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Vapor compression refrigeration cycle problems and solutions

Section-1: The main and modified 10-1-1 (carnot-30C) Carnot vapour cooling cycle uses R-134a as a working liquid. The refrigerant enters the capacitor as a saturated vapor at 30o C and leaves as a saturated liquid. The vaporizer works at -5 o C. Determine, in kJ per kg of refrigerant flow, a) working input into the compressor, (b) work developed by the turbine, (c) the transfer of heat to the refrigerant passing through the vaporizer and (d) the performance factor of the cycle? (e) Scenario What if: What would be the answer partially (d) and (c) if the R-134a were replaced by R-12? (Editing problem) (TEST Solution) Answers: a) 23.36 kJ/kg, (b) 3.36 kJ/kg, (c) 153.29 kJ/kg, (d) 7.66, (e) 7.66, 119.43 kJ/kg Anim. 10-1-1 (click) 10-1-2 carnot-r22 R-22 refrigerant R-22 is a working liquid in the Carno vapor cooling cycle, for which evaporation temperature is 0 o C. Saturated vapor enters the capacitor at 40 o C, and saturated liquid outputs at the same temperature. The velocity of the refrigerant is 4 kg/min. Determine (a) the rate of heat transfer to the refrigerant passing through the vaporizer, (b) the net input of energy into the cycle in kW and c) the performance factor. (d) What if the scenario: What would be the answer partly a) if the mass flow rate was 1 kg/min? (Editing problem) (TEST solution) Answers: a) 9.70 kW, b) 1.42 kW, (c) 6.83, (d) 2.43 kW 10-1-3 carnot-40F Carnot vapor cooling cycle works between thermal tanks at 40 o F and 100 oF. For a) R-12, b) R-134a, (c) water, (d) R-22 and (e) ammonia as working liquid, determine operational pressures in the capacitor and vaporizer, in lbf/in 2, and performance factor. (Editing problem) (TEST solution) Answers: a) 131.83 lbf/in 2 ; 51.64 lbf/in 2 ; 8.3, (b) 138.87 lbf/in 2; 49.87 lbf/in 2 ; 8.3, (c) 0.95 lbf/in 2; 0.12 lbf/in 2 ; 8.3 (d) 210.54 lbf/in 2; 83.15 lbf/in 2 ; 8.3 (e) 211.86 lbf/in 2; 73.28 lbf/in 2 8.3 10-1-4 carnot-0F Carno vapour cooling cycle is used to maintain a cold area at 0 o F, where the ambient temperature is 75o F. The R-134a refrigeration agent enters the capacitor as a saturated vapor at 100 pounds/in 2 and comes out as saturated at the same pressure. The vaporizer pressure is 20 pounds/in 2 . The refrigerant flow rate is 12 pounds/s. Calculate a) the power of the compressor and turbine in the Btu/min and (b) performance factor. (Editing problem) (TEST solution) Answers: a) 9993.44 btu/min; 1679.28 btu/min, (b) 5.59 10-1-5 carnot-120kPa Carnot Sustainable Cooling Cycle uses refrigerant-134a as a working liquid. The refrigerant changes from saturated vapor to saturated liquid at 30o C in the capacitor as it rejects heat. The vaporizer pressure is 120 kPa. (a) Show the cycle on the T-s chart saturation lines, determine (b) coefficient ratio (c) The amount of heat absorbed from the refrigeration space and (d) a clean entrance to the work. (Editing problem) (TEST solution) Answers: b) 4.77, (c) 143.26 kW, (d) 30.03 kW 10-1-6 carnot-100psy refrigerant R-134a enters the capacitor of the refrigerator Carno in the form of a saturated vapor at 100 psia, and it comes out as a saturated liquid. The absorption of heat from the refrigeration space occurs under pressure of 30 psi, and the mass flow rate is 1 kg/s. a) Show the cycle on the T chart in relation to saturation lines, determine (b) performance factor, (c) quality at the beginning of the heat absorption process and d) net input work. (Editing problem) (Test Solution) Answers: b) 7.42, (c) 0.22, (d) 20.99 kW, 10-1-7 perfect-1MPa Fridge uses R-12 as the working fluid works on an ideal vapor compression cycle between 0.15 MPa and 1 MPa. If the mass flow speed is 0.04 kg/s, determine (a) system tonnage, b) compressor power and (c) COP. (d) What if the scenario: What would the COP be like if the P-12 was replaced by R-134a, a more environmentally friendly refrigerant? (Editing problem) (TEST solution) Answers: a) 1.165 tonnes, b) 1.36 kW, c) 3.01, (d) 3.33 Anim. 10-1-7 (click) 10-1-8 (ideal 10 kW) The fridge uses R-134a as a working liquid and runs on a perfect steam compression cycle between 0.15 MPa and 1 MPa. For a cooling load of 10 kW, determine the velocity of the refrigerant mass through the vaporizer. (Editing problem) Answers: 0.0938 kg/s 10-1-9 perfect-20kW R-134a refrigerant enters the compressor of the ideal vapor compression system in the form of saturated steam at -10 o C and leaves the capacitor as a saturated liquid at 35 o C. To cool 20 kW, determine (a) mass flow speed, (b) compressor power per kW and (c) performance factor. What if scenario: Editing Problem (TEST Solution) Answers: a) 0.1397 kg/s, b) 4.31 kW, c) 4.64 10-1-10 (ideal-015MP) The fridge uses P-12 as a working liquid and runs on an ideal steam compression cycle between 0.15 MPA and 0.8 MPA. The refrigerant mass flow rate is 0.04 kg/s. a) Show the loop