Refrigeration Conversion

By ERIC WILDE

This article covers the steps necessary to convert a refrigeration system, including air conditioning, from older refrigerants such as R-12 to newer refrigerants such as R-22 and HFC-134a.

It's hard to think, in the aftermath of the great freeze of '94, that global warming is a reality but scientists assure us that it is. They also assure us that ozone depletion and greenhouse gasses are the primary causes of the warming so we all must do our part to reduce the release of harmful gasses into the atmosphere.

How does the reduction of the release of such gasses affect private car owners and what can they do to help in the fight against global warming? You may notice that the formulation of the paints that you use is changing as well as other products, but the primary area where major impact will be felt is in air-conditioning and refrigeration.

In the good old days (which perhaps weren't as good as we all remember) Freon was a fabulous replacement for its predecessors (principally ammonia). Its convenience and ease of use undoubtedly lead, in part, to the problems we face today. The stuff was relatively harmless, and it was all too easy to vent it to the air in the course of a day's air-conditioning work. Now we realize what an ecological ugly it is and that something must be done about it.

Around the world a search is on for replacements for the Freons (more properly known as CFCs and HCFCs). R-12 has been identified as the primary culprit and so will be phased out immediately (the date for the cessation of production in the USA was 1996). The death penalty (death by suntan) will be imposed for its use. This is an unfortunate development for private car owners because many of their cars, being old, have air-conditioning and refrigeration systems based on R-12.

Do not despair, however. If yours is one of these cars, there is no need to consign it to Naporano Brothers just yet. Rather, it is possible to convert your air-conditioning and refrigeration systems to the newer refrigerants.

Production of R-22, being a lesser culprit, will continue until 2005 at which time it too will be phased out. Its continued use may be safely considered in the interim and you may even wish to use it as your R-12 retrofit refrigerant since there should be an acceptable replacement developed for it by 2005.

As I said, global warming is caused by two mechanisms, one being the depletion of the ozone layer (allowing the admission of more energy into the planet's energy system) and the other being the increase of greenhouse gasses in the atmosphere (causing a rise in the amount of energy retained by the planet's energy system). Either mechanism would cause the global mean temperature to climb but the two, working in conjunction, make the change much larger.

When considering the release (either accidental or intentional) of refrigerant gasses into the atmosphere, both mechanisms must be taken into account because all common refrigerants exhibit the potential to deplete the ozone layer and/or raise the concentration of greenhouse gasses. This is why refrigerant gasses should never be intentionally vented to the atmosphere.

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The effects caused by ozone depletion are greater than those caused by greenhouse gasses (when dealing with refrigerants) thus the emphasis on replacing R-12 in such a hurry. Although all of the replacements have the potential to cause greenhouse warming, none are as bad at ozone-depletion as R-12 or mixtures containing R-12.

I will concentrate mostly on retrofitting R-12 systems in this article because the need to do something about them is pressing. There are a number of alternative refrigerants that can be used as substitutes for R-12 including blends of HCFCs and HFCs as well as straight HFCs.

Before we discuss refrigerants, let's discuss lubricants. One of the keys to understanding the conversion process is to first understand the need for lubrication in a refrigeration system (air-conditioning being a special case of refrigeration). Carrier thinks that lubrication is so fundamental that they devote an entire chapter to lubricants in their System Design manual (which, incidentally, is an excellent book to acquire and read). As this monograph unfolds you will see that lubrication and the oils that provide it are one of the major considerations in a retrofit.

A refrigeration system is simply a mechanism for pumping heat. Heat is taken up by the evaporator or cooling coil inside the object to be cooled (in this case the object of our affection, **THE RAILROAD CAR**) and pumped to the outside where it is rejected by the condenser. This pumping is continuous because it needs to offset the heat leaking into the object (undoubtedly, through all those cracks that you have yet to plug).

Now heat is a pretty nebulous thing and by itself is a little difficult to pump. Enter our former hero and now villain, Freon. Freon likes to absorb heat but also can be made to release it fairly readily. So, instead of pumping heat directly, we pump Freon and the heat goes along for the ride. The Freon is referred to as the system's refrigerant.

The heart of any pumping system is a pump (remember, this is not rocket science). Refrigeration systems are no different from any other pumping system except that the refrigeration cognoscenti call the pump a compressor (the reason is obvious to all of the tech-heavies among us, but otherwise unimportant). Pumps are by and large mechanical devices and, as such, have a lot of moving parts. In some cases the moving parts are pistons, in others they are vanes (new compressors, for example sonic, are being developed that have no moving parts but they aren't yet available). The moving parts must be lubricated to ensure long life (i.e., greater than half an hour) and, as for most things requiring lubrication, the lubricant of choice is oil.

Why worry so much about the oil anyway? Well, it turns out that, due to the way compressors are designed, the miscibility of oil and refrigerant, etc., etc., much of your refrigeration system's oil spends most of its time not in your compressor's crankcase or sump where it should be doing its job but out in the system's piping roaming around mingling with the refrigerant so the two had better get along. In addition, the compressor is actually pretty efficient at pumping oil out into the system piping so there had better be a way for it to get back, otherwise, lubrication will quickly go out the window.

The "getting back" is the real nub of the problem. As I said, the compressor will pump the oil out into the system very efficiently. It then becomes the job (albeit secondary) of the circulating refrigerant to entrain the oil and return it to the compressor.

The various oils that can be used with each refrigerant depend largely on their miscibility with the refrigerant. If an oil is not sufficiently miscible in the refrigerant, it will not be carried along with the gas. This poses two problems. The first is that the compressor will be starved for lubrication and the second is that the oil will accumulate in the evaporator, coating its tubes and inhibiting heat transfer.

Table 1 shows the various oils and their acceptability for use with the available refrigerants. Basically, mineral oil is only acceptable for use with CFC and HCFC refrigerants such as R-12 and R-22. If one of the azeotropic blends such as MP39 or MP66 is used, alkylbenzene oil can be used. If HFCs are to be used (e.g., HFC-134a or HFC-404a) a polyol ester oil must be used.

The major factor in converting to one of the drop-in replacement refrigerants then becomes changing the oil. A large proportion of the mineral oil in an existing system must be removed and replaced by the new oil. If one of the interim azeotropic mixtures is to be used, at least 80% of the mineral oil must be replaced (this can usually be accomplished by a single oil change). If HFCs are to be used, 95% replacement of the mineral oil is desirable (this usually entails 3-4 oil changes).

Production of R-12 ceased in 1996 whereas the Montreal Protocol allows production of HCFCs until 2030. Consequently, R-12 can be replaced by one of the HCFC/HFC blends (intermediate-term replacement) or straight HFC (long-term replacement). DuPont, in their literature, does not recommend HFCs (specifically HFC-134a) for retrofits of R-12 systems. Rather, they suggest using one of the blends, as service life is acceptable (35 years) and the retrofit is easier and cheaper. They do suggest using HFC-134a for new systems where the proper steps can be taken to ensure cleanliness and where the proper oils can be used without adulteration.

