Solar-Powered Air Conditioner

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General Description

Despite connotations of the title, this device does not use photovoltaics ("solar cells") as a primary source of energy, although solar cells could be used to power the control system or move mechanical parts, thus creating an air conditioner that is completely independent of the electrical power grid.

This device uses solar energy in a heat engine to generate mechanical work that is directly used to power a heat pump. Unlike other heat engines, there is no conversion to electrical energy and later re-conversion back to mechanical energy. By eliminating these energy conversions, this design also eliminates the inevitable energy losses due to heat generation in electrical wires. These conversions favor high-velocity rotational motion, as evident by steam power plants that use turbines with generators and also conventional air conditioners that use compressors with electrical motors. Velocity is proportional to voltage in generators, as described by the right-hand rule. In motors, mechanical power output is the product of force and velocity. In contrast, some thermodynamic processes have performance advantages in using slow linear motion, in cases where there is no need for electrical energy conversions. This can reduce losses due to turbulence, friction, and heat transfer over finite temperature differences.

Slow-moving heat engines may be perceived with skepticism because of the common use of combustion engines such as the Otto and Diesel cycles. However, it is important to emphasize that there is no need for high-velocity rotational motion in this device, unlike an automobile which requires rotating wheels and driving speeds of 75 mph. The mechanical work is instead transferred to a slow-moving heat pump and avoids the logistical problems that exist in some applications where a slow-moving heat engine would not be practical.

$$\boxed{\xrightarrow{\text{Solar Energy}} \text{Heat Engine} \xrightarrow{\text{Mechanical Work}} \text{Heat Pump}}$$

Figure 1

Physical Diagrams and Details

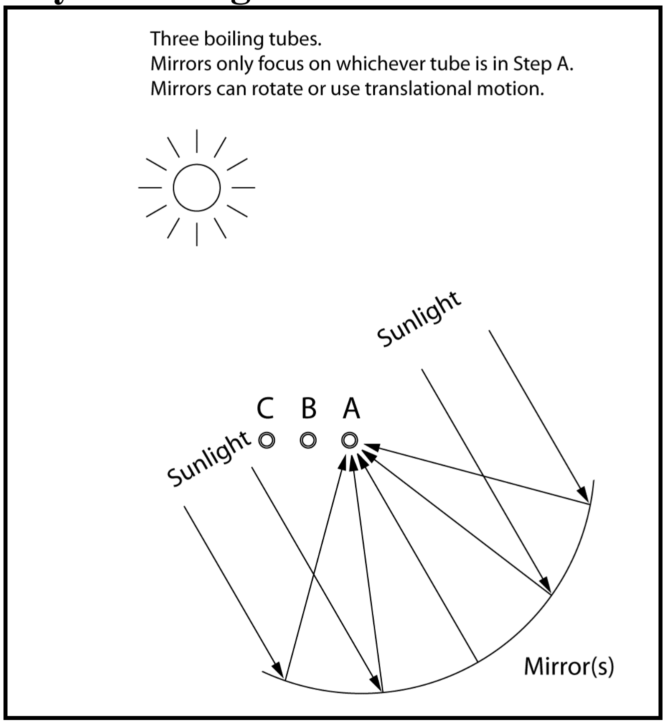

Figure 2 Mirrors concentrate solar energy to heat working fluid. To avoid the cost of curved mirrors, it is possible to use numerous slender flat mirrors, with each mirror angle controlled by a computer.

