What is a Refrigerator?

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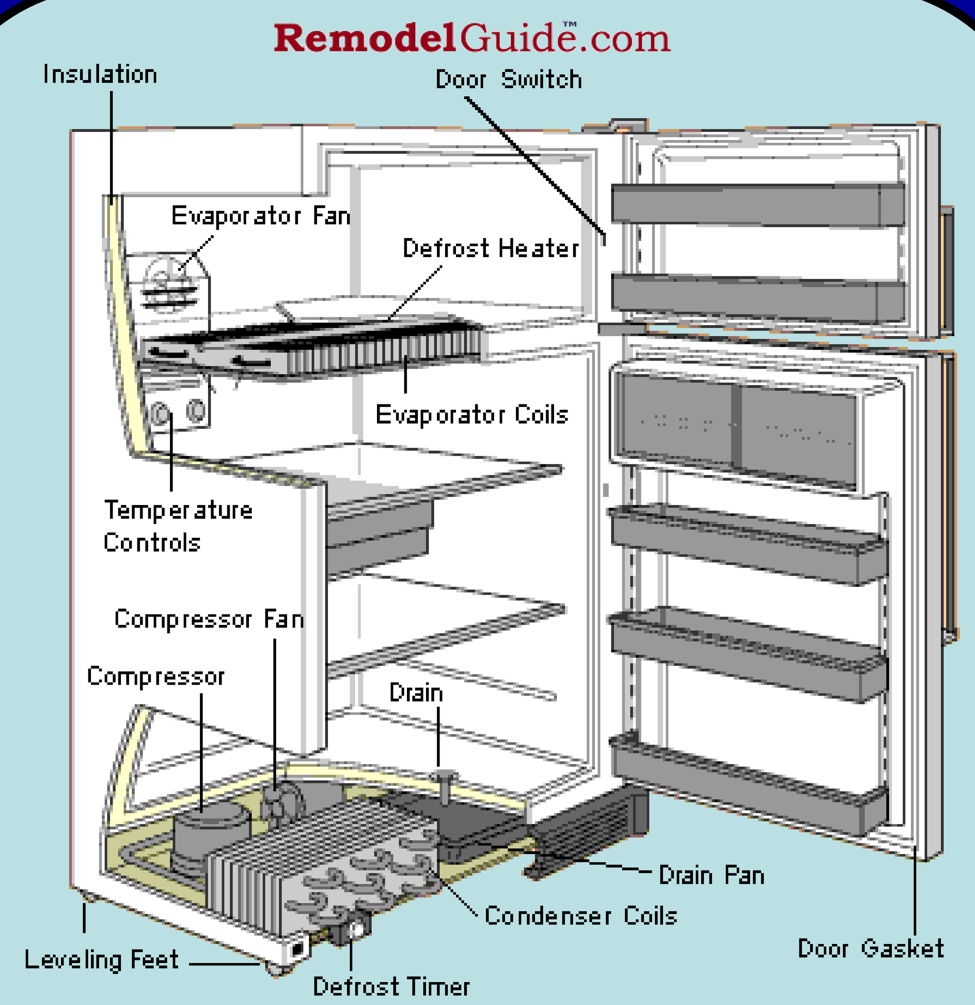
A Common Idea of What a Refrigerator is:



A dictionary definition of what a refrigerator is:

A space where food is kept cool by means of ice or mechanical refrigeration.

An engineering definition of a refrigerator:

A device that moves energy from a low temperature source to a high temperature sink.

