adiabatic process. Show the two processes in P–v and T–s diagrams, and determine the final temperature and the net work.

Entropy Generation

6.115 Consider a heat transfer of 100 kJ from 1500 K hot gases to a steel container at 750 K that has a heat transfer of the 100 kJ out to some air at 375 K. Determine the entropy generation in each of the control volumes indicated in Fig. P6.115.

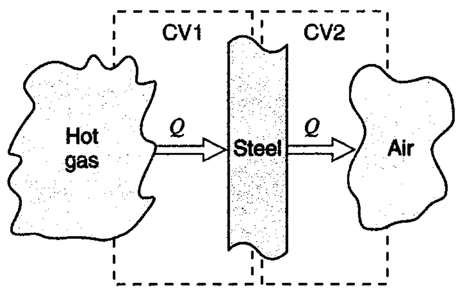

FIGURE P6.115

6.116 A rigid tank has 0.1 kg saturated vapor R-410a at 0°C that is cooled to −20°C by a −20°C heat sink. Show the process in a T–s diagram; find the change in entropy of the R-410a, the heat sink, and the total entropy generation.

6.117 One kilogram of water at 500°C and 1 kg saturated water vapor, both at 200 kPa, are mixed in a constant-pressure and adiabatic process. Find the final temperature and the entropy generation for the process.

6.118 A car uses an average power of 25 hp for a 1-h round trip. With a thermal efficiency of 35%, how much fuel energy was used? What happened to all the energy? What change in entropy took place if we assume an ambient temperature of 20°C?

6.119 A computer chip dissipates 2 kJ of electric work over time and rejects that work as heat transfer from its 50°C surface to 25°C air. How much entropy is generated in the chip? How much entropy, if any, is generated outside the chip?

6.120 An insulated cylinder/piston contains R-134a at 1 MPa, 50°C, with a volume of 100 L. The R-134a expands, moving the piston until the pressure in the cylinder has dropped to 100 kPa. It is claimed that the R-134a does 190 kJ of work against the piston during the process. Is that possible?

6.121 A rigid tank holds 0.75 kg ammonia at 70°C as saturated vapor. The tank is now cooled to 20°C by heat transfer to the ambient at 20°C. Determine the amount of entropy generation during the process.

6.122 The unrestrained expansion of the reactor water in Problem 3.101 has a final state in the two-phase region. Find the entropy generated in the process.

6.123 Heat transfer from a 20°C kitchen to a block of 1.5 kg ice at −10°C melts it to liquid at 10°C. How much entropy is generated?

6.124 Ammonia is contained in a rigid sealed tank of unknown quality at 0°C. When heated in boiling water to 100°C its, pressure reaches 1200 kPa. Find the initial quality, the heat transfer to the ammonia, and the total entropy generation.

6.125 Water in a piston/cylinder is at 101 kPa, 25°C and mass 0.5 kg. The piston rests on some stops, and the pressure should be 1000 kPa to float the piston. We now heat the water from a 200°C reservoir, so the volume becomes five times the initial value. Find the total heat transfer and the entropy generation.

6.126 Do Problem 6.125 assuming the piston/cylinder is 1.5 kg of steel and has the same temperature as the water at any time.

6.127 A cylinder fitted with a movable piston contains water at 3 MPa, 50% quality, at which point the volume is 20 L. The water now expands to 1.2 MPa as a result of receiving 600 kJ of heat from a large source at 300°C. It is claimed that the water does 124 kJ of work during this process. Is this possible?

6.128 A piston/cylinder device keeping a constant pressure has 1 kg water at 20°C and 1 kg of water at 100°C, both at 500 kPa separated by a thin membrane, shown in Fig. P6.128. The membrane is broken and the water comes to a uniform state, with no external heat transfer. Find the final temperature and the entropy generation for the process.

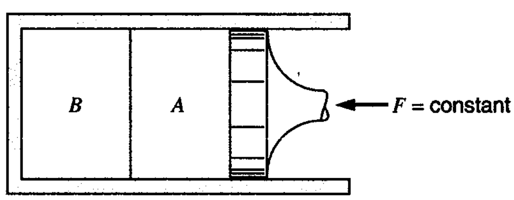

FIGURE P6.128

6.129 Reconsider problem 3.109 where carbon dioxide is compressed from $-20°C$, $x = 0.75$ to a state of 3 MPa, 20°C in a piston/cylinder where pressure is linear in volume. Assume heat transfer is from a reservoir at 100°C and find the specific entropy generation in the process (external to the carbon dioxide).

