Building Operator Certification – Level I

*A Partnership of the
NYC Department of Education
Division of School Facilities,
International Union of Operating Engineers, and the
City University of New York*

Department of Education
Dennis M. Walcott, Chancellor

The City University of New York

planYC

Class 11

Module 3 : Heating & Ventilation

Objectives

To think systematically and critically about your heating system operations, possible sources of inefficiency, and how they might be addressed.

Consider questions such as:

1. Is your boiler plant over-sized and if so, so what?
2. Is your building subject to dynamic load conditions?
3. Is your distribution system balanced?
4. Are you able to control your system to match the facility’s schedule?
5. Do you start-up and shut-down the system at optimal times?

Module 3 Outline

- Building Loads & Dynamics
- Boilers and Efficiency
- Heating Distribution
- Controls
- Ventilation and Air Distribution Systems

Building Loads and Dynamics – Class 11

Objectives

- Understand building thermal loads, how they are calculated, and what it means for your boiler plant operations.

- Understand part-load operation and why it matters to your energy efficiency.

- Understand how your building behaves thermally, what variables matter to thermal comfort, and how this can affect your control strategies and response to complaints

BUILDING OPERATOR CERTIFICATION

Agenda

- Heat Transfer, Heat Load Calculation and Part-load Operations
- Dynamic Building Conditions and Thermal Comfort
- Assign Practical Project 1C
- Reading Assignment
- Exam Review

Building loads - Definitions

Heating Loads and Cooling Loads:

- Heating Load - the heat lost from a building
  - the heat replaced by the heating system
- Cooling Load - the heat gained into a building
  - the heat removed by the cooling system

- Heating or cooling must be supplied to match the losses or gains in order to maintain steady temperature within the building

Heat normally flows, “downhill”, from higher temperature to lower

BUILDING OPERATOR CERTIFICATION

Fundamental Energy Unit

BTU = British Thermal Unit

The amount of heat required to raise one pound of water by one degree Fahrenheit.

Raised 1 degree Fahrenheit

or

1 match

BUILDING OPERATOR CERTIFICATION

How buildings lose heat or gain heat

3 Forms of Heat Transfer

- Conduction
  - Movement of heat through materials
  - Trapped air has low heat conductivity
- Convection
  - Movement of air carries heat
  - **Infiltration and Ventilation**
- Radiation
  - Transfer of heat from body to body
  - Through space – no medium
  - Direct line of sight

How Loads are Calculated

Heating Load = **Conduction** + Convection = Btu/Hour

Heating Load, Q = **Conduction** + Infiltration / Ventilation

Conduction = U x A x dT

A = building surface areas

U = insulation value of the surfaces

dT = "delta" Temperature = the difference between the Indoor Temperature and the Outdoor temperature

BUILDING OPERATOR CERTIFICATION

How Loads are Calculated

Heating Load = Conduction + **Convection** = Btu/Hour

Heating Load, Q = Conduction + **Infiltration / Ventilation**

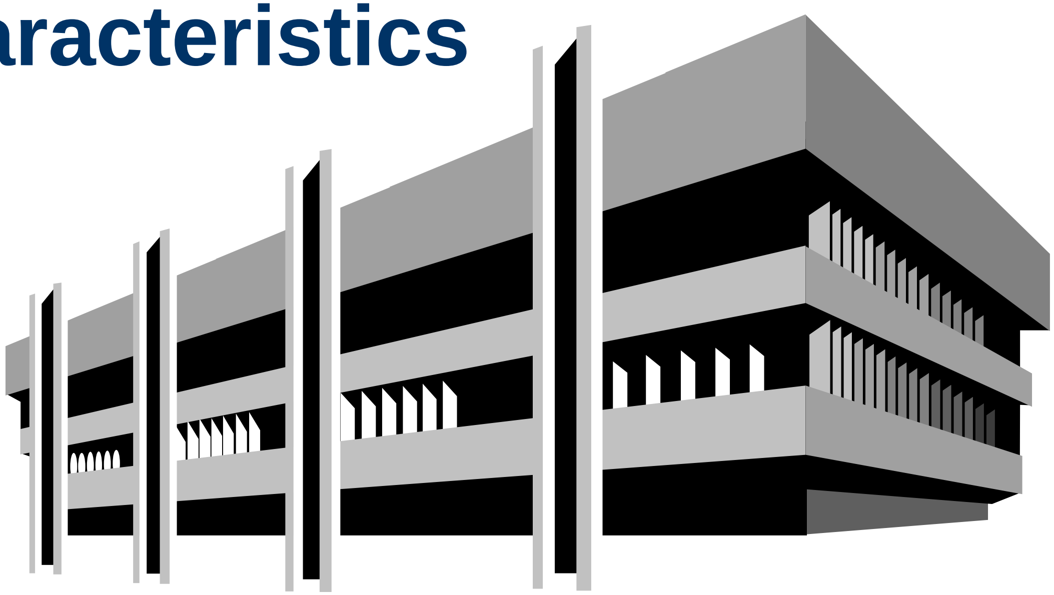
Infiltration/Ventilation = CFM x 60 min/hr x .018 x **dT**