on the T-s chart relative to saturation lines. Determine (b) the rate of heat removal from the refrigeration space, c) putting energy into the compressor, (d) the rate of heat rejection in the environment and (e) performance factor. (f) What scenario: What would be the answer partly (b) and (c) if the mass flow rate doubled?. (Editing problem) (TEST solution) Answers: (b) 4.45 kW, c) 1.19 kW, d) 5.64 kW, e) 3.76, (f) 8.91 kW, 2.37 kW 10-1-11 (ideally-neg5C) The ideal compression vapor cooling cycle works in a stable condition with the R-134a refrigerant as a working liquid. Saturated steam enters the compressor at -5 o C, and the saturated liquid leaves the condenser at 35 o C. The velocity of the refrigerant is 5 kg/min. Determine (a) the compressor's capacity per kW, (b) refrigeration capacity in tons and (c) performance factor. (d) What scenario: what would a COP be like if the capacitor worked at 50 o C? (Editing problem) (TEST solution) Answers: a) 2.23 kW, (b) 3.46 tons, c) 5.45, (d) 3.51 10-1-12 (ideally-0C) Repeat the problem 10-1-11, changing the condensation temperature from 0 o C to 60 o C. Plot as COP and COP Carnot (based on maximum and minimum cycle temperature) vary depending on the output temperature. (Editing problem) TEST Solution 10-1-13 ideal-200 kW Large refrigeration unit should be maintained at -18 o C requires cooling at a speed of 200 kW. The condenser plant should be cooled by liquid water, which experiences an increase in temperature of 8o C as it flows over the capacitor coils. Assuming that the plant works on an ideal vapor compression cycle using a refrigerant-134a as a working liquid between the pressure limits of 120 kP and 700 kP, determine (a) the rate of mass flow of refrigerant, (b) input energy into the compressor and (c) the rate of mass flow of cooling water. (Editing problem) (Test Solution) Answers: a) 1.36 kg/s, (b) 49.65 kW, c) 7.41 kg/s Refrigeration Plant Image 10-1-14 (ideal-10F) The ideal steam-compression cooling system works in a stable condition with the R-12 Refrigenant as a working liquid. The heated vapor gets into the compressor at 25 pounds/2, 10 o F, and the saturated liquid leaves the capacitor at 200 pounds/in 2. The refrigeration capacity is 5 tons. Determine (a) horsepower compressor power, (b) the rate of heat transmission from the working fluid passing through the capacitor to the Btu/min and (c) performance factor. (d) What if the scenario: what would be the power of the compressor if the refrigeration capacity was 10 tons? (Editing problem) (TEST solution) Answers: a) 9.76 hp, b) 1413.88 btu/min, (c) 2.41, (d) 19.52 hp 10-1-15 (ideally-neg10C) The R-12 refrigeration unit enters the compressor of the ideal compression vapor system in the form of saturated steam at -10 o C with a volume speed of 1 m 3/min. Determine (a) compressor power per kW (b) refrigeration capacity in tons and c) performance factor. (Editing problem) (Test Solution) Answers: a) 5.9 kW, b) 7.01 tonne, (c) 4.17 10-1-16 perfect-1kgs Fridge uses R-134a as the working liquid works on an ideal steam compression cycle between 0.15 MPa and 1 MPa. If the mass flow speed is 1 kg/s, determine (a) the pure power required to run the system and (b) the COP. (c) What if scenario: What would the COP be like if the expansion valve had been replaced by an isentropic turbine? (Editing problem) (TEST solution) Answers: a) 39.63 kW, 3.33, (c) 4.50 Anim. 10-1-16 (click) 10-1-17 10-1-17 The steam compression cooling system, which uses ammonia as a working liquid, has vaporizer and capacitor pressure of 1 bar and 14 bar, respectively. The refrigerant passes through each heat-freezing with a slight drop in pressure. When the compressor enters and exits, the temperature is -12 o C and 210 o C, respectively. The rate of heat transmission from the working liquid passing through the capacitor is 15 kW, and the liquid comes out of the capacitor at 12 bar, 28 o C. If the compressor works adiabathically, determine (a) the compressor's power in kW and (b) performance factor. (c) What scenario: What would be the power of the compressor if the condensate temperature rose to 250 o C? (Editing problem) (TEST solution) Answers: a) 4.44 kW, (b) 2.37, (c) 5.40 kW 10-1-18 (compressor-12bar) steam compression cooling system, 15 tons overheated refrigerant R-134a steam, enter compressor at 15 o C, 4 bar output and 12 bar. The compression process can be considered polytropic, with n No 1.01. At the exit of the capacitor, the pressure is 11.6 bar and the temperature of 44 o C. The capacitor is cooled by water, the water enters 20o C and leaves at 30o C with a slight change in pressure. The transfer of heat from the outside of the capacitor may be neglected. Determine (a) compressor power in kW, (b) performance factor and c) the irreversibility of the capacitor per kW for T 0 and 20 o C. Answers to questions: a) 26.09 kW, (b) 2.02, (c) 0.00604 kW 10-1-19 (ideal-20bar) The ideal