MaintenancePRO℠ Technical Training

Maintenance Training Course Catalog

Applied Industrial Technologies®

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GEN-001: Basic Math

Course Description

This course provides information on the concepts associated with basic Algebra, basic Geometry, Measurements, and basic Trigonometry.

Terminal Objective

Upon completion of this course, the participants will be able to reduce fractions, calculate with mixed numbers, perform calculations with measurements, perform conversion of measurements, read a number line, define exponents, define bases, use algebra to solve know formulas, perform multiplication and division of polynomials, perform calculations using the Pythagorean Theorem, define plane geometry, perform calculations using Geometry principles, and use trigonometric functions to calculate the sides of a triangle.

Target Audience

This course is designed for mechanical and electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises

Course Objectives

- Define the following terms; fraction, numerator, denominator.
- Reduce a fraction to its lowest term.
- Calculate with mixed numbers.
- Perform mathematical operations with fractions; addition, subtraction, multiplication, division.
- Read decimals.
- Convert Decimals to and from Fractions.
- Perform calculations using decimals, and fractions.
- Calculate the percentage of a number.
- Convert numbers into percentages.
- Define measurement.
- Perform calculations with measurements.
- Perform conversion of measurements.
- Read a number line.
- Perform addition and subtraction of signed numbers.
- Perform multiplication and division of signed numbers.
- Define exponents.
- Define Bases.
- Perform calculations with exponents.
- Calculate the square root of a number.
- Write algebraic expressions.

- Evaluate algebraic expressions.
- Use algebra to solve known formulas.
- Solve an equation with one unknown.
- Solve equations with multiple unknowns.
- Define polynomial.
- Perform addition and subtraction of polynomials.
- Perform multiplication and division of polynomials.
- Use polynomials to solve word problems.
- Define the following; Angle, Vertex, Acute Angle, Obtuse Angle, Straight Angle, Reflex Angle.
- Describe how to measure an angle.
- Describe the method of labeling angles.
- Explain the use of a protractor to measure angles.
- Define the Pythagorean Theorem.
- Perform calculations using the Pythagorean Theorem.
- Define a triangle.
- List the rules of a triangle.
- Use the rules of a triangle to calculate the side lengths and angles of a triangle.
- Define the following types of triangles; Equilateral, Isosceles, Scalene.
- Define Plane Geometry.
- List five types of polygons.
- Calculate the perimeter of a polygon.
- Calculate the area of a square.
- Calculate the perimeter and area of plane figures.
- Identify solid figures given a picture.
- Calculate volume of a solid figure.
- Perform calculations using Geometry principles.
- Define Sine of an angle.
- Define Cosine of an angle.
- Define Tangent of an angle.
- Using trigonometric functions calculate the sides of a triangle.

Topical Outline

I. Fractions
   A. Numerator And Denominator
   B. Types Of Fractions
   C. Reducing Fractions
   D. Raising A Fraction To A Higher Term
   E. Changing Improper Fractions to A Whole Or Mixed Number
   F. Changing Mixed Numbers to Improper Fractions

G. Comparing Fractions
H. The Fractional Part One Number Is To Another
I. Addition of Common Denominator Fractions
J. Addition of Fractions With Different Denominators
K. Fraction Word Problems
L. Subtraction of Fractions With A Common Denominator
M. Subtraction of Fractions With Unlike Denominators
N. Borrowing
O. Multiplication of Fractions
P. Canceling
Q. Multiplication with Fractions And Whole Numbers
R. Multiplication with Mixed Numbers
S. Division by Fractions
T. Division of Fractions And Mixed Numbers By Whole Numbers
U. Division by Mixed Numbers

II. Decimals
A. Reading and Writing Decimals
B. Comparing Decimals
C. Converting Decimals To and From Fractions
D. Addition and Subtraction Of Decimals
E. Multiplication and Division Of Decimals

III. Percentages
A. Percentage
B. Percents and Fractions
C. Common Fractions, Decimals, and Percents
D. Finding a Percent Of A Number
E. Finding the Percentage Of A Number Or A Number From A Percentage

IV. Measurements

V. Signed Numbers
A. Positive and Negative Number
B. Number Line
C. Adding and Subtracting Signed Numbers
D. Multiplying and Dividing Signed Numbers

VI. Powers and Roots
A. The Power of A Number
B. Square Root

VII. Algebra
A. Writing Algebraic Expression
B. Evaluating Algebraic Expressions
C. Evaluating Formulas

VIII. Equations

A. Addition or Subtraction Equations
B. Solving Multiplication and Division Equations
C. Equation Operations
D. Solving an Equation With Separated Unknowns
E. Parentheses
F. Ratio and Proportion
G. Solving an Equation With Two Unknowns

IX. Polynomials
A. Polynomials - Their Addition and Subtraction
B. Multiplication of Polynomials
C. Division of Polynomials

X. Angles
A. Introduction to Angles
B. Types of Angles
C. Measuring an Angle
D. Labeling an Angle
E. Measuring, Drawing, and Transversal Cutting Of Angles

XI. Pythagorean Theorem
A. Definition of Pythagorean Theorem

XII. Triangles
A. Labeling a Triangle
B. Rules of a Triangle
C. Definitions

XIII. Plane Figures
A. Perimeter and Area
B. Working With Squares and Rectangles
C. Working with Triangles
D. Working with Parallelograms and Trapezoids
E. Working with Circles
F. Two-Step Area Problems

XIV. Solid Figures
A. Recognizing Common Solid Figures
B. Volume
C. Cubes and Rectangular Solids
D. Cylinders
E. Cones
F. Two-Step Volume Problems

XV. Geometric Application
A. The Work Triangle
B. Applying the Pythagorean Theorem
C. Changing Volume to Capacity

D. Geometry in Photography

XVI. Trigonometry

A. Basic Trigonometric Functions

Time Required

24 to 40 hours (depending upon audience, and audience experience).

Sources

None

MM-101: Measurement & Tools

Course Description

This course provides information on the proper use of measuring tools to make basic linear and angular measurements, hand tools and power tools.

Terminal Objective

Upon completion of this course, the participants will be able to use measuring tools to make basic measurements, hand tools to perform basic operations, and use portable and other power tools to drill, cut, bend, and thread.

Target Audience

This course is designed for electrical and mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Discuss units of measurement and tolerances.
- Calculate tolerances.
- Make measurements with rulers, calipers, squares, micrometers, and verniers.
- Use hand tools to install and remove fasteners.
- Use hand tools to cut and strip wires.
- Use hand tools to cut and flare tubing.
- Use hand tools and power tools to cut and drill hole in metal.
- Use hand tools to tap threads.
- Apply and measure torque to fasteners
- Use a pipe machine to cut, bend, and thread small pipes.

Topical Outline

I. Measurement
   - A. Units of Measurement
     1. American Standard/Imperial English
     2. Metric
     3. Tolerances
   - B. Rulers
   - C. Calipers and Squares
   - D. Micrometers and Verniers
   - E. Measurement Exercises

II. Tools
   - A. Hand Tools
     1. Screwdrivers
     2. Wrenches

3. Pipefitting Wrenches
4. Punches, Files, and Chisels
5. Taps and Dies
6. Electrician's tools – Tapes, pliers, punches, wire and cable strippers
7. Force, Torque, and Torque Wrenches

B. Portable Power Tools
   1. Electric Drills
   2. Pneumatic Drills and Hammer
   3. Saws
   4. Grinders and Shears

C. Presses

D. Band Saws

E. Pipe Machines

Time Required

16 to 24 hours (depending upon audience, and audience experience).

Sources

None

MM-102: Rigging

Course Description

This course provides information on the concepts and principles associated with rigging equipment, its use, inspection, planning and proper selection of rigging equipment. There are hands on exercises used to familiarize the trainee with equipment selection and safety when tasked with rigging a given load.

Terminal Objective

Upon completion of this course, the participants will be able to explain and demonstrate the different functions and use of equipment used to safely lift a load or install components using given rigging equipment.

Target Audience

This course is designed for electrical and mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Identify the safety hazards associated with rigging.
- Identify the actions necessary for safe operation of rigging equipment.
- Describe wire rope and its proper use.
- Identify the wire rope inspection points.
- Describe slings and their proper use.
- Identify the sling inspection points.
- Describe the different types of rigging hardware and their proper use.
- Identify the rigging hardware inspection points.
- Describe chain hand hoists and their proper use.
- Describe the proper and safe use of beams.
- Describe the proper installation/removal and safe use of beam clamps.
- Describe the proper installation/removal and safe use of trolleys.
- Describe the proper and safe use of jacks, rollers, and skids.
- Describe the proper and safe use of winches.
- Describe the proper and safe use of cribbing.
- Describe how to properly plan a rigging job.
- Describe how to properly select and inspect rigging equipment.
- Describe proper rigging techniques.
- Describe the proper use of arm and hand signals.
- Describe safe operating considerations.
- Describe the different methods to safely use while moving and manipulating loads including; drifting a load, rotating a load using one hook, two hooks, and single sling, tipping a load, inverting a load.

Topical Outline

I. INTRODUCTION TO RIGGING
- A. Rigging Safety
- B. Rigging Precautions
- C. Safe Working Loads

II. RIGGING GEAR
- A. Wire Rope
  1. Selection
  2. Safety Factors
  3. Inspection
- B. Slings
  1. Synthetic Webbing Slings
  2. Metal (Wire or Chain) Mesh Slings
  3. Chain and Chain Mesh Slings
  4. Wire Rope Slings
  5. Sling Configurations
  6. Sling Angles
  7. Fiber Rope Slings
  8. Sling Storage and Care
- C. Rigging Hardware
  1. Hooks
  2. Shackles
  3. Eyebolts
  4. Turnbuckling
  5. Links and Rings
  6. Snatch Blocks
- D. Hoists
  1. Chain Hand Hoists
  2. Powered Hoists
  3. Hoisting Equipment Safety Precautions
- E. Beams
  1. Beam Clamps
  2. Installation
  3. Safe Use of Beam Clamps
- F. Trolleys
  1. Installation
  2. Removal
  3. Safe Use
- G. Jacks
- H. Rollers and Skids

I. Winches
   1. Major Components of Winches
   2. Safety Precautions
J. Cribbing

III. RIGGING FUNDAMENTALS
A. Planning the Rigging Job
   1. Weight of the Load
   2. Center of Gravity
   3. Dimensions of the Object and Travel Path
   4. Hazards Associated with the Movement of the Object
B. Selection of Equipment
C. Using Proper Rigging Techniques
D. Arm and Hand Signals for Rigging Operations
E. Safe Operating Considerations

IV. ADVANCED METHODS OF DETERMINING THE WEIGHT OF A LOAD

V. MOVING AND MANIPULATING LOADS
A. Drifting a Load
B. Rotating a Load
   1. One-Hook Rotating
   2. Single-Sling Rotating
   3. Two-Hook Rotating
C. Tipping a Load
D. Inverting a Load

Time Required

16 hours (depending upon audience, and audience experience).

Sources

None

GEN-002: Scaffolding

Course Description

This course provides information on the concepts associated with procedures, precautions and limitations for safely erecting and/or dismantling fabricated frame scaffolding. There are hands-on exercises for erecting scaffolding.

Terminal Objective

Upon completion of this course, the participants will be able to safely set-up inspect and then dismantle fabricated frame scaffold.

Target Audience

This course is designed for electrical and mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Discuss the procedures, precautions, limitations, and practices surrounding the following aspects of erecting, using, and dismantling fabricated frame scaffolding; Base Section, Support Structure, Access, Fall Protection, Platform, Keeping Upright, Electrical Hazards
- Erect and dismantle a two-tier scaffold.

Topical Outline

VI. Base Section
VII. Support Structure
  A. Capacity
  B. Bracing
  C. Pinning
  D. Components
VIII. Access
  A. General
  B. Integral (Built-in) Access
  C. Ramps and Walkways
  D. Direct Access
  E. Erectors or Dismantlers
IX. Fall Protection
  A. Fall-Arrest Systems
  B. Guardrail Systems
  C. Erectors and Dismantlers
X. Platform
  A. Working Distance
  B. Overlap
  C. Brackets

D. Capacity

XI. Falling Object Protection
- A. Workers on the Scaffold
- B. Workers Below

XII. Keeping Upright
- A. Guys, Ties, and Braces
- B. Moving Scaffolds
- C. Weather

XIII. Electrical Hazards
- A. Overhead Power Lines
- B. Portable Electric Tools

XIV. Case Reports From The OSHA Files
- A. Scaffold Collapses, Worker Injured
- B. Worker Falls from Collapsing Scaffold
- C. Improper Coupling Results in Two Deaths
- D. Improper Access Leads to Serious Injuries
- E. Employee Pulled off Scaffold, Guardrails Saved Him
- F. Planking Not Overlapped, Causes Fatal Fall
- G. Worker Dies During Scaffold Erection

Time Required

16 to 24 hours (depending upon audience, and audience experience).

Sources

None

EM-001: Electrical Safety & Lockout/Tag-out

Course Description

This course provides information potential safety hazards, safety precautions, personnel protection equipment, general emergency response, and the local lockout/Tagout program.

Terminal Objective

Upon completion of this course, the participants will be able to discuss potential workplace hazards and the associated precautions, general responses to plant emergencies, personnel protection equipment used in the plant, and personnel responsibilities under the local lockout/Tagout program.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation.

Course Objectives

- Discuss the hazards and precautions/counter-measures for each hazard.
- List and explain the personnel protective equipment required for work in mill areas
- Discuss some hazards particular to electrical work and the precautions/counter-measures for each hazard.
- Describe the general response to plant emergencies.
- Describe the energy isolation requirements for safely work on equipment.
- Describe the local Lockout/Tagout program and the requirements placed on the personnel doing work

Topical Outline

I. Workplace Hazards
   A. General Industrial Hazards
      1. Precautions/Counter-Measures
      2. Personnel Protection Equipment
   B. Steel Mill Hazards
      1. Precautions/Counter-Measures
      2. Personnel Protection Equipment
   C. Electrical Work Hazards
      1. Precautions/Counter-Measures
      2. Personnel Protection Equipment

II. Safety Department

III. Additional Safety Programs and Training Courses

IV. Emergency Response
   A. Types of Emergencies
   B. Initial Responders

C. Response Teams
D. Assembly Areas

V. Energy Isolation for Maintenance

A. Sources of Energy and Means of Isolation
B. OSHA Lockout/Tagout Requirements
C. Local Lockout/Tagout Requirements

Time Required

8 hours

Sources

None

EM-101: Basic Electricity – Direct Current

Course Description

This course provides information on the basic concepts of DC electricity and magnetism, including electrostatics, basic circuit concepts, measurement of electrical quantities and associated numerical concepts, Ohm's Law, practical circuits, electromagnetism, and electrical measurements. There are hands-on exercises device operation and simple circuit construction and analysis.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function and operation of DC electrical devices, and the function and characteristics of basic DC circuits.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation, with workshop hands-on exercises.

Course Objectives

- Define and explain the following technical terms; alternating current (AC), insulators, atom, iron, compound, molecule, conductors, neutron, direct current (DC), polyphase AC, electricity, proton, electron, rectifier, electronics, single-phase AC, and element.
- Give examples of elements and compounds.
- Sketch a simple atom and label its parts.
- State the law of attraction and repulsion related to electrical charges.
- Name the three basic parts of an atom.
- Explain the difference between atoms and molecules.
- Distinguish between AC and DC.
- Define and explain the following technical terms; dry cell, primary cell, efficiency, P-type silicon, electrode, secondary cell, electrolyte, semiconductor, electromagnetic induction, solar cell, N-type silicon, thermocouple, Photoconductive, thermoelectric effect, Photon, thermopile, Photovoltaic, ultrasonic, piezoelectric effect, and wet cell.
- Describe six different principles of energy conversions employed in the generation of electricity. An example of each conversion process should be given.
- Discuss and explain six different principles of energy conversion in the practical utilization of electrical energy.
- Define and explain the following technical terms; electroscope, potential energy, electrostatic induction, selenium, electrostatics, smoke precipitators, foot-pound joule, Van de Graff generator, lightning arrester, and voltage.
- Recognize potentially dangerous situations involving electrostatic induction.
- Give examples of nuisance aspects of static electricity.
- Discuss some useful applications of static electricity.

- Draw, from memory, the pattern of an electrostatic field between like and unlike charges.
- Define and explain the following technical terms; ampere (A), fuse, circuit breaker, load, closed circuit, ohm (Ω), control, open circuit, conventional current, resistance (*R*), coulomb, schematic, current (*I*), short circuit, electromotive force, source, electron current, and volt.
- Draw a schematic diagram of a simple circuit.
- Use correct circuit notation to describe the values of voltage, current, and resistance.
- Differentiate between conventional current flow and electron current flow.
- Explain the concept of a short circuit.
- Observe proper safety precautions in working with electrical circuits.
- Define and explain the following technical terms; giga-, milli-, kilo-, nano-, mega-, pico-, and micro-.
- Express decimal numbers in powers of 10 and vice versa.
- Convert any number into scientific notation.
- Round off numbers to three-digit accuracy.
- Express any number with any appropriate metric prefix.
- Convert numbers with metric prefixes into decimal numbers or scientific notation.
- Perform the basic arithmetic operations (add, subtract, multiply, and divide) with numbers expressed in powers of 10.
- Define and explain the following technical terms; ammeter, ohmmeter, analog meter, range, digital meter, range switch, DVM, scale, linear, voltmeter, multiplier, VOM, nonlinear, and VTVM.
- Choose the proper instrument for the measuring task.
- Connect a meter correctly to the circuit.
- Read and interpret meter scales accurately.
- Define and explain the following technical terms; American Wire Gauge (AWG), Nichrome, circular mil, potentiometer, color code, resistivity, conductance, rheostat, conductivity, semiconductors, conductor, specific resistance, insulators, temperature coefficient mil, wattage rating, and mil-foot.
- Name various materials classified as either good conductors, poor conductors, or insulators
- Explain the four factors that determine the amount of resistance in a wire
- Discuss the aspects of conductivity and resistivity
- Perform computations involving the resistance equation
- Use the charts and tables in this chapter
- Compare wire sizes using the American Wire Gauge
- Determine the correct values of resistors by using the color code
- Describe the interrelationship of voltage (*E*), current (*I*), and resistance (*R*)
- Apply Ohm’s law in calculating an unknown circuit quantity

- Use Ohm's law in conjunction with metric prefixes
- Define and explain the following technical terms; Btu, kilowatt-hour (kWh), efficiency, kinetic energy, foot-pound, potential energy, force, power (P), horsepower (hp), watt (W), I^2R losses, watt-hour (Wh), joule (j), and work.
- Calculate the power dissipation of a resistor
- Use the power equation in conjunction with Ohm's law to find an unknown circuit quantity
- Explain the derivation of the formulas embodies in the PIRE wheel
- Calculate the cost of electrical energy expended by a load
- Define and explain the following technical terms; ground, series-opposing, series-aiding, voltage divider, series circuit, and voltage drop.
- Describe and explain the behavior of voltage, current, resistance, and power in a series circuit
- Write four mathematical statements describing the relationships of *E*, *I*, *R*, and *P* in a series circuit
- Calculate unknown components and/or circuit quantities in a given series circuit
- Identify correct polarity with respect to a common reference point (ground)
- Determine the next voltage from series-connected voltage sources
- Explain five different methods of computing the total resistance of a parallel circuit.
- Compute any unknown circuit quantity in a parallel circuit having sufficient data.
- Define and explain the following technical terms; bleeder resistor, loaded voltage divider, equivalent resistance, unloaded voltage divider, heavy load, and voltage regulation.
- Identify the series-connected and parallel-connected components of a complex circuit
- Simplify complex circuits by redrawing them with resistor values equivalent to their series and parallel combinations
- Write and explain Kirchoff's voltage and current laws
- Apply Kirchoff's laws in the solution of complex circuits
- Design voltage divider circuits to meet specific load conditions
- Define and explain the following technical terms; anode, electrolysis, arcs, electrolyte, cathode, negative ion, cathode ray, positive ion, cathode-ray tube, and sparks.
- Describe how the ionization of liquids differs from that of gases.
- Explain some useful processes that depend on conduction in liquids and gases.
- Correctly employ the graphic representation associated with electromagnetism
- Predict magnetic polarity and/or direction of current by use of left-hand rules
- State the law of magnetic attraction and repulsion
- Explain the factors determining the strength of an electromagnet
- Describe the uses and applications of solenoids.
- Draw a functional circuit diagram involving a control relay.

- Define and explain the following technical terms; analog meters, ohms per volt rating, d'Arsonval meter, sensitivity, digital instruments, shunt resistor, galvanometer, Wheatstone bridge, megohmmeter, and multiplier.
- Describe and explain the operating principles of voltmeters, ammeters, ohmmeters, wattmeters, megohmmeters, and Wheatstone bridges
- Calculate the value of shunt resistors to extend the range of an ammeter
- Calculate the value of multiplier resistors to extend the range of a voltmeter
- Compute an unknown resistor from the settings of a Wheatstone bridge

Topical Outline

VI. Introduction to Electricity & Electronics
- A. What Are Electricity and Electronics
- B. Direct & Alternating Current Fundamentals
- C. Early History of Electricity
- D. One Hundred Elements - Building Blocks of Nature
- E. The Atom Analyzed - Electrons, Protons, and Neutrons
- F. The Atomic Theory - Cornerstone of Electrical Theory

VII. Electrical Production and Use
- A. Electricity Production By Energy Conversion
- B. Electricity From Friction
- C. Electricity From Magnetism
- D. Electricity From Chemical Energy
- E. Electricity From Light
- F. Electricity From Heat
- G. Electricity From Mechanical Pressure: Piezoelectricity
- H. The Effects Of Electricity
  1. Chemical Reactions From Electricity
  2. Mechanical Pressure From Electricity: The Piezoelectric Effect
  3. Magnetism From Electricity

VIII. Electrostatics
- A. Stationary Electrons
- B. Electroscopes
  1. Unknown Charges
- C. Electrostatic Induction
- D. Lightning
- E. Nuisance Static Charges
- F. Useful Static Charges
  1. Painting
  2. Sandpaper Manufacture
  3. Smoke Precipitators; Rug Manufacture
  4. Xerography (Dry Copying)
  5. Electrostatic Generators
- G. Potential Energy Of Electrons
- H. Electric Lines Of Force

IX. Basic Circuit Concepts
- A. Three Measurable Circuit Quantities
  1. Voltage
  2. Current
  3. Resistance

B. A Simple Electric Circuit
C. Open Circuits And Closed Circuits
D. The Schematic Diagram
E. Basic Circuit Notation
F. The Short Circuit
G. Electrical Safety
H. National Electrical Code

X. Scientific Notation and Metric Prefixes
A. Rationale For Studying This Unit
B. Powers Of 10
C. Scientific Notation
1. Suggested Procedure
D. Significant Digits
E. Rounding Off To Three Significant Digits
F. Metric Prefixes
G. Multiplication And Division With Powers Of 10

XI. Electrical Quantity Measurement
A. Types of Meters
B. Ammeter And Voltmeter Scale Interpretation
C. Ohmmeter Scale Interpretation
D. Electrical Meter Connection

XII. Resistance
A. Conductive Vs. Resistance
B. Resistivity Of Materials
C. Length Of A Conductor
D. Cross-Sectional Area Of A Conductor In Circular Mils
1. Calculating The Resistance Of A Wire
E. Effect Of Temperature On Resistance
F. Using The Temperature Coefficient To Find The Resistance At Higher Temperatures
G. The American Wire Gauge (AWG)
H. Stranded Wire And Cable
1. Bunch Stranding
2. Concentric Stranding
3. Rope Stranding
I. Commercial Resistors
1. Fixed Resistors
2. Variable Resistors
3. The Resistor Color Code

XIII. Ohm’s Law
A. Voltage, Current, and Resistance
B. Ohm’s Law with Metric Prefixes

XIV. Electrical Power and Energy
- A. Energy
  1. Mechanical Energy
  2. Potential Energy
  3. Kinetic Energy
- B. Units Of Energy
- C. Power
  1. The Horsepower
  2. The Watt – Unit Of Electrical Power
  3. A Second Equation For Power
  4. A Third Equation For Power
  5. The PIRE Wheel
- D. Energy and Cost Calculations
  1. The Kilowatt-Hour Meter
- E. Efficiency of Energy Conversion

XV. Series Circuits
- A. Characteristics Of Series Circuits
- B. The Voltage Drop
- C. Resistance And Current In Series Circuits
- D. Power Consumption In Series Circuits
- E. Calculation Of Series Circuit Quantities
- F. Voltage Drop On A Line
- G. Voltage At An Open Element
- H. Series Circuits As Voltage Dividers
- I. Polarity Considerations
- J. Ground As A Reference Point
- K. Voltage Sources In Series

XVI. Parallel Circuits
- A. The Nature Of Parallel Circuits
- B. Five Methods Of Computation
  1. Method #1 Use Of Ohm's Law For Compiling RT
- C. Power Dissipation In Parallel Circuits
  1. Method #2 Use Of The Reciprocal Equation
  2. Method #3 Practical Method
  3. Method #4 The Product Over The Sum Formula
  4. Method #5 A Special Condition: All Equal Resistors
- D. Power Dissipation In Parallel Circuits
- E. Voltage Sources In Parallel

XVII. Voltage Dividers
- A. Simplifying Series-Parallel Circuits
- B. Kirchoff's Voltage Law

C. Kirchoff's Current Law
D. Loaded Voltage Dividers

XVIII. Conduction in Liquids and Gases
A. The Ionization Process
B. Useful Chemical Compounds
C. Electroplating And Electrolysis
1. Electrolysis Of Sulfuric Acid In Water
2. Electrolytic Corrosion
D. Gases As Insulators
1. Sparks And Arcs
E. Gaseous Conduction By Ionization
1. How Ionization Occurs
2. Why Low-Pressure Gas Conducts Better Than High Pressure Compressed Gas
3. Electrons And Ions Formed By Collisions
F. Conduction And Ions In Nature
G. Conduction In A Vacuum

XIX. Magnetism and Electromagnetism
A. Electricity And Magnetism
B. Simple Magnets
C. The Magnetic Field
D. Ferromagnetic Materials And The Magnetizing Process
E. Magnetic Materials And The Atomic Theory
F. Permanent Magnets
G. Electromagnetism Of A Straight Wire
H. Electromagnetism Of A Coil
I. The Magnetic Core In The Coil
J. Magnetic Quantities
1. Magnetic Flux
2. Flux Density
3. Magnetomotive Force
4. Magnetic Intensity
5. Permeability
6. Reluctance
7. Ohm's Law For Magnetic Circuits
8. Core Design
9. Demagnetizers
10. Residual Magnetism

XX. General Safety Precautions

XXI. The Atom And Electrical Charges
A. The Atom
B. Electrical Charges

XXII. Conductors And Insulators
XXIII. Electromotive Force (EMF)
XXIV. Current Flow, Voltage Potential, And Resistance
    A. Current Flow
    B. Voltage Potential
    C. Resistance
        1. Characteristics Of Resistance
        2. Resistor Color Code

Time Required

Up to 40 hours (depending upon audience and audience experience).

