Understanding and refilling an Engine driven boat Fridge/Freezer

Firstly, I must say I am NOT a licensed refrigeration engineer. However, I have been using these systems for over 15 years (before that my boats didn't have freezers!), and have learned a thing or two about them. Like most items on my boat, I try to DIY whenever possible. There are SOME things that you are likely to need a fridge tech for, but much less than you think! In many locations around the world, there are no technicians available, it's up to you!

So here we go. The first part here is about the components, and how the system works – if you are already familiar with the basics, and just want recharge instructions, scroll on down!!

System components and functions;

Here I will be talking about a eutectic fridge freezer – one that uses holding tanks/condensers in the fridge/freezer compartment, as that is the most common engine driven system, and what I'm used to. There are other systems, but this is the most common on our older, NZ boats. With engine driven systems.

Let's begin at the basics. A fridge (or freezer) works by forcing refrigerant through a restrictive device, causing a pressure drop. To force the refrigerant anywhere you need a compressor. Here is a pic of a common one, the Sanden SD508;

Forcing (compressing) the refrigerant causes heat. To get rid of the heat a "condenser" is used. It's just a heat exchanger, normally cooled by seawater in this application. It's called a "condenser" as it condenses the gas refrigerant to liquid by cooling it. The Condensor can take many forms, but it will be something like this;

So the compressor pushes the refrigerant thru condenser then the restrictive device, as I said, causing a pressure drop. This pressure drop lowers the boiling point of the refrigerant causing it to evaporate, a which significantly lowers it's temperature. The restrictive device is normally, on the engine driven systems, a small hole called an expansion valve. Here is a common example of an expansion valve;

After the expansion valve the cold refrigerant is lead through a tank of liquid, know as holding tanks or plates. They also work like a heat exchanger, and the cold refrigerant transfers its temperature into the liquid in the tank/plate which should freeze solid when fully cold. The liquid in the tank can be several things, common ones being meths solutions, or ethylene glycol solutions. It is very important to make sure that these tanks have the right level of solution in them to ensure that they freeze solid when fully cold. This is because the "change of state" between liquid and solid holds and releases MUCH more energy as it is warmed/cooled than just a liquid. You can adjust the freezing point by adding more or less water to the solution. Remember not to fill the tanks to the top – the frozen solution will expand, and could rupture the tank or crush the internal refrigerant lines if overfilled.

When the refrigerant leaves the holding tank, it will have warmed, as it has given that energy to the holding tank. It won't be warm, just warmer! It may (Should) cause Ice to form on the return line to the compressor. It is VERY important that the ice does not go all the way back to the compressor, as if it does, the compressor could be trying to compress liquid refrigerant. Liquid cannot be compressed, so it will break the compressor! $$$

Fortunately, the amount of refrigerant coming back from the system controls the amount of frosting on the return (or low pressure) line, and this can be adjusted with the expansion valve. The expansion valve should only be adjusted when the system is COLD! Adjust in small increments, no more than ½ a turn of the adjustment each time. The system will take a bit of time (5 mins or more) to settle to the new setting, so be patient!! More on this later!

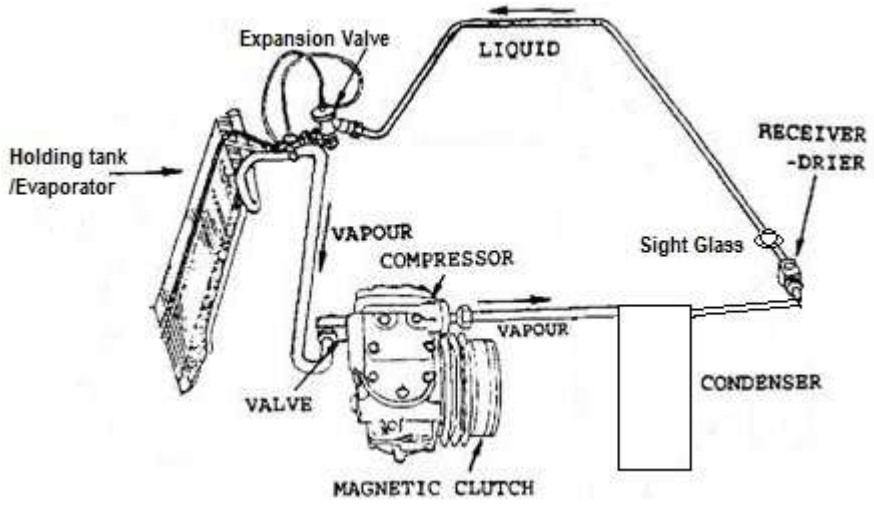
That is the complete circuit, once returned to the compressor; the refrigerant goes around again...

