# Thesis Proposal

# Chicago Building Code Analysis

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NEIU El Centro
Chicago, IL

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# Table of Contents

# Executive Summary

The purpose of this report is to investigate alternative designs for the mechanical system for Northeastern Illinois University's new campus building El Centro. These alternatives were aimed to reduce annual cost of operation and energy consumption. The current design of the system far exceeds the requirements set forth by ASHRAE and the calculated loads. The system was designed using the Chicago Building Code of 2010 (CBC), which has stricter mechanical system requirements than other codes across the country.

The current mechanical design of El Centro does not utilize a centralized cooling plant because this is the first building on its new campus. There are two identical roof top air handling units (RTU) that utilize 1/3 outside air and 2/3 return air for supply air. These RTU's serve all of the ventilation and cooling requirements of the building. They operate year round and supply 55°F air all year. Two identical boilers on the first floor produce hot water to serve the hot water radiant finned tubes that serve the buildings heating loads. Further information about the current mechanical system is discussed later in this report.

Several alternative designs were investigated such as a dedicated outdoor air system (DOAS) with variable refrigerant volume (VRV) or a chilled beam system connected to a chiller plant. However, after finding that the current system seemed to be grossly oversized according to the loads and ASHRAE 62.1 in the technical reports, the engineer of record was contacted. It was learned that the Chicago Building Code (CBC) requires you supply a certain amount of airflow to a space regardless of the loads. This airflow must also be at least 1/3 outdoor air, regardless of what type of space the air is being supplied to. This led to larger equipment and ductwork.

In the past decade or so, with advancements in lighting efficiencies and thermal envelopes, the difference between the CBC required airflow and what is required for the load has increase significantly. For educational value and design experience, I would like to propose to resize some of the equipment for the currently designed system to conform to code as if the building was located outside of Chicago, keeping all other parameters constant. This should lead to smaller roof top air handling units and smaller ductwork. I will get good design experience resizing the RTUs and redesigning some of the main ductwork.

A study will also be done to calculate what the annual energy consumption reduction will be. Carbon emissions will be another factor that will decrease. This is a relatively small building, so I expect the results to be fairly accurate because there are fewer variables then in a larger building. A further analysis can also be conducted to see what the larger impact would be on the city of Chicago, which has thousands of buildings, if they did not conform to the stringent mechanical requirements of the CBC, but instead followed national standards.

# Building Overview

Northeastern Illinois University (NEIU) El Centro is a new educational facility that is being built in the northwest side of Chicago, Illinois. It is located along Kennedy Expressway and will be passed by an estimated 400,000 vehicles per day. The building was completed September 2014, in time for Fall Semester classes. It is a 55,000 square foot building with three stories; there is no basement in El Centro. The building will include classrooms, art studios, computer rooms, lecture halls, music studios, wet labs, damp labs, a library, student lounges, resource rooms, administrative space, and offices.

Nearly the entire building is enveloped in a curtain wall façade. The curtain wall features fins that are designed to limit solar gains on the building and to control the amount of natural daylight into the building. The fins will appear gold when driving into the city, and blue when leaving the city, reflecting the school colors as can be seen in the rendering below (courtesy of JGMA). Photovoltaic panels are mounted to the majority of the roof area. Other green initiatives include low flow plumbing fixtures, high-efficiency equipment, and creative lighting that have made this project eligible for a LEED gold rating.

The owner will be contacted to see if there is energy consumption data available from the first semester of classes.

