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TECH MEET 13.0

ALBATROSS
ENERGETICS

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ALBATROSS ENERGETICS

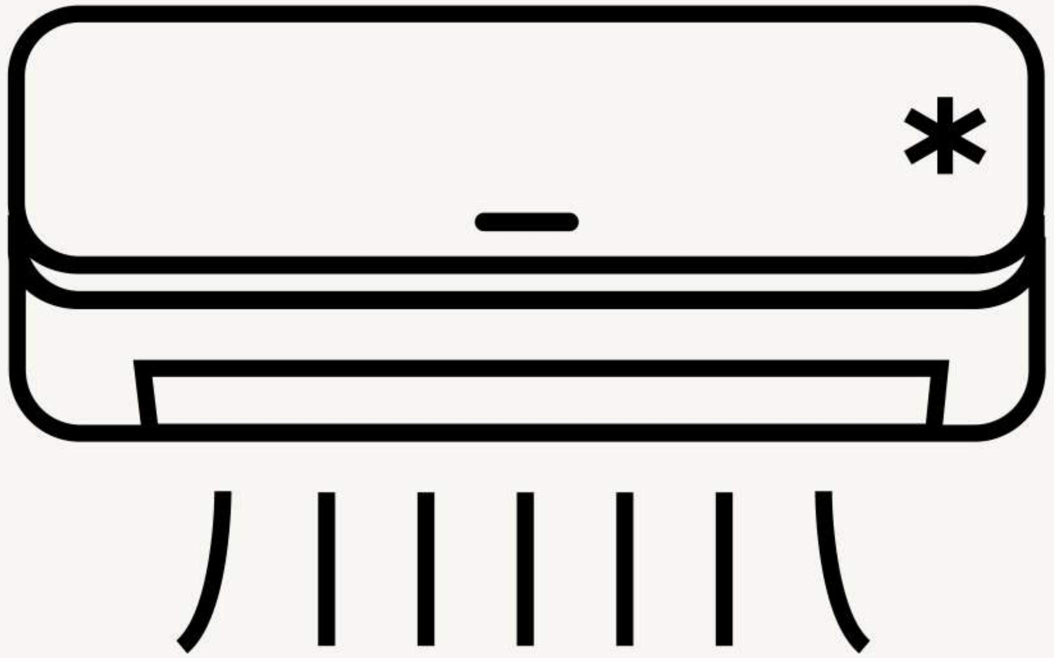
Innovative Cooling and Dehumidification Solutions

Team 30

Problem Statement

- The problem statement primarily focuses on designing an **energy-efficient refrigeration system** that achieves optimal performance by analysing critical parameters such as Coefficient of Performance (COP) and Energy Efficiency Ratio (EER).

- The system must ensure effective thermal management while adhering to **sustainable energy practices**.



Model Design

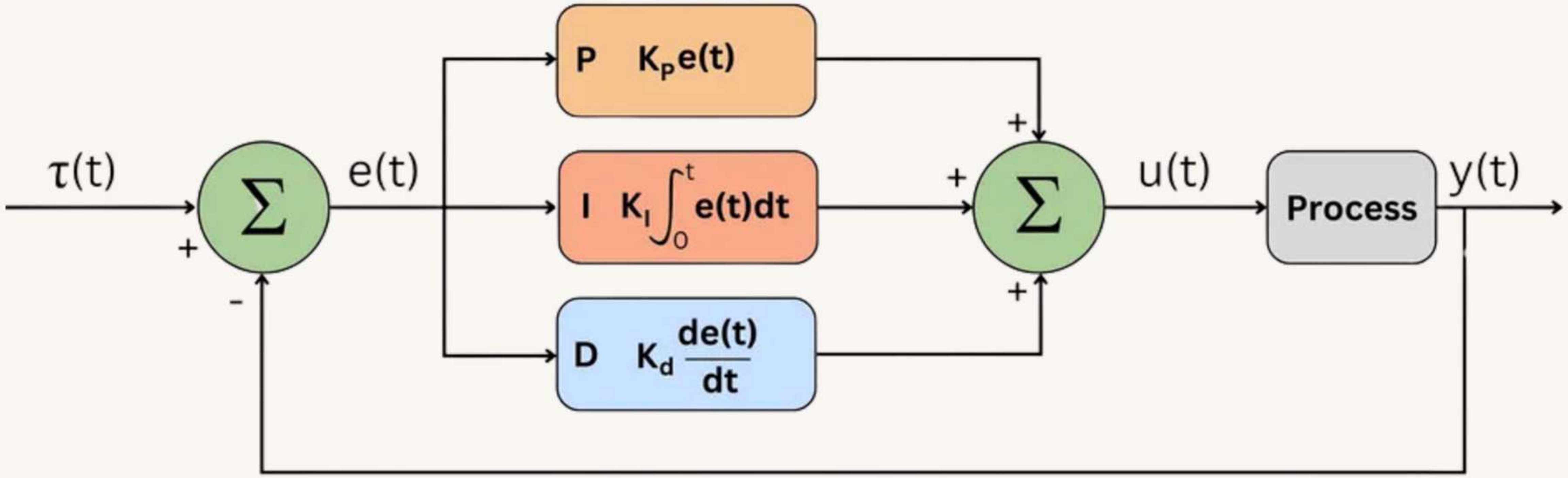
Control Logic

PID Control

- **Indoor Fan**
  - **Temperature**
  - **Humidity**
- **Compressor Motor**
  - **Combined Temperature & Humidity**

Error Calculation: Difference in Temperature and Humidity Setpoints.

PID Controller:



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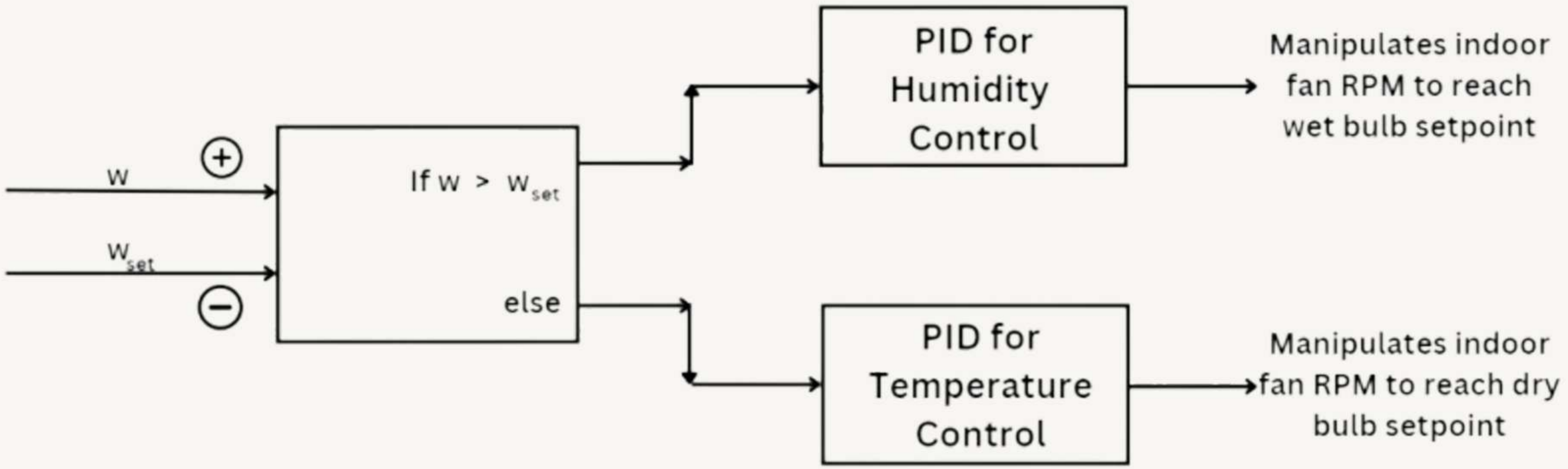
Control Logic

Control logic for Indoor Fan RPM

- Rate of decrease of temperature, increases with higher indoor RPM, while dehumidification rate decreases.
- Errors for temperature and relative humidity are calculated based on their setpoints.

