Alternatives Homework

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Problem 2-4 (Resnick):

List and discuss several methods for effecting separations in (a) gas-solid, (b) solid-solid, and (c) liquid-solid systems. Place special empahsis on the physical or chemical basis for the separation.

(a) gas-solid

1. electrostatic precipitation: separates via electrostatic foces. Discharge wires are in the middle of two collecting plates. An electric field from a high voltage run through the wires ionizes the gas between the wires and collecting plates. The solid particles become charged from the air and are forced to the collecting plates. An example of this is dust collection from the air.
2. gas cyclone separation: separates via rotational effects and gravity. air forced to flow up a cylender causes lighter particles to flow in rotation and exit at the top while the larger particles hit the wall and fall to be collected. An example of this is removing ash from smoke in smoke stacks.

(b) solid-solid

1. Winnowing: separates via mass. Wind will blow away lighter particles while heavier ones remain. An example of this is ash and rocks.
2. Sieving: separates via size. Holes in a sieve allow smaller particles to pass though while larger particles do not. An example of this is separating sand from pennies.
3. Sublimination: separates via phase. Assuming the materials have different triple points, the mixture is heated under low pressures and one material transforms to a gaseous state. An example of this is separating iodine from sand.

(c) liquid-solid

1. Centrifugation: separates via mass. solid particles are spun down to the bottom of a tube while the solution remains. A example of this is separating cell mass from DNA and solution for biotechnological lab methods.
2. Filtration: separates via size. Pores allow liquid to pass through the membrane and solid is retained. An example of this is separating whey proteins from milk.

Problem 10-1 (Resnick, beet sugar only):

Perform a functional analysis of the major steps in the production of beet sugar. Flowcharts and brief descriptions of these processes can be found in R. N Shreve and J. A. Brink, "Chemical Process Industries," 4th ed., McGraw-Hill, New York, 1966.

There are four steps to produce beet sugar.

1. extraction: accumulates the beet sugar and extracts flavor and taste in a juice by keeping thinly sliced beets in hot water.
2. pressing: continues to extract the useful sugars from the beets by pressing the slices
3. carbonation: cleans the juice before it can be used by growing small clumps of chalk in the juice to attract and remove non-sugars
4. boiling: forms sugar crystals by placing the syrup in a large pan and boiling off the water

Problem 10-2 (Resnick):

Desalination of seawater can be achieved by a freezing process. Potable water is produced by melting the ice crystals after they have been washed free of adhering brine. Perform a morphological analysis of the ice-crystal separation and washing operations. List a number of alternatives for performing these operations, briefly discuss their applicability to the ice-brine system, and consider the possibility of combining the separation and washing operations. After completing the analysis compare with A.F. Snyder, Freezing Methods, chap. 2 in K.S. Spiegler (ed.), "Principles of Desalination," academic, New York, 1966.

Ice-Crystal Separation	Washing
Direct freezing	Countercurrent wash flow
Vacuum freezing	Oil and water flow
Eutectic freezing	Filtration
Suspension freezing	
Progressive indirect freezing	
Falling Film indirect freezing	

Direct freezing uses crystalization of the seawater by direct contact with a cold material. It has low operating temperatures, a high production rate at a low driving force, and a compact design, but it limits the type of refrigerant to something chemically stable, non-toxic or flammable, and with a suitable boiling temperature and it can lead to impurities in the water if it is mixed poorly with the refrigerant.

Suspension, progressive, and falling film indirect freezing uses crystalization of the seawater by indirect contact with a cold material. In suspension, small ice crystals are produced in a nucleator and then introduced to a crystallizer to produce crystal growth. It allows for indirect contact to choos a diversity of refrigerants, but it is costly and the nucleation and crystal growth processes are complex. Progressive freezing uses a tube filled with the water that is progressively immersed in a cold material. It has lower impurities due to one-dimensional crystal growth and the stirrer lowers the impurity content near the ice growth surface, but thebath size limit makes the process difficult to scale up. Falling film freezing is a dynamic method where a solution flows over a cold vertical surface. It involves one dimensional crystal growth and the shear from the flow increases the mass transfer coefficient to prevent impurities. It is easy to scale up, but the ice separation is difficult.

