Commissioning Heat Pump Systems: Fundamentals and System Types

Please Visit This Link While We Are Waiting to Begin

https://tinyurl.com/HeatPumpD1Intro

Presented By:
David Sellers
Senior Engineer, Facility Dynamics Engineering

Disclaimer

The information in this document is believed to accurately describe the technologies described herein and are meant to clarify and illustrate typical situations, which must be appropriately adapted to individual circumstances. These materials were prepared to be used in conjunction with a free, educational program and are not intended to provide legal advice or establish legal standards of reasonable behavior. Neither Pacific Gas and Electric Company (PG&E) nor any of its employees and agents:

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Learning Objectives – Class Series

1. Attendees will be able to discuss some of the issues and opportunities associated with applying heat pumps as a source of heat for buildings as we move towards electrification

Learning Objectives – Class Series

2. Attendees will be able to name the common heat pump types and describe their general characteristics (ground source, air source, water source, variable flow refrigeration, etc.)

Learning Objectives – Class Series

3. Attendees will be able to discuss ventilation strategies that can be applied in conjunction with heat pump systems and how they can be integrated with the heat pumps and the zones they serve

Learning Objectives – Class Series

4. Attendees will be able to discuss the design and commissioning issues associated with applying heat pumps to new construction and retrofit projects

Learning Objectives – Class Series

5. Attendees will be able to identify existing building commissioning issues and opportunities associated with heat pumps and heat pump systems

Learning Objectives – Today's Session

Attendees will be able to:

1. Discuss some of opportunities associated with applying heat pumps as a source of heating and cooling for buildings as we move towards electrification

Learning Objectives – Today's Session

Attendees will be able to:

2. Describe how buildings use heat and how heat pumps can be used to meet this need along with the fundamental goals associated with building HVAC systems

Learning Objectives – Today's Session

Attendees will be able to:

3. Recognize the typical components of the vapor-compression (refrigeration) cycle

Learning Objectives – Today's Session

Attendees will be able to:

4. Identify the common heat pump system types and describe their general characteristics (ground source, air source, water source, variable flow refrigeration, etc.)

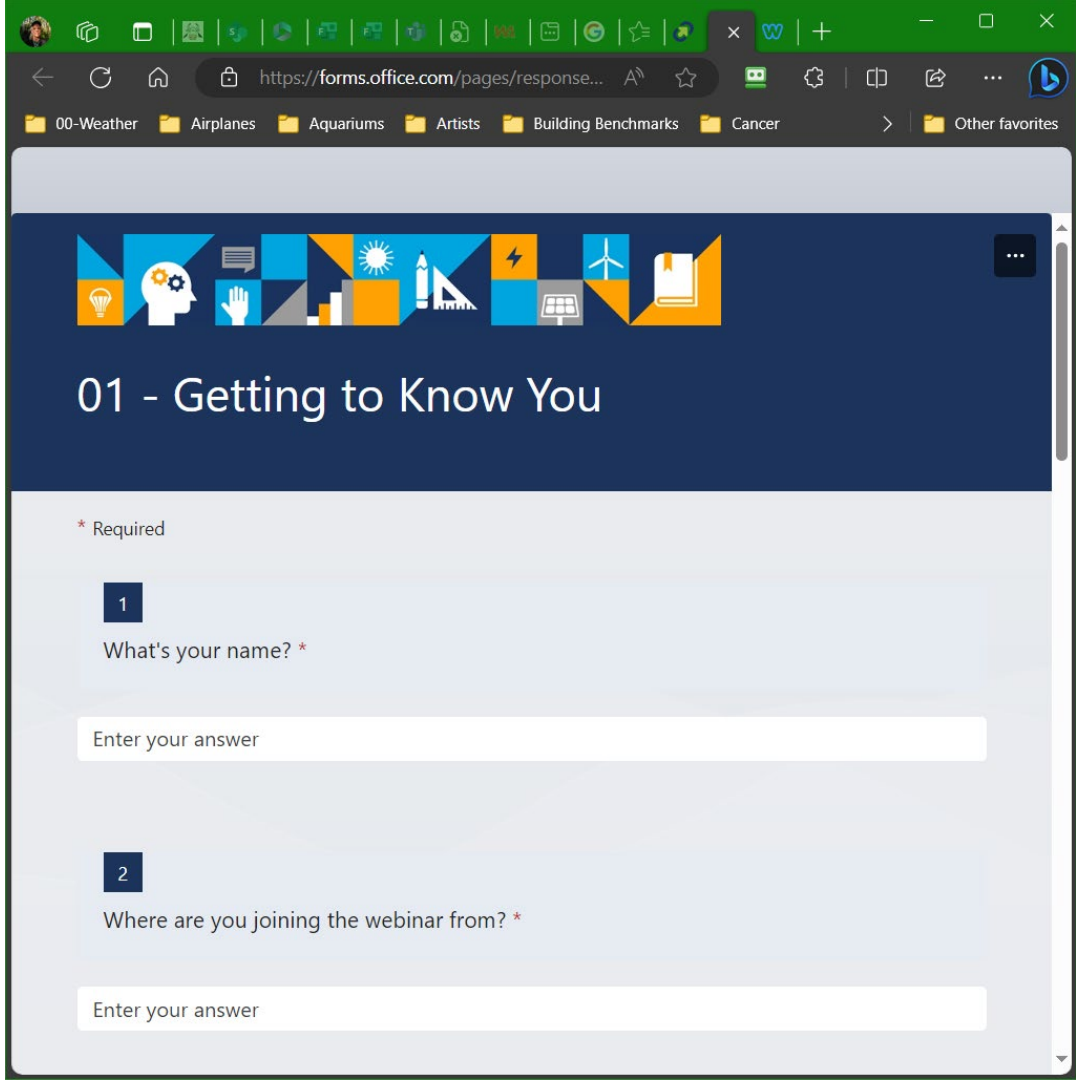
Today's Agenda

1. Introduction
2. How Buildings Use Heat
3. Heat Pumps, Electrification, and the Fundamental Goals of HVAC
4. Fundamental Heat Pump Concepts
5. Heat Pump System Types

Introduction

Introductions

https://tinyurl.com/HeatPumpD1Intro



A Bit About Me

I intended to be an aircraft maintenance engineer

A Bit About Me

I intended to be an aircraft maintenance engineer

- I’m doing something *totally* different

A Bit About Me

I’m doing something *totally* different

- HVAC field technician

A Bit About Me

- HVAC field technician
- Control system designer

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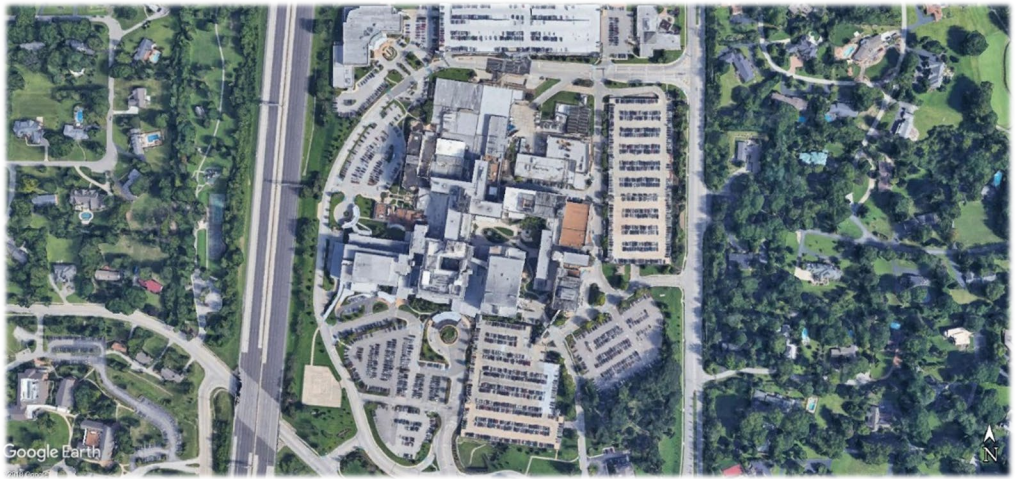

A Bit About Me

- HVAC field technician
- Control system designer
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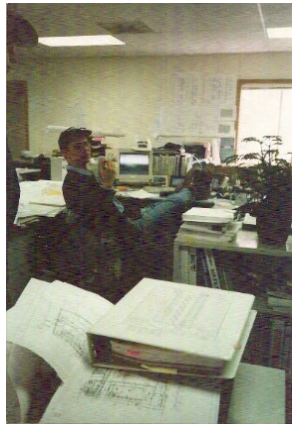
- MCC Powers system engineer
- Murphy Company controls and start-up engineer
- Project engineer
- Wafer fab facilities engineer and system owner



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- Project engineer
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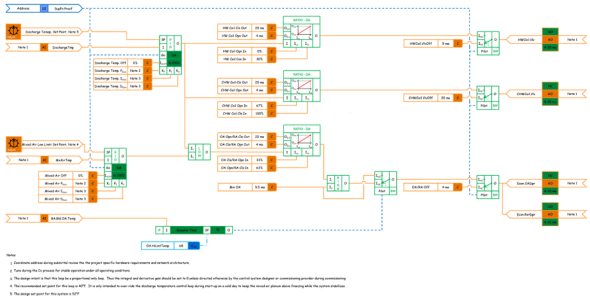
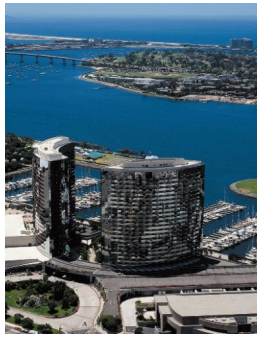
- A happily married PECI technical support engineer and trainer
- FDE Senior Engineer





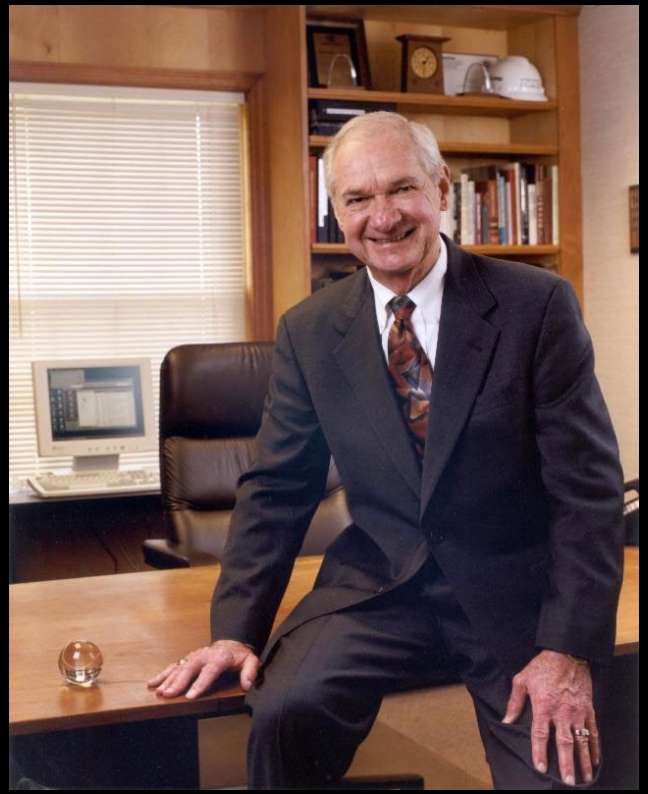
I’ve Had Great Mentors Along the Way

Bill Coad's Thoughts on Energy Conservation

"… that is to practice our profession with an emphasis upon our responsibility to protect the long-range interests of the society we serve and, specifically, to incorporate the ethics of energy conservation and environmental preservation in everything we do."

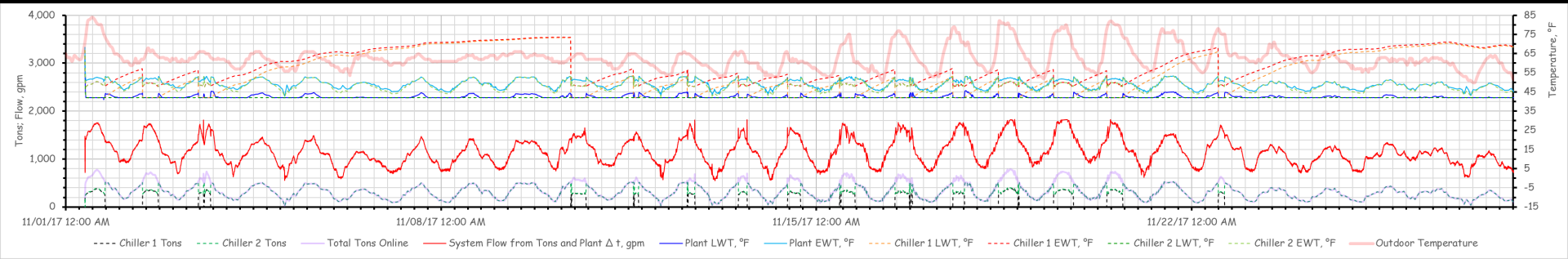
Energy Conservation is an Ethic
ASHRAE Journal, vol. 42, no. 7, p. 16-21

PDF available at
https://tinyurl.com/EnergyConservationEthic



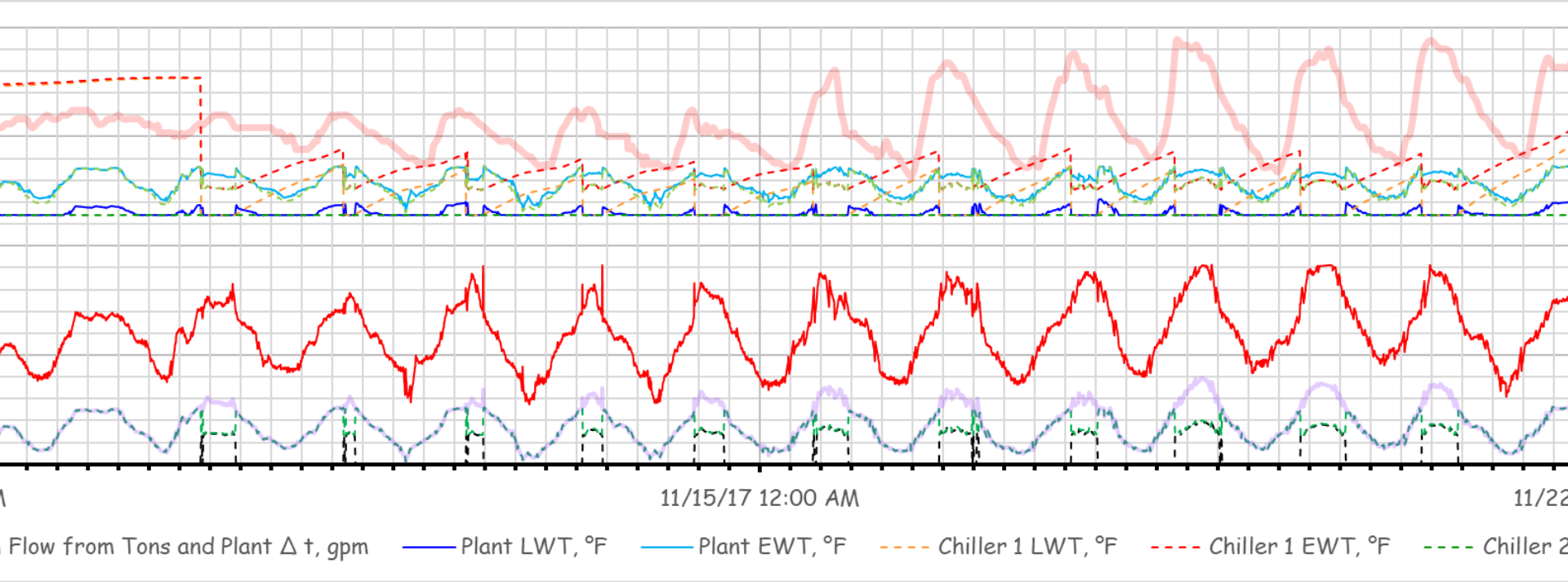
My Most Important Lesson

It’s all about the load profile



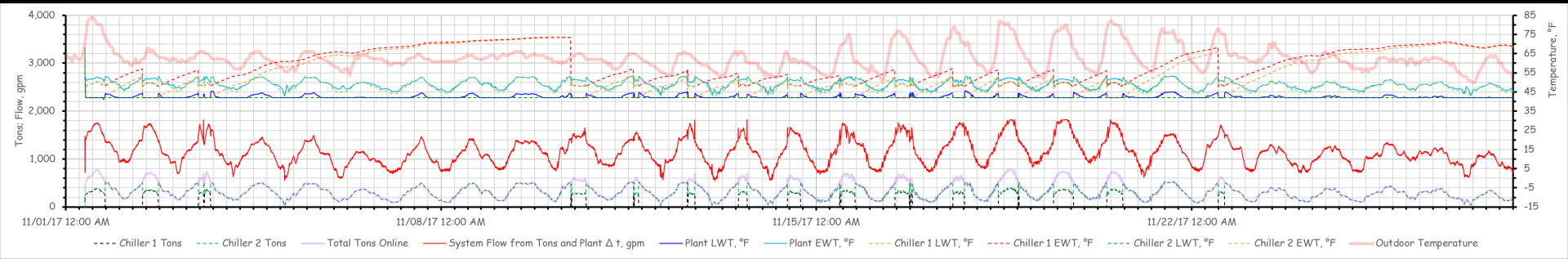
My Most Important Lesson

It’s all about the load profile, both daily and seasonal



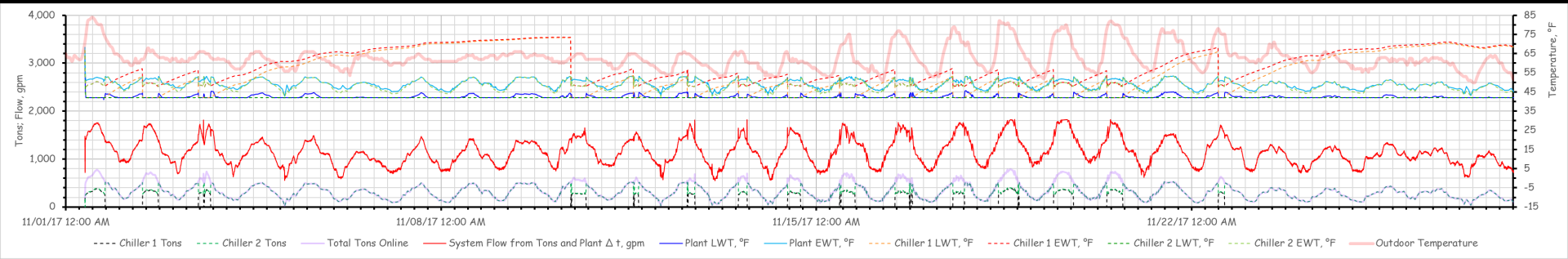
Corollaries

The system design intent needs to address the peak day and all the days in between