Sources

None

EM-102: Basic Electricity – Alternating Current

Course Description

This course provides information on the basic concepts of AC electricity, including AC waveforms, electrical measurements, resistance, inductance, capacitance, impedance, multi-phase circuits, and transformer action. There are hands-on exercises device operation and simple circuit construction and analysis.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function and operation of AC electrical devices, and the function and characteristics of basic AC circuits.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation, with workshop hands-on exercises.

Course Objectives

- Define sine wave and explain how one is generated.
- Define the following terms: frequency, period, wavelength, peak AC voltage, peak AC current, effective AC voltage, and effective AC current.
- Given a diagram of a sine wave, identify the peak AC voltage values.
- Given a diagram of a sine wave, identify the effective AC voltage values.
- Explain AC phase relationships.
- Given two diagrams of AC waveforms, calculate the phase relationship between the two.
- Draw a current and voltage waveform of a resistive AC circuit to show the phase relationship.
- Given a drawing of a series AC circuit, use Ohm's Law to solve for the unknown quantity.
  Given a drawing of a parallel AC circuit, use Ohm's Law to solve for the unknown quantity.
- Given a drawing of a series-parallel AC circuit, use Ohm's Law to solve for the unknown quantity.
- Explain the characteristics of and factors controlling inductance.
- Describe the voltage and current transients that occur in an inductive circuit.
- Define inductive reactance and explain how it is affected by frequency.
- Define impedance.
- Explain the relationship between voltage and current in a resistive-inductive (RL) circuit.
- Given a diagram, calculate impedance in an RL circuit.
- Explain the operation of a capacitor.
- Explain factors affecting capacitance.

- Describe the voltage and current transients that occur in a capacitive circuit.
- Define capacitive reactance and explain how it is affected by frequency.
- Explain the relationship between voltage and current in the following AC circuits; RC circuit, LC circuit, RLC circuit
- Given a diagram, calculate impedance for the following AC circuits; RC circuit, LC circuit, RLC circuit
- Describe how reactive components are used as filters
- Explain what a transformer is and how it operates.
- Explain the phase relationship between primary and secondary voltages of like wound and unlike wound transformers.
- Explain turn ratio in power transformers.
- Explain the following power losses in a power transformer; Copper Losses, Eddy-Current Losses, Hysteresis Loss.
- Identify the following types of transformers and briefly explain the characteristics of each; Air core, Iron core, Shell type, Solid core ferrite, Autotransformer, Current transformer, Potential transformer.
- Describe the basic components in a power distribution system.
- Identify and explain the function of protective devices in a distribution system.

Topical Outline

I. AC Waveforms
   A. Generation of a Sine Wave
   B. Terms Associated with a Sine Wave
      1. Frequency
      2. Period
      3. Wavelength
      4. Angular Measure
      5. Radian Measure
      6. Angular Velocity
      7. Values in a Sine Wave
   C. Voltage and Current Values for a Sine Wave
      1. Peak Values
      2. Average Value
      3. Root-Mean-Square, or Effective Value
   D. Identification of Peak and Effective Values on Waveforms
      1. Peak
      2. Peak-to-Peak Value
      3. Average Value
      4. Effective Value
   E. AC Phase Relationships

1. Phase Concepts
2. Phase Angle
3. Phase Angle Diagrams

F. Identification of Phase Relationships between Two Waveforms
1. In-Phase Waveforms
2. Out-of-Phase Waveforms

II. Resistors in AC Circuits
A. Resistors
B. Voltage and Current Relationships of Resistive AC Circuits
C. Resistances in Series Circuits
D. Series String
E. Series Resistive Formula
F. Resistances in Parallel

III. Inductors in AC Circuits
A. Characteristics of Inductance
1. Electromotive Force
2. Self-Inductance
B. Factors Controlling Inductance
C. Voltage and Current Transients in an Inductive Circuit
D. Inductive Reactance
E. Series RL Circuit
1. Voltage Characteristics
2. Phase Angle
3. Impedance
F. Parallel RL Circuit
1. Voltage Characteristics
2. Current Characteristics
3. Impedance
4. Phase Angle

IV. Capacitors in AC Circuits
A. Operation of A Capacitor
1. Units of Capacitance
2. Capacitor Characteristics
B. Factors Affecting Capacitance
1. Areas of the Plates
2. Distance between the Plates
3. Dielectric Permittivity
C. Voltage and Current Transients in a Capacitive AC Circuit
D. Capacitive Reactance
E. Series RC Circuit
1. Current Characteristics

2. Voltage Characteristics
3. Phase Angle
4. Impedance

F. Parallel RC Circuits
1. Voltage Characteristics
2. Current Characteristics
3. Phase Angle
4. Impedance

V. Complex Reactive Circuits

A. LC Circuits
1. Series LC Circuit
2. Parallel LC Circuit

B. RLC Circuits
1. Series RLC Circuits
2. Parallel RLC Circuits

VI. Filters

A. Filter Types and Applications
1. Tank Circuits
2. Pi Filter
3. Bandpass Filters
4. Filter Networks

VII. Transformers Action and Transformers

A. Basic Construction of a Transformer
1. Core Characteristics
2. Transformer Windings

B. Basic Operation of a Transformer
1. Phase Relationship
2. Coefficient of Coupling

C. Turns and Voltage Ratios
D. Winding Characteristics
E. Transformer Connections
F. Transformer Losses
1. Copper Losses
2. Eddy-Current Losses
3. Hysteresis Loss

G. Types of Transformers

VIII. Power Distribution Overview

A. Generation
B. Transmission
C. Distribution
D. Protective Devices

E. Delta and Wye Configurations
F. Feeder Circuits
G. Branch Circuits

Time Required

Up to 80 hours (depending upon audience and audience experience).

Sources

None

EM-103: Electrical Print Reading

Course Description

This course provides the participant with the basic understanding of electrical prints and components associated with electrical print reading, it also provides the participant with the ability to interpret simple ladder logic diagrams used for PLC programming. There are hands-on exercises for print reading.

Terminal Objective

Upon completion of this course, the participants will be able to explain and interpret electrical prints and ladder logic diagrams.

Target Audience

This course is designed for electrical maintenance technicians, but is also used for cross-training of mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Explain and describe the purpose of the Title Block, Legend, Revisions, and Material List in terms of location and content.
- Given an electrical print, identify the organizational make-up of the print.
- Discuss and be familiar with common electrical print symbols and the components they represent.
- Identify and interpret an electrical block diagram and a one-line diagram.
- Identify and interpret an electrical three-line diagram.
- Identify and interpret connection diagrams.
- Identify and interpret simple ladder logic diagrams used for PLC programming.
- Describe the purpose of the Piping and Instrumentation Diagram.
- Given a P&ID, identify the organizational make-up of the diagram.
- Discuss and be familiar with common Process Loop symbols and their functions.
- Identify and interpret a P&ID.
- Given a simplified P&ID, identify the controlled variable, the measured variable, the manipulated variable and the final control element.

Topical Outline

I. Electrical Prints
   A. Organization of Electrical Prints
   B. Electrical Diagram Symbology
      1. Meter Abbreviations
      2. Indicating Lamp Abbreviations
      3. Relay Abbreviations
   C. Standard Numbers
   D. Title Block

E. Special Areas on Electrical Drawings
F. Block Diagrams
    1. Analyzing Block Diagrams
    2. Recognizing Graphic Symbols
G. One-Line Diagrams
    1. Analyzing a One-Line Diagrams
    2. Recognizing Symbols in One-Line Diagrams
H. Wiring Diagrams
    1. Interconnection Diagrams
    2. Connection Diagram

II. Analyzing Technical Drawings
A. Analyzing an Electrical Diagram
B. Motor Circuit
C. Control Circuit
D. Tracing Current

III. Analysis Of An Electrical Circuit
A. Circuit Components and Their Functions
B. Test Operation
C. Automatic Operation
D. Standby Operation

IV. Use Of An Interconnection Diagram

V. Ladder Logic Diagrams
A. Relay Instructions
B. Timer and Counter Instructions
    1. Timers
    2. Counters
    3. Arithmetic Instructions
    4. Data Manipulation Instructions
    5. Data Transfer Instructions
    6. Program Control Instructions

VI. Digital Electronic Logic Diagrams
A. AND Gate
B. Multiple Input AND Gates
C. OR Gate
D. Amplifier
E. Inverter
F. NAND Gate
G. NOR Gate
H. Exclusive OR Gate

VII. Piping And Instrumentation
A. P&ID Loop Diagrams

1. P&ID Symbology
2. P&IDs AND PROCESS CONTROL

B. Process Control Loop Diagrams
1. Closed-Loop and Open-Loop P&ID

Time Required

24 to 40 hours (depending upon audience, and audience experience).

Sources

None

EM-104: Test Equipment

Course Description

This course provides information on the four categories of testing, safety precautions associated with testing and the use and care of different test equipment to include Doble test sets, megohmmeter function and operation and various applications for thermography and infrared scanning. There are hands-on exercises for inspection and use of given test equipment.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, design, and use of given test equipment.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises

Course Objectives

- List and briefly describe the four categories of testing.
- Describe methods of classifying test equipment.
- List at least ten general safety precautions
- Explain the purpose of insulation testing.
- Describe different parameters tested on insulation.
- Describe high voltage megohmmeter function and operation.
- Describe the DC high-potential test.
- Describe use of the high-potential tester.
- Describe the purposes of the Doble Test.
- Describe the basic operation of the Doble Test Set
- Describe thermography.
- Discuss the factors affecting infrared sensing
- Describe various applications for infrared scanning.
- Discuss the use of infrared imaging.

Topical Outline

I. Introduction To Test Equipment
   - A. Categories Of Testing
   - B. Classification Of Test Equipment
   - C. General Safety Precautions

II. Analog Meters
   - A. Meter Movements
   - B. Moving-Coil Meter Movement (D'Arsonval)
     1. Taut-Band Instrument
     2. Scales For Moving-Coil Meters
   - C. Moving-Iron Meter Movement

1. Meter Sensitivity
2. Voltmeter
3. Voltage Tester
4. Ohmmeter

D. Series Resistance Measurement
E. Shunt Resistance Measurement
F. Ohms Adjust
G. Ammeter
1. Shunt Resistors
2. Precautions
H. Analog Meter Use
1. Specifications
2. Proper Use
3. Measuring DC Voltage 0-250 Millivolts
4. Measuring DC Voltage 0-1 Volt
5. Measuring DC Voltage 0-2.5 Through 0-500 Volts
6. Measuring DC Voltage 0-1000 Volts
7. Measuring AC Voltages 0-25 Through 0-500 Volts
8. Measuring AC Voltage 0-1000 Volts

III. Digital Meters
A. Application
B. Basic Operation
C. A/D Converter
D. Control and Display
E. Data Output Unit (DOU)
F. Checking Diodes
G. Checking Transistors

IV. Methods To Locating A Cable Fault
A. Terminal Techniques
B. Capacitance Bridge Method
C. Radar Method
1. Arc Radar System
2. Free Oscillation System
3. Differential Radar System
D. Resonance Method
E. Tracer Techniques
1. Tracing Current Method
2. Audio Frequency Method (Tone Tracing)
3. Impulse Method (Thumper Method)
4. Earth Gradient Method

V. Fault Location Technique Application

VI. Insulation Testing
VII. Purpose Of Insulation Testing
VIII. High Voltage Megohmmeter
    A. Controls and Indications
        1. Voltmeter and Controls
        2. Megohmmeter and Controls
        3. AC Power Controls
        4. Guard/Ground/Positive Connections
        5. Negative Post
        6. High Voltage Controls
IX. Non-Destructive High-Potential Testing
    A. DC High-Potential Test
    B. AC High-Potential Test
X. High Potential Testers
    A. Controls and Indications
        1. Voltmeter And Range Selector
        2. Current Meter And Range Selector
        3. Ac Power Controls
        4. Guard/Ground/Return Connections
        5. High Voltage Controls
        6. Interlock And Auxiliary Power Socket
    B. Operation
XI. Doble Testing
    A. Purpose of Test
    B. Testing of an Insulating System
    C. Controls and Indicators
    D. Safety
    E. Modes of Operation
    F. Test Set Operation
    G. Connection to Insulating System
    H. Operating Procedure
    I. Obtaining Readings
XII. Calculation Of Results
    A. Calculation of Current (Milliamperes or Microamps)
    B. Calculation of Watts
    C. Calculation of Percent Power Factor
    D. Calculation of Capacitance
    E. Temperature Correction
    F. Radio-Influence Voltage
    G. Electrostatic Interference Voltage
    H. Resonator

XIII. System Applications
- A. Bushings
- B. Circuit Breaker
- C. Insulating Oil

XIV. Infrared Scanning
- A. Basic Theory
- B. Factors Affecting Infrared Sensing
- C. Infrared Sensing Equipment
- D. Application
- E. Bearings
- F. Electrical Equipment
- G. Trend Analysis

Time Required

24 hours

Sources

None

EM-105: Wiring

Course Description

This course provides information on the wiring requirements, material identification, and the installation and splicing of wiring. There are hands-on exercises for wiring installation.

Terminal Objective

Upon completion of this course, the participants will be able to properly identify wiring materials, determine the wire required for a given installation, install and splice wiring.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Identify wiring and wiring materials.
- Use an American Wire Gauge to determine wire size.
- Determine the size wire needed for a given installation.
- Splice wires
- Install wires

Topical Outline

I. Conductors
   A. Annealed Copper
   B. Wire Measurements
   C. Circular and Square Mils
   D. Wires Parallel
   E. Wire Data
   F. Calculating Circuit Conductors
   G. Voltage Drop
   H. Correction Factors
   I. Wires in Conduit
   J. Magnet Wire
   K. Copper Wire Formulas
   L. Soldering
   M. Oxyacetylene Equipment

II. Power Wiring
   A. Rigid Conduit
   B. Rigid-Conduit Fittings
   C. Mounting Electrical Equipment
   D. Motor Wiring

E. Current Ratings
F. Branch-Circuit Ampacity
G. Branch-Circuit Overcurrent Protection
H. Motor Overcurrent Protection
I. Disconnecting Means
J. Motor Controllers
K. Conductors Supplying Several Motors
L. Code Letters

Time Required

24 hours

Sources

None

EM-106: Conduit Bending

Course Description

This course provides information on the calculating and making conduit bends. There are hands-on exercises for bending and installing conduit.

Terminal Objective

Upon completion of this course, the participants will be able to calculate bends, make bends and install conduit runs.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Use basic trigonometry to calculate conduit bends
- Use offset and shrink tables to calculate conduit bends.
- Determine bender take-up, bend gains, and offset shrinkage in order to determine a conduit run
- Make various bends with a hand bender
- Make various bends with a “Chicago” style bender.

Topical Outline

I. Basic Trigonometry
II. Types of Conduit Material
III. EMT
IV. Rigid Metal
V. Rigid Aluminum
VI. IMC
VII. Hand Benders
VIII. “Chicago” Bender
IX. Determining bender take-up
X. 90 degree bends
XI. Kicks
XII. Offsets
XIII. Determining Conduit Run
    A. Determine bend gains, coupling loss, and offset shrinkage to find initial length
    B. Determine offset location
    C. Cut conduit
    D. Thread conduit
    E. Install Conduit
XIV. Matching Conduit Runs (Parallel Offsets)

XV. Concentric Bends
XVI. Saddles

Time Required

24 hours

Sources

None

MM-103 Introduction To Bearings & Lubrication

Course Description

This course provides information on the concepts associated with bearings, bearing function, bearing design, bearing maintenance, installation and removal, expected load and wear patterns, bearing faults, and lubrication. There are hands-on exercises for bearing removal and installation.

Note: This course is an abbreviated combination of MM-206 Lubrication, and MM-207 Bearings.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, design, and construction of bearings; install, remove and maintain bearings; identify causes of bearing failure, able to explain the function of lubricants, and the proper methods for greasing bearings.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

BEARINGS

- Discuss the basic concepts behind forces and stress.
- Discuss some of the basic terms used to describe and understand bearing design.
- Describe some of the materials used in the construction of bearings and why they are used.
- State the basic requirements of any bearing.
- Describe the differences between radial and thrust bearings.
- Describe the types of lubrication systems used for anti-friction and friction bearings.
- State the importance of and describe how to perform a soft foot check.
- State the procedure for performing various clearance checks on anti-friction and friction bearings.
- State the reasons for interference fits.
- Describe the various methods of heating bearings.
- Describe the various methods of cold mounting roller bearings.
- Describe the various methods of mounting tapered bore bearings.
- Explain the purpose of pre-load.
- Describe the methods of setting tapered roller bearings.
- State the differences and purposes of fixed and float bearings.
- Describe the various methods of roller bearing removal.
- State the importance of crush and torque on a journal bearing.

- Describe the various expected load and wear patterns of bearings that have been operating.
- Identify the various types of failures that occur in bearings.
- Describe the various types of failures that occur in bearings.
- Describe methods for reducing the various bearing failures.

LUBRICATION

- Discuss the origin of oil and its chemical make up.
- Discuss the basic principles of lubrication.
- Describe a basic lubricant and be familiar with the make-up of lubricants.
- Explain viscosity and use of viscosity terms.
- Differentiate between sliding and rolling friction.
- Discuss boundary/thin film lubrication.
- Discuss the origin of grease and its chemical make-up.
- Discuss various lubricant contaminants.
- Discuss lubrication of gears.
- Discuss the use of extreme pressure (EP) oils vs. non-EP oils.
- Be familiar with various methods of supplying gears with lubrication.
- Describe various causes of gear failure.
- Discuss the lubrication of worm gears, couplings, and bearings.
- Be familiar with the proper methods for greasing bearings.

Topical Outline

BEARINGS

I. BEARING CONCEPTS, TERMS, AND MATERIALS
   A. Forces in Effect
   B. Bearing Terms
   C. Friction Bearing Materials

II. BEARING DESIGN AND CONSTRUCTION
   A. Bearing Requirements
      1. Load
      2. Friction
   B. Bearing Types
      1. Anti-Friction Bearings
      2. Friction Bearings
   C. Bearing and Housing Seals
      1. Contact Seals
      2. Clearance Seals

III. BEARING MAINTENANCE

- A. Bearing Lubrication
- B. Oil Lubrication
  1. Anti-Friction Bearing Oil Lubrication
  2. Friction Bearing Oil Lubrication
- C. Grease Lubrication
- D. Bearing Inspections
  1. Alignment
  2. Clearances
- E. Bearing Care
  1. Cleaning Bearings
  2. Protection and Temporary Storage
  3. Handling Practice
- F. Roller Bearing Installation
  1. Roller Bearing Installation Precautions
  2. Interference Fits
  3. Methods of Mounting Bearings
  4. Axial Positioning
- G. Roller Bearing Removal
  1. Bearing Pullers
  2. Bearing Press
- H. Journal Bearing Maintenance
  1. Crush
  2. Torque
  3. Babbitt Bearing Fitting
  4. Bearing Scraping

IV. BEARING FAILURE ANALYSIS

- A. Normal and Abnormal Load Patterns
  1. Load Distribution in a Bearing
  2. Axial Loads
  3. Thrust and Radial Load
  4. Pre-Loads
  5. Out-of-Round Housing Bores
  6. Load Zones with Misaligned Rings
- B. Lubrication-Related Failures
  1. Lubrication Properties
  2. Spalling
  3. Discoloration and Softening
  4. Glazing
  5. Pulling

6. Smearing
7. Pitting
8. Skid Smearing
9. Grooves
10. Broken Cage
11. Welded Rollers
12. Avoiding Surface Failures
13. Examples of Surface Failures

C. Maintenance-Related Failures
1. Failure Due to Defective Bearing Seats
2. Bearing Misalignment
3. Faulty Mounting Practice
4. Damage Due to Improper Fits

D. Operational-Related Failures
1. Stationary Bearing
2. False and True Brinelling

LUBRICATION

V. Lubrication Fundamentals
A. Lubrication
B. What Is A Lubricant?
C. Basic Principles Of Lubrication
1. Viscosity
2. SAE Viscosity Grades
3. ISO Viscosity Grades
4. Sliding Versus Rolling Friction
5. Boundary/Thin Film Lubrication

VI. Basic Types Of Lubricants
A. Oil, What Is It?
1. Additives
2. Compatibilities
3. Applications
4. Testing

B. Grease, What Is It?
1. Additives
2. Compatibilities
3. Applications
4. Testing

VII. Principles Of Lubrication
A. Types Of Lubrication
1. Hydrodynamic Lubrication

2. Elastohydrodynamic Lubrication (EHD/EHL)
3. Contaminants

VIII. Lubrication Applications

A. Bearing Lubrication
   1. Grease Applications
   2. Oil Applications
   3. Proper Methods of Greasing (How Much, How Often?)

