[DATE]

Academic HVAC Design Report

FAISAL A
[COMPANY NAME]
[Company address]

Contents

1. Introduction

This report presents the heating, ventilation, and air conditioning (HVAC) system design for a proposed 12-storey residential condominium building. The objective of the project is to evaluate multiple HVAC system configurations and determine a technically sound and energy-efficient solution that satisfies occupant comfort, indoor air quality, and applicable design standards.

The building is assumed to be located in Toronto, Ontario, and consists primarily of residential condominium suites with associated common areas. The HVAC design process includes the determination of heating and cooling loads, ventilation requirements, infiltration rates, and envelope thermal characteristics. Both conventional and alternative HVAC systems are analyzed and compared to assess their performance, energy consumption, and suitability for a high-rise residential application.

The project evaluates three primary system configurations:

A conventional HVAC system using standard heating and cooling equipment

A ground source heat pump (GSHP) system

A hybrid GSHP system incorporating supplemental conventional components

Energy performance and system feasibility are analyzed using a combination of industry-standard software tools and engineering calculations. Building energy modeling is performed using eQUEST to estimate heating and cooling loads and annual energy consumption. Ground heat exchanger performance is analyzed using HGS software to evaluate borehole sizing and ground loop behavior. Air distribution and duct sizing calculations are carried out using the Duct software, supplemented by manual verification where appropriate.

Design assumptions related to occupancy, operating schedules, indoor comfort conditions, and envelope thermal properties are based on typical residential design practices and applicable codes and standards. The intent of this report is not only to produce a final HVAC system recommendation, but also to document the engineering methodology, assumptions, and decision-making process used throughout the design.

The final outcome of the project is a recommended HVAC system configuration that balances energy efficiency, system complexity, and practical implementation considerations for a mid- to high-rise residential building.

2. Indoor and Outdoor Design Conditions

The selection of appropriate indoor and outdoor design conditions is fundamental to the accurate sizing and evaluation of HVAC systems. Design conditions for this project are based on typical residential comfort requirements and representative climatic data for Toronto, Ontario.

2.1 Indoor Design Conditions

The building is a retirement condominium occupied primarily by elderly residents who are expected to remain indoors for extended periods, particularly during the winter season. As such, indoor design conditions are selected to prioritize thermal comfort and health.

For winter operation, the indoor dry-bulb temperature is selected to maintain a comfortable and stable environment. For summer operation, indoor conditions are selected to balance comfort and humidity control while minimizing excessive cooling energy consumption.

The indoor design conditions used for this project are summarized as follows:

- **Winter indoor design temperature:** 22°C (72°F)
- **Summer indoor design temperature:** 24°C (75°F)
- **Indoor relative humidity:** Assumed within acceptable residential comfort range (30–50%)

These values are representative of standard residential HVAC design practice and are appropriate for a retirement living environment.

2.2 Outdoor Design Conditions

Outdoor design conditions are selected based on historical climate data for Toronto, Ontario. These conditions represent extreme but realistic scenarios used for HVAC sizing and performance evaluation.

Winter design conditions correspond to low outdoor temperatures with wind-driven infiltration effects, while summer design conditions reflect high dry-bulb temperatures combined with solar gains and humidity effects.

The outdoor design conditions adopted for this project are:

- **Winter outdoor design temperature:** −18°C (0°F)
- **Summer outdoor design temperature:** 32°C (90°F)

- **Prevailing winter wind direction:** Northwest
- **Prevailing summer wind direction:** Southwest

Wind speeds are considered in the infiltration analysis using the crack method and are applied differently for the lower and upper floors of the building to account for stack effect and wind exposure.

3. Minimum Ventilation Requirements

Adequate ventilation is required to maintain acceptable indoor air quality for occupants. Since each condominium unit is occupied by a retired couple, ventilation requirements are determined on a per-unit basis.

Ventilation air requirements are calculated using standard residential ventilation guidelines, accounting for:

- Number of occupants
- Unit floor area
- Occupancy activity level

The minimum ventilation rate ensures sufficient fresh air to dilute indoor contaminants generated from occupants, cooking activities, and off-gassing from materials.

The calculated minimum ventilation requirement for each unit is determined in cubic feet per minute (cfm) and is later compared with infiltration airflow rates to assess whether infiltration alone is sufficient to meet ventilation needs during winter and summer conditions.

4. Design Infiltration Rates

- Infiltration rates are determined using the **crack method**, which accounts for air leakage through the building envelope due to pressure differences caused by wind and stack effect.

