
# Building Operator Certification – Level I

BUILDING OPERATOR CERTIFICATION

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

NYC Department of Education
*Dennis M. Walcott, Chancellor*

NYC DEPARTMENT OF EDUCATION • DIVISION OF SCHOOL FACILITIES • DSF

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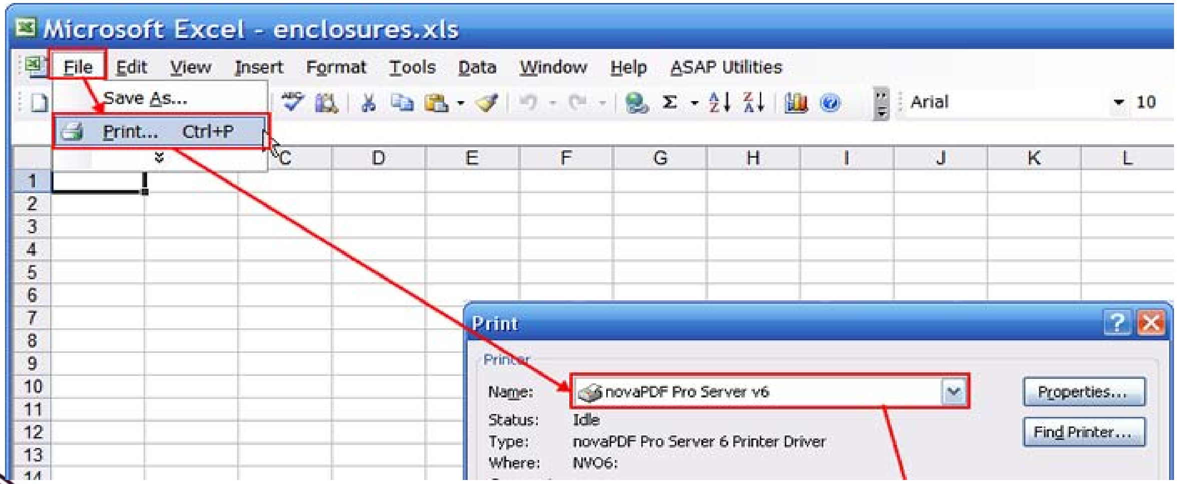
CUNY The City University of New York

Class 10

# Excel Training for BOC Program

- Excel Worksheet – Increase your Skills
- Useful for the Energy Project – Practical Project 2B
- One Hour class – just one hour
- Offered during lunch break of Class 11
- Mon, Tues, Wed, Thurs - August 22, 23, 24,25
- Reserve with Deslyn: DGeorge5@schools.nyc.gov



# 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.

# Welcome to Class 10

- Practical Project 1B is due
- Lighting Survey Form – Exercise
- Major Loads & Demand Response List
- Please put into your Project Folder

Recommended to keep all of your other class materials to review for the exams:

- Pop Quizzes
- Hand Outs
- Keep these in your Course Book
  not in your Project Folder

# Routine for Class 10 – Class and Exam

- **Hour 1 – Class with some new material**
- **Hour 2 – Review for Exam**
- **Hour 3 – Exam is multiple choice – 25 Q**

**Routine –** We move the desks into longer columns during the break, right before the exam.  We slide the desks into columns.

CERTIFICATION

# Refrigeration & Air Conditioning

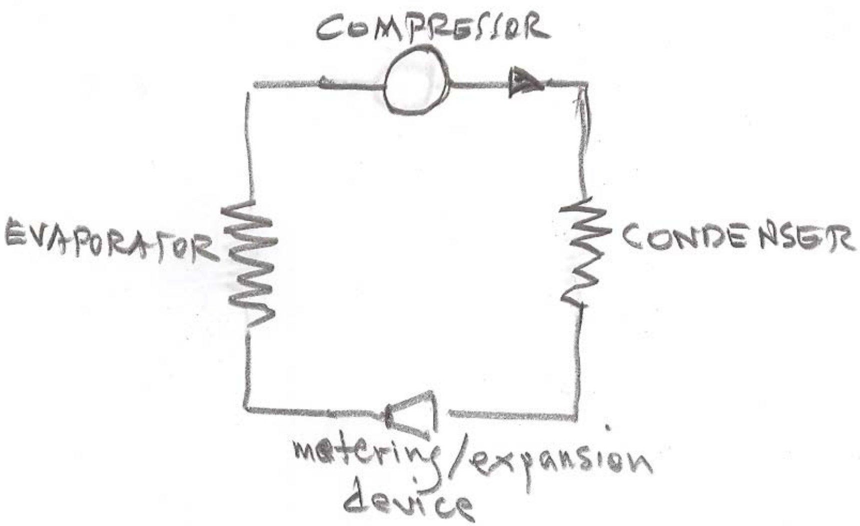
**Objectives**

- What is the vapor-compression cycle?
- What are the basic components in v-c cycle refrigeration / and air-conditioning equipment?
- What are key sources of inefficiency in refrigeration and AC equipment that can be addressed through O&M?
- Recall learning from section 2 classes

# Agenda

- Basic Vapor-Compression Refrigeration Cycle – How it Works
- Operational Impacts on Refrigeration Cycle – Efficiency and Energy Use
- Review for Exam
- Exam
- Reflections and Evaluation Form
- Reading Assignments

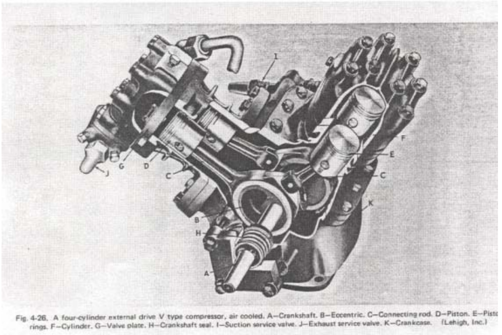
# Refrigeration: Vapor-Compression Cycle




## 4 Basic Components

- compressor
- expansion valve
- evaporative coil
- condenser coil

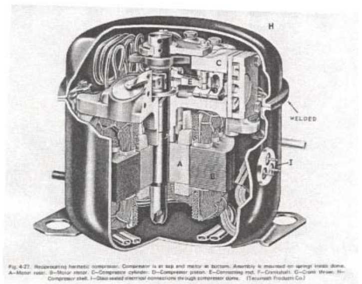
## Types of Compressors



**Reciprocating Compressor**

*Photo courtesy of Modern Refrigeration and Air Conditioning, 1979*

Compressor Illustrations

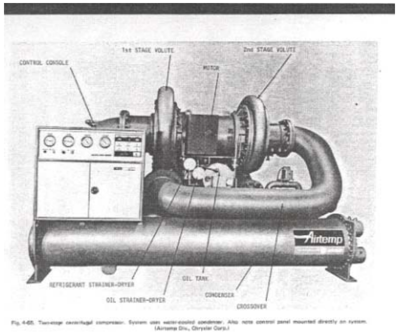



**Hermetic Reciprocating Compressor**

*Photo courtesy of Modern Refrigeration and Air Conditioning, 1979*

Electric drive most common but also can be

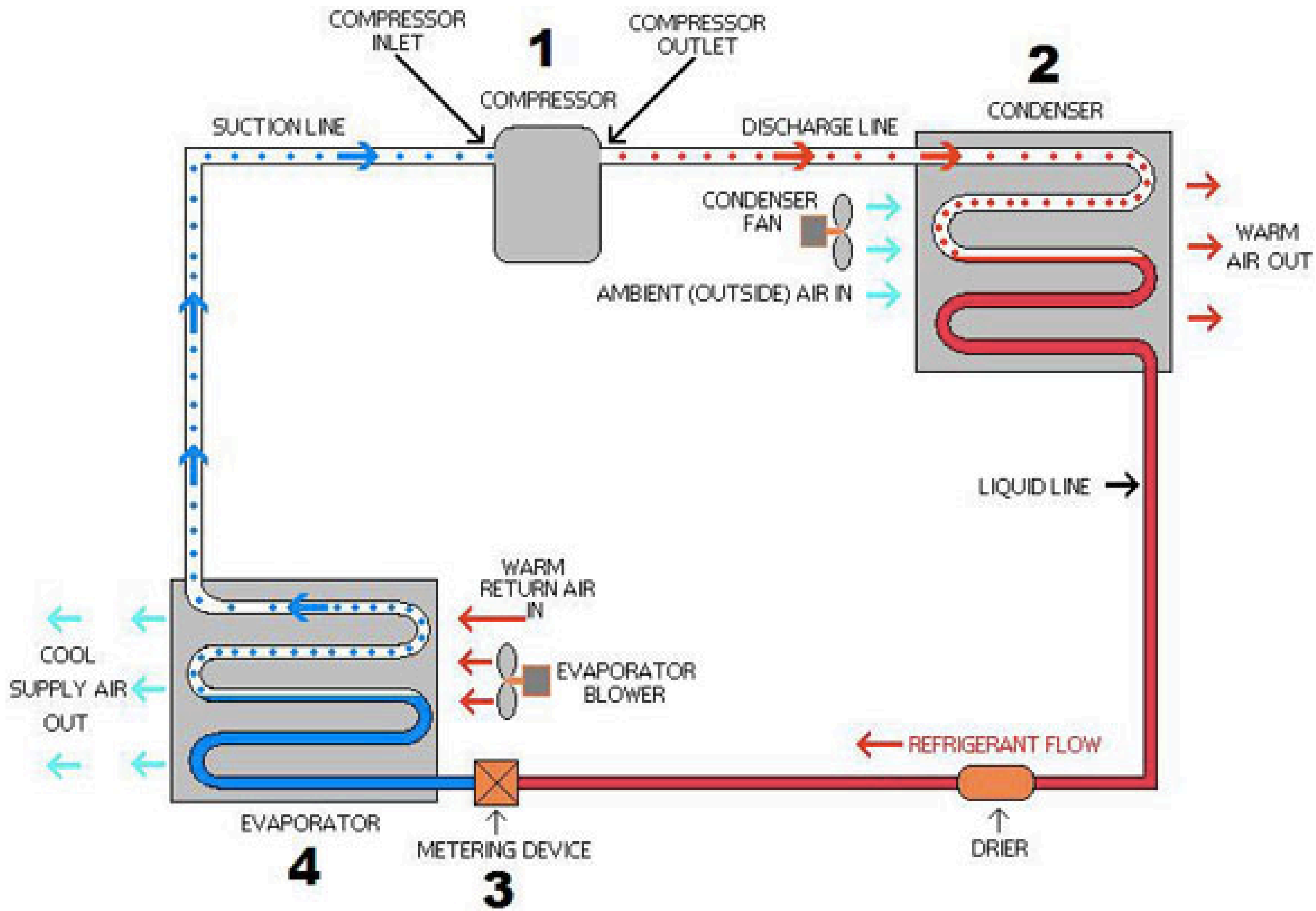
- Steam
- Gas engine



**Centrifugal Compressor**

*Photo courtesy of Modern Refrigeration and Air Conditioning, 1979*

# Refrigeration: Vapor-Compression Cycle



# Refrigerants

- CFC
  - R11, R12, R502 – out of production
- HCFC
  - R22, R123 – being phased out
- HFC
  - R134a
- Ammonia
  - R717 in industrial and food processing