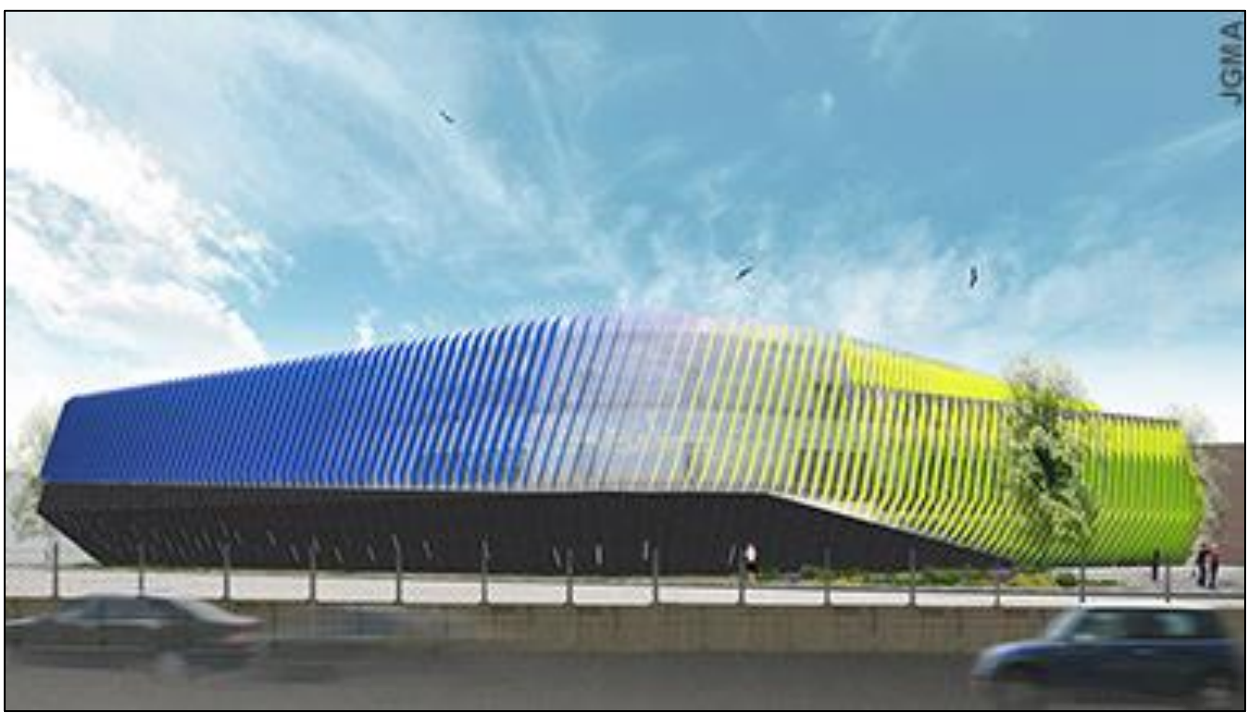



***Image 1 – Showing El Centro's curtain wall and unique dual coloring of the fins***

# Mechanical Systems Overview

## Equipment & Operation

### Roof Top Air Handling Units

There are two identical packaged air handling units located on the roof called RTU-1 and RTU-2 respectively. They will serve all of the ventilation and cooling requirements of the building year round. They each comprise of: (in order of airflow) return fan, economizer, filter, cooling coil, supply fan, indirect gas fired furnace, sound attenuator, and discharge plenum. RTU-1 and RTU-2 are both served by separate air cooled condensing units, also located on the roof. Architecturally and mechanically, the building is split up into two distinct zones: A and B. See the simplified floor plan in Figure 1 to the right. RTU-1 serves all of the first floor, and zone B on the second floor. RTU-2 serves zone B on the second floor and all of the third floor. Refer to Figure 2 below for a system operation and schematic of each RTU.

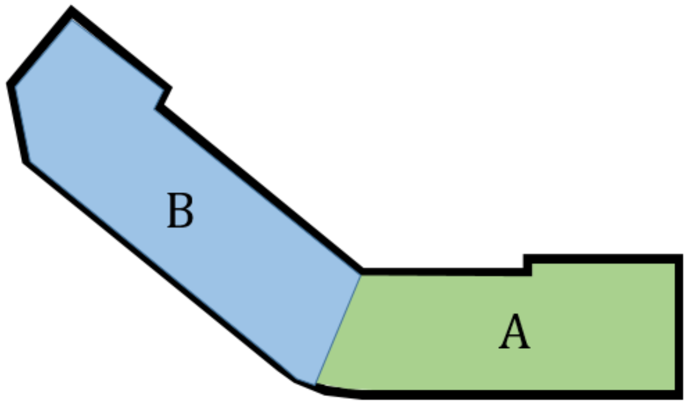



***Figure 1 - Simplified Typical Floor Plan Sketch***

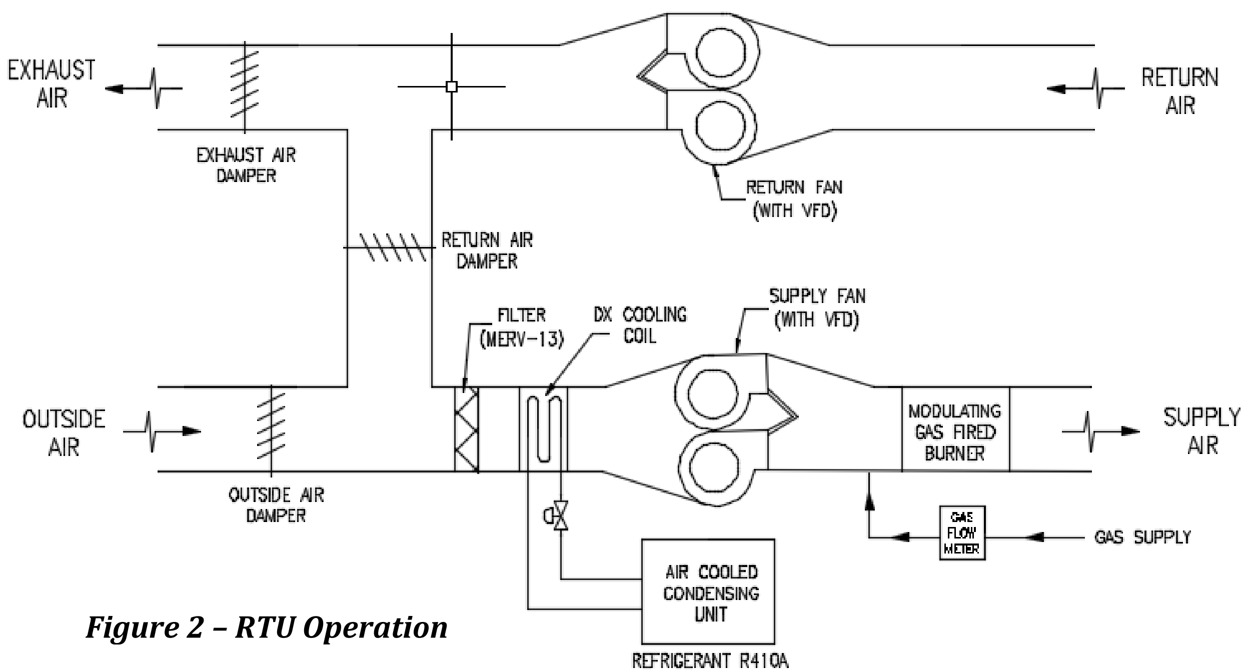



***Figure 2 – RTU Operation***

### VAV Boxes

El Centro is served by 71 variable air volume boxes, which in turn are all served by the rooftop air handling units. The VAV boxes have reheat coils that are served by two boilers located in the first floor mechanical room.

