tests, to confirm whether the symptoms you experience are the ones he or she is complaining about.

Find out if anyone else worked on the system recently – this is important if you think the system could be contaminated with something other than the intended refrigerant. If you suspect a system's been contaminated, you can have the refrigerant analyzed. Avoid mixing contaminated refrigerant with other refrigerant – that will contaminate the whole tank, and could contaminate your recycling machine.

Once you know exactly what the operators' complaint is, you're in a better position to diagnose the complaint correctly.

Now it's time to try the air conditioner

By this time you know the operator's complaint; begin your diagnosis by turning the air conditioner on, and see if it goes through the motions of working, while the operator's still around.

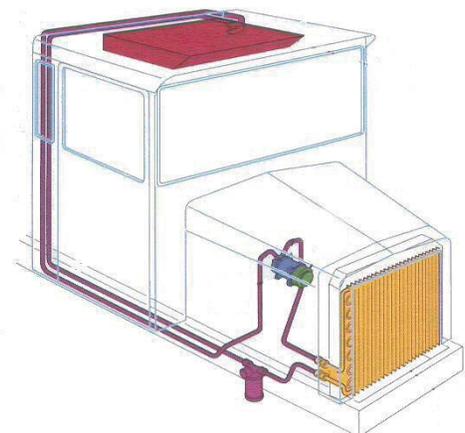
Start the engine, and set the air conditioning controls on. First try the fan – make sure it's coming on, and it works on all the speeds. Keep in mind that some vehicles don't have low fan when the engine's cold.

Once you're sure the fan works okay, run through the controls.

If all the controls seem to be working properly, set the air conditioner to Maximum Air, with the fan on High. You should hear the compressor turn on, and within a few moments the air should become cold. Don't try to check the system performance yet – for now, all we want to know is whether the compressor turns on.

Then inspect the system visually

Your next step is to make a complete visual inspection of the air conditioning system. Examine the condition of the belts and hoses, for both the air conditioning and the engine.



A/C SYSTEM DIAGNOSIS

Make sure the service ports all have caps screwed on. These caps are the primary seal for service ports. If any caps are missing, you must replace them as part of the service. Those caps are more than dust covers – they help prevent refrigerant from escaping into the atmosphere.



All the caps for the service ports screw on, and each cap has an O-ring inside. These caps are the primary seal for service ports.

Look for oil stains or caked-on dirt along all exposed air conditioning system parts and hoses; these can be indications of a refrigerant leak. Check the bottom of the evaporator housing – if the evaporator leaks, refrigerant oil may soak the bottom of the housing around the evaporator drain. An oil-soaked evaporator housing is a good indication of a leak in the evaporator.

Finally, make sure the condenser is clear and clean. Leaves, trash, mud and large numbers of insect corpses can reduce air flow over the condenser coils. Good condenser combs can help to clean and straighten the fins. You may not be able to see it, but any coating can destroy the system's ability to transfer heat. Water works great to remove that caked-on mud and silt.

If the compressor doesn't come on...