Vacuum freezing vaporizes some of the water and reduces the temperature to cause crystallization. Refrigerant recovery is prevented in this method when atmospheric operation conditions are used, but the compressor must handle a large volume and low water vapor pressure and it needs a more efficient design of the melting unit.

Eutectic freezing operates at the eutectic point temperature of the solution, causing crystalization of ice and salt. The salt and water are easy to separate due to their density differences and ther eis high water recovery, but a very low operating temperature is necessary and so the operation is expensive.

The countercurrent washing operates in such a way that fresh water flows down over the ice and brine mixture. The ice is less dense than the water and brine so it flows upward and the brine and water flow downward.

The oil and water washing operation works in the same way asa the countercurrent washing operation, but the oil acts as an extra barrier between the ice and brine-water solution. Due to the addition of the oil, this operation is more costly.

The filtration wash operation occurs by allowing the water and brine to pass through the filter while the solid ice remains behind. This can lead to the pump becoming clogged and slowing down the operation.

Direct and indirect freezing can be combined with any wash operation. Vacuum freezing would probably be best combined wth a countercurrent or oil and water washing operation because it requires a large volume and low pressure while the filtration would cause the pump to clog with high pressure. The eutectic freezing method would best be combined with the countercurrent washing operation due to the density differences produced.

Problem 10-3 (Resnick):

An installation to supply 1.5 MJ/s of refrigeration is being designed. The design calls for an ammonia vapor-compression system in which the ammonia is to evaporate at -20C and condense at 40C. Cooling water is available at 25C.

```
Te = -20 + 273; % K
Tc = 40 + 273; % K
Tw = 25 + 273; % K

refrig = 1.5; % MJ/s
```

(a) Calculate the minimum power requirement and condenser duty for a primitive design involving a condenser, expansion valve, evaporator, and single-stage compressor.

```
cop = Te / (Tc - Te); % coefficient of performance
w = refrig / cop * 1000 % power requirement, kJ/s
```

```
w = 355.7312
```

(b) improve the design by an evolutionary procedure. Calculate the minimum power requirements and heat-exchanger duties and list any additoinal equipment requirements for each design. Make at least two improved designs.

The coefficient of performance being incresed improves the system. Increase the evaporator temperature and decreasse the condenser temperature. The condenser temperature is limited by atmospheric temperature of the system.

```
% Improvement 1:
Tc = 30 + 273; % K

cop = Te / (Tc - Te); % coefficient of performance, new
W = refrig / cop * 100 % power requirement, new, kJ/s
```

```
W = 29.6443
```