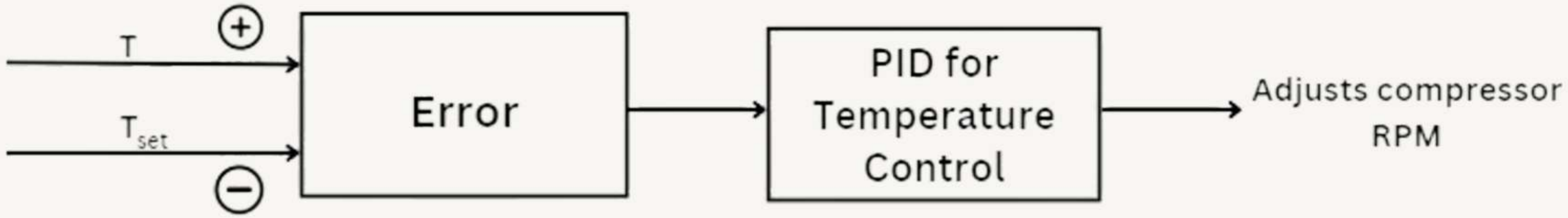


- Two **PID controllers** process the error signals: one for **temperature** and the other for **humidity**.
- Controllers operate alternately based on the humidity setpoint vs. actual room humidity.
- Control signals adjust indoor fan RPM **within operational limits** using saturation.

Control Logic

Control logic for Compressor RPM

- PID controller dynamically adjusts compressor RPM to **control dry-bulb temperature and humidity**.
- **Only temperature deviation** from the setpoint is used to generate the control signal for compressor RPM.
- Closed-loop control system ensures feedback for accurate error correction.
- Compressor RPM is **constrained within safe operational limits using saturation**.



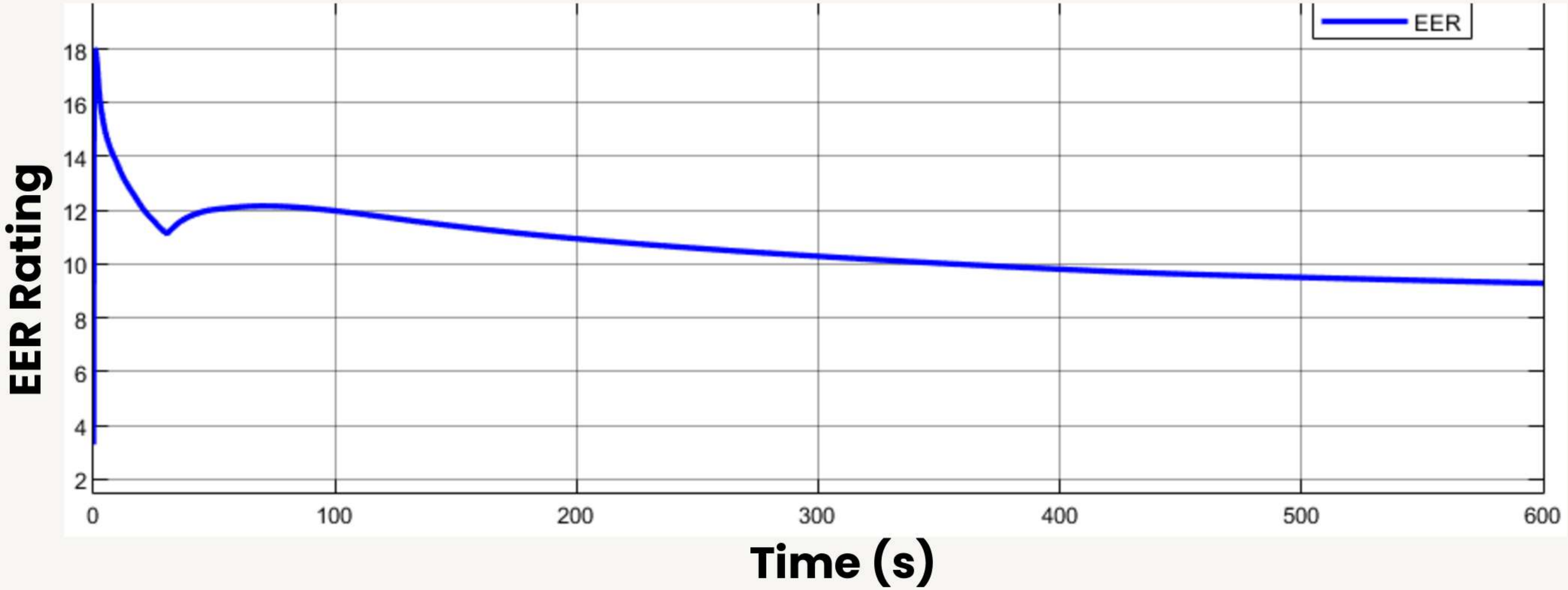
Control logic for Condenser RPM

- Condenser fan RPM doesn’t have considerable effect on rate of decrease of temperature or dehumidification
- Therefore, condenser fan operates at **maximum RPM** for optimal temperature and humidity change rates.

Performance

Performance Metrics

Energy Efficiency Ratio (EER) vs Time



The value of EER is calculated in the simulation with **35 °C Outdoor Temperature** and **1.25 Ton Net Heat Load**

Performance Metrics

Indian Seasonal Energy Efficiency Ratio (ISEER)

Temperature (℃)	24	25	26	27	28	29	30	31	32
Average Annual Hours	527	590	639	660	603	543	451	377	309
Fraction	9.1	10.2	11.1	11.4	10.4	9.4	7.8	6.5	5.4
Bin Hours	146	163	177	183	167	150	125	104	86
EER (BTU/h/W)	12.21	12.02	11.85	11.68	11.51	11.34	11.18	11.02	10.88

33	34	35	36	37	38	39	40	41	42	43	Total
240	196	165	130	101	79	59	44	31	20	10	5774
4.2	3.4	2.9	2.3	1.7	1.4	1.0	0.8	0.5	0.3	0.2	100
67	54	46	36	28	22	16	12	9	6	3	1600
10.75	10.60	10.47	10.34	10.23	10.12	10.01	9.89	9.79	9.69	9.60	

