INTER IIT TECH MEET 13.0

LOW PREP

ALBATROSS ENERGETICS

# INNOVATIVE COOLING AND DEHUMIDIFICATION SOLUTIONS

# About Albatross Energetics

Albatross Energetics envisions a world where climate-conscious thermal comfort solutions are universally accessible, driven by the belief that the right to protection against the adverse impacts of climate change is fundamental. Our mission is to transform how industries and communities approach climate control, creating solutions that ensure energy efficiency and sustainability without compromising comfort.

Today, they specialize in advanced cooling and dehumidification technologies tailored for industrial and commercial environments. By leveraging innovative desiccant-based methods, we enable precise humidity and temperature control, offering industries such as pharmaceuticals, textiles, and food processing the ability to reduce their carbon footprint and energy consumption.

Their solutions are designed for versatility, seamlessly integrating into both new and existing HVAC systems, and ensuring environmental benefits are achievable across diverse applications. Through strategic partnerships and ongoing research, Albatross Energetics is leading the charge toward a sustainable future where comfort and climate responsibility go hand in hand.

# Introduction

The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) in August 2021 cautioned that the Indian subcontinent could expect increased occurrences of severe and frequent heat waves in the next decade. The G20 Climate Risk Atlas also warned in 2021 that heat waves across India would likely last 25 times longer by 2036-65 if carbon emissions remain high, as in the IPCC's worst-case emission scenario. Soon, India could become one of the first places in the world to experience heat waves that would break the human survival limit.

In India, between 2019 and 2022, there was a 21% rise in electricity usage attributed to space cooling. Presently, approximately 10% of the total electricity demand is driven by the need for space cooling and by 2050, 45% of India's peak electricity demand is expected to come from space cooling alone.

However, only 10% of the households were air-conditioned as of 2021, making us one of the countries with the lowest access to efficient and affordable cooling solutions, given the high capex and opex costs of the existing solutions.

Thermal comfort is a basic necessity that should be accessible to all rather than a privilege reserved for a select few. Bridging this gap and making affordable solutions widely available is crucial to ensure that thermal comfort becomes a universally accessible standard of living in an affordable and efficient way.

The average efficiency of ACs in India is relatively low, given the cost-sensitive nature of the Indian market. The building sector offers huge potential for reducing cooling demand and improving energy efficiency, considering buildings consume 30-35% of India's total energy. Broadly, 75-85% of the emissions generated by a building occur during its operations, of which 35-40% is by the HVAC systems.

Space cooling requirements consistently indicate that technological advancements in AC systems are key to significantly reducing electricity consumption and, consequently, greenhouse gas emissions cost-effectively.

# Problem Statement

Participants are tasked with creating a detailed model of a vapor compression-based air conditioning (AC) system for effective cooling and dehumidification. The system will operate using a single compressor, and the objective is to achieve optimal cooling, dehumidification, and energy efficiency within safe operational limits under varying load conditions.

The entire system, including the choice of components, refrigerant, and control logic, must be modeled in **MATLAB/Simulink**.

System Requirements:

**1. Compressor Selection:**

- You may select a compressor from the list provided:

| | **Scroll Compressor 1** | **Scroll Compressor 2** | **Scroll Compressor 3** | **Scroll Compressor 4** |
|---|---|---|---|---|
| Suitable Refrigerants | R290 | R134a, R407C, R513A, R454C, R1234yf | R134a, R407C, R450A, R513A | R410A |
| Isentropic Efficiency (%) | 68.4% | 68.8%, 69.1%, 67.5%, 67.9%, 64.8% | 63.9%, 65.3%, 65.6%, 65.8% | 65.1% |
| Displacement (at 50Hz, in L/s) | 1.6 | 2.2 | 1.6 | 1.1 |
| High Side Pressure Max (gauge, bar) | 28 | 38 | 29 | 45 |
| Low Side Pressure Max (gauge, bar) | 17 | 23.5 | 21 | 29.5 |
| Low Side Temperature Max (°C) | 50 | 50 | 50 | 50 |
| Low Side Temperature Min (°C) | -35 | -35 | -35 | -35 |
| High Side Temperature Max (°C) | 150 | 150 | 150 | 150 |
| High Side Temperature Min (°C) | -35 | -35 | -35 | -35 |
| Stub Suction (inch) | 3/4 | 3/4 | 3/4 | 3/4 |
| Stub Discharge (inch) | 1/2 | 1/2 | 1/2 | 1/2 |

## 2. Refrigerant Choice, Component Design, Control Logic:

- You are free to select any refrigerant, balancing performance and environmental impact.
- The design of the evaporator and condenser is open-ended and up to the participants' discretion.
- You are encouraged to implement custom control logic to vary the compressor RPM and indoor/outdoor fan speeds based on load profiles.