CFM = volume of air moving through the building

.018 = a constant for the heat capacity of air (per cubic foot per dF)

dT = "delta" Temperature = the difference between the Indoor Temperature and the Outdoor temperature

Building Envelope
Components & Characteristics



- Roofs
- Walls
- Insulation
- Doors
- Windows
- Tightness of Building
- Shading devices

Insulation values

R-Value **is the** **<u>Resistance</u>** **of** ***heat flow through a material***

U-Value **is the** **<u>Conductance</u>** **of heat through a material**

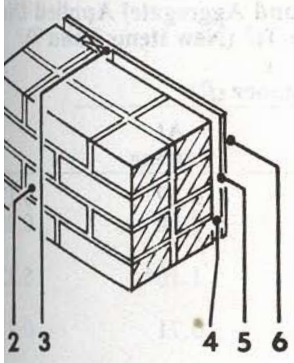
R = 1/ U U = 1/ R

Values for many materials and constructions via standardized lab tests and found in handbooks such as ASHRAE Fundamentals

Table 4B Coefficients of Transmission *(U)* of Solid Masonry Walls[a]

…efficients are expressed in Btu per (hour) (square foot) (degree Fahrenheit difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph

Replace Furring Strips and Air Space with 1-in. Expanded Polystyrene Extruded, Smooth Skin Surface, 2.2 lb/ft³ (New Item 4)



Construction	1 Resistance *(R)* Between Furring	At Furring	2
1. Outside surface (15 mph wind)	0.17	0.17	0.17
2. Common brick, 8 in.	1.60	1.60	1.60
3. Nominal 1-in. ×3-in. vertical furring	—	0.94	—
4. Nonreflective air space, 0.75 in. (50 F mean; 10 deg F temperature difference)	1.01	—	5.00
5. Gypsum wallboard, 0.5 in.	0.45	0.45	0.45
6. Inside surface (still air)	0.68	0.68	0.68
Total Thermal Resistance (R)	$R_i = 3.91$	$R_s = 3.84$	$R_i = 7.90 = R_s$

…vertical furring on masonry @ 16-in. o.c.)

Envelope Performance is Reduced by:

Insulation may not perform as expected

- "Effective" R-Value – less than rated R-Value
- Thermal "Bridges" – studs and columns in walls
- Air by-passes - allow heat to be carried around insulation
- Moisture in Walls - condensation and migration

Construction may not provide a Tight Building

- Air infiltration at joints between different materials
- Seals deteriorate, caulks dry out, weather-stripping fails
- No good testing procedure for larger buildings
  ("Blower Door" used for testing homes)

How is Equipment Sized?

Design Load Calculation:

Determine the maximum heating load on coldest day in winter.
The “Design Day” in New York City is 10 degrees outdoor temp.

What is **dT** for the heating design condition?

dT = *70 degrees indoor - 10 degree outdoor for NYC =* ***60 dT***

Q = Conduction + Infiltration / Ventilation = Heating Load

= [(U x A) + (CFM x 60 x .918)] x **dT**

What is the common **dT** for heating your building?

A common outdoor temperature is ***40*** *degrees.*

Why is this significant?

How is Equipment Sized?

Further Boiler Plant sizing rules

- Sizing of Boilers
  - Most schools have 100% redundancy
    Older practice, say before 1975
  - Current SCA rules:
    - If 2 boilers, each 75% of design load = 150%
    - If 3 boilers, each 50% of design load = 150%
    - If 4 boilers, each 30% of design load = 120%
    - Safety margins - addition of 10 - 20% capacity

How much is equipment over-sized?

- Depends on the outdoor temperature
- If plant was designed to a 10 degree out door temp day, then the design dT = 70 - 10 = **60 degrees**
- If the outdoor temperature is 40 degrees, then the heating load dT at that time = 70 - 40 = **30 degrees**
- 60 / 30 = 2, so the boiler plant is oversized by a factor of 2 (100% extra capacity) for that heating condition
- But wait, if 2 Boilers are designed for **150%** of design load, it's even worse. Two Boilers are **300%** of design load when **dT is 30 degrees** on a 40 degree day.

