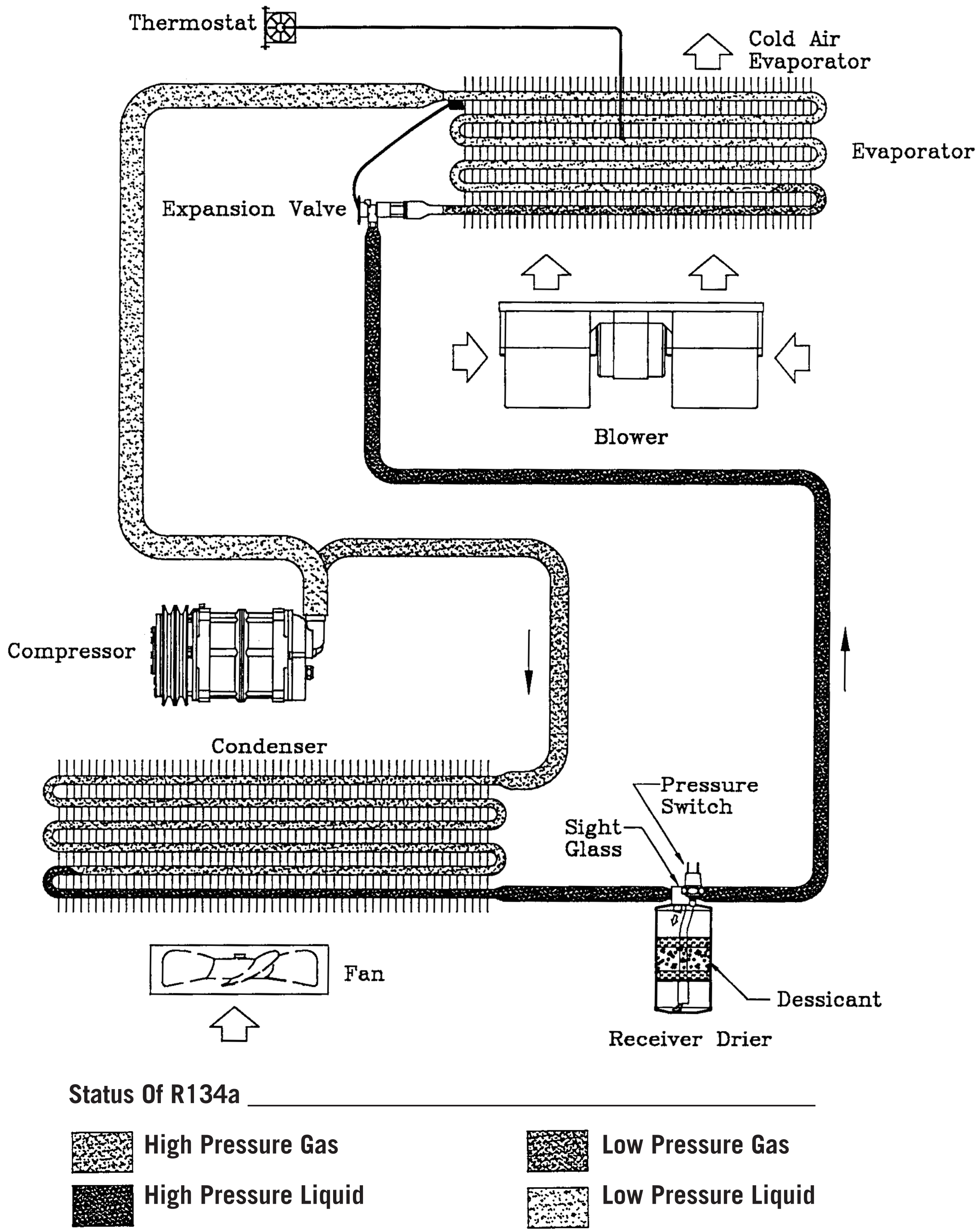
I. Introduction to AC

Air Conditioning/Refrigeration Cycle



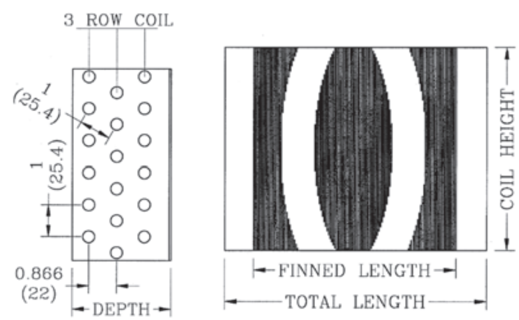
MCC Coil Manufacturing And Oil Coolers

MCC Coil Manufacturing

To ensure product quality MCC decided in the beginning to invest in a tube and fin production line. As a result of this decision it has been proven early that MCC's customers enjoy a higher degree of design flexibility. Additionally MCC decided to adapt the machinery to produce rough coils for the heavy-duty vehicle market. This meant low fin density, thick fins and heavy duty mounting brackets. With the realization by most off-road vehicle manufacturers that coils designed for the on-road and light vehicle markets would not stand up to the off-road environment, the MCC coils soon became a winner. At MCC coils are designed to fulfill each customer's individual needs.

