R.V. Refrigerators

Theory of Operation

One of the most expensive misunderstood and misused appliances in the typical RV is the gas/electric refrigerator. Let's take a look at how they work- what can go wrong- and how to keep from having problems.

There are two basic systems to deal with in these types of refrigerators- the control system, and the refrigeration system (cooling unit) itself. The control system will be very different for every make and model of refrigerator, but the refrigeration systems all basically work the same way.

First we will see how the refrigeration actually happens, and how to help your refrigerator work its best.

When I first started Rving, I took LP gas refrigeration for granted, but after a while, curiosity began to take hold- how in the world can you put in fire at one end, and get cold out of the other? While I read and studied and kind of had an idea how it worked, I finally had the "epiphany" in a Norcold course, taught by Brent Grieves, a technical trainer/technician for Norcold, who explained it so that I could finally understand it.

Now- I will try to explain it to you.... (in a fairly non-technical way)

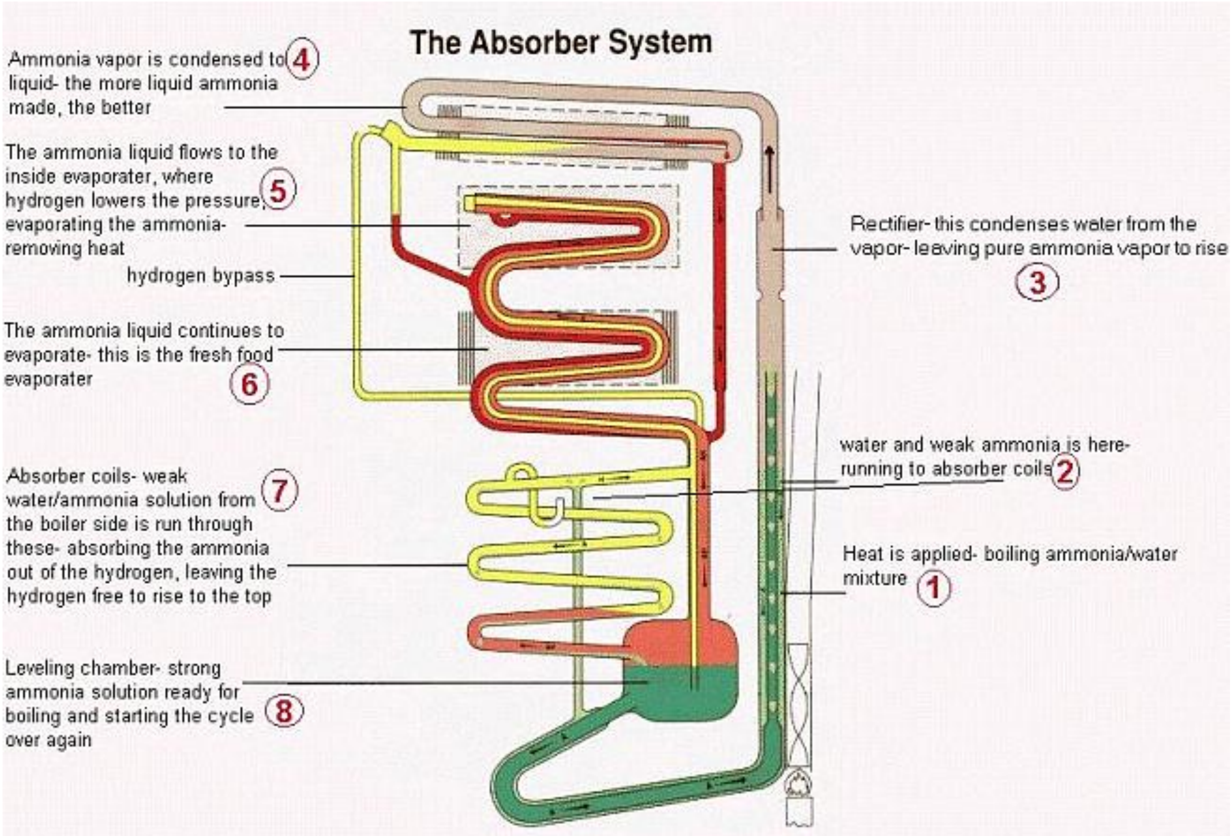
The refrigerant in LP gas/ electric refrigerators is ammonia- the oldest refrigerant used. In addition to the ammonia, the refrigeration system contains water, hydrogen, and an anti-corrosive agent.