## Boilers

The mechanical heating hot-water system is comprised of two natural-gas fed boilers each capable of providing 750 MBH of sensible heat. The boilers are variable flow condensing type, and the hot water system is variable-primary.

The hot water pumps operate in a lead/standby mode. Only one pump will operate at any given time. Each pump will have VFD control. The VFD speed for the lead pump will modulate to maintain differential pressure in the hydronic loop as measured by the differential pressure transmitter (DPT).

All of this equipment is located in the mechanical room on the first floor. The hot water system will serve the radiant finned tubes that run along the corridors located along the perimeter of the building. It will also serve the 71 VAV reheat coils, and the ten cabinet unit heaters. Refer to Figure 3 below for a detailed flow diagram.

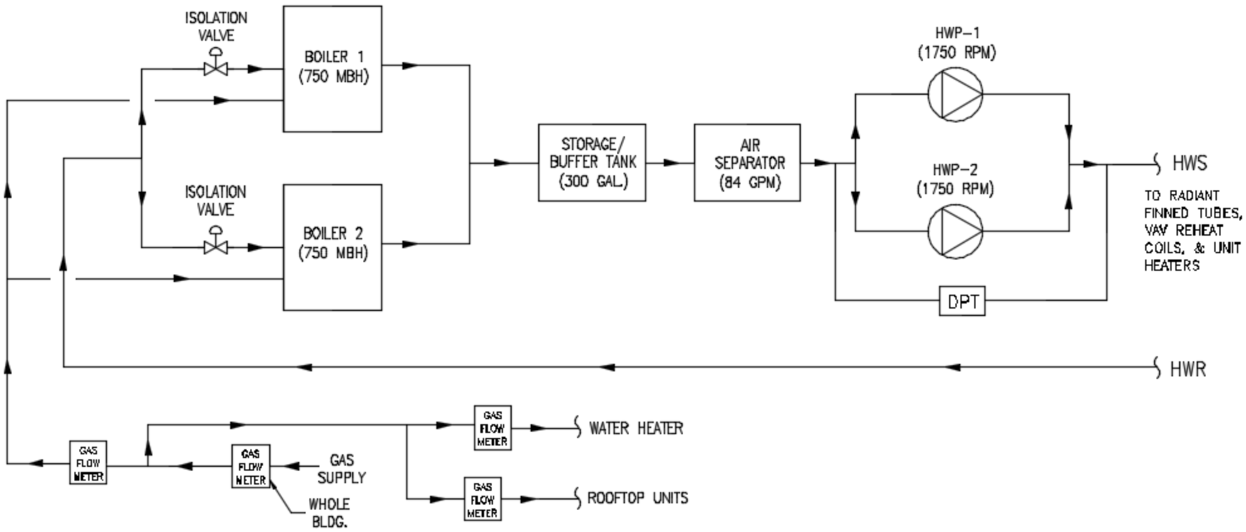



***Figure 3 – Hot Water Flow Diagram***

## Design Objectives

El Centro is the first building to be built on Northeastern Illinois's newest campus, so there is no centralized heating or cooling system. The mechanical HVAC system was designed to exhibit energy efficiency goals outlined in LEED and will aim to achieve a LEED Gold Certification. The design will provide fresh outside air in conformance with building code requirements and thermal comfort based on ASHRAE standards. Heating and cooling will be provided to all occupied spaces. Spaces that have high moisture and/or odor content, such as laboratories and bathrooms, are exhausted to the outside and supplemented with conditioned makeup air. The spaces with large exposure to glass is supplemented with radiant heat from perimeter tubes. Mechanical equipment such as boilers and pumps are located on the first floor in a designated mechanical room and ventilation equipment such as AHU's are located on the roof. All equipment, such as VAV boxes, are located appropriately to achieve LEED required sound levels.

# Mechanical System Evaluation & Proposal

## Current Design

The goal for the design of this new construction project is to establish a sustainable building that will be the forefront of Northeastern Illinois University's new campus. El Centro's mechanical system more than exceeded all of the requirements to adequately heat, cool, and ventilate the building. There is sufficient data to suggest that the project will achieve satisfactory indoor air quality and comfort to most of the occupants.

The overall project cost is $22 million dollars while the mechanical system first cost is expected to have been $2.4 million (38$/SF). Only 1.4% of the gross building area was dedicated to the mechanical system, yet it was 11% of the total project cost. The design utilizes minimal occupiable space for the mechanical system. The project team also expects for the building to receive $400,000 in rebates from the government for its impressive sustainable design.

The rooftop air handling units seem to be oversized and exceed the minimum requirements for heating, ventilation, and air conditioning. It seems that smaller air handling units could be appropriate that would consume less energy. Upon further investigation and after discussions with the design engineer, it was found that the rooftop air handling units are grossly oversized according to ASHRAE 62.1 because the Chicago Building Code is unique in that it requires a certain amount of air be supplied to a space, regardless of the loads required. It also requires that supply air contain at least 1/3 outdoor air fraction regardless of the occupancy type. The CBC does allow for demand ventilation control which would apply to some of the classrooms and lecture halls in the building.

