AUTOFROST Technical Discussions

A/C in a Nutshell

Here is a simple three minute course in automotive Air Conditioning. All it really boils down to is one evaporates (boils) a working fluid in the vicinity of a body to be cooled, usually finned pipes (coils) called an evaporator which has air blowing through it and the air is cooled. The evaporated working fluid, now a vapor, is then compressed by a compressor and becomes hot vapor. The vapor runs through another set of finned pipe coils, called the condenser where it condenses back to a liquid, giving off (rejecting) the heat absorbed when it was first boiled. A *metering device* (orifice, expansion valve, etc) is used to admit a small amount liquid working fluid from the condenser (high pressure, typically 200 PSIG) to the low pressure side (evaporator, typically 30 PSIG), where the cycle repeats.

Water has been and could be used as the working fluid in a refrigeration system, but water has an inconveniently high boiling point (212 deg F at sea level), thus requiring an extreme vacuum in the evaporator to achieve the necessary cool temperatures. Compressors (vacuum pumps) to do this cost thousands of dollars, so we will forgot about using water as the working fluid now. “FREON” (registered trademark of Dupont) as it is known in automotive jargon is actually a family of refrigerants made by Dupont and other Chemical manufacturers (Genetron for Allied, Isotron for Atochem, etc). Freon-12, or refrigerant-12 or R-12 which is the chemical called dichlorodifluoromethane and has a boiling point of about -21 deg F at atmospheric pressure (0 PSIG) and it is commonly used as a working fluid for Automotive A/C. See Figure 1 on the following page for a diagram of a simplified A/C system (no driers, controls, etc) are shown. See Figures 1-3 following. Temperature-pressure curves generated using NIST REFPROF V5.10.