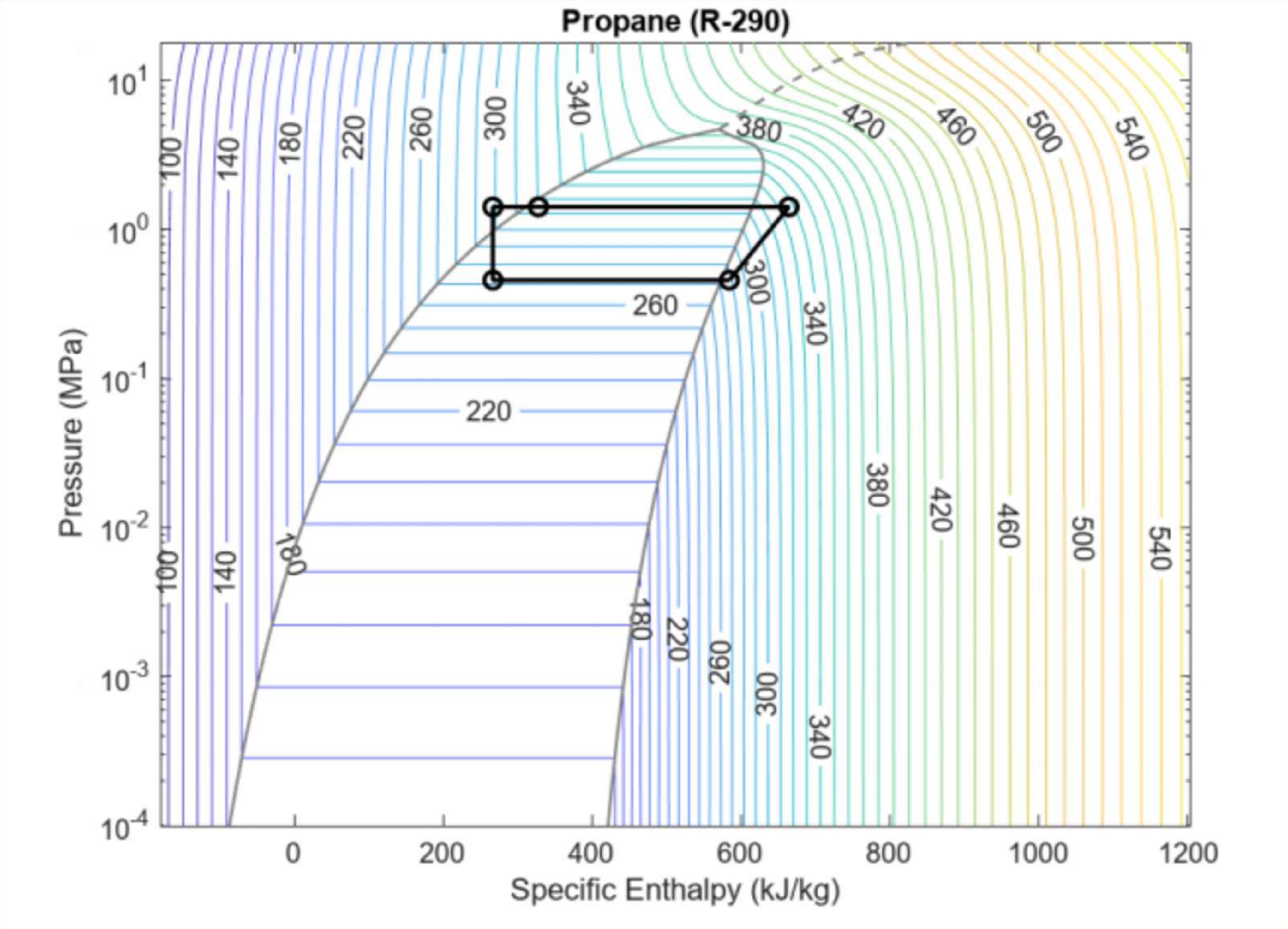
From our model, the calculated **average EER** is **11.35** and **ISEER** is **3.33**

Performance & Output
Requirements Metrics

Pressure-Enthalpy Graph

The dry bulb temperature of room is set to 27 °C and the wet bulb temperature is set to 19 °C.

P-h chart when the outdoor temperature is 35 °C.



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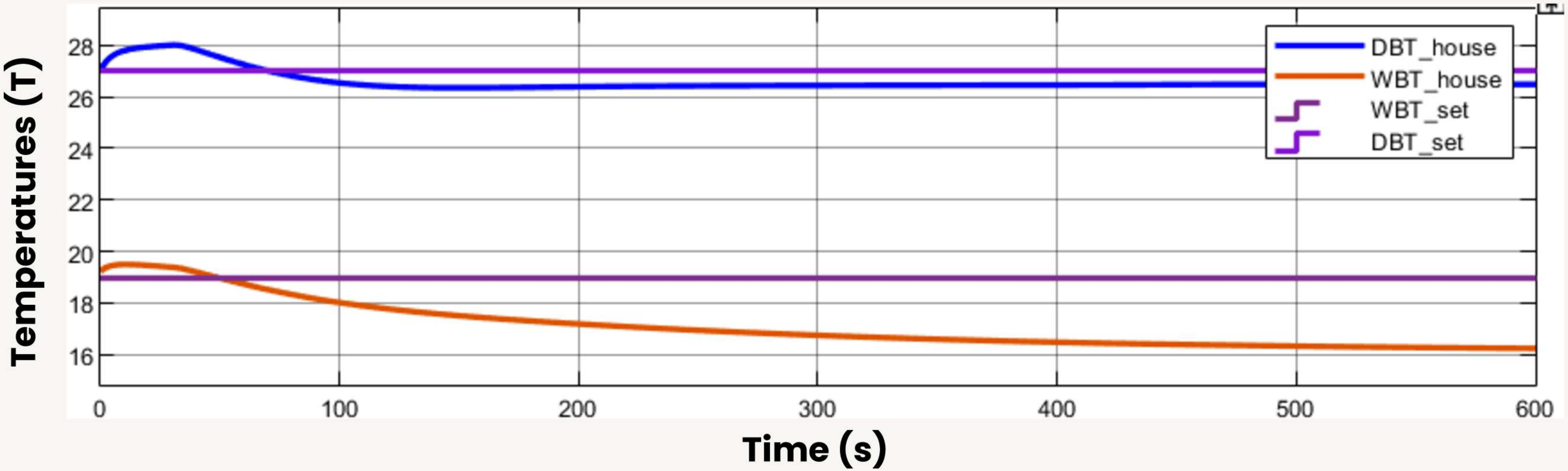
Performance & Output
Requirements Metrics

Indoor Conditions



The dry bulb and wet bulb temperature set-points was reached in around **80 seconds** from the start of the simulation

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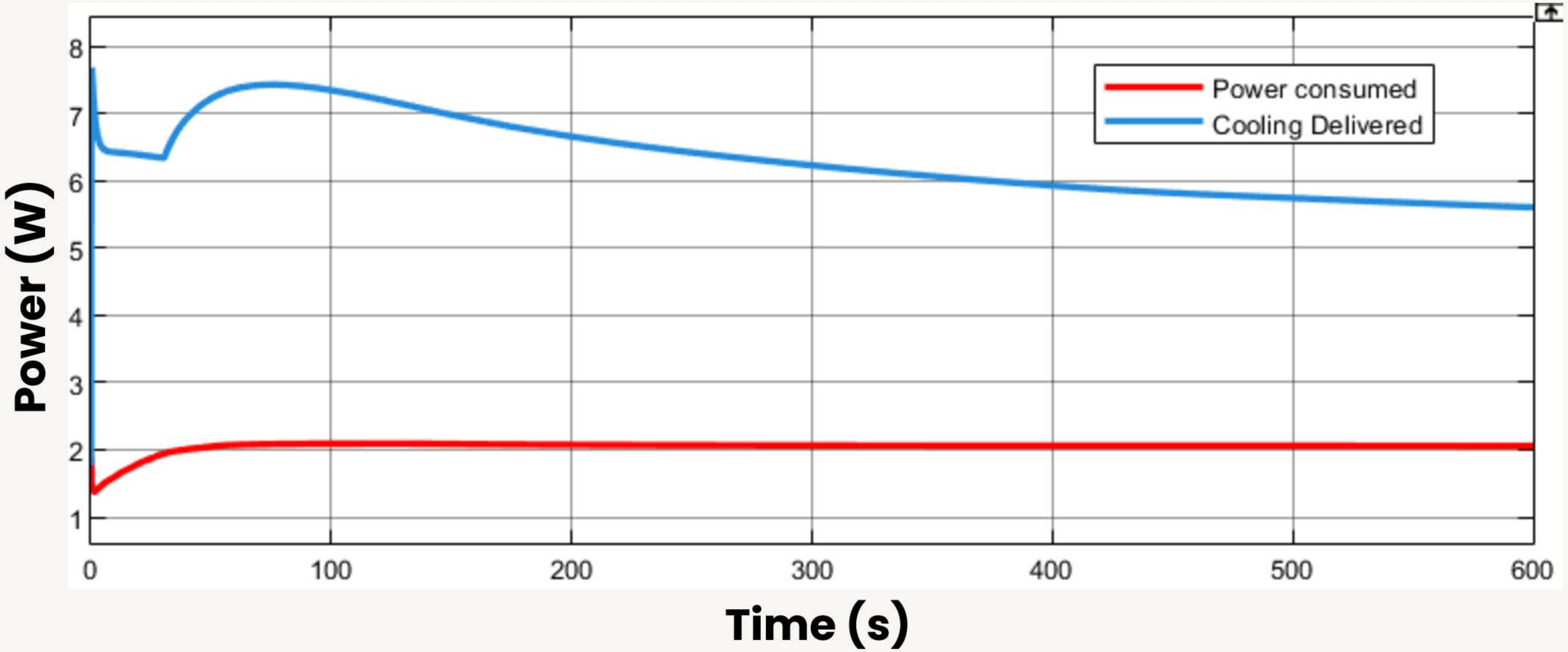
Performance & Output Requirements Metrics