## Alternatives Considered

Several alternatives were considered for the redesign of NEIU's El Centro mechanical system. Factors taken into account during the decision making process include cost, energy savings, system controllability, building codes, and climate. Options that were considered to redesign the system are listed below:

- Chilled Beam installation, including a chiller plant
- DOAS in accordance with a VRV system
- Building Envelope Investigation
    - Decrease the amount of glass because the curtain wall is so large
    - Use a glass with a lower u-value.
- Heat Recovery
- Ground coupled heat pump

Ultimately, it was decided that none of the above design alternatives will be implemented next semester. A detailed description of the depth and breadths that will be studied for this thesis project can be found below.

# Depth

## Chicago Building Code Analysis

This project was designed using the 2010 Chicago Building Code (CBC). The CBC is unique in that it requires a certain amount of supply air to the space, regardless of what the heating and cooling loads require. This forces equipment to be larger, and therefore more expensive. In the last few years with the improvement of thermal envelopes and lighting efficiencies, the difference between the load required supply air and the CBC required supply air has increased. For example, it was found that from the TRACE Model built in Technical Report 2, Art Classroom A304 required 0.56 cfm/sf to cool the space. However, according to the CBC, art classrooms must have a minimum supply air of 1.5 cfm/sf. This is a nearly 300% increase than what standard codes require across the country. The CBC table requiring these air flows can be found in the appendix at the end of this report.

Both RTU's were sized to supply 38,000 cfm of supply air each. I believe that these RTU's can be sized somewhere in the neighborhood of 20,000 - 25,000 cfm of supply air if the building was located outside of Chicago and did not conform to the dated CBC. Another unique requirement of the CBC is that it requires a minimum of 1/3 of all supply air be outside air. This requirement also often exceeds ASHRAE 62.1 requirements and is more stringent than other codes across the country. This leads to equipment being oversized and for buildings in Chicago to consume more energy than their counterparts in different cities.

## Resizing Equipment Savings

Next semester, I would like to resize the air handling units to not comply with the CBC, but instead comply with ASHRAE 62.1 and 90.1 requirements. Savings that are associated with smaller air handling units include, but are not limited to, equipment first cost, energy savings, less structural steel, and smaller ductwork. Resizing the RTU's and the main ductwork will be good design experience and will be an interesting analysis of the Chicago Building Code.

## Carbon Emission Reduction

Cost and energy savings associated with complying and not complying with the CBC will be compared and analyzed. Pollution emission reduction will also be analyzed. Chicago is a city with 2.7 million residents and is the third largest city in the United States. It is believed that buildings account for about 40% of all energy consumed in the United States. Although my analysis will focus on energy reduction for El Centro, a study can be conducted to look into the impacts on a grand scale if Chicago was to update their building code and change the mechanical HVAC system sections to be more in line with other codes across the country.

There will most likely not be any alternative design aspects for the mechanical system because than the values for cost and energy savings by not complying with the CBC will be altered. The purpose of this thesis will be to explore how wasteful the CBC can cause mechanical systems to be.

# Breadths

## Structural Breadth

Since there will most likely be a significant decrease in the size of the roof top air handling units, some of the steel on the roof will have to be reframed to appropriately support the load. There will be a material and cost analysis conducted to see how much less steel can used and how much money can be saved by using a smaller frame to support the RTU's. The AISC Steel Construction Manual will be utilized for the calculations and sizing.

## Electrical Breadth

The power to the new roof top air handling units is likely to be decreased, although the buildings electrical arrangement will remain the same. Electrical equipment for the RTUs such as conductors, circuit boards, and conduit may need to be resized according to the new horsepower and/or load amps associated with the RTUs. The main power delivery line into the building may be able to decrease in feeder size. The National Electric Code will be utilized for the calculations and sizing.

# Preliminary Research

## Chilled Beams

A chilled beam system was not in the original design for El Centro because the owner did not want to pay the first cost because chillers are expensive. Chilled beams use convection to heat or cool buildings. Pipes filled with hot or cold water are passed through "beams" and this causes air around the pipes to become denser and fall into the space around it. It is a very efficient way to cool and heat buildings because it does not require a fan power, which is a major consumer of power in the roof top air handling units. Although considered, a chilled beam redesign will not be implanted in this project. S

Tredinnick, Steve, PE. "Chilled Beams." *Inside Insights* (n.d.): n. pag. Syska Hennessy. <http://www.syska.com/cms/docs/articles/DistrictEnergy_strednnick_0809.pdf>

## Carbon Emissions in Chicago

In 2008, Mayor Richard Daley of Chicago implemented an ambitious plan to reduce Chicago's carbon emissions by 80% below 1990 levels by 2050. The buildings in Chicago account for over 70% of all energy consumption in the city, compared to a national average of 40% for buildings elsewhere in the country. The stringent mechanical section of the Chicago Building Code could have something to do with this.

Richard Daley, Mayor. *Chicago Climate Action Plan*. Chicago: Richard Daley, Mayor, 2005. Print.
<http://www.chicagoclimateaction.org/filebin/pdf/finalreport/CCAPREPORTFINALv2.pdf>

# Tools and Methods

## Load and Energy Simulation

The loads and energy usage of El Centro will be calculated using Trane TRACE 700. A model was developed for Technical Report 2 for this purpose as well, but shortcuts were taken because of time constraints (such as not angling the curtain wall even though it is not perpendicular to the ground). The model will be improved to more accurately represent the actual design of the building. This will lead to more accurate load and energy consumption results. Excel spreadsheets will be utilized further to calculate and compare supply air required by ASHRAE and supply air required by the Chicago Building Code.