## 3. Arbitrary Testing Conditions:

- Indoor Set Point: 27°C DB (dry bulb), 19°C WB (wet bulb).
- The outdoor air conditions, initial room air conditions, and internal room loads will be set by the organizers. Specifically, the organizers will determine the inputs for the House Subsystem and the House Thermal Network Subsystem in Simulink, and will adjust design parameters to vary the sensible and latent heat loads in the room. Participants can assume that the total heat load will not exceed 1.25 TR (ton of refrigeration).

## 4. ISEER Rating Conditions:

- Indoor Set Point: 27°C DB (dry bulb), 19°C WB (wet bulb).
- Outdoor Air Conditions:

| Temperature (°C) | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 |
|---|---|---|---|---|---|---|---|---|---|---|
| Average Annual Hours | 527 | 590 | 639 | 660 | 603 | 543 | 451 | 377 | 309 | 240 |
| Fraction | 9.1 | 10.2 | 11.1 | 11.4 | 10.4 | 9.4 | 7.8 | 6.5 | 5.4 | 4.2 |
| Bin Hours | 146 | 163 | 177 | 183 | 167 | 150 | 125 | 104 | 86 | 67 |

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| Temperature (°C) | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Annual Hours | 196 | 165 | 130 | 101 | 79 | 59 | 44 | 31 | 20 | 10 | 5774 |
| Fraction | 3.4 | 2.9 | 2.3 | 1.7 | 1.4 | 1.0 | 0.8 | 0.5 | 0.3 | 0.2 | 100 |
| Bin Hours | 54 | 46 | 36 | 28 | 22 | 16 | 12 | 9 | 6 | 3 | 1600 |

**5. Safety Requirements:**

- The AC system must operate safely under all practical load conditions. It should remain within the compressor's safe operating envelope, with no negative superheat allowed. Penalties will apply for any deviations from safe operating conditions.

# Performance and Output Requirements

1. Pressure-Enthalpy (P-h) Chart of the Refrigeration Cycle.
2. Graphs Displaying:
- Indoor DB and WB
- Cooling Delivered, Power Consumption, and Energy Efficiency Ratio (EER)
- Condenser and Evaporator Pressures/Saturation Temperatures
- Superheating and Subcooling

# Evaluation Pattern

The scoring will be divided as follows:

1. **Performance Score: 70 Points**
- **Scoring Based on Average EER at Arbitrary Testing Conditions** (35 Points)

- **Scoring Based on ISEER** (35 Points)

If the highest EER/ISEER amongst all the submissions is H, and a team's EER/ISEER is X, the team's score will be calculated as X/H*35.

- **Penalties:**
  - Violation of Safe Operating Conditions: If the system operates outside of safe conditions (e.g., compressor envelope violations), a 15% deduction will be applied to the performance score.
  - Response Time Requirements: The system should cool AND dehumidify the room down to the target set point within 10 minutes.
    - If cooling or dehumidification takes more than 10 minutes, a 5% penalty will be applied to the performance score.
    - If cooling or dehumidification takes more than 20 minutes, a 15% penalty will be applied to the performance score.

**2. Project Documentation Score: 10 Points**

- The document should detail your model, design choices, controls, ISEER achieved, cost analysis and viability of the designed AC system.

**3. Final Presentation: 10 Points**

- Participants will present their model, design choices, and results to the panel.

**4. Bonus Points**

- Environmental Impact - Refrigerant GWP (Global Warming Potential): +10 Points

  +10 marks for refrigerants with GWP < 500.
  +5 marks for refrigerants with GWP ≥ 500 and < 1500.
  0 marks for refrigerants with GWP ≥ 1500.

# Resources

1. Model of refrigeration Cycle
    a. System-Level Refrigeration Cycle (2P)
    b. Thermostatic Expansion Valve (2P)

2. Modelling Moist Air System
    a. Condenser Evaporator (2P-MA)
    b. System-Level Condenser Evaporator (2P-MA)
    c. Considerations for Microchannel Heat Exchangers
    d. E-NTU Heat Transfer

3. Refrigeration Cycle (Air Conditioning)

4. Developing Thermal Management System with Simulink