Project 1 – A Refrigeration Cycle

By

Mike Zwiers
Matt Brower
Matt Trommater

Grand Valley State University
School of Engineering

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Instructor: Dr. Mohammadzadeh

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Introduction

The refrigeration cycle is used in most homes and businesses around the world today. Concerns about the integrity of the ozone layer necessitate the use of an environmentally friendly refrigerant in refrigeration cycles. After the Montreal protocol, use of any coolant containing chlorine was banned. This project will analyze the alternatives to the formerly widely used refrigerant R-12.

Analysis

Alternatives to R-12 include R-22, R-134a, and Ammonia. The popularity of R-12 was largely based on its saturation characteristic. Figure 1 compares the saturation curves of R-12 and the alternative refrigerants. Based on this comparison, R-134a has been selected for this design.

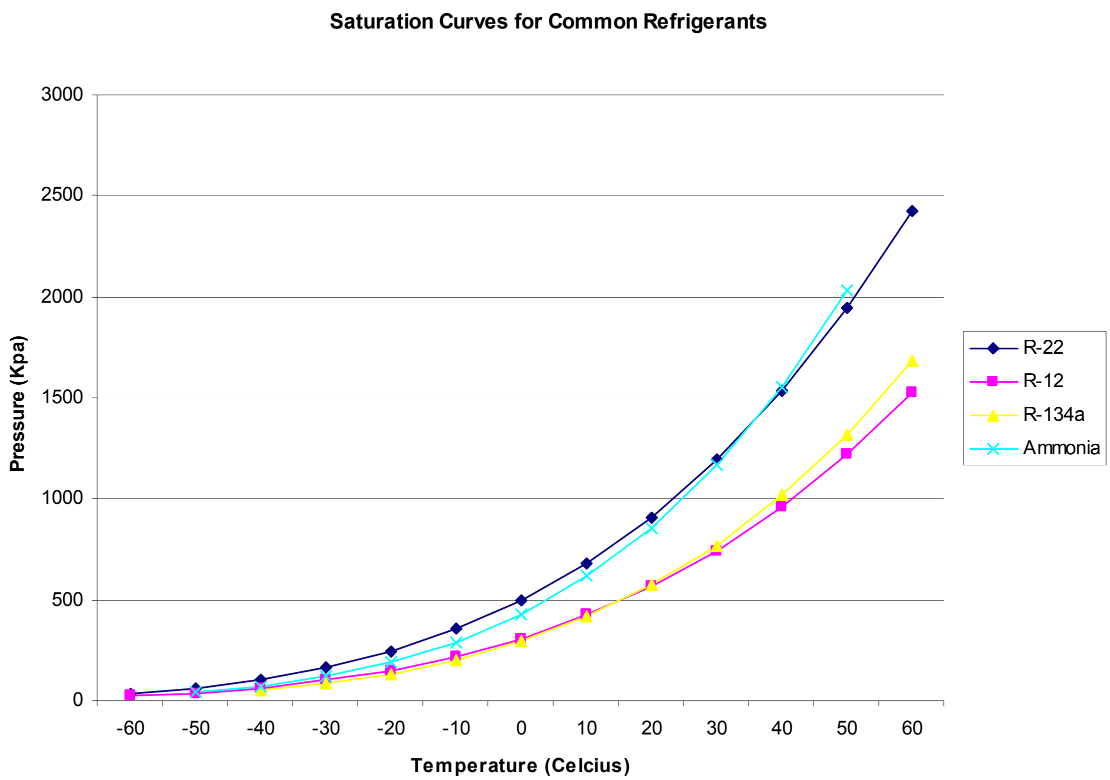

Figure 1: Saturation curves for refrigerant alternatives

In order to proceed with design the volumetric efficiency of the compressor must be evaluated. Volumetric efficiency is expressed as Equation 1.

$$\eta_v = 1 - \frac{V_c}{V_s}\left[(pr)^{\frac{1}{n}} - 1\right] \qquad (1)$$

All parameters except compression pressure ratio, *pr*, are supplied in the problem statement. The compression pressure ratio is defined as the condenser pressure divided by the evaporator pressure. To assist in evaluating the impact of the compression ratio on volumetric efficiency, the relationship was plotted as show in Figure 2.

