Experiment 8

AIR AND WATER HEAT PUMP

(UNIT – R832)

1. OBJECTIVE

- Enhance students' knowledge on the concept of how heat can move from a region of low temperature to that of a higher one due to work done.
- Draw the actual vapor compression cycle on the P-h diagram and compare it with the ideal cycle.
- Determine the coefficient of performance of heat pump.
- Compare the coefficient of performance of both the air and water evaporator.

2. INTRODUCTION & THEORETICAL BACKGROUND

Heat pump finds applications in countless industrial, commercial and domestic situations and activities throughout the world. The major uses of heat pumps are in the form of air conditioners. Other applications are home heating in cooler climates, pool heaters and so on. A heat pump is a device which allows transport of heat from lower temperature level to a higher one (in a direction that is opposite of spontaneous flow), by using external energy (European Renewable Energy Council, 2008).

The air and water heat pump being used in this experiment relies on the vapor compression cycle which needs a small work input to transfer heat from either air source evaporator or water source evaporator to a water cooled condenser.

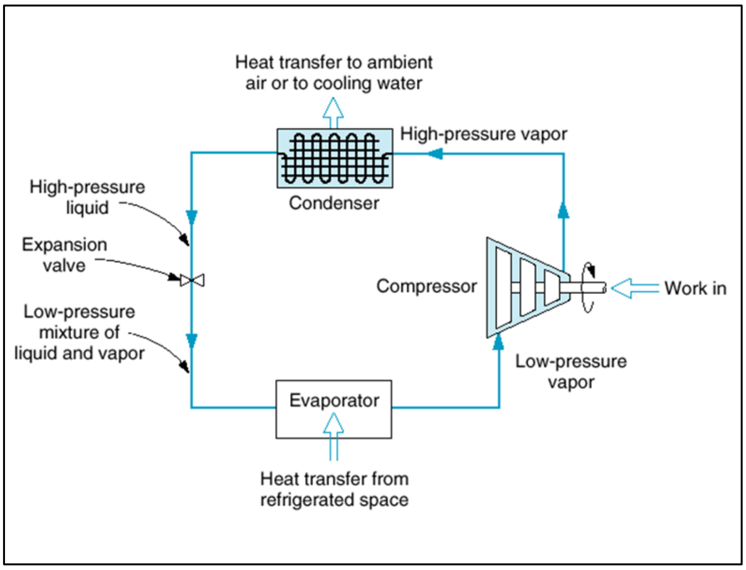


Fig. 1: Basic Vapor Compression Cycle

The Hilton Air and Water Heat Pump R-832 is a vapor compression cycle unit utilizing a small work input to transfer heat from either an air evaporator or water evaporator source to a water cooled condenser. All relevant temperatures, pressures and power inputs are measured enabling the complete cycle to be investigated both diagrammatically and numerically.

1- Ideal Vapor-Compression Cycle

The vapor compression cycle has four components: evaporator, compressor, condenser, and expansion (or throttle) valve. In an ideal vapor-compression cycle, the refrigerant enters the compressor as a saturated vapor and is cooled to the saturated liquid state in the condenser. It is then throttled to the evaporator pressure and vaporizes as it absorbs heat from the refrigerated space. The ideal vapor compression cycle consists of four processes. (See Figure 2)

Process	**Description**
1-2	Isentropic compression
2-3	Constant pressure heat rejection in the condenser
3-4	Throttling in an expansion valve
4-1	Constant pressure heat addition in the evaporator

Component	Process	First Law Result
Compressor	s = Const.	$\dot{W}_{in} = \dot{m}(h_2 - h_1)$
Condenser	P = Const.	$\dot{Q}_H = \dot{m}(h_2 - h_3)$
Throttle Valve	Δs > 0	$h_4 = h_3 \quad \dot{W}_{net} = 0 \quad \dot{Q}_{net} = 0$
Evaporator	P = Const.	$\dot{Q}_L = \dot{m}(h_1 - h_4)$