	R-12	R-22	R-500	MP39	MP66	HFC-134a	HFC-404a
Mineral Oil	Yes	Yes	Yes				
Alkylbenzene	Yes	Yes	Yes	Yes	Yes		
Polyol Ester	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 1
Oil/Refrigerant Compatibility

Depending on how much work we wish to do to change the system's oil and what the life-expectancy of the retrofit is, we can now pick a replacement refrigerant. Take a look at Table 2 to determine which politically correct refrigerant you wish to use. Bear in mind that the working temperatures that can be achieved by R-22 are not as low as those of R-12, HFC-134a and HFC-404a and that the system working pressures for R-22 are approximately double that of the others.

HFC-134a is billed as a drop-in replacement for R-12. Do not let that fool you. You still will incur considerable expense and effort to replace

Refrigerant	Use	Notes
R-12	No-no	Causes excessive tanning in beach bunnies.
R-22	Acceptable until 2005	We are developing a workable substitute for this so its OK for now
R-500	No-no	Azeotropic mixture containing R-12
SUVA® MP39	Acceptable until 2030	Azeotropic, ternary blend of HCFC-22, HFC-152a and HCFC-124 (trust us, its good stuff). Replaces R-12 in medium-temperature applications (evaporator temperatures to -10°F [-23°C])
SUVA® MP66	Acceptable until 2030	Azeotropic, ternary blend of HCFC-22, HFC-152a and HCFC-124 (trust us, its good stuff). Replaces R-12 in low-temperature applications (evaporator temperatures below -10°F [-23°C])
HFC-134a	All the rage	Probably causes cancer in lab rats that bathe in it but who knows? Not a good replacement for R-12 in low temperature applications (evaporator temperatures below -10°F [-23°C]) ... use MP66 or HFC-404a instead.
HFC-404a	The latest	Use as an HFC replacement for R-502.

Table 2
Refrigerant Political-correctness

R-12 with HFC-134a. I would suggest that if you don't want to be on the cutting edge of technology and you don't need the lower temperatures (e.g., your application is air-conditioning) that you use R-22 or MP39 as your refrigerant. If you need lower temperatures (e.g., freezer compartment) use one of the azeotropic replacements for R-12 such as MP66. If you are lucky enough to be building a new system from scratch, consider HFC-134a or HFC-404a. I will discuss converting from R-12 to R-22, R-12 to MP39 and MP66 and R-12 to HFC-134a in that order.

Note that, before starting any work on your system, you should hook up a recovery unit to it and recover all of the old refrigerant. It is illegal to vent it to the atmosphere, it may come in useful later and, if worst comes to worst, you can get money back for turning it in to be recycled (since R-12 is no longer produced in this country, the only source of it is from recycling so used R-12 is fast becoming like gold, only better).

The first consideration in either case is, in my opinion, the system piping. If people had been careful about not venting refrigerants to the atmosphere in the first place, mother earth wouldn't be in trouble now. On a forty-year old railroad car, the refrigerant piping, which was undoubtedly soft-soldered probably leaks like a sieve. You have to fix this first or the atmosphere police will get you.

Another consideration is oil return. If you are switching from R-12 to R-22 the suction lines may be too large to ensure adequate oil return. This is because, for the same tonnage rating on R-12, it was necessary to move twice as much refrigerant as with R-22. Thus, the suction line is much bigger (perhaps as large as 2"-2 1/2" diameter). When you switch to R-22 the gas flow in the line won't entrain enough oil to be returned to Mr. Compressor and he will be sad.

My suggestion is to trash all of the old piping. Put in brand-new and braze it together with a silver-bearing brazing rod such as Harris Sta-Silv 5%. You'll need an oxy-acetylene torch for this, and it's a little different from soldering but it's worth the effort. A word of caution is necessary. Try to do most of the assembly outside or under well-ventilated conditions as the fumes from this rod are definitely not nice to breathe.

Select the pipe sizes for the new piping from Chart 1 (use the system's tonnage rating and length of pipe runs to make the selection) and/or match the pipe sizes to the inlet/outlet of your compressor. Pay particular attention to the inside and outside diameters of the pipe because all refrigeration fittings, etc. are sized by outside diameter but many of the newer systems use piping which is intended for use as water piping (water pipe is sized by inside diameter). To convert from inside to outside diameter in the pipe sizes that are typically used, add 1/8". It may be necessary to use sleeves and/or reducers to adapt the new piping to any old piping that is retained.

It is important that any suction risers be sized appropriately to ensure adequate oil return. In general, on railroad cars, the evaporator is located in the ceiling and the compressor is situated under the car so there will be no uphill suction lines. However there may be some portions of the suction line that slope upwards so it pays to check. For each size of suction line and type of refrigerant, there is a minimum tonnage rating that will carry oil along and

	Copper Pipe Outside Diameter							
Refrigerant	1/2"	5/8"	3/4"	7/8"	1-1/8"	1-3/8"	1-5/8"	2-1/8"
R-22	0.18	0.33	0.54	0.81	1.6	2.7	4.1	8.2
R-12 replacement[1]	0.132	0.238	0.390	0.59	1.15	1.94	3.0	6.0

Table 3
Minimum Tonnage for Oil Entrainment up Suction Lines

[1] Tonnage figures are for R-12 but should extrapolate to its replacements, since they are formulated to act like R-12.

ensure that what is pumped out of the compressor will be returned to it. If the oil isn’t returned, it will accumulate in the evaporator, affecting heat transfer and starving the compressor of lubrication.

Check Table 3 to see if your suction line is too large. Don’t forget to take into account the reduction in tonnage that results from unloading on systems that have unloader-equipped compressors (usually the unloaded ratings are 1/3, 1/2 or 2/3 of the full rating) and note that R-22 requires a significantly higher tonnage rating than R-12 to move oil properly. If the old suction line is too large, it should be replaced.

If you can't or don't want to replace the system's piping, you can still silver-solder or braze up the leaks as you find them. This may be easier than replacing all of the piping but maybe not. Sometimes it is very difficult to get at pipe fittings in tight locations. With new piping, it is possible to plan the sequence of assembly so that most of the parts are brazed together out in the open and only the easily accessible joints where gravity is on your side are made in-situ.

You will probably be able to keep the existing evaporator as they were solidly built in past years. Most of the ones that I have seen were hydro-static tested at 400 pounds and pressure tested even higher. Although they were typically soft soldered, the workmanship was excellent and the joints are unlikely to leak. If a leak does appear you may be able to braze it. Also, bear in mind, that the evaporator is downstream from the expansion valve so it is not a particularly high-pressure component. Replacing the evaporator is a nasty job, since it is located in a difficult place to get at and having a new one of the same quality fabricated is likely to be costly. Better to just vacuum out the crud and clean the fins with a good coil cleaner, if necessary.