BUILDING OPERATOR CERTIFICATION

Practice the Calculation

Fraction of Design Load

$$= \frac{\text{Actual Load}}{\text{Design Load}}$$

$$= \frac{\text{Actual dT}}{\text{Design dT}}$$

$$= \frac{70F - 40F}{70F - 10F}$$

$$= \frac{30F}{60F} = \frac{1}{2}$$

If one boiler is sized at 100% of Design Load, it is 200% of Actual Load

Section 2

- Equipment Sizing and Part-load Operations, continued
- Dynamic building conditions and thermal comfort

What is the effect of boiler plant over-sizing?

Boiler Part-Load Curves

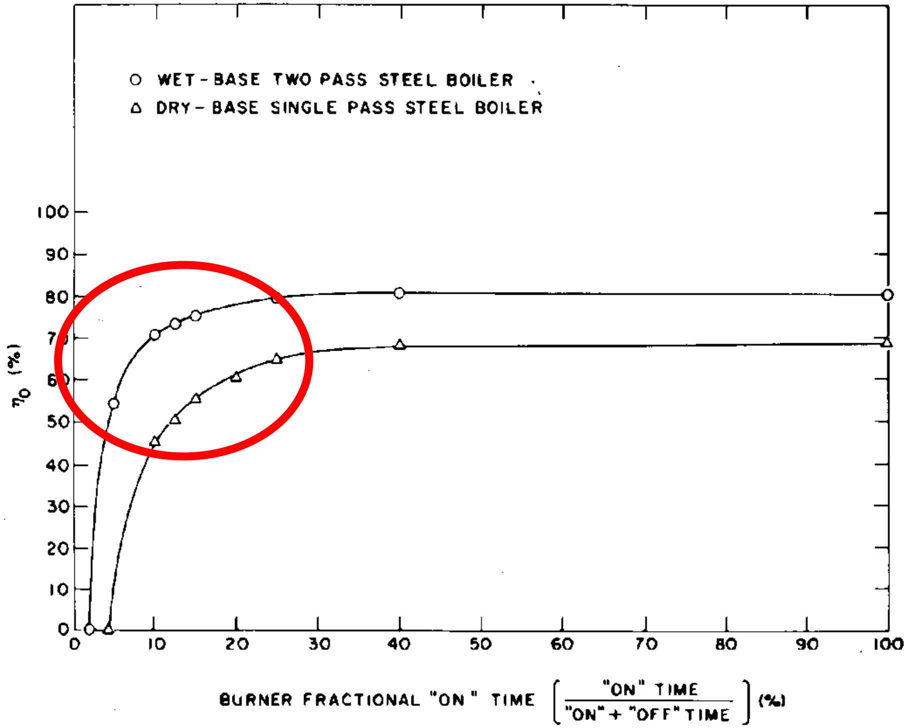


Figure 3b. Overall efficiency (η_o) vs. burner fractional "on" time (%)

Source: Brookhaven Nat'l Lab 1978

- Burner Fractional "On Time" plotted against boiler efficiency
- Steep fall-off at 30% of "Burner On Time"
- IMPLICATION: BOILER CAPACITY CONTROL IS VERY IMPORTANT.
- AVOID SHORT-CYCLING. HOW?