Corollaries

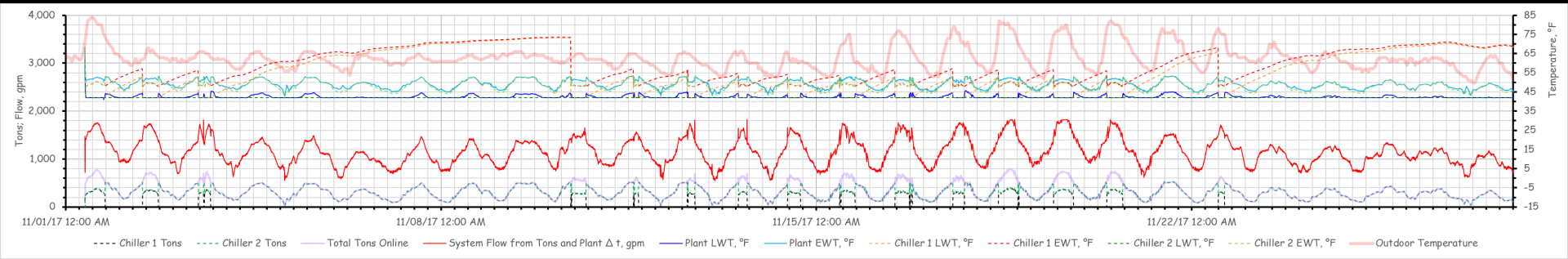
Equipment selections need to be made in light of the load profile dynamics



Corollaries

The control system logic needs to reflect the dynamics of:

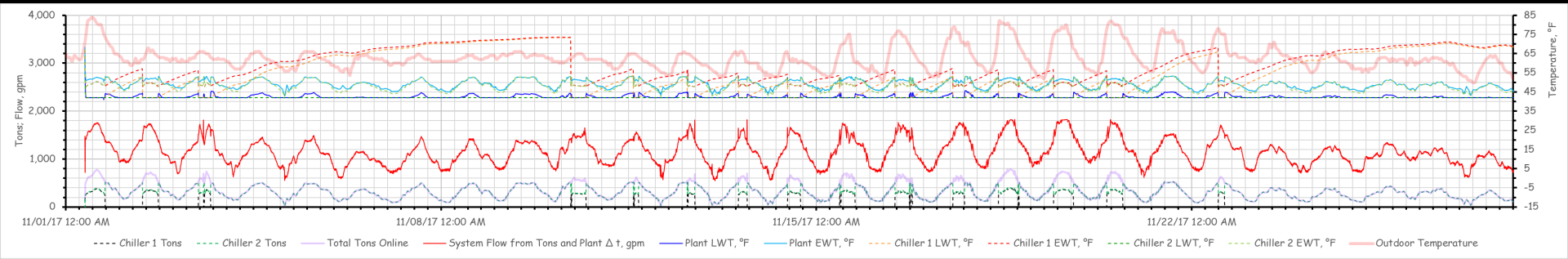
- The design intent
- The system
- The equipment serving the system
- The physical configuration of the system



Corollaries

The control system hardware needs to be able to respond to and manage the dynamics of:

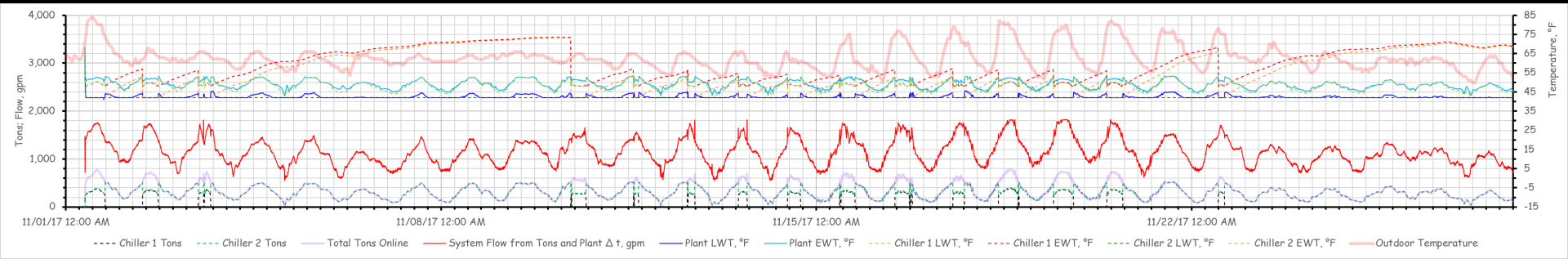
- The system
- The equipment serving the system



Corollaries

- Point lists,
- Detailed specifications,
- Well thought out and detailed control narratives,
- System diagrams, and
- Logic diagrams

are powerful tools for achieving design intent



Corollaries

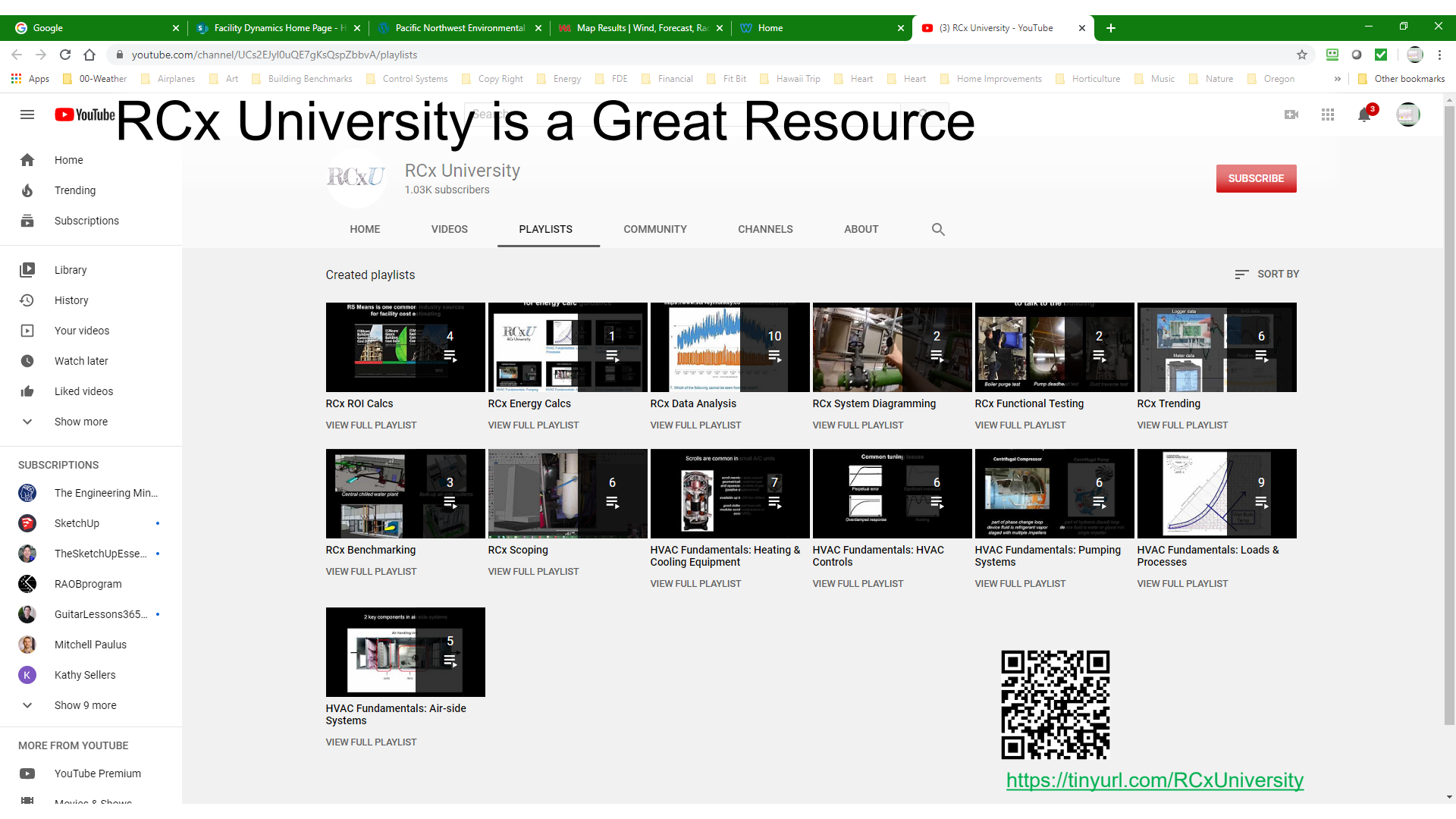
The most efficient equipment, installed in the best manner possible but:

- *Without turn down capabilities tailored to the dynamics of the load profile*
- *Without a robust control system tailored to the dynamics of the load profile, system, and equipment*

will result in an inefficient mess and occasionally, debris

A Few Resources

RCx University is a Great Resource



The EBCx Skills Guidebook is Built Around the 10 Skills

http://www.av8rdas.com/ebcx-skills-guidebook.html

Existing Building Commissioning Skills Guidebook

The guidebook is organized using the 10 Key Commissioning Skills as a framework and provides:

- A description and example of why the skill is important;
- Learning objectives to help guide a self study effort;
- Links to primary resources that can be used to learn about the skill in a self study effort;
- Links to secondary resources that can be used to dig in deeper if you have a particular interest in a particular topic.

The *10 Skills Learning Objectives Checklist* is intended to complement the guidebook by providing a list of all of the learning objectives with a check-box that allows you to track your progress as you work your way through the guidebook in a self study effort.

EBCx Skills Guidebook (ebcx_technical_skills_guidebook_v2017-07-07_web.pdf)
Download File

10 Skills Learning Objectives Checklist (skills_table_web_v5.xlsx)
Download File

Facility Dynamics Engineering *Existing Building Commissioning Guidebook*

Introduction

Over the years, Facility Dynamics has been involved with providing technical training with a focus on existing building commissioning in a number of different venues and for a number of different clients including the Pacific Energy Center, Marriott, and IMCOM. For those programs, I have frequently been the lead technical trainer.

As the training agendas evolved, it started to become clear that there were a number of key skills that it would be desirable to develop if you were going to pursue existing building commissioning. About 5 years ago, Russ Good and Barry Estes of Marriott International asked me to make a list of the ten most important skills and to complement it with a list of the three primary resources that were available were available to help develop each skill.

At that point in time, I had already compiled a list of technical resources that we used to support the classes, but it was about 40 pages long and always growing. So, it could be a bit overwhelming if you were just getting into this and Russ and Barry wanted me to figure out how to focus things a bit.

That forced me to think about what really mattered from a technical stand point if you are out in the field doing this sort of work. It was really hard for me to whittle the list down to only 10 skills, but Barry and Russ were pretty firm on that, and I finally pulled it off. Truth be told, I kind of cheated in a way because I made one of the skills Familiarity with HVAC fundamentals and then put 10 sub-skills under that.

But the exercise was a really good one and when I was finished, I realized that the list was a pretty good framework for organizing the technical side of any of the training classes and I have been using it ever since in that manner. In addition, I reorganized the resource list so that the resources were grouped under headings that correlated with the 10 skills.

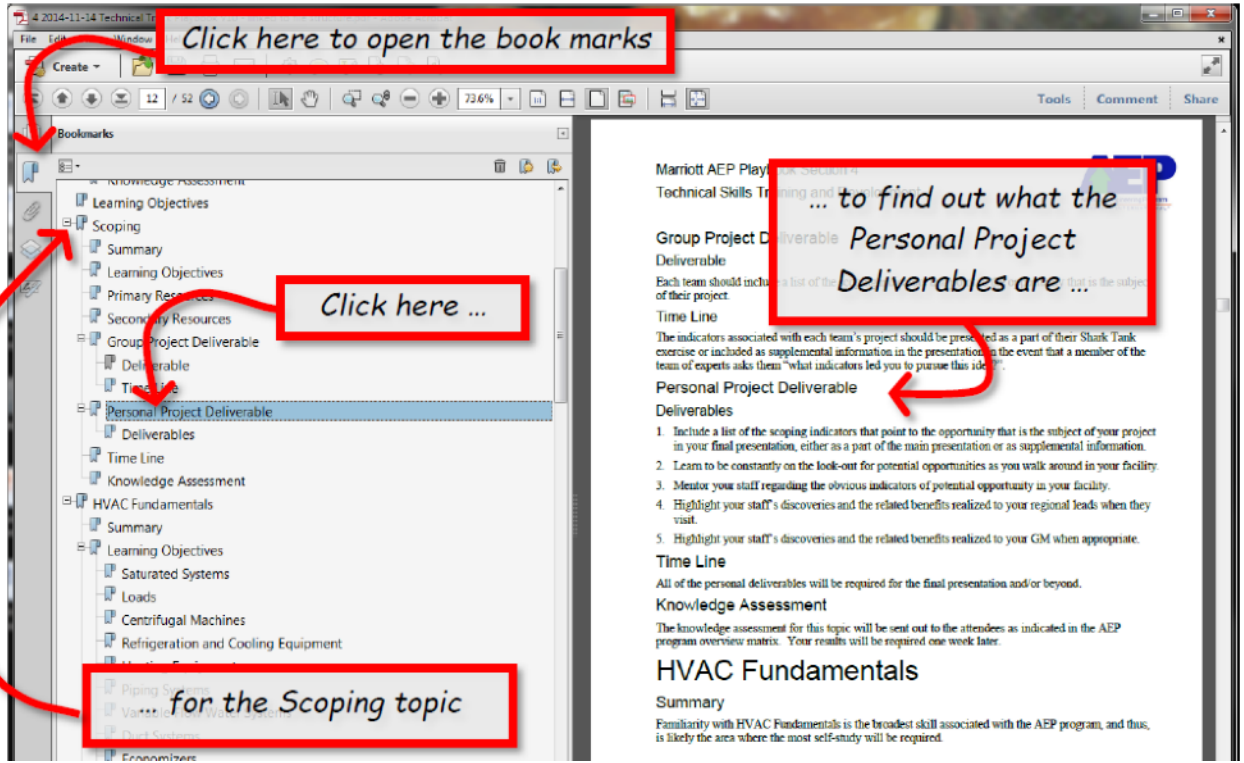
I also should point out that while the driver for developing the list of the 10 skills was Existing Building Commissioning training, the skills really apply across the boards. In other words, you generally will use the same skills for new construction commissioning, ongoing commissioning, and general building operations.

In fact, one of my little jokes in class is that there are all sorts of names and acronyms applied to processes where you apply the 10 skills, including Existing Building Commissioning, EBCx, Retrocommissioning, RCx, Building Tune-ups, Ongoing Commissioning, NCx, Facility Operations, etc. I have had the opportunity to work on projects where all of those names have been applied to what I was doing.

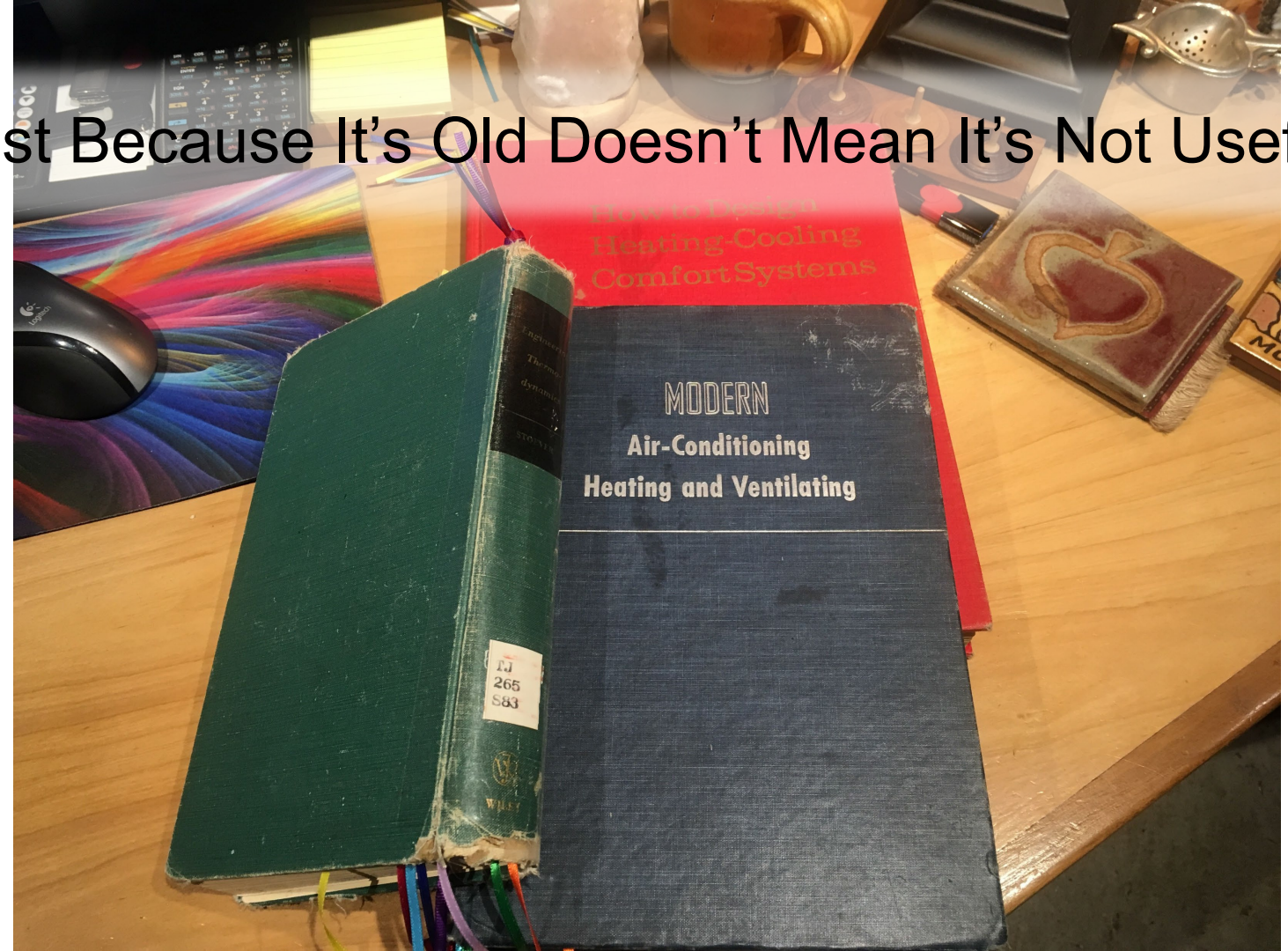
But when I think about it, all of them generally are technically the same thing that I was doing back in 1976, when I first became involved with the industry. Back then, we just called it

Navigating Through the Guidebook

If you are reading this document in the electronic version, you can use the bookmarks included in this document to jump to a topic of interest as indicated in as illustrated in Figure 1.