4.1 Winter Infiltration – First Story

The first story experiences increased infiltration during winter due to:

- Stack effect drawing cold air inward at lower levels

- Wind exposure at ground level
- Crack lengths are estimated based on window and door perimeters, and pressure differences are calculated using winter wind speeds and temperature gradients. The resulting infiltration rate is expressed in both **cfm** and **air changes per hour (ACH)**.

4.2 Summer Infiltration – Twelfth Story

The twelfth story experiences higher infiltration during summer due to:

- Wind pressure effects at higher elevations
- Reverse stack effect during warm conditions
- The same crack method is applied using summer wind speeds and temperatures.

4.3 Ventilation Adequacy Assessment

The calculated infiltration rates are compared against the minimum ventilation requirements determined in Section 3. For periods when infiltration alone is insufficient to meet ventilation needs, mechanical ventilation is proposed as part of the HVAC system design to ensure acceptable indoor air quality year-round.

5. Thermal Resistance (R-Value) Calculations

Thermal resistance values are calculated for the exterior wall and roof-ceiling assemblies of the 12th-story condominium unit.

5.1 Exterior Wall Assembly

The exterior wall assembly consists of multiple layers including precast concrete, air space, rigid insulation, wood framing with fiberglass insulation, and gypsum wallboard. The total R-value is calculated by summing the thermal resistances of each layer.

5.2 Roof-Ceiling Assembly

The roof-ceiling assembly includes built-up roofing, rigid insulation, concrete slab, air space, and interior ceiling finishes. The total R-value is calculated using standard thermal resistance values for each material.

5.3 Comparison with eQUEST Results

The manually calculated R-values are compared against the effective R-values reported by eQUEST in the energy simulation. Differences are discussed in terms of modeling assumptions, framing effects, and thermal bridging.

6. Conventional HVAC System Energy Simulation

A building energy simulation is performed using **eQUEST** to evaluate the performance of a conventional HVAC system.

6.1 Building Zoning and Modeling Approach

The building is divided into seven distinct thermal zones:

1. Basement (conditioned)
2. Twelve stories of condominium units (conditioned)
3. Northwest greenspace (unconditioned)
4. Northeast greenspace (unconditioned)
5. Elevator and stairwell shaft (unconditioned)
6. Eleventh-floor greenspace (unconditioned)
7. Twelfth-floor mechanical/electrical room (unconditioned)

6.2 System Description

The conventional HVAC system consists of a single-zone constant-volume air handling unit (AHU) serving each condominium unit. Heating is provided via hot water from a natural gas boiler, and cooling is provided via chilled water from an electric chiller.

6.3 Simulation Results

From the eQUEST simulation:

- Peak building heating and cooling loads are identified along with the corresponding dates and times.
- Peak heating and cooling loads for the 12th-story unit are extracted.
- Annual electricity and natural gas consumption are determined.

- Total greenhouse gas emissions are calculated using prescribed carbon dioxide coefficients.

Detailed simulation outputs are included in Appendix A.

7. Ground Source Heat Pump (GSHP) System Design

A full GSHP and water-loop system is modeled using eQUEST.

7.1 System Configuration

Each unit is equipped with a water-to-air heat pump connected to a centralized ground heat exchanger via a circulating water loop.

7.2 Borehole Field Optimization

With borehole depth fixed at 500 ft, multiple borehole field configurations and spacings are evaluated to determine an optimal design that avoids under-sizing warnings while minimizing total borehole length.

7.3 Energy Performance

Annual electricity consumption and greenhouse gas emissions are determined and reported. Detailed GSHP simulation outputs are included in Appendix B.

8. Hybrid GSHP System Design

A hybrid GSHP system is designed using HGS online software.

Hourly heating and cooling load data exported from eQUEST are used as inputs to HGS. Multiple borehole configurations are evaluated to determine an optimized hybrid system that balances capital cost and performance.

The finalized HGS report and CSV files are included in Appendix C.

9. System Comparison and Recommendation

The three HVAC system options are compared based on:

- Borehole length requirements
- Annual energy consumption
- Operating costs
- Capital costs and payback period

- Greenhouse gas emissions

Based on these criteria, a recommended HVAC system is selected for the project.

10. Airflow, Equipment Selection, and Duct Design

10.1 Supply Air Flow Rate Determination

The required supply air flow rate for the 12th-floor unit is calculated based on the design cooling load and a supply air temperature of 55°F.

10.2 Heating Mode Verification

The calculated airflow rate is evaluated against heating load requirements using the specified heating supply air temperatures.

10.3 Equipment Selection

An appropriate AHU or water-to-air heat pump is selected using manufacturer data. External static pressure values are obtained.

10.4 Duct Design and Noise Evaluation

Supply and return duct systems are designed using the Duct software. Noise levels are evaluated and confirmed to be acceptable.