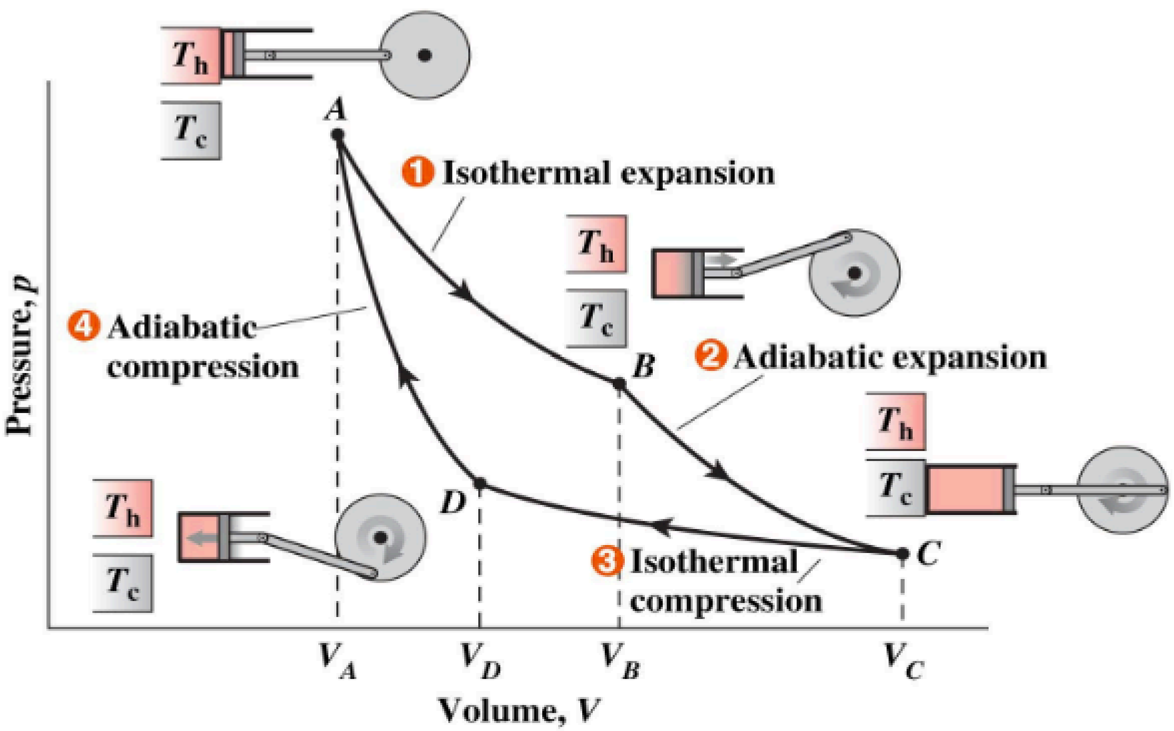
```
% Improvement 2:
Te = -10 + 273; % K

cop = Te / (Tc - Te); % coefficient of performance, newest
W = refrig / cop * 100 % power requirement, newest, kJ/s
```