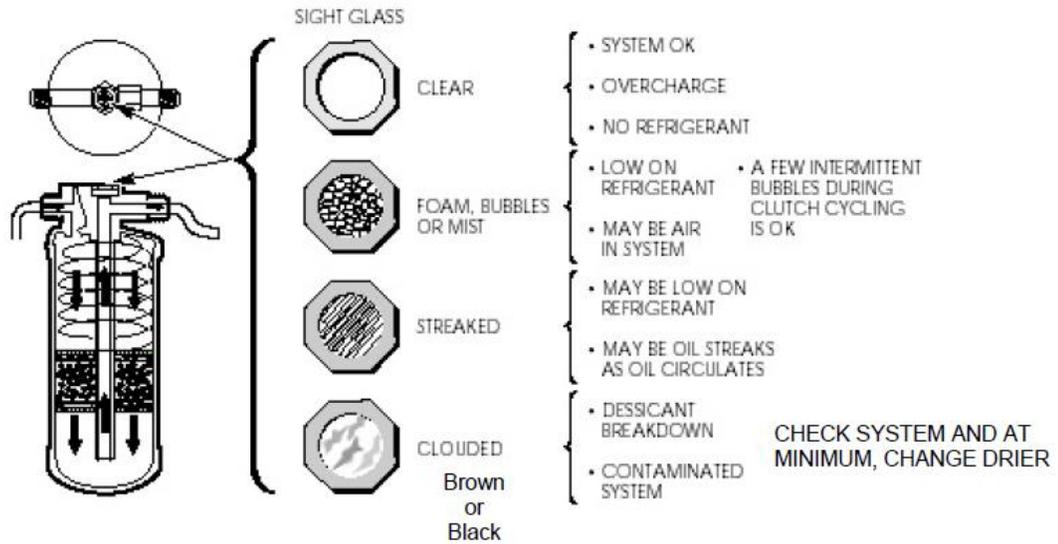
...in most cases, the system is probably just low on refrigerant – the Low Pressure Cutoff Switch is open, so current can't reach the compressor clutch to turn it on. You can do a quick system check on any system by unplugging the compressor and running a fused hot lead directly from the battery and ground wire. This provides a rough indication of the compressor and system operation.

If the compressor clutch kicks in okay when you bypass the controls, you know the compressor *can* engage; next you'll need to see why the controls wouldn't let the compressor engage. Is the Low Pressure Cut-Off Switch bad or is the system low on refrigerant? Most of the time the system will just be low on refrigerant. If that's the case, you'll have to run a leak check on the system, take care of any problems you find, and recharge the system.

While the tests we've looked at so far look like a lot of work on paper, once you get used to them you should be able to run through all these checks in a matter of a minute or two. But these quick tests serve a real purpose: they enable you to get a clear picture of the overall system condition. The object is to check the easy things first, before you waste any time or money on the more complex, time-consuming tests.

Sight Glass Conditions

Do not use sight glass for charging



If the system has a sight glass, check it and record your results...but never use the sight glass as your final indicator for recharging the system on R-134a systems.

Diagnosing an Expansion Valve System

Refrigerant Pressure Diagnosis

Here are a couple of charts designed to help you diagnose air conditioning problems. This chart covers systems using an expansion valve; the chart on the next page covers systems using an orifice tube.

System Operating Normally – Fully Charged

Low Side	High Side	Sight Glass	Evaporator Outlet	Duct Temperature
5-30 PSI Pressure will be higher at higher blower speeds	150-285 Low air flow past the condenser increases high side pressures	Clear – any color other than white or clear indicates system contamination	Cold – Lines sweating heavily, no frost	40° – 50°

Diagnostic Chart

Low Side	High Side	Symptoms	Diagnosis	Solutions
Low 5-30 PSI	Low 110-150 PSI	Poor or no cooling Foamy bubbles in the sight glass. Compressor cycles rapidly. Warm evaporator outlet line.	Low or improper refrigerant charge.	Check and repair any leaks in the system. Recharge system as needed.
Low or Vacuum. -20 to 5 PSI	Low to Normal. 115-160 PSI	No cooling. Sight glass is clear. Warm evaporator outlet line.	Low or improper refrigerant Bad expansion valve. Gauge reading may be higher if the restriction is directly past service fitting.	Check the expansion valve and screen. Look for icing on the high-side lines. Clear the restriction or replace necessary components. Evacuate and recharge the system.
Normal to Low. 0-25 PSI	Normal 150-285 PSI	Unit works fine for a while, then begins to blow warm air. Evaporator pipes frozen. Compressor doesn't cycle.	Evaporator freeze-up. Bad thermostatic switch, clutch or clutch relay.	Replace thermostatic switch, clutch or clutch relay.
High or Equal to High Side gauge. 70-90 PSI	Low or Equal to Low Side gauge. 90-110 PSI	No cooling. Warm evaporator outlet pipe. Compressor won't cycle.	Expansion valve stuck open. Bad compressor.	Repair or replace compressor. Replace expansion valve. Evacuate and recharge the system.
Normal to High. 30-60 PSI	High 250-350 PSI	Fair to poor cooling Sight glass clear to foamy. Evaporator outlet cool to warm.	System overcharged.	Recover excess R12 or R134a until system operation returns to normal.
Normal to High. 30-60 PSI	High 250-400 PSI	Fair to poor cooling. Sight glass clear. Evaporator outlet cool to warm.	Restricted airflow past Condenser. High temperature air across condenser	Check cooling fan operation. Clear radiator or condenser restriction. Check for excess heat load if near hydraulic oil cooler, etc.