Just Because It's Old Doesn't Mean It's Not Useful



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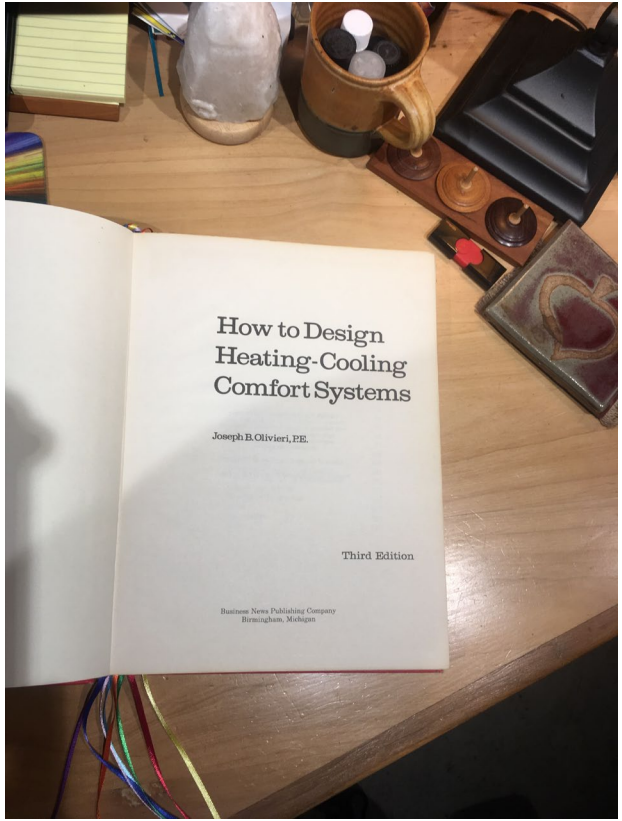

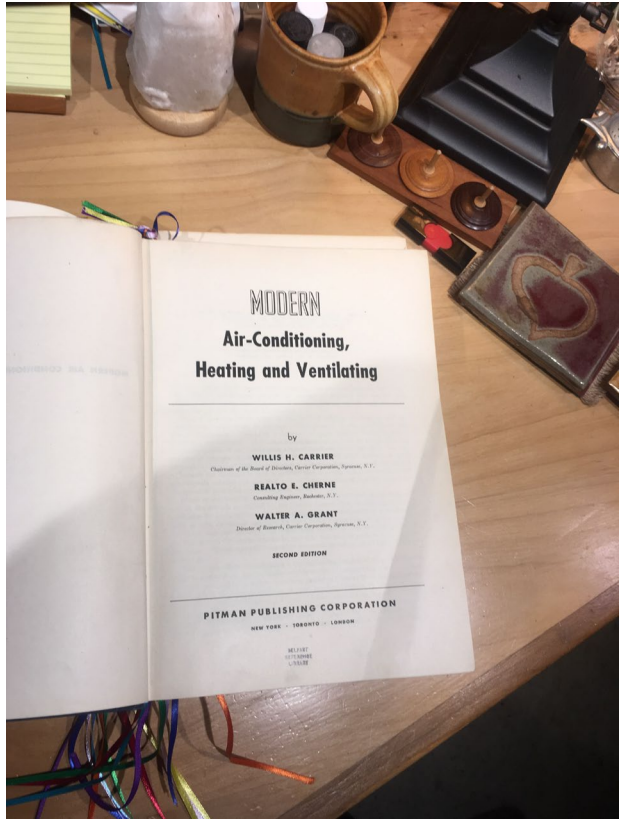

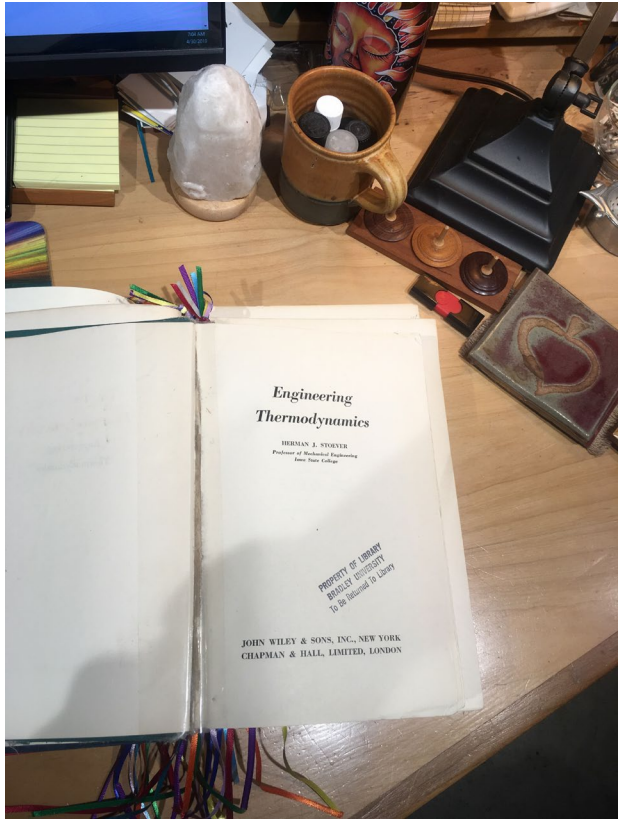

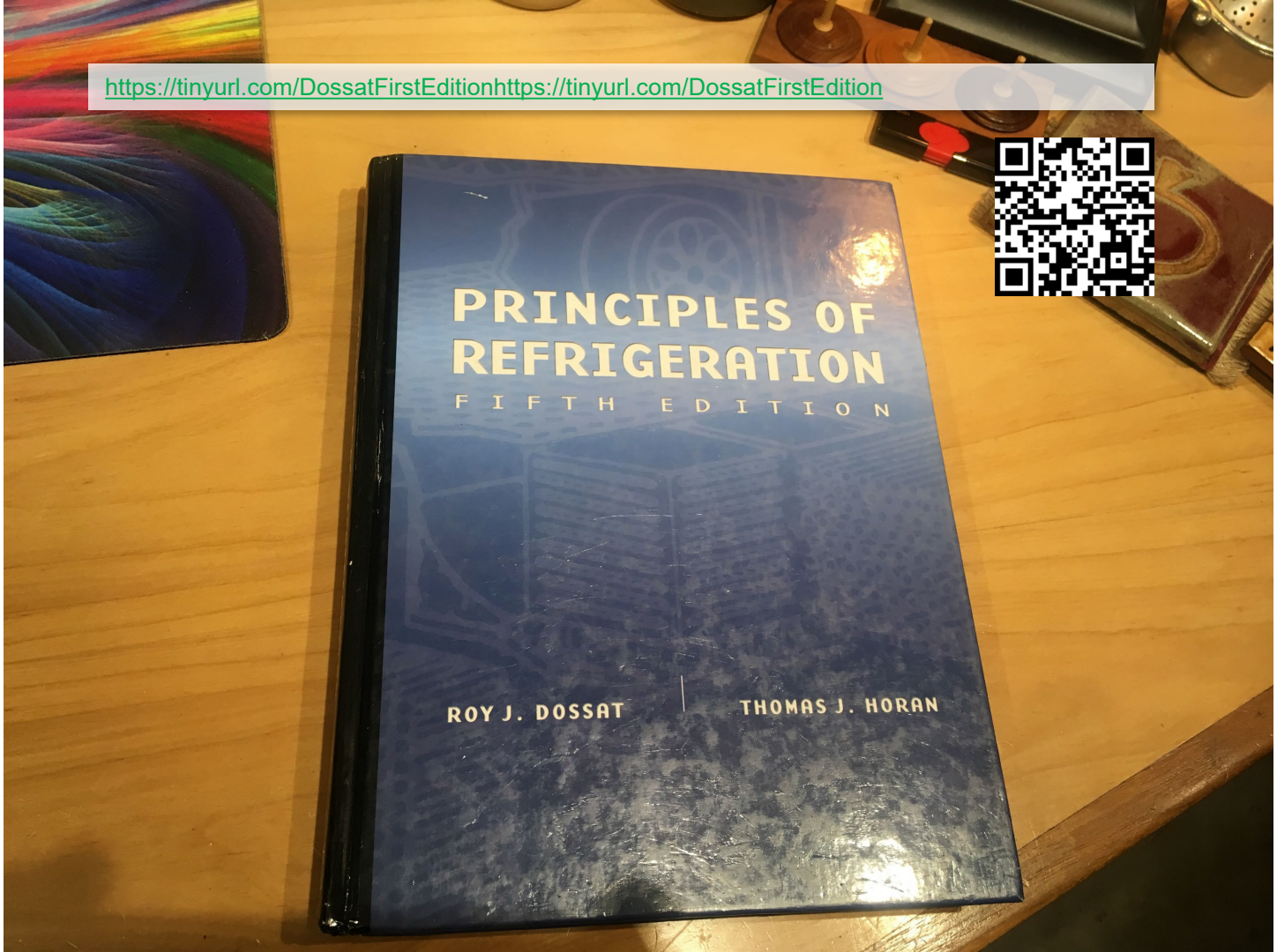
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PRINCIPLES OF REFRIGERATION
FIFTH EDITION
ROY J. DOSSAT
THOMAS J. HORAN

A Blog with a Field Perspective on Building Systems

https://av8rdas.wordpress.com/

A Field Perspective on Engineering

Engineering lessons from the field

Home About

Creating a Third Axis In Excel

Posted on April 19, 2019

One of the challenges that came up when I was creating the time series graph of a 9,000 ton chiller plant load profile that I show in my previous post was that I wanted to plot data series that had numbers in them with very large differences in the order of magnitude.

Click the Image to Visit Our Commissioning Resources Website

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What's New?

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Buildings are Talking to Us

We Just Need to Learn How to Listen

My Goal

Welcome to A Field Perspective on Engineering's commissioning resource website. For those who don't know me from my blog or some other venue, I am a senior engineer for a company named Facility Dynamics Engineering a.k.a FDE, which specializes in commissioning, control system design, and some forensic engineering work.

Facility Dynamics ENGINEERING

http://www.av8rdas.com/

Introduction to Heat Pumps

A Few Definitions

Heat Pump

- A heat pump extracts heat from a source and transfers it to a sink at a higher temperature

  2020 ASHRAE Handbook of Systems and Equipment, Chapter 9

A question for you

https://tinyurl.com/HeatPumpDef

Common Examples of Heat Pumps

Air Conditioner

Refrigerator

Common Examples of Heat *Pumps*

The “pump” term is important

- Energy naturally flows from Hot to Cold

  Heat pumps move heat in the opposite direction

- They don’t create energy; they use energy to move additional energy from a Cold Location to a Hot Location

https://tinyurl.com/HeatPumpBlogPost

A Few Definitions

Heat Source

- No matter how much heat is removed from it, the temperature of the source will not change
- Also called the “infinite source”

A Few Definitions

Heat Sink

- No matter how much heat is added to it, the temperature of the sink will not change
- Also called the “infinite sink”

A Few Definitions

Heat

- Energy in motion; the amount of energy flowing from one object to another due to their temperature difference
- There are grades of heat
  - High – Temperature greater that 650°C/1,202°F
  - Medium – Temperatures between 200°C and 650°C/392°F and 1,202°F
  - Low – Temperatures below 200°C/392°F
- Low grade heat is harder to make use of

A Few Definitions

Heating

- A process that adds energy
  - For a space, this is often accomplished by circulating air through it at a temperature above the required set point
  - For a fluid stream, this is often accomplished by passing it over a surface that is above the required supply temperature

A Few Definitions

Heating Load

- The amount of energy that needs to be added to a space to maintain the space at the desired set point under the design condition

A Few Definitions

Cooling

- A process that removes energy
  - For a space, this is often accomplished by circulating air through it at a temperature below the required set point
  - For a fluid stream, this is often accomplished by passing it over a surface that is below the required supply temperature
  - If the surface is below the dew point of the fluid stream, dehumidification (moisture removal) will also occur

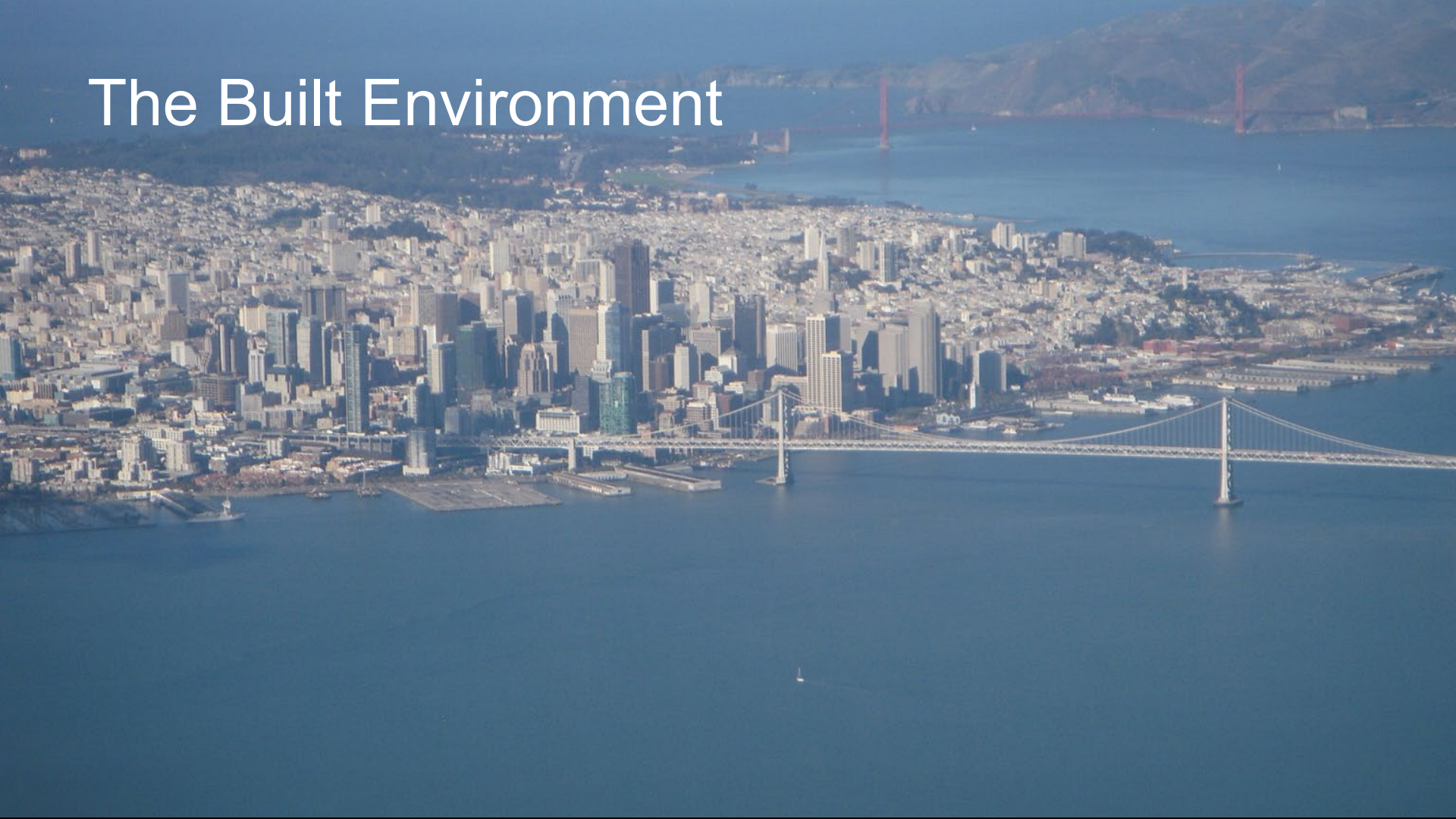
A Few Definitions

Cooling Load

- The amount of energy that needs to be removed from a space to maintain the space at the desired set point under the design condition
- Usually, this includes both sensible and latent energy