# Masters Coursework

Several aspects of 500-level Architectural Engineering coursework will be incorporated into this thesis project. Centralized Heating Production and Distribution Systems (AE 558) will help aid in a life-cycle cost of the heating plant for the building. Content from Building Automation and Control Systems (AE 555) will help to appropriately re-size the rooftop air handling units to minimally optimize energy consumption.

# Work Plan

See the appendix for an annotated work schedule for next semester.

# References

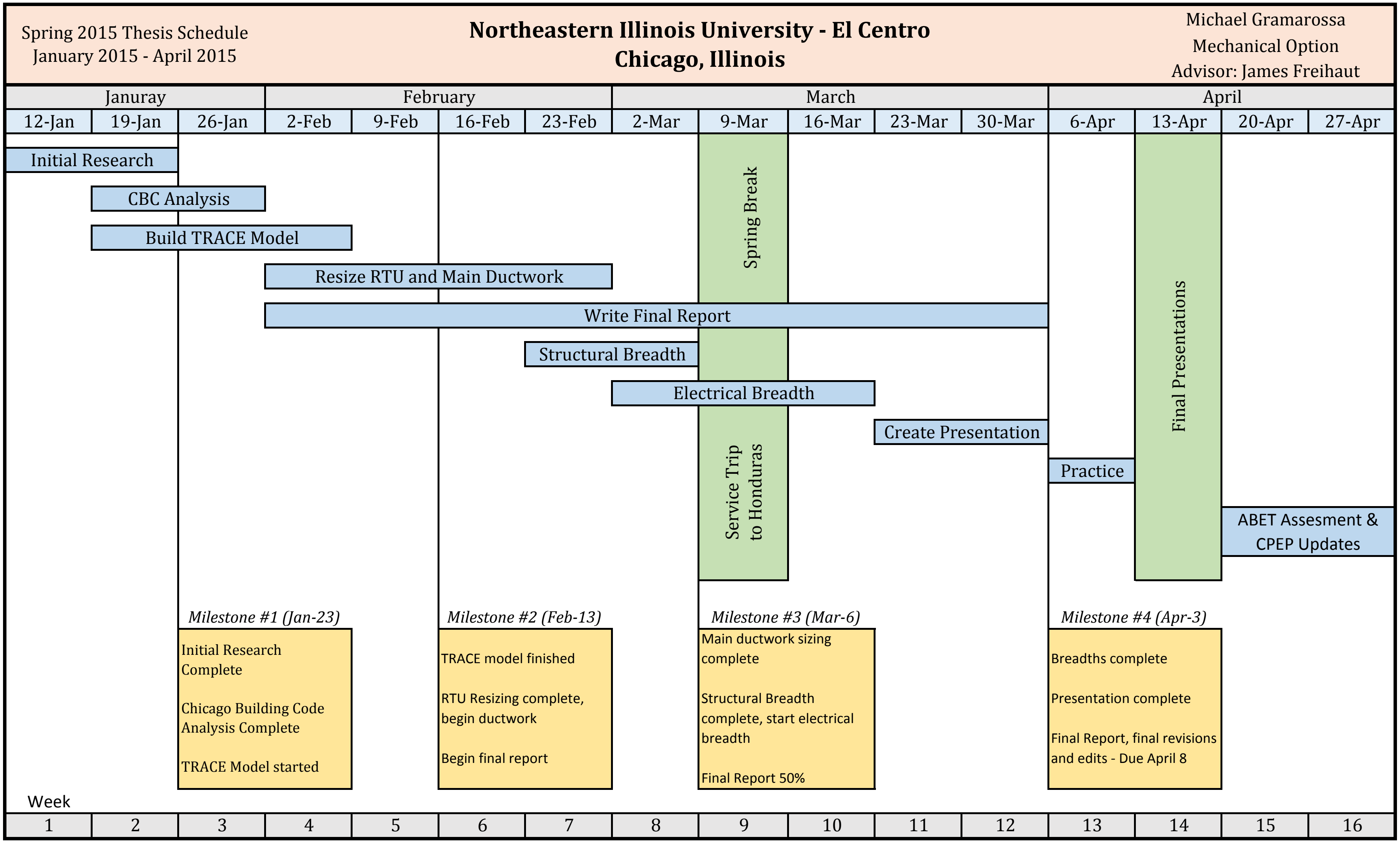
ANSI/ASHRAE. (2013). *Standard 62.1 – 2013*, Ventilation for Acceptable Indoor Air Quality. Atlanta, GA: American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc.

ANSI/ASHRAE. (2013). *Standard 90.1 – 2013*, Energy Standard for Buildings Except Low-Rise Residential Buildings. Atlanta, GA: American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc.

ASHRAE. (2009). *2009 ASHRAE Handbook – Fundamentals.* Atlanta, GA: American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc.

Primera Engineers Ltd., Construction Documents, John Palasz and Lindsay Bose, Primera Engineers, Chicago, Illinois.

Trane Trace® 700 Version 6.2.10.0.