vapor-compression cooling cycle, with ammonia as a working liquid, has a vaporizer temperature of -25 o C and a condenser pressure of 20 bar. Saturated steam gets into the compressor, and the saturated liquid comes out of the condenser. The rate of mass flow of refrigerant is 3 kg/min. Determine (a) performance factor and (b) refrigeration capacity in tons. c) What if the scenario: What would the cop be like if the vaporizer temperature was -40o C? (Editing problem) (Test Solution) Answers: a) 2.59, (b) 15.11 tonne, (c) 1.87 10-1-20 ideal-500kJmin Consider a 500 kJ/min refrigeration system that works on an ideal compression cycle with a refrigerated-134a as a working liquid. The refrigerant enters the compressor in the form of saturated steam at 150 kP and is compressed to 800 kP. (a) Show the cycle on the T-s chart in relation to saturation lines and determine (b) the quality of the refrigerant at the end of the regulatory process, c) performance factor and (d) the input of energy into the compressor. (e) What scenario: What would be the answers if the R-12 was a working liquid? (Editing problem) (TEST Solution) Answers: b) 0.31553, (c) 0.24, (d) 34.83 kW, (e) 0.30825; 0.28; 29.64 kW 10-1-21 compressor-07MP P-12 refrigerant enters the refrigerator compressor as steam at 0.14 MPA, -20o C at a speed of 0.04 kg/s, and leaves at 0.7 MPA, 50 o C. Refrigeration is cooled in the capacitor to 24o C, 0.65 MPa and strangled to 0.15 MPa. Ignoring any heat transmissions and pressure drops in the connecting lines between components, a) show the loop on the T-s diagram against saturation lines, determine (b) the rate of heat removal from the refrigeration space, (c) input energy into the compressor, (d) the isentropic efficiency of the compressor and (e) the refrigerator cop. (Editing problem) (TEST solution) Answers: b) 4.81, c) 1.43, (d) 79.7%, (e) 3.35 Image of refrigerant chain 10-1-22 (compressor-1MPa) Refrigent R-12 enters the refrigerator compressor at 140 kP, -10 o C at a speed of 0.3 m 3/min and at 1 MPa. The compression process is isentropic. The refrigerant enters the control valve at 0.95 MPA, 30o C and leaves the vaporizer in the form of saturated vapor at -18.5 o C. (a) Show the cycle on the T-s chart in relation to saturation lines, determine (b) the input of energy into the compressor, (c) the rate of heat removal from the cooled space, (d) the drop in pressure and the rate of heat gain in the line between the vaporizer and the capacitor. (Editing problem) (TEST solution) Answers: b) 1.5 kW, c) 6.06 kW, d) 20 kPa; 0.23 kW 10-1-23 capacitor-7bar vapor compression cooling system circulates R-134a at a speed of 10 kg/min. Refrigerant enters the compressor at -10 o C, 1.2 bar and goes into 7 bar. The efficiency of the isentropic compressor is 68%. There are no significant drops in pressure as the refrigerant passes through the capacitor and vaporizer. The refrigerant leaves the capacitor at 7 bar and 24 o C. Ignoring the transfer of heat between the compressor and its environment, determine (a) performance factor, (b) refrigeration capacity in tons and (c) irreversibility of the compressor and valve expansion of each in kW at ambient temperature 20 o C. Answers to questions: a) 2.83, (b) 7.65 tons, (c) 2.704 kW; 1.107 kW Anim. 10-1-23 (click) 10-1-24 (evap-5F) The steam-compression cooling system for the household refrigerator has a refrigeration capacity of 1500 Btu/h and uses R-12 as a refrigerant. The refrigerant enters the vaporizer at 21,422 lbf/in 2 and comes out at 5 o F. The efficiency of the isentropic compressor is 70%. The refrigerant condenses at 122.95 pounds/in 2 and comes out of the capacitor as sub-cooled at 90o F. There are no significant pressure drops in the streams through the vaporizer and the capacitor does not. Determine (a) the mass flow of the refrigerant in pound/min, (b) the compressor's power input into horsepower and (c) performance factor. (Editing problem) (TEST solution) Answers: a) 30.34 lb/min, (b) 13.92 hp, (c) 2.54 10-1-25 (ideal-01kgs) fridge-freezer shown in the diagram below, uses R-134a as a working and works on a perfect steam compression cycle. The temperature in the capacitor, refrigerator and freezer is 25o C, 2 o C and -20o C, respectively. The rate of mass flow of the refrigerant is 0.1 kg/s. If the quality of the refrigerant at the exit of the refrigerator is 0.4, determine the rate of heat removal from the refrigerator and (b) freezer. Also, determine (c) the input of the power compressor and (d) cop unit. (Editing problem) (TEST solution) Answers: a) 4.68 kW, b) 10.46 kW, c) 3.33 kW, d) 4.55 Anim. 10-1-25 (click) 10-1-26 (capacitor-11bar) Refrigerator 134a is a working liquid in the vapor compression cooling system with two vaporizers. The system uses only one compressor. The saturated liquid leaves the capacitor at 11 bar, one part of the liquid is smothered to 3 bar, the second part is smothered to the second vaporizer