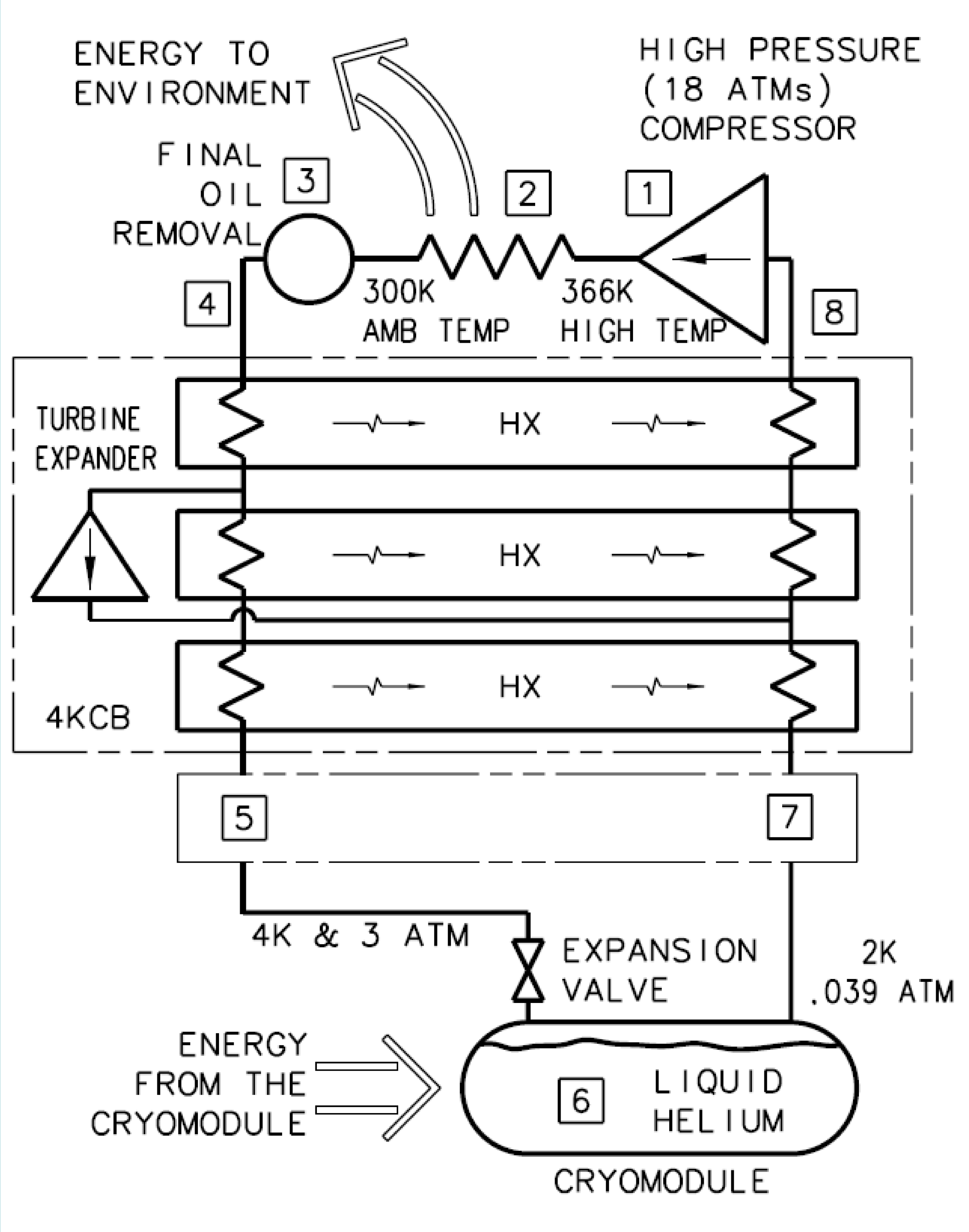
How Does Jefferson Lab's Refrigerator Work?

Background:

- 2 Kelvin equals -456ºF. 300 Kelvin equals 80º F
- 1 atmosphere is 14.696 pounds per square inch.
- 2 Kelvin refrigerators use helium because helium does not solidify at 2 Kelvin. All other gases solidify and either damage moving parts or stop flow of the cryogenic system.
- At ambient pressure (1 atm), the boiling point of helium is 4.2 Kelvin (-452ºF).
- At 0.039 atmospheres (0.57 psia or -14.122 psig), the boiling point of helium is 2.1 Kelvin
- A heat exchanger is a device where energy can freely move from one fluid to another without mixing the fluids.

A simplified process of Jefferson Lab's refrigerator:

- Helium is compressed by oil flooded helium compressors. The oil reduces the temperature and keeps the compressor from overheating. Because helium molecules are small, the oil helps to create a seal between moving parts.
- The majority of the oil is separated from the helium, cooled in separate water heat exchangers, and returned back to the compressor. The water that provides the cooling comes from a cooling tower, which uses the same principles of vaporization explained in step four of "How Does a Household Refrigerator Work?"
- Helium is sent to a device that removes the remaining oil so it does not freeze at cryogenic temperatures and cause damage.
- After the helium is at high pressure, ambient temperatures, and has no oil or other contaminations, the helium gas goes to the 4 Kelvin Cold Box (4KCB) where it goes through several stages of turbines and heat exchangers. The turbines and heat exchangers remove energy from the helium and provide helium at approximately 4 Kelvin and 3 atmospheres of pressure.
- The cold gas is transferred from the 4KCB to the cryomodules through a heat exchanger in the Sub-Atmospheric Cold Box (2KCB). There are approximately 47 cryomodules and each one has its own expansion valve. With the pressure drop across the expansion valve and the correct conditions, the helium is liquefied in the cryomodule.
- The cryomodule is similar to the inside of household refrigerator in that the contents are kept cold. Like the household refrigerator, the energy from the cryomodules causes the helium to vaporize.
- The 2KCB reduces the pressure in the cryomodule to change the properties of the liquid helium. At 0.048 atmospheres, liquid helium becomes a "super fluid," which has no resistance to heat, i.e., helium does not boil below 0.048 atmospheres. Instead the heat is conducted to the surface and is vaporized from the surface of the liquid helium bath.
- At the exit of the 2KCB, helium returns to the 4KCB and goes through the same heat exchangers that cooled the gas in a previous stage. The helium is then returned to the suction side of the compressors slightly above 1 atmosphere and ambient temperature.