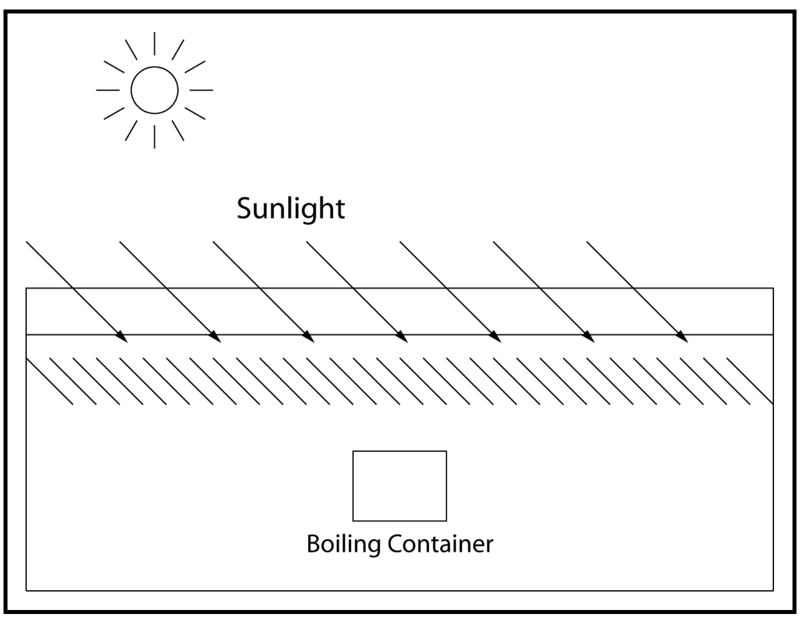

Figure 3 Diffuse reflectors may be used as an alternative to mirrors. The two sets of slits (90˚ offset in the horizontal plane) are angled directly at the sun according to latitude, time of year, and time of day. The slits, walls, and floor are white (low emissivity). The boiling container surface is black (high emissivity) and absorbs solar energy that is reflected about the room.