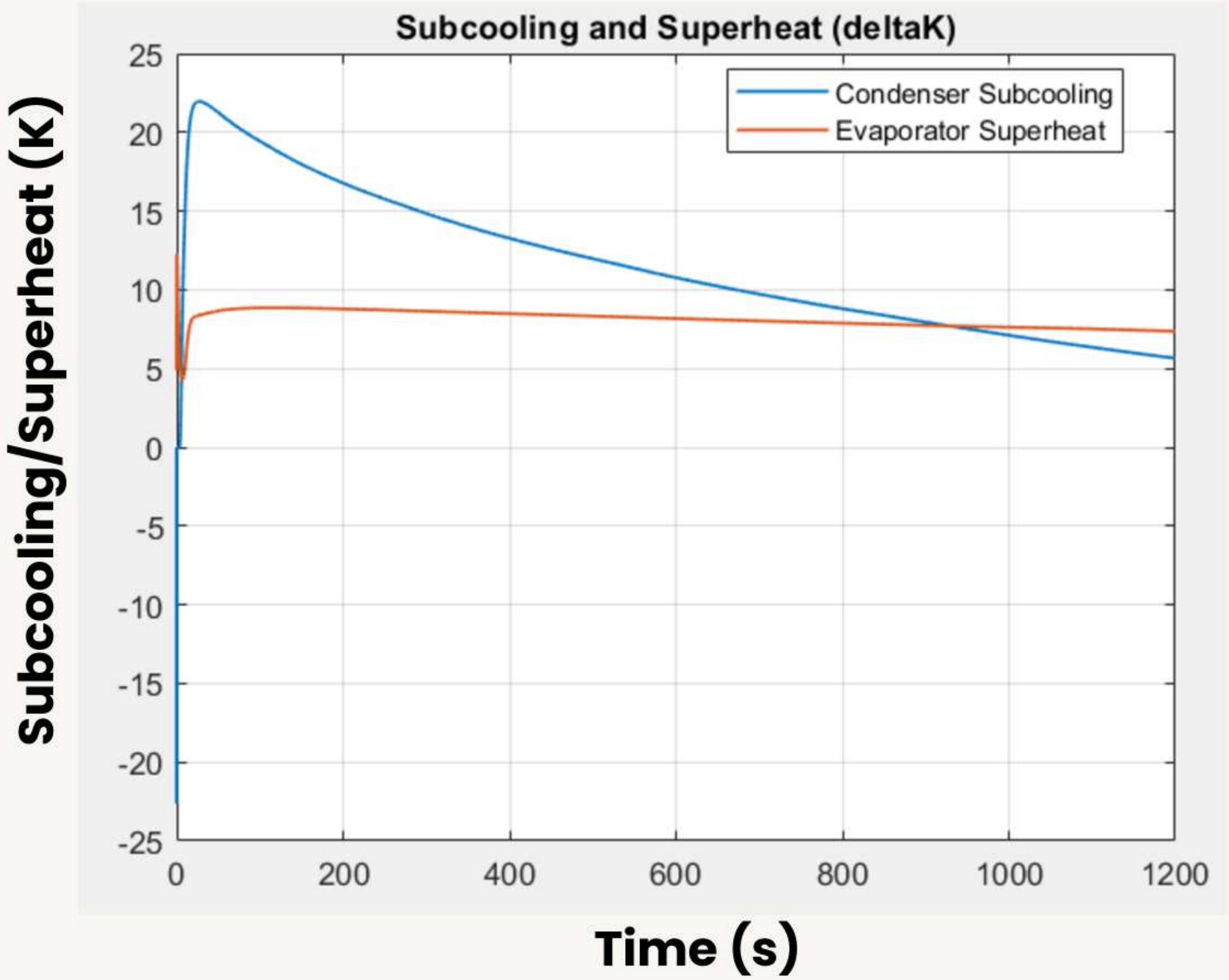
System Performance



The **Coefficient of Performance** can be calculated as the ratio of the **Cooling Delivered** and **Power Consumed**