6.130 A piston/cylinder contains 1 kg water at 150 kPa, 20°C. The piston is loaded, so the pressure is linear in volume. Heat is added from a 600°C source until the water is at 1 MPa, 500°C. Find the heat transfer and the entropy generation.

6.131 A closed, rigid container is filled with 1.5 kg water at 100 kPa, 55°C, 1 kg of stainless steel and 0.5 kg of polyvinyl chloride, both at 20°C and 0.1 kg of hot air at 400 K, 100 kPa. It is now left alone, with no external heat transfer, and no water vaporizes. Find the final temperature and the entropy generation for the process.

6.132 A cylinder/piston contains water at 200 kPa, 200°C with a volume of 20 L. The piston is moved slowly, compressing the water to a pressure of 800 kPa. The loading on the piston is such that the product PV is a constant. Assuming that the room temperature is 20°C, show that this process does not violate the second law.

6.133 A rigid steel tank of mass 2.5 kg contains 0.5 kg R-410a at 0°C with a specific volume of $0.01 m^3/kg$. The system heats up to the room temperature, 25°C. Find the process heat transfer and the entropy generation.

6.134 A piston/cylinder has ammonia at 2000 kPa, 80°C with a volume of $0.1 m^3$. The piston is loaded with a linear spring and outside ambient is at 20°C, shown in Fig. P6.134. The ammonia now cools down to 20°C, at which point it has a quality of 15%. Find the work, the heat transfer, and the total entropy generation in the process.

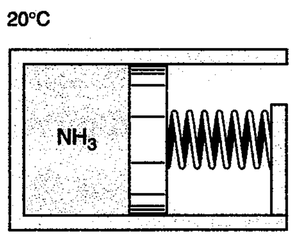

FIGURE P6.134

6.135 One kilogram of ammonia (NH_3) is contained in a spring-loaded piston/cylinder, similar to Fig. P6.134, as saturated liquid at $-20°C$. Heat is added from a reservoir at 100°C until a final condition of 800 kPa, 70°C is reached. Find the work, heat transfer, and entropy generation, assuming the process is internally reversible.

6.136 A 5-kg aluminum radiator holds 2 kg of liquid R-134a, both at $-10°C$. The setup is brought indoors and heated with 220 kJ from a heat source at 100°C. Find the total entropy generation for the process, assuming the R-134a remains a liquid.

6.137 A piston/cylinder of total 1 kg steel contains 0.5 kg ammonia at 1600 kPa, both masses at 120°C. Some stops are placed that so a minimum volume is $0.02 m^3$, shown in Fig. P6.137. Now the whole system is cooled down to 30°C by heat transfer to the ambient at 20°C, and during the process the steel keeps the same temperature as the ammonia. Find the work, the heat transfer, and the total entropy generation in the process.

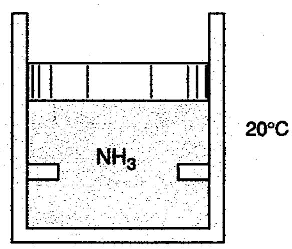

FIGURE P6.137

6.138 A piston/cylinder contains 0.1 kg water at 500°C, 1000 kPa. The piston has a stop at half of the original volume, similar to Fig. P6.137. The water now cools to room temperature, 25°C. Find the heat transfer and the entropy generation.

6.139 A hollow steel sphere with a 0.5-m inside diameter and a 2 mm-thick wall contains water at 2 MPa, 250°C. The system (steel plus water) cools to the ambient temperature, 30°C. Calculate the net entropy change of the system and surroundings for this process.

6.140 A cylinder/piston arrangement contains 10 g ammonia at 20°C with a volume of 1 L. There are some stops, so if the piston is at the stops, the volume is 1.4 L. The ammonia is now heated to 200°C by a 240°C source. The piston and cylinder are made of 0.5 kg aluminum, and assume that the mass has the same temperature as the ammonia at any time. Find the total heat transfer and the total entropy generation.

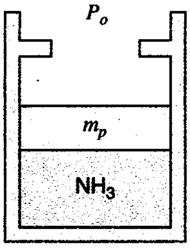

FIGURE P6.140

6.141 A cylinder/piston arrangement contains 0.1 kg R-410a of quality $x = 0.2534$ at −20°C. Stops are mounted, so $V_{stop} = 3V_1$, similar to Fig. P6.140. The system is now heated to the final temperature of 20°C by a 50°C source. Find the total entropy generation.