Spring 2015 Thesis Schedule
January 2015 - April 2015
Northeastern Illinois University - El Centro
Chicago, Illinois
Michael Gramarossa
Mechanical Option
Advisor: James Freihaut
Januray
February
March
April
12-Jan
19-Jan
26-Jan
2-Feb
9-Feb
16-Feb
23-Feb
2-Mar
9-Mar
16-Mar
23-Mar
30-Mar
6-Apr
13-Apr
20-Apr
27-Apr
Initial Research
CBC Analysis
Build TRACE Model
Resize RTU and Main Ductwork
Write Final Report
Structural Breadth
Electrical Breadth
Create Presentation
Practice
ABET Assesment & CPEP Updates
Spring Break
Service Trip to Honduras
Final Presentations
Milestone #1 (Jan-23)
Initial Research Complete
Chicago Building Code Analysis Complete
TRACE Model started
Milestone #2 (Feb-13)
TRACE model finished
RTU Resizing complete, begin ductwork
Begin final report
Milestone #3 (Mar-6)
Main ductwork sizing complete
Structural Breadth complete, start electrical breadth
Final Report 50%
Milestone #4 (Apr-3)
Breadths complete
Presentation complete
Final Report, final revisions and edits - Due April 8
Week
1
2
3
4
5
6
7
8
9
10
11
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15
16

### 18-28-403 Mechanical Ventilation.

### 18-28-403.1 Source of air supply.

The air supply for every ventilation system, either natural or mechanical, shall be taken from out of doors, except in the following situations:

**Exceptions:**

1. Recirculation. When air is supplied by a mechanical ventilating supply system, a portion of the code required air supply may be recirculated, provided the system is equipped with such devices for control of temperature and dust content in the spaces to be ventilated and that the conditions of the air so supplied, (except as to temperature) are substantially the same as though all of the supply air were taken from out-of-doors. Under such conditions, not less than thirty-three and one-third percent of the Code requirements shall be taken from out-of-doors by the mechanical ventilating supply system; and sixty-six and two-thirds percent of the code requirements may be recirculated air, plus any additional air volume of system design capacity in excess of code requirements.

2. When air is supplied by a mechanical ventilating supply system which is not equipped with devices prescribed in paragraph 1, then only such portions of the air volumes of the system design capacity in cfm that exceed the total code requirements in cfm may be recirculated during the time of room occupancy. The air intake and all equipment and ducts shall be so arranged that all of the code required air supplied by the system can be taken from outside, with provisions made for release or exhaust of such air to the atmosphere.

3. Prohibited exhaust. No air exhausted from bath, toilet, urinal, or similar room, lavatory, locker, coat room, kitchen, boiler room, or rooms of similar use in which such air might be contaminated by smoke, gases, or dust which might be noxious, dangerous, or detrimental to health shall be recirculated at any time; except that air exhausted from locker and coat rooms or kitchens may be recirculated when unoccupied.

#### 18-28-403.1.1 Air reduction to actual load.

For Variable Air Volume (VAV) systems, the amount of air delivered to any given space shall be allowed to be reduced to track the load in the space provided that the minimum amount of air delivered to the space is not less than 1/3 of the code required air supply.

#### 18-28-403.1.2 Demand ventilation.

The amount of outside air delivered by a mechanical supply system may be reduced during operation below the quantities listed in Table 18-28-403.3 if the system is capable of measuring and maintaining $CO_2$ levels in occupied spaces no greater than 1000 ppm. The system capacity shall be greater than or equal to the ordinance requirements.

#### 18-28-403.1.3 Systems with water economizers.

If a system is equipped with a Water Economizer in accordance with the Chicago Energy Conversion Code, the amount of outside air delivered by the mechanical air handling system shall be no less than 1/3 of the code-required supply air. The area of the outside air intake shall be sized so that at least 1/3 of the code-required supply air can be taken from outdoors at velocities not in excess of 1,000 feet per minute (304.8 mpm) through the free area. The remaining air may be supplied by a recirculating air system if the system is equipped with devices to control temperature and dust content. The total quantity of air delivered to the space shall be 100 percent of the code-required air.

### 18-28-403.2 Structural requirements of a mechanical system.

Any system which conveys ventilation air shall be designed and installed in accordance with Article 6, Duct Systems.

### 18-28-403.3 Ventilation requirements.

See Table 18-28-403.3, Ventilating Requirements.

## Table 18-28-403.3
## Ventilating Requirements*

* S = Mechanical Supply; E = Mechanical Exhaust From Room; RO = Relief Opening; NR = No Requirement; NV = Natural Ventilation; Vent opening = percentage of floor area.

| | Vent Opening Percent of Floor Area | | Mechanical Ventil. CFM/SF | | |
|---|---|---|---|---|---|
| **Room Purpose** | **Less Than** | **Not Less Than** | **S, Supply** | **E, Room Exhaust** | **Remarks** |
| **Correctional** | | | | | |
| Cell rooms | | 4 | 0 | 0 | |
| | 4 | | 1.2 | 1.2 | |
| **Dry Cleaners/Laundries** | | | | | |
| Dry Cleaning | | 4 | 0 | 4 | See 18-28-403.3.3 |
| | 4 | | 1.5 | 4 | |
| Laundries (Residential for less than 30 units) | | 4 | 0 | 0 | |
| | 4 | | 0 | 1 | |
| Laundries serving general public | | | 1.5 | 1.5 | See 18-28-403.3.3 |
| Linen Rooms | | | 0.5 | 0.5 | |
| **Education** | | | | | |
| Music Rooms | | 4 | 0 | 0 | |
| | 4 | | 1.5 | 0.75 | |
| Class Rooms/Auditoriums | | 4 | 0 | 0 | |
| | 4 | | 1.5 | 0.75 | |
| Cooking Rooms for Instruction only | | 4 | 0 | 1.5 | |
| | 4 | | 1.0 | 1.5 | |
| Libraries/Reading Rooms | | 4 | 0 | 0 | |
| | 4 | | 1.2 | 0.6 | |
| **Food and Beverage Service** | | | | | |
| Cafeterias/Food Courts | | 4 | 0 | 0 | |
| | 4 | | 1.5 | 2.0 | |
| Public Dining Rooms - no cooking equipment | | 4 | 0 | 0 | |
| | 4 | | 1.5 | 1.5 | |
| Public Dining Rooms - with cooking equipment | | 4 | 0 | 2 | |
| | 4 | | 1.5 | 2 | |
| Grills | | 1 | 0 | 2 | |
| | 1 | | 1.5 | 2 | |
| Kitchen, public | | 3 | 0 | 4 | See Note 5. |
| | 3 | | 1.2 | 4 | |
| Lounges/Bars | | 4 | 0 | 0 | |
| | 4 | | 1.0 | 1.5 | |