Chlorine impacts on upper atmosphere - Ozone depletion

International agreement – Montreal Protocol, eliminating use of CFC

Certification for handling, especially to prevent venting to atmosphere during service

# Refrigerant Pressure-Temperature Table

- Specifies what pressures and temperatures should be around the cycle for any given refrigerant

- Provides basis for diagnosis of cycle performance

| °F Temp | R717 psig | R22 psig | R134a psig | R404a psig |
|---|---|---|---|---|
| -60 | 18.6 | 11.9 | 21.6 | – |
| -55 | 16.7 | 9.2 | 20.2 | – |
| -50 | 14.4 | 6.4 | 18.6 | 0.64 |
| -45 | 11.8 | 2.7 | 16.7 | 2.77 |
| -40 | 8.8 | 0.6 | 14.7 | 5.12 |
| -35 | 5.5 | 2.6 | 12.3 | 7.72 |
| -30 | 1.7 | 4.9 | 9.7 | 10.57 |
| -25 | 1.2 | 7.5 | 6.8 | 14.39 |
| -20 | 3.5 | 10.2 | 3.6 | 17.08 |
| -18 | 4.5 | 11.4 | 2.2 | 18.52 |
| -16 | 5.6 | 12.6 | 0.7 | 19.47 |
| -14 | 6.7 | 13.9 | 0.4 | 21.55 |
| -12 | 7.8 | 15.2 | 1.2 | 23.15 |
| -10 | 9.0 | 16.5 | 2.0 | 24.79 |
| -8 | 10.2 | 17.9 | 2.8 | 26.50 |
| -6 | 11.5 | 19.4 | 3.7 | 28.25 |
| -4 | 12.8 | 20.9 | 4.6 | 30.07 |
| -2 | 14.2 | 22.4 | 5.5 | 31.94 |
| 0 | 15.6 | 24.0 | 6.5 | 33.87 |
| 1 | 16.4 | 24.8 | 7.0 | 34.86 |
| 2 | 17.1 | 25.7 | 7.5 | 35.87 |
| 3 | 17.9 | 26.5 | 8.0 | 36.89 |
| 4 | 18.7 | 27.4 | 8.6 | 37.92 |
| 5 | 19.5 | 28.3 | 9.1 | 38.97 |
| 6 | 20.3 | 29.1 | 9.7 | 40.04 |
| 7 | 21.1 | 30.0 | 10.2 | 41.12 |
| 8 | 22.0 | 31.0 | 10.8 | 42.22 |
| 9 | 22.8 | 31.9 | 11.4 | 43.34 |
| 10 | 23.7 | 32.8 | 12.0 | 44.47 |
| 11 | 24.6 | 33.8 | 12.6 | 45.62 |
| 12 | 25.5 | 34.8 | 13.2 | 46.79 |
| 13 | 26.4 | 35.8 | 13.8 | 48.97 |

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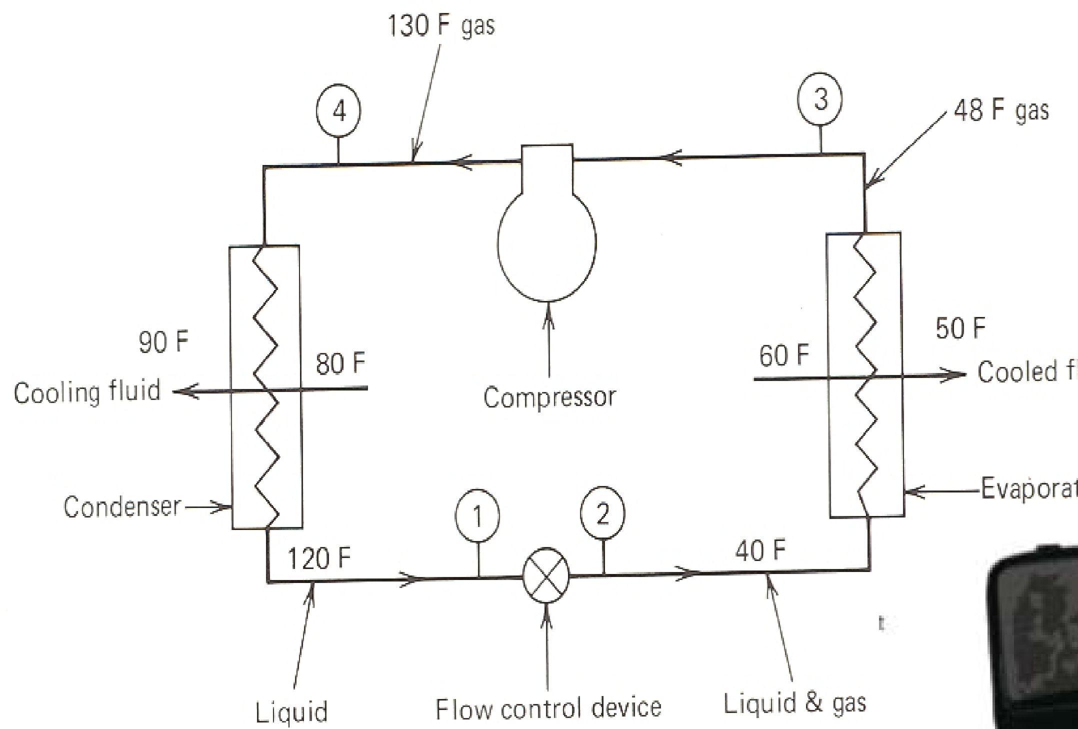
# V-C Cycle Performance

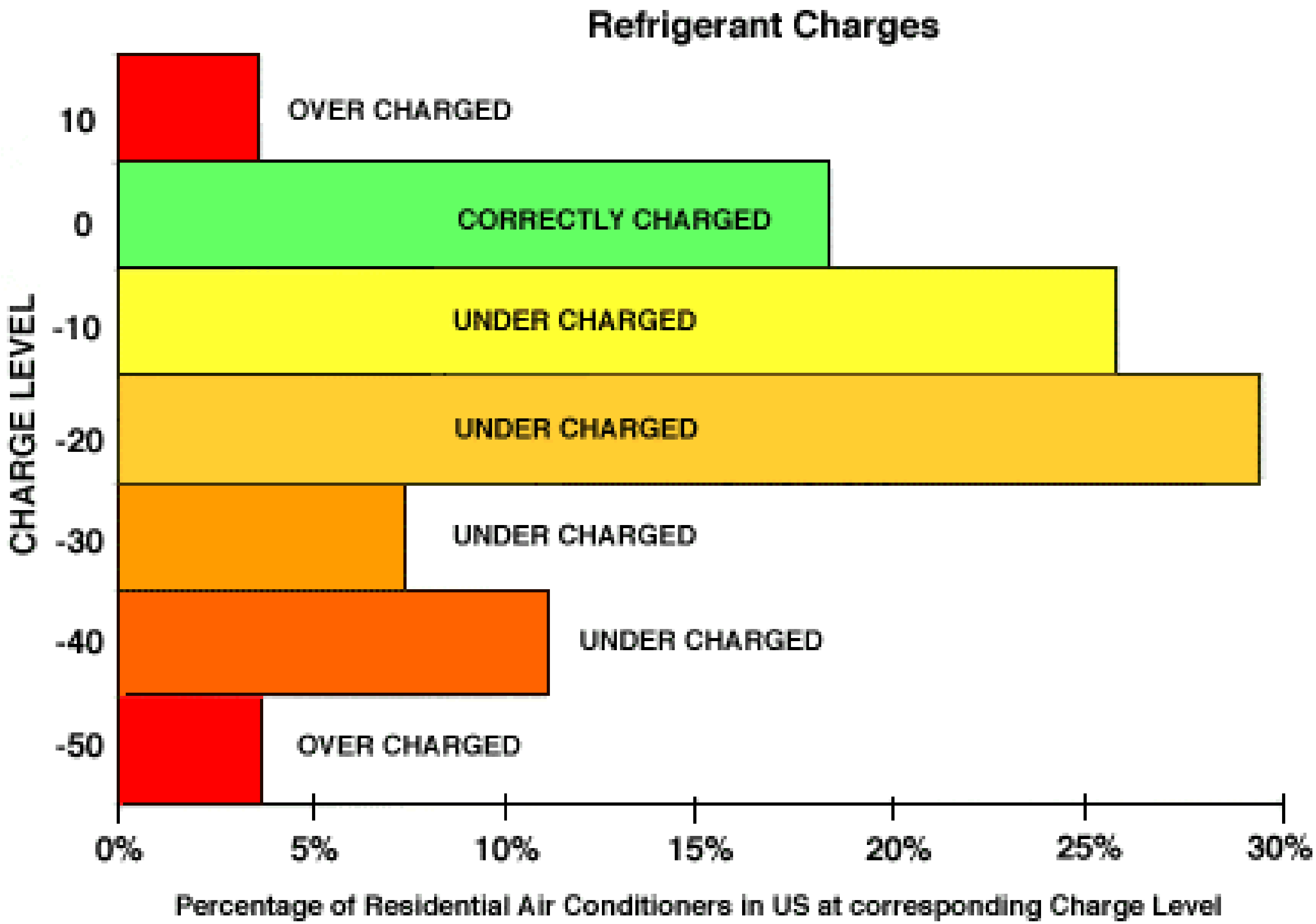
- Diagnose using temperature and pressures across the cycle
- **Some of the most common defects are addressable by maintenance**:
  - Dirty coils
  - Blocked air flow
  - Low refrigerant charge