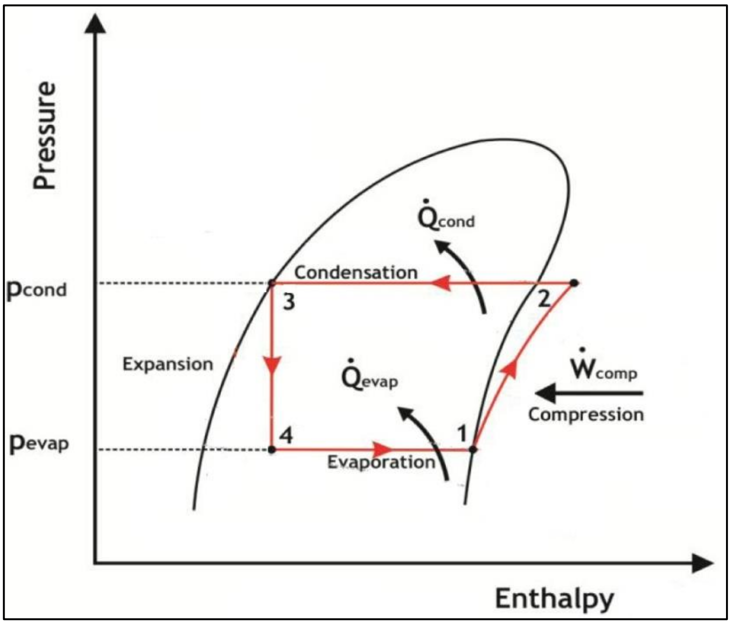


Fig. 2: The P-h Diagram of Ideal Vapor-Compression Cycle

2- Actual Vapor-Compression Cycle

An actual vapor-compression refrigeration cycle differs from the ideal one in several ways, owing mostly to the irreversibility's that occur in various components, mainly due to fluid friction (causes pressure drops) and heat transfer to or from the surroundings. The COP decreases as a result of irreversibility's. DIFFERENCES: Non-isentropic compression, superheated vapor at evaporator exit Subcooled liquid at condenser exit, Pressure drops in condenser and evaporator. (See Figure 3)

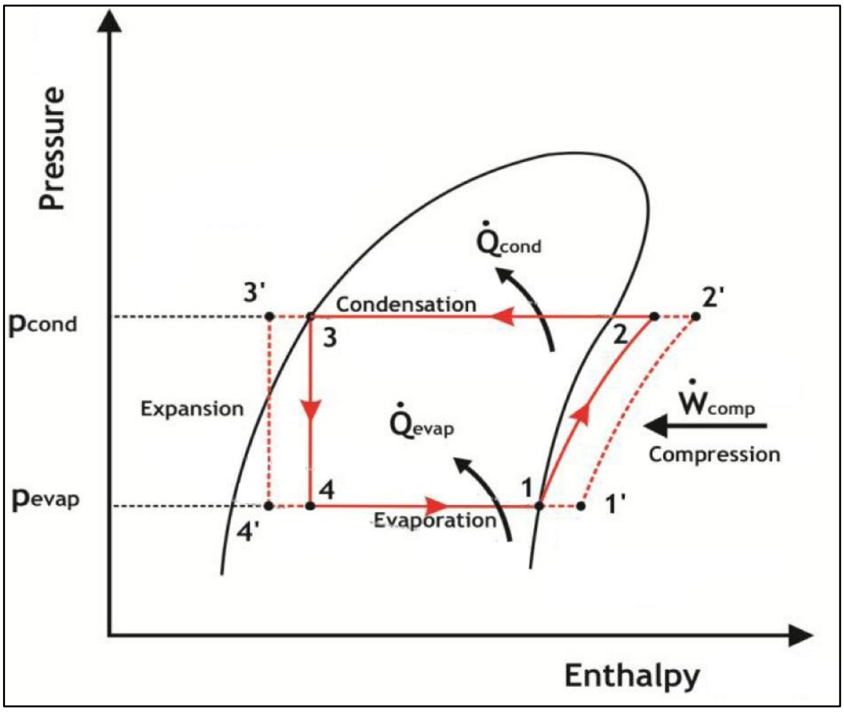


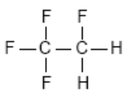
Fig. 3: The P-h Diagram of Actual Vapor-Compression Cycle