Design Specifications

The tube spacing selected for MCC coils are 1" (25.4mm) x0.866" (22mm) staggered 30°. The coils can be produced with a height of even inches (25.4mm) and with a depth of multiples of 0.866" (22mm) .



The width can be made to any dimension. Copper tubes with a burst pressure of 1790 PSI or 12.3 MPa are the preferred choice for refrigeration and water. Headers and connectors can be changed to fit each customer's unique requirements. Tubes are brazed and can therefore be easily customized.

The most common fin material for coils is aluminum. Copper is also used in difficult high corrosion and abrasive environments. Copper enjoys a higher degree of heat transfer but is also heavier and more costly. Fins can be produced to a maximum thickness of 0.02" or 0.5 mm. MCC has two common fin shapes. An aggressive sinus waved shape with high heat transfer and high pressure drop makes it possible to reduce fin density for dirty conditions. The corrugated fin shape has a lower heat transfer and pressure drop than the sinus waved fin. Wet paint, dry powder coating and several other special anti-corrosive coatings are available for the MCC coils.

The copper tubes, end plates and fins are mechanically expand ed together to ensure a strong and effective coil. The tube is expand ed against the aluminum collar of the fin, which results in a very strong assembly. Headers and fittings are then brazed on the open side of the copper tubes. Every coil is pressure tested to confirm its integrity.

In addition to the above we can also offer other fin and tube products plus microchannel coils.

Oil Coolers

Primary difference between a refrigeration/water coil and an oil cooler coil is the turbulator. Due to the boundary layer effects of oil, customized turbulators are used in each tube of the MCC oil cooler. The turbulator improves heat transfer greatly and can be designed to modify the degree of pressure drop. The MCC designed and manufactured turbulators are highly effective and produce a high liquid pressure drop. The liquid pressure drop is adjusted through header design. Generally copper tubes with a burst pressure of 2310 PSI or 15.9 MPa are used for oil coolers.

R134a Temperature Pressure Chart

NORMAL EVAPORATOR RANGE				
TEMP°F	TEMP°C		PSIG	BAR (g)
16	-8.9		15.69	1.082
18	-7.8		17.04	1.175
20	-6.7		18.43	1.271
22	-5.6		19.87	1.370
24	-4.4		21.35	1.472
26	-3.3		22.88	1.578
28	-2.2		24.47	1.688
30	-1.1		26.10	1.800
32	0.0	EVAPORATOR RANGE	27.79	1.917
34	1.1		29.52	2.036
36	2.2		31.32	2.160
38	3.3		33.17	2.288
40	4.4		35.07	2.419
42	5.6		37.03	2.554
44	6.7		39.05	2.693
45	7.2		40.09	2.765
50	10.0		45.48	3.137
55	12.8		51.27	3.536
60	15.6		57.47	3.963
65	18.3		64.10	4.421
70	21.1		71.19	4.910
75	23.9		78.75	5.431
80	26.7		86.80	5.986
85	29.4		95.40	6.579
90	32.2		104.40	7.200
91	32.8		106.30	7.331
92	33.3		108.20	7.462

NORMAL CONDENSER RANGE				
TEMP°F	TEMP°C		PSIG	BAR (g)
93	33.9		110.27	.600
94	34.4		112.17	.731
95	35.0		114.17	.869
100	37.8		124.38	.572
102	38.9		128.58	.862
104	40.0		132.99	.166
106	41.1		137.39	.469
108	42.2		141.99	.786
110	43.3		146.5	10.103
112	44.4		151.3	10.434
114	45.6		156.1	10.766
116	46.7		161.1	11.110
118	47.8		166.1	11.455
120	48.9		171.3	11.814
122	50.0		176.6	12.179
124	51.1	CONDENSER RANGE	182	12.552
126	52.2		187.5	12.931
128	53.3		193.1	13.317
130	54.4		198.9	13.717
135	57.2		213.7	14.738
140	60.0		229.4	15.821
145	62.8		245.8	16.952
150	65.6		263	18.138
155	68.3		281.1	19.386
160	71.1		300.1	20.697
165	73.9		320	22.069
170	76.7		340.8	23.503

The numbers above represent boiling points for R-134a. All values are rounded two places.

Evaporator

Pressures represent gas temperatures inside the coil, and not the coil surfaces. Add to temperature for coil air-off temperatures (8-10°F) .

Example: 90°F ambient temperature
+40°F
130°F condenser temperature = 200 PSIG*
*(Based on 30 MPH air flow)

Condenser

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

R134a – your best choice Based on hard facts and figures

9 facts you need to know about R134a

Can I get the same cooling performance with R134a as a system with R407C?

Yes. Any cooling capacity can be obtained from a correctly designed system using any type of refrigerant, given the refrigerant is suitable for the evaporating and condensing temperatures of the application. The coils and the quantity of air moved remain essentially the same. Only the size of the compressor and refrigerant lines need to be designed to match the required capacity.