The condenser may be another story. It is located in a much harsher environment (under the car) and is likely to be suffering from corrosion. Add to that the higher pressure employed in an R-22 vs. R-12 system and there is plenty of potential for leaks. Replacing it may be a good idea. Since all refrigeration heat-exchangers are essentially custom-built, you won't have much trouble getting one made to fit. Just be careful to spec. everything (size of tubes, number of rows and columns, inlet/outlet location and size, air flow direction, fin material, attachment points)

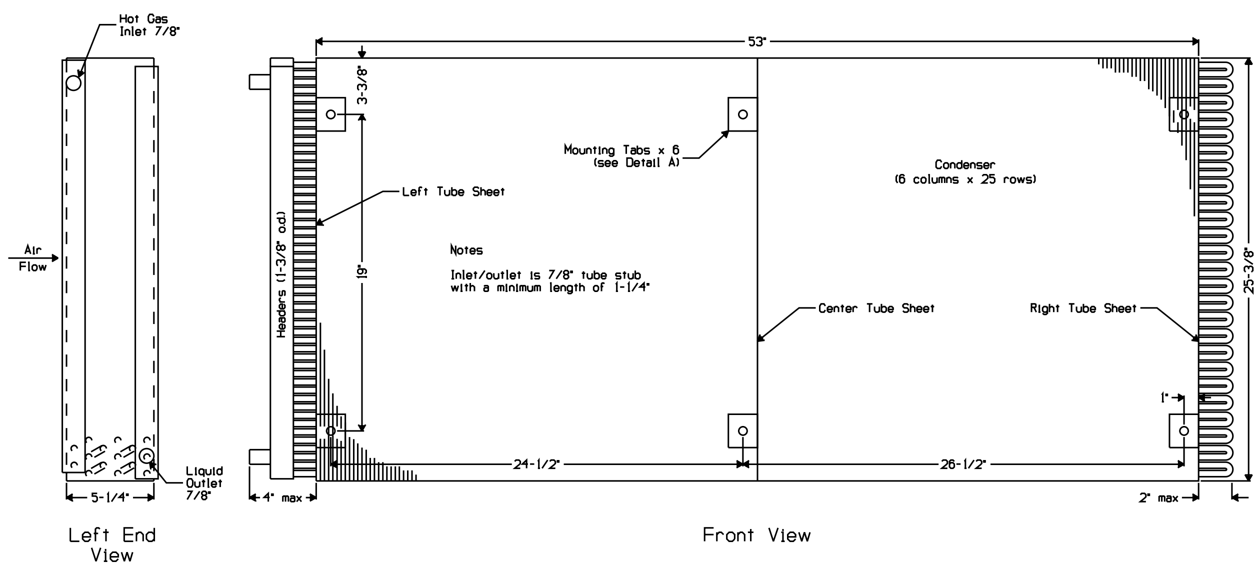

Figure 1

and do not assume that the manufacturer will do the right thing. Supply a good drawing, if possible (see Figure 1) and then check everything before you pay for it. If it doesn't match the drawing/specs., they have to fix it but once you pay for it, you own it.

Next, we arrive at the compressor. The air-conditioning compressor on an old railroad car is usually your basic boat anchor. Any refrigeration compressors (e.g. for the refrigerator and freezer compartments) probably are too. In the good old days (remember them) compressors were typically reciprocating units, belt-driven by an external motor. This arrangement worked fine when nobody cared about how much Freon leaked out into the air. And that's pretty much what it did do too. It is highly unlikely that the shaft seals worked well and so the Freon leaked out. Topping it up regularly was just considered proper-maintenance.

Modern compressors are what is known as hermetic, that is they are sealed from the atmosphere. Whether they are rotary or reciprocating, the motor and the compressor are built on a common shaft and then enclosed in a single case. The case can be sealed tight because there are no rotating seals. The motor windings are cooled by the flow of refrigerant which is passed over them before it is compressed. Heat from the motor is rejected by the condenser, along with heat from the object being cooled.

The most popular compressor among the railroad industry (both commercial and private) for air-conditioning is a semi-hermetic reciprocating compressor made by the Carlyle division of Carrier. This compressor can be obtained in a whole range of sizes (see Table 4) that virtually ensure a drop in replacement for the compressor on your car. If you do decide to use one of these compressors, you should be ensured of a readily available supply of parts in the unlikely event of a breakdown.

Model	Current 240V 3ϕ	Nominal HP[2]	Approx Tons[3]	#Cyls	CFM	~ Tons R-12[4]	~ Tons R-22[5]	KW[6]
06DA-818	31.4	6.5	8.6	4	18.3	5.8	9.2	10.8
06DA-824	39.6	7.5	10.0	6	23.9	7.6	12.0	14.1
06DA-328	44.3	10.0	13.3	6	28.0	8.9	14.1	15.9
06DA-337	44.3	10.0	13.3	6	37.1	11.8	18.7	16.5
06DA-537	63.6	15.0	20.0	6	37.1	11.8	18.7	20.7
06EM-150	72.0	15.0	20.0	4	50.3	16.0	25.4	24.9

Table 4
Carrier Semi-Hermetic Reciprocating Compressors

The trick to getting the compressor is to bypass the usual distributors and order it directly from Carrier's service department as if it were a replacement. Normally, there is a return credit for the old, burned-out, compressor that you are supposedly replacing but not this time. The old compressors are rebuilt and there is a good chance that you'll get a remanufactured one but everything is really new except for the cast-iron casing (which doesn't wear out) so you should get years of service from it and eliminate the middle man in the bargain. Another source is Johnstone Supply which sells the Carrier Compressor rebuilt by A-1 Compressor.

Note that it is frequently impossible to obtain the ideal conditions, under which compressors are rated, when the system is installed on a railroad car. Typically, the

[2] Current rating may appear high based on horsepower stated but these are manufacturer's nameplating values and they match actual observed values.

[3] Based on 0.75 HP/Ton (40°F - 105°F).

[4] Based on 3.14 CFM/Ton (40° - 105°F).

[5] Based on 1.98 CFM/Ton (40° - 105°F).

[6] KW rating of compressor must be multiplied by 0.285 and added to the tonnage rating of the system to arrive at condenser heat rejection tonnage rating.

condensor is forced to operate in an environment other than the 105°F indicated in Table 4. This being the case, it is often wise to pick a compressor that is larger than the calculated load and/or size the condensor much larger than normal.

It is very important that the compressor have service valves. If it doesn't come with them (the Carrier units don't) purchase the correct valves at the same time.

Popular compressors for refrigeration (typically smaller tonnage ratings) are hermetic rotary compressors (you know those things that look like a large can of tomato juice painted black). There are many manufacturers, all of them acceptable. Repair parts suppliers such as Grainger are good sources for them and they can be obtained with integral condensers and receivers, to boot.

Compatibility of the materials used in the construction of the refrigeration system and the replacement refrigerants/lubricants must also be considered in a retrofit. Fortunately, the metals commonly used in refrigeration systems exhibit excellent stability in the presence of the new refrigerants and oils. In fact, the stability of commonly used metals in the presence of the new refrigerants/oils is at least as good or better than their stability in the presence of R-12 and mineral oil.