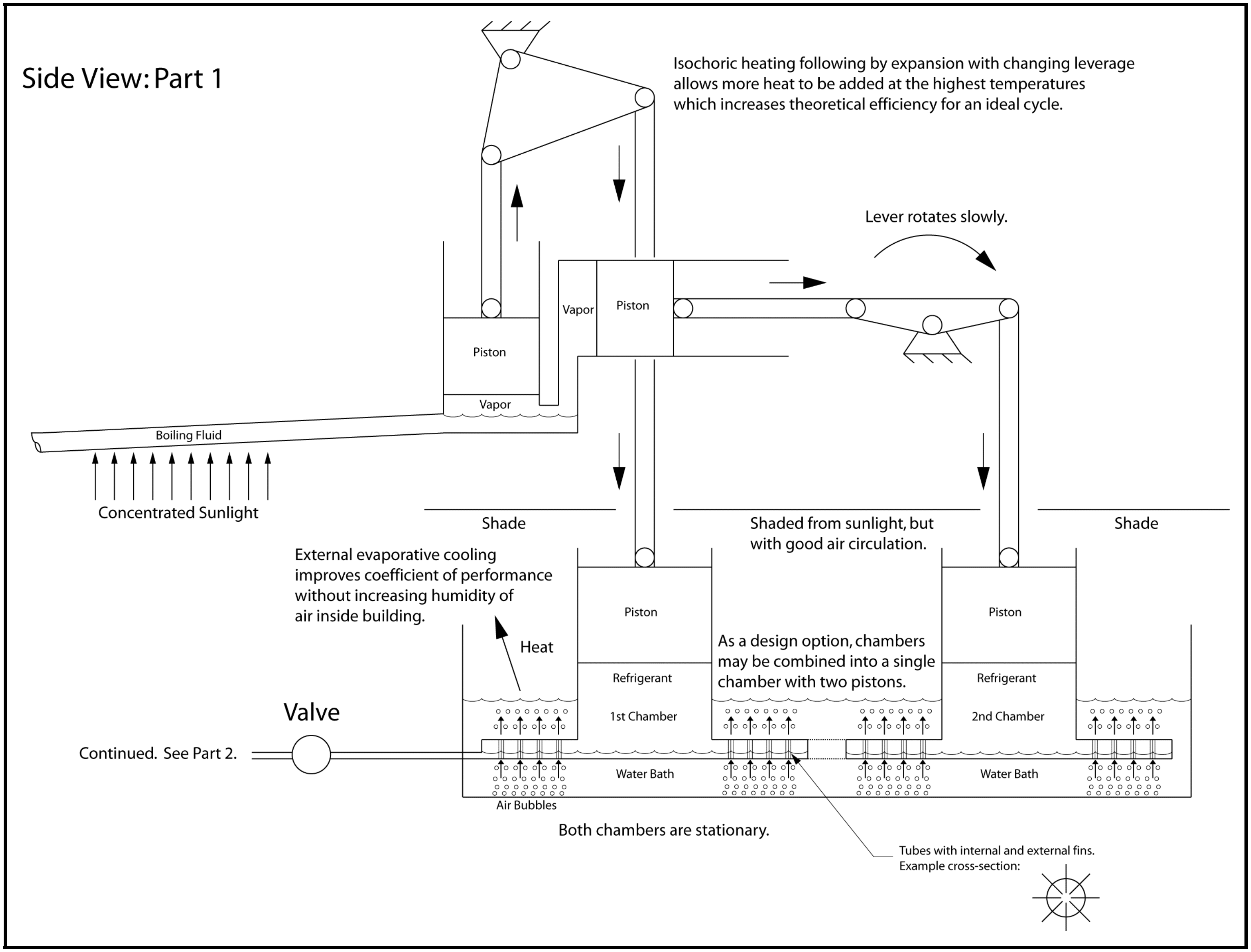

Figure 4 Mechanical linkage for the first chamber may change leverage or maintain constant pressure, depending on the desired thermodynamic process (see Figure 9). Positions may be rearranged as necessary. Forced evaporative cooling may be achieved through use of bubbles. Diffuse reflectors shown in Figure 3 may be used to compress air via pistons. This requires significantly less energy than refrigerant compression. Alternatively, solar cells could power aquarium aerators ("fish tank bubblers").

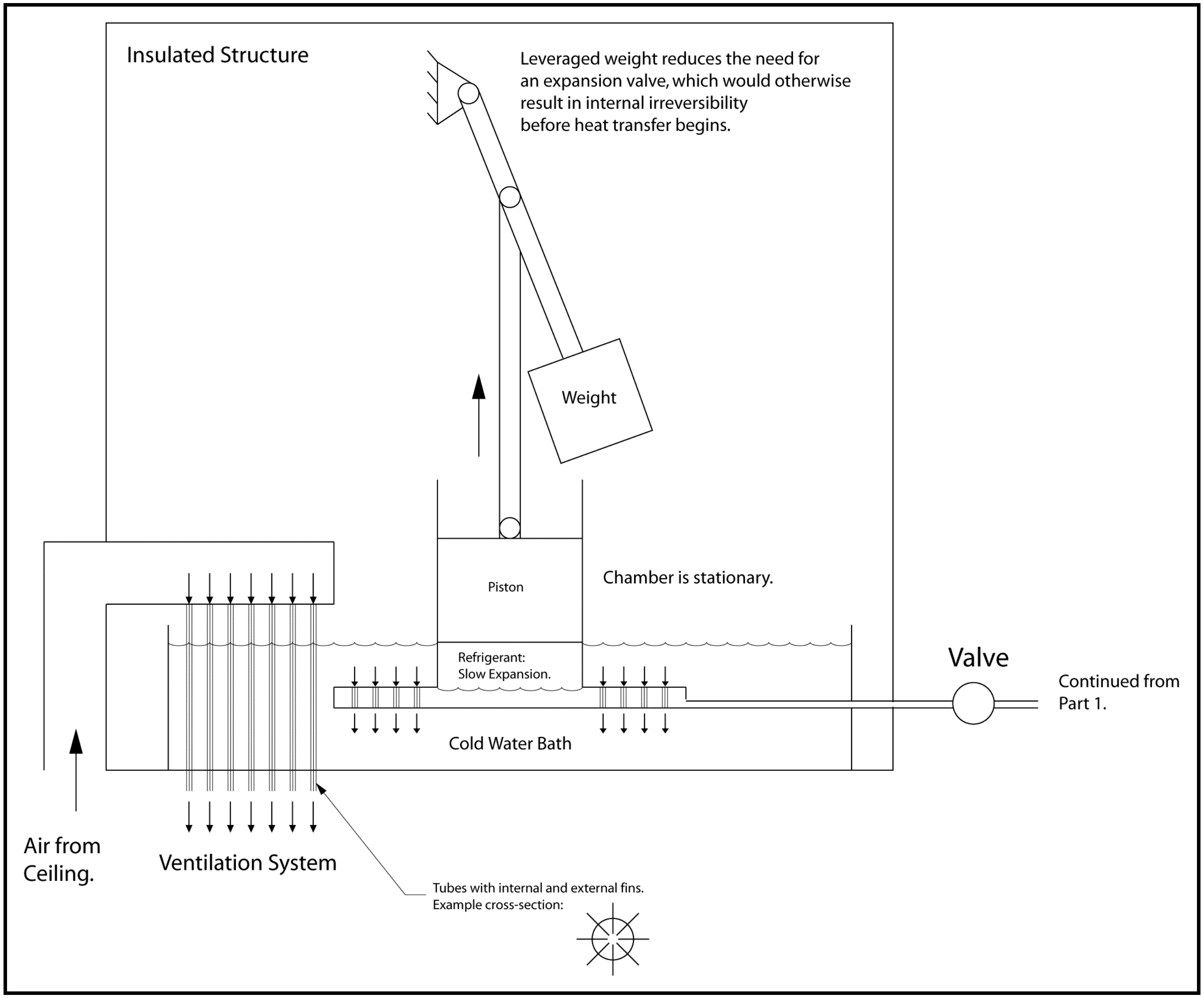

Figure 5 Natural or forced convection may be used. Water is shown as an example, but other fluids may be used for immersion. This device can optionally be combined with a swamp cooler if air is mixed with water vapor instead of the physical separation shown here. A more complex leverage system, such as a 4-bar mechanism, may provide a more controlled expansion that further reduces internal irreversibility.