A/C in a Nutshell

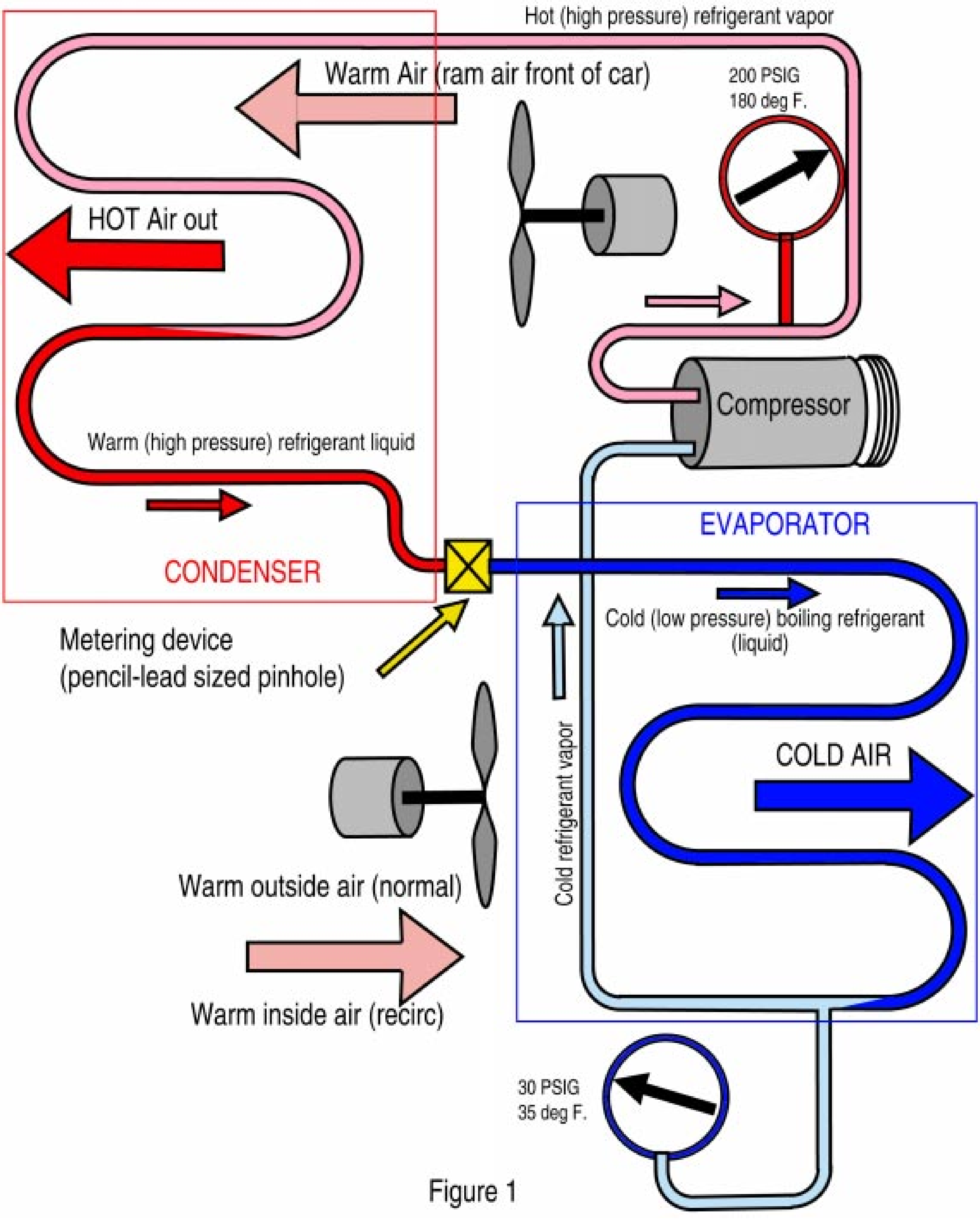


Figure 1

There are many types of Freons, like Freon-11, Freon-12, Freon-22, Freon-113, Freon-502 (also called Genetron-12 if from Allied, etc), or generically called “R-12, R-22, etc”. All these refrigerants have different boiling points and serve different purposes. R-11 boils at around 75 deg F, and once made an effective “flush” for cleaning and servicing A/C systems to clean out debris from failed compressors, etc. R-11 and R-12 are also known as *CFC-11* and *CFC-12*. CFC means “chlorinated fluorocarbon”. As you know, CFCs are thought by some to harm the ozone layer in the upper atmosphere. Whether CFCs hurt the ozone or not is immaterial now, as laws are in place to “ban” them in the US (no new production of them, you can still use what you hoarded). For the automotive industry “Freon” means R-12.