The system is made up of several different parts- we will start at the boiler. ***1*** In the boiler, the ammonia/water solution is heated, vaporizing it. In an RV refrigerator, the heat can by generated by an LP gas flame or an electric heating element- the heating element can be 120 volt AC, or 12 volt DC. Once the ammonia/water mixture is heated and turned to vapor, 3 it naturally rises into the next part of the system- the water separator or rectifier, where the water condenses, and runs back down into the boiler. ***2***

The ammonia stays a vapor, and rises to the condenser fins, at the top of the system ***4***- these are the fins that you will see if you remove the top vent over the refrigerator. The only purpose of this part of the system is to make liquid ammonia out of the ammonia vapor- the more liquid ammonia it can make, the better the system will cool, as pure liquid ammonia is the heart of the cooling cycle.

Once the evaporator has made liquid ammonia, gravity takes over, running the liquid down into the evaporator section, which is actually inside the refrigerator box. In this section, the liquid ammonia comes in contact with the hydrogen, which causes the ammonia to evaporate again, ***5*** drawing heat from the inside of the refrigerator. In a properly charged system, which has enough air flowing over the condenser, enough liquid ammonia is made that there is enough to keep evaporating until it has run down the evaporator coils into the fresh food compartment. ***6***

From here, the ammonia/ hydrogen mixture vapor, being heavier than pure hydrogen, sinks through the lower coils, where it is combined with a weak water/ ammonia solution, which absorbs the ammonia, leaving the hydrogen free to rise to the top of the system. ***8***



While I have left out some steps- this is the basis for gas fired refrigeration.. so... We can see that the three basic requirements are the proper amount of heat at the boiler, a good air flow over the condenser fins (and absorber coils), and the real kicker- gravity (down has to be down).

While most modern RV refrigerators will adequately somewhat off level (the popular recommendation is that if it is comfortable to walk in your rig, it is good enough for the refrigerator), they will still work better and last longer the more level you make them.

Testing

So .. to applying this knowledge to troubleshooting a cooling problem (as opposed to a control problem) is fairly easy- start by leveling the rig, next carefully check the venting, both upper and lower, to make sure that the air flow is unobstructed, and finally, you need to apply a set amount of heat to the boiler.

The two ways that heat is applied are by an LP gas flame, or by an electric heating element. Because the LP flame is so small (~1500 BTUs average), it is very difficult to determine if the flame is the right size, generating the correct amount of heat. Fortunately, because of an electrical formula named Ohm's law, determining the output of a heating element is easy, so this is the method that we use.

You need to know the voltage rating and the wattage rating of the heating element - you can find a chart here (link coming soon) - (which will actually give you the resistance value- cheating!), square the voltage rating (example, if the element is rated at 120 volts, multiply 120 X 120 = 14400). Next, divide this sum by the wattage rating (example, if the element is rated at 300 watts, 120 volts, divide 14400 by 300 for a result of 48). This result will be the resistance of the element- in the example the resistance is 48 ohms.

So- if you disconnect the 120 volt heating element, measure the resistance, and it is within +- 10 % of the value you came up with, and if you measure the supply voltage, and verify it is within 10%, you can hook the heater directly to the supply power (bypassing the controls) and know that you have applied the correct amount of heat the the cooling unit boiler. This is, in my opinion, the only way to determine if there is a problem with the control system, or the cooling unit itself. After you have done this, wait at least 12 hours, and the freezer should be near or below zero, and the fresh food compartment should be near or below freezing. The only caveats are that if it is very hot, and the refrigerator side of the RV is in the sun, it may take a little longer to cool this well, and if it is extremely hot (the south in summer), and the area around the condenser coils gets above 110 - 120 or so (which, in the sun, isn't that hard to do), the condenser will not be able to make enough liquid ammonia to adequately cool the "box" (but- before you condemn absorption refrigerators- virtually no modern refrigerator will cool if its' condenser temperatures are above 130).