Automated diagnostics:

Honeywell Service Assistant

# Survey of DX equipment by Proctor Engineering



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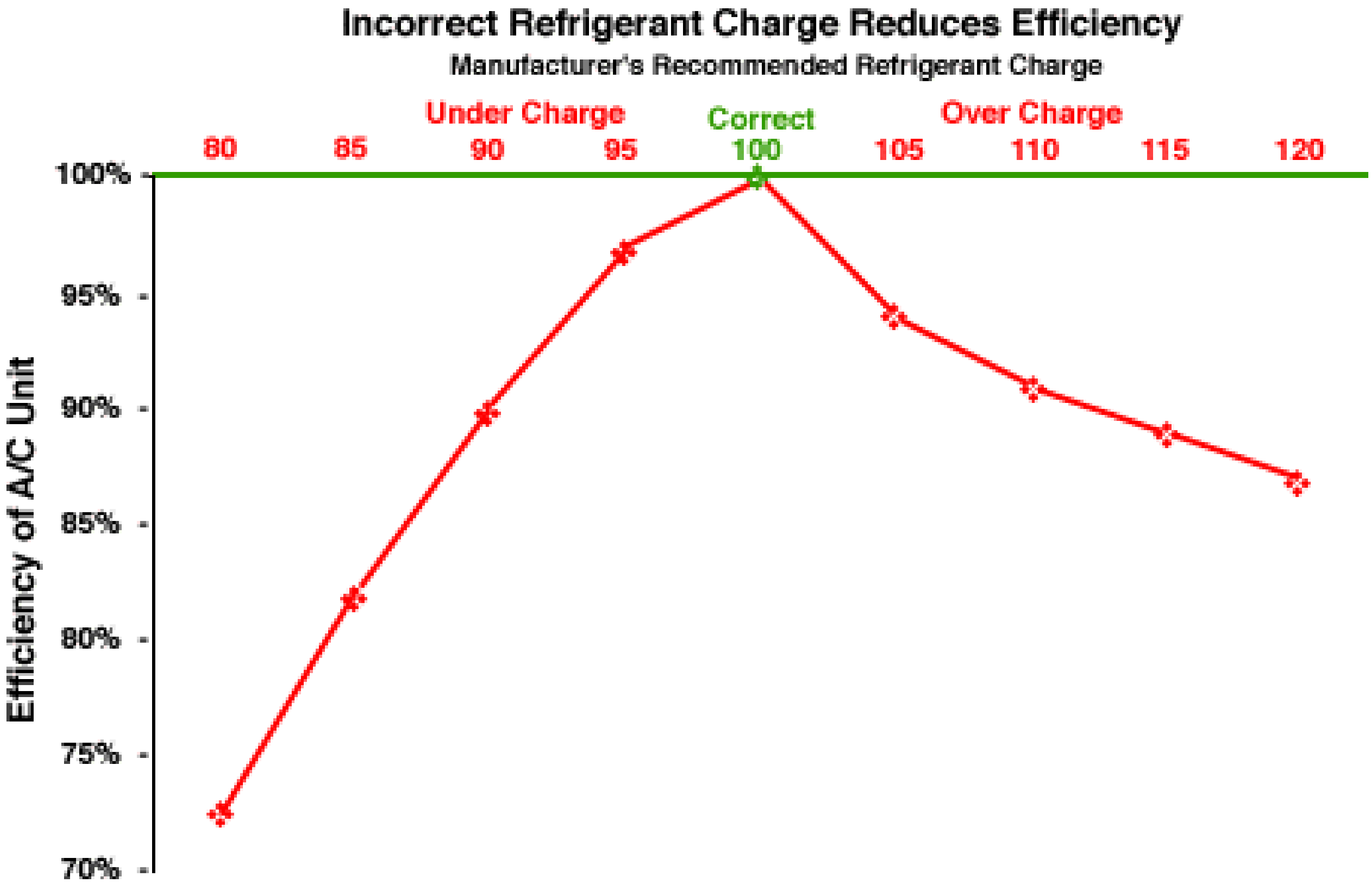
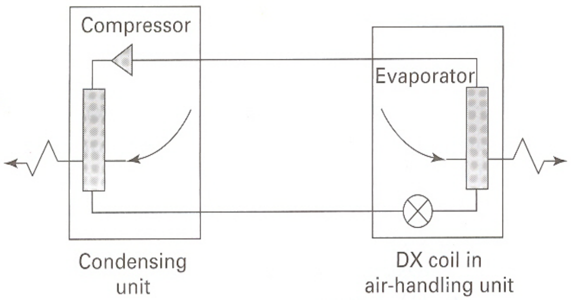


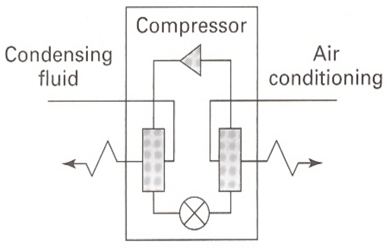
# Refrigeration & Air Conditioning Equipment

The Vapor-Compression cycle is used in many different configurations and equipment packages, based on direct refrigerant expansion (**DX units**):

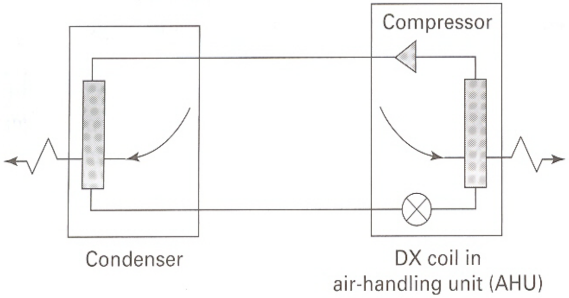
- Room unit air conditioners
- Split Systems
- Packaged Rooftop units
- Heat Pumps



Split system



Unitary package

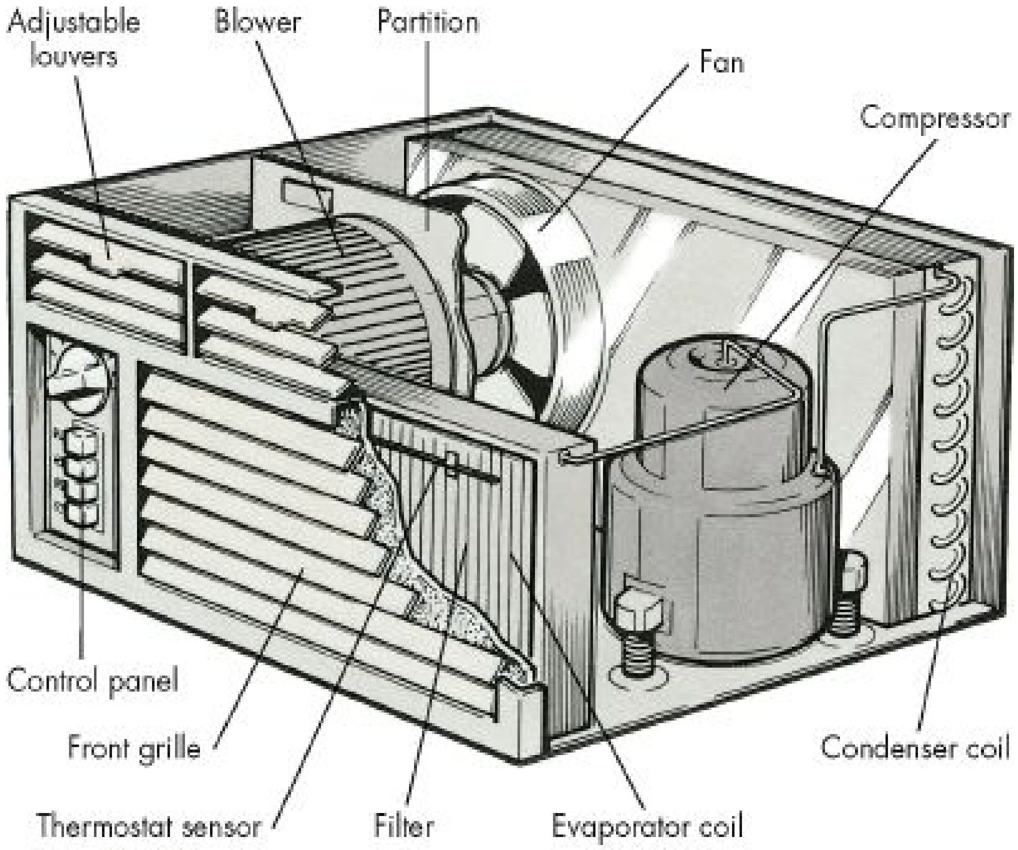


Unitary with remote condenser

# Refrigeration & Air Conditioning Equipment

The Vapor-Compression cycle is used in many different configurations and equipment packages, based on Direct refrigerant expansion units (DX):

- **Room unit air conditioners**
- Split Systems
- Packaged Rooftop units
- Heat Pumps