Performance & Output Requirements Metrics

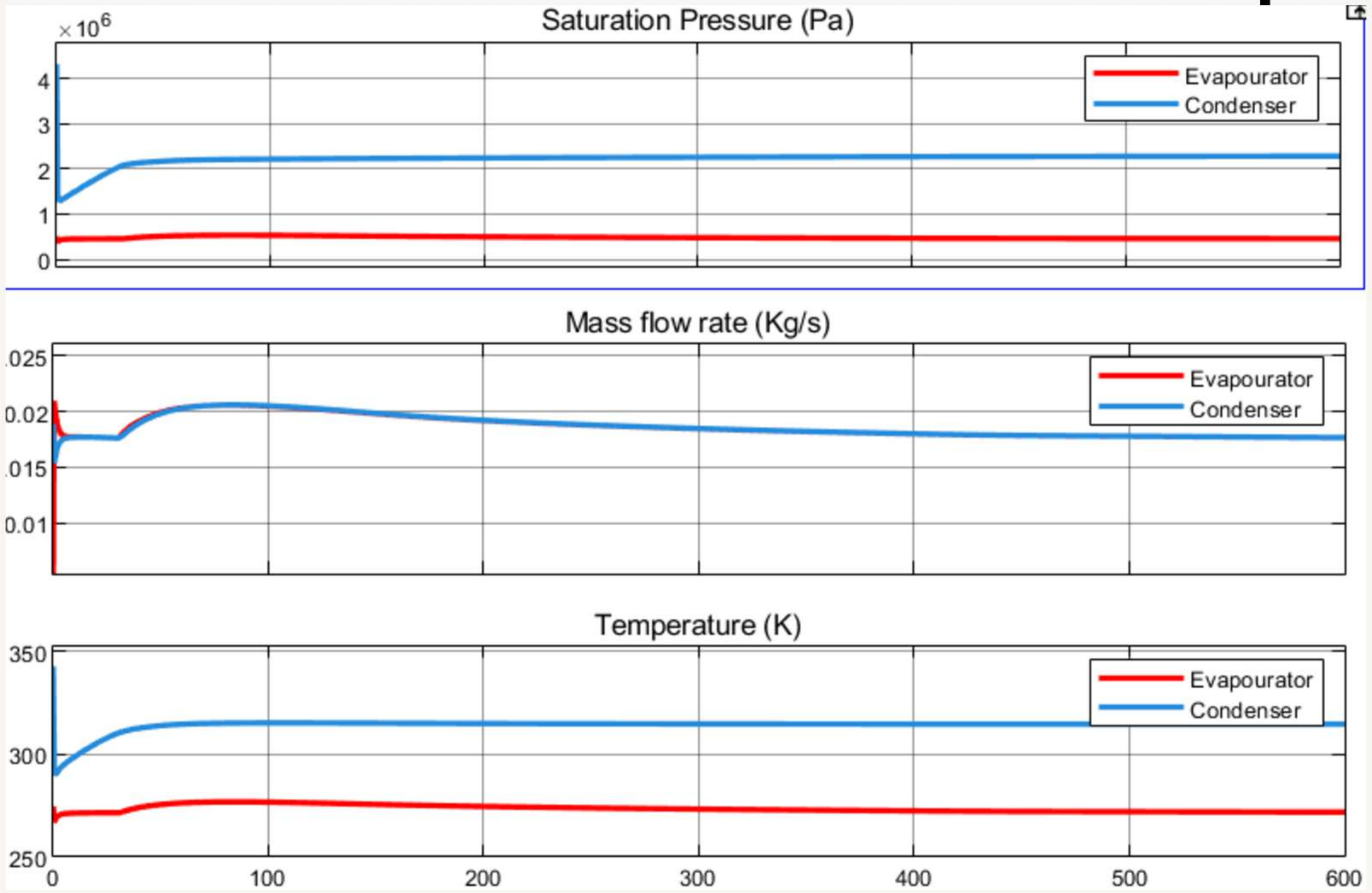
Superheat and Subcooling



Evaporator super-heat never drops below zero
throughout the runtime of the simulation

Performance & Output
Requirements Metrics

Saturation Pressure, Mass Flow Rate and Saturation Temperature



Time (s)

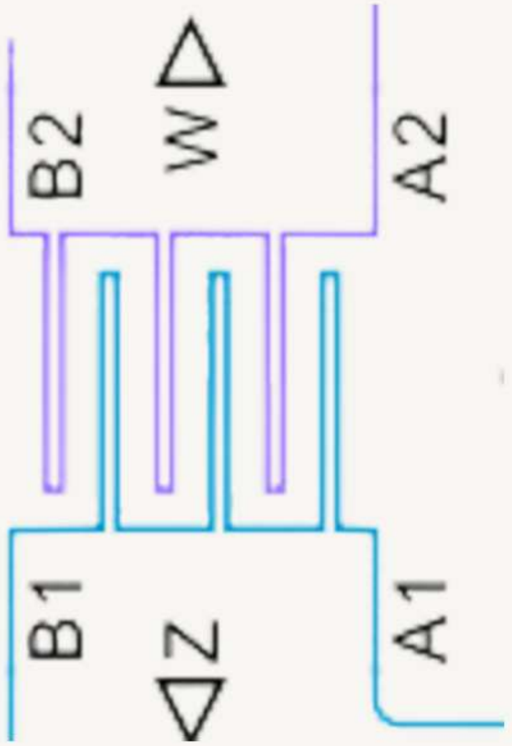
Parameters

Assumptions and Component Choice

- The model blocks and parameters where chosen based on the data given in problem statement.
- The values of different parameters were **selected based on the given condensation/evaporation temperature, superheating and subcooling**.
- Peak values used are **20%** more than nominal values.
- Fan block property table is used and a **curve-fitting method** is implemented, which is explicitly mentioned and calculated in the model as well in the 'Work Function Subsystem'.
- The nominal values for pressure, temperature, density and specific enthalpy are derived from ideal VCRC cycle using P-h graph.

Block Selection:

- Compressor and Expansion Valve used were same as of example model.
- Condenser and Evaporator were changed from **System Level** to **Heat Exchanger blocks**.
- The changes were done so as to **add fins** to the condenser and evaporator.
- The values for fin area was derived from the ones available in market so as to justify its usability in model.



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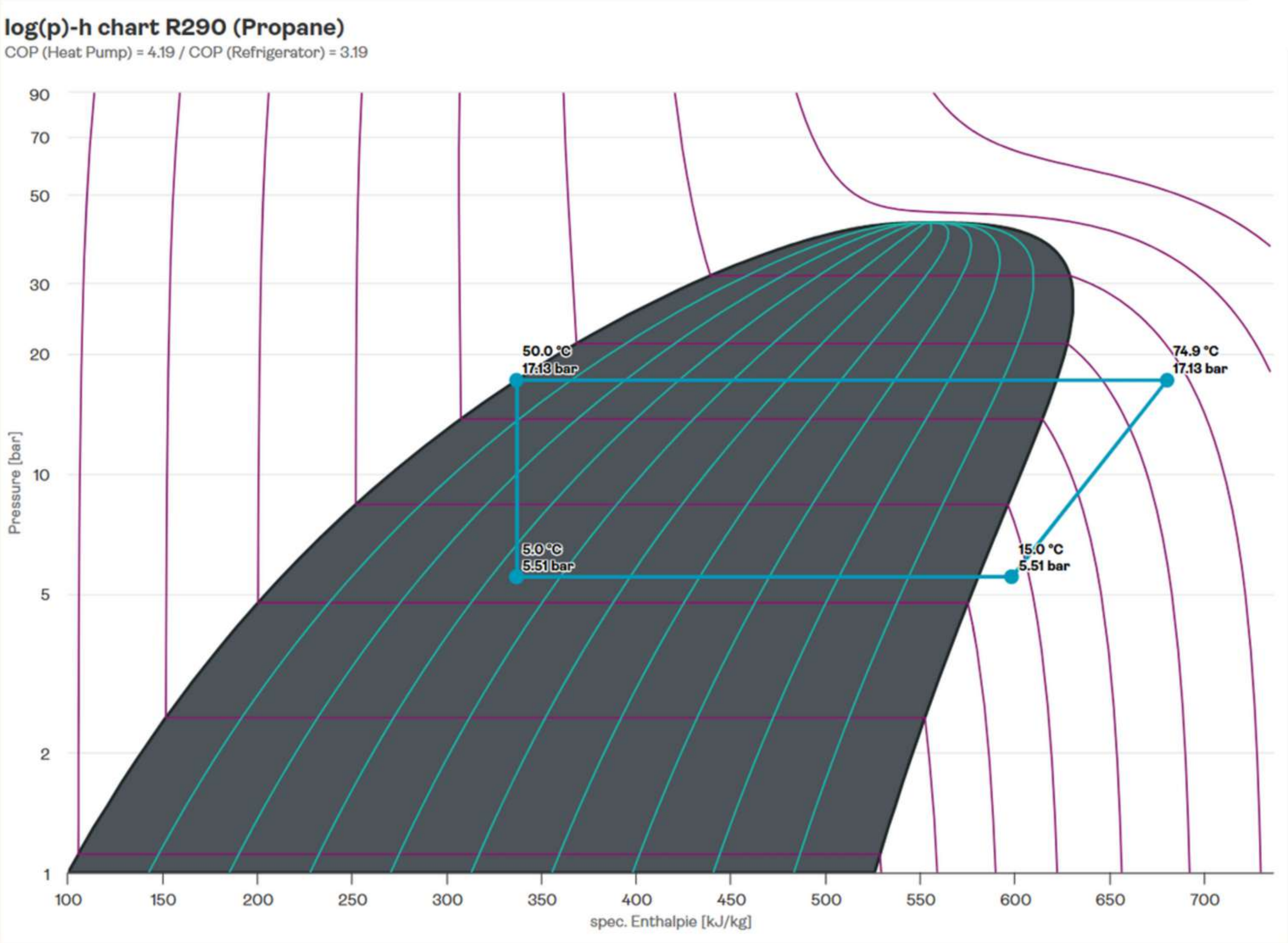
Refrigerant and Compressor Analysis

Analysis of P-h graph of Refrigerants



- The P-h graph for all refrigerants, along with their compatible compressors and isentropic efficiency, was analyzed.
- The ideal cycle of the refrigerants provides insight into various parameters such as pressure and specific enthalpies under nominal conditions.