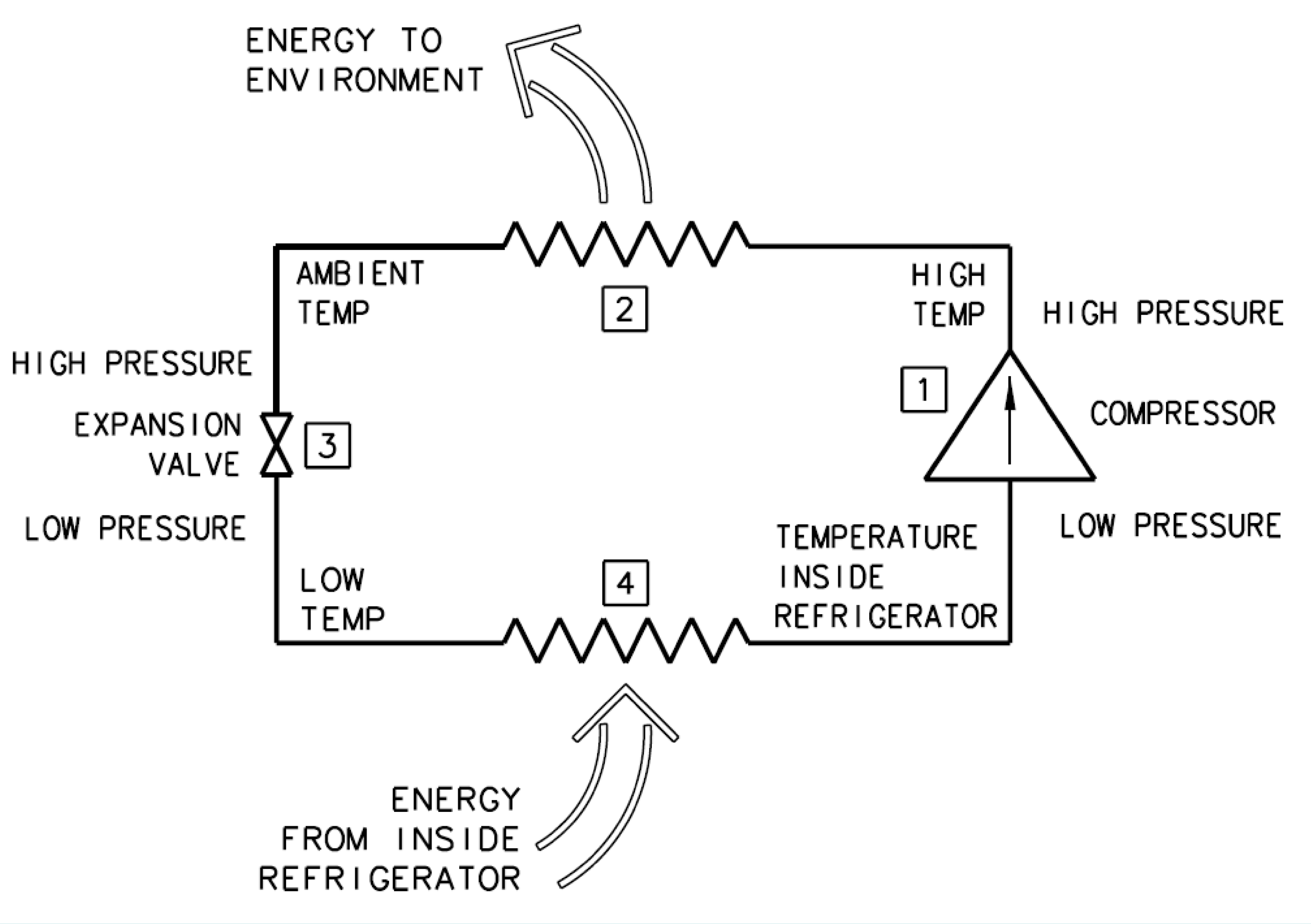
How Does a Household Refrigerator Work?

Background:

- Heat naturally flows from high temperature to low temperature.
- All fluids have a temperature and pressure at which they boil when heated and condense when cooled.