Too bad that the same cannot be said for the elastomers that are commonly used as refrigeration seal materials. Some older systems may be found to contain elastomers that are prone to deteriorate rapidly in the presence of the newer refrigerants and oils. When converting a refrigeration system, all of the seals should be checked for compatibility. If there is any doubt, they should be replaced. Table 5 shows the acceptability of various elastomers.

	R-12[7]	MP39 & MP66	HFC-134a	Recommended
ADIPRENE® Urethane	A	B	B	
Buna N	A	N/T	A	Yes
Buna S	U	N/T	U	
Butyl Rubber	U	U	U	
HYPALON® 48	A	A	A	Yes
Natural Rubber	U	U	B	
NBR Nitrile	N/T	B	N/T	
Neoprene W	A	A	B	
NORDEL® EPDM	B	U	A	
SBR	N/T	U	N/T	
Silicone	U	U	B	
THIOKOL® FA	A	U	A	
VITON® A	U	U	U	

Table 5
Elastomer Compatibility

Filter/drier materials are yet another item that must be considered during a retrofit. The desiccants used in filter/driers have changed in order to be compatible with the newer refrigerants and oils. Thus, it is important to change the filter/drier core when a retrofit is done (when changing from R-12 to R-22, the filter/drier should be of the same type as originally found in the system but it should be changed anyway). Actually, this makes good sense because putting a new filter/drier into the

[7] A - Acceptable
B - Borderline
U - Unacceptable
N/T - Not Tested

system will help to ensure cleanliness after a retrofit.

Table 6 shows the types of filter/driers suitable for use with each type of refrigerant. Be sure to indicate to your refrigeration supplier, when you purchase new cores, the type of refrigerant being used so that the proper desiccant will be supplied.

	R-12	R-22	MP39/MP66	HFC-134a
4A-XH-5	Yes	Yes	No	No
XH-6	-	-	Yes	No
XH-7	-	-	-	Yes
XH-9	-	-	Yes	Yes

Table 6
Desiccant Compatibility

The last items to replace, and only when changing from R-12 to R-22 are the expansion valves. Expansion valves are designed to meter the proper amount of refrigerant into the evaporator so that the optimal amount of heat is removed via the exiting refrigerant. To do this, the expansion valve has a temperature sensing capillary tube that is affixed to the suction line at its attachment point to the evaporator[8]. The capillary tube is filled with the same gas as is used for the system refrigerant so that its coefficient of expansion is identical to that of the refrigerant, thus the need to replace it when changing the system refrigerant. Note that the drop-in replacements for R-12 (i.e. MP39, MP66 and HFC-134a) act the same as R-12 so the existing expansion valves may be retained.

Incidentally, the expansion valve works by maintaining a constant temperature differential between the refrigerant inlet and outlet. It does this by allowing more refrigerant into the evaporator as the outlet temperature rises and vice versa. If you think about it, it is fairly intuitive that adding more refrigerant as the outlet temperature increases will carry away more heat and this is exactly what the expansion valve does. The temperature differential that the expansion valve maintains is known as the superheat. For air-conditioning it should be between 5 and 10 degrees while for refrigeration it should be around 10 degrees. Although expansion valves are adjustable, there should be no need to touch new ones as they are factory-set.

Expansion valves should also be matched closely to the load of the system. Typically, you will be dealing with expansion valves in the 1/4 to 1-1/2 ton or 1-1/2 to 5 ton ranges. If your evaporator is split into multiple sections, an expansion valve is required for each section.

When the expansion valves are installed, be sure to attach the sensing bulb of the valve directly to the suction line exiting from the suction header that drains the portion of the evaporator that the valve feeds. The attachment should be via a piece of copper strap that usually comes with the valve. Then, insulate the suction line and valve together so that the sensing bulb senses the suction line temperature only.

You should also check the solonoid valves and replace them as necessary. You will want to provide single-pumpout control for your compressor so that it won't be slugged on startup. Older systems may not have had this feature so it usually needs to be added. It is essential with the Carrier Compressor, for example.

We have discussed replacing practically every component of the system so what pieces can be kept? There is likely to be a large component just before the evaporator that looks like a heat exchanger. It is. Its function is to increase the amount of superheat by exchanging heat between the incoming refrigerant liquid and outgoing refrigerant gas. You can keep this

[8] Refrigeration systems sometimes use an expansion valve that has no sensing bulb. Instead, the valve merely meters a constant amount of refrigerant into the evaporator. If this type of valve is present, there is no need to touch it.

subcooler or remove it. Keeping it improves the system's efficiency. Removing it simplifies plumbing. The transition between existing piping and new piping can be made using reducers from the plumbing or air-conditioning shop or can be built up using sleeves and brazing rod. You can also simplify plumbing but get the benefits of subcooling by running the liquid and suction lines together in close proximity for a long distance and insulating them as a single bundle.

The filter/drier can also be kept, providing that it is possible to easily find desiccant cores, suitable for use with the replacement refrigerant, that fit it. Otherwise, it will need replacement. The receiver may need to be replaced (but only if it leaks) or added, if there isn't one. The receiver allows anyone charging the system to be less accurate (which is desirable given the circumstances under which refrigerant may be added ... 15 minutes at the next station stop), thus it is essential.

Take a look at a typical railroad car air-conditioning system, shown in Figure 2, to see what other components you may wish to add at this time (plumbing, etc. for a refrigerator or freezer is simpler but you get the idea). Now, before a refrigerant charge is added, is the time to do it. Things to consider are extra valves to isolate portions of the system, charging ports, sight glasses, etc.