Example:

MCC Eco 353 series using R134a
and a 6TFC Bitzer compressor .... 113 k Btu/hr (33 kW)
Standard market available unit using R407C
under same rating conditions .... 113 k Btu/hr (33 kW)

Will my R134a system weigh more than an R407C equipped system of the same capacity?

No. System weight will vary by construction and options. This is much more of a factor in system weight than refrigerant.

Example: Eco 353 roof mounted AC unit with R134a weight 450 lb (204 kg) with Bitzer 6TFC compressor weight – 113 lb (51.5 kg). The equivalent capacity roof unit on the market with R407C weight 513 lb (233 kg) and piston compressor weight – 115 lb (52.2 kg).

Is R134a more expensive per pound?

No R407C is.

Example: Recent price quote per 1000 lb cylinder at a major refrigerant

distributor

R407C: .... $12,000/1000 lbs ($12/lb)

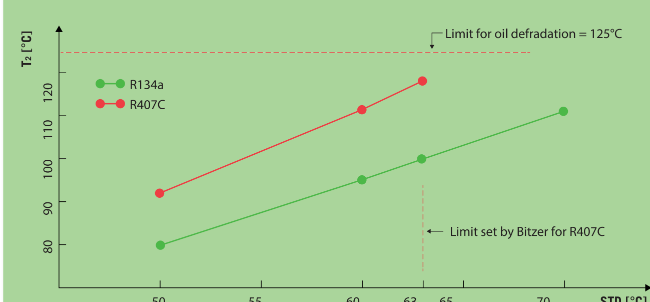
R134a: .... $5,875/1000 lbs ($5.88/lb)

Will I be able to get a replacement for R134a if it's ever phased out in the future?

Yes there is an identified replacement for R134a, HFO1234yf, which GM will use. The future for R407C is uncertain. Other things to consider; R407C is a blend which requires total change replacement after 50% loss of charge; this also limits the reuse of refrigerant on site and the recycling of the used refrigerant.

Will my system run higher temperature with R134a?

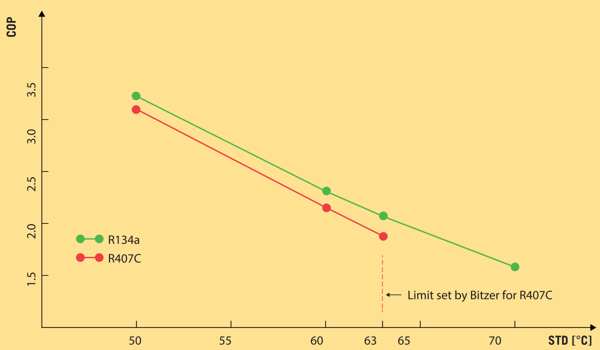
No. With air-conditioning systems that are similarly optimized, the compressor discharge temperature in an R134a system shall be 18 – 30 °F (10 – 17 °C) lower than that in an R407C system.



Is R407C a more energy efficient refrigerant?

No. With air-conditioning systems that are similarly optimized, R134a is more energy-efficient than R407C. This fact is explained by the below graph and is demonstrated by the calculation of both cycles using the data and tools published by the leading refrigerant manufacturer – DuPont.

The chart shows the relationship between COP (coefficient of performance) and condensing temperature. The green line represents the curve for R134a and the red the one for R407C.



Will I use more fuel with a properly designed R134a system as compared to one running with R407C?

No, an optimized R134a system when compared to a similarly optimized R407C system shall consume less fuel to produce the same cooling capacity. That difference becomes even greater when the ambient temperature or the load on the unit increases beyond the design point. However, a sub- optimised system will always consume more fuel no matter what the refrigerant. This is illustrated in the following chart which shows some system examples.

	R407C (optimized)	R134a (optimized)
Cooling Capacity [kW]	28.0	28.0
(Btu/hr)	(95.560)	(95.560)
Compressor Power [kW]	9.63	8.70
(HP)	(13.1)	(11.8)
COP	2.91	3.21
(Btu/hr per HP)	(7295)	(8098)

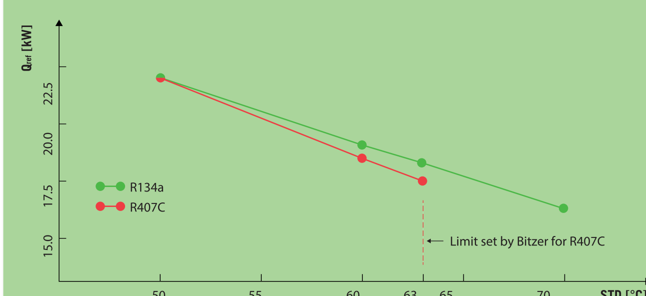
What is the best refrigerant for high ambient temperature?

It is R134a. Common refrigeration oils have an ultimate service temperature of around 265°F (125°C) after which oil degradation is unavoidable.

As the ambient temperature increases, the condensing temperature (SDT-Saturated Discharge Temperature) has to follow. This increase in condensing temperature shall be accompanied with an even bigger increase in compressor discharge temperature (T2) that shall reach the oil degradation temperature far before an R134a system will. The below chart represents the relationship for both refrigerants where the red line is the curve for R407C and the green for R134a.