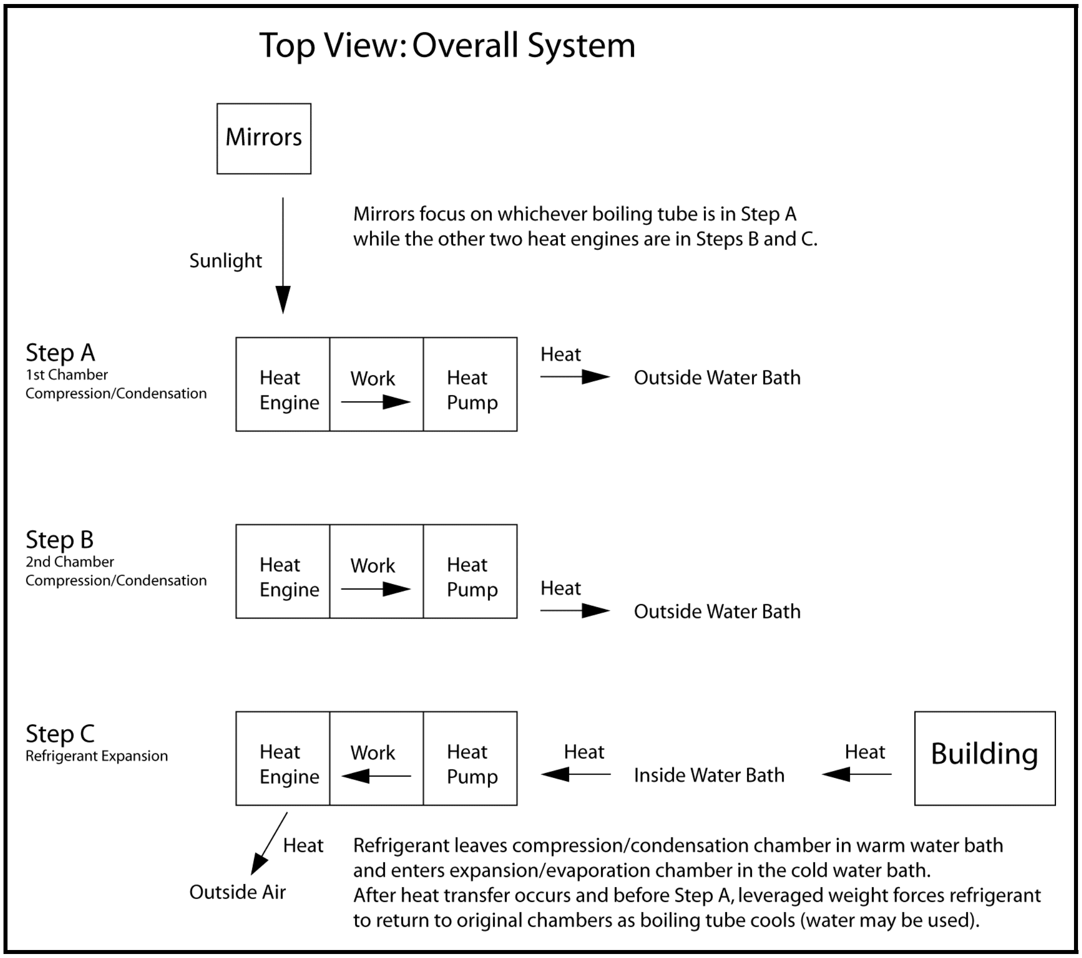

Figure 6

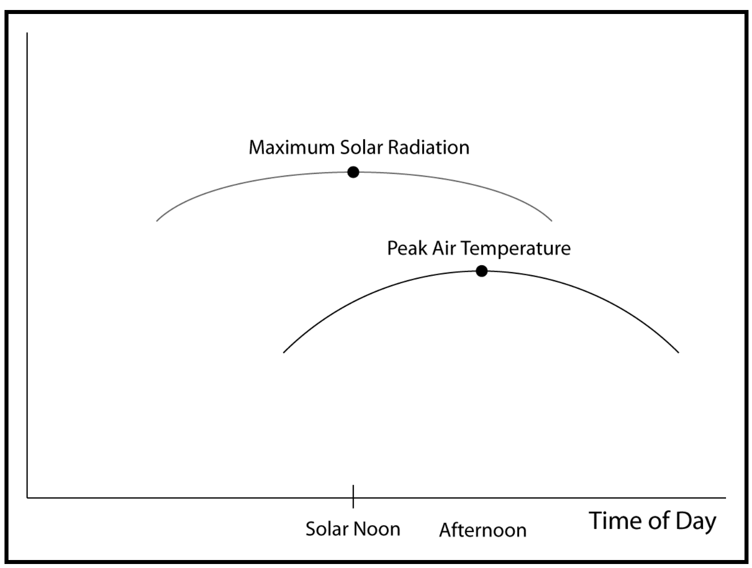

Figure 7 Time delay between maximum sunshine and high temperature of the day. Heat transfer may be further delayed due to heat capacity of the building. The heat capacity of the water bath allows morning sunshine to cool the building in the afternoon when it is most needed. Because each building has its own unique heat transfer and heat capacity, a computer could use temperature measurements to customize controls for a specific building.

In Figures 4 and 5, a series of pins (with bearings) and rods change leverage between pistons. Another option is to provide lateral support to the rods connecting the pistons, then use rollers to contact the leverage-changing mechanism. This would eliminate lateral forces that could otherwise affect the seals and friction on the piston surfaces.

Thermodynamic Processes