at -15 o C. Par leaves the first vaporizer as saturated steam and strangled under the pressure of the second vaporizer. The refrigeration capacity of the first vaporizer is 1 ton, in the second - 2 tons. All working fluid processes are internally reversible, except for expansion through each valve. The compressor and valves work adiabatically. Kinetic and potential energy effects are negligible. Determine (a) the mass flow rate through each vaporizer, (b) the input power of the compressor, c) the transfer of heat from the refrigerant passing through the capacitor. (d) What if the scenario: What would the compressor power input be if all the cooling power of the first vaporizer was transferred to the second? (Editing problem) (TEST solution) Answers: (a) 1.53 kg/min; 3.29 kg/min, (b) 3.24 kW, c) 13.79 kW, d) 3.26 kW Anim. 10-1-26 (click) 10-1-27 (heatEx-10C) The ideal vapor compression cycle uses R-134a as a working liquid running between pressures of 0.1 MPA and 1.5 MPAs. The refrigerant leaves the capacitor at 30o C and the heater at 10o C. The refrigerant is then smothered to vaporizer pressure. The refrigerant leaves the vaporizer in the form of saturated steam and moves to heat-reflective. The mass flow rate is 1 kg/s. Determine (a) the rate of heat removal from the cooled space per mass flow unit and b) COP. (c) What if the script: What would be the answers if the heat-markic had been removed? (Editing problem) (TEST solution) Answers: a) 167.5 kW, (b) 2.52, (c) 139.6 kW, 2.45 Anim. 10-1-27 (click) 10-1-28 heatEx-r12 Repeat the problem of 10-1-27 with R-12 as a working liquid. (Editing problem) (TEST Solution) Answers: a) 128 kW, (b) 2.27, (c) 109 kW, 2.24 10-1-29 (camera-04MP) Consider a two-to-one refrigerated P-12 system operating between 0.15 MPA and 1 MPA. The refrigerant leaves the capacitor as a saturated liquid and is smothered until the flash camera runs at 0.4 MPA. Steam from the flash camera is mixed with a refrigerant, leaving the compressor pressure and and compressed by a high-pressure compressor to the pressure of the capacitors. In the flash chamber, the liquid is adjusted to the pressure of the vaporizer, where the cooling load is processed through evaporation. Assuming that the refrigerant leaves the vaporizer in the form of saturated vapor and both compressors are isentropic, determine (a) the lobe of the refrigerant that evaporates in the flash chamber, b) cooling load and (c) cop. (d) What if the script: What would cop if the interim pressure were changed to 0.8 MPA? (Editing problem) (TEST solution) Answers: a) 0.2215, (b) 29.9 tonnes, (c) 3.49, (d) 3.18 Anim. 10-1-29 (click) 10-1-30 (camera-r134a) Repeat the problem 10-1-29 with R-134a as a working fluid. (Editing problem) (TEST Solution) Answers: a) 0.2278, b) 38.6 tons, (c) 3.88, (d) 3.60 10-1-31 (evap-neg70C) Consider the ideal two-scureth cooling system (see Figure 10-1-29), which uses R-12 as a working fluid. The saturated liquid leaves the capacitor at 40o C and is smothered to -20 o C. At this temperature, the liquid and steam are separated, and the liquid is gasiated to a vapor at -70o C. Steam, leaving the vaporizer, compressed to saturation pressure corresponding to -20o C, then mixed with the steam leaving the flash chamber. Determine (a) the performance factor of the system. (b) What scenario: What would the COP be like if the flash camera was removed with the entire stream pointing to the second expansion valve? (Editing problem) (Test Solution) Answers: a) 1.43, (b) 1.03 10-1-32 pmin-008MPa Consider a two-vegent compression cooling system (see Figure 10-1-29), working between pressure limits 1.2 MPa and 0.08 MPa. Working liquid R-12. The refrigerant leaves the capacitor as a saturated liquid and is smothered until the flash camera runs at 0.4 MPA. Part of the refrigerant evaporates during this blinking process, and this vapor is mixed with the refrigerant, leaving the compressor low pressure. The mixture is then compressed to capacitor pressure by a high-pressure compressor. In the flash chamber the liquid is carbonated to the pressure of the vaporizer and it cools the cooled space as it evaporates into the vaporizer. Assuming that the refrigerant leaves the vaporizer in the form of saturated steam and both compressors are isentropic, determine (a) a fraction of the refrigerant that evaporates when processed before the flash chamber, (b) the amount of heat removed from the cooled space, c) compressor work per unit of refrigerant mass flowing through the capacitor, and (d) performance factor. (e) What scenario: What would be the answers if R-134a were used instead? (Editing problem) (TEST solution) Answers: a) 0.2701, b) 93.55 kW, (c) 40.93 kW, (d) 2.28, (e) 0.2826; 119.80 kW; 47.22 kW; 2.54 10-1-33 pmax-1MPa Double-fitting compression refrigeration units runs between the pressure limits of 1 MPa and 0.12 MPa. The refrigerant leaves the capacitor as a saturated liquid and