That fact explains why compressor manufacturers limit the condensing temperature for R407C to around 145 – 150°F (60°C – 65°C) whereas for R134a compressors, the top limit for condensing temperature is 158 – 175°F (70 – 80°C) for air conditioning applications.

Another reason why R134a is the choice refrigerant for high ambient is that in air-conditioning systems that are similarly optimised to deliver the same cooling capacity, an R407C system shall lose more cooling capacity than an R134a when the ambient temperature increases beyond the design point. This at the time when the cooling capacity is most needed.



Is R407C a more environmentally friendly refrigerant?

No, GWP (Global Warming Potential) Value:

R407C – 1653

R134a – 1300

Both refrigerants have 0 ODP (Ozone depleting potential)

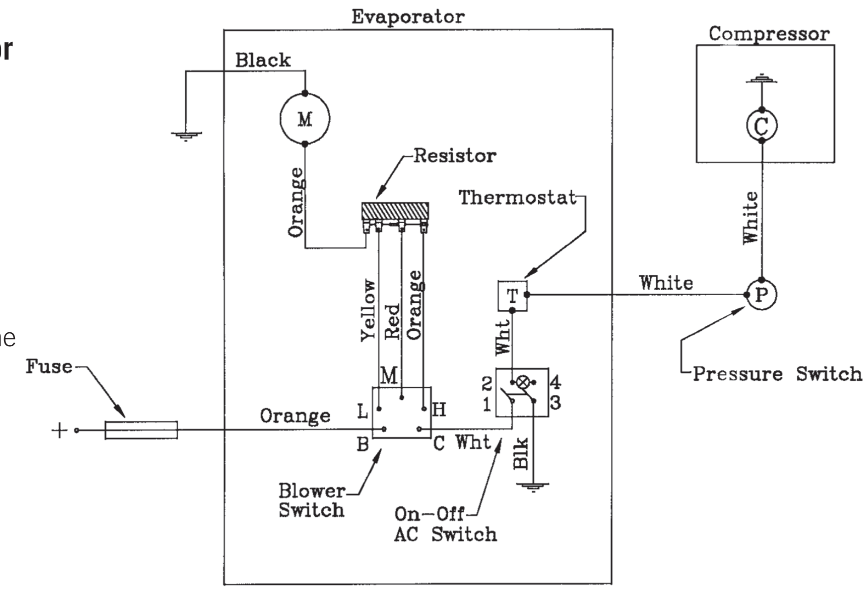
Wiring Schematics

Heater-AC System With Radiator Mount Condenser

Blower Switch

Off - Off
L - Low Speed
M - Medium Speed
H - High Speed

The “**C**” circuit will close when the blower is on.

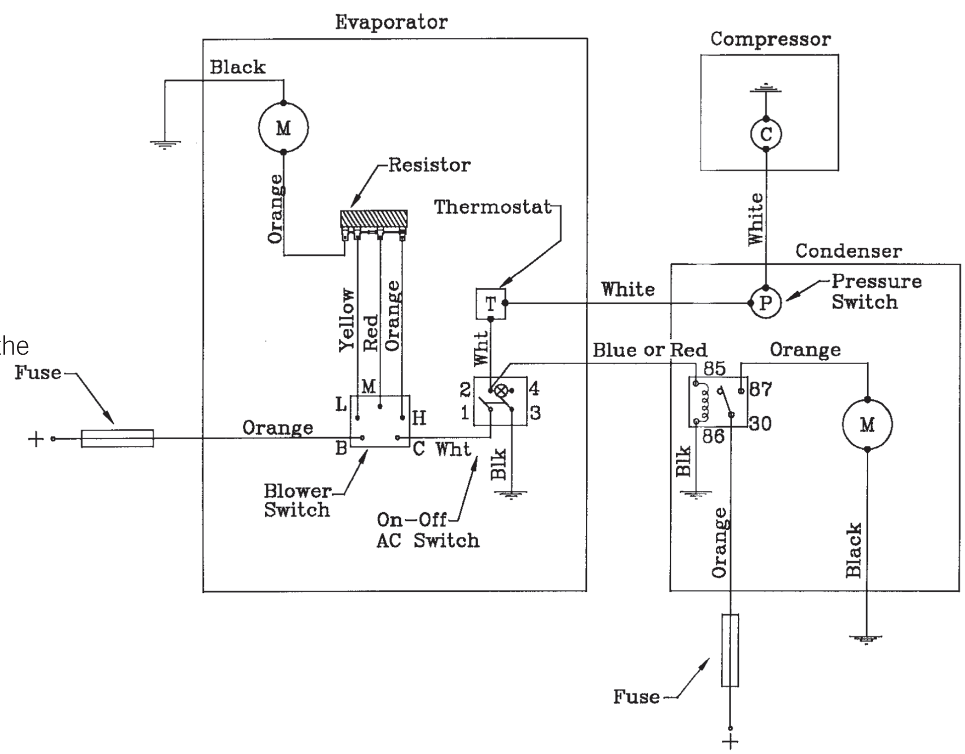


Heating-AC System With Fan Condenser

Blower Switch

Off - Off
L - Low Speed
M - Medium Speed
H - High Speed

The “**C**” circuit will close when the blower is on.