3. APPARATUS

This experiment will be conducted on the Hilton Computer-Linked Air and Water Heat Pump Unit R832, see figure 3 and 4. The unit was provided with a fully instrumented vapor compression heat pump operating on ***R134a** with an aluminum finned air source evaporator, high efficiency plate type condenser and similar water source evaporator. The evaporator source may be selected using a simple switch. Instrumentation allows investigation of heat transfers at each component of the refrigeration cycle. Instrumentation includes digital temperature indicator, condenser and evaporator pressure gauges, refrigerant flowmeter and compressor power meter. Water flow rate may be measured and controlled by variable area flowmeters on both the evaporator and condenser, thereby varying both evaporating pressure and condensing pressure. Safety devices include condenser high pressure switch and compressor thermal overload switch, residual current circuit breaker and a combined double pole main switch and overload cut out. (See figure 1 & 2)

Fig. 1: Air and Water Heat Pump (Unit R832) - General View

* The chemical properties of **HFC-134a** are listed below:
Chemical Name: Tetrafluoroethane
Molecular Formula: CH_2FCF_3
Molecular Weight: 102.0

Chemical Structure: 

Boiling Point: at 1 atm (101.3 kPa or 1.013 bar): –26.1°C

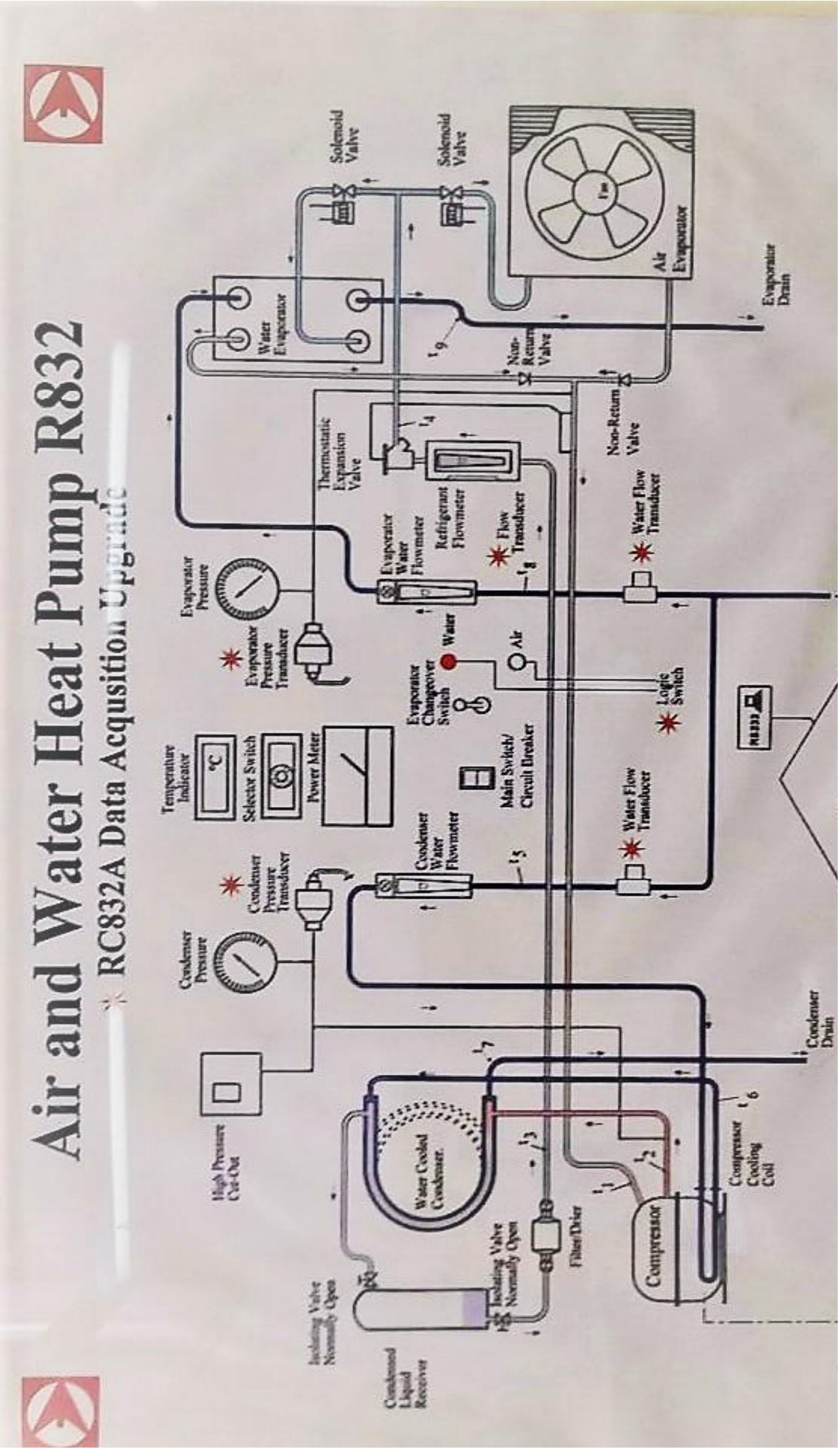


Fig. 2: Air and Water Heat Pump (Unit R832) - Schematic Diagram

4. PROCEDURE

1. Turn on the water supply to the unit and then turn on the main switch.
2. Select the water evaporator by pressing the evaporator change over switch down.
3. Set the condenser gauge pressure to between 700 and 1100 kpa by adjustment of the condenser cooling water flow rate.
4. Allow the unit time for all of the system parameters to reach a stable condition and fill up the observation sheet.