Diagnosing a CCOT System

Refrigerant Pressure Diagnosis

System Operating Normally – Fully Charged

Low Side	High Side	Sight Glass	Evaporator Outlet	Duct Temperature
22-35 PSI	130-375 PSI (Depending on Fan)	None	Cold	40°-50°

Diagnostic Chart

Low Side	High Side	Symptoms	Diagnosis	Solutions
Low to Normal 10-46 PSI	Low 120-170 PSI	Poor cooling Warm evaporator outlet line. Compressor clutch cycling rapidly.	Low refrigerant charge.	Check and repair any leaks in the system. Recharge system as needed.
Low or Vacuum. -10 to 10 PSI	Low to Normal. 90-170 PSI	Poor cooling. Warm evaporator outlet line. Compressor clutch cycling rapidly.	High side restriction. Orifice tube plugged. Gauge reading may be Higher if the restriction is directly past service fitting.	Check for a clogged expansion tube. Replace the accumulator if the system's contaminated. Evacuate and recharge the system.
Normal to Low. 5-48 PSI	Normal 185-375 PSI	No air or warm air from the ducts. Evaporator lines cold or iced.	Evaporator freeze-up. Bad thermostatic switch or Cycling switch. Evaporator freeze-up at low blower or during long runs.	Replace cycling switch or thermostatic switch. Make sure you reinstall capillary tube in the original location.
High 60-100 PSI	Low 70-120 PSI	No cooling. Warm evaporator outlet pipe.	Bad compressor.	Repair or replace compressor. Replace accumulator and orifice. Evacuate and recharge the system.
High 40-60 PSI	High 200-400+ PSI	Fair to poor cooling Evaporator outlet cool to warm. Compressor doesn't cycle.	System overcharged. Air in system.	Recover excess refrigerant until system operation returns to normal or recycle & recharge.
Normal to High. 15-55 PSI	High 200-400 PSI	Fair to poor cooling. Evaporator outlet cool to warm.	Restricted airflow past condenser.	Check cooling fan operation. Clear radiator and condenser restriction. Check condenser fan.

R-134a AUTOMOTIVE

R-134a TEMPERATURE PRESSURE CHART

TEMP F.	PSIG	TEMP F.	PSIG
16	15.69	93	110.20
18	17.04	94	112.10
20	18.43	95	114.10
22	19.87	100	124.30
24	21.35	102	128.50
26	22.88	104	132.90
28	24.47	106	137.30
30	26.10	108	141.90
32	27.79	110	146.50
34	29.52	112	151.30
36	31.32	114	156.10
38	33.17	116	161.10
40	35.07	118	166.10
42	37.03	120	171.30
44	39.05	122	176.60
45	40.09	124	182.00
50	45.48	126	187.50
55	51.27	128	193.10
60	57.47	130	198.90
65	64.10	135	213.70
70	71.19	140	229.40
75	78.75	145	245.80
80	86.80	150	263.00
85	95.40	155	281.10
90	104.40	160	300.10
91	106.30	165	320.00
92	108.20	170	340.80

All values rounded two places

The numbers above represent boiling points for R-134a

EVAPORATOR pressures represent gas temperatures inside the coil and not the coil surfaces. Add to temperature for coil air-off temperatures (8-10f.)

CONDENSER temperatures are not ambient temperatures. Add to ambient (35-40F) for proper heat transfer, then refer to pressure chart.

