HVAC SYSTEM DESIGN & THERMAL LOAD CALCULATION

Synapse Headquarters Corporate Office Complex

Prepared For:
Synapse Systems Corp.
Corporate Facilities Group
Austin, Texas

Prepared By:
Nexa Engineering Design, LLP
Mechanical Systems Department
Project ID: NX-2026-SHQ-HVAC

Lead Mechanical Engineer:
Sarah Jenkins, P.E.

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1 Introduction and Project Scope

This report presents the detailed heating, ventilation, and air conditioning (HVAC) system design and thermal load calculations for the new Synapse Headquarters corporate office complex in Austin, Texas. The project, commissioned by Synapse Systems Corp. and engineered by Nexa Engineering Design, LLP, represents a state-of-the-art office building designed to achieve high energy efficiency, exceptional indoor environmental quality (IEQ), and low operational costs.

The building is a two-story modern office block with a total conditioned floor area of approximately 40,000 ft^2 (3,716 m^2). The space distribution includes:

- Open-plan workspaces on both levels.
- High-occupancy conference rooms and collaborative spaces.
- A dedicated IT server and network operations center (NOC) on the first floor.
- Administrative offices, cafeteria, and building services area.

The thermal load calculations and mechanical equipment selections have been executed in strict compliance with current codes and standards, including ASHRAE Standard 55-2023 for thermal comfort conditions [1], ASHRAE Standard 62.1-2023 for ventilation and indoor air quality [2], and ASHRAE Standard 90.1-2023 for energy-efficient building envelope and mechanical systems design [3].

1.1 Design Methodology

The peak cooling and heating thermal loads were calculated using the Radiant Time Series (RTS) method, as detailed in the ASHRAE Handbook of Fundamentals [4]. The RTS method, a simplified hourly method direct from the heat balance method, accounts for the delay in convective and radiative heat transfer through the building envelope.

The calculation steps include:

1. Determination of outdoor and indoor design conditions.

2. Characterization of envelope thermal properties (U-values) for walls, roof, and glazing.
3. Estimation of internal loads from occupants, lighting, plug loads, and process equipment.
4. Evaluation of ventilation and infiltration airflow rates.
5. Estimation of peak hourly heating and cooling loads to size primary air handling and water-side equipment.

2 Design Conditions and Criteria

The geographical location for the project is Austin, Texas (Latitude 30.30°N, Longitude 97.70°W, Elevation 500 ft above sea level). Austin is categorized under ASHRAE Climate Zone 2A (Hot-Humid), characterized by high summer ambient temperatures and high humidity levels.

2.1 Ambient and Indoor Design Parameters

Outdoor design conditions were selected from the 2025 ASHRAE Fundamentals climate database. The summer cooling design corresponds to the 1.0% monthly cumulative frequency of occurrence, while the winter heating design is based on the 99.0% frequency of occurrence. Indoor design parameters are set to maintain thermal comfort for occupants dressed in typical summer/winter office attire performing light sedentary activities, as defined by ASHRAE Standard 55 [1].

The specific design values are summarized in Table 1.

Table 1. Outdoor and Indoor Design Conditions

Parameter	Description	Outdoor Value	Indoor Value
Dry Bulb Temp (Cooling)	Summer peak cooling design (1.0% limit)	102°F (38.9°C)	75°F (23.9°C)
Wet Bulb Temp (Cooling)	Coincident wet-bulb temperature	78°F (25.6°C)	62.5°F (16.9°C)
Relative Humidity	Calculated indoor relative humidity	–	50%
Dry Bulb Temp (Heating)	Winter peak heating design (99.0% limit)	26°F (-3.3°C)	70°F (21.1°C)
Ventilation Rate	Standard office occupancy minimum	15 CFM/person	–

2.2 Building Envelope Performance

The building envelope construction was designed to exceed the prescriptive requirements of ASHRAE Standard 90.1-2023 [3] to minimize envelope conductive heat transfer. The high-performance double-glazed fenestration incorporates low-emissivity coatings and argon gas fill to reduce solar heat gain while maintaining daylighting.

The envelope design specifications and U-values are detailed in Table 2.

3 Thermal Load Calculations

The peak cooling and heating thermal loads were calculated for each zone of the Synapse Headquarters using hourly weather data. Conductive heat transfer through the opaque envelope elements was modeled using:

$$q_{\text{cond}} = U \cdot A \cdot \Delta T_{\text{eff}} \tag{1}$$

Table 2. Envelope Construction and Design U-Values

Element	Construction Specification	Design U-Value [Btu/h·ft^2·°F]	ASHRAE 90.1 Limit [Btu/h·ft^2·°F]
Exterior Wall	Steel studs, R-13 batt + R-7.5 continuous polyiso	0.064	0.084
Roof	Metal deck, R-30 continuous rigid PIR insulation	0.032	0.048
Slab-on-Grade	Unheated slab, F-factor slab edge insulation	0.050	0.070
Glazing	Double-glazed, low-E, argon-filled, SHGC = 0.25	0.380	0.400

where U is the thermal transmittance, A is the surface area, and ΔT_{eff} is the effective temperature difference, incorporating solar radiation effects on exterior surfaces via the sol-air temperature.