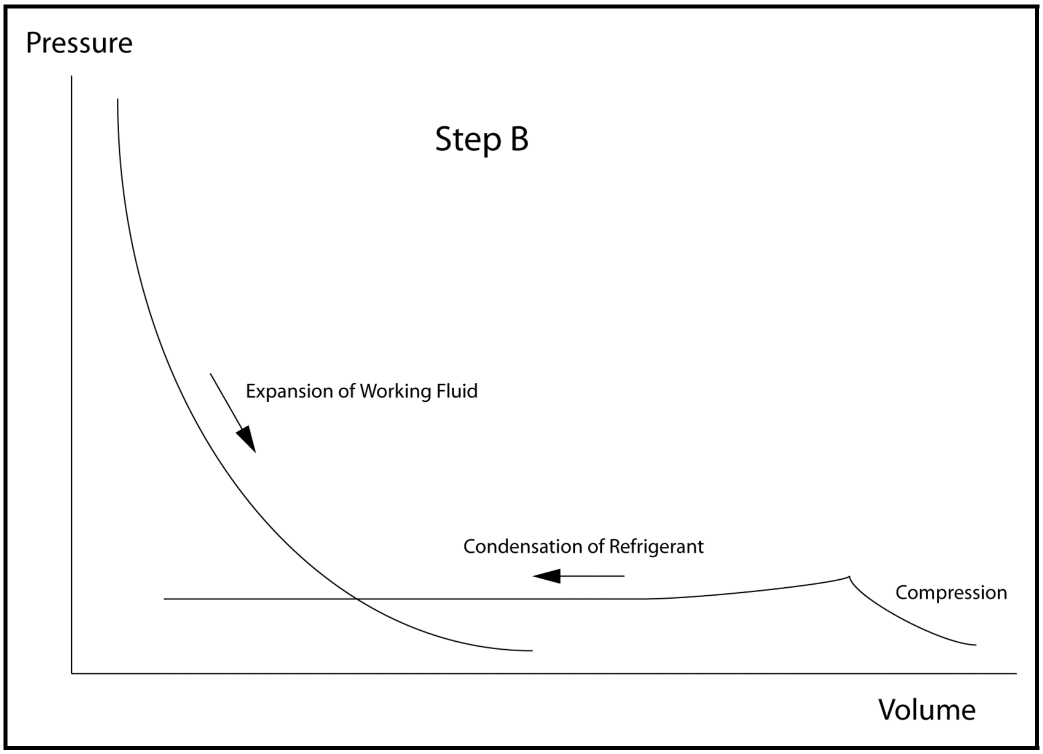

Figure 8

A sinusoidal function describes the change in leverage (Figure 4) that compensates for the changing pressure (Figure 8) as described by the polynomial function for adiabatic isentropic expansion of an ideal gas. The heat transfer in the water bath (natural or forced) can provide stability by changing the refrigerant pressure to compensate for any approximations in leverage calculations, thus allowing for a slow controlled expansion of the working fluid of the heat engine with simultaneous compression and condensation of the refrigerant. There are multiple ways of accomplishing this, including but not limited to use of elliptical gears, cams, and 4-bar mechanisms. The force equations need not be limited to sinusoidal functions and may be perfected using data from real gas expansion at a finite rate (possibly with condensation) and heat transfer analysis.