is smothered until the flash camera runs at 0.7 MPA. The refrigerant, which leaves the low-pressure compressor at 0.7 MPA, is also in the flash chamber. The steam in the flash chamber is then compressed to capacitor pressure by a high-pressure compressor, and the liquid is smothered until the vaporizer pressure. Assuming that the refrigerant leaves the vaporizer in the form of saturated steam and both compressors are isentropic, determine (a) a fraction of the refrigerant that evaporates when soda to the flash chamber, (b) the heat rate removed from the cooled space for a mass flow speed of 1 kg/s through the capacitor and (with) performance factor. (d) Scenario what if: Work out a parametric study of how the COP changes at the pressure of a flash camera as it increases from 0.5 MPA to 0.9 MPA. (Editing problem) (TEST solution) Answers: a) 0.1055, (b) 131.98 kW, c) 3.27, d) COP falls from 3.43 to 3.03 Anim. 10-1-33 (click) 10-1-34 (pmin-005MPa) Consider a two-toe cascading refrigeration system running between the pressure limits of 2 MPAs and 0.05 MPAs. Each stage runs on a perfect steam compression cycle with R-134a as a working fluid. The rejection of heat from the lower cycle to the upper cycle occurs in the adiabatic counterflow of heat exchange, where both streams are 0.5 MPAs. If the rate of mass flow of the refrigerant through the upper cycle is 0.25 kg/s, determine (a) the rate of mass flow of the refrigerant through the lower cycle, (b) the rate of heat removal from the refrigeration space, (c) the input of power into the compressor in the lower cycle and (d) the performance factor of this cascading refrigerator. Scenario what if: What would the COP be if the pressure of heat meacenica was (e) 0.4 MPA or (f) 0.7 MPA. (Editing problem) (TEST solution) Answers: a) 0.135 kg/s, b) 20.42 kW, c) 6.36 kW, d) 1.51, e) 1.49, (f) 1.50 10-1-35 (lower-key-r13) Consider a two-cup cascading refrigeration system running between -80 o C and 80 o C. Each stage works on a perfect steam compression cycle. The upper cycle use R-12 as a working fluid, the lower cycle of use of R-13. In the lower cycle, the refrigerant condenses at 0 o C, in the upper cycle the refrigerant evaporates at -5 o C. If the mass flow rate in the lower cycle is 1 kg/s, determine (a) the rate of mass flow through the upper cycle, (b) the amount of heat removed from the cooling space, and (c) cop. (d) What-if scenario: What would happen to the cop if we took into account the one-year ideal steam compression system between -80 o C and 80 o C with R-13 as a working liquid? (Editing problem) (Test Solution) Answers: a) 1.78 kg/s, (b) 66.75 kW, (c) 1.32, d) COP does not exist 10-1-36 (upper-01kgs) Consider a two-toe cascading refrigeration system running between 0.1 and 1 MPa. Each stage runs on a perfect cycle with R-134a as a working fluid. The heat from the bottom to the upper cycle is rejected at 0.4 MPA. If the mass flow rate in the upper cycle is 0.1 kg/s, determine (a) the mass flow rate through the lower cycle and (b) cop. (c) What if the scenario: What would the COP be like if the interim pressure were changed to 0.6 MP? (Editing problem) (TEST Solution) Answers: a) 0.075 kg/s, (b) 3.15, (c) 3.05 Anim. 10-1-36 (click) 10-1-37 (bottomCy-r22) Consider a two-foot cascading refrigeration system running between -60 o C and 50 o C. Each stage runs on an ideal steam compression cycle. The upper cycle uses R-134a as a working fluid, the lower cycle uses R-22. In the lower cycle, the refrigerant condenses at 10o C, in the upper cycle the refrigerant evaporates at 0 o C. If the mass flow rate in the upper cycle is 0.5 kg/s, determine (a) the rate of mass flow through the lower cycle, (b) the cooling rate in tons, c) the performance factor and (d) the compressor power entry to the co. (Editing problem) (TEST solution) Answers: a) 0.26 kg/s, (b) 12.49 tons, c) 1.25, (d) 34.99 kW Section-2: Gas cooling cycles 10-2-1 IS-10C The air enters the gas cooling system at 10o C, 50 kP and turbine at 50o C, 250 kPa. The mass flow speed is 0.08 kg/s. Assuming variable specific temperature, determine (a) cooling speed, (b) clean power intake and (c) COP. (d) What-if scenario: What would the cop be like if the compressor input temperature was 15oo C? (Editing problem) (Decision TEST) Answers: a) 6.35 kW, b) 3.7 kW, c) 1.72, (d) 1.71 Anim. 10-2-1 (click) 10-2-2 (PG-45F) Air enters the ideal gas refrigeration cycle compressor at 45o F, 10 psia and turbine at 120o F, 30 psia. The mass flow of air through the cycle is 0.5 pounds/s. Determine (a) cooling speed, (b) net input to energy and (c) performance factor. (Editing problem) (TEST Solution) Answers: a) 584.56 Btu/min, (b) 215.79 Btu/min, (c) 2.70 10-2-3 (PG-15C) Air enters the compressor of the ideal gas cooling cycle at 15 o C, 50 kPa and turbine at 50o C, 300 kPa. The mass flow rate through the cycle is 0.25 kg/s. Assuming variable specific air temperature (IG model), determine (a) cooling speed, (b) net power input and (c) performance factor. (d) What scenario: what would the COP be like if the IG model were used for air? (Editing problem) (TEST solution) Answers: a) 23.72 kW, b) 15.88 kW, c) 1.49, d) 1.50 10-2-4 Brayton-200kPa air enters the compressor of braiton's ideal cooling cycle at 200 kPa, 270 k, with a volume speed of 1 m 3/s and compressed to 600 kp. The temperature at the turbine entrance is 330 K. Treatment of air as an ideal gas, definition (a) clean energy per kW, (b) refrigeration capacity per kW and tons and (c) (c) Performance. (d) What if the scenario: What would the COP be like if it were possible to manage the reverse cycle between the highest and lowest temperatures of the cycle? (Editing problem) (TEST solution) Answers: (a) 27.70 kW, b) 75.05 kW; 21.34 tons, c) 2.7, (d) 1.87 10-2-5 ideal-pr4 The ideal gas refrigeration cycle uses air as a working liquid to maintain refrigeration space at -30 o C when heat is not warm to the environment at 30 o C. If the compressor pressure ratio is 4, determine (a) the maximum and minimum temperature in the cycle, (b) the performance factor and (c) the cooling speed for the mass flow rate of 0.05 kg/s. (d) What scenario: What would be a COP if the PG model was used for air? (Editing problem) (TEST solution) Answers: a) 87.99 o C; -69.22 o C, b) 2.057, (c) 1.97 kW, (d) 2.055 10-2-6 (brayton-pr6) Brayton's ideal cooling cycle has a compressor pressure ratio of 6. At the entrance of the compressor pressure and temperature entering the air 55 lbf/in 2 and 600 o R. The temperature at the exit of the turbine is 370 o R. For refrigeration capacity of 15 tons, determine a) clean energy input, in Btu/min, (b) performance factor and (c) specific amounts of air at the entrance of the compressor and turbine, each foot in 3/lb. (Editing problem) (TEST Solution) Answers: (a) 1983.51 Btu/min, (b) 1.51, (c) 4.04064 ft 3 /lb; 0.69294 ft 3/lb 10-2-7 (brayton-275K) Air is included in Brayton's ideal refrigeration cycle compressor at 120 kP and 275 K. The compressor pressure factor is 3, and the temperature at the turbine entrance is 325 K. Treating air as an ideal gas, determining (a) net input per unit of airflow mass, in kJ/kg, b) refrigeration power per unit of airflow mass, in kJ/kg and (c) performance factor. (d) What scenario: what would the COP be like if the IG model were used for air? (Editing problem) (TEST Solution) Answers: a) 13.94 kJ/kg, (b) 37.76 kJ/kg, (c) 2.71, (d) 2.72 10-2-8 helium-neg10C Gas cooling system uses helium as the working liquid works with a pressure factor of 3.5. The helium temperature is -10 o C at the compressor entrance and 50 o C at the turbine entrance. Assuming an adiabathic efficiency of 80% for both compressor and turbine, determine (a) the minimum cycle temperature, (b) the mass flow rate for a cooling speed of 1 ton and (c) COP. (d) What if the scenario: What would the COP be like if adiabatic efficiency increased to 85%? (Editing problem) (TEST solution) Answers: a) -51.89 o C, b) 0.016 kg/s, c) 0.37, (d) 0.52 Anim. 10-2-8 (click) 10-2-9 (compressor-85pct) In the problem 10-2-6 believe that the compressor and turbine each has an isentropic efficiency of 85%. Determine for a modified cycle, (a) mass flow rate in pounds/s and (b) performance ratio. (c) What if scenario: Make parametric parametric how the COP will change if the efficiency ranges from 50% to 100%. (Editing problem) (Test Solution) Answers: a) 0.906 lb/s, (b) 0.35, (c) COP rises from 0.25 to 1.51 10-2-10 (turbine-90pct) In 10-2-7 believe that the compressor and turbine have an isentropic efficiency of 80% and 90%, respectively. Determine for a modified cycle((a) performance factor and (b) irreversibility ratio, per unit of airflow mass, compressor and turbine, each in kJ/kg, for T 0 and 300 K. Editing problem (TEST Solution) Responses: a) 0.6, (b) 0.06546 kJ/kg; 0.03638 kJ/kg 10-2-11 (helium-pr3) Gas cooling cycle with pressure factor 3 uses helium as a working liquid. The helium temperature is -15 o C at the compressor entrance at 50 o C at the turbine entrance. Assuming an adiabatic efficiency of 85% for both the turbine and the compressor, determine (a) the minimum cycle temperature, b) performance factor and (c) the mass helium flow rate for a cooling speed of 10 kW. (d) What if the scenario: What would the cop be like if the temperature at the turbine entrance was increased to 60 o C? (Editing problem) (TEST solution) Answers: a) -47.67 o C, b) 0.46, (c) 0.0589 kg/s, (d) 0.38 10-2-12 regen-neg15C Gas-cooling system uses air, as the working liquid has a pressure factor of 4. The air enters the compressor at -7 o C. High-pressure air is cooled to 30o C, weaning heat from the environment. It is additionally cooled to -15o C by regenerative cooling before it enters the turbine. Assuming that both the turbine and the compressor will be isentropic and using the PG model for air, determine (a) the