For fenestration elements, solar heat gain was calculated as:

$$q_{\text{solar}} = A \cdot \text{SHGC} \cdot I_{\text{solar}} \tag{2}$$

where SHGC is the solar heat gain coefficient, and I_{solar} is the incident solar irradiance.

3.1 Internal Load Assumptions

Internal loads were modeled based on the actual planned layout and typical equipment density.

- **Occupancy:** Design density is 100 ft^2/person in open offices and 20 ft^2/person in conference rooms. Heat dissipation is assumed to be 250 Btu/h sensible and 200 Btu/h latent per person.
- **Lighting:** High-efficiency LED lighting is utilized throughout the facility, with an average lighting power density (LPD) of 0.65 W/ft^2.
- **Equipment:** General office equipment (computers, printers, copiers) is estimated at 1.0 W/ft^2 in general office zones, while the IT Server Room has a dedicated load profile of 30 kW continuous sensible load.

3.2 Peak Load Breakdown

The peak sensible and latent cooling loads and heating loads were determined. Peak cooling occurs in July at 16:00, driven by coincident solar radiation on the west facade and high ambient temperatures. Peak heating is calculated for the worst-case winter night with no solar or internal heat gains.

The load summary breakdown is detailed in Table 3.

Engineering Design Tip: High Latent Loads

In Climate Zone 2A, the latent cooling load from ventilation and occupant respiration represents a significant portion of the total cooling capacity. Design engineers must ensure the selected system has a low Sensible Heat Ratio (SHR $\approx$ 0.77) to guarantee effective dehumidification at peak and part-load conditions.

Table 3. Peak Cooling and Heating Thermal Load Summary

Load Category	Source Details	Sensible [MBH]	Latent [MBH]
Solar Heat Gain	East/West exterior glass windows	142.5	–
Envelope Heat Gain	Walls, roof, slab conduction	85.3	–
Occupant Heat Gain	250 occupants (steady state)	62.5	50.0
Lighting Load	LED fixtures (LPD = 0.65 W/ft^2)	55.4	–
Equipment	Server room (30 kW) + desktop office load	120.0	–
Ventilation Air	3,750 CFM outdoor air intake	110.2	95.8
Infiltration	Building envelope leakage (0.05 CFM/ft^2)	15.6	12.4
Subtotal	Calculated envelope and internal loads	**591.5**	**158.2**
Total Peak Cooling	Including 10% safety factor	**650.7**	**174.0**
Total Peak Heating	Design winter condition (26°F)	**320.4**	–

4 Air Flow and Air Distribution System Design

The supply airflow rate required to satisfy the sensible cooling loads is calculated using:

$$Q_{\text{supply}} = \frac{q_{\text{sens}}}{1.1 \cdot \rho_{\text{std}} \cdot (T_{\text{room}} - T_{\text{supply}})} \tag{3}$$

where Q_{supply} is the airflow rate in CFM, q_{sens} is the sensible cooling load in Btu/h, ρ_{std} is the air density correction factor, T_{room} is the room design dry-bulb temperature (75°F), and T_{supply} is the design supply air temperature off the cooling coil (55°F).

For the total sensible peak load of 591.5 MBH (excluding ventilation load which is handled directly by the pre-conditioner), the required zone supply airflow is:

$$Q_{\text{supply}} = \frac{591,500}{1.1 \cdot (75 - 55)} \approx 26,886 \text{ CFM} \tag{4}$$

4.1 Ductwork Design and Sizing

Duct design was performed using the equal friction method, setting a design pressure drop of 0.1 in. w.g. per 100 ft (0.82 Pa/m) for supply ducts, and 0.08 in. w.g. per 100 ft (0.65 Pa/m) for return ducts. Velocities in main ducts were capped at 1,500 FPM (7.6 m/s) to control noise and vibration levels, in compliance with ASHRAE Handbook guidelines for commercial office buildings.

4.2 External Static Pressure (ESP) Calculation

A detailed pressure loss estimation was carried out for the index run (longest run) to size the supply fan motor. The results are summarized below:

- Straight duct friction losses: 0.35 in. w.g.
- Duct fittings and transitions (tees, elbows, dampers): 0.28 in. w.g.
- Terminal units (VAV boxes with reheat coils): 0.45 in. w.g.
- Diffusers, grilles, and registers: 0.15 in. w.g.