BUILDING OPERATOR CERTIFICATION

Part-Load Control Strategies

Load Matching

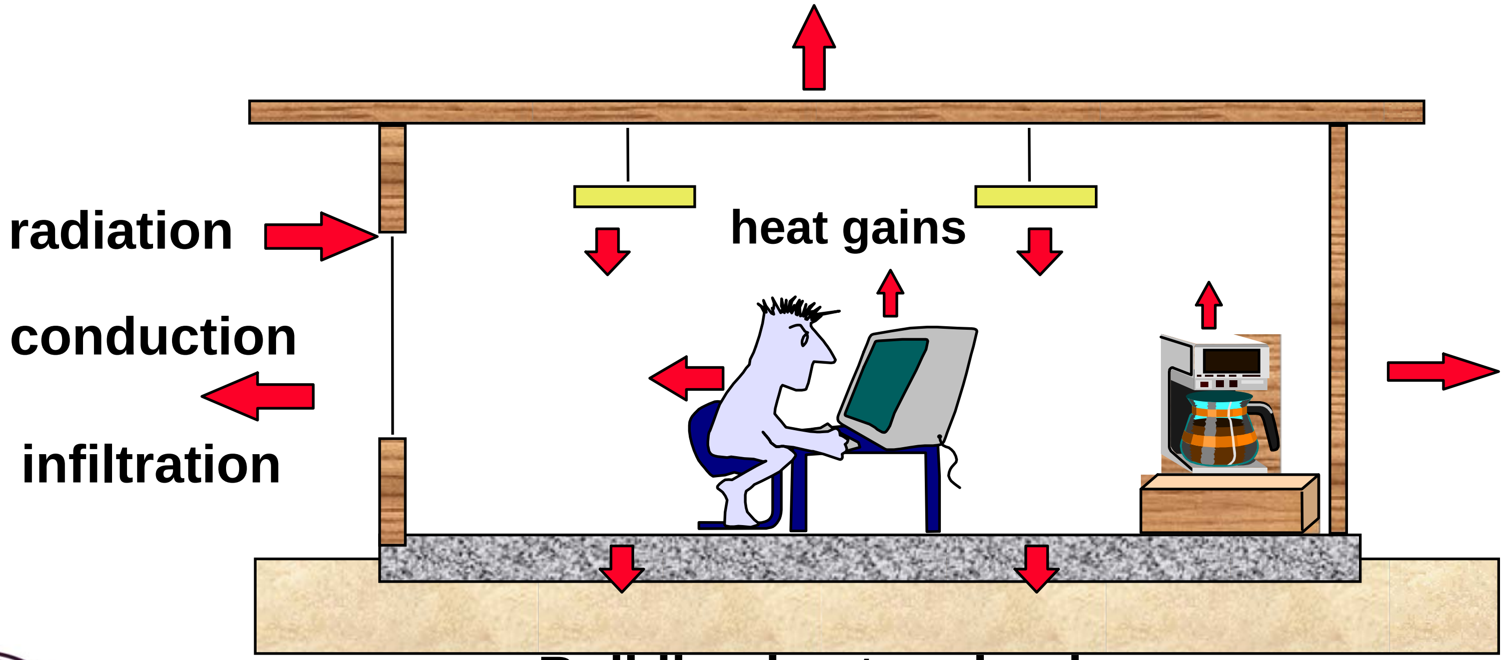
- Modulation - Control of the capacity of the equipment over a range. Example 25% to 100%
- Lead-lag – Control of the capacity on-line by controlling the number of boilers on-line
- Temperature Reset – To change the set point of the working fluid of a system based on outdoor temperature. Applies well to hot water but not to steam
- Variable speed/frequency drives for pumps and fans

BUILDING OPERATOR CERTIFICATION

Building Dynamics

Loads are not steady over the course of a day or in all areas of a building

- Morning start-up issues
- Thermal momentum
- Varying solar gains and activities



Building heat-up loads

Boiler Plant Dynamics -
Loads vary even within the course of a day

- Outside temperatures
- Morning start-up issues
- Varying solar gains and activities affect loads
- Times when only part of a building is in use
  Example: After-school programs

Do you control your boiler plant to match these varying loads?

BUILDING OPERATOR CERTIFICATION

Boiler Plant Dynamics -

Loads vary even within the course of a day

Outdoor Temp	% Heating Load	dT
10F	100%	60
20F	83%	50
30F	66%	40
40F	50%	30
50F	33%	20
60F	17%	10

Building Dynamics
Loads are not steady over the course of a day or in all areas of a building

- Morning start-up issues
  - How long does it take your building to come up to temperature?
- Thermal momentum
  - “heavy” vs “light” construction makes a difference
  - How do you deal with “control overshoot”
  - How early could you shut-down?
- Varying solar gains and activities
- How do you experience these kinds of variations in your facilities?
- *Some good datalogger projects here!*

Building Dynamics & Comfort

- **COMFORT FACTORS**
  - Air temperature and air mixing (steady temp)
  - Air movement
  - Relative Humidity
  - Thermal Radiation
  - Activity Levels and Clothing