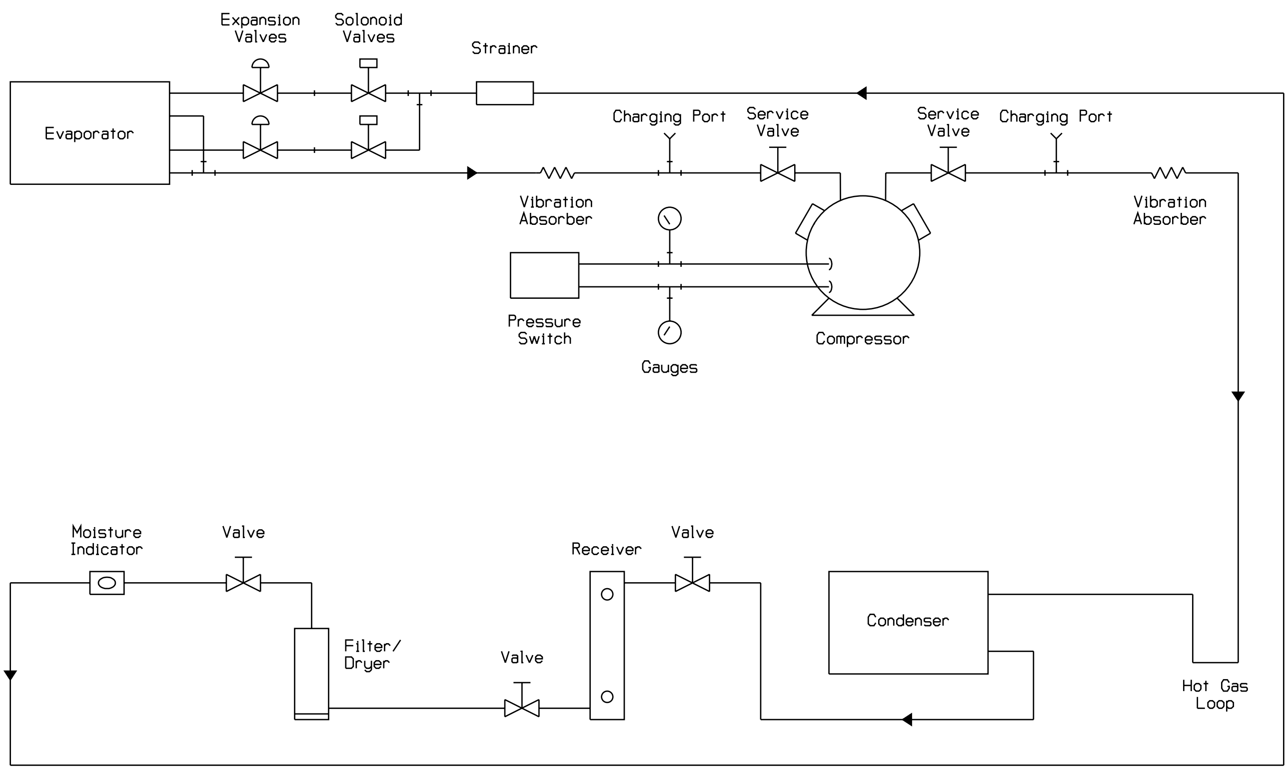

Figure 2
Typical Air-conditioning System

Once the plumbing is done, it is time to begin leak testing. You should have assembled or reassembled everything using the proper gaskets and gasket compound. All of the bolts, fittings, etc. should be torqued to the proper values, as recommended by the manufacturer.

The first step is gross leak testing. Make yourself an adapter that goes between a quickconnect coupler for your air compressor and a 1/4" refrigeration fitting. Using a charging hose, put 90-100 lbs. of air into the system and then listen for leaks. You'll probably hear a few. Once these are fixed, move on to step two.

Step two involves looking for small leaks with soapy water. I use approximately one teaspoon of dishwashing liquid in a half pint of water in a coffee can. Brush it on and work it into every joint, gasket, etc., with a soft paint brush, all the while looking for bubbles. If any bubbles appear, fix the leaks and repressurize.

The third step is high-pressure testing. To do this, I use a cylinder of nitrogen that I borrow from my welding supplier along with a regulator capable of reducing the cylinder pressure to 400 pounds (available from refrigeration suppliers such as Johnstone). I add an adapter to the regulator so that I can attach a charging hose to it.

Using a fresh cylinder of nitrogen, pressurize the system to 400 lbs. Go around with the soapy water and check every joint, gasket, etc. If there are any leakers, fix them. If not, carry on with the next step.

Step four, the last step, is to disconnect the charging hose, cap the charging port and note the system pressures. Then leave everything for a week. Check the pressures after a week has passed (do this under the same ambient temperature conditions as those prevailing the week before since the gas pressure will fluctuate with temperature). If the pressure remains constant at 400 lbs. for a week, there aren't any leaks that you're going to find. If not, go back and keep looking for leaks.

You can make some or all of the changes mentioned in the preceding paragraphs regardless of the type of refrigerant that is planned for the system. Presumably, the reason to switch to MP39, MP66, HFC-134a or HFC-404a is to eliminate the need to mess with the system's piping, expansion valves, etc. so, if you are going to be using one of them, you'll probably skip most of the work described above although elastomer replacement and leak-testing is still an excellent idea.

It is at this point that the upgrade path to R-22 and the drop-in replacements diverge. To charge your system with R-22 , merely proceed as described next. The oil to be used is a napthenic-based oil which is what was in the original system. You simply need to fill the compressor up with napthenic-based oil and, if there are a lot of new components (e.g. pipe), add perhaps 20% more.

To begin charging the system with refrigerant, depressurize it, install clean desiccant cores in the filter/drier and seal it up using a fresh gasket and an appropriate (refrigerant compatible) gasket goo. Torque the bolts properly for a tight seal.

Connect a vacuum pump (filled with a fresh charge of vacuum oil) to the system via a set of charging gauges. The high-pressure and low-pressure lines should go to the hot gas and suction sides of the compressor, respectively. Usually, these connections are made at the service valves. Button everything up and turn on the vacuum pump. If the pump has a bypass valve that lets you pull low vacuums without contaminating the oil, start out with it open. After a half hour, close the bypass valve and call it a day, leaving the vacuum pump to run overnight. Pulling vacuum for at least 24 hours allows all of the crap in the system to out-gas and be extracted by the pump.

Now we come to the really exciting part. Adding the dreaded killer refrigerant! As my refrigeration supplier says, "Remember, the earth loves you. Don't hurt it by letting your Freon out." Always be careful to close service valves and check that they're closed before opening anything to the atmosphere. Work cautiously and don't try to take any shortcuts.

Shut the valve on the charging hose and disconnect the vacuum pump. Break the vacuum by charging 15 p.s.i. of refrigerant into the system. Connect your recovery unit and extract the refrigerant. Then re-connect the vacuum pump and evacuate. Repeat this step once more. This is known as triple-evacuating, and it should remove the last remaining contaminants in the system.

You are now ready to add a full charge of refrigerant. You should calculate roughly how much this is by adding up the volumes of all of the system components. Table 7 gives the required charge for piping. Use the length of your pipe-runs for the hot gas, liquid and suction lines. Use the number of rows x columns x length for the evaporator and condenser. The receiver, filter/drier and compressor should have refrigerant volume marked.

Once the charge is calculated, you can begin adding refrigerant. Your goal is roughly what you calculated (60-70 lbs. is pretty typical for air-conditioning while a pound or three is typical for refrigerators). Hang the refrigerant container from a scale to weigh it as you add refrigerant or set the container on top of a scale. Wrapping the container in a heating blanket meant for this purpose speeds charging.