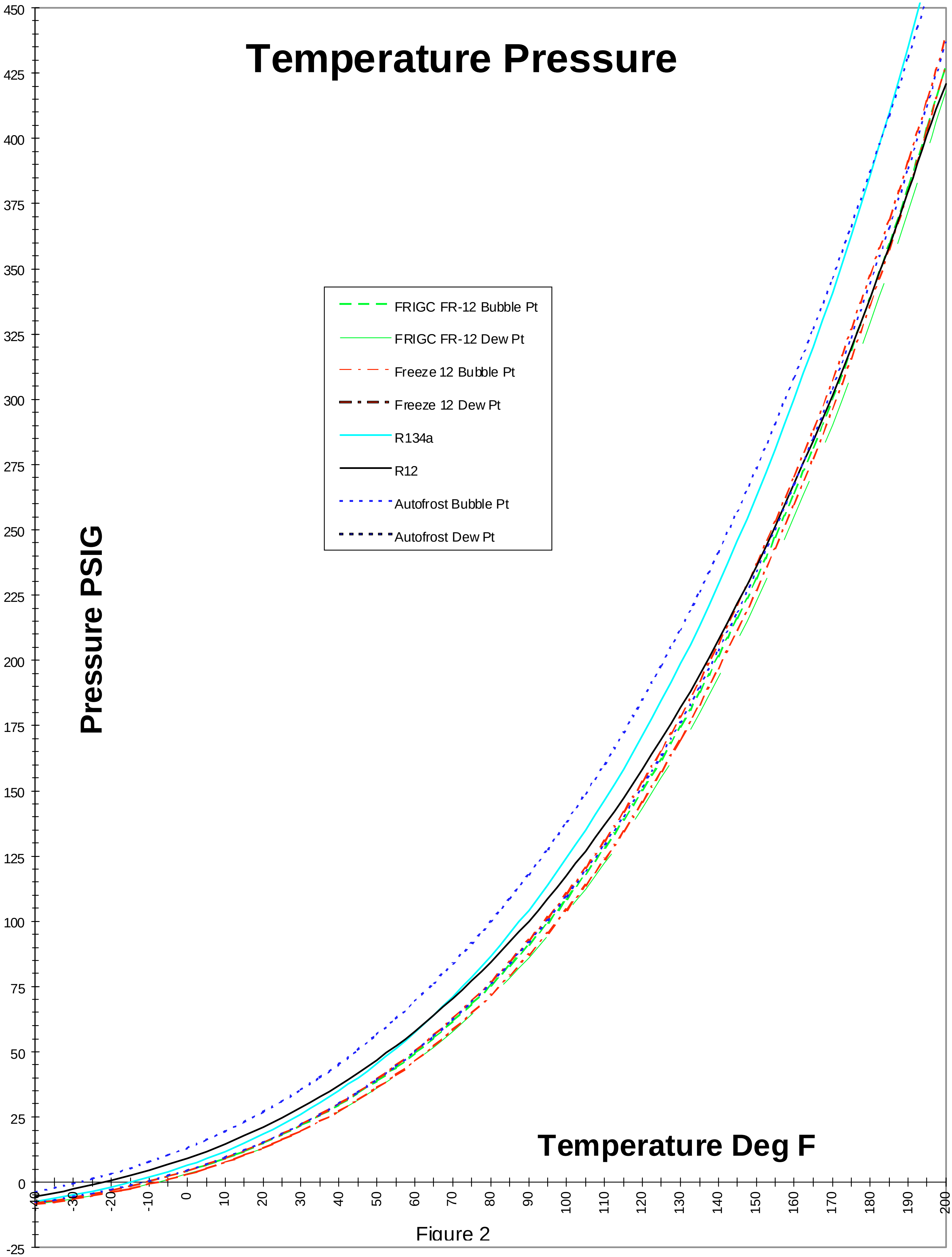
A second class of compounds are called “HCFCs” (hydrochlorofluorocarbons). These contain a hydrogen atom, and once released into the atmosphere, this hydrogen bond is usually broken down by sunlight before it reaches the ozone layer, rendering it almost harmless. HCFCs are figured to harm the ozone only about 1-6% as much as do the CFCs, so their phaseout date is quite away off yet (currently 2029). R-22. R-142b and R-124 are HCFCs and are used as blend components in the Autofrost refrigerants.

A third class of compounds are called “HFCs” (hydrofluorocarbons), they have no chlorine atoms (or bromine) and cannot hurt the ozone layer. They do usually have a high global warming potential (GWP) though. R-134a is an HFC and is the refrigerant being used in new vehicle manufacture. A/C systems designed for R-12 have a heavy weight (usually 525 viscosity) “mineral” oil inside which circulates with the refrigerant and provides lubrication for the compressor. For a system to function properly, this mineral oil must be “miscible” (dissolve in) the refrigerant being used in order for it to return to the compressor properly. R-134a has zero miscibility in mineral oil, so new oils (mostly PAG and POE) oils have been developed for R-134a systems. PAG oils will usually be destroyed if a chlorinated refrigerant is used such as R-12, or Autofrost. If an R-12 vehicle is “retrofitted” to R-134a (the oil changed to PAG), sometimes the PAG oil will fail from existing chloride deposits (which cannot be flushed out) from the previous R-12 in the system. POE oils also have their problems, one being low lubricity and another being poor stability (breaks down easily and very moisture sensitive). Both Autofrost refrigerants are miscible with R-12 mineral oil (no oil change).