  - These all contribute to the sensation and perception of the temperature

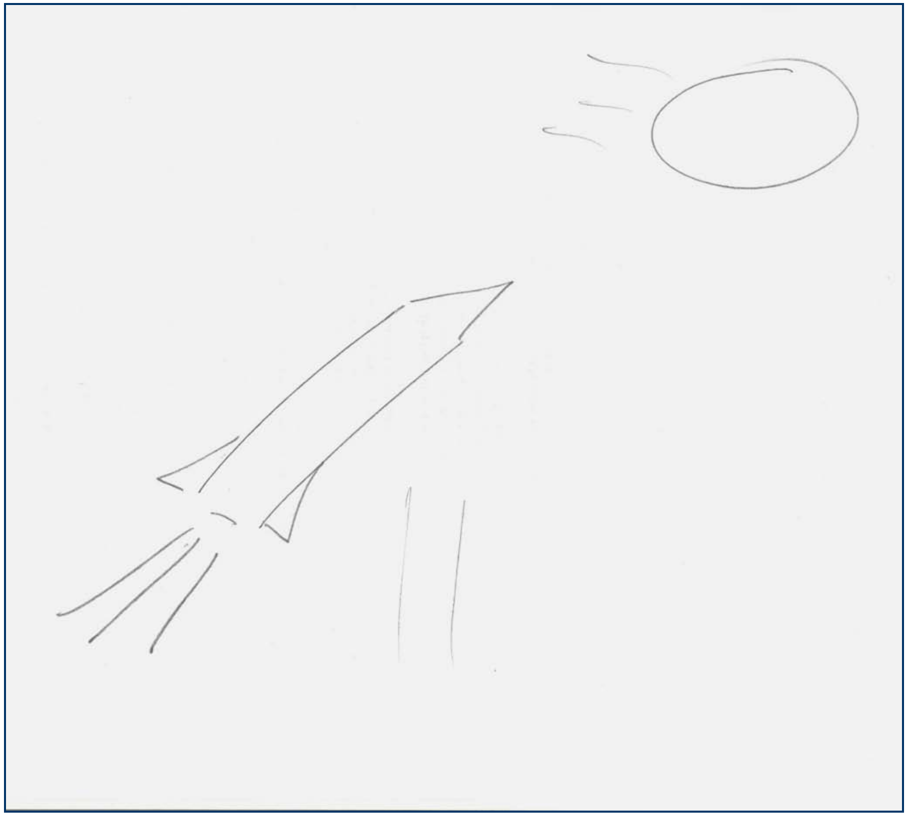
  - And people are acutely sensitive to ***change*** in conditions

Building Dynamics & Comfort

ASHRAE Standard 55 - Thermal Environmental Conditions for Human Occupancy

- This standard specifies the combinations of indoor space environment and personal factors that will produce thermal environmental conditions **acceptable to 80% or more of the occupants** within a space.
- The environmental factors addressed are temperature, thermal radiation, humidity, and air speed
- The personal factors are activity and clothing.

Is it Rocket Science?



- Moving target
- Energy inputs
- Constraining forces
- Figuring trajectories
- Hit or miss?

A number of factors at play – heat loss and gain sources

Review for Energy and Comfort Optimization

- Most of your plant operation is at Part Load.
  What happens to equipment efficiency at part-loads?

- Thermal conditions are changing throughout the building.
  What can you anticipate about how the building or specific areas will behave thermally?

Are you utilizing strategies that

- Reduce overheating and heat imbalances to get the best thermal comfort possible?

- Are better for operating a heating system at part-load?

Section 3

- Assign Project 1C - Discussion of requirements
- Review Self-Evaluation Form
- Exam Review

Practical Project – Part 1C
HVAC System Schematic

- Sketch of your HVAC System (Boiler Plant)
- Review of Project Instructions – Yellow Sheets
- Review of Example Sketch – Course Book
- HVAC Survey Form
- Start to make a rough sketch of boiler room

Note: The completed Project 1A is being removed from the Project Folders.

Make a copy before you submit projects.

BUILDING OPERATOR CERTIFICATION

Review of Class and Self-Evaluation Forms

1. Is your boiler plant over-sized and if so, so what?
2. Is your building subject to dynamic load conditions?
3. Are you able to control your boilers to match the facility's schedule?
4. Do you start-up and shut-down the system at optimal times?

Self-Evaluation Forms - Review

Class Reading Assignments

- FEMP 9.2, pages 9.3 to 9.30

Announcements

The Instructors will rotate their classroom teaching assignments at mid-point in the course.

We can expect the change of Instructors to take place in Week 12 – after the break.

The reason is to provide you with more exposure to Instructors to give you a bigger perspective on the course content and the operations and maintenance of buildings.

Announcements

Break – 2 Weeks

Week of August 29th - No Class

Week of September 5th – No Class

Week of September 12th – Class 12

Module 2 Exam Review

- 15 minute review of the exam last week