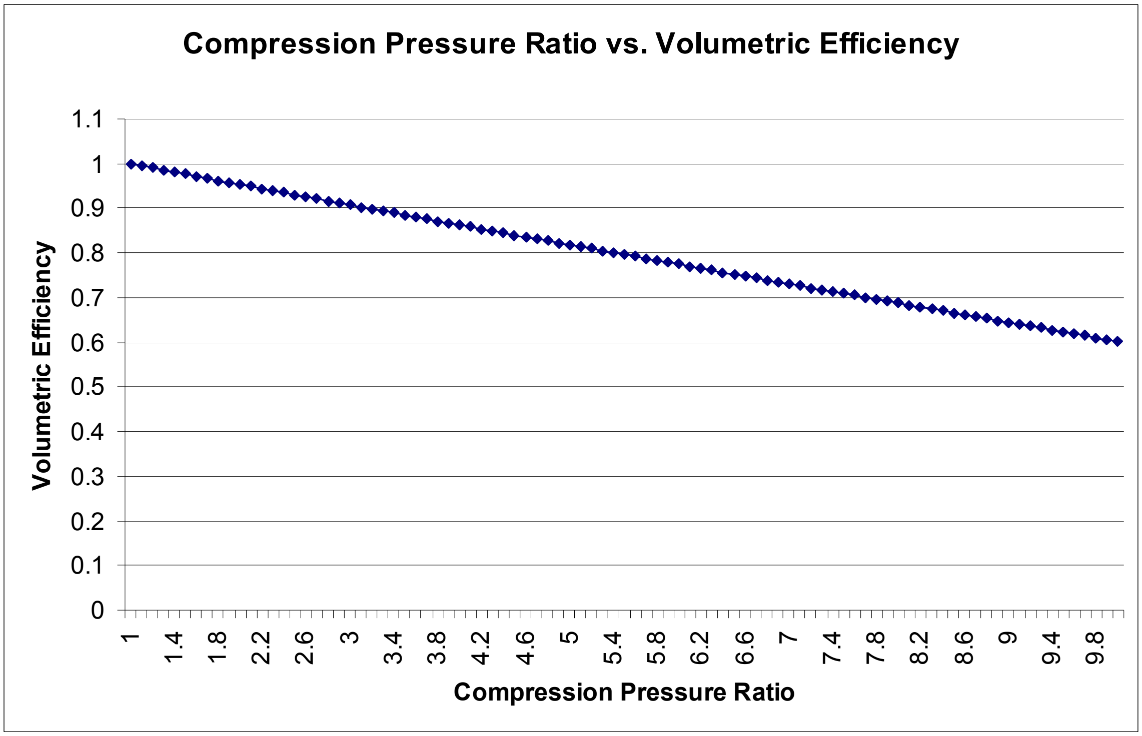

Figure 2: Volumetric efficiency compared to the compression ratio

Figure 3 provided a diagram of the refrigeration cycle. The cycle runs refrigerant 134a through a compressor, condenser, expansion valve, and evaporator to cool water from 15ºC to 3ºC. The refrigerant exists in 4 different states within the cycle. The location of each state is indicated on Figure 3. Properties at each state are listed in Table 1. All property calculations are detailed in Appendix A. Appendix B provides p-h and T-s diagrams of the designed unit.

State	Pressure (bar)	Temperature (ºC)	h (kJ/kg)	s (kJ/kg*K)
1	2.9282	3	249	0.917
2s	9	38.8	269.9	0.917
2	9	38.9	270	0.918
3	9	33.53	96.62	0.356
4	2.9282	0	96.62	0.368