Pure (single component) working fluids such as R-12 and R-134a have what is known as a “temperature-pressure” relationship for a closed container containing both liquid and vapor phases. In other words, at a given temperature of 32 deg F, R-12 will have a gauge pressure (PSIG) of about 30 PSIG. At 170 deg F, R-12 will have a pressure of about 300 PSIG. R-134a has a “steeper” temperature-pressure curve then does R-12, so it has problems with high head pressures on hot days when there is poor airflow through the condenser, such as gridlock traffic.

Blend (multiple component) working fluids (refrigerants) (ASHRAE R-400 series) which are zeotropic (components separate as they boil off) can offer performance gains over single component refrigerants. Autofrost (R-406A) is one of these. Single component refrigerants like R-12, in the condenser, do the active “phase change” (changing vapor to liquid) mostly in one part of the condenser. This releases lots of heat in that one area, but other areas where vapor just cools down, or liquid cools down release relatively little heat. Autofrost has a “glide” (Bubble and Dew Points), where at any given temperature, it can exist at a small range of pressures and vice versa. This “glide” causes the phase change region of the condenser to widen, thus rejecting more total heat than with a single component refrigerant. The glide for Autofrost is about 10-15 deg F. “Azeotropic” refrigerants, are blends, which in general, all the components boil off at the same rate and they perform like single component refrigerants. R502 is the best known example. Azeotropes are assigned R-500 series numbers by ASHRAE. Another name for zeotrope fluids/refrigerants is “nonazeotrope” -- sure is confusing.

We now begin a deeper discussion of Autofrost’s (and competitors’) temperature-pressure curves and show why Autofrost works better. Zeotropic refrigerant blends such as Autofrost/R406A/Chillit, actually have two temperature-pressure curves. The upper one is the “bubble” point curve. The bubble point (at a given pressure) is the temperature (as it is raised) where the liquid first starts to bubble (boil). The lower curve is the “dew point”. If vapor is cooled down (at a given pressure), the dew point is the temperature at which the first droplets of condensation form. Check out Figures 2 and 3, whole range and expanded (evaporator) range temperature-pressure curves for some refrigerants. Autofrost’s bubble and dew point curves nicely bracket the single temperature-pressure curve of R12.


Temperature Pressure
Pressure PSIG
Temperature Deg F
FRIGC FR-12 Bubble Pt
FRIGC FR-12 Dew Pt
Freeze 12 Bubble Pt
Freeze 12 Dew Pt
R134a
R12
Autofrost Bubble Pt
Autofrost Dew Pt
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
-25
-40
-30
-20
-10
0
10
20
30
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80
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100
110
120
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150
160
170
180
190
200