Bottom line

With the proper ventilation- enough air over the condenser coils to make liquid ammonia, if the unit is level, and with the correct amount of heat applied to the boiler, unless the cooling unit is bad, it will cool.

Tips

A couple of tips- if the refrigerator has been working, and it suddenly stop cooling, turn it off for one to two hours, re-level the RV, and turn it back on. Sometimes the flow of ammonia can become "vapor locked", and turning it off will allow the pressures to equalize (the old method was called "burping", and consisted of taking the refrigerator out of the coach and turning it upside down.. newer models- built since the early 1980's, do not need this, nor will it help).

A venting tip is that there is a minimum clearance at the back of the refrigerator. If the back wall is more than one inch away from the refrigerator coils, an added baffle will greatly improve the efficiency, because a large gap will allow the air drawn in by convection to bypass the coils, but if you put a baffle in to force the air to pass over the coils, the refrigerator will cool much more efficiently.

Theory of operation

While all RV gas/electric refrigerators use the same principal to cool, the method used to control the cooling, in addition to energy source selection, has evolved over the years.

In its' most basic form, the control simply applies heat to the cooling unit when cooling is required, and removes the heat when it is cold enough. In the early years, purely mechanical controls were used, requiring the user to go outside, open the exterior access door, and flip a switch to turn on the electric part, which was controlled by a mechanical thermostat that turned the heating element on and off, or light the burner, which was controlled by a mechanical gas thermostat- because the flame had to be lit by hand, the gas thermostat would not shut the flame off when the refrigerator was cold enough, rather they had a "bypass" in them which would let the flame keep burning at a very low level.

It is worthwhile to note that the smallest modern gas/electric refrigerators still operate this way.

The electric side of these refrigerators is pretty straight forward, consisting of a switch (which should have some sort of interlock to prevent the electric and gas from operating at the same time), the thermostat (which simply turns the electricity to the heating element on and off as required), and the heating element itself.

The gas side is slightly more involved, simply because it will contain a safety valve which will shut the flow of propane off if the flame is extinguished- other than that, it consists of a valve (with the interlock), a thermostat (which closes when the refrigerator is cool enough- but has a bypass in it so as to keep the flame burning on low), and the burner itself, which consists of a precision drilled orifice (to regulate the flow of gas on high), and the burner head.

On purely mechanical refrigerators, there have been a few different types of safety valves- the first being a "Klixon" valve which consisted of a bimetal disc, which when heated would pop up and open the valve- if the flame went out, it would cool down, snapping closed and shutting the flow of propane. Because these have been obsolete since the mid 1960's, you probably will not ever see one, unless you are interested in vintage rigs. The next type of safety valve, which is still in wide use today, is the thermocouple/mechanical valve setup. In this type, when the thermocouple is heated, it produces a very small electrical current, which is used to hold an electromagnetic valve open. The tell-tale sign of using this type of safety is that you will always have to hold the valve open (either by pulling, pushing, or turning something) until the thermocouple is heated enough, at which time the current will hold the valve open. Again, if the flame blows out, the thermocouple will cool and stop producing the current, which will allow the valve to close, shutting the flow of propane.

Something to keep in mind is that even though it looks like a small tube, the thermocouple is actually an electric device. The tube like "lead" simply contains some insulation and an inner wire- the outer sheath is the ground, and looking at the end that screw in to the safety valve, you will see the outer nut, and the contact on the very end, which is separated by a small piece of insulating material.

Igniting the flame in the first place has evolved from lighting it with a match, to having a flint spark lighter, to a piezoelectric lighter, to the electronic re-igniters that are still in use today. The benefit of the electronic igniter is that it will stay active (though not sparking), and be ready to re-light the flame in the case of a blow out.

