

# cylinder piston

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“A cylinder - Piston arrangement contains Freon -12 at 70 °C and 1.2 MPa where the total volume is 32.736L (State 1) The system is cooled down following an isochoric until it reaches 0.85MPa (State2) The System is cooled down following an isobaric process until the 90% of the total volume is vapor (state3)”

**Calculate:**

- 1.1. Specific volume ( $v_1$ ), mass ( $m_1$ ) at State 1. Find quality if saturated.
- 1.2. Temperature ( $T_2$ ), specific volume ( $v_2$ ), and volume ( $V_2$ ) at State 2. Find quality if saturated.
- 1.3. Define State 3 and find volume ( $V_3$ ) and specific volume ( $v_3$ ) at State 3.
- 1.4. Show the process in a P-v diagram
- 1.5 Find the total work ( $W$ ) and work per unit mass ( $w$ ) for the whole process.

**Answer:**

- 1.1. Pressure ( $P_1$ ), specific volume ( $v_1$ ) at State 1. Find quality if saturated.

STATE 1

$m_1 = 2 \text{ kg}$  (Freon 12)  
 $T_1 = 70 \text{ }^\circ\text{C} \Rightarrow v_g = 0.008725 \text{ m}^3/\text{kg}$   
 $V_1 = 32.736 \text{ L} = 0.03273 \text{ m}^3$   
 $v_1 = V_1 / m_1 = 0.016368 \text{ m}^3/\text{kg} > v_g \rightarrow \text{SHV}$   
 $P_1 = 1.2 \text{ Mpa}$   
 $h_1 = 222.687 \text{ kJ/kg}$   
 $u_1 = h_1 - P_1 v_1 = 203.05 \text{ kJ/kg}$

- 1.2. Temperature ( $T_2$ ), specific volume ( $v_2$ ), and volume ( $V_2$ ) at State 2. Find quality if saturated.

STATE 2

Isochoric process  $\Rightarrow V_2 = V_1 = 32.736 \text{ L} = 0.03273 \text{ m}^3$   
 $m_2 = m_1 = 2 \text{ kg}$   
 $v_2 = v_1 = 0.016368 \text{ m}^3/\text{kg}$   
 $T_2 = 35 \text{ }^\circ\text{C} \rightarrow \text{LVM}$   
 $X_2 = 0.785$   
 $P_2 = 0.8477 \text{ MPa}$

1.3. Define State 3 and find volume ( $V_3$ ) and specific volume ( $v_3$ ) at State 3.

STATE 3

"The system is cooled down following an isobaric process until the **10 % of the total volume is liquid**"  $\Rightarrow$  This is **NOT** quality!!!

$$P_3 = P_2 = 0.8477 \text{ MPa}$$

10% of total volume is liquid  $\Rightarrow$  LVM

$$T_3 = T_2 = 35 \text{ }^\circ\text{C} \Rightarrow v_f = 0.000786 \text{ m}^3/\text{kg} \text{ and } v_g = 0.0200641 \text{ m}^3/\text{kg}$$

$$V_{\text{liquid}} = 0.1 V_3 \Rightarrow V_{\text{vapor}} = 0.9 V_3$$

$$m_3 = m_2 = 2 \text{ kg} \Rightarrow m_3 = m_{\text{liquid}} + m_{\text{vapor}} = 2 \text{ kg}$$

$$m_{\text{liquid}} = V_{\text{liquid}} / v_f$$

$$m_{\text{vapor}} = V_{\text{vapor}} / v_g$$

$$V_3 = 0.011708 \text{ m}^3$$

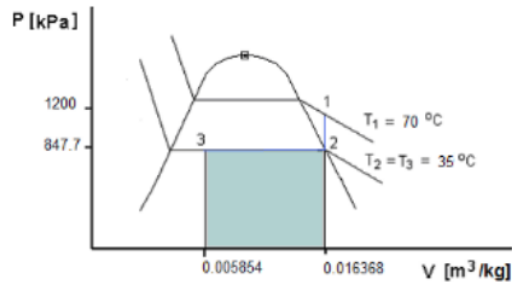
$$v_3 = 0.005854 \text{ m}^3/\text{kg}$$

$$x_3 = 0.255$$

$$h_3 = 103.11 \text{ kJ/kg}$$

$$u_3 = h_3 - P_3 v_3 = 98.15 \text{ kJ/kg}$$

1.4. Show the process in a P-v diagram



1.5. Work for the process

Total Work [ ${}_1W_3$ ]