Table 1: Refrigeration system state properties

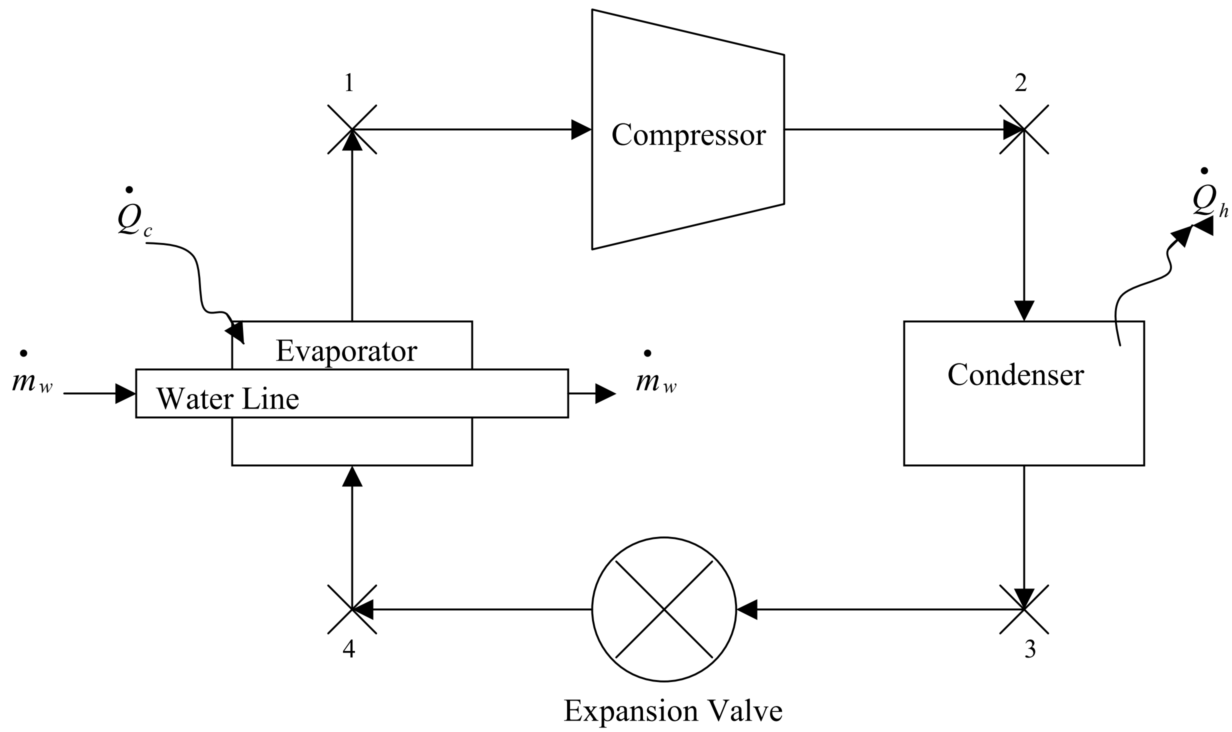

Figure 3: Refrigeration cycle diagram

Water at 15ºC is used to evaporate the refrigerant in the evaporator. The heat transfer from the water to the refrigerant should first evaporate the liquid portion of the refrigerant completely, and then increase the refrigerant temperature in the final segment of the evaporator. To do this the mass flow rate of both the water and the coolant must be known. The flow rate of the coolant was found first. This was calculated by using the specific volume of the refrigerant at the temperature entering the compressor. The flow rate of the refrigerant is 0.01 kg/s. By using the first law of thermodynamics the energy required to convert the given amount of refrigerant back into gas and raise the temperature 3 degrees Celsius was used to calculate the flow rate of the water. From the calculation the flow rate of the water needs to be 0.037 kg/s.

The tonnage of the system must also be found. The unit of measure used in air conditioning to describe the cooling capacity of a system. One ton of cooling is based on the amount of heat needed to melt one ton (2000 lbs.) of ice in a 24 hour period. One ton of cooling is equal to 12,000 Btu/hr. For our case we used kJ/min. The tonnage of our system is 26.44 kJ/min.

The use of power is another important factor in refrigeration. It is desirable to use the least amount of power as possible. At a mechanical efficiency of 85% the refrigeration cycle needs 252.5 W of power to run. A typical refrigerator needs 700 W to run.

To gage the difference between the ideal amount of work being done and the actual amount of work being done the isentropic efficiency of the compressor needs to be found. This efficiency was found to be 99.8%

In this refrigeration cycle it is important to know how much heat is given off so that it does not affect its surroundings. In the refrigeration cycle the component that gives off the most heat is the compressor. The heat loss from the compressor is 37.73 W. This amount of heat loss should not affect its surroundings.

To conclude, this design provides a small, environmentally friendly water cooling system. The resulting refrigeration cycle has a coefficient of performance of 6.2 and monthly electric cost of $10.56.