Load Profiles

The Built Environment



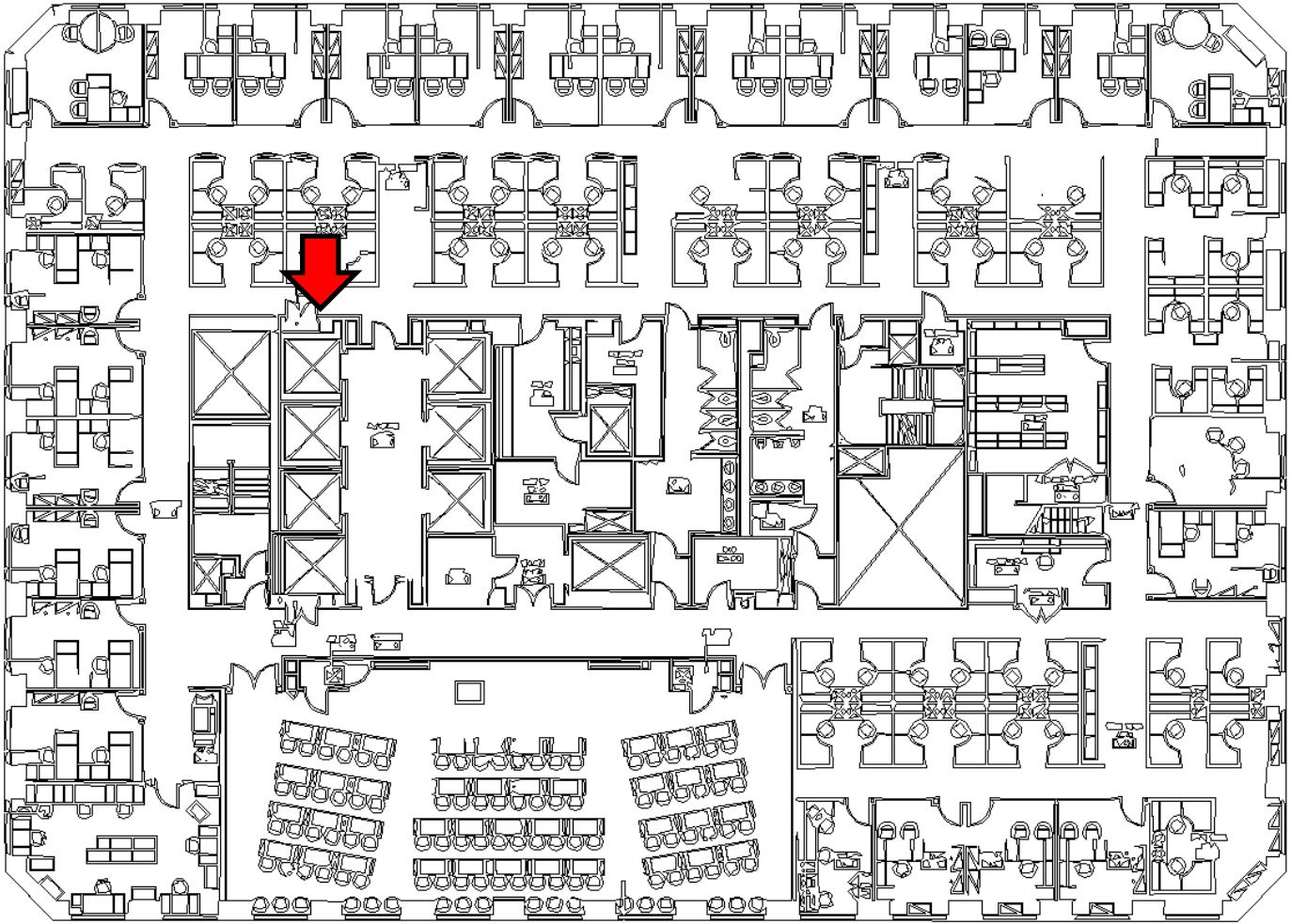
The Built Environment

Keeping the built environment safe, productive, clean, and comfortable is a fundamental goal of HVAC systems and their controls

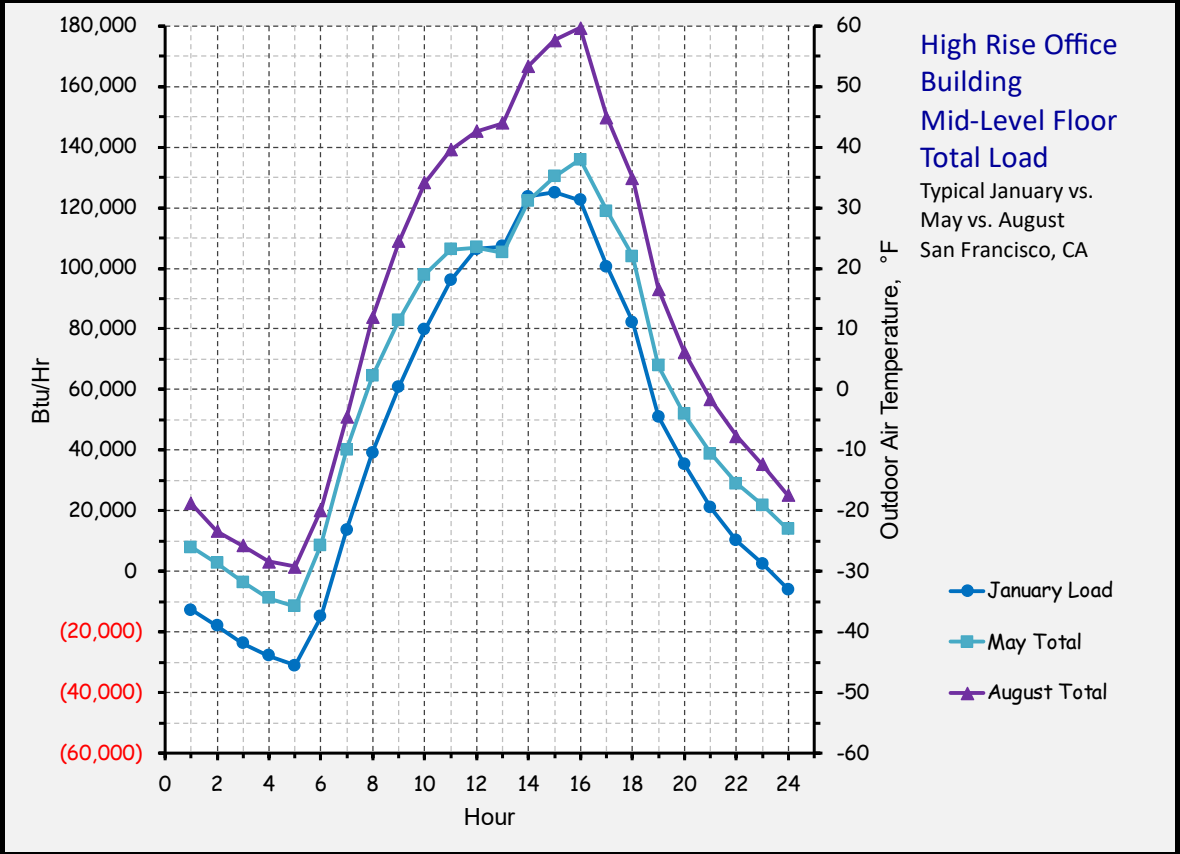
- Ventilation systems control contaminants by introducing filtered, conditioned outdoor air
- Heating and cooling systems track the loads to control comfort

The Built Environment

The



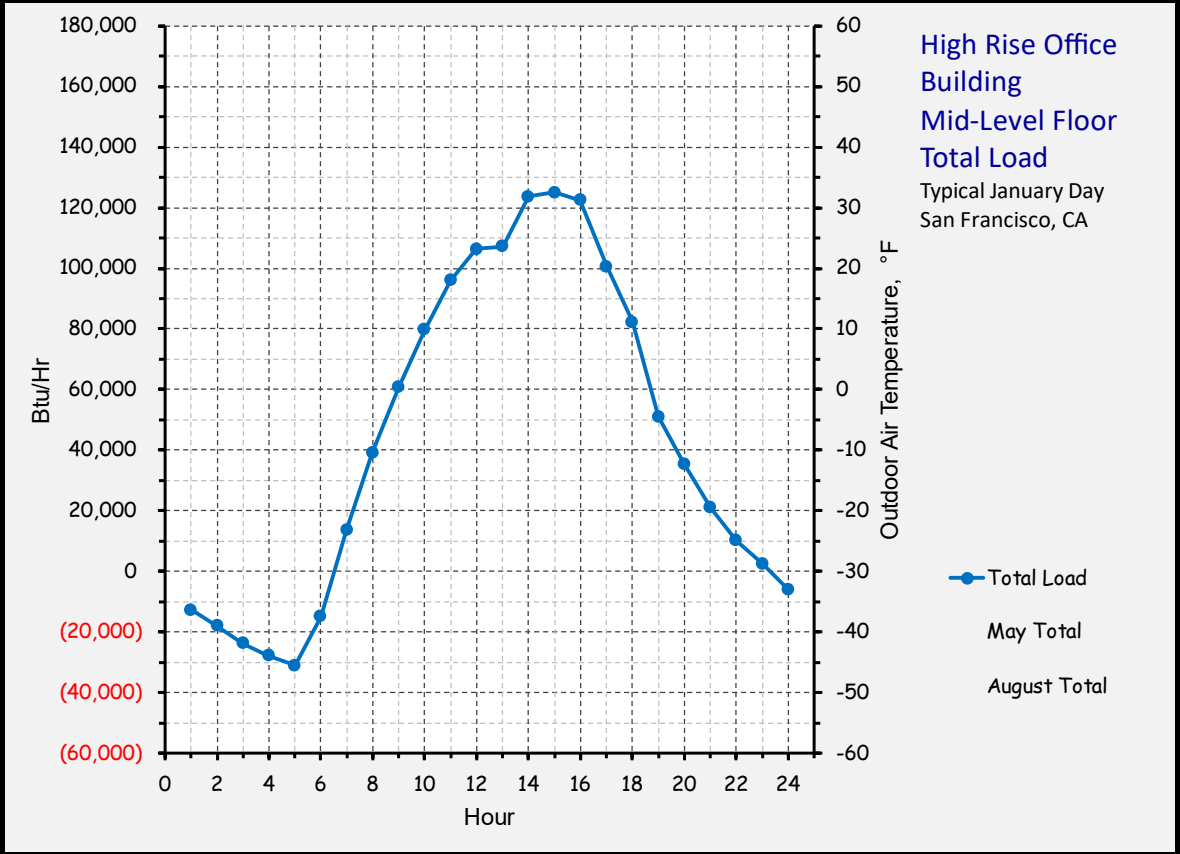
The Loads can be Very Dynamic



Requirements Vary with:

- Time of Day
- Time of Year

The Loads Can Be Very Dynamic



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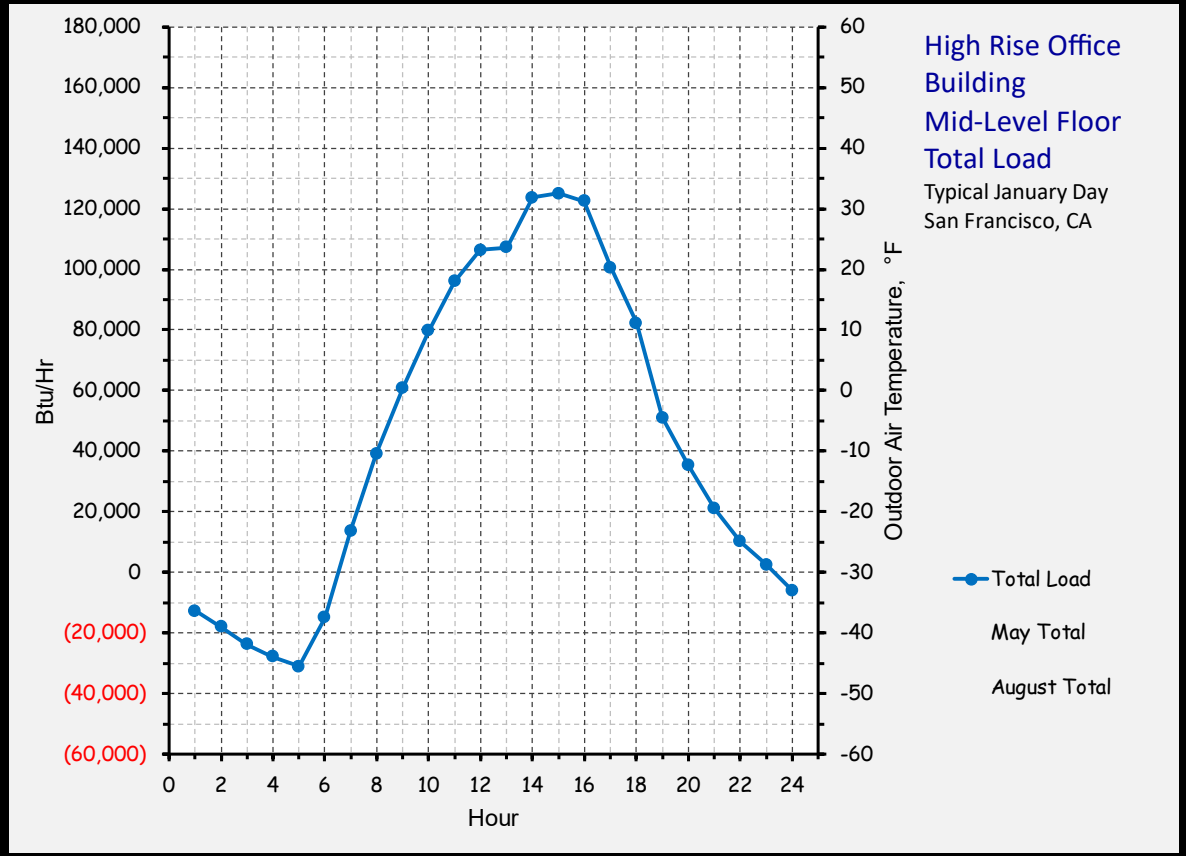
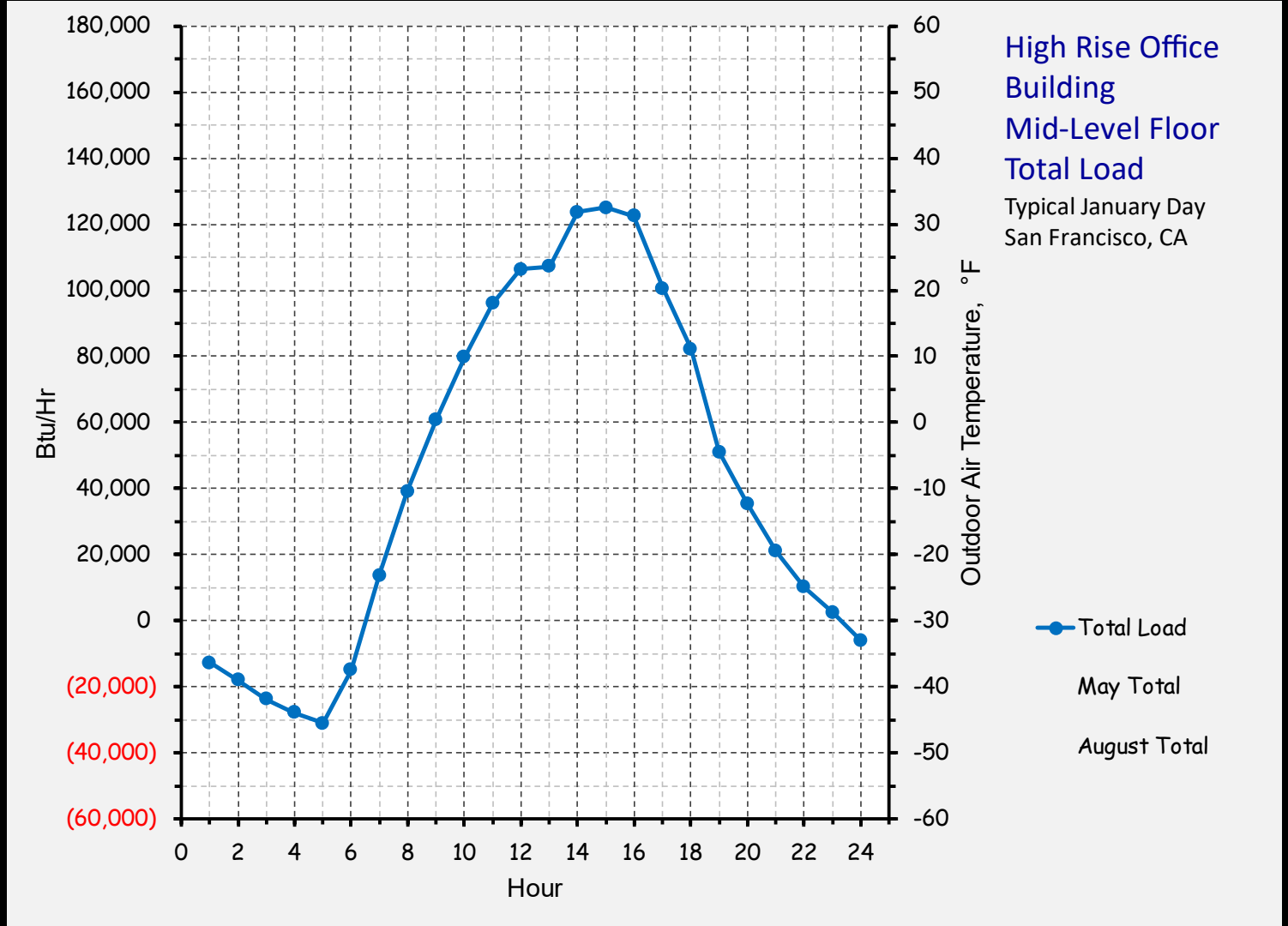