lowest temperature you can get in this cycle, (b) cycle performance factor and c) the mass air flow rate for cooling speed of 12 kW. (d) What if the scenario: What would the COP be like if the pressure ratio was 5? (Editing problem) (TEST solution) Answers: a) -99.49 o C, (b) 1.055, c) 0.253 kg/s, (d) 1.055 Rice. 10-2-12 10-2-13 (regen-cop) In problem 10-2-12 assess the effect of regeneration on the COP by changing the temperature of the input turbine at (a) -10 o C, (b) 0 o C, c) 10 o C and d) 20 o C. (Editing Problem) (TEST Solution) Responses: a) 1.133, (b) 1.307, (c) 1.512, (d) 1.757 Section-1.7573: Heat Pump Systems 10-3-1 Perfect-02kgs heat pump that works on an ideal The R-12 steam compression cycle is used to heat water from 5o C to 30o C at a mass flow rate of 0.2 kg/s. The capacitor and vaporizer pressure is 0.8 MPA and 0.2 MPA, respectively. Determine (a) the power supply of the heat pump and (b) the cos of the heat pump. c) What if the scenario: Can we heat the water if the R-12 were replaced by R-22? (Editing problem) (TEST decision) Answers: (a) kW, (b) 5.67, (c) No. Anim. 10-3-1 (click) 10-3-2 (evap-neg10F) Ammonia is a working liquid in the heat pump's steam compression system The 25,000 Btu/h. Capacitor works at 250 pounds/in 2, and the vaporizer temperature is -10 o F. The refrigerant is a saturated steam at the output of the vaporizer and the liquid is 100 o F at the exit of the capacitor. The drop in pressure in the streams through the vaporizer and capacitor is negligible. The compression process is adebatic, and the temperature at the compressor output is 400 o F. Determine (a) the rate of mass refrigerant flow, pound/min, b) the compressor's input into horsepower, (c) the efficiency of the isentropic compressor and (d) the performance factor. (Editing problem) (Test Solution) Answers: a) 0.6 lb/min, b) 3.15 l,15 litres, (c) 74%, (d) 3.12 10-3-3 ideal-p22 small heat pump used to heat water for hot water. Let's say the device uses the R-22 and runs on a perfect cooling cycle. The temperature of the vaporizer is 0 o C and the capacitor temperature is 50 o C. If the required amount of hot water is 0.1 kg/s, determine the amount of energy saved by the heat pump, rather than directly heating the water from 0o C to 50oC. Responses to the Editing Problem: 16.03 kW 10-3-4 ideal-10kW Ideal cycle of heat pump steam-compression with R-134a refrigerant, as the working liquid provides 10 kW to maintain the building at 22 o C, when the external temperature is 5 o C. The agent leaves the capacitor as a saturated liquid. Calculate (a) the input of energy into the compressor in kW, (b) performance factor and (c) performance ratio of the reversible cycle of the heat pump running between the thermal tanks at 22 o C and 5 o C. (d) What-if scenario: What would the answers partially (b) and (c) be if the external temperature was at 0 o C? (Editing problem) (TEST solution) Answers: a) 0.63 kW, b) 14.94, (c) 15.94, (d) 11.13; 12.13 10-3-5 perfect-20C heat pump that works on an ideal steam compression cycle with R-12 is used to heat the house and maintain it at 20 o C using groundwater at 25oC as a heat source. The house loses heat at a rate of 90,000 kJ/h. Vaporizer and capacitor pressure is 0.35 MPA and 0.8 MPA, respectively. Determine (a) the power supply of the heat pump. (b) Scenario What if: If an electric resistance heater is used instead of a heat pump, calculate the increase in electricity input. (Editing problem) (TEST Solution) Answers: (a) 1.68 kW, b) 23.32 kW 10-3-6 capacitor-9bar Heat pump steam compression system uses R-134a refrigerant as a working liquid. The refrigerant enters the compressor at 2.4 bar, 0o C and a flow speed of 0.8 m 3/min. Compression adiabatic to 10 bar, 50o C and saturated liquid overlooks the capacitor on 9 bar. Determine (a) the power injected into the compressor in kW, (b) the heating capacity of the system in kW and tons, c) coefficient and (d) the efficiency of the isentropic compressor. (e) What if scenario: What cop be if the temperature of the refrigerant at the exit compressor were 70o C? (Editing problem) (TEST solution) Answers: (a) 1.85 kW, b) 27.1 kW; 7.71 tons, c) 5.59, (d) 97%, (e) 2.75 10-3-7 (compressor-75pct) P-22 is used as a working liquid in a normal heat pump cycle. Saturated steam gets into the compressor of this unit at 15 o C; The output temperature from the compressor is 90 o C. If the isentropic efficiency of the compressor is 75%, (a) what is the performance factor of the heating pump. (b) What is the scenario: What will be the performance factor if the efficiency of the isentropic compressor is changed to 65%? (Editing problem) (TEST Solution) Answers: a) 3.77, (b) 3.40 10-3-8 (powerCy-25pct) A 500 kJ/min steam-compression heat pump is controlled by a 25% heat cycle. For the heat pump, the 134a refrigerant is compressed from saturated steam at -10 o C to a capacitor pressure of 10 bar. The efficiency