Thermodynamics, Problem Sheet 7: Vapor Power Cycles (from Sonntag)

1. Consider a solar-energy-powered ideal Rankine cycle that uses water as the working fluid. Saturated vapor leaves the solar collector at 175°C, and the condenser pressure is 10 kPa. Determine the thermal efficiency of this cycle. Also find the second-law efficiency of the cycle.

2. A steam power plant has a high pressure of 3MPa, and it maintains 60°C in the condenser. The quality at the turbine exit should not be lower than 90% at any state in the turbine. Find the specific work and heat transfer in all components and the cycle efficiency.

3. A steam power plant operating in an ideal Rankine, cycle has a high pressure of 5 MPa and a low pressure of 15 kPa. The turbine exhaust state should have a quality of at least 95%, and the turbine power generated should be 7.5MW. Find the necessary boiler exit temperature and the total mass flow rate. Also find the specific work output and the work ratio.

4. A small power plant produces main steam at a rate of 25 kg/s at 3 MPa, 600°C, in the boiler. The condenser is cooled with ocean water coming in at 12°C and returned at 15°C, so the steam inside the condenser condenses at 45°C. The boiler has an efficiency of 90% and it burns coal of calorific value of 10,000 kJ/kg. Find (i) the net power output, (ii) the required mass flow rate of ocean water, (iii) coal consumption rate, and (iv) the cycle efficiency.

5. If in the previous cycle a reheater is added, so that the turbine steam at 500 kPa is taken through the reheater and heated to 400°C before passing through the low-pressure turbine, determine the (i) the net power output, (ii) the required mass flow rate of ocean water, (iii) coal consumption rate, and (iv) the cycle efficiency.

6. Consider an ideal steam reheat cycle, where steam enters the high-pressure turbine at 3 MPa and 400°C and then expands to an intermediate pressure p_R. It is then reheated at constant pressure of p_R to 400°C and expands to 10 kPa in the low-pressure turbine. Calculate the thermal efficiency and the moisture content of the steam leaving the low-pressure turbine if p_R is equal to (i) 1 MPa, (ii) 0.7 MPa, and (iii) 0.4 MPa.

7. Consider an ideal steam regenerative cycle in which steam enters the turbine at 3MPa and 400°C and exhausts to the condenser at 10 kPa. Steam is extracted from the turbine at 0.8 MPa for an open feedwater heater. The feedwater leaves the heater as saturated liquid. The appropriate pumps are used for the water leaving the condenser and the feedwater heater. Draw the cycle diagram, and plot it neatly on the T-s and h-s diagrams. Calculate the thermal efficiency of the cycle and the net work per kilogram of steam. Compare the cycle performance with a regular Rankine cycle, with the same main steam parameters and condenser pressure.