B. Coupling Lubrication
   1. Types Of Couplings
   2. Proper Greasing Of Couplings

C. Gear Lubrication
   1. EP (Extreme Pressure) Vs. Non-EP Oils
   2. Methods Of Supplying Lubricant
   3. Splash Lubrication
   4. Force-Fed Lubrication
   5. Intermittent Lubrication
   6. Hydraulic Lock
   7. Gear Failure Analysis

D. Worm Gear Lubrication
   1. Proper Lubrication Of Worm Gears
   2. Greasing/Oil Change Intervals

Time Required

16 hours

Sources

None

EM-300 Basic Programmable Logic Controllers

Course Description

This course provides information on PLC concepts, hardware, software, ladder logic functions (relay contacts, timers, counters). There are hands-on exercises for configuration and programming.

Terminal Objective

Upon completion of this course, the participants will be able to create simple ladder logic programs and trace ladder logic states.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with hands-on exercises.

Course Objectives

- Define programmable logic controller (PLC).
- Discuss the programmable controller operations.
- List the hardware of a programmable controller.
- List the programming software features.
- Describe the function of the programmable controllers Central Processing Unit (CPU).
- Describe the function of the programmable controllers Input/Output (I/O) interface system.
- Describe the difference between a programmable controller and computer controls.
- Describe the function of the ladder diagram.
- List the inherent features of and benefits of the PLC.
- Describe the function of the base of a number system.
- Describe the decimal number system.
- Manipulate numbers in the decimal number system.
- Describe the binary number system.
- Manipulate numbers in the binary number system.
- Describe the octal number system.
- Manipulate numbers in the octal number system.
- Describe the hexadecimal number system.
- Manipulate numbers in the hexadecimal number system.
- Perform conversions from one number system to another.
- Describe the purpose of one's and two's complement.
- Describe the purpose of the one's complement.
- Describe the purpose of the two's complement.
- Discuss the binary concept.

- Describe the purpose of the AND function.
- Describe the purpose of the OR function.
- Describe the purpose of the NOT function.
- Describe basic Boolean logic.
- Identify general PLC circuit and logic contact symbology.
- Describe the purpose of the address in memory.
- Identify contact symbols.
- Use the programming software to configure a PLC
- Use the programming software to create and edit ladder logic programs
- Create a ladder logic motor controller
- Use the programming software to force bit state.
- Create a timer-based program
- Create a counter-based program.

Topical Outline

I. Introduction to Programmable Logic Controllers
II. Number Systems
III. Logical (Boolean) Expressions
  A. Logical Functions
  B. Boolean Logic
IV. Introduction To The Plc-5
  A. Plc-5 Hardware
  B. Plc-5 System Operation
V. Rslogix 5 Introduction
  A. Screen Layout And Organization
  B. Finding Help
VI. Files, Memory Areas, And Addressing
  A. Memory Areas
  B. Addressing
VII. Using Rslogix 5
  A. Going On-Line With A Controller
  B. Uploading A Project From A Plc-5
  C. Saving A Project
  D. Downloading A Project To A Plc-5
  E. Editing Ladder Logic
  F. Inserting And Appending Rungs Of Ladder Logic
  G. Branching
VIII. Programming With Bit Instructions
  A. Selected Bit Instructions
  B. Using Bit Instructions

IX. Programming With Timers
- A. Timer Operation
- B. Reset Timer/Counter Instruction (Res)
- C. Using Timer Instructions

X. Programming With Counters
- A. Counter Operation
- B. Using Counter Instructions

XI. Troubleshooting
- A. Systematic Troubleshooting
- B. Clearing Processor Memory
- C. Forcing I/O Bits
- D. Cross Referencing Instructions
- E. Data Table Monitoring
- F. Searching
- G. Histograms

Time Required

40 hours

Sources

None

EM-106: Batteries

Course Description

This course provides information on the concepts associated with industrial batteries and Universal Power Supplies (UPS), battery and UPS function, battery and UPS design, battery maintenance, storage and transportation, installation and removal, and potential faults.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, design, construction and hazards of industrial batteries; install, remove and maintain industrial batteries; identify potential battery faults; and describe the purpose of a UPS in a battery system.

Target Audience

This course is designed for mechanical and electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises

Course Objectives

- Discuss the differences between a primary cell and a secondary cell.
- Discuss the purpose of the major components of a large storage battery.
- Describe the purpose of the electrolyte in the following batteries; Lead-Acid, Nickel-Cadmium
- Discuss how a battery produces electrical energy.
- Describe the operation of large storage batteries during the following condition; Steady State, Discharge, Charge
- Describe how to measure the following battery parameters; Total Battery Voltage, Individual Cell Voltage, Specific Gravity of Electrolyte
- Describe the use of total battery voltage and individual cell voltage measurements
- State the relationship between specific gravity and state of battery charge for; Lead-Acid Battery, Ni-Cad Battery
- Discuss how battery capacity is affected by different discharge rates.
- Determine current state of charge of a lead acid battery given the rated capacity and specific gravity drop.
- Identify several specific battery hazards.
- Describe the potential dangers involved with these hazards.
- List precautions associated with handling electrolyte.
- Describe how to handle an electrolyte spill.
- List the electric shock precautions.
- List the hydrogen gas precautions.
- Describe proper battery storage and transportation procedures.
- Describe monthly battery checks, including what is covered on a visual inspection and what pilot cell measurements are taken.
- Discuss proper battery ventilation check.
- Discuss battery grounds.
- Describe quarterly battery checks, including intercell connectors and cell measurements.

- Describe purpose and procedure for a test discharge.
- Discuss importance of maintaining battery records.
- Explain battery replacement criteria and procedure.
- Describe cell jumpering.
- Explain the theory of operation of static inverters.
- Describe the purpose of an Uninterruptible Power Supply (UPS).
- Explain the role of the battery within the UPS system.

Topical Outline

I. Principles Of Large Battery Operation
   A. Construction
      1. Primary Cell
      2. Secondary Cell
   B. Major Components
      1. Battery Element
      2. Cell Jar
      3. Vent or Flame Arrestor
      4. Service Tube
      5. Intercell Connections
      6. Racks and Frames
   C. Electrolytes
      1. Acid Solutions
      2. Alkaline Solutions
   D. Chemical Reactions
      1. Lead-Acid Cell
      2. Nickel-Cadmium Cell
      3. Primary Lithium Cell
   E. Battery Operations
      1. Lead-Acid Discharge Operation
      2. Nickel-Cadmium Discharge Operation
      3. Battery Charging Methods
      4. Charging Lead-Acid Batteries
      5. Charging Nickel-Cadmium Batteries
      6. Charging Methods

II. Battery Related Terminology
   F. Battery Voltages
      1. Total Battery Voltage
      2. Individual Cell Voltage (ICV)
   G. Specific Gravity
      1. Specific Gravity Corrections
      2. Use of Hydrometer
   H. Battery Capacity

1. Normal Capacity Rating
2. Effects of Temperature
3. Effects of Specific Gravity
4. Specific Gravity Versus State of Charge

III. Battery Safety

I. Specific Battery Hazards
1. Electrolyte Hazards
2. Electric Shock Hazards
3. Hydrogen Gas Hazards

J. Electrolyte Precautions
K. Electric Shock Precautions
L. Hydrogen Gas Precautions
M. Battery Storage And Transportation

Iv. Battery Maintenance

N. Battery Preventive Maintenance Requirements
1. Recommended Monthly Checks
2. Recommended Quarterly Checks
3. Test Discharge
4. Battery Records

O. Battery Replacement/Removal
1. Cell Jumpering

V. Uninterruptible Power Supply (UPS) Operation

P. Purpose Applications
1. Power Sensitive Equipment
2. Vital Equipment
3. Prevention of Power Surges
4. Effect

Q. Role Of The Battery
1. Reason for Using a Battery
2. How the Battery is Used in the UPS
3. How Parameter Changes in the Battery Effect the UPS
4. Reason for Proper Battery Maintenance

R. Normal Operation
1. Theory of Operation
2. Voltage Regulation

S. Loss Of Normal Ac Source (Role Of The Battery)
1. Purpose of the UPS
2. The Uninterruptible Power Supply
3. AC Output

T. Loss Of Inverter (Back Up Power Supplies)

U. Power Conditioning
   1. High-Voltage Surge Suppressors
   2. Noise Suppression Filters
   3. High Isolation Transformers

V. Emergency Diesel Generator (EDG)
   1. Engine-Generator Operation

VI. Appendix A - Battery Regulations

Time Required

8 hours

Sources

None

EM-200: Industrial Electronics

Course Description

This course provides information on the function and circuit analysis of power supplies, amplifiers, integrators, comparators, and oscillators. There are hands-on exercises for wiring and analyzing the various circuits.

Terminal Objective

Upon completion of this course, the participants will be able to assemble and analyze common electronic circuits.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with hands-on exercises.

Course Objectives

- Discuss the basic structure of a semiconductor atom and the movement of free electrons and holes.
- Discuss the purification and doping of semi-conductors.
- Describe the p-type region, n-type region, and junction of a PN junction diode.
- Discuss the characteristic curves and specification ratings of a diode.
- Describe the operation of a light-emitting diode, a photoconductive device, and a photovoltaic device.
- Describe the differences between an NPN transistor and a PNP transistor and identify the schematic symbol for each.
- Discuss transistor performance in the active region, saturation region, and cutoff region.
- Explain how the three kinds of transistor connections affect circuit values.
- Discuss four common transistor characteristics.
- Describe several kinds of semiconductor packages.
- Explain how to identify leads.
- Discuss the basic functions of power supplies and power conditioners.
- Compare the operation of transformer-driven and oscillator-driven inverters.
- Discuss the functions of filters, voltage regulators, voltage dividers, switching power supplies, and ferroresonant power supplies.
- Explain why low voltages can be dangerous.
- Define the term rectifier.
- Explain how to interpret diode ratings on a manufacturer's specification sheet.
- Compare the effects of connecting diodes in parallel and in series.
- Describe the operation of a silicon-controlled rectifier.
- Compare the operation of half-wave and full-wave rectifiers.
- Discuss the operation of bridge and three-phase rectifiers and explain how voltage multipliers work.
- Name several kinds of filters used in power supplies.
- Discuss the effects of ripple and describe ways ripple is measured.

- Discuss the use of capacitors, inductors, and resistors in filter circuits.
- Compare the advantages and disadvantages of capacitance, inductance, RC, and LC power supply filters.
- Explain why capacitor power supplies should include bleeder resistors.
- Discuss the uses of bypass filters and input filters.
- Discuss the purposes of voltage regulators in power supplies.
- Explain the function of the control circuit and the current limiting circuit in series voltage regulators.
- Discuss the advantages of IC voltage regulators.
- Describe the operation of switching regulators and explain how it differs from that of other kinds of regulators.
- Discuss the use of SCRs and triacs in primary circuit regulators.
- Discuss at least five kinds of test equipment and tools used to troubleshoot power supplies.
- Describe the three main steps in troubleshooting a power supply.
- Describe the basic procedures for preliminary checks and power-off visual inspection and fuse tests.
- Describe the basic procedures for power-on tests and output tests.
- Explain how to perform section tests and part tests.
- Explain how gain, bandwidth, and distortion relate to amplifier operation.
- Compare bipolar transistor amplifiers and FET amplifiers.
- Explain how to use characteristic curves to predict transistor performance.
- Explain how to use an input/output curve to determine transistor gain.
- Discuss the effect of ambient temperature on amplifier performance.
- Discuss the uses of operational amplifiers and switching amplifiers.
- Discuss the transistor characteristics that define operating region limits.
- Explain how to draw an amplifier load line.
- Explain how to find the operating point of an amplifier.
- Discuss biasing as a means of establishing a stable operating point in an amplifier circuit.
- Discuss five ways that amplifiers can be classified and compare Class A, AB, B, and C amplifiers.
- Explain how to calculate amplifier power gain, efficiency, current gain, and voltage gain.
- Explain how nonlinearity and clipping cause amplifier distortion.
- Discuss the importance of impedance matching in interconnecting circuits.
- Explain how to calculate multistage amplifier gain and bandwidth.
- Compare the advantages and disadvantages of capacitive-coupled, transformer-coupled, and direct-coupled amplifiers.
- Describe the operation of differential amplifiers.
- Compare the properties of an ideal op amp and a typical actual op amp.
- Describe the operation of inverting amplifiers in terms of virtual ground.
- Compare the advantages of inverting amplifiers and noninverting amplifiers.
- Explain how integrators and comparators work.
- Explain how Zener diodes are used in squaring circuits.

- Compare the frequency characteristics of low-pass and high-pass filters and of band-pass and band-reject filters.
- Discuss the calculation of time constants in timing circuits.
- Describe methods of creating and shaping complex waveforms, including the differentiator and integrator circuits.

Topical Outline

I. Semiconductor Diodes And Power Supplies
II. Conductors, Semiconductors, And Insulators
III. PN Junctions
  A. The Basic PN Junction
  B. Biasing PN Junctions
IV. Diode Specifications
  A. Rectifier Diodes
  B. Signal Diodes
V. Rectifier Circuits
  A. Half-Wave Rectifier
  B. Full-Wave Rectifier
  C. Bridge Rectifier
  D. Three-Phase Bridge Rectifier (Full-Wave)
VI. Junction Diode Considerations
VII. Power Supply Filters
  A. Capacitor Input Filter
  B. Choke Input Filter
  C. Multiple Section Choke Input Filter
  D. Pi Filter
  E. Rc Capacitor Input Filter
VIII. Voltage Dividers
  A. Series Voltage Divider
  B. Series Voltage Divider - Parallel Load
  C. Current Divider
  D. Bleeder Resistor Voltage Divider
IX. Voltage Regulators
  A. Simple Series Voltage Regulator
  B. Simple Shunt Voltage Regulator
  C. Zener Voltage Regulator
X. Voltage Multipliers
  A. Half Wave Voltage Doubler
  B. Full Wave Voltage Doubler
  C. Voltage Tripler
  D. Voltage Quadrupler
XI. Semiconductor Types And Applications

A. Scrs
B. Zener Diodes
C. Varistors
D. Light Emitting Diode (Led)

XII. Bipolar Transistors
A. Transistors
B. Transistor Biasing
C. Transistor Operation
D. Transistor Testing Using An Ohmmeter
E. Transistor Configurations
F. Transistor Gain Characteristics
G. The Common Base Circuit
H. The Common Emitter Circuit
I. The Common Collector Circuit
J. Transistor Circuit Characteristics Summary
K. Classes Of Amplifiers
L. Transistor Coupling

XIII. Opto-Electronic Devices
A. Photodiodes
B. Phototransistors
C. Light Emitting Diodes
D. Light-Activated Scr
E. Opto-Isolators

XIV. Integrated Circuits
A. Ic Op Amp
B. Ic Op-Amp General Description
C. Open Loop Characteristics
D. Closed Loop Characteristics
E. Inverting Amplifier
F. Noninverting Amplifier
G. Summing Amplifiers
H. Summing Amplifier Operation
I. Integrator
J. Differentiator

Time Required

40 hours

Sources

None

WE-101: Welding And Burning

Course Description

This course provides information on oxyfuel cutting and SMAW structural welding. There are extensive hands-on exercises for burning and welding.

Terminal Objective

Upon completion of this course the participants will be able to make cuts using oxyfuel equipment and weld T-joints using SMAW equipment

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Describe fusion welding, resistance welding, filler rods, and electrodes.
- Compare the oxyfuel and arc welding processes and compare the SMAW, GMAW, and GTAW processes.
- Describe and sketch the following kinds of joints-butt, lap, tee, corner, and edge.
- Describe the following kinds of welds-groove, fillet, plug, slot, spot, and seam.
- Name and locate the parts of a weld.
- Discuss basic considerations in joint design and fitup.
- Explain the importance of good housekeeping in an area where welding is taking place.
- List at least three precautions to take to avoid fires and explosions when welding.
- Describe two methods of protecting yourself against the fumes and gases associated with welding.
- Describe the personal protective equipment required when welding.
- Explain the precautions to take when using and handling cylinders and regulators.
- Briefly describe the oxyfuel welding process and the components of an oxyfuel welding outfit, including the lighting device.
- Discuss safety precautions and personal protective gear required for working with oxyfuel equipment.
- List the steps involved in preparing to weld.
- Compare the neutral, carburizing, and oxidizing flames.
- List the steps in safely shutting down an oxyfuel welding system.
- List similarities and dissimilarities between oxyfuel welding and arc welding.
- Describe the electric welding circuit, including choice of ac or dc, dc polarity, and power sources.
- Discuss welding machine ratings in terms of amperage and duty cycle and describe features and uses of transformer, generator, rectifier, and inverter welding machines.

- Discuss welding cable considerations and describe the electrodes and electrode holders used for SMAW, GMAW, and GTAW processes.
- Discuss the personal safety gear and precautions necessary for arc welding and explain how arc welding accessories are used.
- Explain what considerations affect the selection of a welding process.
- Describe the four welding positions.
- Explain why overhead welds are difficult to make and tell how to make them.
- Describe the preparation required for oxyfuel welding, SMAW, GMAW, and GTAW processes.
- Describe the procedures involved in oxyfuel welding, SMAW, GMAW, and GTAW processes
- Describe the effects of electrode selection, current, arc length, and travel speed on arc welding procedures.
- Describe common causes of arc blow, a hard-to-start arc, and spatter, and explain why proper fitup is important.
- Define the terms overlap, undercut, blowhole, and inclusion and explain the causes of each.
- Explain how expansion and contraction can be controlled when welding.
- Name and describe the various tests used to identify metals.
- Identify the kind of chamfer to be cut on a joint to be welded, and which part is to be chamfered.
- State the required dimensions of a weld.
- Identify the contour required on a finished weld.
- State how a weld contour is to be finished.
- Differentiate between welds that are to be made at the site of final assembly and welds that are to be made before the parts are shipped to the site.
- Explain the similarities and differences between oxyfuel cutting and oxyfuel welding.
- Describe the equipment and safety precautions necessary for torch cutting and list standard steps in the torch cutting operation.
- Describe special equipment or methods used in cutting bevels, piercing holes, cutting circles, and cutting away rivets.
- Explain why gouging, scarfing, and washing are used.
- Explain methods used on metals that are otherwise difficult to cut.
- Explain how the shielded metal arc welding process works.
- Tell what provides the shield in shielded metal arc welding.
- Define arc length and explain its importance.
- List factors to consider when selecting an electrode.
- Describe the personal protective equipment necessary for welding.
- Explain the factors involved in selecting SMAW electrodes.
- Explain how to identify different welding electrodes.

- Give examples of several kinds of electrode coverings and tell when each is used.
- Describe correct procedures for handling, storing, and conserving electrodes.
- Cut metal using oxyfuel equipment.
- Make t-joint welds using SMAW equipment

Topical Outline

I. Fundamentals of Welding
II. Welding Safety
III. Oxyfuel Welding Equipment
IV. Arc Welding Equipment
V. Welding Techniques
VI. Avoiding Weld Faults
VII. Welding Symbols
VIII. Oxygen Cutting
IX. Shielded Metal Arc Welding
X. Selecting Electrodes for SMAW
XI. Oxyfuel Cutting Demonstration
XII. Oxyfuel Cutting Exercises
XIII. SMAW Plate (T-Joint) Demonstrations
XIV. SMAW Plate (T-Joint) Exercises
XV. SMAW Plate (T-Joint) Practical Exam

Time Required

240 hours (6 weeks)

Sources

None

EM-201: Transformers

Course Description

This course provides information on the concepts associated with transformers, transformer function, transformer design, transformer maintenance, transformer faults, and transformer inspecting and testing. There are hands-on exercises for transformer wiring and installation.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, various designs, and construction of transformers; maintain and identify causes of transformer failure.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises

Course Objectives

- Describe the basic principles of electromagnetic induction
- Describe the application of electromagnetic induction in an elementary transformer.
- Describe the major components of a transformer.
- Describe the operation of a transformer.
- Describe the properties of three-phase circuits.
- Describe the construction of a three-phase transformer.
- Describe the standard three-phase transformer wiring configurations.
- Describe the information found on a transformer nameplate.
- Describe the process of changing taps on a three-phase distribution transformer.
- Describe transformer general safety precautions.
- Describe the basic types of transformers.
- Describe how to size a transformer for a specific application.
- Describe types of transformer malfunctions.
- Describe transformer testing and inspection.

Topical Outline

I. Transformer Theory And Operation

A. Review Of Principles Of Electromagnetic Induction

1. Basic Definitions and Measures of Magnetism
2. Magnetic Flux
3. Magnetic Flux Density
4. Permeability
5. Retentivity
6. Magnetic Field Strength
7. Magnetomotive Force (MMF)
8. The Magnetic Field Surrounding a Current-Carrying Conductor
9. The Left-Hand Rule for a Current-Carrying Conductor

10. The Magnetic Field Surrounding a Coil
11. The Left-Hand Rule for a Coil
12. Inducing a Voltage in a Coil

B. Review of Inductance In AC Circuits
1. Factors Affecting Inductance
2. Voltage and Current in an Inductive Circuit
3. Inductive Reactance
4. Power Factor

C. Elementary Transformers
1. Transformer Construction
2. Transformer Cores
3. Hollow Core
4. Shell Core
5. Transformer Windings
6. Transformer Operation
7. Turns Ratio
8. Voltage Ratio
9. Step-Up and Step-Down Transformers
10. Current Ratio
11. Phase Relationship of Current and Voltage in the Windings
12. Polarity and Winding Markings
13. Dual Voltage Primaries
14. Primary Windings Connected in Series
15. Primary Windings Connected in Parallel
16. Dual Voltages From the Secondary Side
17. Transformer Connections
18. Transformer Taps
19. Transformer Losses
20. Copper Losses
21. Hysteresis Loss
22. Saturation Loss
23. Eddy Current Loss

II. Three-Phase Transformers

A. Three-Phase Circuits
1. Delta Configuration
2. Wye Configuration

B. Three Phase Transformer Construction

C. Three-Phase Winding Configurations
1. Delta-Delta Circuit
2. Delta-Wye Circuit
3. Wye-Delta Circuit

4. Wye-Wye Circuit

D. Transformer Nameplate Data
   1. KVA Rating
   2. Rated Frequency
   3. Phase
   4. Impedance
   5. Voltage Ratings
   6. Winding Connection Diagram
   7. Jumper Connection Chart
   8. Coil Tap Arrangement Diagram
   9. Phase Relationship Diagram

E. Changing Taps On Three-Phase Distribution Transformers

III. Transformer Applications

A. Transformer Safety

B. Polychlorinated Biphenyl (PCB) Safety

C. Types Of Transformers
   1. Distribution Transformers
   2. Isolation Transformers
   3. Autotransformers
   4. Current Transformers
   5. Removing a CT from Service

D. Transformer Sizing

E. Transformer Malfunctions
   1. Loss of Cooling
   2. Ferro-Resonance
   3. Over-Excitation
   4. Low Energy Internal Arcing
   5. Harmonics

F. Transformer Testing And Inspection
   1. Transformer Tests
   2. Transformer Inspections

Time Required

Up to 40 hours (depending upon audience and audience experience).

Sources

None

EM-202: Motor Theory

Course Description

This course provides information on the principles of operation associated with motors and motor components, to include AC/DC theory of operation including torque, pullout torque and slip,

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, design, and construction of motors, identify different types of motors and their applications and interpret information found on a motor nameplate.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises

Course Objectives

- Define the following terms; Motor, Motor action, Generator action
- Explain the left-hand and right-hand rules for motors and generators.
- Define the following terms; Counter Electromotive Force, Commutator
- Describe the operation of an elementary DC motor.
- Describe the methods used to minimize the effects of armature reaction.
- Identify the major components of a basic DC motor.
- State the purpose of the major components of a basic DC motor.
- Describe the operation and characteristics of the following DC motors; Shunt DC motor, Series DC motor, Compound DC motor
- Explain the operating principles of a basic AC motor.
- Describe the operation of the following AC motors; Three-phase induction motor, Three-phase synchronous motor, Split-phase induction motor, Shaded-pole induction motor, Capacitor-start induction motor, Capacitor-run motor, Repulsion-start motor, Reluctance motor
- Describe the construction of a squirrel cage and wound rotor motor.
- Define *slip* and calculate the percent slip for an induction motor.
- Define *torque*.
- Explain *pull-out torque*.
- Identify three types of single-phase AC motors.
- Compare the differences between multiple winding and consequent pole multiple speed induction motors.
- List the parameters used to determine a motor's rating.
- State the four classes of motor insulation.
- List the information found on a typical motor nameplate.
- Compare delta to wye wiring for voltage, current, and power capabilities.