Operating Instructions For Small AC Systems

Hot Climate

1. Turn on AC mode.
2. Close heater control valve.
3. Set air recirculation to maximum for the first 5-10 minutes to assure rapid cool down.
4. Set AC thermostat to maximum.
5. Turn blower switch to high.

When desired cab temperature has been reached, increase fresh air blend by adjusting air recirculation towards minimum. Adjust AC thermostat setting and fan speed as desired.

High Humidity and Demisting

Even though the ambient temperature is in your comfort zone, the air humidity might reach unacceptable levels. The HVAC system can also be used as a dehumidifier.

1. Turn on AC mode.
2. Set air recirculation to medium position.
3. Set AC thermostat to minimum.
4. Turn blower switch to low/medium.
5. Adjust heater control valve as desired.

Cold Climate

1. Turn off AC mode.
2. Open heater control valve to maximum.
3. Set air recirculation to maximum for the first 5-10 minutes to assure rapid warm-up.
4. Turn blower switch to high.

When desired cab temperature has been reached, increase fresh air blend by adjusting air recirculation towards minimum. Adjust heater control valve setting and blower speed as desired.

Maintenance

The fresh air filter must be cleaned sometimes as often as twice a day, depending on the operating environment. This is done by removing the filter and shaking it. Air pressure can also be used to blow out dust. The filter will clean outside air when pressurizing the cab. The filters should be replaced when required.

The recirculation air filter is made of aluminum mesh or open cell foam and should be cleaned with water. A mild detergent may also be used. It does not require cleaning as frequently as the fresh air intake filter.

<u>The AC system must be turned on for at least 5 minutes weekly throughout the year to lubricate internal components.</u>

Inspect the sight glass on the Receiver Drier (RD) weekly, or if the AC system does not perform to its fullest capacity, Bubbles indicate that the system is due for recharging. This occurs approximately every second year. If the RD is equipped with a moisture indicator, make sure the color is blue (OK) . If beige, the system needs to be recharged and refrigeration oil replaced. Please see AC installation instructions.

If recharging is required more frequently, a complete system leak test should be performed.

It is a good rule to regularly inspect (weekly) the compressor drive belt tension and wear. The condenser should be kept clean and the function of the electrical motors on the remote condensers (if any) should be checked frequently. To minimize compressor damages and repair costs, do not use the AC system when recharging is due or when the system is not operating adequately.

Installation Instructions For Small AC Systems

For MCC designed systems using the TM13HD, TM15HD and TM16HD compressors.

Condenser:

The larger condenser inlet fitting (#8 hose) which is connected to the compressor discharge side, should be located at the top of the radiator mounted condensers. The refrigerant condenses to a liquid in the condenser. The outlet (#6 hose) which is connected to the receiver drier, should be located at the bottom. **The condenser can be installed flat, but must never be installed with the liquid outlet higher than the inlet.**

Receiver Drier:

Do not open seals on fittings until the system is ready to be vacuumed. The desiccant material in the receiver drier is very moisture sensitive. It is designed to attract moisture in the refrigerant. Nitrogen (N) is injected into the receiver drier to prevent moisture from using up the desiccant material prior to installation. Some receiver driers from MCC are equipped with a moisture indicator. A blue "dot" on a screw threaded into the tank will turn beige when the moisture content reaches an unacceptable level. If this occurs, follow the procedures under "Leaking Systems and Replacing Components".

Refrigerant Hose With Fittings:

When performing leak testing on a refrigerant hose, pay special attention to pin pricking and hose ends. A double braided hose is used for refrigerant systems. The hose is pin pricked down to the braiding for evacuation of air when the hose is under pressure. Do not confuse a refrigerant leak with the purging of air. Use an electronic refrigerant leak detector to determine refrigerant leaks. A thermoplastic inner-liner installed inside of the braiding will break if the hose radius is less than 4 times the hose OD.

Lubricate O-rings with mineral or ester oil prior to installation. There are two different types of fittings used in A/C systems: All steel for heavy duty applications like construction machinery and aluminum for lighter duty applications like agricultural machinery. A steel ferrule and nut are also used on aluminum fittings.

The following torque specifications should be used for the various fittings. Use the table as follows: If steel fittings are installed on a receiver drier, cast iron compressor connection or charge fitting, use the "steel to steel" column. If installed on an aluminum block valve or brass condenser connection, use the "one side aluminum or brass" column.

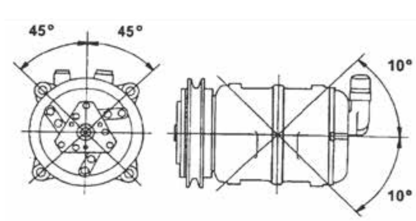
For aluminum fittings, use the "one side aluminum or brass" column.