Figure 2

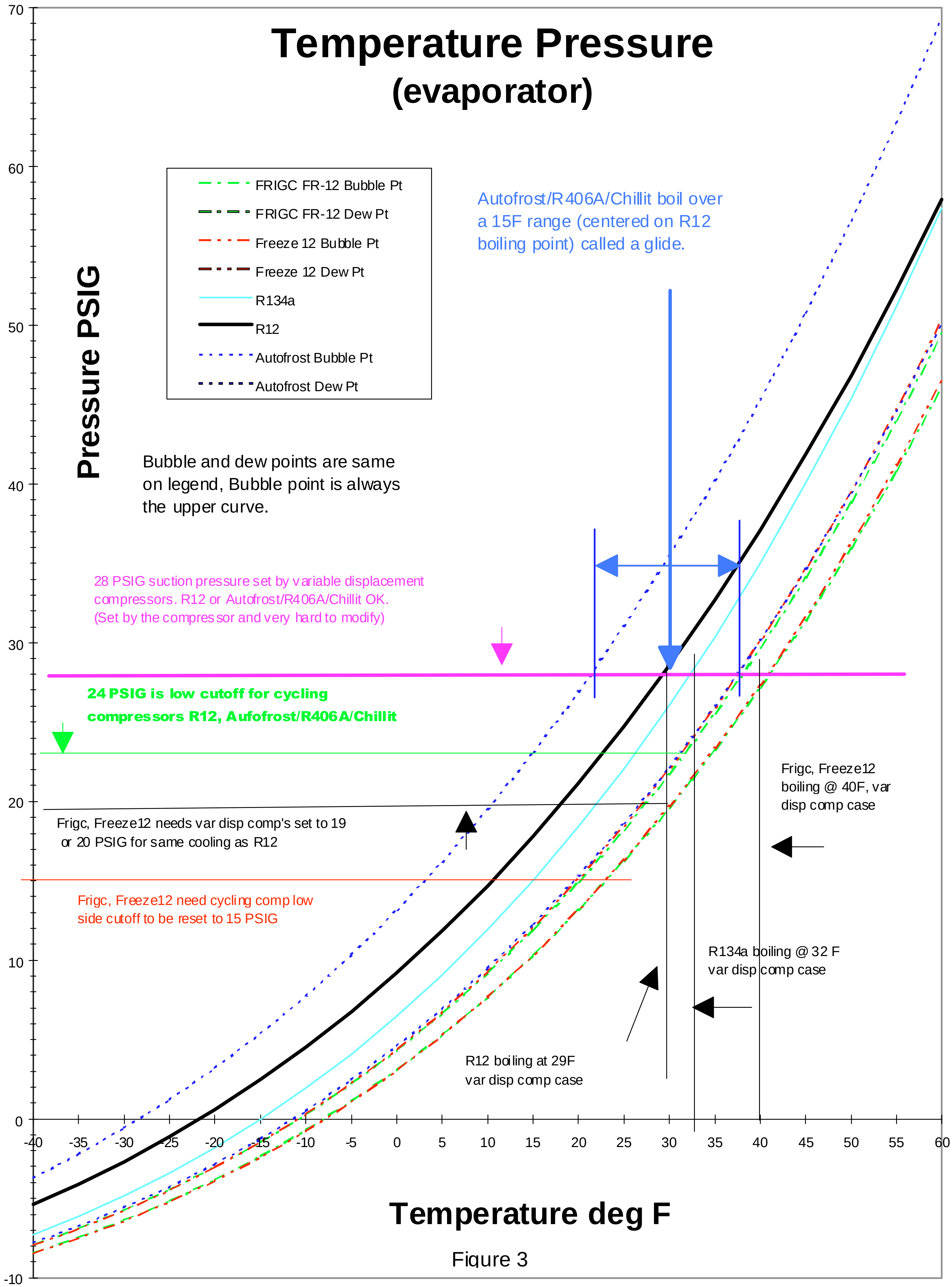
Temperature Pressure
(evaporator)
Pressure PSIG
Temperature deg F
FRIGC FR-12 Bubble Pt
FRIGC FR-12 Dew Pt
Freeze 12 Bubble Pt
Freeze 12 Dew Pt
R134a
R12
Autofrost Bubble Pt
Autofrost Dew Pt
Autofrost/R406A/Chillit boil over a 15F range (centered on R12 boiling point) called a glide.
Bubble and dew points are same on legend, Bubble point is always the upper curve.
28 PSIG suction pressure set by variable displacement compressors. R12 or Autofrost/R406A/Chillit OK. (Set by the compressor and very hard to modify)
24 PSIG is low cutoff for cycling compressors R12, Aufofrost/R406A/Chillit
Frigc, Freeze12 needs var disp comp's set to 19 or 20 PSIG for same cooling as R12
Frigc, Freeze12 need cycling comp low side cutoff to be reset to 15 PSIG
Frigc, Freeze12 boiling @ 40F, var disp comp case
R134a boiling @ 32 F var disp comp case
R12 boiling at 29F var disp comp case
70
60
50
40
30
20
10
0
-10
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
35
40
45
50
55
60

Figure 3

The refrigerant manufacturers who have trouble with refrigerant pressures being too low in the evaporator (FRIGC & Freezone/Freeze 12), will often distribute literature that shows the entire temperature-pressure curve from 0 to 200 degrees F or so, with pressures from vacuum through 500 PSIG or more. On that scale, all the evaporator pressures for all the refrigerants look "about the same" (in the thickness of the graph line). They then will argue that "their refrigerant" operates at the same pressures as R12, etc, One needs to show an expanded graph, showing the temperature-pressure relationships which occur in the evaporator, as they are critical to proper performance. (See figure 3).