5. Repeat the above procedures for water evaporator by switching the changeover switch up condition and fill up the observation sheet.
6. Set the condenser cooling water flow rate to approximately 50 % of full flow and evaporator water flow as set by instructor.

5. OBSERVATIONS

Table 1: DATA OBSERVED

Heat Source: Water Evaporator **Atmospheric Pressure: ________ *kpa***

SERIES	No.	Parameter	1	2	3	UNITS
Refrigerant HFC134a	1	Condenser Pressure, Pc (Abs.)*				kpa
	2	Evaporator Pressure, Pe (Abs.)*				kpa
	3	Compressor Suction Temp. (t_1)				℃
	4	Compressor Delivery Temp. (t_2)				℃
	5	Refrigerant Leaving the Cond. (t_3)				℃
	6	Evaporator Inlet Temp. (t_4)				℃
	7	R134a flow rate, $\dot{m}_r$				g/s
Water Compressor Cooling	8	Cooling water inlet Temp. (t_5)				℃
	9	Cooling water outlet Temp. (t_6)				℃
	10	Water flow rate, $\dot{m}_w$				g/s
Water Condenser Cooling	11	Cooling water inlet Temp. (t_6)				
	12	Cooling water outlet Temp. (t_7)				
	13	Water flow rate, $\dot{m}_w$				g/s
Water Source Evaporator	14	Water inlet Temp. (t_8)				
	15	Water inlet Temp. (t_9)				
	16	Water flow rate, $\dot{m}_w$				g/s

6. DATA ANALYSIS

The heat delivered to cooling water from compressor

$$\dot{Q}_{cmp} = \dot{m}_w \times Cp_w \times (T_6 - T_5) \quad (1)$$

The heat delivered to cooling water from condenser

$$\dot{Q}_{cond} = \dot{m}_w \times Cp_w \times (T_7 - T_6) \quad (2)$$

The total heat delivered to cooling water from compressor & condenser

$$\dot{Q}_T = \dot{Q}_{cmp} + \dot{Q}_{cond} \quad (3)$$

The COP if the heat delivered to condenser is considered

$$COP_{HP} = \frac{Rate\ of\ Heat\ Delivered}{Compressor\ Electrical\ Power\ Input} = \frac{\dot{Q}_{cond}}{W} \quad (4)$$

The COP if the total heat delivered is considered

$$COP_{HP} = \frac{Rate\ of\ Heat\ Delivered}{Compressor\ Electrical\ Power\ Input} = \frac{\dot{Q}_T}{W} = \frac{\dot{Q}_{cond} + \dot{Q}_{cmp}}{W} \quad (5)$$