6.142 One kilogram of air at 300 K is mixed with 2 kg air at 400 K in a process at a constant 100 kPa and $Q = 0$. Find the final T and the entropy generation in the process.

6.143 Air in a rigid tank is at 900 K, 500 kPa, and it now cools to the ambient temperature of 300 K by heat loss to the ambient. Find the entropy generation.

6.144 Two rigid, insulated tanks are connected with a pipe and valve. One tank has 0.5 kg air at 200 kPa, 300 K and the other has 0.75 kg air at 100 kPa, 400 K. The valve is opened and the air comes to a single uniform state, without external heat transfer. Find the final T and P and the entropy generation.

6.145 One kilogram air at 100 kPa is mixed with 2 kg air at 200 kPa, both at 300 K, in a rigid, insulated tank. Find the final state (P, T) and the entropy generation in the process.

6.146 A rigid storage tank of 1.5 m^3 contains 1 kg argon at 30°C. Heat is then transferred to the argon from a furnace operating at 1300°C until the specific entropy of the argon has increased by 0.343 kJ/kg K. Find the total heat transfer and the entropy generated in the process.

6.147 Argon in a light bulb is at 110 kPa, 90°C. The light is turned off, so the argon cools to the ambient temperature of 20°C. Disregard the glass and any other mass and find the specific entropy generation.

6.148 A rigid tank contains 2 kg air at 200 kPa and ambient temperature, 20°C. An electric current now passes through a resistor inside the tank. After a total of 100 kJ of electrical work has crossed the boundary, the air temperature inside is 80°C. Is this possible?

6.149 A piston/cylinder system contains 50 L air at 300°C, 100 kPa, with the piston initially on a set of stops. A total external constant force acts on the piston, so a balancing pressure inside should be 200 kPa. The cylinder is made of 2 kg steel initially at 1300°C. The system is insulated, so heat transfer occurs only between the steel cylinder and the air. The system comes to equilibrium. Find the final temperature and the entropy generation.

6.150 A spring-loaded piston/cylinder contains 1.5 kg air at 27°C, 160 kPa. It is now heated in a process in which pressure is linear in volume, $P = A + BV$, to twice its initial volume, where it reaches 900 K. Find the work, the heat transfer, and the total entropy generation, assuming a source at 900 K.

6.151 A rigid container with volume 200 L is divided into two equal volumes by a partition, shown in Fig. P6.151. Both sides contain nitrogen; one side is at 2 MPa, 200°C and the other at 200 kPa, 100°C. The partition ruptures, and the nitrogen comes to a uniform state at 70°C. Assume the temperature of the surroundings is 20°C. Determine the work done and the net entropy change for the process.

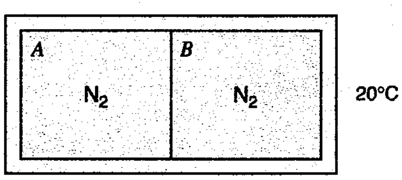

FIGURE P6.151

6.152 A constant pressure piston/cylinder contains 0.5 kg air at 300 K, 400 kPa. Assume the piston/cylinder has a total mass of 1 kg steel and is at the same temperature as the air at any time. The system is now

6.180 A closed tank, $V = 10$ L, containing 5 kg of water initially at 25°C, is heated to 150°C by a heat pump that is receiving heat from the surroundings at 25°C. Assume that this process is reversible. Find the heat transfer to the water and the work input to the heat pump.

6.181 A resistor in a heating element is a total of 0.5 kg with specific heat of 0.8 kJ/kgK. It is now receiving 500 W of electric power, so it heats from 20°C to 180°C. Neglect external heat loss and find the time the process took and the entropy generation.

6.182 Two tanks contain steam and they are both connected to a piston/cylinder, as shown in Fig. P6.182. Initially the piston is at the bottom, and the mass of the piston is such that a pressure of 1.4 MPa below it will be able to lift it. Stream in A is 4 kg at 7 MPa, 700°C and B has 2 kg at 3 MPa, 350°C. The two valves are opened, and the water comes to a uniform state. Find the final temperature and the total entropy generation, assuming no heat transfer.