A Question

https://tinyurl.com/HeatPumpLoad01


High Rise Office Building
Mid-Level Floor
Total Load
Typical January Day
San Francisco, CA
Btu/Hr
180,000
160,000
140,000
120,000
100,000
80,000
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40,000
20,000
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(60,000)
Outdoor Air Temperature, °F
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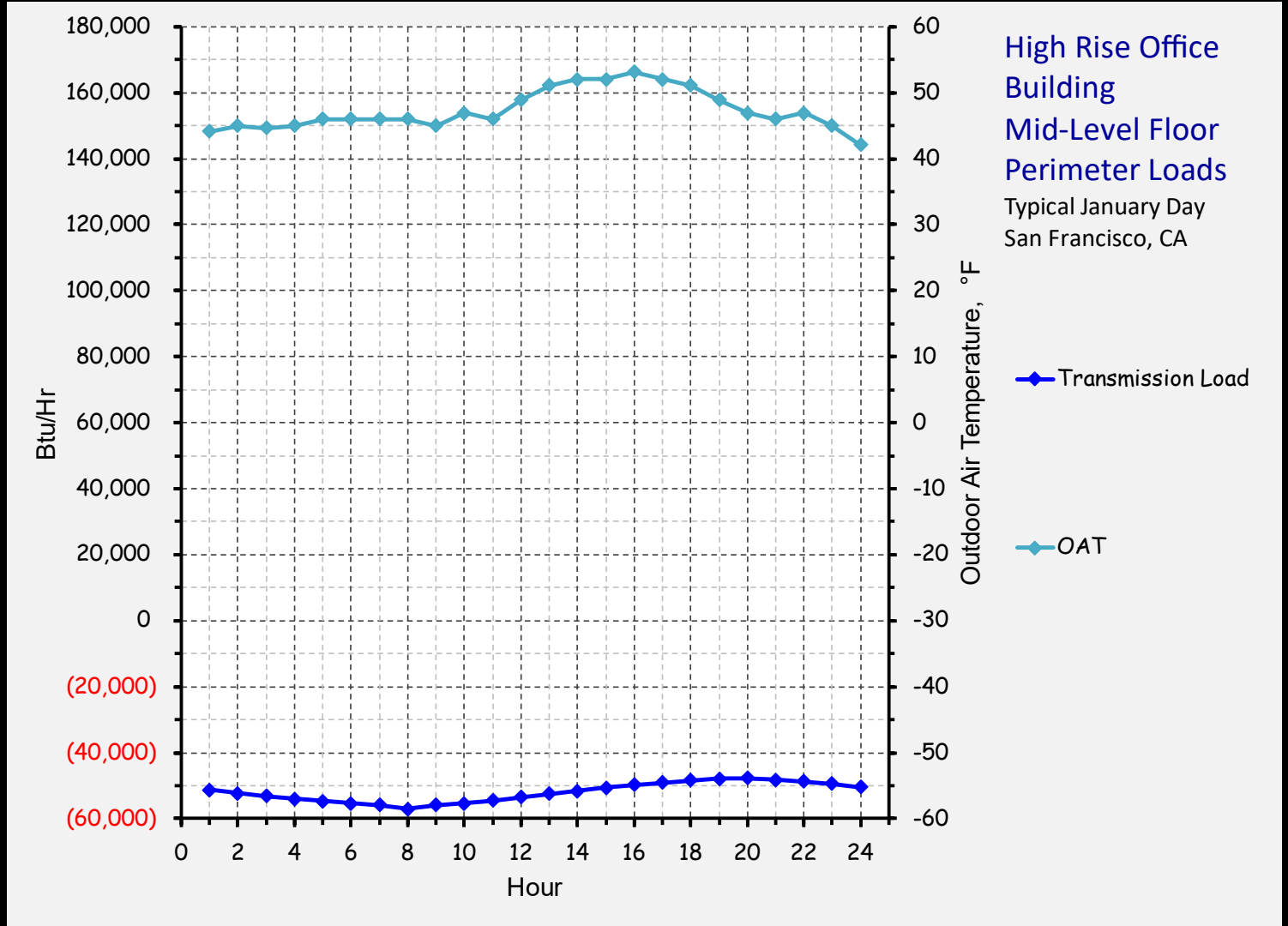
May Total
August Total


High Rise Office Building
Mid-Level Floor Perimeter Loads
Typical January Day
San Francisco, CA
Btu/Hr
Outdoor Air Temperature, °F
Hour
Transmission Load
OAT
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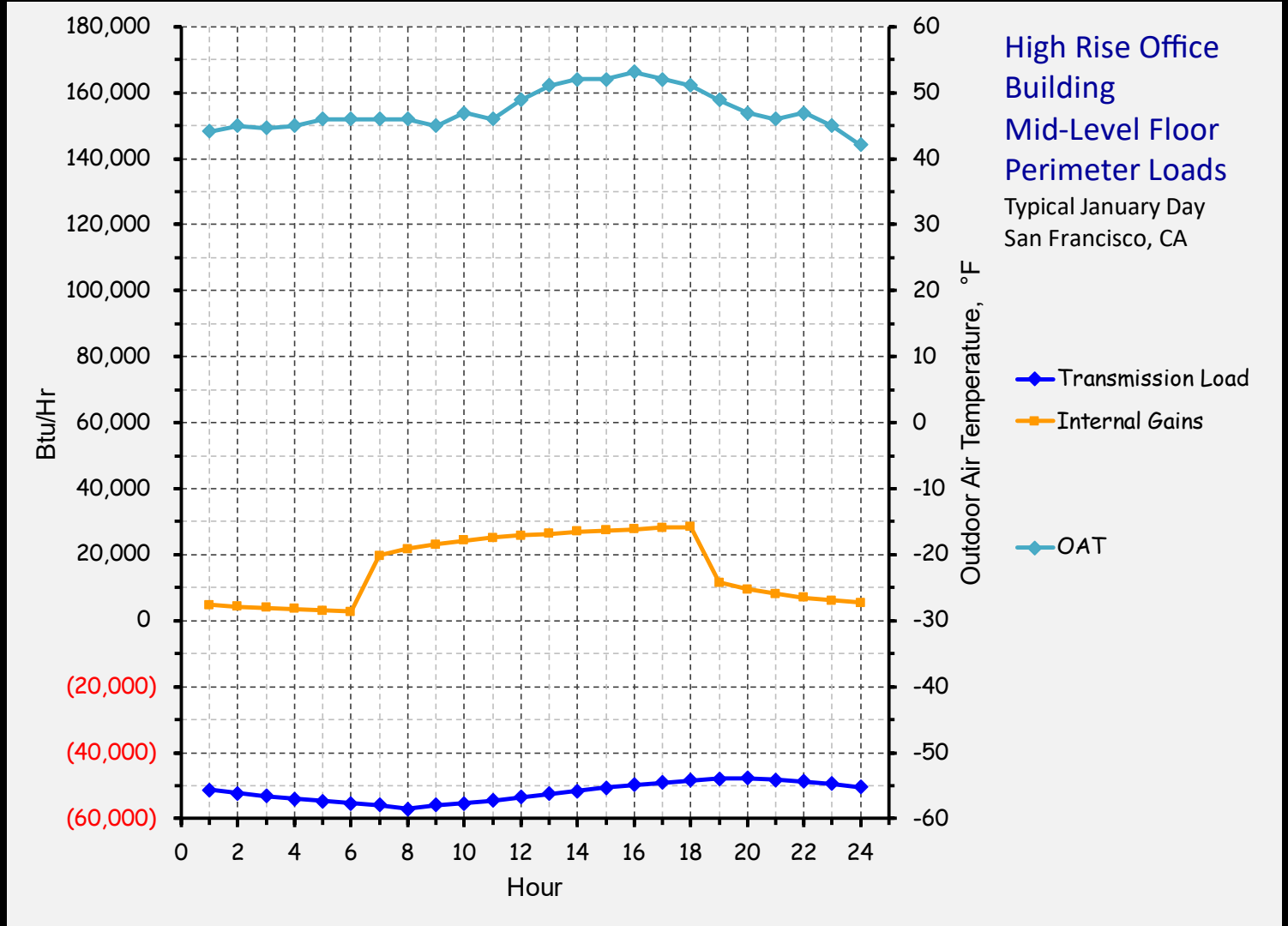
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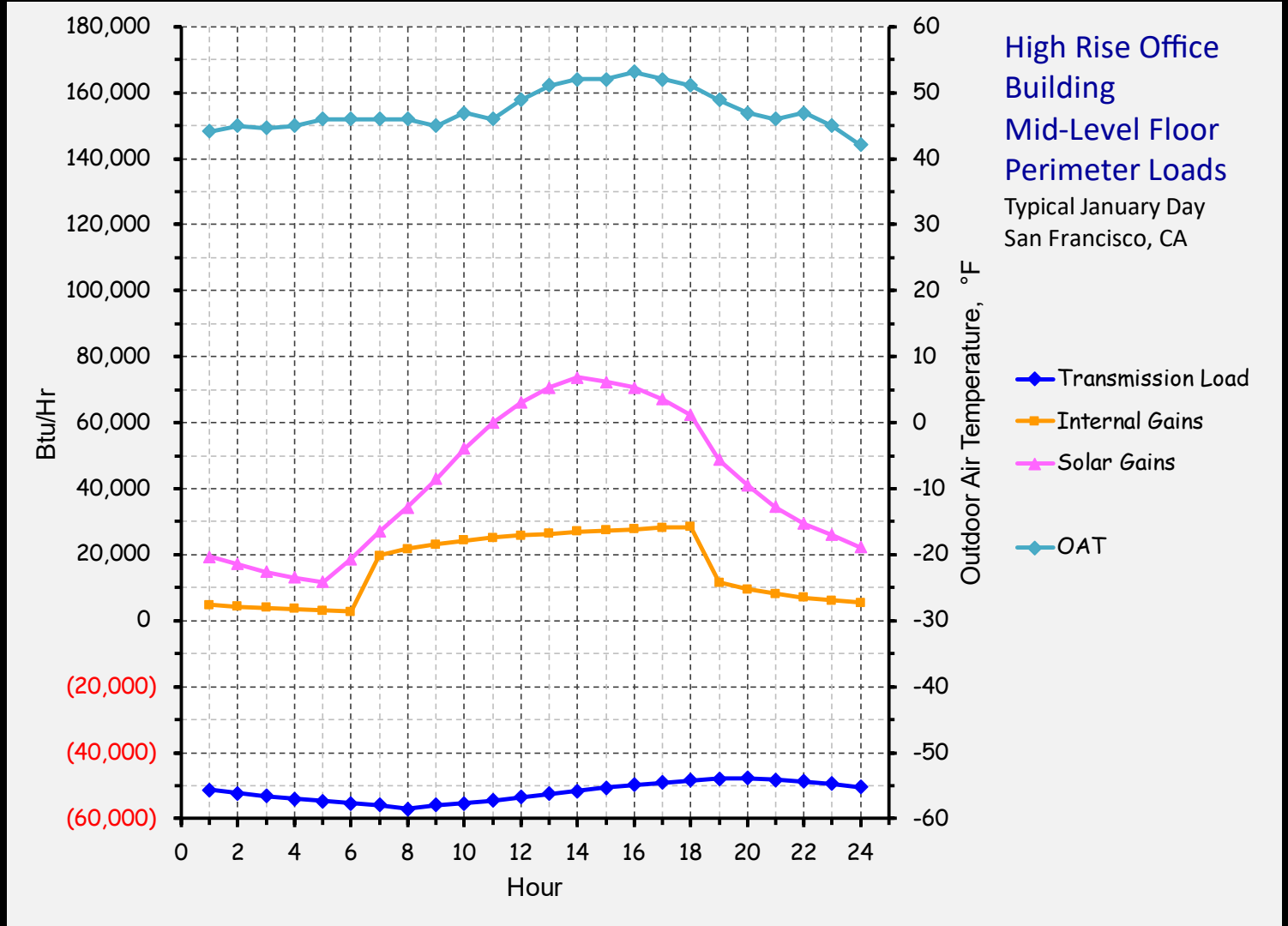
High Rise Office Building
Mid-Level Floor Perimeter Loads
Typical January Day
San Francisco, CA
Btu/Hr
Outdoor Air Temperature, °F
Hour
Transmission Load
Internal Gains
Solar Gains
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180,000
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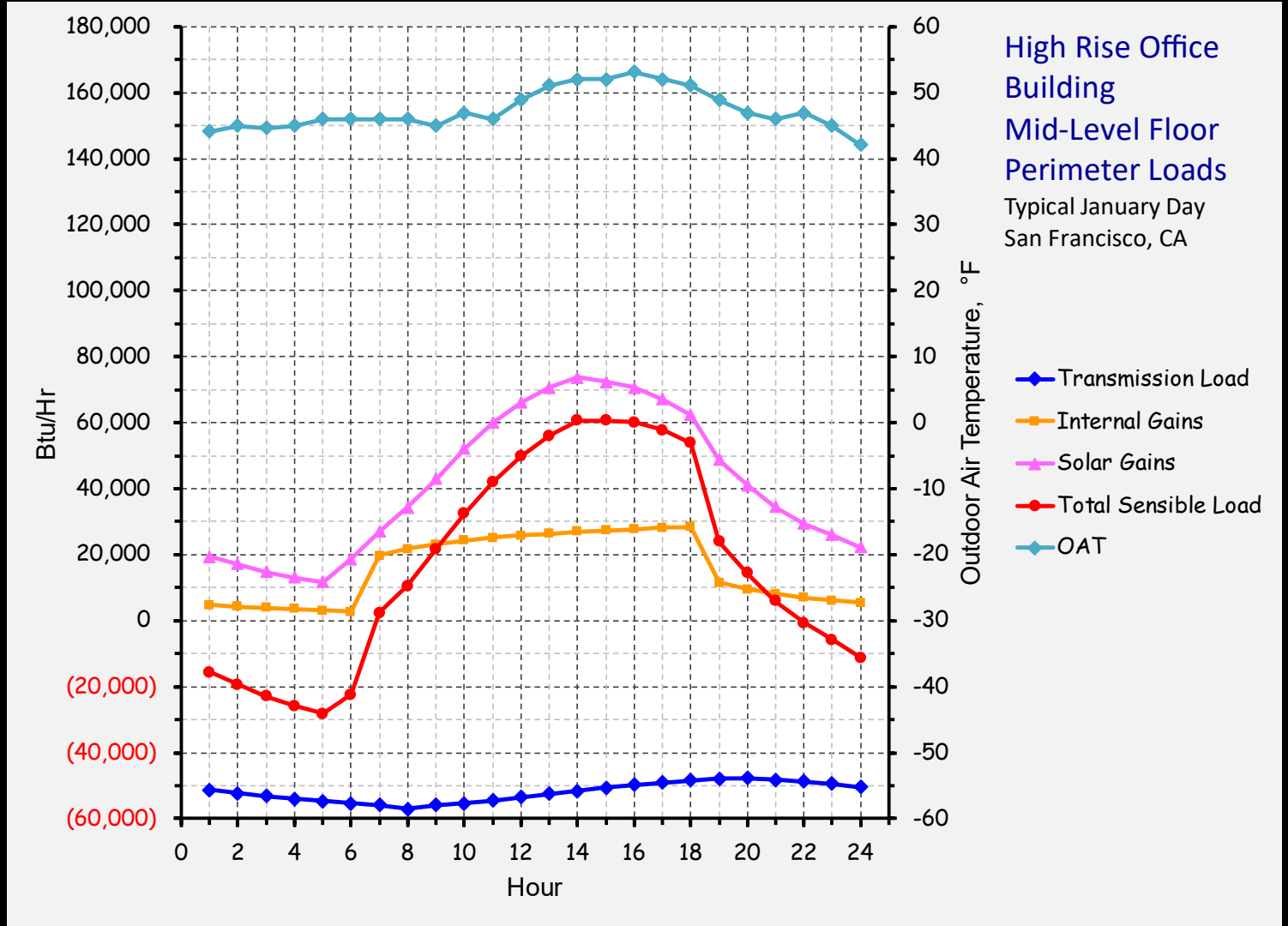
High Rise Office Building
Mid-Level Floor Perimeter Loads
Typical January Day
San Francisco, CA
Btu/Hr
Outdoor Air Temperature, °F
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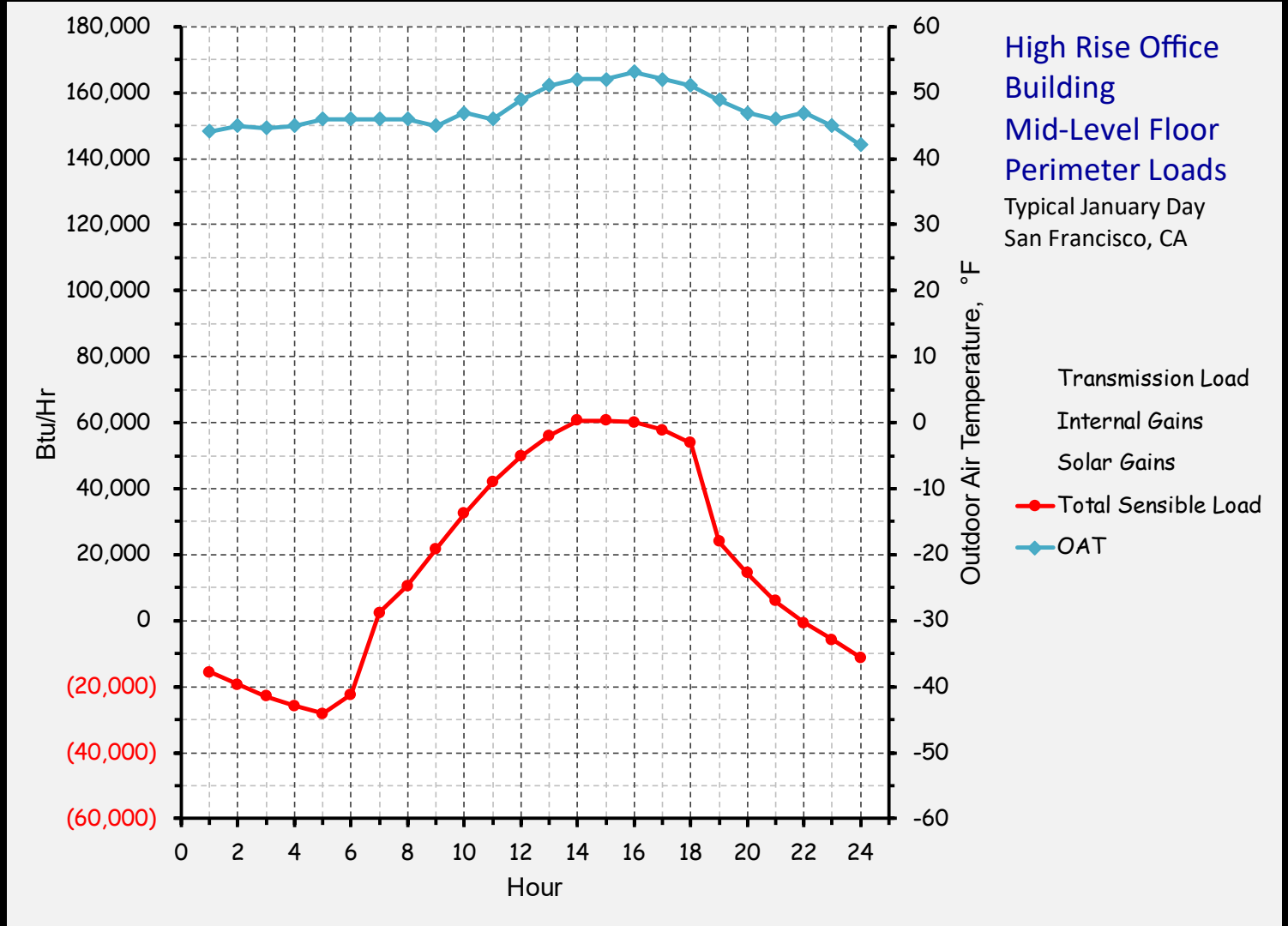
Transmission Load
Internal Gains
Solar Gains
Total Sensible Load
OAT