# Refrigeration & Air Conditioning Equipment

## Typical Packaged Rooftop Unit

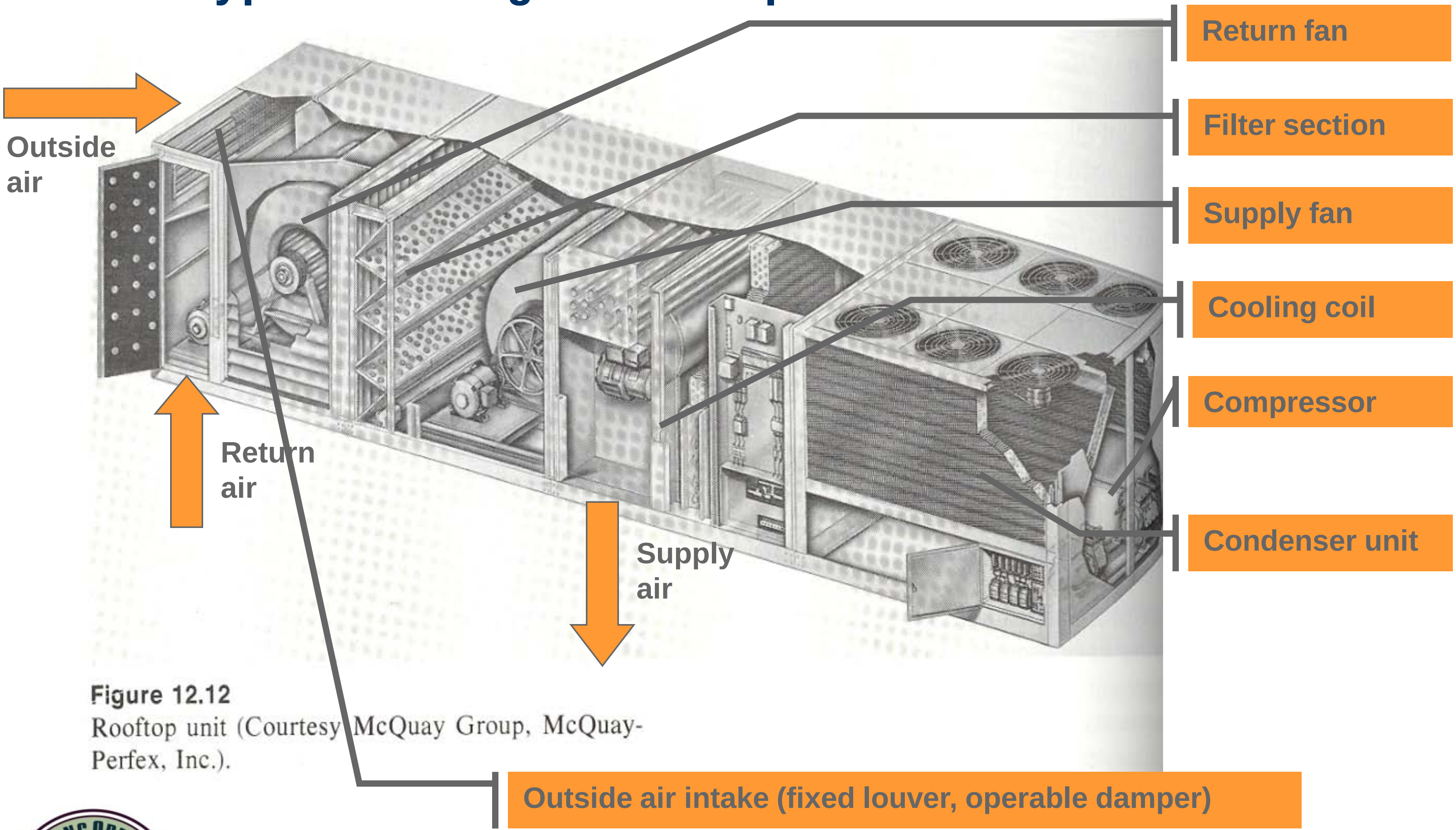



**Figure 12.12**
Rooftop unit (Courtesy McQuay Group, McQuay-Perfex, Inc.).

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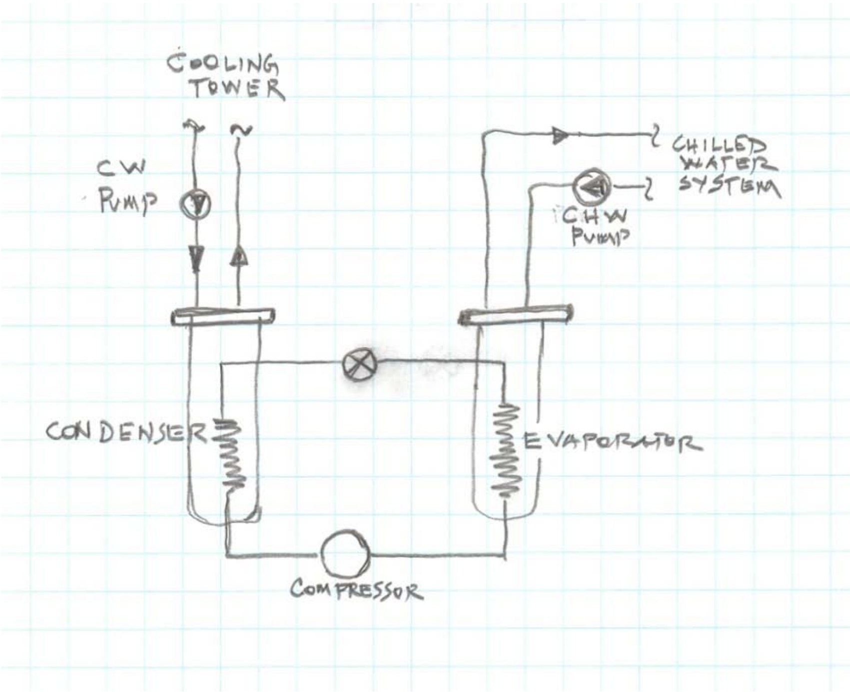
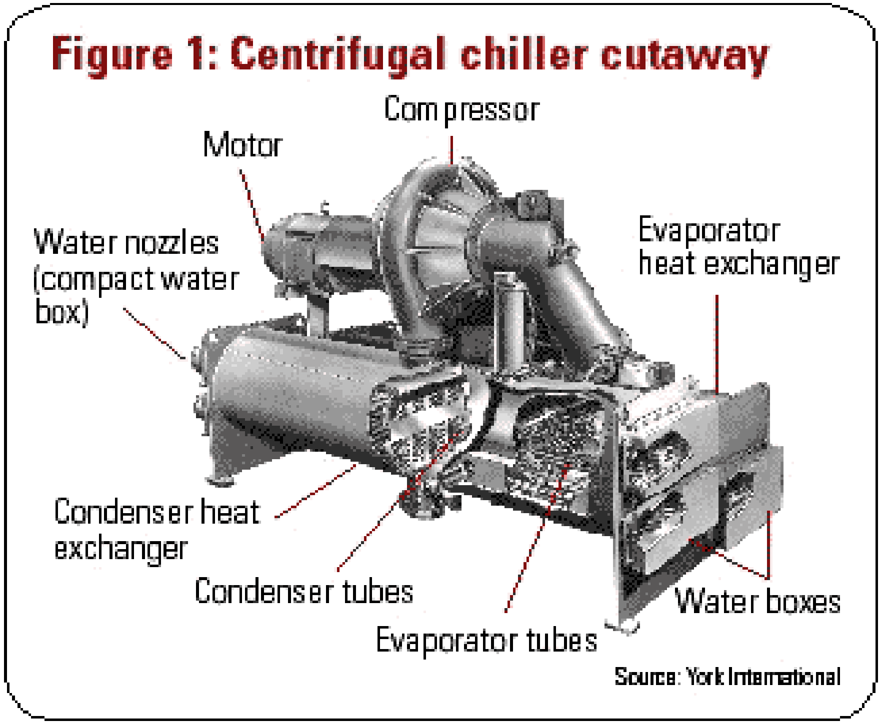
# From Air Cooled Direct-Expansion System to a Water Cooled Chiller System – Simplified Schematic