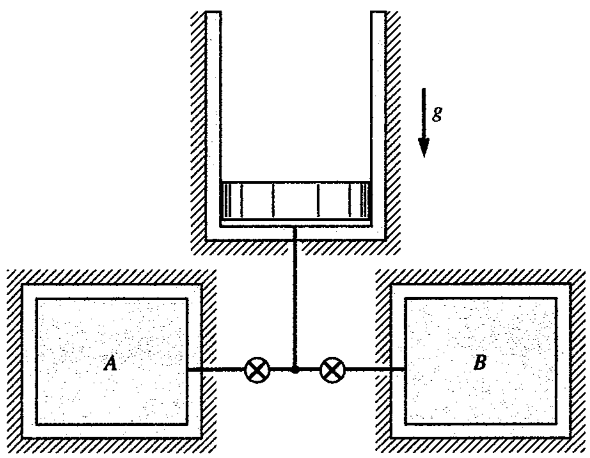

FIGURE P6.182

6.183 Assume the heat source in Problem 3.217 is at 300°C in a setup similar to Fig. P6.182. Find the heat transfer and the entropy generation.

6.184 A cylinder fitted with a piston contains 0.5 kg of R-134a at 60°C, with a quality of 50%. The R-134a now expands in an internally reversible polytropic process to ambient temperature, 20°C, at which point the quality is 100%. Any heat transfer is with a constant-temperature source, which is at 60°C. Find the polytropic exponent n and show that this process satisfies the entropy equation.

6.185 A device brings 2 kg ammonia from 150 kPa, −20°C to 400 kPa, 80°C in a polytropic process. Find the polytropic exponent n, the work, and the heat transfer. Find the total entropy generated, assuming a source at 100°C.

6.186 A rigid tank with 0.5 kg ammonia at 1600 kPa, 160°C is cooled in a reversible process by giving heat to a reversible heat engine that has its cold side at ambient temperature, 20°C, shown in Fig. P6.186. The ammonia eventually reaches 20°C and the process stops. Find the heat transfer from the ammonia to the heat engine and the work output of the heat engine.

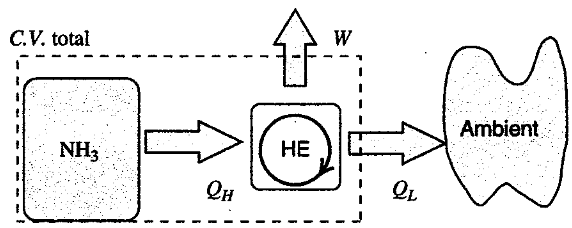

FIGURE P6.186

6.187 A piston/cylinder with constant loading of the piston contains 1 L water at 400 kPa, quality 15%. It has some stops mounted, so the maximum possible volume is 11 L. A reversible heat pump extracting heat from the ambient at 300 K, 100 kPa heats the water to 300°C. Find the total work and heat transfer for the water and the work input to the heat pump.

6.188 An uninsulated cylinder fitted with a piston contains air at 500 kPa, 200°C, at which point the volume is 10 L. The external force on the piston is now varied in such a manner that the air expands to 150 kPa, 25 L volume. It is claimed that in this process, the air produces 70% of the work that would have resulted from a reversible adiabatic expansion from the same initial pressure and temperature to the same final pressure. Room temperature is 20°C.

a. What is the amount of work claimed?
b. Is this claim possible?

6.189 A small halogen light bulb receives electrical power of 50 W. The small filament is at 1000 K and gives out 20% of the power as light and the rest as heat transfer to the gas, which is at 500 K; the glass is at 400 K. All the power is absorbed by the room walls at 25°C. Find the rate of generation of entropy in the filament, in the total bulb including the glass, and in the total room including the bulb.

the conditions are given in the figure. Assume that both the turbine and the compressor are reversible and adiabatic, having also the same mass flow rate. Calculate the turbine exit temperature and power output. Also find the compressor exit pressure and temperature.

7.42 Two flows of air are both at 200 kPa; one has 3 kg/s at 400 K, and the other has 2 kg/s at 290 K. The two lines exchange energy through a number of ideal heat engines, taking energy from the hot line and rejecting it to the colder line. The two flows then leave at the same temperature, as in a co-flowing heat exchanger. Assume the whole setup is reversible, and find the exit temperature and the total power out of the heat engines.