When the A/C is first turned on, the car is usually hot, and warm or hot air is being blown through the evaporator. This makes the refrigerant boiling in the evaporator warmer, thus raising it's pressure (look at the temperature-pressure charts). Pick a pressure (or temperature), go across (or up) to find the corresponding temperature (or pressure). For blends, use an average point roughly midway between the bubble and dew point curves. A minute or so after start-up, evaporator temperatures might be 50-60 degrees F, with a corresponding evaporator pressure of 40-70 PSIG, depending on the refrigerant. High glide refrigerants like Autofrost/R406A/Chillit, and Hotshot (Hotshot has problems returning the oil in many systems) will perform superbly during the initial cool down (pull down).

As the car cools down, the evaporator becomes colder as well. Typically, the air being blown through the evaporator is about 10 degrees warmer than the temperature at which the refrigerant is boiling. On the lower right hand quadrant of figure 3, several temperatures are listed for boiling points (in the evaporator at 28 PSIG) of different refrigerants. One must add on about 10 degrees F to each of these to get an approximate cold air duct temperature, to allow for the thermal drop across the evaporator.

Three common methods exist for "throttling back" the A/C when (or if) the car gets cold enough. The simplest method is to have a thermometer at the evaporator (air) outlet and shut off the compressor when it drops to approximately 32F. The last two are much more common and both look at the suction (low side) pressure to decide when to stop/slow down cooling. As the evaporator cools down, the suction pressure also drops. Older cars (such as using the infamous GM "R4" compressor), have a switch in the low pressure side of the system which opens at about 24 PSIG, cutting off the compressor. The evaporator warms up, and when the pressure reaches around 40 PSIG, the switch closes again, restarting the compressor. This method causes a lot of wear and tear on the compressor clutch. Newer cars, have "variable displacement" compressors, which run continuously instead of cycling off and on. They have a "swash plate" instead of a "crank shaft" to anchor the pistons. The "stroke" of the pistons in this type of compressor may be varied from maximum to almost zero, by varying the angle of the swash plate. A GM "V5" is a common example of this type of compressor. These compressors usually have an internal mechanical arrangement to control the swash plate based on the suction (low side) pressure. They are usually set for about 28 PSIG. When the car is hot, the suction pressure will be much higher than 28 PSIG, so the compressor operates at full stroke. The car cools down, the suction pressure drops down through 28 PSIG, and the swash plate moves, reducing the stroke of the pistons, and lowering the capacity of the A/C, and the suction pressure will stop dropping, and stay at around 28 PSIG. The compressor will continue to reduce displacement by maintaining the suction line at 28 PSIG if the car cools down too much. If the sun comes out, and the car begins to heat up, the suction pressure will rise above 28 PSIG, and the compressor will increase it's displacement to bring the pressure back down to 28 PSIG.

Autofrost/Chillit/R-406A work well in all three types of systems. Frigc FR-12 and Freezone / Freeze 12 offer inferior cooling capacity with the last two (most common) types. Go to figure 3. We will discuss the variable displacement compressor case first. There is a horizontal red (really magenta) line crossing the vertical (pressure) axis at 28 PSIG, the common setpoint for variable displacement compressors. The 28 PSIG line intersects R12 at about 29F temperature, so that is where R12 will "boil" once the A/C system has stabilized at 28 PSIG suction pressure, and the evaporator air should be about 39F or 10 degrees warmer allowing for thermal drop across the evaporator. This will vary somewhat depending on the blower fan speed. The 28 PSIG line intersects the (average) of the Frigc & Freezone/Freeze 12 curves at about 40F. Adding the 10F evaporator drop, means that the duct temperatures will never get below about 50F for FRIGC/Freezone/Freeze12 or about 10F warmer than with R12. Autofrost/Chillit/R406A (average between bubble and dew points) closely match R12. However, the wide glide of Autofrost will result in sometimes 6-10F colder duct temperatures during cool down.