The COP using p-h diagram and rate of enthalpy change

$$COP_{HP} = \frac{Q_H}{W} = \frac{\dot{m}_r \times (h_2 - h_3)}{\dot{m}_r \times (h_2 - h_1)} = \frac{(h_2 - h_3)}{(h_2 - h_1)} \quad (6)$$

Determine location of state points:

No.1 is located by intersection of Pe Bar abs. and t_1°C (in superheated region)

No.2 is located by intersection of Pc Bar abs. and t_2 °C (in superheated region)

No.3 is located by intersection of Pc Bar abs. and t_3 °C (in subcooled region)

No.4 is located by dropping a vertical line from point 3 to the intersection with the Pe line, assumed adiabatic process.

Note that pressure drops in both the evaporator and condenser are assumed to be negligible and Pe and Pc are horizontal lines of constant pressure. (See Figure 6)

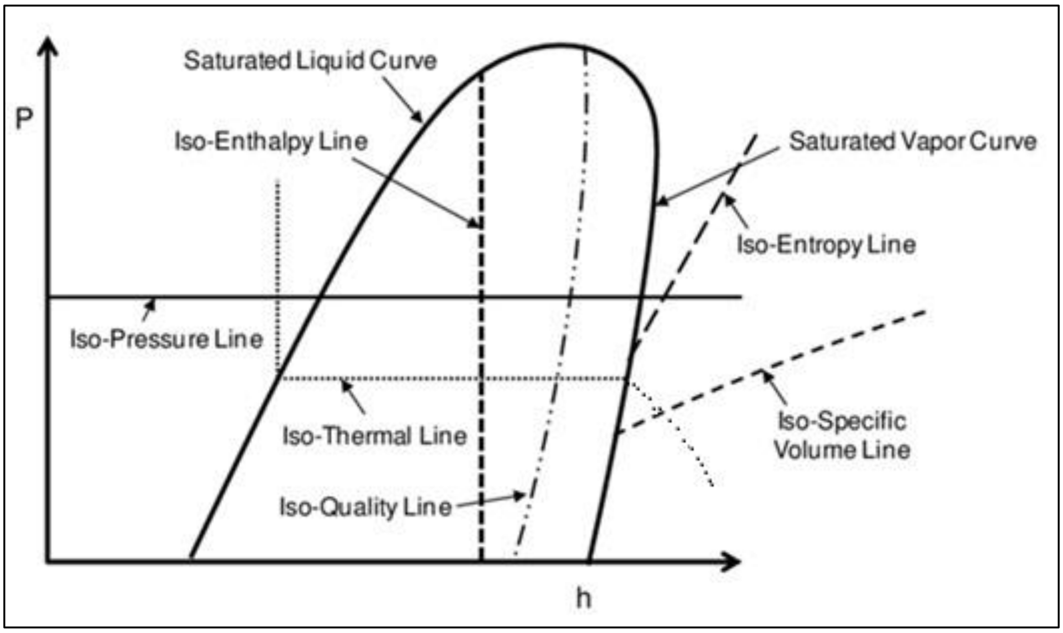


Fig. 6: Pressure - Enthalpy Diagram (Basics)

7. RESULTS & DISCUSSION

Table 2: SUMMARY OF RESULTS

	$\dot{Q}_{cmp}$ Watt	$\dot{Q}_{cond}$ Watt	$\dot{Q}_{T}$ Watt	COP_{HP} Considering Condenser Heat	COP_{HP} Considering Total Heat	COP_{HP} Using p-h Diagram
1						
2						

1. Sketch the refrigeration cycle on the p-h diagram of R-134a with actual property values at all points.
2. Find h1, h2, h3, and h4. [You may find h3, and then set h4 = h3]
3. All the results were recorded and tabulated under the results table.
   - By using p-h diagram.
   - By using ″Direct Measurements″.
4. Calculate the percentage difference between the two values found.
5. Discuss the results obtained and comment on discrepancies.
6. Do you think the cycle COP will increase or decrease with the evaporator temperature T_E increase?