Topical Outline

I. Principles Of Operation Of Simple Motors
- A. Principles Of Magnetism
  1. Magnetic Field Around a Current-Carrying Conductor
  2. Magnetic Field of a Coil
- B. Motor Action
  1. Motor Action
  2. Right Hand Rule for Motors
  3. Left Hand Rule fro Generators
- C. Induction

II. DC Motors
- A. DC Motor Operation
- B. Counter Electromotive Force
- C. Types Of DC Motors
  1. Shunt Motors
  2. Series Motors
  3. Compound Motors
- D. Operating Characteristics

III. AC Motors
- A. Simple AC Motors
  1. Types of AC Motors
  2. Rotating Magnetic Field
- B. Three Phase Induction Motors
  1. Squirrel Cage Induction Motor
  2. Wound Rotor Induction Motor
  3. Torque
  4. Overload Condition
- C. Three Phase Synchronous Motors
  1. Starting Principle
  2. Starting Techniques
  3. Operating Principles
  4. Synchronous Motor Applications
- D. Single-Phase AC Motors
  1. Single-Phase Induction Motors
- E. Multiple Speed Induction Motors
  1. Multiple Winding Motor
  2. Consequent-Pole Motor
- F. Motor Ratings and Nameplate Data
  1. Motor Ratings
  2. Motor Insulation

3. Nameplate Data

G. Connecting Three Phase Loads
   1. Delta Connection
   2. Wye Connection
   3. Power in a Three-Phase System
   4. Delta and Wye Relationships

Time Required

Up to 40 hours (depending upon audience and audience experience).

Sources

None

EM-203: AC & DC Generator Theory

Course Description

This course provides information on the concepts associated with generators, generator function, generator design, three phase voltage, and load sharing.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, design, and construction of AC and DC generators.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Explain the principles of magnetism.
- Define the generator action.
- Define electromotive force.
- Explain the purpose of generators.
- Describe the construction of basic DC generators.
- Demonstrate the left-hand rule for generators.
- Explain how voltage is induced in an armature.
- State the function of the commutator and brushes.
- Describe the construction and operation of a basic D.C. generator commutator.
- Explain why electromagnets are used to produce the field in generators.
- Describe copper loss and its effects.
- Explain how voltage is induced in a stationary armature.
- Explain how a magnetic field is produced on a rotor.
- Explain how three-phase voltage is produced.
- Describe the construction of an AC generator stator.
- Describe the construction, including advantages and disadvantages, of the following; AC generator salient pole rotors, AC generator turbo rotors
- Describe armature reaction and its effects in AC generators.
- Describe armature impedance and its effects.
- Describe load sharing.

Topical Outline

I. DC Generators
   A. DC Generator Theory
      1. Hand Rules for Generators
      2. Producing Voltage
      3. Induced Voltage
   B. DC Generator Construction

C. Electrical and Rotational Losses
D. Types of DC Generators
    1. Series Generator
    2. Shunt DC Generator

II. AC Generators
A. Types of AC Generators
B. Theory of Operation
    1. Generating an AC Sine Wave
    2. Three-Phase Sine Wave
    3. Armature Connections
    4. Rotor Excitation
C. Mechanical Construction
    1. Rotor Construction
    2. Stator Construction
D. AC Generator Operating Characteristics
    1. Armature Impedance
    2. Armature Resistance
    3. Armature Reactance
    4. Armature Reaction
    5. Load Sharing

Time Required

Up to 20 hours (depending upon audience and audience experience).

Sources

None

EM-204: Motor Controls

Course Description

This course provides information on the concepts associated with AC and DC motor fundamentals, motor control fundamentals, control of motor starting, and motors and motor controllers. The lessons cover a wide range of topics such as motor enclosures, nameplate data, AC motors, DC motors, magnetic contactors, control circuits, Wye-Delta starters, speed controllers, AC/ DC machine maintenance, and motor control circuit maintenance.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, design, and construction of motor controllers; install, remove and maintain motor controllers; and identify the causes of motor controller failure.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Define motor control terms (Ampacity, Branch circuit, Circuit breaker, Controller, Duty, Equipment, Full load amps, Ground-fault circuit interrupter, Interrupting rating, Motor circuit switch, NEMA design letter, Nonautomatic, Overcurrent, Overload, Power factor, Rated full load speed, Rated horsepower, Remote control circuit, Service factor, Thermal cutout, Thermal protector).
- Describe the various types of motor enclosures.
- Describe how the rated voltage of a motor differs from the system voltage.
- Describe the basic construction and components of a three-phase squirrel cage induction motor.
- Explain the relationship between speed, frequency and number of poles in a three-phase induction motor.
- Describe how torque is developed in an induction motor.
- Explain how and why torque varies with rotor reactance and slip.
- Define percent slip and speed regulation.
- Explain how a three-phase motor's direction is reversed.
- Describe the component parts and operating characteristics of the three-phase wound-rotor induction motor.
- Describe the component parts and operating characteristics of the three-phase synchronous motor.
- Define torque, starting current, and armature reaction as they apply to DC motors.
- Explain how the direction of rotation of a DC motor is changed.
- Describe the design and characteristics of a DC shunt, series, and compound motor.

- Given a set of initial data, determine how a synchronous motor can correct the lagging power factor of induction motors by; Calculating watts, volt-amperes, and lagging vars of induction motors, Calculating watts, volt-amperes, and leading vars of a synchronous motor, Calculating the total load of the system, Calculating the corrected power factor.
- Describe dual voltage motors and their application.
- Describe the methods for determining various motor connections.
- Describe general motor protection requirements as delineated in the National Electrical Code.
- Describe the common types of motor controller enclosures.
- Define manual control, semiautomatic control, and automatic control.
- Identify the basic symbols used in motor control circuits.
- Explain the difference between manual starters and automatic starters.
- State the effects of voltage variations on magnetic contactors.
- State the possible cause of AC hum of a magnetic contactor.
- Describe magnetic blowout contactors.
- Explain the term starting sequence.
- Describe the operation of main and auxiliary contacts.
- Define *seal-in* contacts.
- Describe the difference between two-wire and three-wire control.
- State the conditions under which a 120-volt control circuit may operate ungrounded.
- Describe how interlocking for reversing control is accomplished.
- Identify standard symbols on MCC feeder prints and MCC one-line diagrams.
- Identify the function of various devices using standard symbology and device numbers.
- Develop a control circuit using a variety of common control features.
- Describe the following types of voltage starting circuits; Line resistance starter, Line reactance starter, Autotransformer starter, Wye-Delta starter, Increment resistance starter, Part-winding starter, Full voltage starter.
- Describe the methods of acceleration control.
- Given an electric print of a motor starting circuit, troubleshoot basic problems associated with motor control circuits.
- Given an electrical print, identify power supplied for motor primary power and control power.
- Describe the function of two-speed consequent pole controllers.
- Describe the operation of wound-rotor motor controllers.
- Identify the reason why out of step relays are used in synchronous motor controllers.
- Explain the operation of an automatic synchronizer.
- Describe the function and operation of a counter-EMF controller.
- Describe the function and operation of a DC magnetic time limit controller.
- Describe variable frequency drives.
- Describe the operation of a vacuum contactor.
- List the most common items in motor controller inspection and maintenance.
- Distinguish between normal contact wear and abnormal contact wear.
- Identify the possible causes and suggested remedies of various contactor troubles.
- List and briefly explain six causes for rotating machinery failure.

- Describe the following types of rotating machinery maintenance; Visual inspection, Tightness check, Air gap distance, Lubrication and bearing replacement.
- Describe the following rotating machinery tests; Insulation resistance, Continuity, Vibration analysis, DC high potential, Power factor, Thermography.
- Describe the following types of brush and brush rigging maintenance; Brush rigging inspection and adjustments, Brush arm spacing, Brush inspection, Brush replacement and installation, Neutral plane setting.
- Describe the following types of commutator and slip ring maintenance; Film conditions, Surface cleaning, Resurfacing rotating conductor surfaces, Mica undercutting and repair
- List and describe various commutating surface problems, including brush flashover.
- Describe motor and generator maintenance guidelines as defined by the National Electric Testing Association (NETA).
- Describe the following types of motor control circuit maintenance and tests; Visual inspection, Tightness check, Insulation resistance, Continuity testing, Relay maintenance, Protective device functional checks, Alarms and warning lights functional test, System operational testing.
- Describe how to troubleshoot a motor control circuit fault.

Topical Outline

I. AC And DC Motor Fundamentals
   A. Terms And Definitions
   B. Motor Enclosures
      1. Open Motor
      2. Enclosed Motor
   C. Nameplate Data
      1. Rated Voltage
      2. Full-Load Amps (FLA)
      3. Rated Full-Load Speed
      4. Rated Horsepower
      5. Frame Sizes
      6. Duty or Time Rating
      7. NEMA Design Letter
      8. Insulation Class
      9. Nominal Rated Voltage
      10. Minimum Starting Voltage
      11. Frequency
      12. Service Factor
      13. KVA Code Letter
      14. Bearings
      15. Rated Amperage
      16. Rated Horsepower
      17. Locked-Rotor Current
      18. Starting Current

19. Temperature Rise
20. Power Factor

D. Motor Protection
   1. Branch Considerations
   2. Thermal Protectors

E. Alternating Current Motors
   1. Motor Theory
   2. Rotating Fields
   3. Rotor Behavior in a Rotating Field
   4. Induction

F. Induction Motors
   1. Construction
   2. Stator
   3. Rotor
   4. Torque
   5. Starting Current
   6. Power Factor
   7. Speed Control
   8. Reversing Rotation

G. Synchronous Motors
   1. Characteristics
   2. Construction
   3. Principle of Operation
   4. Rotor Field Excitation
   5. Synchronous Motor Pullout
   6. Synchronous Motor Torque Angle
   7. Wound Rotor Motors
   8. Wound Rotor Speed Control

H. Direct Current Motors
   1. Principles of Operation
   2. Armature Construction
   3. DC Motor Ratings
   4. Types of DC Motors
   5. Torque
   6. Starting Current and Counter EMF
   7. Starting Resistance
   8. Armature Reaction
   9. Interpoles
   10. Direction of Rotation of DC Motors

I. Shunt Motors
   1. Speed Control

2. Torque
3. Speed Regulation

J. DC Series Motors
1. Torque
2. Speed Control and Speed Regulation
3. Motor Ratings

K. DC Compound Motors
1. Torque
2. Speed
3. Speed Regulation
4. Industrial Applications

L. Connections And Terminal Markings For AC Motors
1. Rotation
2. Double-Voltage Motors
3. Three-Phase Star Connection
4. Three-Phase Delta Connection
5. Two-Phase Double-Voltage Connection
6. Two-Speed Consequent-Pole Motors
7. Star Connection
8. Delta Connection
9. Delta Connection for Constant Horsepower
10. Open-Delta Connection, Constant Torque
11. Open-Delta, Constant-Horsepower

M. Direct Current Motors Directional Connections
1. Direct Current Shunt Motors
2. Series-Wound Motors
3. Direct Current Compound-Wound Motor

II. Motor Control Fundamentals

A. Functions
B. Codes And Standards
C. Enclosures
1. Manual Controller
2. Semiautomatic Controller
3. Automatic Controller

D. Control Devices And Symbols
1. Primary Control and Pilot Control Devices
2. Contacts
3. Pushbutton Switches
4. Toggle Switches
5. Indicating Lights
6. Coils, Relays and Contactors

E. Magnetic Contactors
   1. Types of Magnetic Contactors
   2. Inrush Current
   3. Ratings
   4. Voltage Variations
   5. AC Hum
   6. Magnetic Blowout
   7. Magnetic Coil Control Circuits
   8. Magnet Coil Data
   9. Holding Circuit Interlocks
   10. Interlocks
   11. Overloads
   12. Overload Selection
   13. Ambient Compensation
   14. Rotary Switches
   15. Automatic Switches
   16. Float Switches
   17. Pressure Switches
   18. Temperature Switches
   19. Flow Switches
   20. Timer
   21. Limit Switches
   22. Foot Switches
F. Control Circuits
   1. Diagrams
   2. Circuit Analysis
   3. Three Wire Control
   4. Two Wire Control
   5. Common Control
   6. Control Power Transformers
G. Hand-Off-Auto Controls
H. Interlocking Methods For Reversing Control
   1. Mechanical Interlocking
   2. Pushbutton Interlocks
   3. Auxiliary Contact Interlock
I. Sequence Control
J. Motor Control Center Power Supplies
K. MCC Single Line Diagrams
L. Elementary Diagram Analysis
M. Standard Device Numbers
N. Developing A Control Circuit

III. Control Of Motor Starting
- A. Full-Voltage Starters
- B. Reduced Voltage Starters
- C. Wye-Delta Starters
  1. Delta Connections
  2. Wye Connections
  3. Open Transition
  4. Closed Transition
- D. Part Winding Starters
- E. Speed Controllers
- F. Consequent Pole Controllers
- G. Variable Frequency Drives
  1. Rectifier Section
  2. Inverter Section
  3. Pulse Width Modulation
  4. Speed Control of AC Motors
  5. Frequency Changes
  6. Solid State DC Motor Speed Control
- H. Wound Rotor Motor Controllers
- I. Synchronous Motor Controls
- J. Acceleration Control
- K. Control Power
- L. DC Controllers
  1. Counter EMF Controller
  2. Magnetic Time Limit Controller
  3. Voltage Drop Acceleration
  4. DC Series Relay Acceleration
  5. Dashpots
- M. Vacuum Contactors
- N. Routine Inspection And Maintenance
  1. Quick Checks
  2. Contact Wear and Replacement
- O. Circuit Troubleshooting
  1. Common Problems
  2. Main Contactor Energizes but Motor does not Start
  3. Main Contactor does not Close when Energized
  4. Contactor Closes and then Opens when Start Button is Released
  5. Main Fuse Blows or Breaker Trips When the Start Button is Pushed
  6. Control Power Fuse Blows
  7. Main Contactor Does Not Energize
  8. Identifying a Faulty Component

9. Troubleshooting For A Specific Fault

IV. Motors And Motor Controls

A. AC Machine Maintenance
B. Causes Of Rotating Machinery Failure
   1. Abnormal Voltage
   2. Restricted Ventilation
   3. Overloads
   4. Vibration
   5. Improper Lubrication
   6. Moisture
   7. Electrical Connections
C. AC Rotating Machine Maintenance
   1. Visual Inspection
   2. Cleanliness
   3. Grounding
   4. Damage
   5. Ventilation
   6. Tightness Check
   7. Air Gap Distance
   8. Lubrication
   9. Bearing Replacement
D. AC Machine Testing
   1. Operational Parameters
   2. Insulation Resistance
   3. Continuity Testing
   4. Vibration Analysis
   5. DC High Potential Testing
   6. Power Factor
   7. Thermography
E. Special AC Rotating Machines
F. DC Machine Maintenance
   1. Commutator and Slip-Ring Maintenance
   2. Commutator and Slip-Ring Surface Film
   3. Cleaning Commutators and Slip-Rings
   4. Commutator Problems
   5. Commutator and Slip Ring Surfacing
   6. Flashover
   7. Mica Undercutting and Repair
G. Brush Rigging And Brush Maintenance
   1. Brush Rigging Inspections and Adjustments
   2. Brush Holder Clearance

3. Brush Holder Staggering
4. Brush Holder Angles and Types
5. Brush Arm Spacing
6. Brush Inspection
7. Brush Replacement or Reinstallation
8. Connecting Brush Pigtails
9. Brush Seating
10. Brush Pressure
11. Neutral Plane Setting

H. Causes Of Unsatisfactory Brush And Commutator Function
I. National Electric Testing Association Guidelines
1. DC Motors and Generators
2. Visual and Mechanical Inspection
3. Electrical Tests
4. Synchronous Motors and Generators
5. Visual and Mechanical Inspection
6. Electrical Tests
7. Induction Motors
8. Visual and Mechanical Inspection
9. Electrical Tests
10. Test Values

J. Motor Control Circuit Maintenance
1. Visual Inspection
2. Cleanliness
3. Grounding
4. Damage
5. Ventilation
6. Tightness Check
7. Insulation Resistance
8. Continuity Testing
9. Relays
10. Mechanical Operational Test
11. Chatter Test
12. Operational Check
13. Protective Devices
14. Alarms and Warning Lights

K. Circuit Troubleshooting
1. Common Problems
2. Main Contactor Energizes but Motor does not Start
3. Main Contactor does not Close when Energized
4. Contactor Closes and then Opens when Start Button is Released

5. Main Fuse Blows or Breaker Trips When the Start Button is Pushed
6. Control Power Fuse Blows
7. Main Contactor Does Not Energize
8. Identifying A Faulty Component
9. Troubleshooting For A Specific Fault

Time Required

40 hours

Sources

None

EM-302: AC and DC Drives

Course Description

This course provides information on solid-state drive concepts, drive-based motor control, drive and motor setup, and drive programming. There are hands-on exercises for setting up AC and DC drives.

Terminal Objective

Upon completion of this course, the participants will be able to explain operation of AC and DC drives, setup AC and DC drives, and configure and program AC and DC drives.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with hands-on exercises.

Course Objectives

- Describe the operation of diodes, SCRs and transistors.
- Match the proper motor, gearing drive, and electrical power to a load
- Describe the basic functions of AC drive hardware.
- Identify the characteristics of shunt and series wound motors.
- Differentiate between field control and armature control of a DC motor
- Describe the operation of various types of AC drives
- Describe the operation of various types of DC drives.
- Use the parameters associated with a drive to control motor operation

Topical Outline

I. Machine Loads
   A. Constant Torque Loads
   B. Constant Horsepower Loads
   C. Centrifugal Torque Loads

II. Introduction To Ac Drive Hardware
   A. Ac Drive System
   B. Power Section
   C. Logic Section
   D. The Interface
   E. Voltage Source Drives
   F. Variable-Voltage Source Drives
   G. Constant-Voltage Source Drives
   H. Scr Pwm Drive

III. Variable-Speed Drive Parameters
- A. Analog Output Frequency
- B. Accel Time
- C. Decel Time
- D. Rated Frequency
- E. Rated Motor Voltage
- F. Maximum Speed
- G. Minimum Speed
- H. Stop Mode
- I. Fault Log
- J. Dc Voltage Boost
- K. Preset Speed
- L. Jog Speed
- M. Plug Current Level
- N. Stall Time
- O. Analog Output Menu
- P. Analog Output Current
- Q. Analog Output Voltage
- R. Analog Output Power

IV. Dc Motor Speed Controls
- A. Field Control
- B. Armature Control
- C. Thyristor Control Of Armature Voltage And Current
- D. Single-Phase, Full-Wave Speed Control System
- E. Reversible Speed Control
- F. Three-Phase Drive Systems For Dc Motors

Time Required

40 hours

Sources

None

EM-205: DC Cranes and Controls

Course Description

This course provides information on the function and troubleshooting of DC Crane Controls.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, design, and construction of DC Cranes and the control equipment; interpret crane control prints, and troubleshoot crane control faults.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Describe the physical layout of the crane.
- Describe operation of the crane from no speed to full speed.
- Discuss the function of the resistor banks in the power circuit.
- Describe the appearance and function of all major crane components.
- Explain the information in the Title Block, Legend, Revisions, and Material List portions of a drawing.
- Given an electrical print, identify the organizational make-up the print.
- Identify the common electrical print symbols and the components represented.
- Identify and interpret an electrical block diagram and a one-line diagram.
- Identify and interpret connection diagrams.
- Describe the motor operating quadrants.
- Explain the function of a freewheeling diode.
- Explain the use and electrical function of a reversing switch.
- Explain the use of a synchronous motor as a DC machine
- Describe proper motor inspection techniques and points of inspection.
- Describe common commutator problems.
- Describe common bearing problems.
- Describe the electrical operation of the following sections of a crane; Bridge Control, Main Trolley, Main Hoist, Auxiliary Trolley, Auxiliary Hoist.
- Explain the function of an overload relay.
- Explain the function of an undervoltage relay.
- Explain the function of a plugging relay.
- Explain the functions of timing relays.
- Explain the operation of dynamic brakes.
- Describe the proper resistor bank connections

Topical Outline

I. Crane Functional Description
   A. Components
      1. Main Lines
      2. Bridge
      3. Main Trolley
      4. Auxiliary Trolley
      5. Main Hoist
      6. Auxiliary Hoist
      7. Resistor Banks
      8. Cab
      9. Control Switches
      10. Bridge Control Switch
II. Printreading Review
   A. Organization of Electrical prints
      1. Symbology
      2. Standard Device Numbering
      3. Title Block
      4. Special Areas
      5. Block Diagrams
      6. One-Line Diagrams
      7. Wiring Diagrams
      8. Connection and Interconnection diagrams
   B. Analyzing Technical Drawings
      1. Motor Circuits
      2. Control Circuits
      3. Tracing Current
      4. Circuit Components and Functions
      5. Modes of Operation
III. DC Drives
   A. Adjustable Speed
   B. Constant Speed
   C. Varying Speed
   D. Principle of Operation
IV. Motors and Motor Controls
V. Review of Motor Fundamentals
VI. Starters
VII. Crane Print and Control Device Function Summary
   A. Bridge Control Components
   B. Main Trolley Control Components

C. Main Hoist Control Components
D. Auxiliary Trolley Control Components
E. Auxiliary Hoist Control Components

VIII. Troubleshooting

A. Troubleshooting Basics
B. Troubleshooting Philosophy
C. Equipment History/Trouble Log
D. Seven Step Troubleshooting Method
E. Troubleshooting using Flowcharts
F. Troubleshooting Intermittent Failures

IX. Troubleshooting Exercises

Time Required

40 hours

Sources

None

EM-303: Basic Digital Circuits

Course Description

This course provides information on the basic digital electronics concepts, gates, circuits, flip-flop based circuits, and troubleshooting techniques. There are hands-on exercises for circuit construction.

Terminal Objective

Upon completion of this course, the participants will be able to perform number system conversions, write simple logical expressions, create simple logic circuits, evaluate expressions using Boolean algebra and Karnaugh Maps, and troubleshoot digital circuits

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with hands-on exercises.

Course Objectives

- Represent numbers in decimal, binary, octal, binary-coded decimal, and hexadecimal.
- Convert between number systems.
- Perform binary arithmetic, using ones and twos complement methods.
- Create simple Boolean expressions and evaluate the expressions using Boolean algebra
- Recognize symbols for logic gates
- Create logical expressions and truth table for basic gates and circuits composed of multiple gates.
- Evaluate logical expressions using Karnaugh Maps.
- Troubleshoot circuits by tracing logic
- Trace logic using logic pulsers and logic probes
- Describe basic flip-flop operation.
- Recognize symbols for various flip-flops.
- Create State Table for combinations of flip-flop input conditions.
- Describe the operation of J-K flip-flops.
- Construct simple register circuits.
- Construct simple counter circuits.