Example 90 F ambient temp

$$\begin{array}{r} 90 \\ +40 \\ \hline 130 \end{array}$$
 130 F condenser temp = 200 psig*
 *(Based on 30 MPH air flow)

Conditions will vary for different system configurations.
 Refer to manufacturers specifications.



Electrical Info – Sensors & Actuators

Overview



- Electronic Sensors and Actuators are becoming common place
- They are simple to troubleshoot if you understand the basics

Most Common Failures:

- Bad Electrical Connection
 - Terminal backed out of the connector
 - Broken Wire
 - Corrosion
- Physical Damage
- End of Life (active components)



Wire Guide

Maximum Wire Length for 0.5 Voltage Drop

* Include return wire length (i.e. ground path)

WIRE GAUGE	Maximum Current In Amps													
	1	2	3	4	5	7.5	10	15	20	25	30	35	40	50
18	91	45	30	23	18	12	9	6	5					
16	116	58	39	29	23	16	12	8	6	5				
14	185	93	62	46	37	25	19	12	9	7	6	5		
12	294	147	98	74	59	39	29	20	15	12	10	8	7	6
10	455	227	152	114	91	61	45	30	23	18	15	13	11	9
8	714	357	238	179	143	95	71	48	36	29	24	20	18	14
ATO Fuse Color	Black	Gray	Violet	Pink	Tan	Brown	Red	Blue	Yellow	White	Green	Blu/Gm	Orange	Red

RD-5-12560-0 Rev--

Maximum wire length in feet [multiply by 0.3048 to convert to meters]

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Wire Insulation O.D.

WIRE GAUGE	Metric Wire Size (mm ²)	Insulation Diameter in Inches [MM]		
		TXL	GXL	SXL
18	0.80	0.08 [2.0]	0.09 [2.3]	0.11 [2.7]
16	1.00	0.09 [2.3]	0.10 [2.6]	0.12 [3.0]
14	2.00	0.10 [2.5]	0.12 [3.0]	0.14 [3.6]
12	3.00	0.12 [2.9]	0.14 [3.6]	0.16 [4.1]
10	5.00	0.15 [3.8]	0.17 [4.4]	0.19 [5.0]
8	8.00	0.18 [4.6]	0.21 [5.3]	0.23 [5.8]



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Voltage Drop Through Connectors*

TERMINAL	Current in Amps RESULTS BELOW in Millivolts DC								
	5	7.5	10	15	20	25	30	35	40
0.250" Blade	2	4	5	7	10	12	15	17	20
630 Metri-Pack	5	7	10	15	20	25	30	35	
280 Metri-Pack	6	9	12	18	23	29	35		
Weather-Pack	9	14	18	27	36				
150 Metri-Pack	13	20	26	39					
100 Micro-Pack	19	29	38						
Deutsch Size 12	2	3	4	7	9	11			
Deutsch Size 16	4	6	8	13					
Deutsch Size 20	9	13							
Thermostat	61	70							
ISO Relay	46	54	62	79	95	111	128	144	161
Butt Splice	1	2	2	3	4	5	6	7	8
Ring Terminal	2	3	3	5	7	9	10	12	14

* Millivolt drop through connector terminals/components @ 20°C
Estimate only - values may vary due to condition and age of terminal/component and other ambient conditions.
Consult manufacturer for specific information and usage limitations.

REFERENCE

Sensors



- **Temperature Sensors**
 - Air Temperature
 - Cab
 - Ambient
 - Unit Air Discharge
 - Freeze Probe
 - Coolant Temperature
 - Refrigerant