Copper O.D. Pipe Size	R-22			R-12[9]		
	Hot Gas	Liquid[10]	Suction	Hot Gas	Liquid[10]	Suction
1/4"	.01	.16	.0033	.007	.17	.0028
3/8"	.026	.39	.0082	.017	.43	.0069
1/2"	.047	.72	.016	.032	.80	.013
5/8"	.075	1.15	.025	.051	1.28	.021
3/4"	.114	1.73	.037	.076	1.91	.031
7/8"	.16	2.4	.051	.105	2.65	.043
1-1/8"	.27	4.09	.087	.18	4.52	.073

Table 7
Refrigerant Charge for Piping (lbs./10 ft.) at standard temperatures

Add as much refrigerant as the container will supply to the system. This should approach 100 p.s.i. on your charging gauges. Bypass the low-pressure cut-out on the compressor pressure switch, check that all of the service valves are open and fire the sucker up. Add refrigerant to the suction side, observing suction pressure and watching that it doesn't get too high (lest the compressor suck liquid and get slugged). Keep your eye on the amount of refrigerant being added and the oil in the sight glass. Oil will be pumped out of the compressor and be circulated through the system. Some oil will wet the insides of the pipes and not be returned. If the oil level gets too low, you will need to stop and add some (this is a major pain in the butt so it is better to have a little too much to start with but don't go overboard as this may harm the compressor).

When the amount of refrigerant charged approaches the amount that you calculated, pay attention (arriving at this point could take several hours). Watch the receiver and/or liquid-line sight-glass. The receiver sight-glass is easier to work with but not all receivers have one. If you know what to look for, the liquid-line sight-glass is easy to use. Basically, you are looking for clear liquid. Any bubbles represent flash gas which indicates that the refrigerant is boiling or flashing in the liquid line. When the charge is complete there won't be any bubbles. At this point (or when the bottom receiver sight-glass fills up), add two or three more pounds of refrigerant to top up the receiver and you're done.

Or so you thought. Now comes the really fun part. Changing the oil. You'll want your system's oil to be nice and clean so that your compressor can lead a long, happy and productive life. The chances of the oil staying clean after what you just did (i.e. rebuild a good

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[9] The charge for R-12 may be used to calculate the charge necessary for MP39, MP66 and HFC-134a. For MP39 and MP66 the values given should be multiplied by 0.82 and for HFC-134a the values given should be multiplied by 0.92.

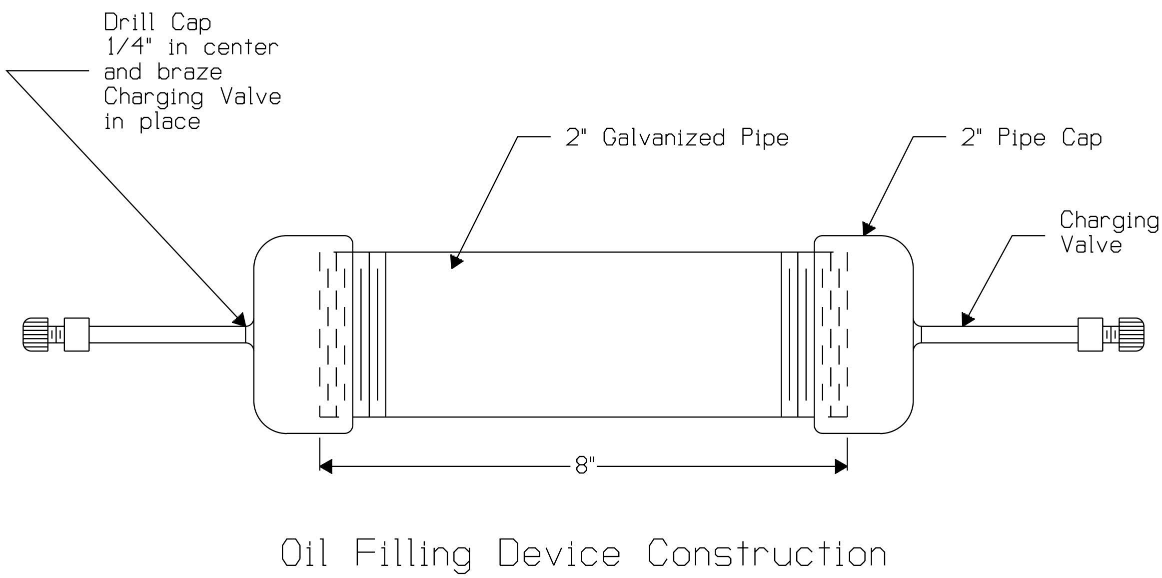
[10] Some value between the Liquid and Hot Gas values may be chosen for the evaporator and condenser charge however it varies depending on the degree of flooding. Perhaps a value of one half of the Liquid value is a good estimate, if the charge is unknown.

part of the system) are slim. One indication of the health of the oil is acidity. Another is color.

You should check the oil at regular intervals (perhaps as frequently as hourly) for the first little while after the system is commissioned. Observe the level and add more, if necessary. Observe the color through the sight-glass. A healthy, golden glow is good. A muddy or peanut butter brown isn't. If the oil looks bad,

about five or six hours. If you have to do it three or four times, it's pretty annoying.

A couple of improvements are possible. First, replace the oil drain plug with a short pipe nipple and a 90 degree refrigeration valve facing downward. This arrangement allows you to drain oil under control of the valve without opening the compressor to the atmosphere, (when you do this, make sure the oil is hot so that little



Usage Notes:
1) Put pipe dope on one end and thread cap in place.
2) Fill with charge of oil.
3) Put pipe dope on other end and thread cap in place.
4) Holding one end up, evacuate from top.
5) Connect charging hose from bottom to compressor oil fill.
6) Blow oil charge in with refrigerant.

Figure 3
Compressor Oil Filling Device

drain it out and replace it.

Now, draining out the oil and replacing it sounds easy but remember that the compressor is filled with Freon. It means sealing off the compressor, recovering the Freon, draining the oil and replacing it, evacuating the compressor (three times) and recharging it. All of this takes

or no Freon is dissolved in it). Second, construct an oil charging device as shown in Figure 3 and add a charging port to the low pressure gauge point on the compressor's cylinder head. The oil charging device can be filled with oil, evacuated and the charge of oil blown in the charging port with Freon in a half hour without loosing the compressor's refrigerant charge. This will allow you to remove and add oil very easily, to change the oil, and/or adjust the oil level.

After the oil looks healthy and stays looking that way, run the system for a couple of days and then remove a sample of oil for acid testing. Obtain an acid test kit from your refrigeration supplier and test the oil. If it passes the test, you're laughing. If not, change the oil again (sigh) and then run it in and test it. Keep repeating this test until the oil is not acidic.

That's all there is to replacing R-12 with R-22. To replace R-12 with MP39, MP66 or HFC-134a, you must change the type of oil used in the system. MP39, MP66 and HFC-134a are not compatible with napthenic oils. Instead, for systems employing MP39 or MP66, alkylbenzene or polyol ester oils must be used. For systems employing HFC-134a, only polyol ester oils may be used.

In addition to being incompatible with napthenic oils, here are some other difficulties that can be expected with HFC-134a. The lubrication properties of the new oils aren't as good as napthenic oils. Ester oils can react over time with HFC-134a and contaminants in the system to form waxy residues that clog valves, piping, etc. Ester oils may react with moisture to form compounds that can corrode system components so that eliminating water from the system is vital. You may not be able to obtain suitable oils yet for low-temperature applications (i.e. -40°F to -10°F range), but this shouldn't pose a problem for air-conditioning.