Topical Outline

I. Number System
   A. Binary
   B. Octal
   C. Binary Coded Decimal
   D. Hexadecimal
   E. Converting between number systems.
   F. Binary Arithmetic

1. One's Complement
2. Two's Complement

II. Boolean Expressions and Boolean Algebra
III. Logic Gates and Truth Tables
   A. AND
   B. OR
   C. NOR
   D. Exclusive OR
   E. Hands-on exercises
IV. Logical Expressions
V. Truth Tables
VI. Karnaugh Mapping
VII. Flip-Flops
   A. Function
   B. Hands-on exercises
VIII. J-K Flip-Flops
   A. Function
   B. Hands-on exercises
IX. Registers
   A. Function
   B. Hands-on exercises
X. Counters
   A. Function
   B. Hands-on exercises

Time Required

40 hours

Sources

None

EM-400: Process Control & Instrumentation

Course Description

This course provides information on the concepts associated with process control and instrumentation. The lessons cover a wide range of topics such as measurement methods, pressure measurement devices, temperature measurement devices, flow measurement devices, level measurement devices, pilot valves, pneumatic controls, electronic controls, and process controls. There are extensive hands-on exercises for process measurements, controller setup, and process tuning.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, design, and construction of process control instrumentation; install, remove and maintain process control instrumentation, and identify causes of process control instrumentation failure.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises

Course Objectives

- Define the term *measurement*.
- State the importance of specifying the units of measurement.
- List the fundamental units of measurement in the MKS, CGS, and English Engineering systems.
- Draw and label a block diagram of a Basic Measurement Channel.
- Contrast the terms direct and inferred measurement.
- Discriminate between the terms range and span and between the terms elevated zero and suppressed zero.
- Define the following commonly encountered static characteristics of a process measurement channel; Accuracy, Resolution, Sensitivity, Deadband, Hysteresis, Linearity, Conformity
- Given a diagram, explain each of the following dynamic characteristics of an instrument channel; Dead Time, Time Constant, Rise Time
- Define the terms pressure and hydrostatic pressure and different means of creating pressure.
- Define Pascal's Law and explain its practical applications.
- Explain the different units of pressure and vacuum and convert between them.
- Explain the operation of a manometer, its applications, and how to correctly read one.
- Explain the difference of operation between a bourdon tube and a diaphragm pressure device.
- Explain the operation of a bellows pressure device and its practical application.
- Describe the theory of a dead weight tester and its contribution to pressure measurement.
- Explain the theory and operation of a capacitance type pressure sensor.
- List the major concerns associated with pressure sensor positioning.

- Identify the major components within a pressure switch given a diagram of the switch.
- Convert between the Fahrenheit and Celsius temperature scales.
- State the three methods of heat transfer and give an example of each.
- Explain the principles of operation of liquid-in-glass and filled-system thermometers.
- Explain the principle of operation of a bimetallic strip thermometer.
- State the principles of operation of a thermocouple.
- List three requirements that determine selection of thermocouple type.
- Given a thermocouple table, calculate measurement junction temperature for any millivolt output and reference junction temperature.
- State the law of intermediate metals and intermediate temperatures and explain their significance in thermocouple installations.
- Explain the principle of operation of an RTD and a; 2 wire RTD bridge, 3 wire RTD bridge, 4 wire RTD bridge
- List the advantages and disadvantages of each type of temperature sensor.
- Name three other types of sensors besides thermocouples and RTD's.
- Explain the principle of Radiation Pyrometry and the four types of Pyrometers.
- Discriminate between flow rate and total flow.
- Identify the two classes of flowmeters.
- Explain how Bernoulli's equation relates to head flowmeters.
- Explain the two basic elements of a head flowmeter.
- Explain the three main types of orifice plate construction.
- Explain the operation and construction of venturi tubes, flow nozzles and Dall flow tubes.
- Explain how capacitance sensors and differential pressure transmitters are used as secondary elements in flow measurement channels.
- Explain the operation of a Pitot Tube and Annubar using a simple sketch.
- Explain the operation of a target flowmeter.
- Explain the operation of a magnetic flowmeter including its major advantage and limitation.
- Explain the basic concepts of ultrasonic flow measurement.
- Explain the construction and operation of a rotameter.
- Explain the construction and operation of a nutating disk.
- Explain the difference between direct and inferred methods of level measurement, giving an example of each.
- State the difference between the ball float and chain float noting relative advantages and disadvantages.
- Explain the principle of operation of displacers.
- State the principle of operation for a differential pressure detector used for level measurement and the effect of temperature on its accuracy.
- Explain the operation of bubbler tube level detectors.
- Calculate zero elevation and suppression with respect to level detector placement.
- Define the terms "wet" and "dry" reference leg and when each might be used.
- Explain the principle of operation for capacitance level detectors.
- Explain the principle of operation of ultrasonic level detectors.
- Provide functional definitions for the pneumatic instrument components/subassemblies.

- Explain the purpose of the spring in a bellows-spring, diaphragm-spring or rolling diaphragm-spring subassembly.
- List the two functions of a restriction in pneumatic instrumentation applications.
- Describe how a flapper/nozzle can detect motion and produce a proportional pressure signal.
- Describe how a pilot motion detector can detect motion and produce a proportional pressure signal.
- List the disadvantages of a standard pilot or pilot valve.
- Label the component parts of a pilot motion detector.
- Explain the operation of a non-bleed pilot.
- Explain the operation of a pneumatic relay.
- Discuss the energy conversions which occur in the following pneumatic relays; Direct-acting bleed type, Reverse-acting bleed type, Direct-acting non-bleed type.
- List the five basic functions that instruments perform.
- Define the term feed-forward.
- Define the term feedback.
- State when a moment-balance instrument will be in balance.
- Describe the operation of basic pneumatic devices used to measure temperature, pressure, flow, and level
- Explain the basic steps involved in the calibration of pneumatic measurement devices.
- Identify the feedback mechanism used by the instruments covered.
- State the two types of Motion-Balance Feedback instruments.
- Describe the principles of operation of angle Motion-Balance Feedback type instruments.
- Describe the principles of operation of Linear Motion-Balance Feedback type instruments.
- State when a motion-balance instrument will be in balance.
- List four specific functions performed by an electronic transmitter.
- List six basic sections of an electronic controller.
- Describe the difference in operation between two-wire and four wire power supplies.
- Describe one method of compensating for the effects of drift in a discrete component amplifier.
- Describe how Op-Amps compensate for the effects of drift.
- List the three general categories of electronic transmitters.
- Given a description of any electronic transmitters, state which of the three general categories it fits into.
- Given a basic block diagram describe the operation of the following; LVDT Motion to Current Transmitter, Force Balanced Motion to Current Transmitter, Capacitive Motion to Current Transmitter
- Draw a block diagram of a typical electronic controller.
- Describe how an error signal is generated in an electronic controller.
- Define the term process control.
- Given a simplified block diagram of a process loop, identify the controlled variable, the measured variable, the manipulated variable and the final control element.
- Describe how feedback is used in closed-loop process control.

- Define open-loop control.
- Given a simplified block diagram of a process loop, describe the effect of each components phase shift on control loop operation.
- Calculate the error signal given the setpoint and measured variable signal.
- List the three degrees of stability possible following a disturbance to a closed-loop control system.
- List the three criteria for evaluating the performance of closed loop control.
- List the three key characteristics that determine the response of a system to a supply or demand disturbance.
- Define time constant.
- Define process gain.
- Define dead time.
- Given a simplified process diagram, identify the location of the system capacity and the system resistance.
- Describe the response of a single capacity process to a step change disturbance.
- Describe the response of a multiple capacity process to a step change disturbance.
- Given the response curve of a multi-capacity process, determine the system dead time and time constant.
- Explain the relationship between process gain and time constant.
- Describe the input and output of a two position controller.
- Describe the effect of varying the neutral zone in a two position control system.
- Describe the effect of system delays on two position control.
- List two advantages and two disadvantages of two position control.
- List one common application of two position control.
- List three characteristics of two position control.
- Define proportional control.
- Describe the relationship between proportional band and gain.
- Given the mathematical equation describing proportional control, calculate the controller output for various system conditions.
- List one advantage and one disadvantage of proportional control.
- Describe why offset error occurs in a proportional controller.
- Explain the effect of changing the controller gain on offset error.
- Using a graph, describe the output of a proportional controller in response to a step change in demand. Include the response of the measured variable.
- Define integral control.
- Given the mathematical equation that expresses integral control, describe each term in the equation.
- Describe the relationship between the following terms: integration time constant, minutes per repeat, and repeats per minute.
- List one advantage and one disadvantage of integral control.
- Using a graph, plot the response of an integral controller following a demand disturbance.
- Given the equation and the applicable system parameters, calculate the output of an integral controller at some time after a step change in input.
- Define proportional plus integral control.

- Given the mathematic equation that expresses proportional plus integral control, describe each term in the equation.
- List one advantage and one disadvantage with proportional plus integral control.
- Discuss the effect of changing the gain on the integral section.
- Explain reset windup.
- Using a graph, describe the output of a proportional plus integral controller in response to both a step and ramp charge in demand. Include the response at the measured variable.
- Define derivative control.
- Define derivative time.
- Given the equation and applicable system parameters, calculate the output of a P&D controller at some time during a ramp change input.
- Discuss the effect of changing the proportional band on the derivative action.
- Discuss the effect of changing the derivative time on the proportional action.
- Given a graph of the effects of a demand disturbance, identify the derivative time as too long, too short or optimum.
- Discuss the effect of derivative action on system stability and zero offset.
- List one application where P&D control is used often and one application where it is not used.
- List the advantage gained by the use of each mode in a PID controller.
- Describe the phase relationship between the proportional, integral and derivative action in a PID controller.
- Given the equation for a PID controller, identify the proportional term, the integral term and the derivative term.
- Describe the effect of each mode of a PID controller on stability.
- Graph the response of a PID controller to a ramp change input.
- Describe the three responses of a control system following a disturbance.
- Describe the following closed loop tuning methods; Notch Method, Ultimate Period Method, Dampened Oscillation Method
- Describe the following open loop tuning methods; Time Constant Method, Reaction Rate Method
- Define integral time and derivative time.
- List the six basic control actions.
- List the advantages and disadvantages of the three most commonly used control actions.
- State how the basic proportional controller can be modified to perform the following control actions; Two position control, Proportional plus integral control, Proportional plus derivative control, Proportional plus integral plus derivative control
- Explain the basic steps involved in the calibration of controllers.
- List eight functions of an electronic controller.
- Draw a block diagram of a typical electronic controller.
- Describe how an error signal is generated in an electronic controller.
- Given a simplified schematic of a proportional controller computing unit, identify the circuit components which will vary the following controller responses; Proportional, Derivative, Integral
- Describe the open loop response of a PID controller to a step change in input.

- Given a simplified schematic of a specific commercial controller, identify the circuits that perform the basic controller functions.
- Explain the terms commonly used when referring to micro-processor controls.
- Describe the basic components in a typical microprocessor based controller.
- Define memory and the different types used.
- Recognize the indications on a Moore Mycro 352.
- Describe the operation of a typical microprocessor based controller.
- Describe the typical installation for a microprocessor based controller.
- State the different modes of a Moore 352 and their functions.
- Explain the difference between feedback control and cascade control.
- Describe the function of a cascade control process.
- Evaluate a control loop and determine if it is a feedback or feed-forward control.
- List the major differences of feedback, feedforward, and cascade control.
- Analyze three-element control and describe its use in a control system as compared to one and two element control.
- Describe the function at ratio control.

Topical Outline

I. Introduction To Measurement
   A. Fundamental Units
   B. Basic Principles
      1. Basic Instrument Channel
      2. Direct Versus Inferred Measurements
   C. Concepts and Terminology
      1. Range And Span
      2. Elevated And Suppressed Zero
      3. Static Characteristics
      4. Accuracy
      5. Resolution
      6. Sensitivity
      7. Deadband
      8. Hysteresis
      9. Linearity
      10. Conformity
      11. Calibration Errors
      12. Dynamic Characteristics
      13. Dead Time
      14. Rise Time
      15. Time Constant

II. Pressure Measurement
   A. Definition Of Pressure
      1. Hydrostatic Pressure
      2. Pressure From Mechanical Force

3. Pressure From Heat
4. Units Of Pressure

B. Pressure Measurement Devices
1. Manometer
2. Bourdon Tube
3. Diaphragm Pressure Devices
4. Pressure Capsules
5. Bellows Pressure Devices
6. Dead Weight Gauge
7. Strain Gauge
8. Capacitance Type Pressure Sensor
9. Diaphragm Seals
10. Pulsation Dampeners
11. Pressure Sensor Positioning

C. Commercial Examples
1. Pressure Switches
2. Mercoid Pressure Switch
3. Asco Tripoint Industrial Pressure Switch
4. Static "O" Ring Pressure Switch
5. Custom Components Pressure Switch
6. Transmitters
7. Foxboro Force-Balance Transmitter
8. Rosemount Model 1151 Transmitter

III. Temperature Measurement

A. The Basics of Temperature Measurement
1. Temperature Scales
2. Fundamentals of Temperature Measurement
3. Factors Affecting Temperature Measurement

B. Temperature Measurement Devices
1. Liquid-In-Glass Thermometers
2. Bimetallic Strip Thermometers
3. Filled System Thermometers
4. Thermocouples
5. Thermocouple Theory
6. Thermoelectric Power
7. Thermocouple Metals
8. Thermocouple Laws
9. Thermocouple Tables
10. Designations For Thermocouple Wire
11. Thermocouple Construction
12. Thermocouple Testing

13. Thermocouple Measuring Circuits
14. Resistance Temperature Detector
15. RTD Construction
16. Resistance Temperature Detector Measuring Circuits
17. Thermistors
18. Thermistor Construction
19. Thermistor Applications
20. Comparison Between Sensor Types

C. Radiation Pyrometry
1. Electromagnetic Radiation
2. Thermal Radiation
3. Pyrometer Types
4. Broadband Pyrometers
5. Bandpass Pyrometer
6. Brightness Pyrometers

IV. Flow Measurement

A. Units Of Flow
1. Flowmeters
2. Properties Of Fluids
3. Flow Characteristics
4. Continuity Of Flow
5. Bernoulli's Equation
6. Head Flowmeters

B. Primary Elements
1. Orifice Plate
2. Venturi Tube
3. Flow Nozzle
4. Dall Flow Tube
5. Target Flowmeter
6. The Pitot Tube
7. Annubar Tubes

C. Secondary Elements
1. Magnetic Flowmeters
2. Ultrasonic Flowmeters
3. Rotameters
4. Nutating Disc

V. Level Measurement

A. Direct Methods
1. Point - Contact Method
2. Gauge Glass
3. Ball Float

4. Chain Float
5. Magnetic Bond Method

B. Inferred Methods
1. Ultrasonic Level Measurement
2. Displacers
3. Hydrostatic Head Pressure Detectors
4. Bubbler Tube Level Detector
5. Differential Pressure Detectors
6. Capacitance Type Level Detectors

VI. Pneumatic Instrument Components and Subassemblies
A. Levers
B. Beams
C. Springs
D. Spring Scale
E. The Bourdon Tube
F. Diaphragms
G. Bellows
H. The Diaphragm Capsule
I. Bellows Spring Subassembly
J. Diaphragm Spring Subassembly
K. Rolling Diaphragm Spring Subassembly

VII. The Flapper/Nozzle, The Pilot Valve, and The Pneumatic Relay
A. Restrictions
B. The Flapper/Nozzle Detector
C. Pilot Motion Detector
D. The Pneumatic Relay
E. Direct Acting Bleed Type Relay
F. Reverse Acting Bleed Type Relay
G. Direct Acting Non-Bleed Type Relay

VIII. Force Balance Instruments
A. The Process Variable Transmitter, Feedforward Type
B. The Displacement Transmitter, Feedforward Type
C. The Variable Indicator, Feedforward Type
D. The Proportional Controller, Feedforward Type
E. The Actuator, Feedforward Type
F. Feedback Instruments
1. Moment-Balance Feedback Type Instruments
2. The Process Variable Transmitter, Moment Balance Feedback Type
3. The Motion Transmitter, Moment Balance Feedback Type
4. The Variable Indicator, Moment-Balance Feedback Type
5. The Proportional Controller, Moment-Balance Feedback Type

6. The Actuator/Positioner, Moment-Balance Feedback Type
7. True Force-Balance Type Feedback Instruments
8. The Process Variable Transmitter, True Force-Balance Type
9. The Motion Transmitter, True Force-Balance Type
10. The Variable Indicator, True Force-Balance Type
11. The Proportional Controller, True Force-Balance Type
12. The Actuator/Positioner, True Force-Balance Type

IX. Pneumatic Measurement Instruments

A. Temperature Measurement Instruments
   1. Foxboro Model 12a Temperature Transmitter
   2. Moore Series 33 Temperature Transmitter

B. Pressure Measurement Instruments
   1. Foxboro Model 45 Pressure Transmitter
   2. Taylor 210 Pressure Transmitter

C. Flow Measurement Instruments
   1. Moore Model Gc-11 Differential Pressure Transmitter
   2. Foxboro Model 557 Square Root Extractor
   3. Low Signal Cutoff

D. Level Measurement Instruments
   1. Foxboro Model 13 Differential Pressure Transmitter
   2. Fisher Controls Level-Trol Transmitter

E. Pneumatic Indication Instruments
   1. Moore Series 2000 Recorder

X. Motion-Balance Instruments

A. Angle Motion-Balance Feedback Type Instruments
B. The Process Variable Transmitter, Angle Motion-Balance Type
C. The Motion Transmitter, Angle Motion-Balance Type
D. The Recorder, Angle Motion-Balance Type
E. The Proportional Controller, Angle Motion-Balance Type
F. The Actuator/Positioner, Angle Motion-Balance Type
G. Linear Motion-Balance Feedback Type Instruments
H. The Process Variable Transmitter, Linear Motion-Balance Type
I. The Motion Transmitter, Linear Motion-Balance Type
J. The Recorder, Linear Motion-Balance Type
K. The Proportional Controller, Linear Motion-Balance Type
L. The Actuator/Positioner, Linear Motion-Balance Type

XI. Fundamentals Of Electronic Instrumentation

A. Electronic Transmitters
B. Electronic Controllers
C. Power Supplies
D. Discrete Component Instrument Amplifiers

E. Chopper Input DC Amplifier
F. Integrated Circuit Instrument Amplifiers
G. LVDT Motion-To-Current Transmitters
H. Force-Balance Motion-To-Current Transmitters
I. Capacitive Motion To Current Transmitters
J. Resistance To Current
K. Motion To Resistance To Current Converters
L. Controller Block Diagram

XII. Introduction To Process Control
A. Fundamental Terminology
B. Block Diagrams
C. Closed-Loop And Open-Loop Control Systems
D. Feedback
E. Operation Of Closed-Loop Control
F. Performance Of Closed-Loop Control
G. Criteria For Closed-Loop Control

XIII. Characteristics Of The Process
A. Single Capacity Process
B. Dead Time
C. Two-Capacity Processes
D. Multiple-Capacity Process

XIV. Two Position Control
A. Open Loop Characteristics
B. Closed Loop Characteristics

XV. Proportional Control
A. Definition Of Proportional Band
B. Open Loop Characteristics
C. Closed Loop Characteristics

XVI. Integral Control
A. Definition Of Integral Control
B. Open Loop Characteristics
C. Closed Loop Characteristics

XVII. Proportional Plus Integral Control
A. Proportional Control
B. Open Loop Characteristics
C. Closed Loop Characteristics

XVIII. Proportional Plus Derivative Control
A. Definition Of Derivative Control
B. Open Loop Characteristics
C. Closed Loop Characteristics

XIX. Proportional Plus Integral Plus Derivative Control

A. Proportional Plus Integral Plus Derivative Control
B. Open Loop Characteristics
C. Closed Loop Characteristics

XX. Controller Tuning Basics
A. Factors Affecting Stability
B. Closed Loop Methods
C. Open Loop Methods

XXI. Pneumatic Control Instruments
A. Two-Position Controller
B. Integral Controller
C. Proportional-Plus Integral Controller
1. Reset Windup
2. Proportional-Plus-Derivative Controller
3. Proportional-Plus-Integral-Plus-Derivative Controller
4. Fisher Controls Level-Trol Two-Position Controller
5. Masoneilan 12000 Series Proportional Controller
6. Fisher 4150/4160 Series Controller
7. Foxboro Model 40 Proportional Plus Derivative Controller
8. Taylor Proportional Plus Reset Plus Rate Controller
D. Pneumatic Control Arrangements
1. Basic Control Loop
2. Temperature Control Loop
3. Pressure Control Loop
4. Flow Control Loop
5. Level Control Loop
6. Computing Relays
7. Foxboro Model 136 Summing Unit

XXII. Electronic Control
A. Electronic Controller
1. Physical Arrangements - Front
2. Physical Arrangements - Side
3. Controller Proportional Response
4. Controller Proportional Plus Integral Response
5. Controller Proportional Plus Integral Plus Derivative Response
6. Controller Output
7. Fisher Tl101
8. L & N Electromax V + General Purpose Controller
B. Electronic Control Arrangements
1. Basic Control Channel
2. Process Control Loops
3. Temperature Control Loop

4. Pressure Control Loop
5. Flow Control Loop
6. Level Control Loop

XXIII. Microprocessor Based Control

A. Data Logging
   1. Supervisory Control
   2. Direct Digital Control
B. Microprocessor System Overview
   1. Support Components
   2. Clock
   3. Memory
   4. Input/Output (I/O Circuits)
   5. Analog Multiplexers
   6. Analog To Digital Converter
   7. Digital To Analog Converter
   8. Communication Buses
C. Basic Microprocessor Components
   1. Accumulator
   2. Address Circuits
   3. Instruction Decoder Circuits
   4. Arithmetic-Logic Circuits
   5. Stack Pointer (SP)
   6. Status Flags
   7. Status Bits - Zeros And Sign
   8. Status Bits - Carry And Borrow
   9. Overall Structure
D. Memory
   1. Memory Storage Devices
   2. Organization Of Memory
   3. Storage Capability
   4. Memory Operations
   5. Addressing
   6. Read Operation
   7. Write Operation
   8. Chip Select
   9. Common Input/Output Pins
   10. Types Of Memory
   11. Read/Write Memories
   12. Read-Only Memories
E. Programmable ROMS (PROMs And EPROMs)
F. PROMs

G. PROM Programming
H. EPROMs
I. UV EPROMs
J. EEPROMs
K. Software
L. Comparison Of Software To Hardware
M. Moore Mycro 352 SLDC
    1. System Configuration
    2. Factory Calibration
    3. System Indications
    4. 4-1/2 Digit Display
    5. Alphanumeric Display
    6. Bargraph Displays
    7. Pulser Knob
    8. Unit Pushbuttons
    9. Operating Modes
    10. Display Test
    11. System Installation
    12. Component Descriptions
    13. Controller Board
    14. Expander Board
    15. Display Assembly
    16. Display Interface Board
    17. Display Driver Board
    18. Display Board
    19. Keyboard
    20. No. 3 Input Board
    21. Pulse Input Board
    22. Thermocouple/Millivolt Input Board
    23. Voltage Input Board
    24. RTD Input Board
    25. Frequency Input Board
    26. Link Interface Board
    27. System Installation
    28. Environmental Requirements
    29. Mounting And Wiring
    30. Single Station Mounting
    31. Multiple Station Row Mounting
    32. Circuit Board Installation
    33. Handling Guidelines
    34. Controller Board And Display Assembly

35. No. 3 Input Board
36. Expander Board
37. Link Interface Board
38. Setting Link Address
39. Configuration
40. Station Clearing
41. Configuration Modes
42. Levels
43. Programming
44. Factory Configured Options
45. Controller Tuning
46. T Mode
47. H Mode
48. S Mod
49. C Mode
50. Moore 352 Signals And Codes

XXIV. Advanced Control Methods
- A. Advanced Control Methods
- B. Cascade Control
- C. Feedforward Control
- D. Three Element Control
- E. Ratio Control
- F. Summary

XXV. Operational Amplifiers
- A. Introduction
- B. IC Op Amp General Description
- C. Open Loop Characteristics
- D. Closed Loop Characteristics
- E. Comparator
- F. Buffer
- G. Inverting Amplifier
- H. Non-Inverting Amplifier
- I. Summer
- J. Differential Amplifier
- K. Integrator
- L. Differentiator

XXVI. Transducers And Converters
- A. Pneumatic To Current Or Voltage Converters
- B. Electronic To Pneumatic Transducers

Time Required

120 hours (3 weeks).

Sources

None

EM-401: Final Control Elements

Course Description

This course provides information on the types of valves and actuator used as control elements, valve components, and valve applications. There are hands-on exercises for equipment setup and evaluation.