Temperature Sensors

Temperature Sensor Resistance Chart

Temperature		Nom Inal Resistance		
°C	°F	3K Ohms	5K Ohms	10K Ohms
66	150	600	1,000	2,000
63	145	700	1,100	2,200
60	140	700	1,200	2,400
57	135	800	1,400	2,700
54	130	900	1,500	3,000
52	125	1,000	1,700	3,300
49	120	1,100	1,900	3,700
46	115	1,300	2,100	4,100
43	110	1,400	2,300	4,600
41	105	1,600	2,600	5,200
38	100	1,800	2,900	5,800
35	95	2,000	3,300	6,500
32	90	2,200	3,700	7,400
29	85	2,500	4,100	8,300
27	80	2,800	4,700	9,400
25	77	3,000	5,000	10,000
24	75	3,100	5,200	10,500
21	70	3,600	5,900	11,900
18	65	4,000	6,700	13,600
16	60	4,600	7,600	15,500
13	55	5,200	8,700	17,700
10	50	5,900	9,900	20,200
7	45	6,800	11,300	23,300
4	40	7,800	13,000	26,700
2	35	9,000	14,900	30,900
-1	30	10,300	17,200	35,700
-4	25	11,900	19,900	41,400
-7	20	13,800	23,000	48,200
-9	15	16,000	26,700	55,900
-12	10	18,700	31,100	65,700
-15	5	21,800	36,300	76,100
-18	0	25,500	42,500	90,300

- Most Temperature Sensors are Resistive Devices (Thermistors)
- They are Negative Temperature Coefficient (NTC)
- Troubleshooting Easily Done with Multimeter

REFERENCE

Sensors



- Pressure Transducers
 - Three Wire Devices (+12Vdc, GND, Signal)
 - High Side Pressure 0-500
 - 3.25 V out @ 100psig
 - Low Side Pressure 0-150
 - 1.15 V out @ 100psig



- Solar Sensors
 - Photo Diodes

Actuators

- Devices that respond to a Control Signal to perform a function
- Two Categories
 - Smart (Built-In Control Logic)
 - Dumb (On/Off, Positionable with Feedback)



ISO Control Relays



- Standard
- With Diode (Polarity Sensitive)
- With Resistor

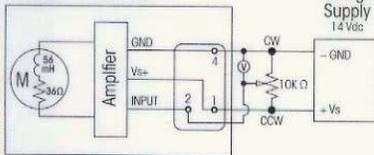


Actuator Tech Guide

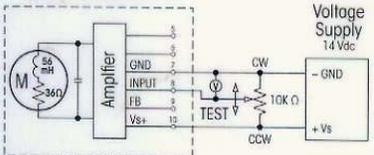
Red Dot Part Number	Mfg P/N	Supplier	Type	Sealing	Description	Test Circuit	Pin Outs
RD-5-6320-0 or 71R3575	41000 or 66004	CEI	"Red D"	Unsealed	Servo Control - 104 Degree Travel	B	7 - Ground 8 - Control Sig. 10 - +12V
RD-5-8988-0 or 71R3571	50004 or 66002	CEI	"Red N"	Unsealed	Servo Control - 126 Degree Travel	B	7 - Ground 8 - Control Sig. 10 - +12V
RD-5-8791-0 or 71R3573	50000 or 66011	CEI	"Green T"	Unsealed	Two Position (Open - Close)	D	5 - +12V 6 - Open = CW, Ground = CCW 7 - Ground
RD-5-9021-0 or 71R3578	41009 or 66027	CEI	"White H"	Unsealed	Potentiometer Feedback Only	C	5 - Motor + 6 - Motor - 8 - Ground 9 - Feedback Sig. 10 - Voltage Ref.
RD-5-9063-0 or 71R3576	51067	CEI	—	Sealed	Sealed - Servo Control	A	A - +12V C - Ground D - Control Sig.
N/A	51058	CEI	—	Sealed	Sealed - Servo Control	A	A - +12V C - Ground D - Control Sig.
N/A	51811	CEI	—	Sealed	Sealed - Motor Only, No Feedback	C	A - Motor + F - Motor -
RD-5-11518-0	50601	CEI	—	Sealed	Sealed - Potentiometer Feedback Only	C	A - Motor + C - +12V D - Ground E - Feedback Sig. F - Motor -
RD-5-11470-0	RD-5-11470-0	Red Dot	—	Sealed	Sealed - 12/24v Servo Control	A	1 - +12/24V 2 - Control Sig. 4 - Ground
RD-5-10623-0	F7UH-19E616-AA	Ford / Visteon	"Ford"	Unsealed	Servo Control	B*	1 - To Pot Ground 2 - Control Sig. 5 - Ground 6 - +12V 7 - To Pot Vcc