Troubleshooting

If you have already performed the troubleshooting for the cooling unit, you will know that the cooling unit and heating element are OK. The next question is whether the problem appears on electric operation, or LP gas operation.

Electric operation testing is fairly straight forward- with a volt-ohm meter check the outlet the refrigerator is plugged in to. Then check the power coming out of the selector switch (note that on some models the selector switch is not easily accessible, so it is easier to check the power in to the thermostat) - then the power out of the thermostat. A tip - be sure to check across the two leads - on some later model refrigerators, both the hot and the neutral lead are switched, and if you are checking with a grounded lead on your meter, you might miss a bad neutral side connection in the switch (I know I have).

These tests, along with the resistance tests of the heating element (which would have been done in the cooling unit test) pretty much cover all of the 120 volt electric side of the refrigerator.

The LP gas side, as far as troubleshooting is concerned, isn't much more difficult, though different techniques are used to test, as well as different testing tools.

If a refrigerator works fine on 120 volt ac power, but doesn't cool on gas, I generally work backwards from my electric troubleshooting- making only a rough test of the LP supply first- by simply lighting three or four burners on the range and visually "guestimating" whether the LP pressure is good by seeing if the range burner flames look good, and do not decrease in size when all burners are lit. Note that this is not the "book" way- but it is the first thing that I do.

After doing a rough test on the LP supply, I do a visual inspection of the flame. If the flame will not ignite, I will light it manually by having a helper hold the safety valve (on most refrigerators you need someone on the inside to engage the safety, while you light the flame- but not all). If the flame lights and burns well, you know that the problem is in the ignition system. Troubleshooting these is usually fairly straight forward- if it is a push button system which snaps when you push it, it is a piezo electric system. These are really very reliable, and if they still "snap", the problems will usually be either in the spark probe/ gap, or in the spark cable itself. Problems in the spark probe or gap are generally confined to an improper gap or rust flakes shorting out the gap, or a broken porcelain insulator around the probe. Problems with the spark cable are generally caused by the cable having been damaged in some way- either burned or cut. Many times these can be found by waiting until dark, and having a helper push the sparker button while you look at the cable- just like a spark plug cable in an auto, you will usually be able to see where the cable is shorted. For electronic igniters, a simple test of 12 volt power going to the electronic ignition module will be first - if that is good, then inspect the cable, probe and gap as above - if these test good, the module is probably bad.

Once the flame is ignited, you can do a visual check. The flame should be clean, "hard" and blue. If it is "lazy" (not a well defined flame), or yellow- I will generally carry out the standard maintenance procedures, which should be done once a year, but usually are not. This consists of cleaning the burner and orifice by removing them and soaking them in alcohol, then letting them air dry. While you are checking these things, something else to watch for is whether the flame is getting a good draft- whether it is going up the flue well. If the flame has been burning poorly for a while there is a good chance that the flue a baffle could be covered in carbon soot. While the "proper" way to deal with this is to remove the refrigerator and physically remove the baffle and run a brush down the flue, many time compressed air blown up the flue will get the job done.

A couple of points here- until the past few years (everything up to the 9XX and N series), Norcold has used a very inexpensive orifice together with a copper sealing ring. If you remove the orifice in one of these, you need to have a new copper ring to reinstall, and because the ring/ orifice together cost less than $5.00, I don't bother cleaning them, I just replace.

Dometic orifices are somewhat more expensive, consisting of a synthetic sapphire that has been laser drilled. The laser drilling operation actually leaves "rifling" in the orifice, which spins the LP gas stream. These rifling slots are easily clogged, so it is good practice to clean these whenever maintenance is performed on the burner.

Once these procedures have been done, I move on to actually testing the LP pressure at the burner- which most manuals call for earlier in the process, but I usually leave this far later, simply because the cleaning problems seem to be more prevalent. Checking the LP pressure is not terribly hard, but it does take an instrument called a manometer . While this sounds expensive (and can be), a perfectly accurate manometer can be built very inexpensively. Rather than duplicate the plans here, check out Les Dolls' website - RVer's Corner- here.