Refrigerant and Compressor Analysis

Compressor	Compressor 1	Compressor 2	Compressor 2	Compressor 2	Compressor 2	Compressor 2	Compressor 3	Compressor 3	Compressor 3	Compressor 3	Compressor 4
Refrigerant	R290	R134a	R407C	R513A	R454C	R1234yf	R134a	R407C	R450A	R513A	R410A
Dispalcement (cm^3/rev)	33.1	45.5	45.5	45.5	45.5	45.5	33.1	33.1	33.1	33.1	22.8
Isoentropic Efficiency	68.40%	68.80%	69.10%	67.50%	67.90%	64.80%	63.90%	65.30%	65.60%	65.80%	65.10%
COP (Refrigeration)	3.19	3.28	2.76	3.1	3.1	2.92	3.04	2.61	3.08	3.02	2.77
T_Max_Out (Celsius)	74.9	75.6	91	69.9	68	66.7	78.6	93.6	68	70.7	93.6
T_Max_In (Celsius)	5	5	1.1	5	5	5	5	5	5	5	4.9
P_Max_Out (Bar)	17.13	13.18	22.16	13.77	23	13.02	13.18	22.16	11.7	13.77	30.71
P_Max_In (Bar)	5.51	`	5.47	3.85	6	3.73	3.5	5.47	3.1	3.85	9.33
GWP	3	1430	1774	573	148	4	1430	1774	602	573	2088

- This analysis eliminated most of the refrigerants with **high GWP** and **low CoP values**.
- To analyze the remaining refrigerants, MCDM method was used.
- Multi-Criteria Decision Making (MCDM) is a systematic approach to choosing the best option from multiple alternatives when faced with multiple criteria.
- Weightage was given to each criterion based on points and collective significance in improving the efficiency of the system.

Refrigerant and Compressor Analysis

Refrigerant	R290 (C1)	R134a (C2)	R513A (C2)	R454C (C2)	R1234yf (C2)	R134a (C3)	R450A (C3)	R513A (C3)
GWP (0.35)	5	4	4	5	5	4	4	4
COP (0.5)	5	5	4	4	3	4	4	4
Vol_disp (0.15)	4	5	5	5	5	4	4	4
TOTAL	**4.85**	**4.65**	4.15	4.5	4	4	4	4

- This method gave two refrigerants available satisfying our requirement best.
- To achieve the target temperature within 10 minutes, we required a refrigerant with **higher cooling power** under the same nominal conditions.

Refrigerant	Displacement Volume (cm^3/s)	Nominal RPM	Nominal Temp (T_N)(K)	Density @ T_N (kg/m^3)	Mass flow (kg/s)	del H (kJ/kg)	Cooling Power
R290	0.0331	2900	288.15	11.36	18.1741 x 10^(-3)	261.4	4.7507
R134a	0.0455	2900	288.15	16.23	35.6924 x 10^(-3)	139	4.96124

- On analyzing, both refrigerants had comparatively same cooling power.
- Thus, **R290 was selected** as refrigerant for system due to its high score in MCDM and **lower mass flow rate** for same power output.

Innovations

Optimisation of Condenser Unit

Increase volumetric flow rate within confined volume

Use of Tangential Fan:

Axial Fan

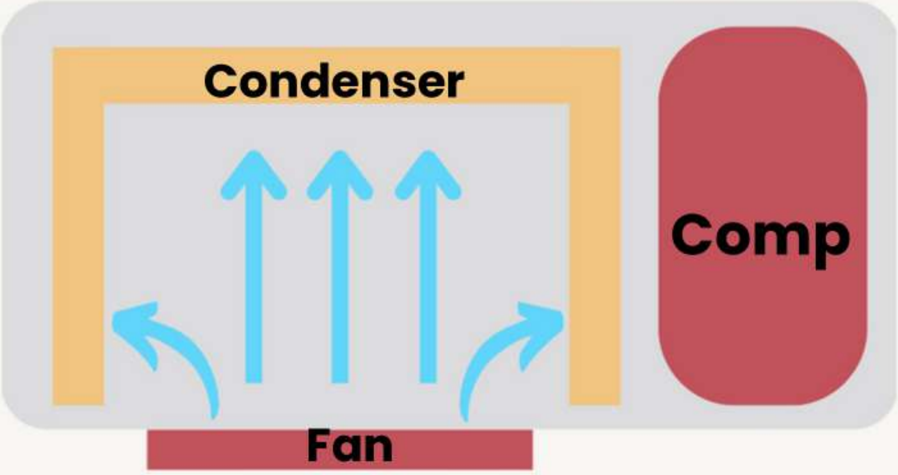
Replaced by

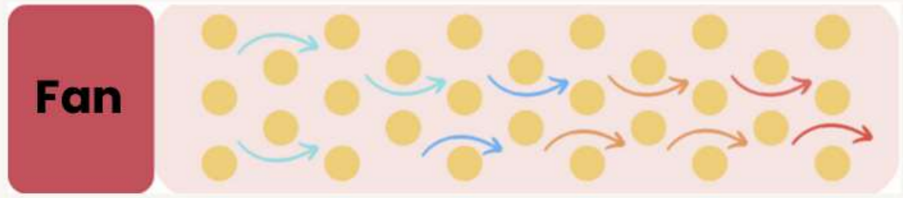
Tangential Fan

- **Uniform Air Distribution:** Cylindrical fans produces **uniform and wide airflow** across length; ideal for applications where even distribution of air is crucial, such as HVAC systems, and air curtains.

- **Compact Design:**
  - Compact in height; suitable for narrow or low-profile area.
  - Axial and centrifugal fans may require larger spaces depending on their design and airflow requirements.

- **Low Noise Operation:** Due to their design and lower speed of operation, cylindrical fans generally operate more quietly than conventional fans.