The other consideration with HFC-134a is cost. The polyol ester oil is five to ten times more expensive than napthenic oil (and you'll use a lot of it, if you're flushing out the old mineral oil with it). HFC-134a itself is no bargain, it being only slightly less cheaper than the new tax-enhanced price of R-12. The difference in cost between R-22 and HFC-134a (or MP39 for that matter) can be significant.

Do you still think you want to use HFC-134a? Do you still believe HFC-134a is a drop-in replacement? Do you want to buy a bridge? You do? Are you sure you wouldn't rather use one of the interim replacements such as MP39 or MP66? Well, it's up to you. In either case you should proceed as follows.

First, before the old refrigerant is removed from the system, collect the system's performance data (using the correct refrigerant charge in the system), as outlined in Chart 2. This information may prove useful in tuning the system (to run like it did in the good old days), once the refrigerant is replaced.

Next, remove the old refrigerant. This should be done with a recovery device capable of pulling 10-20 inches of mercury vacuum and the refrigerant should be stored in a proper recovery cylinder. Don't dispose of the old refrigerant just yet, though, as you may still need it during the conversion process. While you're at it, weigh the amount of refrigerant removed and record it as an aid to charging the new refrigerant later.

Note that, if your system does not have a charge in it and/or it isn't working, you may be reduced to calculating the amount of charge required as if the system were new. Furthermore, ensuring complete oil replacement without the old refrigerant in place may prove difficult.

The third step is to remove all of the old oil from the system. Some of its favorite haunts are the compressor sump and the evaporator. DuPont suggests removing the compressor from the system and turning it upside-down to drain it via the suction line, if there is no sump drain and the unit is sealed (i.e. small hermetic units). You may also be able to open the piping at a low point near the evaporator and drain or blow it out. However you do it, remove as much oil as possible. If there is an oil separator, drain it too.

Your goal is to remove 80% or more of the existing lubricant for MP39 and MP66 retrofits or 90% or more of it for HFC-134a retrofits. Always measure the volume of old lubricant removed and compare it to the system's specifications to determine if the goal has been met.

Incidentally, now, while the system is torn apart, is an opportune moment to replace any suspect elastomers (e.g. valve seals, valve seats, gaskets) with new, compatible components and repair any obvious leaks or problems (see Table 5). Also, rationalizing the plumbing, if necessary should be undertaken now.

If you were unable to remove enough mineral oil from the system to meet the goal, it can be removed via flushing. Unfortunately, besides being expensive, flushing requires you to put back the old refrigerant since mineral oil is not miscible in the newer refrigerants. If your system didn't come with any charge, you are faced with obtaining some R-12 or finding some other method to remove the oil.

To proceed with flushing, fill the system with a like quantity of a similar viscosity, replacement oil to that removed (alkyl benzene for MP39 or MP66, polyol ester for HFC-134a). Button everything up and re-charge it with the old refrigerant. Then run the system for 24 to 48 hours, thereby ensuring adequate mixing of the mineral oil/replacement oil. Note that you must do this with the old refrigerant in the system as mineral oil is immiscible in the new refrigerants and won't be mixed with the new oil.

After running the system, remove and recover the refrigerant, drain out the oil mixture and re-fill with more new oil. If you are retrofitting with MP39 or MP66, this is probably sufficient and you can proceed to charging the system with the new refrigerant. If you are retrofitting with HFC-134a, you must run the system once or twice more (yes, it means recharging with the old refrigerant, yes, it means 24-48 hours of operation, yes, it means removing and recovering the refrigerant and oil and yes, its a royal pain).

The lubricant manufacturers have developed test kits to determine what the content of mineral oil is in the system's lubricant mixture. If you are unsure how much mineral oil remains, it is perhaps better to err on the side of caution and flush that system an extra time. Otherwise, the residual mineral oil is sure to show up as a problem later, most likely in the evaporator.

Once you have the old oil flushed out, you can recover the old refrigerant with your recovery machine for the last time. Be sure to return the recovered refrigerant to an authorized recycling facility (it means big bucks for you).

Now the filter/drier material or cores can be replaced (since it or they won't be getting steeped in mineral oil any longer). Exercise care when installing the desiccant. It should not be exposed to the atmosphere for any length of time since it will absorb moisture and be rendered in-effective. If you didn't leak test the system, do it before you replace the filter/drier cores and fix all leaks.

Hook up a vacuum pump to the system and evacuate it thoroughly. The longer you do this, the less chance of there being any non-condensibles left in the system to form wax or cause other problems. Now you can go back to the section on calculating the amount of charge and adding refrigerant and proceed as outlined therein.

If you extracted an original refrigerant charge, use it as a guide to determining how much replacement refrigerant to use. Table 8 shows the amounts of new charge to use, depending on the original and replacement refrigerant.

	MP39		MP66		HFC-134a	
Original Refrigerant	Initial Charge	Optimum Charge	Initial Charge	Optimum Charge	Initial Charge	Optimum Charge
R-12	70-75%	75-90%	70-75%	75-90%	90%	90-95%
R-500	95-100%	105%	95-100%	105%	---	---

Table 8
Refrigerant Charge

When charging your system with HFC-134a, you can proceed as already outlined, adding either liquid or vapor to the system. (Of course, liquid should never be added to the suction side of the compressor). When charging MP39 or MP66, vapor must never be charged into the system (this is because the refrigerant is not a true azeotrope so the composition of the liquid and vapor phases is different). The shipping container is equipped with a dip tube to prevent ever charging vapor so liquid will always be supplied. This is all right for adding the initial charge to the discharge side of the compressor but what about adding more refrigerant to the suction side after equilibrium is reached? You must do so very slowly (to ensure that the refrigerant flashes) or (preferably) use a throttling valve to prevent sucking liquid into the compressor.

Start out with an initial charge equal to the amount shown in the initial charge column of Table 8. Once the system is charged with that amount of refrigerant, run it for a while and observe its performance. Compare the data obtained before the retrofit with fresh data taken now. If the system is not measuring-up, add more refrigerant as needed. The azeotropes MP39 and MP66 are more sensitive to charge size than R-12 so pay particular attention to changes in system performance as a full charge is approached. Also, be aware that bubbles may occur in the liquid-line sight glass, even when a full charge of MP39 or MP66 is reached (if the sight glass is close to the condenser exit or if there is little chance for sub-cooling to take place), thus, this technique (observing bubbles) may not be valid for determining full charge.

After your conversion is complete, be sure to label everything with the proper refrigerant, oil and charge size so that nothing untoward happens during maintenance. Identification labels are available from your refrigerant supplier.

A word about a couple of anomalies of the azeotropic mixtures is in order here. The first is temperature glide. It will occur in both the evaporator and condenser and it is merely the result of a near-azeotrope beginning to boil (or condense) at one temperature and completing boiling (or condensing) at another temperature as the blend separates. The effect of temperature glide is to cause the inlet and outlet temperatures of the evaporator and condenser to be different (about 8-10°F with MP39 and MP66) rather than equivalent (as with R-12 and HFC-134a). Other than causing temperature differences to be measured during system tuning, temperature glide should have no real effect on performance.