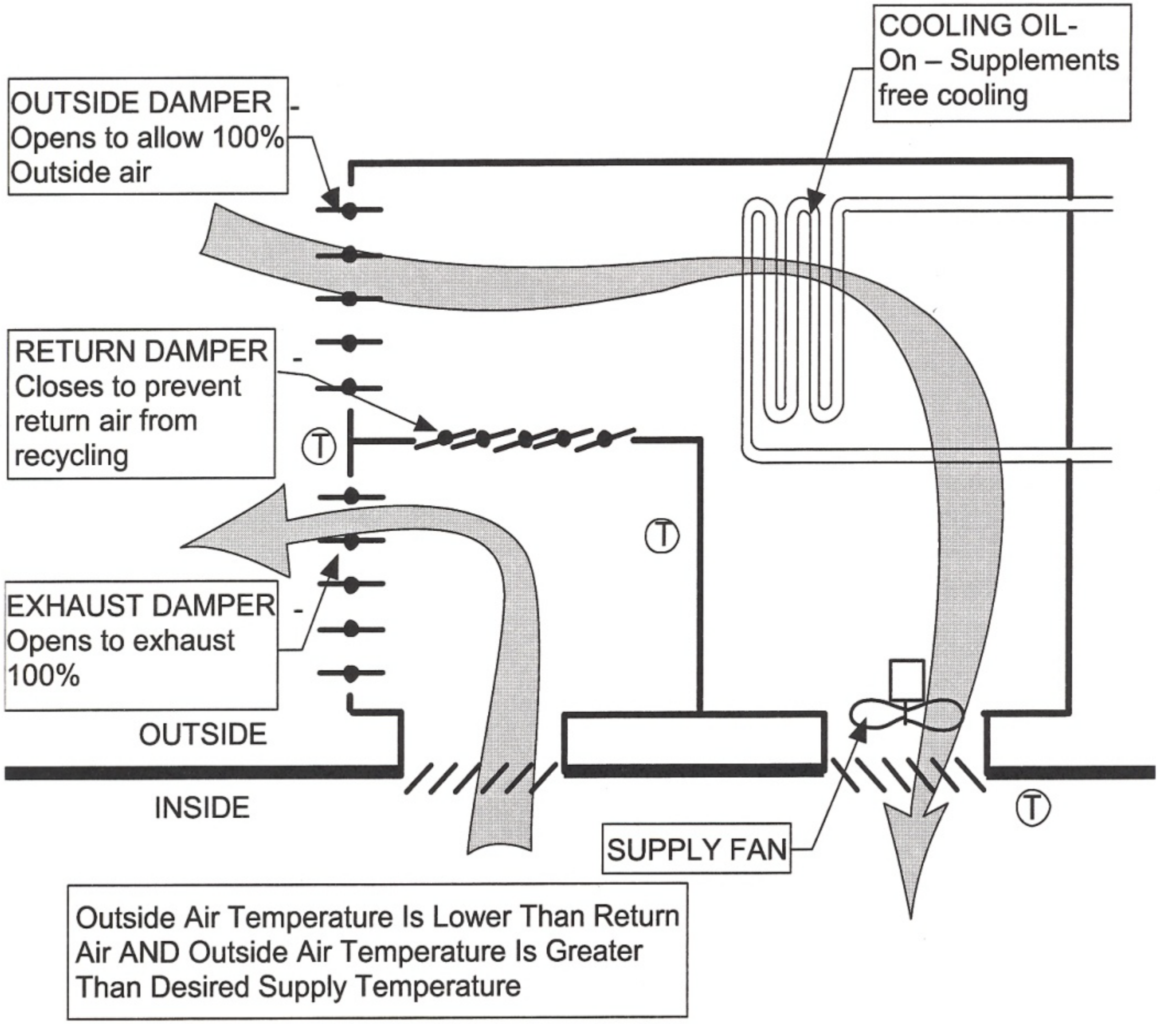

- Larger central systems use Shell-and-tube heat exchangers
- Evaporator coils produce chilled water
- Circulating pumps for chilled water and condenser water systems

# Maintenance and Optimizing

- General & Preventive maintenance can significantly improve efficiency !!
- Clean filters and coils (for good air flow)
- Maintain correct refrigerant charge
- Thermostat – Check for correct temperature
  Controls are calibrated
- Use time-clocks for end-of-day shut-down
- Make sure outside air economizer cycle works properly - have a Functional Test procedure

# Air-side Economizer on RTU or AHU

- Use outside air when temperature is cooler than the return air temperature
- Coordination of dampers
- Reliability of sensors



# Break

**Routine –**

We move the desks into longer columns during the break, right before the exam.

Slide the desks into columns now.

**Next: Review for Exam**

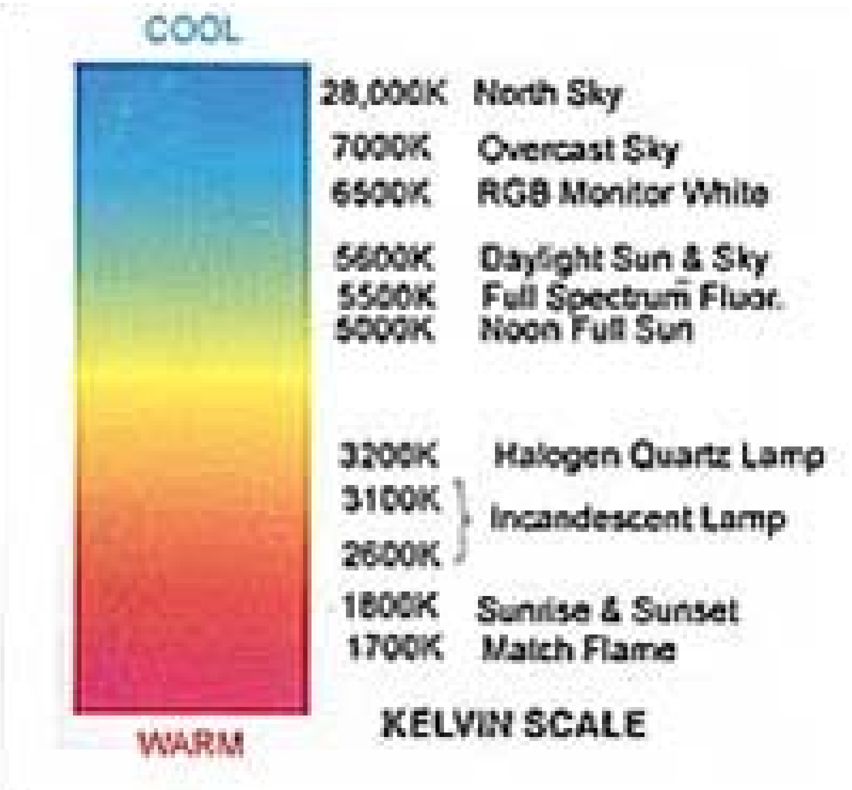
# Light Level Recommendations

**Lighting Level Recommendations**

The Oregon Office of Energy has developed a list of lighting level recommendations for the
performed in buildings. Lighting levels for various function areas have been identified. Th
levels have been selected based on criteria established by the Illuminating Engineering Soci

| Functional Area | Light Level | Lighting Power Density |
|---|---|---|
| Classrooms | | |
| • Standard | 50 FC | 1.2 W/SF |
| • High Task - Drafting | 75 FC | 1.5 W/SF |
| • Science Labs | 50-75 FC | 1.2 - 1.5 W/SF |
| • Home Economics | 50-75 FC | 1.2 - 1.5 W/SF |
| • Industrial Arts | 50-75 FC | 1.2 - 1.5 W/SF |
| Cafeteria | | |
| • Eating Area | 20 FC | 0.6 W/SF |
| • Food Preparation | 75 FC | 1.5 W/SF |
| Computer Rooms | 35 FC | 0.8 W/SF (1) |
| Conference Rooms | 35 FC | 0.9 W/SF |
| Hallways/Lobbies | 20 FC | 0.7 W/SF |
| Gymnasium | | |
| • General | 30 FC | 1.0 W/SF (2) |
| • Exhibitions/Matches | 50 FC | 1.4 W/SF (2) |
| Library | | |
| • Reading Area | 50 FC | 1.2 W/SF |
| • Stacks | 35 FC | 1.0 W/SF |
| • Check in/out | 75 FC | 1.5 W/SF |

# Color Temperature




5000K Blue

4500K Cool

4100K Cool White

3500K Warm

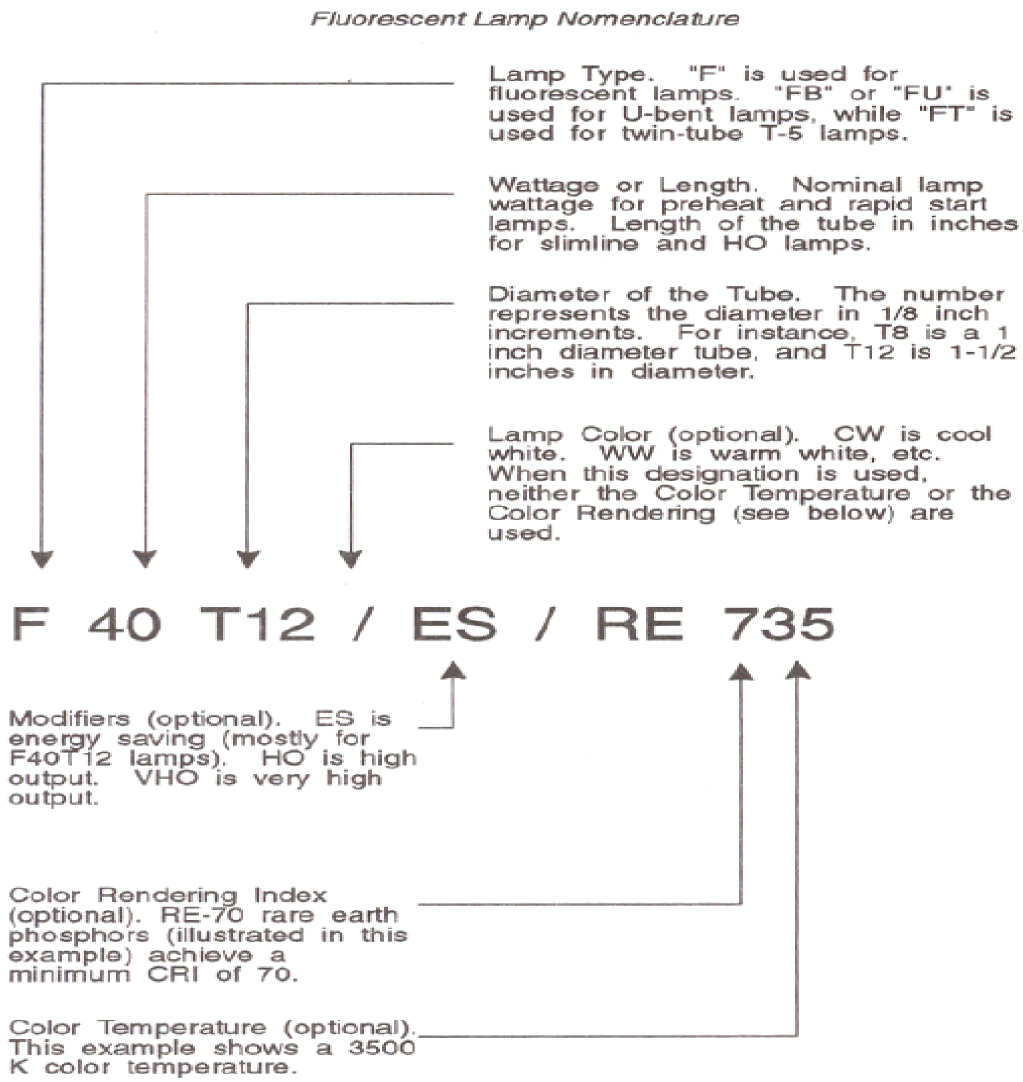
# Lighting O&M: Hard-to-reach spots

How much does it cost to change a lamp?