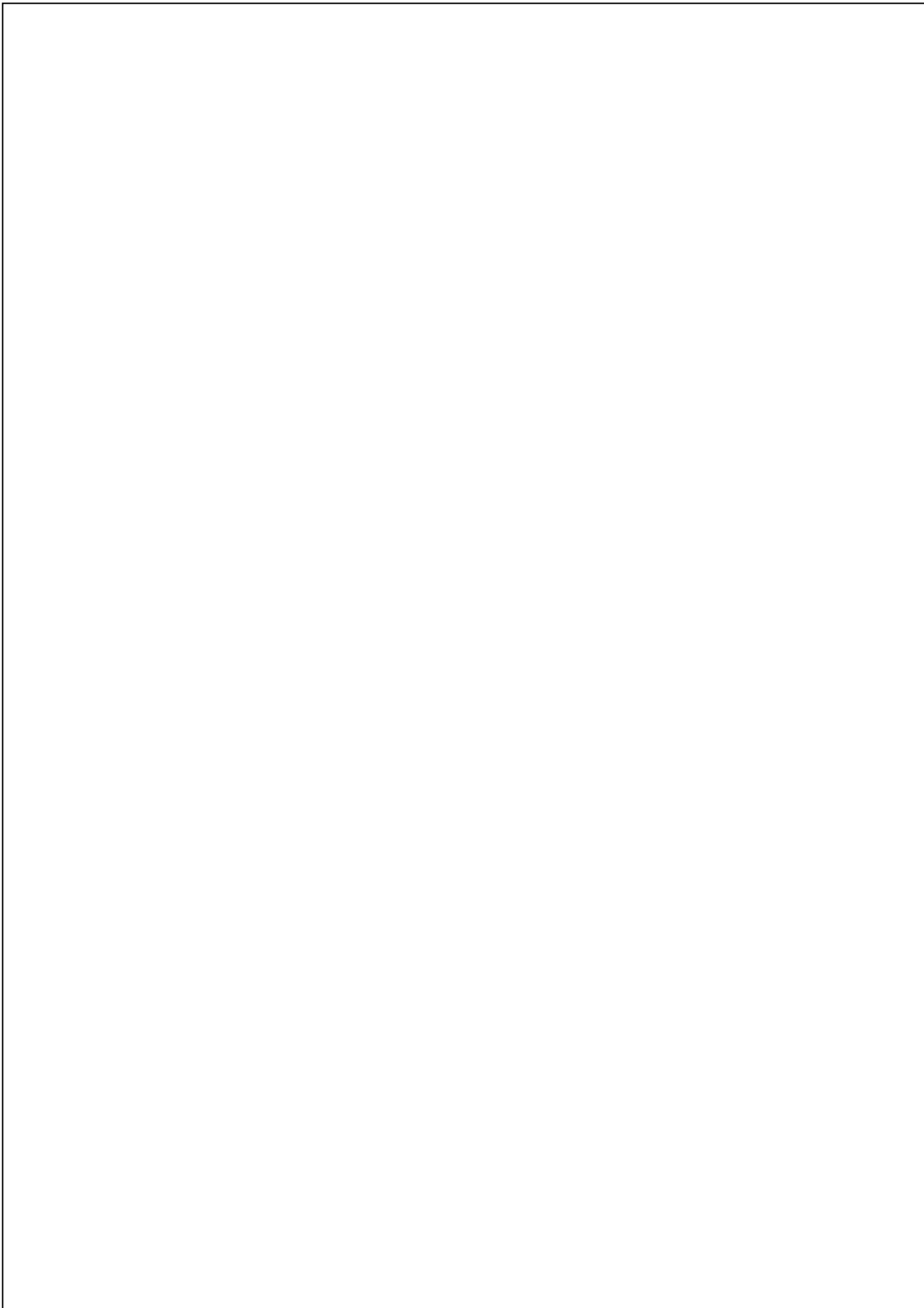
$${}_1W_3 = {}_1W_2 + {}_2W_3 = {}_2W_3 = P_2 [V_3 - V_2]$$

$${}_2W_3 = - 17.83 \text{ kJ}$$

Work per unit mass [ ${}_1w_3$ ]

$${}_1w_3 = {}_2w_3 = {}_2W_3 / m = - 17.83 \text{ kJ} / 2 = - 8.915 \text{ kJ/kg}$$

**NOTE:** The work is negative since it is done to the system



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