7.43 A flow of 5 kg/s water at 100 kPa, 20°C should be delivered as steam at 1000 kPa, 350°C to some application. We have a heat source at constant 500°C. If the process should be reversible, how much heat transfer should we have?

7.44 A heat-powered portable air compressor consists of three components: (a) an adiabatic compressor, (b) a constant-pressure heater (heat supplied from an outside source), and (c) an adiabatic turbine (see Fig. P7.44). Ambient air enters the compressor at 100 kPa, 300 K and is compressed to 600 kPa. All of the power from the turbine goes into the compressor, and the turbine exhaust is the supply of compressed air. If this pressure is required to be 200 kPa, what must the temperature be at the exit of the heater?

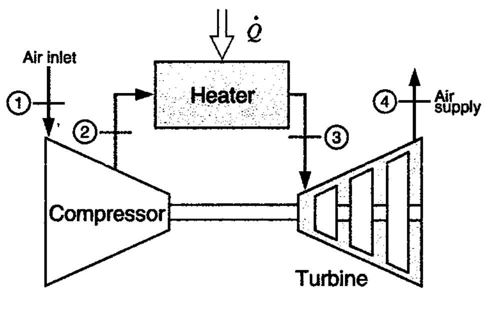

FIGURE P7.44

7.45 A two-stage compressor having an intercooler takes in air at 300 K, 100 kPa, and compresses it to 2 MPa, as shown in Fig. P7.45. The cooler then cools the air to 340 K, after which it enters the second stage, which has an exit pressure of 15 MPa. Both stages are adiabatic and reversible. Find q in the cooler, total specific work, and compare this to the work required with no intercooler.

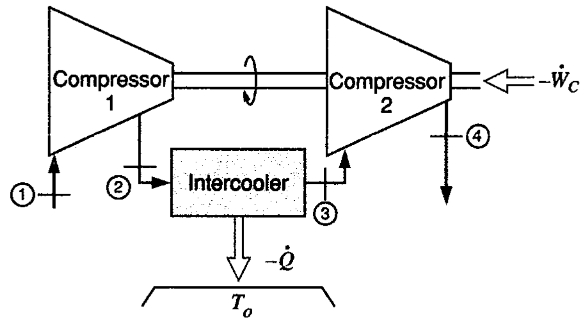

FIGURE P7.45

7.46 A certain industrial process requires a steady supply of saturated vapor steam at 200 kPa at a rate of 0.5 kg/s. Also required is a steady supply of compressed air at 500 kPa at a rate of 0.1 kg/s. Both are to be supplied by the process shown in Fig. P7.46. Steam is expanded in a turbine to supply the power needed to drive the air compressor, and the exhaust steam exits the turbine at the desired state. Air into the compressor is at the ambient condition, 100 kPa, 20°C. Give the required steam inlet pressure and temperature, assuming that both the turbine and the compressor are reversible and adiabatic.

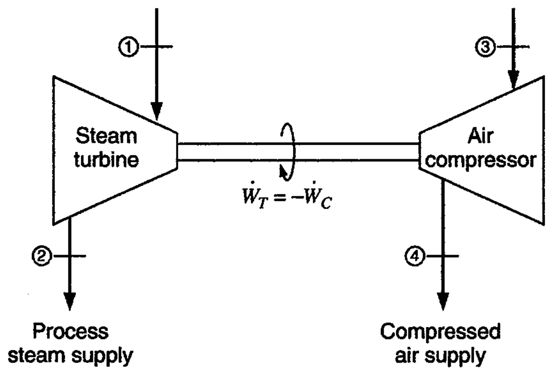

FIGURE P7.46

7.47 A certain industrial process requires a steady 0.75 kg/s supply of compressed air at 500 kPa at a maximum temperature of 30°C, as shown in Fig. P7.47. This air is to be supplied by installing a compressor and an aftercooler. Local ambient conditions are 100 kPa, 20°C. Using a reversible compressor, determine the power required to drive the compressor and the rate of heat rejection in the aftercooler.