Terminal Objective

Upon completion of this course, the participants will be able to identify valve components, types of valves and their uses, explain actuator and positioner operation, and identify valve information from markings and nameplate information.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Describe the major functions a valve performs.
- List the major parts of a valve.
- Describe the function of the following valve components; Actuator, Body, Bonnet, Stem, Disc, Collar or Yoke, Seat, Packing or Stem Seal, Valve Position Indicators.
- Explain the advantages of a needle valve over a standard globe valve.
- State the purpose of bench set information of a pneumatic actuator.
- Explain the function of a valve positioner.
- State when a valve positioner should and should not be used.
- Explain how to set up a valve positioner.
- List the different types of valves.
- For each type of valves discuss it typical applications, benefits, and limitations.
- Identify the information available via valve markings and nameplate information.

Topical Outline

I. Final Control Element Components
   A. Actuator
   B. Body
   C. Bonnet
   D. Stem
   E. Disc
   F. Yoke or Collar
   G. Seat
   H. Packing or Stem Seal
   I. Valve Position Indicator

II. Valve Types
- A. Globe Valves
- B. Needle Valves
- C. Control Valves
- D. Reducing Valves
- E. Check Valves
- F. Gate Valves
- G. Butterfly Valves
- H. Ball Valves
- I. Diaphragm Valves
- J. Valve Characteristics
- K. Valve Actuators
- L. Valve Positioners
- M. Valve Position Indication

III. Valve Markings and Nameplate Information
- A. Rating Description
- B. Material Designations

Time Required

40 hours

Sources

None

EM-206: System Problem Solving & Troubleshooting

Course Description

This course provides information on the concepts associated with systematic troubleshooting of instrumentation systems.

Terminal Objective

Upon completion of this course, the participants will be able to explain systematic troubleshooting and instrumentation particulars.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation.

Course Objectives

- Define troubleshooting.
- State the ultimate purpose of troubleshooting.
- Discuss the need for a troubleshooting methodology.
- List four general guidelines for good troubleshooting.
- Identify the key troubleshooting action items.
- State the preferred troubleshooting philosophy.
- Explain the importance of maintaining accurate documentation.
- Describe the type of information that is useful in a trouble log.
- Using a given scenario complete a typical trouble log.
- List the steps of the seven-step troubleshooting method in their logical order.
- Discuss each step of the seven-step troubleshooting method.
- Discuss the concept of using flowcharts.
- Identify standard flowchart symbols.
- List the steps of the five-step systematic troubleshooting process steps in their logical order.
- Describe each step of the five-step systematic troubleshooting process.
- Discriminate between diagnosis and repair.
- Identify sources of problems in instrument systems.
- Contrast new versus replacement “in kind.”
- Discuss how calibration can be a source of problems.
- Discuss the difference between sound and unsound reasons for deviating from ideal troubleshooting strategies.
- Identify the steps to take to develop a customized troubleshooting strategy.
- Define intermittent failure.
- Identify three types of intermittent failure.

- Describe the basic steps for troubleshooting intermittent failures.
- Describe the importance of finding the root cause of a trouble.
- Identify the major elements of a Cause and Effect Diagram.
- Describe the six basic steps for constructing a Cause and Effect Diagram.
- Given a sample scenario, construct a Cause and Effect Diagram.

Topical Outline

I. Troubleshooting Basics
II. Troubleshooting Philosophy
III. Equipment History/Trouble Log
IV. Seven-Step Troubleshooting Method
V. Troubleshooting using Flowcharts
VI. Five Detailed Steps to Systematic Troubleshooting
VII. Troubleshooting Process Instrumentation
    A. Philosophy of Troubleshooting
        1. How far do you go? (Component versus Board versus System Troubleshooting)
        2. Using the Information Available
        3. Diagnosis versus Repair
        4. Evaluation of "Off-Normal" Readings and System Alignments
    B. Sources of Problems in Instrument Systems
        1. Wear and Tear
        2. Installation Related Problems
        3. Calibration as a Source of Problems
VIII. Customized Troubleshooting Techniques
IX. Troubleshooting Intermittent Failures
X. Identifying the Root Cause
    A. Cause And Effect Diagrams
    B. Six Steps of Constructing the Diagram

Time Required

40 hours

Sources

None

MM-104: Combustion

Course Description

This course provides information on the theory of combustion, associated equipment applied to combustion, safety and related safety issues associated with combustion. There are hands-on exercises for inspection and identification of equipment.

Terminal Objective

Upon completion of this course, the participants will be able to explain the theory, function, and design of combustion equipment, understand heat transfer and the safety issues when working on or maintaining this equipment.

Target Audience

This course is designed for mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises

Course Objectives

- Discuss the theory of combustion.
- Describe the flame structure.
- Define the relationship between heat, temperature and specific heat.
- Recognize the concept of fuel/air ratio.
- Explain the significance of % CO_2, O_2 and combustibles.
- Identify the general types of burners.
- List the various control valves, blowers, regulators and switches associated with various burners.
- Describe the three modes of heat transfer.
- Discuss the factors affecting heat transfer rates.
- Review the combustion fundamentals regarding preheating and drying in steel mills.
- Discuss the modes of heat transfer in the steel making and casting shops.
- Recognize the chemical make-up of natural gas, coke oven gas, and blast furnace gas.
- Explain coal preheating.
- Describe the stove blast air operation at the blast furnaces.

Topical Outline

I. Theory of Combustion
   A. Chemical Reaction
   B. Flame Structure
   C. Heat and Temperature
      1. Mass & Specific Heat Relations
      2. Gas Temperature/Heat
   D. Fuels
   E. Properties of Gaseous Fuels
   F. Excess Air/Oxygen Enrichment

II. Combustion Equipment
- A. Burners
- B. Blowers
- C. Limiting Orifice
- D. Ratio Regulator
- E. Valtex Valves
- F. Automatic Shutoff Valves and Block Valves
- G. Gas Metering Orifice

III. Combustion Systems
- A. Mass Flow Sensors
- B. Temperature Measurement
- C. Electronic Control Systems

IV. Heat Transfer
- A. Forms of Heat Transfer
  1. Conduction
  2. Convection
  3. Radiation
- B. Temperature and Heat Transfer
- C. Thermal Efficiency
- D. Transient Heat Transfer

V. Ladle Preheating
- A. Ladle Heat Content
- B. Steel Temperature Loss in the Ladle
- C. Rate of Heat Transfer during Preheat
- D. Preheat Criteria

VI. Tundish Preheating
- A. Steel Temperature Loss in the Tundish
- B. Rate of Heat Transfer during Preheat

VII. Oxy-Fuel Ladle Preheating
- A. Preheating in the cycle
- B. Flame Temperature
- C. Heat Transfer

VIII. Drying vs. Preheating
- A. Goals
- B. Humidity
- C. Air Flow
- D. Combustion Products

IX. Safety
- A. General Combustion Hazards
- B. Redundant Safety Valves
- C. Oxygen Combustion Safety

X. Terminology

Time Required

24 hours

Sources

None

EM-402: Analytical Measurement

Course Description

This course provides information on the concepts associated the operation and calibration of analytical sensors.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, and calibration of sensors and instruments for conductivity, pH, ORP, and selected optical and combustion product measuring equipment.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation.

Course Objectives

- Define conductivity and discuss the basic principles governing conductivity.
- Compare the operation of electrode probes and inductive probes.
- Describe two procedures for calibrating conductivity probes.
- Discuss proper installation and maintenance practices for conductivity probes.
- Discuss the operation of stack gas analyzers.
- Describe pH and ORP measurement processes.
- Describe the instruments used for the measurement of pH and ORP.
- Discuss calibration procedures for pH and ORP measurement instruments.
- Discuss general installation and maintenance procedures for pH and ORP measurement instruments.
- Describe the components that make up an optical analyzer.
- Discuss the basic operating procedures of silica ion and COD optical analyzers, turbidimeters and nephelometers, refractometers, and capacity analyzers.
- Compare procedures for calibrating an optical analyzer with standards, with grab samples, and electronically.
- Discuss installation considerations and basic maintenance procedures for an optical analyzer.
- Identify the main components in the combustion process.
- Describe the various kinds of instruments used for measuring the products of combustion.
- Discuss the principles of operation of instruments that measure the products of combustion.
- Describe the basic maintenance procedures for instruments that measure the products of combustion.
- Discuss the various sampling techniques for measuring the products of combustion.

Topical Outline

I. Conductivity Measurement
II. pH and ORP Measurement

III. Optical Measurements

A. Transmission-Type Analyzers
B. Turbidimeter
C. Nephelometers
D. Refractometers
E. Capacity Analyzers

IV. Combustion Product Measurement

A. Gas
B. Oxygen
C. Carbon Dioxide
D. Carbon Monoxide Sensors

Time Required

16 hours

Sources

None

EM-107: National Electrical Code Overview

Course Description

This course provides overview of proper wiring practices as presented in the National Electrical Code (NEC).

Terminal Objective

Upon completion of this course, the participants will be able to list the general topics covered in the NEC, and given a copy of the NEC, be able to locate and discuss the requirements pertinent to industrial electrical wiring and distribution.

Target Audience

This course is designed for electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation.

Course Objectives

- Understand the layout of the National Electrical Code.
- Understand the relationship between the National Electrical Code and the National Electrical Safety Code.
- Differentiate between NEC and OSHA examination, installation and use requirements.
- Understand the proper locations for electrical equipment to provide for proper working clearances and free space requirements.
- Determine proper methods of identification for grounded conductors, grounding conductors, and multi-wire branch circuits.
- Understand installation requirements for services.
- Understand bonding and grounding requirements for services, feeders, branch circuits, and utilization equipment.
- Select the proper size and location of overcurrent protection for various types of utilization equipment.
- Be knowledgeable of requirements for temporary wiring and GFCI applications.
- Be knowledgeable of acceptable wiring methods and materials including recent changes in acceptable industrial wiring methods and materials.
- Select the proper size of raceway, fitting, and boxes, including wire bending space, component sizing and conductor identification.
- Size motor circuits and required components according to recent code changes.
- Understand transformer installations including various types of delta and wye connections.
- Understand acceptable wiring methods for hazardous (classified) locations.

Topical Outline

I. Relationships Between the National Electrical Safety Code and the National Electrical Code

II. Determining Proper Working Clearances and Free Space Requirements

III. Services, Feeders and Branch Circuits

A. Sizing

1. How to determine branch circuit loads for receptacle outlets, multi-outlet assemblies, motors resistance-type ovens, AC welders and lighting fixtures

2. How to determine ampacity and minimum size requirements for feeder conductors
3. How to determine ampacity and minimum size requirements for distribution panels and services

B. How to determine minimum clearances for conductors

C. How to apply rules for more than one service per building

D. How to determine maximum numbers of disconnecting means.

E. Rules and Calculations for Overcurrent Protection

1. Determining conductor ampacities
2. Tap conductor requirements

F. Grounding and Bonding

1. How to identify DC and AC wiring systems that require grounding
2. How to compute minimum sizes for bonding jumper and grounding electrode conductors
3. New requirements on structural steel and separately derived systems
4. How to ground conductors for supply-side/load-side equipment
5. Special grounding requirements for Data Processing and electronic equipment

IV. Acceptable Industrial Wiring Methods

A. General Wiring Methods

B. Temporary Wiring

C. GFCI Requirements

D. Cable Tray

E. Rigid Metal Conduit

F. Liquid tight Flexible Metal Conduit

G. Boxes, Fittings, etc.

V. Equipment for General Use

A. Luminaires and Receptacles

B. Fixed Electric Heating Equipment for Pipelines and Vessels

C. Calculate motor loads, conductor and raceway sizing, disconnecting means and motor controller size

D. Calculations for overload protection, ground-fault/short circuit protection, motor control circuit protection

E. Transformers - how to calculate overcurrent protection for transformers

VI. Hazardous (Classified) Locations

A. Location and General Requirements
B. Special Precaution
   1. Area Classification
   2. Approval for Class and Properties
   3. Marking
C. Temperature
D. How to identify Class I, II, and III locations
E. Protecting hazardous locations from electrical ignition sources
F. Class I, II, and III wiring methods
G. How to apply requirements for intrinsically safe circuits and equipment
H. How to apply requirements for purging and pressurizing enclosures
I. Class I, Zone 0, Zone 1, and Zone 2 alternate area classification methods

VII. Approved Wiring Methods for Hazardous Locations

A. Sealing and Drainage
B. Switches, Circuit Breakers, Motor Controllers, and Fuses
C. Motors and Generators
D. Lighting Fixtures
E. Utilization Equipment
F. Flexible Cords
G. Receptacles and Attachment Plugs
H. Conductor Insulation
I. Signaling, Alarm, Remote-Control, and Communications Systems
J. Live Parts
K. Grounding
L. Surge Protection

Time Required

16 hours

Sources

National Electrical Code, NEC, Industrial Electricity Training by Training Technology

MM-001: Mechanical Safety & Lockout/Tagout

Course Description

This course provides information potential safety hazards, safety precautions, personnel protection equipment, general emergency response, and the local lockout/Tagout program.

Terminal Objective

Upon completion of this course, the participants will be able to discuss potential workplace hazards and the associated precautions, general responses to plant emergencies, personnel protection equipment used in the plant, and personnel responsibilities under the local lockout/Tagout program.

Target Audience

This course is designed for mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation.

Course Objectives

- Discuss the hazards and precautions/counter-measures for each hazard.
- List and explain the personnel protective equipment required for work in mill areas
- Discuss some hazards particular to mechanical work and the precautions/counter-measures for each hazard.
- Describe the general response to plant emergencies.
- Describe the energy isolation requirements for safely work on equipment.
- Describe the local Lockout/Tagout program and the requirements placed on the personnel doing work

Topical Outline

I. Workplace Hazards
   A. General Industrial Hazards
      1. Precautions/Counter-Measures
      2. Personnel Protection Equipment
   B. Steel Mill Hazards
      1. Precautions/Counter-Measures
      2. Personnel Protection Equipment
   C. Mechanical Work Hazards
      1. Precautions/Counter-Measures
      2. Personnel Protection Equipment

II. Safety Department

III. Additional Safety Programs and Training Courses

IV. Emergency Response
   A. Types of Emergencies
   B. Initial Responders

C. Response Teams
D. Assembly Areas

V. Energy Isolation for Maintenance
A. Sources of Energy and Means of Isolation
B. OSHA Lockout/Tagout Requirements
C. Local Lockout/Tagout Requirements

Time Required

8 hours

Sources

None

MM-104: Bolts & Fasteners

Course Description

This course provides information on the concepts associated with threaded and bolted fasteners, retaining rings, clamps, pins, keys, and locking devices; the specifications for fasteners, and the assembly of fasteners.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function and selection of fasteners, and be able to properly assembly fasteners.

Target Audience

This course is designed for mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation.

Course Objectives

- Describe the bolted connection and how it functions.
- Describe the different types of basic fasteners and their applications.
- Discuss the appropriate specifications and selection criteria for fasteners.
- Discuss the effects of fastener system variables and assembly practices on the reliability of the connection.
- Describe the various types of fasteners in common use
- Describe the various types of locking devices in common use
- Describe the use of dowel pins, keys, and cotter pins
- Explain the various screw thread designations
- Discuss materials and grades as they apply to threaded fasteners
- Discuss the finishes and coatings sometimes used on threaded fasteners
- Describe the dangers associated with using counterfeit fasteners
- Describe how to identify counterfeit fasteners

Topical Outline

I. Bolted Connections
   A. Components
      1. Bolts
      2. Nuts
      3. Studs
   B. Assembling Threaded Fasteners
      1. Alignment
      2. Torquing Threaded Fasteners
      3. Surface Considerations
      4. Locking Methods
   C. Bolted Connection Problem Correction Procedure

II. Mechanical Fasteners

A. Machine Screws
B. Setscrews
C. Thread Forming Screws
D. Threaded Inserts
E. Washers
F. Retaining Rings
G. Hose Clamps
H. Dowel Pins
I. Keys and Keyways
J. Mechanical Locking Devices and Methods
    1. Lock Washers
    2. Self-Locking Nuts
    3. Plastic Inserts Nuts
    4. ANCO Nuts
    5. Beam-Type Nuts
    6. Jam Nuts
    7. Castle or Slotted Nuts
    8. Cotter Pins
    9. Lock Wire

III. Fastener Specifications And Selection Criteria

A. Type or Style
B. Screw Thread Designations
    1. Size
    2. Thread Pitch
    3. Thread Series
    4. Class or Fit
    5. Thread Direction
C. Materials and Grades
    1. Materials
    2. Grades
D. Metric Fasteners
    1. Thread Pitch
    2. Grades Versus Property Classes
E. Hex Cap Screws
    1. Socket Head Screws
    2. Standardized Lengths
F. Finishes and Coatings
G. Counterfeit Bolts

Time Required

8 to 16 hours (depending upon audience, and audience experience).

Sources

None

MM-105: Mechanical Print Reading

Course Description

This course provides understanding of information found on mechanical drawings and prints, provides the participant with the ability to understand and identify components and how to identify dimensions of tapered and machined surfaces. There are hands-on exercises for print reading.

Terminal Objective

Upon completion of this course, the participants will be able to read understand and identify given components on a mechanical print and have the ability to draw a pictorial of a mechanical system to include pneumatic or hydraulic circuits.

Target Audience

This course is designed for mechanical maintenance technicians, but is also used for cross-training of electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises

Course Objectives

- Explain and describe the purpose of the Title Block, Legend, Revisions, and Material List in terms of location and content.
- Describe and identify the meaning of each of the six types of lines used in drawings.
- Identify and define the types of views used in drawings.
- Given a drawing, identify its construction, size, and location dimensions.
- Measure and identify screw threads.
- Identify the dimensions of tapered and machined surfaces.
- Describe the various types of sketches used in drawings.
- Identify a pneumatic or hydraulic component by its symbol
- Draw the common pneumatic and hydraulic component symbols.
- Trace the flow of air or fluid through a drawing of a circuit.
- Draw a pictorial of a circuit using a pneumatic or hydraulic schematic as a reference.
- Draw schematics of simple pneumatic and hydraulic systems.

Topical Outline

I. Types Of Mechanical Drawings
   A. Site Plan
   B. Flow Diagram
   C. General Arrangement
   D. Piping Drawings
   E. Isometrics and Spools
   F. Machine Drawings
   G. Parts Of A Drawing
      1. Title Block

2. List of Materials
3. Drawing Notes
4. Revisions

II. Mechanical Drawing Views
- A. The Front View
- B. The Top View
- C. The Side View
- D. Front, Top, and Right Side Views
- E. Working Drawings

III. Arrangement Of Views
- A. Two-View Drawings
- B. Representing Invisible Circles
- C. One-View Drawings
- D. Auxiliary Views
- E. Application of Auxiliary Views
- F. Exploded Views
- G. Lines
  1. Object Lines
  2. Hidden Lines
  3. Center Lines
  4. Extension Lines
  5. Dimension Lines
  6. Projection Lines
  7. Other Lines

IV. Dimensions and Drawing Notes

V. Standards For Dimensioning

VI. Construction, Size, and Location Dimensions
- A. Construction Dimensions
- B. Size Dimensions
- C. Location Dimensions
- D. Placing Dimensions
- E. Continuous Dimensions
- F. Dimensions in Limited Spaces
- G. Dimensioning Cylinders, Circles, and Arcs
  1. Dimensioning Cylinders
  2. Dimensioning Arcs
  3. Dimensioning Holes
- H. Dimensioning Counterbored Holes
- I. Dimensioning Countersunk Holes
- J. Dimensioning Angles
- K. Dimensioning a Point or a Center

L. Dimensioning Equally Spaced Holes on a Circle
M. Dimensioning Unequally Spaced Holes on a Circle
N. Dimensioning Holes Not on a Circle
O. Dimensioning Arcs with Centers Outside the Drawing
P. Base Line Dimensioning
Q. Shop Dimensions

VII. Tolerance
A. Specifying Fractional Tolerances
B. Specifying Angular Tolerances
C. Unilateral and Bilateral Tolerances

VIII. Decimal Dimensions

IX. Specifying Decimal Tolerances

X. Representing and Dimensioning Screw Threads
A. The Unified and the American National Thread Form
B. Thread Series
C. Representing Screw Threads
D. Dimensioning Screw Threads
E. Pipe Thread Representation
F. Representation of Internal Threads
G. Dimensioning a Threaded Hole
H. Class of Fit: Unified and American National Thread Forms
I. Specifying Left-Hand Threads

XI. Dimensioning Tapers and Machined Surfaces
A. Finished Surfaces
B. Finish All Over
C. Surface Finish

XII. Dimensioning with Shop Notes
A. Dimensioning Knurled Surfaces
B. Dimensioning Chamfers and Grooves
C. Keyways
D. Change Notes
E. Sections

XIII. Cutting Planes, Section Lining, and Full Sections
A. Cutting Plane Lines
B. Cross Hatching or Section Lining
C. Half Sections
D. Broken or Partial Sections

XIV. Conventional Breaks

XV. Flow Diagrams
A. Piping and Instrumentation Drawings
B. Pipe Specifications

C. Instrumentation Symbology
D. Process Variables
E. Instrument Representation
F. Signal Leads
G. Equipment Symbols
H. Valve Symbols

XVI. Piping Plans and Elevations
A. Pipe Representation
B. Pipe Breaks
C. Single Line Piping
D. Dimensioning
E. Piping Elevations
F. Section Identification
G. Structural Features
H. Dimensioning

XVII. Piping Isometrics
A. Isometric Layout
B. Isometric Scales
C. Direction and Location
D. Isometric Planes
E. Isometric Offsets

XVIII. Pneumatic and Hydraulic Printreading
A. Simple Pneumatic Circuits
B. Pneumatic Timing Circuits
C. Pneumatic Safety Circuits
D. Pneumatic Circuits
1. Pneumatic Stamping Press
E. Hydraulic Symbols
1. Simple Hydraulic Circuits
2. Hydraulic Circuits
3. Two Position Hydraulic Movement
4. Multiple Speed Hydraulic Systems
5. Emergency Actuating Features
6. Directional Mode
7. Failure Mode
8. Reset Mode
9. Automatic Pallet Entry and Discharge

Time Required

24 to 40 hours (depending upon audience, and audience experience).

Sources

None

MM-201: Power Transmission: Shafts

Course Description

This course provides information on the concepts associated with clutches, clutch function, clutch design, clutch maintenance, installation and removal, and basic clutch faults.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, design and construction of clutches; install, remove and maintain bearings, and identify causes of clutch failure.

Target Audience

This course is designed for mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Identify the various methods of clutch engagement
- Identify the various types of clutches
- Describe how to properly install a clutch and perform maintenance

Topical Outline

I. Clutch Classifications
II. Clutch Engagement Methods
  A. Mechanical Engagement
  B. Electrical Engagement
  C. Hydraulic Engagement
  D. Pneumatic Engagement
  E. Automatic Engagement
III. Clutching Methods
  A. Positive Contact Clutches
  B. Friction Clutches
  C. Axial Friction Clutch Designs
  D. Axial Friction Disc Design
  E. Torque Limiting Clutches
IV. Overrunning Clutches
  A. Simple Overrunning Clutch
  B. Indexing
  C. Holdbacks/Backstops
  D. Types of Overrunning Clutches
V. Magnetic Clutches
  A. Hysteresis

B. Magnetic Particle
C. Eddy-Current Clutch

VI. Centrifugal Clutches
A. Centrifugal Shoe Clutch
B. Fluid Clutch
C. Dry-Charged Fluid Clutches

VII. Clutch Installation
A. Engine Flywheel Clutch Assemblies

VIII. Plate and Disc Maintenance

Time Required

8 hours

Sources

None

MM-202: Power Transmission: Pulleys

Course Description

This course provides information on the concepts associated with belt drives, belt drive function, belt drive design, belt drive maintenance, installation and removal, and belt drive faults.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, design, and construction of belt drives; install, remove and maintain belt drives; and identify causes of belt drive failures.