In a hard-to-reach spot?

What does this tell you about lamp selection?

# Lamp Nomenclature



# Total Lighting Power

Example Problem:

You have two classrooms with 20 fluorescent lamps per room, and each lamp is a F32T8EL835. The ballast use 10% of the total power.

What is the total lighting wattage of the classrooms?

2 x 20 x 32 = ______ Watts

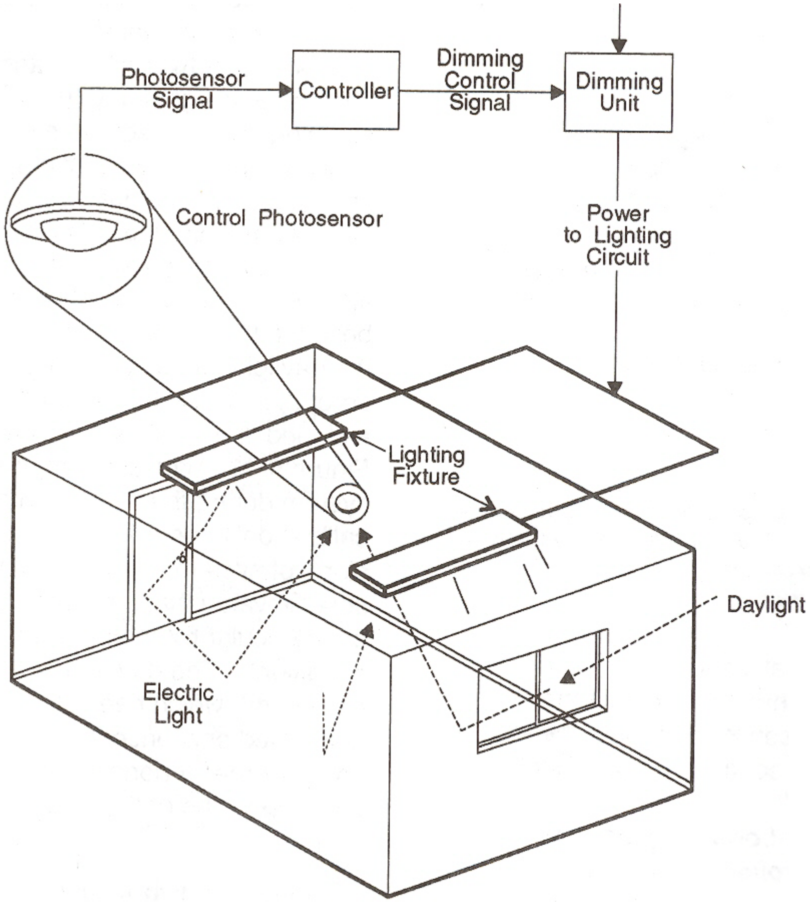
Ballast +10% = ______ Watts

Total = ______ Watts

# Energy Usage of Lighting

- Lighting Power Density = Watts per sq foot
  - Energy Codes are written to set a Maximum Limit on Watts per sq foot
  - Reflects “connected lighting load”, KW
  - Does not take lighting level into account

# Lighting Controls:  Day-lighting




## Control systems

- Control in relation to available daylight.
- Measure light level, dim electric when above set-point.

## Operational Issues

- Avoid “hunting”
- How do you know if it’s working?

# Series and Parallel Circuits

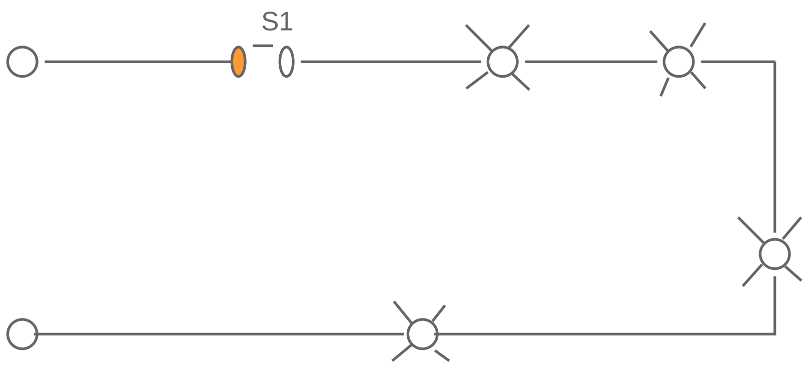
*Series circuits*

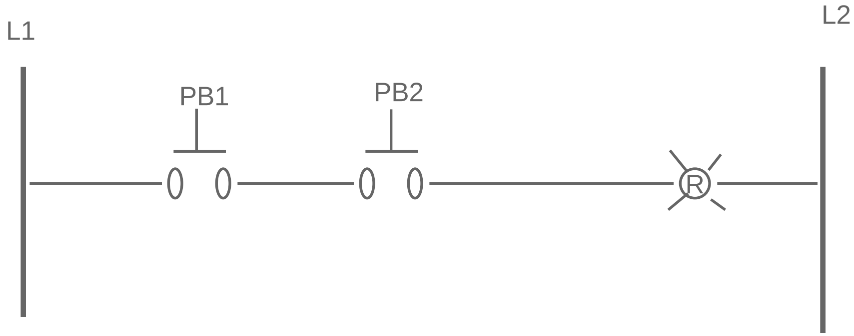
...have only one pathway for current flow.

*Parallel circuits*

...have at least two pathways for current flow.

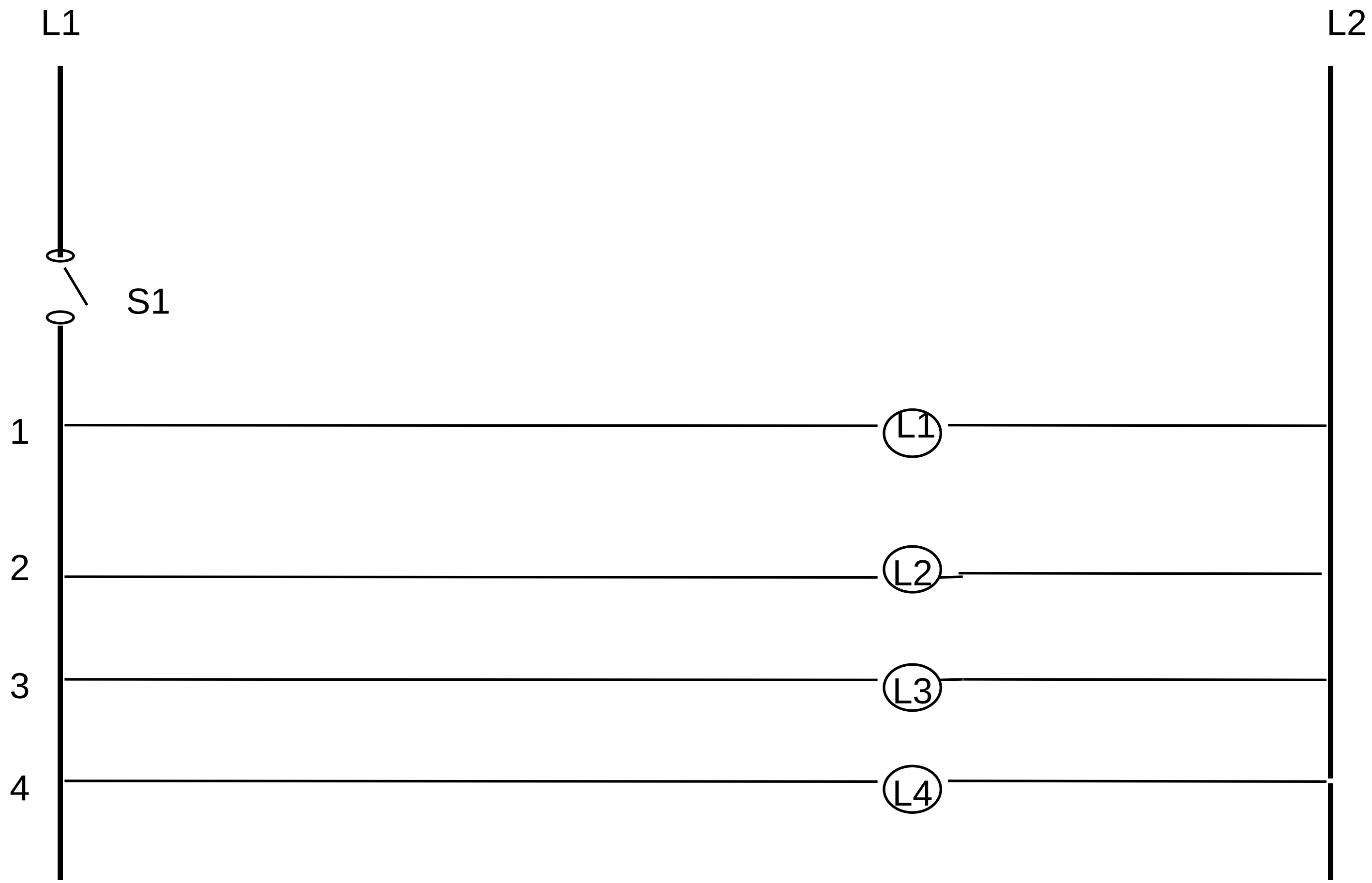
# Series Circuits




- There is only one pathway for current flow
- Switch is controlling all the lights in the circuit
- The two Push Buttons are in series with the light
- When either one is open, what happens?