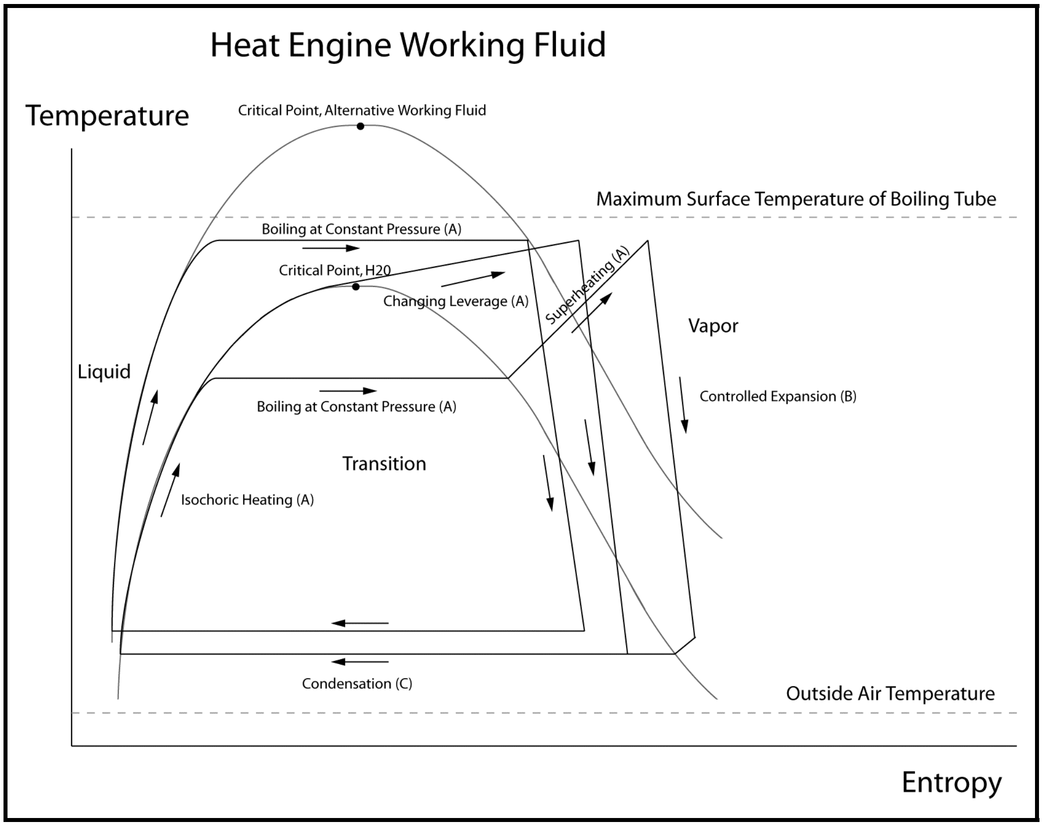

Figure 9

If water is used as the working fluid for the heat engine, then superheating the vapor would be preferred to increase the theoretical efficiency. However, an alternative working fluid could be used that has a higher critical point. Given a maximum temperature due to material limitations, a chamber device is able to expand a saturated vapor because there is no need to eliminate condensation that would otherwise damage the blades in the low-pressure end of a turbine. This allows more heat to be added at the highest temperature possible and more closely resembles the rectangular shape of a Carnot cycle, thus increasing theoretical efficiency for an ideal Rankine cycle. (The disadvantages are the inability to condense below atmospheric pressure and having a higher condensation temperature than water.) If an alternative working fluid cannot be used, then it is also possible to change leverage during compression and/or condensation of the first chamber of refrigerant. The cycle would begin with isochoric heating until a high temperature and pressure is reached, then heat is added at high temperature while pressure decreases, followed by controlled expansion of the working fluid with simultaneous compression and/or condensation of the second chamber of refrigerant.