Target Audience

This course is designed for mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Describe the purpose of the belt drive.
- List the factors affecting the selection of the belt.
- Describe the advantages of the belt drive.
- Describe the disadvantages of the belt drive.
- Describe the three principles that determine the potential of grip.
- Describe the proper technique for belt tensioning.
- Define coefficient of friction.
- Describe the construction of the v-belt.
- Describe the construction of the double v-belt.
- Describe the use of the power band v-belt.
- Identify the method for correct v-belt selection.
- Describe the advantages of the poly v-belt.
- Describe the construction of the variable speed belt.
- Describe the use of the variable speed sheave.
- Describe the three basic variable speed drives that are used.
- Describe the advantages of the positive drive belt.
- Describe the construction of the positive drive belt.
- Describe the purpose of the pulley.
- Describe the positive drive belt codes.
- Describe the purpose of the positive idler drives.
- Describe the construction of the three common flat belts.
- Define pulley crown.
- Describe the different flat belt pulleys used.
- Describe the method for checking belt alignment.

Topical Outline

I. Belt Selection Considerations
II. Belt Drive Advantages
III. Belt Drive Disadvantages
IV. Belt Drive Principles
    A. Area of Contact
    B. Belt Tension
    C. Coefficient of Friction
V. Pulley Ratios
VI. Belt Speed
VII. Pulley Size
VIII. V-Belts
    A. V-Belt Construction
    B. V-Belt Components
    C. V-Belt Length
    D. V-Belt Performance
    E. V-Belt Types
    F. Correct V-Belt Selection
    G. Variable Speed Belts
    H. Variable Speed Belt Construction
    I. Variable Speed Cross-Sections
    J. Variable Speed Belt Sheaves
IX. Variable Speed Drives
    A. Single Variable Sheave
    B. Dual Variable Sheaves
    C. Countershaft Dual Variable Sheave
    D. Variable Speed Sheave Alignment
    E. Variable Sheave Maintenance
X. Positive Drive Belts (Synchronous)
    A. Positive Drive Belt Advantages
    B. Timing Belt Pulleys
    C. Positive Drive Pitch Sizes
    D. Positive Drive Belt Pulleys
    E. Minimum Pulley Diameters
    F. Selecting Positive Drive Belts
    G. Positive Drive Idlers
    H. Linked V-Belts
    I. Flat Belts
    J. Flat Belt Pulleys
    K. Crowned Pulleys

L. Flat Belt Idler Pulleys
M. Cone Pulleys

XI. Flat Belt Joining
A. Vulcanized Advantages
B. Flat Belt Fasteners

XII. V-Belt Sheaves
A. Standard Dimensions
B. Routine Sheave Maintenance
C. Checking Belt Alignment
D. Sheave Balancing
E. Sheaves for V-Belt Drives
F. Taper Lock Bushing Installation
G. Taper Lock Bushing Removal
H. Belt Installation
I. Worn Belt Removal
J. Belt Tensioning Motor Bases

XIII. Troubleshooting Belt Drives
A. Causes of Shortened Belt Life

Time Required

8 hours

Sources

None

MM-203: Power Transmission: Couplings

Course Description

This course provides information on the concepts associated with couplings, coupling function, coupling design, and the difference between a rigid and flexible coupling.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, design and construction of couplings; the difference between rigid and flexible coupling; and explain the following coupling terms: hub, shaft, key, match, marks, bore and gap.

Target Audience

This course is designed for mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises

Course Objectives

- Explain the purpose of a coupling.
- Explain the difference between a rigid and flexible coupling.
- Explain the following terms as they relate to a coupling; Hub, Shaft, Key, Match marks, Bore, Gap

Topical Outline

I. Terminology
II. Purpose of a Coupling
III. Types of Couplings
  A. Rigid Couplings
  B. Flexible Couplings

Time Required

8 hours

Sources

None

MM-204: Power Transmission: Chain Drives

Course Description

This course provides information on the concepts associated with chain drives, chain drive function, chain drive design, chain drive maintenance, installation and removal, and chain drive faults.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, design, and construction of chain drives; install, remove and maintain chain drives; and identify causes of chain drive failure.

Target Audience

This course is designed for mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises

Course Objectives

- Describe the purpose of the chain drive
- Describe the three basic functions of the chain
- Describe the advantages of the chain drive
- Describe the disadvantages of the chain drive
- Describe the principle of operation of the chain drive
- List the six styles of chain used for power transmission
- Describe the construction of the six styles of chain
- Define chain pitch
- Define tolerances of chain length
- Define measuring load
- Describe minimum ultimate tensile strength
- Describe the function of the standard roller chain numbers
- Describe the construction of the multiple strand roller chain
- Describe the special features of the roller bearings
- Describe the use of the detachable chain
- Describe the use of the silent chain
- Discuss the various silent chain assemblies
- Describe the use of the leaf chain
- Describe the basic construction of the roller chain sprocket
- Identify the four designs of sprocket hubs
- Define the following as related to the sprocket; Pitch Diameter, Bottom Diameter, Caliper Diameter, Outside Diameter, Face Width
- List the factors that affect shaft location chain drives

- Describe the function of the chain tightener.
- Describe the affects of the incorrect chain tension
- Describe the procedure for aligning shaft and sprocket
- List the points checked on a chain inspection
- Describe the elements that affect lubrication
- Describe the five methods for chain lubrication

Topical Outline

I. Chain Functions
   A. Transmitting Power
   B. Conveying Materials
   C. Timing
II. Chain Drive Advantages
III. Chain Drive Disadvantages
IV. Chain Drive Principles
V. Power Transmission Chains
   A. Roller Chain
   B. Heavy Series Chain Numbers
   C. Multiple Strand Roller Chain
   D. Double-Pitch Roller Chain
   E. Self-Lubricated Roller Chain
   F. Pre-Lubed Roller Chain
   G. Offset Roller Chain Links
   H. Connecting Links
   I. Detachable Chain
   J. Pintle Chain
   K. Silent Chain
   L. Leaf Chain
   M. Laminated Metal Chain
VI. Roller Chain Sprockets
   A. Sprocket Types
   B. Shear Pin Sprockets
   C. Tapered Bushing/Sprocket Installation
   D. Tapered Bushing/Sprocket Removal
   E. Taper Bushings
   F. Roller Chain Sprocket Diameters
   G. Hunting Tooth Sprocket Design
VII. Chain Drive Arrangements
   A. Chain Drive Design Factors
   B. Vertical Chain Drives
   C. Horizontal Chain Drives

D. Chain Tighteners
E. Roller Chain Tension
F. Shaft and Sprocket Alignment

VIII. Chain and Sprocket Maintenance

A. Chain Inspection
B. Sprocket Inspection
C. Installing Roller Chain
D. Detaching Roller Chain
E. Roller Chain Lubrication
F. Lubricant Selection
G. Chain Lubrication Methods
H. Lubrication of Open-Running Chain Drives under Abrasive Conditions

Time Required

8 hours

Sources

None

MM-205: Power Transmission: Gearing

Course Description

This course provides information on the concepts associated with gears, gear function, gear backlash, gear lubrication, and gear ratios.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function of gears, terminology associated with gears; identify the following gear arrangements: Spur gear, Helical gear, Herringbone gear, Bevel gear, Worm gear, and Planetary gear; and describe how to measure backlash in a gearing arrangement.

Target Audience

This course is designed for mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- State the purpose of gears
- Define the terminology associated with gears
- Identify the following types of gear arrangements; Spur gear, Helical gear, Herringbone gear, Bevel gear, Worm gear, Planetary gear
- Describe how to measure backlash in a gearing arrangement

Topical Outline

I. Gear Terminology
II. Shaft Position Influence On Gear Mounting
  A. Gears for Parallel Shafts
    1. Spur Gears
    2. Parallel Shafts with Helical Gears
  B. Gears for Shafts that Meet at 90 Degrees
    1. Bevel Gears
  C. Gears for Cross Shafts
    1. Hypoid Gears
    2. Worm Gears
    3. Worm Gear Terms
    4. Planetary Gears
  D. Gear Backlash
    1. Determining the Proper Amount of Backlash
    2. Zero Backlash
    3. Recommended Backlash
    4. Measurement of Backlash

5. Control of Backlash

III. Gear Materials

IV. Gear Lubrication

A. Circulating Systems

1. Bath/Splash System
2. Idler Immersion System
3. Intermittent Lubrication System

V. Gear Ratios

A. Calculating Gear Ratio for a Pair of Gears

B. Calculating Gear Ratio for Long Gear Trains

C. Calculating Gear Ratio for a Compound Gear Train

Time Required

8 hours

Sources

None

MM-206: Lubrication

Course Description

This course provides information on the concepts associated with lubrication, lubrication properties, lubrication testing, lubricant contaminants, and gear lubrication.

Terminal Objective

Upon completion of this course, the participants will be able to explain the chemical composition of lubrications, the testing methods of lubrications; discuss hydraulic lock, hydrodynamic lubrication, elasto-hydrodynamic lubrication, EP oils, and non-EP oils; describe causes of gear failure, and the proper methods for greasing bearings; and explain the aspects of a good lubrication program.

Target Audience

This course is designed for mechanical and electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Discuss the origin of oil and its chemical make up.
- Discuss the basic principles of lubrication.
- Describe a basic lubricant and be familiar with the make-up of lubricants.
- Explain viscosity and use of viscosity terms.
- Differentiate between sliding and rolling friction.
- Discuss boundary/thin film lubrication.
- Be familiar with the additives used with oil and the reasons for their use.
- Be familiar with factors that determine oil compatibility.
- Describe some applications for which oil is used as a lubricant.
- Be familiar with various oil testing procedures.
- Discuss the origin of grease and its chemical make-up.
- Be familiar with the additives used with grease and the reasons for their use.
- Be familiar with some factors which determine grease compatibility.
- Describe some applications for which grease is used as a lubricant.
- Be familiar with various grease testing procedures.
- Differentiate between hydrodynamic lubrication and elasto-hydrodynamic lubrication.
- Discuss various lubricant contaminants.
- Discuss lubrication of gears.
- Discuss the use of extreme pressure (EP) oils vs. non-EP oils.
- Be familiar with various methods of supplying gears with lubrication.
- Define hydraulic lock.
- Describe various causes of gear failure.

- Discuss the lubrication of worm gears, couplings, and bearings.
- Be familiar with the proper methods for greasing bearings.
- Discuss basic hydraulic principles.
- Describe characteristics of hydraulic fluid.
- Be familiar with additives used with hydraulic oils and reasons these additives are used.
- Understand the reason for filtering hydraulic fluids.
- Be familiar with methods of preventing fluid-related hydraulic system problems.
- Discuss the differences between synthetic and mineral oils.
- Be familiar with various types of synthetic oils and their origins.
- Discuss the advantages of synthetic oils over mineral oils.
- Be familiar with various uses and applications of synthetic oils.
- Discuss the purpose of a lubrication program.
- Be familiar with some aspects of a good lubrication program.
- Be familiar with proper storage and handling procedures for lubricants.
- Be familiar with proper oil sampling techniques, reports, and analysis.
- Discuss the benefits of a good lubrication program.

Topical Outline

I. Lubrication Fundamentals
   A. Lubrication
   B. What Is A Lubricant?
   C. Basic Principles Of Lubrication
      1. Viscosity
      2. SAE Viscosity Grades
      3. ISO Viscosity Grades
      4. Sliding Versus Rolling Friction
      5. Boundary/Thin Film Lubrication

II. Basic Types Of Lubricants
   A. Oil, What Is It?
      1. Additives
      2. Compatibilities
      3. Applications
   B. Testing
      1. Viscosity Index
      2. Cloud And Pour Points
      3. Specific Gravity
      4. Flash/Fire Point
      5. Color
      6. Neutralization Number (TAN)
      7. Total Base Number (TBN)
      8. Precipitation Number

9. Foaming
10. Oxidation
11. Lubricity

C. Grease, What Is It?
1. Additives
2. Compatibilities
3. Applications
4. Testing

III. Principles Of Lubrication
A. Types Of Lubrication
1. Hydrodynamic Lubrication
2. Elastohydrodynamic Lubrication (EHD/EHL)
3. Contaminants

IV. Lubrication Applications
A. Bearing Lubrication
1. Grease Applications
2. Oil Applications
3. Proper Methods Of Greasing (How Much, How Often?)

B. Coupling Lubrication
1. Types Of Couplings
2. Proper Greasing Of Couplings

C. Gear Lubrication
1. EP (Extreme Pressure) Vs. Non-EP Oils
2. Methods Of Supplying Lubricant
3. Splash Lubrication
4. Force-Fed Lubrication
5. Intermittent Lubrication
6. Hydraulic Lock
7. Gear Failure Analysis

D. Worm Gear Lubrication
1. Proper Lubrication Of Worm Gears
2. Greasing/Oil Change Intervals

V. Hydraulics
A. Principles Of Hydraulics
B. Hydraulic Fluids
C. Viscosity
D. Film Strength And Lubricity
E. Oxidation And Deposits
F. Water Separability
G. Anti-Rust
H. Foam Resistance

I. Filterability
J. Anti-Fatigue
K. Seals
L. Corrosion Protection
M. Fire-Resistant Hydraulic Fluids
N. Fluid Characteristics And Additives
O. Filtration
P. Preventing Eight Common Fluid-Related Hydraulic Problems

VI. Synthetic Vs. Mineral Oils
A. Types Of Fluids And Their Origins
B. Applications And Advantages Of Synthetics

VII. What Is A Lubrication Program?
A. Fewest Correct Lubricants
B. Scheduling Program
C. Proper Lubricating Devices
D. Storage And Handling Of Lubricants
1. Storing Lubricants
2. Handling Lubricants
E. Oil Sampling (Tribology)
1. Proper Sampling Procedures
2. Reports/Interpretation
3. Precision
4. Plotting
F. Benefits Of A Good Lubrication Program

VIII. Glossary Of Lubrication Terms

Time Required

24 to 40 hours (depending upon audience, and audience experience).

Sources

None

MM-207: Bearings

Course Description

This course provides information on the concepts associated with bearings, bearing function, bearing design, bearing maintenance, installation and removal, expected load and wear patterns, and bearing faults. There are hands-on exercises for bearing removal and installation.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, design, and construction of bearings; install, remove and maintain bearings; and identify causes of bearing failure.

Target Audience

This course is designed for mechanical and electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises

Course Objectives

- Discuss the basic concepts behind forces and stress.
- Discuss some of the basic terms used to describe and understand bearing design.
- Describe some of the materials used in the construction of bearings, and why the materials are used.
- State the basic requirements of any bearing.
- Describe the differences between radial and thrust bearings.
- Given an anti-friction bearing, classify it as to type and operating characteristics.
- Given an anti-friction bearing, identify its individual components and give their purpose.
- Given a friction bearing, classify it as to type and operating characteristics.
- Given a friction bearing, identify its individual components and give their purpose.
- Describe the types of lubrication systems used for anti-friction and friction bearings.
- State the importance of and describe how to perform a soft foot check.
- State the procedure for performing various clearance checks on anti-friction and friction bearings.
- State the reasons for interference fits.
- Describe the various methods of heating bearings.
- Describe the various methods of cold mounting roller bearings.
- Describe the various methods of mounting tapered bore bearings.
- Explain the purpose of pre-load.
- Describe the methods of setting tapered roller bearings.
- State the differences and purposes of fixed and float bearings.
- Describe the various methods of roller bearing removal.
- State the importance of crush and torque on a journal bearing.

- Describe the various expected load and wear patterns of bearings that have been operating.
- Identify the various types of failures that occur in bearings.
- Describe the various types of failures that occur in bearings.
- Describe methods for reducing the various bearing failures.

Topical Outline

I. BEARING CONCEPTS, TERMS, AND MATERIALS
- A. Forces in Effect
- B. Bearing Terms
- C. Friction Bearing Materials

II. BEARING DESIGN AND CONSTRUCTION
- A. Bearing Requirements
  1. Load
  2. Friction
- B. Bearing Types
  1. Anti-Friction Bearings
  2. Friction Bearings
- C. Bearing and Housing Seals
  1. Contact Seals
  2. Clearance Seals

III. BEARING MAINTENANCE
- A. Bearing Lubrication
- B. Oil Lubrication
  1. Anti-Friction Bearing Oil Lubrication
  2. Friction Bearing Oil Lubrication
- C. Grease Lubrication
- D. Bearing Inspections
  1. Alignment
  2. Clearances
- E. Bearing Care
  1. Cleaning Bearings
  2. Protection and Temporary Storage
  3. Handling Practice
- F. Roller Bearing Installation
  1. Roller Bearing Installation Precautions
  2. Interference Fits
  3. Methods of Mounting Bearings
  4. Axial Positioning
- G. Roller Bearing Removal
  1. Bearing Pullers

2. Bearing Press

H. Journal Bearing Maintenance
   1. Crush
   2. Torque
   3. Babbitt Bearing Fitting
   4. Bearing Scraping

IV. BEARING FAILURE ANALYSIS

A. Normal and Abnormal Load Patterns
   1. Load Distribution in a Bearing
   2. Axial Loads
   3. Thrust and Radial Load
   4. Pre-Loads
   5. Out-of-Round Housing Bores
   6. Load Zones with Misaligned Rings

B. Lubrication-Related Failures
   1. Lubrication Properties
   2. Spalling
   3. Discoloration and Softening
   4. Glazing
   5. Pulling
   6. Smearing
   7. Pitting
   8. Skid Smearing
   9. Grooves
   10. Broken Cage
   11. Welded Rollers
   12. Avoiding Surface Failures
   13. Examples of Surface Failures

C. Maintenance-Related Failures
   1. Failure Due to Defective Bearing Seats
   2. Bearing Misalignment
   3. Faulty Mounting Practice
   4. Damage Due to Improper Fits

D. Operational-Related Failures
   1. Stationary Bearing
   2. False and True Brinelling

Time Required

16 to 40 hours (depending upon audience, and audience experience).

Sources

None

MM-301: Shaft & Coupling Alignment

Course Description

This course provides information on the importance of proper alignment and alignment methods, cause of misalignment and how to correct for error such as soft foot and thermal growth using dial indicators, and coupling alignment using dial indicators and lasers where applicable. There are hands-on exercises for shaft and equipment alignments.

Terminal Objective

Upon completion of this course, the participants will be able to successfully identify and correct a given source of misalignment using dial indicators or lasers where applicable, the participant will also be able to demonstrate an alignment exercise using given tools and equipment.

Target Audience

This course is designed for electrical and mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises

Course Objectives

- Explain the importance of shaft alignment
- Describe the symptoms of misalignment
- Define the goal of the alignment process.
- Understand the most common causes of misalignment.
- Explain the effects of misalignment on machines.
- Describe the relationship between vibration and shaft alignment
- Describe the tools used in alignment work.
- Explain the importance of conducting a thorough inspection of the machine prior to attempting to perform an alignment
- Describe the effects of not conducting a thorough inspection of the machine prior to attempting to perform an alignment
- Explain the term “soft foot.”
- Describe the effects soft foot has on a machine.
- Describe the various types of soft foot.
- Explain how to measure and correct soft foot.
- Describe the phases of alignment and the acceptable methods of completing them.
- Make accurate adjustments in each phase of alignment (lab assignment).
- Describe the various methods available to perform alignment.
- Explain the advantages and disadvantages of each method.
- Measure bar sag.
- Perform an alignment using the reverse dial indicator method.
- Make accurate elevation changes on the machine.
- Make controlled horizontal moves.

- Describe acceptable solutions for the problem of a machine becoming bolt bound.
- Explain the importance of thermal growth in a machine.
- Calculate thermal growth.
- Determine acceptable limits of an alignment.
- Describe factors that can affect the limits of an alignment.
- Be aware of various alignment procedures for equipment other than horizontally mounted motors and pumps.
- Perform an alignment on machines with multiple feet.
- Perform an alignment on multiple machine trains.
- Perform an alignment on non-rotational machines.
- Perform an alignment on machines with jackshafts.
- Perform an alignment on machines with an unobtainable indicator reading.
- Upon completion of this section, you will be able to perform the following:
- Explain the purpose of a coupling
- Explain the difference between a rigid and flexible coupling.
- Explain the following terms as they relate to a coupling; Hub, Shaft, Key, Match Marks, Bore, Gap.

Topical Outline

I. IMPORTANCE OF SHAFT ALIGNMENT
   A. Symptoms of Misalignment
II. ALIGNMENT FUNDAMENTALS
   A. Types of Misalignment
   B. Shaft Considerations
      1. Axial Positioning of Shafts
      2. Static Deflection
      3. Operational Deflection
   C. Causes of Misalignment
   D. Effects of Misalignment
   E. Indications of Misalignment
   F. Vibration and Shaft Alignment
III. ALIGNMENT TOOLS
   A. Back Plunger Dial Indicators
   B. Bottom Plunger Dial Indicators
   C. Adjustable Parallels
   D. Feeler Gauge
   E. Taper Gauge
   F. Shims
   G. Micrometer
   H. Other Tools
IV. PRE-ALIGNMENT CHECKS

A. Pre-Alignment Checklist

V. SOFT FOOT CORRECTION

A. Soft Foot
B. Effects of Soft Foot
   1. Case Strain
   2. Distorted Bearing Housing
C. Types of Soft Foot
   1. Air Gap or Parallel Soft Foot
   2. Induced Soft Foot
   3. Stacking Error
   4. Stress Induced Case Strain
   5. Outward Bent Foot
   6. Inward Bent Soft Foot
D. Measuring and Correcting Soft Foot
E. Soft Foot Analysis
F. Soft Foot Tolerance

VI. PHASES OF ALIGNMENT

A. Phases Of Alignment
B. Rough-In Phase
C. Precision Phase

VII. ALIGNMENT METHODS

A. Alignment Methods
B. Straight Edge/Feeler Gauge
C. Rim and Face
D. Reverse Dial
E. Laser

VIII. PERFORMING A REVERSE DIAL INDICATOR ALIGNMENT

A. Bar Sag Compensation
   1. Measuring Bar Sag
   2. Transferring the Alignment Rig to the Machine
B. Graphical Solutions to Misalignment (Reverse Indicator)

IX. MOVING THE MACHINE

A. Moving the Machine
   1. Vertical Moves
   2. Horizontal Moves
B. Bolt Binding
C. Pipe Strain Check

X. THERMAL GROWTH

A. Thermal Growth
B. Thermal Growth Calculation
C. Height of the Machine

D. Recording the Hot and Cold Temperature Readings
E. Where to Take the Readings

XI. TOLERANCES
A. Tolerances
B. Additional Considerations

XII. NON-STANDARD ALIGNMENTS
A. Multiple Bolts
B. Non-Rotational Machine
C. Jackshafts
D. Unobtainable Indicator Reading

XIII. COUPLINGS
A. Purpose of a Coupling
B. Types of Couplings
1. Rigid Couplings
2. Flexible Couplings

Time Required

40 hours

Sources

None

MM-302: Pipefitting

Course Description

This course provides information on the codes and standards, types of piping and associated components, specifications, and fitting and supporting techniques. There are hands-on exercises for bending fitting and installing pipe.

Terminal Objective

Upon completion of this course, the participants will be able to; read and interpret pipefitting information from drawings and blueprints, identify piping materials, identify and discuss standards and specifications, and fit-up and join pipes, tubes, and associated system components.

Target Audience

This course is designed for mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Discuss common codes/standards processes.
- List codes/standards applicable to pipefitting.
- Identify authority system used to enforce private codes and standards.
- Describe typical ASME code symbols.
- Discuss ANSI, ASTM, AWS, and ASNT applicable codes to pipefitting.
- Identify the multitude of terms associated with piping.
- Describe the appropriate safety precautions associated with pipefitting.
- Identify piping specifications used in pipefitting.
- Interpret and illustrate piping drawings.
- Describe the three major dimensions associated with piping.
- Identify methods used to identify pipes and their associated components.
- Identify basic tools used in pipefitting and their appropriate uses.
- Describe basic pipe bending techniques.
- Identify the four major types of metal piping.
- Identify ferrous and non-ferrous materials.
- Describe the basic manufacturing techniques employed for the various types of metal piping.
- Discuss the advantages/disadvantages of the different types of metal piping.
- List some examples of special metals and their unique applications.
- Identify the five major types of non-metallic piping.
- Identify the three forms of concrete and their applications.
- Discuss advantages/disadvantages and applications of glass piping.
- Identify the types of plastic piping; its uses and advantages.
- Describe types of piping resins.
- Discuss basic differences between tubing and piping.
- List the advantages of using tubing.