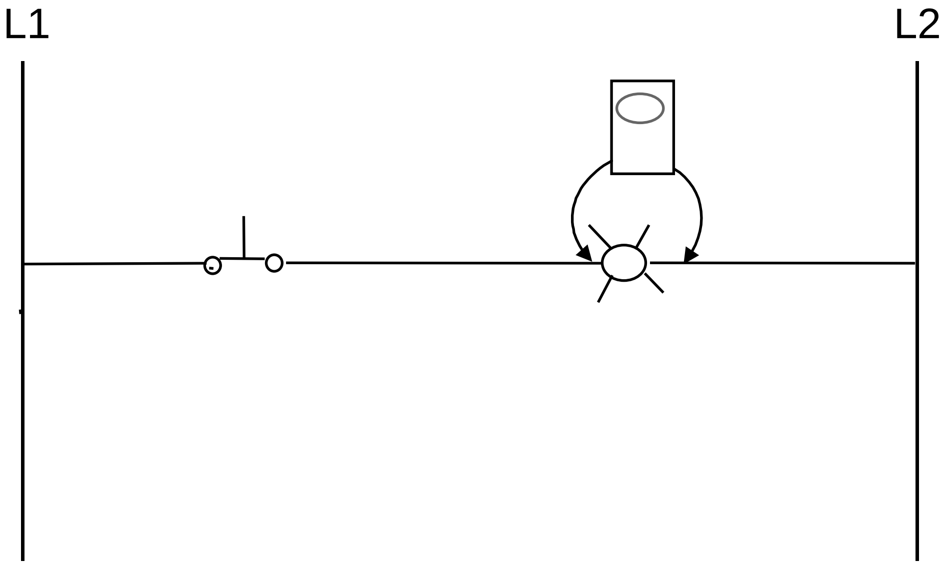
# Parallel Circuits




This Parallel circuit contains four separate pathways for current flow.

# Measuring Voltage

- Voltage measurements are taken in parallel
- Voltage drop is voltage used at a load




Connect the volt meter in parallel with the component being tested.

# Electrical Laws & Equations

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

$$\text{Current} = \frac{120\ \text{Volts}}{10\ \text{Ohms}} = 12\ \text{Amps}$$

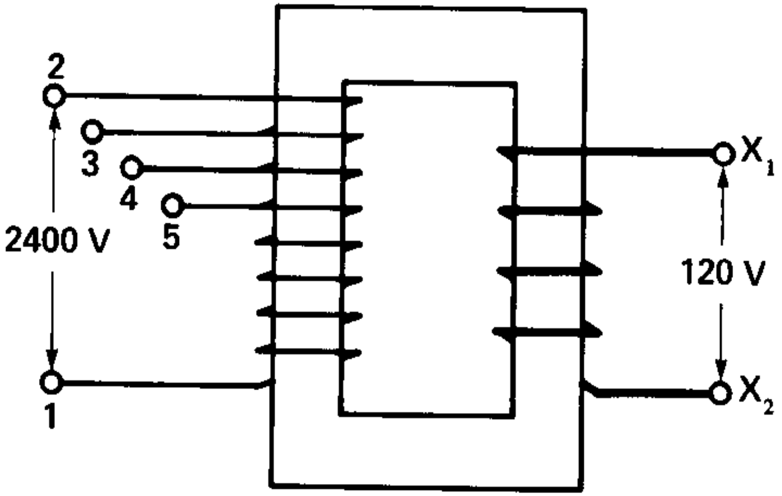
**Power = Voltage x Current**

**Power = 120 Volts x 5 Amps**

**Power = 600 Watts**

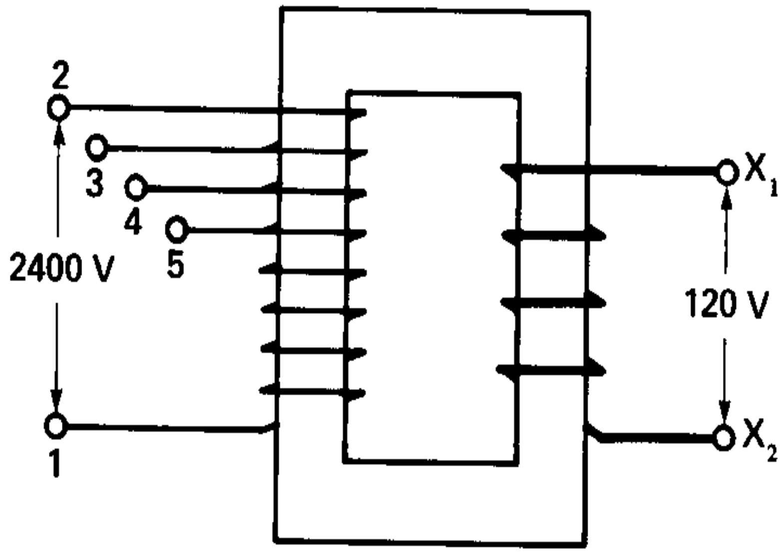
# Electrical Induction: Transformers

- Raise or lower voltages
- Have primary and secondary coils
- Ratio of Turns = Ratio of Voltage



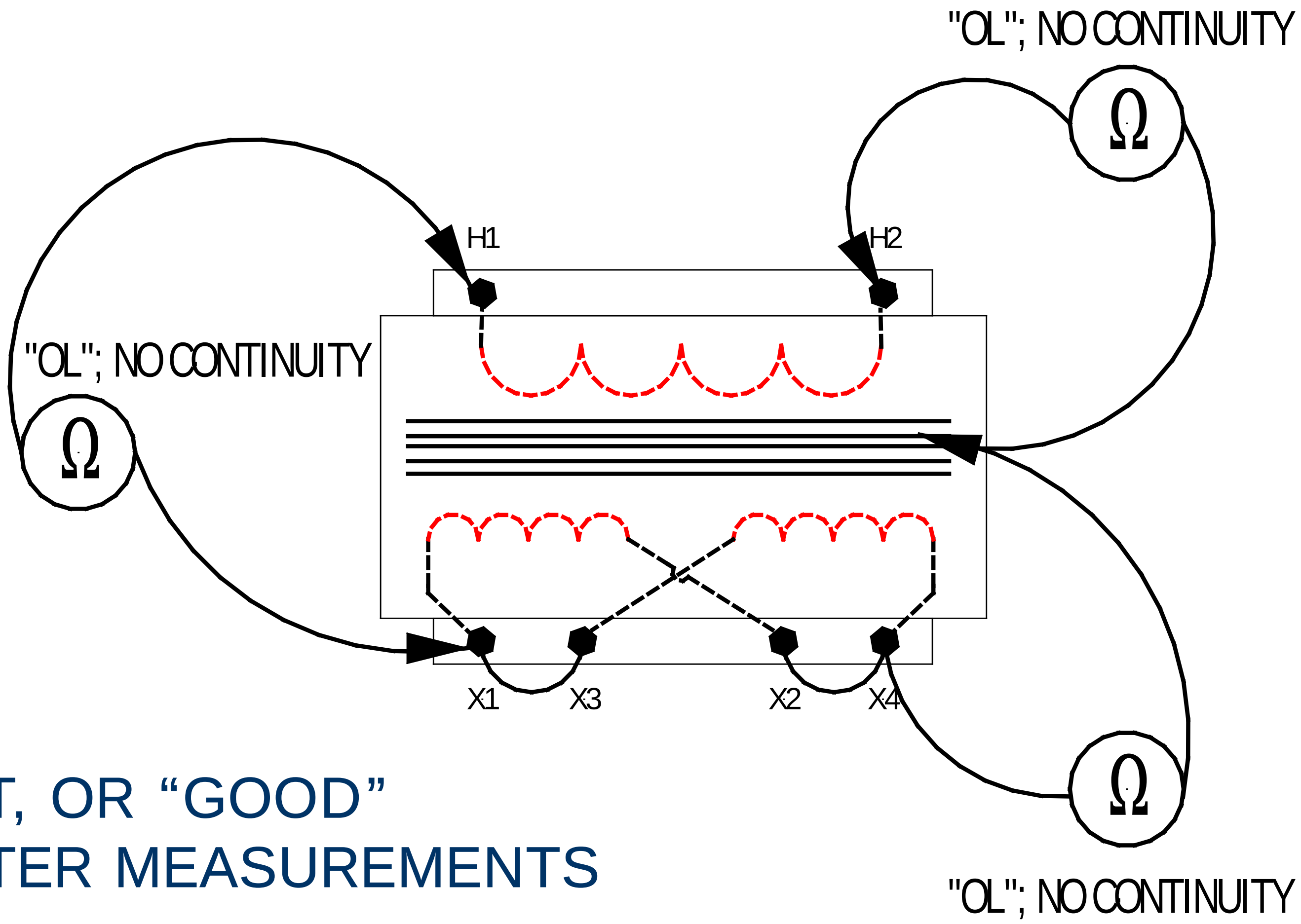
# Electrical Induction: Transformers

- Power in = Power out
- Volts x Amps in = Volts x Amps out
- 480V x 100 Amps = 240V x