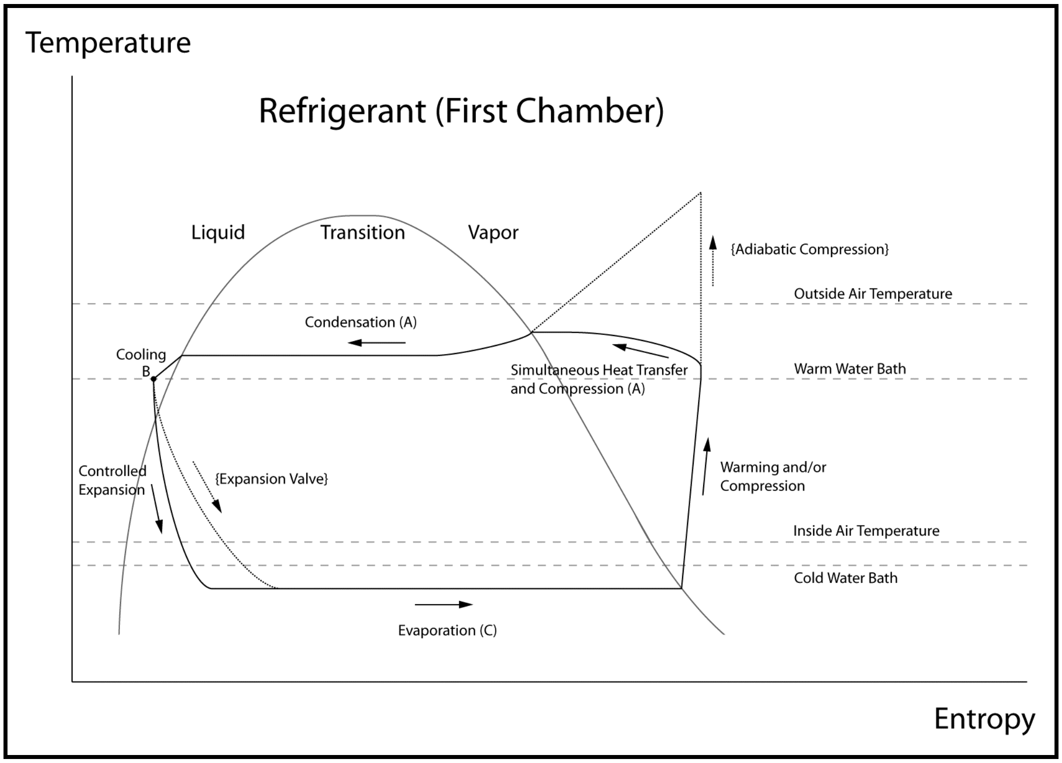

Figure 10 Due to evaporative cooling, warm water bath is colder than outside air.