The second is the effect that leaks will have on performance. If a leak does occur in the system, the composition of the blend will change, since the vapor phase (which is presumed to leak) is different from the liquid phase. In simulations of static leaks that DuPont has done, the performance of the system after leaks were topped up was found to change but not significantly. In actual running systems, even less change in performance was observed but it is important to know that if a large vapor-phase leak does occur, it will cause a change in performance.

A few words of caution about the new materials are also in order. The new oils are very hydroscopic and so should not be exposed to the atmosphere for any length of time lest they absorb a large amount of moisture. Nor should they be allowed to come in contact with one's skin as they will dry it out and prove very irritating.

Although MP39, MP66 and HFC-134a are non-toxic when inhaled in low concentrations they become toxic when high concentrations are present. Acceptable exposure levels are: 800 ppm for MP39; 840 ppm for MP66; and 1000 ppm for HFC-134a. Above these levels you can expect all those nasty effects associated with flurocarbon inhalation such as: narcosis; lethargy; anesthesia; dizziness; intoxication; loss of coordination; cardiac irregularities (sensitization); unconsciousness; and finally (pun intended) death. Read all of the information in the applicable MSDS and PUSH data sheet (DuPont P-MP for MP39/66 or P134a for HFC-134a) before handling this stuff and pay attention to it.

One further feature of HFC-134a is its flammability. Although it is *nonflammable* (DuPont's italics ... **they** want to stress that it is safe) at ambient temperatures and pressures, it sure ain't under other, relatively easy to obtain, conditions. Just mix it with the right amount of air and raise its pressure a tad and bang! For more information, obtain the HFC-134a PUSH from DuPont and read and follow its guidelines.

My parting thoughts to you are these. If you put everything together properly, there shouldn't be any leaks. You'll rarely need to add refrigerant to the system and will get many years of life out of the compressor (typical compressors are designed to last a long time) with the occasional use that it will have. Won't it be nice to simply forget all of this brouhaha and enjoy cool air and ice-cold cocktails?

Item				Source & P/N		Cost
Polyol Ester Oil	(Mobil EAL-ARTIC-22C)		1 qt	Grainger	5E759	$16.50
	(Mobil EAL-ARTIC-22CC)		1 gal		5E760	$51.70
KMP #184 Ester Oil	(RL32)	150 SUS	1 gal	Johnstone	B81-406	$45.95
	(RL68)	300 SUS	1 gal		B81-477	$47.75
Alkyl Benzene Oil	(Zerol 4310-07)	150 SUS	1 gal	Johnstone	B81-409	$18.10
	(Zerol 4311-07)	300 SUS	1 gal		B81-411	$19.26
KMP residual oil test kit (RTK)				Johnstone	B11-957	$11.97
KMP acid test kit (TKO)	Alkylbenzene/mineral oil			Johnstone	B11-678	$5.75
	Polyolester oil				B12-497	$5.75
DuPont SUVA® MP39			30 lbs	Grainger	5E058	
DuPont HFC-134a			30 lbs	Grainger	5E057	
Brand X HFC-134a			30 lbs	Johnstone	B92-373	

Table 9
Sources Of Supply

Checklist For MP39, MP66 or HFC-134a Retrofit

1. Establish baseline performance with R-12 or R-500 (fill out System Data Sheet).

2. Remove and weigh the original refrigerant charge from the system. Do not vent the refrigerant to the atmosphere, rather recover it using a recovery machine and proper recovery cylinder. The recovery machine should be capable of pulling 10-20 inches of vacuum for proper recovery.

3. If there is any doubt about plastics and/or elastomers, replace them as required with the proper types for the refrigerant to be used.

4. Drain the lubricant from the system and measure the original amount. The goals are 80-85% lubricant removal for MP39 or MP66 and 90-95% removal for HFC-134a. The compressor and/or other components may need to be removed.

5. Add the correct lubricant (alkyl benzene for MP39 or MP66, polyol ester for HFC-134a), using the same quantity as that removed in Step 4, to the system.

6. Reinstall any components that were removed, such as the compressor, to drain the oil.

7. Replace the filter/drier with one compatible with the refrigerant being used.

8. Close up the system and leak test it then triple-evacuate the system, breaking vacuum with the new refrigerant.

9. Charge the system with MP39, MP66 or HFC-134a and record the amount of refrigerant charged. The initial charge should be: 70-75%, if the original refrigerant was R-12 and the replacement is MP39 or MP66; 100%, if the original refrigerant was R-500 and the replacement is MP39 or MP66; 90%, if the original refrigerant was R-12 and the replacement is HFC-134a.

10. Start the system and compare the performance measurements with those taken when the original refrigerant was in the system. If the system is low in charge, add more refrigerant in increments of 2-3%. Record the quantity of additional refrigerant.

11. Label the system with the type of lubricant and refrigerant as well as the amount of lubricant and refrigerant (the amount of refrigerant is the sum of that added in Steps 9 and 10).

Note: If flushing is being employed to remove the original lubricant, repeat Steps 2, 4-6, 8 and 9 as many times a required (followed by a period of operation of the system) to acheive the desired oil dilution (likely once for alkyl benzene, two to three times for polyol ester).

System Performance Data

Compressor Manufacturer ___________________________ Compressor Model ___________________________________

Original Refrigerant Charge __________________________

Lubricant type _____________________________________ Lubricant Volume __________________________________

Drier Manufacturer __________________________________ Drier Model ____

Drier Type (check) Loose Fill _____ Soild Core _____ Dessicant ____

Expansion Device (check) Capilliary Tube _____ Expansion Valve _____

Expansion Valve Manufacturer ________________________ Expansion Valve Model ______________________________

Expansion Valve Set Point ____________________________ Expansion Valve Sensor Location _______________________

Unloader Type _____________________________________ Unloader Steps ______________________________________

Datum	Original Charge	Initial New Charge	Intermediate Charge	Final Charge
Date/Time				
Ambient Temp (°F)				
Relative Humidity				
Chage (lbs. or oz.)				
Compressor				
Suction Temp (°F)				
Suction Pressure (psig)				
Discharge Temp (°F)				
Discharge Pressure (psig)				
Motor Current (amps)				
Cycle Time (typical On/Off)				
Unloader Step 1 Suction Press. (psig)				
Unloader Step 2 Suction Press. (psig)				
Evaporator				
Refrigerant Temp at Expansion Device Inlet (°F)				
Refrigerant Inlet Temp (°F)				
Refrigerant Outlet Temp (°F)				
Refrigerant Temp at Sensor (°F)				
Coil Air Inlet Temp (°F)				
Coil Air Outlet Temp (°F)				
Condenser				
Refrigerant Inlet Temp (°F)				
Refrigerant Outlet Temp (°F)				
Coil Air Inlet Temp (°F)				
Coil Air Outlet Temp (°F)				