- Identify the common types of tubing.
- Describe tubing joints and their make-up.
- Identify tube bending techniques commonly used.
- Identify the means of joining piping systems.
- Describe the different methods to perform welding connections.
- Identify the types of flanges and their applications.
- Identify forms of threaded connections.
- Describe joint preparation and fit-up.
- Identify different types of valves available and discuss the characteristics of each type
- Identify different types of valve actuators available and discuss the characteristics of each type.
- Describe the three types of steam traps and their operations.
- Describe the operations of filters and strainers.
- Describe the operation and construction of a tube and shell heat exchanger
- Describe miscellaneous piping components commonly seen in piping systems
- Identify the basic designs of pipe hangers and supports.
- Describe hanger selection and support location criteria.
- Describe the effects of thermal transients on the hangers/piping systems.
- List the two major types of hangers.
- Identify various pipe hangers and attachments.
- Describe the types of snubbers and their uses.
- Discuss the operation, installation, and maintenance of snubbers.

Topical Outline

I. Codes and Standards
   A. Codes and Standards
      1. ANSI
      2. ASTM
      3. AWS
      4. ASNT
   B. ASME Code Symbols

II. Piping and Piping Systems
   A. Applications
   B. Safety Precautions
   C. Associated Drawings and Blueprints
   D. Dimensions and Specifications
   E. Identifying Materials
   F. Pipefitting Tools
   G. Pipe Bending Techniques

III. Metal Piping
   A. Ferrous and Nonferrous Materials
   B. Applications (Advantages and Disadvantages)

IV. Non-Metallic Piping
- A. Concrete
- B. Glass
- C. Plastic

V. Tubing
- A. Applications Suited for Tubing
- B. Tube Bending
- C. Tube Joining

VI. Pipe and Joint Fittings
- A. Methods of Joining Pipes
- B. Pipe Welding
- C. Flanges
- D. Threads
- E. Preparation and Fit-Up

VII. Piping System Components
- A. Valves and Actuators
- B. Steam Taps
- C. Filters and Strainers
- D. Tube and Shell Heat Exchangers
- E. Miscellaneous Components

VIII. Pipe Supports
- A. Thermal expansion and Transients
- B. Mechanical Shock and Vibration
- C. Hangers
- D. Snubbers

IX. Pipefitting Exercises

Time Required

Up to 40 hours (depending upon audience and audience experience).

Sources

None

MM-303: Seals & Packing

Course Description

This course provides information on identification and installation of packing and mechanical seals and their applications. There are hands-on exercises for removing and installing packing and mechanical seals.

Terminal Objective

Upon completion of this course, the participants will be able to explain and/or demonstrate the correct way to safely inspect, install packing and/or mechanical seals on a given piece of equipment.

Target Audience

This course is designed for mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Identify the different types of compression packing, and explain when each is used.
- Identify the different types of molded packing, and explain when each is used.
- List the advantages and disadvantages of pump mechanical seals.

Topical Outline

I. Compression Packing
   A. Braided or Twisted Packing
   B. Graphite Packing
   C. Packing Size
   D. Lantern Rings
   E. Packing Glands
   F. Cutting Packing
   G. Packing Replacement
   H. Shaft Sleeves

II. Molded (Automatic) Packing
   A. Floating Packing (Split Ring Seals)

III. Standard Seals
   A. Double/Tandem Seals
   B. Seal Circulating Fluid System
   C. Stationary Seals
   D. Package Seal
   E. Lip Seal
   F. O-Rings and Gaskets
   G. Identifying Seal Problems

Time Required

8 hours

Sources

None

MM-304: Pumps & Pump Repair

Course Description

This course provides information on the concepts associated with pumps and pump application, operation, hazards, troubleshooting and repair common problems, it also explains how to draw and label simple pump curves. There are hands-on exercises for inspection and repair of pumps and its associated equipment.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, design, and construction of given pumps and be able to troubleshoot a given problem.

Target Audience

This course is designed for mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises

Course Objectives

- State the centrifugal pump laws
- Define the terms used when discussing centrifugal pumps
- State the safety hazards associated with rotating equipment
- Describe the hazards associated with pumps
- Explain the operation of a centrifugal pump
- Identify and state the function of the various centrifugal pump components
- Classify centrifugal pumps as to position, impeller design, number of stages, and direction of flow
- Explain how slip effects the operation of a centrifugal pump
- Draw and label simple pump curves
- Define net positive suction head and cavitation
- Describe the process for troubleshooting a centrifugal pump
- Identify and state the function of the various positive displacement pump components
- Explain the operation of a positive displacement pump
- Explain how slip effects the operation of a positive-displacement pump
- Describe the process for troubleshooting a positive displacement pump

Topical Outline

I. CENTRIFUGAL PUMP LAWS, TERMINOLOGY, AND SAFETY
   A. Pump Laws
   B. Pump Terminology
   C. Pump Construction Materials
   D. Rotating Mechanical Equipment Safety
   E. Pump Safety

II. CENTRIFUGAL PUMPS

A. Centrifugal Pump Theory
B. Centrifugal Pump Operation
C. Types Of Centrifugal Pumps
D. Centrifugal Pump Classifications
E. Parts of a Centrifugal Pump
F. Pump Characteristic Curves
G. Factors Affecting Performance
H. Symptoms of Performance Loss
I. Troubleshooting Centrifugal Pumps

III. POSITIVE DISPLACEMENT PUMPS

A. Reciprocating Pumps
B. Piston Pumps
C. Rotary Pumps
D. Special Purpose Pumps
E. Warren Rupp Sandpiper® Pumps
F. Factors Affecting Pump Performance
G. Wear Areas and Inspection Points

Time Required

16 to 24 hours (depending upon audience, and audience experience).

Sources

None

MM-400 : Hydraulics & Pneumatics

Course Description

This course provides information on the concepts associated with pneumatics and pneumatic systems, fluid principles, pneumatic system design, and pneumatic schematic symbology.

Terminal Objective

Upon completion of this course, the participants will be able to explain the advantages of pneumatics, Boyle's Law, Charles Law, the General Gas Law, fluid dynamics, pneumatic system symbols, filtration in pneumatic systems, and pneumatic system cylinders and valves.

Note

This course is a combination of MM-401 and MM-402.

Target Audience

This course is designed for mechanical and electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises

Course Objectives

- List and describe the advantages offered by the use of pneumatics.
- State the relationship between force, pressure, and area.
- Discuss the compressibility and expansion of gases as defined by Boyle's Law, Charles' Law, and General Gas Law.
- Describe the basic principle of fluid dynamics.
- Identify standard symbols used to illustrate the operation of a pneumatic system.
- Given a drawing of a plant pneumatic system, identify the components and how they function in that system.
- Discuss the use of filtration and purification equipment installed in pneumatic systems.
- List the types and uses of cylinders installed in pneumatic systems.
- List the types and uses of valves installed in pneumatic systems.

Topical Outline

I. Pneumatic Applications
II. Piping And Connectors
   A. Basic Piping Requirements
   B. System Airflow
   C. Metallic Tubing
   D. Nonmetallic Tubing
   E. Hoses
   F. Hose Installations
III. Pneumatic Cylinders
   A. Single-Acting Cylinders
   B. Double-Acting Cylinders

C. Two-Piston Cylinder
IV. Pneumatic Control Valves
A. Control Valve Elements
B. Two-Way Valves
C. Three-Way Valves
D. Four-Way Valves
E. Five-Way Valves
F. Manually Operated Valves
G. Solenoid Valves
V. Air Compressors
A. Compressor Classification
1. Types of Compressing Elements
2. Sources of Power
3. Pressure Classifications
B. Reciprocating Compressors
C. Rotary Compressors
D. Centrifugal Compressors
VI. Pneumatic Motors
A. Motor Classification
B. Pneumatic Motor Construction
C. Vane Motors
D. Piston Motors
E. Rotary Actuators
F. Turbines
1. Pinwheel Turbine
2. Single and Multistage Turbines
VII. Pneumatic Tools
A. Abrasive Tools
B. Drills
C. Impact Wrenches
D. Hammers
E. Hoists
VIII. Hydraulic Applications
IX. Hydraulic Principles
A. Pressure
B. Pascal's Law
C. Pressure and Force in Hydraulic Systems
1. Multiplication of Forces
2. Differential Areas
3. Volume and Distance Factors
D. Fluid Flow

1. Volume and Velocity of Flow
2. Streamline and Turbulent Flow
3. Minimizing Friction

X. Hydraulic Fluids
- A. Properties
  1. Viscosity
  2. Viscosity Measurement
  3. Viscosity Index
  4. Lubricating Power
- B. Types of Hydraulic Fluids
  1. Water Base Fluids
  2. Petroleum Base Fluids
  3. Synthetic Base Fluids

XI. Hydraulic Pumps
- A. Rotary Pumps
  1. Gear-Type Pumps
  2. Vane-Type Pumps
  3. Piston-Type Pumps
- B. Reciprocating Pumps
  1. Single Acting
  2. Double Acting

XII. Control Valves
- A. Directional Control Valves
- B. Flow Control Valves
- C. Solenoid-Operated Valves

XIII. Relief Valves
- A. Direct-Acting Relief Valve
- B. Pilot-Operated Relief Valves

XIV. Cylinders/Actuators
- A. Ram-Type Cylinders
  1. Single-Acting Ram
  2. Double-Acting Ram
- B. Piston-Type Cylinders

XV. Hydraulic Reservoirs and Accumulators
- A. Weight-Loaded Type
- B. Spring-Loaded Type
- C. Air or Gas Type

XVI. Strainers and Filters
- A. Materials
  1. Synthetic Rubber
  2. Cork

3. Metal

B. Types of Seals
   1. O-Rings
   2. Quad-Rings
   3. V-Rings
   4. Cup Seal
   5. U-Rings
   6. Flange Seals

C. Wipers and Backup Washers
   1. Wipers
   2. Backup Washers

XVII. Piping And Connectors

A. Rigid Pipe
B. Semi-Rigid (Tubing)
C. Flexible Piping (Hose)
D. Flared Connectors
E. Bite-Type Connectors

Time Required

Up to 40 hours (depending upon audience and audience experience).

Sources

None

WE-102: Structural Welding

Course Description

This course provides information on oxyfuel cutting and SMAW structural welding. There are extensive hands-on exercises for burning and welding.

Terminal Objective

Upon completion of this course the participants will be able to make cuts using oxyfuel equipment and weld T-joints using SMAW equipment

Target Audience

This course is designed for mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Describe fusion welding, resistance welding, filler rods, and electrodes.
- Compare the oxyfuel and arc welding processes and compare the SMAW, GMAW, and GTAW processes.
- Describe and sketch the following kinds of joints-butt, lap, tee, corner, and edge.
- Describe the following kinds of welds-groove, fillet, plug, slot, spot, and seam.
- Name and locate the parts of a weld.
- Discuss basic considerations in joint design and fitup.
- Explain the importance of good housekeeping in an area where welding is taking place.
- List at least three precautions to take to avoid fires and explosions when welding.
- Describe two methods of protecting yourself against the fumes and gases associated with welding.
- Describe the personal protective equipment required when welding.
- Explain the precautions to take when using and handling cylinders and regulators.
- Briefly describe the oxyfuel welding process and the components of an oxyfuel welding outfit, including the lighting device.
- Discuss safety precautions and personal protective gear required for working with oxyfuel equipment.
- List the steps involved in preparing to weld.
- Compare the neutral, carburizing, and oxidizing flames.
- List the steps in safely shutting down an oxyfuel welding system.
- List similarities and dissimilarities between oxyfuel welding and arc welding.
- Describe the electric welding circuit, including choice of ac or dc, dc polarity, and power sources.
- Discuss welding machine ratings in terms of amperage and duty cycle and describe features and uses of transformer, generator, rectifier, and inverter welding machines.

- Discuss welding cable considerations and describe the electrodes and electrode holders used for SMAW, GMAW, and GTAW processes.
- Discuss the personal safety gear and precautions necessary for arc welding and explain how arc welding accessories are used.
- Explain what considerations affect the selection of a welding process.
- Describe the four welding positions.
- Explain why overhead welds are difficult to make and tell how to make them.
- Describe the preparation required for oxyfuel welding, SMAW, GMAW, and GTAW processes.
- Describe the procedures involved in oxyfuel welding, SMAW, GMAW, and GTAW processes
- Describe the effects of electrode selection, current, arc length, and travel speed on arc welding procedures.
- Describe common causes of arc blow, a hard-to-start arc, and spatter, and explain why proper fitup is important.
- Define the terms overlap, undercut, blowhole, and inclusion and explain the causes of each.
- Explain how expansion and contraction can be controlled when welding.
- Name and describe the various tests used to identify metals.
- Identify the kind of chamfer to be cut on a joint to be welded, and which part is to be chamfered.
- State the required dimensions of a weld.
- Identify the contour required on a finished weld.
- State how a weld contour is to be finished.
- Differentiate between welds that are to be made at the site of final assembly and welds that are to be made before the parts are shipped to the site.
- Explain the similarities and differences between oxyfuel cutting and oxyfuel welding.
- Describe the equipment and safety precautions necessary for torch cutting and list standard steps in the torch cutting operation.
- Describe special equipment or methods used in cutting bevels, piercing holes, cutting circles, and cutting away rivets.
- Explain why gouging, scarfing, and washing are used.
- Explain methods used on metals that are otherwise difficult to cut.
- Explain how the shielded metal arc welding process works.
- Tell what provides the shield in shielded metal arc welding.
- Define arc length and explain its importance.
- List factors to consider when selecting an electrode.
- Describe the personal protective equipment necessary for welding.
- Explain the factors involved in selecting SMAW electrodes.
- Explain how to identify different welding electrodes.

- Give examples of several kinds of electrode coverings and tell when each is used.
- Describe correct procedures for handling, storing, and conserving electrodes.
- Cut metal using oxyfuel equipment.
- Make t-joint welds using SMAW equipment

Topical Outline

I. Fundamentals of Welding
II. Welding Safety
III. Oxyfuel Welding Equipment
IV. Arc Welding Equipment
V. Welding Techniques
VI. Avoiding Weld Faults
VII. Welding Symbols
VIII. Oxygen Cutting
IX. Shielded Metal Arc Welding
X. Selecting Electrodes for SMAW
XI. Oxyfuel Cutting Demonstration
XII. Oxyfuel Cutting Exercises
XIII. SMAW Plate (T-Joint) Demonstrations
XIV. SMAW Plate (T-Joint) Exercises
XV. SMAW Plate (T-Joint) Practical Exam

Time Required

200 hours (5 weeks)

Sources

None

WE-103: Pipe Welding

Course Description

This course provides information on SMAW pipe welding. There are extensive hands-on exercises for welding.

Terminal Objective

Upon completion of this course the participants will be able to weld pipe in 2G and 5G positions using SMAW equipment

Target Audience

This course is designed for mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Compare the advantages of welded pipe joints to bolted or screwed connections.
- Discuss pipe welding codes and what they cover.
- List the welding processes used for joining pipe and their advantages and disadvantages.
- Identify some special methods and accessories that are used in pipe welding as opposed to flat welding.
- Give examples of the uses of preheating and postheating in pipe welding.
- Make 2G and 5G pipe welds.

Topical Outline

I. Review of Welding Material from MTM-22 Structural Welding

II. Pipe Welding

A. Metal Arc Pipe Welding

1. SMAW Pipe Welding Principles
2. Equipment
3. Grooved Welds for Pipe
4. Fillet Welds for Pipe
5. The Five Essentials for Pipe Welds with Quality

B. Pipe Welding Procedures

1. The Purpose of a Pipe Welding Procedure
2. Welding Procedure Interpretation
3. Preparing a Weld Specimen for Testing
4. Electrodes/Filler Metal
5. Weld Joint Specifications
6. Preheating
7. Electrical Characteristics
8. Operations during Welding
9. Post Weld Operations

10. Testing Of the Welded Joint

C. Preparation and Assembly of a Pipe Joint without Backing
   1. Preparation of Weld Surface
   2. Assembly and Alignment
   3. Tack Weld Installation

D. Quality of the Weld
   1. Reading the Puddle
   2. Weld Defect Interpretation
   3. Using Travel Angle to Control Heat Input
   4. Weld Defects
   5. Joint Preparation

E. Applying the Root Pass
   1. Processes/Electrodes for Welding Of Pipe
   2. Processes for Applying a Root Pass

F. Preheat and Interpass Temperatures
   1. Purpose of Preheating
   2. Preheat Temperature
   3. Preheating Methods
   4. Monitoring Preheat Temperatures
   5. Preheat and Weld Quality
   6. Maintaining Interpass Temperatures

G. Preparation and Assembly of a Pipe Joint with a Backing Ring
   1. Workpiece Preparation
   2. Workpiece Assembly

III. Pipe Welding Demonstrations
IV. Pipe Welding Exercises
V. Pipe Welding 2G Practical Examination
VI. Pipe Welding 5G Practical Examination

Time Required

200 hours (5 weeks)

Sources

None

MM-208: Mechanical Crane Inspections

Course Description

This course provides information on the mechanical inspection of EOT Cranes.

Terminal Objective

Upon completion of this course, the participants will be able to discuss the mechanical inspections performed on EOT cranes, and be able to assist in the inspection of EOT cranes.

Target Audience

This course is designed for mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom.

Course Objectives

- List and discuss the major mechanical assemblies of EOT cranes
- List the inspection points on an EOT crane.
- Locate the inspection points on an EOT crane.
- Discuss the criteria for the inspection points.

Topical Outline

I. EOT Cranes
   A. Structure and Function
   B. Major Components
   C. General Crane Control and Controls

II. Mechanical Inspection Points
   A. Brake Mechanisms
   B. Trolley and End Stops
   C. Hoist – Couplings, Gearbox and Drive Components, Bearings, Sheaves, Structure
   D. Bridge – Wheels, Bearings, Gearbox and Drive Components, Structure
   E. Trolley - Wheels, Bearings, Gearbox and Drive Components

Time Required

16 hours

Sources

IPT's Crane and Rigging Handbook

MM-209: Fans, Blowers, & Compressors

Course Description

This course provides information on the concepts associated with air systems, air system functions, air system design, air system maintenance, installation and removal, and air system faults.

Terminal Objective

Upon completion of this course, the participants will be able to explain the function, design, and construction of air systems; install, remove and maintain air systems, and identify causes of air system failures.

Target Audience

This course is designed for mechanical and electrical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises

Course Objectives

- Explain the purpose of a fan as compared to a blower.
- State the differences in operation between a centrifugal fan and an axial fan.
- State the major design classification of blowers.
- Explain the operation of a positive displacement blower.
- Explain the operation of an axial flow blower.

Topical Outline

I. Fans
   A. Fan Laws
   B. Fan Characteristic Curves
   C. Calculating Fan Efficiency
   D. Classifications of Fans
   E. Fan Control
   F. Fan Drives
II. Fan Applications
   A. Forced-Draft System
   B. Induced-Draft System
III. Blowers
   A. Lobed Rotary Blowers
   B. Centrifugal Flow Blowers
   C. Axial Flow Blowers
IV. Compressors
   A. Compressor Principles
      1. Basic Operation
      2. Compressibility and Expansion Of Gases
   B. Compressor Construction And Classification

1. Rotary Compressors
2. Rotary Screw Compressors
3. Sliding-Vane Rotary Compressor
4. Liquid-Ring Rotary Compressor
5. Reciprocating Air Compressors
6. Compression Cycle
7. Double-Acting Compressor
8. Multi-Stage Compressor

C. Compressor Components
1. Compressing Element
2. Thin Plate Type Air Valves
3. Feather Strip Type Air Valve
4. Crankshaft
5. Pistons
6. Lubrication System
7. Cooling System
8. Control System
9. Unloaders
10. Operation of Unloading Valve

D. Compressor Auxiliaries
1. Compressor Silencers and Filters
2. Traps
3. Air Receivers
4. Moisture Separators, Dryers, Pre-Filters, and After-Filters

E. Compressor Safety Features

F. Compressor Maintenance, Operation, And Troubleshooting
1. Compressor Start
2. Routine Operational Checks
3. Compressor Shutdown
4. Preventive Maintenance
5. Adjusting Head Clearance
6. Troubleshooting

Time Required

24 Hours

Sources

None

MM-403: Industrial Electricity and Electronics for Mechanics

Course Description

This course provides information on basic electricity and electronic concepts and devices. There are hands-on exercises for component and circuit operation.

Terminal Objective

Upon completion of this course, the participants will be able to identify electrical and electronic components and explain the operation of these components, and the operation of simple circuits.

Target Audience

This course is designed for mechanical maintenance technicians.

Recommended Media/Mode

Instructor-led classroom presentation with workshop hands-on exercises.

Course Objectives

- Describe the structure of an atom.
- Tell the difference between a compound and an element.
- Explain how electrical forces cause objects to attract or repel other objects.
- Describe electron flow.
- State the definition of a cell.
- Explain the difference between a conductor and an insulator.
- State the definition of grounding.
- List the common causes of static electricity in an industrial plant.
- State the definition of bonding.
- List the main methods of producing potential difference.
- State the main difference between a primary cell and a secondary cell.
- Explain how to connect cells in parallel and in series.
- Describe how a photoelectric device works.
- Identify potential hazards when recharging batteries.
- State the most basic law of magnetic force.
- Describe how magnetic force operates.
- Describe the left-hand rule for magnetic field direction.
- Describe an electromagnet.
- Explain how to use lifting magnets, magnetic pulleys, and magnetic clocks.
- State the characteristics of an electrical conductor and an electrical insulator.
- State the definition of electric current.
- Explain the relationship of potential difference to the flow of electric current.
- State the definition of Ohm's Law.
- Identify the purpose and parts of an ammeter.
- Identify symbols for resistors, capacitors, and relays in an electric circuit diagram.

- Explain the operating principles of resistors, capacitors, and inductors.
- State the meaning of each band in the resistor color-code system.
- List the factors to consider when choosing a resistor.
- Explain how to connect capacitors in parallel and in series.
- State the difference between ac and dc.
- Solve for R, E, I, and P in a simple electrical problem.
- Solve for potential difference, current, and resistance in a series and parallel circuit.
- Describe the operation of a transformer
- Explain the difference between the primary winding and the secondary winding in a transformer.
- Explain the importance of the transformer in ac electricity.
- Explain what a complete cycle of ac consists of and how it is produced.
- State the definition of ac inductance.
- List the ways inductive reactance differs from resistance.
- Explain the difference between the terms in-phase and out-of-phase in an ac circuit.
- List the main advantages of the three-phase AC system.
- Explain the difference between system grounding and equipment grounding.
- List the benefits of system grounding.
- Name the parts of a vacuum tube, and describe the function of each part.
- Explain the difference between p-type semiconductor materials and n-type semiconductor material.
- List the parts of a transistor.
- State the definition of an integrated circuit.
- Name each of the blocks of the block diagram of a programmable logic controller system.
- Explain how each of the blocks functions with the system as a whole.
- Describe the relationship of the programmable logic controller system to the real world.
- Explain the basic concepts of ladder logic software.
- Describe the relationship of an input device to an input point on an input module.
- Identify the symbols for common input and output devices.

Topical Outline

I. Fundamentals of Electricity
   A. Atomic Structure, Charge, and Electron Flow
   B. Static Electricity
   C. Conductors and Insulators
   D. Direct and Alternating Current

II. Magnetism
   A. Theory of Magnetism
   B. Left-Hand Rule for Generators
   C. Right –Hand Rule for Motors

III. Current, Resistance, and Voltage
IV. Electrical Components
    A. Resistors
    B. Capacitors
    C. Inductors
    D. Solenoids and Relays
V. DC Circuits
VI. AC Circuits
VII. Power Distribution
    A. Transformers
    B. Three-Phase Power
    C. Industrial Power Distribution
VIII. Electronics
    A. Vacuum Tubes
    B. Solid-State Electronics
        1. Diodes
        2. Transistors
        3. Silicon Controlled Rectifiers (SCR)
IX. Programmable Logic Controllers
    A. Function
    B. Typical System Components
    C. Typical Program Function and Control Examples

Time Required

40 hours

Sources

None