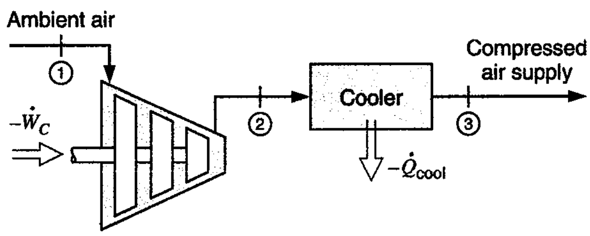

FIGURE P7.47

7.48 Consider a steam turbine power plant operating near critical pressure, as shown in Fig. P7.48. As a first approximation, it may be assumed that the turbine and the pump processes are reversible and adiabatic. Neglecting any changes in kinetic and potential energies, calculate

a. The specific turbine work output and the turbine exit state
b. The pump work input and enthalpy at the pump exit state
c. The thermal efficiency of the cycle

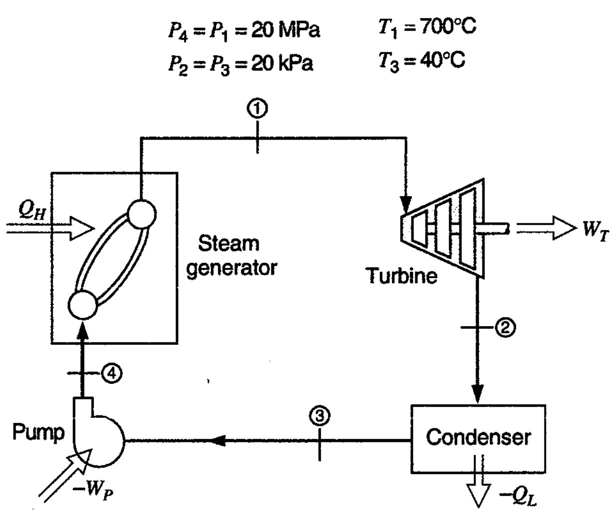

FIGURE P7.48

Transient Processes

7.49 A 10-m-tall, 2-m^2 cross-sectional-area water tank is on a tower, so the bottom is 5 m up from ground level and the top is open to the atmosphere. It is initially empty and then is filled by a pump taking water at ambient $T = 17°C$, 100 kPa from a small pond at ground level. Assume the process is reversible and find the total pump work.

7.50 Air in a tank is at 300 kPa, 400 K with a volume of 2 m^3. A valve on the tank is opened to let some air escape to the ambient to a final pressure inside of 200 kPa. Find the final temperature and mass, assuming a reversible adiabatic process for the air remaining inside the tank.

7.51 A 0.5-m^3 tank containing carbon dioxide at 300 K, 150 kPa is now filled from a supply of carbon dioxide at 300 K, 150 kPa by a compressor to a final tank pressure of 450 kPa. Assume the whole process is adiabatic and reversible. Find the final mass and temperature in the tank and the required work to the compressor.

7.52 A tank contains 1 kg of carbon dioxide at 6 MPa, 60°C, and it is connected to a turbine with an exhaust at 1000 kPa. The carbon dioxide flows out of the tank and through the turbine until a final state in the tank of saturated vapor is reached. If the process is adiabatic and reversible, find the final mass in the tank and the turbine work output.

7.53 Air in a tank is at 300 kPa, 400 K with a volume of 2 m^3. A valve on the tank is opened to let some air escape to the ambient to a final pressure inside of 200 kPa. At the same time the tank is heated, so the air remaining has a constant temperature. What is the mass average value of the air leaving, assuming this is an internally reversible process?

7.54 A supply line is supplied by an insulated compressor that takes in R-134a at 5°C, quality of 96.5%, and compresses it to 3 MPa in a reversible process. An insulated 2-m^3 tank is charged with R-134a from the line, the tank is initially evacuated, and the valve is closed when the pressure inside the tank reaches 2 MPa. Calculate the total work input to the compressor to charge the tank.

7.55 An underground salt mine, 100 000 m^3 in volume, contains air at 290 K, 100 kPa. The mine is used for energy storage, so the local power plant pumps it up to 2.1 MPa using outside air at 290 K, 100 kPa. Assume the pump is ideal and the process is adiabatic. Find the final mass and temperature of the air and the required pump work.

7.56 R-410a at 120°C, 4 MPa is in an insulated tank, and flow is now allowed out to a turbine with a backup pressure of 800 kPa. The flow continues to a final tank pressure of 800 kPa, and the process stops. If output using Table A.7 and repeat using constant specific heat from Table A.5.

7.32 An expander receives 0.5 kg/s air at 2000 kPa, 300 K with an exit state of 400 kPa, 300 K. Assume the process is reversible and isothermal. Find the rates of heat transfer and work, neglecting kinetic and potential energy changes.