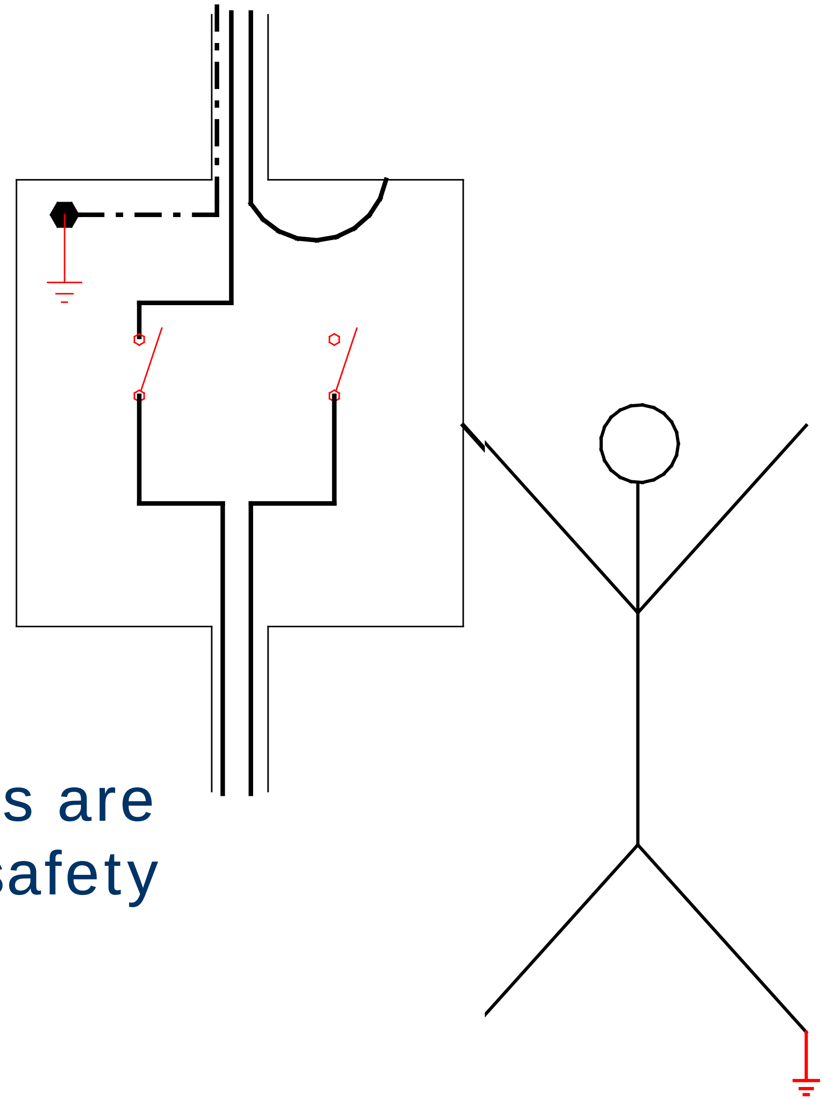

- Capacity = Volts Amps

# Testing a Transformer with Ohm Meter
# Multi-Meter is set to measure Resistance




CORRECT, OR "GOOD"
OHM METER MEASUREMENTS

# How Ground Circuits Work



Ground wires are part of the safety circuit.

For a water source near electricity …

# Lock-outs and Tag-outs

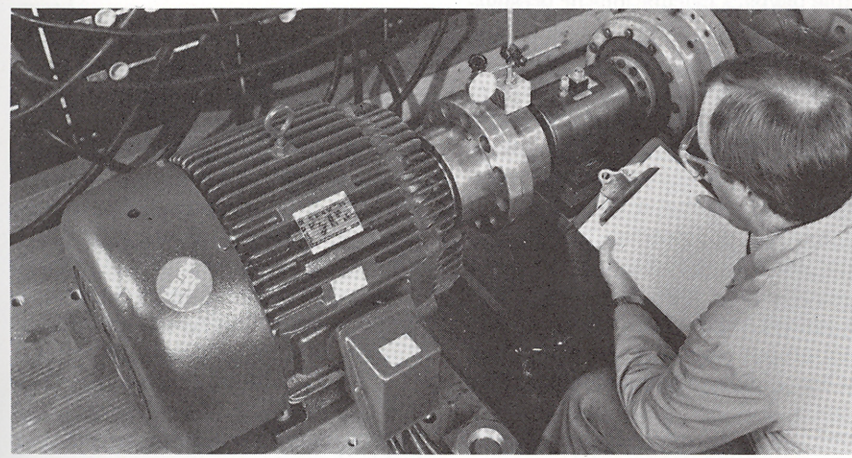
- De-energize circuit
- Lock out and Tag out the breaker
- Test circuit first
- Work with a partner
- Let people know where you are working

# Electric Motor Nameplate Data

- HP - mechanical work produced at the shaft
- Voltage, Phases
- Efficiency
  - 83 - 86% typical
  - 90% high efficiency
  - 92%+ premium efficiency

# Motors: some common causes of early failure

- Bearings (lubrication)
- Alignment, movement and vibration (supports)
- Overheat – excessive start/stop, poor air flow, phase imbalance, loose connections



**PROPER COUPLING ALIGNMENT** is critical to a motor's overall performance. Dial indicator positioned at motor-load coupling measures both parallel and angular variation. In the typical motor-drive application, losses occur anywhere in the drive train.

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# Checklist of Maintenance Practices for Motors

- Check load conditions to ensure that the motor is not over or under loaded. ("Amp" motors)
- Inspect regularly the connections at the motor and starter to be sure that they are clean and tight. (Thermograph scan)
- Provide adequate ventilation and keep motor cooling ducts clean to help dissipate heat to reduce excessive losses. **For every 18°F increase** in motor operating temperature, motor life is estimated to be halved.

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# Voltage Irregularities

- Voltage surges
- Transients
- Spikes
- Voltage dips

# Voltage Variations

- Low voltage can cause operational problems
- Increased amps will increase heat
- 5% voltage loss maximum

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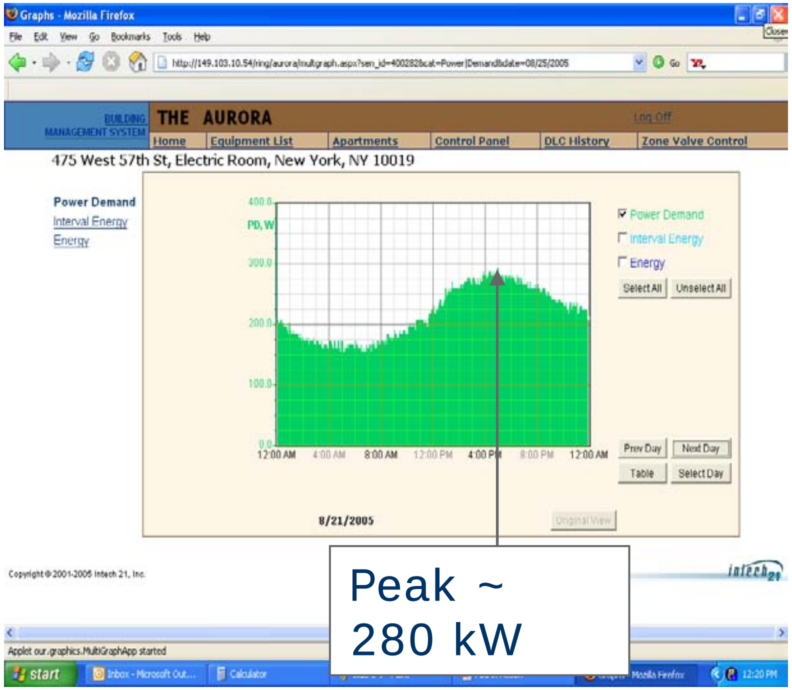
# Load Management in the Facility
# Reduce the Demand Charge

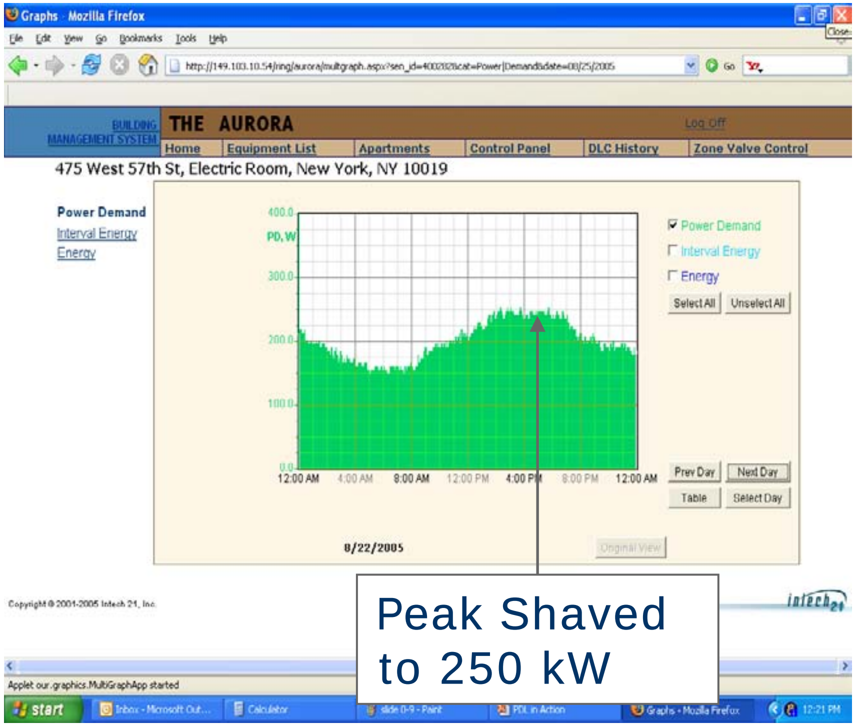
- **Demand Charge** (KW): The highest 30-minute electric requirement over the course of a month
  - Can be up to 40% of billings

- Facility level vs System level
  - Peak demand can be at any time of day or night – ***not same as "System Peak"***
  - System peak is for the utility grid overall and is typically in mid-late afternoon

# Load Management in the Facility – Demand & Usage

## Load profile & peak demand limiting



# Load Management: Strategies

- **Turn off: Non-priority electric loads**
  - Un-occupied areas
  - Lights
  - Supply Fans
  - Exhaust Fans

# Section 3

- Reading Assignment
- Exam
- Reflection / Evaluation

# Class Reading Assignments

BOC Handbook 107 – Facility Electrical System

Finish reading this book

Consider your next Practical Project:

HVAC System Schematic

See the instructions for Project 1C

# Section 1 Exam

- Remove everything from your desks
- No Cell Phones – we have calculators for you
- Work individually to complete exam questions
- Remember to put your name on top of your answer sheet
- Hand in your answers and question sheets together

## Time

- 50 minutes to complete the exam
- Complete the “Self Evaluation Form” after the exam

# Reflection and Evaluation Form

**Complete your Self-Evaluation form**

*In your Course Book*

*Third Divider Tab – "Electric Lighting & Power"*

*When you have filled out – keep for your own reference*

**Time** 10 minutes