of the isentropic compressor is 85%. The expansion valve receives liquid with 9.6 bar and 34 o C. For the power cycle, 90% of the rejected heat is transferred to the heated space. Determine (a) putting energy into a heat pump compressor in a kW and (b) assess the ratio of the total speed of heat delivery to a heated space at the rate of heat entering the energy cycle. (Editing problem) (TEST solution) Answers: (a) 1.84 kW, b) 2.32 10-3-9 water-8C Heat pump uses R-12 to heat the house with groundwater at 8 o C as a heat source. The house loses heat at a rate of 30,000 kJ/h. The refrigerant enters the compressor at 250 kph, -2 o C and goes out at 1.2 MPA, 70 o C. The refrigeration agent leaves the capacitor at 30 o C. Determine (a) the input of energy into the heat pump and b) the rate of heat absorption from the water. (c) Scenario What if: If instead of a heat pump used an electric resistance heater, calculate the increase in electricity input. (Editing problem) (TEST Solution) Answers: a) 1.85 kW, (b) 6.48 kW, (c) 6.48 kW 10-3-10 (evap-neg12C) In a real cooling cycle, the heat pump uses R-12 as a working liquid at a mass flow rate of 0.1 kg/s. Steam gets into the compressor at 200 kP, -5 o C, and leaves at 1.5 MPa, 90 o C. The compressor power is 2.6 kW. The refrigerant enters the expansion valve at 1.2 MPa, 40o C and leaves the vaporizer at 200 kPa, -12 o C. Identify (a) irreversibility during the compression process, b) refrigeration power and (c) COP heating pump. (Editing problem) (TEST solution) Answers: (a) -0.00441 kW, (b) 12.97 kW, c) 6.15 Anim. 10-3-10 (click) Section-4: Exergy analysis of cooling cycles and heat pump 10-4-1 (ideally-004 kg) The fridge uses R-134a because the working liquid works on the ideal vapor compression cycle between 0.15 1 MPa. Разница 5 or C C to effectively heat-cover the refrigerant and its surroundings on the vaporizer and capacitor. Atmospheric conditions of 100 kPa and 25 o C. If the mass flow speed is 0.04 kg/s, a) perform speed-based (kW) exergment inventory throughout the cycle complete with an exergy flow diagram. Determine (b) exergetical efficiency and c) cop system. (d) Identify a device with the highest rate of exergy destruction. (Editing problem) (Manual solution) (TEST solution) Answers: b) 62.66%, (c) 3.33 Anim. 10-4-1 (click) 10-4-2 (compressor-7bar) The steam compression cooling system circulates R-134a at a speed of 10 kg/min. The refrigerant enters the compressor at -10 o C, 1.2 bar and goes into the 7 bar. The edentropic efficiency of the adiabatic compressor is 68%. There are no significant drops in pressure as the refrigerant passes through the capacitor and vaporizer. The refrigerant leaves the capacitor at 7 bar and 24 o C. Temperature difference of 5o C is maintained for effective heat storage between the refrigerant and its surroundings on the vaporizer and capacitor. Atmospheric conditions of 100 kPa and 25 o C. (a) Perform an exergity of an inventory based on speed (kW) for the entire cycle complete with an exergy flow chart. Determine (b) exergetical efficiency and c) cop system. (d) Identify a device with the highest rate of exergy destruction. (Editing problem) (Manual solution) (TEST Solution) Answers: b) 60.53%, (c) 2.83 Anim. 10-4-2 (click) 10-4-3 perfect-1kgs The ideal steam compression cycle uses R-134a as the working liquid works between 0.1 MPa and 1.5 MPa. The refrigerant leaves the capacitor at 30o C and the heater at 10o C. The refrigerant is then smothered to vaporizer pressure. The refrigerant leaves the vaporizer in the form of saturated steam and moves to the heat. The mass flow rate is 1 kg/s. Temperature difference of 5 o C is maintained for effective heat storage between the refrigerant and its surroundings on the vaporizer and capacitor. Atmospheric conditions of 100 kPa and 25 o C. (a) Perform an exergity of an inventory based on speed (kW) for the entire cycle complete with an exergy flow chart. Determine (b) cooling power, c) exergetic efficiency and d) cop system. (Editing problem) (Manual solution) (TEST solution) Answers: b) 167.5 kW, c) 59.0%, (d) 2.52 Anim. 10-4-3 (click) 10-4-5 ideal-20kW heat pump that works on the ideal steam compression cycle with R-134a, Used to transfer heat at a rate of 20 kW to a space stored at 50o C from the outer atmosphere at 0 o C. Scenario what if: for effective heat storage between the refrigerant and its surroundings on the vaporizer and capacitor retains a temperature difference of 5 o C. Atmospheric conditions of 100 kPa and 0 o C. (a) with an exergy flow diagram. Determine (b) the rate of energy consumption, c) exergetic efficiency and (d) cop system. (Editing problem) (TEST Solution) Answers: b) 4.91 kW, (c) 62.93%, (d) 4.06 Anim. 10-4-5 (click) 10-4-6 (atm-neg5C) Repeat problem 10-4-5 with external atmosphere at 100 kP and -5 o C. Answers to questions: (b) 5.42 kW, (c) 57.08%, (d) 3.69 Version No: 25; Last Updated: 2010-10-31 11:03:49