* Connect 10K pot directly to pins (7) Vcc, (1) GND and (2) Signal

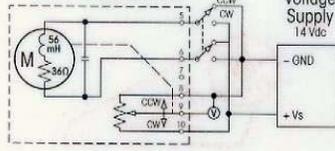
TEST CIRCUIT A



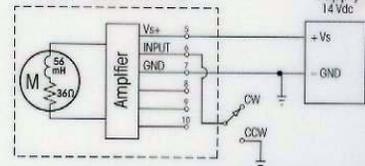
TEST CIRCUIT B



TEST CIRCUIT C

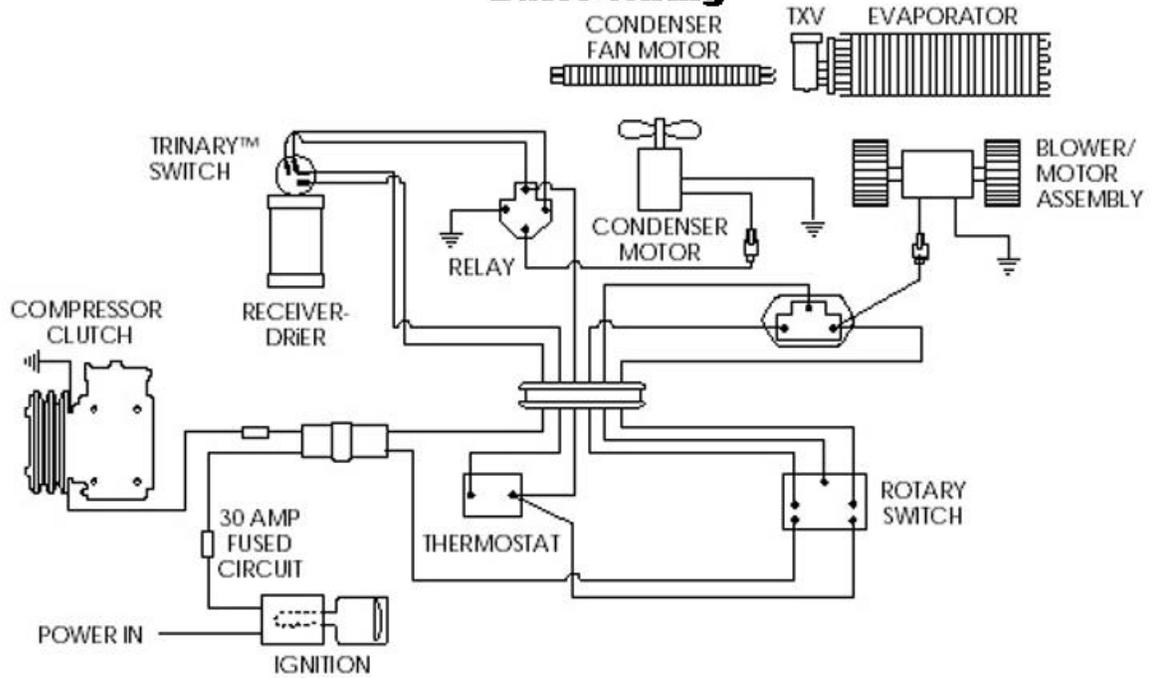


TEST CIRCUIT D