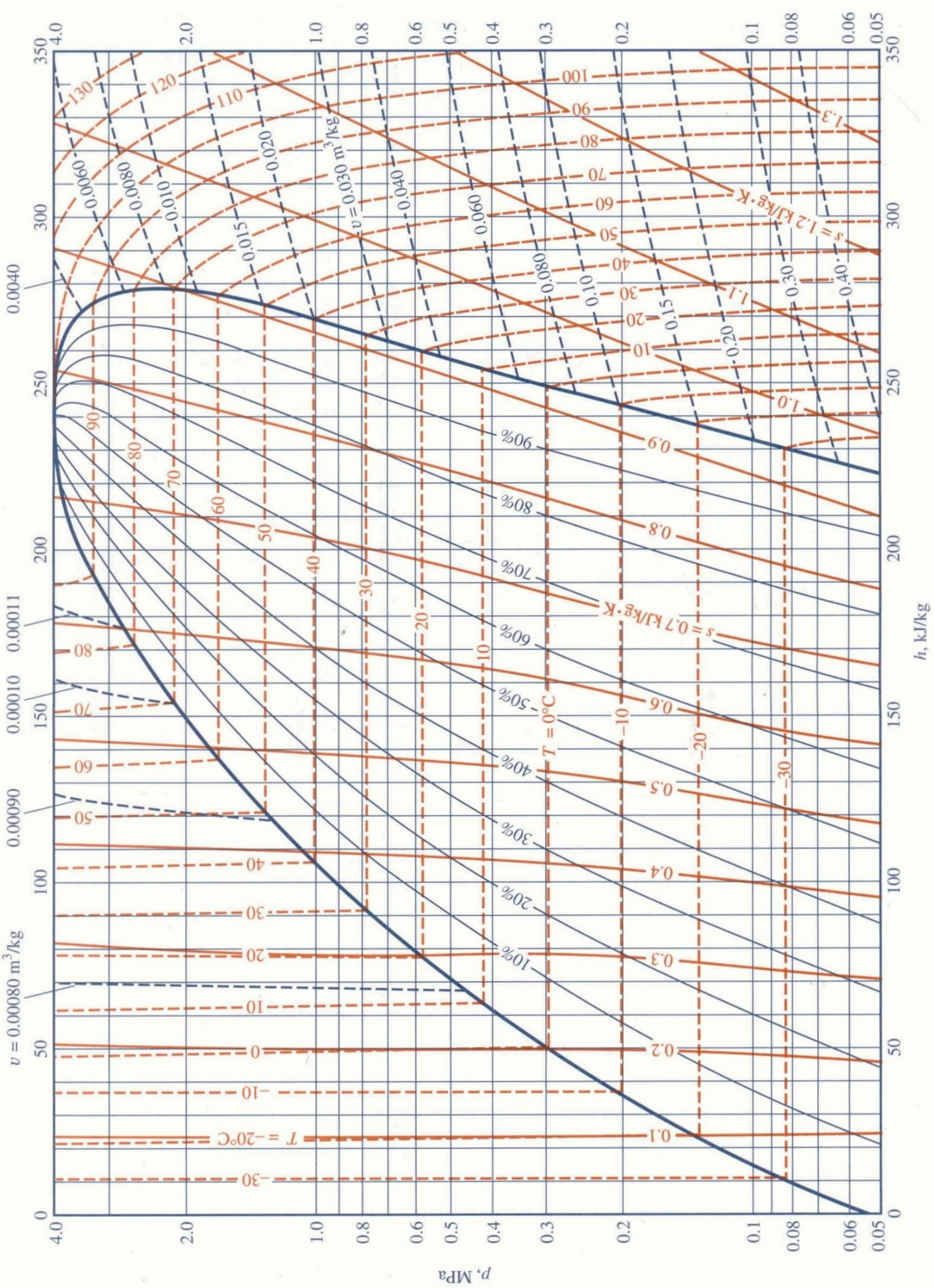


Chart A·11 R134a *ph* diagram. (*Source:* Based on *Thermodynamic Properties of HFC-134a (1,1,1, 2-tetrafluoroethane)*, DuPont Company, Wilmington, Delaware, 1993, with permission.)

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