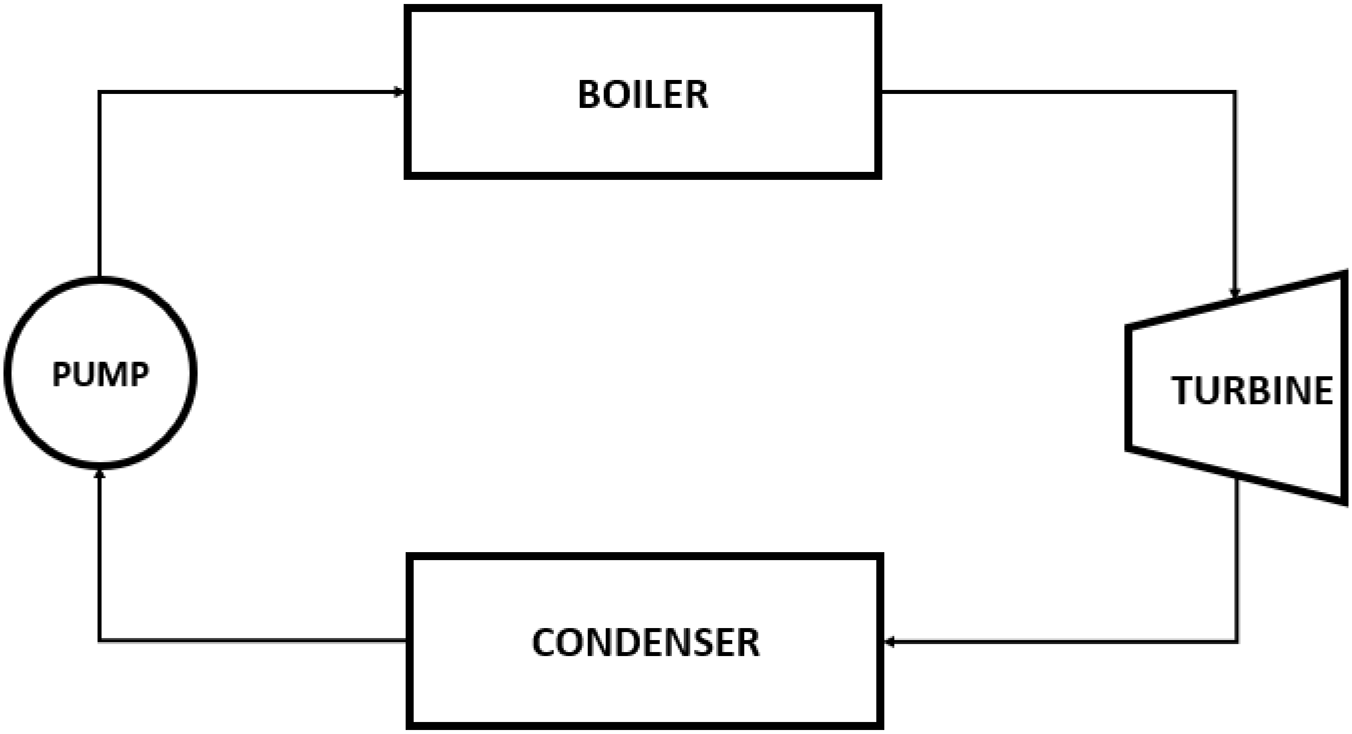
```
W = 22.8137
```

Assigned Problem:

A. Design an process to both heat and cool a building with ammonia using the Carnot cycle. The building which to be maintained at 70F has an outside surface area of 20,000 FT^2 and an overall heat transfer coefficient of 0.12 Btu/(hr-ft^2-F). Water is available at 55F and the outside ambient conditions range for design is from -20F to 110F with average low temperature of 40F and average high temperature of 80F. The minimum temp difference for all heat exchangers is 15F. Determine the compressor size (Hp) needed for the design, the average COP, and the average and maximum water flow rate. Develop a flow diagram of the piping and valves so that the same compressor can be used for both heating and cooling.



Carnot Cycle basics



Flow Diagram: flow starts before the boiler and moves clockwise.

```
T_building = 70; % [F]
area = 20000; % [ft^2]
U = 0.12; % [BTU/h-ft^2-F]
T_water = 55; % [F]
T_ambient_min = -20; % [F]
T_ambient_max = 110; % [F]
T_ambient_low_avg = 40; % [F]
T_ambient_high_avg = 80; % [F]
delta_T = 15; % [F]
M = 17.02; % [kg mass / kg mol]
R = 8314;

cp = 80.8;
cv = 37;

Te = -20 + 273; % K
Tc = 40 + 273; % K
Tw = 25 + 273; % K

COP = Te / (Te - Tc)
```

```
COP = -4.2167
```

```
compression = Te / Tc
```

```
compression = 0.8083
```

```
gamma = cp / cv
```

```
gamma = 2.1838
```

```
shaft_work = - gamma / (gamma - 1) * R * Te / M * (Te / Tc - 1)
```

```
shaft_work = 4.3703e+04
```

```
design_param = 0.2; % [kg/s]
eff = 0.8;
brake_kw = shaft_work * design_param / (eff * 1000)
```

```
brake_kw = 10.9258
```

```
hp = brake_kw * 1.34
```

```
hp = 14.6406
```

```
p1 = 140; % kPa, chosen design parameter
p2 = 550; % kPa, chosen design parameter
compression_iso = 2.3 * R * Te / M * log(p2 / p1)
```

```
compression_iso = 3.8893e+05
```

```
brake_kw_iso = compression_iso * design_param / (eff * 1000)
```

```
brake_kw_iso = 97.2327
```

```
hp_iso = brake_kw_iso * 1.34
```

```
hp_iso = 130.2919
```

B. For the unit operation you are designing and optimizing for your semester project, A) list the heuristics that will be helpful in the design and performance, and B) list the alternative unit operations to the unit operation you are designing.

A) Different atomizers are used in different circumstances. A pressure nozzle is used for feeds with low viscosity and few lumps, a two-fluid nozzle atomizer creates high shear forces and are used for low capacity applications and in the creation of ceramic powders, and a centrifugal disk atomizer is best for atomizing suspensions and pastes that erode and plug nozzles.

B) Spray drying alternatives are freeze-drying, microwave vacuum drying, refractance window drying.