Conclusions

This project illustrated that certain criteria must be assumed for the design of a refrigeration cycle, the other variables are found based on the laws of thermodynamics. For this project, the refrigerant was chosen based on the lowest possible temperature and pressure at saturation. This was done to keep the cost of the unit down since lower pressures correspond to thinner lines and weaker fittings. Other deciding factors in this design include: the capacity of the compressor, the pressure in the condenser, and the temperature change of the water. These factors dictated the mass flow rates of the refrigerant and water and thus the work required to run the compressor. This problem could be approached differently if the mass flow rate of water, for instance, was dictated. Then a condenser pressure and compressor volume would have to be chosen to meet these new criteria.

Appendix A

Appendix B

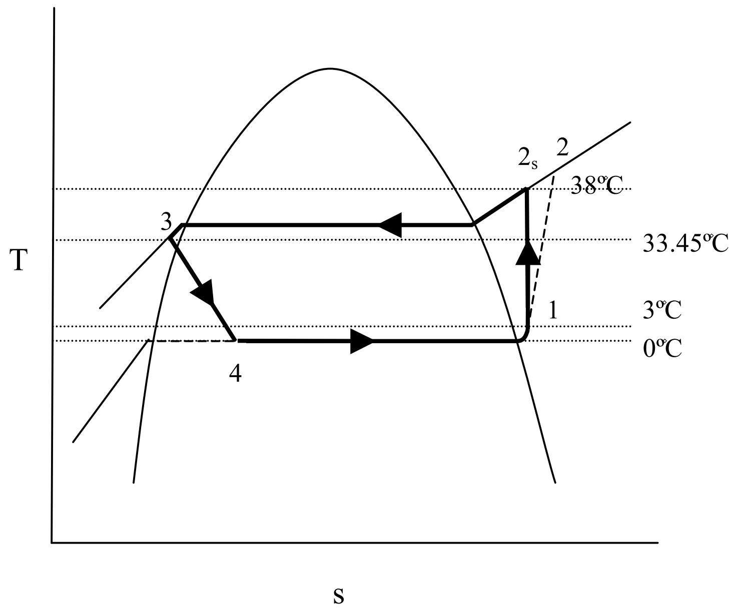

Figure 4: T – s refrigeration cycle diagram

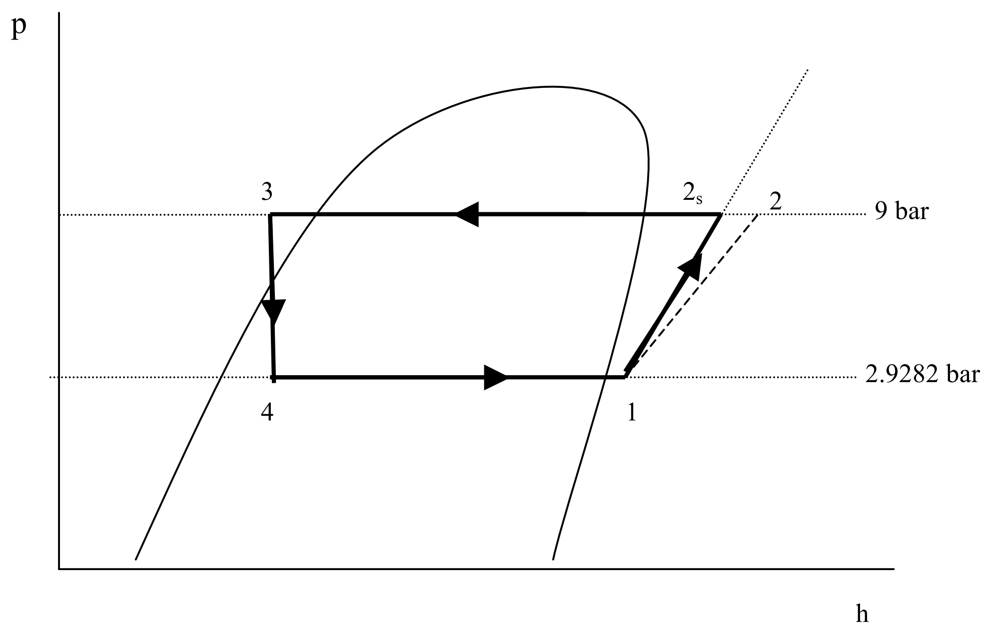

Figure 5: p – h refrigeration cycle diagram