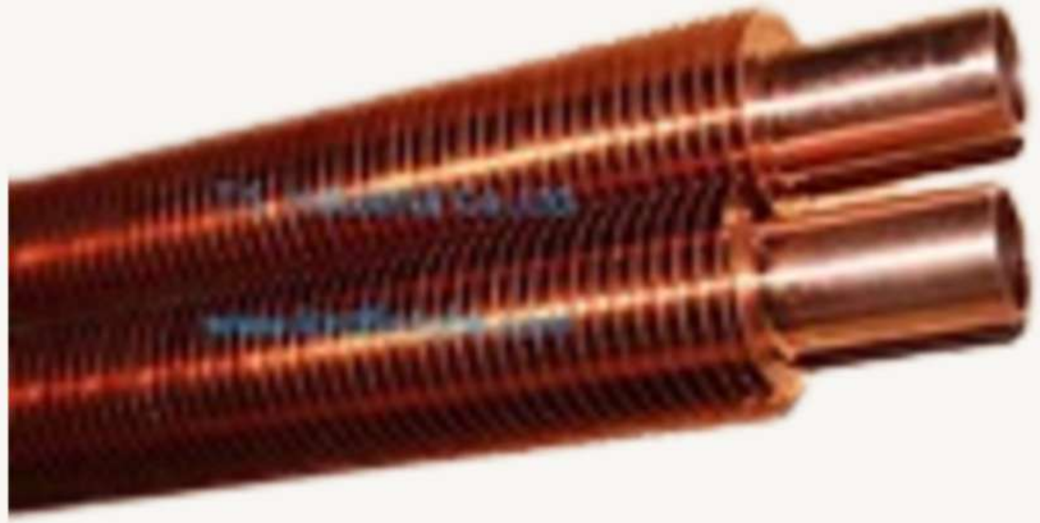




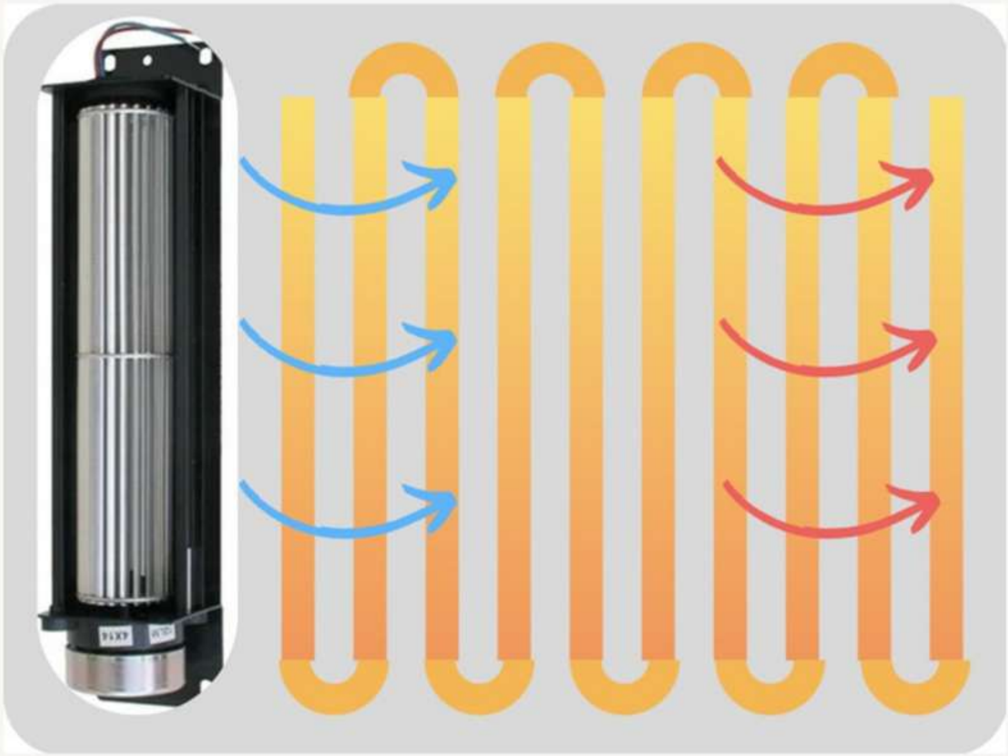
Redesigned Pipeline

Rearrangement of Pipeline

- Fins in condenser pipes **enhance the surface area** in contact with air.
- This increase boosts net heat transfer in the condenser.
- Fins improved the surface area by **15.6 m^2** within the same volume.



Finned Condenser Pipe



Pipeline Arrangement

- The design was updated from a conventional one to an **elongated spiral structure** compatible with a tangential fan.
- This structure **improves packing efficiency** by allowing **air to flow parallel to the fins** for maximum heat transfer.
- The design features constrained inlet and outlet sources, **ensuring air flows through all condenser pipes**.

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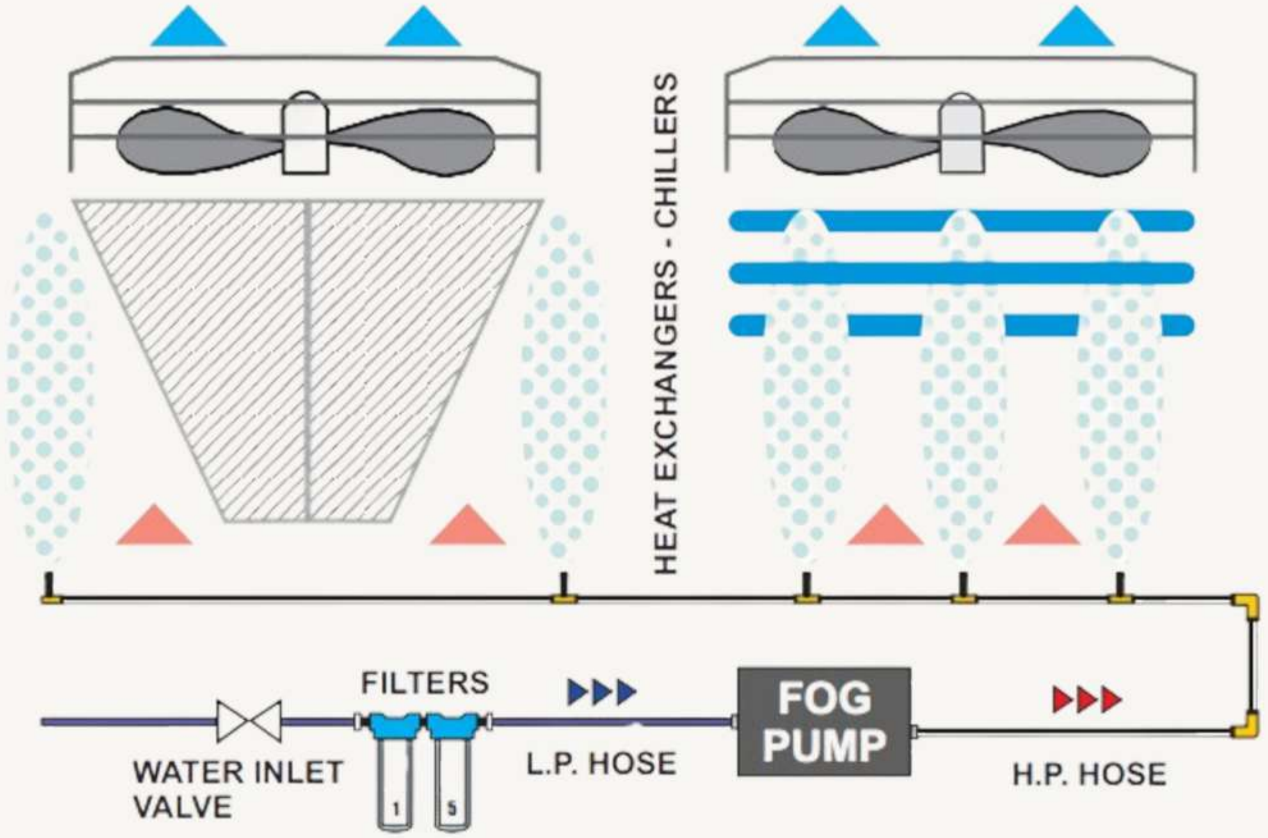
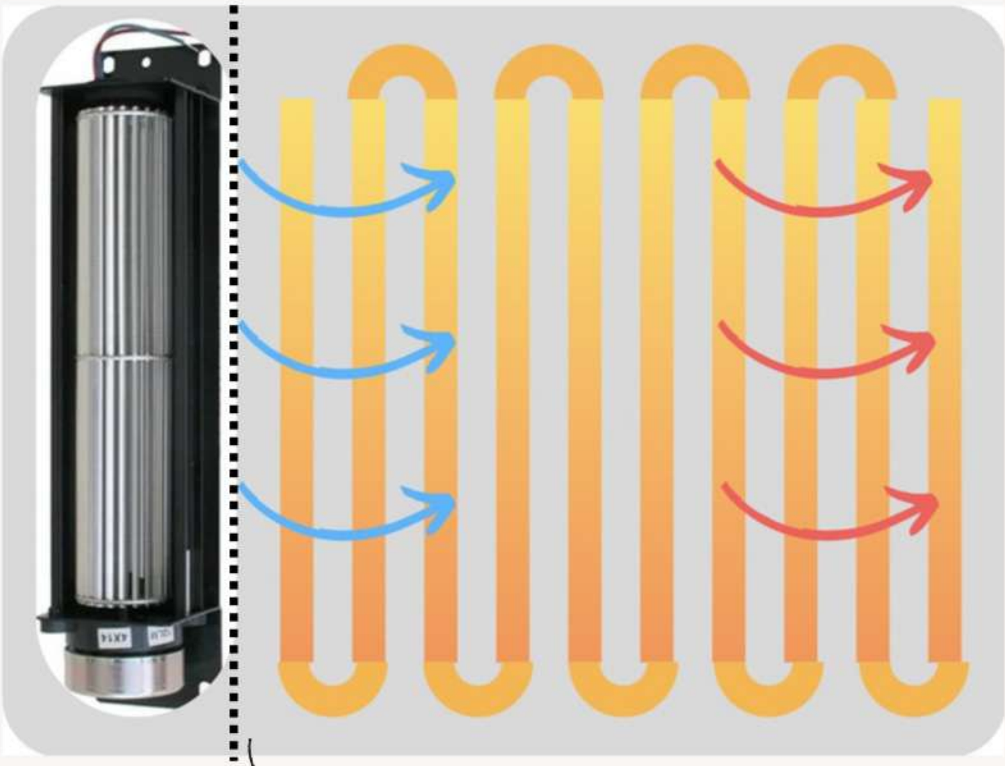
Mist-Assisted Cooling