There are a couple more components. Refrigerant is hydroscopic – that is it will absorb moisture – and, if it does, it won't work properly. It will even suck moisture out of Air. Therefore it must be handled with care and kept away from any moisture source. A tiny bit of moisture will get into the system regardless of how careful you are, so in between the condenser and expansion valve there should be a Filter/Drier. It likely looks like this pic. Like it's name says, it is a filter and a drier. Filters crap out, and absorbs moisture.

There are two more components, a sight glass, like this; It is not on all systems, but if it is not on yours, it should be! The sight glass allows monitoring of the refrigerant levels, moisture content, and condition of the refrigerant. As you can see in the pic, the colors of the central spot show moisture content – this one is wet.

The final component is an accumulator. I have not put in a pic, as there are many different possibilities, but basically it is just a reservoir for refrigerant, and allows a bit more tolerance in charge levels. Often it's just a cylindrical tank.

So, here is a basic pic of the components in general arrangement;



It does not show the accumulator, or that the Holding tank/Evaporator is in the Fridge/Freezer, nor that the condenser is seawater cooled, but they are!

So, now you know what is in there. Next are refrigerant types.

Refrigerant

The old R12 is no longer available, and most systems have been upgraded, often to R134A, but not always. There are several others. You NEED to know what is in yours – it is often written on the system somewhere. You cannot mix refrigerant types!! They may also use different oils which are not compatible. This brings us to the next topic, Oil.

Oil

The system contains a small amount of oil (normally 250-300mls). Many systems that were upgraded to R134A from R12 refrigerant use an Ester oil, but your system could use PAG or mineral oil instead. Again, they cannot be mixed, and you NEED the correct one, and the correct amount. If in doubt, and you need to change or top up your oil, employ a refrigeration engineer! The wrong one will likely kill the compressor, and/or make the system less efficient.

It is not common to require an oil change, unless changing the refrigerant, compressor, or commissioning a new system.

Problems with engine driven compressor systems

The most common issue with these systems is lack of refrigerant. It is not difficult to recharge them, but some basic knowledge is required. The problem can be caused by leaks in the lines, or any of the components, and can be difficult to fix, as it is common for them to take months to lose the refrigerant.

In systems that are not used for months, the compressor seals can dry out and leak. When you turn it on again, the seals recover (to a degree) and the system will work, if sufficient refrigerant remains. If the system is old, the rubber hoses that normally attach to the compressor to allow for engine movement can become permeable, and need to be replaced. Note – systems designed for R12 and then upgraded to R134A NEED new hoses. The old ones were not designed for R134A and they will leak, albeit slowly.

When your fridge/freezer won't cool

So, you go down to the boat for the annual cruise, and the fridge won't get cold. What to do? Here is the basic fault finding;

1. Does the compressor turn when switched on – not just the belt, but does the clutch engage with an audible click, and the compressor shaft begin to rotate?
2. With the system off (for 10 mins or more if it has been on) the sight glass should be empty. Turn on the compressor, and watch the sight glass – there will be bubbles, then the sight glass should be full, after a few mins with NO bubbles. Be patient – it takes a while, sometimes ½ and hour or more dependent on the compressor and the size of the system.

Most likely, if the compressor is going, there are bubbles in the sight glass, and/or it is not full, all that is wrong is the system is low on refrigerant.

Pressure Switches

If your system has a pressure switch to control the compressor on/off, it is likely you will hear the compressor switch on and off quite rapidly (seconds not minutes) after it has been running for some minutes. A rapidly cycling compressor is a classic sign of low refrigerant levels. Some systems do not have pressure control, and will just keep running regardless of refrigerant levels. Pressure switches safeguard the compressor, and will not allow them to run at either very high, or very low pressures. They are, however, more time consuming and complex (therefore expensive) to set up correctly than electric thermostat switches.

Recharging a system with refrigerant.