For a variable displacement compressor to offer good performance with FRIGC / Freezone / Freeze12, it would have to have it's "setpoint" changed to 19 or 20 PSIG from 28 PSIG. This is very difficult to do at the present time. This pressure is fixed and there is no easy adjustment. Even if the setpoint could be lowered to 19 PSIG to make FRIGC/Freezone/Freeze 12 work better, there is roughly a 25% reduction in pressure and corresponding reduction in "mass flow" and lowered capacity. The suction pressure is lower, therefore less gas molecules enter the compressor (about 25% lower) and circulate in the system so it cools less.

The cycling clutch type system also performs well with Autofrost/Chillit/R406A. The normal compressor cutout switch is set to about 24 PSIG. FRIGC / Freezone / Freeze12 "wants" to run about 19-20 PSIG instead of 28-30 PSIG (R12, Autofrost/R406A/Chillit) to produce it's best results. If the 24 PSIG cutout switch is not changed with these refrigerants, then compressor clutch cycling will begin at much warmer temperatures than with R12/Autofrost/R406A/Chillit and the clutch will cycle more often, further warming up the duct temperatures and causing excessive clutch wear, possibly causing it to fail in a couple of months. The best performance from FRIGC / Freezone/ Freeze12 is obtained when the low side cutout switch is changed from 24 PSIG to about 14 or 15 PSIG. This will reduce compressor cycling to about what R12 sees. However, there will still be about a 25% loss in capacity due to reduction in mass flow due to lower suction pressures compared to R12. (less gas is circulated in the system).

Oil Return to the Compressor

While some other blends, notably ICOR "HOTSHOT" and Atochem "FX-56" (R-409A) [FX-56 is not EPA SNAP approved for cars, only stationary equipment] will offer similar "good cooling" performance like Autofrost / Chillit / R406A, they do not dissolve well in the standard mineral oil and may not properly return it to the compressor from the evaporator. This can result in compressor failure (lack of oil) in some systems. It is estimated that 70-80% of systems will still function OK with poor oil return. 100% of the systems will function for some period of time, often a few months, as the oil slowly works it's way out of the compressor and becomes stranded in other parts of the system. There is no way to really know before hand which systems will continue to run and which ones will fail the compressor from poor oil return. FX-56, HOTSHOT, FRIGC FR-12, Freezone, Freeze 12 will provide good oil return if the oil is changed to alkylbenzene (AB) oil, which is a super refined form of mineral oil.

Of the FRIGC FR-12 / Freezone / Freeze 12 group, all of them are very poor at properly returning mineral oil to the compressor. FRIGC admitted in a full page ad (Jan 1996) in the "Air Conditioning, Heating and Refrigeration NEWS" to having to add POE (polyol ester) oil to work in car A/C systems. Freezone adds 2% of a special lubricant to their refrigerant since the raw gas does not return mineral oil well. What happens after a few "recharges" with Freezone? The oil can build up in the system, break compressor valves, and other "slugging" from the excessive oil. We guess that Freeze 12, just hopes for the best (no oil additive).

Compatibility issues

KNOWN compatibility issues (11/29/96)

There is a suspected seal compatibility problem with Autofrost (R-406A) and Autofrost-X4 with York (automotive) compressors using Butyl rubber seals in some cases. Seals may fail (usually 30 mins to one hour) after the car is turned off, due to heat soak from the radiator bleeding into the condenser and raising pressures. Leaky heater water valves contribute to the problem since they allow heat to build up in the evaporator area, further increasing pressures. Dirt buildup in the radiator and condenser area also contributes by preventing the release of trapped heat after the engine is turned off.

Neoprene seals are available which appear not to have this problem. For more info, contact Bobby Burke, ATC specialists, 1-800-622-5008, or email bburke@intersource.com. Web page: http://www.kiva.net/~bburke Autofrost (R-406A) and Autofrost-X4 (GHG-X4) move more heat than does R-12.