High Rise Office Building
Mid-Level Floor Perimeter Loads
Typical January Day
San Francisco, CA
Btu/Hr
Outdoor Air Temperature, °F
Hour
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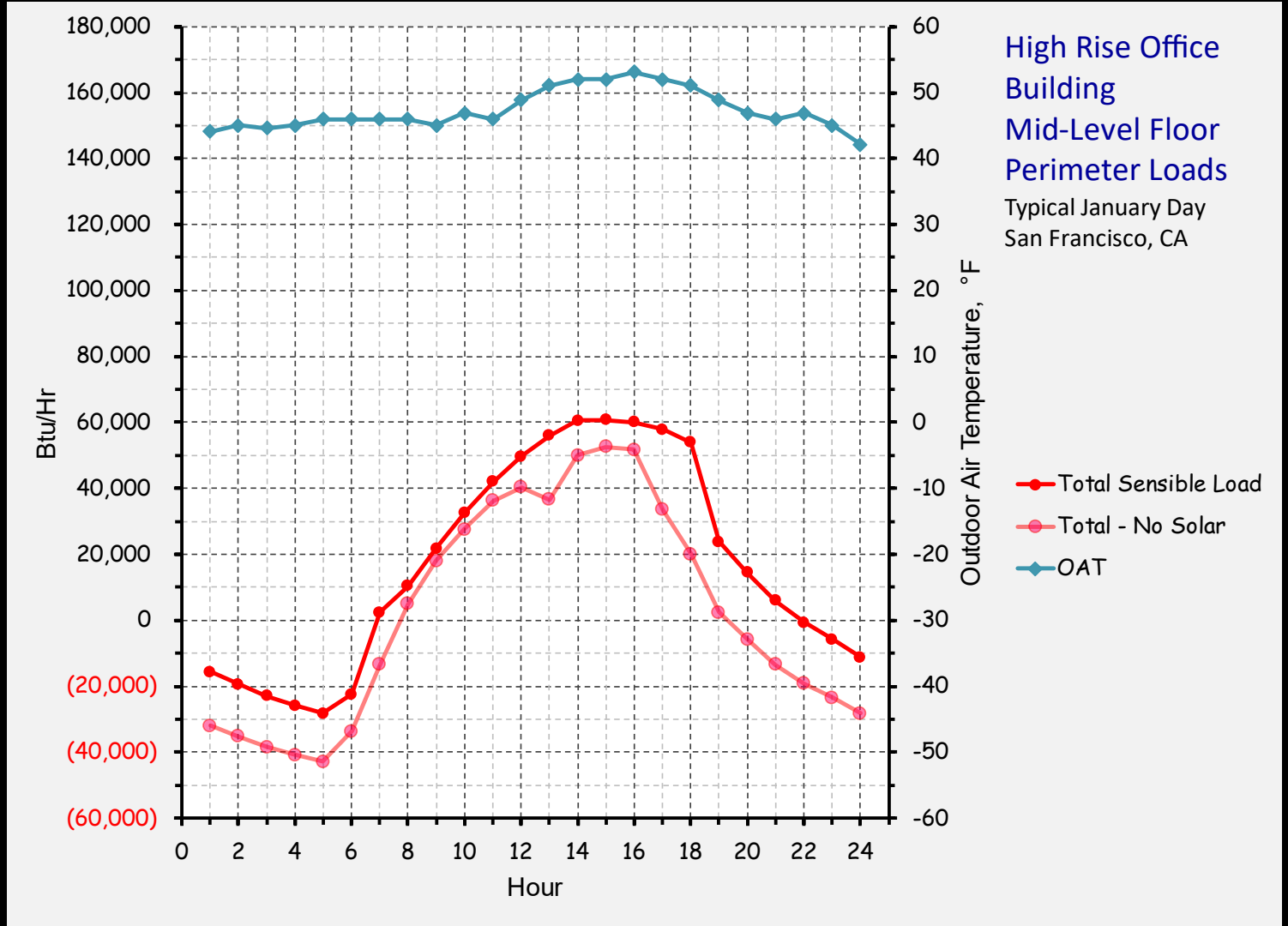
Transmission Load
Internal Gains
Solar Gains
Total Sensible Load
OAT


High Rise Office Building
Mid-Level Floor Perimeter Loads
Typical January Day
San Francisco, CA
Btu/Hr
Outdoor Air Temperature, °F
Hour
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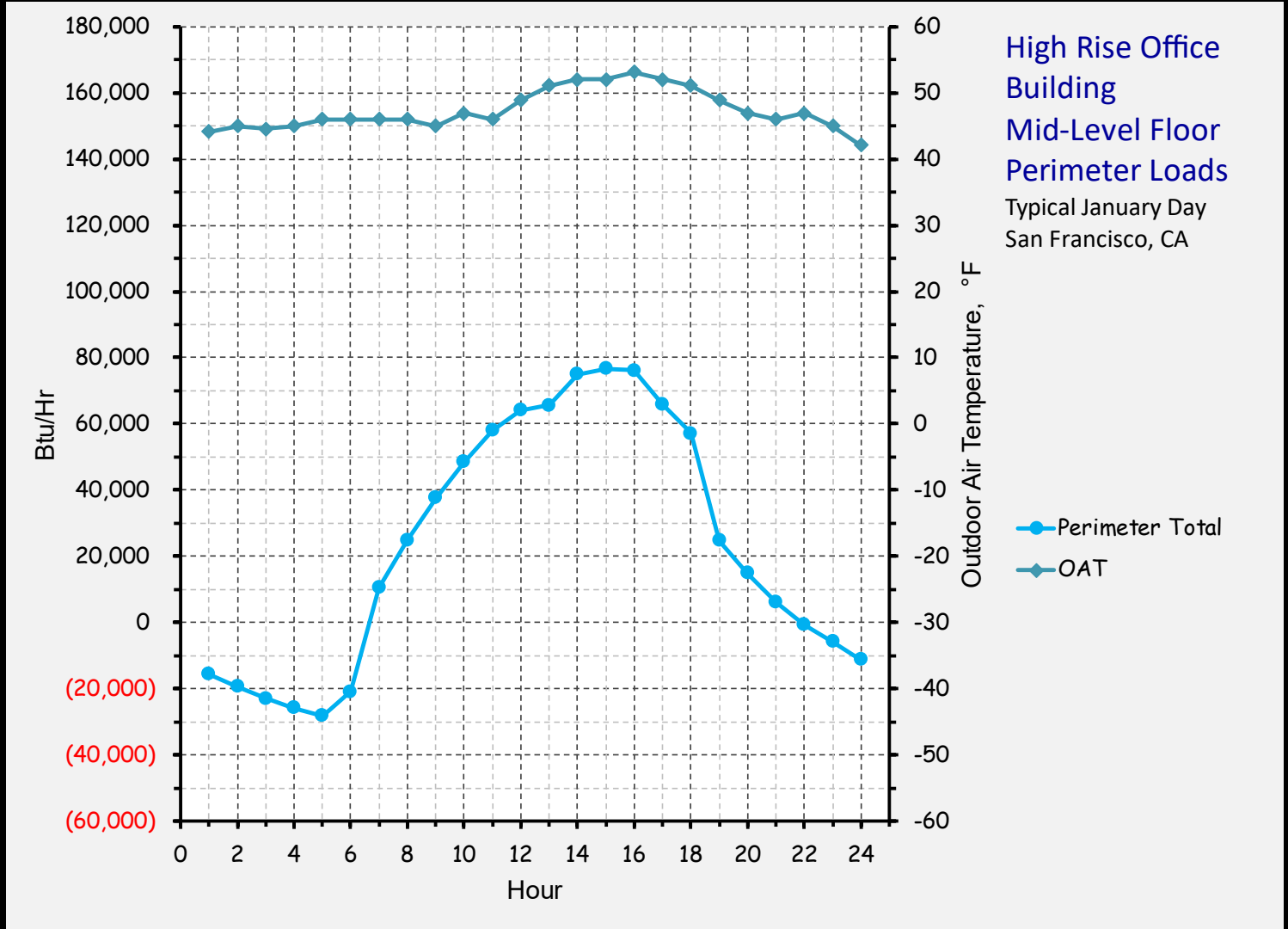
Total Sensible Load
Total - No Solar
OAT


High Rise Office Building
Mid-Level Floor Perimeter Loads
Typical January Day
San Francisco, CA
Btu/Hr
Outdoor Air Temperature, °F
Hour
Perimeter Total
OAT
180,000
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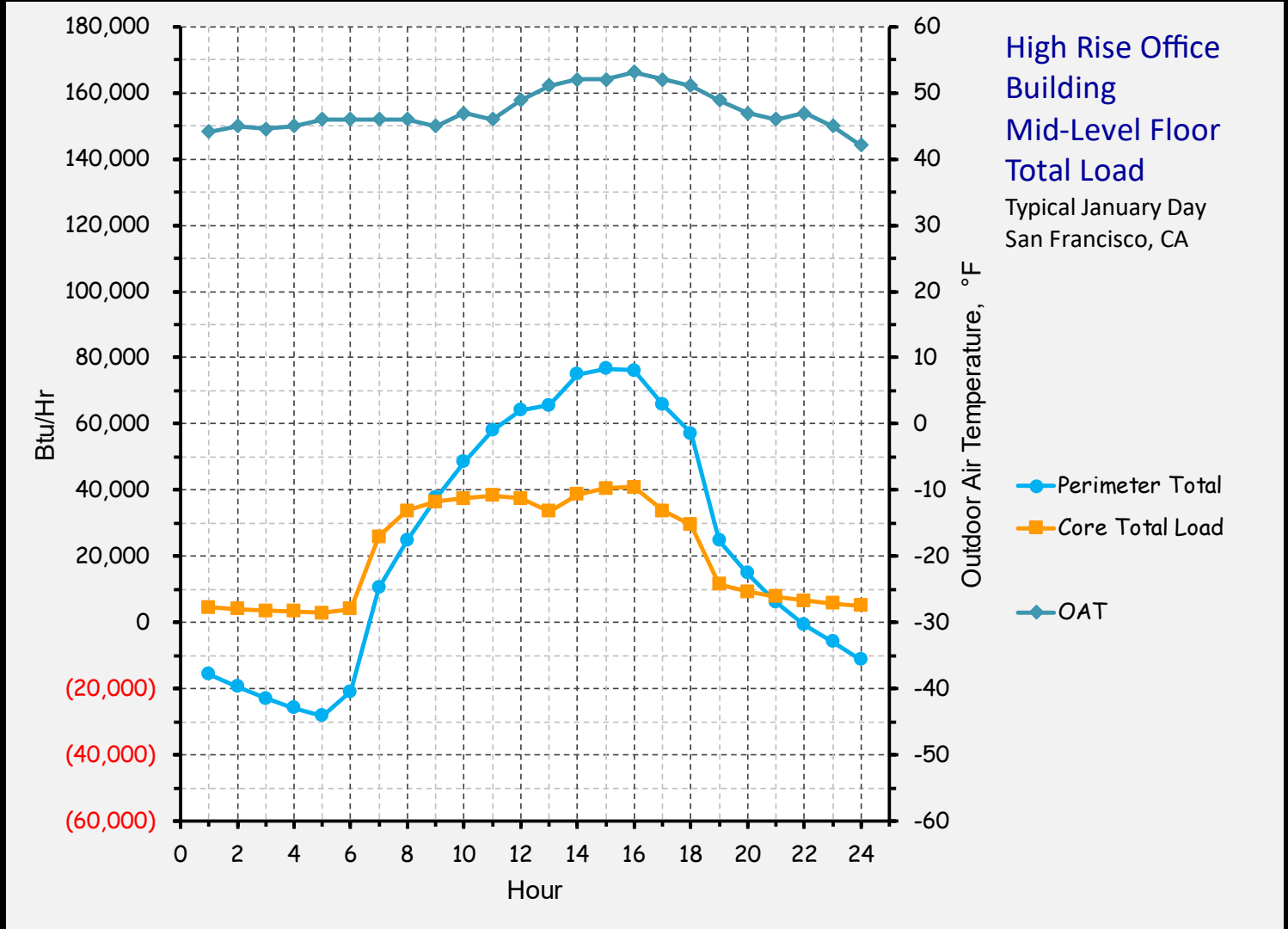
High Rise Office Building
Mid-Level Floor
Total Load
Typical January Day
San Francisco, CA
Btu/Hr
180,000
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Outdoor Air Temperature, °F
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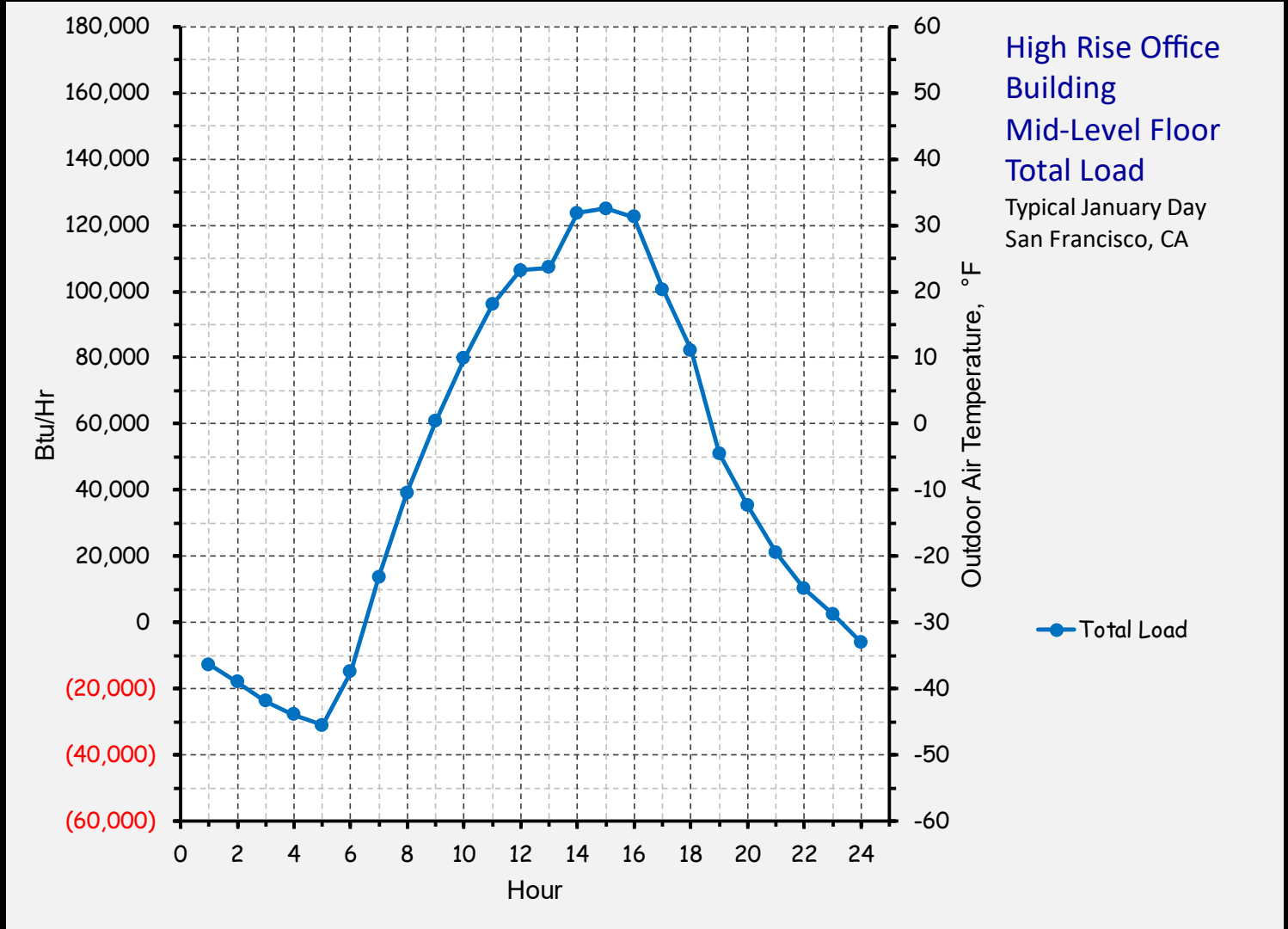
Hour
Perimeter Total
Core Total Load
OAT