So, you need to add refrigerant? Fridge techs are rare and elusive beasts. Often, outside of the main boating areas, you cannot find one who has any experience on boats. If you just need to top up the refrigerant, you can do it yourself, quite legally, and easily. What you normally cannot do, is to

empty the gas – the recovery equipment is expensive and normally it is cheaper to get a fridge guy to come and do it. It is ILLEGAL to vent the gas to the atmosphere. Don't do it! It really is bad for the environment.

Starting with an empty system

A completely empty (but with oil!) system must be vacuumed down to remove any moisture in the system. For this a vacuum pump is needed. Many offshore boats carry refrigerant, gauges, and a vacuum pump, as do I. You may be able to borrow one. If your system is absolutely empty (nothing at all happens at the sight glass with the compressor starting up from a warm system), then you must find out why before refilling, as you'll just be wasting your time. Personally for this I've used compressed air and a 50/50 mix of dish liquid and water to find the leak. You may have to test the system piece by piece, and it can be slow work, but find the leak you must. Remember it can be inside the condenser, holding tank/evaporator etc. Once the leak is found and repaired...

Connecting a Gauge Set/Manifold

Connect the gauge set – to the compressor – blue is low pressure, yellow is for the vacuum pump or refrigerant bottle, and red is high pressure.

Connect the vacuum pump to the yellow hose, and open the low pressure valve on the blue side of the manifold set. Now start the vacuum pump to pull the system down to -30psi, and leave the pump running at that pressure overnight. The next day, close the valve on the gauge manifold set, and switch off the pump. The vacuum should remain, provided the system has no more leaks. Some leave the vacuum for several hours to see what happens, but I've always found if it holds the vacuum for 20 mins without the pump running it should be ok. You are now ready to fill up the system.

Purging the Gauge Set/Manifold

It is very important to "purge" the hoses of air – even the amount of air in the hoses will add moisture to the system that you don't want. So, to do this with you need to fill the hoses with refrigerant. Connect the refrigerant tank to the yellow hose, and open the tank valve. Now the hose is pressurised. At the manifold end, slightly loosen the yellow hose, and you will hear the air in the hose hiss out. Let that go until you are sure the hose is full of refrigerant (a second or two). Now tighten the hose connection again. OK, ready to start.

To being to fill, open the low pressure valve the manifold (by the blue gauge), and refrigerant will get sucked into the system by the vacuum, as well as pushed by the pressure in the refrigerant tank. Fill the system to about 60 psi (if the refrigerant in the tank is a bit low, it might not go that high, but that is ok). This is the "initial charge". Now close the refrigerant tank valve (on the bottle), and shut the LP valve on the manifold. Time to start the compressor.

Refilling a partially charged system

If you are just recharging, then you can start the instructions from here, and forget about the vacuum stuff! Attach your gauges and Manifold and purge the gauge set, as above.

Start the compressor, and watch the sight glass. It should start empty, and fill. As the initial charge is unlikely to be sufficient for the system, there will be bubbles. Run the system for a few mins, then you are ok to begin to add refrigerant. Do it slowly! It takes some time for the refrigerant to cycle around the system as to stabilise the pressures. Completing charging can only be done once the system is fully cold. You add refrigerant simply by opening the refrigerant bottle valve, then the manifold valve, and the compressor will suck in the refrigerant. Watch the low pressure gauge, it will rise when you open the valve to allow more refrigerant in. Let it go in for a few seconds (10??) then shut it off and give in a couple of mins. Then look at the sight glass – you should monitor this pretty well all the time. Still got bubbles going passed, or the glass is not full? Add a bit more. Monitor the sight glass. Repeat until no bubbles, and sight glass is full. This can take up some time – an hour or two on a large freezer. It is not done until the unit is fully cold, AND the sight glass is free of bubbles and full.

During this process, (indeed at any time the freezer is running) you will see frost forming on the return line to the compressor. If the frosting is getting close to the compressor, you need to prevent frost from reaching it. Sweating is ok, frosting is not. It means that liquid refrigerant is coming back down the return line. The compressor cannot compress liquid – it will break. You can move the frosting point back up the line by closing the expansion valve slightly – then wait, while it settles down for a few mins. You will see the frost line moves up and down the return line a bit while running – in a rough cycle. This is fine – it is the expansion valve working against it's spring, and is completely normal!

So, the system is full, the frosting on the return line never gets to the compressor, and you have a fully cold fridge/freezer? Great! Load up the supplies and go sailing!!

Merry Christmas!!

Matt