- Air Handling Unit internal losses (filters, coils, silencers): 0.85 in. w.g.
- **Total Static Pressure Required: 2.08 in. w.g.** (including 15% safety margin).

5 Equipment Selection and System Schematic

Based on the peak thermal load and airflow calculations, the primary mechanical equipment was selected to meet the heating, cooling, and ventilation demands of the Synapse Headquarters.

A modular Variable Air Volume (VAV) system was chosen for the office zones, served by a central Air Handling Unit (AHU-1) located on the roof. Central chilled water is provided by an air-cooled scroll chiller (CH-1) utilizing low-GWP refrigerant R-454B. Heating is provided by a gas-fired condensing boiler (BLR-1) delivering hot water to the VAV reheat coils and cabinet unit heaters.

5.1 Central Equipment Schedule

The major mechanical equipment selections are presented in Table 4.

Table 4. HVAC Scheduled Equipment Specifications

Tag	Manufacturer	Model/Series	Design Capacity	Design Airflow
AHU-1	Apex Systems	Series 400 Modular VAV	60 Tons (720 MBH)	22,000 CFM
CH-1	Nimbus Corp.	Centrifugal Scroll Chiller	80 Tons (960 MBH)	160 GPM
BLR-1	Meridian Thermal	Condensing Fire-tube Boiler	450 MBH	45 GPM
FCU-1..12	Synapse Tech	Thin-Line Ducted FCU	2 Tons (24 MBH) ea	800 CFM ea

5.2 System Air Loop Flow Schematic

The central airflow distribution and conditioning loop is illustrated schematically in Figure 1.

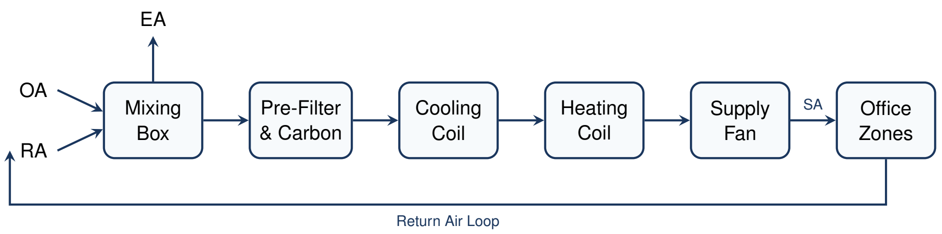

Figure 1. Air Handling Unit AHU-1 central conditioning air loop flow schematic.

6 Conclusion and Recommendations

The detailed HVAC design and thermal load calculations for the Synapse Headquarters office complex demonstrate a robust engineering approach tailored to the demanding hot-humid climate of Austin, Texas. By employing high-performance envelope materials exceeding ASHRAE 90.1 standard limits, peak cooling and heating thermal loads were kept within manageable bounds:

- Peak Cooling Load: 650.7 MBH sensible/latent (54.2 Tons capacity).
- Peak Heating Load: 320.4 MBH sensible.
- Central Supply Airflow: 22,000 CFM based on central VAV zoning.

6.1 Energy Efficiency Enhancements

While the current design baseline represents a highly efficient VAV system, the following engineering enhancements are recommended during the detailed design phase to further improve sustainability and reduce operational costs:

1. **Energy Recovery Ventilation (ERV):** Implementing an air-to-air energy recovery wheel within the pre-conditioner unit. This would pre-cool and dehumidify the warm, humid outdoor air in summer using the cool, dry exhaust air, reducing peak ventilation load by up to 22%.
2. **Demand Controlled Ventilation (DCV):** Installing carbon dioxide (CO_2) sensors in high-occupancy zones (conference rooms, cafeteria) to modulate outdoor air dampers based on real-time occupancy, avoiding unnecessary conditioning of ventilation air during partial occupancy.
3. **Chilled Water Reset Strategy:** Implementing a controls algorithm that raises the chilled water supply temperature during low cooling load periods, increasing the chiller COP by 1.5% per degree Fahrenheit of reset.

By incorporating these strategies, the mechanical systems will not only provide excellent thermal comfort but will also position the Synapse Headquarters as a leader in sustainable facility design.

References

[1] ASHRAE, “Standard 55-2023: Thermal environmental conditions for human occupancy,” 2023.

[2] ASHRAE, “Standard 62.1-2023: Ventilation for acceptable indoor air quality,” 2023.

[3] ASHRAE, “Standard 90.1-2023: Energy standard for sites except low-rise residential buildings,” 2023.

[4] American Society of Heating, Refrigerating and Air-Conditioning Engineers, *ASHRAE Handbook—Fundamentals (I-P Edition)*. Atlanta, GA: ASHRAE, 2025.