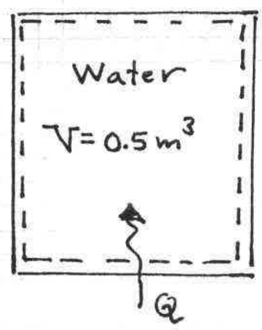
PROBLEM 3.62

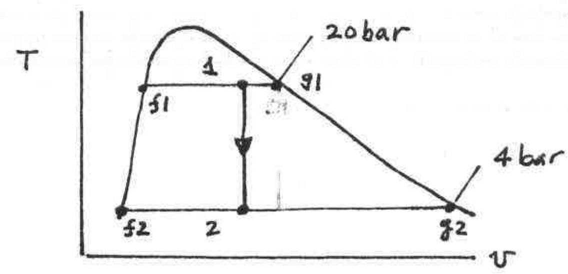
KNOWN: A closed rigid tank filled with water, initially a two-phase liquid-vapor mixture, is cooled. State data is provided.

FIND: Show the process of the water on a T-v diagram and evaluate the accompanying heat transfer, in kJ.

SCHEMATIC & GIVEN DATA



Initial:
$P_1 = 20$ bar
$x_1 = 0.8$
Final:
$P_2 = 4$ bar



ENGINEERING MODEL:

1. The water in the tank is the closed system.
2. Energy transfer occurs only by heat.
3. Kinetic and potential energy effects can be ignored.

ANALYSIS:

Since the total mass and total volume each remain constant, the process occurs at constant specific volume, as shown in the T-v diagram.

An energy balance reduces as follows: $\Delta U + \cancel{\Delta KE} + \cancel{\Delta PE} = Q - \cancel{W}$

$\Rightarrow Q = \Delta U = m(u_2 - u_1)$. Accordingly, m, u_1 and u_2 are required.

Using data from Table A-3 at 20 bar,

$$v_1 = v_{f1} + x_1(v_{g1} - v_{f1}) = \frac{1.1767}{10^3} + 0.8\left(0.09963 - \frac{1.1767}{10^3}\right) = 0.07994\ m^3/kg$$

$$u_1 = u_{f1} + x_1(u_{g1} - u_{f1}) = 906.44 + 0.8(2600.3 - 906.44) = 2261.53\ kJ/kg$$

Using data from Table A-3 at 4 bar with $v_2 = v_1$,

$$x_2 = \frac{v_2 - v_{f2}}{v_{g2} - v_{f2}} = \frac{0.07994 - (1.0836/10^3)}{0.4625 - (1.0836/10^3)} = 0.1709$$

$$u_2 = u_{f2} + x_2(u_{g2} - u_{f2}) = 604.31 + 0.1709(2553.6 - 604.31) = 937.44\ kJ/kg$$

The mass is

$$m = \frac{V}{v_1} = \frac{0.5\ m^3}{0.07994\ m^3/kg} = 6.255\ kg$$

Finally

$$Q = m(u_2 - u_1) = (6.255\ kg)(937.44 - 2261.53)\ kJ/kg$$
$$= -8282\ kJ \quad \leftarrow$$

Energy transfer by heat is from the water.