| Room Purpose | Vent Opening Percent of Floor Area | | Mechanical Ventil. CFM/SF | | Remarks |
|---|---|---|---|---|---|
| | Less Than | Not Less Than | S, Supply | E, Room Exhaust | |
| **Health Care** | | | | | |
| Anesthesia Storage Rooms | | | 1.2 | 1.2 | See Note 5. |
| Autopsy Rooms | | | 1.5 | 3.0 | See Note 5. |
| Doctor's - Dentist exam rooms | | 4 | 0 | 0 | |
| | 4 | | 0.6 | 0.3 | |
| Delivery Rooms/Birthing Rooms | | | 2.0 | 1.0 | |
| Intensive Care | | | 2.0 | 1.0 | No recirculation within room. |
| Morgues | | | 1.5 | 3.0 | See Note 5. |
| Nurseries | | | 2.0 | 1.0 | |
| Operating Rooms | | | 2.0 | 1.0 | No recirculation within room. |
| Patient Rooms | | 4 | 0 | 0 | May exhaust through toilet room. |
| | 4 | | 0.3 | 0.3 | |
| Physiotherapy | | 4 | 0 | 0 | |
| | 4 | | 0.6 | 0.3 | |
| Recovery Rooms | | | 1.0 | 1.0 | No recirculation within room. |
| Sterilizing Equipment Rooms | | | 1.6 | 1.6 | No recirculation within room. See Note 5. |
| Treatment Rooms | | | 0.6 | 0.3 | |
| X-Ray operator's rooms | | | 0.6 | 0.3 | |
| **Hotels, Motels and Dormitories** | | | | | |
| Banquet Halls/Assembly Pre-function | | | 2.0 | 1.5 | |
| Hotels (Lobby) | | 4 | 0 | 0 | |
| | 4 | | 1.0 | NR | |
| Sleeping Rooms | | 4 | 0 | 0 | May exhaust through toilet room. |
| | 4 | | 0.3 | 0.3 | |
| Foyers except the above | | | 0 | 0 | |
| Sleeping Rooms (Dormitories) | | 4 | NV | NV | See Chapter 13-172 Light and Ventilation. |
| **Offices** | | | | | |
| Lunch Rooms - no cooking | | 4 | 0 | 0 | |
| | 4 | | 1.5 | 1.5 | |
| Offices and computer rooms | | 4 | 0 | 0 | |
| | 4 | | 0.6 | 0.3 | |
| Entrance lobby | | 4 | 0 | 0 | |
| | 4 | | 1.0 | NR | |

| Room Purpose | Vent Opening Percent of Floor Area | | Mechanical Ventil. CFM/SF | | Remarks |
|---|---|---|---|---|---|
| | Less Than | Not Less Than | S, Supply | E, Room Exhaust | |
| **Private Dwellings (Single and Multiple)** | | | | | |
| Living Quarters | | | NV | NV | See Chapter 13-172. |
| Living Quarters (Kitchen) | | 4 | 0 | 0 | See Notes 1 and 4. |
| | 4 | | 0 | 1.5 | |
| Toilet Rooms (residential) | | 4 | 0 | 0 | See Notes 2 and 4. |
| | 4 | | 0 | 1.5 | |
| Residential Dryers | NA | NA | 0 | | See Notes 3 and 4. |
| **Public Spaces** | | | | | |
| Corridors | | | NR | NR | |
| Dressing Rooms | | 4 | 0 | 0 | |
| | 4 | | 1.0 | 1.2 | |
| Janitor's Closet | | | 0 | 2.0 | See Note 5. |
| Locker Rooms | | 4 | 0 | 0 | See Note 5. |
| | 4 | | 0.3 | 1.2 | |
| Pedestrian Passageways (below grade) | | | 1.5 | 1.0 | |
| Pedestrian Passageways (above grade) | | 4 | 0 | 0 | |
| | 4 | | 1.5 | 1.0 | |
| Shower Rooms | | 4 | 0 | 0 | |
| Smoking Rooms | | 4 | 0 | 0 | See Note 5. |
| | 4 | | 1.0 | 1.5 | |
| Toilet Rooms | | 4 | 0 | 0 | See Note 5. |
| | 4 | | 0 | 2.0 | |
| Waiting Rooms | | 4 | 0 | 0 | |
| | 4 | | 1.0 | 1.0 | |
| **Retail Stores** | | | | | |
| Malls | | 4 | 0 | 0 | |
| | 4 | | 1.0 | 1.0 | |
| Retail Stores | | 4 | 0 | 0 | |
| | 4 | | 1.0 | 1.0 | |
| **Specialty Shops** | | | | | |
| Auto and vehicle washing (attended) | | | 1.0 | 1.0 | See Note 5. |
| Auto repair shops | | | 1.0 | 1.0 | See Note 5. |
| Photo materials and engraving | | 4 | 0 | 0 | See 18-28-403.3.3 |
| | 4 | | 1.0 | 1.0 | |
| Beauty Parlors/Barber Shops | | 4 | 0 | 0 | See Note 5. |
| | 4 | | 1.2 | 1.2 | |