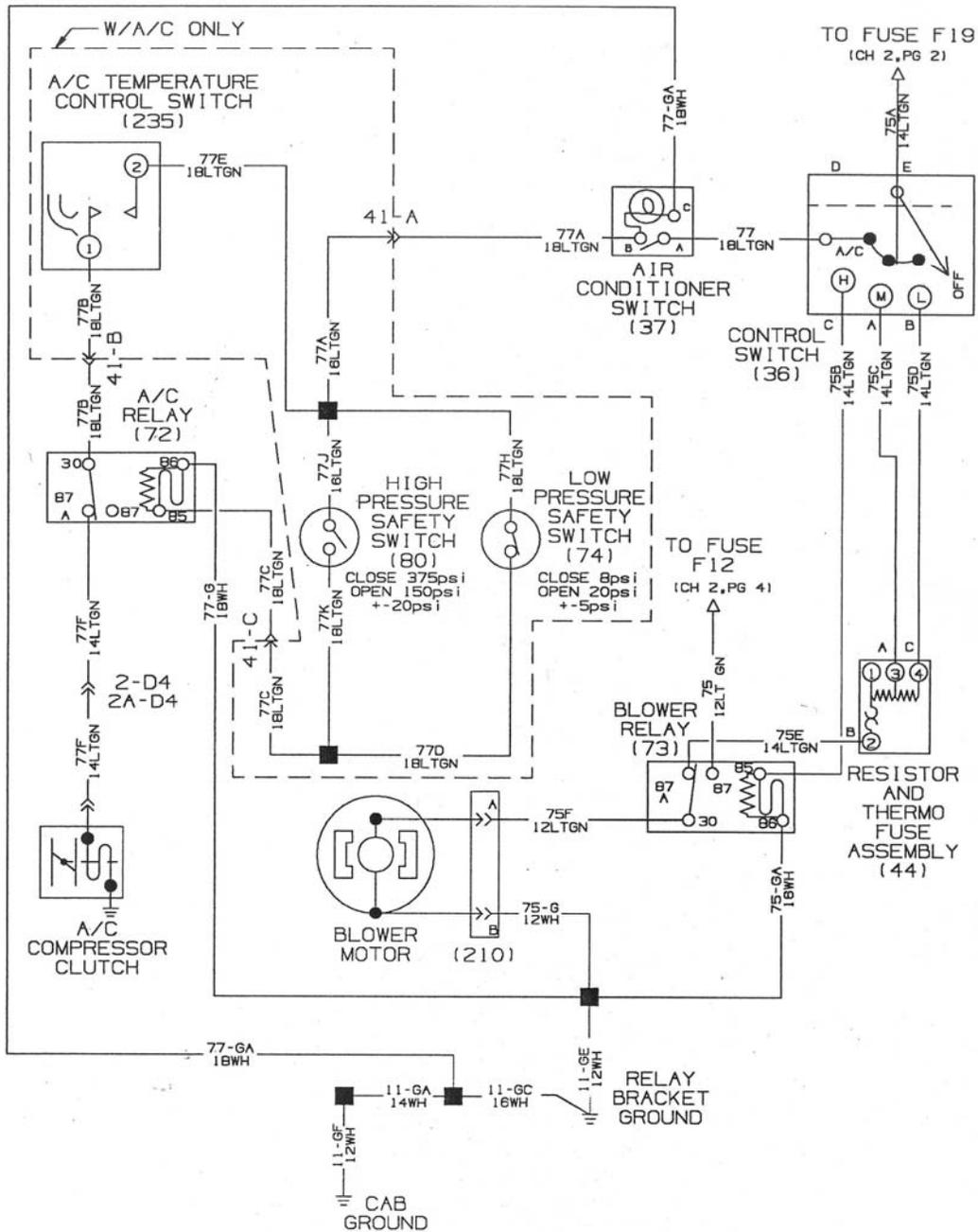


REFERENCE

Basic Wiring

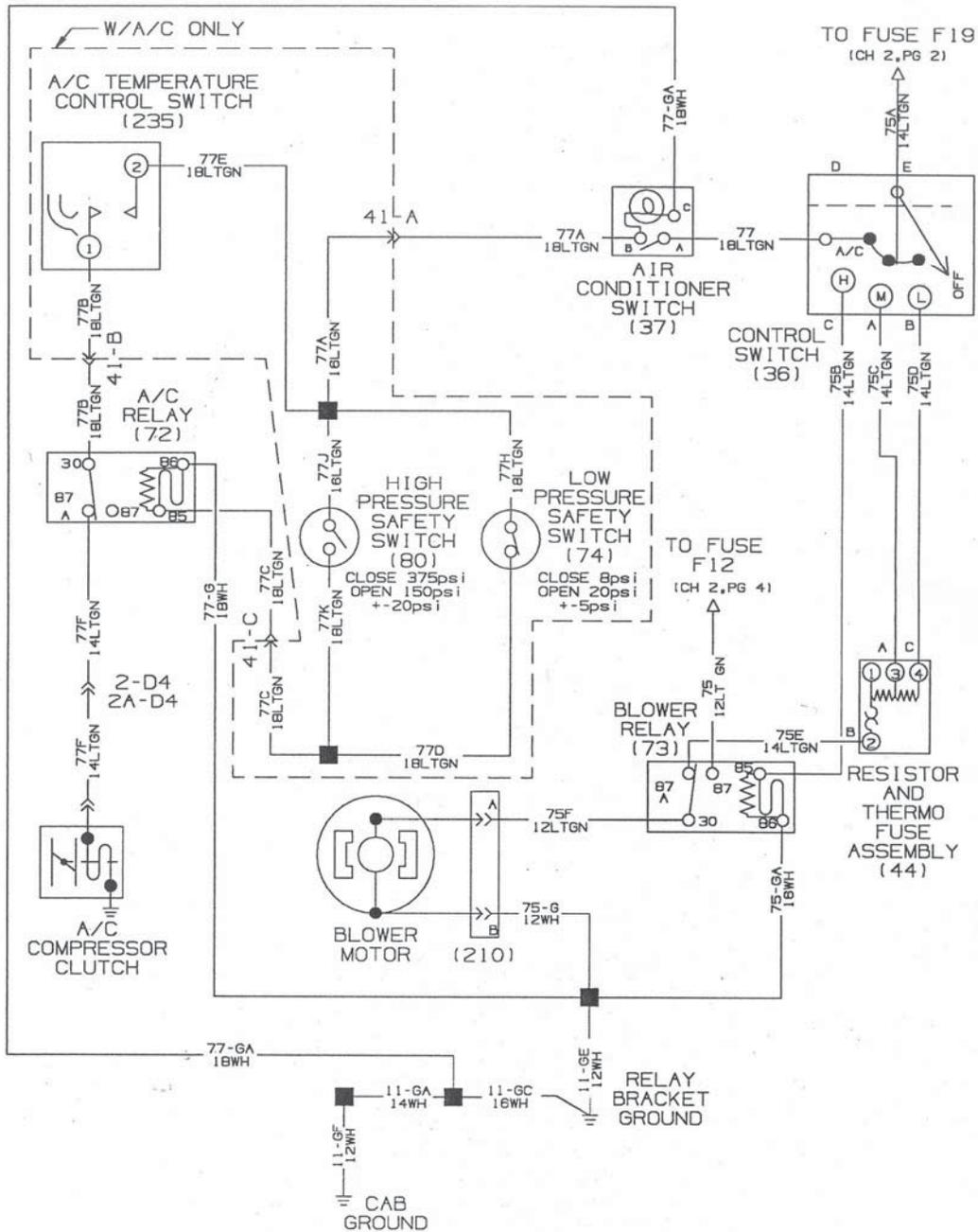


REFERENCE



CHK	DATE	CHANGE	REV	REFERENCE	DRWN	NAME
SRL	01MAR99	RMVD CIR 77L FROM (72)	A	P52949L	EFC/RJM	2000,4000,8000,ELECTRICAL CIRCUIT DIAGRAMS
					RELEASE NO.	DATE
					P52669J	09OCT98
						PART NO.
						AE08-52229
						SHEET
						01

REFERENCE



CHK	DATE	CHANGE	REV	REFERENCE	DRAWN	NAME
SRL	01MAR99	RMVD CIR 77L FROM (72)	A	P52949L	EFC/RJM	2000,4000,8000,ELECTRICAL CIRCUIT DIAGRAMS
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					AE08-52229	01