Metal tube OD	Thread size	Steel to Steel		One side Alu or Brass	
		lb. ft.	Nm	lb. ft.	Nm
0.375	5/8	30-35	41-48	11-13	15-18
0.5	3/4	30-35	41-48	15-20	20-27
0.625	7/8	30-35	41-48	21-27	29-37
0.75	1-1/16	30-35	41-48	28-33	38-45

Note: Do not connect hoses to moisture sensitive parts like the receiver drier and compressor if the system cannot be vacuumed and charged within 1 hour.

Compressor: See Also The Compressor Service Manual.

Do not open seals on fittings until the system is ready to be vacuumed. The compressor is filled with refrigeration PAG oil (which is very moisture sensitive) and with nitrogen (N) . Unlike engine oil, it is not necessary to check or change the compressor oil. Never leave the compressor upside down for periods longer than 30 seconds. The permissible compressor speed is 700-6000 RPM. It is important that the compressor speed is adapted to the performance of other components in the system. The compressor must be positioned within the range indicated in the picture.



Installation Instructions For Small AC Systems

Refrigerant Charge:

Vacuum the system for 30 minutes, preferably with a two stage pump. There are two methods in determining the correct refrigerant charge. Run the system at maximum capacity and the blower at highest speed with the cab doors fully open for 5 minutes after the initial charge.

1. Have one person inspecting the sight glass on the receiver drier at all times. Remove the protective foil covering the glass. Pre-charge the system with an amount below correct estimated charge. The bubbles will make the glass grayish. Charge with 3 oz (0.09 kg) of refrigerant and allow the system to stabilize for 2 minutes. Repeat until sight glass clears. Liquid will be present at the receiver drier when the glass clears. Add 8 oz (0.23 kg) of refrigerant to top up the receiver drier.
2. Charge the system with an amount estimated to be the correct amount. Add 3 oz (0.09 kg) of refrigerant and allow to stabilize for 2 minutes. Repeat until the high pressure increases rapidly. The receiver drier contains 100% liquid at this time. Remove 8 oz (0.23 kg) of refrigerant.

Refrigeration Oil Charge:

The compressor is pre-filled with PAG (Poly Alkelene Glycol) oil. The pre-filled amount will support an A/C system charged with up to 2 lb. 14 oz or 1.3 kg of refrigerant. This amount represents the size of an A/C system in a passenger car. Most off-road A/C systems are considerably larger and require an additional oil charge as listed below.

To retain a valid warranty, PAG oil must be used. Add oil to the suction port of the compressor prior to vacuuming, or use the automatic oil injector on the charge station (if available) . Add an estimated correct amount of oil to the system when initially determining the refrigeration charge.

Note: If the amount of refrigeration oil used is lower than recommended, the life expectancy of the compressor will be reduced.

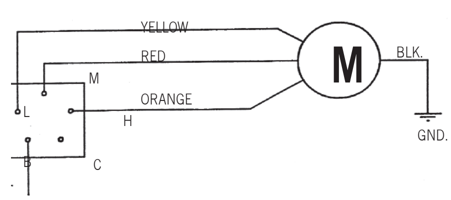
REFRIGERANT CHARGE (WEIGHT)								ADD PAG OIL (VOLUME)		
lb.	oz	-	lb.	oz	kg	-	kg	fl oz	dl	cm^3
2	14	-	3	5	1.3	-	1.5	2.0	0.6	60
3	5	-	3	11	1.5	-	1.7	2.4	0.7	70
3	11	-	4	10	1.9	-	2.1	3.0	0.9	90
4	3	-	4	10	1.9	-	2.1	4.1	1.2	120
4	10	-	5	2	2.1	-	2.3	5.0	1.4	140

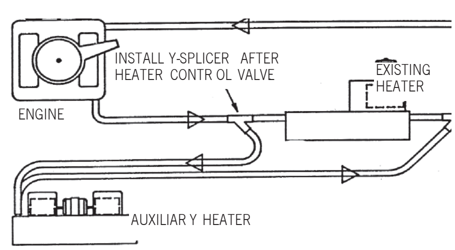
Leaking Systems And Replacing Components:

Refrigerant leaks and component replacement require the oil and receiver drier to also be replaced.

1. Drain the oil in the compressor through the drain plug, suction and discharge fittings while rotating clutch simultaneously.
2. Replace the oil in the compressor with the original amount (printed on the compressor) plus the add on amount established for the system, minus one fl oz (30 cm^3) .
3. Replace the receiver drier.