Cars with poorly maintained cooling (radiator) systems, may encounter radiator boilovers and overheating problems when changing to Autofrost, since more heat is transferred to the condenser, which rejects the heat into the radiator. It is a good idea to have the engine cooling system checked over when switching to Autofrost to prevent a dirty/clogged radiator or leaking heater water valve from causing A/C problems.

There was a suspected seal compatibility problem with Autofrost. York, Techumseh and the old Chrysler RV2 compressors were thought to have a butyl rubber seal, however it has been discovered that these seal kits were made of Buna-N rubber. It has been known for many years that R-22 and Buna-N rubber are not compatible. Our research indicates that neoprene 70 is the best material for both compressor shaft seal kits and system O-rings. The makers of the York compressor have now started making their seal kits with Neoprene and manufacture neoprene seal kits for most other compressors on the market as well. Neoprene is the ideal rubber for both compressor seal kits and O-rings since it will work with all refrigerants including Autofrost and R-134a. There might still be “new old stock” seal kits on the shelves at local parts stores so technicians should ask before they buy them.

We are currently discussing stocking and selling these seal kits and we are working on a master O-ring kit that will service most vehicles, foreign and domestic. We will make these available through Monroe Air Tech Inc. or tell you where they are available as we are constantly searching for other sources. O-rings are already available at most parts places. Four Seasons, Murray, and Everco have Neoprene and they are dark blue in color. GM has used a black neoprene for several years. These are available from GM dealers or AC Delco distributors. There are also green O-rings known as HNBR. This rubber was developed for R-134a because it was thought to have better heat characteristics. Also Ford used this material for their spring lock fittings. They even used an odd size (thicker) to try and keep these fittings from leaking. Autofrost will work fine with this rubber if it came from the OEMs, however HNBR O-rings that are purchased elsewhere are many times of cheap quality and will not fare well. For this reason we ask that you to always ask for Neoprene. [4/15/97 update: Bob Burke @ ATC Specialists now has shaft seal kits and O-ring kits available]

On 86 and newer Ford models, safety pop-off valve on or near the compressor has a rubber seat. If this valve ever opens, then it might not reseal and leak. The cure is to use a GM pop-off valve instead (they use steel ball and seat?). We have also seen the Ford pop-off valves open at about 250 PSI, which is way too low.

ALL BLENDS, INCLUDING AUTOFROST, *MUST TO BE CHARGED AS LIQUID to prevent composition change, and possible damage resulting to the system*. Autofrost/R-406A/Chill-it/R-414A cylinders contain a DIP TUBE that withdraws the product as liquid from the bottom with the cylinder UPRIGHT. DO NOT turn the cylinder upside down to get liquid!! This will give you vapor instead. Cylinders are marked with arrows to keep upright for liquid.

No matter how much laboratory testing is done under simulated and elevated temperature conditions on materials compatibilities, field conditions are not always simulated properly. For instance, some material breakdown will be noted in a lab sealed tube test, at say, 300 degrees Fahrenheit. Most chemical reaction speed is determined by temperature, often decreasing by a factor of two for each 10 degrees the temperature is lowered. Failures in a sealed tube test in a lab at high temperatures often equate to 40 or 50 years or longer at normal temperatures encountered, far longer than the life of the car. Quoting from a DuPont publication materials compatibility section: "Actual refrigerant compatibility in real systems can be influenced by the operating conditions, the nature of the polymers used, compounding formulations of the polymers, and the curing or vulcanization processes used to create the polymer. Polymers should always be tested under actual operating conditions before reaching final conclusions about their suitability" [1].

Compositions close to Autofrost (R-406A) have been used in actual vehicles since August 1990.

For further information on compatibility issues, contact Bob Burke, ATC Specialists, 1-800-622-5008 or MEA, 1-888-AUTOFROST [1-888-288-6376], ask for code 10.

[1] "DuPont SUVA(R) MP Refrigerant Blends: Properties, Uses, Storage and Handling, page 20,_stock number H-45944-2 (5/93), DuPont Chemicals, Fluorochemicals Customer Service Center, Wilmington, DE 19898.