7.33 A highly cooled compressor brings a hydrogen gas flow at 300 K, 100 kPa up to a pressure of 800 kPa in an isothermal process. Find the specific work assuming a reversible process.

7.34 A compressor receives air at 290 K, 95 kPa and shaft work of 5.5 kW from a gasoline engine. It should deliver a mass flow rate of 0.01 kg/s air to a pipeline. Find the maximum possible exit pressure of the compressor.

7.35 A reversible steady-state device receives a flow of 1 kg/s air at 400 K, 450 kPa and the air leaves at 600 K, 100 kPa. Heat transfer of 900 kW is added from a 1000 K reservoir, 50 kW is rejected at 350 K, and some heat transfer takes place at 500 K. Find the heat transferred at 500 K and the rate of work produced.

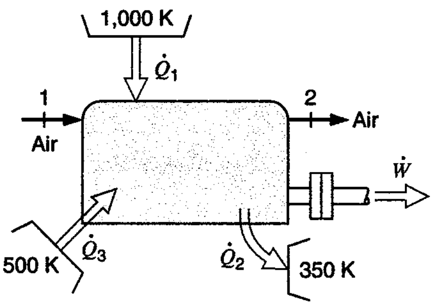

FIGURE P7.35

Multiple Devices and Cycles

7.36 A steam turbine in a power plant receives 5 kg/s steam at 3000 kPa, 500°C. Twenty percent of the flow is extracted at 1000 kPa to a feedwater heater, and the remainder flows out at 200 kPa. Find the two exit temperatures and the turbine power output.

7.37 A reversible adiabatic compression of an air flow from 20°C, 100 kPa to 200 kPa is followed by an expansion down to 100 kPa in an ideal nozzle. What are the two processes? How hot does the air get? What is the exit velocity?

7.38 A small turbine delivers 1.5 MW and is supplied with steam at 700°C, 2 MPa. The exhaust passes through a heat exchanger where the pressure is 10 kPa and exits as saturated liquid. The turbine is reversible and adiabatic. Find the specific turbine work and the heat transfer in the heat exchanger.

7.39 One technique for operating a steam turbine in part-load power output is to throttle the steam to a lower pressure before it enters the turbine, as shown in Fig. P7.39. The steamline conditions are 2 MPa, 400°C, and the turbine exhaust pressure is fixed at 10 kPa. Assuming the expansion inside the turbine is reversible and adiabatic, determine the specific turbine work for no throttling and the specific turbine work (part-load) if it is throttled to 500 kPa. Show both processes in a T–s diagram.

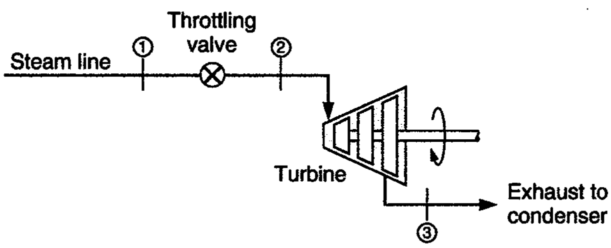

FIGURE P7.39

7.40 An adiabatic air turbine receives 1 kg/s air at 1500 K, 1.6 MPa and 2 kg/s air at 400 kPa, T_2 in a setup similar to that of Fig. P4.87 with an exit flow at 100 kPa. What should the temperature T_2 be so that the whole process can be reversible?

7.41 A turbocharger boosts the inlet air pressure to an automobile engine. It consists of an exhaust gas-driven turbine directly connected to an air compressor, as shown in Fig. P7.41. For a certain engine load

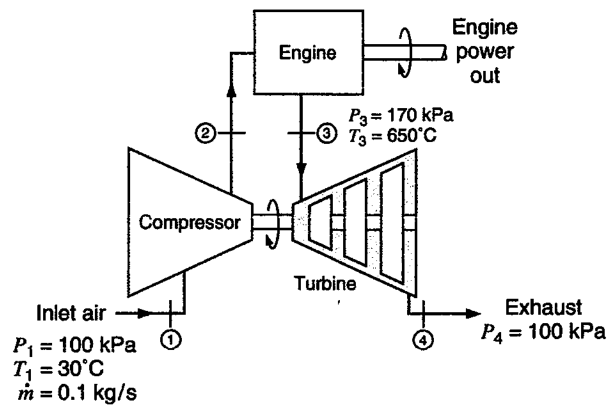

FIGURE P7.41