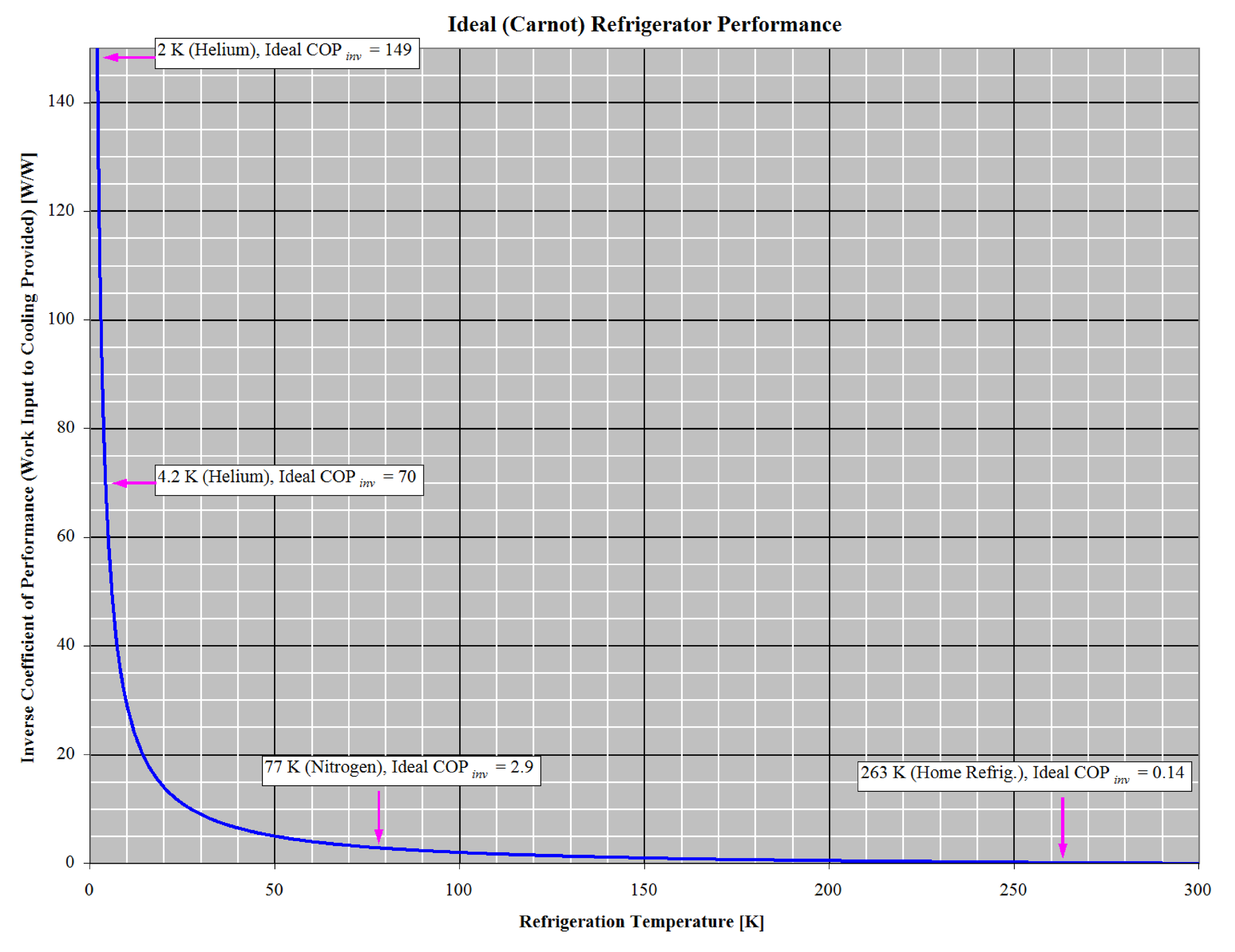
A Simplified Refrigerator Process:

- Refrigerant is compressed, causing higher pressure and temperature where heat can be removed.
- Coils on the back or below the refrigerator let the hot refrigerant gas dissipate its heat to the surrounding environment and condense the fluid.
- High-pressure fluid flows through an expansion valve. You can think of the expansion valve as a small hole. On one side of the hole is high-pressure liquid. On the other side of the hole is low-pressure and low temperature.
- Liquid refrigerant in coils, inside of the refrigerator vaporizes, absorbs heat from inside of the refrigerator, and turns back into gas. The cold gas returns to the suction side of the compressor to repeat the cycle.



Energy Potential of Different Temperature Refrigerators

A 2 Kelvin helium refrigerator requires approximately 1000 times more energy input than that of a household refrigerator to get the same amount of cooling. Between 50 and 263 Kelvin, the difference in required energy per amount of cooling changes little. But, the difference in required energy per amount of cooling does change significantly as colder refrigeration is required.



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