High Rise Office Building
Mid-Level Floor
Total Load
Typical January Day
San Francisco, CA
Btu/Hr
180,000
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Outdoor Air Temperature, °F
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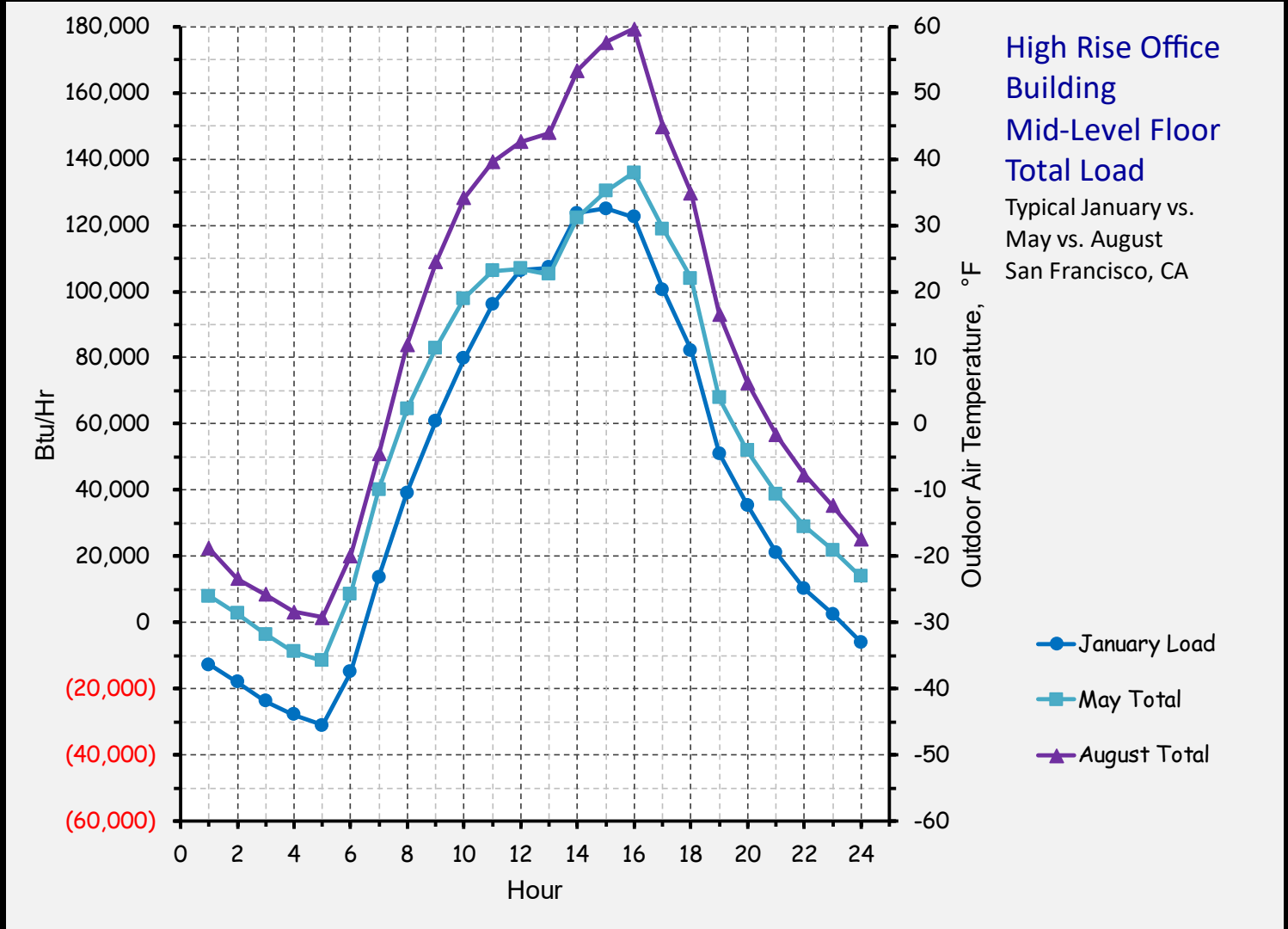
Hour
Total Load


High Rise Office Building
Mid-Level Floor
Total Load
Typical January vs. May vs. August
San Francisco, CA
Btu/Hr
Outdoor Air Temperature, °F
Hour
180,000
160,000
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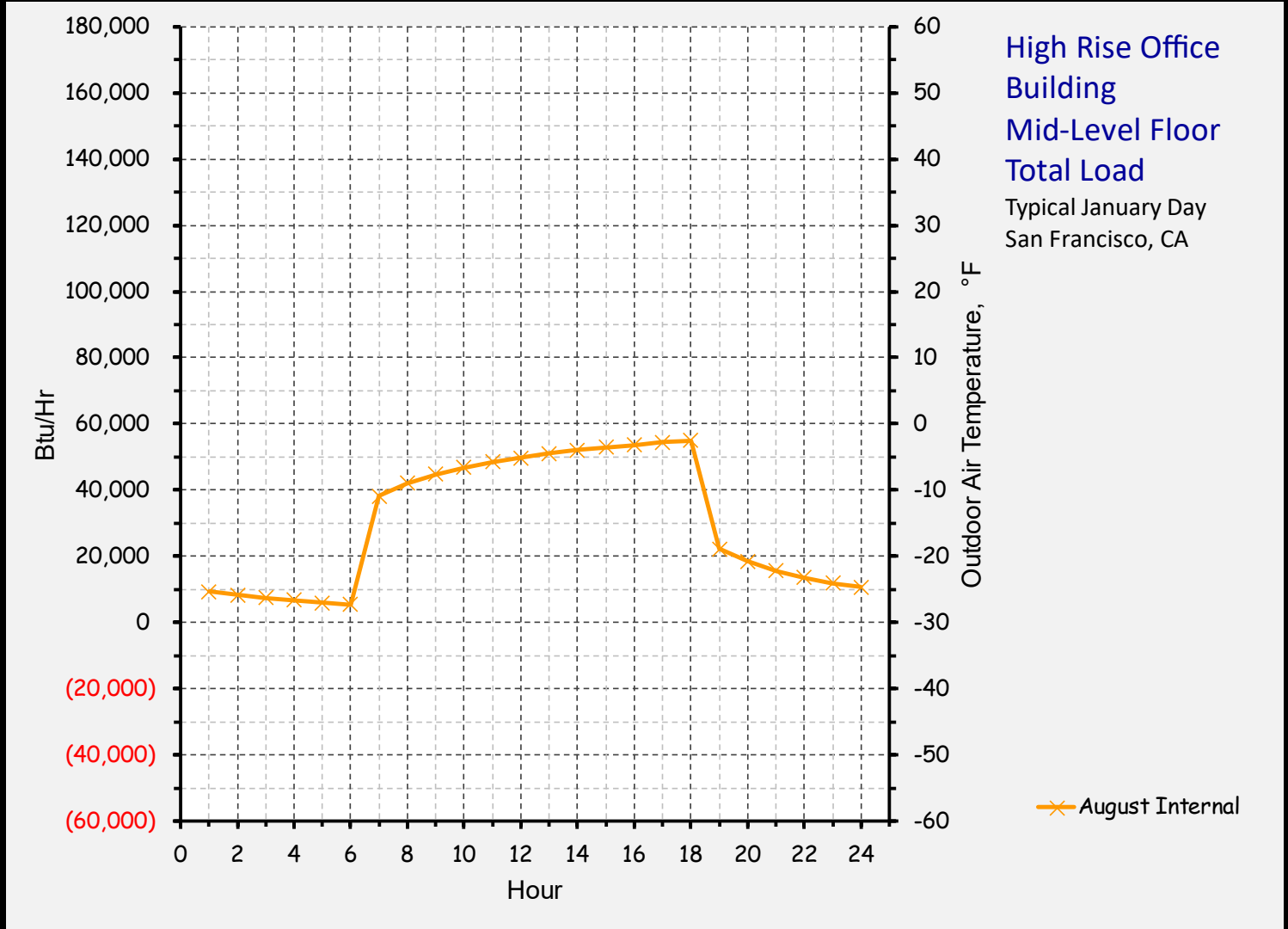
January Load
May Total
August Total


High Rise Office Building
Mid-Level Floor
Total Load
Typical January Day
San Francisco, CA
Btu/Hr
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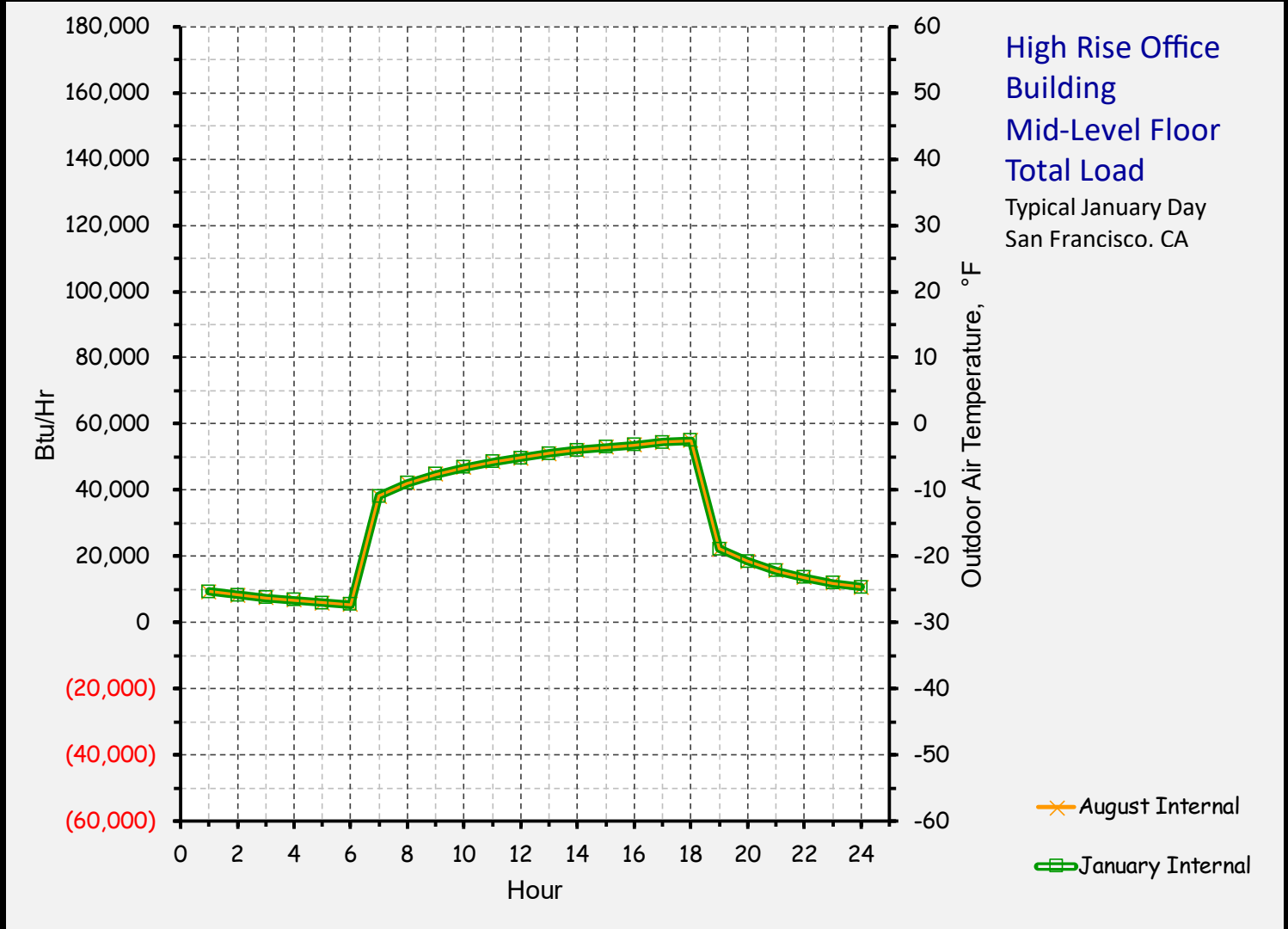
Hour
August Internal


High Rise Office Building
Mid-Level Floor
Total Load
Typical January Day
San Francisco. CA
Btu/Hr
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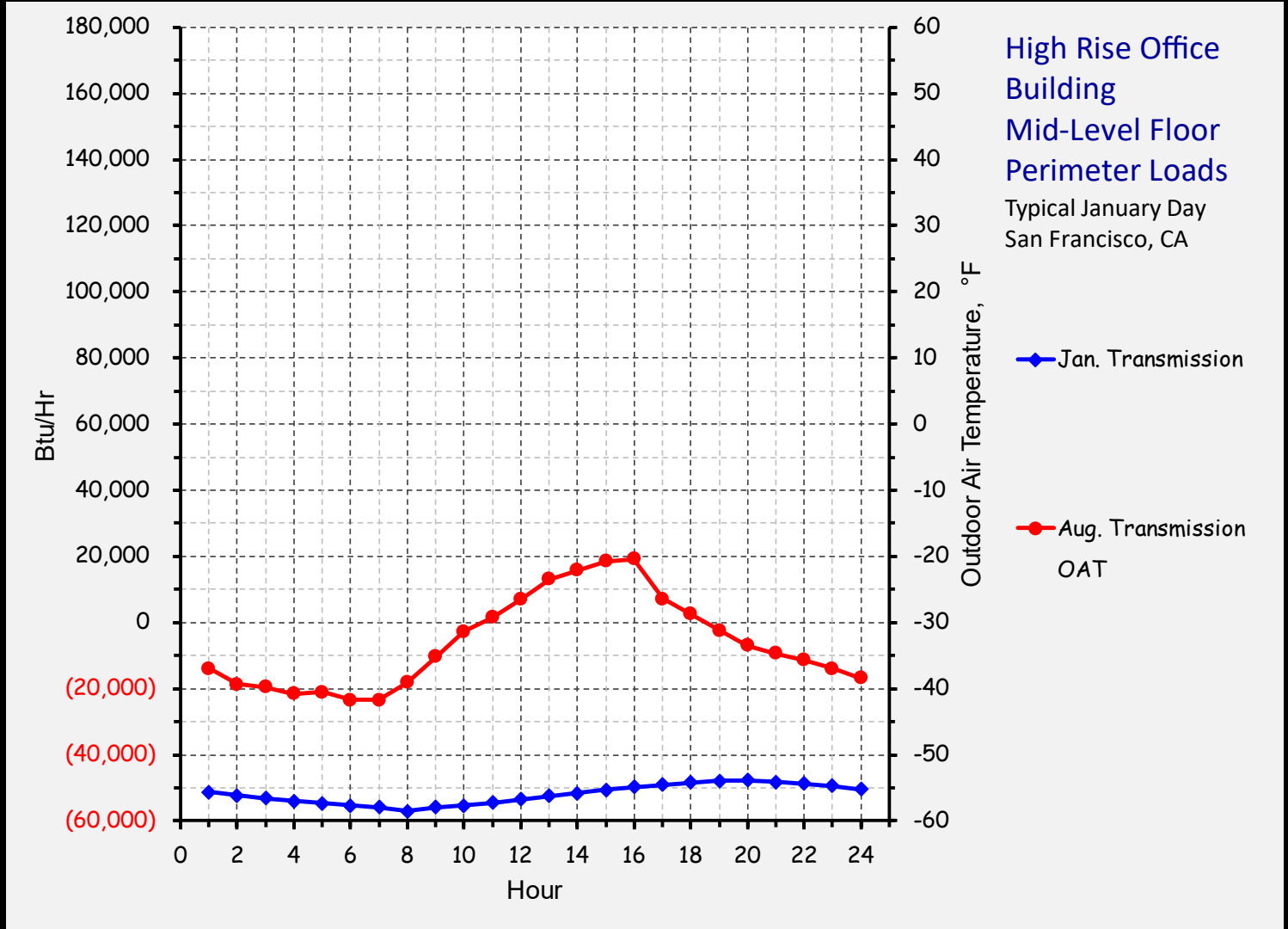
Hour
August Internal
January Internal


High Rise Office Building
Mid-Level Floor Perimeter Loads
Typical January Day
San Francisco, CA
Btu/Hr
Outdoor Air Temperature, °F
Hour
Jan. Transmission
Aug. Transmission
OAT
180,000
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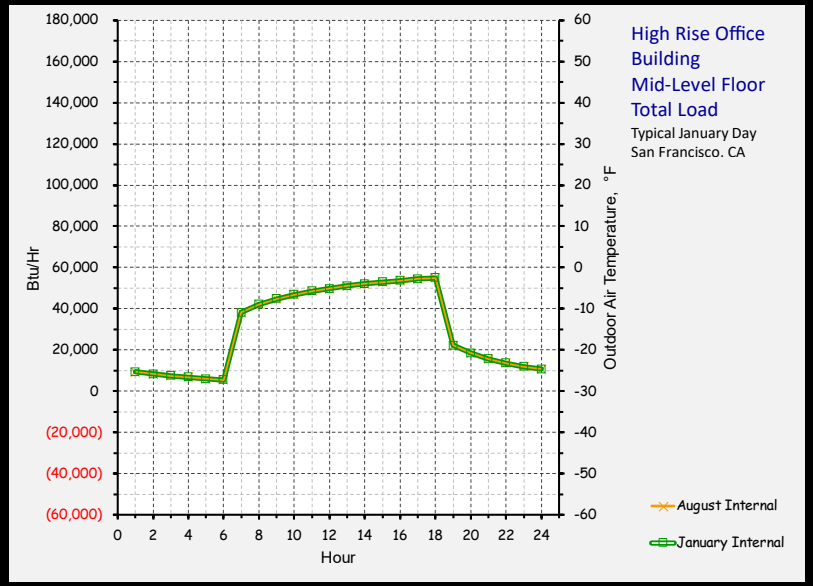
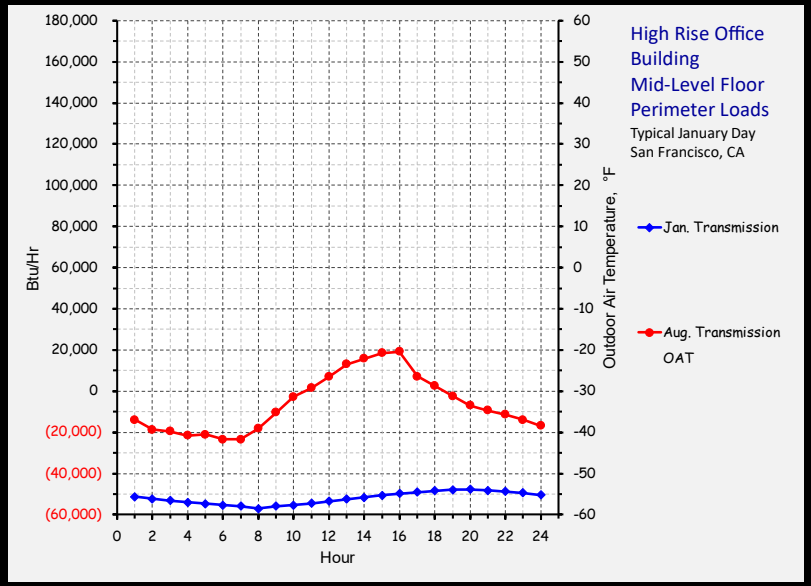
Given the Preceding:

A Question

https://tinyurl.com/HeatPumpLoad02

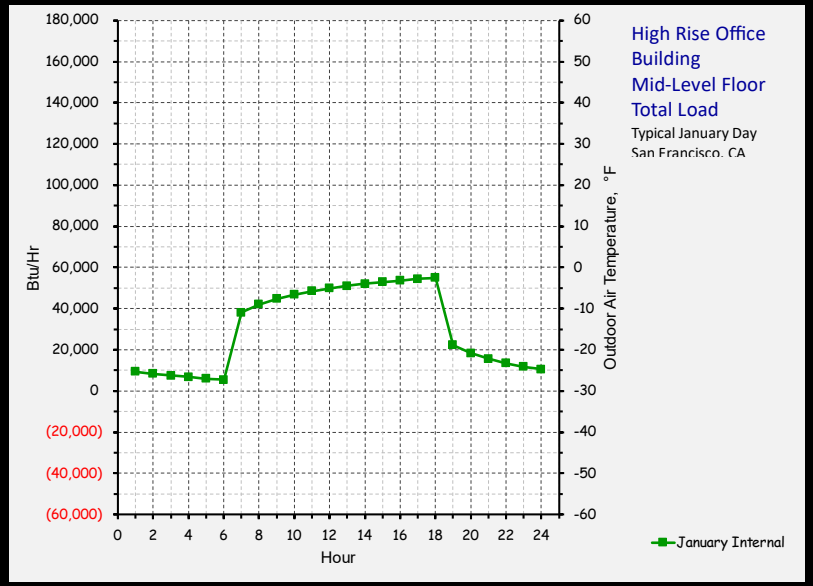


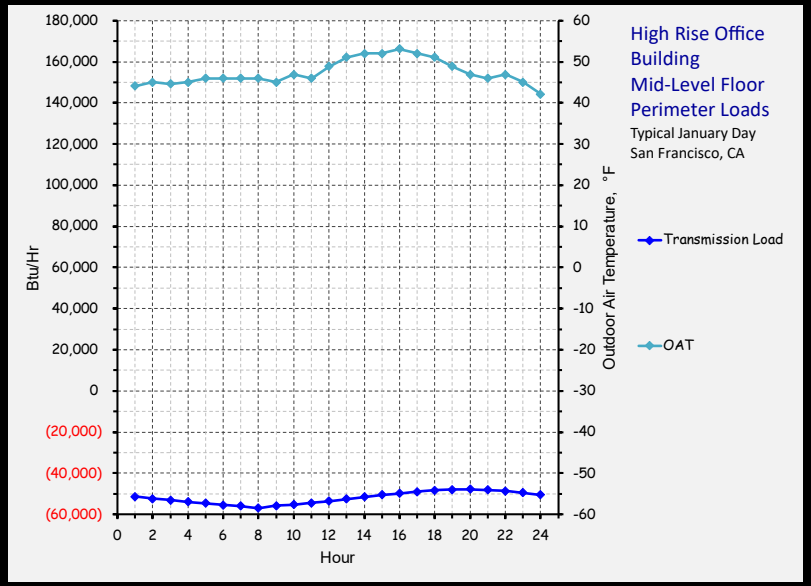


Focusing on January

A Question

https://tinyurl.com/HeatPumpLoad03





Taking a Broader Perspective

A Question

https://tinyurl.com/HeatPumpLoad04

Annual Building Energy Consumption Totals

Facility Description	Annual Site Thermal, kBtu	Annual Site Electric, kBtu
Monterey, California Office/Training Facility	1,299,800	1,245,199
Monterey, California Dental Clinic	402,149,182	650,914,664
Seattle High-rise Office and Courthouse	589,732,280	938,067,784
Columbus Ohio Full Service High Rise Hospitality Facility	36,513,882,901	22,107,926,113
San Francisco California Full Service High Rise Hospitality Facility	18,507,084,000	20,176,973,400

Taking a Broader Perspective

A Question

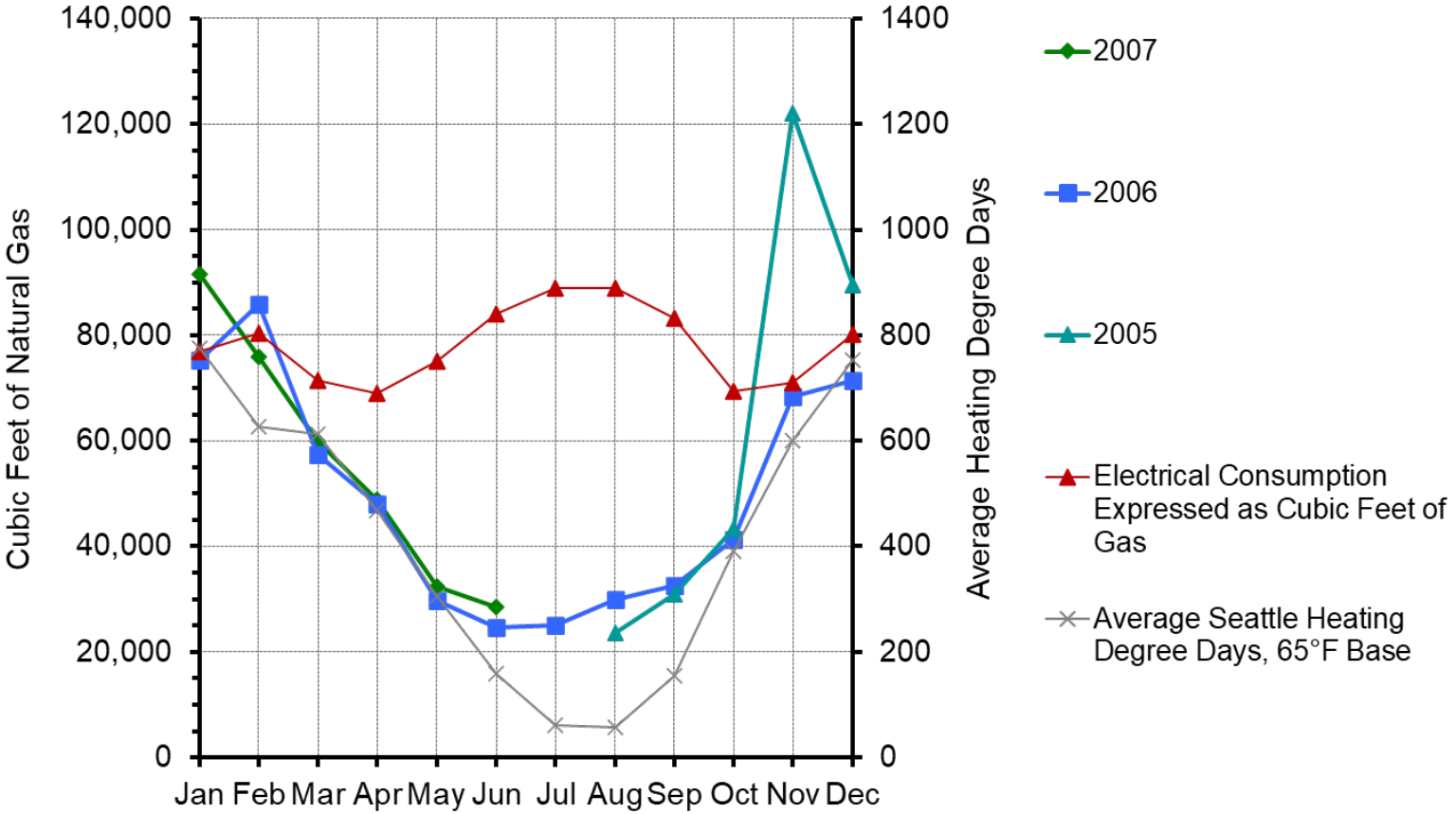
https://tinyurl.com/HeatPumpLoad04

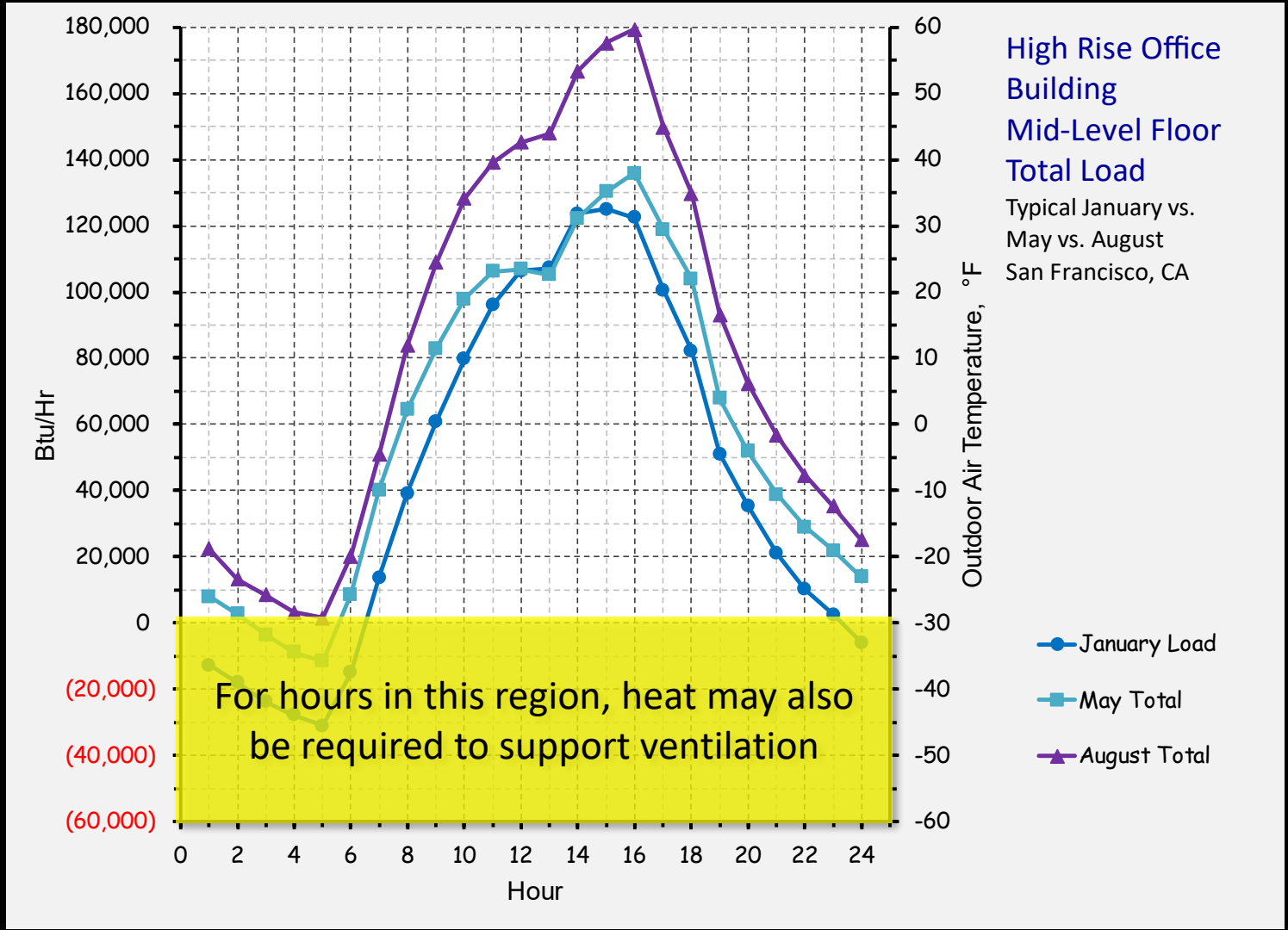
Annual Building Energy Consumption Totals

Facility Description	Annual Site Thermal, kBtu	Annual Site Electric, kBtu	Thermal vs. Electric Difference	
			kBtu (Positive means thermal exceeds electrical)	% of thermal met by electrical when electrical converted to heat
Monterey, California Office/Training Facility	1,299,800	1,245,199	54,601	96%
Monterey, California Dental Clinic	402,149,182	650,914,664	-248,765,482	162%
Seattle High-rise Office and Courthouse	589,732,280	938,067,784	-348,335,504	159%
Columbus Ohio Full Service High Rise Hospitality Facility	36,513,882,901	22,107,926,113	14,405,956,788	61%
San Francisco California Full Service High Rise Hospitality Facility	18,507,084,000	20,176,973,400	-1,669,889,400	109%

Normalized Average Daily Gas Consumption

495 Foot Tall Seattle, WA High Rise




High Rise Office Building
Mid-Level Floor
Total Load
Typical January vs. May vs. August
San Francisco, CA
Btu/Hr
Outdoor Air Temperature, °F
Hour
180,000
160,000
140,000
120,000
100,000
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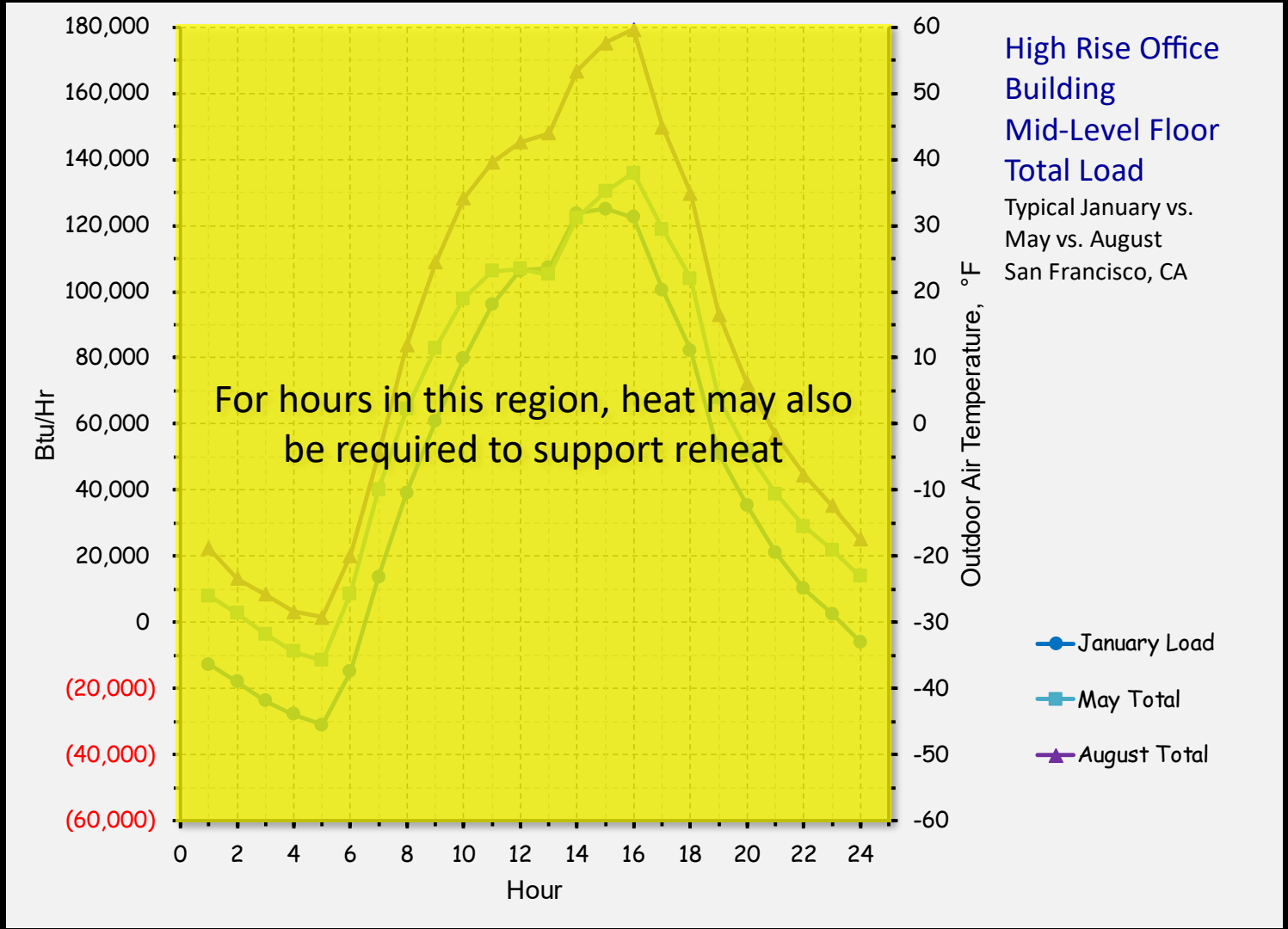
For hours in this region, heat may also be required to support ventilation
January Load
May Total
August Total


High Rise Office Building
Mid-Level Floor
Total Load
Typical January vs. May vs. August
San Francisco, CA
For hours in this region, heat may also be required to support reheat
Btu/Hr
Outdoor Air Temperature, °F
Hour
January Load
May Total
August Total
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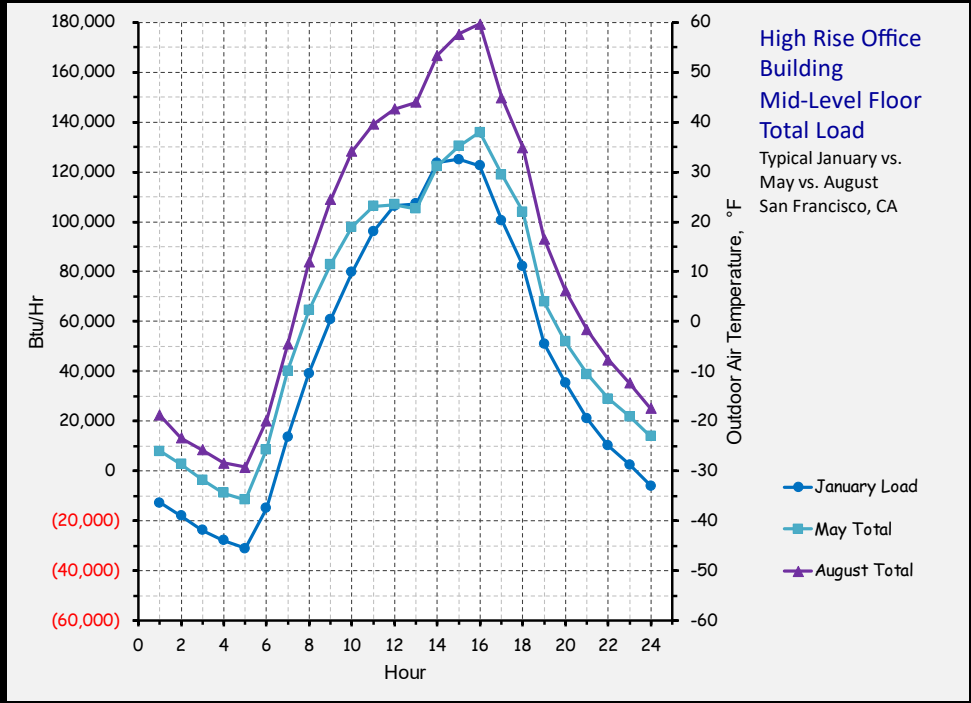
Bottom Line

- Modern buildings generate a lot of heat
- Heat pumps allow us to move that heat from where it is not needed to where it is needed



Question?

Together, Building
a Better California