| Room Purpose | Vent Opening Percent of Floor Area: Less Than | Vent Opening Percent of Floor Area: Not Less Than | Mechanical Ventil. CFM/SF: S, Supply | Mechanical Ventil. CFM/SF: E, Room Exhaust | Remarks |
|---|---|---|---|---|---|
| **Theaters** | | | | | |
| Auditoriums (including stage) | | 4 | 0 | 0 | |
| | 4 | | 2.0 | 1.5 | |
| Concert Halls | | 4 | 0 | 0 | |
| | 4 | | 2.0 | 1.5 | |
| Foyers in Theaters | | | 1.0 | 1.0 | |
| | 4 | | 2.0 | 1.0 | |
| Studios – motion picture, radio, TV | | | 1.5 | 0.75 | Or RO. |
| Theatrical Community Centers | | 4 | 0 | 0 | |
| | 4 | | 1.5 | 0.75 | |
| **Workrooms** | | | | | |
| Workshops not otherwise classified | | 4 | 0 | 0 | See 18-28-403.3.3. |
| | 4 | | 1.2 | 1.2 | |
| Wood working shop | 0 | 4 | 0 | 0 | See Article 5 - Makeup air is required when direct exhaust > 5, 000 CFM. |
| | 4 | | 1.2 | 1.2 | |
| Spray Finishing | | 4 | | | See Article 5 - Makeup air is required when direct exhaust > 5, 000 CFM. |
| | 4 | | 1.5 | 1.2 | |
| Spray Booths | | 4 | | | See Article 5 - Makeup air is required when direct exhaust > 5, 000 CFM. |
| | 4 | | 1.5 | 1.5 | |
| Bank Vaults Attended | | | 0.6 | 0.3 | |
| Battery Charging - Dry Cell Batteries | | | NR | 0.5 | 3 or more batteries. |
| - Other Batteries | | | NR | 1.0 | |
| **Sports and Amusement** | | | | | |
| Bowling Alleys (seating areas) | | 4 | 0 | 0 | |
| | 4 | | 1.7 | 0.85 | |
| Ball Rooms | | 4 | 0 | 0 | |
| | 4 | | 2.0 | 1.5 | |
| Cabarets | | 4 | 0 | 0 | |
| | 4 | | 2.0 | 1.5 | |
| Dance Halls/Discos | | 4 | 0 | 0 | |
| | 4 | | 2.0 | 1.5 | |
| Game Rooms/Arcades | | 4 | 0 | 0 | |
| | 4 | | 1.6 | 1.6 | |
| Gymnasiums | | 4 | 0 | 0 | Or RO. |
| | 4 | | 2.0 | 1.5 | |
| Natatoriums (deck and seating) | | 4 | 0 | 0 | |
| | 4 | | 2.0 | 1.5 | |

| Room Purpose | Vent Opening Percent of Floor Area | | Mechanical Ventil. CFM/SF | | Remarks |
|---|---|---|---|---|---|
| | Less Than | Not Less Than | S, Supply | E, Room Exhaust | |
| **Sports and Amusement** (Cont.) | | | | | |
| Recreation Rooms | | 4 | 0 | 0 | |
| | 4 | | 2.0 | 1.5 | |
| Skating Rinks, Ice Arenas | | 4 | 0 | 0 | |
| | 4 | | 1.5 | 1.5 | |
| Skating Rinks, Roller | | 4 | 0 | 0 | |
| | 4 | | 2.0 | 1.5 | |
| **Storage** | | | | | |
| Storage inactive | | | 0 | 0 | |
| Storage active | | | 0.5 | 0.5 | |
| Storage cold (no permanent occupancy) | | | 0 | 0 | |
| Vault, Storage | | | NR | NR | |
| **Laboratories** | | | | | |
| Laboratories | | 5 | 0 | 0 | See 18-28-403.3.3. |
| | 5 | | 1.2 | 1.2 | |
| Animal Rooms | | | 0 | 1.5 | |
| **Religious** | | | | | |
| Auditoriums for worship/Chapels | | 4 | 0 | 0 | |
| | 4 | | 1.5 | 0.75 | Or RO. |
| **Special Use** | | | | | |
| Convention Halls | | 4 | 0 | 0 | |
| | 4 | | 2.0 | 1.5 | |
| Council Chambers | | 4 | 0 | 0 | |
| | 4 | | 2.0 | 1.5 | |
| Court Rooms | | 4 | 0 | 0 | |
| | 4 | | 2.0 | 1.5 | |
| Exhibition Rooms | | | 1.5 | 0.75 | Or RO. |
| Fraternal Rooms | | | 1.5 | 0.75 | Or RO. |
| Lodge Halls | | | 1.5 | 0.75 | Or RO. |
| Museums | | | 0.6 | NR | Or RO. |
| **Garages/Parking Structures** | | | | | See Miscellaneous |
| Garages, 5 or more cars | | | RO | 1.0 | |
| Garages, 5 or more cars | | | 0.75 | 1.0 | |
| Garages, less than 5 cars | | | RO | RO | 1.0 sf of opening per car. |
| Garages in or attached to Hospitals | | | 0.75 | 1.0 | Exhaust duct, 14 gauge. |
| | | | RO | 1.0 | |