- Newton's law of cooling states heat transfer is proportional to the **temperature difference between refrigerant and air**.
- Cooling the air enhances heat transfer.
- A mist sprayer is used at the **condenser unit's opening** to cool the air.
- The **mist lowers the air temperature** and increases its relative humidity as it flows through the unit.





Mist sprayer

- Spraying mist over a saturated pipeline lowers its temperature.
- Water used comes from the evaporator, **recycling typically wasted water** for efficiency.
- This cooling method can greatly **improve the heat transfer rate and overall efficiency**.

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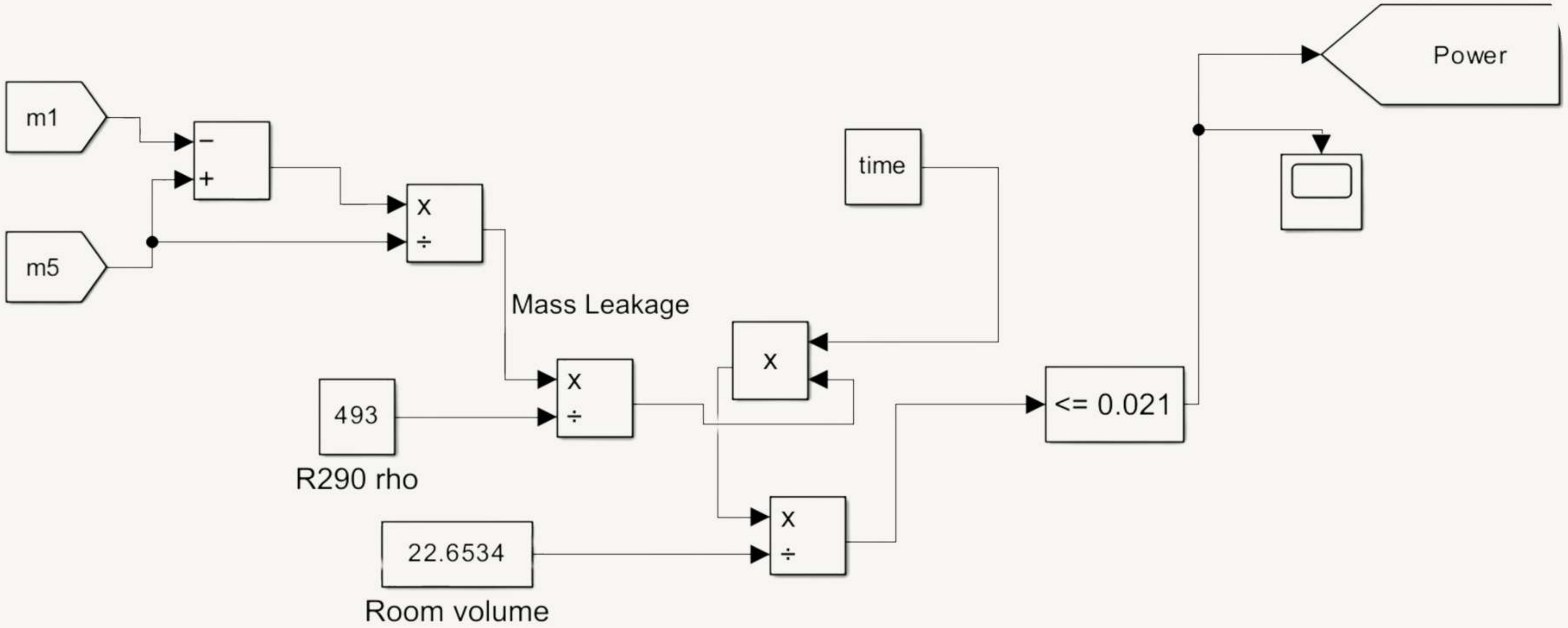
Refrigerant Safety Management System

R290: Refrigerant Grade Propane

- R290 was selected for its **low GWP** and **better efficiency**.
- ASHRAE classifies it as **A3—non-toxic** in typical concentrations but **highly flammable**, with a 2.1% LEL.
- Easy to ignite; poses fire, explosion, and suffocation risks in enclosed spaces.
- Safe management of R290 is essential to prevent hazards.



Simulink Subsystem

- RSMS is a safety subsystem integrated into the AC unit.
- RSMS **calculates refrigerant leakage** by measuring changes in mass flow rate across the evaporator, then **recalculates the refrigerant's volumetric ratio in the room**.
- If this concentration exceeds the LEL, **the system triggers a warning, cuts power**, and **shuts the expansion valve and compressor to prevent further leakage**.

Cost Analysis

Cost Analysis

Capital Expenditure

Material	Specification	Price
Pressure Safety Valve	15 inch	Rs. 2220
Fin Copper Tube	40 fins/inch, 50 metres	Rs. 6666
Thermostatic Expansion Valve	Compatibility with R290	Rs. 3560
Air Filter	34 cm x 22 cm x 0.1 cm	Rs. 399 x 2
Refrigerant	R290, Weight 1.2 kg	Rs. 1400
High Efficiency BLDC Motor	2000-2500 RPM, 0.138 kW	Rs. 3835 x 2
Fan	Aerodynamic ABS Anti-Tower, 13.5 inch	Rs. 400 x 4
Thermostat	Range: -10℃ to 60℃	Rs. 2055
Wiring	Length: 2 metres, Diameter: 4 mm	Rs. 10 x 3
PCB	Thickness: 1.6 mm	Rs. 6500
Gas/Smoke Sensor	Propane Detection	Rs. 1289
Active Peizo Buzzer	85 dB	Rs. 46
Mist Maker	24 Watt	Rs. 290
AC Aluminium Outdoor Cabinet	1.5 Ton	Rs. 2745
AC Aluminium Indoor Cabinet	1.5 Ton	Rs. 2130
Scroll Compressor	33.1 cm^3/rev	Rs. 14000

Capital Expenditure : Rs 52,999 /-

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Cost Analysis

Operational Expenditure :

Power Rating:	1.25 Ton of Refrigeration (~4.4 kW)
Usage Hour:	12 hours
Electricity Tariff:	The average cost of electricity in India is ₹8/kWh
Days per year:	365 days

Annual operational cost : Rs 46,357.92 /-

Metrics	Savings
Energy Saved	1095 kWh/year
Operational Cost Savings	₹8,760 /year
Capital Cost Excess	₹18,000
Cost Recovery Time	2 years

Thank You