Heater Installation Schematics

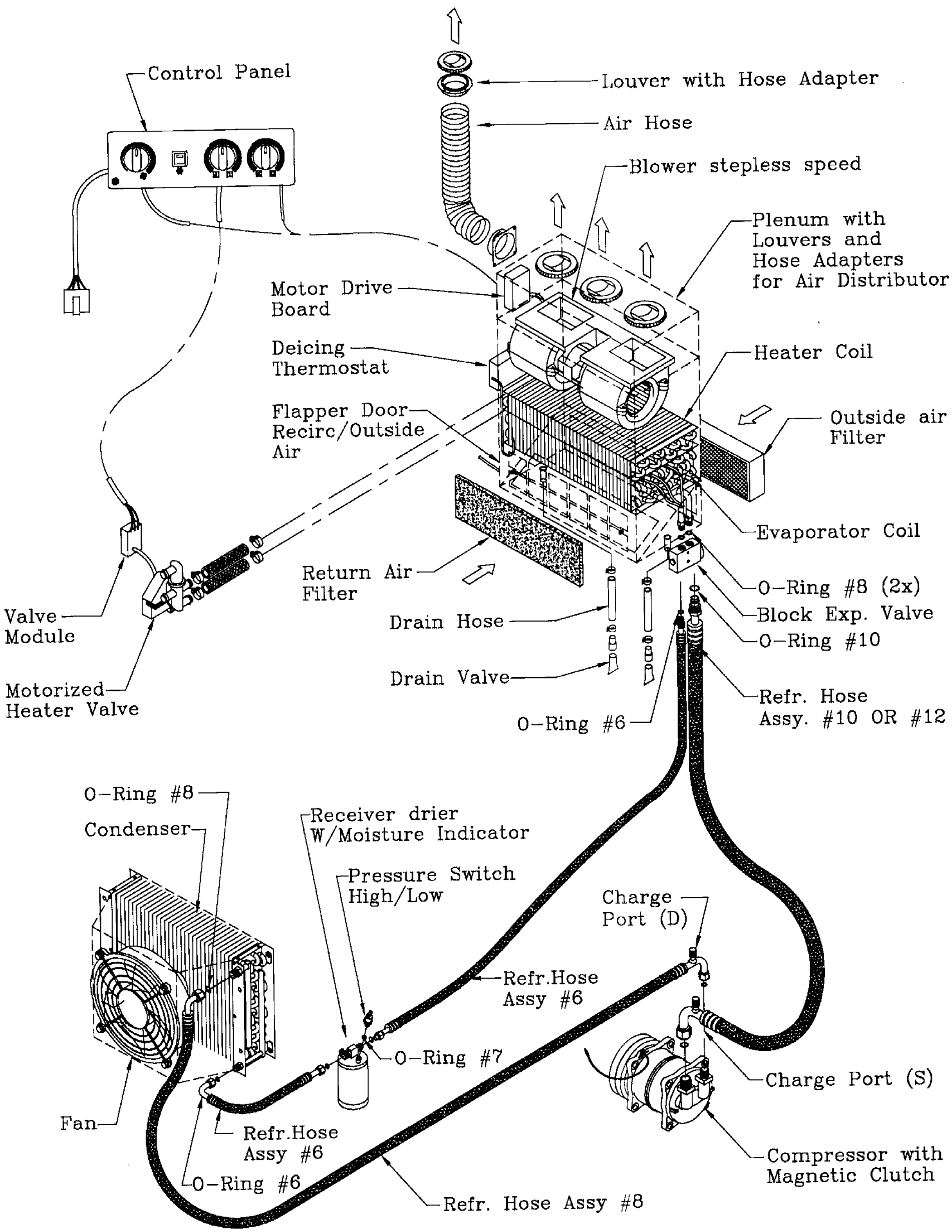




POWER SUPPLY B + MUST BE FUSED. USE 15 - 20 AMP FUSE. L= LOW SPEED M = MEDIUM SPEED HIGH = HIGH SPEED

The hose clamp torque specification for the 5/8" ID heater hose varies from 16 lb. ft. or 22 N•m to 35 lb. ft. or 47.6 N•m. It is essential to re-tighten non constant torque clamps regularly. For ducted units, use air hose to connect to louvers. Avoid running blower with all louvers closed as this will reduce motor life.

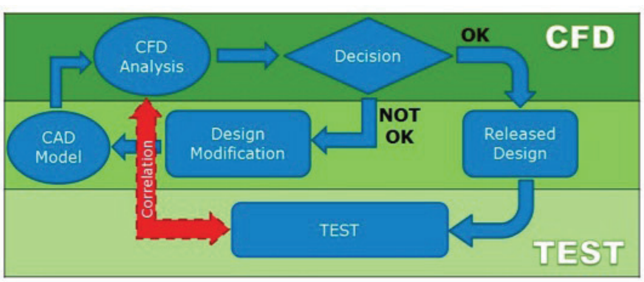
Installation Schematic For Small AC Systems



Virtual Testing Problems **Finding Solutions**

Mobile Climate Control's CFD Technology

Here at MCC, by using the latest developments in Computational Fluid Dynamics (CFD) analysis, we are able to embed CFD technology into the design process at an early stage of design cycle. This ensures that as soon as a reasonable CAD model is available, a CFD analysis can be conducted to verify whether there are any flow or thermal issues. This assures that design can be changed and optimized at the earlier CAD stage, instead of waiting for prototypes to be built, thereby guaranteeing significant savings of time and money.