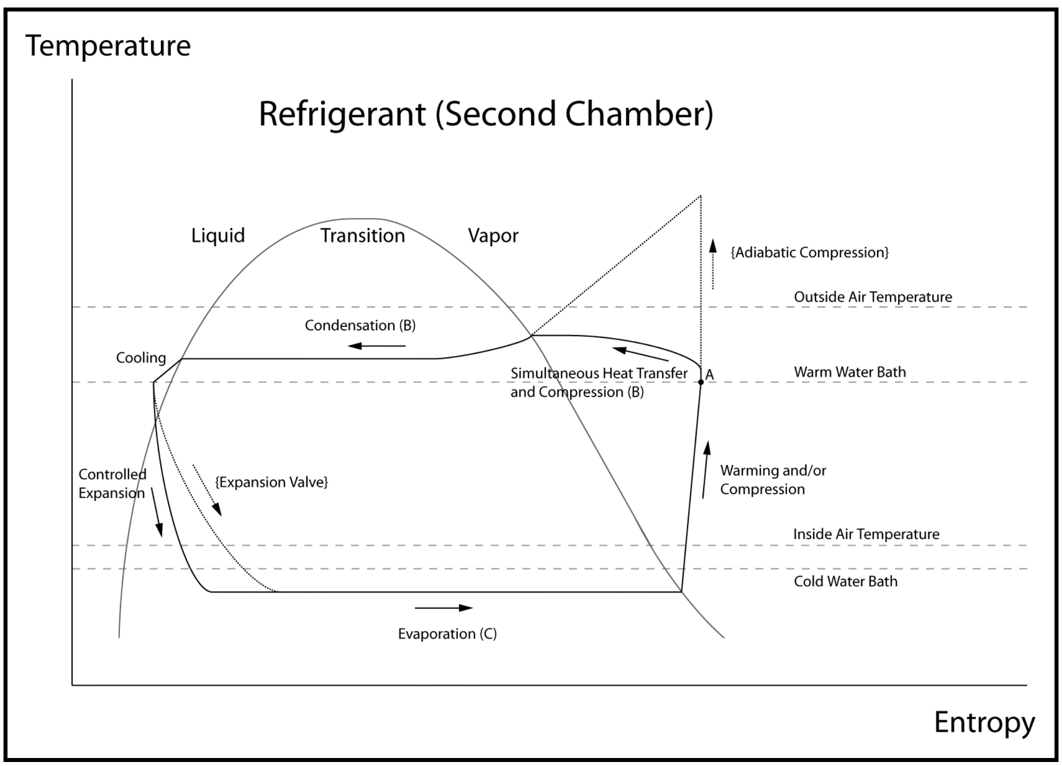

Figure 11

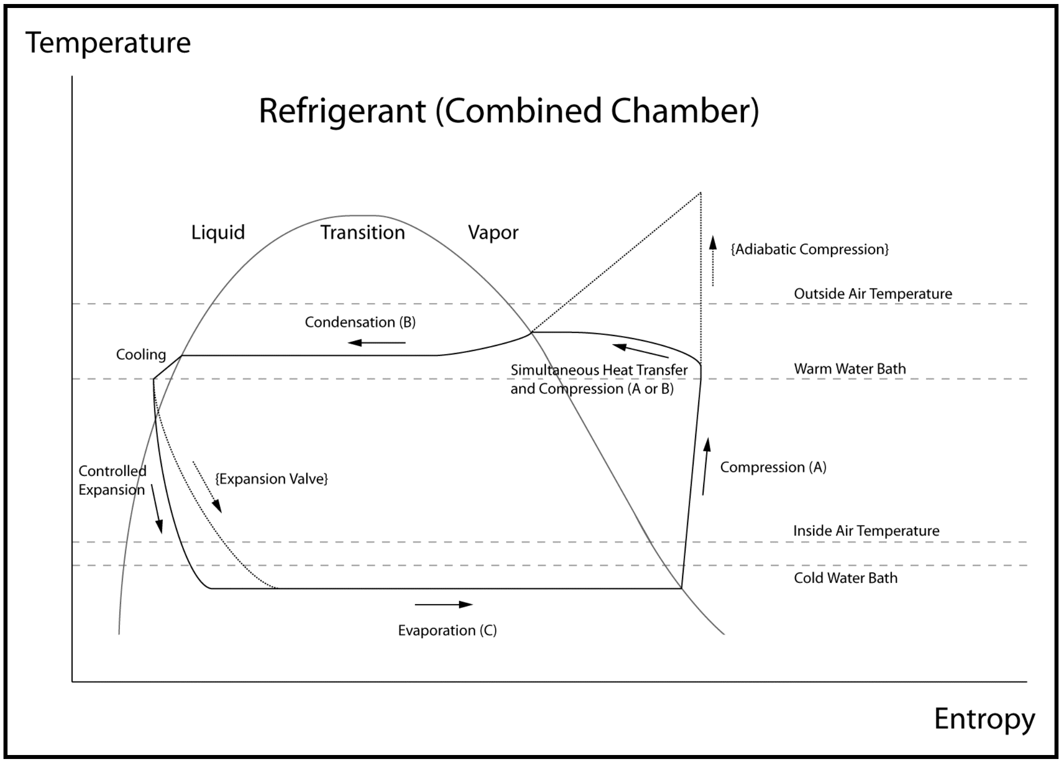

Figure 12 Alternatively, the chambers may be combined into a single chamber with two pistons. This may give a higher coefficient of performance because the refrigerant in the second chamber would be compressed immediately after Step C.

In Figures 10, 11, and 12, simultaneous heat transfer and compression decreases the work input compared to adiabatic compression which unnecessarily raises the refrigerant temperature well above the temperature of the warm water bath and causes external irreversibility by transferring heat over a large temperature difference. Slow controlled expansion (instead of using an expansion valve with turbulence) increases heat transfer from the building because there is less entropy increase before the refrigerant temperature drops below the temperature of the cold water bath. Both of these observations can be made using the following equations:

$Q_{in} = \int TdS - \int TdS_{irreversible}$ (internal irreversibility)

$W_{out} = \int PdV$ for a control mass.

$\sum Q_{in} = \sum W_{out}$ for a thermodynamic cycle of a control mass.

Performance Estimation

Calculating performance of a real device requires finite-element analysis and design optimization search methods. Based on the diagrams of the previous section, it might be possible to achieve a higher coefficient of performance than conventional air conditioners because heat is pumped over a smaller temperature difference and also because the thermodynamic cycle more closely approximates the rectangular shape of a theoretical Carnot cycle. Heat engine efficiency may exceed that of photovoltaics because solar thermal electric power plants have higher efficiencies than consumer-type solar cells.