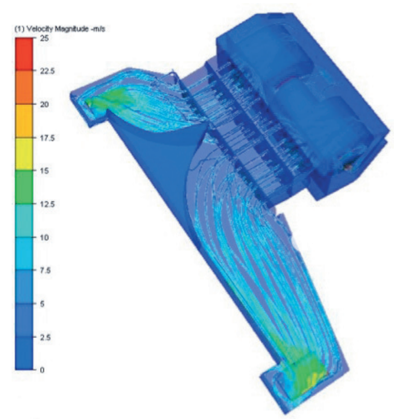
Mobile Climate Control prides itself on the outstanding quality of its engineering support. MCC Provides a complete range of Computational Fluid Dynamics consulting services including laminar, turbulent, steady state, transient, conjugate heat transfer and multiphysics analyses to drive products from concept to reality.

Experience and skills

Within MCC, the most recent CFD technology is used across various applications in on-road, off-road, utility vehicles and customized special designs to prove and improve designs in a cost effective manner. We are highly experienced in variety of applications in automotive industry including:

- Passenger comfort
- Defrost/Demist
- HVAC System
- Rotating Machinery
- Optimization studies for various flow path profiles
- Aerodynamics
- Fluid Structure Interaction
- Underhood flow
- Electronic Cooling

Our CFD consulting service has consistently met or exceeded the expectations and demands from all our clients. Some of our clients are Blue Bird, New Flyer, Gillig, MCI, Nova Bus, and Dousan/Bobcat.



CFD analysis of a custom designed HVAC unit

State of the art CFD tools

We have considerable experience with the world's class CFD/ FEA tools such as:

- Autodesk Simulation CFD
- Autodesk Simulation Mechanical
- OpenFoam
- SpaceClaim
- STAR-CCM+
- Ansys-CFD

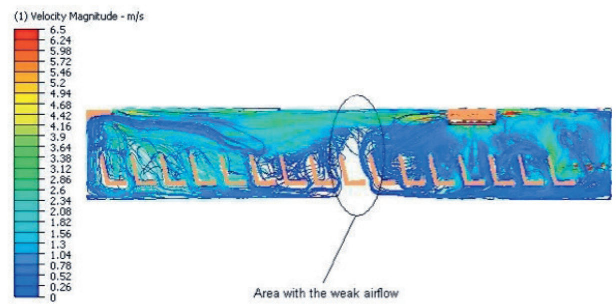
The default CFD tools at MCC are Autodesk CFD Simulation and OpenFoam, however we could accommodate CFD projects on other CFD tools based on customer request.

MCC CFD Process

The MCC CFD process includes the following steps:

- Define and specify the Flow Problem
- Elaborate the (Computational) Geometry
- Determine the Flow Domain
- Create and Optimize Mesh
- Devise Overall Simulation Strategy
- Set the CFD simulation Input and Boundary Conditions
- Execute & Monitor the CFD Simulation Process
- Post processing of the CFD Results
- Make Comparisons of the Results and Provide Design Recommendations
- Repeat the Analysis if it is needed
- Document Findings and Provide a Professional Report

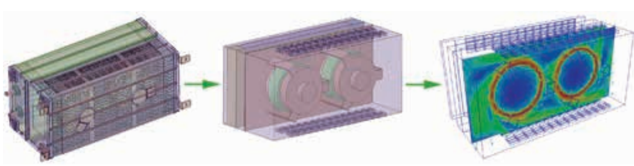
Aerodynamics analysis of a transit bus



Passenger comfort analysis of a transit bus.

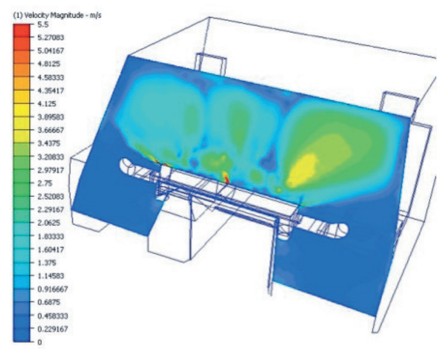
CFD Applications

These are some of the most common analyses which are conducted at MCC on a daily bases:

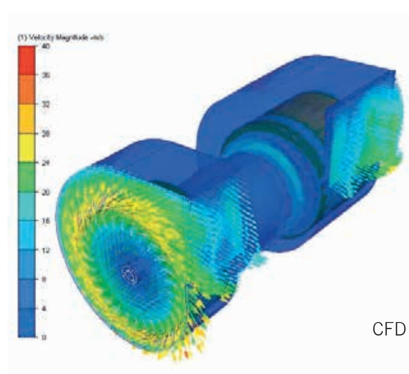


- Analyze climate control functions and passenger comfort under various harsh conditions.
- Defrost analysis of windshields to optimize the defroster system of vehicles.
- Flow analysis of HVAC systems to design and optimize of their casing and ducting system.
- Flow analysis of blowers to optimize their performance curve.
- Thermal analysis of coils.
- Aerodynamic analysis of bus to determine the aerodynamic forces on the rood unit case.

We provide exceptional CFD/FEA consulting analysis service to help our clients to reduce the design costs and shorten the design cycle.



Defrost analysis of a military vehicle



CFD analysis of a centrifugal blower